FROM STRUCTURE TO ACTION

MACHINE REASONING AND THE LOGICS OF REPAIR

Tizian Rein

Professorship of Digital Fabrication
TUM School of Engineering and Design
Technical University of Munich

From Structure to Action

Machine Reasoning and the Logics of Repair

Master Thesis
Department of Architecture
TUM School of Engineering and Design
Technical University of Munich

Supervised by Prof. Dr. Kathrin Dörfler
& Begüm Saral
Professorship of Digital Fabrication

Submitted by Tizian Rein
Munich, 08.09.2025

Abstract

While reuse and recycling address the afterlife of materials, repair enables direct and deliberate engagement with what already exists. It extends the lifespan of objects, prevents further degradation, and opens opportunities for transformation and upgrading. Beyond maintenance, repair can be understood as a creative design practice that reimagines and reshapes the existing.

This thesis investigates how emerging digital systems and workflows can support such repair practices and integrate them into early design stages. To explore this potential, a mobile-first application was realized that structures repair into coherent, interlinked steps. The system combines multimodal artificial intelligence with interactive 3D models and graph-based diagrams to capture both spatial and logical dimensions of repair. Building on recent advances in vision language models, the research introduces an operative framework with three phases: generating knowledge (assembly creation and damage cataloging), generating actions (reasoning and planning repair strategies), and executing actions (guiding interventions and documenting results).

The methodology is tested through two case studies: the repair of 1960s Santo chairs by designer Edlef Bandixen and the Forest Cemetery Chapel in Rhöndorf. In the first study, digital twins and repair plans were generated within minutes using a smartphone and validated through hands-on application. The second study demonstrated scalability to architectural complexity, integrating historical data, point-cloud surveys, and on-site assessments into a coherent action model.

Results show that AI-guided repair can transform a fragmented and improvised activity into a systematic, transparent, and creative design process. By embedding repair into digital workflows, this thesis presents a pathway toward sustaining and upgrading the built environment with precision, adaptability, and long-term design intelligence.

Zusammenfassung

Während Wiederverwendung und Recycling das Nachleben von Materialien adressieren, ermöglicht Reparatur eine direkte und bewusste Auseinandersetzung mit dem Bestehenden. Sie verlängert die Lebensdauer von Objekten, verhindert weiteren Verfall und eröffnet Möglichkeiten zur Transformation und Aufwertung. Über reine Instandhaltung hinaus lässt sich Reparatur als kreative Gestaltungspraktik verstehen, die das Vorhandene neu interpretiert und formt.

Diese Arbeit untersucht, wie neue digitale Systeme und Workflows solche Reparaturpraktiken unterstützen und in frühe Entwurfsphasen integrieren können. Um dieses Potenzial zu erschließen, wurde eine mobile Anwendung realisiert, die den Reparaturprozess in kohärente, miteinander verknüpfte Schritte gliedert. Das System kombiniert multimodale künstliche Intelligenz mit interaktiven 3D-Modellen und graphbasierten Diagrammen, um sowohl räumliche als auch logische Dimensionen der Reparatur abzubilden. Aufbauend auf aktuellen Fortschritten im Bereich multimodaler KI-Modelle führt diese Forschungsarbeit einen Prozess mit drei Phasen ein: Wissensgenerierung (Konstruktion und Schadenskatalogisierung), Handlungsgenerierung (Schlussfolgern und Planen von Reparaturstrategien) und Handlungsausführung (Anleiten der Interventionen und Dokumentation der Ergebnisse).

Die Methodik wird anhand zweier Fallstudien erprobt: der Reparatur von „Santo"-Stühlen aus den 1960er-Jahren des Designers Edlef Bandixen sowie der Friedhofskapelle in Rhöndorf. In der ersten Studie konnten digitale Zwillinge und Reparaturpläne innerhalb weniger Minuten mit einem Smartphone erzeugt und praktisch erprobt werden. Die zweite Studie zeigte die Skalierbarkeit auf architektonische Komplexität, indem historische Daten, Punktwolkenaufnahmen und Untersuchungen auf der Baustelle zu einem kohärenten Aktionsmodell integriert wurden.

Die Ergebnisse zeigen, dass KI-gestützte Reparatur einen fragmentierten und improvisierten Vorgang in einen systematischen, transparenten und kreativen Gestaltungsprozess verwandeln kann. Durch die Einbettung von Reparatur in digitale Abläufe weist diese Arbeit einen Weg, die gebaute Umwelt mit Präzision, Anpassungsfähigkeit und langfristiger Designintelligenz zu erhalten und weiterzuentwickeln.

Contents

List of Abbreviations

2D	2-dimensional
3D	3-dimensional
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
BIM	Building Information Modeling
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
DBR	Design-Based Research
DAG	Directed Acyclic Graph
JSON	JavaScript Object Notation
LLM	Large-Language-Model
OBB	Oriented Bounding Box
UI	User Interface
VR	Virtual Reality
VLM	Visual-Language-Model
XR	Extended Reality

Glossary

Assembly (Model)	A structured digital representation of an object decomposed into its parts, including the connections.
Augmented Reality	A technology that overlays computer-generated information onto a user's view of the real world.
Canonical Object	A standard model that embodies the essential features of a type, serving as a reference for analysis or comparison.
Computer Vision	A field of AI that enables computers to interpret and understand visual information from the world.
Digital Fabrication	Manufacturing processes that are controlled by a computer, using digital models.
Digital Twin	A precise digital replica of a physical object, system, or process that continuously updates through real-time data.
Embodied Reasoning	AI intelligence that is developed through physical interaction with an environment.
Extended Reality	The umbrella term for all immersive technologies that merge the real and virtual worlds.
Framework	A conceptual structure used to guide the development of a system or process.
Generative Design	An iterative design process where AI generates multiple solutions based on specified constraints.
In-situ	A Latin term meaning "in the original place" or "on-site."
JSON	A lightweight data-interchange format that stores information in a readable and machine-parsable way.

Large Language Model	An AI trained on vast text data to understand, generate, and reason about human language.
Machine Learning	A subset of AI in which systems learn and improve from experience without being explicitly programmed.
Machine Perception	The ability of an AI system to interpret data from its environment in a way that mimics human senses.
Multimodal AI	An AI system that can process and understand information from multiple data types, like images and text.
Oriented Bounding Box	A box aligned with an object's dominant geometric axes, used to describe 3D shapes compactly.
Photogrammetry	The science of creating 3D models of objects and environments from photographs.
Point Cloud	A spatial dataset made up of 3D points that represent the surface geometry of an object or environment.
Prompt Engineering	The method of designing structured textual instructions to guide AI models toward producing consistent and meaningful outputs.
Repair	The act of restoring a damaged or faulty object or structure to a functional state.
Shearing Layers	A concept that views buildings as distinct layers that change at different rates over time.
Vision-Language-Model	An AI model that connects vision, language, and physical action to interact with the world.

"All buildings, once handed over by the builders to the client, have three possible fates, namely to remain unchanged, to be altered or to be demolished. The price for remaining unchanged is eventual loss of occupation, the threat of alteration is the entropic skid, the promise of demolition is of a new building. For the architect, the last course would seem the most fruitful."[1]

FRED SCOTT, 2007.

---

[1] Fred Scott, *On Altering Architecture* (London: Routledge, 2007).

1. INTRODUCTION

Repair is integral to building culture. It sustains continuity between generations of use, craft, and knowledge. In contemporary practice, however, repair has been marginalized. Industrially prefabricated systems, glued material composites, and increasingly complex construction details leave little room for adaptation. Rather than evolving with their environment, major effort is invested in designing buildings and objects that appear durable yet make repair impractical or economically irrational. At the same time, we have become accustomed to viewing a building as complete at the moment of handover, expecting a fixed ideal state of permanence. Any later need for maintenance or repair is therefore perceived as a failure of design, execution, or material performance instead of an inherent aspect of the building's life.

Figure 1: Repair of a window frame, where damaged parts are replaced with the same type of wood, still visibly distinguished by color. Image: Johannes Mosler

As a result, repair in everyday practice is frequently discouraged. It is regarded as undesirable and uneconomical, even mediocre work. What disappears in this imbalance is a broader architectural intelligence that includes skills, practices, and design sensibilities which emerge when intervention into the existing is understood as a creative act rather than a reluctant compromise. However, the routine work that sustains this continuity stays often hidden. Maintenance and repair are delegated to those whose labor remains undervalued,[2] carried out beyond the architect's authorship and outside the realm of

---

[2] Material Cultures, *Material Cultures: Material Reform* (London: MACK, 2022), 49.

celebrated design. However, it is within these ordinary acts of making that agency unfolds and a deeper comprehension of fabrication takes shape. Reintegrating such practices into architectural thinking means acknowledging not only the building's temporal life but also the social and ethical dimensions of the work that sustains it.

To understand what is lost when repair is sidelined, it is necessary to be precise about what repair entails. When we think of repair, we often imagine a simple technical fix. Something is broken and potentially someone (rarely the original author) arrives with a solution. But repair is more than this. It is not a single act but an unfolding process. It begins with careful observation and judgment, seeing not only surfaces but also materials, joints, and systems. This requires interpretation, since not every crack calls for intervention and not every irregularity is a defect. From these observations, reasoning follows. Alternatives are compared, implications are weighed, and consequences are projected. These decisions arise through direct engagement with the object or structure. The process culminates in action, whether reinforcing, replacing, disassembling, or reassembling. In this sense, repair sustains, upgrades, and reimagines the built environment. It opens possibilities for continuity and transformation that differ from both new construction and conservation, placing the architect within a longer temporal horizon of change.

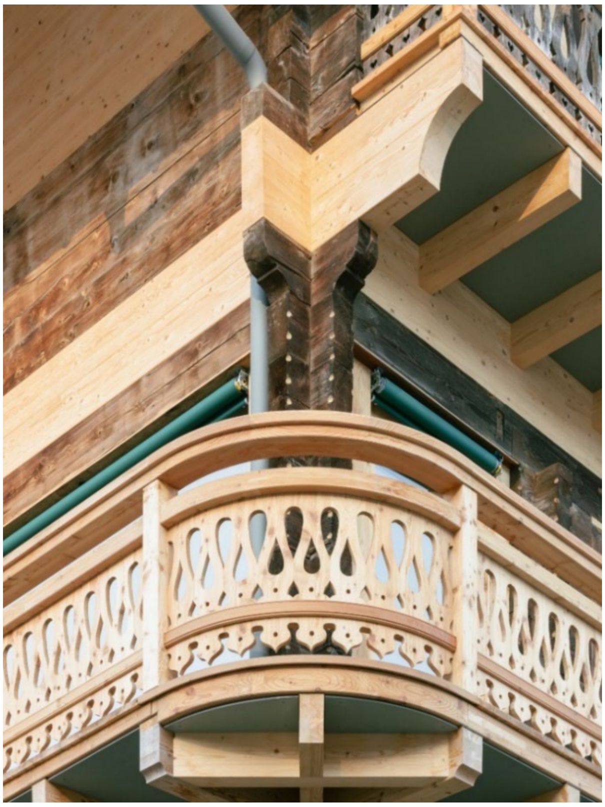


Figure 2: Detail of the façade of the Val-d'Illiez town hall, where original and new wood elements interlock. Through the intervention the building is not only preserved but also upgraded. Part of the structure was lifted by the introduction of additional beams, improving the interior height. Image: Madeleine Architectes

Yet translating this understanding into practice remains a major challenge. Knowledge is fragmented. Tacit expertise resides in craft traditions, while codified information is dispersed across technical manuals, norms, and construction details. Few of these resources are available when decisions must be made on site. Digital BIM and CAD processes promise precision and control, but these workflows are primarily designed for new construction. The default interface of our CAD environments presents users with a pristine, empty workspace, reflecting the assumption that design begins from a blank slate rather than from the complexity of the existing. This gap reveals a deeper challenge: the absence of systematic methods that allow repair to be treated as a structured and creative design activity. Unlike new construction, repair lacks shared frameworks, consistent documentation, and computational support. Decisions often rely on individual intuition and tacit craft knowledge rather than organized reasoning.

This thesis investigates how digital systems can address this gap. By capturing, analyzing, and structuring knowledge about assemblies, materials, and damages, digital workflows can offer new ways of diagnosing conditions, developing strategies, and guiding interventions. The research examines how advances in multimodal Artificial Intelligence, particularly vision-language models capable of reasoning about complex assemblies, can make repair more feasible and more deeply integrated into architectural design processes. To test this hypothesis, a mobile application was developed that organizes repair into distinct stages. Each stage is supported by specialized AI models, or agents, that combine visual and textual reasoning with interactive three-dimensional models and graph-based representations. The framework was applied across diverse case studies, from canonical objects to architectural structures, to demonstrate how repair can become a systematic, collaborative, and adaptable process.

While the ethos of repair as a generative act also exists in analogue approaches, the digital framework presented here is distinct in its structured and data-driven methodology. It moves beyond reliance on fragmented, tacit knowledge by creating accessible, transparent workflows. By integrating multimodal AI and interactive 3D models, this approach transforms repair from a reactive and improvised act into a proactive and creative design practice. It combines the deep intelligence of craft with the analytical power of computation, enabling a more precise and forward-looking engagement with the built environment. By positioning repair as a central design activity, it argues that computation can reshape the way we interact with the built world. Instead of treating existing structures as disposable, digital augmented repair can be understood as a generative process for an architecture that builds with time rather than against it.

2. THEORETICAL FRAMEWORK

2.1. The Past: Historical Discourses of Repair

> "*It is for all these buildings, therefore, of all times that we plead, and call upon those who have to deal with them, to put Protection in the place of Restoration. Stave off decay by daily care*."[3]
>
> WILLIAM MORRIS, 1877.

The concept of repair in architecture has historically been entangled with adjacent notions of alteration, restoration, conservation, and preservation.[4] Each of these terms reflects different cultural values and theoretical positions regarding the treatment of existing buildings. In the 19th century, figures such as Eugène-Emmanuel Viollet-le-Duc and John Ruskin shaped opposing schools of thought, whose impact remains evident to this day.[5] Viollet-le-Duc defined restoration as the act of returning a building to a "finished state that may in fact never have existed"[6], emphasizing stylistic completion and creative reconstruction, without dedication to historical and material authenticity.

In contrast, Ruskin, in *The Seven Lamps of Architecture* (1849), vehemently opposed restoration, arguing that any attempt to remake or embellish the old was a falsification. He insisted instead on preserving the material authenticity of historic fabric, even in decay.[7] Influenced by Ruskin's philosophy, it was William Morris who grounded these ideals in practice, establishing the Society for the Protection of Ancient Buildings (SPAB) in 1877. Its "Anti-Scrape" manifesto argued against heavy-handed restoration and in favor of minimal intervention, maintenance, and repair that respected the accumulated history of structures.[8] It remains till this day unchanged as the guiding principle of the SPAB.

These debates also laid the foundation for an increasingly global discourse on building preservation in the 20th century. *The Venice Charter* (1964), foundational to modern heritage conservation and the International Council on Monuments and Sites (ICOMOS), distinguishes between conservation (safeguarding and maintenance of heritage fabric)

---

[3] William Morris and Philip Webb, *The Society for the Protection of Ancient Buildings Manifesto* (London: Society for the Protection of Ancient Buildings, 1877), https://www.spab.org.uk/about-us/spab-manifesto.
[4] Scott, *On Altering Architecture*.
[5] Vittorio Magnano Lampugnani, "On Restoration," *Domus*, April 1990.
[6] Viollet-le-Duc, *Dictionnaire Raisonné de l'architecture Française Du XIe Au XVIe Siècle* (Paris, 1854).
[7] John Ruskin, "The Lamp of Memory," in *The Seven Lamps of Architecture* (London, 1849), 203–6.
[8] Morris and Webb, *SPAB Manifesto*.

and restoration (recovery of aesthetic or historical value while respecting authentic material). The two strategies have converged, as ICOMOS has articulated restoration in more restrained and careful terms. Although the Charter refers to “repair” only implicitly, it emphasizes minimal intervention and reversibility as guiding principles. The Charter codifies this approach most clearly in Article 9, which stresses that restoration must preserve and reveal value while respecting authentic material, and must stop where conjecture begins. Article 12 further requires that any replacement parts harmonize with the whole yet remain visibly distinct, ensuring honesty of intervention. Article 15 rejects reconstruction outright, except for the reassembly of existing fragments (anastylosis), while Article 16 introduces the principle of systematic documentation. Repair shifts from an ad-hoc practice toward an internationally agreed framework grounded in authenticity, restraint, and transparency, following scientific guidelines and respecting cultural heritage.

Later ICOMOS documents, such as the *Principles for the Preservation of Historic Timber Structures* (1999), explicitly refer to repair as a preferred strategy. They recommend traditional techniques and compatible materials to ensure structural safety while preserving authenticity.

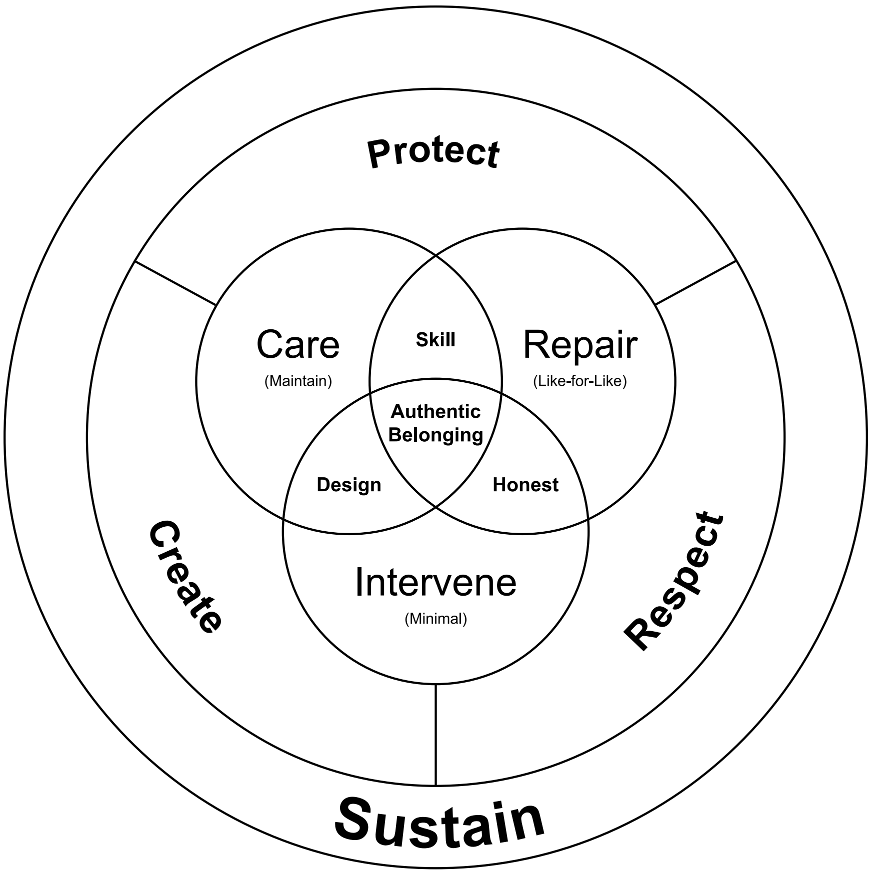


Figure 3: The SPAB Approach: A framework balancing care, repair, and intervention to protect, respect, create, and sustain our built heritage. Image: The Author, after Mary Kerrigan.

2.2. The Present: Repair under Pressure

Reflecting on these discussions, it becomes apparent that repair has historically been framed in relation to authenticity, material continuity, and the ethics of intervention. However, this historical tension between the different perspectives reveals a deeper, more complex truth: there is often no single, objectively correct or logical repair strategy. The ideal of preserving an object's complete material authenticity often clashes with practical realities. Despite its noble character, this conviction may in practice serve as a comfortable retreat.[9]

Ultimately, when thought through to the end, the nature of repair emerges as a negotiation between multiple, competing value systems, each governed by its own internal logic. Every intervention initiates a chain of further decisions that must be anticipated in advance.[10] Intact elements may need to be dismantled or compromised to access the part requiring attention. One must also determine if a repair is even feasible, as this depends on the available resources, knowledge, and skills.[11] What makes a repair "valid" is not its adherence to a universal logic, but its alignment with a particular set of priorities. Consider a rotten beam in a timber structure:

The conservator, following Ruskin's logic, would argue for a minimal, honest repair that preserves as much authentic material of the beam as possible, even if it is structurally less perfect. However, it satisfies the demand for honesty.

The engineer, guided by a logic of performance, might propose reinforcing it with modern solutions or replacing it entirely to guarantee safety and longevity, viewing the preservation of weakened material as illogical and striving for optimization (upgrade).

The architect, potentially echoing Viollet-le-Duc's creative impulse, could see the damage as an opportunity for a contemporary aesthetic intervention, where the repair is intentionally expressed as a new layer of history.

The client, maybe driven by a logic of economy, finds the most valid solution to be the fastest and cheapest replacement that meets basic code requirements, hoping for a quick and cost-effective solution.[12]

---

[9] Michael Petzet and Gert Mader, *Praktische Denkmalpflege* (Stuttgart: Kohlhammer, 1993), 210.
[10] Petzet and Mader, 210.
[11] Silke Langenberg, ed., *Repair "Encouragement to Think and Make"* (Berlin: Hatje Cantz, 2018), 13.
[12] In his works, Bruno Reichlin questions whether the existing building stock should also be regarded as an economic resource in relation to new construction, flipping the argument. While the interventions required to comply with contemporary standards are often extensive, the costs of demolition and rebuilding may

Each of these strategies can be justified through a coherent line of reasoning, yet they lead to profoundly different physical outcomes. No one would concede that their conclusion is devoid of reason and could find arguments for all of their intended alterations. These underlying assumptions – the *priorities* – are what shape the solution.

Divergence in priorities is often rooted in a failure of communication across the various disciplines involved in a building's lifecycle. Without a collaborative dialogue, the decision-making chain becomes fragmented. The fate of a building is sealed not by a single, malicious choice, but by a series of disconnected, well-intentioned decisions. A feature of cultural value may be lost simply because the right specialists were never in the same room, at the same time, to discuss its significance. This fragmentation highlights a fundamental truth: a building is not a single, unified object but a complex system of interacting components, each governed by a different logic and timeline.

The concept of "Shearing Layers", articulated by Frank Duffy and later expanded by Stewart Brand, provides a conceptual framework for understanding why repair is so often hindered and demolition can become the path of least resistance. Duffy, a British architect, observed that a building is not a single, monolithic entity but is composed of several layers, each with a different lifespan. Brand expanded this idea into six distinct layers:[13]

SITE: The geographical location, which for Brand is "eternal".

STRUCTURE: The foundation and load-bearing elements, which can last from 30 to 300 years. To Brand, these are the most difficult and expensive components to alter.

SKIN: The exterior surfaces, which may change according to Brand every 20 years due to fashion, technological upgrades, or wear and tear.

SERVICES: The "working guts" of a building, including electrical wiring, plumbing, HVAC systems, and elevators. Brand estimates obsolescence every 7 to 15 years.

SPACE PLAN: The interior layout of walls, ceilings, and floors, which can change as frequently as every 3 years in a commercial space.

STUFF: The furniture or appliances, which are in constant flux, moving daily or monthly.

---

ultimately be even higher. Decisions regarding repair or upgrading can therefore, in the end, also be determined by a consideration of overall real-world costs. Bruno Reichlin, Bruno Reichlin, "Überlegungen zur Erhaltung des Architektonischen Erbes des 20. Jahrhunderts," in *Bestand der Moderne. Von der Produktion eines Architektonischen Werts* (Zurich: Park Books, 2012), 31.

[13] Stewart Brand, *How Buildings Learn: What Happens After They're Built* (NY: Viking Press, 1994), 13.

The central insight of the shearing layers concept is that these layers do not age in harmony. Instead, "a building is always tearing itself apart"[14] : The fast- moving inner layers (Stuff, Space Plan, Services) are in constant tension with the subsequent slow-moving outer layers (Skin, Structure, Site). According to Brand, this inherent conflict is a primary driver behind demolition.

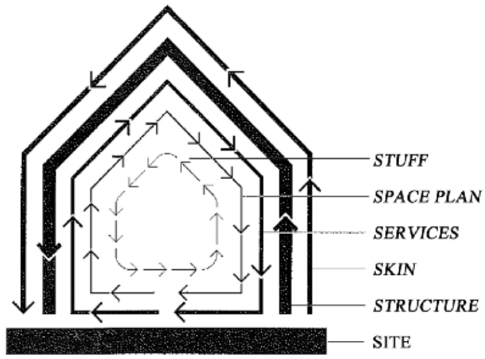


Figure 4: Brand describes the building in state of turmoil, as some components need to be replaced sooner than other. Image: Stewart Brand.

We can conclude, that fundamental problem arises when these layers are too tightly integrated. When fast-changing systems are deeply embedded within slow-changing ones, repair and maintenance becomes a destructive and costly act.

Consider the Services. A building's plumbing and electrical systems are vital to its function, yet they have a relatively short lifespan compared to the structure that houses them. When these systems are cast into concrete foundations or threaded through inaccessible structural cavities, what should be a straightforward repair becomes a logistical nightmare. To replace a failing pipe, one might have to break apart the floor. To run new data cables, one might have to tear open parts of walls and ceilings that were meant to last for decades.

This conflict between layers renders many buildings maladaptive. The durability of the slow layers prevents the necessary evolution of the quick ones. When the costs and disruptions of upgrading essential services outweigh the benefits, economic reasoning often favors demolition and replacement. Such decisions, however, come with a staggering ecological toll. The construction industry is already a primary source of global emissions, and the demolition of existing structures generates enormous amounts of waste, discarding the embodied energy and material value of entire buildings. This is not

[14] Brand, 13.

an isolated problem but a systemic condition represented by a vast amount of buildings that have been demolished in recent years. To address it, repair must be rethought as a design problem: an integrated practice that links technical precision with long-term adaptability. Only through such systemic understanding can repair evolve into a coherent, strategic, and sustainable mode of architectural action.

2.3. The Future: Towards a Repair Society

> *"If you let things slide, a small water stain turns into major damage – and in the end, it always becomes much more expensive than if you had taken care of it right away."*[15]

As addressed by Uta Hassler, the current situation frames a central conflict in our relationship with the built environment: Buildings and their components are simultaneously viewed as potential resources (repositories of embodied energy, material value, and cultural memory), and on the other hand as potential burdens: a structure that is materially contaminated, functionally obsolete, or economically unviable under the current paradigm.[16] Hassler recognizes the strategic challenge to develop practices that can transform a potential burden back into a valuable resource.

The need of repair will become increasingly urgent in the future. The majority of the building stock in countries like Germany was erected during the economic boom of the mid-20th century.[17] These structures are now collectively reaching an advanced age, presenting systemic maintenance and adaptation issues on an unprecedented scale for the future. This condition is particularly evident in the public sector: schools, town halls, and community centers that shape everyday life. Yet, many of them suffer from decades of deferred maintenance. Currently we witness an municipal investment gap exceeding 200 billion euros, roughly a fifth of all municipalities lack the resources to properly maintain their public buildings and their infrastructure.[18] On top of the neglect and oversight of many decades, the legislative pressure to quickly reduce energy consumption adds a new layer of urgency and complexity to the existing challenges.

---

[15] "Widerstand gegen Abrisspläne der Kapelle auf dem Waldfriedhof Rhöndorf," *General Anzeiger*, November 15, 2025.
[16] Michael Petzet and Uta Hassler, eds., *Das Denkmal als Altlast? Auf dem Weg in die Reparaturgesellschaft*, vol. 21, ICOMOS – Hefte des Deutschen Nationalkomitees (Munich: Lipp GmbH, 1996).
[17] Statistische Ämter des Bundes und der Länder, *Wohngebäude nach Baujahr* (Statistikportal, n.d.), https://www.statistikportal.de/de/wohngebaeude-nach-baujahr.
[18] *KfW Kommunalpanel 2025 – Summary* (Frankfurt am Main: KfW Research, 2025), 1.

The current marginalization of repair may be not accidental. Some believe it may be rooted in both the material culture of our building industry and the economic logic of a "throwaway society”[19]. Silke Langenberg argues that the dominance of industrially prefabricated components, complex assemblies, and sealed systems has made repair increasingly difficult.[20] Designed for speed and seamless assembly rather than disassembly, these systems often preclude modification or piecemeal replacement, making demolition and substitution the default response. Even further, for Langenberg, repair should not be confined to restoring a previous state. In the book *Upgrade* (2016), she presents a broad spectrum of experimental student projects, which collectively explore how interventions can serve not only to restore but to enhance.[21] These works illustrate her conviction that not only does “everything have value”[22], but repair should also be seen as upgrading: a process aimed at improving performance, resilience, and adaptability to future needs. In the face of resource scarcity and the urgent demand for sustainability, such an approach fundamentally challenges the prevailing paradigm. The emerging imperative is to transition towards what Wilfried Lipp discussed as a “Repair Society”[23]. For Lipp, society has already, in many respects, entered this state,[24] and he regarded the twenty-first century as destined to become a century of repair.[25] Within such an optimistic framework, repair and upgrading shift from peripheral maintenance tasks to strategic practices essential for a sustainable future.

The practical barriers to repair in modern construction remain significant, despite growing attention to circular construction and the reuse of building elements. The sector’s immense footprint, with raw material consumption projected to double by 2060,[26] shows that recycling and reuse alone will not suffice. This raises the urgent task of identifying which structures are readily repairable and how future buildings can be designed to meet this standard. What is to be gained from this approach is not merely a more sustainable building practice, but a more profound valuation and empathetic engagement with our built environment. This resonates with Thomas Will's powerful metaphor of architectural

---

[19] Wilfried Lipp, “Aspekte zur Reparaturgesellschaft,” in *Vom Modernen zum Postmodernen Denkmalkultus? Denkmalpflege am Ende des 20. Jahrhunderts*, Arbeitshefte Des Bayerischen Landesamtes Für Denkmalpflege (Munich: Bayerisches Landesamt für Denkmalpflege, 1993), 69:9.
[20] Langenberg, *Repair*, 14.
[21] Silke Langenberg, *UPGRADE Making Things Better*, ed. Silke Langenberg (Hatje Cantz, 2022).
[22] Silke Langenberg, “Silke Langenberg: «Alles hat einen Wert»,” interview by Marc Frochaux, 2023, Website, https://education.espazium.ch/de/hochschulpublikationen/interview-silke-langenberg-ethz.
[23] Lipp, “Aspekte zur Reparaturgesellschaft.”
[24] Wilfried Lipp, *Rettung von Geschichte für die Reparaturgesellschaft im 21. Jahrhundert. Sub Specie Conservatoris*, ICOMOS – Hefte Des Deutschen Nationalkomitees (Berlin: Deutsches Nationalkomitee von ICOMOS, 1996), 21:146.
[25] Lipp, “Aspekte zur Reparaturgesellschaft,” 9.
[26] OECD, *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences* (Paris: OECD Puplishing, 2019), 122.

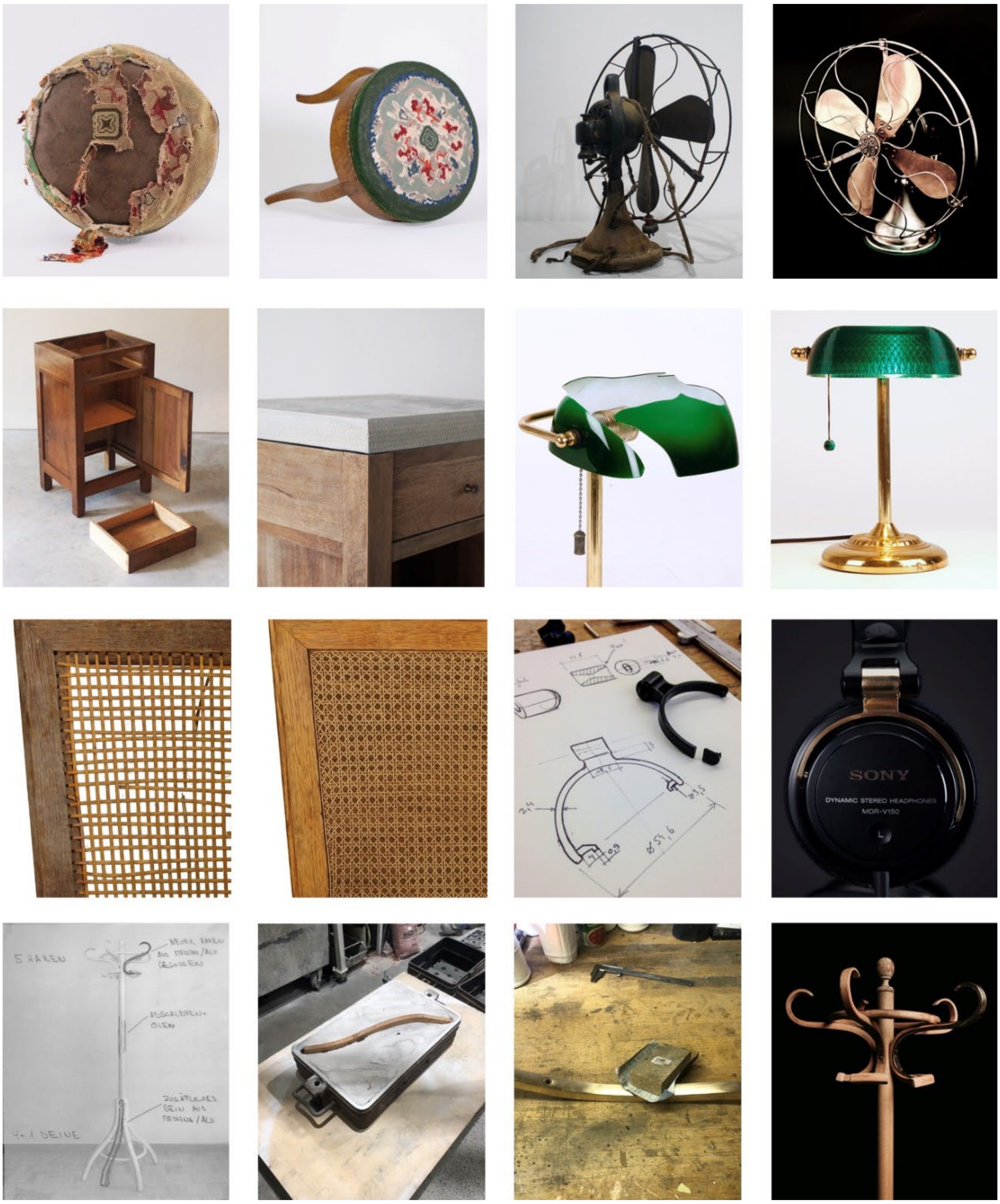


Figure 5: Student works, depicting the original state of an object and the repaired state. The objects are often times more resilient than before. Image: Silke Langenberg, ETH Zurich.

practice as “geriatrics”. Rather than seeking to replace an aging structure with a new, optimized reproduction, the goal is to care for the existing, aging body of the building. This ethos involves accepting its history, its imperfections, and its inherent otherness, while intervening thoughtfully to ensure its continued life and vitality.[27]

Such a care-driven mindset fosters a deep familiarity with a structure. By thoughtfully intervening to ensure its continued life, the process transcends material maintenance. It cultivates place attachment and, more fundamentally, enacts a practice that the philosopher Martin Heidegger identified as the ontological core of "dwelling". Heidegger posits that dwelling is not an activity we *do* within a building, but rather the fundamental condition of human existence on earth. This state of being is characterized by an active "sparing and preserving" of the world, which allows things to remain in their own nature and to be themselves.[28] The act of repair, therefore, becomes a primary mode of this engagement through thinking about the built environment. It is not simply a reaction to decay but an affirmation of the building’s being, a practice that allows it to persist and evolve alongside us. Psychological impacts like this are empirically supported by the studies of Norton, Mochon and Ariely, which demonstrated that the investment of one's own labor into an object significantly increases its perceived value and the emotional bond to it.[29]

Repair is therefore on track to become a central focus of design practice, with its importance resonating far beyond the field. As the profession increasingly confronts the task of working with the existing, the architect's primary role evolves: to continue a building's narrative with new layers that are both respectful of the old and responsive to contemporary needs while looking into the future and consider adaptability. This evolution transforms repair from a reactive measure into a conscious and proactive design strategy, a shift best described by Bruno Reichlin as an “inverted design process”. [30] Here, the architect does not move from a program to a building; rather, they start with the existing structure – its materials, history, construction, craft or technology – and derive from this deep analysis a program of latent possibilities. The architect’s task, Reichlin concludes, is less about the imposition of a grand gesture and more about a humble and intelligent act of interpretation. It is the recognition that a structure often already holds within itself the means of its own future.

---

[27] Will, “Weiterbauen oder Wiederbauen? Über Tradition, Geriatrie und Reproduktion,” in *Kunst des Bewahrens: Denkmalpflege, Architektur und Stadt* (Dietrich Reimer Verlag, 2020), 51–61.
[28] Martin Heidegger, “Building Dwelling Thinking,” in *Poetry. Language. Thought*, trans. Albert Hofstadter (New York: Harper Colophon, 1975), 143–59.
[29] Michael I. Norton, Daniel Mochon, and Dan Ariely, “The IKEA Effect: When Labor Leads to Love,” *Journal of Consumer Psychology* 22, no. 3 (2012): 453–60.
[30] Reichlin, “Überlegungen,” 38.

3. RESEARCH OBJECTIVE & CONTEXT

Establishing a digital framework for repair requires both a clear definition of objectives and careful testing in real-world contexts. The research therefore formulates its goals in direct response to the absence of structured workflows for repair, and explores them through case studies that span different scales and materials. These experiments not only validate feasibility but also reveal the limits, constraints, and opportunities that shape the design of the system. From this process a set of challenges emerges, highlighting where representation, workflow, and usability demand particular attention if multimodal AI is to become a meaningful partner in repair practice.

3.1. Problem and Goal Definition

The problem addressed in this thesis is the absence of structured, digital workflows for guiding repair processes that combine both visual and logical reasoning. Conventional BIM and CAD systems are primarily oriented toward new construction and offer no structured workflows for diagnosing, planning, guiding or documenting repair.

Multimodal AI offers distinctive capacities that make it relevant for repair design. Trained on vast amount of technical, scientific, and cultural knowledge. It functions as a cumulative memory able to retrieve and recombine fragments of dispersed expertise. It can interpret diverse, unstructured inputs, that can range from documents and text to images and scans, which can be immediately translated into coherent structures that support further reasoning. Beyond static knowledge, it reacts flexibly to user feedback and contextual constraints, adapting proposals as conditions change. Through its ability to connect to external resources such as internet search, multimodal AI further expands the available knowledge space. Together, these capacities enable it not only to answer questions but also to structure complex problems, generate strategies, and guide decision-making across varying scales of repair.

The purpose of this thesis is a digital workflow that leverages multimodal AI to structure repair into a coherent and creative process, coupled with an user interface that can expand the designers capacity to analyze and intervene in existing structures. By embedding these representations in a mobile environment, the application seeks to provide accessible, intuitive, and context-specific guidance.

3.2. Experimental Case Studies: A Multi-Layer Approach

The central effort of this research is a mobile-first web application designed to support and augment repair processes using Artificial Intelligence. The development follows a Design-Based Research (DBR) approach, allowing for continuous and iterative refinement of the system based on its performance in real-world contexts. To evaluate both feasibility and scalability, the prototype is tested through two case studies spanning different scales.

1. **Canonical Objects:** A set of 1960s “Santo” chairs by the Swiss designer Edlef Bandixen serves as the initial testbed. These chairs combine diverse materials and complex joints while retaining standardized geometry, making them ideal objects for comparative analysis. The aim is to demonstrate that a chair photographed with a smartphone can be transformed into a structured assembly, have damages detected, and receive a repair plan within minutes. With multiple copies of the chair available, several users were provided with the generated repair plans to test not only the effectiveness and repeatability of the proposed strategies and the usability of the mobile interface, but also to explore the design space of possible interventions, their guidance and flexibility, as well as the constraints revealed in practice.

2. **Architectural Structures:** To test the framework’s ability to handle increased complexity, scale, and contextual dependencies, the workflow is applied to a real building: the Forest Cemetery Chapel in Rhöndorf, designed by Hans-Uwe Rein. At this scale, the system must not only capture and model geometric complexity but also incorporate historical data, material weathering, and site-specific conditions. The integration of multimodal inputs, including historical photographs, point cloud surveys, and on-site damage assessments, becomes essential to build a reliable assembly and action model. This larger case demonstrates how the system can move beyond isolated artifacts toward architectural environments, bridging detailed repair reasoning with broader questions of conservation strategy, material authenticity, and long-term maintenance planning.

Together, these two case studies validate the workflow across different scales. At the canonical object scale, assembly generation and repair planning can be achieved rapidly and tested with experimental interventions on the actual chairs. At the architectural scale, the system demonstrates its potential to evolve into an accessible and scalable platform for repair assessment and action guidance.

3.3. Key Challenges

Several challenges arise in this research:

- **Input Data:** Identifying what kinds of input data (images, text, scans, historical records) are needed and how to accumulate them consistently for knowledge generation.
- **Representation:** Designing data structures that can balance geometric detail (3D assemblies) with logical clarity (graph-based reasoning) in order to capture damages, actions, and repair histories.
- **Workflow Design:** Translating repair from a situated, embodied practice into a structured digital sequence without reducing its complexity or ignoring tacit knowledge.
- **Flexibility and Adaptation:** Allowing the system to incorporate user feedback and contextual constraints, while keeping outputs coherent.
- **Usability:** Creating a mobile application that is accessible and intuitive, while still handling complex structural data and multimodal inputs.
- **Integration:** Combining multimodal AI reasoning with human expertise so that the system supports, rather than replaces, decision-making.

4. OPERATIVE FRAMEWORK

This chapter outlines the methodological framework used to develop and evaluate the intelligent system for architectural repair. The approach is rooted in a constructive research paradigm, where the primary contribution is the design, implementation, and testing of a novel artifact to address the defined problem.

4.1. System Overview and Scope

The prototype establishes a digital environment where repair is organized into distinct phases supported by Artificial Intelligence. Its scope ranges from small objects to larger architectural components, ensuring that the approach can be tested at different levels of complexity. The system is developed as a mobile-first application to allow direct use in situ and to provide consistent interaction across devices.

4.2. Conceptual Workflow: From Perception to Action

The application's core logic is structured around a sequential, three-phase workflow that translates the logic of repair into a coherent, AI-assisted process. This framework forms the backbone of the system's design and user experience:

PHASE I – GENERATING KNOWLEDGE: This initial phase focuses on translating unstructured, real-world data (photographs, documents, text descriptions) into a structured, machine-readable format. The system first deconstructs an "ideal" version of an object into a hierarchical assembly of parts. It then compares this canonical model to photographic evidence of the actual object to identify and classify damages (e.g., cracks, missing parts, defects), augmenting its data model accordingly.

PHASE 2 – GENERATING ACTIONS: With a comprehensive digital understanding of the object's assembly and its damages, this phase addresses logical reasoning. The system utilizes AI to generate a coherent, step-by-step repair plan that is both logical and actionable for a human user. The emphasis is on task decomposition, breaking down complex repairs into a sequence of simple, manageable actions.

PHASE 3 – EXECUTING ACTIONS: This final phase focuses on the interactive guidance of the physical repair process. The system provides the user with the generated plan and features a conversational AI agent to offer context-specific advice, clarify procedures, and answer questions.

All observations and actions are recorded, creating a structured digital history of the intervention for future analysis and review.

4.3. Technical Implementation

The conceptual framework was translated into a working prototype through a mobile-first web application. A web app was chosen for its accessibility across devices, ease of deployment, and ability to run directly on site without installation. Updates can be rolled out centrally, ensuring that the system remains lightweight and usable for both experts and non-experts.

At its core, the application integrates visual–language models (VLMs). These models combine image and text interpretation in a single reasoning process, making them ideal for repair scenarios where photographs and descriptions must be analyzed together. By merging both modalities into one structured output, VLMs reduce complexity for the user, who only needs to provide simple inputs while the system generates coherent assemblies, damage catalogs, or repair plans.

4.3.1. Prompt Engineering Layer

A central methodological decision in this research was not to train or fine-tune a model, but instead to design a robust prompt engineering strategy. The aim was to achieve repeatable, high-quality results while keeping the workflow lightweight, transparent, and adaptable. Training or fine-tuning would have required extensive domain-specific datasets, high computational resources, and limited flexibility to adjust to different repair contexts. By contrast, prompt engineering allows the system to leverage the broad multimodal capabilities of large pretrained models while steering their behavior toward domain-specific outputs.

The prompts used in the prototype are carefully structured to enforce consistency and reliability (A simplified Example can be seen in Figure 6). For every step and each query, the backend defines strict output schemas in JSON format, ensures that responses remain machine-readable, and specifies rules for geometric orientation, part descriptions, or damage categories. This design allows the AI model to function as a flexible reasoning engine while keeping the structure of the output predictable and directly usable in subsequent steps of the pipeline.

In cases where more precision is required, the backend appends few-shot prompting examples that illustrate the desired output format and content. This means that the model is shown a small number of concrete examples of valid input–output pairs within the prompt itself. These serve as mini training instances, guiding the model toward the expected structure without the need for full retraining or fine-tuning. The included examples act as templates that anchor the model's responses and reduce ambiguity. By embedding such examples directly into the backend prompt, the system ensures that outputs remain close to the defined schema even when user inputs are vague or incomplete.

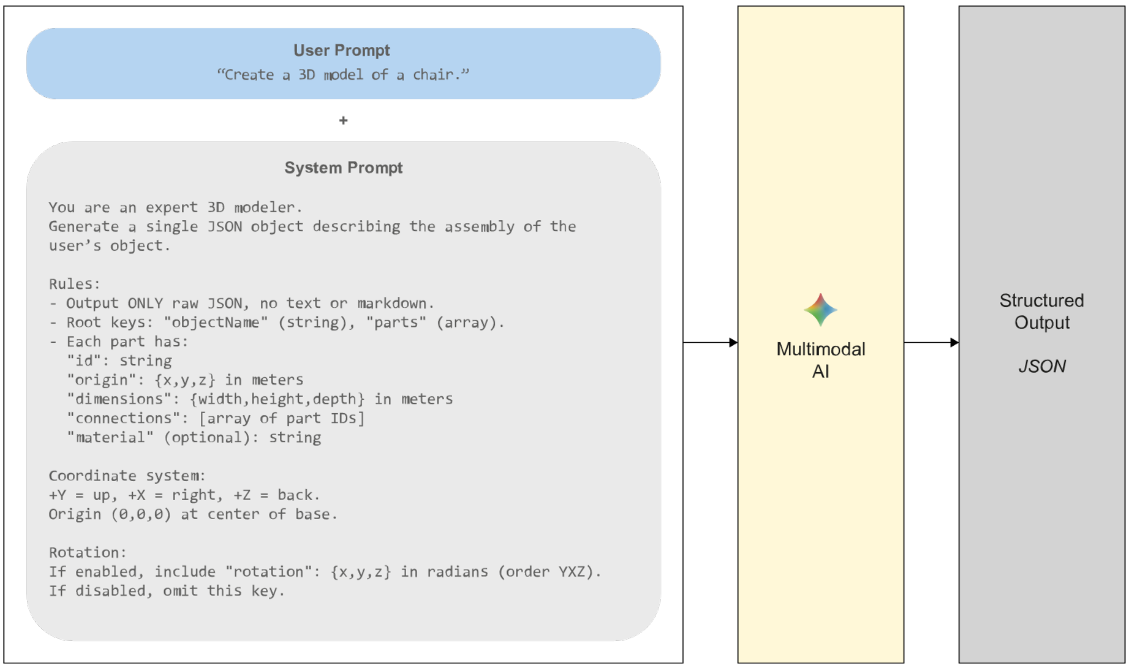


Figure 6: Interaction between user input and system prompt. A simple request is paired with a backend enforcement prompt that specifies rules and schema, ensuring the multimodal AI produces a structured JSON output.

4.3.2. AI Engine Selection and Validation

Based on a preliminary comparative study to ensure the highest quality output for the task of assembly generation, a selection of suitable models was made. Several leading generative multimodal AI systems were tested using a consistent input setup: a single reference image of the chair, accompanied by textual prompts. To provide an objective benchmark, a CAD model of the chair was generated by hand, serving as the ground truth against which all model outputs could be compared. Each AI-generated assembly was qualitatively evaluated according to part–whole coherence, geometric accuracy, and responsiveness to iterative refinement through natural language feedback. While all models demonstrated some ability to capture basic form, their performance varied significantly in terms of completeness, scale, and logical consistency of parts. Among them, Gemini 2.5 Pro was selected as the most suitable model for further development. It produced assemblies with the highest geometric fidelity, consistent part relationships, and reliable responsiveness to corrective input, making it the most robust foundation for integrating into the repair workflow.

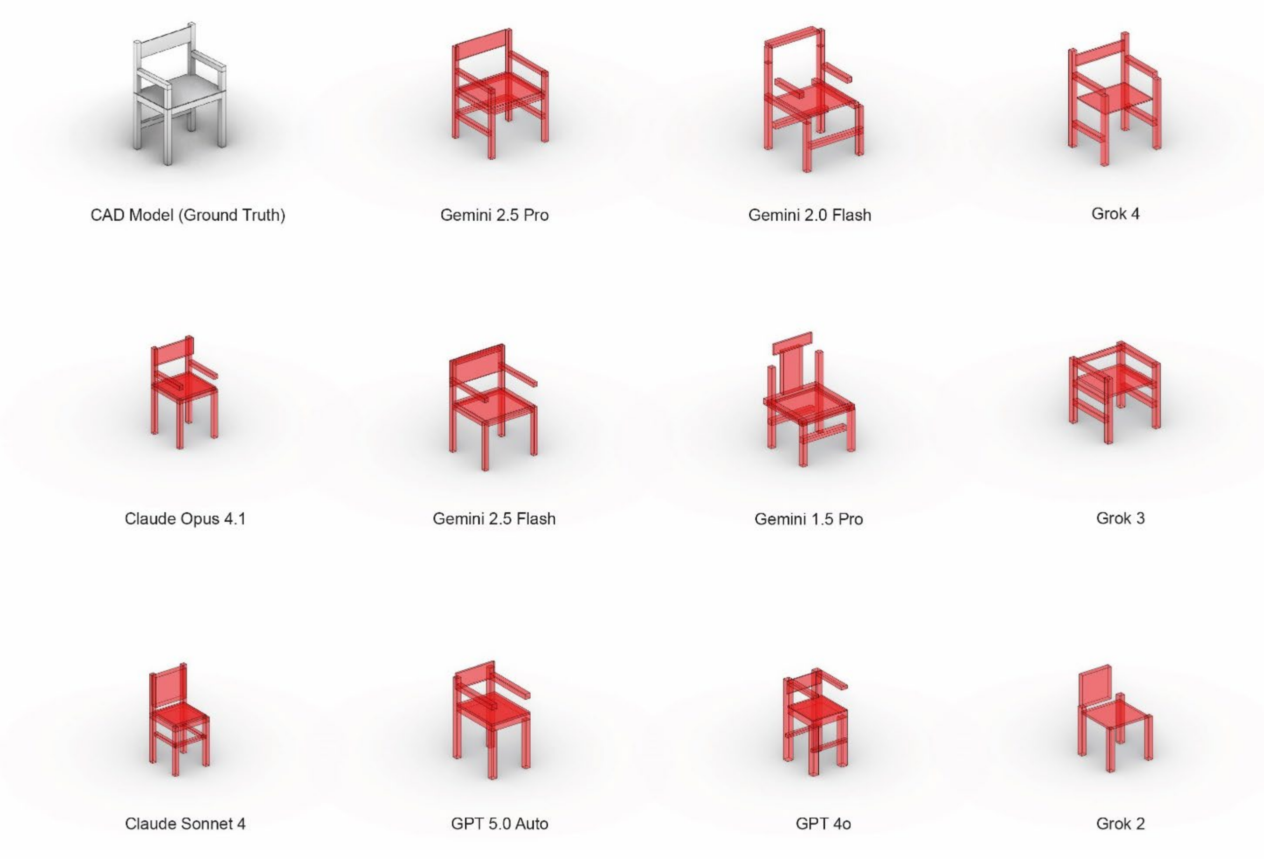


Figure 7: Results of the AI comparison of the same chair

4.3.3. System Architecture and Stack

To realize the conceptual framework, a dedicated system architecture and structured data pipeline were developed. The prototype takes the form of a mobile-first web application, ensuring accessibility across devices without requiring native installation. Its role is to translate unstructured inputs, such as images or documents into structured repair data that can be visualized, reasoned about, and documented (See Figure 8).

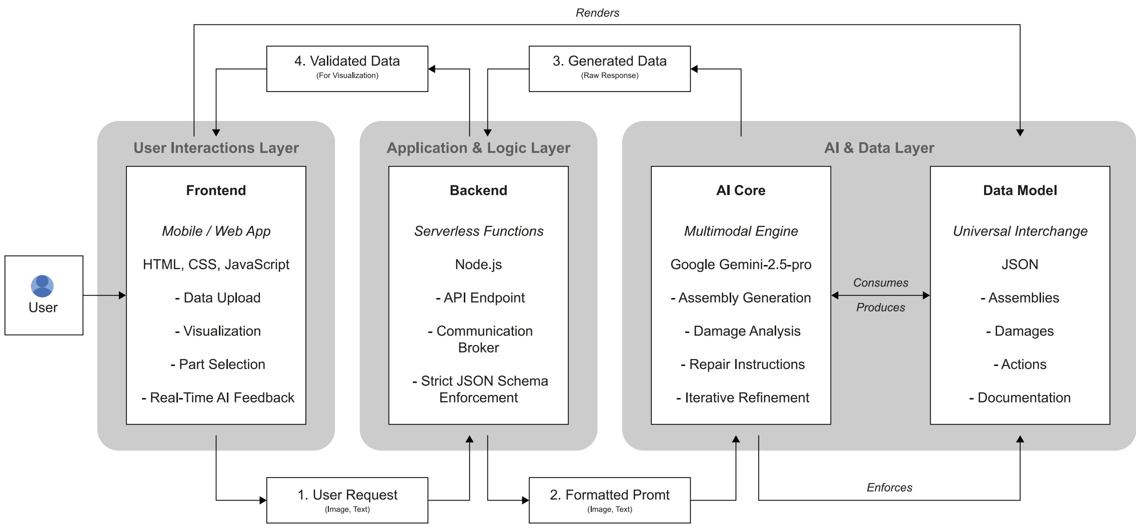


Figure 8: System architecture of the AI-assisted repair workflow from user input to validated repair data.

The application is implemented with standard web technologies including HTML5, CSS3, and JavaScript ES6 modules. Interactive three-dimensional assemblies are rendered using the Three.js library, while graph-based visualizations of connections and repair plans are generated with D3.js. The backend is organized into serverless functions written in Node.js, which communicate with multimodal Google Gemini AI models through REST API calls. This modular approach ensures that the system remains lightweight and scalable while allowing individual components such as rendering, reasoning, or documentation to evolve independently.

At the center of the pipeline lies JSON as the universal interchange format. JSON was selected because it integrates natively into JavaScript environments, is human readable, and remains minimal while supporting nested structures. This makes it possible for both developers and non-technical users to inspect and modify repair data without specialized tools. Its language independent design guarantees interoperability across platforms, so that the same dataset can flow consistently between AI models, visualization libraries, and the user interface. JSON is also flexible enough to represent both simple numerical values, such as dimensions, and complex relational structures, such as part connections or repair dependencies. This combination of clarity, interoperability, and structural rigor makes JSON the backbone of the workflow, supporting transparent documentation and reliable data exchange throughout all phases of perception, reasoning, and action.

4.4. Pipeline

The initial conceptual framework was structured in three phases: **Generating Knowledge, Generating Actions,** and **Executing and Guiding Actions.** While this captured the broad logic of repair, implementation revealed that phases contained distinct sub-processes that needed to be explicitly modeled in the interface and in the data pipeline.

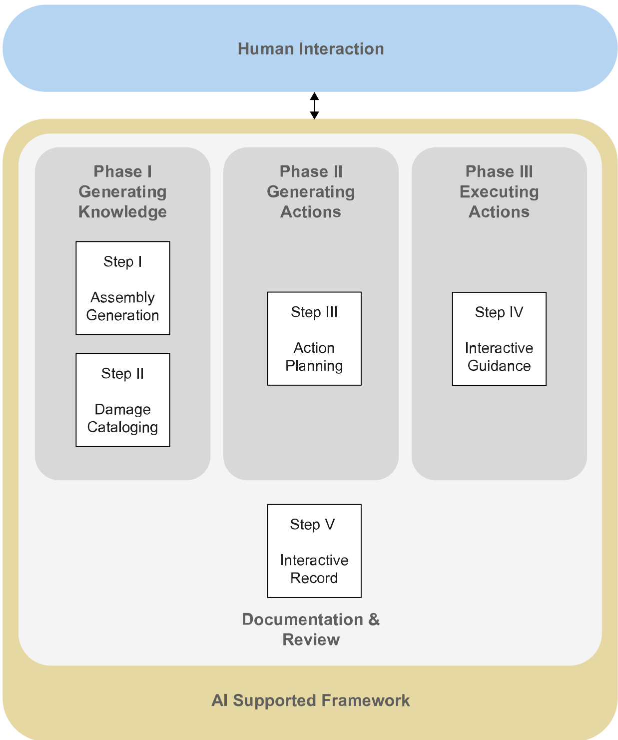


Figure 9: The final Five-step pipeline combining human interaction and AI support, from generation of knowledge and actions to documentation and review.

In Phase I (Generating Knowledge) two tasks emerged: the creation of a canonical assembly model and the comparison of this model with real-world evidence to catalog damages. This separation ensures that a reusable blueprint can be generated independently of specific cases and that damages are classified consistently. The phase was therefore divided into Step I: Assembly Generation and Step II: Damage Cataloging.

In Phase II (Generating Actions) the reasoning process required further structuring. This is the stage where nearly all design decisions are made, as user and AI collaborate to translate the repair strategy into a graph of dependent tasks, where each action is atomic, ordered, and connected. This became Step III: Action Planning.

In Phase III (Executing Actions) two complementary needs appeared: interactive guidance for the repair itself, and systematic documentation of the process for accountability and reuse. This led to Step IV: Interactive Guidance

At a later stage, Step V: Review and Documentation allows for a structured record of the entire object, including its assembly, detected damages, performed interventions, and any modifications made during the process. This creates a comprehensive digital history that can be revisited for accountability, learning, or future repair cycles.

By expanding the three phases into five steps, the pipeline becomes more granular, transparent, and directly actionable. Each step corresponds to a discrete dataset (assembly.json, damages.json, plan.json, guidance process, and review record), ensuring that both AI reasoning and human input are traceable at every stage.s

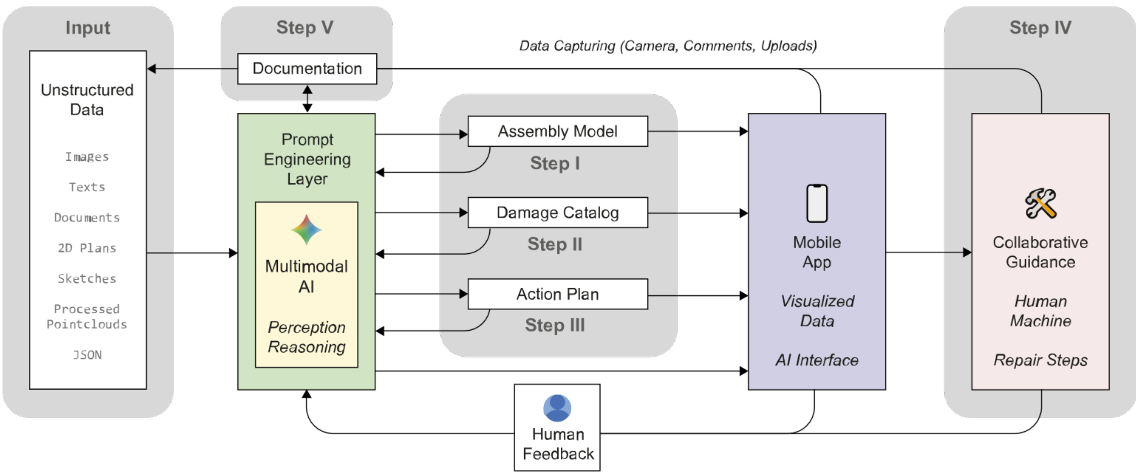


Figure 10: System architecture and data pipeline, showing how unstructured inputs are processed into structured assembly models, damage catalogs, and action plans, which are visualized, guided, and documented through the mobile app.

Figure 10 shows how unstructured inputs such as photographs, scans, or text are processed into structured assembly models, damage catalogs, and repair plans. The system's data pipeline transforms these qualitative, user-centric inputs into JSON data sets that drive the repair process, enabling users to generate knowledge, assess damages, formulate actions, and document outcomes, leveraging multimodal AI in every step.

4.4.1. Generating Knowledge

In this framework any building object or piece of furniture is described as an **assembly**. An assembly is a structured representation of constituent parts, each defined by its geometry in three dimensions and its topological relations to other parts. This abstraction functions as a reusable container. At first it holds only the canonical description of the object's form, and later it is enriched by recording, identifying, and locating damages. By treating the assembly as the primary data structure, the workflow ensures that all subsequent reasoning steps from damage cataloging to repair planning and execution are grounded in a consistent and machine readable model.

Step 1 - Assembly Generation: The process begins with the user providing initial data, such as photographs, documents, or a text prompt describing the object or the user's goal. Preferably, this input represents an ideal, undamaged object. A generative multimodal AI model analyzes the data to produce assembly.json, a structured file detailing each part's ID, origin, dimensions, and connections.

