

Article

Designing with Absence: Advanced Design Approaches to Missing Data in Digital Cultural Heritage

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Abstract

The digital transformation of cultural heritage has expanded the availability of data while revealing structural forms of incompleteness. This study investigates how missing data are conceptualised in the scientific and design literature on digital cultural heritage and how Advanced Design can transform absence into a resource. The research combines a critical thematic review of peer-reviewed publications from 2010 to 2025 with Research through Design practices and case studies developed within the PNRR CHANGES project. The analysis identifies three main configurations of absence: processual gaps arising along the data lifecycle, epistemic exclusions embedded in standards and knowledge models, and projectual shortcomings related to governance and participation. Based on these findings, a design taxonomy and an operational model are proposed, linking each form of absence to specific levers of intervention, such as transparency of workflows, community-grounded annotation and narration, collaborative metadata writing, and long-term maintenance practices. The results show that Advanced Design provides an infrastructural and reflective framework capable of connecting technical processes, cultural interpretation, and community involvement. The study concludes that incompleteness, rather than a defect, can act as a generative condition for digital heritage, fostering more inclusive, situated, and transformative design practices.

Keywords: missing data; digital cultural heritage; advanced design; situated epistemologies; critical data studies



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1. Introduction

The digital transformation of cultural heritage represents one of the most significant challenges and opportunities of recent times [1]. International programmes such as European [2] but also, looking at the Italian context, the National Digitisation Plan [3] and, more recently, the National Recovery and Resilience Plan [4] have accelerated the digitization of archives, collections, and cultural infrastructure, expanding the accessibility, dissemination, and use of contents in an unprecedented way.

Digitisation policies have often emphasised the need to expand access and ensure long-term preservation, but the emergence of large digital ecosystems has made it clear that the mere availability of data does not automatically translate into a real capacity to activate it culturally [5]. Part of the digitised heritage tends to remain in a state of latency: it exists in systems, but is difficult to locate, interpret, or reuse if it is not supported by narrative structures, readable metadata, and experience-oriented meaning devices.

In this sense, the term “vanishing culture” [6], used in an Internet Archive report to indicate the loss of digital rather than material visibility, can be read not as a generalised condition, but as a sign of the structural fragilities that emerge when data are produced faster than they can be interpreted and contextualised. Rather than total disappearance, the risk concerns a form of overexposure without activation, in which data are present in systems, but lacks a cultural device that makes it meaningful.

1.1. Design and Cultural Heritage: From Material to Digital

Within this complex scenario, design emerges as a strategic discipline, capable of mediating between technological infrastructures and cultural values. Over the last two decades, the relationship between design and cultural heritage has gradually consolidated, shifting from approaches focused on tangible assets and territorial enhancement to more systemic and interpretative perspectives.

Early reflections highlighted the ability of design to influence the conservation and communication of cultural heritage [7], while subsequent research has explored the role of design as a tool for connecting heritage and local development [8] and as a lever for innovation through dialogue with craftsmanship and cultural production [9].

In recent years, the field has expanded towards the intersection with the humanities and social sciences [10], the exploration of immaterial and interactive dimensions [11,12] and the construction of design narratives capable of connecting experiences, values, and knowledge [13]. With the proliferation of digital technology, attention has progressively focused on the design challenges of digitisation and the development of visualisation and data storytelling tools [14,15].

1.2. Problem Statement and Contribution

The digital transformation of cultural heritage has produced a large amount of data and metadata. This massive production is often considered a sign of the success of digitisation policies, which have focused on expanding accessibility and public dissemination of contents. However, the increase in data does not automatically correspond to an increase in the quality of information or its ability to generate cultural value [16].

Much of the data produced is in fact partial, discontinuous, or difficult to reuse. Digitisation takes place at different times and with different tools, often without an integrated view of the processes. Even the description of content (e.g., through metadata, text fields, or cataloguing systems) is affected by fragmented logic, linked more to the need to complete technical procedures than to build a coherent information system that can be queried over time. This situation highlights a key aspect for research: digitisation is not a neutral or technical act, but a cultural practice that selects, orders, and makes visible only certain aspects of heritage. In this sense, what appears to be a lack of data is the result of operational, projectual, and cultural choices that determine what is recorded and what is left out. In this paper, “missing data” refers to different forms of incompleteness, rather than to technical data loss. In relation to this definition, “Designing with Absence” describes the design stance adopted to read and work with such incompleteness.

In this scenario, the present research, which began in March 2023, is part of the Piano Nazionale di Ripresa e Resilienza (PNRR) CHANGES programme—Cultural Heritage Active Innovation for Next-Gen Sustainable Society [17], and, in particular, to the activities of Spoke 4, dedicated to the use of advanced digital technologies for the enhancement of cultural heritage in museums and collections. Within CHANGES—Spoke 4, the research drew on the pilot for the digital twin of the Aldrovandi exhibition at the Palazzo Poggi Museum in Bologna (Italy). The museum, part of the University of Bologna’s historical collections, hosts the natural history specimens assembled by Ulisse Aldrovandi in the six-

teenth century, including zoological, botanical, and mineralogical materials of considerable scientific and cultural value. The pilot allowed the team to observe the full digitisation pipeline, from 3D acquisition and mesh refinement to metadata creation and the preparation of assets for online dissemination. Access to intermediate files, technical reviews and collaborative cataloguing sessions made it possible to identify processual absences linked to undocumented steps and workflow discontinuities, as well as epistemic absences emerging from the constraints of standardised metadata structures. The observation also revealed projectual absences with a concrete technical impact, such as the lack of contextual and qualitative information needed to construct coherent narratives, the absence of mechanisms to record interpretative decisions, and the scarcity of technical notes explaining modelling or optimisation choices. These empirical insights informed the identification of processual, epistemic, and projectual absences and contributed directly to the formulation of the interpretative framework and the design-driven model developed in this study.

The research takes this context as a field of observation for developing a design-driven digitisation model that interprets and connects data as project materials, while recognising missing data as a critical layer of cultural information, revealing the limits, biases and priorities embedded in digitisation processes.

