Treddì. A Semantic Digital Library

Master's program in *Digital Humanities and Digital Knowledge*

Semantic Digital Libraries

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1. Introduction

Purpose

The aim of *Treddì* is to collect, organize and make accessible 3D models of international cultural heritage, allowing their dissemination and free reuse.

But why have we focused on 3D models? They're a fundamental tool for the preservation, research and analysis of cultural heritage, enabling the documentation of monuments, finds and archaeological sites with a high level of detail and offering new opportunities for study and dissemination.

Creating 3D models requires time, technical skills and resources, and often, once used for specific research projects, they end up being forgotten. Our aim is to centralize and collect these models within a single portal, allowing scholars, professionals and enthusiasts to access, consult and reuse them.

To ensure effective cataloging and facilitate research, the project is based on appropriate metadata and ontologies, which allows each model to be accurately described based on criteria such as technical characteristics.

State of the art

To have a better picture of the approaches used in collecting 3D models we identified notable examples of digital libraries that include these types of assets. Our goal was to understand their features, strengths, and limitations to identify common practices and possible opportunities for improvement.

We've selected three relevant initiatives to analyze: *Twin it!3D*, *OpenHeritage3D* and *Open Heritage*.

Twin it! 3D - Europeana
Twin it! 3D is a campaign conducted by the *European Commission* and the *Europeana Initiative* that collects 3D models of buildings, sites and objects in Europe. European Union Member States have been invited to share one emblematic and high-quality 3D model to the common European data space for cultural heritage. Contents are described following the Europeana Data Model ontology, which currently lacks the necessary terminology to accurately describe the technical characteristics of 3D models, although further extensions are still in development.

Goals of the Project
  - Accelerate the use and re-use of 3D in the common European data space
  - Raise awareness of the opportunities and benefits of 3D use in the cultural heritage domain
  - Encourage Member States to digitise all monuments and sites that are at risk of degradation

The OpenHeritage3D Project

Run by the *Cultural Heritage Engineering Initiative* (CHEI) at Qualcomm Institute, **OpenHeritage3D** is an initiative that provides free access to raw 3D data and the related metadata of cultural heritage sites across the world. It's a joint project between *CyArk*, *Historic Environment Scotland* and the University of South Florida Libraries.

All models are provided by institutions that collect high resolution 3D data of cultural heritage and contact the staff of the project to participate. OpenHeritage3D makes available five types of data: LiDAR - Terrestrial, LiDAR - Aerial, Photogrammetry - Terrestrial, Photogrammetry - Aerial and Short Range Scans.The content is open and freely available for anyone to download; however, due to its highly specialized nature, it is primarily intended for a professional audience rather than the general public.

Goals of the Project
- Promoting access to 3D cultural heritage datasets
- Reducing technical, financial, and legal obstacles for publishers
- Allowing the discovery and reuse of datasets by adopting standardized metadata
- Encouraging collaboration and knowledge exchange within the 3D cultural heritage community
- Sharing best practices and methodologies for capturing, processing, and preserving 3D cultural heritage data

Open Heritage

Open Heritage is part of the *Google Arts & Culture* initiative created in collaboration with *CyArk* and The *Digital Heritage & Humanities Collection*s (DHHC) with the University of South Florida (USF) Libraries.
The main aim of the initiative is to preserve and share the world's art and culture with anyone on the web, in collaboration with more than 2000 institutions across the globe. Few items are properly described with extensive metadata

Goals of the Project
- Give access to 3d models of different cultural heritage objects around the world and allow the user to download of the models

Having analysed the characteristics and qualities of these three initiatives we considered how our project could differentiate itself from them.

Our strength lies in the creation of an international platform dedicated sorely to 3D models of the cultural heritage domain. While many digital resources mix different types of content, Treddì is meant to be a specific point of reference for the collection, cataloging and dissemination of 3D models, making them accessible to researchers, professionals and enthusiasts around the world.

The use of appropriate metadata and ontologies ensures structured descriptions of the models facilitating their reuse and promoting greater collaboration between scholars and institutions. Technical details, such as data acquisition methods and the processes involved in model creation, significantly impact the quality and reliability of the models. However, we observed a lack of adequate mechanisms to fully describe these aspects. To address these limitations, we focused on identifying suitable approaches to represent the activities and techniques involved in 3D model creation, using established ontologies in the cultural heritage domain, such as Dublin Core and CIDOC CRM.

Stakeholders

These are the individuals or organizations actively involved in the project or who will use the system and are therefore directly impacted.

Cultural Institutions & Content Providers
Provide digitized 3D models of cultural heritage objects, contribute academic knowledge, metadata, and research on digital preservation.

