DIGITAL HERITAGE 2025

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Collaborative Cloud for CH (ECHOES SESSION)

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H2IOSC Project Development

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Paola Stolfi, Elia Onofri, and Gabriella Bretti

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dh.20253331 | Small Codes: a platform for digital resources and tools for minority languages and dialects
Carlo Zoli, Greta Mazzaggio, and Neri Binazzi

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dh.20253336 | HERIFORGE Polish Hub As Digital Heritage Growing XR Community
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Victor Yuan and Alan Miller

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Phygital Worlds and XR in Cultural Heritage

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DIGITAL HERITAGE (2025)
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Early Stage of Community-Driven UI/UX Refactoring of the Open-Source ATON Framework

C.F. Amadei† [1], M. Massidda[1], S. Menconero[1], G. Gosti [1], B. Fanini [1]

[1] National Research Council (CNR), Institute of Heritage Science, Italy

Abstract

The digitisation of Cultural Heritage has become a central practice in recent years, responding to the needs for the preservation, enhancement and study of cultural assets. The increasing production of digital resources has seen the development of online platforms for visualising and sharing 3D models and 360 panoramas, also facilitating access and management of this type of data. The democratisation of these tools, coupled with their increasing user-friendliness, has expanded and diversified the scientific communities involved, widening the catchment area from a single audience of experts to general users. This has led to the emergence of new needs on the part of the users involved, necessitating a re-evaluation of the logic underpinning the consumption of digital services. This paper analyses the case study of ATON: an open-source framework design for creating Web3D/WebXR apps interacting with CH objects and 3D scenes on the Web, which underwent a complete refactoring of the User eXperience (UX) and User Interface (UI) through the H2IOSC project. Starting with the analysis of the framework and its structure, we define which parts are involved in the complete refactoring. We discuss the milestones of the application's development from 2015 to the present, through the framework's increasing involvement in national and international project activities, highlighting the evolving user needs and implementations of new tools and functionalities through a bottom-up design approach. We first illustrate the community's role in the co-creation of ATON and its involvement in UX and UI refactoring activities. We present user research and design parts. Through the research plan, we describe the project from the objectives and research questions, debating the chosen methodologies, the target audience involved and the expected results. Finally, we present and discuss the choices related to the design process, covering the conceptualization of essential components, the development of the Design System (DS), and its implementation as a renewed built-in UI module. We also explore its integration into various ready-to-use blueprints and templates, analysing how it improves performance in the development phase. Additionally, we examine the trade-offs encountered in the components' abstraction level definition and the selection of suitable UI libraries by comparing existing solutions.

CCS Concepts

• ***Human-centered computing*** → *User interface toolkits;* ***User centered design;*** *User interface design; Interface design prototyping; User centered design; Interactive systems and tools;* ***User interface design;*** *User interface toolkits; Interface design prototyping;* ***User centered design;*** *Interactive systems and tools;*

1. Introduction

The digitisation of Cultural Heritage has become a central practice in recent years, fostering the development of advanced tools for managing acquired data. Among these, Web3D technologies and new digital standards are significant examples, as they allow data to be visualised, managed and shared directly through the web, thus opening up new perspectives and opportunities for the Cultural Heritage sector. In addition, the rapid spread of these tools among the various scientific communities has made it necessary to adapt them to an ever-widening audience of users with specific needs.

This paper discusses the refactoring case study of ATON, an open-source framework developed since 2015 for creating Web3D/WebXR applications that interact with CH objects and 3D scenes on the Web. Within the H2IOSC project, under task 6.3 (under E-RIHS infrastructure) 'WebXR Services for HS', several refactoring activities are planned. In particular, we explore the initial phase of refactoring from the evaluation of the framework, to the creation of the research plan and the adoption of reusable components. The redesign of the ATON framework followed objectives such as improving the UX, updating the UI and ensuring that the logic behind the product remains intuitive. Close attention will be paid to the role of the community in guiding the evolution of the framework, particularly in identifying usability issues and architectural limitations that have emerged over ten years of development.

† chiaraflorise.amadei@cnr.it

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The refactoring process covered both visual and structural aspects, introducing a more modular and maintainable code base and a redesigned interface tailored to WebXR's modern functionality. The focus will be on the user interface and user experience, with attention to the user needs that emerged during the early research phases. The ongoing architectural refactoring of the framework will be discussed in a separate paper. The technical and social aspects of this transformation will be highlighted, assessing its impact on performance, accessibility and long-term community involvement. The accent will be placed on the User Centred Design process chosen to guide the three project phases: project research, project design and project evaluation. This article deals with the first phase and the first results of the second, analysing the methodologies and tools chosen. We close the article by articulating conclusions and recommendations and briefly discussing some possible future solutions for project evaluation.