1.3. Research Aims and Theoretical Framework

In light of this scenario, this paper has two objectives:

1. to construct a critical map of the literature on the subject of missing data in digital cultural heritage, highlighting how these are interpreted and addressed;
2. to propose a taxonomy of missing data that makes the different natures of absences visible and opens up space for the contribution of Advanced Design as a cultural infrastructure capable of transforming absences into opportunities for knowledge and activation. The conceptual grounding of Advanced Design is further clarified in the following sections, drawing on four core references that inform its theoretical orientation.

The analytical framework of the research is aligned with the main theoretical references of critical heritage studies [18] and design research [19], with the aim of developing a project-based methodology that understands incompleteness as a generative space, where the gaps and absences of digital heritage become triggers for new design, research, and interpretive practices.

2. Materials and Methods

2.1. Research Questions and Framework

The aim is to understand how Advanced Design [20] can transform incompleteness into a generative space for knowledge, collaboration, and innovation in cultural digitisation processes. The study follows a hybrid design approach, combining a critical thematic review of peer-reviewed publications with Research through Design practices and empirical observation of digitisation workflows within PNRR CHANGES. The literature review provides the conceptual ground, while the CHANGES case offers a situated context through which the taxonomy and the model have been refined. Three research questions guide the entire process and define the interpretative directions:

1. How does the literature on digital cultural heritage conceptualise missing data in its technical, epistemic, and design dimensions?
2. How do patterns and tensions between standardisation and inclusion, interoperability and situatedness contribute to shape these forms of missing data?
3. In what contexts and with what tools can Advanced Design transform missing data into resources?

Starting from these questions, the research investigates the possibility of conceiving missing data as an active component of digitisation processes. Incompleteness is assumed to be a structural condition of the digital heritage ecosystem. This theoretical grounding is consistent with contributions that position Advanced Design as a systemic and anticipatory approach within design research, supported by interpretative mapping, knowledge-creation processes, exploratory prototyping, and extended practices [21–23]. Advanced Design offers a methodological framework capable of reading and interpreting these gaps as generative phenomena, in which the lack is not a gap to be filled, but an element that produces questions, reflections, and new configurations of meaning. From this perspective, the observation conducted as part of the PNRR CHANGES programme (Spoke 4) provides a privileged context for analysing how the dynamics of digital data production, description, and management highlight tensions between uniformity and plurality, between technical prescription and situated interpretation. The aim is to highlight the ways in which digitisation processes generate absences and how these can be made legible through design strategies of interpretation, visualisation, and narration.

Design thus takes the form of a theoretical-methodological lens capable of bringing different skills into dialogue and promoting a more articulated understanding of the relationship between data, context, and culture. Its function is not to resolve incompleteness, but to activate forms of knowledge that are usable by different types of users involved (or not involved) in the processes, from experts to researchers and citizens.

2.2. Analytical Framing and Methodology

The preliminary methodological phase involved constructing a bibliographic corpus through qualitative analysis integrated with the operational use of Artificial Intelligence. ChatGPT-4o (OpenAI) was employed to generate variations in search prompts for advanced queries on Scopus. The aim was to broaden the semantic field associated with “missing data” in digital heritage by exploring alternative combinations of keywords and disciplinary descriptors. These AI-generated cues were considered exploratory suggestions and were subsequently verified and refined manually to ensure coherence with the theoretical perspective of Advanced Design.

The first stage of the research consisted of an analytical and thematic mapping of international literature published between 2010 and 2025. This timespan captures both the consolidation of large-scale digitisation programmes and the emergence of critical debates on data incompleteness. The search strategy combined three main groups of terms—heritage-related descriptors, notions linked to data and metadata, and design-oriented or critical concepts—sembled in multiple configurations to expand the field of inquiry. This process produced an initial set of 143 publications addressing missing data, gaps, fragmentation, uncertainty or incompleteness in digital heritage domains. Alongside the material retrieved through Scopus, the corpus incorporates references that had already surfaced in earlier research work and contributed to defining the conceptual boundaries of the study. Through an iterative process combining automated filtering, qualitative interpretation, and progressive theoretical alignment, the corpus was narrowed to 24 peer-reviewed contributions of particular relevance [24]. This final selection does not aim to represent the field statistically; rather, it forms a coherent cluster of works that articulate distinct and theoretically significant interpretations of absence in digital cultural heritage.

The definition of the corpus followed a set of criteria designed to ensure conceptual relevance and methodological clarity:

- Explicit engagement with incompleteness: only publications examining forms of absence or missing data within digitisation processes were included;

- Methodological transparency: studies needed to clearly describe their analytical, technical, or interpretative procedures;
- Relevance to design-oriented or critical perspectives: inclusion required a demonstrable link to design research, critical data studies, or digital humanities.
- Peer-reviewed status: only peer-reviewed works were retained to ensure scholarly reliability;
- Non-technical framing of missing data: priority was given to contributions interpreting incompleteness as a cultural, methodological, or institutional phenomenon rather than solely as a technical issue;
- Attention to design cultures and plural disciplinary origins: journals and keywords associated with design, participatory cultures, or interdisciplinary methodologies were favoured.

The analysis of these contributions was developed through triangulation between the bibliographic corpus, case studies, and empirical observation. Observations of digitisation workflows within the PNRR CHANGES programme—including acquisition, processing, metadata creation, and preparation for online dissemination—were used to refine the analytical categories emerging from the literature by comparing documented procedures with actual practices. This process highlighted recurrent dynamics: the role of incompleteness as productive friction, the situated and partial nature of digital knowledge, and the importance of making absences legible rather than neutralised. These insights provide the theoretical foundation for the taxonomy and analytical framework presented in the following section.

3. Results

The results of the study take the form of an interpretative framework that organises the forms of incompleteness observed in the literature and in the empirical workflows analysed within PNRR CHANGES. Two outcomes were produced: (1) a taxonomy that classifies processual, epistemic, and projectual absences, and (2) a design-driven model that connects these forms of incompleteness to the operational phases of digitisation processes. Together, these results provide the analytical structure for the discussion presented in the following section.