End Users
- Researchers and Academics: use the platform for historical, archaeological, and cultural studies
- Students: access 3D models for learning purposes
- General Public: explore and interact with heritage objects for educational or personal interest

Audience

The platform is intended to collect material shared by cultural institutions for the purposes of study, research and digital preservation, therefore the expected audience is primarily composed of researchers, scholars and students. Even so our aim is to share these materials with anyone who is interested, for any (non-commercial) purpose.

Primary Audience   Secondary Audience

Students, Researchers and Scholars
study and research

General Public
information, curiosity, artistic projects

2. Curating the Content

Gather Digital Resources

Treddì aims to gather high-quality 3D models related to cultural heritage. This will include a wide range of models in terms of size and complexity. The platform will feature both larger structures, such as buildings or monuments, as well as smaller items, for example statues, artworks and various artifacts.

Models will be provided by cultural institutions, such as research centers, museums, or archives, from around the world, that create models for research purposes and wish to make them available to the public once they have completed their studies, allowing others to discover and reuse them. In addition to the models themselves, partner institutions are required to provide a set of information regarding both the 3D model and its physical counterpart that will be included in the metadata. The actual uploading and integration of the materials into the platform would be carried out by the project team. Because the project is being developed as a student initiative it does not include active institutional partners: all materials used have been sourced from the open platform Sketchfab, serving as placeholders.

Licensing and Copyright

Treddì is designed as an open platform where content can be accessed, visualized, and shared. Users will be able to download and reuse models for research purposes or simply for enjoyment. For this reason models will be available under a CC BY-NC-SA license, allowing users to share and adapt content for non-commercial purposes, with appropriate credit given to the creators, mentions of eventual changes made to the model and without the possibility of changing the license.

Since *Treddì* serves as a portal to make content available, it is extremely important to us that due credit is attributed to the people and institutions that spent time and effort in creating these resources. Since cultural heritage is a merit good, we want content to remain freely accessible to everyone, while preventing the exploitation of institutional work for profit. Any user interested in profiting from the content can contact the institution that owns the model and make direct arrangements to obtain and use the material in a manner outside of our platform.

3. Treddì Ontology

We developed the Treddì Ontology, a metadata model designed to treat 3D models as independent digital entities while maintaining their connection to the original physical artifacts. Inspired by recent research, including the work of María-Eugenia Polo et al., we've focused on capturing technical and procedural information essential for describing important characteristics of 3D cultural content.
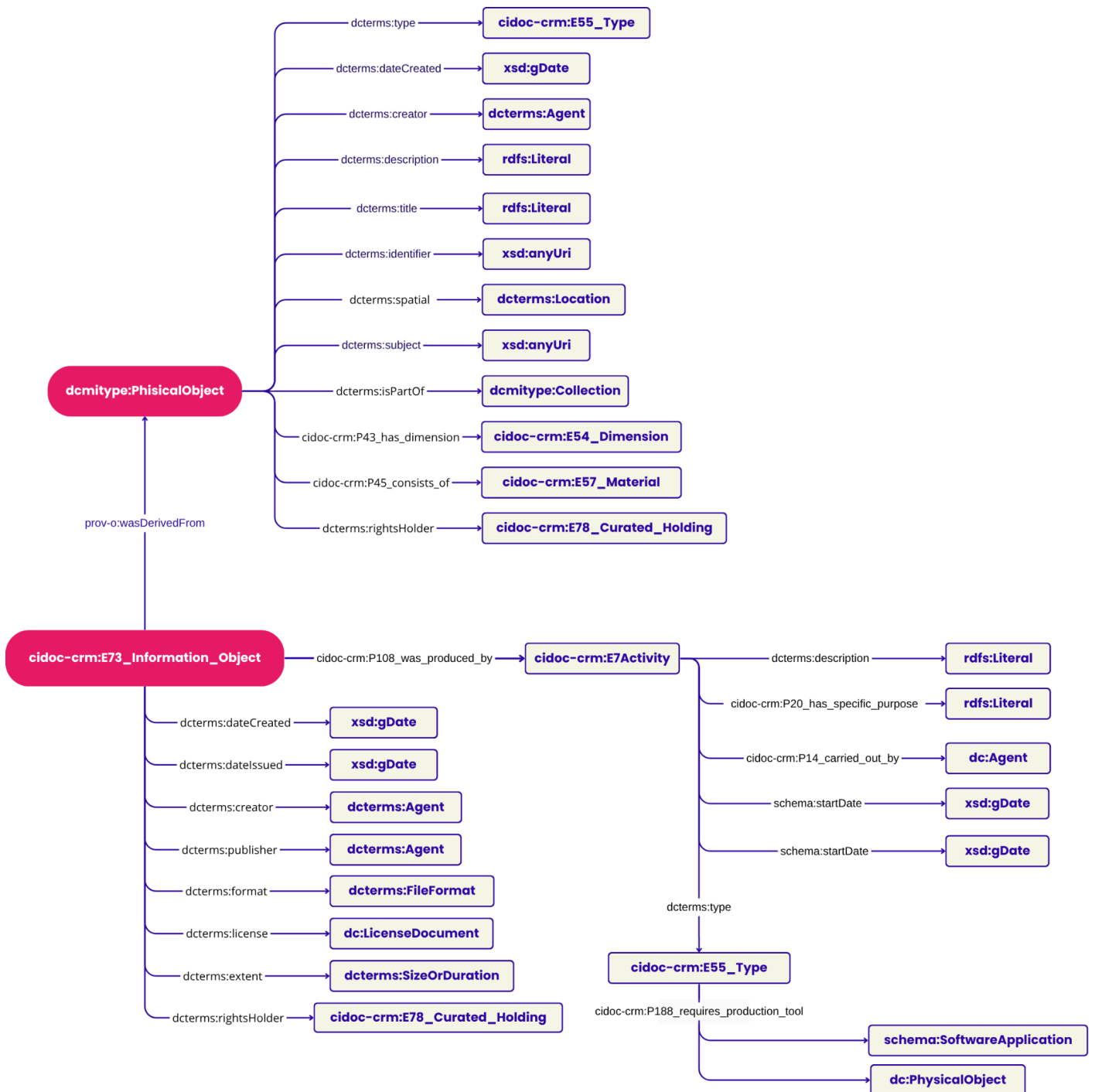
Treddì Ontology