2. Background

2.1. Overview of the framework's history and its ecosystem

ATON is an open-source framework based on Node.js and Three.js designed to create Web3D/WebXR applications (presenters, applied games, tools, etc.) that interact with CH objects and 3D scenes on the Web [Ato]. A flexible and modular solution, offering innovative and advanced functionalities for the Cultural Heritage sector in terms of 3D presentation, annotation, immersive interaction and real-time collaboration. Its core components and continuously updated functionalities are available to users in cross-sectoral fields to realise and deploy rich, universal and liquid Web3D applications. Among the various components, the framework offers "Hathor" (the official built-in front-end) and Shu (basic back-end). The first is used to present 3D models and scenes to the final users, without any code development required, with the possibility to extend it with custom functionalities. In particular, Hathor offers several built-in components and elements: buttons, toolbars, modal pop-ups, etc [FFD*21]. While the latter (Shu) is the basic back-end where authors, editors or content creators can access to publish and manage 3D collections and scenes. Shu allows authenticated users to create scenes from objects in their collections (*e.g.*, 3D models, panoramas, media) and publish them on the main landing page, making the content publicly accessible from any device. Through the profiler and scalable rendering system, ATON ensures responsive, universal and liquid consumption of 3D content on the web, from mobile devices, PCs, museum kiosks and 3-DoF or 6-DoF HMDs for immersive VR.

The ATON architecture and its components are the product of national and international projects, experiences and user feedback gathered during the last years, which allowed the framework to evolve into the current state (version 3.0). Indeed, the involvement in projects and the continuous developments have opened up a new scenario: the demand to implement custom logic and features within the ATON core. The urge to refactor and offer an internal library of reusable components also stems from the need to offer users the possibility of developing new customised apps in an agile manner, thanks also to the new architecture developed within the H2IOSC project.

2.2. Role of Community in Shaping the Framework

The open-source ATON framework is the result of research and development activities carried out since 2015 through national and international projects. The use of ATON within the projects is growing steadily; this is due both to the increase of digitisation in the field of Cultural Heritage and to the continuous involvement of the community in its improvement (see Table 1). Over the years, researchers and museum organisations (*e.g.*, project participants, researchers, fellows, museums, etc.) have actively contributed to its creation, maintenance, dissemination and improvement. The open-source approach of the framework provided a collaborative ecosystem within the community that fostered project innovation. Community members continue to provide support in various forms: bug fixes, proposals for new functionalities, creation of documentation (*e.g.*, guides, tutorials, use cases), promotion of the framework through participation in conferences and dissemination events [FFD*21]. In addition, its development also depends on bottom-up input from the community through requests derived from recognition of the real-world experiences and contexts of end users from different domains [AVDD20]. We decided to base the refactoring on co-design, trying to merge requests based on theoretical evidence ('top-down input') with requests derived from mapping the lived experiences and everyday contexts of end-users ('bottom-up input'). Our approach to the redesign ATON framework involves the potential users as part of the design team from the very outset, when their perspectives can have the most influence, rather than using them post hoc as part of an analysis team (of) end user representatives [GL85]. The decision to promote these bi-directional strategies (top-down and bottom-up input) enabled the early stages of the co-design process to be improved so as to promote synergy rather than concession.

2.3. Previous attempts around refactoring

2.3.1. Preliminary Attempt: The First ATON UI Toolkit

In the starting phases of ATON's UI/UX refactoring, a first attempt has been conducted on the design of a built-in UI toolkit aimed to support faster realization of UI elements, both for ATON's elements and for web-apps created through it. The intention was to provide a lightweight, internal library that would empower users by reducing effort in creating web interfaces (providing utilities to create from single elements to full interface layouts) without relying on external frameworks. This first work, carried out between 2023 and 2024, allowed us to experiment with different patterns of abstraction and flexibility, identifying key critical points and questions. The emerging considerations have proved to be relevant as remarkable steps toward a more structured design system.

2.3.2. Starting Questions and Early Objectives

This attempt started from two main questions:

- what kind of features should be developed, considering common Web-design requirements into ATON applications contexts;
- how these elements should be proposed, framed within a hierarchical structure of inheritance.