3.1. From Error Taxonomy to Missing Data

The analysis resulted in the elaboration of a taxonomy of absences, which represents the main analytical outcome of this study. The following section discusses its structure and underlying rationale. In the literature on error studies, the taxonomy proposed by Reason [25] distinguishes between two main types of errors: “slips”, which occur when the objective is correct but its execution is not carried out appropriately, and “mistakes”, which arise when the objective itself is poorly set, based on inadequate rules or partial knowledge. Within this distinction, the author further articulates the cases, showing how failures can result from errors of action, memory lapses, incorrect application of rules, or insufficient cognitive frameworks. In any case, error cannot be reduced to an accidental or contingent defect but is an expression of systemic conditions that traverse the relationship between objectives, processes, and knowledge.

This perspective proves useful for analytically reading what and how the gaps generated by the digitisation of cultural heritage are. Digitisation, as already mentioned, should not be considered a neutral and linear process, but a complex operation that continuously produces absences, gaps, and shortcomings. Just as the errors studied by Reason are symptoms of structural tensions in cognitive and organisational systems, we can say that missing data reveal profound conditions concerning the digital infrastructures, epistemic models, and design practices that generated them and guide their interpretation.

From this perspective, the analogy with error studies allows us to consider missing data not as defects to be corrected, but as diagnostic signals that reveal the tensions and asymmetries of digital heritage production systems, providing design with tools to critically interpret their structure and cultural implications. Building on this approach, the research proposes a taxonomy articulated into three macro-clusters, Processual, Epistemic, and Projectual, which map the different origins and meanings of incompleteness within digital heritage practices.

3.2. *Processual Absences: Data Lifecycle and Infrastructural Gaps*

Processual absences are one of the most evident manifestations of the systemic and design conditions that generate missing data. They emerge in the transformation of digital content, when operational decisions and technical logic are intertwined with criteria of efficiency, readability and standardisation. Recent literature on the digitisation of cultural heritage highlights a growing focus on the gaps that occur throughout the data lifecycle, in the subsequent stages of acquisition, processing, optimisation, and publication. Bossema et al. [26] show how digital acquisition practices are never linear: scanning, volumetric reconstruction and refinement require continuous negotiation between technical parameters, interpretative sensibilities and readability objectives. Each intermediate version of the digital model incorporates choices, exclusions, and adaptations, but these steps are rarely tracked or made accessible, resulting in a loss of operational memory and reducing the possibility of replicating or critically understanding the process.

With regard to the evaluation process, Uzelac and Lovrinić Higgins [27] describe this condition as an evaluative absence: the production of large amounts of digital data does not in itself guarantee cultural or scientific impact unless accompanied by devices capable of making data transformations legible and explaining their origin, purpose and trajectory. A convergence can also be found in the reflections of Prescott [28], who speaks of infrastructural incompleteness to describe the loss of traceability within digital workflows. The author points out that the lack of available versions, operational metadata or tools to document intermediate choices not only produces technical shortcomings, but also a form of documentary invisibility that limits the transparency and comprehensibility of digital processes.

As Gitelman [29] says, the expression “raw data” is an oxymoron: there is no such thing as raw data, since every collection or codification involves an act of selection and interpretation. Data is always “cooked with theory”, filtered by tools, conventions and disciplinary perspectives. This awareness overturns the perception of incompleteness: gaps do not only result from what is missing, but from what has never been recognised as data. In the context of the digitisation of cultural heritage, such missing data reveal the constructed nature of knowledge infrastructures (standards, formats, vocabularies) that determine what can be documented and what remains invisible.

From this perspective, it is clear that design approach to heritage digitisation processes is not limited to filling technical gaps, but is oriented towards building proximity through the systemic use of data and phygital mediation between material and immaterial experiences [30]. Design thus becomes a tool for transforming absences into spaces for relationship and cultural innovation, promoting forms of access and participation that integrate people, contexts, and technologies [31].

From this perspective, processual absences reveal how every digital infrastructure is also a system of cultural selection, in which what is excluded or not traced becomes an integral part of the very meaning of digitised heritage.

Similar dynamics have been widely recognised in data-intensive research, where undocumented transitions between workflow stages shape the trajectory and intelligibility

of digital objects. These hidden transformations influence the stability of datasets and redefine their intermediate states, revealing how data mutate across processes and tools rather than remaining fixed entities [32,33]. Recent analyses have also shown how breakdowns, interruptions and partial outputs become constitutive aspects of data production, especially when information passes through fragmented or opaque pipelines [34]. Within preservation contexts, such shifts accumulate across iterative manipulations, generating forms of “data craft” that shape what becomes legible or is silently lost [35].

At the same time, scholarship on data curation and infrastructural studies has highlighted how the absence of documented intermediate stages compromises verification, reuse, and accountability. These gaps reveal structural weaknesses in documentation cultures and repository practices, where missing metadata and undocumented decisions prevent the reconstruction of provenance and methodological context [36].

3.3. Epistemic Absences: Knowledge Models and Exclusions

If processual absences reveal the operational discontinuities of digital systems, epistemic absences reveal the logic of knowledge that underpins them. In this case, it is not the execution that is incomplete, but the objective itself that is formulated within partial knowledge frameworks or inadequate rules. The practices of digitising heritage do not develop in a neutral vacuum: they are structured by established standards, disciplinary taxonomies, institutional priorities and regulatory constraints that select which aspects of heritage should be made visible and which can remain invisible.

These absences stem from systemic conditions that transcend individual projects: the constant evolution of digital technologies, the instability of formats and metadata standards, and the growing pressure of a datafied society [37] that tends to translate every cultural phenomenon into quantifiable data. In this context, absences are not occasional accidents, but the structural effect of an ecosystem that privileges certain dimensions, often material, visible, interoperable, and marginalises others, such as local knowledge, intangible practices, or emotional relationships with heritage.

Examples of this dynamic clearly emerge in datasets that favour the physical preservation of objects at the expense of lived experiences, or in catalogue records that do not include fields to describe the community relevance of an asset. In these cases, what is missing is not forgotten information, but an entire perspective that has no place in the adopted epistemic model. Epistemic absences therefore show that incompleteness cannot be treated simply as a technical defect to be corrected, but as a structural condition of digital heritage, which requires critical and design tools capable of making gaps visible, problematising their origins, and opening up to plural narratives.