Structure of the JSON:

```
Object: Name of Object
  Parts:
    Part: Unique Identifier
      - Position: x=0, y=0, z=0
      - Size: width, depth, height
      - Rotations: x=0, y=0, z=0,
      - Connected to: Other Part
  …
```

Example:

```
{
  "objectName": "chair",
  "parts": [
    {
      "id": "leg_front_left",
      "origin": { "x": 0, "y": 0,
"z": 0 },
      "dimensions": { "width":
0.05, "height": 0.45, "depth": 0.05
},
      "connections": ["seat_panel"]
    }
…
```

To ensure robust, tool-consumable output, the backend constructs a system prompt that strictly enforces JSON-only responses without markdown or prose, specifies the assembly JSON-schema (objectName; parts with id, origin, dimensions, connections), and fixes a global coordinate frame (+Y up, +X right, +Z back; origin at base center). All lengths are in meters. As rotations may not be always necessary for generating desired structures, a runtime switch (allowRotations) appends one of two rotation policies: either every part must include a rotation {x,y,z} field applied in YXZ order, or rotation is disallowed, speeding up the thought process of the AI. Orientation is then expressed solely via origin and dimensions. Depending on the user's action, the request can include different types of input: a textual instruction, one or more files (images or documents), a combination of both, an existing assembly JSON to be modified with human feedback, a JSON generated from a point cloud, or a text-only instruction (see Figure 11).

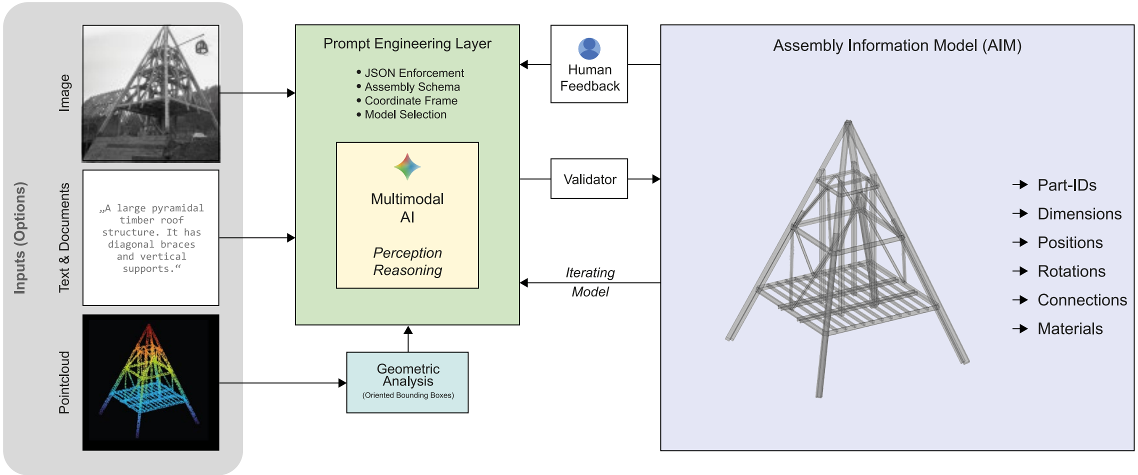


Figure 11: Multiple input variations feed a single prompt engineering layer (situated in the backend) that filters all data and sets fixed rules to the desired output, the assembly information model. This data can be visualized and used again for an iterative query together with human feedback.

Only box-shaped geometries (cuboids) are used, as they offer a simple yet effective parametric description (width, height, depth) that approximates most structural elements. While this is limited in representing more complex geometries, the use of cuboids ensures computational efficiency and clear graph-based connections

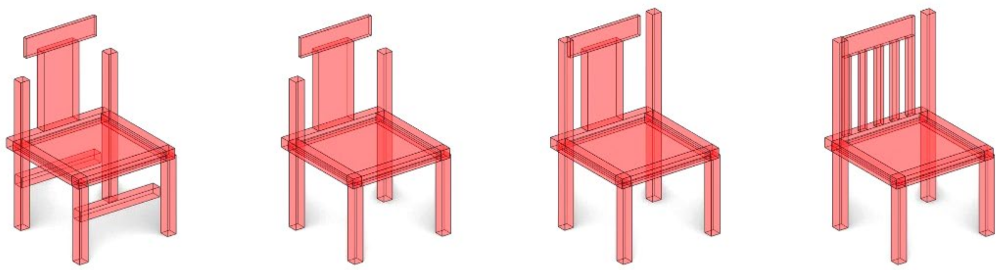


Figure 12: Iterative refinement of the generated chair model through user feedback: a) initial output, b) removal of lower supports, c) extension of back legs, d) subdivision of backrest. The sequence shows how geometry remains editable via natural-language comments.

Once generated, the model is visualized for the first time, allowing the user to interact with the output and refine it through comments (Figure 12). For example, the model generated from a single chair image was acceptable but not fully satisfying, and was subsequently adapted with comments such as: “Remove lower supports,” “Extend back legs upwards,” or “Divide backrest into smaller elements”. Each iteration builds on the last. The file also provides the raw data for rendering the interactive 3D model and a structural assembly graph (Figure 13), which visualizes the relationships between components.

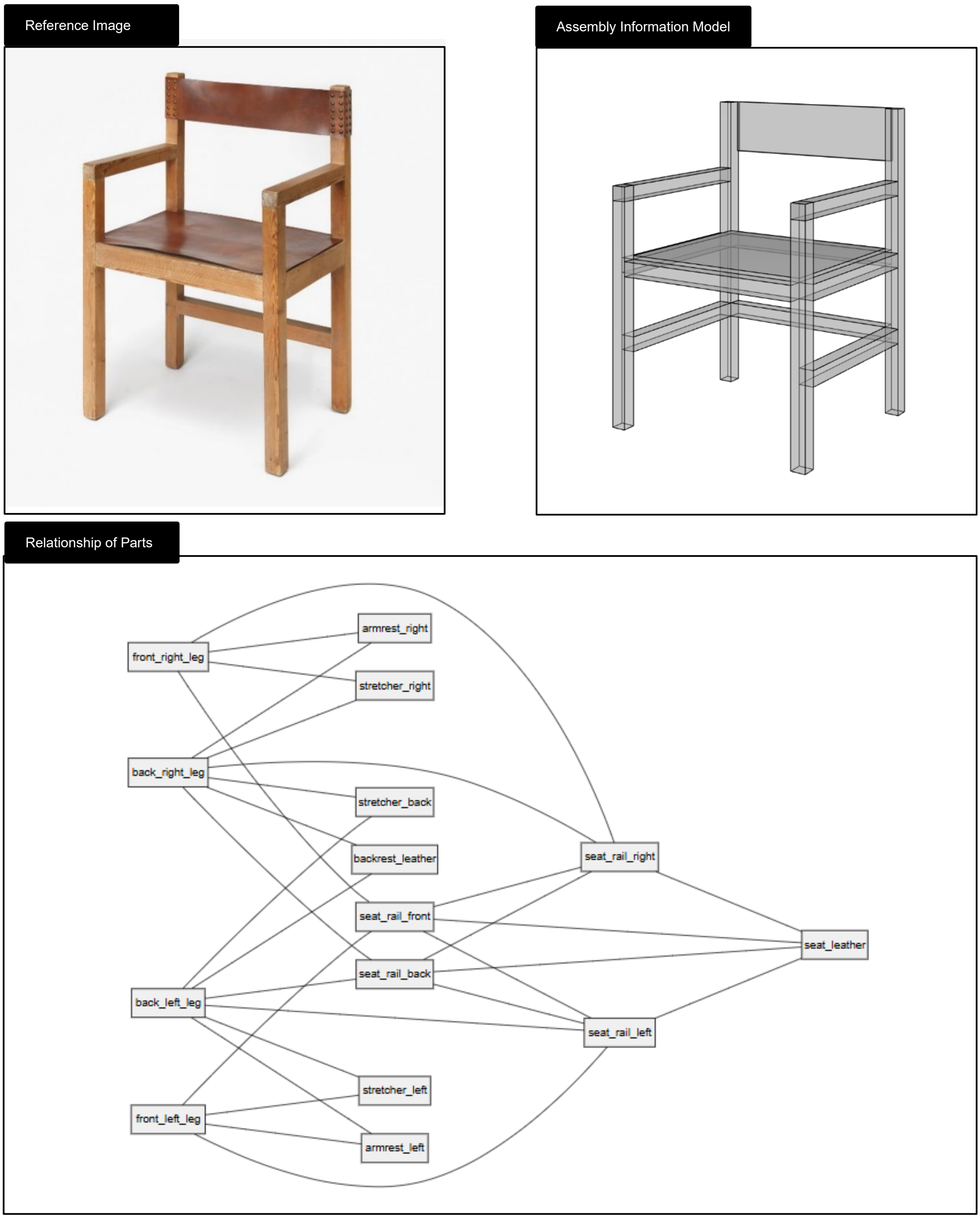


Figure 13: A chair image (top left) is converted into a cuboid-based assembly model (top right), which can also be represented as a graph (bottom) to visualize parts and their relationships. In this example, two additional elements are hallucinated by the model: An additional stretcher between the front and back legs.

In addition, an algorithmic pointcloud-to-cuboid workflow was realized in Rhino/Grasshopper that can be run local, enabling precise spatial measurement to be translated into the JSON assembly structure. While the segmentation process itself lies outside the scope of this thesis (pre-separated pointclouds were provided), the workflow enables a robust translation of dense scan data into structured part representations. The central method computes oriented minimum bounding boxes (OBBs) for each pointcloud

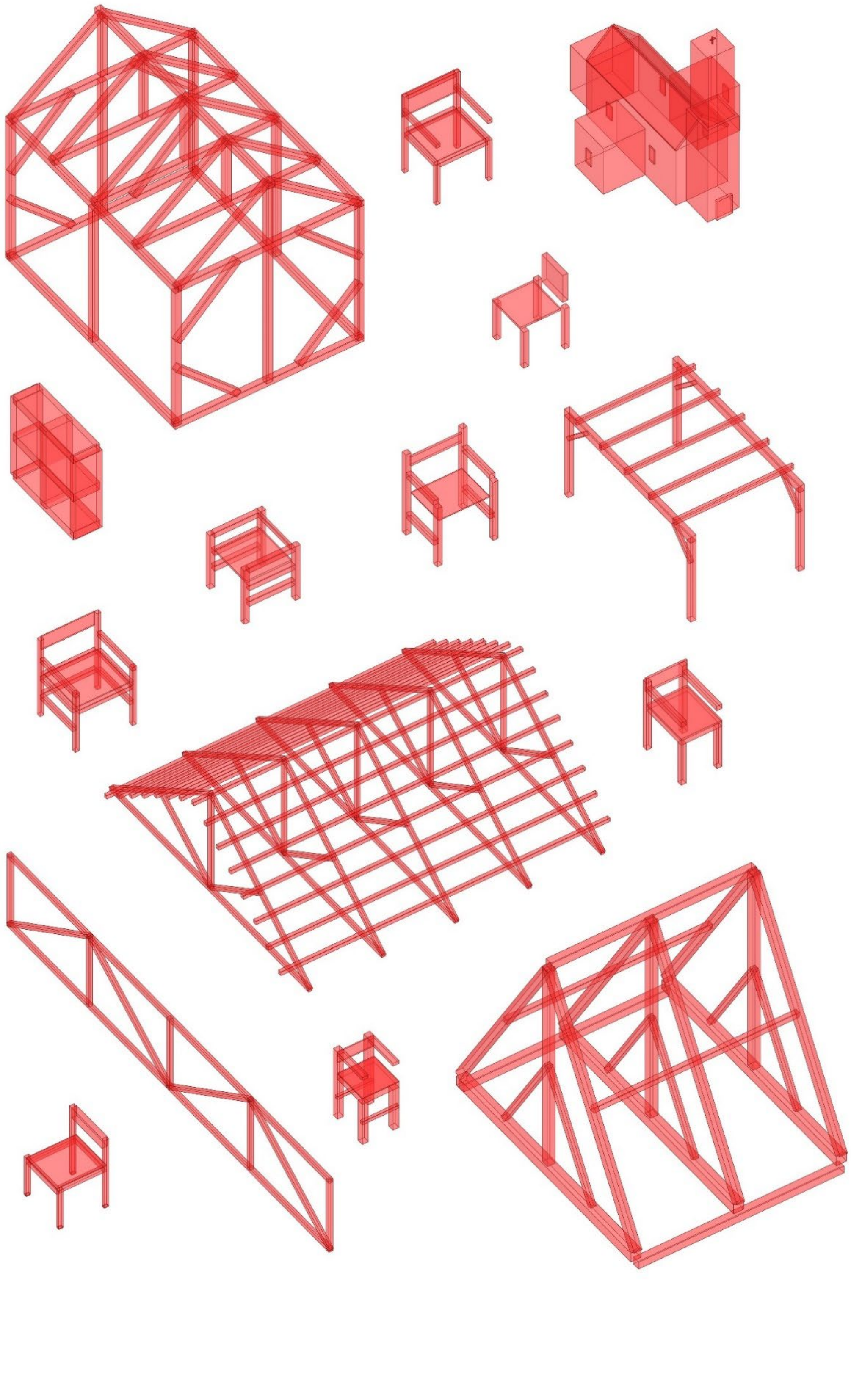
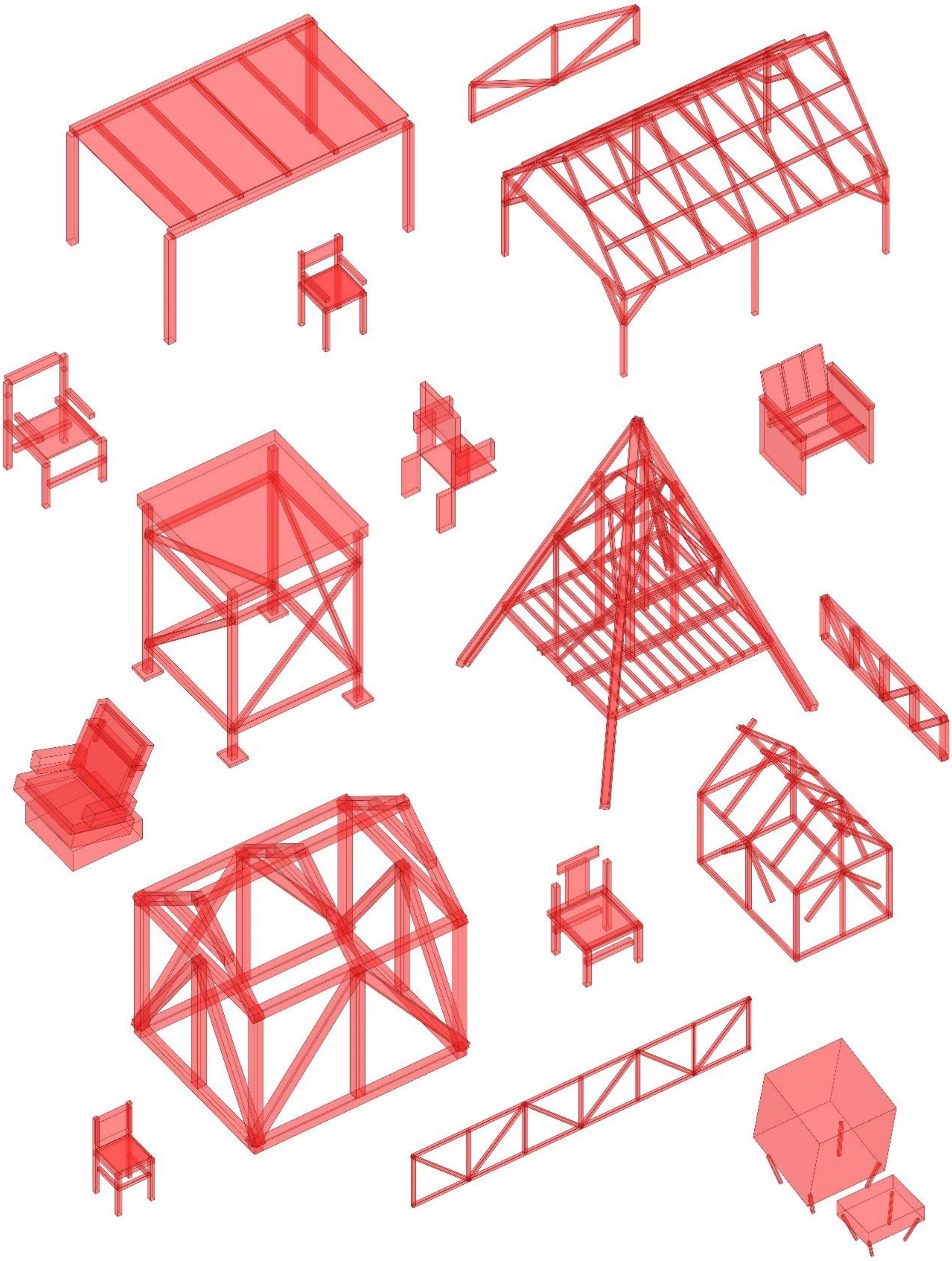


Figure 14: Various assembly models, created from images, pointclouds and text inputs.



segment by iteratively rotating candidate planes and minimizing the resulting bounding box volume. This approach yields a cuboid aligned to the dominant geometric orientation of the scanned part rather than a generic axis-aligned box, thereby improving the fidelity of part shape approximation.

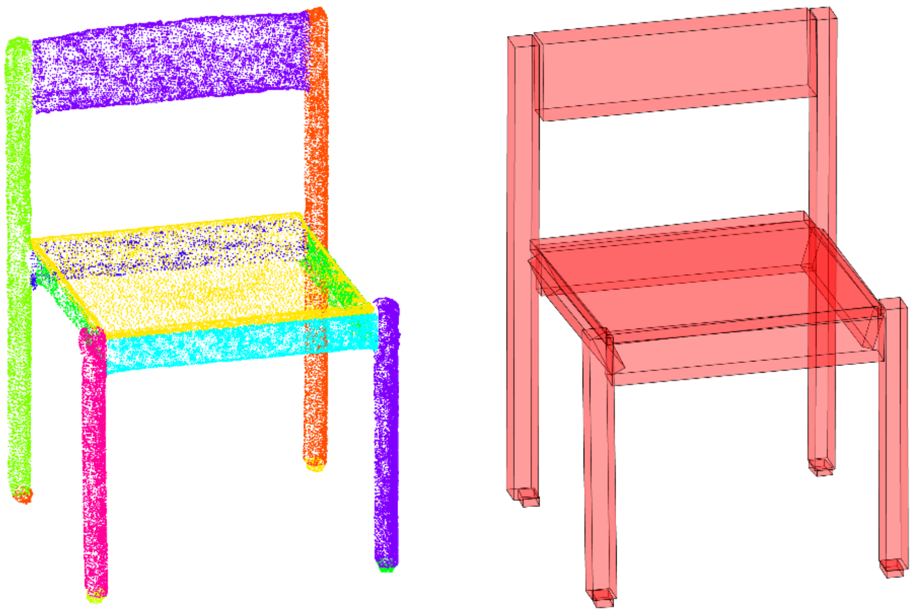


Figure 15: Transformation of a pre-segmented pointcloud into cuboid representations. Left: segmented chair with parts highlighted in color. Right: oriented bounding boxes approximating structural elements, which are exported into JSON and enriched with semantic labels and connections by the AI to form the final assembly file.

This method significantly strengthens the assembly generation pipeline in two ways. First, it overcomes the limitation of image-only input, where dimensions are merely approximated and prone to error. In controlled experiments, supplementing photographs with manufacturer's datasheets or dimensioned drawings already improved accuracy, but pointclouds extend this further by providing direct spatial measurements. Second, the integration of pointcloud-derived cuboids ensures that complex geometries can still be represented in the same structured JSON format as simple image-based assemblies. By embedding this workflow, the system can flexibly scale from quick approximations based on photos to precise, measurable reconstructions derived from scans, always keeping the human user in control through inspection and refinement in the 3D viewer. The pointcloud-derived assembly model integrates seamlessly with the web interface, enabling continued processing within the pipeline.

Step II - Damage Cataloging: Once the assembly model has been generated, the workflow progresses from an abstract description of the object's ideal structure to an assessment of its actual condition. This step introduces variability and specificity, capturing the discrepancies between the canonical model (a condition the object or structure should have) and the physical artifact under repair. Where Step 1 defines a universal "shadow", Step 2 situates this "shadow" in the real world by attaching damages, defects, and absences to its parts. The pipeline ingests multiple forms of input. Photographs of the damaged object, PDF documents, or descriptive text can be uploaded in combination or individually. The backend aligns these inputs against the existing assembly.json, enabling the model to infer which parts are present, missing, or defective. The damages are stored as discrete objects in damage.json.

Structure of the JSON:

```
Object: Name of Object
  Damages:
    Damage: Unique Identifier
      - Affected Part
      - Type
      - Description
      - Position: x=0, y=0, z=0
      - Severity: 1-4
      - Confidence: 0.0 – 1.0
      - Evidence
  …
```

Example:

```
{
  "objectName": "chair",
  "damages": [
  {
    "id": "damage_01",
    "part_id": "leg_front_left",
    "type": "Crack",
    "description": "A long vertical
crack on the inner face of the left
front leg.",
    "coordinates": { "x": 0.0, "y":
0.3, "z": 0.0 },
    "severity": "major",
    "confidence": 0.87,
    "evidence": "Clearly visible in
photo IMG_3045."
  }
 ]
}
```

Each part in the assembly is iterated over and assigned a status field: *intact*, *defective*, or *missing*. This enriches the object model by turning a generic composition into a condition-specific representation that can serve as the basis for later reasoning. The schema of the updated assembly remains consistent with Step 1 but is extended with status annotations and a separate damages array.

This schema ensures that every irregularity is localized, qualified, and verifiable. Importantly, the system distinguishes between what is absent, what is structurally compromised, and what is merely surface-level. Such distinctions allow for differentiated handling in subsequent planning steps.

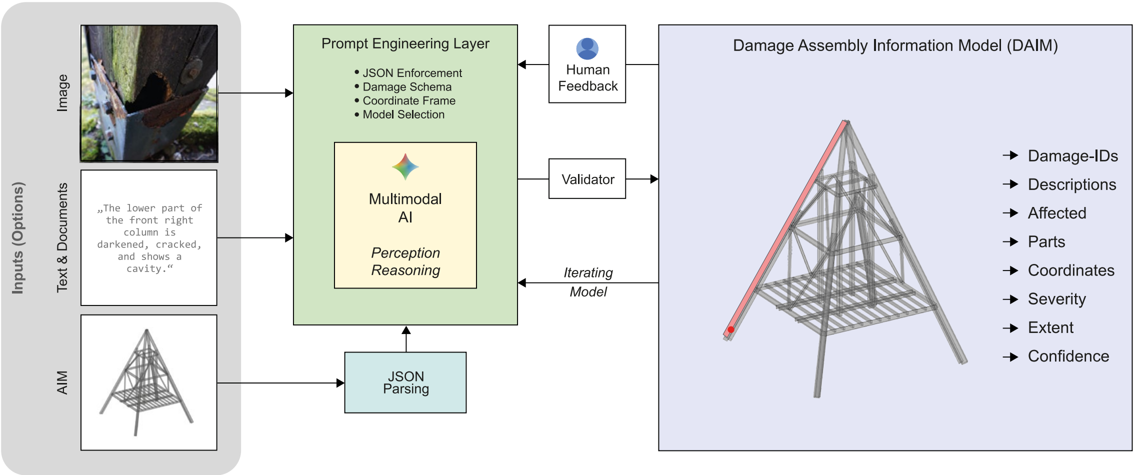


Figure 16: Multiple input variations feed a single prompt engineering layer (situated in the backend) that filters all data and sets fixed rules to the desired output, the updated assembly information model paired with a list of all damages. This data can be visualized and used again for an iterative query together with human feedback.

The catalog is iteratively expandable. Users can add new photos, refine descriptions, or delete erroneous entries. Each change updates both the 3D visualization and the underlying data model. In the viewer, damages appear as animated red spheres whose pulsating scale makes them visible even on small mobile screens. The user may click on each marker to inspect details, while an exploded view separates overlapping components for clearer inspection.

Through this dual interface of structured data and visual feedback, the cataloging step becomes more than an annotation task. It is a negotiation between human and machine perception. The AI proposes a first mapping based on uploaded evidence, but the user remains in control, validating, correcting, or discarding entries. The result is a hybrid artifact: a structured map of vulnerabilities that is precise enough for computational reasoning yet transparent enough for human judgment.

Figures 16 and 17 illustrate this process. A segmented chair scan (left) is enriched with animated damage markers in the 3D viewer (right), while the JSON structure on the backend lists the exact coordinates and classifications of each defect. Together these views ensure that both technical precision and intuitive comprehensibility are preserved.

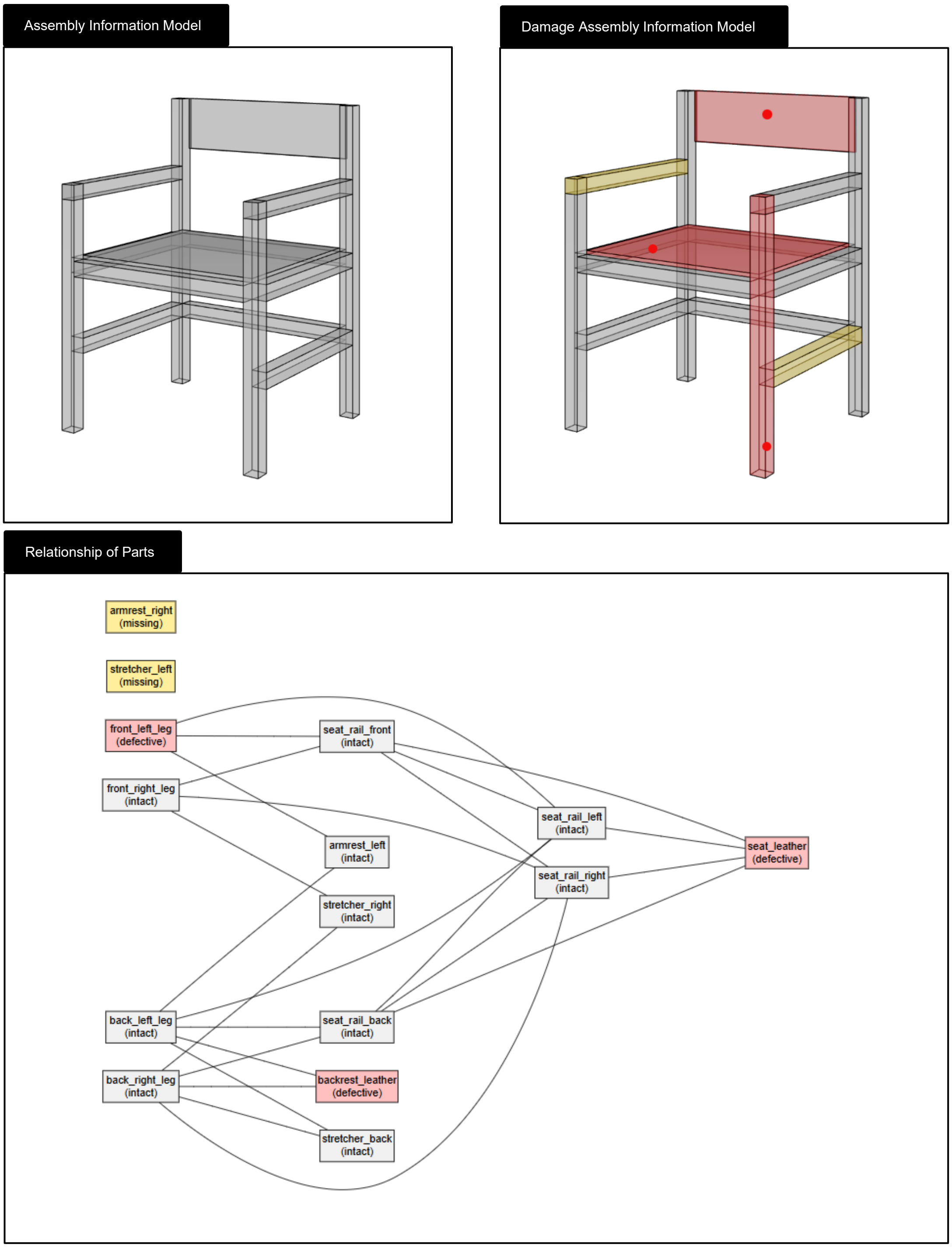


Figure 17: Reference images (top left) are translated into a structured assembly information model (top right), where intact, missing, and defective parts are visually distinguished and damages are marked with red spheres. The resulting graph (bottom) represents the object as a network of parts, annotated with their condition and interconnections, forming the basis for reasoning about repair actions.

4.4.2. Generating Actions

Step III - Action Planning:

Up to this point, the workflow has been concerned with Parts: discrete objects that make up the assembly model. Each part is defined by its geometry, position, connections, and condition. This object-based representation establishes a baseline of what exists and what is damaged. Yet planning a repair requires more than reasoning about parts. Repair is not only about what exists but about what needs to be done. This marks the transition from a part-based to an action-based representation.

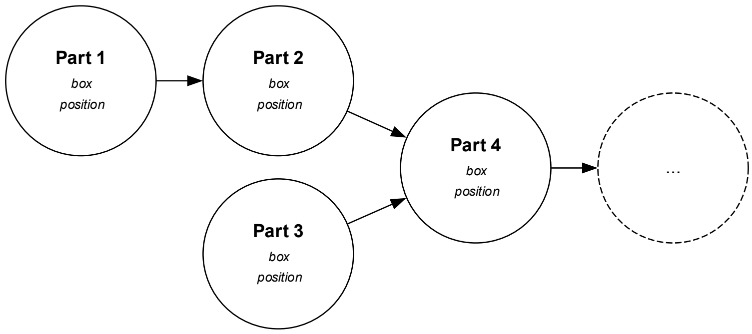


Figure 18: Object Map

In a part-based graph, dependencies arise from physical connections: a chair leg is linked to the seat, a panel depends on the frame. Such a graph captures geometry and topology but has no notion of time or process. By contrast, an action graph encodes tasks and their temporal dependencies. Actions are modeled as nodes, while edges express logical sequencing (e.g., cleaning before gluing). This difference is not trivial: while parts remain static elements, actions are dynamic, procedural units of knowledge. They capture *how* repair unfolds rather than merely *what* is being repaired.

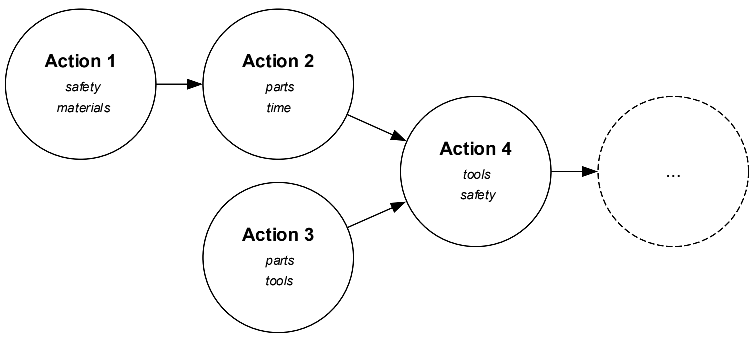


Figure 19: Repair Action Map

In the repair framework, this transition allows the AI to decompose complex repair objectives into atomic, human-executable tasks. Each task is enriched with metadata (tools, affected parts, linked damages) and embedded in a dependency graph that ensures coherence. Not all actions are sequential: for instance, sanding and priming can proceed in parallel once disassembly is complete. The plan is displayed as an interactive graph alongside the 3D model, highlighting parallelizable tasks, tool requirements, and affected parts. Users can explore not just a linear sequence but the structure of repair itself. The result is a strategy that is modular, editable, and transparent, avoiding the opaqueness of a “black-box” recommendation. It is essential, that the reasoning process is not purely automated and the AI never becomes an ‘oracle’ to the User. Rather, they should actively shape the outcome by commenting on proposed actions and requesting alternative strategies. Six potential strategies can be formulated:

The Logic of Material Authenticity: A strategy that prioritizes minimal intervention, uses historically accurate materials (even if they are less performant), and ensures any new work is "legible" and reversible, as discussed in the Venice Charter (see apendix). This logic would find a modern epoxy-fill on a timber beam to be an invalid solution, even if it's structurally sound and cheap.

The Logic of Structural Performance: A strategy that uses the best available modern materials and techniques to maximize strength, longevity, and safety. This logic might favor replacing a weakened timber beam with a steel one, finding it a more "valid" solution than a complex and less certain timber splice.

The Logic of Economic Viability: The fastest, cheapest repair that meets the minimum safety and functional requirements. This logic would prioritize off-the-shelf replacement parts over time-consuming, bespoke craft.

The Logic of Cultural Continuity & Craft: One that involves traditional craftspeople using heritage methods. The process itself is as important as the outcome. Digitally milling a perfect replacement part would be seen as "invalid" because it fails to engage with and sustain the human craft tradition.

The Logic of Ecological Sustainability: A plan that prioritizes retaining as much as possible, but not because of historical significance. It would favor locally sourced, low-impact materials and design for future disassembly and reuse. A repair using a high-energy, non-recyclable composite would be deemed invalid.

The Logic of Aesthetic Intervention: This is where repair becomes a design act, as mentioned. A valid strategy might not hide the repair but to celebrate it, using a contrasting material or form to tell a new story about the object's life. This is the logic of Japanese *Kintsugi*, where broken pottery is repaired with gold, making the object more beautiful for having been broken.

By combining multiple of these strategies, a set of predefined “repair brains” can be envisioned – conceptual archetypes that embody different philosophies of intervention. The AI integrates these stances with the updated assembly and damage data to produce task sequences that reflect both practical constraints and intent. The following set of archetypes are presented as exemplary, illustrating the diversity of possible strategies (see Figure 20) rather than representing a complete catalogue:

🔨 **The Janitor’s Cookbook (Friends of the Custodian)** – Pragmatic survival logic: repair is fast, cheap, and robust, prioritizing function over aesthetics or authenticity.

⏳ **The Long-Term Thinker (Friends of Stewart Brand)** – Systemic, temporal logic: repairs are modular, reversible, and designed to prepare for future failures.

🚲 **The Readymade Brain (Friends of Marcel Duchamp)** – Conceptual re-appropriation: everyday objects are cleverly repurposed as repair solutions, often with irony or wit.

🪓 **The Anarchitect (Friends of Gordon Matta-Clark)** – Subtractive: alteration by cutting away, destabilizing, or exposing hidden structures, even if function is compromised.

🕸️ **The Purist (Friends of John Ruskin)** – Authentic preservation: interventions stabilize without replacing or beautifying, scars remain visible as dignified traces of time.

🛠️ **The Gentle Craftsman (Friends of SPAB)** – Modest, conservative repair with traditional skills and sympathetic materials, focusing on continuity over perfection and craftsmanship.

✨ **The Jeweler of Joints (Friends of Carlo Scarpa)** – Crafted articulation: celebrates the joint between old and new as an ornamental, jewel-like detail that highlights contrast.

🏙️ **The Urbanist (Friends of Jane Jacobs)** – Civic repair: interventions aim to strengthen community and human-scale vitality, not just restore physical function.

🧪 **The Preservation Scientist (Friends of ICOMOS)** – Evidence-based repair: guided by international standards and scientific principles, grounded in material analysis, risk assessment, and predictive data to ensure durability and global consistency in conservation practice.

🏰 **The Stylistic Idealist (Friends of Eugène Viollet-le-Duc)** – Reconstructive authorship: repair as completion of an ideal whole, supplementing or re-inventing missing or defective parts to achieve stylistic unity and erasing all traces of wear and tear.

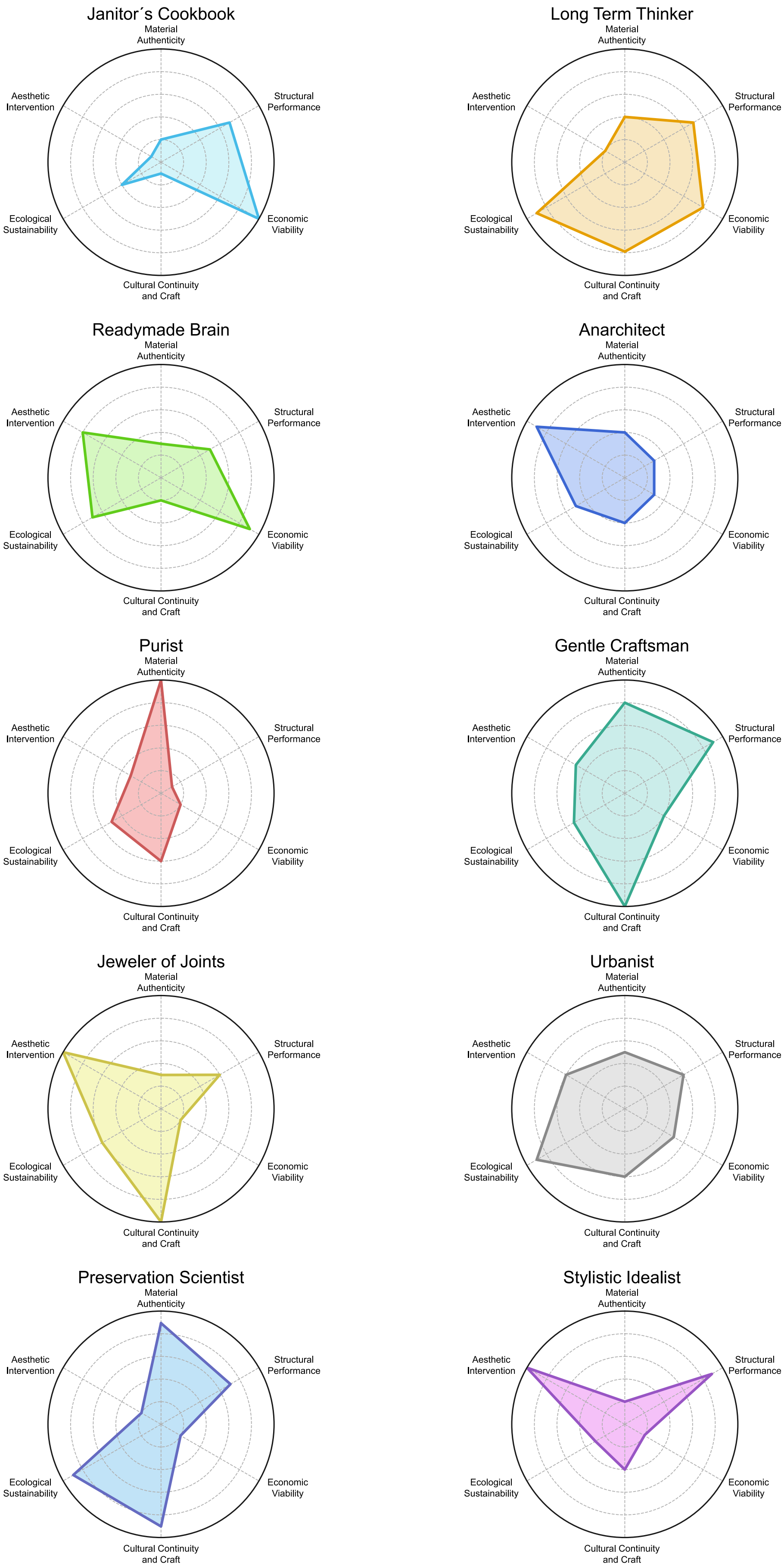


Figure 20: Each archetype represents a finetuned intention.

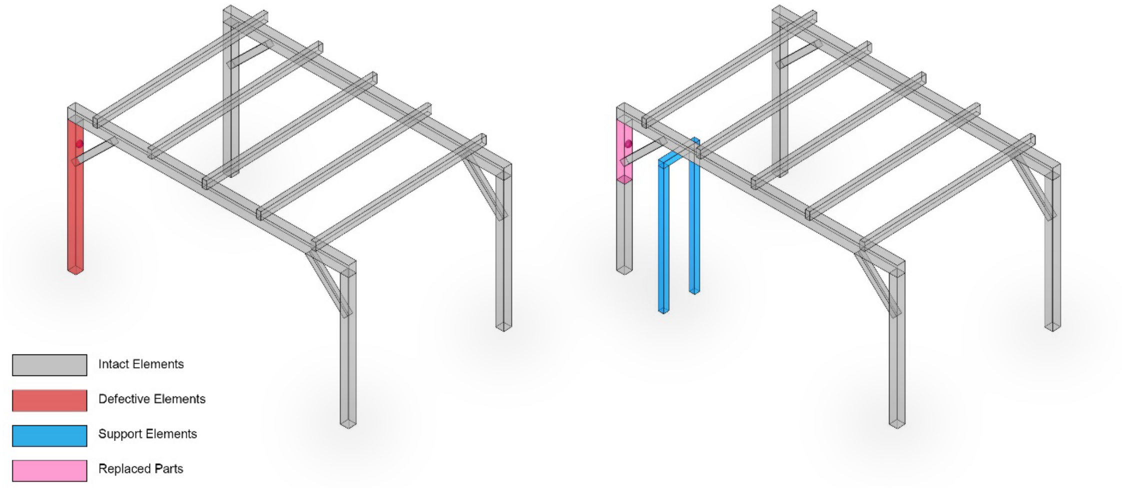


Figure 21: After the damaged structure is classified into intact (grey), defective (red) in the previous step, an intervention is proposed by the model: temporary support elements (blue) are introduced, and the defective part is replaced (pink).

An intervention can be initiated either directly by the user through textual input or automatically by the AI when formulating a repair strategy. In this way, the system does not only treat damages in a chronological order, it needs to understand the severity of the suggested methods. In one example (Figure 21), the AI recognizes that replacing part of the defective post requires temporary stabilization. It therefore augments the action plan and the assembly: the positioning of support beams (blue) is inserted as explicit steps within the action map. These actions ensure structural safety during the replacement.

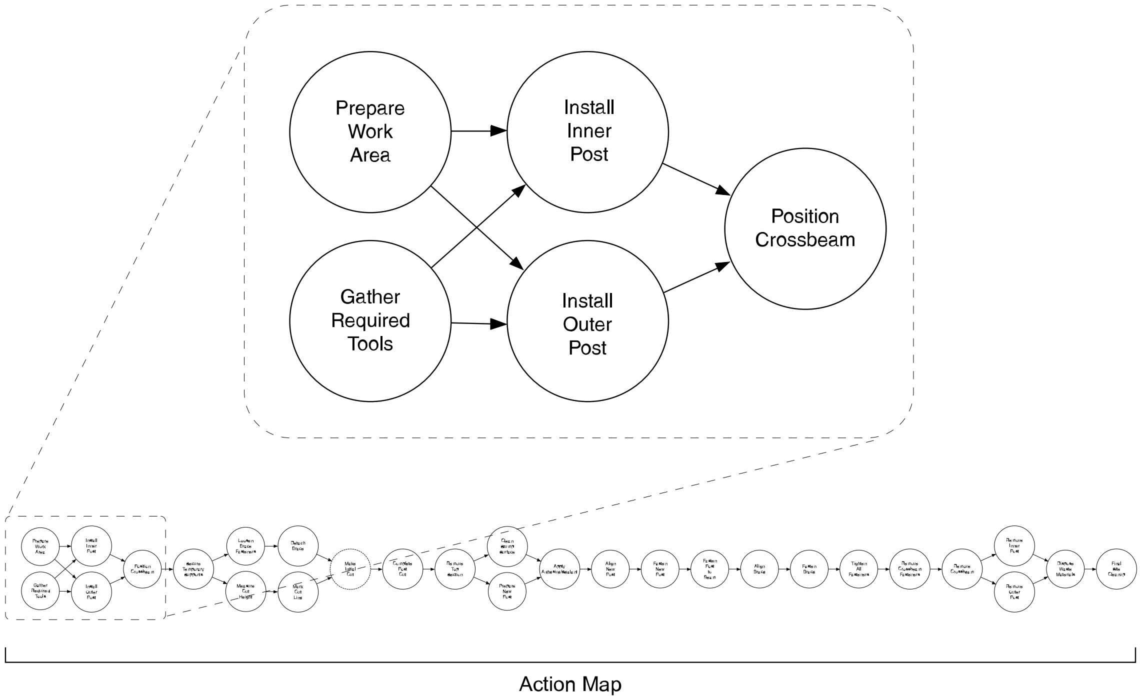


Figure 22: Steps of the repair strategy for the timber structure. The action map contains task dependencies and sequencing, while also allowing parallel execution of tasks that are independent from each other.

4.4.3. Executing and Guiding Actions

Step IV - Interactive Guidance:

Once a repair plan has been approved by the user, it moves into the execution phase, where the repair site becomes a digitally augmented workspace. The user follows instructions by navigating flexibly through the action graph, adapting the sequence to on-site conditions. Each task can be marked as completed or skipped, but tasks themselves are not modified at this stage. If a step proves infeasible, the user can record comments about deviations, which are saved as part of the permanent repair documentation.

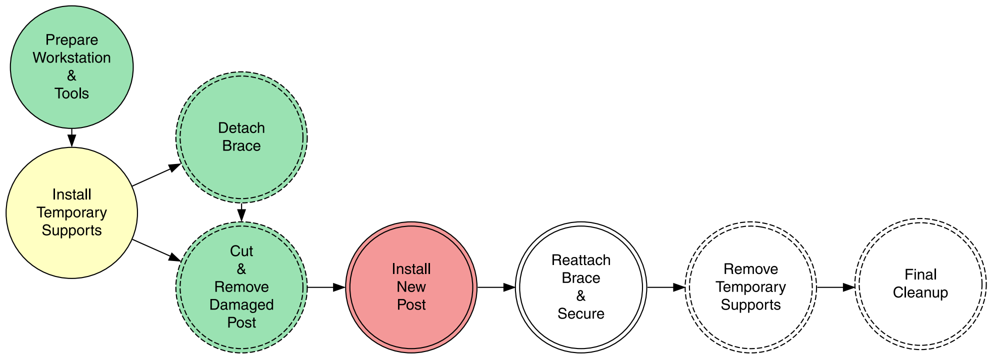


Figure 23: The repair plan remains a guidance, tasks can be skipped (yellow).

In the action graph, visual cues indicate both the type and the status of each task. Actions that add elements to the structure are shown with a solid double circle, while actions that remove elements use a double circle with dashed lines.

The color scheme encodes progress: *green = completed, yellow = skipped, red = current action, and white = pending/not yet executed.*

In this phase it is also crucial, that part currently addressed is highlighted within the assembly model. Part attributes are represented with an expanded color scheme:

grey = intact	*cyan = support structure*
red = defective	*pink = replacement or new*
yellow = missing	*orange = discarded*
blue = selected	*pink/cyan = replacement or new*

A conversational AI assistant supports the process by answering context-specific questions with concise, expert-level guidance on materials, tools, and safety measures. Its primary knowledge source is the approved repair plan; if the project-specific data is insufficient, the assistant supplements answers with its broader trained expertise, as seen from this example of an user-experiment:

USER

```
The plan involves cutting the old post and attaching a new section on top. What's the best way to cut and connect these two pieces to ensure the repair is as strong as the original post?
```

H.E.L.G.A.

```
For a strong integrated connection without visible hardware, cut a half-lap joint, where you notch both ends to interlock before fastening. A scarf joint (long angled cuts) is even stronger but much harder to execute perfectly.
```

4.4.4. Documentation

Step V - Interactive Record:

The final step closes the loop of the repair workflow. Every action—whether executed exactly as planned or adapted on site—is logged directly into the shared data model. Crucially, documentation is not an afterthought: all perception, reasoning, and actions from previous steps are continuously written to structured JSON. At any later moment, this record makes it straightforward to reconstruct what has been done and why. Each step is automatically timestamped and can include user comments, photos, or modifications. This produces a transparent digital history of the intervention that serves several purposes:

- **Traceability**: Future caretakers and professionals can precisely follow what was done, when, and for what reason.
- **Certification and Compliance**: In architectural contexts, the structured record supports facility management, insurance claims, or conservation requirements.
- **Knowledge Accumulation**: Aggregating repair histories across many projects creates a growing dataset that strengthens AI reasoning for future repairs.

4.4.5. Conclusion

During the development it became apparent, that the workflow should not be understood as a rigid, linear sequence. Instead the phases form an interconnected cycle that supports backtracking, parallel work, and handover between user (See Figure 24).

At any moment, users can return to an earlier phase in order to add a new damage, revise a repair plan, or edit information directly in the JSON file with any text editor. This flexibility ensures that the model remains changeable and shareable. Importantly, the phases do not have to be carried out by the same person: one user might generate the assembly, another catalog damages, and a third execute the repair. Together, the framework enables any repair-strategy to be collaborative, adaptable, and transparent.

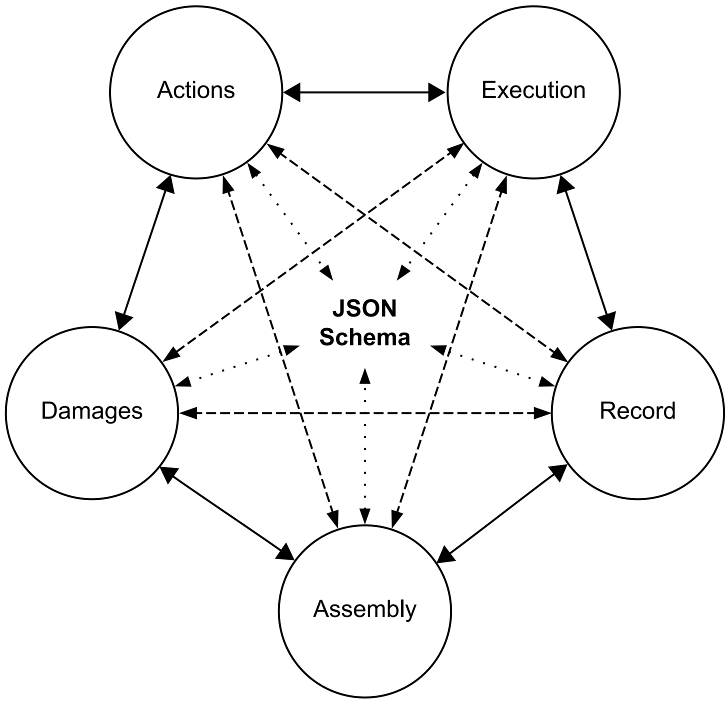


Figure 24: Cyclical workflow.

4.5. User Interface Design

The application's user interface (UI) is designed to make the complex process of perception, reasoning, and action intuitive and accessible on a mobile platform. The design prioritizes a dual-representation system, allowing users to switch between spatial and logical views of the repair process.

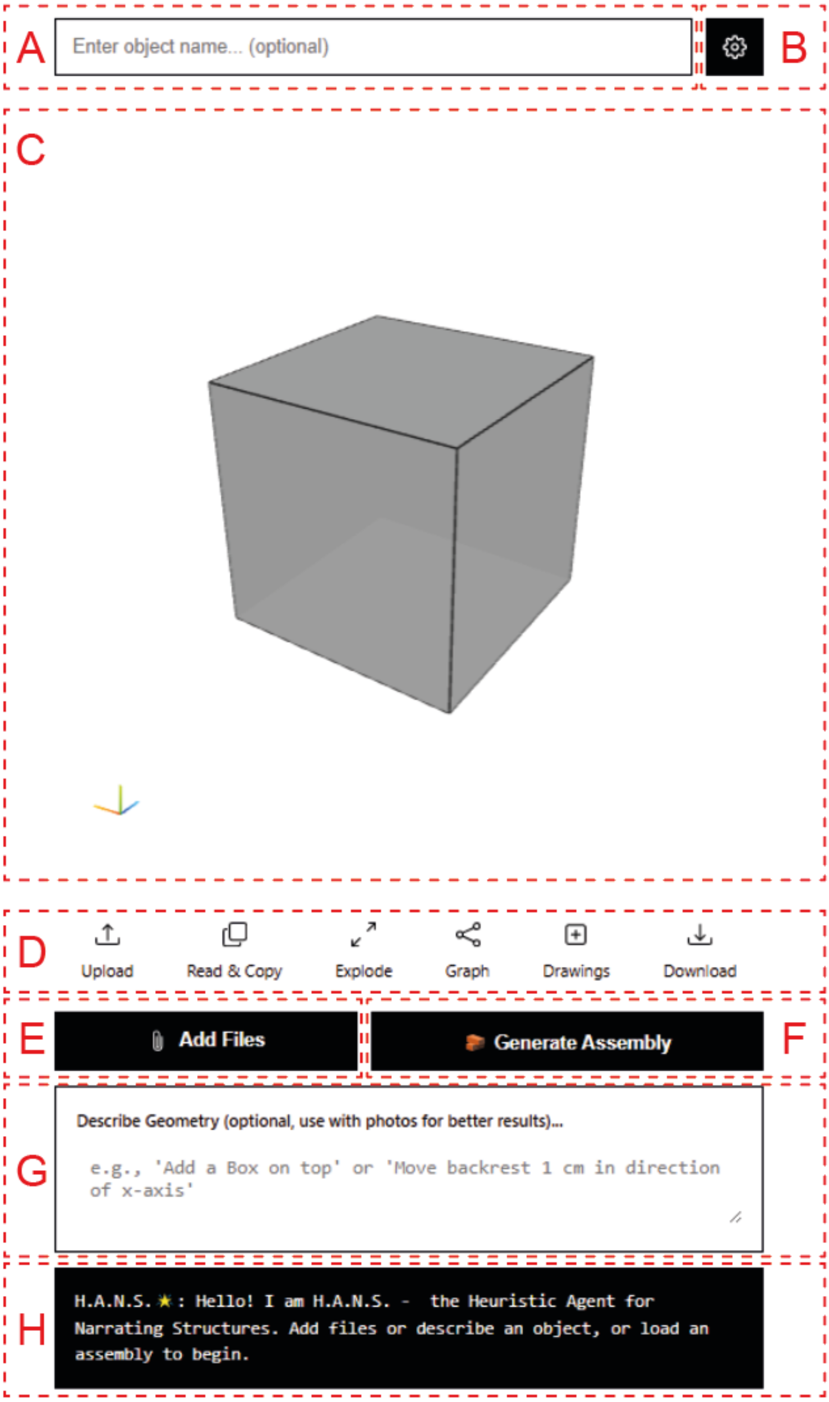


Figure 25: User interface of the first step.

- **A – Object Name:** At the top of the interface, an object name is always visible, ensuring continuity across sessions. When a new model is created, the user may freely assign a descriptive name; when loading existing data, the stored object name is automatically displayed.

- **B - Setting:** Adjacent to this field lies the settings panel, which adapts to the current step but consistently includes the choice of AI model. Users can select between fast, balanced, or accurate reasoning modes, trading off speed against depth of analysis. In addition, adjustable sliders allow the tuning of creativity and the scale of damage markers, while in the assembly step an additional toggle activates or suppresses part rotations. These parameters let the user calibrate the AI's interpretative range without leaving the workflow.

- **C - The 3D Interaction View:** The central element of the interface is the three-dimensional interaction view. It provides the familiar navigational affordances of a CAD environment—panning, orbiting, and zooming by gestures or mouse actions—while extending them with context-sensitive overlays. Selected parts are highlighted by raycasting, with their properties displayed in a small information box at the corner of the viewport. Damage markers appear as pulsating spheres whose animation ensures visibility even on small screens. Exploded and reset views can be toggled to clarify hidden joints or restore the object's intact state, while instructions from the reasoning engine are projected as translucent annotations directly onto the model. This tight coupling of visualization and guidance transforms the viewport into an active workspace rather than a passive display.

- **D - Menu:** Beneath the viewport, a row of icons gives access to auxiliary functions that cut across all phases of the workflow. JSON files can be uploaded or downloaded, either as assemblies, damages, or repair plans. A read-and-copy function exposes the structured data for direct inspection. Structural clarity is further supported by the option to generate a graph, which in the perception phases displays part-to-part connections, and in the reasoning phase renders the repair plan as a directed acyclic network of steps. For documentation purposes, the same model can be exported as orthogonal drawings, providing six standardized views of the assembly.

- **E - Input:** This component allows the user to upload supporting materials. Multiple file types are accepted: images (JPG, PNG), PDFs, or JSON structures. A multi-file input supports uploading photo sets, for example, to capture damages from different angles. Additionally, users can set timers for specific actions, which ensures that longer processes (such as curing times during repair) can be integrated into the workflow.

- **F - Prompt Trigger:** Once the necessary inputs are prepared, the *Prompt Trigger* button initiates the backend query. The system packages the assembly or damage data together with user-provided instructions and forwards them to the selected AI model. This ensures that the reasoning process always has a clear context, combining machine-readable data with natural-language input.

- **G - Comment Panel:** A free-text area for annotations, clarifications, or instructions. During perception phases (Step 1 and 2), this allows users to describe object features or damages in their own words, supplementing visual data. During the reasoning phase (Step 3), it becomes an interactive dialogue channel: users can directly ask the AI agent about the repair process, request alternative strategies, or refine previously generated steps. These comments are archived in the JSON output, maintaining transparency of the human–AI interaction.

- **H – AI Agent Output:** Finally, the AI output panel functions as the system's conversational interface. Here, feedback from the agent is displayed: hints for the next step, detailed reasoning about detected damages, structured repair steps, or error notes if inputs cannot be processed. The output is rendered in monospaced type to emphasize its role as machine-generated content. For clarity, the system prefixes every message with an agent identifier (e.g., H.A.N.S. for assemblies, M.A.G.D.A. for damages, or R.O.L.F. for repair plans), making it transparent which phase of the workflow the user is in.

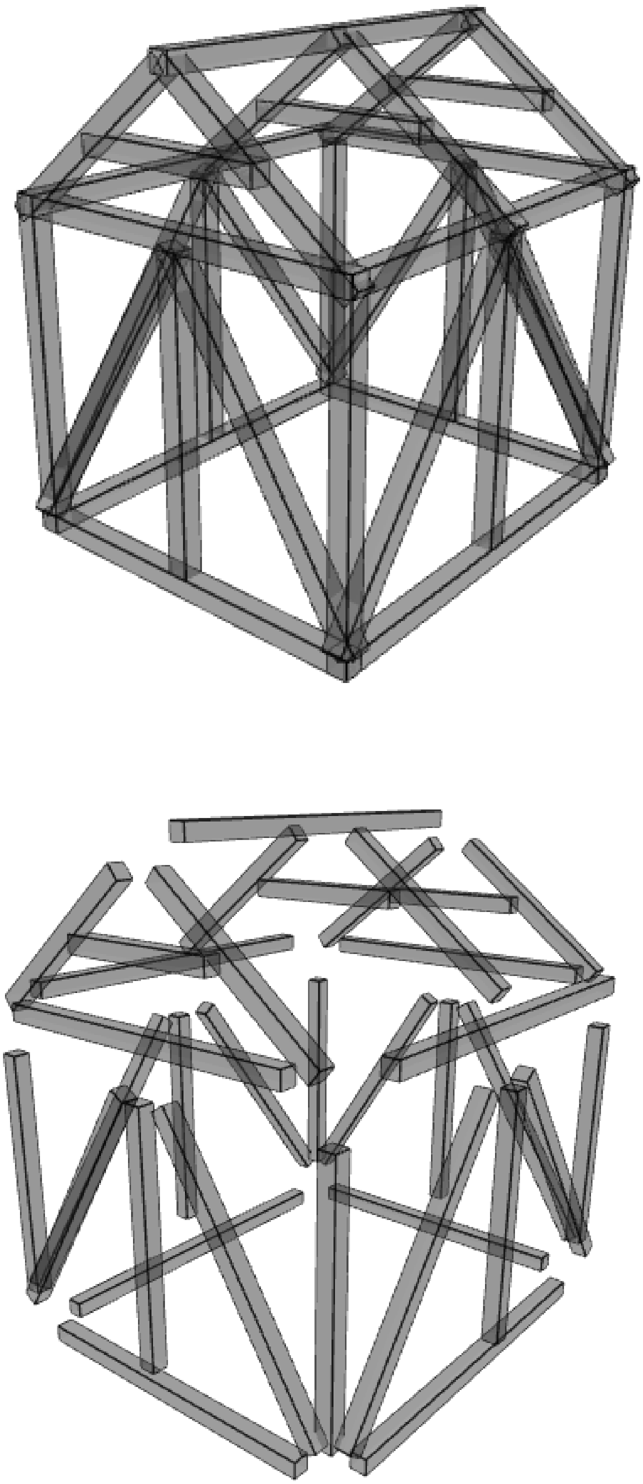


Figure 26: Digital representation in the web-app of a timber frame structure. The top image displays the complete assembly, while the bottom image provides an exploded diagram to illustrate the individual parts.

4.6. Evaluation Metrics

The evaluation of this framework does not rely solely on abstract performance criteria but is grounded in the concrete explorations and experiments carried out during its development. Following a design-based research approach, the central "metric" is the ability of the system to support design reasoning through iterative testing, prototyping, and repair interventions. Evaluation therefore operates across three complementary layers:

- **Technical Reliability and Output Coherence:** Initial tests focused on whether multimodal AI could generate assemblies and damage catalogs that were structurally consistent and machine-readable. Metrics included schema validity of JSON outputs, logical coherence of part hierarchies, and responsiveness to iterative refinements. Failures such as hallucinated parts or inconsistent orientations were recorded as equally important indicators, since they revealed the limits of current model capabilities and informed the refinement of prompts and interface design.

- **Usability and Human-in-the-Loop Interaction:** The system was evaluated through hands-on experiments where users engaged with generated repair plans. For the Santo chairs, multiple participants attempted repairs guided by the mobile interface. Metrics included repeatability of actions across users, clarity of instructions, and the degree of user intervention required to adjust or correct the AI's proposals. Here, usability testing served as a direct measure of whether the framework could structure complex information into actionable, legible steps.

- **Design Space Exploration and Scalability:** Perhaps the most decisive evaluation metric lies in the framework's capacity to open a design space of possible repair strategies. This was tested through explorations such as the "10 Brains" set of divergent logics, which demonstrated the ability of the system to generate, compare, and adapt alternative repair approaches. At the architectural scale of the Forest Cemetery Chapel, evaluation shifted toward the integration of multimodal data (historical photos, point clouds, on-site assessment) and the system's ability to handle increased complexity without collapsing into oversimplification.