Project	Output	Typology	Year(s)	Reference
SSHOC	EMviq-Extended Matrix Visual Inspector and Querier	Web 3D tool	2015-ongoing	[EMv]
Sarmizegetusa	Turn on the History	Web-app (V1.0)	2016	[CDL16]
ARIADNE	Landscape Services	Set of cloud-based services	2016	[Ari]
ARIADNE	Calore Valley Virtual museum	Web-app (V 1.0)	2016	[Val]
THE WINCKELMANN300	NIXAMP	Web-app (V 2.0)	2018	[GBML*18]
B.A.C.K. TO T.H.E. F.U.T.U.RE	REDRASK	Web-app (V 2.0)	2020	[Bac]
Archeologia e Calcolatori	Archeologia e Calcolatori 3D viewer	Hathor	2021	[RP21]
Montebelluna Posmon	Montebelluna Web-App	Web-app	2021	[Mon]
VAR.HEE	H2O Web-App	Web-app	2021	[LFBB20]
Arzachena Civiltà Millenaria	ArzApp	Hathor	2022	[Arz]
Brancacci Project	Brancacci POV	Web-app	2022-ongoing	[FRF*23]
e-Archeo	e-Archeo 3D	Web-app	2022	[MFP24]
Segni Archeologia	Segni app	Web-app	2022	[Seg]
N.A.	Geophysics App @ festival della scienza	Web-app	2022	[fds]
N.A.	San Massimo a Forcona	Web-app	2022	[San]
ARTEMISIA	Digital twin	Web-app	2023	[Art]
Bilateral Project	Vani Virtual eXperience	Hathor	2023	[Van]
Codex4D	Codex4D Web-app	Web-app	2023	[POFC23]
H2IOSC, PERCEIVE, Changes	Experiment Planner pilot	Web-app	2023	[MBF*24]
100 Years of Science	100 Years of Science online experience	Web-app	2023	[100]
CHANGES	Aldrovandi Digital Twin	Web-app	2024-ongoing	[BBB*24]
Grotte di Castro	N.A.	Hathor	2024	[GG*24]
PERCEIVE	MuLaX	Web-app	2024	N.A.
MetaMic	N.A.	Web-app	2024-ongoing	[Met]
H2IOSC	/imagine	Web-app	2024	[FG24]
H2IOSC	HeriVerse, SENNSE, Illuminated manuscript	Web-apps	2024-ongoing	N.A.
H2IOSC	Merkhet (Interlumo pilot)	Web-app	2024-ongoing	[FG24]
PhD in Heritage Science, H2IOSC	illuminAI	Web-app	2024-ongoing	N.A.
H2IOSC	AnGa	Web-app	2025	[Ang]
Knowledge of Things (KNOT)	N.A.	Hathor	2025	N.A.
TRACE	N.A.	Web-app	2025	N.A

Table 1: *ATON's involvement in national and international projects from 2015 to 2025.*

First, we identified a series of UI elements that would be most useful for ATON users, investigating what kind of components, interactions, and composite elements could facilitate interface creation in Web3D applications. We considered the most used UI elements in web design: from low-level elements (*e.g.*, buttons, images, inputs); to mid-level components (*e.g.*, popups, navigation panels); also scouting higher-level aggregations such as forms and data visualizations. Second, we explored the structural approach that could ensure consistency and extensibility. This included reasoning around the level of abstraction to adopt, choosing between functional or class-based structure, defining inheritance or component wrapping patterns, and how to keep the options flexible but manageable. Early on emerged the core principle of maximize reuse and prioritize flexibility.

2.3.3. Implementation and Technical Choices

The toolkit was implemented as a lightweight library, keeping the structure as simple as possible in the early stage of development. We avoided integrating external UI libraries, opting for a dependency-free implementation with core but flexible functionalities to generate UI elements with a small styling footprint.

In progression, components of increasing complexity have been added:

- atomic elements such as `ui.button`, `ui.image`,`ui.input`;
- wrappers like `ui.group`, `ui.container`, `ui.popup`, `ui.sidebar`, `ui.navbar`;
- compound elements such as `ui.card`, `ui.form`, `ui.summary`, `ui.prompt`.

2.3.4. Discoveries Along the Way

During the development of the UI toolkit two key considerations emerged: one referring to the lowest levels of abstraction, into the toolkit's core, and the other one referring to the external sides, questioning the boundaries of our implementation.

2.3.5. Core

During the experimentation, a building block that emerged as a key element was the `createEl` function: a generic utility used to produce Document Object Model (DOM) elements based on a flexible options parameter, which takes several properties (10) to generate a highly customizable object. This function became the internal engine behind most other components. It enabled fast development and reuse, but it also revealed a limitation: as options became more complex, the function became less usable, particularly for non-expert users working with HTML/JS. This function, and others similarly, internally serves as a backbone and proved invaluable for fast and standardized element creation; but externally, its abstraction hindered simplicity of usage, letting emerging the consideration that there is a threshold where reusability conflicted with clarity.

2.3.6. Examples and Use Cases

Despite its exploratory nature, the toolkit highlights several effective scenarios of practical use and experiments within ATON-

based applications. One example is `ui.promptDialog`: a specific component designed to request user input through a modal interaction. It receives a list of `ui.input` components as parameters, automatically assembles a form, wraps it in a popup, and returns the user-submitted data in a structured format. Each of these subcomponents (`ui.form, ui.input, ui.popup`) can be also used independently, enabling users to build custom interfaces. This component was adopted in the Experiment Planner Prototype [MBF*24], where users are prompted at the startup of the application to configure experiment parameters. Another example is the `ui.summary`: used to visualize the contents of an ATON collection. Using ATON API, the function scans the list of available .gltf models and dynamically generates a nested structure of buttons, each of which loads the corresponding model in the 3D scene. This function created a lightweight, interactive browsing interface that could be easily adapted to various collections.