One of the most radical expressions of criticism of data neutrality can be found in the work of Catherine D’Ignazio and Lauren Klein [38], who propose a veritable epistemic reversal with “Data Feminism”. The authors show that data are not only cultural products but also instruments of power: collected, classified, and disseminated through infrastructures that reflect inequalities of gender, race, class, and access. Datasets are to be considered political constructions that incorporate the hierarchies and omissions of the contexts in which they arise. What is recorded and what remains invisible depends on who owns the means of observation and what interests guide collection practices.

From this perspective, epistemic absences are not the result of occasional shortcomings, but of systems of visibility that decide what counts as knowledge and what can be excluded. The feminist approach to data, in addition to highlighting numerical imbalances or integrating marginal voices, calls for a shift in focus from quantity to relationships, from possession to care, from extraction to responsibility. D’Ignazio and Klein [38] talk about

data justice, a principle that does not concern the correctness of data, but the justice of the practices that produce it.

Applied to the digitisation processes of cultural heritage, this perspective highlights how information gaps and semantic exclusions derive from institutional structures that determine which narratives are legitimate. Metadata standards, taxonomies, and controlled vocabularies tend to favour material and documentary dimensions, while marginalising affective experiences, local knowledge, and community practices. In this sense, epistemic missing data reflect a data culture that is still extractive, measuring but not listening, cataloguing, but not understanding.

The contributions of D'Ignazio and Klein intersect with those of Loukissas [39] and Haraway [40]: although from different perspectives, they all invite us to recognise that data are not abstract or universal entities but situated relationships. In *All Data Are Local*, Loukissas shows how every data collection is a product of specific contexts, institutional practices and technical infrastructures that condition its form, meaning, and dissemination. Data, he argues, do not exist outside the places that generate them: they carry with them material and cultural traces of the relationships from which they emerge and are, therefore, indices of local knowledge.

Haraway, with her theory of situated knowledge, offers a complementary epistemological framework: all knowledge, including digital knowledge, is partial, embodied, and positioned. Applied to the digitisation of heritage, this view implies that cultural infrastructures and platforms cannot be neutral, but reflect the perspectives, exclusions and desires of the communities that build them. In this direction, thinking of heritage data as situated knowledge allows us to value the plurality of cultural experiences and to design more inclusive information architectures, capable of accommodating polyphonic narratives, local temporalities and forms of affective and territorial knowledge.

Müller's work [41] highlights how the processes of digitisation and putting heritage online are determined by different visions of what constitutes memory and knowledge. Choices about what to digitise, how to organise interfaces, or which communities to involve reflect priorities, values, and power relations. In this sense, the digital archive becomes a field of cultural negotiation, where technical infrastructures, representation policies, and social practices meet. It is therefore not only a place of preservation, but a dynamic process of knowledge construction, which continually defines what can be remembered, shared, or reinterpreted.

A further example of epistemic absences concerns the way in which culture and creativity remain on the margins of economic development models due to the lack of adequate measurement tools and theoretical frameworks [42]. What is lacking is not data, but the ability of systems to recognise and represent the cultural and relational value of creative practices. This absence of metrics constitutes an epistemic void that produces systemic invisibility, similar to that found in the digitisation processes of cultural heritage.

In this framework, epistemic absences show that every digital infrastructure is not only an archive of content, but also a device of power that guides the production of knowledge. Recognising them means restoring depth to digitisation processes and opening up space for a design capable of critically acting on the structures that define what can be known and shared. The notion of "data before the fact" sharpens this perspective by showing that epistemic absences originate even earlier, in the pre-analytic categories and classificatory assumptions that determine what qualifies as data in the first place [43].

3.4. Projectual Absences: Governance, Participation, and Design Shortcomings

Projectual absences fall somewhere between slips and mistakes, displaying a hybrid nature. They stem from planning and governance choices which, while pursuing consistent

objectives (such as the digitisation of heritage), often result in a reduction in co-design and participatory processes, limiting opportunities for involvement and shared decision-making. The outcome is twofold: on the one hand, process errors emerge, such as the absence of collaborative workflows, annotation tools or opportunities for discussion that are activated too late; on the other hand, design errors concern decisions that affect the final configuration of the project, where technical, aesthetic or curatorial constraints may lead to selective representations, simplifications or omissions that contribute to missing data.

These design shortcomings therefore constitute a wicked problem [44], in which operational limitations and ill-defined objectives are intertwined. To address them, it is not enough to intervene on individual procedures: it is necessary to rethink the design framework as a whole, actively, including communities, stakeholders, and context.

The design dimension of missing data also concerns governance and forms of collaboration in digitisation processes. Some studies propose reading digital cultural heritage as commons, highlighting how rules of participation and models of cooperation directly influence the quality and completeness of datasets. Absences do not depend solely on process errors, but also on how institutions distribute decision-making power and access to the communities involved. From this perspective, missing data becomes the result of design practices that favour some voices over others, confirming the link between governance, communication, and incompleteness [45].

A relevant aspect of missing design data also concerns communication in participatory processes. In several cultural projects involving migrant communities, for example, the difficulty of expressing problems, the preference for direct interactions and mistrust of digital tools have generated relational gaps. These absences depend on the way communication is organised, showing how it can become a critical factor in understanding missing project data [46].

Prescott [28] analyses the biases generated by big data and artificial intelligence systems, highlighting how many gaps in the data stem from opaque design choices: lack of documentation, opacity of models and absence of audit tools. These gaps compromise the ability to understand how data is collected, filtered, and interpreted, creating a form of infrastructural and systemic missing data. To address these critical issues, the author proposes a ten-principles manifesto based on transparency, openness, accountability, and diversity, inviting the Digital Humanities to develop practices of documentation, verification, and reflexivity. These principles outline an operational framework useful for filling design gaps and promoting more traceable, inclusive and fair data production processes.

In this scenario, design takes on a critical and enabling role: not only as a tool for optimisation, but as a practice of mediation capable of promoting co-design and restoring a collective and reflective dimension to digitisation processes. Design gaps thus become a learning ground, where design contributes to improving the connection between infrastructure, knowledge and participation, putting communities and users back at the centre of their cultural heritage [47]. From this perspective, digitisation can be understood as a shared process of recognition and representation. Taken together, these perspectives reveal how projectual absences are shaped not only by procedural shortcomings, but by the infrastructural and governance choices that organise metadata, redistribute context, and ultimately determine which cultural traces remain in place and which are rendered invisible [48–50].