- **Iterative Prototyping as Evaluation:** Each prototype developed—from assembly generation and damage cataloging to action graphs and interactive guidance—served simultaneously as a design tool and an evaluation instrument. Metrics were therefore not limited to the output quality of AI models, but included the system's adaptability to different contexts, its transparency in failure modes, and its potential to support collective decision-making in repair scenarios.

In summary, the evaluation is not a detached measurement exercise but is embedded within the act of designing and testing the framework itself. Success is indicated by the framework's ability to structure knowledge, generate alternatives, and guide interventions across scales, while failure cases illuminate both technical and methodological limits. The explorations presented in the following case studies therefore constitute the most direct and meaningful evaluation of the approach.

5. CASE STUDIES

5.1. Preliminary Tests: Proof-of-Concept Applications

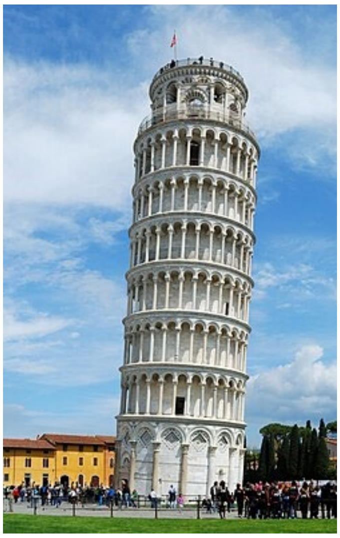
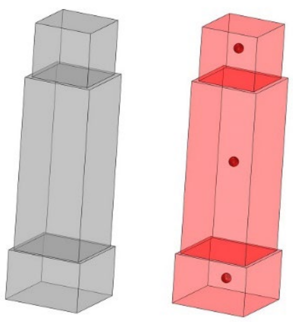


Figure 27: A notable example of a structural flaw that has been kept by intention. Image: Saffron Blaze.

The Leaning Tower of Pisa offers a compelling case for exploring repair strategies, as its condition is at once iconic and structurally precarious. From a single image, a cuboid assembly model was generated (Figure 28), already capturing the characteristic tilt and segmenting the structure into three parts: the tower base, the mid-section, and the belfry. The model was produced at a 1:1 scale, with a total height of 56 m corresponding to the actual dimensions of the tower. Given the monument's global prominence and extensive digital footprint, it is plausible that the VLM did not derive these measurements solely from the provided image but instead drew on available reference data from the web.



M.A.G.D.A:
The tower base is observed to be significantly tilted from the vertical axis, causing the entire structure to lean.

The mid-section of the tower is tilted, consistent with the overall lean of the structure due to foundation issues

The belfry, the topmost section of the tower, is tilted, consistent with the overall lean of the structure.

Figure 28: Based on the assembly, the Agent M.A.G.D.A. correctly identifies the signifact structural weakness of the tower base, affecting also the mid-section of the tower and the belfry.

The next phase is the planning of an actual repair method. Without further commentary by the user, two opposing repair methods were modeled after each other and compared:

The Purist Plan (Friends of John Ruskin): This approach considers the lean as part of the tower's temporal and material authenticity. Rather than erasing the evidence of time and failure of the foundation, this strategy limits itself to stabilization.[31] Actions focus on securing the foundation and masonry to prevent collapse, while the lean remains visible. The scars of history, here embodied in the tilt, are preserved as part of the object's dignity and truth.

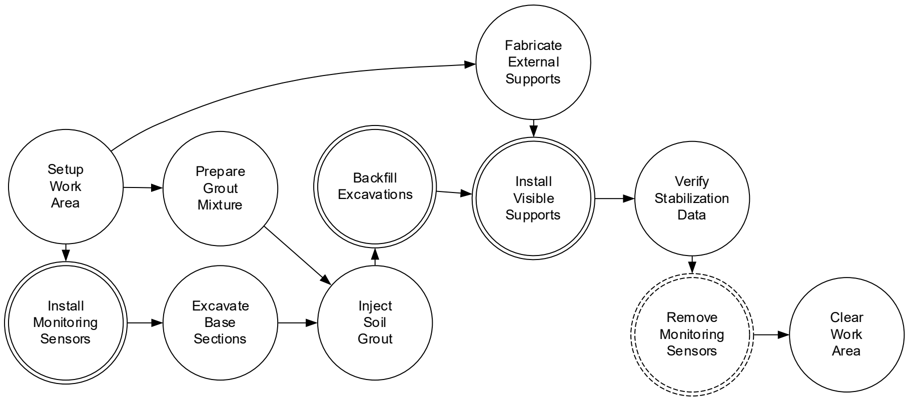


Figure 29: Action-Map of a repair, following principles of the "Purist", that prefers historical authenticity by showcasing flaws and damages.

The Stylistic Idealist Plan (Friends of Eugène Viollet-le-Duc): This approach treats the tower as an architectural whole to be perfected. The tilt is regarded as a deviation to be corrected, aiming toward a stylistically "ideal" verticality. Repair actions generated under this plan emphasize realignment with extensive use of machinery, aiming at structural correction and stabilizing the foundation in pursuit of a harmonious final form.[32] The tower is interpreted as a composition that should be completed according to an imagined stylistic truth.

[31] The model suggests for example the careful injection of soil grout in order to sustain the leaning of the tower: *„Monitor pressure and volume closely with real-time data from the installed sensors to ensure consolidation occurs without altering the existing lean or causing new stresses. The goal is to stabilize the ground, not to straighten the tower."*

[32] The model suggests pouring a completely level foundation and a vertical alignment of the tower: *"Carefully and precisely lower the tower_base onto the new, perfectly level and cured foundation. Adjust its position minutely to ensure the entire structure is brought to a perfectly vertical alignment, correcting the lean."*

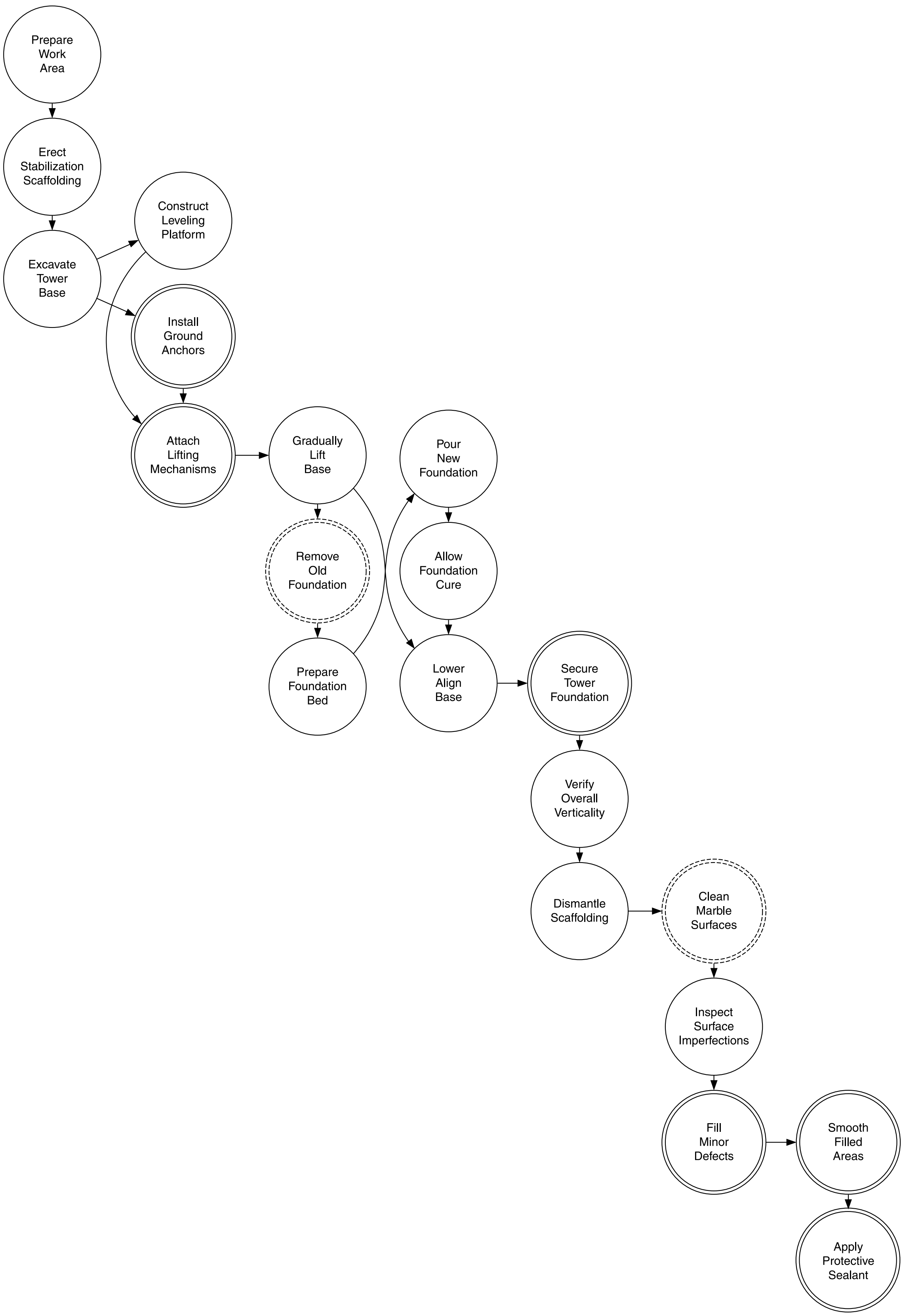


Figure 30: Action-Map of a repair, that follows the intention of the "Stylistic Idealist".

The contrast between the two repair plans highlights the cultural and philosophical stakes of intervention. The Stylistic Idealist produces a coherent, perfected structure but risks falsifying history. The Purist, by contrast, safeguards authenticity and continuity but accepts ongoing fragility, with the likelihood of further interventions in the future. This latter approach is indeed similar to the strategy ultimately adopted in the 1990s, when the tower was at risk of collapse. At that time, a committee of thirteen international experts was selected by the Italian government to evaluate possible interventions, balancing historical integrity with urgent structural stabilization.[33]

5.2. 10 Artifacts: Canonical Objects and their Repair

The experimental validation of the workflow was conducted using a set of 52 Santo chairs, designed by Edlef Bandixen in 1969 for the Swiss manufacturer Dietiker. The original set belonging to the Cemetary Chapel in Rhöndorf was unfortunatly lost during early renovation work,[34] with only three salvaged in heavily damaged condition. A fortunate donation of 49 retired chairs of the same model from a church in Berlin provided replacements, creating a hybrid dataset.

Figure 31: The original furniture of the Cemetary Chapel in Rhöndorf.

[33] Burland, Jamiolkowski and Viggiani 1998, 63.
[34] This happened during initial cleanup and renovation work in the spring of 2025, after years of uncertainty about the future of the building: the entire church furnishings, 42 pieces of "Santo" model designer chairs created by the renowned Swiss designer Edlef Bandixen, were carelessly discarded during the process. The shattered pieces of the chairs were discovered by chance of the author of this thesis. This act resulted again in intensified criticism of the city's handling of the building.

All 52 chairs share the same standardized geometry, yet each exhibits distinct types and degrees of damage. This makes them particularly suitable as canonical objects: they combine multiple materials and complex joints, while their uniform form allows direct comparison across different conditions.

The Santo is a robust stacking chair made of solid beech wood. Its construction features straight, cambered legs joined with double tenons, a solid form-milled headpiece, and a 6 mm thick molded plywood seat with an integrated hollow for comfort.

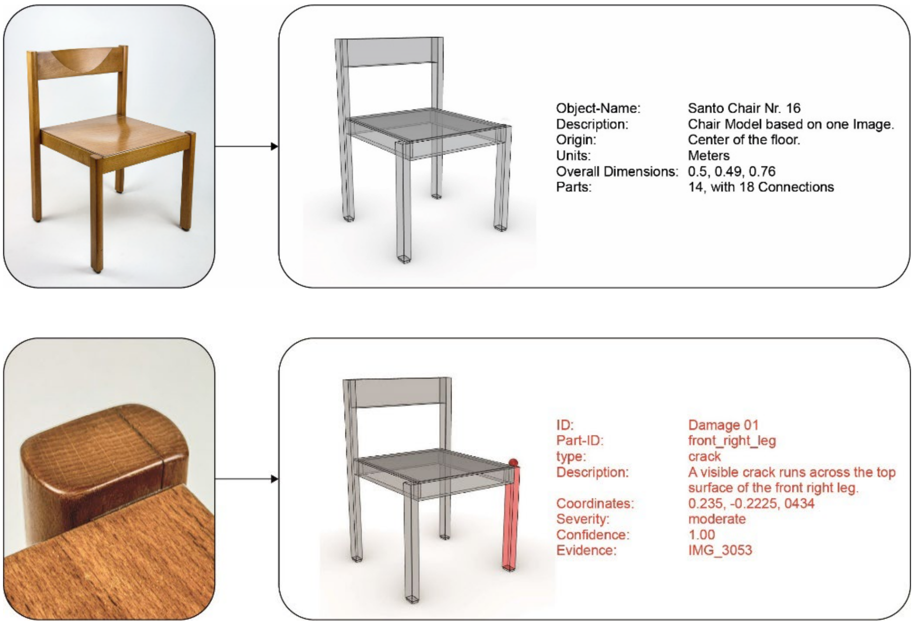


Figure 32: Generation of an assembly-model from a single reference image and user comments (top), as well as damage detection and annotation, linking a visible crack on the front right leg to structured metadata (bottom).

The first stage of the workflow, assembly generation, focused on reconstructing a digital reference model. Instead of modeling each of the fifty-two damaged chairs individually, a single intact example was selected as a baseline. Photographs of this chair, together with the original CAD model and technical data sheet supplied by Dietiker, were processed by the AI system. The outcome was a graph-based assembly model stored in JSON format and visualized in 3D through the prototype interface. This model defined every part with a unique identifier, origin, dimensions, and material attributes, capturing both geometry and semantic relationships.

Building on this reference, the second stage addressed damage cataloguing. All chairs were systematically photographed from multiple angles to document their current condition (Figure 32). These images were analyzed by the AI, which detected and classified cracks, missing elements, surface wear, and other forms of deterioration. Each observation was linked to the corresponding part in the assembly model and annotated with metadata describing type, location, severity, and confidence. The result was a set of corresponding 52 structured damage files in JSON format, overlaid onto the 3D assembly for interactive inspection. The dataset was then ranked according to the severity of damages, allowing the selection of ten chairs in the worst condition for the subsequent phases of the workflow. This sampling provided a balanced compromise: it reduced the practical effort of conducting detailed repair experiments while still preserving sufficient diversity to test the robustness and repeatability of the system.

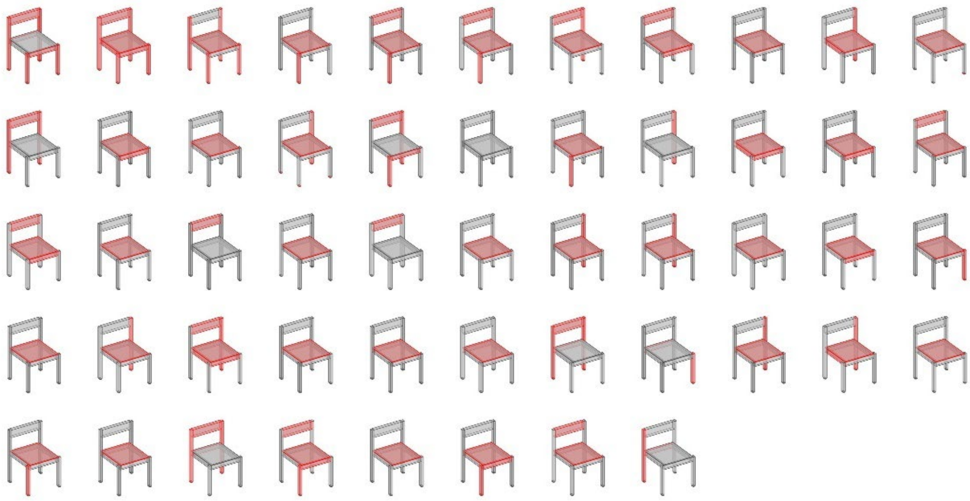


Figure 33: All 52 Santo chairs with documented damages.

The third stage, action planning, combined the assembly and damage data with user instructions and a chosen repair philosophy. Here the concept of the “brains” (as introduced in the theoretical framework) became central: each brain embodies a distinct logic of repair, from pragmatic maintenance to purist preservation or artistic reinterpretation. Guided by these philosophical orientations, the AI generated step-by-step repair strategies. The plans were represented as directed action graphs, where tasks were decomposed into atomic actions, ordered by explicit dependencies, and grouped for efficiency. Users could edit and adapt the proposed sequences, preserving human agency within the automated reasoning process. The output of this stage was a repair plan in JSON format, ready for execution and visualization.

The fourth stage translated these plans into interactive guidance on a mobile device. Using the prototype interface, participants could navigate through the repair sequence in three dimensions, viewing highlighted parts and damages, advancing step by step, and receiving contextual advice from the conversational agent.

The system also tracked completion times and allowed users to attach comments during the process. This transformed the repair site into an augmented workspace, where digital reasoning and physical action were closely interwoven. The outcome was an execution history JSON, recording each performed intervention. The system consolidated the reference assembly, the damage catalogue, the repair plan, and the execution history into a unified dataset. This created a transparent digital record of the entire repair process, including what was repaired, how, and by whom.

Figure 34: Typical damages of the chairs: Cracking on the legs (left) and chippings and scuff marks (right).

Among the ten selected specimens, chair 16 was representative for both structural and surface-level deterioration. Six damages were catalogued: a severe crack at the top of the back right leg near the backrest, heavy scuffing along both rear legs, a faint scratch on the seat surface, a deep horizontal scratch across the whole backrest, and a minor chip on the right side apron (Figure 35).

After comparing multiple strategies, the *Janitor's Cookbook* was chosen to generate the repair strategy for chair 16 (Figure 36). In line with its philosophy of expedience and robustness, the plan prioritized eliminating weak elements over preserving form. The AI proposed cutting the back legs down to match the front leg height and discarding the entire backrest, thereby converting the chair into a stable stool. This intervention simultaneously removed the cracked joint and the damaged backrest surface. Remaining surface flaws, like scuffs, seat scratch, and chipped apron, were addressed through a quick overall sanding. Finally, heavy-duty gliders were installed and a coat of white enamel paint applied across all exposed areas.s

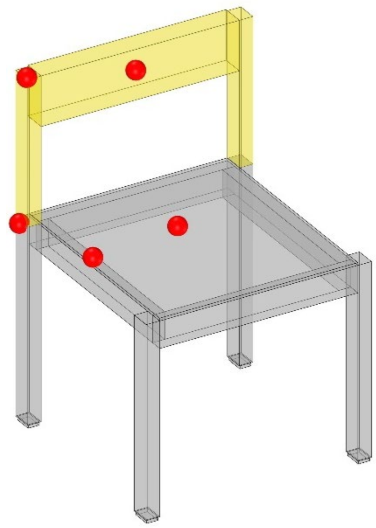


Figure 35: Chair 16, with damages (red) and intervention displayed (yellow).

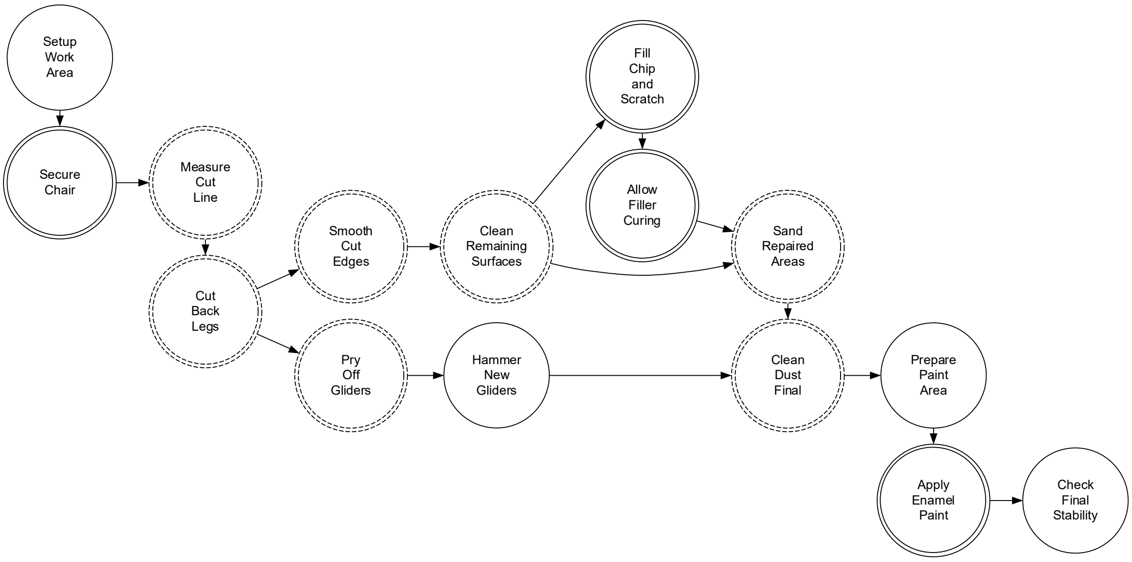


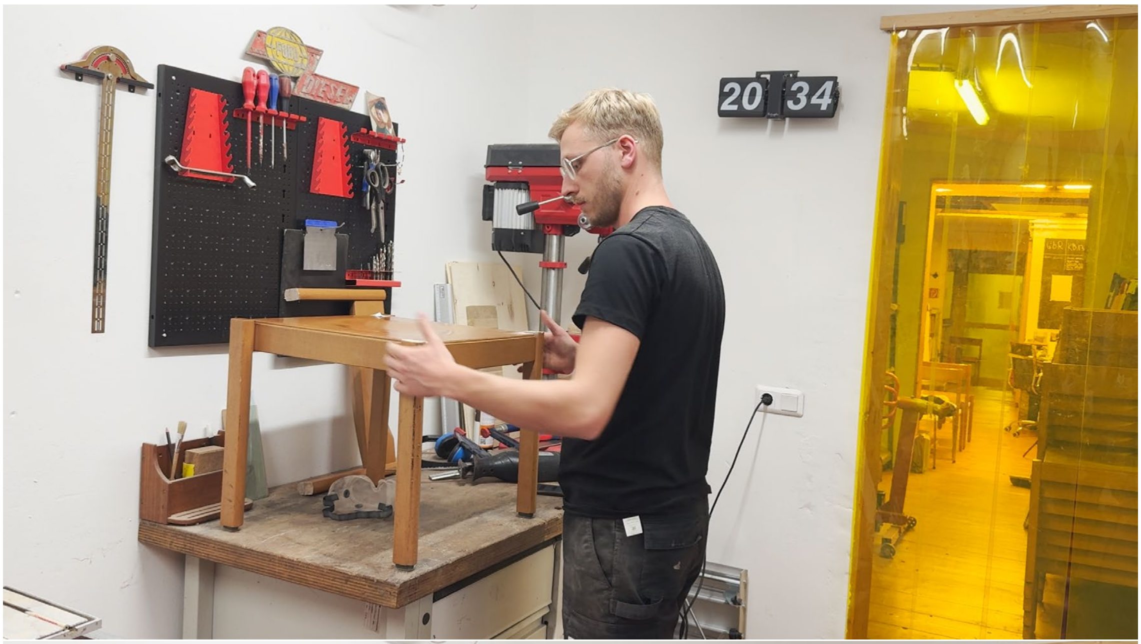
Figure 36: All tools and materials needed (top) for the selected repair-strategy (bottom) of chair 16.

Figure 37: The final outcome: The chair became a stool, painted in white enamel paint.


DIESEL
20 22
PROXXON


DIESEL
20 24
PROXXON


DIESEL
20 32


20 34


20 37


20 52

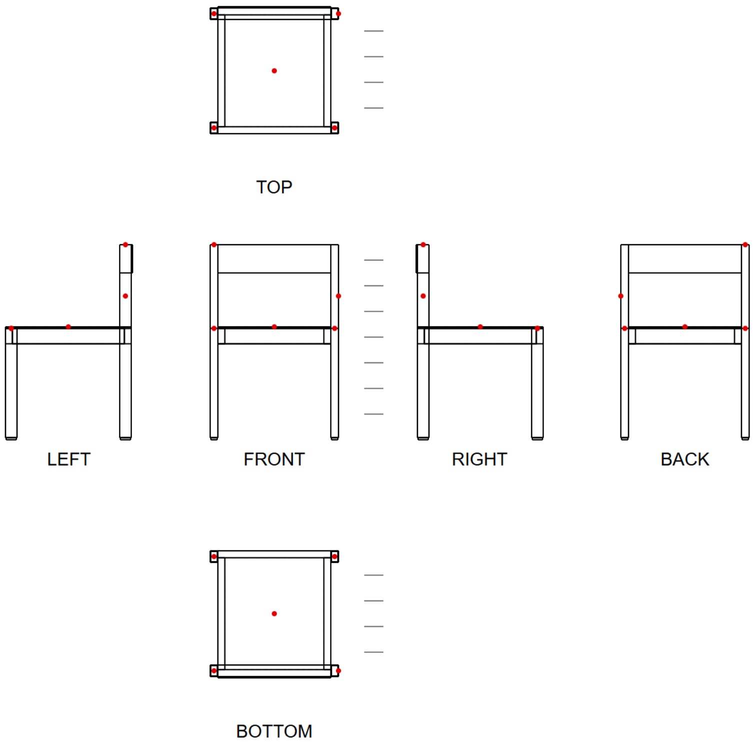


Figure 38: Damages of Chair 5

Figure 39: Previous attempt of a repair on chair 5.

Chair 5 presented a mixture of structural weakness and surface deterioration. The most striking issues were a poorly executed earlier repair on the front right leg, where an in-appropriate adhesive had been applied and left visible residues. In addition, scuff marks and scratches are visible on many surfaces.

Rather than pursuing minimal intervention, the *Stylistic Idealist* brain was chosen. This philosophy conceives of repair as completion: the goal is not to preserve patina or mark continuity, but to achieve a perfected, stylistically coherent state – even if this means reconstructing or reinventing parts of the object.

The first generated plan started with complete disassembly of the chair, removal of all gliders, and elimination of previous repair traces. Cracks in the legs were consolidated using high-strength wood epoxy, after which every surface was stripped of its old finish. A sequence of sanding, sealing, and multiple varnish coats followed, each layer sanded between applications to ensure flawless smoothness. The chair was then fully reassembled, topped with a new set of uniform gliders, and presented in a state indistinguishable from a newly manufactured object.

The second plan pushed the stylistic completion even further. Rather than stopping at natural refinishing, the user in collaboration with the model specified a striking transformation of appearance: all damages were filled with stainable epoxy, the entire chair was stripped, sanded, and conditioned, then coated with a vivid bright red stain. This chromatic intervention was sealed beneath successive layers of high-gloss polyurethane, producing a reflective, almost lacquer-like surface. The worn gliders were replaced with new ones, completing the chair's reinvention as a pristine, stylized artifact.

The two variants demonstrate how the *Stylistic Idealist* logic departs radically from conservative repair. In both cases, wear and patina are not preserved but erased; flaws are not left visible but dissolved into a seamless surface. While the first plan aimed for an idealized version of the chair as it might once have been, the second took a more radical stance, using color and gloss to project an imagined perfected state that never existed. Chair 5 thus exemplifies how this repair philosophy prioritizes stylistic unity over authenticity, treating repair, or rather restauration as an act of authorship rather than conservation.

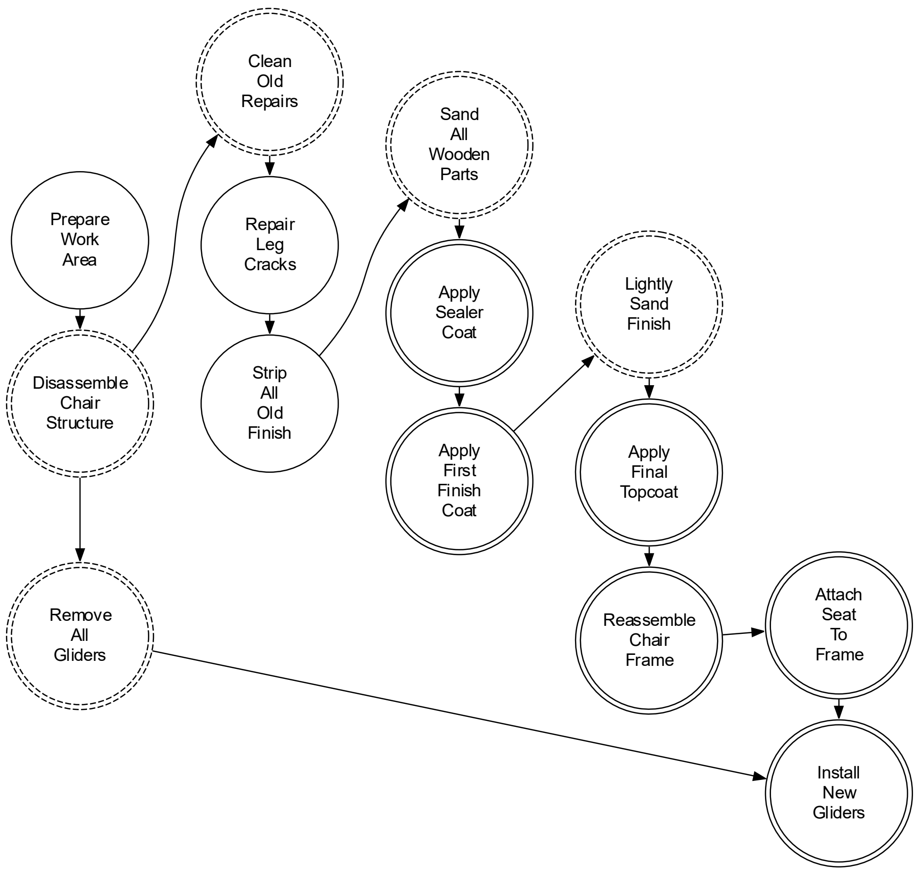


Figure 40: The initial action map of chair 5.

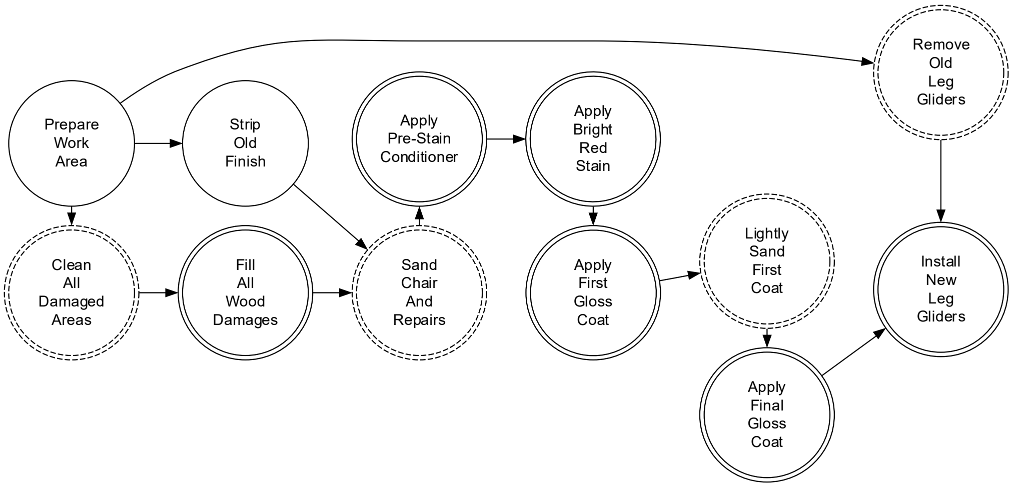


Figure 41: Action map (top) of chair 5 after multiple iterations by the user. The shown image of the chair (bottom) is an AI generated rendering from the original image of the chair and the repair plan as input.

Chair 3 was among the most severely damaged examples. At the start of the process, the chair consisted only of fragments that were salvaged from the church building site. Both front legs showed severe cracks and breakage, at the back apron material was also missing, and the seat displayed a chipped and broken area. Despite this level of deterioration, the chosen repair philosophy was the *Gentle Craftsman*. This orientation emphasizes modest, careful mending with sympathetic materials, using reversible techniques, and retaining as much original fabric as possible.

The final plan for Chair 3 is guided by the *Gentle Craftsman* philosophy, emphasizing modest intervention, sympathetic materials, and the preservation of patina.

The sequence begins with securing the workspace, laying out and labeling all parts, and cleaning damaged areas with fine tools to retain sound fibers. Cracks in the back apron and front right leg are to be consolidated with warm hide glue and padded clamps. More severe losses are treated through precise removal and preparation: the chipped seat is squared into a small recess, the broken back apron is cut into a rectangular void, and the front left leg is prepared for a scarf joint to replace unstable material. New inserts are fabricated from timber chosen for grain and color sympathy, glued with hide glue, and clamped until cured. Once hardened, the repairs are leveled flush with the surrounding surfaces and sealed with a thin coat of dewaxed shellac, ensuring the interventions remain both visible and reversible.

The chair is then to be dry-fitted and finally reassembled with original hardware and hide glue where needed. The intended outcome is a stabilized chair in which repairs are evident yet harmonized, demonstrating continuity rather than replacement.

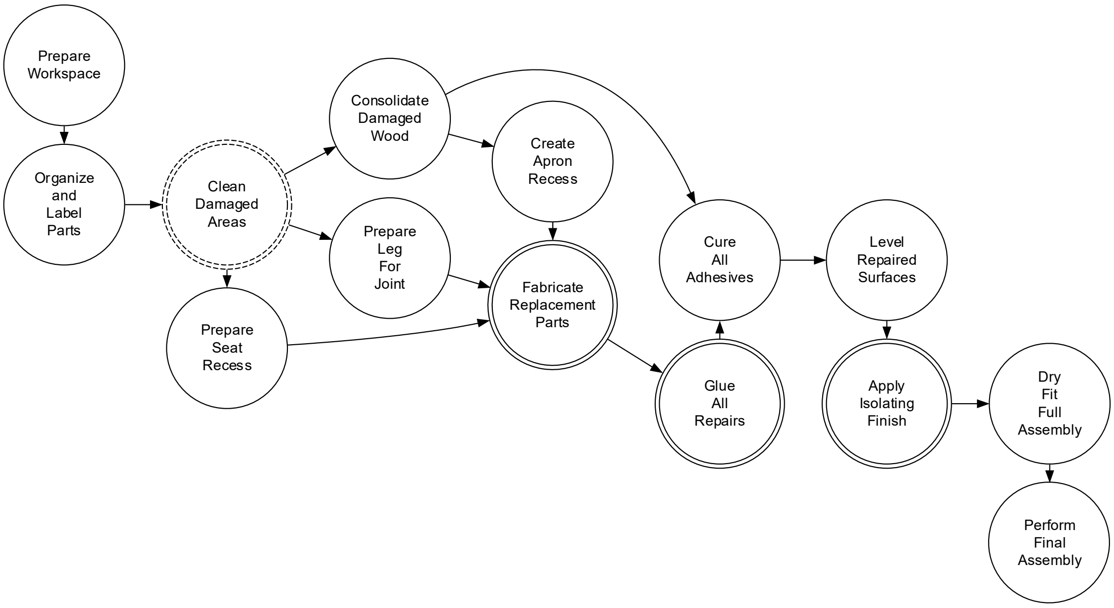


Figure 42: Action map of Chair 3 (top) and comparison of repaired leg with intact leg (bottom).

Figure 43: The following pages show the results of the Case Studies.










5.3. The Forest Cemetary Chapel: Architectural Implementation.

The case study at architectural scale focuses on the Forest Cemetary Chapel in Rhöndorf, designed by Hans-Uwe Rein in the late 1960s. Built as part of the cemetery’s post-war expansion, the chapel combines a pyramidal tower with a saddle-roofed hall, set into the slope with a partially buried basement. Four angled timber supports carry the steep slate-clad roof, while a recessed glass façade at ground level creates a sheltered transitional space between inside and outside. The interior includes a funeral hall, structured by a grid that organizes flooring, timber ceiling panels, and lighting. The design emphasizes clarity and openness, with large glazed areas connecting the ritual space to the surrounding forest landscape.

Figure 44: The chapel at the day of the *Richtfest,* a traditional German ceremony and celebration held when the structural frame and roof of a new building are completed. Image: Günter Groote

The chapel has been closed since 2017 due to severe defects recognized by municipal employees during an examination of the structure. The primary cause was moisture damage resulting from faulty drainage on the hillside and the roof, which led to water ingress, mold growth, and a deterioration of the building's fabric, especially in the basement and the timber structure of the bell tower. Citing high restoration costs (estimated at 353,510 EUR for a full renovation), the city administration initially proposed a partial demolition of the chapel. The plan was to preserve and renovate only the basement level, which houses restrooms and storage areas, for approximately 207,700 EUR.

This proposal was met with broad and vehement public opposition. The local community association and engaged citizens launched a campaign to save the building, supported by the Konrad Adenauer House Foundation,. In open letters and appeals, they highlighted not only the chapel's architectural value but also its immense importance as a place of remembrance, mourning, and community – a significance amplified by the fact that the cemetery is listed as a monument-site and in addition, Germanys first chancellor Konrad Adenauer's grave is located in the cemetery, making it a site of national interest.

Figure 45: The cemetery chapel in Rhöndorf following initial measures to preserve the structure.

In response to sustained public pressure and the compelling arguments from the community, the city's political leadership reversed its course. The demolition plans were definitively abandoned. The city administration was tasked with developing a more cost-effective plan for the chapel's preservation.

The result is a "frugal restoration" plan, which has been approved for implementation by the city council. This approach involves a phased renovation with an estimated cost of 182,950 EUR in total, including repair-work that was already done. The most urgent measures, such as waterproofing the basement and repairing the windows and roof, were carried out first to make the chapel usable again in the medium term. Larger-scale projects, like a complete roof replacement, have been postponed. The decision, made by the responsible committee in November 2024, marks a significant victory for the citizen-led initiatives that fought for the building's preservation.

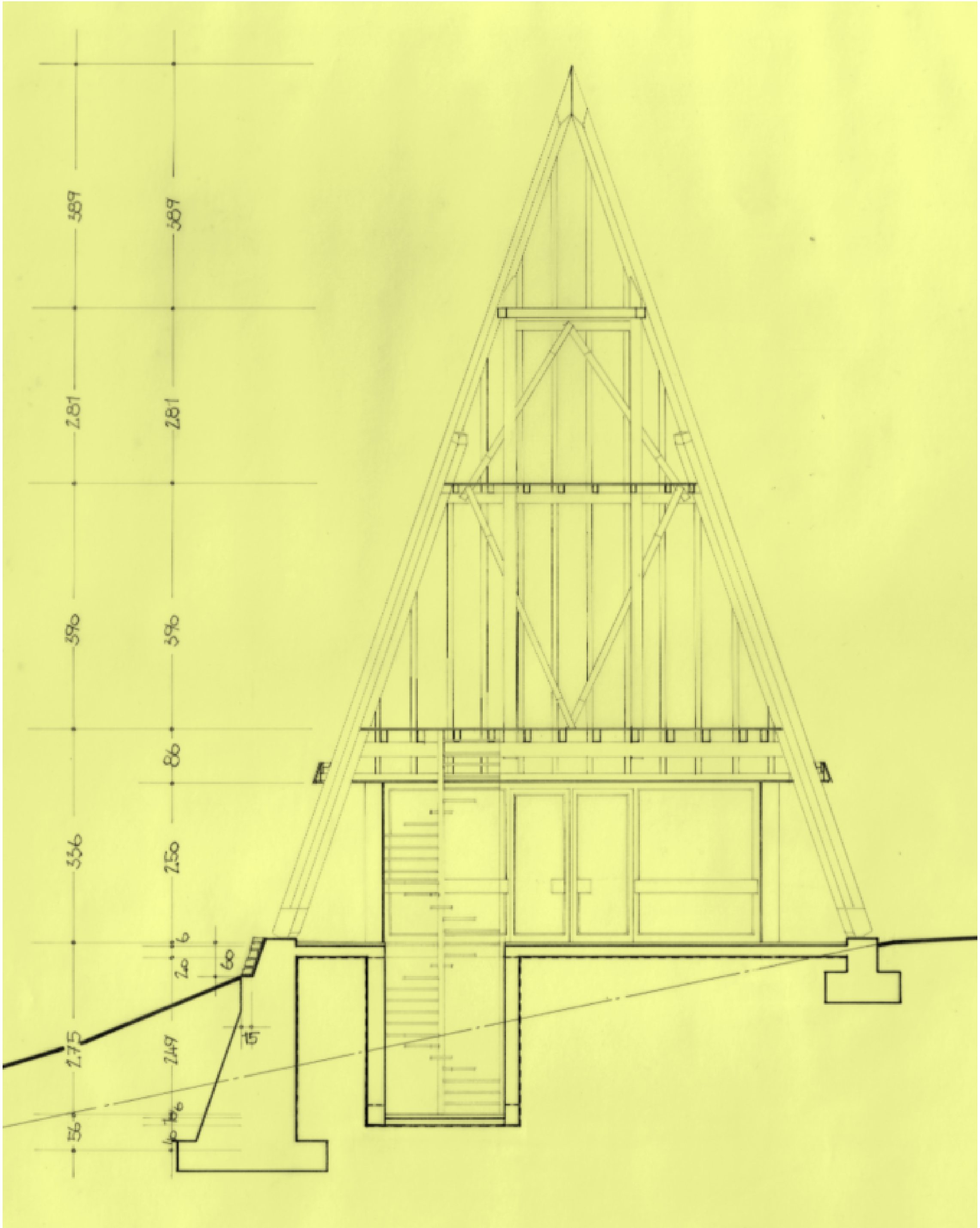


Figure 46: Section of Belltower.

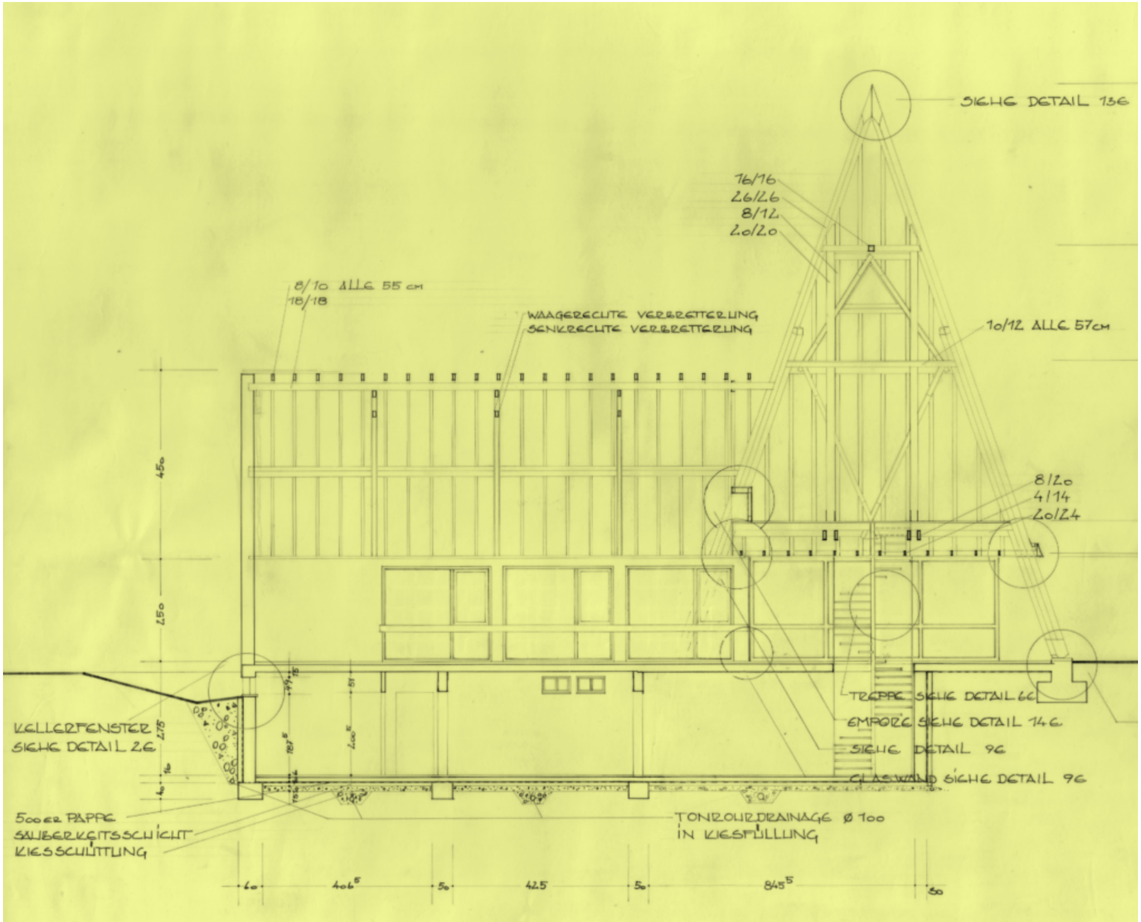


Figure 47: Section of the Chapel.

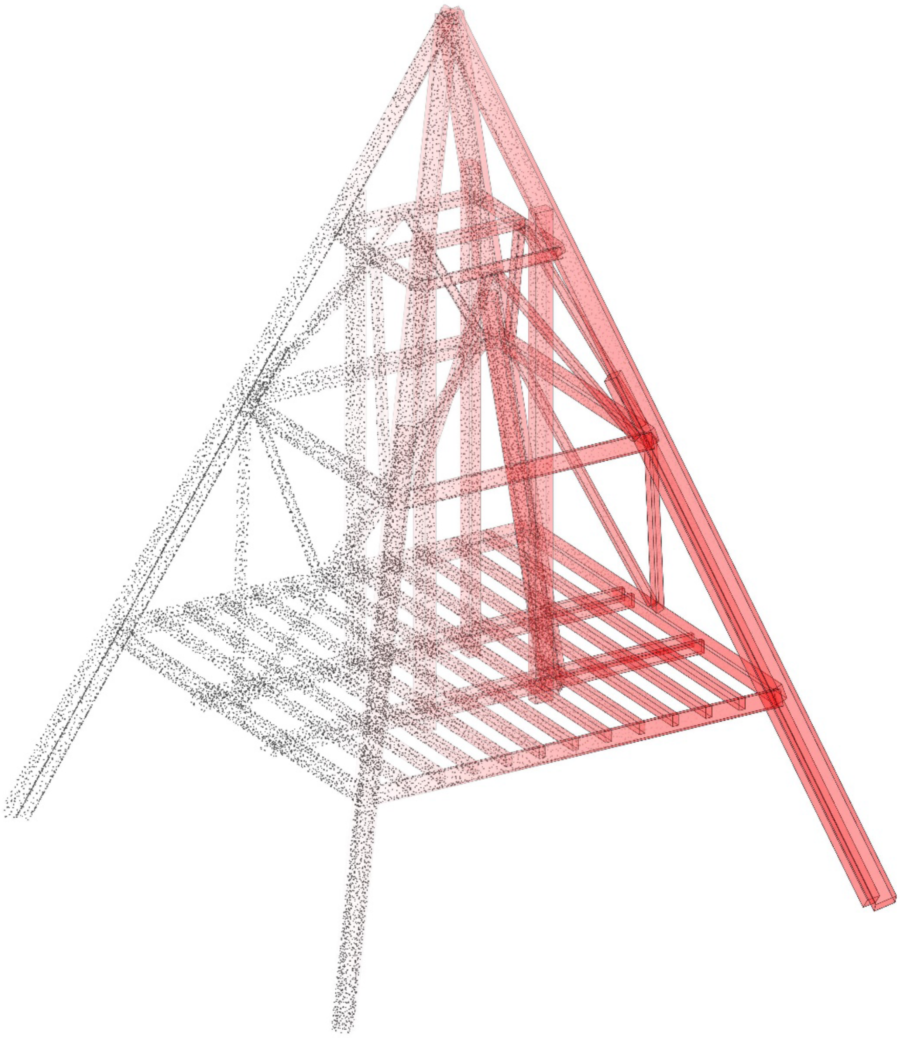


Figure 48: Overlay of assembly model of the church tower with an generated point cloud.

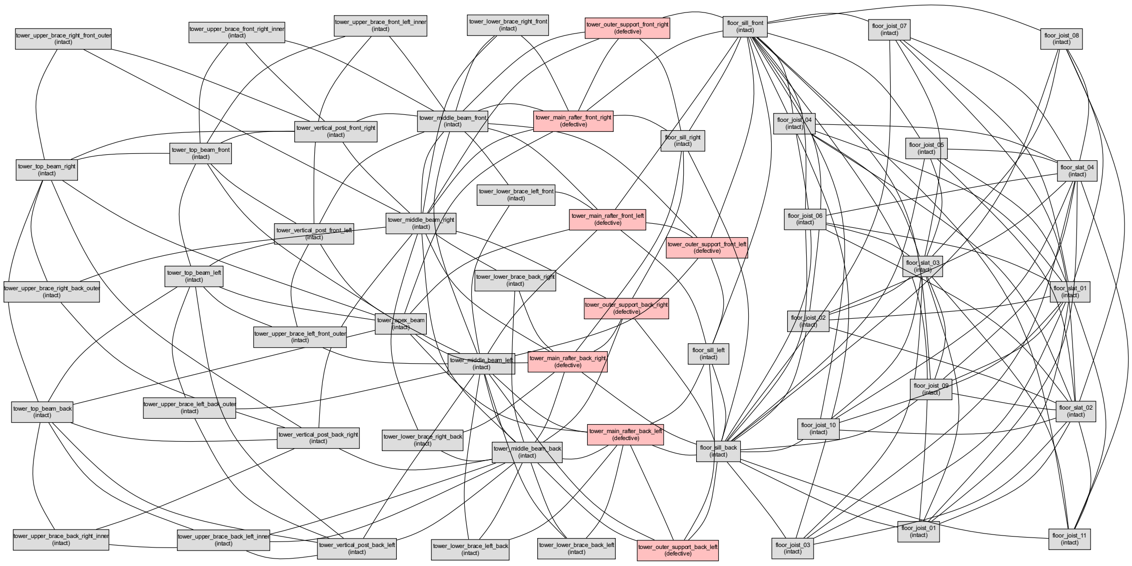


Figure 49: Visualization of the connections of parts and their status after the first two steps in the process.

Figure 50: Front right column of the church.

Figure 51: Extensive rot on all four main columns was documented.

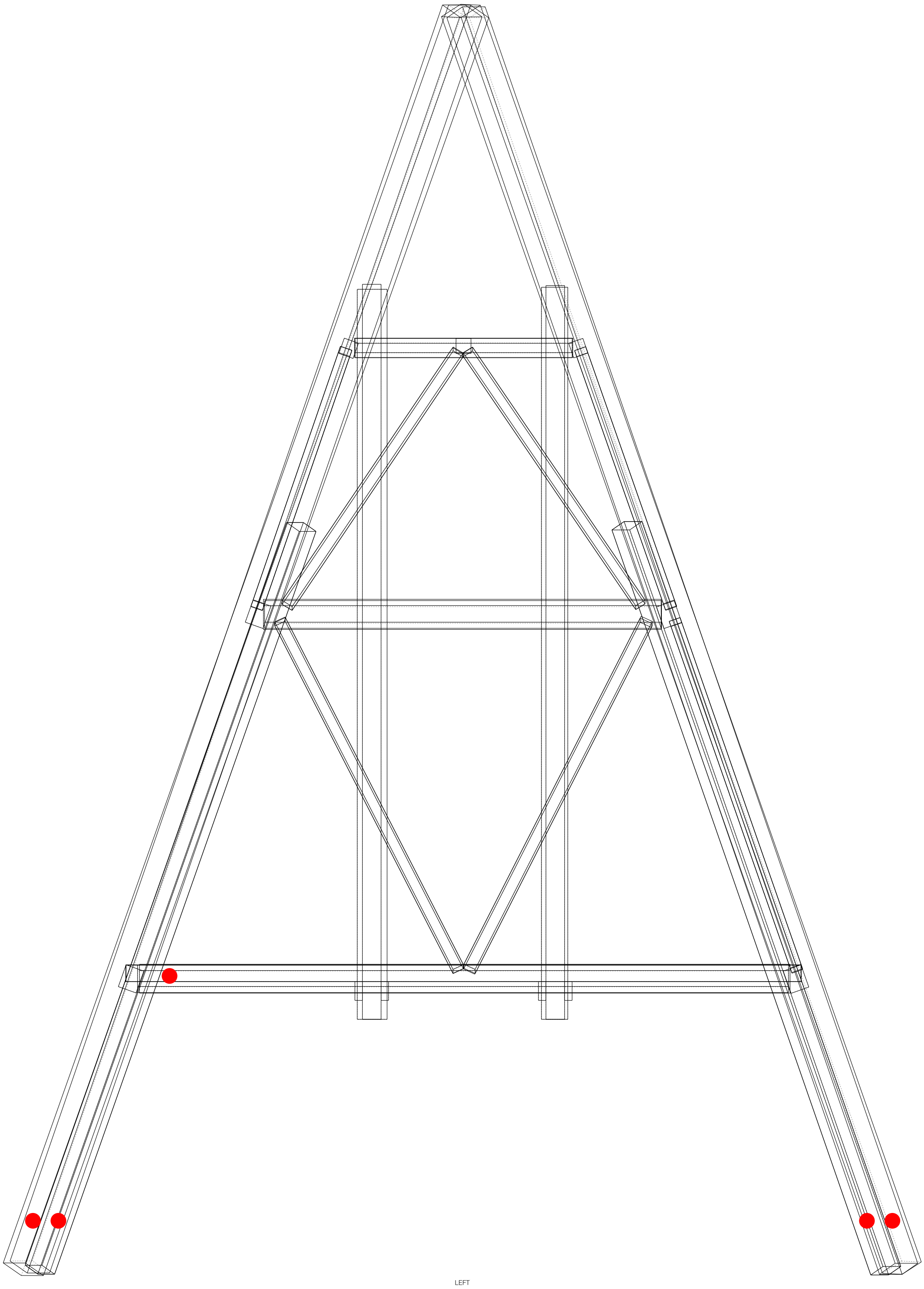
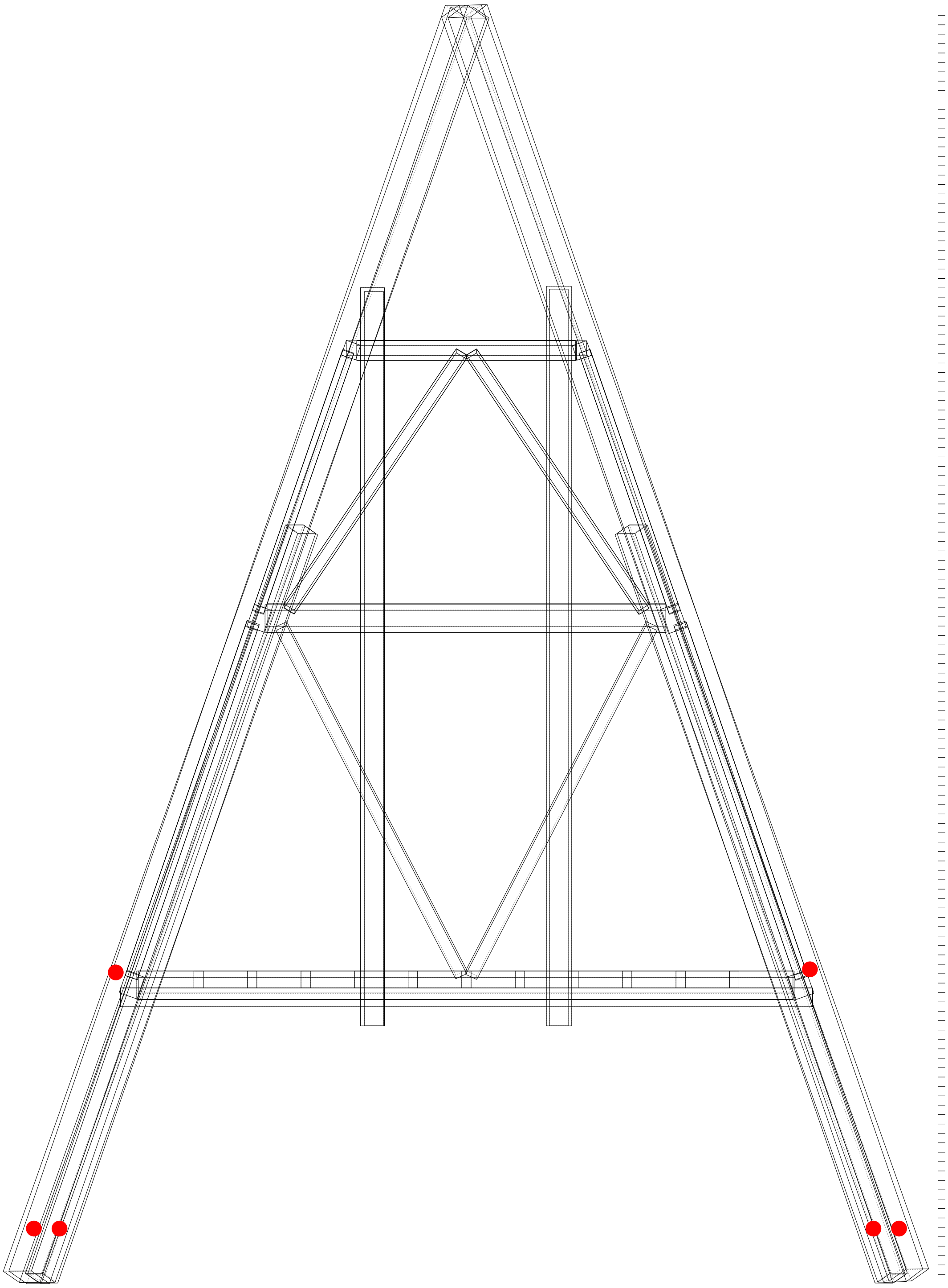
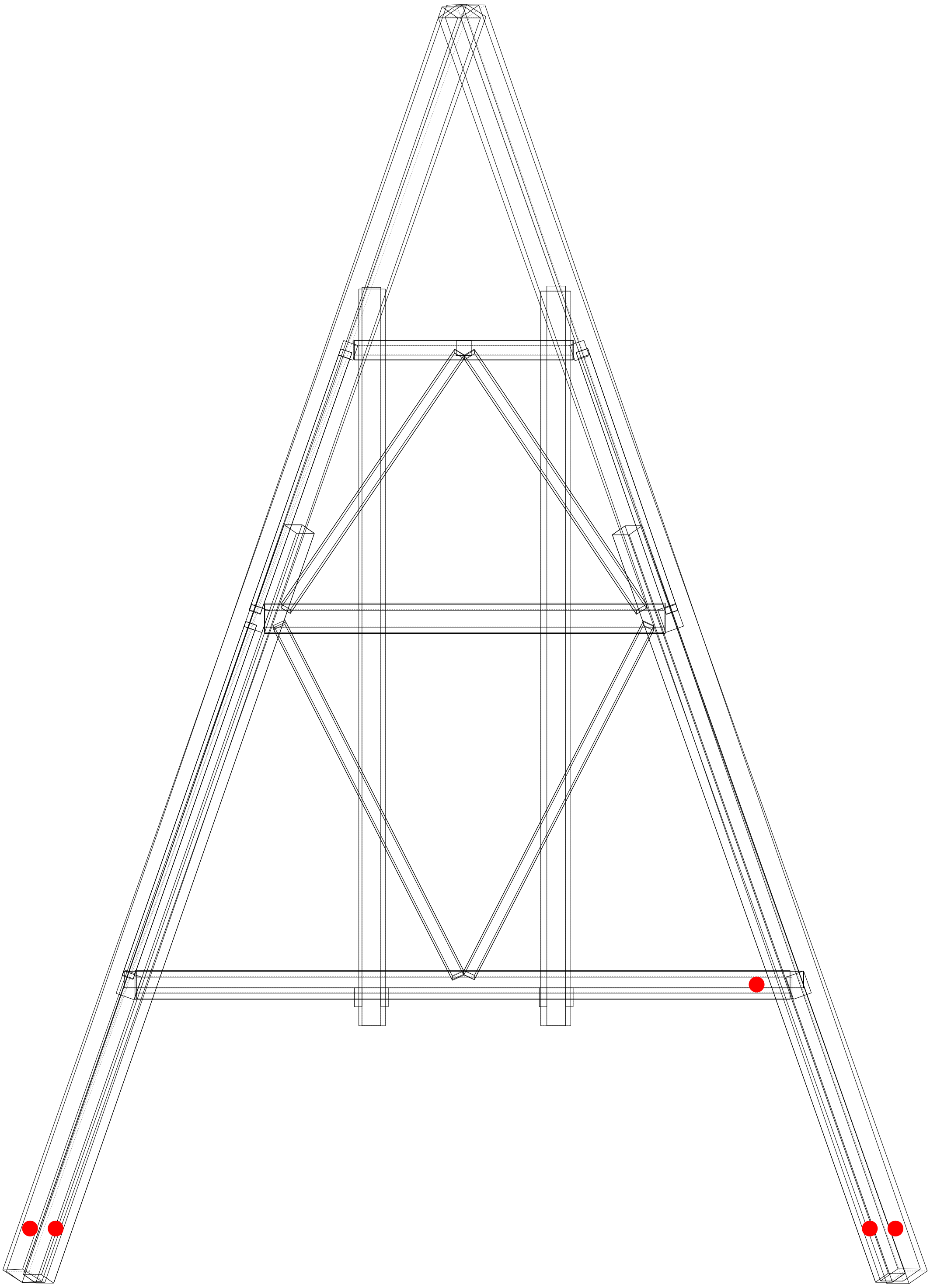


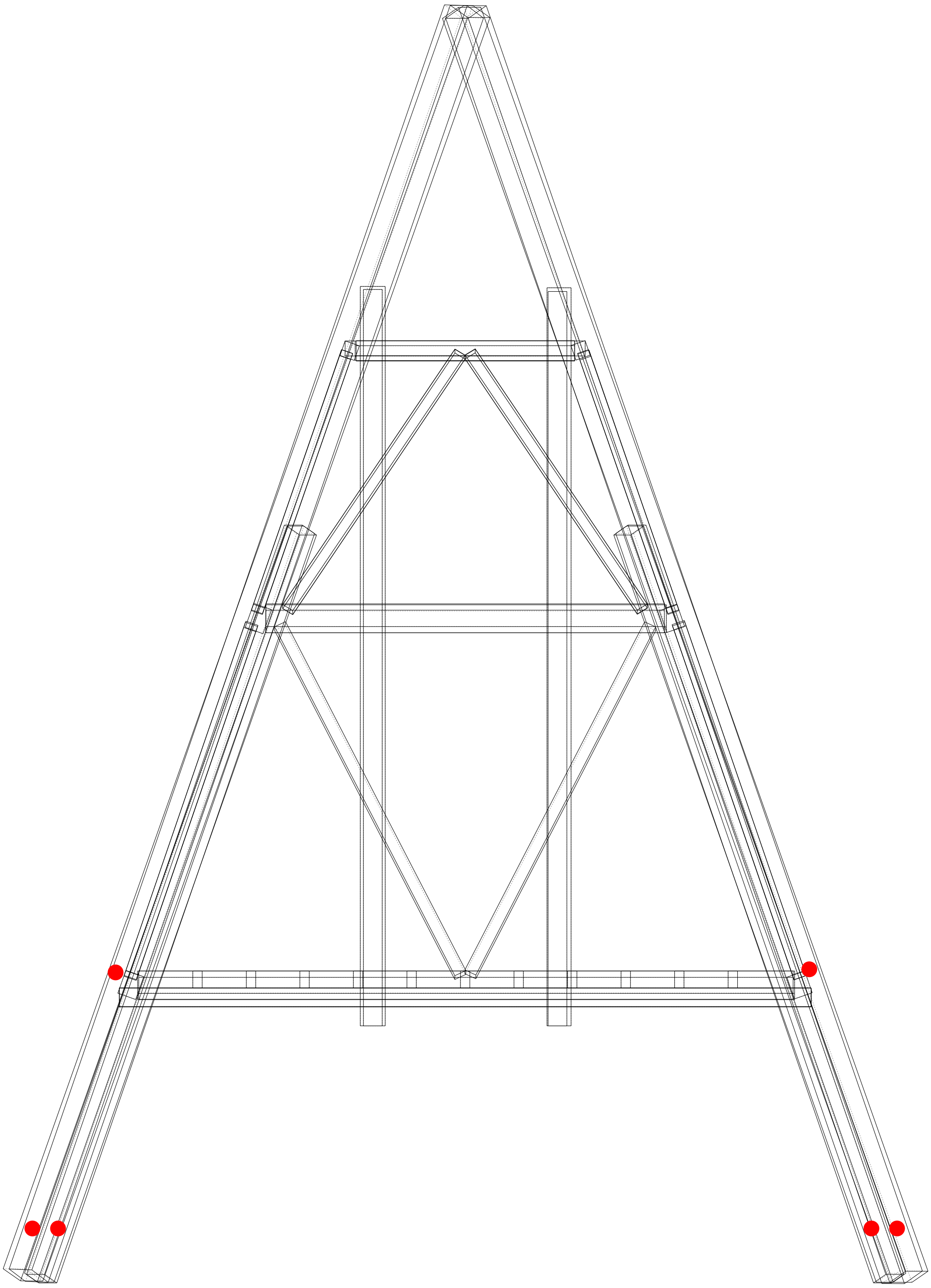
Figure 52: Damage catalog of the church belltower (Including the following pages).