2.3.7. Conclusion comments

Considering insights and tentatives, the first toolkit acted as a playground for design decisions. It helped us understand where flexibility becomes over-complication, and where abstraction loses its usefulness. It revealed the value of layered architecture and moved us to prioritize a sense of balance, where modularity supports flexibility, without sacrificing user's readability.

3. User Research as a Design Driver

The following sections provide an overview of the role of user research in this early stage of refactoring. The methodologies, objectives, participants involved and first results will be analysed.

3.1. Overview: Methodology, goal and target

The initial phase of the refactoring process encompassed conducting research on the end users, organised in a research plan. This process involves the collection of information regarding user demographics, needs, habits, context, constraints and requests. This data serves to guide the future design and development phases of the project. The main objectives of the research plan were to: (a) identify design problems, (b) formulate hypotheses on new functionalities, (c) investigate user and community needs. In particular, to achieve these objectives, the following research questions (RQs) were posed:

RQ1 Are there design problems in the framework?
RQ2 Are there different user requirements that have arisen in recent years?
RQ3 What are ATON's main competitors?
RQ4 How much and why are potential users loyal to the competitor?

In order to obtain results that were reliable and representative of the end users, the selection of testers included both internal laboratory users and external users. For the first category, was selected a sample of users as broad as possible taking in consideration salient user characteristics such as experience, seniority and research focus (*e.g.* archaeology, architecture, diagnostic, museum exhibition). While external users were involved from the ATON community

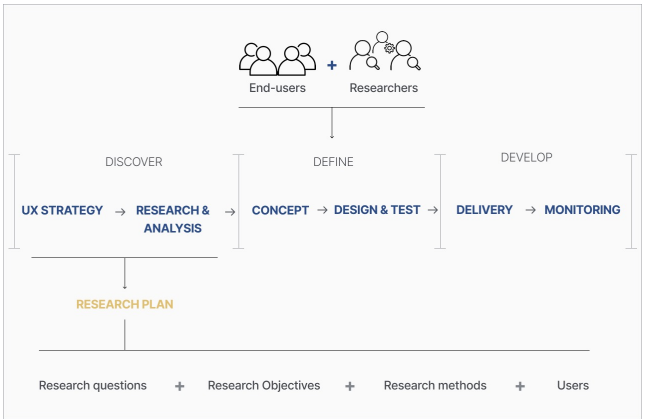

Figure 1: *Research Plan: Overview of research activities for the redesign of ATON framework.*

members by an open call diffused through the framework's channels. From the outset, it became evident that it would be beneficial to gather feedback from users across different domains and those with varying levels of knowledge of the system. In fact, the User centered design (UCD) principle was adopted. UCD is concerned with incorporating the user's perspective into the software development process in order to achieve a usable system [Mag01]. One of the key principles concerns placing users at the center of design decisions, actively involving them and clearly understanding their needs and tasks.

Once the objectives, research questions, users and principles had been defined, it was necessary to establish the testing method. Since the range of questions and objectives to be achieved was so wide, it was decided to proceed with different research methods, each specific to gain the set objectives. Therefore, different survey methods such as summative and formative evaluations were considered, obtaining both qualitative and quantitative data. Specifically, summative evaluations describe how well a design performs, often compared to a benchmark such as a prior version of the design or a competitor. While formative evaluations focus on determining which aspects of the design work well or not, and why. These evaluations occur throughout a redesign and provide information to incrementally improve the interface. The formative evaluation is done in order to help improve the interface as part of an iterative design process. Its main goal is thus to learn which detailed aspects of the interface are good and bad, and how the design can be improved [Nie94b].

3.2. Research plan

The research phase was structured as a design driver: an iterative process involving a multidisciplinary team. In the next sections, the early stages of the research plan will be discussed (see Figure 1).

3.2.1. Analysis of the existing system and competitors

One of the first steps of the research plan was the evaluation of the current app, to highlight the strengths and weaknesses of the framework and to prioritise re-factoring intervention flows. Through a

summative evaluation, the main workflows of the framework were analysed, with the aim of analysing the UX and determining in which flows a major redesign is concentrated. The analysis phase of the system in its current state was performed from three main flows: the dashboard and login, the creation of a new scene and the modification of an existing scene. To check for pain points and possible loops, user flows were created from three use cases to assess the usability of the framework. The use cases were: (a) visualisation of a public scene (b), creating a new scene (c), modification of an existing scene. The evaluation was based on the 10 Usability Heuristics [Nie94a] and the usability design principles developed for the study of mobile devices [JPLY06], where usability was characterised into five components, namely cognition support, information support, interaction support, user support and performance support. The five components address the impact on user performance, cover a wide range of design considerations, and offer a comprehensive understanding of usability that informs mobile application design. Particular attention was paid to this stage since the appearance of a framework plays a fundamental role in how users perceive its usability [TKI00, HAV16]. Through a comprehensive and detailed evaluation, usability problems were identified and allowed to be corrected in an iterative design process [HB23]. The results of the evaluation are shown in Table 2.