3.5. Taxonomy of Absence

The construction of the taxonomy of missing data represents a synthesis between the critical review of the literature and the empirical observation conducted within the PNRR CHANGES—Spoke 4 programme. The aim is to offer an interpretative lens capable

of relating the various forms of absence that have emerged—processual, epistemic, and projectual—to their systemic causes and to the possible levers for design intervention.

The taxonomy, presented in Table 1, constitutes an operational lens for Advanced Design and allows incompleteness to be read not as a lack, but as a productive condition that cuts across infrastructure, knowledge models and governance practices. In this sense, it allows absences to be interpreted as signs of tension and as spaces for design opportunities, guiding the development of strategies capable of making data, relationships and processes more readable, inclusive, and regenerative.

Table 1. Taxonomy of absences in cultural heritage digitisation processes.

Category	Brief Definition	Systemic Condition	Effect on Digital Heritage	Advanced Design Levers
Processual Absence	Discontinuities and intermediate stages that are removed in the transition from process to consolidated data.	Workflows oriented toward the final deliverable, which do not include mechanisms for recording the process.	Data appear as finished and decontextualized objects: they do not make visible the actors, choices, and conditions that have shaped their identity.	Take missing data as design material, creating interfaces and representations that make the trajectory of data legible and keep its processual dimension open.
Epistemic Absence	Situated forms of knowledge, usage relations, and community interpretations that find no place within descriptive structures.	Standardised metadata models that predefine what can be recorded as data.	Digital heritage appears formally complete but culturally limited: it does not represent the plurality of actors and contexts involved, inhibiting recognition and a sense of belonging.	Treat absence as a space for co-interpretation, designing formats that enable distributed writing, situated annotation, and the progressive integration of perspectives not foreseen by the original model.
Projectual Absence	Lack of infrastructures that sustain over time the relationship between data, actors, and communities.	Projects conceived as closed episodes, lacking mechanisms of continuity, care, and shared responsibility.	Data do not evolve into activated cultural infrastructures: they remain isolated and fail to generate belonging or processes of community appropriation.	Use absence as a community activator, designing platforms and practices of cultural maintenance that keep data open to uses, interpretations, and reactivations over time.

This taxonomy does not have a rigid classificatory value, but rather an operational one. Each category implies a different level of design intervention: the first requires maintenance strategies and transparency of flows; the second, tools for interpretation and critical visualisation; the third, co-curation and inclusive governance devices. Together, these axes and categories define the main contribution of the research: shifting the discourse on missing data from the technical to the cultural and design level, showing how design can act not only as a corrector of gaps, but as a knowledge infrastructure capable of inhabiting and enhancing incompleteness.

3.6. Advanced Design-Driven Model for Digitisation Processes

To make the taxonomy and the model more operational, this section presents a brief illustrative application drawn from the CHANGES project workflows. In order to systematise taxonomy and design practices, a design-driven model (Figure 1) was developed that offers a dynamic view of missing data, linking its three main forms—processual, epistemic, and projectual—to the various operational phases involved in designing a process for

digitising cultural heritage. Incompleteness is considered a structural condition that runs through the entire data life cycle and that design can interpret as material that generates knowledge and action.

From Missing Data to an Advanced Design Model for Cultural Heritage Digitisation

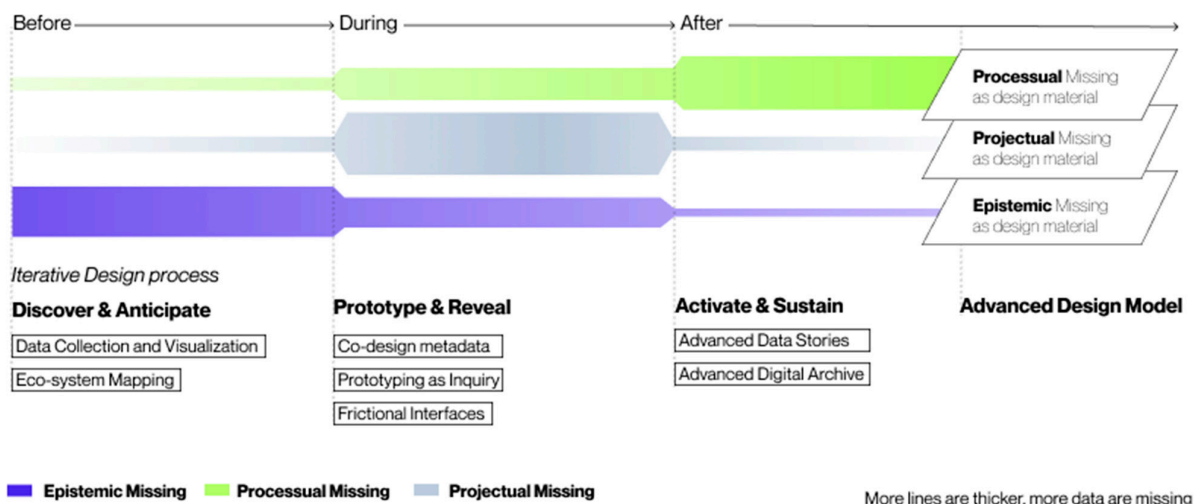


Figure 1. Advanced Design Model for Cultural Heritage Digitisation Processes.

Within this framework, design takes on a reflective and strategic function, articulating its operations in three interconnected moments: before, during, and after the process.

In the preliminary phase, design acts in an exploratory and diagnostic manner, using ecosystem mapping and data collection and visualisation tools to critically read what has already been digitised and what has not. In this phase, missing data of an epistemic nature emerge, linked not to the technical absence of information, but to perspectives and knowledge excluded from descriptive structures. Identifying these gaps allows us to recognise the selective logic already at work in digitisation processes and to guide interventions capable of broadening the field of heritage representation. Mapping what already exists allows us to understand who and what is included, who remains on the margins and which connections have not yet been activated. This type of analysis does not immediately produce operational results but lays the foundations for a more conscious digitisation process, capable of critically questioning the context and guiding subsequent choices towards a more open and inclusive representation of heritage.