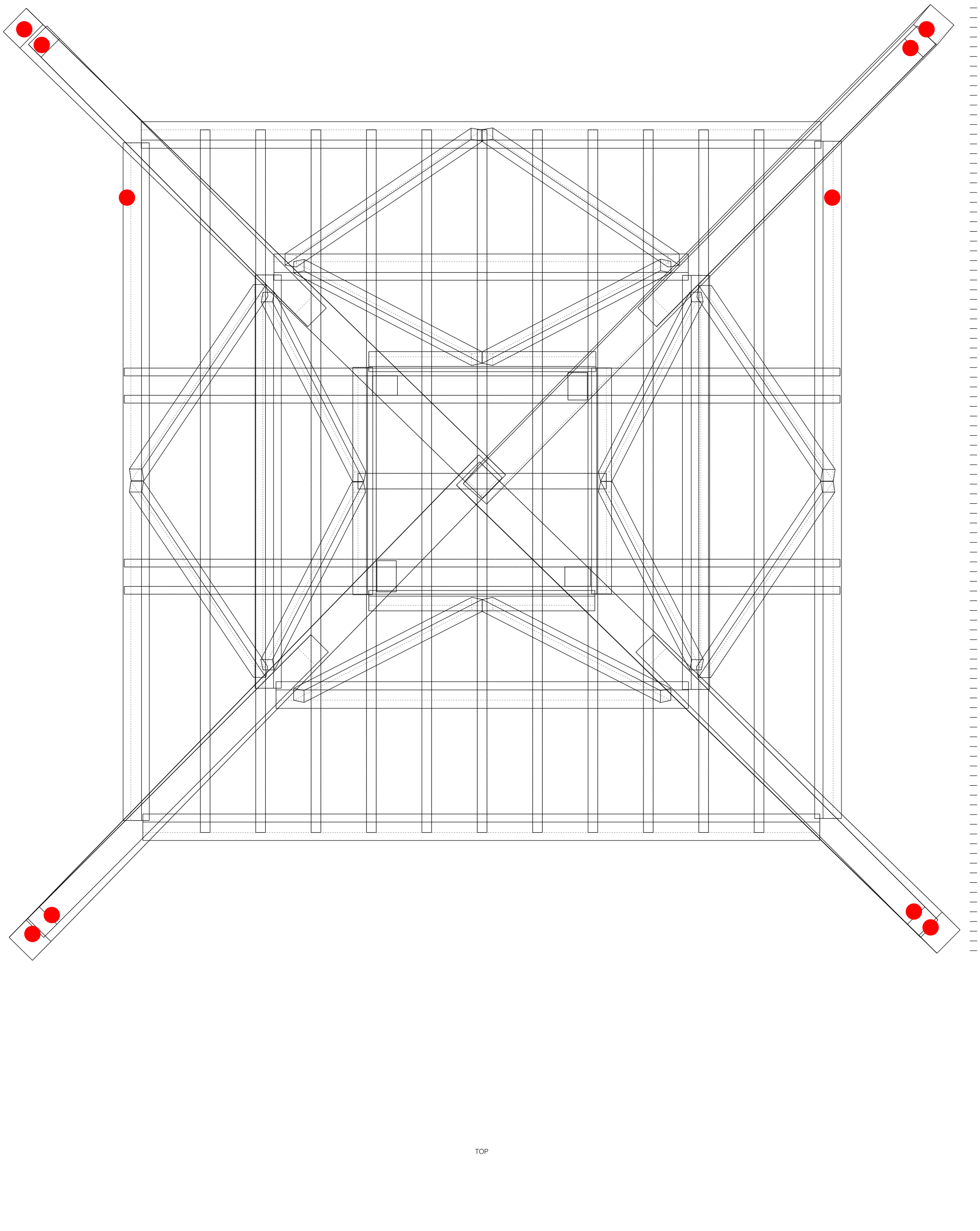
FRONT



RIGHT



BACK



TOP

To test the workflow at a larger architectural scale, a digital assembly of the church tower frame was created. Damage detection identified widespread rot at the bases of the outer supports and the adjoining rafters, with particularly severe losses on the back right support and its connected rafter.

Based on this input, the *Gentle Craftsman* brain generated a repair plan. The sequence begins with stabilizing the structure by installing temporary supports, followed by careful removal of rotted material from the affected outer support and the adjoining rafter base. A scarf joint is proposed for the tower's back right outer support, while a Dutchman patch is suggested for the base of the rafter. Both interventions are designed to retain maximum original timber while providing structurally sound replacements.

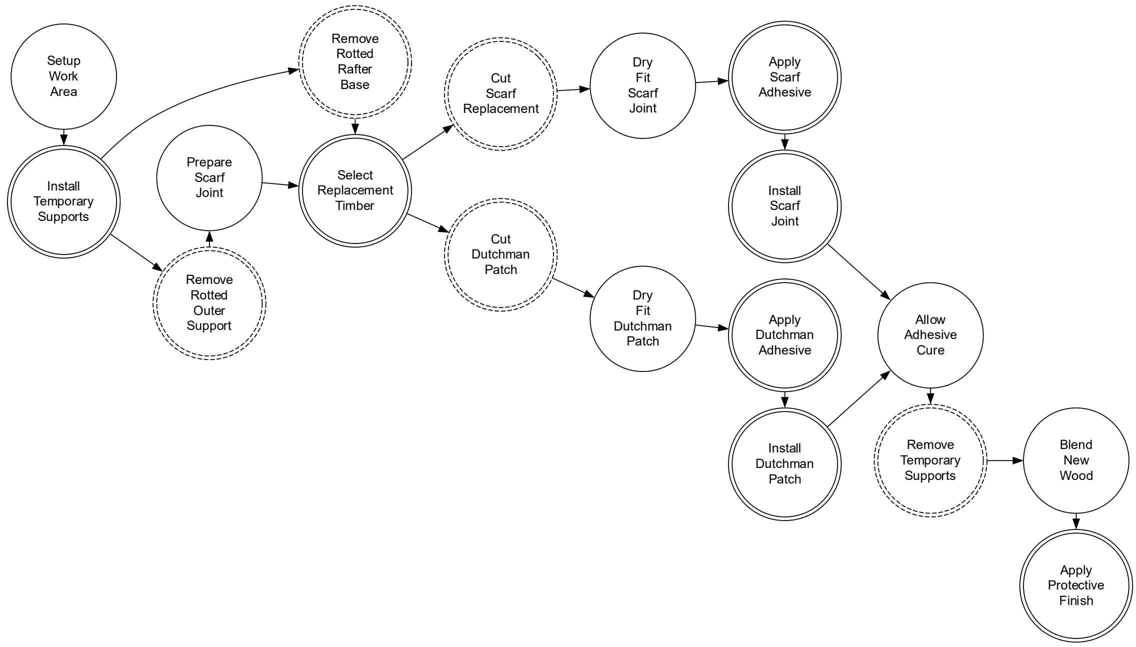


Figure 53: Repair plan for one of the supports.

New timber of matching species and grain is to be selected, cut, and dry-fitted before final adhesion with reversible wood glue. Mechanical reinforcement with dowels or screws is included, and finishing steps call for gentle blending of the new timber with the old, followed by a breathable protective coating such as oil or lime wash.

The focus is clearly on targeted interventions, minimal loss of original fabric, and visible continuity between old and new. After the generation of the repair process, Images were generated to illustrate the sequence (Figure 56). Gemini 2.5 Image Generation was provided with the resulting repair plan as JSON and one original image of the dataset (Figure 50).

In addition to repair operations on specific joints, the AI also extended the assembly model to propose multiple temporary support strategies. For the whole tower, it suggests a central frame placed in the middle to bear loads during intervention. Alternatively, supports can be positioned locally near weakened outer columns if needed. These proposals show how the system not only generates repair sequences but also considers structural safety during execution.

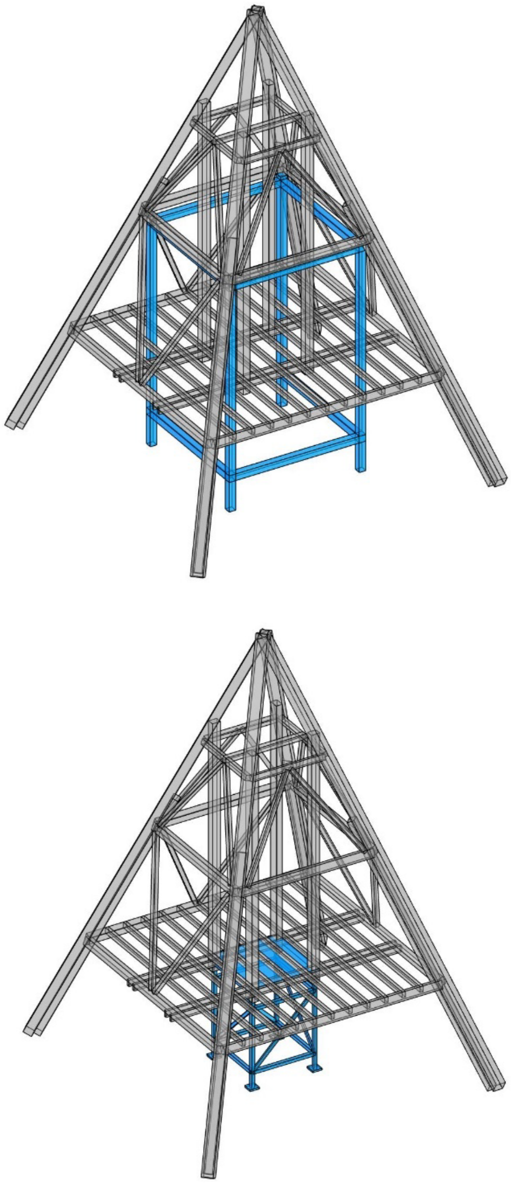


Figure 54: Examples of support strategies generated by the AI.

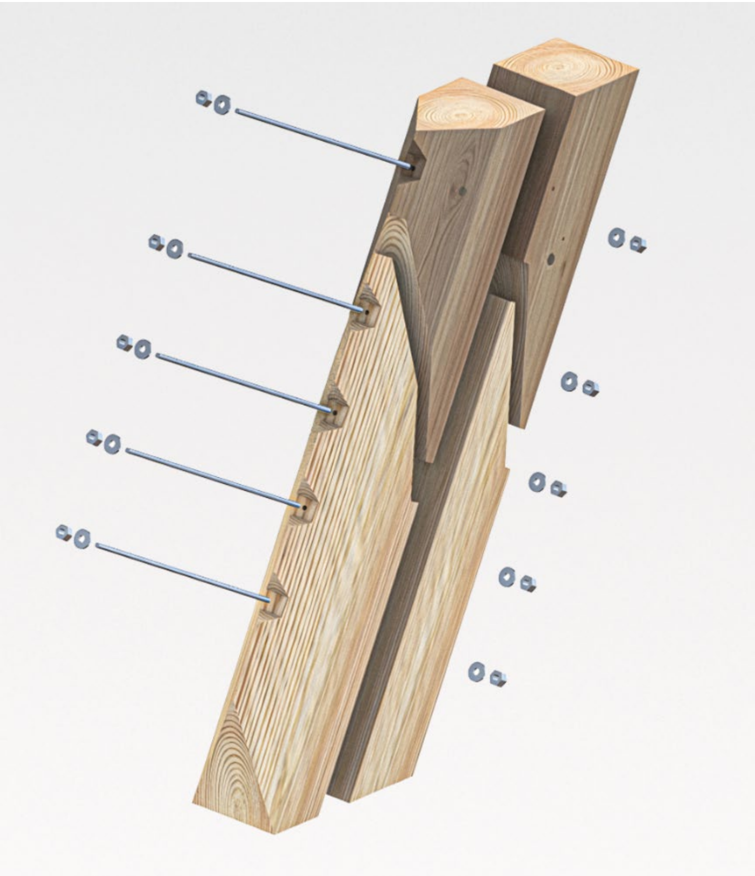


Figure 55: Repair of the column with two scarf-joints.

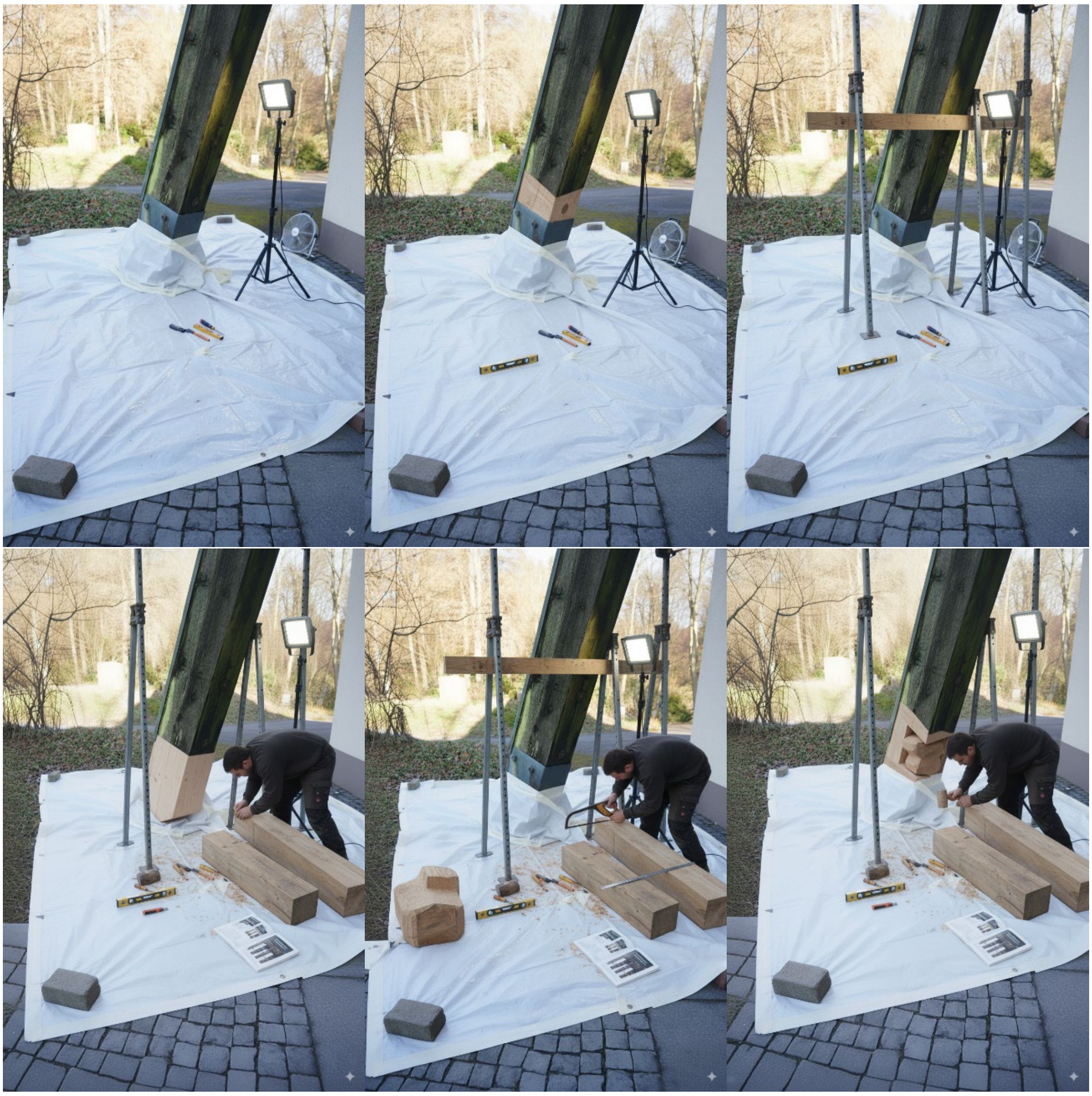


Figure 56: Image sequence (AI generated), depicting the repair suggestion.

6. RESULTS

The case studies confirm that the developed framework is both functional and resilient across different scales and logics of intervention. In the Santo chair tests, even non-experts were able to execute repair strategies with a high degree of repeatability. Most importantly, the experiments showed that unstructured input could be transformed into structured models and repair plans within minutes, which could then be endlessly re-structured and edited through simple text or image prompts. For the same object, dozens of alternative repair strategies could be generated and compared with minimal effort. Practical constraints such as limited time or tools were integrated into the reasoning process and resulted into contextually reasonable solutions.

At the same time, several limitations became evident. The geometric fidelity of the generated assemblies, while sufficient for reasoning and planning, occasionally introduced “hallucinated” parts or imprecise dimensions. The detection of damages relied also heavily on detailed images and even then user annotations were sometimes necessary for correct mapping. These inaccuracies rarely prevented repair but underscored the continued need for human oversight and correction.

Similarly, the integration of different predefined repair philosophies revealed both opportunities and challenges. While they demonstrated the richness of divergent reasoning paths, several risks became apparent. The system can overfit to a chosen philosophy, producing plans that are internally consistent but blind to practical feasibility. At times, the influence of a philosophy remains superficial, shaping only the language of the plan while the actual repair steps remain generic. More critically, philosophy-framed strategies may appear overly authoritative and convincing, which can mislead users into accepting flawed or impractical proposals without sufficient scrutiny.

At the same time, the framework carries a risk of amplifying confirmation bias. Once a user approaches the repair with a strong pre-conceived intention, the system readily generates convincing arguments and a seemingly professional strategy that aligns with that intention. This tendency may reinforce rather than challenge initial assumptions. The framework cannot evaluate whether a proposed method is actually suitable, nor determine whether the person carrying out the intervention is qualified to do so.

The visualization of repair steps provided limited value in this context (Figure 56): despite their hyper-realism, the images often contained logical flaws that required interpretation by an experienced user.

At the architectural scale, further constraints appeared. In the chapel study, the system successfully catalogued damages and proposed phased interventions, but its suggestions often lacked the embodied knowledge of experienced carpenters or conservators. For example, the proposal of a scarf joint for the rotted tower support was plausible at a conceptual level, yet the precise implementation and structural performance could not be determined without expert judgment. Such examples confirm that the framework is best understood as a decision support tool, not a replacement for craft expertise.

The case studies also demonstrate the pluralistic nature of repair. The transformation of Chair 16 into a stool under the Janitor's Cookbook philosophy showed that the system can accept radical adaptation as a legitimate outcome: the function of sitting was preserved, while typology and aesthetics were sacrificed. In contrast, the Gentle Craftsman repair of Chair 3 preserved damaged wood through careful inserts and hide glue, producing a materially continuous but visibly scarred artifact. These divergent outcomes, generated from the same dataset, underscore that repair is not governed by universal truth but by a negotiation between priorities. The user's role remains decisive, as their prompts and adjustments strongly influence the generated plans (Figures 57 and 58).

The chapel results deepen this finding. The AI-generated strategies mirrored genuine engineering logics of structural safety, reflecting a machine form of reasoning about fragility. Yet the explanations of how to implement these strategies remained vague and required further human interpretation. At this point, multiple humans would be involved in the repair process, making clear communication and the allocation of responsibilities essential for deciding who conducts which task. Yet the current framework does not support coordinating different users or distributing responsibilities across them.

Taken together, the results suggest that the framework succeeds in making repair systematic, repeatable, and pluralistic. It provides users with structured reasoning tools, reduces ambiguity, and supports the exploration of alternative logics of intervention. At the same time, it relies on human oversight for precision, feasibility, and judgment. The framework showed it strengths not as an autonomous repair engine but as an interactive decision support system that broadens the design space of repair.

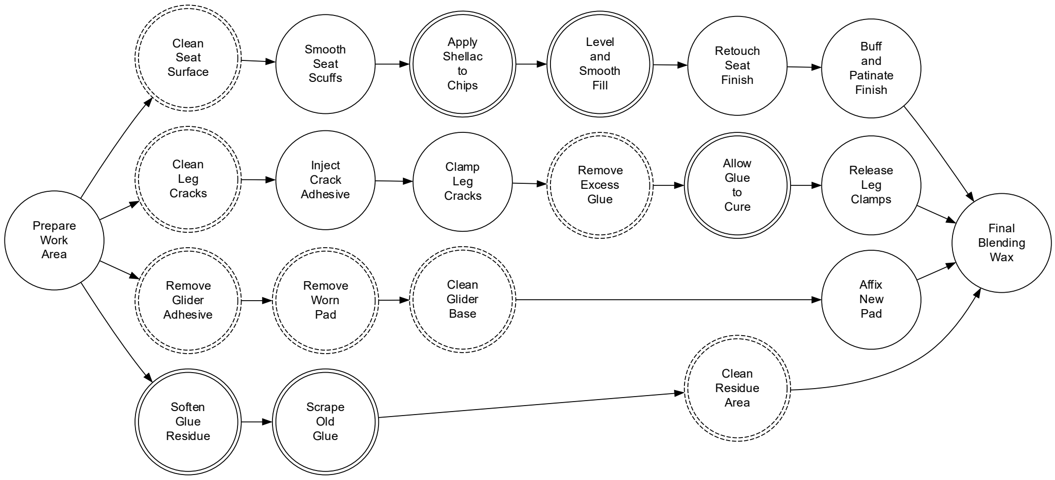


Figure 57: The repair action map of chair 5 before additional user input.

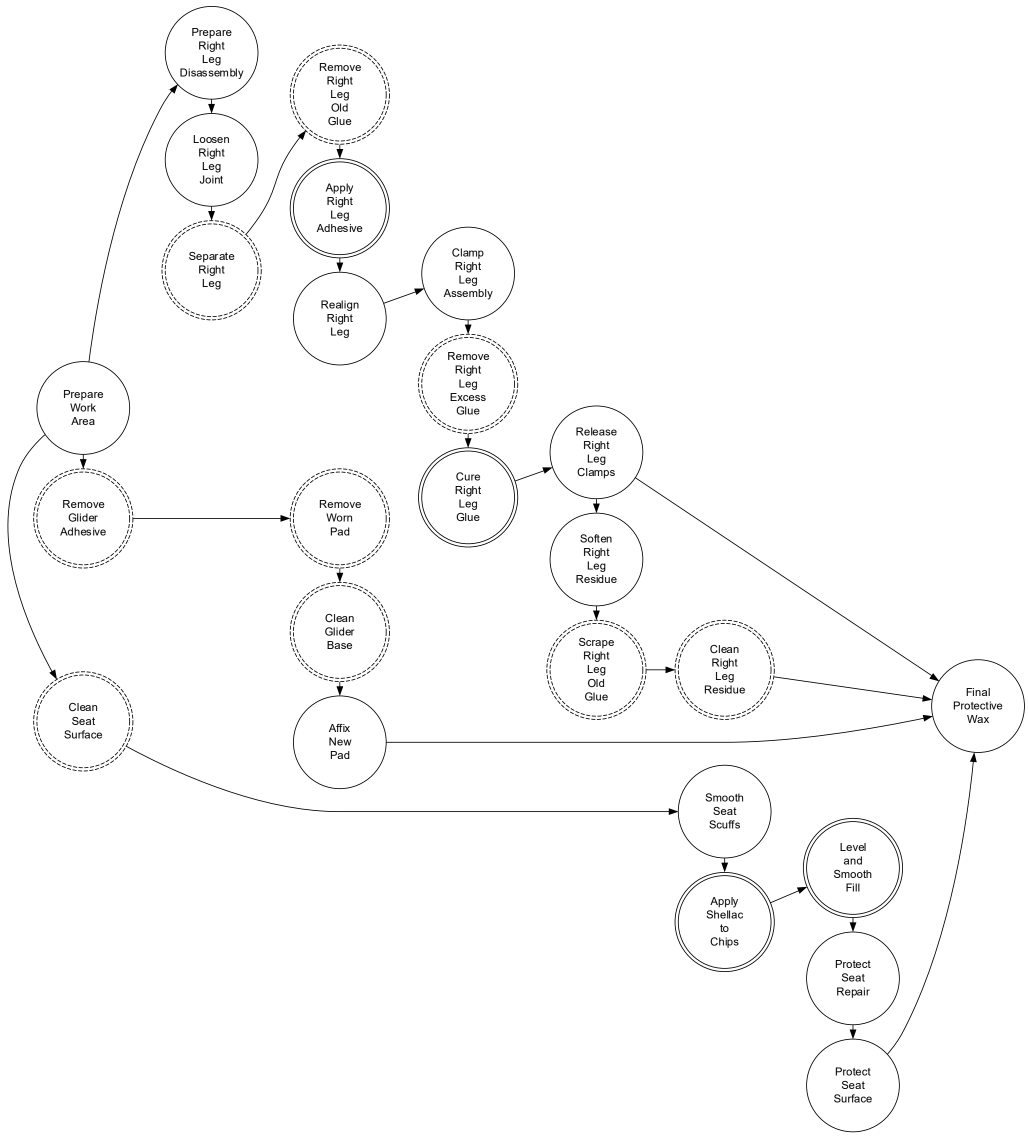


Figure 58: The repair strategy of chair 5 was rapidly extended after user input (five iterations).

7. CONCLUSION

This thesis defines and validates a new paradigm for architectural intervention, transforming repair from an ad-hoc craft into a systematic and data-driven design practice. The work’s core contribution is not merely a tool, but an operative framework that makes the complex, often competing logics of repair computationally legible. By translating unstructured reality (photographs, scans, and historical documents) into a coherent digital model, the system reveals repair as a negotiable design space where philosophical intent can be directly translated into actionable, transparent, and repeatable strategies.

The framework allows for the direct comparison of divergent strategies, as it can host and articulate a multitude of positions. This makes the underlying values of any intervention explicit and debatable. The case studies provide proof of this concept. The Santo chair experiments demonstrated the framework's power to democratize repair, enabling to execute complex tasks and make well-informed decisions with a broad spectrum of intentions. This thesis therefore establishes a new, symbiotic model of practice where the machine handles the burden of data synthesis and logistical planning, freeing the human expert to apply the irreplaceable faculties of contextual judgment and craft.

In this sense, the thesis repositions repair as a **structured reverse design process**, echoing Bruno Reichlin’s insight: to not begin with a blank page, but with what already exists. With its material scars, construction logics, and latent possibilities. By operationalizing repair as a structured, pluralistic, and communicable process, this thesis demonstrates how digital intelligence can extend the architect’s capacity to care for, upgrade, and reimagine the built environment.

8. OUTLOOK

The project demonstrates how unstructured input can be transformed into structured assemblies, damage catalogues, and action plans, establishing repair as a systematic and data-rich process. Looking ahead, this framework opens a range of possibilities. Its ability to scale from small artifacts to architectural structures suggests applications across heritage conservation, adaptive reuse, and contemporary construction. The capacity to generate, compare, and refine repair strategies could evolve into a collaborative platform, connecting practitioners, institutions, and machines within shared digital environments.

In the future, the structured and machine-readable outputs could serve as a foundation for further automation, linking AI reasoning with robotic fabrication or augmented reality guidance on site (Figure 59). Beyond the technical domain, the framework invites reflection on how design intelligence itself might change when repair becomes a primary mode of architectural production.

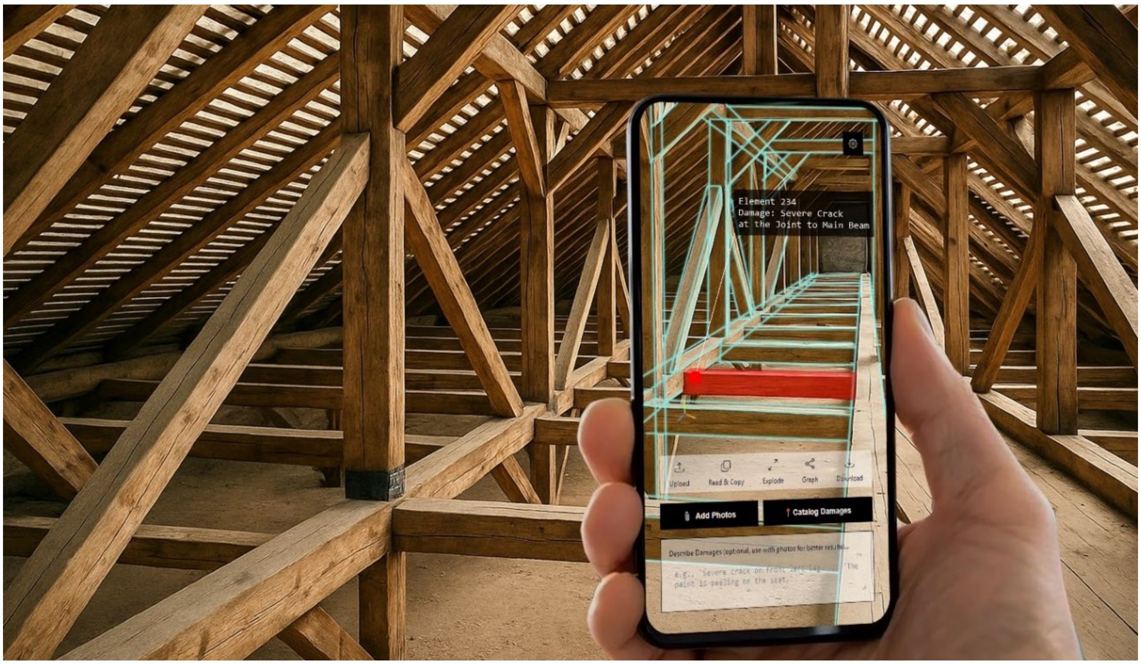


Figure 59: Potential future use of XR applications coupled with AI guided repair.

9. ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor, Prof. Dr. Kathrin Dörfler, and the entire Professorship of Digital Fabrication for their guidance and feedback during my time at TUM. My warmest thanks go to Begüm Saral for her incredible support and the time she spent throughout my thesis project for me.

I am grateful to Lancelot and Christian for their thoughtful discussions with me and for truly investing their interest and time in the development of my thesis topic.

Special thanks go to the people of my hometown for their commitment to preserving the chapel at our cemetery. I am particularly thankful to Christine Lutz, who established the connection to a school in Berlin that generously offered the 49 Santo chairs as replacement for the church. Christine not only facilitated this but also donated the chairs to our hometown, allowing me to use a few damaged pieces for this project.

Finally, I would like to thank Marie and my whole family for their constant support.

I deeply appreciate all the help I have received in the course of this project. Thank you.

10. BIBLIOGRAPHY

Brand, Stewart. *How Buildings Learn: What Happens After They're Built*. NY: Viking Press, 1994.

General Anzeiger. "Widerstand gegen Abrisspläne der Kapelle auf dem Waldfriedhof Rhöndorf." November 15, 2025.

Heidegger, Martin. "Building Dwelling Thinking." In *Poetry. Language. Thought*, translated by Albert Hofstadter, 143–59. New York: Harper Colophon, 1975.

KfW Kommunalpanel 2025 – Summary. Frankfurt am Main: KfW Research, 2025.

Lampugnani, Vittorio Magnano. "On Restoration." *Domus*, April 1990.

Langenberg, Silke, ed. *Repair "Encouragement to Think and Make."* Berlin: Hatje Cantz, 2018.

Langenberg, Silke. "Silke Langenberg: «Alles hat einen Wert»." Interview by Marc Frochaux. 2023. Website. https://education.espazium.ch/de/hochschulpublikationen/interview-silke-langenberg-ethz.

Langenberg, Silke. *UPGRADE Making Things Better*. Edited by Silke Langenberg. Hatje Cantz, 2022.

Lipp, Wilfried. "Aspekte zur Reparaturgesellschaft." In *Vom Modernen zum Postmodernen Denkmalkultus? Denkmalpflege am Ende des 20. Jahrhunderts*, vol. 69. Arbeitshefte Des Bayerischen Landesamtes Für Denkmalpflege. Munich: Bayerisches Landesamt für Denkmalpflege, 1993.

Lipp, Wilfried. *Rettung von Geschichte für die Reparaturgesellschaft im 21. Jahrhundert. Sub Specie Conservatoris*. Vol. 21. ICOMOS – Hefte Des Deutschen Nationalkomitees. Berlin: Deutsches Nationalkomitee von ICOMOS, 1996.

Material Cultures. *Material Cultures: Material Reform*. London: MACK, 2022.

Morris, William, and Philip Webb. *The Society for the Protection of Ancient Buildings Manifesto*. London: Society for the Protection of Ancient Buildings, 1877. https://www.spab.org.uk/about-us/spab-manifesto.

Norton, Michael I., Daniel Mochon, and Dan Ariely. "The IKEA Effect: When Labor Leads to Love." *Journal of Consumer Psychology* 22, no. 3 (2012): 453–60.

OECD. *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*. Paris: OECD Puplishing, 2019.

Petzet, Michael, and Uta Hassler, eds. *Das Denkmal als Altlast? Auf dem Weg in die Reparaturgesellschaft*. Vol. 21. ICOMOS – Hefte Des Deutschen Nationalkomitees. Munich: Lipp GmbH, 1996.

Petzet, Michael, and Gert Mader. *Praktische Denkmalpflege*. Stuttgart: Kohlhammer, 1993.

Reichlin, Bruno. "Überlegungen zur Erhaltung des Architektonischen Erbes des 20. Jahrhunderts." In *Bestand der Moderne. Von der Produktion eines Architektonischen Werts*. Zurich: Park Books, 2012.

Ruskin, John. “The Lamp of Memory.” In *The Seven Lamps of Architecture*, 203–6. London, 1849.

Scott, Fred. *On Altering Architecture*. London: Routledge, 2007.

Statistische Ämter des Bundes und der Länder. *Wohngebäude nach Baujahr*. Statistikportal, n.d. https://www.statistikportal.de/de/wohngebaeude-nach-baujahr.

Viollet-le-Duc. *Dictionnaire Raisonné de l’architecture Française Du XIe Au XVIe Siècle*. Paris, 1854.

Will. “Weiterbauen oder Wiederbauen? Über Tradition, Geriatrie und Reproduktion.” In *Kunst des Bewahrens: Denkmalpflege, Architektur und Stadt*, 51–61. Dietrich Reimer Verlag, 2020.

11. APENDIX

The Canonical Object

A minimalist wooden stacking chair, made of beech or a similar light-colored timber with a clear lacquer finish. Its frame is constructed from four rectangular legs with softly rounded edges. They are connected with glued dowel connections. The front and back legs are connected by side and front/back aprons, providing support for the flat, square seat panel. The two rear legs extend vertically to support a single, solid, curved backrest. The chair features plastic gliders on the bottom of each leg for floor protection and metal hardware on the underside for stacking.

```
{
  "objectName": "santo",
  "parts": [
    {
      "id": "front_left_leg",
      "origin": {
        "x": -0.235,
        "y": 0.221,
        "z": -0.2225
      },
      "dimensions": {
        "width": 0.03,
        "height": 0.426,
        "depth": 0.045
      },
      "connections": [
        "front_apron",
        "left_side_apron",
        "seat",
        "front_left_glider"
      ],
      "rotation": {
        "x": 0,
        "y": 0,
        "z": 0
      }
    },
    {
      "id": "front_right_leg",
      "origin": {
        "x": 0.235,
        "y": 0.221,
        "z": -0.2225
      },
      "dimensions": {
        "width": 0.03,
        "height": 0.426,
        "depth": 0.045
      },
      "connections": [
        "front_apron",
        "right_side_apron",
        "seat",
        "front_right_glider"
```

```
      ],
      "rotation": {
        "x": 0,
        "y": 0,
        "z": 0
      }
    },
    {
      "id": "back_left_leg",
      "origin": {
        "x": -0.235,
        "y": 0.384,
        "z": 0.2225
      },
      "dimensions": {
        "width": 0.03,
        "height": 0.752,
        "depth": 0.045
      },
      "connections": [
        "back_apron",
        "left_side_apron",
        "seat",
        "backrest",
        "back_left_glider"
      ],
      "rotation": {
        "x": 0,
        "y": 0,
        "z": 0
      }
    },
    {
      "id": "back_right_leg",
      "origin": {
        "x": 0.235,
        "y": 0.384,
        "z": 0.2225
      },
      "dimensions": {
        "width": 0.03,
        "height": 0.752,
        "depth": 0.045
      },
```

```
    "connections": [
      "back_apron",
      "right_side_apron",
      "seat",
      "backrest",
      "back_right_glider"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
  },
  {
    "id": "front_apron",
    "origin": {
      "x": 0,
      "y": 0.404,
      "z": -0.2315
    },
    "dimensions": {
      "width": 0.44,
      "height": 0.06,
      "depth": 0.027
    },
    "connections": [
      "front_left_leg",
      "front_right_leg",
      "seat"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
  },
  {
    "id": "back_apron",
    "origin": {
      "x": 0,
      "y": 0.404,
      "z": 0.2315
    },
    "dimensions": {
```

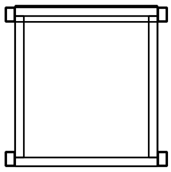
```
      "width": 0.44,
      "height": 0.06,
      "depth": 0.027
    },
    "connections": [
      "back_left_leg",
      "back_right_leg",
      "seat"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
  },
  {
    "id": "left_side_apron",
    "origin": {
      "x": -0.2065,
      "y": 0.404,
      "z": 0
    },
    "dimensions": {
      "width": 0.027,
      "height": 0.06,
      "depth": 0.436
    },
    "connections": [
      "front_left_leg",
      "back_left_leg",
      "seat"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
  },
  {
    "id": "right_side_apron",
    "origin": {
      "x": 0.2065,
      "y": 0.404,
      "z": 0
```

```
    },
    "dimensions": {
      "width": 0.027,
      "height": 0.06,
      "depth": 0.436
    },
    "connections": [
      "front_right_leg",
      "back_right_leg",
      "seat"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
  },
  {
    "id": "seat",
    "origin": {
      "x": 0,
      "y": 0.437,
      "z": 0
    },
    "dimensions": {
      "width": 0.44,
      "height": 0.006,
      "depth": 0.49
    },
    "connections": [
      "front_left_leg",
      "front_right_leg",
      "back_left_leg",
      "back_right_leg",
      "front_apron",
      "back_apron",
      "left_side_apron",
      "right_side_apron"
    ],
    "rotation": {
      "x": 0,
      "y": 0,
      "z": 0
    }
```

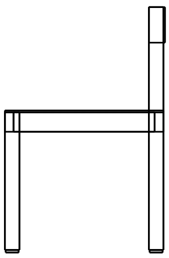
```
},
{
  "id": "backrest",
  "origin": {
    "x": 0,
    "y": 0.705,
    "z": 0.225
  },
  "dimensions": {
    "width": 0.44,
    "height": 0.11,
    "depth": 0.05
  },
  "connections": [
    "back_left_leg",
    "back_right_leg"
  ],
  "rotation": {
    "x": 0,
    "y": 0,
    "z": 0
  }
},
{
  "id": "front_left_glider",
  "origin": {
    "x": -0.235,
    "y": 0.004,
    "z": -0.2225
  },
  "dimensions": {
    "width": 0.025,
    "height": 0.008,
    "depth": 0.04
  },
  "connections": [
    "front_left_leg"
  ],
  "rotation": {
    "x": 0,
    "y": 0,
    "z": 0
  }
},
```

```
{
  "id": "front_right_glider",
  "origin": {
    "x": 0.235,
    "y": 0.004,
    "z": -0.2225
  },
  "dimensions": {
    "width": 0.025,
    "height": 0.008,
    "depth": 0.04
  },
  "connections": [
    "front_right_leg"
  ],
  "rotation": {
    "x": 0,
    "y": 0,
    "z": 0
  }
},
{
  "id": "back_left_glider",
  "origin": {
    "x": -0.235,
    "y": 0.004,
    "z": 0.2225
  },
  "dimensions": {
    "width": 0.025,
    "height": 0.008,
    "depth": 0.04
  },
  "connections": [
    "back_left_leg"
  ],
  "rotation": {
    "x": 0,
    "y": 0,
    "z": 0
  }
},
{
  "id": "back_right_glider",
```

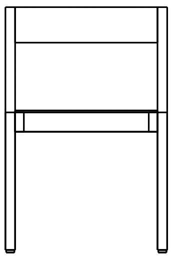
```
      "origin": {
        "x": 0.235,
        "y": 0.004,
        "z": 0.2225
      },
      "dimensions": {
        "width": 0.025,
        "height": 0.008,
        "depth": 0.04
      },
      "connections": [
        "back_right_leg"
      ],
      "rotation": {
        "x": 0,
        "y": 0,
        "z": 0
      }
    }
  ]
}
```



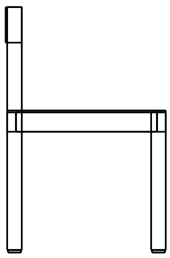
TOP



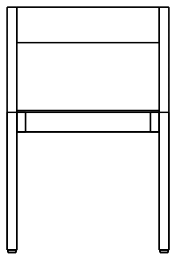
LEFT



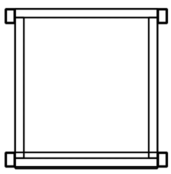
FRONT



RIGHT

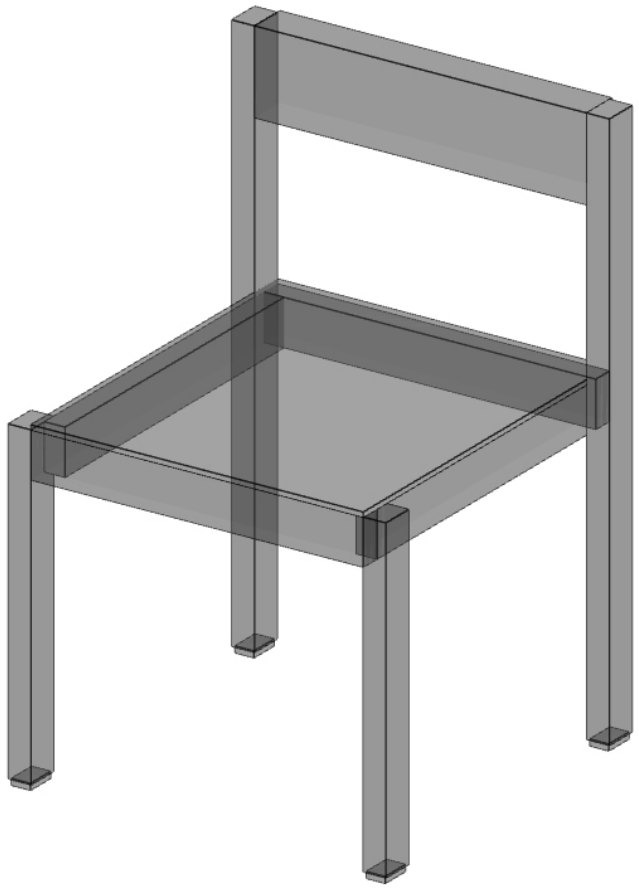


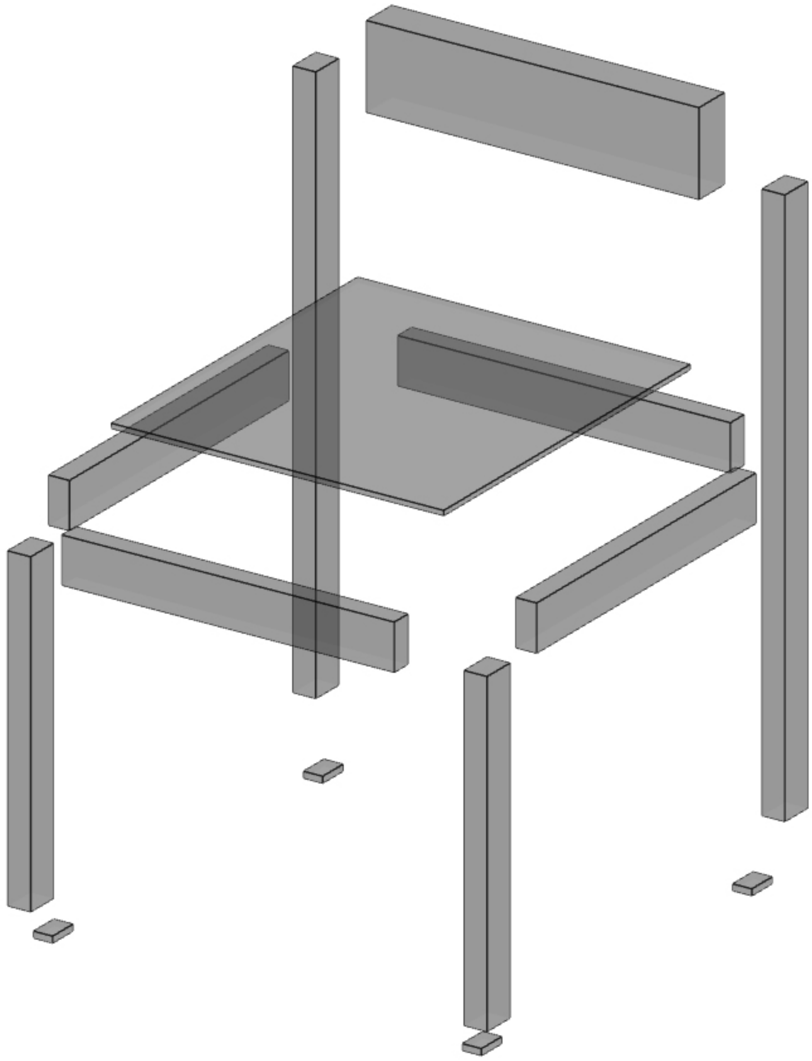
BACK



BOTTOM

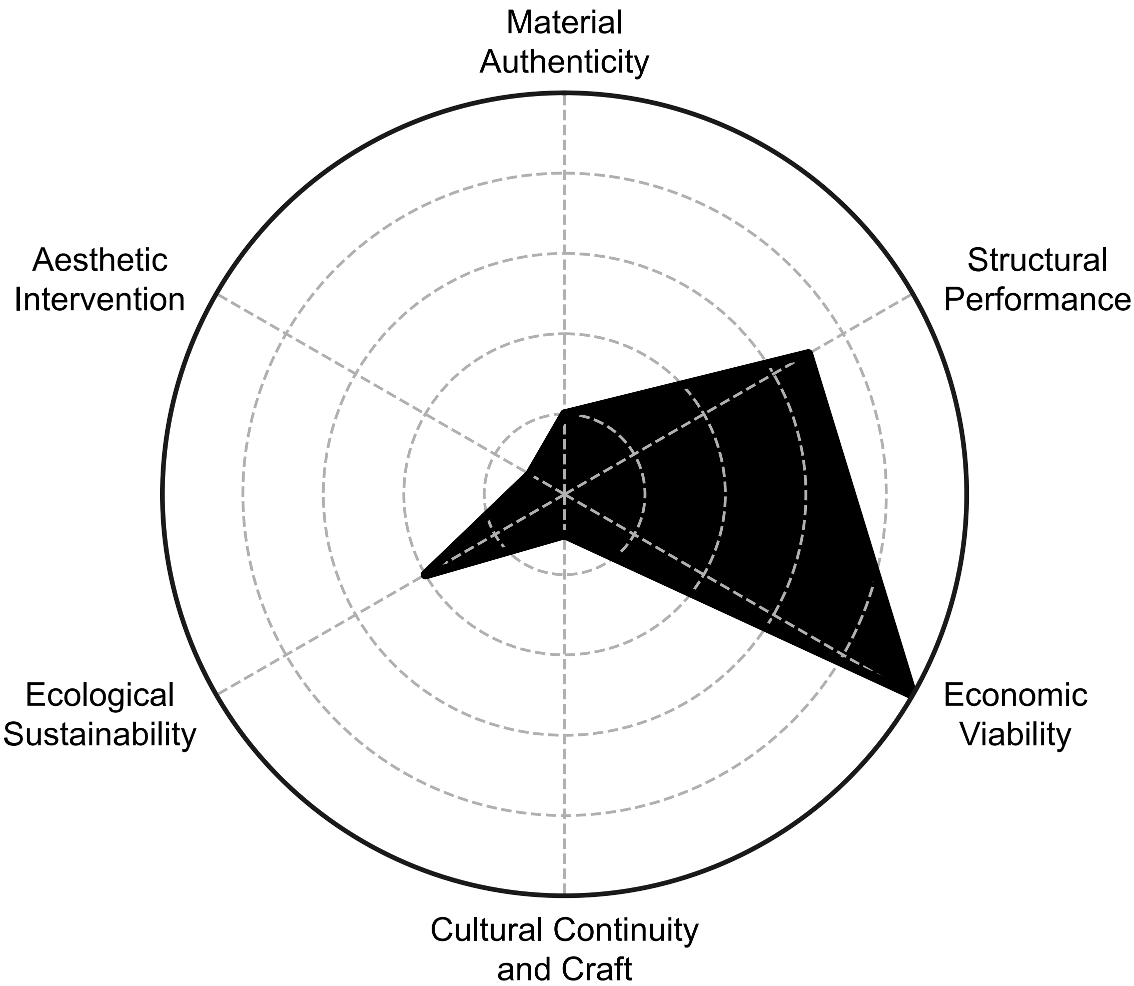

front_right_leg
front_right_glider
front_apron
right_side_apron
front_left_glider
front_left_leg
seat
left_side_apron
back_right_leg
back_right_glider
back_apron
back_left_leg
backrest
back_left_glider





The Janitor’s Cookbook

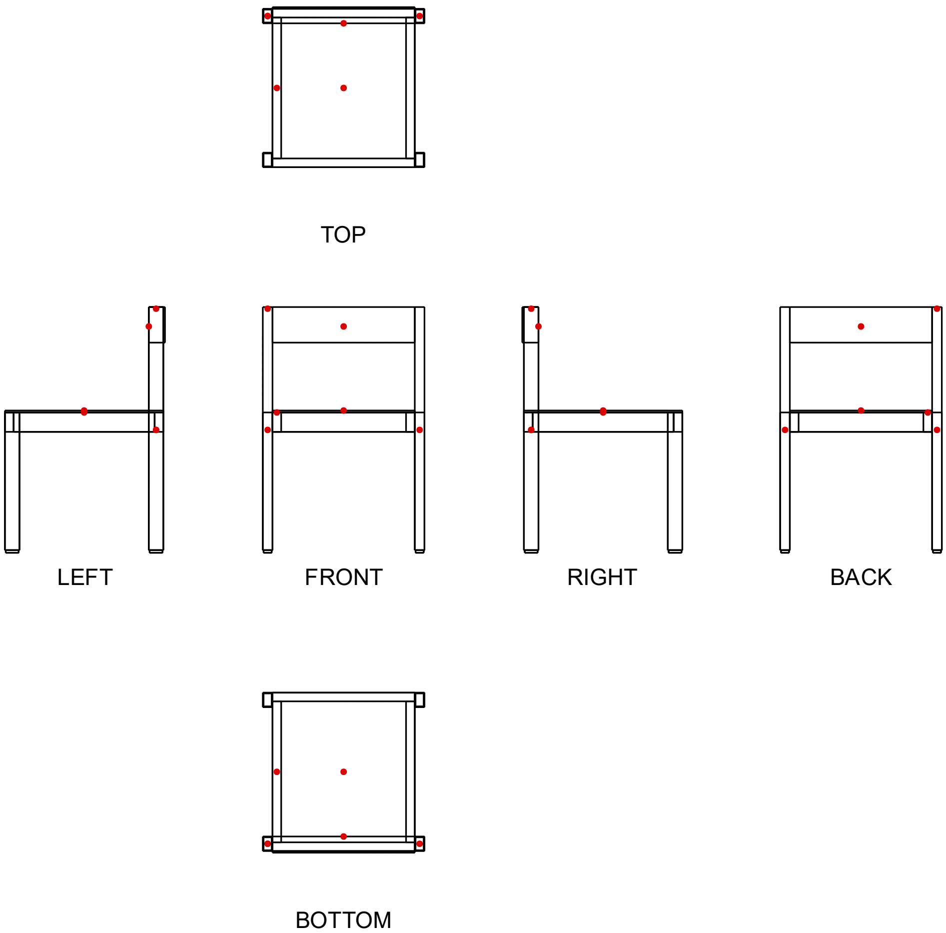
A ruthlessly pragmatic approach to repair, where expedience, low cost, and brute-force durability are the only metrics that matter. All considerations of aesthetics, historical importance, and material authenticity are deliberately discarded in favor of a quick, robust solution. Weak or non-essential elements are unceremoniously abandoned or removed as long as the object's core function can be maintained. The result is an unsentimental, industrial-style fix: a repeatable and resilient intervention that values immediate and lasting functionality above all else.



Santo Chair 16

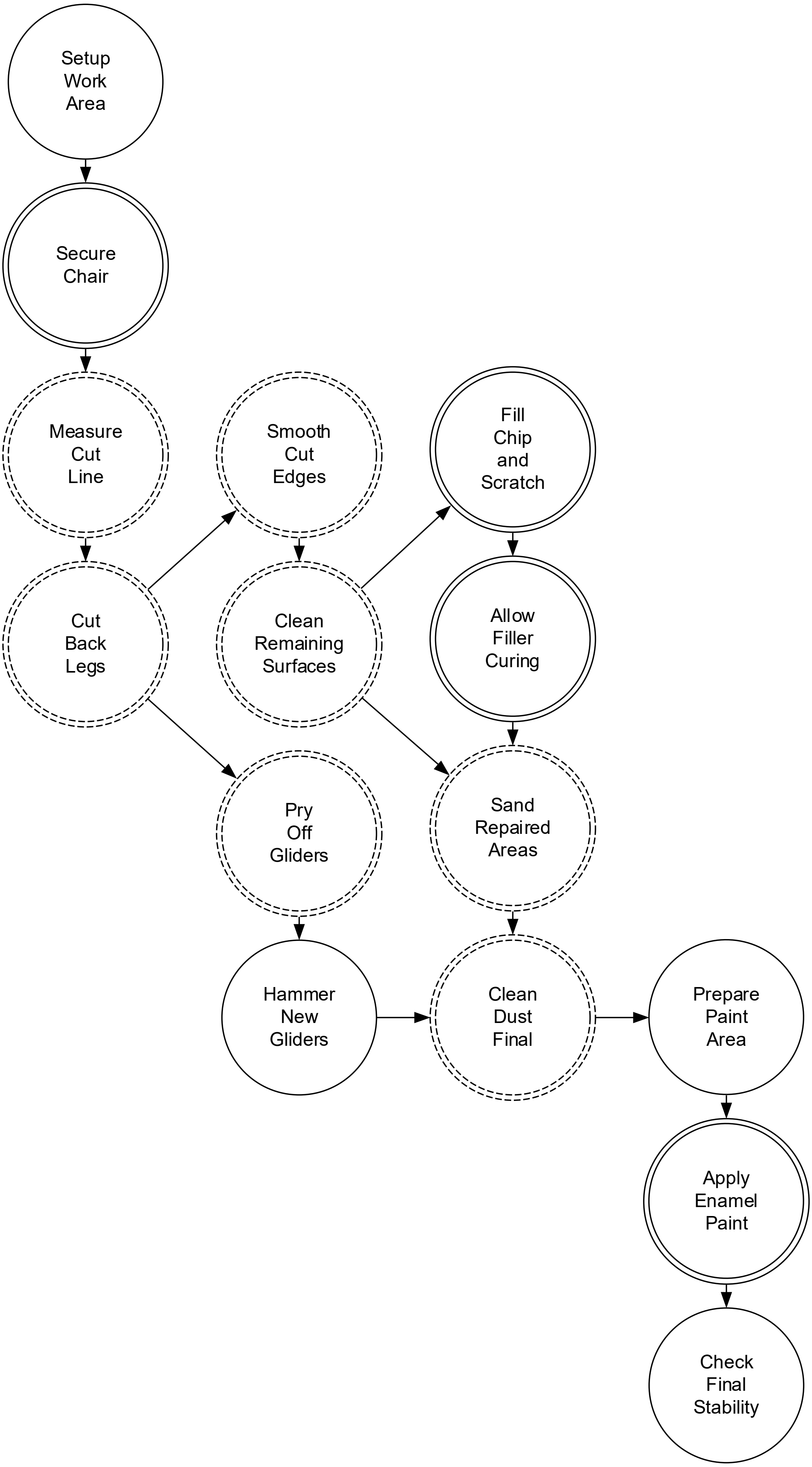
The chair has several issues, including a severe crack on the top of the back right leg at the joint, heavy scuff marks and wear along both back legs, a faint scratch mark on the seat surface, a long horizontal deep scratch on the front face of the backrest, and minor chipping and wear on the top edge of the right side apron.