The evaluation phase was an opportunity to uncover some bugs in the use case of modifying an existing scene (c).

Finally, a competitor analysis was conducted to stimulate innovation and improvement. After an evaluation of the competitors, based on the functionality and tools provided by ATON, it was decided to focus on Sketchfab. The selection was determined by the presence of similar functionalities to those of ATON, or to be implemented in the future, and by the widespread use of the tool. Competitor analysis allowed us to find solutions to some of ATON's weaknesses in order to develop similar functionalities and implement design solutions. In particular:

- **UX of the scene creation**: drag-drop of files to upload;
- **Functionality in edit mode**: light management, moving and rotating the model, advanced management of VR/AR settings, post-processing filters

3.2.2. Contextual inquiry

A behavioural research study was also conducted to observe how users interact with the ATON framework through direct observation. Contextual investigation was chosen as one of the methodologies. This approach involved the observation and in-depth interview of a small sample of users, in order to investigate practices and behaviour. The target audience identified for this phase was a group of four users within the laboratory, with varying degrees of expertise and research interests (See Figure 2). Our primary objective was to identify potential patterns of behaviour in the use of the framework and to find out the main needs of the users.

The contextual inquiry was conducted in the laboratory by two researchers, a facilitator who explained the tasks and set the questions and an observer who took notes. The users were given simple tasks to perform, and their performance, thoughts and attitudes were recorded and analysed at the end of each session by the two researchers. To avoid conducting the test directly on the chosen sample of users, an internal pilot test was planned to verify the effectiveness and efficiency of the script. During the pilot test, a limited help policy was discussed concerning when and how to provide help to the tester.

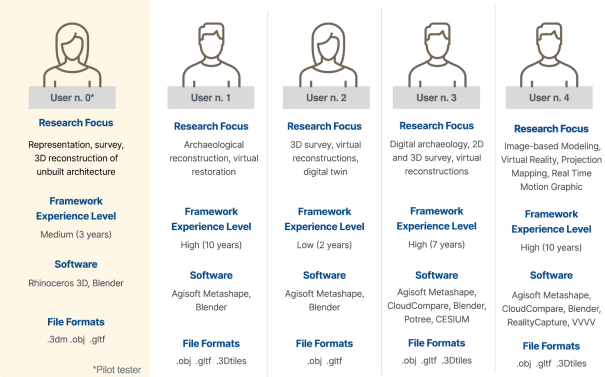

Figure 2: *Sample of users for contextual inquiry research phase.*

The test consisted of two parts: in the first part, each user was asked to upload their own 3D model and create a scene from it. In the second part, they were asked open-ended questions and, if necessary, follow-up questions not included in the script. The questions were formulated openly and neutrally, encouraging users to answer in full sentences. During the second part of the contextual inquiry, the following questions (RQ) were set:

RQ1 What kind of files do you upload? What format?
RQ2 In your opinion, are there any weak points in the upload and creation flow of a scene?
RQ3 Have you ever had to modify a scene you have already created? How did you do it?
RQ4 If you could add new features to the ATON framework, what would they be?
RQ5 Is there anything we have not covered that you would like to talk about?

The tasks and questions were chosen to provide reasonable coverage of the most important parts of the framework and user interface. The Thinking Aloud protocol was chosen to conduct the contextual interview, which is considered the most valuable usability engineering method [Nie94b]. This technique was developed and popularised within cognitive psychology by Newell and Simone (1972) for the study of problem-solving [Lew82]. The think-aloud technique is a qualitative data collection technique in which user participants express verbally their thoughts about their interaction experience, including their motives, rationale, and perceptions of UX problems. It is effective in accessing user intentions, what they are doing or are trying to do, and their motivations, the reasons why they are doing any particular actions. Analysis of the results reveals similar needs and behaviour (See Table 3).

Table 2: *Results of the ATON framework evaluation phase of the three use cases: (a) visualisation of a public scene, (b) creating a new scene, (c) modification of an existing scene.*