During the construction and experimentation phase, design operates as a practice of critical mediation, capable of making processes visible. Epistemic absences are not simply gaps in content, but effects of models of knowledge and power embedded in the descriptive structures and technical languages of digitisation. At this stage, design can introduce tools and reading devices that restore complexity and plurality to data, transforming the interface from a place of consultation to a space for dialogue [39]. The design of critical visualisations, frictional interfaces, and distributed annotation practices allows the uncertain and relational dimensions of digital knowledge to be made explicit [51].

Finally, in the post-digitisation phase, design is confronted with design gaps concerning the sustainability and continuity of cultural processes and infrastructures over time. Here, the project is not limited to ensuring access and preservation but aims to keep heritage alive through activation and reuse practices. Digital data is conceived as a relational artefact, capable of evolving through new meanings and new forms of participation. In this sense, design becomes a practice of cultural maintenance and collective care, capable

of reactivating the content and relationships that support it, restoring centrality to the communities that are part of that heritage [52].

The model links processual, epistemic, and projectual absences to the phases of preparation, construction, and post-digitisation activation, and summarises the main analytical outcomes of the study.

3.7. Illustrative Application: Making Processual Absences Legible

The pilot for the digital twin of the Aldrovandi exhibition (2023–2025) provided a situated context for examining how processual absences emerge within real digitisation workflows. Approximately 300 objects were digitised through photogrammetry and structured-light scanning during museum closing days. The workflow involved mesh cleaning and optimisation, metadata harmonisation, dataset organisation and the preparation of assets for online publication. In parallel, design activities—such as the prototyping of the digital library, the definition of the content architecture and the development of UX pathways through iterative Figma prototypes—offered a mediating perspective that connected technical decisions with future interpretative and experiential needs. In this phase, the illustrative application verified only one of the three mapped dimensions of the taxonomy.

Direct observation and co-design work with the modelling and cataloguing teams revealed a recurrent pattern. For each object, multiple intermediate versions were produced during the 3D processing pipeline, typically corresponding to key stages such as alignment, cleaning and simplification. These intermediate meshes were generally stored temporarily on local workstations and subsequently overwritten during optimisation, resulting in the preservation of only the final lightweight model. As a consequence, the sequence of transformations shaping the final geometry remained largely undocumented.

From a design perspective, the absence of these operative steps had clear implications. The lack of traceability made it difficult to reconstruct modelling decisions, assess how specific adjustments influenced the geometry or compare potential alternatives. Through co-design sessions and iterative prototyping, the need to retain at least a minimal set of intermediate versions emerged as a tangible requirement to support more transparent and reusable digitisation processes.

Within the proposed taxonomy, this condition is interpreted as a processual absence: a form of missing data that does not stem from the lack of source information, but from the absence of mechanisms that document transitions within the workflow. Seen through a Research through Design perspective, the case served as a situated design insight grounded in the needs expressed by researchers, highlighting the importance of retaining selected intermediate versions and associating them with brief process notes. This example illustrates how the analytical model responds to needs emerging directly from practice and supports improvements in real digitisation contexts by making workflow decisions more legible and reusable.

4. Discussion: Missing Data as a Project Material

The taxonomy and the model presented in Section 3 show that incompleteness is a structural condition of digital heritage practices. Through an Advanced Design perspective, absences emerge as analytical materials that reveal epistemic assumptions, infrastructural limits and organisational priorities embedded in digitisation processes. This section discusses the implications of these findings for design research and for the cultural understanding of digital heritage.

After the digitisation phase, data often enter preservation-oriented systems that stabilise content and limit later reinterpretation. In this context, design provides a mediating

role by keeping heritage open to questioning and reuse. Narrative paths, data stories and alternative visualisations support continuous engagement, enabling new readings and different forms of connection with the material.

Openness also highlights which data remain active and which risk falling into disuse. Digital longevity depends on the capacity of a system to accommodate new activations over time. The work carried out during the project indicates that digital data production involves interpretations, choices and negotiated relations among multiple actors. Collective discussions showed that data gain meaning when circulated and re-examined. They behave less like completed artefacts and more like materials that evolve through collaborative practices, including metadata co-creation [53].

Considering data as a dynamic element shifts attention toward their construction and interpretation. This aligns with participatory design approaches, which focus on shared responsibility in the production and use of information. Visibility and invisibility within datasets depend on design configurations and on the relations between those who digitise, those who interpret and those who rely on the content.

Otherwise, the analysis of the workflows and the design-led reading of processual absences revealed a series of elements that deepen the understanding of how missing data emerge within operational contexts, including:

- processual opacity, visible in the limited preservation of intermediate steps and the consequent difficulty in retracing modelling decisions;
- fragmented information flows, due to the movement of data across tools and workstations without stable connections;
- limited interoperability of practices, linked to local routines, storage constraints and tool-specific approaches that prevented the formation of a coherent workflow.

The results also indicate broader critical issues that shape the conditions under which incompleteness appears, such as:

- temporal misalignment between digitisation, cataloguing and design activities, which follow different rhythms and create discontinuities across the process;
- technical and infrastructural constraints, including large file sizes, limited storage and the absence of repositories for intermediate stages;
- the tension between situated practices and standardisation, since local design decisions do not always converge with interoperability requirements.

These elements show that incompleteness develops through the interaction between technical systems, institutional structures and everyday practices. The contribution of Advanced Design lies in making these dynamics visible and in enabling their transformation through design-led forms of mediation, interpretation and activation.

5. Conclusions

The observations carried out in the project show that the role of design in digitisation processes does not lie solely in the final stage of delivering content. A substantial part of its contribution unfolds earlier, while data are being produced and interpreted, and later, when they begin to circulate within systems that tend to stabilise or fragment them. At these moments, many operational decisions remain implicit or disperse across workflows, making it difficult to retrace how digital heritage comes into being. The perspective of Advanced Design makes it possible to approach these dynamics with a broader interpretative lens, one that connects technical infrastructures, knowledge models and forms of participation.