Overall Condition Rating: 6/10



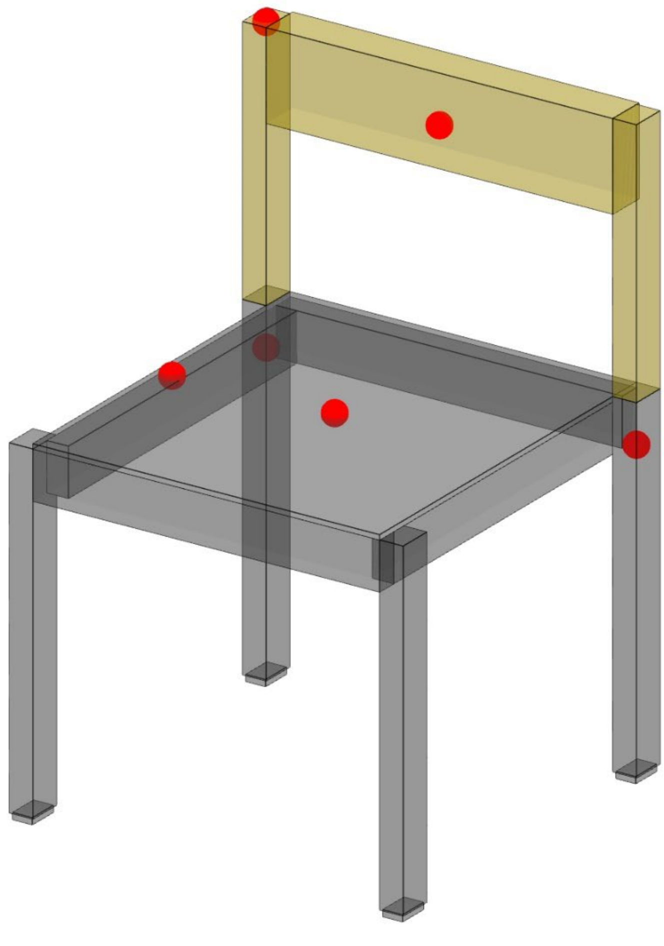
```
[
  {
    "id": "damage_01",
    "type": "Crack",
    "description": "Severe Crack on the top of the back
right leg at the joint.",
    "part_id": "back_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.755,
      "z": 0.2225
    }
  },
  {
    "id": "damage_02",
    "type": "Scuff Mark",
    "description": "Heavy scuff marks and wear along
the back legs.",
    "part_id": "back_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.38,
      "z": 0.2225
    }
  },
  {
    "id": "damage_03",
    "type": "Scuff Mark",
    "description": "Heavy scuff marks and wear along
the back legs.",
    "part_id": "back_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.38,
      "z": 0.2225
    }
  },
  {
    "id": "damage_04",
    "type": "Scratch",
    "description": "Faint scratch mark visible on the
seat surface.",
    "part_id": "seat",
    "coordinates": {
```

```
        "x": 0,
        "y": 0.44,
        "z": 0
      }
    },
    {
      "id": "damage_05",
      "type": "Scratch",
      "description": "Long, horizontal deeo scratch on
the front face of the backrest.",
      "part_id": "backrest",
      "coordinates": {
        "x": 0,
        "y": 0.7,
        "z": 0.2
      }
    },
    {
      "id": "damage_06",
      "type": "Chip",
      "description": "Minor chipping and wear on the top
edge of the right side apron.",
      "part_id": "right_side_apron",
      "coordinates": {
        "x": 0.2065,
        "y": 0.434,
        "z": 0
      }
    }
```


Setup Work Area
Secure Chair
Measure Cut Line
Cut Back Legs
Smooth Cut Edges
Clean Remaining Surfaces
Fill Chip and Scratch
Allow Filler Curing
Pry Off Gliders
Sand Repaired Areas
Hammer New Gliders
Clean Dust Final
Prepare Paint Area
Apply Enamel Paint
Check Final Stability

Repair

The process begins by cutting off the backrest and the upper section of the back legs, effectively removing the most severe damage. The newly cut edges are smoothed for safety. Next, all four gliders at the bottom of the legs are replaced to ensure stability. Remaining cosmetic issues, such as scuffs, scratches, and chips, are then addressed by cleaning, filling with wood filler, and sanding the surfaces. Finally, the entire stool is cleaned of dust and coated with a durable enamel spray paint for protection.



```
{
  "steps": [
    {
      "step_id": "setup_work_area",
      "title": "Setup Work Area",
      "description": "Clear and prepare a stable work
surface. Gather all necessary tools and materials for
the repair process, ensuring adequate lighting and ven-
tilation. Lay down protective sheeting to prevent dam-
age to the work surface.",
      "rationale": "A prepared workspace is fundamental
for safety and efficiency. It prevents damage to the
surroundings and ensures the repair can be executed
pre-cisely and without interruption.",
      "tools_required": [
        "Work bench",
        "Protective sheeting",
        "Gloves",
        "Safety glasses"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "secure_chair_for_work",
      "title": "Secure Chair",
      "description": "Secure the chair on a stable work
surface using clamps or other stabilizing methods to
prevent movement during cutting and other repair opera-
tions, ensuring safety and precision.",
      "rationale": "Stabilizing the object is a criti-
cal safety measure. It prevents unexpected movement
during the cutting phase, ensuring clean, accurate cuts
and protecting the operator.",
      "tools_required": [
        "Work clamps",
        "Vise (optional)"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "setup_work_area"
      ]
```

```
    },
    {
      "step_id": "measure_cut_line",
      "title": "Measure Cut Line",
      "description": "Measure the height of the front
legs (0.426m) as the target height for the back legs.
Mark a precise, straight cut line around both back legs
using a measuring tape and a square, ensuring the re-
sulting stool will be stable and level. This prepares
the chair for conversion into a stool.",
      "rationale": "Precision in this step is paramount
for the final stability of the stool. An accurate cut
line ensures all four legs will be of equal height,
transforming the unstable chair into a level and func-
tional piece.",
      "tools_required": [
        "Measuring tape",
        "Pencil",
        "Combination square"
      ],
      "affected_parts": [
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "secure_chair_for_work"
      ]
    },
    {
      "step_id": "cut_back_legs_remove_backrest",
      "title": "Cut Back Legs",
      "description": "Carefully cut the back legs along
the marked line using a reciprocating saw. Ensure
clean, straight cuts. Once the legs are severed, remove
and discard the upper sections of the back legs and the
en-tire backrest. This action eliminates the backrest
and the top portion of the back legs, addressing the
severe crack on the back right leg and the deep scratch
on the backrest by removal.",
      "rationale": "This is the central act of the
radi-cal intervention. By removing the entire upper
back, multiple points of failure (crack, scratch) are
elimi-nated in a single, efficient action, prioritizing
```

the object's swift return to utility over preserving its original form.",
      "tools_required": [
        "Reciprocating saw",
        "Safety glasses",
        "Clamps"
      ],
      "affected_parts": [
        "back_left_leg",
        "back_right_leg",
        "backrest"
      ],
      "affected_damages": [
        "damage_01",
        "damage_05"
      ],
      "prerequisites": [
        "measure_cut_line"
      ]
    },
    {
      "step_id": "smooth_new_cut_edges",
      "title": "Smooth Cut Edges",
      "description": "Use a rasp or coarse sandpaper (80-grit) to quickly smooth and deburr the newly cut top edges of the back legs. The goal is to remove sharp edg-es and splinters for safety and basic functional-ity, not to achieve a fine aesthetic finish.",
      "rationale": "Removing sharp edges and splinters prevents injury and makes the object safe for handling and use, focusing on function over finish.",
      "tools_required": [
        "Rasp",
        "80-grit sandpaper",
        "Sanding block"
      ],
      "affected_parts": [
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "cut_back_legs_remove_backrest"
      ]

```
    },
    {
      "step_id": "remove_old_gliders",
      "title": "Pry Off Gliders",
      "description": "Carefully pry off the four old
gliders from the bottom of each leg using a pry bar or
screwdriver. Discard the old gliders.",
      "rationale": "Removing the old, worn gliders is
necessary to prepare for a functional upgrade. This
clears the way for new components that will restore
sta-bility and protect flooring, a key aspect of re-
turning the object to service.",
      "tools_required": [
        "Pry bar",
        "Flat-head screwdriver"
      ],
      "affected_parts": [
        "front_left_glider",
        "front_right_glider",
        "back_left_glider",
        "back_right_glider"
      ],
      "affected_damages": [],
      "prerequisites": [
        "cut_back_legs_remove_backrest"
      ]
    },
    {
      "step_id": "install_new_gliders",
      "title": "Hammer New Gliders",
      "description": "Position the new heavy-duty glid-
ers onto the bottom of each leg. Use a hammer to firmly
tap them into place, ensuring they are securely seated
and provide a stable base for the stool.",
      "rationale": "Installing new, heavy-duty gliders
is a direct functional upgrade. It ensures the stool is
stable, does not wobble, and can be used on various
sur-faces without causing damage, completing its trans-
for-mation into a safe and practical object.",
      "tools_required": [
        "Heavy-duty gliders (4x)",
        "Rubber mallet",
        "Hammer"
      ],
```

"affected_parts": [
  "front_left_leg",
  "front_right_leg",
  "back_left_leg",
  "back_right_leg"
],
"affected_damages": [],
"prerequisites": [
  "remove_old_gliders"
]
},
{
"step_id": "clean_remaining_surfaces",
"title": "Clean Remaining Surfaces",
"description": "Thoroughly clean all areas af-fect-ed by scuff marks, scratches, and the chip that remain after the modification. Use a degreaser or iso-propyl al-cohol to remove any dirt, grease, or loose debris. En-sure surfaces are dry before proceeding with repairs.",
"rationale": "Proper surface preparation is cru-cial for the adhesion and durability of subsequent re-pairs. Cleaning removes contaminants that could inter-fere with wood filler and paint, ensuring the cosmetic fixes are effective and long-lasting.",
"tools_required": [
  "Degreaser",
  "Clean rags",
  "Isopropyl alcohol"
],
"affected_parts": [
  "back_left_leg",
  "back_right_leg",
  "seat",
  "right_side_apron"
],
"affected_damages": [
  "damage_02",
  "damage_03",
  "damage_04",
  "damage_06"
],
"prerequisites": [
  "smooth_new_cut_edges"

```
      ]
    },
    {
      "step_id": "fill_chip_and_scratch",
      "title": "Fill Chip and Scratch",
      "description": "Apply a fast-drying, durable wood
filler to the faint scratch on the seat surface and the
minor chip on the top edge of the right side apron.
Overfill slightly to allow for quick leveling. Ensure
the filler is pressed firmly into the damaged areas for
a robust repair.",
      "rationale": "Filling these imperfections creates
a smooth, uniform surface, which is essential for
achieving a consistent and protective final coating.",
      "tools_required": [
        "Wood filler",
        "Putty knife",
        "Spatula"
      ],
      "affected_parts": [
        "seat",
        "right_side_apron"
      ],
      "affected_damages": [
        "damage_04",
        "damage_06"
      ],
      "prerequisites": [
        "clean_remaining_surfaces"
      ]
    },
    {
      "step_id": "allow_filler_curing",
      "title": "Allow Filler Curing",
      "description": "Allow sufficient time for the
wood filler applied to the seat and apron to fully cure
and harden according to the manufacturer's instruc-
tions. This is critical for the durability of the re-
pairs.",
      "rationale": "Allowing the filler to cure com-
pletely ensures it becomes a hard, durable part of the
structure, capable of withstanding sanding and future
use without failing.",
      "tools_required": [],
```

```
        "affected_parts": [
          "seat",
          "right_side_apron"
        ],
        "affected_damages": [
          "damage_04",
          "damage_06"
        ],
        "prerequisites": [
          "fill_chip_and_scratch"
        ]
      },
      {
        "step_id": "sand_all_repaired_areas",
        "title": "Sand Repaired Areas",
        "description": "Once all fillers are fully cured,
  sand the scuff marks on the back legs, the filled
  scratch on the seat, and the filled chip on the apron.
  Start with 80-100 grit sandpaper to quickly level
  filled areas and smooth out surface imperfections. Fo-
  cus on creating a smooth, functional surface for dura-
  bility, not a fine aesthetic finish.",
        "rationale": "Sanding creates a uniform surface
  by blending the filled repairs with the original wood
  and smoothing out scuff marks. This mechanical prepara-
  tion is essential for the final paint coat to adhere
  properly and look consistent.",
        "tools_required": [
          "Orbital sander (optional)",
          "Sanding block",
          "80-100 grit sandpaper"
        ],
        "affected_parts": [
          "back_left_leg",
          "back_right_leg",
          "seat",
          "right_side_apron"
        ],
        "affected_damages": [
          "damage_02",
          "damage_03",
          "damage_04",
          "damage_06"
        ],
```

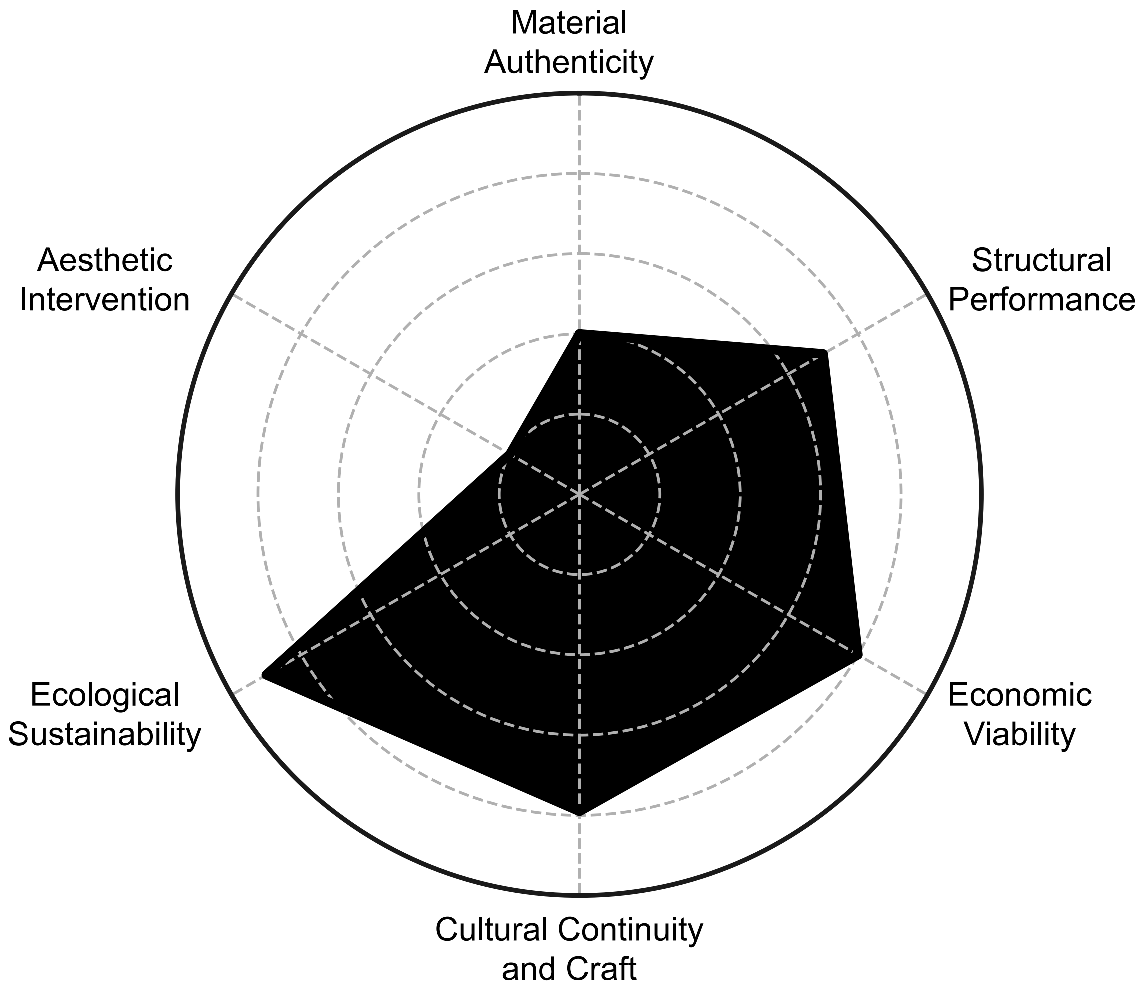
```
      "prerequisites": [
        "allow_filler_curing",
        "clean_remaining_surfaces"
      ]
    },
    {
      "step_id": "clean_dust_final",
      "title": "Clean Dust Final",
      "description": "Thoroughly wipe down the entire
stool to remove any sanding dust and debris from all
re-paired surfaces and newly installed gliders. Use a
tack cloth or compressed air followed by a damp cloth
to en-sure the surfaces are perfectly clean before ap-
plying the protective coating.",
      "rationale": "The final cleaning is a critical
step for a successful finish. Removing all sanding dust
ensures the paint will have a clean substrate to bond
to, resulting in a smooth, durable, and professional-
looking protective coat.",
      "tools_required": [
        "Tack cloth",
        "Compressed air",
        "Damp cloth"
      ],
      "affected_parts": [
        "back_left_leg",
        "back_right_leg",
        "seat",
        "right_side_apron",
        "front_left_leg",
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_06"
      ],
      "prerequisites": [
        "sand_all_repaired_areas",
        "install_new_gliders"
      ]
    },
    {
```

```
      "step_id": "prepare_paint_area",
      "title": "Prepare Paint Area",
      "description": "Set up a well-ventilated area for
painting. Lay down additional protective sheeting to
prevent overspray. Ensure adequate lighting for even
ap-plication of the paint.",
      "rationale": "Creating a dedicated painting envi-
ronment protects the surroundings from overspray and
en-sures operator safety through proper ventilation. It
al-lows for a controlled application of the final fin-
ish.",
      "tools_required": [
        "Ventilation fan (optional)",
        "Protective sheeting",
        "Respirator mask"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "clean_dust_final"
      ]
    },
    {
      "step_id": "apply_enamel_spray_paint",
      "title": "Apply Enamel Paint",
      "description": "Apply a thick, robust coat of
enamel spray paint to all repaired and sanded areas,
in-cluding the newly cut top edges of the back legs,
the back legs, seat, and right side apron. Focus on
achiev-ing full coverage for maximum protection and du-
rability, rather than a fine aesthetic finish. Follow
manufactur-er's instructions for application and drying
times.",
      "rationale": "The enamel coat serves a dual pur-
pose: it provides a tough, protective barrier against
future wear and tear, and it unifies all the repairs
and original surfaces under a single, cohesive finish,
mark-ing the completion of the repair.",
      "tools_required": [
        "Enamel spray paint",
        "Respirator mask",
        "Gloves"
      ],
      "affected_parts": [
```

```
        "back_left_leg",
        "back_right_leg",
        "seat",
        "right_side_apron"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_06"
      ],
      "prerequisites": [
        "prepare_paint_area"
      ]
    },
    {
      "step_id": "check_final_stability",
      "title": "Check Final Stability",
      "description": "Once the paint is fully cured,
flip the stool over and place it on a level surface.
Gently apply pressure and check for any wobbling or in-
stability. Ensure all legs are firmly on the ground and
the stool is robust for immediate use.",
      "rationale": "This final quality control check
validates the success of the entire intervention. It
confirms that the object is not only repaired but is
now structurally sound. ",
      "tools_required": [],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "apply_enamel_spray_paint"
      ]
    }
  ]
}
```

The Long-Term Thinker

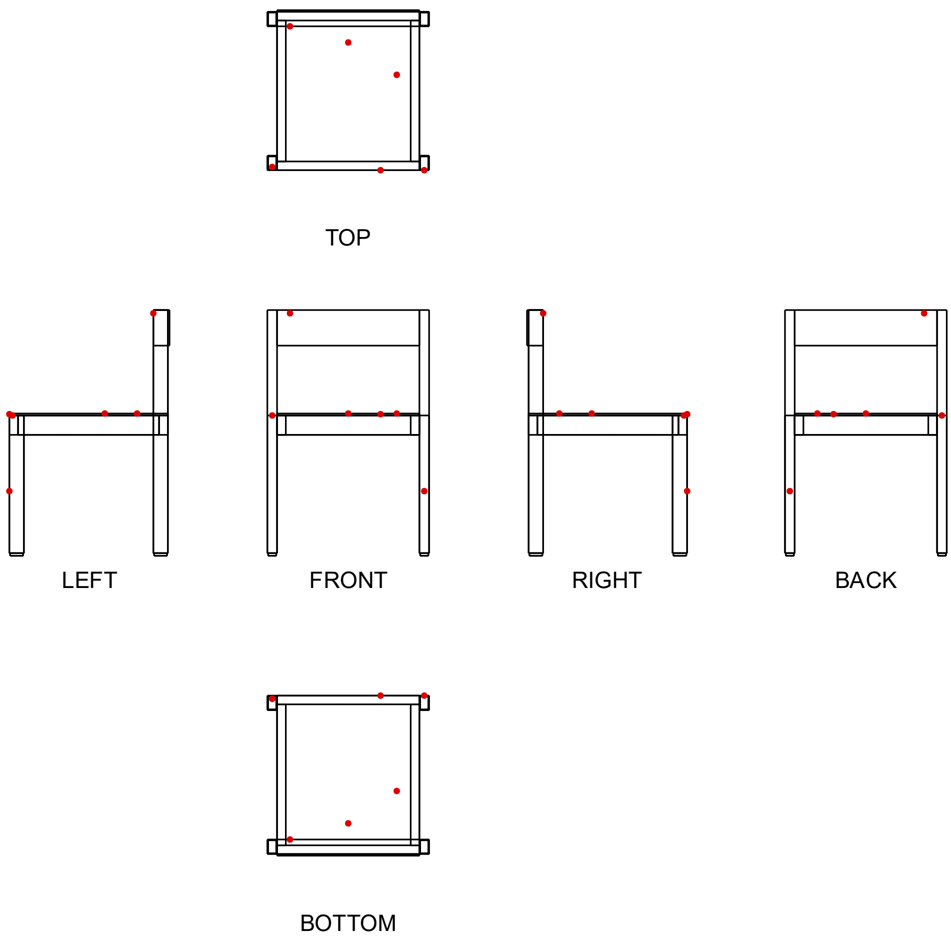
Repair as a strategic, forward-looking intervention into an object's life. The goal is not simply to fix the current failure but to anticipate and design for the next one. It views the object as a system of layers that wear at different rates, and therefore prioritizes modularity, reversibility, and easy access for future maintenance. The intervention systematically upgrades the object, making components prone to failure easily replaceable. The result is a more resilient and adaptable system.



Santo Chair 04

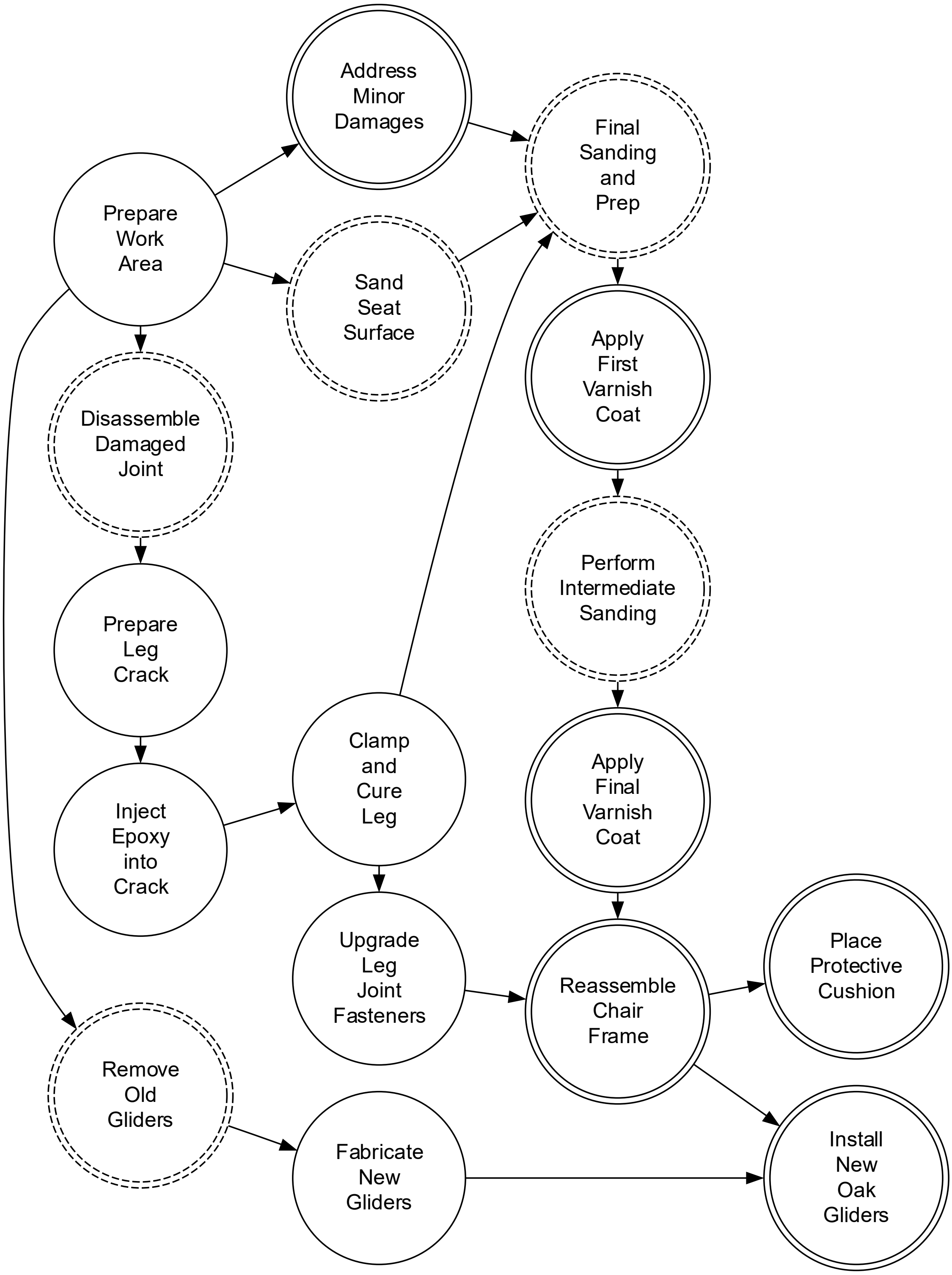
This chair exhibits a range of cosmetic and structural damages. A moderate hairline crack is present on the front right leg near the joint with the seat. The seat itself is marred by noticeable scuffing and discoloration on its front edge, a cluster of small dark stains, and a long scratch on the top surface. Additionally, the backrest has a small circular dent, and the front left leg shows multiple scuff marks.

Overall Condition Rating: 5/10



```
[
  {
    "id": "damage_01",
    "part_id": "front_right_leg",
    "type": "Crack",
    "description": "A small hairline crack is visible
on the top surface of the front right leg, near the
front.",
    "coordinates": {
      "x": 0.235,
      "y": 0.434,
      "z": -0.235
    },
    "severity": "moderate",
    "confidence": 0.9,
    "evidence": "Visible in close-up photograph of the
front-right leg/seat joint."
  },
  {
    "id": "damage_02",
    "part_id": "seat",
    "type": "Scuff Mark",
    "description": "Noticeable scuffing and discolora-
tion along the front edge of the seat.",
    "coordinates": {
      "x": -0.1,
      "y": 0.438,
      "z": -0.245
    },
    "severity": "minor",
    "confidence": 0.95,
    "evidence": "Clearly visible in the close-up image
of the seat's front corner."
  },
  {
    "id": "damage_03",
    "part_id": "seat",
    "type": "Stain",
    "description": "A cluster of small, dark stains or
impressions on the top surface of the seat.",
    "coordinates": {
      "x": 0,
      "y": 0.44,
      "z": 0.15
```

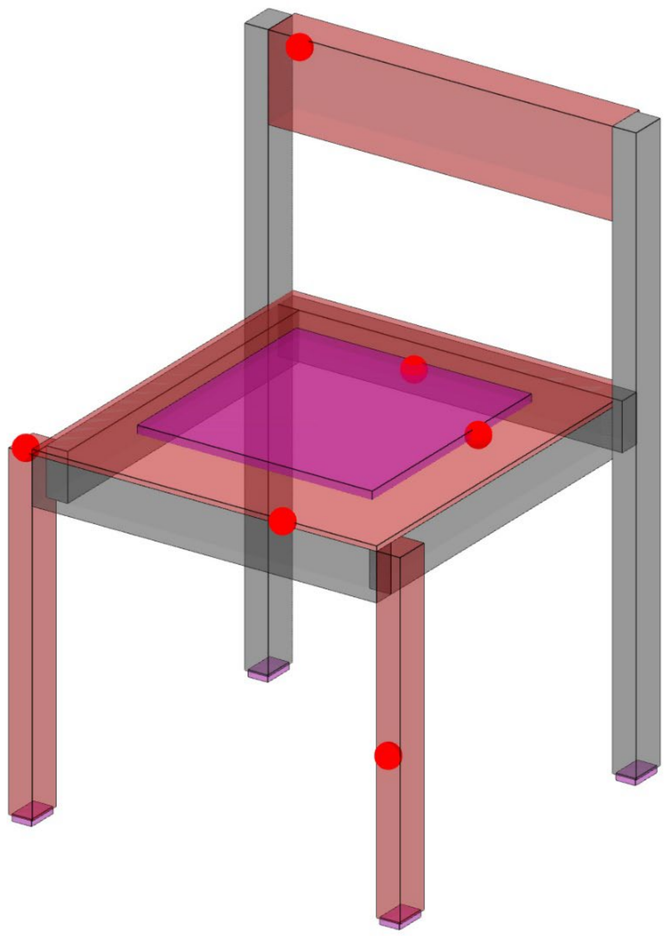
    },
    "severity": "minor",
    "confidence": 0.85,
    "evidence": "Visible in a top-down close-up of the
seat surface."
  },
  {
    "id": "damage_04",
    "part_id": "seat",
    "type": "Scratch",
    "description": "A long, light-colored scratch on
the seat's top surface toward the left side.",
    "coordinates": {
      "x": -0.15,
      "y": 0.44,
      "z": 0.05
    },
    "severity": "minor",
    "confidence": 0.9,
    "evidence": "Visible in a photograph showing the
left side of the seat."
  },
  {
    "id": "damage_05",
    "part_id": "front_left_leg",
    "type": "Scuff Mark",
    "description": "Multiple horizontal scuff marks are
visible on the front face of the front left leg.",
    "coordinates": {
      "x": -0.235,
      "y": 0.2,
      "z": -0.245
    },
    "severity": "minor",
    "confidence": 0.8,
    "evidence": "Visible in a close-up photograph of a
leg, identified as the front left."
  }



Address Minor Damages
Final Sanding and Prep
Prepare Work Area
Sand Seat Surface
Apply First Varnish Coat
Disassemble Damaged Joint
Perform Intermediate Sanding
Prepare Leg Crack
Clamp and Cure Leg
Apply Final Varnish Coat
Inject Epoxy into Crack
Upgrade Leg Joint Fasteners
Reassemble Chair Frame
Place Protective Cushion
Remove Old Gliders
Fabricate New Gliders
Install New Oak Gliders

Repair

A cracked leg joint is disassembled, repaired with high-strength epoxy, and re-engineered with mechanical bolts instead of glue for easier future maintenance. The entire seat is sanded to erase all blemishes and refinished with a durable new varnish. Disposable plastic gliders are replaced with custom-fabricated, screw-on oak ones for longevity. Finally, a felt cushion is added to protect the restored seat, completing a comprehensive upgrade designed for a longer, more resilient life.



```
{
  "steps": [
    {
      "step_id": "prepare_workspace",
      "title": "Prepare Work Area",
      "description": "Set up a clean, well-lit, and
ventilated work area. Lay down protective coverings on
the floor and workbench to prevent damage from dust,
glue, and varnish. Organize all required tools and ma-
terials for easy access.",
      "rationale": "A systematic setup is the founda-
tion of a strategic repair. It ensures safety, effi-
ciency, and prevents collateral damage, reflecting a
forward-looking approach to the entire intervention
process.",
      "tools_required": [
        "workbench",
        "protective sheeting",
        "ventilator",
        "task lighting"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "remove_old_gliders",
      "title": "Remove Old Gliders",
      "description": "Carefully pry off the existing
plastic gliders from the bottom of all four legs. Use a
flat-head screwdriver or a pry tool, taking care not to
damage the wood at the end of the legs.",
      "rationale": "This initial step removes a compo-
nent identified for upgrade. It clears the way for a
more resilient and replaceable solution, aligning with
the philosophy of enhancing modularity.",
      "tools_required": [
        "pry tool",
        "flat-head screwdriver"
      ],
      "affected_parts": [
```

"front_left_glider",
"front_right_glider",
"back_left_glider",
"back_right_glider"
],
"affected_damages": [],
"prerequisites": [
"prepare_workspace"
],
"completed": false,
"time_minutes": 0,
"comments": ""
},
{
"step_id": "disassemble_damaged_joint",
"title": "Disassemble Damaged Joint",
"description": "Carefully separate the front_right_leg from the front_apron and right_side_apron. Since these are glued dowel joints, apply localized heat with a heat gun to soften the adhesive, then gently use a rubber mallet and wooden block to tap the joint apart. Work slowly to avoid causing new damage.",
"rationale": "Disassembly is essential for upgrading the joint from a permanent, glued connection to a modular, mechanical one. This intervention makes future repairs significantly easier, embodying the principle of designing for the next failure.",
"tools_required": [
"heat gun",
"rubber mallet",
"wood block",
"joint separator tool"
],
"affected_parts": [
"front_right_leg",
"front_apron",
"right_side_apron"
],
"affected_damages": [
"damage_01"
],
"prerequisites": [
"prepare_workspace"

```
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "clean_and_prepare_crack",
      "title": "Prepare Leg Crack",
      "description": "Use a dental pick and compressed
air to thoroughly clean any dust, debris, or old glue
from inside the hairline crack on the front_right_leg.
This ensures maximum adhesion for the repair.",
      "rationale": "Meticulous preparation of the dam-
aged area is critical for the structural integrity of
the repair. This ensures the intervention is robust and
extends the life of the component before its next po-
tential failure.",
      "tools_required": [
        "dental pick",
        "compressed air"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "disassemble_damaged_joint"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "inject_epoxy_into_crack",
      "title": "Inject Epoxy into Crack",
      "description": "Mix a high-strength, slow-curing
wood epoxy. Use a syringe to carefully inject the epoxy
deep into the cleaned crack, ensuring full penetration
to rebond the wood fibers.",
      "rationale": "Using a high-strength epoxy doesn't
just fix the crack; it reinforces the area against
```

future stress, increasing the component's overall re-
silience.",
      "tools_required": [
        "wood epoxy",
        "syringe",
        "mixing container",
        "stirring stick"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "clean_and_prepare_crack"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "clamp_and_cure_leg",
      "title": "Clamp and Cure Leg",
      "description": "Use clamps with protective wood
blocks to apply firm, even pressure across the repaired
crack on the front_right_leg. Wipe away any excess
epoxy squeeze-out. Allow the epoxy to cure for the man-
ufacturer's recommended time.",
      "rationale": "Proper clamping ensures a strong,
seamless bond, restoring the structural integrity of
the leg. This step transforms a point of failure into a
point of strength.",
      "tools_required": [
        "bar clamps",
        "wood blocks"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [

```
          "inject_epoxy_into_crack"
        ],
        "completed": false,
        "time_minutes": 0,
        "comments": ""
      },
      {
        "step_id": "fabricate_new_gliders",
        "title": "Fabricate New Gliders",
        "description": "Using a piece of oak, cut and
shape four new gliders to match the footprint of the
chair legs. Drill a countersunk pilot hole in the cen-
ter of each glider for the attachment screw. Sand them
smooth.",
        "rationale": "Fabricating new gliders from a du-
rable material like oak and designing them for screw-on
attachment is a direct upgrade. It replaces a disposa-
ble component with a robust, easily replaceable one,
perfectly aligning with the philosophy of modularity
and future maintenance.",
        "tools_required": [
          "oak wood stock",
          "saw",
          "drill press",
          "countersink bit",
          "sandpaper"
        ],
        "affected_parts": [
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg"
        ],
        "affected_damages": [],
        "prerequisites": [
          "remove_old_gliders"
        ],
        "completed": false,
        "time_minutes": 0,
        "comments": ""
      },
      {
        "step_id": "address_minor_damages",
        "title": "Address Minor Damages",
```

"description": "Address the minor surface damages on various parts. Use a steam iron and a damp cloth to swell the wood fibers and reduce the dent on the backrest. Hand-sand the scuff marks on the front_left_leg.",
"rationale": "Addressing these minor issues in parallel improves efficiency. The chosen methods are minimally invasive, preserving the original material while preparing it for a new, more resilient finish.",
"tools_required": [
  "steam iron",
  "cloth",
  "sandpaper"
],
"affected_parts": [
  "backrest",
  "front_left_leg"
],
"affected_damages": [
  "damage_05",
  "damage_06"
],
"prerequisites": [
  "prepare_workspace"
],
"completed": false,
"time_minutes": 0,
"comments": ""
},
{
"step_id": "sand_seat_surface",
"title": "Sand Seat Surface",
"description": "Using an orbital sander with progressively finer grits of sandpaper (e.g., 120, 180, 220), sand the entire top surface of the seat. This will remove the old finish, scuff marks, stains, and scratches, creating a uniform surface for the new coating.",
"rationale": "Sanding removes all superficial signs of past failures (scratches, stains) and prepares the surface for a new, more durable protective layer, enhancing its resilience to future wear.",
"tools_required": [
  "orbital sander",

```
          "sandpaper (multiple grits)"
        ],
        "affected_parts": [
          "seat"
        ],
        "affected_damages": [
          "damage_02",
          "damage_03",
          "damage_04"
        ],
        "prerequisites": [
          "prepare_workspace"
        ],
        "completed": false,
        "time_minutes": 0,
        "comments": ""
      },
      {
        "step_id": "upgrade_leg_joint",
        "title": "Upgrade Leg Joint Fasteners",
        "description": "Drill out the old dowel holes on
the front_right_leg and its corresponding aprons to the
correct diameter for threaded inserts. Install M6
stainless steel threaded inserts into the holes using
an Allen key, ensuring they are flush with the sur-
face.",
        "rationale": "This is a core philosophical up-
grade. Replacing the permanent glue-and-dowel joint
with threaded inserts and bolts transforms it into a
strong, reversible mechanical connection. This makes
future disassembly for maintenance or repair trivial,
embodying the principle of designing for adaptabil-
ity.",
        "tools_required": [
          "power drill",
          "drill bits",
          "M6 threaded inserts (stainless steel)",
          "Allen key"
        ],
        "affected_parts": [
          "front_right_leg",
          "front_apron",
          "right_side_apron"
        ],
```

```
      "affected_damages": [],
      "prerequisites": [
        "clamp_and_cure_leg"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "final_sanding_and_prep",
      "title": "Final Sanding and Prep",
      "description": "Perform a final light sanding
with 220-grit sandpaper on all repaired and refinished
parts (seat, front_right_leg, front_left_leg,
backrest). Wipe down all sanded surfaces with a tack
cloth to remove all dust particles in preparation for
finishing.",
      "rationale": "This unified preparation step en-
sures that all repaired and original surfaces will ac-
cept the new finish uniformly, creating a cohesive and
durable protective layer across the entire object.",
      "tools_required": [
        "sandpaper (220-grit)",
        "tack cloth"
      ],
      "affected_parts": [
        "seat",
        "front_right_leg",
        "front_left_leg",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "clamp_and_cure_leg",
        "address_minor_damages",
        "sand_seat_surface"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "apply_first_varnish_coat",
      "title": "Apply First Varnish Coat",
```

"description": "Apply a thin, even first coat of
a high-durability, transparent polyurethane varnish to
the prepared seat surface. Use a high-quality brush,
following the direction of the wood grain.",
"rationale": "The application of a modern, dura-
ble varnish is a strategic upgrade to the chair's most-
used surface. This new layer is designed to be more re-
silient to wear than the original, anticipating and
mitigating future damage.",
"tools_required": [
"polyurethane varnish",
"natural bristle brush"
],
"affected_parts": [
"seat"
],
"affected_damages": [],
"prerequisites": [
"final_sanding_and_prep"
],
"completed": false,
"time_minutes": 0,
"comments": ""
},
{
"step_id": "intermediate_sanding",
"title": "Perform Intermediate Sanding",
"description": "Once the first coat of varnish is
fully cured, lightly sand the surface with 320-grit
sandpaper. This de-nibs the surface and creates a bet-
ter mechanical bond for the final coat. Wipe clean with
a tack cloth.",
"rationale": "This step is crucial for achieving
a professional-grade, resilient finish. It ensures the
final protective layer is as strong and smooth as pos-
sible, maximizing its functional lifespan.",
"tools_required": [
"sandpaper (320-grit)",
"tack cloth"
],
"affected_parts": [
"seat"
],
"affected_damages": [],

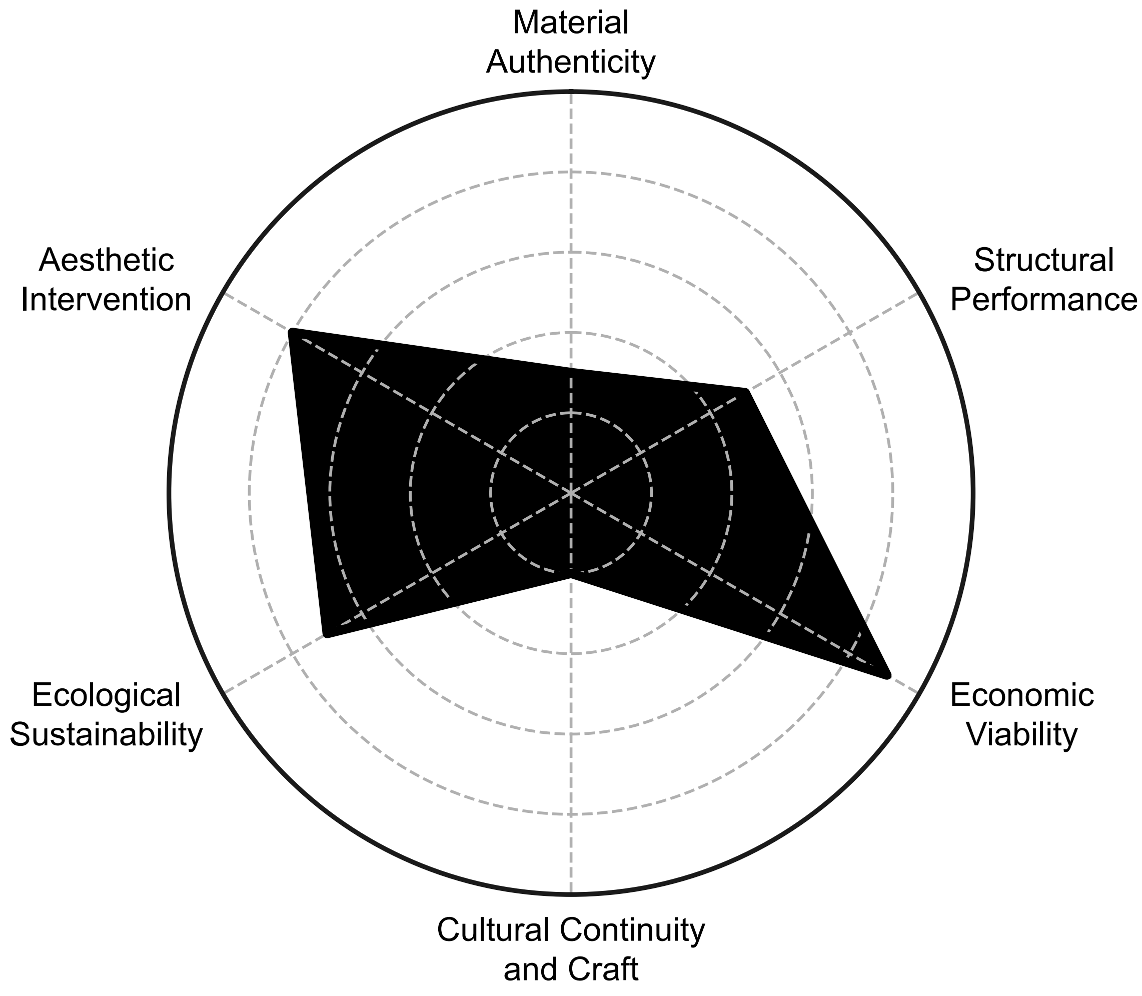
```
      "prerequisites": [
        "apply_first_varnish_coat"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "apply_final_varnish_coat",
      "title": "Apply Final Varnish Coat",
      "description": "Apply a final, slightly thicker
coat of the polyurethane varnish to the seat. Ensure
even coverage and allow it to cure completely in a
dust-free environment as per the manufacturer's in-
structions.",
      "rationale": "The final coat completes the up-
graded protective system for the seat, providing a ro-
bust barrier against future scratches, stains, and
wear.",
      "tools_required": [
        "polyurethane varnish",
        "natural bristle brush"
      ],
      "affected_parts": [
        "seat"
      ],
      "affected_damages": [],
      "prerequisites": [
        "intermediate_sanding"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "reassemble_chair_frame",
      "title": "Reassemble Chair Frame",
      "description": "Reattach the repaired
front_right_leg to the aprons using M6 stainless steel
bolts that correspond to the newly installed threaded
inserts. Tighten securely but do not overtighten.",
      "rationale": "Reassembly with mechanical fasten-
ers completes the strategic upgrade of the joint. The
chair is now not only repaired but also reconfigured
```

for easy future maintenance, demonstrating the value of a modular system.",
      "tools_required": [
        "M6 stainless steel bolts",
        "Allen key"
      ],
      "affected_parts": [
        "front_right_leg",
        "front_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "upgrade_leg_joint",
        "apply_final_varnish_coat"
      ],
      "completed": false,
      "time_minutes": 0,
      "comments": ""
    },
    {
      "step_id": "install_new_gliders",
      "title": "Install New Oak Gliders",
      "description": "Drill small pilot holes in the center of the bottom of each leg. Attach the newly fabricated oak gliders to all four legs using stainless steel screws. Ensure they are seated firmly and level.",
      "rationale": "Installing the screw-on gliders finalizes their upgrade from a weak point to a strong, user-serviceable component. This enhances the object's long-term functionality and adaptability.",
      "tools_required": [
        "power drill",
        "drill bit (pilot)",
        "stainless steel screws",
        "screwdriver"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],

```
        "affected_damages": [],
        "prerequisites": [
          "fabricate_new_gliders",
          "reassemble_chair_frame"
        ],
        "completed": false,
        "time_minutes": 0,
        "comments": ""
      },
      {
        "step_id": "place_protective_cushion",
        "title": "Place Protective Cushion",
        "description": "Place the new felt cushion onto
the newly refinished seat surface. Ensure it is cen-
tered and sits flat.",
        "rationale": "Adding a felt cushion is a forward-
looking intervention. It acts as a sacrificial layer,
protecting the newly restored seat surface from future
scratches and wear, thus extending the interval until
the next maintenance cycle is needed.",
        "tools_required": [
          "felt cushion"
        ],
        "affected_parts": [
          "seat"
        ],
        "affected_damages": [],
        "prerequisites": [
          "reassemble_chair_frame"
        ],
        "completed": false,
        "time_minutes": 0,
        "comments": ""
      }
    ]
  }
```

The Readymade Brain

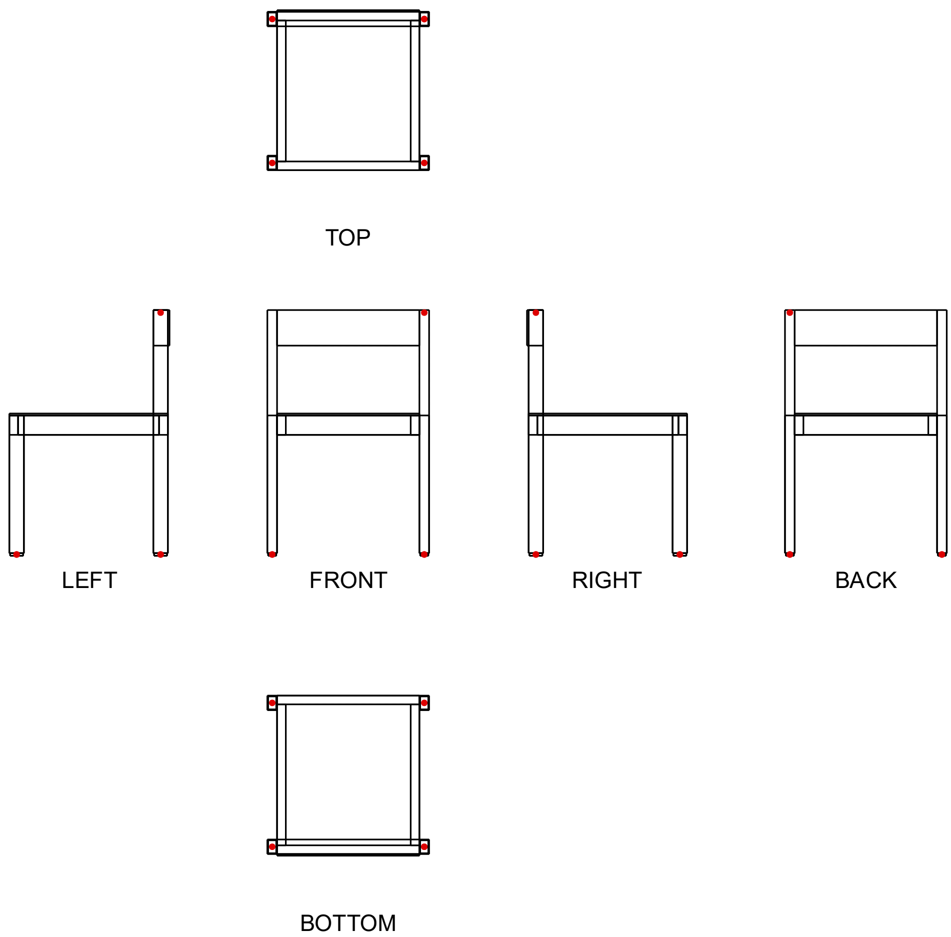
This philosophy treats repair as an act of radical re-appropriation, sourcing its materials from the mundane, the discarded, and the mass-produced. The process itself is often a chaotic bricolage, where commonplace items are forcefully transformed through inventive, ad-hoc techniques to serve an entirely new function. Success is measured not by seamless integration but by the wit and audacity of the solution. A piece of packaging or household trash becomes the repair, redefining authenticity in a resourceful leap that gives a found object a new and unexpected purpose.



Santo Chair 18

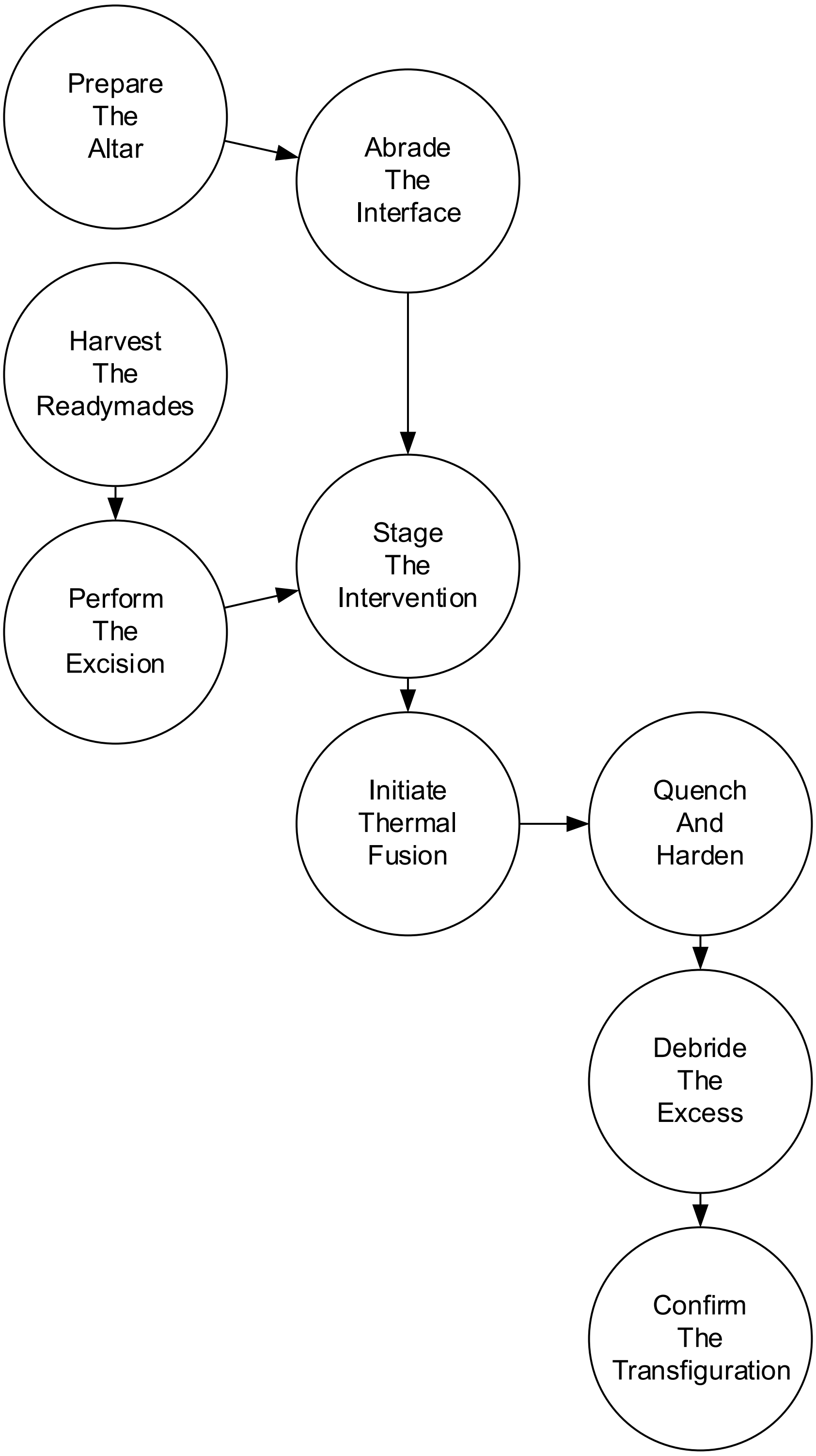
This chair exhibits a range of cosmetic and structural damages. A moderate hairline crack is present on the front right leg near the joint with the seat. The seat itself is marred by noticeable scuffing and discoloration on its front edge, a cluster of small dark stains, and a long scratch on the top surface. Additionally, the backrest has a small circular dent, and the front left leg shows multiple scuff marks.

Overall Condition Rating: 5/10



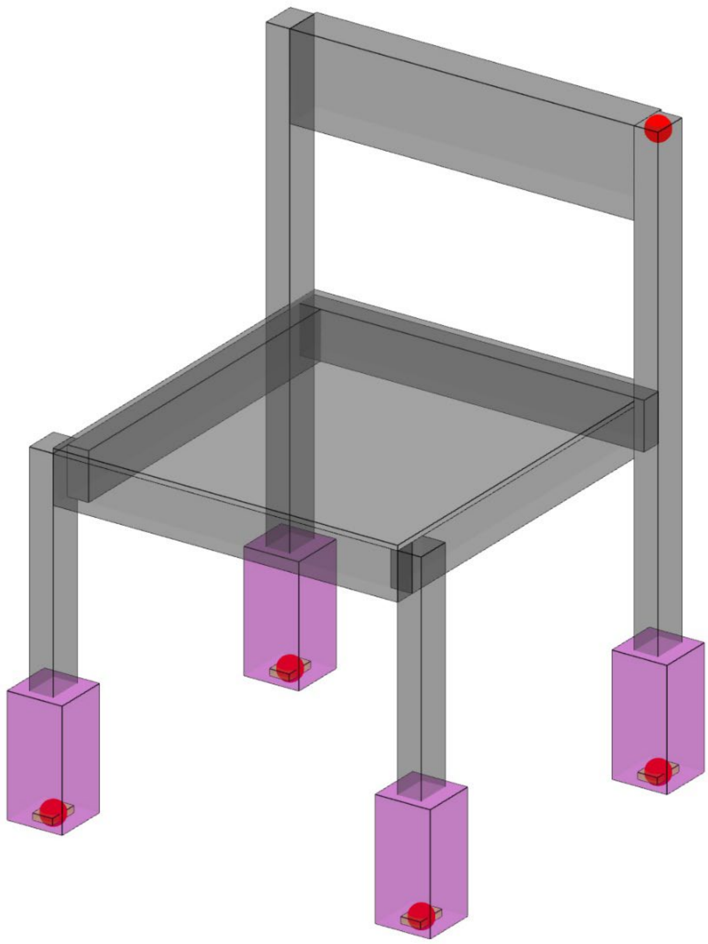
```
[
  {
    "id": "damage_01",
    "type": "Wood Chipping",
    "description": "Multiple instances of wood chipping
are observed on the back left leg.",
    "part_id": "back_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.752,
      "z": 0.2225
    }
  },
  {
    "id": "damage_02",
    "type": "Missing",
    "description": "The glider is visually confirmed to
be missing from its expected position.",
    "part_id": "front_left_glider",
    "coordinates": {
      "x": -0.235,
      "y": 0.004,
      "z": -0.2225
    }
  },
  {
    "id": "damage_03",
    "type": "Missing",
    "description": "The glider is visually confirmed to
be missing from its expected position.",
    "part_id": "front_right_glider",
    "coordinates": {
      "x": 0.235,
      "y": 0.004,
      "z": -0.2225
    }
  },
  {
    "id": "damage_04",
    "type": "Missing",
    "description": "The glider is visually confirmed to
be missing from its expected position.",
    "part_id": "back_left_glider",
    "coordinates": {
```

```
        "x": -0.235,
        "y": 0.004,
        "z": 0.2225
      }
    },
    {
      "id": "damage_05",
      "type": "Missing",
      "description": "The glider is visually confirmed to
be missing from its expected position.",
      "part_id": "back_right_glider",
      "coordinates": {
        "x": 0.235,
        "y": 0.004,
        "z": 0.2225
      }
    }
]  }
]
```


Prepare The Altar
Abrade The Interface
Harvest The Readymades
Perform The Excision
Stage The Intervention
Initiate Thermal Fusion
Quench And Harden
Debride The Excess
Confirm The Transfiguration

Repair

The main goal is transforming the chair's missing feet into an artistic statement. The process involves harvesting discarded plastic bottles and excising their tops to create new collars. The chair's leg ends are aggressively abraded to ensure a strong bond. Then, in a climactic act, intense heat is applied to shrink-fit the plastic collars directly onto the wood, creating a permanent, fused union. This audacious intervention doesn't just fix the chair; it re-contextualizes trash into a bespoke, functional solution, celebrating the act of resourceful re-creation.



```
{
  "steps": [
    {
      "step_id": "prepare_the_altar",
      "title": "Prepare The Altar",
      "description": "Clear a stable work surface. In-
vert the chair and secure it so all four leg ends are
accessible and facing upwards. This is not a workshop;
it's a stage for transformation.",
      "rationale": "The repair is a deliberate act, a
performance. Preparing the space and positioning the
ob-ject correctly establishes the necessary focus and
ele-vates the mundane act of fixing into a ritual of
re-creation.",
      "tools_required": [
        "Stable work surface",
        "Clamps or weights (optional)"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "harvest_the_readymades",
      "title": "Harvest The Readymades",
      "description": "Procure four identical PET plas-
tic beverage bottles, with their caps securely at-
tached. En-sure they are empty and rinsed. These are
not raw mate-rials; they are pre-fabricated solutions
waiting to be re-contextualized.",
      "rationale": "The philosophy rejects conventional
repair materials in favor of finding solutions in the
discarded. 'Harvesting' these 'readymades' is the foun-
dational act of resourceful appropriation, seeing po-
ten-tial where others see trash.",
      "tools_required": [
        "Four PET plastic bottles (with caps)"
      ],
      "affected_parts": [],
```

```
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "perform_the_excision",
      "title": "Perform The Excision",
      "description": "Using a sharp utility knife,
care-fully cut the top section from each of the four
bottles. Make the cut approximately 2 inches (5 cm) be-
low the base of the threaded neck, creating four iden-
tical plas-tic collars.",
      "rationale": "This is an act of creative destruc-
tion. By excising the functional form from the larger
object, we destroy the bottle's original purpose to
lib-erate its new one. The precision of the cut con-
trasts with the crudeness of the source material.",
      "tools_required": [
        "Utility knife",
        "Safety gloves",
        "Eye protection",
        "Measuring tape"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "harvest_the_readymades"
      ]
    },
    {
      "step_id": "abrade_the_interface",
      "title": "Abrade The Interface",
      "description": "Vigorously sand the bottom 2
inch-es (5 cm) of each chair leg. The goal is not
smoothness but a rough, chaotic texture that will bite
into the plastic during fusion. Blow away all dust.",
      "rationale": "A seamless, invisible repair is
anathema. Abrading the surface is a forceful prepara-
tion that ensures the new part doesn't just sit on the
old, but aggressively bonds to it, creating a visibly
strong and unapologetic union.",
      "tools_required": [
        "Coarse-grit sandpaper",
        "Cleaning cloth"
      ],
```

```
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "prepare_the_altar"
      ]
    },
    {
      "step_id": "stage_the_intervention",
      "title": "Stage The Intervention",
      "description": "Place one of the excised bottle-
top collars over each of the abraded leg ends. The cap
should face down, acting as the new foot. Ensure a snug
but not forced fit. This is the final dress rehearsal
before the permanent transformation.",
      "rationale": "This step physically manifests the
absurd proposal. The juxtaposition of the refined chair
leg and the crude plastic collar is a deliberate chal-
lenge to aesthetic norms, a moment of wit before the
act of forceful fusion makes it permanent.",
      "tools_required": [],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "perform_the_excision",
        "abrade_the_interface"
      ]
    },
    {
      "step_id": "initiate_thermal_fusion",
```

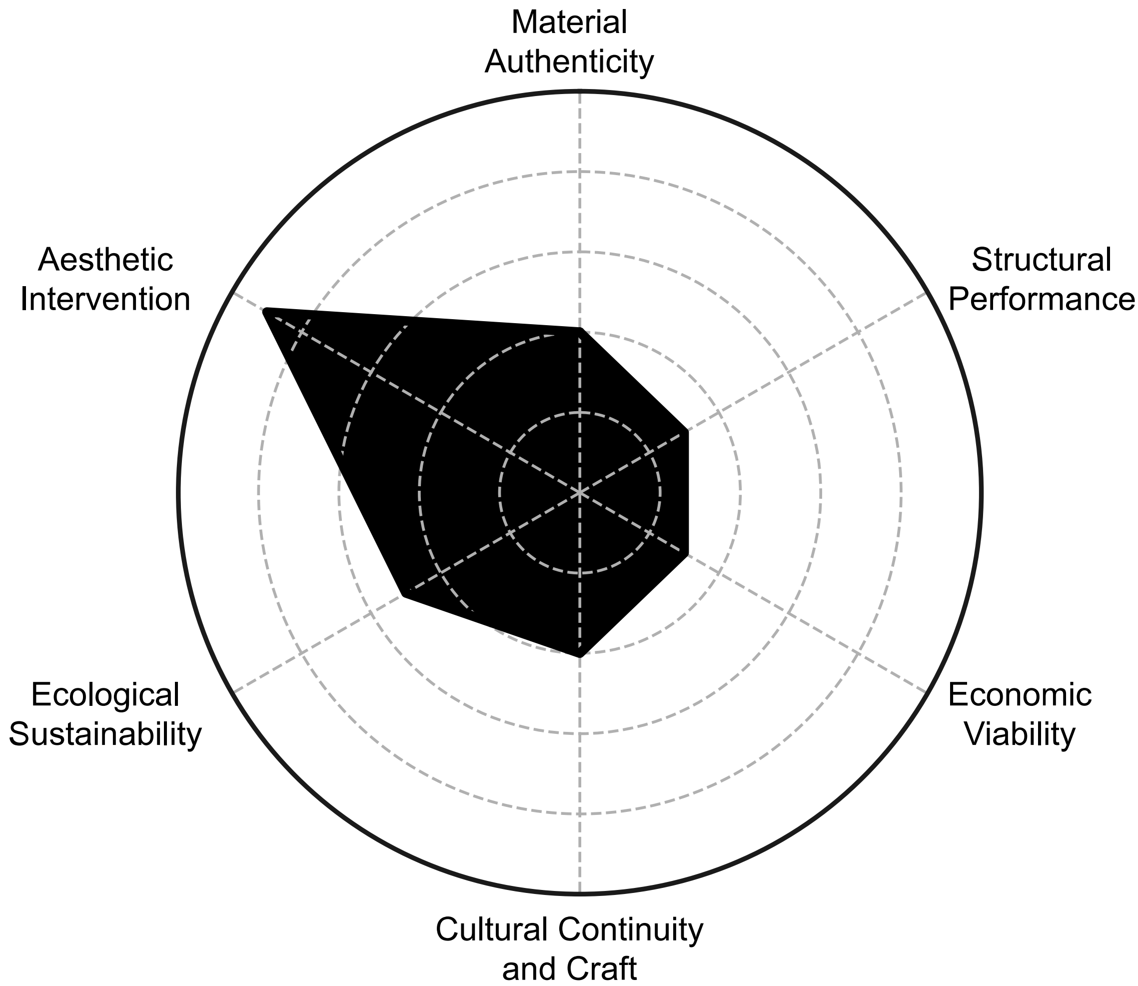
```
      "title": "Initiate Thermal Fusion",
      "description": "Apply intense, moving heat from a
heat gun to one of the staged collars. Circle the leg
continuously until the plastic visibly shrinks and con-
forms tightly to the wood, creating a single, fused
form. Repeat for the other three legs.",
      "rationale": "This is the climax of the repair.
Raw energy is used to force a violent transformation,
turning a piece of trash into a bespoke, perfectly
mold-ed component. The process is chaotic but yields a
pre-cise, functional result, embodying the core
philoso-phy.",
      "tools_required": [
        "Heat gun",
        "Heat-resistant gloves"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "stage_the_intervention"
      ]
    },
    {
      "step_id": "quench_and_harden",
      "title": "Quench And Harden",
      "description": "Allow the newly fused plastic on
all four legs to cool completely to room temperature
without any external intervention. Do not touch or move
them. This period of stillness is critical for the
mate-rial to achieve its final, hardened state.",
      "rationale": "After the violent application of
heat, a period of calm is necessary to lock in the
transformation. This step allows the re-appropriated
ma-terial to settle into its new form, gaining the
```

```
strength and permanence required for its new func-
tion.",
      "tools_required": [],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "initiate_thermal_fusion"
      ]
    },
    {
      "step_id": "debride_the_excess",
      "title": "Debride The Excess",
      "description": "Once fully hardened, use a util-
ity knife to carefully trim away any melted, uneven, or
aes-thetically displeasing plastic flashing around the
top edge of the new collars. The goal is a clean, de-
liberate edge, not a perfect one.",
      "rationale": "This final shaping refines the
chaos of the fusion. It's not about hiding the repair's
origin but about giving the raw result a finished, in-
tentional form. The act of 'debriding' acknowledges the
violent process while asserting control over the final
out-come.",
      "tools_required": [
        "Utility knife"
      ],
      "affected_parts": [
        "front_left_glider",
        "front_right_glider",
        "back_left_glider",
        "back_right_glider"
      ],
      "affected_damages": [
        "damage_01",
```

```
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "quench_and_harden"
      ]
    },
    {
      "step_id": "confirm_the_transfiguration",
      "title": "Confirm The Transfiguration",
      "description": "Carefully turn the chair upright.
Place it on a flat surface and press down on the seat
to test for stability and levelness. The chair is no
longer simply repaired; it has been fundamentally al-
tered.",
      "rationale": "The ultimate test of the audacious
solution is its function. This step proves that the
rad-ical re-appropriation was not just an artistic
statement but a successful act of engineering, validat-
ing the en-tire philosophy by confirming the object's
new, altered reality.",
      "tools_required": [
        "Level surface"
      ],
      "affected_parts": [
        "front_left_glider",
        "front_right_glider",
        "back_left_glider",
        "back_right_glider"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "debride_the_excess"
      ]
    }
  ]
}
```

The Anarchitect

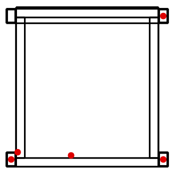
Repair as a critical act of subtraction and perception. Instead of mending, it deliberately cuts away, carves into, and destabilizes the object to create radical new perceptions. This subtractive process is a form of dissection, exposing hidden internal structures, forgotten layers, and the inherent fragility of the material itself. The intervention transforms the object into a state of critical tension, a dialogue between solid and void. Functionality is willingly sacrificed for a profound aesthetic experience, challenging all assumptions about the object's original state and purpose.