Use case	Heuristic	Usability Issue	Severity (1-4)	Recommendation	Support Principle
a, b, c	Help and documentation	No onboarding assistance is available for new users	3	Provide tutorials, help popups, or guides	User Support
b	Aesthetic and minimalist design	The information hierarchy is unclear	2	Review layout and visual priority of UI elements	Cognition Support
	User control and freedom	The "+" button to add a file to the scene is not intuitive	4	Change the user experience of this function	Interaction support
	Visibility of system status	No feedback when loading 3D models or 360° panorama	2	Add a progress indicator	Information Support
	Help users recognize and recover from errors	There is no indication of the file formats accepted during upload	3	Display supported formats near the upload area or on hover	Information Support
	Recognition rather than recall	Light probe settings are unclear when loading PBR maps	2	Add tooltips or short explanations for light probe configuration	Information Support
	Error prevention	Create Scene button is enabled even when required fields are empty	3	Either disable the button or validate required fields with visual cues	Interaction Support
	User control and freedom	Files added to a level cannot be removed afterward	4	Allow deletion of files from the level or offer undo options	Interaction support
	Visibility of system status	Environment section lacks visual previews of available panoramas	1	Add thumbnails or visual cues for each panorama	Information support
	Recognition rather than recall	Scene creation stage lacks a preview before final loading	3	Include a thumbnail before loading a scene	Cognition support
	Match between system and real world	Scene cards miss key information like title and creation date	3	Display essential metadata on scene cards	Information support
	Flexibility and efficiency of use	No way to organize or filter scenes in "My Scene" page (*e.g.*, by year)	3	Implement sorting, filtering, or hierarchical folders for scenes	Performance Support
c	Aesthetic and minimalist design	Modal window appears at the center of the scene, obstructing view of the 3D model	2	Reposition modal or make it movable/resizable	Interaction Support
	Recognition rather than recall	Editing features are deeply nested and toolbar lacks labels, reducing discoverability	3	Flatten menu hierarchy and add text labels or tooltips to toolbar icons	Cognition support
	Match between system and real world	Temporary vs. persistent changes are not clearly distinguishable to the user	2	Add visual indicators or confirmation when making persistent changes	Cognition Support
	User control and freedom	Users may not replace, rotate or modify a model after it has been uploaded	4	Enabling the transformation and complete replacement of added models	Interaction support
		Scene elements like measurements or viewpoints cannot be deleted individually	3	Allow selective deletion of added elements	Interaction support
		No undo/redo for annotation removal or scene changes	3	No undo/redo for annotation removal or scene changes	Interaction support
	Error prevention	Deletion of scene elements (*e.g.*, measurements) does not request confirmation	4	Add confirmation dialogs before destructive actions	Interaction Support

Table 3: *Results of the user interview.*

User	RQ1 – File types and formats	RQ2 – Weak points in scene upload	RQ3 – Scene modification	RQ4 – Desired new features	RQ5 – Additional comments
1	3D models / .obj .gltf PBR maps	"+" button not intuitive; Lack of panoramas with neutral colours; Modifying the default panoramas	Via cloud or by deleting the scene and creating a new one	Possibility to change the colours of pano, Layers always visible, Orthogonal views and a metric reference, Custum colours for semantic shapes, Modify model material in editor mode	Scalable spherical annotations
2	3D models / .obg .gltf PBR maps	Light management within the framework	Yes, replacing models via cloud	Better UI for editing and preview, metadata editing.	More control over camera positions
3	3D models, point cloud / .las .3Dtiles .obj .gltf	Panel of lights and their management (*e.g.*, direction and position); Annotation ID maximum number of keystrokes; Flow for creating free form annotations; Difference between displaying lights from Blender and imported lights on ATON	Yes, replacing models via cloud or Web Dav	Filtering the scenes in my collection; Panoramas with gradients; Orthogonal views; Metric reference; Cross-section of the model and the possibility of extracting it	Limit the functionality of users in a collaborative environment
4	3D models, pano .3Dtiles / .obj .gltf .png	Picker to display the position of the model within the scene	Yes, replacing models via cloud or Web Dav	Creating a UI to manage virtual tours of 360 panoramas	-

3.2.3. Questionnaire

The first part of the research plan concluded with the conception of a questionnaire, which is one of the best tools to determine the user community composition and what their opinions are, thereby obtaining feedback on a large scale and guiding design decisions [Kun03]. Furthermore, questionnaires are one of the usability methods that makes such extensive coverage feasible, with the possibility to discover differences between various user categories as well as the specific needs of various small groups of users [Nie94b]. For this type of survey the collected sample was broad: mostly users with limited or in-depth knowledge of ATON, interested in the visualisation of digitised objects. In order to reach this type of target group, it was decided to use two ways of disseminating the questionnaire: the telegram group of the ATON community (157 members, updated to March 2025) and to include a call to action with a direct link to the questionnaire in the header of the ATON framework.

The submission of the questionnaire had three main objectives:

1. Define the demographic, technological and scientific profile of our audience
2. Obtain a prioritized rating of the utility of our main features to the survey audience
3. Get a list of ATON competitors for the presentation of 3D models via Web3D/XR.

The questionnaire was structured in five sections, with a combination of open and closed questions, as well as multiple-choice and 5-point Likert-type questions. The initial section is dedicated to gathering information on the use of the framework and its features. This is followed by an examination of competitors and software used for the creation of 3D/360 models. The third section is devoted to an analysis of the framework's weaknesses and user needs. The fourth section provides information on the user, including their scientific field or professional sector, their role and other relevant details. The questionnaire concludes with a section for suggestions and the possibility of being involved in the subsequent refactoring phases [Que].