The taxonomy proposed in this study, together with the model that operationalises it, does not aim to resolve the question of absences. Rather, it offers a framework for recognising them as expressions of systemic conditions that shape the production, organisation and

activation of digital heritage. What is missing is not always an error or a technical oversight; more often, it signals priorities, constraints and epistemic assumptions embedded in the infrastructures through which data are constructed. The CHANGES case study made these dynamics particularly tangible, revealing how absences can become design material once they are made visible and collectively discussed.

In this sense, Advanced Design informs practices that help keep digital heritage open, interpretable and capable of evolving over time. Three directions emerge as particularly significant:

- Anticipatory and systemic practices, which support the design of infrastructures and processes able to sustain data, relations and narratives in the long term, preventing premature stabilisation or isolation of content;
- Frictional and speculative practices, which bring ambiguities and blind spots to the surface, treating absences as opportunities for critical reflection and enabling new forms of inquiry and interpretation;
- Co-design and inclusive practices, which widen the interpretative field through the involvement of communities, experts and users, fostering distributed writing, collective revision and shared care of data and metadata.

These directions do not provide definitive solutions, but articulate a design attitude attuned to the situated and relational nature of digital heritage. Further work is needed to understand how such practices can be consolidated in different institutional contexts and translated into stable operational tools. What clearly emerges, however, is that working with absence means keeping open the conditions for future reinterpretations: not filling gaps but accompanying them, allowing digitisation to become a dialogic and continually reactivatable cultural process.

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References

1. Council of the European Union. Council Conclusions on the recovery, resilience and sustainability of the cultural and creative sectors. *Off. J. Eur. Union* **2021**, *C 209*, 3–9. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2021_209_R_0003 (accessed on 27 October 2025).
2. Europeana Foundation. *Annual Report & Accounts 2024*; Europeana Foundation: The Hague, The Netherlands, 2025.
3. *Piano Nazionale di Digitalizzazione del Patrimonio Culturale: Versione 1.1—2022–2026*; Ministero della Cultura: Rome, Italy, 2023.
4. Presidency of the Council of Ministers. *Piano Nazionale di Ripresa e Resilienza (PNRR)*; Government of Italy: Rome, Italy, 2021.
5. Finnis, J.; Kennedy, A. *The Digital Transformation Agenda and GLAMs: A Quick Scan Report for Europeana*; Culture24 for Europeana Foundation: The Hague, The Netherlands, 2020.
6. Messarra, L.; Freeland, C.; Ziskina, J. *Vanishing Culture: A Report on Our Fragile Cultural Record*. 2024. Available online: <http://archive.org/details/vanishing-culture-report> (accessed on 27 October 2025).

7. Celaschi, F.; Trocchianesi, R. *Design & Beni Culturali: La Cultura del Progetto Nella Valorizzazione del Bene Culturale*; Poli Design: Milan, Italy, 2004.
8. De Giorgi, C.; Germak, C.; Bozzola, M. *Design per i Beni Culturali Territoriali: Merchandising Museale e Artigianato*; Celid: Turin, Italy, 2012.
9. Lupo, E.; Trocchianesi, R. (Eds.) *Design & Cultural Heritage 3: Progetto e Memoria del Temporaneo*; Mondadori Electa: Milan, Italy, 2014.
10. Celi, M.; Formia, E. (Eds.) *Humanities Design Lab: Le Culture del Progetto e le Scienze Umane e Sociali*; Maggioli Editore: Santarcangelo di Romagna, Italy, 2016.
11. Irace, F.; Ciagà, G.L. (Eds.) *Design & Cultural Heritage*; Mondadori Electa: Milan, Italy, 2013.
12. Lupo, E. Design e Innovazione del Patrimonio Culturale: Connessioni Phygital per un Patrimonio di Prossimità. *Agathón* **2021**, *10*, 186–199. [[CrossRef](#)]
13. Lupton, E. *Design is Storytelling*; Cooper Hewitt: New York, NY, USA, 2017.
14. Mason, M.; Vavoula, G. Digital Cultural Heritage Design Practice: A Conceptual Framework. *Des. J.* **2021**, *24*, 405–424. [[CrossRef](#)]
15. Trocchianesi, R.; Bollini, L. Design, Digital Humanities, and Information Visualization for Cultural Heritage. *Multimodal Technol. Interact.* **2023**, *7*, 102. [[CrossRef](#)]
16. Belteki, J.; Rees, A.; Sichani, A.-M. Datafication and Cultural Heritage Collections Data Infrastructures: Critical Perspectives on Documentation, Cataloguing and Data-Sharing in Cultural Heritage Institutions. *J. Open Humanit. Data* **2025**, *11*, 277. [[CrossRef](#)]
17. *Cultural Heritage Active Innovation for Next-Gen Sustainable Society*; PNRR CHANGES Programme: Rome, Italy, 2023.
18. Smith, L. *Uses of Heritage*; Routledge: London, UK, 2006. [[CrossRef](#)]
19. Laurel, B. (Ed.) *Design Research: Methods and Perspectives*; MIT Press: Cambridge, MA, USA, 2003.
20. Celi, M.; Celaschi, F. *AdvanceDesign: Visioni, Percorsi e Strumenti per Predisporsi All'innovazione Continua*; McGraw-Hill: Milan, Italy, 2010.
21. Deserti, A. Mappe dell'advance design. In *Advance Design: Visioni, Percorsi e Strumenti per Predisporsi All'innovazione Continua*; McGraw-Hill: Milan, Italy, 2010.
22. Iñiguez Flores, R.; Hernandis Ortuño, B.; Holliger, C.; Monterrubio Soto, J.C. Advanced design as a process for knowledge creation. In Proceedings of the 5th International Forum of Design as a Process "The Shapes of the Future as the Front End of Design Driven Innovation", Guadalajara, Mexico, 18–20 September 2014; Design as a Process International Forum: Guadalajara, Mexico, 2014; pp. 151–156.
23. Iñiguez Flores, R.; Celaschi, F.; Formia, E.; León Morán, R.M. The extended praxis of design: Towards a characterization of the advanced design cultures. In The Design After, Proceedings of the Cumulus Conference Proceedings, Bogota, Colombia, 30 October–1 November 2019; Cumulus Association of Universities and Colleges of Art, Design and Media: Bogota, Colombia, 2019; pp. 449–458.
24. Colitti, S. Key References on Missing Data in Cultural Heritage Digitisation. Zenodo. 2025. Available online: <https://zenodo.org/records/17663057> (accessed on 27 October 2025).
25. Reason, J. *Human Error*; Cambridge University Press: Cambridge, UK, 1990. [[CrossRef](#)]
26. Bossema, F.G.; Coban, S.B.; Kostenko, A.; Van Duin, P.; Dorscheid, J.; Garachon, I.; Hermens, E.; Van Liere, R.; Batenburg, K.J. Integrating Expert Feedback on the Spot in a Time-Efficient Explorative CT Scanning Workflow for Cultural Heritage Objects. *J. Cult. Herit.* **2021**, *49*, 38–47. [[CrossRef](#)]
27. Uzelac, A.; Lovrinić Higgins, B. From Data to Impact: Assessing the Value of Cultural Heritage in the Digital Age. *Heritage* **2025**, *8*, 117. [[CrossRef](#)]
28. Prescott, A. Bias in Big Data, Machine Learning and AI: What Lessons for the Digital Humanities? *Digit. Humanit. Q.* **2023**, *17*, 689.
29. Gitelman, L. *"Raw Data" is an Oxymoron*; MIT Press: Cambridge, MA, USA, 2013.
30. Bosco, A.; Bulegato, F.; Gasparotto, S. The Digital Archive as an Inclusive Tool for Knowledge Construction through Design Practices. *Diid Disegno Ind. Ind. Des. (DSI 1)* **2023**, *2023*, 238–247. [[CrossRef](#)]
31. Leonelli, S. *Data-Centric Biology: A Philosophical Study*; University of Chicago Press: Chicago, IL, USA, 2016.
32. Borgman, C.L. *Big Data, Little Data, No Data*; MIT Press: Cambridge, MA, USA, 2015.
33. Kitchin, R. *The Data Revolution*; Sage: London, UK, 2014.
34. Duque, M.; Willim, R.; Ruckenstein, M.; Pink, S. Broken data: Conceptualising data in an emerging world. *Big Data Soc.* **2018**, *5*, 2053951717753228. [[CrossRef](#)]
35. Acker, A. *Data Craft: The Manipulation of Data in Digital Preservation*; Data & Society Research Institute: New York, NY, USA, 2018; Available online: <https://datasociety.net/library/data-craft/> (accessed on 27 October 2025).
36. Faniel, I.M.; Yakel, E. Practices do not make perfect: Disciplinary data sharing and reuse practices and their implications for repository data curation. In *Curating Research Data, Volume 1: Practical Strategies for Your Digital Repository*; Johnston, L., Ed.; Association of College and Research Libraries Press: Chicago, IL, USA, 2017.