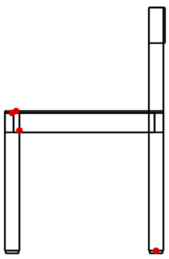
Santo Chair 05

This chair exhibits a range of cosmetic and structural damages. A moderate hairline crack is present on the front right leg near the joint with the seat. The seat itself is marred by noticeable scuffing and discoloration on its front edge, a cluster of small dark stains, and a long scratch on the top surface. Additionally, the backrest has a small circular dent, and the front left leg shows multiple scuff marks.

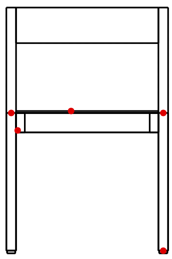
Overall Condition Rating: 6/10



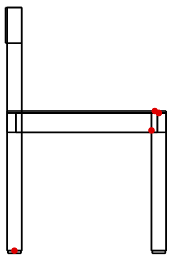
TOP



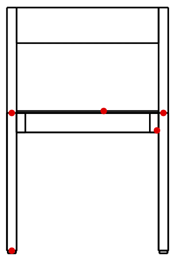
LEFT



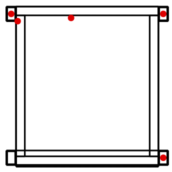
FRONT



RIGHT



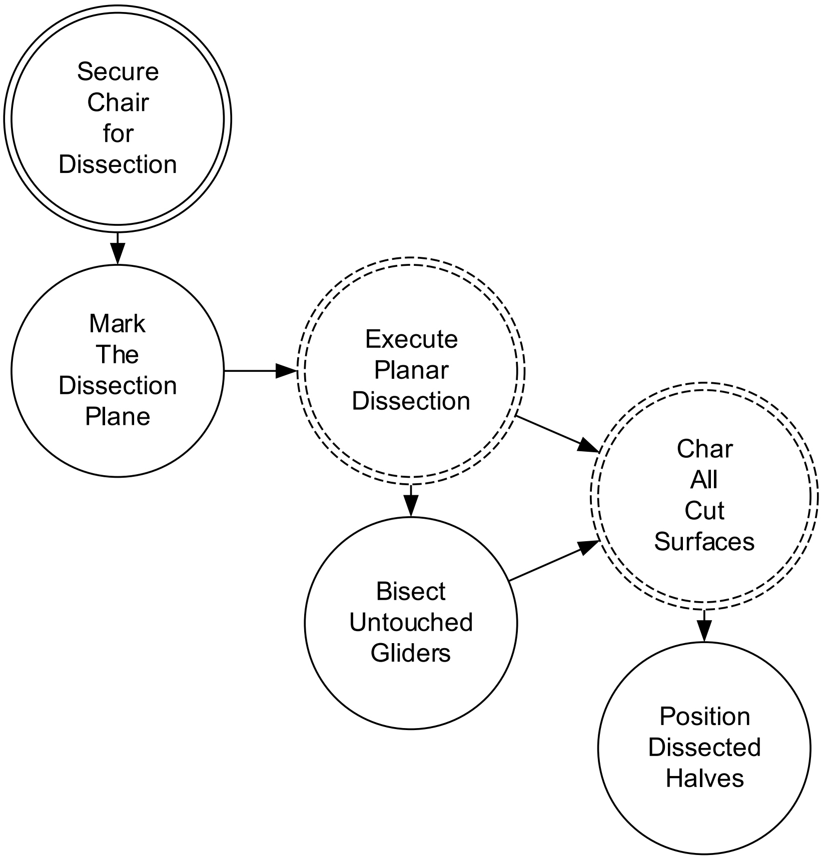
BACK



BOTTOM

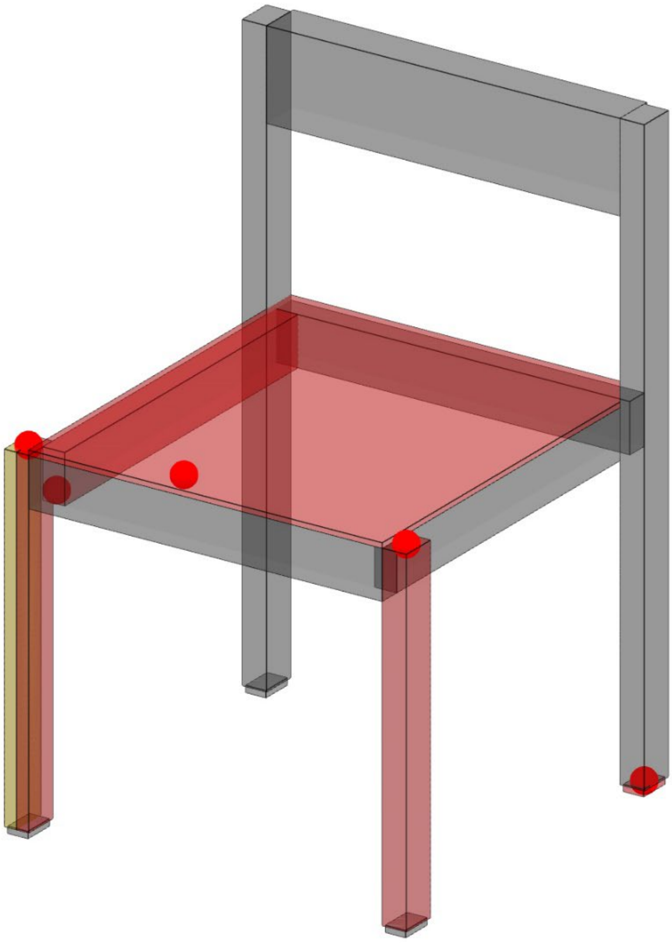
[
  {
    "id": "damage_01",
    "part_id": "seat",
    "type": "Scuff Mark",
    "description": "Multiple light scuff marks and small chips in the finish on the top surface of the seat, mainly near the front edge.",
    "coordinates": {
      "x": 0.05,
      "y": 0.44,
      "z": -0.21
    },
    "severity": "minor",
    "confidence": 1,
    "evidence": "Visible in multiple close-up and wide-angle photos of the chair's seat."
  },
  {
    "id": "damage_02",
    "part_id": "front_right_leg",
    "type": "Crack",
    "description": "A significant crack runs across the top surface of the front right leg.",
    "coordinates": {
      "x": 0.235,
      "y": 0.434,
      "z": -0.2225
    },
    "severity": "moderate",
    "confidence": 1,
    "evidence": "Clearly visible in a close-up photo of the front-right leg joint."
  },
  {
    "id": "damage_03",
    "part_id": "front_left_leg",
    "type": "Crack",
    "description": "A minor crack is visible on the top surface of the front left leg.",
    "coordinates": {
      "x": -0.235,
      "y": 0.434,
      "z": -0.2225

    },
    "severity": "minor",
    "confidence": 0.95,
    "evidence": "Visible in a close-up photo of the
front-left leg."
  },
  {
    "id": "damage_04",
    "part_id": "back_left_glider",
    "type": "Poor Repair",
    "description": "The glider shows signs of a poor
repair, with excess white adhesive visible and a worn
felt pad.",
    "coordinates": {
      "x": -0.235,
      "y": 0.008,
      "z": 0.2225
    },
    "severity": "moderate",
    "confidence": 0.85,
    "evidence": "Close-up photo of the bottom of a leg,
which is assumed to be the back left."
  },
  {
    "id": "damage_05",
    "part_id": "front_right_leg",
    "type": "Poor Repair",
    "description": "Excess transparent glue residue
from a previous repair is visible on the exterior face
of the front right leg, near the joint with the front
apron.",
    "coordinates": {
      "x": 0.215,
      "y": 0.38,
      "z": -0.2
    },
    "severity": "minor",
    "confidence": 0.9,
    "evidence": "Close-up photo of a joint showing
dried, transparent adhesive."
  }
]


Secure Chair for Dissection
Mark The Dissection Plane
Execute Planar Dissection
Bisect Untouched Gliders
Char All Cut Surfaces
Position Dissected Halves

Repair

The entire object is secured and deliberately sliced in half with a single, precise cut from a table saw. This dissection is strategically planned to pass through all existing points of damage, exposing them as a cross-section rather than mending them. Finally, the two resulting halves are permanently separated and positioned for display, completing the chair's transformation from a functional item into a deconstructed work of art.



```
{
  "steps": [
    {
      "step_id": "prepare_workspace_for_cut",
      "title": "Secure Chair for Dissection",
      "description": "Secure the entire, fully assem-
bled chair onto a large, stable table saw sled or jig.
Use multiple clamps to ensure the object is completely
rigid and cannot shift during the cutting operation.
This set-up is critical for a single, clean, and delib-
erate pass.",
      "rationale": "The philosophy demands a precise,
controlled act of subtraction. Securing the object as a
single, monolithic entity ensures the cut is a deliber-
ate dissection that transforms the whole, rather than a
chaotic accident. Stability is paramount to executing
this singular, transformative vision.",
      "tools_required": [
        "Table saw",
        "Custom sled/jig",
        "Heavy-duty clamps",
        "Safety glasses",
        "Hearing protection"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "seat",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "mark_dissection_plane",
      "title": "Mark The Dissection Plane",
      "description": "Using a laser line or a large
straightedge, scribe a single, continuous cut line
```

```
across the entire chair assembly. The plane of this cut
should be strategically chosen to intersect the crack
on the front right leg (damage_02), the glue residue
(damage_05), the crack on the front left leg (dam-
age_03), the scuffs on the seat (damage_01), and the
back left leg with the poorly repaired glider (dam-
age_04).",
      "rationale": "This line is not a guide for repair
but a sentence of dissection, chosen to expose multiple
points of failure and internal structure simultaneously
in one brutal, efficient act.",
      "tools_required": [
        "Laser line",
        "Straightedge",
        "Marking knife"
      ],
      "affected_parts": [
        "front_right_leg",
        "front_left_leg",
        "seat",
        "back_left_leg",
        "back_left_glider"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_05"
      ],
      "prerequisites": [
        "prepare_workspace_for_cut"
      ]
    },
    {
      "step_id": "execute_table_saw_dissection",
      "title": "Execute Planar Dissection",
      "description": "Set the table saw blade to a
height sufficient to cut through the thickest part of
the chair. Power on the saw and smoothly guide the sled
holding the chair through the blade, precisely follow-
ing the marked line. This single, uninterrupted pass
will bisect the chair, including legs, aprons, and
seat, into two separate pieces.",
```

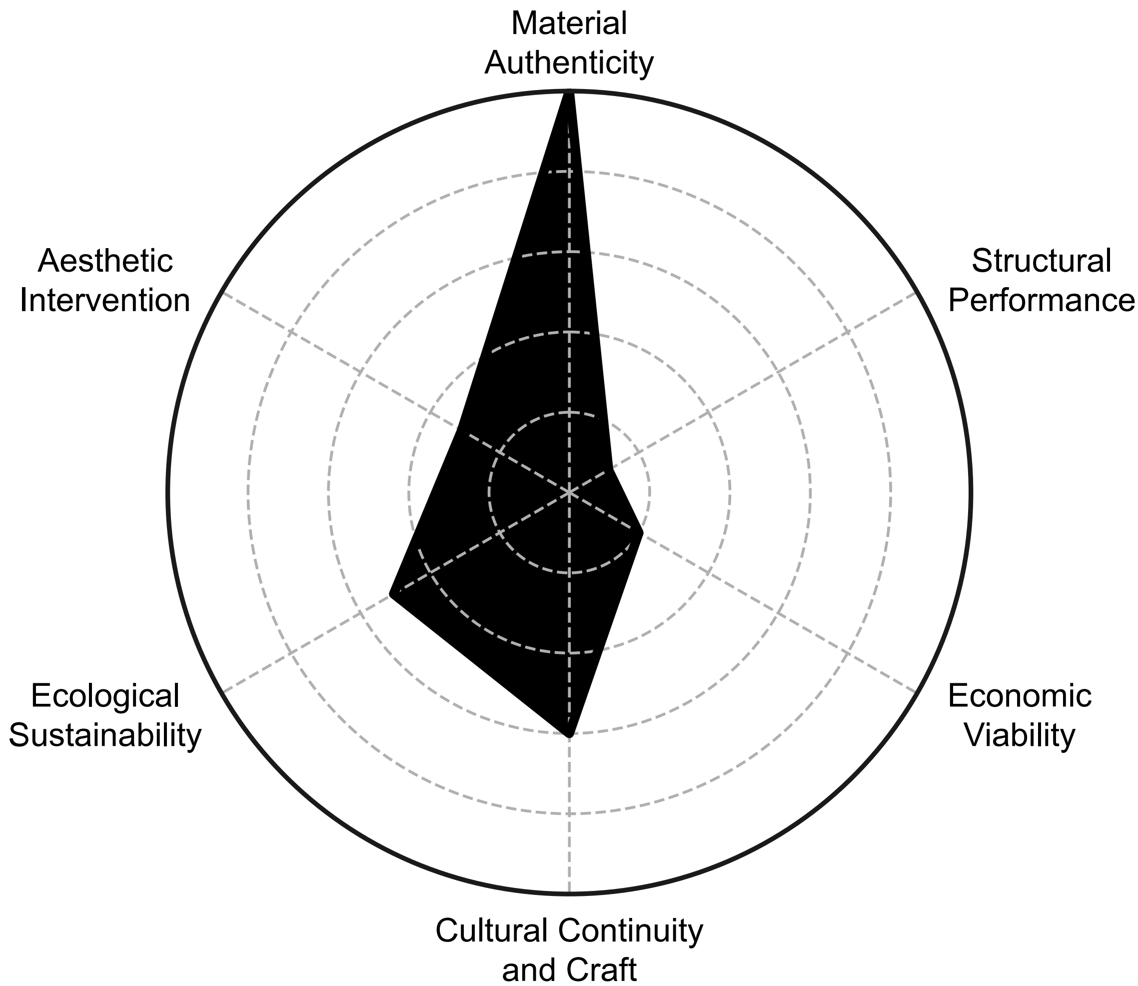
"rationale": "This single, powerful cut is the ultimate act of subtractive transformation, as instructed. It brutally exposes the chair's internal structure and material reality, sacrificing its form and function for a new, critical perception of its components as a cross-section. All damages are addressed not by mending, but by being bisected and revealed.",
      "tools_required": [
        "Table saw",
        "Push sticks"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "seat",
        "front_apron",
        "left_side_apron",
        "back_apron",
        "back_left_glider"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_05"
      ],
      "prerequisites": [
        "mark_dissection_plane"
      ]
    },
    {
      "step_id": "bisect_remaining_gliders",
      "title": "Bisect Untouched Gliders",
      "description": "Identify any gliders that were not sectioned by the main table saw cut. Using a fine-toothed handsaw, perform a separate, precise cut on each of these gliders. The cut should be on the same plane and aesthetic as the main dissection, creating a matching cross-section.",
      "rationale": "This extends the dissection to the object's smallest points of contact with the world. It ensures the subtractive logic is applied consistently,

```
destabilizing even the parts untouched by the primary
cut and unifying the entire object in its transformed
state, as per the user's note to address gliders sepa-
rately.",
      "tools_required": [
        "Japanese pull saw",
        "Bench vise"
      ],
      "affected_parts": [
        "front_right_glider",
        "back_right_glider"
      ],
      "affected_damages": [],
      "prerequisites": [
        "execute_table_saw_dissection"
      ]
    },
    {
      "step_id": "char_exposed_cross_sections",
      "title": "Char All Cut Surfaces",
      "description": "Using a blowtorch, apply a deep
char (shou sugi ban technique) to all newly exposed
wood surfaces created by the table saw and handsaw
cuts. Control the flame to create a uniform, dark, tex-
tured finish across the entire cross-section, then
brush away loose soot with a wire brush.",
      "rationale": "Charring the raw, exposed cross-
sections visually cauterizes the 'wound.' It creates a
stark, dramatic contrast between the chair's original
finish and its newly revealed interior, highlighting
the violence of the cut and framing it as a deliberate
aesthetic feature.",
      "tools_required": [
        "Blowtorch",
        "Wire brush",
        "Fire extinguisher"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "seat",
        "front_apron",
        "left_side_apron",
```

```
        "back_apron",
        "back_left_glider",
        "front_right_glider",
        "back_right_glider"
      ],
      "affected_damages": [],
      "prerequisites": [
        "execute_table_saw_dissection",
        "bisect_remaining_gliders"
      ]
    },
    {
      "step_id": "present_dissected_halves",
      "title": "Position Dissected Halves",
      "description": "Place the two resulting halves of
the chair on a display surface. Position them slightly
apart from each other, with the charred, cut surfaces
facing forward. The gap between them should be inten-
tional, emphasizing the void created by the cut.",
      "rationale": " Separating the halves makes the
act of dissection permanent and central to the piece's
new identity, forcing a confrontation with its decon-
structed form and the space between what was once
whole.",
      "tools_required": [
        "Display surface"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "char_exposed_cross_sections"
      ]
    }
  ]
}
```

The Purist

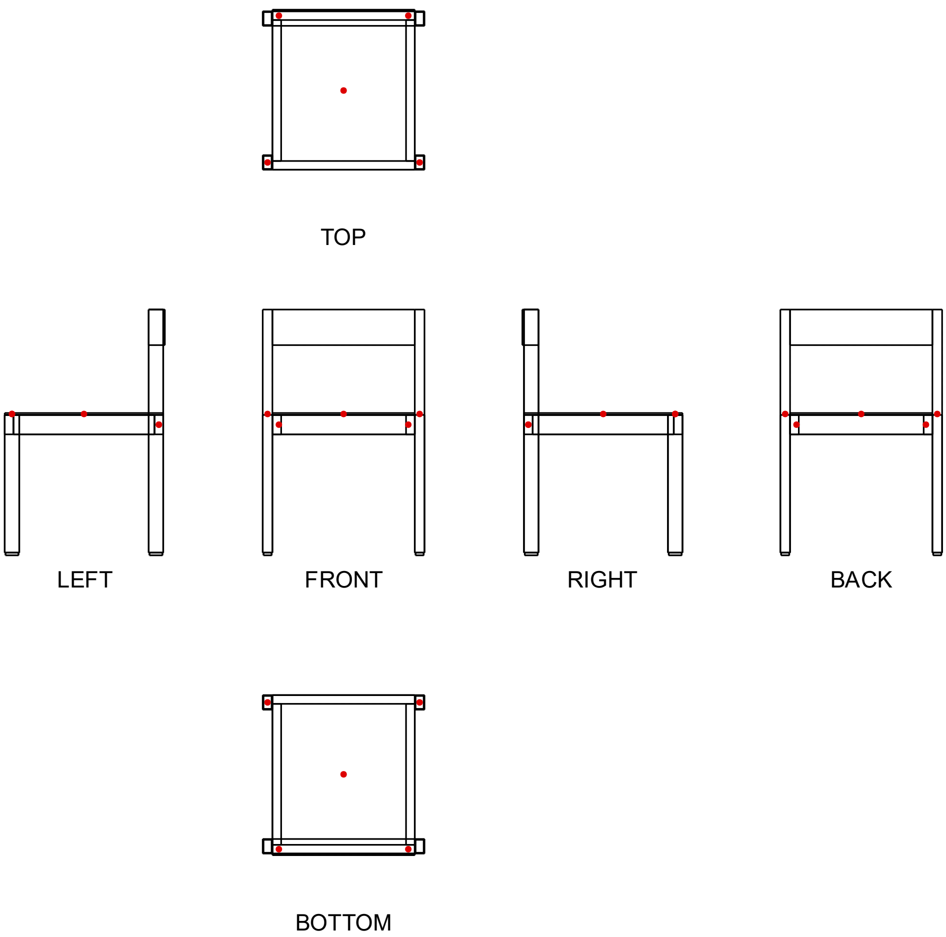
The passage of time is sacred, decay is an integral part of an object's authentic narrative. Interventions are therefore profoundly reluctant, limited strictly to stabilization to prevent catastrophic failure. No attempt is made to replace material or beautify surfaces; the object is preserved in its current, wounded state. Any necessary structural support is introduced as a scrupulously honest and entirely distinct system, crafted with intelligence and robust materials. Every scar is preserved as a testament to its true history.



Santo Chair 03

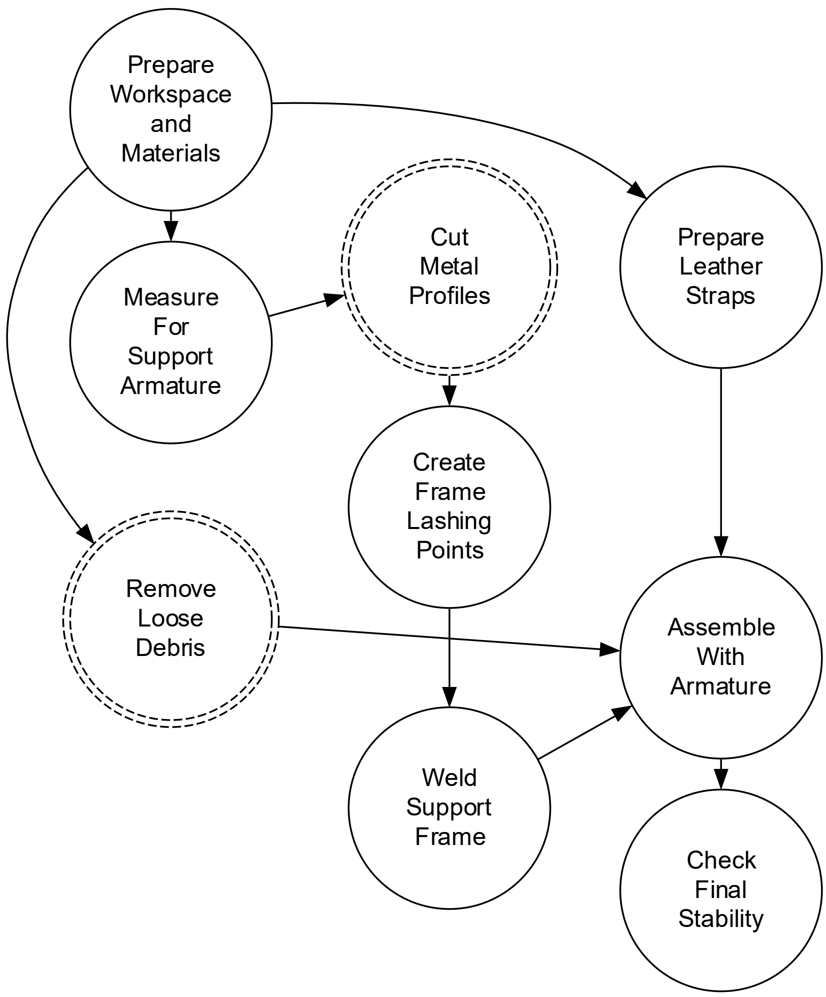
This chair has been violently smashed. The damage is not due to wear but to a deliberate act of force, leaving it in pieces. Evidence of this shattering includes the back apron, which is broken on both sides, and the front left leg, which is splintered apart at the joint, exposing its inner structure. The front right leg is also cracked from the impact. A large piece of wood has been forcefully chipped out from the center of the seat. The object is no longer a chair, but a collection of broken fragments.

Overall Condition Rating: 3/10



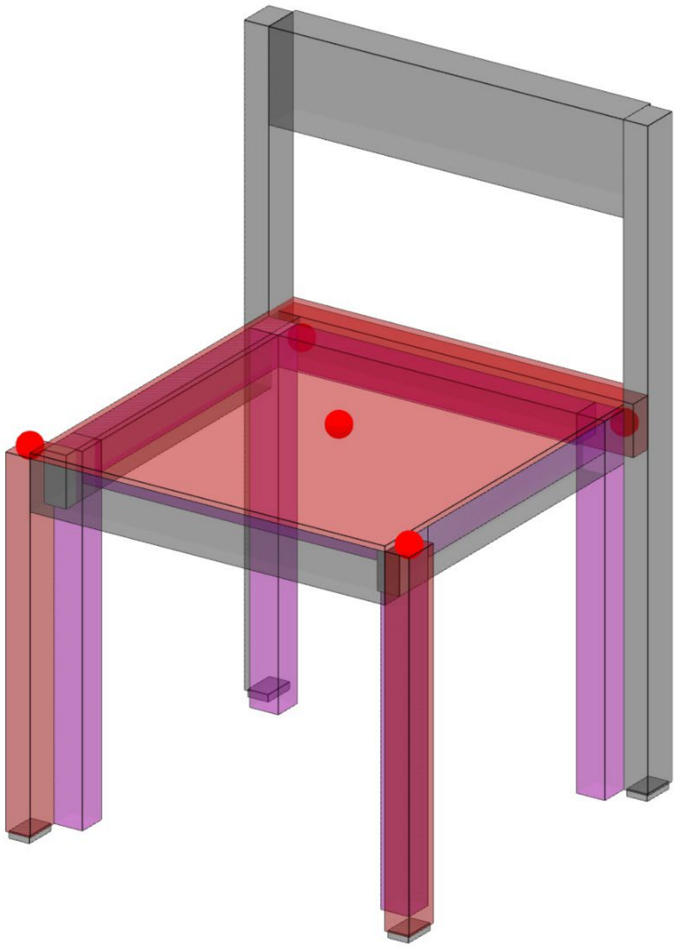
```
[
  {
    "id": "damage_01",
    "type": "Breakage",
    "description": "Severe splintering and breakage of
the wood on the left side of the back apron, near its
connection point with the back left leg.",
    "part_id": "back_apron",
    "coordinates": {
      "x": -0.2,
      "y": 0.404,
      "z": 0.2315
    }
  },
  {
    "id": "damage_02",
    "type": "Breakage",
    "description": "Splintering and minor breakage of
the wood on the right side of the back apron, near its
connection point with the back right leg.",
    "part_id": "back_apron",
    "coordinates": {
      "x": 0.2,
      "y": 0.404,
      "z": 0.2315
    }
  },
  {
    "id": "damage_03",
    "type": "Breakage",
    "description": "Severe splintering and breakage at
the top of the leg, exposing the internal joint struc-
ture, consistent with a connection point for an apron
or seat.",
    "part_id": "front_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.437,
      "z": -0.2225
    }
  },
  {
    "id": "damage_04",
    "type": "Crack",
```

```
    "description": "Crack at the top of the front right
leg, consistent with its connection point for an apron
or seat.",
    "part_id": "front_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.437,
      "z": -0.2225
    }
  },
  {
    "id": "damage_05",
    "type": "Chip",
    "description": "Large piece of wood chipped from
the seat in the middle of the chair.",
    "part_id": "seat",
    "coordinates": {
      "x": 0,
      "y": 0.437,
      "z": 0
    }
  }
]
```


Prepare Workspace and Materials
Measure For Support Armature
Cut Metal Profiles
Prepare Leather Straps
Create Frame Lashing Points
Remove Loose Debris
Assemble With Armature
Weld Support Frame
Check Final Stability

Repair

Instead of gluing the broken wood, a new, external support system is fabricated. A custom-welded metal frame, or armature, is built to sit underneath the chair's components. The original, broken pieces are then carefully lashed to this metal frame using strong leather straps. This non-invasive and reversible method stabilizes the chair and prevents further collapse while intentionally leaving the damage visible. The result is an honest intervention where the new metal and leather support is clearly distinct from the historic, fractured wood it preserves.



```
{
  "steps": [
    {
      "step_id": "prepare_workspace_and_materials",
      "title": "Prepare Workspace and Materials",
      "description": "Set up a safe and organized work-
space suitable for metalwork and assembly. Lay out the
disassembled chair components on a protected surface.
Gather all required materials, including the metal L-
profiles, leather hide, and all necessary tools and
safety equipment.",
      "rationale": "This preparation ensures that the
new, distinct support system can be fabricated without
compromising the integrity of the original object.",
      "tools_required": [
        "Welding machine",
        "Angle grinder with cutting disc",
        "Drill with metal bits",
        "Measuring tape",
        "Protective gloves",
        "Welding mask",
        "Leather cutting tools",
        "Metal L-profiles",
        "Leather hide"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "remove_loose_debris",
      "title": "Remove Loose Debris",
      "description": "Using a soft brush and tweezers,
delicately remove any completely detached splinters and
debris from the broken areas of the back apron and
front legs. No attempt should be made to clean, sand,
or alter the damaged surfaces themselves.",
      "rationale": " It is not an aesthetic repair but
a conservation step, preserving the object's authentic,
'wounded' state as dictated by the philosophy.",
      "tools_required": [
        "Soft-bristle brush",
        "Tweezers"
      ],
```

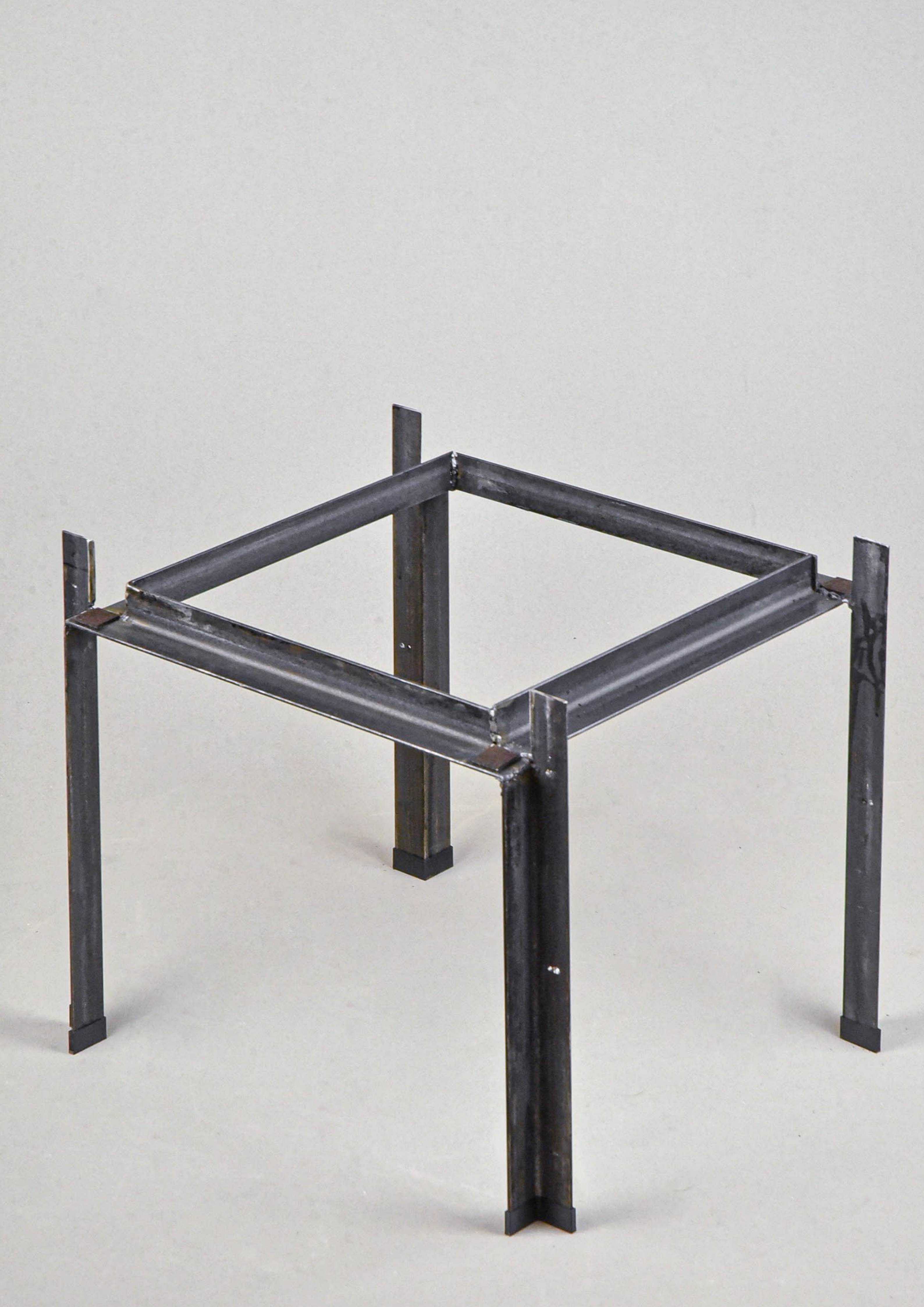
```
      "affected_parts": [
        "back_apron",
        "front_left_leg",
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "prepare_workspace_and_materials"
      ]
    },
    {
      "step_id": "measure_for_armature",
      "title": "Measure For Support Armature",
      "description": "With the components already sepa-
rated, dry-fit them into their original positions to
take precise measurements of the chair's undercarriage.
Plan the dimensions for a rectangular metal frame that
will sit beneath the aprons, providing support without
direct, invasive contact.",
      "rationale": "Accurate measurement is critical to
fabricating an armature that fits perfectly as a dis-
tinct, external system. This ensures the intervention
is non-damaging and respects the absolute integrity of
the original material.",
      "tools_required": [
        "Measuring tape",
        "Caliper",
        "Engineer's square"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
```

"affected_damages": [],
"prerequisites": [
  "prepare_workspace_and_materials"
]
},
{
"step_id": "cut_metal_profiles",
"title": "Cut Metal Profiles",
"description": "Using an angle grinder or metal saw, cut the L-profiles to the lengths determined in the measurement step. Ensure the cuts are clean and precise to facilitate accurate welding.",
"rationale": "This is the first physical step in creating the honest and robust armature. The precision of this step reflects the intelligence of the intervention, which makes no pretense of being part of the original object.",
"tools_required": [
  "Angle grinder",
  "Metal cutting disc",
  "Safety glasses"
],
"affected_parts": [],
"affected_damages": [],
"prerequisites": [
  "measure_for_armature"
]
},
{
"step_id": "create_lashing_points_on_frame",
"title": "Create Frame Lashing Points",
"description": "Using a drill or angle grinder, create evenly spaced slots or holes along the cut metal profiles. These points will serve as anchors for the leather straps, allowing them to be threaded through and securely fastened.",
"rationale": "By modifying the new armature instead of the original object, we uphold the principle of reversibility and absolute integrity of the historic material. These points make the lashing system both intelligent and functional.",
"tools_required": [
  "Drill with metal bits",
  "Angle grinder with cutting disc",

```
        "Center punch",
        "Safety glasses"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "cut_metal_profiles"
      ]
    },
    {
      "step_id": "weld_support_frame",
      "title": "Weld Support Frame",
      "description": "Weld the cut and prepared metal
profiles into a single, rigid rectangular frame. The
welds should be strong and functional, creating the
core of the stabilization armature.",
      "rationale": "Welding fabricates the distinct,
visible armature that will provide the necessary struc-
tural support. This new system is intentionally differ-
ent in material and construction, honestly declaring
itself as a modern intervention.",
      "tools_required": [
        "Welding machine",
        "Welding mask",
        "Welding clamps"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "create_lashing_points_on_frame"
      ]
    },
    {
      "step_id": "prepare_leather_straps",
      "title": "Prepare Leather Straps",
      "description": "Cut the leather hide into long,
uniform straps. These straps will be used to lash the
original chair components to the new metal frame.",
      "rationale": "Leather is selected as the lashing
material because it is strong yet soft, allowing for a
secure, non-damaging, and fully reversible connection.
This method avoids any invasive fasteners like screws
or bolts, preserving the original material's integ-
rity.",
```

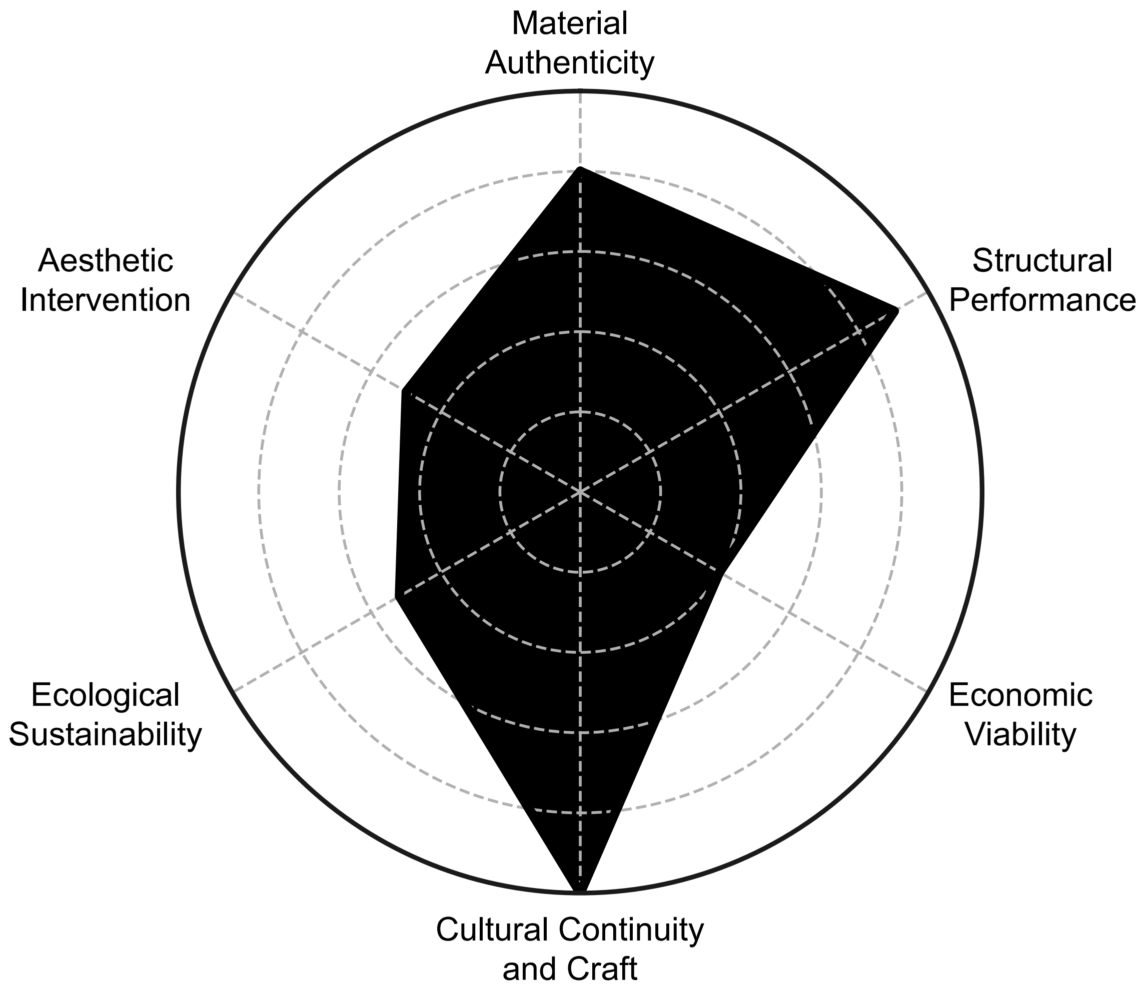
```
      "tools_required": [
        "Utility knife",
        "Cutting mat",
        "Straight edge"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "prepare_workspace_and_materials"
      ]
    },
    {
      "step_id": "assemble_with_armature",
      "title": "Assemble With Armature",
      "description": "Position the welded metal frame.
Carefully arrange the original legs, aprons, and seat
in their correct orientation around and upon the frame.
Thread the prepared leather straps through the lashing
points on the armature and wrap them around the chair
components to securely lash all parts to the metal
frame, creating a stable, unified structure.",
      "rationale": "This step unites the original ob-
ject with the new support system in a way that is both
structurally effective and philosophically honest. The
lashing is a visible, non-invasive binding that stabi-
lizes the chair against catastrophic failure while cel-
ebrating the distinction between the historic object
and its modern support.",
      "tools_required": [
        "Leather straps"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat"
      ],
      "affected_damages": [
        "damage_01",
```

```
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_05"
      ],
      "prerequisites": [
        "weld_support_frame",
        "remove_loose_debris",
        "prepare_leather_straps"
      ]
    },
    {
      "step_id": "final_stability_check",
      "title": "Check Final Stability",
      "description": "Gently test the assembled chair
to confirm that the new armature and lashing provide
sufficient stability. Adjust the tension of the leather
straps as needed to eliminate any wobble or loose-
ness.",
      "rationale": "This final verification ensures the
intervention has met its sole objective: the stabiliza-
tion of the object to prevent catastrophic failure. The
repair is complete once stability is achieved, with no
further aesthetic or restorative actions taken.",
      "tools_required": [],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat"
      ],
      "affected_damages": [],
      "prerequisites": [
        "assemble_with_armature"
      ]
    }
  ]
}
```



The Gentle Craftsman

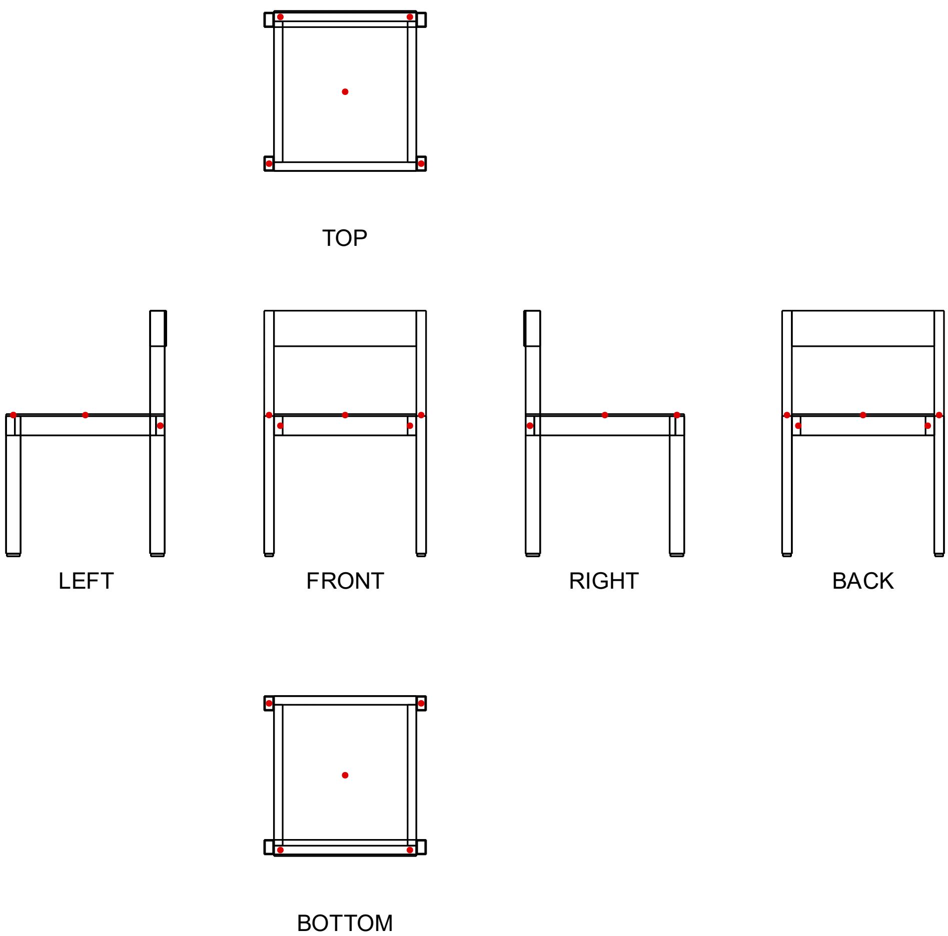
Repair through modest, careful acts of continuous maintenance using traditional skills and sympathetic materials. Crucially, these repairs are honest additions; while materially compatible, they remain visually distinct from the original fabric and are never disguised to create a false sense of perfection. The highest priority is retaining authentic material to preserve historical continuity and the patina of age. The goal is not a flawless, restored look but to celebrate a layered narrative where every act of stewardship is a legible part of the object’s story.



Santo Chair 02

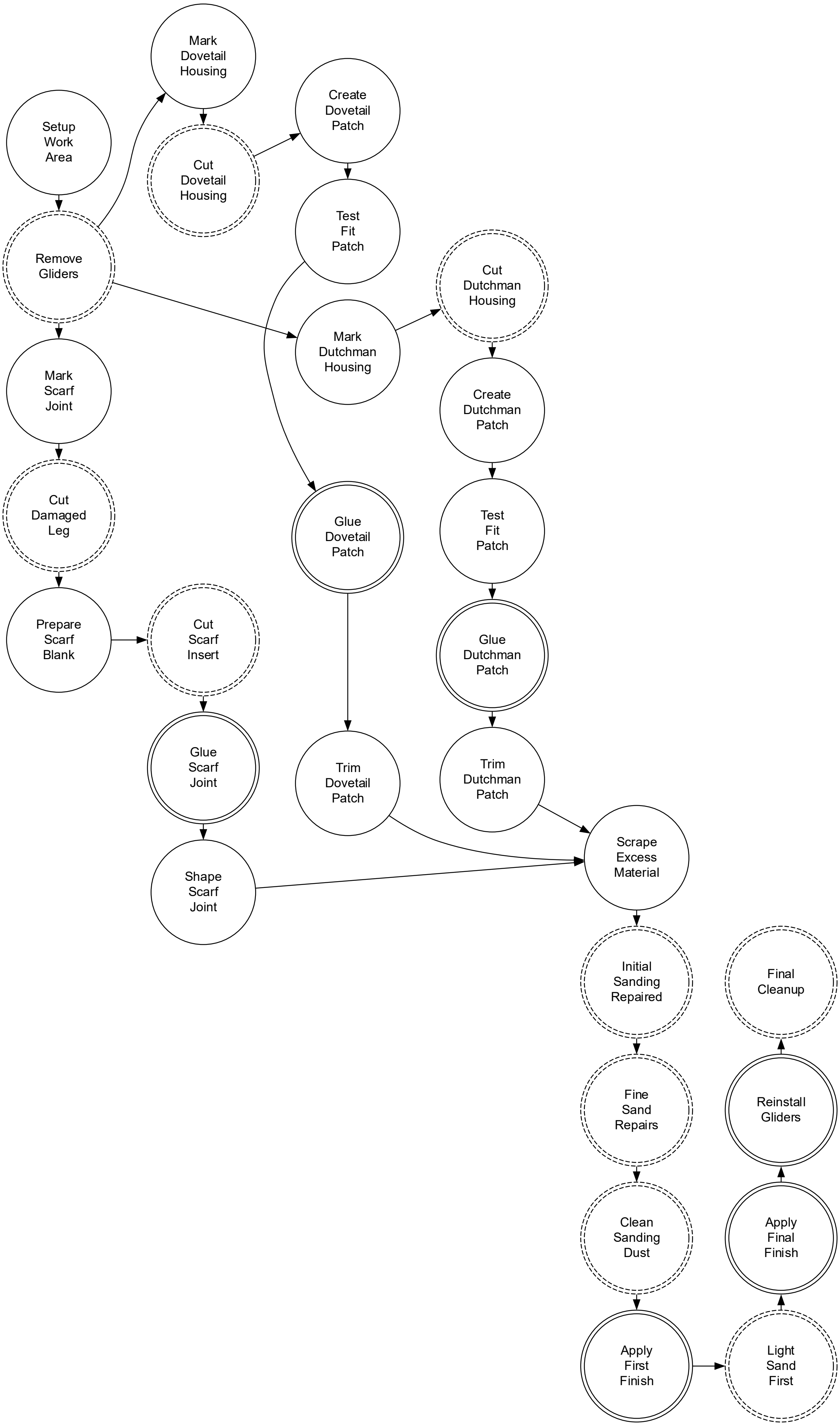
This chair is utterly destroyed, having been smashed into pieces. It has suffered catastrophic structural damage across multiple key areas. The front left leg exhibits a severe wood breakout, a testament to the violent force it endured, while the front right leg is split by a large crack. Further evidence of its destruction includes a large chip on the back right leg and a rough, damaged seat surface. The chair is no longer a piece of furniture but a collection of shattered fragments, well beyond any conventional repair.

Overall Condition Rating: 3/10



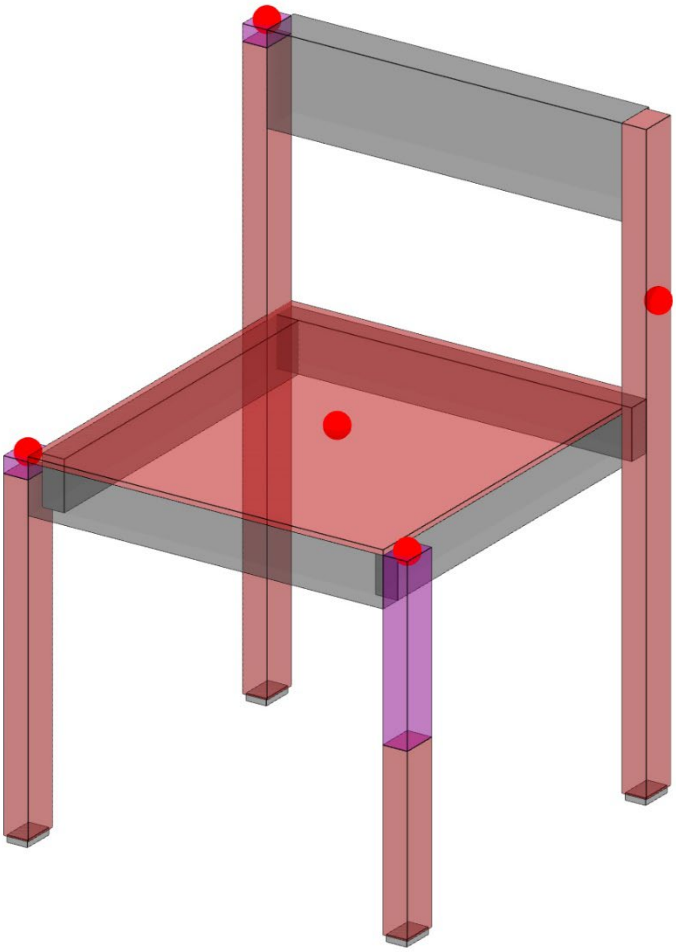
```
[
  {
    "id": "damage_01",
    "type": "Chipping",
    "description": "Big wood chipping on the top sur-
face of the back right leg.",
    "part_id": "back_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.76,
      "z": 0.2225
    }
  },
  {
    "id": "damage_02",
    "type": "Breakout",
    "description": "Severe breakout of wood on the
front left leg.",
    "part_id": "front_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.434,
      "z": -0.2225
    }
  },
  {
    "id": "damage_03",
    "type": "Crack",
    "description": "A big crack  on the top surface of
the front right leg.",
    "part_id": "front_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.434,
      "z": -0.2225
    }
  },
  {
    "id": "damage_04",
    "type": "Rough Surface",
    "description": "Rough surface texture on the top of
the seat.",
    "part_id": "seat",
    "coordinates": {
```

```
      "x": 0,
      "y": 0.44,
      "z": 0
    }
  },
  {
    "id": "damage_05",
    "type": "Scratches",
    "description": "Scratches in the middle of the left
side of the back left leg.",
    "part_id": "back_left_leg",
    "coordinates": {
      "x": -0.25,
      "y": 0.56,
      "z": 0.2225
    }
  }
]
```


Setup Work Area
Remove Gliders
Mark Dovetail Housing
Cut Dovetail Housing
Create Dovetail Patch
Test Fit Patch
Mark Dutchman Housing
Cut Dutchman Housing
Create Dutchman Patch
Test Fit Patch
Glue Dutchman Patch
Trim Dutchman Patch
Glue Dovetail Patch
Trim Dovetail Patch
Mark Scarf Joint
Cut Damaged Leg
Prepare Scarf Blank
Cut Scarf Insert
Glue Scarf Joint
Shape Scarf Joint
Scrape Excess Material
Initial Sanding Repaired
Fine Sand Repairs
Clean Sanding Dust
Apply First Finish
Light Sand First
Apply Final Finish
Reinstall Gliders
Final Cleanup

Repair

Structural damages are addressed with meticulous, handcrafted solutions: a broken leg section is replaced using a strong scarf joint, a crack is stabilized with a mechanically robust dovetail patch, and surface chipping is mended with a Dutchman patch. Each repair uses carefully matched wood, which is then painstakingly shaped, sanded, and finished to blend seamlessly with the chair's original patina. The philosophy prioritizes strength and integrity, preserving the object’s history through minimal, sympathetic intervention.



```
{
  "steps": [
    {
      "step_id": "setup_work_area",
      "title": "Setup Work Area",
      "description": "Clear and protect the work sur-
face. Gather all necessary tools and materials for the
repair process. Ensure good lighting and ventilation
for precision work.",
      "rationale": "A clean, organized workspace is es-
sential for safety, efficiency, and preventing any col-
lateral damage to the object during the repair.",
      "tools_required": [
        "Workbench",
        "Drop cloths",
        "Safety glasses",
        "Gloves"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "remove_gliders",
      "title": "Remove Gliders",
      "description": "Carefully remove the gliders from
the bottom of each leg to prevent damage during repair
and finishing processes. Store them safely to be rein-
stalled later.",
      "rationale": "Removing hardware prevents damage
to both the gliders and the leg bottoms during clamping
and finishing, ensuring all original parts are pre-
served.",
      "tools_required": [
        "Pliers",
        "Screwdriver (if applicable)",
        "Protective padding"
      ],
      "affected_parts": [
        "front_left_glider",
        "front_right_glider",
        "back_left_glider",
        "back_right_glider"
      ],
```

```
      "affected_damages": [],
      "prerequisites": [
        "setup_work_area"
      ]
    },
    {
      "step_id": "mark_scarf_joint_cut_fl_leg",
      "title": "Mark Scarf Joint",
      "description": "Precisely mark the scarf joint
cut on the front_left_leg to remove the damaged area
(damage_02). Ensure the angle is shallow and consistent
for maximum gluing surface and strength, respecting
original material and minimizing loss.",
      "rationale": "A scarf joint provides a large glu-
ing surface, creating a repair that is much stronger
than a simple butt joint while conserving the maximum
amount of original wood.",
      "tools_required": [
        "Pencil",
        "Marking knife",
        "Ruler",
        "Angle gauge"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "remove_gliders"
      ]
    },
    {
      "step_id": "cut_damaged_leg_scarf_fl_leg",
      "title": "Cut Damaged Leg",
      "description": "Carefully cut the front_left_leg
along the marked scarf joint line using a fine-toothed
hand saw. Ensure a clean, straight, and consistent an-
gled cut to provide a strong bonding surface for the
new piece, retaining as much original material as pos-
sible.",
```

```
      "rationale": "A precise, clean cut is critical
for a gap-free joint, which is essential for the
strength and invisibility of the final repair.",
      "tools_required": [
        "Fine-toothed hand saw",
        "Chisel",
        "Bench vise"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "mark_scarf_joint_cut_fl_leg"
      ]
    },
    {
      "step_id": "prepare_scarf_insert_blank_fl_leg",
      "title": "Prepare Scarf Blank",
      "description": "Select a new piece of wood that
closely matches the original front_left_leg in species,
grain, and color. Cut a blank slightly oversized to al-
low for precise shaping of the scarf joint, adhering to
traditional methods.",
      "rationale": "Using sympathetic materials (match-
ing wood) is key to a conservative repair, ensuring the
patch blends aesthetically and behaves similarly to the
original wood over time.",
      "tools_required": [
        "Hand saw",
        "Marking gauge",
        "Matching wood stock"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "cut_damaged_leg_scarf_fl_leg"
      ]
```

```
    },
    {
      "step_id": "cut_scarf_insert_angle_fl_leg",
      "title": "Cut Scarf Insert",
      "description": "Precisely cut the new wood blank
with an angle matching the scarf joint on the
front_left_leg. Test fit frequently to ensure a per-
fect, gap-free mating surface, reflecting careful
craftsmanship.",
      "rationale": "The strength of the repair depends
entirely on the perfect fit of the two surfaces. This
step requires patience and precision to achieve a seam-
less bond.",
      "tools_required": [
        "Fine-toothed hand saw",
        "Chisel",
        "Marking knife",
        "Sanding block"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "prepare_scarf_insert_blank_fl_leg"
      ]
    },
    {
      "step_id": "glue_scarf_joint_fl_leg",
      "title": "Glue Scarf Joint",
      "description": "Apply a traditional hide glue or
a sympathetic wood glue to both mating surfaces of the
scarf joint on the front_left_leg. Carefully align and
join the new piece, clamping securely with even pres-
sure along the entire joint. Allow ample time for the
glue to cure completely.",
      "rationale": "Proper gluing and clamping trans-
form the two separate pieces into a single, strong
unit. Even pressure ensures a consistent, durable bond
across the entire joint.",
      "tools_required": [
        "Wood glue (hide glue recommended)",
```

```
          "Clamps",
          "Cauls"
        ],
        "affected_parts": [
          "front_left_leg"
        ],
        "affected_damages": [
          "damage_02"
        ],
        "prerequisites": [
          "cut_scarf_insert_angle_fl_leg"
        ]
      },
      {
        "step_id": "shape_scarf_joint_fl_leg",
        "title": "Shape Scarf Joint",
        "description": "Once the glue is fully cured,
carefully trim any excess material from the new scarf
joint piece on the front_left_leg using a sharp chisel
or block plane. Blend the new wood seamlessly into the
original leg, maintaining the leg's original profile
and preserving the patina.",
        "rationale": "This step integrates the repair
into the original form of the object, making the inter-
vention as visually unobtrusive as possible while re-
specting the original contours.",
        "tools_required": [
          "Chisel",
          "Block plane",
          "Cabinet scraper"
        ],
        "affected_parts": [
          "front_left_leg"
        ],
        "affected_damages": [
          "damage_02"
        ],
        "prerequisites": [
          "glue_scarf_joint_fl_leg"
        ]
      },
      {
        "step_id": "prepare_dovetail_housing",
        "title": "Mark Dovetail Housing",
```

```
      "description": "Carefully mark out a shallow,
precise dovetail housing around the crack on the front
right leg (damage_03). The housing should be just large
enough to encompass the damage, minimizing removal of
original material and allowing for a strong, sympa-
thetic patch.",
      "rationale": "A dovetail patch provides strong
mechanical reinforcement against forces that might pull
the crack apart, making it a superior choice for struc-
tural integrity.",
      "tools_required": [
        "Pencil",
        "Marking knife",
        "Ruler",
        "Dovetail gauge"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "remove_gliders"
      ]
    },
    {
      "step_id": "cut_dovetail_housing",
      "title": "Cut Dovetail Housing",
      "description": "Using fine chisels and a mallet,
carefully cut the marked dovetail housing into the
front right leg. Ensure clean, precise cuts and a flat
bottom to the housing for optimal fit and adhesion of
the patch. Work slowly to retain as much original mate-
rial as possible.",
      "rationale": "Precision in cutting the housing is
essential for the patch to fit perfectly and provide
its full mechanical strength. Care is taken to avoid
any new damage.",
      "tools_required": [
        "Fine chisels",
        "Mallet",
        "Router plane (optional for flattening)"
      ],
```

```
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "prepare_dovetail_housing"
      ]
    },
    {
      "step_id": "create_dovetail_patch",
      "title": "Create Dovetail Patch",
      "description": "Select a piece of wood that
closely matches the original front right leg in spe-
cies, grain, and color. Carefully cut and shape a dove-
tail patch that precisely fits the prepared housing,
ensuring a snug, gap-free fit, a hallmark of tradi-
tional repair.",
      "rationale": "The craftsmanship of the patch it-
self is a mark of a quality repair. A well-made patch
fits perfectly, looks intentional, and respects the
original object's aesthetic.",
      "tools_required": [
        "Matching wood stock",
        "Hand saw",
        "Chisels",
        "Marking knife",
        "Dovetail gauge"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "cut_dovetail_housing"
      ]
    },
    {
      "step_id": "fit_dovetail_patch",
      "title": "Test Fit Patch",
```