3D models are digital representations that require specific descriptors through metadata to facilitate the process of identification, interpretation, interoperability and reuse.

The hardware and software used to create 3D models significantly influence the models themselves. Therefore, having a structure to describe this information is essential for properly identifying models and distinguishing between different digital representations of the same real-world object.

3D models of cultural heritage are digital representations of real-world objects and should be described as such—not as the objects themselves. When designing a schema to describe 3D models, it's crucial to consider how to treat them as independent entities while also preserving their connection to the original object and its cultural context.

Users should have access to information related to data collection, image acquisition, production, and post-production processes. This technical information is vital for assessing the degree of metric and chromatic fidelity to the real-world object, helping to determine whether a model faithfully represents the original. This is the ultimate goal in the creation of 3D models related to cultural heritage.

Our ontology is available in turtle format at this link.

Treddì Ontology

Classes

Class name	Definition	Uri
dcmitype:PhysicalObject	An instance of a physical inanimate object	http://purl.org/dc/dcmitype/PhysicalObject
cidoc-crm:E73_Information_Object	Identifiable immaterial item that have an objectively recognizable structure and are documented as single units	http://www.cidoc-crm.org/cidoc-crm/E73_Information_Object
cidoc-crm:E7_Activity	Actions that result in changes of state in the cultural, social, or physical systems documented	http://www.cidoc-crm.org/cidoc-crm/E7_Activity
cidoc-crm:E55_Type	concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify resources	http://www.cidoc-crm.org/cidoc-crm/E55_Type
dcterms:Agent	A resource that acts or has the power to act	http://purl.org/dc/terms/Agent
dcmitype:Collection	An aggregation of resources	http://purl.org/dc/dcmitype/Collection
dcterms:Location	A spatial region or named place	http://purl.org/dc/terms/Location
cidoc-crm:E54_Dimension	Quantifiable properties that can be measured	http://www.cidoc-crm.org/cidoc-crm/E54_Dimension
cidoc-crm:E57_Material	Properties of matter before its use, during its use, and as incorporated in an object	http://www.cidoc-crm.org/cidoc-crm/E57_Material
dcterms:FileFormat	A digital resource format	http://purl.org/dc/terms/FileFormat
dcterms:LicenseDocument	A legal document giving official permission to do something with a resource	http://purl.org/dc/terms/LicenseDocument
cidoc-crm:E78_Curated_Holding	Aggregations of assets that are assembled and maintained ("curated" and "preserved," in museological terminology) over time for a specific purpose and audience	http://www.cidoc-crm.org/cidoc-crm/E78_Curated_Holding

dcterms:SizeOrDuration	A dimension or extent	http://purl.org/dc/terms/SizeOrDuration
dcmitype:Software	A computer program in source or compiled form	http://purl.org/dc/dcmitype/Software