37. Schäfer, M.T.; van Es, K. (Eds.) *The Datafied Society: Studying Culture Through Data*; Amsterdam University Press: Amsterdam, The Netherlands, 2017.
38. D'Ignazio, C.; Klein, L.F. *Data Feminism*; MIT Press: Cambridge, MA, USA, 2020.
39. Loukissas, Y.A. *All Data are Local: Thinking Critically in a Data-Driven Society*; MIT Press: Cambridge, MA, USA, 2019.
40. Haraway, D. Situated knowledges: The science question in feminism and the privilege of partial perspective. *Fem. Stud.* **1988**, *14*, 575–599. [[CrossRef](#)]
41. Müller, K. *Digital Archives and Collections*; Berghahn Books: New York, NY, USA, 2021. [[CrossRef](#)]
42. Sacco, P.L.; Bialowolski, P.; Weziak-Bialowolska, D. Culture and Creativity, Skills Building, and Growth: What Have We Missed? *Humanit. Soc. Sci. Commun.* **2025**, *12*, 236. [[CrossRef](#)]
43. Rosenberg, D. Data before the fact. In Proceedings of the 126th Annual Meeting of the American Historical Association, Chicago, IL, USA, 5–8 January 2012.
44. Rittel, H.W.; Webber, M.M. Dilemmas in a general theory of planning. *Policy Sci.* **1973**, *4*, 155–169. [[CrossRef](#)]
45. Pandiani, D.S.M. Bridging the Gap: Decoding Abstract Concepts in Cultural Heritage Images. In *Decoding Cultural Heritage*; Moral-Andrés, F., Merino-Gómez, E., Reviriego, P., Eds.; Springer Nature: Cham, Switzerland, 2024; pp. 157–189. [[CrossRef](#)]
46. Cesário, V.; Campos, P. Bridging Cultural Gaps: Insights from Communication in Migrant-Inclusive Cultural Initiatives. *Societies* **2025**, *15*, 83. [[CrossRef](#)]
47. Lupo, E.; Camosino, G.; Gobbo, B.; Motta, M.; Mauri, M.; Parente, M. Digital for Heritage and Museums: Design-Driven Changes and Challenges. In Proceedings of the IASDR 2023: Life Changing Design, Milan, Italy, 9–13 October 2023. [[CrossRef](#)]
48. Mayernik, M.; Acker, A. Tracing the traces: The critical role of metadata within networked communications. *J. Assoc. Inf. Sci. Technol.* **2018**, *69*, 177–185. [[CrossRef](#)]
49. Thylstrup, N.B. Data out of place. *Big Data Soc.* **2018**, *6*. [[CrossRef](#)]
50. Plantin, J.-C. *Data Cleaners: Practices of Repair in Infrastructures of Data*; Oxford Internet Institute: Oxford, UK, 2019.
51. Dunne, A.; Raby, F. *Design Noir: The Secret Life of Electronic Objects*; Bloomsbury Publishing: London, UK, 2021. [[CrossRef](#)]
52. Costanza-Chock, S. *Design Justice: Community-Led Practices to Build the Worlds We Need*; MIT Press: Cambridge, MA, USA, 2020.
53. Colitti, S.; Lengua, M.; Formia, E.; Gasparotto, S. Designing metadata for plural and participatory cultural heritage. In Proceedings of the Digital Heritage Conference, Siena, Italy, 8–12 September 2025.

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