      "description": "Repeatedly test fit the crafted
dovetail patch into the housing on the front right leg,
making minor adjustments with a chisel or sandpaper un-
til a perfect, tight fit is achieved. The patch should
sit flush with the surrounding original surface without
force, demonstrating careful work.",
      "rationale": "Achieving a perfect friction fit
before gluing ensures the patch will be strong and sit
flush, making the final blending and finishing steps
much more successful.",
      "tools_required": [
        "Chisels",
        "Fine-grit sandpaper"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "create_dovetail_patch"
      ]
    },
    {
      "step_id": "glue_dovetail_patch",
      "title": "Glue Dovetail Patch",
      "description": "Apply a traditional hide glue or
a sympathetic wood glue sparingly to the mating sur-
faces of the dovetail housing and patch on the front
right leg. Gently tap the patch into place using a mal-
let, ensuring it is fully seated and flush. Clamp se-
curely with cauls to distribute pressure evenly, allow-
ing for a strong, lasting mend.",
      "rationale": "Gluing finalizes the repair, creat-
ing a permanent chemical and mechanical bond that sta-
bilizes the crack and integrates the patch into the
leg.",
      "tools_required": [
        "Wood glue (hide glue recommended)",
        "Mallet",
        "Clamps",
        "Cauls"
      ],

```
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "fit_dovetail_patch"
      ]
    },
    {
      "step_id": "trim_dovetail_patch",
      "title": "Trim Dovetail Patch",
      "description": "Once the glue is fully cured,
carefully trim any excess material from the new dove-
tail patch using a sharp chisel or block plane. Blend
the patch seamlessly into the original leg, maintaining
the leg's original profile and preserving the patina
through modest intervention.",
      "rationale": "This final shaping makes the repair
physically and visually part of the original object,
ensuring a smooth feel and a nearly invisible transi-
tion.",
      "tools_required": [
        "Chisel",
        "Block plane",
        "Cabinet scraper"
      ],
      "affected_parts": [
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03"
      ],
      "prerequisites": [
        "glue_dovetail_patch"
      ]
    },
    {
      "step_id": "mark_dutchman_housing_br_leg",
      "title": "Mark Dutchman Housing",
      "description": "Carefully mark out a shallow,
precise housing around the chipping on the back right
leg (damage_01). The housing should be just large
```

enough to encompass the damage, minimizing removal of
original material and allowing for a strong, sympa-
thetic patch, consistent with traditional repair meth-
ods.",
      "rationale": "A Dutchman patch is a traditional
and elegant way to repair localized surface damage like
chips, providing a stable and visually clean solu-
tion.",
      "tools_required": [
        "Pencil",
        "Marking knife",
        "Ruler"
      ],
      "affected_parts": [
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "remove_gliders"
      ]
    },
    {
      "step_id": "cut_dutchman_housing_br_leg",
      "title": "Cut Dutchman Housing",
      "description": "Using fine chisels and a mallet,
carefully cut the marked housing into the back right
leg. Ensure clean, precise cuts and a flat bottom to
the housing for optimal fit and adhesion of the patch.
Work slowly to retain as much original material as pos-
sible, embodying conservative repair.",
      "rationale": "Cleanly cut walls and a flat bottom
for the housing are non-negotiable for a professional
repair, ensuring the patch sits perfectly and bonds
strongly.",
      "tools_required": [
        "Fine chisels",
        "Mallet",
        "Router plane (optional for flattening)"
      ],
      "affected_parts": [
        "back_right_leg"
      ],

"affected_damages": [
  "damage_01"
],
"prerequisites": [
  "mark_dutchman_housing_br_leg"
]
},
{
"step_id": "create_dutchman_patch_br_leg",
"title": "Create Dutchman Patch",
"description": "Select a piece of wood that closely matches the original back right leg in species, grain, and color. Carefully cut and shape a patch that precisely fits the prepared housing, ensuring a snug, gap-free fit, a hallmark of traditional repair and sympathetic material use.",
"rationale": "The patch is crafted as a new, integral part of the leg. Matching the grain and color ensures the repair will be as inconspicuous as possible after finishing.",
"tools_required": [
  "Matching wood stock",
  "Hand saw",
  "Chisels",
  "Marking knife"
],
"affected_parts": [
  "back_right_leg"
],
"affected_damages": [
  "damage_01"
],
"prerequisites": [
  "cut_dutchman_housing_br_leg"
]
},
{
"step_id": "fit_dutchman_patch_br_leg",
"title": "Test Fit Patch",
"description": "Repeatedly test fit the crafted patch into the housing on the back right leg, making minor adjustments with a chisel or sandpaper until a perfect, tight fit is achieved. The patch should sit flush with the surrounding original surface without

```
force, demonstrating careful craftsmanship and minimal
intervention.",
      "rationale": "The process of fitting the patch is
iterative and demands precision. A perfect fit is the
goal, as it ensures the strongest bond and the cleanest
aesthetic result.",
      "tools_required": [
        "Chisels",
        "Fine-grit sandpaper"
      ],
      "affected_parts": [
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "create_dutchman_patch_br_leg"
      ]
    },
    {
      "step_id": "glue_dutchman_patch_br_leg",
      "title": "Glue Dutchman Patch",
      "description": "Apply a traditional hide glue or
a sympathetic wood glue sparingly to the mating sur-
faces of the housing and patch on the back right leg.
Gently tap the patch into place using a mallet, ensur-
ing it is fully seated and flush. Clamp securely with
cauls to distribute pressure evenly, allowing for a
strong, lasting mend that preserves continuity.",
      "rationale": "This step permanently bonds the new
patch, stabilizing the damaged area and making the new
wood an integral part of the original leg.",
      "tools_required": [
        "Wood glue (hide glue recommended)",
        "Mallet",
        "Clamps",
        "Cauls"
      ],
      "affected_parts": [
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01"
```

```
      ],
      "prerequisites": [
        "fit_dutchman_patch_br_leg"
      ]
    },
    {
      "step_id": "trim_dutchman_patch_br_leg",
      "title": "Trim Dutchman Patch",
      "description": "Once the glue is fully cured,
carefully trim any excess material from the new patch
using a sharp chisel or block plane. Blend the patch
seamlessly into the original leg, maintaining the leg's
original profile and preserving the patina through mod-
est intervention.",
      "rationale": "Final shaping ensures the patch is
perfectly flush with the surrounding surface, restoring
the original feel and contour of the leg.",
      "tools_required": [
        "Chisel",
        "Block plane",
        "Cabinet scraper"
      ],
      "affected_parts": [
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "glue_dutchman_patch_br_leg"
      ]
    },
    {
      "step_id": "scrape_excess_material",
      "title": "Scrape Excess Material",
      "description": "Carefully scrape away any dried
excess glue from the scarf joint and dovetail patch,
and excess material from the newly inserted Dutchman
patch. Use a sharp scraper or chisel, being mindful not
to scratch the surrounding original wood, preserving
the patina and original surface.",
      "rationale": "Removing excess glue and material
is a crucial clean-up step that prevents imperfections
```

in the final finish and respects the original sur-
face.",
      "tools_required": [
        "Cabinet scraper",
        "Sharp chisel"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "shape_scarf_joint_fl_leg",
        "trim_dovetail_patch",
        "trim_dutchman_patch_br_leg"
      ]
    },
    {
      "step_id": "initial_sanding_repaired_areas",
      "title": "Initial Sanding Repaired",
      "description": "Using medium-grit sandpaper
(e.g., 120-150 grit), carefully sand all areas that re-
ceived a patch, scarf joint, or Dutchman insert (front
left leg, front right leg, back right leg) to blend
them smoothly with the original surface, respecting the
surrounding material and avoiding aggressive removal.",
      "rationale": "Sanding begins the process of visu-
ally integrating the repairs, creating a smooth transi-
tion between the new and old wood in preparation for
finishing.",
      "tools_required": [
        "Medium-grit sandpaper",
        "Sanding block"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],

```
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "scrape_excess_material"
      ]
    },
    {
      "step_id": "fine_sanding_repairs",
      "title": "Fine Sand Repairs",
      "description": "Using fine-grit sandpaper (e.g.,
220-320 grit), perform a final, thorough sanding of all
repaired areas (front left leg, front right leg, back
right leg) to prepare for finishing, ensuring a sympa-
thetic blend with the original patina and a smooth
transition.",
      "rationale": "Fine sanding is the final step in
surface preparation, creating a perfectly smooth base
that is ready to accept the new finish evenly.",
      "tools_required": [
        "Fine-grit sandpaper",
        "Sanding block"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "initial_sanding_repaired_areas"
      ]
    },
    {
      "step_id": "clean_sanding_dust",
      "title": "Clean Sanding Dust",
      "description": "Thoroughly clean all repaired
surfaces of the chair to remove all sanding dust. Use a
```

tack cloth or compressed air followed by a clean, lint-free cloth to ensure a pristine surface for finishing, promoting good adhesion and a clear finish.",
      "rationale": "A dust-free surface is non-negotiable for a flawless finish. Any remaining dust will get trapped in the new coat, creating imperfections.",
      "tools_required": [
        "Tack cloth",
        "Compressed air",
        "Lint-free cloths"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "fine_sanding_repairs"
      ]
    },
    {
      "step_id": "apply_first_finish_coat",
      "title": "Apply First Finish",
      "description": "Apply a thin, even coat of a sympathetic finish (e.g., shellac, oil finish, or appropriate varnish) to all repaired areas, blending it carefully with the existing patina of the original wood. Allow to dry according to product instructions, aiming for continuity.",
      "rationale": "The first coat of finish seals the new wood and begins the crucial process of color-matching and blending the repair with the surrounding original patina.",
      "tools_required": [
        "Brush",
        "Lint-free applicator",
        "Chosen finish"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],

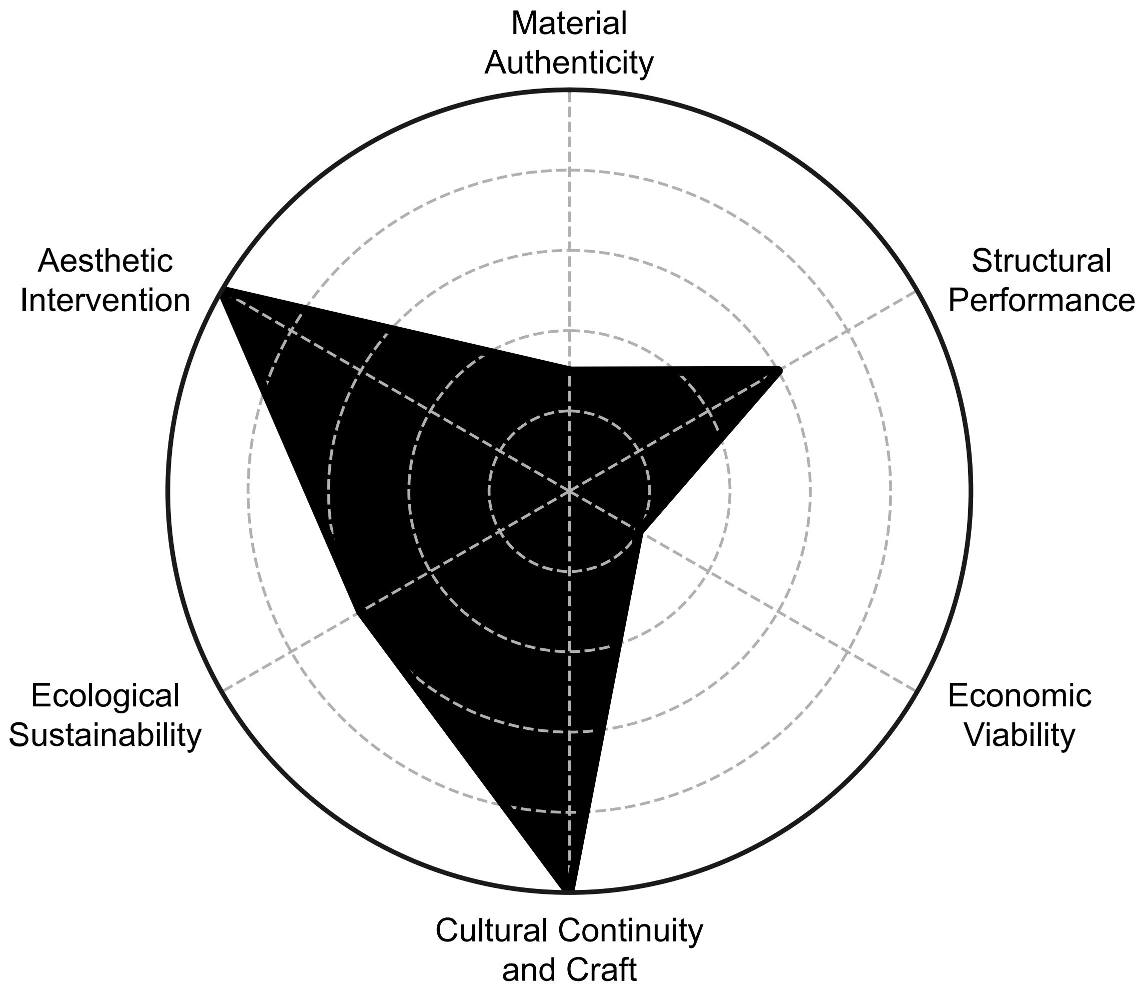
```
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "clean_sanding_dust"
      ]
    },
    {
      "step_id": "light_sanding_first_coat",
      "title": "Light Sand First",
      "description": "If the first coat of finish has
raised the grain or is not perfectly smooth on the re-
paired areas, lightly sand it with very fine-grit sand-
paper (e.g., 400-600 grit) or fine steel wool. Clean
thoroughly before the next coat to ensure a smooth,
continuous finish that respects the original patina.",
      "rationale": "This intermediate sanding step de-
nibs the surface, ensuring the final coat will be per-
fectly smooth and have a strong mechanical bond for
better durability.",
      "tools_required": [
        "Very fine-grit sandpaper",
        "Fine steel wool",
        "Tack cloth"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "apply_first_finish_coat"
      ]
    },
    {
      "step_id": "apply_final_finish_coat",
      "title": "Apply Final Finish",
```

```
      "description": "Apply a second, final coat of the
chosen sympathetic finish to all repaired areas, ensur-
ing an even and consistent sheen that blends seamlessly
with the original patina. Allow to cure completely,
completing the modest and careful mend.",
      "rationale": "The final coat provides long-term
protection for the repaired areas and completes the
visual integration, making the intervention as seamless
as possible.",
      "tools_required": [
        "Brush",
        "Lint-free applicator",
        "Chosen finish"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_02",
        "damage_03",
        "damage_01"
      ],
      "prerequisites": [
        "light_sanding_first_coat"
      ]
    },
    {
      "step_id": "reinstall_gliders",
      "title": "Reinstall Gliders",
      "description": "Carefully reattach the gliders to
the bottom of each leg, ensuring they are secure and
properly aligned.",
      "rationale": "Reinstalling the gliders is the fi-
nal step in restoring the chair's full functionality,
allowing it to be used safely without damaging
floors.",
      "tools_required": [
        "Pliers",
        "Screwdriver (if applicable)"
      ],
      "affected_parts": [
        "front_left_glider",
```

```
        "front_right_glider",
        "back_left_glider",
        "back_right_glider"
      ],
      "affected_damages": [],
      "prerequisites": [
        "apply_final_finish_coat"
      ]
    },
    {
      "step_id": "final_cleanup",
      "title": "Final Cleanup",
      "description": "Clean the work area thoroughly,
properly store all tools and materials, and dispose of
waste responsibly, leaving the workspace tidy and orga-
nized.",
      "rationale": "A final cleanup concludes the pro-
ject professionally, ensuring the workspace is safe and
ready for the next task.",
      "tools_required": [
        "Cleaning supplies"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "reinstall_gliders"
      ]
    }
  ]
}
```

The Jeweler of Joints

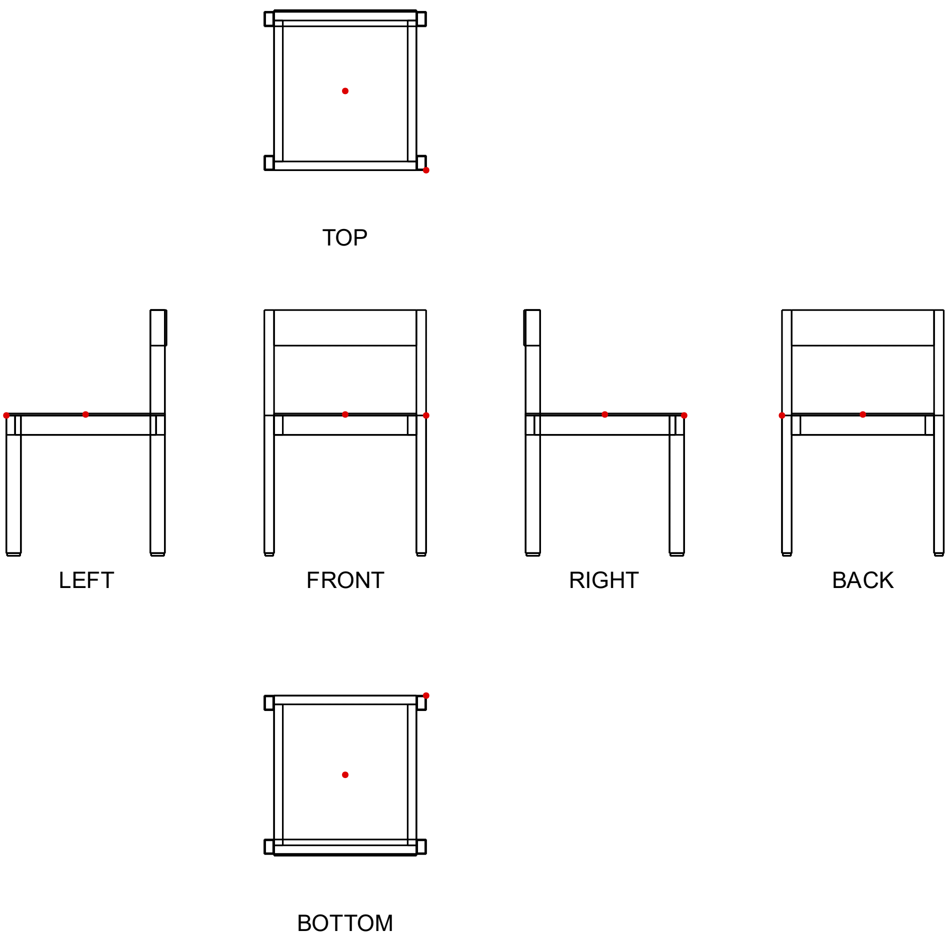
Elevates repair into a high art form where the point of intervention is the masterpiece. Rather than being concealed, the joint between old and new is deliberately celebrated as a meticulously crafted, ornamental detail. The repair becomes a jewel-like connection, an eloquent dialogue between contrasting materials that showcases supreme precision and craftsmanship. This approach creates an exquisite hinge between times, transforming the scar of a failure into a striking feature. Authenticity is redefined, found not in imitation but in the honest, artful expression of the joint itself.



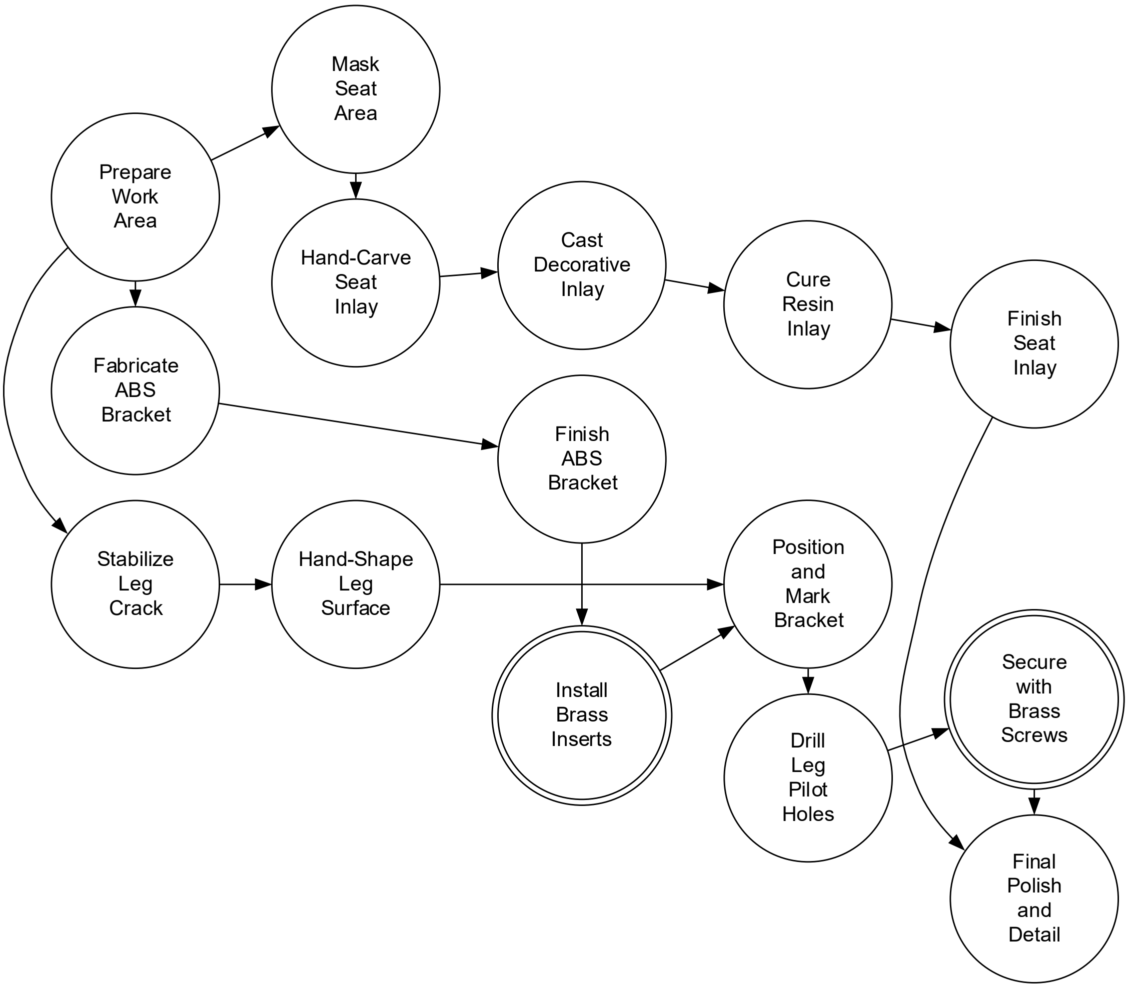
Santo Chair 08

The primary issue is a visible crack on the top corner of the front left leg, which compromises the chair's structural integrity and could worsen over time. Additionally, the chair has cosmetic scuff marks on both sides of the seat, which are indicative of normal wear and tear but do not affect its function. Overall, the chair is intact but requires repair to its leg to ensure long-term stability and safety.

Overall Condition Rating: 7/10

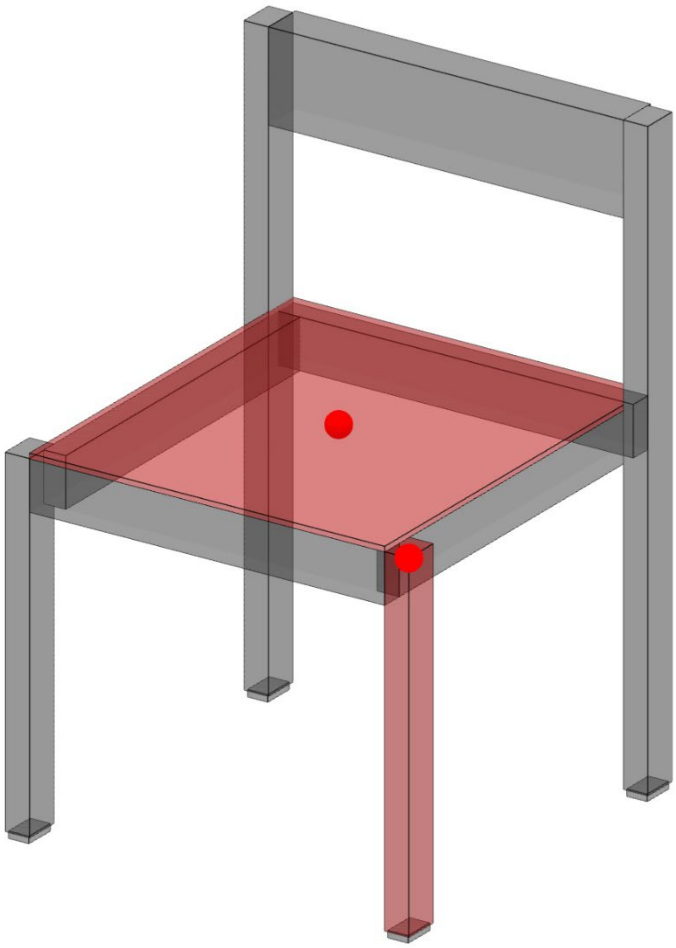


```
[
  {
    "id": "damage_01",
    "type": "Crack",
    "description": "A visible crack is present on the top corner of the front left leg, extending across its top surface.",
    "part_id": "front_left_leg",
    "coordinates": {
      "x": -0.25,
      "y": 0.434,
      "z": -0.245
    }
  },
  {
    "id": "damage_02",
    "type": "Scuff Mark",
    "description": "Scuff marks are visible on the right and left sides of the chair seat.",
    "part_id": "seat",
    "coordinates": {
      "x": 0,
      "y": 0.437,
      "z": 0
    }
  }
]
```


Prepare Work Area
Mask Seat Area
Hand-Carve Seat Inlay
Cast Decorative Inlay
Cure Resin Inlay
Finish Seat Inlay
Fabricate ABS Bracket
Finish ABS Bracket
Stabilize Leg Crack
Hand-Shape Leg Surface
Position and Mark Bracket
Install Brass Inserts
Drill Leg Pilot Holes
Secure with Brass Screws
Final Polish and Detail

Repair

This plan transforms minor damages into celebrated, jewel-like features. A crack in the front leg is first stabilized, then adorned with a custom, 3D-printed ornamental bracket. This black ABS piece is meticulously sanded, polished, and attached with polished brass screws, creating a high-craft focal point. On the seat, scuff marks are not erased but are hand-carved into channels and filled with a decorative resin inlay. This turns a superficial flaw into a beautiful, intentional design element. The result is a chair where the repairs are not hidden but are expressed as exquisite, artful interventions.



```
{
  "steps": [
    {
      "step_id": "setup_workspace",
      "title": "Prepare Work Area",
      "description": "Establish a clean, well-lit, and
organized workspace. Place the intact chair on a sta-
ble, protected surface. Arrange all necessary tools and
materials for easy access to perform the in-situ re-
pairs.",
      "rationale": "A meticulous setup is the founda-
tion for precision craftsmanship. This initial step en-
sures that the artistic intervention can be performed
with the focus and care required to create a jewel-like
repair on the assembled object.",
      "tools_required": [
        "Protective mat",
        "Tool organizer",
        "Task lighting",
        "Stable work stand"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "stabilize_leg_crack",
      "title": "Stabilize Leg Crack",
      "description": "Carefully clean the crack on the
front_left_leg of any debris. Using a fine-tipped ap-
plicator, inject a low-viscosity, clear epoxy deep into
the crack to structurally bond the wood fibers. Tightly
clamp the area and remove any excess epoxy before it
cures.",
      "rationale": "Before the ornamental cap is added,
the underlying damage must be structurally sound. This
step ensures the integrity of the original part,
providing a stable foundation for the celebratory re-
pair that will cover it.",
      "tools_required": [
        "Low-viscosity clear epoxy",
        "Syringe applicator",
        "Small clamps",
        "Isopropyl alcohol",
```

```
        "Clean cloths"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "setup_workspace"
      ]
    },
    {
      "step_id": "fabricate_abs_bracket",
      "title": "Fabricate ABS Bracket",
      "description": "Using a well-calibrated FDM 3D
printer, fabricate the custom-designed bracket from
high-quality black ABS filament. The design must be up-
dated to include appropriately sized holes to accommo-
date threaded brass inserts for superior stability and
finish.",
      "rationale": "Black ABS provides a strong, modern
contrast to the wood, creating a powerful dialogue be-
tween materials. The choice of a robust, engineered
plastic celebrates the repair as a distinct, high-qual-
ity addition, while planning for brass inserts elevates
the craftsmanship.",
      "tools_required": [
        "FDM 3D printer",
        "Black ABS filament",
        "CAD software (for design)"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "setup_workspace"
      ]
    },
    {
      "step_id": "mask_around_scuffs",
```

```
      "title": "Mask Seat Area",
      "description": "Carefully apply high-quality
painter's tape to the seat, masking off the areas imme-
diately surrounding the scuff marks. This protects the
undamaged wood during the inlay process, ensuring
clean, sharp lines for the repair.",
      "rationale": "Precision requires protecting the
original surfaces. This step isolates the work area,
allowing the transformation of the scuffs into a delib-
erate decorative feature without compromising the in-
tegrity of the surrounding material.",
      "tools_required": [
        "Painter's tape",
        "Craft knife"
      ],
      "affected_parts": [
        "seat"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "setup_workspace"
      ]
    },
    {
      "step_id": "hand_prepare_leg_surface",
      "title": "Hand-Shape Leg Surface",
      "description": "After the stabilizing epoxy has
fully cured, use hand files and sanding blocks to care-
fully smooth and level the top surface of the
front_left_leg. The goal is to create a perfectly flat
and clean platform for the ornamental bracket to sit
flush upon.",
      "rationale": "Meticulous hand-shaping of the sur-
face ensures a perfect interface between the original
wood and the new bracket. This act of manual prepara-
tion honors the craft and creates the flawless founda-
tion needed for a jewel-like connection.",
      "tools_required": [
        "Fine-toothed file",
        "Sanding block",
        "Sandpaper (various grits)"
      ],
```

"affected_parts": [
    "front_left_leg"
  ],
  "affected_damages": [
    "damage_01"
  ],
  "prerequisites": [
    "stabilize_leg_crack"
  ]
},
{
  "step_id": "hand_carve_seat_inlay",
  "title": "Hand-Carve Seat Inlay",
  "description": "With the chair intact, use fine hand gouges and carving knives to carefully excavate the scuffed areas on the seat. Transform the amorphous scuffs into a precise, geometric channel with a consistent depth, preparing it for the decorative inlay.",
  "rationale": "In line with the philosophy of celebrating intervention, this step turns a superficial flaw into an opportunity for ornamentation. The act of hand-carving elevates the repair from a cover-up to a deliberate, sculpted feature.",
  "tools_required": [
    "Wood carving knives",
    "Fine gouges",
    "Marking gauge"
  ],
  "affected_parts": [
    "seat"
  ],
  "affected_damages": [
    "damage_02"
  ],
  "prerequisites": [
    "mask_around_scuffs"
  ]
},
{
  "step_id": "finish_abs_bracket",
  "title": "Finish ABS Bracket",
  "description": "Post-process the printed ABS bracket. Carefully sand the part with progressively finer grits of sandpaper (from 220 to 2000) to remove

layer lines. Polish the sanded part with a specialized compound to achieve a flawless, jewel-like surface finish.",
      "rationale": "Supreme craftsmanship demands an impeccable finish. This step transforms the raw FDM print into a beautiful object in its own right, with a surface worthy of being the focal point of the jewel-like repair.",
      "tools_required": [
        "Sandpaper (various grits)",
        "Polishing compound",
        "Microfiber cloths"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [
        "damage_01"
      ],
      "prerequisites": [
        "fabricate_abs_bracket"
      ]
    },
    {
      "step_id": "cast_resin_inlay",
      "title": "Cast Decorative Inlay",
      "description": "Mix a high-quality casting resin with a contrasting pigment (e.g., pearlescent white or gold). Carefully pour the resin into the hand-carved channels on the seat, slightly overfilling to account for shrinkage. Use a torch to remove any surface bubbles.",
      "rationale": "The inlay introduces a new, beautiful material that transforms the scar into a striking feature. This act of filling the void with a contrasting element is a direct expression of creating an eloquent dialogue between materials.",
      "tools_required": [
        "Epoxy casting resin",
        "Pigment powder",
        "Mixing cups",
        "Stir sticks",
        "Propane torch"
      ],

"affected_parts": [
"seat"
],
"affected_damages": [
"damage_02"
],
"prerequisites": [
"hand_carve_seat_inlay"
]
},
{
"step_id": "install_brass_inserts",
"title": "Install Brass Inserts",
"description": "Using a soldering iron with a suitable tip, heat each threaded brass insert and gently press it into its designated hole in the finished ABS bracket. Ensure each insert is seated perfectly flush and perpendicular to the surface for a clean mechanical fit.",
"rationale": "Using threaded brass inserts elevates the mechanical connection to a higher standard of craftsmanship. This detail ensures a durable, precise, and reusable fastening point, reflecting the philosophy of supreme precision even in unseen components.",
"tools_required": [
"Soldering iron",
"Threaded brass inserts",
"Tweezers"
],
"affected_parts": [
"front_left_leg"
],
"affected_damages": [
"damage_01"
],
"prerequisites": [
"finish_abs_bracket"
]
},
{
"step_id": "cure_resin_inlay",
"title": "Cure Resin Inlay",
"description": "Allow the cast resin in the seat to cure completely according to the manufacturer's

instructions, typically for 24-72 hours. Ensure the environment is dust-free and maintains a stable temperature.",
      "rationale": "Patience and proper curing are essential for achieving the full strength and clarity of the new material. This ensures the jewel-like inlay is durable and ready for the final, precise finishing.",
      "tools_required": [
        "Dust cover"
      ],
      "affected_parts": [
        "seat"
      ],
      "affected_damages": [
        "damage_02"
      ],
      "prerequisites": [
        "cast_resin_inlay"
      ]
    },
    {
      "step_id": "position_and_mark_bracket",
      "title": "Position and Mark Bracket",
      "description": "Place the finished ornamental bracket with its installed inserts onto the prepared top surface of the front_left_leg. Ensure perfect alignment and orientation. Use a sharp marking tool to precisely mark the center of each screw hole.",
      "rationale": "Precision in placement is critical to the aesthetic success of the repair. This step ensures the jewel-like bracket will be perfectly centered and aligned, appearing as a deliberate and masterfully executed addition.",
      "tools_required": [
        "Awl or center punch",
        "Small ruler"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "hand_prepare_leg_surface",
        "install_brass_inserts"

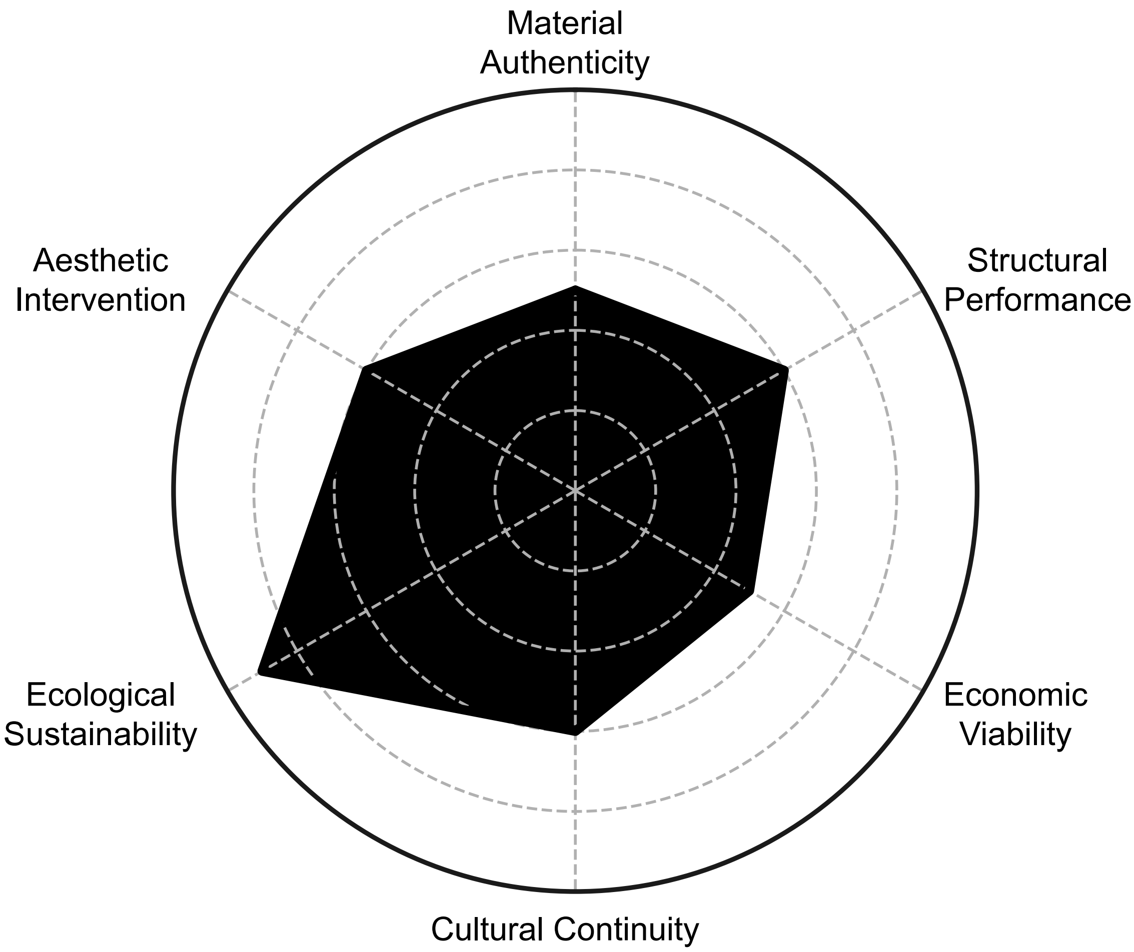
```
      ]
    },
    {
      "step_id": "drill_pilot_holes",
      "title": "Drill Leg Pilot Holes",
      "description": "Using a drill bit slightly
smaller than the screw diameter, carefully drill pilot
holes into the leg at the marked locations. Use a depth
stop to ensure you do not drill deeper than necessary.
This prevents the wood from splitting.",
      "rationale": "This preparatory step is an act of
precision that ensures the final attachment is clean
and does not damage the original wood. It respects the
material while preparing it for its new, ornamental
hardware.",
      "tools_required": [
        "Hand drill or power drill",
        "Drill bits",
        "Drill depth stop"
      ],
      "affected_parts": [
        "front_left_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "position_and_mark_bracket"
      ]
    },
    {
      "step_id": "secure_with_brass_screws",
      "title": "Secure with Brass Screws",
      "description": "Position the bracket over the pi-
lot holes. Fasten it securely using polished brass ma-
chine screws, threading them into the pre-installed
brass inserts. Tighten screws carefully and evenly to
ensure the bracket sits perfectly flush without stress-
ing the ABS.",
      "rationale": "The polished brass screws are not
merely functional; they are a key part of the ornament.
Their warm metallic tone against the black ABS and wood
creates a striking, jewel-like connection, celebrating
the method of attachment itself.",
      "tools_required": [
        "Polished brass screws",
```

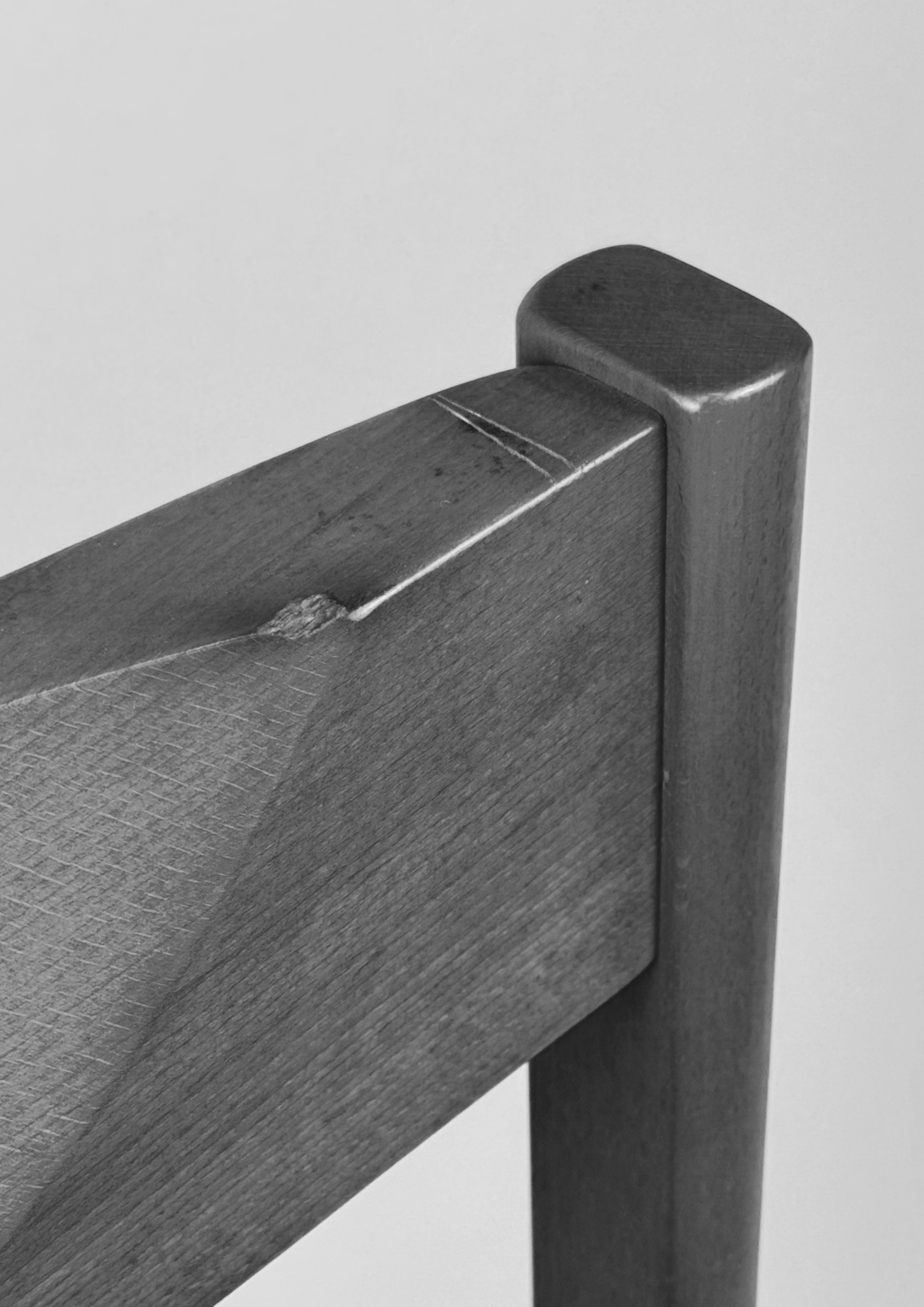
```
          "Precision screwdriver set"
        ],
        "affected_parts": [
          "front_left_leg"
        ],
        "affected_damages": [
          "damage_01"
        ],
        "prerequisites": [
          "drill_pilot_holes"
        ]
      },
      {
        "step_id": "finish_seat_inlay",
        "title": "Finish Seat Inlay",
        "description": "Once the resin is fully cured,
carefully sand the inlay flush with the wooden surface
of the seat using a sanding block. Start with a medium
grit and progress to very fine grits. Remove the mask-
ing tape and polish the entire seat surface to a uni-
form, high-gloss sheen.",
        "rationale": "The final finishing creates a seam-
less transition between the original wood and the new
inlay. The result is a smooth, tactile surface where
the repair is felt as a perfect integration, not an in-
terruption, embodying the artful expression of the
joint.",
        "tools_required": [
          "Sanding block",
          "Sandpaper (various grits)",
          "Polishing compound",
          "Microfiber cloths"
        ],
        "affected_parts": [
          "seat"
        ],
        "affected_damages": [
          "damage_02"
        ],
        "prerequisites": [
          "cure_resin_inlay"
        ]
      },
      {
```

```
      "step_id": "final_polish",
      "title": "Final Polish and Detail",
      "description": "Perform a final cleaning and pol-
ishing of the entire chair. Use a high-quality furni-
ture wax or polish to bring out the luster of both the
original wood and the new repair materials, ensuring a
harmonious and unified finish.",
      "rationale": "The final polish unifies the entire
object, presenting the original form and the celebrated
repairs as a cohesive work of art. This step ensures
the finished piece is not just repaired, but reborn
with a new, enriched history.",
      "tools_required": [
        "Microfiber cloths",
        "Furniture wax/polish"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "secure_with_brass_screws",
        "finish_seat_inlay"
      ]
    }
  ]
}
```

The Urbanist

Expands the act of repair beyond the object to its surrounding social and ecological context. The intervention transcends mere material restoration, becoming a tool for civic action and community engagement. Its success is judged not by historical fidelity but by its capacity to foster human-scale vitality, encourage public participation, and enhance collective safety. This approach deliberately prioritizes ecological sustainability and cultural continuity. The object becomes a catalyst, and the goal is not its own preservation but the revitalization of the public life it supports.

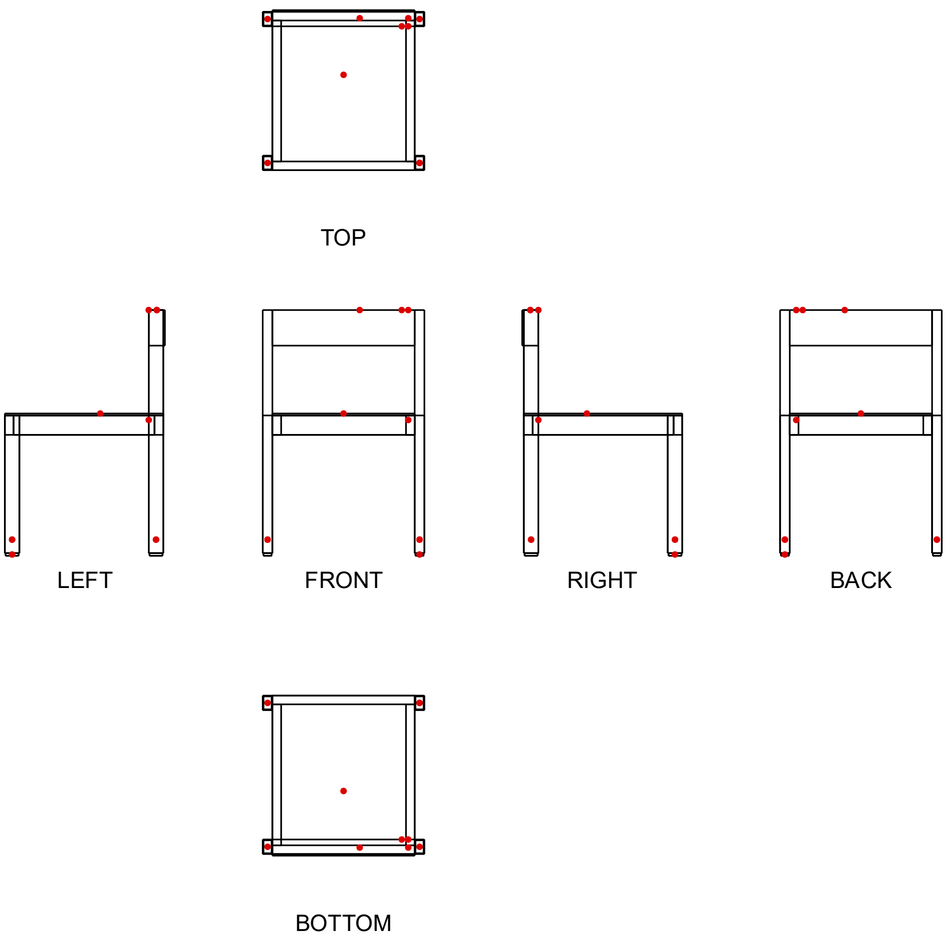




Santo Chair 23

The primary issue is a visible crack on the top corner of the front left leg, which compromises the chair's structural integrity and could worsen over time. Additionally, the chair has cosmetic scuff marks on both sides of the seat, which are indicative of normal wear and tear but do not affect its function. Overall, the chair is intact but requires repair to its leg to ensure long-term stability and safety.

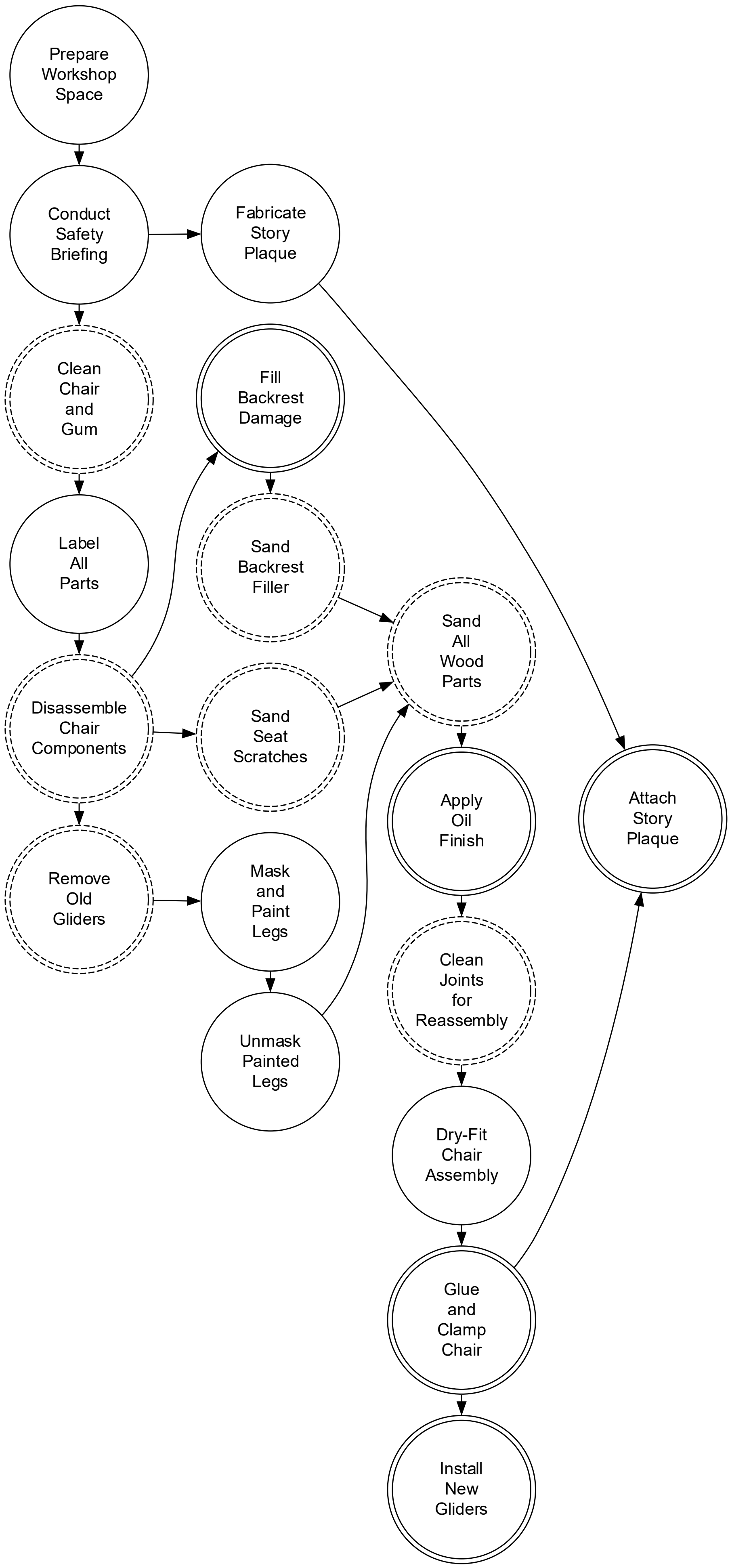
Overall Condition Rating: 6/10



```
[
  {
    "id": "damage_01",
    "type": "Chip",
    "description": "A visible chip or gouge is present on the top-left edge of the backrest.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.18,
      "y": 0.76,
      "z": 0.2
    }
  },
  {
    "id": "damage_02",
    "type": "Cut Mark",
    "description": "Several distinct cut marks, made by a knife or saw, are visible on the top surface of the backrest.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.2,
      "y": 0.76,
      "z": 0.225
    }
  },
  {
    "id": "damage_03",
    "type": "Stain",
    "description": "A small, dark spot or stain is present on the top surface of the backrest, towards the left of the center.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.05,
      "y": 0.76,
      "z": 0.225
    }
  },
  {
    "id": "damage_04",
    "type": "Scratch",
```

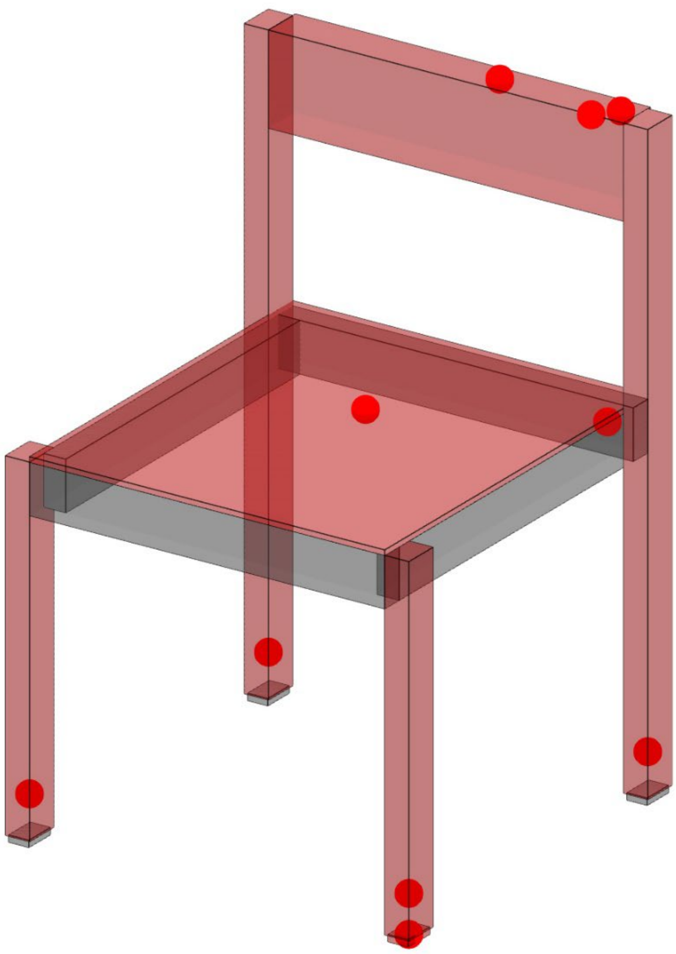
```
    "description": "A distinct light-colored scratch is
visible on the top surface of the seat, slightly to the
back of the center.",
    "part_id": "seat",
    "coordinates": {
      "x": 0,
      "y": 0.44,
      "z": 0.05
    }
  },
  {
    "id": "damage_05",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "front_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.05,
      "z": -0.2225
    }
  },
  {
    "id": "damage_06",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "front_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.05,
      "z": -0.2225
    }
  },
  {
    "id": "damage_07",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "back_left_leg",
    "coordinates": {
```

```
      "x": -0.235,
      "y": 0.05,
      "z": 0.2225
    }
  },
  {
    "id": "damage_08",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "back_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.05,
      "z": 0.2225
    }
  },
  {
    "id": "damage_09",
    "type": "Wear and Tear",
    "description": "The plastic glider on the front
left leg shows visible signs of wear and dirt accumula-
tion.",
    "part_id": "front_left_glider",
    "coordinates": {
      "x": -0.235,
      "y": 0.004,
      "z": -0.2225
    }
  },
  {
    "id": "damage_10",
    "type": "Foreign Object",
    "description": "Chewing gum is present on the un-
derside of the seat, as indicated by the user prompt.",
    "part_id": "seat",
    "coordinates": {
      "x": -0.2,
      "y": 0.42,
      "z": 0.2
    }
  }
]
```


Prepare Workshop Space
Conduct Safety Briefing
Fabricate Story Plaque
Clean Chair and Gum
Fill Backrest Damage
Label All Parts
Sand Backrest Filler
Sand All Wood Parts
Disassemble Chair Components
Sand Seat Scratches
Apply Oil Finish
Attach Story Plaque
Remove Old Gliders
Mask and Paint Legs
Clean Joints for Reassembly
Unmask Painted Legs
Dry-Fit Chair Assembly
Glue and Clamp Chair
Install New Gliders

Repair

The project begins by disassembling the chair, allowing multiple participants to work on different parts simultaneously. Damages are treated as opportunities for beautification: cut marks are filled with colorful, Kintsugi-inspired epoxy, and scuffed legs are painted in a joyful, uniform style. A key element is the creation of a "story plaque," which documents the community's collective effort. The chair is then reassembled, finished with non-toxic oils, and returned to public service, its repairs celebrated as a testament to shared ownership and care.



```
{
  "steps": [
    {
      "step_id": "prepare_community_workspace",
      "title": "Prepare Workshop Space",
      "description": "Set up a designated public area
for the repair. Lay down drop cloths to protect the
floor, arrange workbenches at an accessible height, and
organize all tools and materials into clear, labeled
stations to ensure a safe and welcoming environment for
all participants.",
      "rationale": "This initial step establishes a
safe, organized, and inclusive space, which is funda-
mental to fostering public participation and transform-
ing the repair from a technical task into a community
event.",
      "tools_required": [
        "Workbenches",
        "Drop cloths",
        "Tool trays",
        "Material labels"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "conduct_safety_briefing",
      "title": "Conduct Safety Briefing",
      "description": "Gather all participants to con-
duct a mandatory safety briefing. Demonstrate the cor-
rect use of each tool, explain the properties of the
materials (e.g., glue curing times, ventilation), and
establish clear safety protocols for the workspace. En-
sure everyone has appropriate personal protective
equipment.",
      "rationale": "Prioritizing collective safety is a
core tenet of this repair philosophy. A thorough brief-
ing ensures that the act of community engagement is
safe and empowering for participants of all skill lev-
els.",
      "tools_required": [
        "Safety glasses",
        "Gloves",
```