Properties

Property name	Definition	URI	Domain	Range
dc:tite	A given name to a resource	http://purl.org/dc/elements/1.1/title	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	rdfs:Literal
dcterms:identifier	An unambiguous reference to the resource within a given context	http://purl.org/dc/terms/identifier	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	xsd:anyUri
dcterms:description	Provides a description of a resource or activity	http://purl.org/dc/elements/1.1/description	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object, cidoc-crm:E7_Activity	rdfs:Literal
dcterms:creator	Identifies the person or institution that created a resource	http://purl.org/dc/terms/creator	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	dcterms:Agent
dcterms:dateCreated	Identifies the date of creation of a resource	http://purl.org/dc/terms/created	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	xsd:gDate
dcterms:dateIssued	Identifies the date of formal issuance of the resource	http://purl.org/dc/terms/issued	cidoc-crm:E73_Information_Object	xsd:gDate
dcterms:spatial	Identifies the spatial coverage of the resource	http://purl.org/dc/terms/spatial	dcmitype:PhysicalObject	dcterms:Location
dcterms:isPartOf	A related resource in	http://purl.org/dc/t	dcmitype:PhysicalObject,	dcmitype:C

	which the described resource is physically or logically included	erms/isPartOf	cidoc-crm:E73_Information_Object	ollection
cidoc-crm:P43_has_dimension	Records the result of a measurement of a physical object	http://www.cidoc-crm.org/cidoc-crm/P43_has_dimension	dcmitype:PhysicalObject	cidoc-crm:E54_Dimension
cidoc-crm:P45_consists_of	Identifies a material of which a physical object is composed of	http://www.cidoc-crm.org/cidoc-crm/P45_consists_of	dcmitype:PhysicalObject	cidoc-crm:E57_Material
dc:subject	Identifies a topic of the resource	http://purl.org/dc/terms/subject	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	xsd:anyUri
dcterms:format	Identifies the file format of the 3D model	http://purl.org/dc/elements/1.1/format	cidoc-crm:E73_Information_Object	dcterms:FileFormat
dcterms:licence	Identifies a legal document giving official permission to do something with the resource	http://purl.org/dc/terms/license	cidoc-crm:E73_Information_Object	dcterms:LicenseDocument
dcterms:rightsHolder	A person or organization owning or managing rights over the resource	http://purl.org/dc/terms/rightsHolder	dcmitype:PhysicalObject, cidoc-crm:E73_Information_Object	cidoc-crm:E78_Curated_Holding
dcterms:extent	The size or duration of the resource	http://purl.org/dc/terms/extent	cidoc-crm:E73_Information_Object	dcterms:SizeOrDuration
dcterms:relation	A related resource	http://purl.org/dc/elements/1.1/relation	dcmitype:PhysicalObject	cidoc-crm:E73_Information_Object
prov:wasDerivedFrom	Identifies the provenance of a resource es. the fact that a 3D model is derived from a physical object	http://www.w3.org/ns/prov#wasDerivedFrom	cidoc-crm:E73_Information_Object	dcmitype:PhysicalObject

cidoc-crm:P108i_was_produced_by	Identifies an instance of a 3D model that came into existence as a result of an activity	http://www.cidoc-crm.org/cidoc-crm/P108i_was_produced_by	cidoc-crm:E73_Information_Object	cidoc-crm:E7_Activity
dcterms:type	Identifies the type of a resource or an activity	http://purl.org/dc/terms/type	cidoc-crm:E7_Activity	cidoc-crm:E55_Type
cidoc-crm:P20_had_specific_purpose	Expresses the objectives of a specific activity	http://www.cidoc-crm.org/cidoc-crm/P20_had_specific_purpose	cidoc-crm:E7_Activity	cidoc-crm:E55_Type
cidoc-crm:P14_carried_out_by	Identifies the person person that performed the activity	http://www.cidoc-crm.org/cidoc-crm/P14_carried_out_by	cidoc-crm:E7_Activity	dc:Agent
schema:startDate	Identifies when the activity started	https://schema.org/startDate	cidoc-crm:E7_Activity	xsd:gDate
schema:endDate	Identifies the date when the activity ended	https://schema.org/endDate	cidoc-crm:E7_Activity	xsd:gDate
cidoc-crm:P188_requires_production_tool	Identify a tool that was necessary to perform a specific type of activity	http://www.cidoc-crm.org/cidoc-crm/P188_requires_production_tool	cidoc-crm:E55_Type	dcmitype:PhysicalObject, dcmitype:Software

4. Content Management System

System Architecture

The platform is built on Omeka S, to ensure scalability, accessibility, and long-term sustainability for 3D digital cultural heritage preservation.