The questionnaire was subjected to pilot testing by internal users and iterative design before it was distributed to the users in large numbers. The survey is still in progress, analysis and creation of the final report will follow.

4. Early Outcomes and Prototypes

4.1. Design System: UI elements as modular building blocks

Once we had defined the first steps of the research plan and considered the results that emerged during the preliminary attempt of the UI toolkit, we focused on the set of design guidelines through the creation of a Design System (DS). The main incentive for its implementation was to improve the scalability and consistency of the design by minimising redundancy between the various pages and media [DS1]. Following the preliminary attempts the founding building blocks of ATON's DS include: Style Guide (color system, typography system, spacing system, layout system), Design Guideline (usage, accessibility, brand guidelines), Components (form components, navigation components, grid system, framework-specific components), and Components Libraries (Bootstrap Library, CSS code) discuss in the next section [HKA22] [Mat] [App]. In particular, a modular approach to the development of user interfaces based on multimodal design patterns was chosen for the UI components. The language of patterns of different types and levels of abstraction has been used as a tool to develop interfaces and accelerate the decision-making process between different stakeholders (*e.g.*, developers, programmers, designers) [Kho17] [PHJS12]. Also, creating reusable components across different settings is vital, as it prevents designers from reinventing how users would interact with the application and focuses on the application's content and structure [MLMR20]. Finally, the DS implementation allows the use of an iterative design method: when problems are encountered in user testing, they must be solved. There must be a cycle of design, testing and measurement, and redesign, repeated as often as necessary. With testable behavioural goals and immediate access to user feedback, continuous evaluation and modification of the interface is possible. This approach allows for minimal impact on implementation by planning a modular strategy that allows for easy testing and low-level modification of evolving prototypes. This strategy must provide for rapid and flexible prototyping and a highly modular implementation, achieved through a design pattern approach to adaptive user interfaces [GL85].

4.2. Component Reuse and Interoperability: Bootstrap library

Following a thorough evaluation of the available libraries, it was determined that Bootstrap (version 5.3) was be the optimal choice [Boo]. This library is known for its stability, comprehensive documentation and broad community support, which are necessary to achieve long-term sustainability and improvements in framework performance. The Bootstrap library facilitates the realisation of specific objectives, including (a) the standardisation of the user interface within the framework, thus ensuring a consistent user interface; (b) the acceleration of the development phase through the use of ready-to-use components that can be easily integrated with each other to realise more complex components; (c) the opportunity to manage responsive design, ensuring automatic adaptation to different devices (, mobile, tablet, workstation); (d) fostering teamwork by promoting collaboration between the different teams involved. Finally, the future transition of high-fidelity mock-ups into code will be more efficient due to the adoption of the components. Testing and modification of initial prototypes will also be facilitated.

The benefits of employing a DS were significant from the earliest stages of design and prototyping phases, particularly with regard to the implementation of reusable components. The use of a shared component library guarantees a common language and improves collaboration between the developers and designers involved. To test their effectiveness we designed wireframes and later mockups of two pages 'Homepage' and 'My Scene' (see Figure 3). All wireframes and mockups were released in Figma. The first results are promising, showing a noticeable decrease in effort on the part of the entire team involved, both in the design phase and in the implementation phase through code.

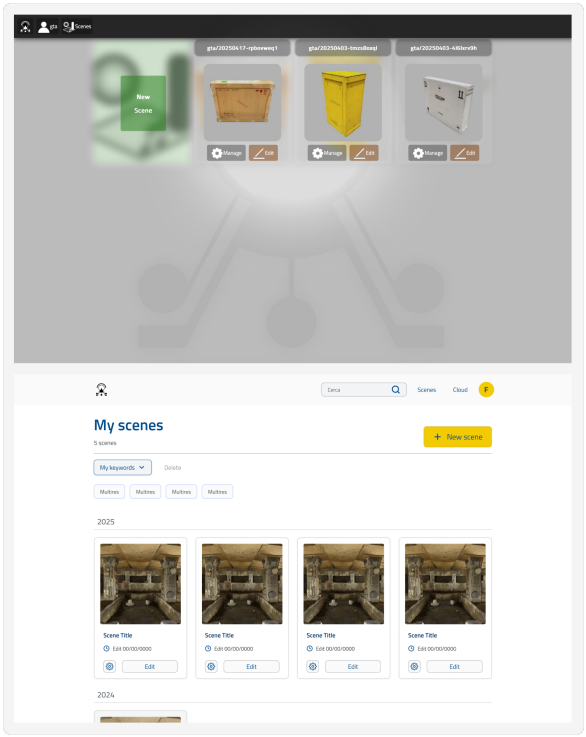

Figure 3: *Top: ATON framework version 3.0 'My Scene' page Bottom: High fidelity mock-up of the 'My Scene' page using DS components.*

4.3. ATON.UI

All the presented activities are also fueling the actual implementation of ATON.UI module (https://aton.ispc.cnr.it/apidoc/client/UI.html): a new, revisited set of UI components based on Bootstrap (see previous section), part of ATON core. The objective of such module is to provide front-end developers with a set of ready-to-use, responsive, modular and customizable building blocks to accelerate creation of UIs.