        "First-aid kit"
      ],
      "affected_parts": [],
      "affected_damages": [],
      "prerequisites": [
        "prepare_community_workspace"
      ]
    },
    {
      "step_id": "clean_chair_and_remove_gum",
      "title": "Clean Chair and Gum",
      "description": "Give the entire chair a thorough cleaning with a biodegradable cleaner. Use a plastic scraper and a freezing agent (like a can of compressed air held upside down) to carefully remove the chewing gum from the underside of the seat before disassembly.",
      "rationale": "Cleaning the object is a simple, accessible first action that allows everyone to participate. Removing contaminants now ensures a clean disassembly process and prepares all parts for their individual repair stations.",
      "tools_required": [
        "Biodegradable cleaner",
        "Soft cloths",
        "Plastic scraper",
        "Freezing agent"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "seat",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [
        "damage_10"
      ],
      "prerequisites": [

```
        "conduct_safety_briefing"
      ]
    },
    {
      "step_id": "label_all_parts_for_reassembly",
      "title": "Label All Parts",
      "description": "Using masking tape and a marker,
carefully label each part and connecting joint of the
chair (e.g., 'Front Left Leg to Front Apron'). This
will create a clear map for reassembly later.",
      "rationale": "This systematic labeling is crucial
for empowering a group to successfully reassemble the
chair. It turns a potentially complex puzzle into a
clear, collaborative task, ensuring the project's suc-
cess and fostering a sense of shared accomplishment.",
      "tools_required": [
        "Masking tape",
        "Permanent marker"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "seat",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "clean_chair_and_remove_gum"
      ]
    },
    {
      "step_id": "disassemble_chair_components",
      "title": "Disassemble Chair Components",
      "description": "Carefully disassemble the chair
into its individual components. Use a rubber mallet and
a protective block of wood to gently tap the glued
dowel joints apart. Work slowly and methodically, fol-
lowing the reverse order of assembly.",
```

```
      "rationale": "Deconstructing the chair is a
transformative act that creates multiple, smaller
tasks, maximizing opportunities for public participa-
tion. It allows different groups or individuals to take
ownership of repairing a specific part.",
      "tools_required": [
        "Rubber mallet",
        "Scrap wood block"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "seat",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "label_all_parts_for_reassembly"
      ]
    },
    {
      "step_id": "remove_old_gliders_from_legs",
      "title": "Remove Old Gliders",
      "description": "With the legs separated from the
frame, use a pry bar or flat-head screwdriver to remove
all four plastic gliders from the bottom of the legs.
This can be done at a dedicated 'Leg Repair' station.",
      "rationale": "This first step in the leg repair
path prepares them for a consistent and sustainable up-
grade. This act of renewal over simple replacement sup-
ports the goal of enhancing the object's long-term pub-
lic utility.",
      "tools_required": [
        "Pry bar",
        "Flat-head screwdriver"
      ],
      "affected_parts": [
        "front_left_glider",
```

```
          "front_right_glider",
          "back_left_glider",
          "back_right_glider"
        ],
        "affected_damages": [
          "damage_09"
        ],
        "prerequisites": [
          "disassemble_chair_components"
        ]
      },
      {
        "step_id": "clean_and_fill_backrest_damage",
        "title": "Fill Backrest Damage",
        "description": "At the 'Backrest Repair' station,
  clean debris from the chip and cut marks. Mix a two-
  part, non-toxic, colored epoxy putty and press it
  firmly into the damaged areas, slightly overfilling
  them. The color should be intentionally distinct from
  the wood.",
        "rationale": "Instead of hiding the repair, we
  celebrate it using a technique inspired by Kintsugi.
  This visible, colorful fill honors the chair's history
  of damage and repair, making its story a part of its
  renewed value and fostering cultural continuity.",
        "tools_required": [
          "Dental pick",
          "Stiff-bristle brush",
          "Colored eco-epoxy putty",
          "Putty knife"
        ],
        "affected_parts": [
          "backrest"
        ],
        "affected_damages": [
          "damage_01",
          "damage_02"
        ],
        "prerequisites": [
          "disassemble_chair_components"
        ]
      },
      {
        "step_id": "sand_seat_scratches",
```

"title": "Sand Seat Scratches",
      "description": "At the 'Seat Repair' station, use a sanding block and medium-grit sandpaper to carefully sand the top surface of the seat, focusing on the area with the scratch until it is no longer visible.",
      "rationale": "This focused task allows a participant to directly address a specific flaw, providing a tangible sense of contribution and restoring the primary functional surface of the chair for future public use.",
      "tools_required": [
        "Sanding block",
        "Medium-grit sandpaper (120)"
      ],
      "affected_parts": [
        "seat"
      ],
      "affected_damages": [
        "damage_04"
      ],
      "prerequisites": [
        "disassemble_chair_components"
      ]
    },
    {
      "step_id": "fabricate_story_plaque",
      "title": "Fabricate Story Plaque",
      "description": "At a separate 'Creative' station, participants can design and create a plaque on recycled material that tells the story of the repair. Use a wood-burning tool or non-toxic markers to include the date and a symbol for the community.",
      "rationale": "The plaque transforms the chair from a mere object into a catalyst for civic memory. This parallel activity allows for artistic expression and explicitly documents the act of community engagement, ensuring the story of its revitalization is passed on.",
      "tools_required": [
        "Recycled plastic or wood piece",
        "Wood-burning tool",
        "Non-toxic markers"
      ],
      "affected_parts": [],

```
      "affected_damages": [],
      "prerequisites": [
        "conduct_safety_briefing"
      ]
    },
    {
      "step_id": "mask_and_paint_leg_bases",
      "title": "Mask and Paint Legs",
      "description": "Clean the scuff marks from the
four legs. Apply painter's tape in a straight line 10cm
from the bottom of each leg. Using brushes, apply two
coats of durable, non-toxic, water-based paint to the
masked-off lower sections.",
      "rationale": "This collaborative painting activ-
ity transforms functional scuff mark repair into a col-
lective act of beautification. It's an accessible task
for all skill levels that gives the chair a new, uni-
fied identity born from community effort.",
      "tools_required": [
        "Painter's tape",
        "Measuring tape",
        "Non-toxic water-based paint",
        "Brushes"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [
        "damage_05",
        "damage_06",
        "damage_07",
        "damage_08"
      ],
      "prerequisites": [
        "remove_old_gliders_from_legs"
      ]
    },
    {
      "step_id": "sand_backrest_filler_flush",
      "title": "Sand Backrest Filler",
```

```
      "description": "Once the epoxy putty has fully
cured, use a sanding block with medium-grit sandpaper
to carefully sand the filled areas on the backrest.
Sand until the filler is perfectly flush and smooth
with the surrounding wood surface.",
      "rationale": "This step ensures the celebrated
repair is also functional and pleasant to the touch. It
integrates the new material smoothly into the old, sym-
bolizing a harmonious blend of history and renewal.",
      "tools_required": [
        "Sanding block",
        "Medium-grit sandpaper (120)",
        "Fine-grit sandpaper (220)"
      ],
      "affected_parts": [
        "backrest"
      ],
      "affected_damages": [
        "damage_01",
        "damage_02"
      ],
      "prerequisites": [
        "clean_and_fill_backrest_damage"
      ]
    },
    {
      "step_id": "unmask_painted_legs",
      "title": "Unmask Painted Legs",
      "description": "After the final coat of paint is
dry, carefully peel away the painter's tape from all
four legs at a 45-degree angle to reveal a clean, sharp
line.",
      "rationale": "This step is a satisfying reveal
that builds a sense of accomplishment among partici-
pants. It finalizes the visual transformation of the
legs, turning signs of wear into a deliberate and joy-
ful design element.",
      "tools_required": [
        "Utility knife (for scoring edge if needed)"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
```

```
          "back_right_leg"
        ],
        "affected_damages": [],
        "prerequisites": [
          "mask_and_paint_leg_bases"
        ]
      },
      {
        "step_id": "sand_and_prepare_all_wood_parts",
        "title": "Sand All Wood Parts",
        "description": "Gather all repaired wooden parts
(seat, backrest, aprons, and the unpainted sections of
the legs). Perform a light, final sanding on all of
them with fine-grit sandpaper to remove the backrest
stain and create a uniform surface for the new fin-
ish.",
        "rationale": "This collective sanding effort is a
convergence point, unifying the individual repairs.
It's a tactile way for the community to connect with
all parts of the chair and prepare them for a new pro-
tective finish that ensures its continued public ser-
vice.",
        "tools_required": [
          "Fine-grit sandpaper (220)",
          "Tack cloth"
        ],
        "affected_parts": [
          "seat",
          "backrest",
          "front_apron",
          "back_apron",
          "left_side_apron",
          "right_side_apron",
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg"
        ],
        "affected_damages": [
          "damage_03"
        ],
        "prerequisites": [
          "unmask_painted_legs",
          "sand_backrest_filler_flush",
```

```
        "sand_seat_scratches"
      ]
    },
    {
      "step_id": "apply_oil_finish_to_parts",
      "title": "Apply Oil Finish",
      "description": "Wipe all sanded parts with a tack
cloth to remove dust. Then, using clean rags, apply a
generous coat of a natural, non-toxic oil finish (e.g.,
tung oil) to all unpainted wood surfaces. Allow it to
penetrate, then wipe off the excess.",
      "rationale": "Applying a natural, sustainable
finish protects the wood without harsh chemicals, rein-
forcing the project's ecological commitment. Treating
the parts before assembly ensures complete coverage and
durability for continued community use.",
      "tools_required": [
        "Natural oil finish (tung or linseed)",
        "Lint-free rags",
        "Tack cloth"
      ],
      "affected_parts": [
        "seat",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "sand_and_prepare_all_wood_parts"
      ]
    },
    {
      "step_id": "clean_old_glue_from_joints",
      "title": "Clean Joints for Reassembly",
      "description": "Once the oil finish is dry, use
chisels, sandpaper, and dowel-hole cleaning tools to
carefully remove any old, brittle glue from all dowels
```

```
and mortise holes. A clean surface is essential for a
strong new glue bond.",
      "rationale": "This meticulous preparation for re-
assembly is a critical step that emphasizes quality and
longevity. It teaches participants that a successful,
durable outcome depends on careful preparation, rein-
forcing the value of thorough, mindful work.",
      "tools_required": [
        "Wood chisel",
        "Sandpaper",
        "Dowel-hole cleaning brush"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "backrest",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "apply_oil_finish_to_parts"
      ]
    },
    {
      "step_id": "dry_fit_chair_assembly",
      "title": "Dry-Fit Chair Assembly",
      "description": "Without using any glue, reassem-
ble the entire chair according to the labels created
earlier. This dry fit ensures all parts align correctly
after their individual repairs and that the team is
ready for the final gluing.",
      "rationale": "The dry fit is a rehearsal for the
final assembly, building confidence and teamwork. It
allows the group to troubleshoot any issues together in
a low-stakes environment, ensuring the final, glued as-
sembly is smooth and successful.",
      "tools_required": [
        "Rubber mallet"
      ],
```

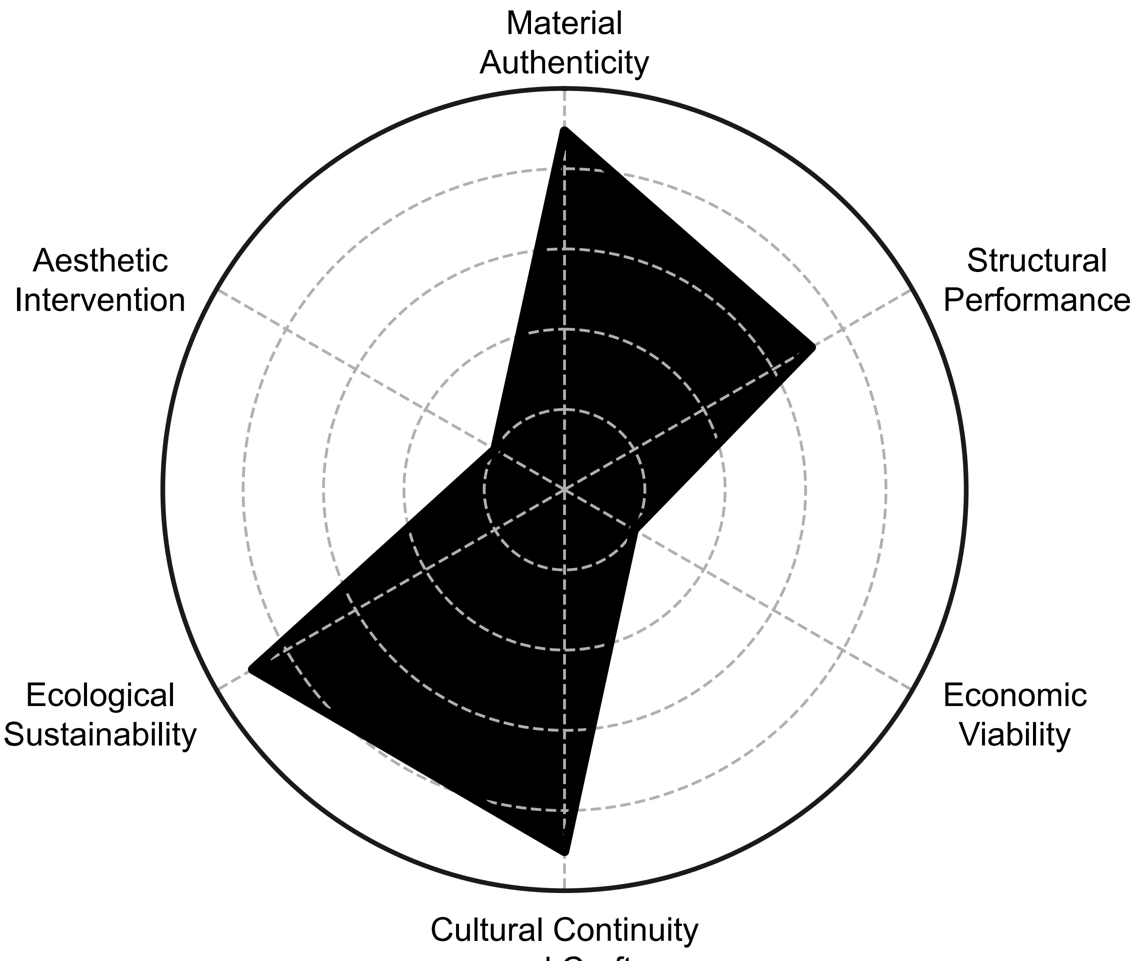
```
        "affected_parts": [
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg",
          "seat",
          "backrest",
          "front_apron",
          "back_apron",
          "left_side_apron",
          "right_side_apron"
        ],
        "affected_damages": [],
        "prerequisites": [
          "clean_old_glue_from_joints"
        ]
      },
      {
        "step_id": "glue_and_clamp_chair",
        "title": "Glue and Clamp Chair",
        "description": "Working as a team, apply a non-
toxic wood glue to the joints and reassemble the chair.
Use bar clamps to hold the frame together securely
while the glue cures. Wipe away any excess glue
'squeeze-out' with a damp cloth.",
        "rationale": "This step is the culmination of the
group's effort, bringing all the individually repaired
parts back into a unified whole. It is a powerful, col-
laborative moment that physically reconstructs the ob-
ject and symbolically strengthens community bonds.",
        "tools_required": [
          "Non-toxic wood glue",
          "Bar clamps",
          "Damp cloth"
        ],
        "affected_parts": [
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg",
          "seat",
          "backrest",
          "front_apron",
          "back_apron",
```

```
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "dry_fit_chair_assembly"
      ]
    },
    {
      "step_id": "install_new_gliders",
      "title": "Install New Gliders",
      "description": "After the glue has fully cured
and the clamps are removed, turn the chair upside down.
Install new, durable gliders made from recycled plastic
or leather onto the bottom of all four legs using a
rubber mallet.",
      "rationale": "Installing upgraded, sustainable
gliders enhances the chair's functionality and safety
for public use. This choice prioritizes long-term per-
formance and ecological responsibility over strict ma-
terial authenticity.",
      "tools_required": [
        "Recycled material gliders",
        "Rubber mallet"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "glue_and_clamp_chair"
      ]
    },
    {
      "step_id": "attach_story_plaque",
      "title": "Attach Story Plaque",
      "description": "Secure the community-made story
plaque to the underside of the seat using two small,
rust-resistant screws. Position it where it can be dis-
covered but won't interfere with use or stacking.",
```

```
      "rationale": "This final act completes the
chair's transformation into a symbol of civic action.
The plaque ensures that the story of the collective re-
pair endures, fostering a deeper connection between the
community and its shared public objects.",
      "tools_required": [
        "Screwdriver",
        "Rust-resistant screws"
      ],
      "affected_parts": [
        "seat"
      ],
      "affected_damages": [],
      "prerequisites": [
        "glue_and_clamp_chair",
        "fabricate_story_plaque"
      ]
    }
  ]
}
```

The Preservation Scientist

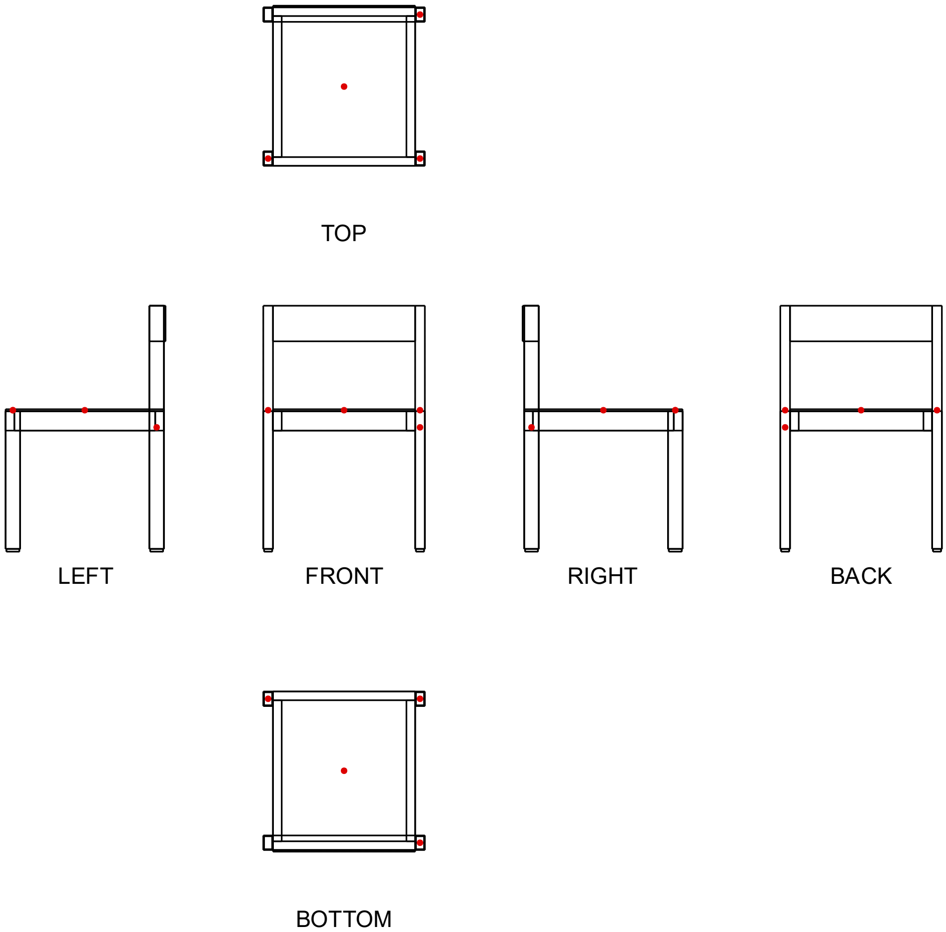
All interventions must be guided by the principles of minimal intervention and reversibility. Justify every action through rigorous, non-destructive analysis and comprehensive documentation, ensuring that the object's historical and material integrity is paramount. Select conservation-grade materials based on their proven compatibility with the original fabric and their long-term stability. The goal is stabilization, not optimization, preserving the object's authentic narrative for the future.



Santo Chair 01

This chair has been completely shattered, suffering a catastrophic structural failure from a violent event. Its back apron is severely broken and fragmented. Both front legs were forcefully torn from their joints, evidenced by rough, splintered connection points. The seat, though merely scuffed, is now a detached piece among the wreckage. The object is no longer a functional chair but a collection of destroyed components.

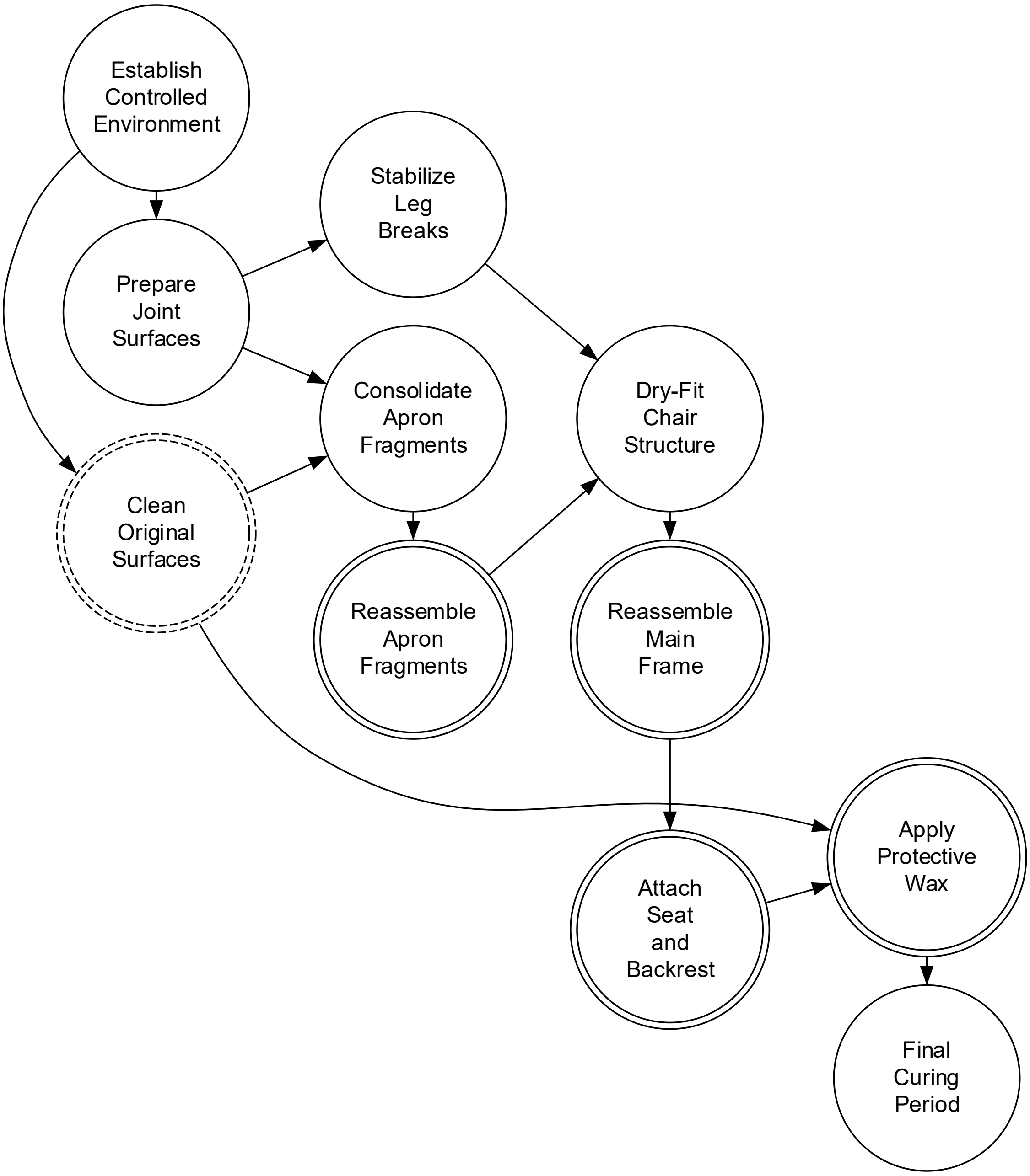
Overall Condition Rating: 3/10



```
[
  {
    "id": "damage_01",
    "type": "Chip",
    "description": "A visible chip or gouge is present
on the top-left edge of the backrest.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.18,
      "y": 0.76,
      "z": 0.2
    }
  },
  {
    "id": "damage_02",
    "type": "Cut Mark",
    "description": "Several distinct cut marks, made by
a knife or saw, are visible on the top surface of the
backrest.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.2,
      "y": 0.76,
      "z": 0.225
    }
  },
  {
    "id": "damage_03",
    "type": "Stain",
    "description": "A small, dark spot or stain is pre-
sent on the top surface of the backrest, towards the
left of the center.",
    "part_id": "backrest",
    "coordinates": {
      "x": -0.05,
      "y": 0.76,
      "z": 0.225
    }
  },
  {
    "id": "damage_04",
    "type": "Scratch",
```

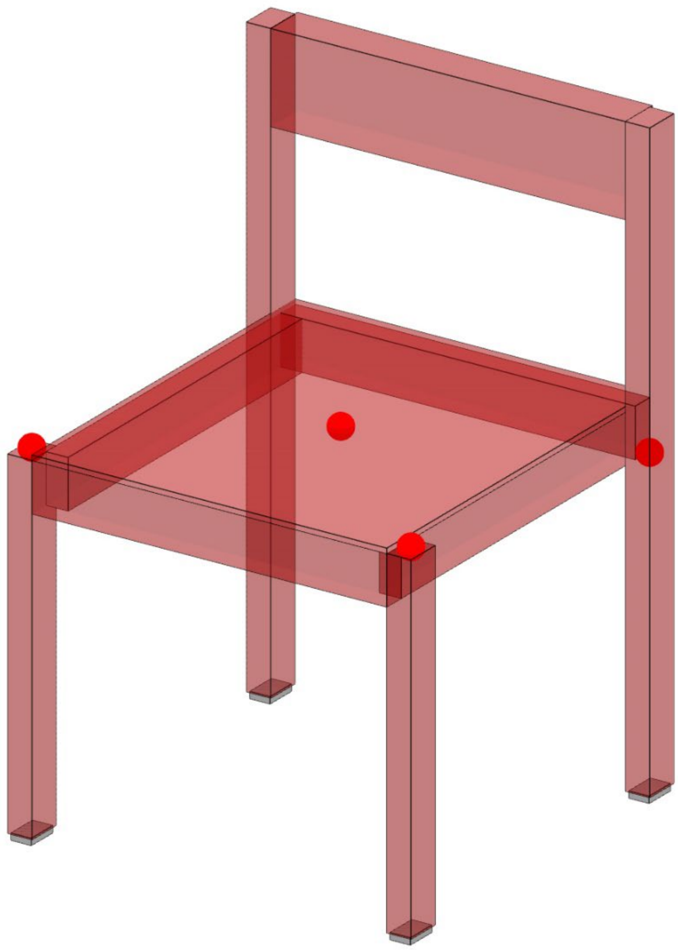
```
    "description": "A distinct light-colored scratch is
visible on the top surface of the seat, slightly to the
back of the center.",
    "part_id": "seat",
    "coordinates": {
      "x": 0,
      "y": 0.44,
      "z": 0.05
    }
  },
  {
    "id": "damage_05",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "front_left_leg",
    "coordinates": {
      "x": -0.235,
      "y": 0.05,
      "z": -0.2225
    }
  },
  {
    "id": "damage_06",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "front_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.05,
      "z": -0.2225
    }
  },
  {
    "id": "damage_07",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "back_left_leg",
    "coordinates": {
```

```
      "x": -0.235,
      "y": 0.05,
      "z": 0.2225
    }
  },
  {
    "id": "damage_08",
    "type": "Scuff Mark",
    "description": "Visible scuff marks and discolora-
tions (red and black) are present on the lower section
of the leg.",
    "part_id": "back_right_leg",
    "coordinates": {
      "x": 0.235,
      "y": 0.05,
      "z": 0.2225
    }
  },
  {
    "id": "damage_09",
    "type": "Wear and Tear",
    "description": "The plastic glider on the front
left leg shows visible signs of wear and dirt accumula-
tion.",
    "part_id": "front_left_glider",
    "coordinates": {
      "x": -0.235,
      "y": 0.004,
      "z": -0.2225
    }
  },
  {
    "id": "damage_10",
    "type": "Foreign Object",
    "description": "Chewing gum is present on the un-
derside of the seat, as indicated by the user prompt.",
    "part_id": "seat",
    "coordinates": {
      "x": -0.2,
      "y": 0.42,
      "z": 0.2
    }
  }
]
```


Establish Controlled Environment
Prepare Joint Surfaces
Stabilize Leg Breaks
Clean Original Surfaces
Consolidate Apron Fragments
Dry-Fit Chair Structure
Reassemble Apron Fragments
Reassemble Main Frame
Attach Seat and Backrest
Apply Protective Wax
Final Curing Period

Repair

Shattered fragments are first strengthened with a chemical consolidant to prevent the loss of original material. The chair is then meticulously pieced back together using traditional, fully reversible adhesives like hot hide glue, ensuring the intervention can be undone by future conservators. The original, scuffed finish is gently cleaned to preserve its history, not stripped or sanded. Finally, a protective, removable conservation wax is applied. The goal is to make the object whole again while honoring its entire history, including its traumatic damage.



{
  "steps": [
    {
      "step_id": "establish_conservation_environment",
      "title": "Establish Controlled Environment",
      "description": "Set up a dedicated, clean, and stable work area. Cover the work surface with a non-abrasive, chemically inert material like Mylar or Tyvek. Carefully lay out all chair components, ensuring they are supported and will not be subjected to stress.",
      "rationale": "A controlled environment is paramount to prevent contamination or further damage to the object.",
      "tools_required": [
        "Stable Worktable",
        "Mylar or Tyvek Sheeting",
        "Padded Blocks/Supports"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "gentle_surface_cleaning",
      "title": "Clean Original Surfaces",
      "description": "Perform a gentle surface cleaning on all components to remove loose dust and grime. Use a soft, natural-bristle brush and a low-suction vacuum with a filtered nozzle. For adhered grime, use a conservation-grade aqueous cleaning solution after testing on an inconspicuous area to ensure it does not harm the original finish.",

"rationale": "This step stabilizes the object by removing potentially acidic or abrasive surface contaminants. The minimal, tested approach ensures the original patina and finish—key parts of the object's history—are preserved, not stripped. This addresses surface scuffs by cleaning, not removing them.",
"tools_required": [
"Soft Natural-Bristle Brush",
"Low-Suction Vacuum with Micro-attachments",
"Distilled Water",
"Conservation-grade Non-ionic Detergent",
"Cotton Swabs"
],
"affected_parts": [
"front_left_leg",
"front_right_leg",
"back_left_leg",
"back_right_leg",
"front_apron",
"back_apron",
"left_side_apron",
"right_side_apron",
"seat",
"backrest"
],
"affected_damages": [
"damage_02"
],
"prerequisites": [
"establish_conservation_environment"
]
},
{
"step_id": "prepare_joint_surfaces",
"title": "Prepare Joint Surfaces",
"description": "Carefully remove failed adhesive and loose splinters from all joint surfaces, including the broken areas on the front legs and back apron connection points. Use mechanical tools like bamboo skewers and dental picks. Avoid altering the original wood geometry. The goal is to prepare the surface for a new, stable bond without removing sound, original material.",

```
      "rationale": "This intervention is minimal and
necessary for structural stabilization. Removing only
the failed adhesive ensures the new, reversible adhe-
sive can bond effectively to the original wood, pre-
serving the integrity of the joint's original fit.",
      "tools_required": [
        "Dental Picks",
        "Bamboo Skewers",
        "Scalpel",
        "Magnifying Lamp"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_apron"
      ],
      "affected_damages": [
        "damage_01",
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "establish_conservation_environment"
      ]
    },
    {
      "step_id": "consolidate_apron_fragments",
      "title": "Consolidate Apron Fragments",
      "description": "Apply a low-concentration solu-
tion of a reversible consolidant, such as Paraloid B-72
in acetone, to the friable and shattered edges of the
back apron fragments. Apply with a fine brush or sy-
ringe, allowing the consolidant to wick into the dam-
aged wood fibers. This will strengthen the fragments
before reassembly.",
      "rationale": " Consolidating the weak, shattered
wood prevents the loss of original material during han-
dling and reassembly, adhering to the principle of pre-
serving the object's material integrity.",
      "tools_required": [
        "Paraloid B-72",
        "Acetone",
        "Fine Sable Brush or Syringe",
        "Fume Extractor",
```

```
          "Glass Beakers"
        ],
        "affected_parts": [
          "back_apron"
        ],
        "affected_damages": [
          "damage_01"
        ],
        "prerequisites": [
          "gentle_surface_cleaning",
          "prepare_joint_surfaces"
        ]
      },
      {
        "step_id": "reassemble_apron_fragments",
        "title": "Reassemble Apron Fragments",
        "description": "Meticulously reassemble the shat-
tered pieces of the back apron using a stable, reversi-
ble conservation adhesive, such as high-strength fish
glue or a more concentrated Paraloid B-72 solution. Use
clamps with padded jaws and sandbags to hold the pieces
together as the adhesive sets, ensuring correct align-
ment.",
        "rationale": "This intervention reconstructs the
component from its original parts, which is paramount
to preserving authenticity. The use of a reversible ad-
hesive ensures that this repair can be undone by future
conservators without damaging the original material.",
        "tools_required": [
          "Fish Glue or Paraloid B-72 Adhesive",
          "Small Clamps with Padded Jaws",
          "Tweezers",
          "Magnifying Lamp"
        ],
        "affected_parts": [
          "back_apron"
        ],
        "affected_damages": [
          "damage_01"
        ],
        "prerequisites": [
          "consolidate_apron_fragments"
        ]
      },
```

```
    {
      "step_id": "stabilize_leg_breaks",
      "title": "Stabilize Leg Breaks",
      "description": "Re-adhere the broken connection
points on the front left and front right legs. Apply a
reversible, gap-filling conservation adhesive like tra-
ditional hot hide glue. Clamp the joints carefully with
padded clamps to ensure a tight fit without crushing
the wood fibers. Remove any excess adhesive with a
warm, damp cloth before it fully cures.",
      "rationale": "This step stabilizes the primary
structure using a historically appropriate and fully
reversible adhesive. The goal is to restore structural
integrity with minimal intervention, avoiding replace-
ment or the use of modern, irreversible polymers.",
      "tools_required": [
        "Hot Hide Glue",
        "Glue Pot",
        "Small Brush",
        "Padded Clamps"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg"
      ],
      "affected_damages": [
        "damage_03",
        "damage_04"
      ],
      "prerequisites": [
        "prepare_joint_surfaces"
      ]
    },
    {
      "step_id": "dry_fit_structure",
      "title": "Dry-Fit Chair Structure",
      "description": "Once all individual component re-
pairs have cured, perform a complete dry-fit of the
chair's main structure. Assemble all legs and aprons
without adhesive to check the fit and alignment of the
repaired joints. Use band clamps or string to temporar-
ily hold the structure together. Make micro-adjustments
if necessary.",
```

```
      "rationale": "A dry-fit is a non-interventive
verification step. It ensures that the structural reas-
sembly will be successful and stress-free, preventing
the introduction of new tensions into the object's
frame, which aligns with the principle of stabiliza-
tion.",
      "tools_required": [
        "Band Clamps or Cord",
        "Padded Blocks",
        "Carpenter's Square"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "reassemble_apron_fragments",
        "stabilize_leg_breaks"
      ]
    },
    {
      "step_id": "reassemble_main_frame",
      "title": "Reassemble Main Frame",
      "description": "Reassemble the chair's structural
frame using hot hide glue. Work methodically, gluing
the side assemblies (legs and side aprons) first, then
joining them with the front and repaired back aprons.
Use appropriate bar or band clamps with padded cauls to
apply even pressure. Check for squareness and remove
all excess glue.",
      "rationale": "The reassembly uses a reversible,
conservation-grade adhesive that is compatible with the
original materials. This ensures the structural stabil-
ity of the object while maintaining the option for fu-
ture retreatability, a core tenet of modern conserva-
tion.",
      "tools_required": [
```

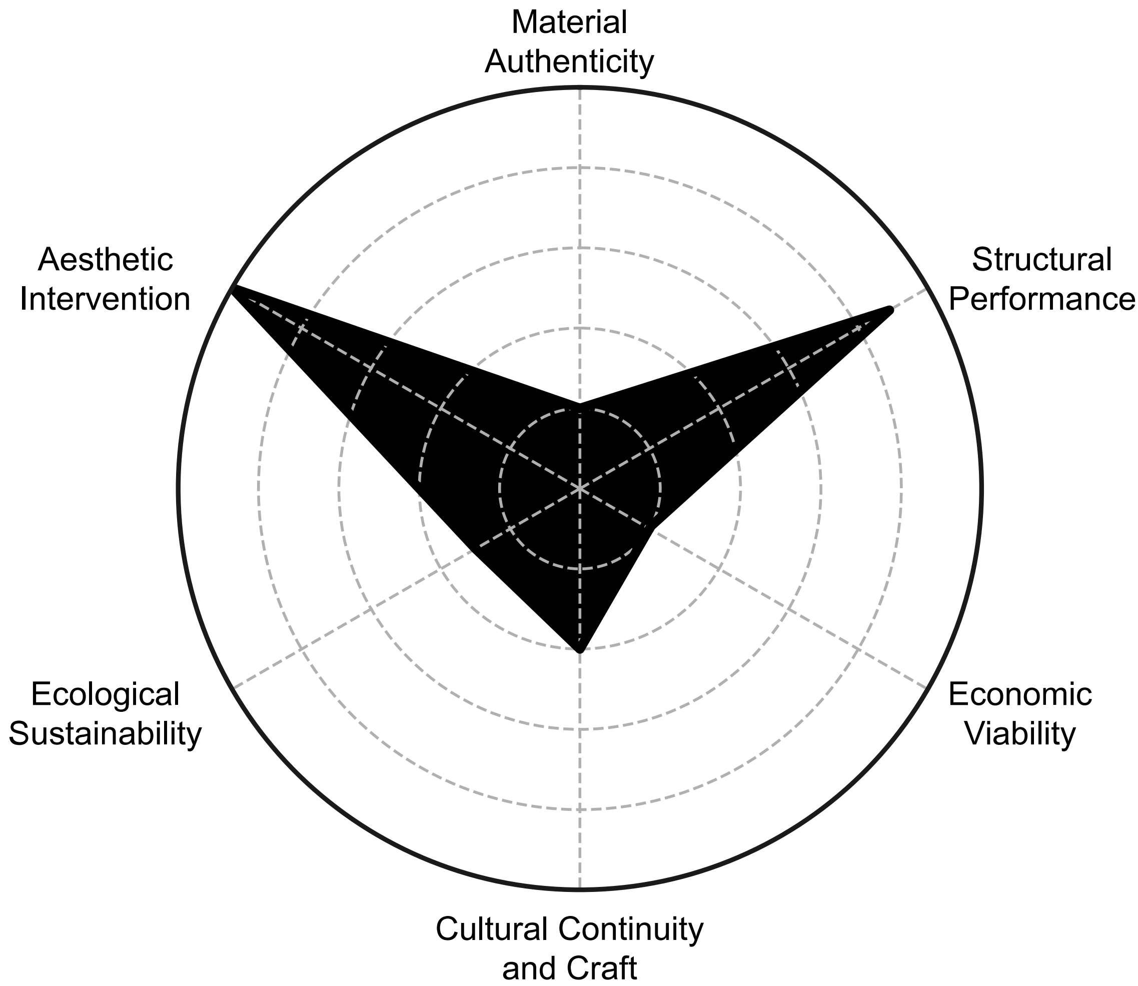
```
          "Hot Hide Glue",
          "Glue Pot",
          "Bar Clamps",
          "Band Clamps",
          "Padded Cauls",
          "Warm Water and Cloths"
        ],
        "affected_parts": [
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg",
          "front_apron",
          "back_apron",
          "left_side_apron",
          "right_side_apron"
        ],
        "affected_damages": [],
        "prerequisites": [
          "dry_fit_structure"
        ]
      },
      {
        "step_id": "attach_seat_and_backrest",
        "title": "Attach Seat and Backrest",
        "description": "After the main frame has fully
cured, attach the seat and backrest using the same hot
hide glue. Apply glue to the relevant connection points
on the frame and legs. Use weights on the seat and
clamps on the backrest, protected by padded cauls, to
ensure a secure bond while the adhesive cures.",
        "rationale": "Completing the assembly with the
same reversible adhesive ensures material consistency
throughout the repair. This final structural step sta-
bilizes the entire object, making it a cohesive whole
once more.",
        "tools_required": [
          "Hot Hide Glue",
          "Glue Pot",
          "Clamps",
          "Padded Cauls",
          "Weights"
        ],
        "affected_parts": [
```

```
        "seat",
        "backrest",
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron"
      ],
      "affected_damages": [],
      "prerequisites": [
        "reassemble_main_frame"
      ]
    },
    {
      "step_id": "apply_protective_wax",
      "title": "Apply Protective Wax",
      "description": "Apply a thin, even layer of mi-
crocrystalline conservation wax to all surfaces of the
chair. Use a lint-free cloth to apply the wax, let it
haze over, and then buff gently with a clean, soft
cloth. This will provide a protective barrier and even
out the sheen without altering the original finish.",
      "rationale": "Instead of applying an irreversible
new finish, a conservation wax protects the preserved
original finish from moisture and pollutants while re-
maining easily removable, thus preserving the object's
authentic surface narrative.",
      "tools_required": [
        "Microcrystalline Wax",
        "Lint-free Cotton Cloths",
        "Soft Buffing Brush"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
```

```
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "attach_seat_and_backrest",
        "gentle_surface_cleaning"
      ]
    },
    {
      "step_id": "final_curing",
      "title": "Final Curing Period",
      "description": "Allow the fully assembled and
treated chair to cure in the controlled environment for
a minimum of one week. This allows the hide glue to
achieve maximum strength and the wax coating to fully
harden. Monitor for any signs of joint movement or
stress.",
      "rationale": "A final curing period is essential
for the long-term stability of the conservation treat-
ments. It ensures all materials have fully set before
the object is handled or returned to a display or stor-
age environment, completing the stabilization pro-
cess.",
      "tools_required": [],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "apply_protective_wax"
      ]
    }
  ]
}
```

The Stylistic Idealist

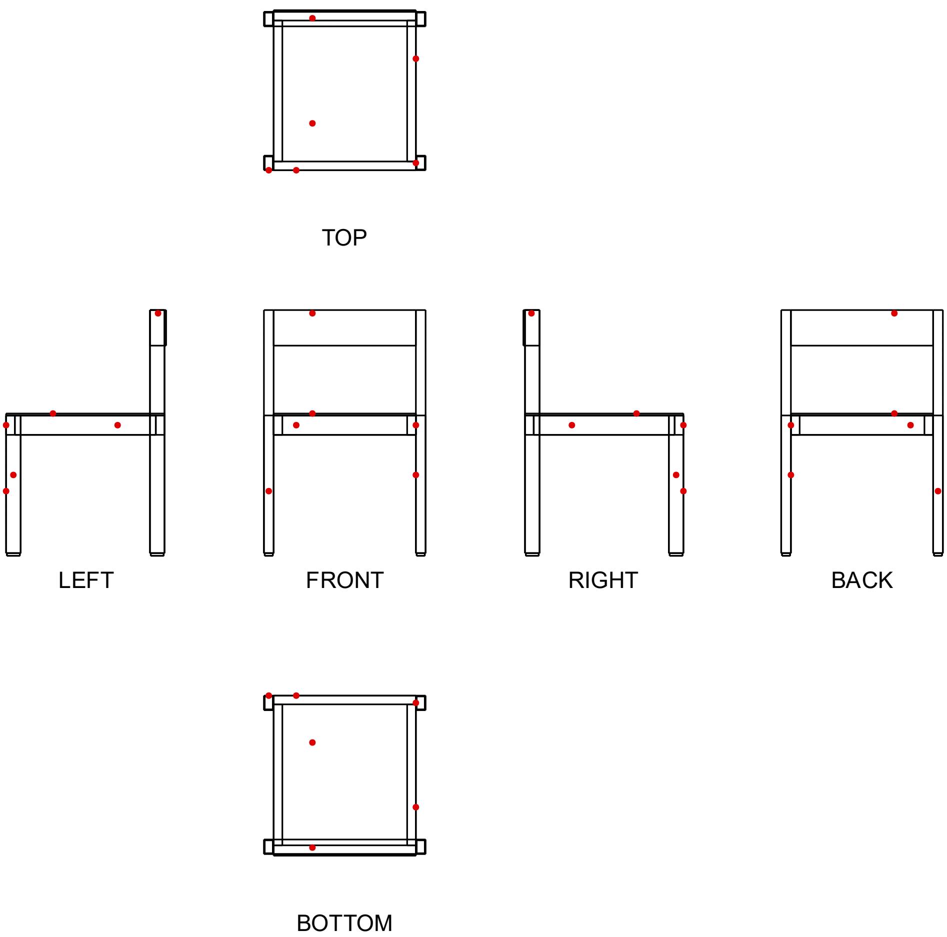
Repair as an act of stylistic completion rather than conservation. It aggressively reconstructs, supplements and invents elements, surfaces and appearance to realize a perfected, idealized state: a form the object may never have known historically. Driven by maximum aesthetic intervention and robust structural performance, this approach willingly sacrifices material authenticity and patina. For the stylistic idealist, true authenticity is not found in the original fabric but in the triumphant unity of the perfected style.



Santo Chair 42

This chair is in structurally sound condition but exhibits widespread cosmetic damage consistent with heavy and careless use. Numerous scratches and scuff marks mar nearly all of its primary surfaces, including a long, deep scratch on the front apron, multiple scratches on the seat, and noticeable scuffs on the backrest. The legs also show signs of impact, with scuff marks and indentations present on both the front left and front right legs.

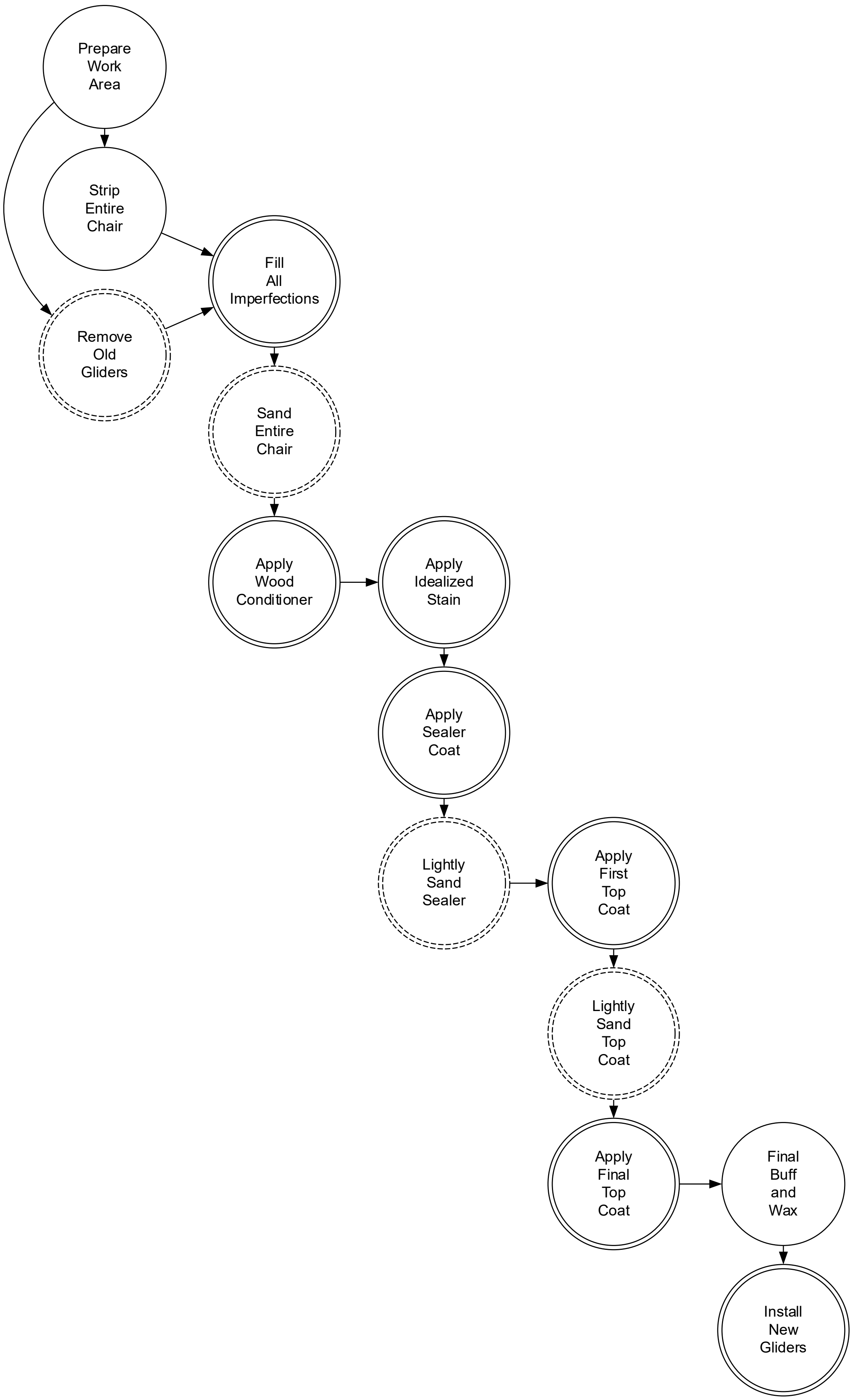
Overall Condition Rating: 6/10



[
  {
    "id": "damage_01",
    "part_id": "front_apron",
    "type": "Scratch",
    "description": "A long, deep vertical scratch is visible on the right side of the front apron.",
    "coordinates": {
      "x": 0.15,
      "y": 0.404,
      "z": -0.245
    },
    "severity": "minor",
    "confidence": 0.95,
    "evidence": "Clearly visible in the close-up image of the front apron and seat."
  },
  {
    "id": "damage_02",
    "part_id": "seat",
    "type": "Scratch",
    "description": "Multiple faint scratches are present on the wooden seat surface.",
    "coordinates": {
      "x": 0.1,
      "y": 0.44,
      "z": -0.1
    },
    "severity": "minor",
    "confidence": 0.85,
    "evidence": "Visible upon close inspection of the seat in multiple images."
  },
  {
    "id": "damage_03",
    "part_id": "front_left_leg",
    "type": "Scuff Mark",
    "description": "Several scuff marks and indentations are located midway up the front left leg.",
    "coordinates": {
      "x": -0.22,
      "y": 0.25,
      "z": -0.2225
    },

```
    "severity": "moderate",
    "confidence": 0.9,
    "evidence": "Clearly shown in a dedicated close-up
image of the leg."
  },
  {
    "id": "damage_04",
    "part_id": "left_side_apron",
    "type": "Scratch",
    "description": "A noticeable horizontal scratch is
present on the left side apron.",
    "coordinates": {
      "x": -0.22,
      "y": 0.404,
      "z": 0.1
    },
    "severity": "minor",
    "confidence": 0.9,
    "evidence": "Visible in the close-up image showing
the connection between the leg and the seat frame."
  },
  {
    "id": "damage_05",
    "part_id": "front_right_leg",
    "type": "Scratch",
    "description": "A cluster of minor scratches and
scuffs on the front-facing side of the front right
leg.",
    "coordinates": {
      "x": 0.235,
      "y": 0.2,
      "z": -0.245
    },
    "severity": "minor",
    "confidence": 0.9,
    "evidence": "Visible in a close-up image of the
leg."
  },
  {
    "id": "damage_06",
    "part_id": "backrest",
    "type": "Scuff Mark",
    "description": "Scuff marks and light scratches are
visible on the top edge of the backrest.",
```

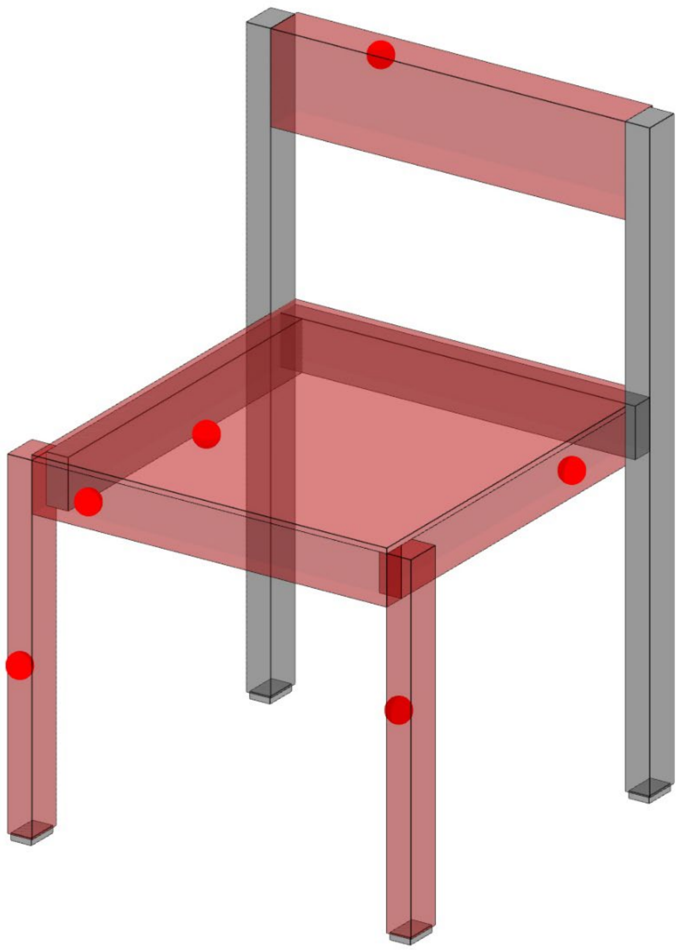
```
    "coordinates": {
      "x": 0.1,
      "y": 0.75,
      "z": 0.225
    },
    "severity": "minor",
    "confidence": 0.8,
    "evidence": "Shown in the close-up image of the up-
per part of the chair."
  }
]
```



Prepare Work Area
Strip Entire Chair
Remove Old Gliders
Fill All Imperfections
Sand Entire Chair
Apply Wood Conditioner
Apply Idealized Stain
Apply Sealer Coat
Lightly Sand Sealer
Apply First Top Coat
Lightly Sand Top Coat
Apply Final Top Coat
Final Buff and Wax
Install New Gliders

Repair

This plan details an aggressive reinvention of the chair, aiming for a new, flawless state rather than preserving its history. The process begins by completely erasing all signs of past use: deep scratches are filled, and the entire original finish and patina are mechanically sanded off. This creates a blank canvas, which is then primed and meticulously coated with a vibrant, high-gloss red paint. A final, durable clear coat completes the transformation, sacrificing the chair's authenticity to create a perfected, idealized object with no trace of its former life.



```
{
  "steps": [
    {
      "step_id": "prepare_workspace_and_chair",
      "title": "Prepare Workspace and Chair",
      "description": "Set up a well-ventilated work
area with drop cloths to protect surrounding surfaces.
Thor-oughly clean the entire chair with a degreasing
agent and a clean cloth to remove all dirt, oils, and
resi-dues.",
      "rationale": "A pristine work environment and a
chemically clean surface are the foundation for achiev-
ing the flawless, idealized finish required. This ini-
tial purification is the first step in erasing the ob-
ject's previous existence.",
      "tools_required": [
        "Drop cloths",
        "Degreaser",
        "Clean cloths"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": []
    },
    {
      "step_id": "remove_old_gliders",
      "title": "Remove Old Gliders",
      "description": "Using a pry bar or flat-head
screwdriver, carefully remove the four existing plastic
gliders from the bottom of each leg. Ensure the leg
bot-toms are clear of any residual plastic or fasten-
ers.",
```

```
      "rationale": "The original, worn gliders are dis-
carded as part of the aggressive reconstruction. They
are replaced to ensure every component, functional or
aesthetic, aligns with the new, perfected state of the
chair.",
      "tools_required": [
        "Pry bar",
        "Pliers"
      ],
      "affected_parts": [
        "front_left_glider",
        "front_right_glider",
        "back_left_glider",
        "back_right_glider",
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "prepare_workspace_and_chair"
      ]
    },
    {
      "step_id": "fill_deep_imperfections",
      "title": "Fill Deep Imperfections",
      "description": "Apply a high-performance, two-
part epoxy wood filler to the deep scratches and inden-
tations on the front apron and front left leg. Overfill
the dam-ages slightly to account for shrinkage and to
allow for sanding flush with the surrounding surface.",
      "rationale": "To create a perfected surface, his-
torical evidence of significant damage must be com-
plete-ly obliterated. This filling step aggressively
recon-structs the form, creating a new, idealized sur-
face that shows no sign of past trauma.",
      "tools_required": [
        "Epoxy wood filler",
        "Putty knife"
      ],
      "affected_parts": [
        "front_apron",
        "front_left_leg"
```

],
"affected_damages": [
"damage_01",
"damage_03"
],
"prerequisites": [
"prepare_workspace_and_chair"
]
},
{
"step_id": "strip_and_sand_chair",
"title": "Strip and Sand Chair",
"description": "Mechanically sand the entire wood-en structure of the chair. Begin with 120-grit sandpaper to remove the original lacquer finish and level the cured wood filler. Progress to 220-grit sand-paper to create a uniformly smooth surface, ready for priming. Pay close attention to all curves and joints.",
"rationale": "This aggressive sanding erases all traces of the chair's past life—the original finish, patina, and minor damages—sacrificing material authen-ticity to create a blank canvas for its new, perfected identity.",
"tools_required": [
"Orbital sander",
"120-grit sandpaper",
"220-grit sandpaper",
"Sanding block"
],
"affected_parts": [
"front_left_leg",
"front_right_leg",
"back_left_leg",
"back_right_leg",
"front_apron",
"back_apron",
"left_side_apron",
"right_side_apron",
"seat",
"backrest"
],
"affected_damages": [
"damage_01",

```
        "damage_02",
        "damage_03",
        "damage_04",
        "damage_05",
        "damage_06"
      ],
      "prerequisites": [
        "fill_deep_imperfections"
      ]
    },
    {
      "step_id": "final_surface_cleaning",
      "title": "Final Surface Cleaning",
      "description": "After sanding, use a vacuum with
a brush attachment to remove the majority of the dust.
Follow up by wiping down the entire chair with a tack
cloth to remove any remaining fine particles, ensuring
a perfectly clean surface for priming.",
      "rationale": "Absolute cleanliness is non-nego-
tiable for achieving a flawless, glass-like finish.
This step ensures the new surface is not marred by any
remnants of the old, guaranteeing the perfection of the
new aesthetic.",
      "tools_required": [
        "Vacuum with brush attachment",
        "Tack cloth"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "strip_and_sand_chair"
      ]
    },
```

    {
      "step_id": "mask_hardware_and_prime",
      "title": "Mask Hardware and Prime",
      "description": "Carefully mask the metal stacking hardware on the underside of the chair with painter's tape. Apply a thin, even coat of high-adhesion wood pri-mer to all sanded surfaces. Allow to cure fully as per the manufacturer's instructions.",
      "rationale": "The primer creates a uniform founda-tion, obliterating the natural wood grain and ensuring the new, vibrant color is pure and consistent. This is a critical step in inventing a new, idealized appearance for the chair.",
      "tools_required": [
        "Painter's tape",
        "High-adhesion wood primer",
        "Paint brush or sprayer"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "final_surface_cleaning"
      ]
    },
    {
      "step_id": "sand_primer_coat",
      "title": "Sand Primer Coat",
      "description": "Once the primer is fully cured, lightly sand the entire surface with 320-grit sandpaper to eliminate any minor imperfections or raised grain. The goal is a surface that is perfectly smooth to the touch. Wipe away all dust with a tack cloth.",

"rationale": "This meticulous sanding of the primer is essential for achieving the 'triumphant unity of the perfected style.' It ensures the subsequent color coats lay perfectly flat, contributing to the final, flawless, high-gloss finish.",
      "tools_required": [
        "320-grit sandpaper",
        "Sanding block",
        "Tack cloth"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "mask_hardware_and_prime"
      ]
    },
    {
      "step_id": "apply_first_color_coat",
      "title": "Apply First Color Coat",
      "description": "Apply a thin, even layer of the high-gloss red paint to all primed surfaces. Use long, consistent strokes to avoid drips and ensure uniform coverage. Allow to dry according to the paint manufacturer's specifications.",
      "rationale": "This step begins the chair's aesthetic rebirth, applying the bold new color that defines its reinvented and perfected stylistic identity.",
      "tools_required": [
        "High-gloss red paint",
        "High-quality paint brush or sprayer"
      ],
      "affected_parts": [

```
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
      "affected_damages": [],
      "prerequisites": [
        "sand_primer_coat"
      ]
    },
    {
      "step_id": "apply_final_color_coat",
      "title": "Apply Final Color Coat",
      "description": "After the first coat is properly
cured, apply a second and final coat of the high-gloss
red paint. This coat should be applied meticulously to
achieve a deep, rich, and completely uniform color
field.",
      "rationale": "A second coat is not for repair but
for perfection. It ensures a flawless, saturated color
field, which is non-negotiable for realizing the ob-
ject's idealized, high-impact visual form.",
      "tools_required": [
        "High-gloss red paint",
        "High-quality paint brush or sprayer"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg",
        "front_apron",
        "back_apron",
        "left_side_apron",
        "right_side_apron",
        "seat",
        "backrest"
      ],
```

```
        "affected_damages": [],
        "prerequisites": [
          "apply_first_color_coat"
        ]
      },
      {
        "step_id": "apply_protective_clear_coat",
        "title": "Apply Protective Clear Coat",
        "description": "Once the final color coat is
fully cured, apply a high-gloss, non-yellowing polyure-
thane clear coat. Apply at least two coats for maximum
depth, durability, and shine, lightly sanding with 400-
grit sandpaper between coats if recommended by the man-
ufac-turer.",
        "rationale": "The clear coat is the final step in
achieving a perfected state. It provides robust surface
performance and enhances the gloss to a level beyond
the original, completing the transformation into a
flawless object that embodies an idealized style.",
        "tools_required": [
          "High-gloss polyurethane clear coat",
          "High-quality paint brush or sprayer",
          "400-grit sandpaper"
        ],
        "affected_parts": [
          "front_left_leg",
          "front_right_leg",
          "back_left_leg",
          "back_right_leg",
          "front_apron",
          "back_apron",
          "left_side_apron",
          "right_side_apron",
          "seat",
          "backrest"
        ],
        "affected_damages": [],
        "prerequisites": [
          "apply_final_color_coat"
        ]
      },
      {
        "step_id": "final_assembly",
        "title": "Install New Gliders",
```

```
      "description": "After the final clear coat has
fully cured for at least 24-48 hours, carefully remove
the painter's tape from the hardware. Install the new
plastic gliders by tapping them gently into place on
the bottom of each leg with a rubber mallet.",
      "rationale": "Installing new, pristine hardware
is the final act of stylistic completion. It ensures
every single component of the chair contributes to its
new, perfected, and idealized form, leaving no trace of
its former state.",
      "tools_required": [
        "New plastic gliders",
        "Rubber mallet"
      ],
      "affected_parts": [
        "front_left_leg",
        "front_right_leg",
        "back_left_leg",
        "back_right_leg"
      ],
      "affected_damages": [],
      "prerequisites": [
        "apply_protective_clear_coat",
        "remove_old_gliders"
      ]
    }
  ]
}
```

Concept and Design

Tizian Rein
www.tizianrein.de

Supervision

Prof. Dr. Kathrin Dörfler
Begüm Saral, M.A.

Professorship of Digital Fabrication
Faculty of Architecture

School of Engineering and Design
Technical University of Munich

Program Development

www.github.com/tizianrein/fsta

Munich, Germany · September 2025