To host the Omeka S installation and make it publicly accessible, a virtual machine has been deployed using Google Cloud Platform (GCP). This allowed us to install a Linux server, set up the necessary web environment, and make our digital archive available to external users.

Omeka S serves as the foundation of the backend: role based access control is supported (Admin, Contributor or Public Viewer) and structured metadata is stored in MySQL, using Dublin Core, CIDOC CRM, and IIIF standards for interoperability. Omeka's file management system is used for file uploads, versioning, and metadata linking.

Treddì exploits Omeka S search functionalities. Omeka's browsing page offers users a wide range of filters to explore the collection and retrieve contents. Filters allow to search items with a certain class or with specific values associated with properties.

Information organization

The main building block of the Omeka S system are the **Items**. They can be used as nodes to represent entities that can be described with metadata and linked to each other to display meaningful relationships. Items can have **Media** attached: they can be created by adding them to an item and cannot exist independently.

We decided to exploit this structure to represent the complex relationship between 3D models and their physical counterpart. Original artifacts are considered as Items, while their virtual representations are linked to them as Media. This solution assures a direct connection between object and model while at the same time allowing separate metadata descriptions, according to their specificity.

Since for the sake of this project 3D models were selected from sketchfab, metadata may lack some information because they are missing from the original resource. In an ideal scenario, this problem would be avoided by having institutions sending both content and metadata directly to Treddì.
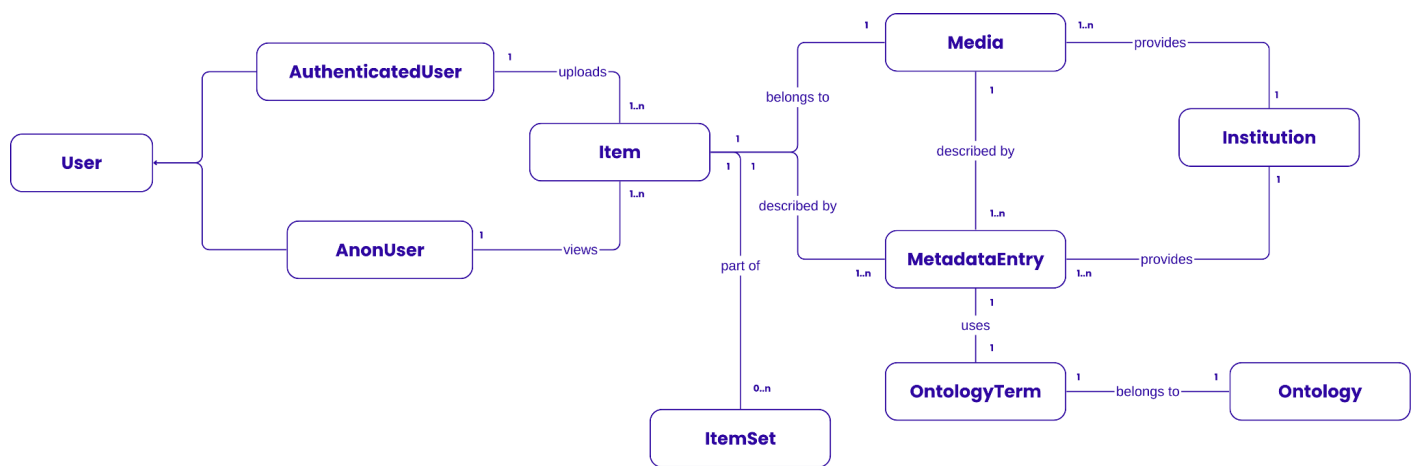
Entity relationship model

Controlled vocabularies and external links

Controlled vocabulary were used to enhance knowledge organization and semantic interoperability:
- The Getty Art & Architecture Thesaurus was used to describe types and subjects of Items and Media.
- Getty's Union List of Artist Names provided standardized references for the authors of physical objects.
- GeoNames was used to identify places and institutions.
- Additionally, links to Sketchfab pages were included to reference the selected 3D models and their creators.

3D models visualization

Omeka S theme Lively was used to style Treddì's website. HTML and CSS were then customised for a user-friendly experience. In particular, item's pages were modified to handle real-time web-based 3D visualization by integrating the <model-viewer> web component. Users can interact with the models directly, without having to open a new page managed by third parties. The models that have been uploaded to Treddì are all in .glb format because it is one of the most common and lighter formats for 3D models, both for the systems (and for our computers).

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