The new module provides access to all UI-related base routines (*e.g.*, loading overlays, internal states, etc.), and building blocks emerged from this work, serving as blueprints to craft UIs quickly. During the module design, special attention was paid to components modularity and nesting, with each UI element created through a set of options. The main goal is to provide fast templates, with less code involved, especially targeting web-app prototypes. Initial assessments already report a significant reduction of code required to craft popular components such as buttons, scene cards, modal dialogs, trees or tab groups. Built-in elements in ATON.UI, intend to provide also smart behaviour on different devices: for instance the VR button (to enter immersive VR via WebXR) internally detects device capabilities, thus automatically hiding if not supported.

Web developers are indeed still free to implement their own components using Bootstrap directly or external libraries, depending on interactive web-app requirements. This could be the case of specific solutions that require special approaches or external UI libraries.

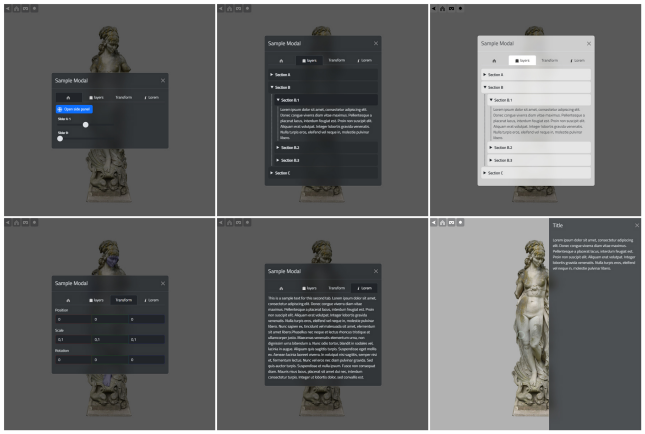

Figure 4: *ATON.UI module samples: modal dialog with tab groups, buttons and sliders (top left); trees (top middle and right), transform controls (bottom left) and side panel (bottom right).*

5. Conclusion and Future Work

We presented the initial results of the refactoring and redesign of the ATON framework, a decade after its development. The design of the research plan, including the objectives and research questions, was discussed. This was a key step in evaluating the most appropriate research methods to achieve the set objectives. The purpose of the research plan was to investigate user needs, strengths and weaknesses of the framework. The involvement of end-users from the earliest stages of the project was a central aspect, facilitating iterative design and the adoption of an agile approach through the application of research methodologies and design tools. The decision to employ a Design System and a library of reusable components enabled the systematisation of interface design, rendering it efficient and scalable. Initial tests showed a significant reduction in effort for the entire team involved. Moreover, the redesign of the framework and the introduction of a DS facilitate a rapid response to emergent community needs. The creation of new scenes, and in particular custom web applications, has been facilitated by the library of building blocks that can be used individually or combined to create more complex and highly customisable components.

The next steps leading to the full development of the new version of the ATON framework will include several phases: (a) collection and analysis of the data resulting from the questionnaire, (b) completion of wireframes and prototypes of the entire framework, (c) conduct of usability tests. These phases will be carried out following the UCD approach that has been used since the first refactoring phases. Indeed, through a co-design process, it will be possible to ground top-down and bottom-up input as part of an ongoing research-through-design investigation. The prototypes of each workflow, through wireframes and mockups, will be continuously evaluated to verify the effectiveness and efficiency of the design choices. Evaluation of the prototypes with users will be of crucial

importance to gather feedback and insights, thus helping to validate the hypotheses and refine the solution based on the feedback gathered.

The perceived usability of the framework will be measured to see if it has changed between version 3.0 and the redesigned version. The next phase of the study involves determining how and to what extent the new aesthetic influences users' perceptions of usability at all stages: before, during and after use [LDS*11, Kat10, LK10]. New participants, such as users reached through H2IOSC project activities – *e.g.*, Trans-National Access (TNA) and National Access (NA) participants https://www.h2iosc.cnr.it/tna-na-calls/–, will be involved in these research and design phases through the survey and observation of the use of the framework.

Abbreviations

CH Cultural Heritage
UCD User Centered Design
UI User Interface
UX User eXperience
HCI Human Computer Interaction
HMD Head-Mounted Display
PBR Physically Based Rendering
3/6-DoF 3/6 Degrees of Freedom (Head-Mounted displays and controllers)

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