



Antonio Espinosa-Ruiz is the Director of Vilamuseu (Museums and Monuments of Villajoyosa). PhD in Prehistory and Archeology (Universidad Autónoma de Madrid, 1996). Associate Lecturer of Archeology at the University of Alicante (1997-2014, since then Honorary Collaborator), and since 1996 director of Vilamuseu (Municipal Network of Museums and Monuments of Villajoyosa).

Co-director of the European Union project ANSER Anciennes Routes Marittimes Méditerranéennes in the Valencian Community, and the Franco-Spanish Villajoyosa Ibérica Project (2005-2011), with universities Paris X and Alicante, and CNRS in France, among others.

Scientific Co-editor of the Manual de Accesibilidad e Inclusión en Museos y Lugares del Patrimonio Cultural y Natural (Ed. Trea, Gijón, 2013), among many other books and publications. Member of the Permanent Committee that organizes the International Congress on Education and Accessibility in Museums and Heritage sites.

Lecturer of Master degrees and courses in several universities in Spain, Mexico or Guatemala, and invited speaker to many courses and lectures in several European and American countries. Member of the Asociación para la Interpretación del Patrimonio (AIP), of which he was president, and the NAI National Association for Interpretation; and member of the ICOFOM (International Committee for Museology) of the International Council of Museums (ICOM).



Néstor F. Marqués is an archaeologist, specialist researcher in technology applied to heritage and cultural disseminator. He combines his technological work with historical and archaeological research, as well as technological and historical teaching. He works internationally digitizing heritage in 3D with the highest quality and resolution using photogrammetry. In recent years, he has also focused especially on facilitating access for researchers and the general public to heritage monuments and museum collections through 3D models. Based on these, he also develops universal accessibility strategies through the creation of life-size, increased or reduced replicas of museum pieces and structures thanks to 3D printing, in collaboration with experts such as the Vilamuseu team. Together with them he won the international award in 2020 for Silver of Universal Design (IAUD). He is a founding partner of the company 3D Stoa - Heritage and technology together with Pablo Aparicio and Miguel Fernández, of which comprehensive projects such as azoguejo1520.com stand out. He is a heritage Research Scientist at the Global Digital Heritage Foundation. He is also a co-founder and teacher of the [Koré Formación](#) platform, specialized in technology applied to heritage. Master of the [Sketchfab](#) platform community for visualizing 3D models and director of the project for the dissemination of the Roman world [Antigua Roma](#)

al Día, which has more than 300,000 followers and with which he has published, to date, three books.

Augmented accessibility in virtualization and 3d printing of heritage

Antonio Espinosa-Ruiz, Director of Vilamuseu (Museums and Monuments of Villajoyosa).

<https://vilamuseu.es/en/>

antonio.espinosa@villajoyosa.es

Néstor F. Marqués, co-founder and teacher of the [Koré Formación](#)

<https://www.koreformacion.com/>

<http://nestormarques.com/>

nestor.marques@3dstoa.com

Abstract

Augmented accessibility in virtualization and 3D printing of heritage is a project and a non-formal strategic alliance between a leading museum in UD, that is, Vilamuseu, the Museum of the City of Villajoyosa/La Vila Joiosa; and a leading professional in 3D technologies applied to heritage, Néstor F. Marqués - Patrimonio Virtual y Divulgación Cultural, now 3D Stoa - Heritage and technology. AA refers to the whole process of improving accessibility and usability of a 3D model or replica.

The main objective of the project is to develop a standardized method in creation and management of accessible 3D collections, affordable, sustainable and innovative, that can be replicated by any museum or

cultural institution, being within their reach, *de facto* democratizing practices that seemed complicated or expensive just a few years ago.

Keywords: *augmented accessibility, 3D printing, sustainability, heritage, Vilamuseu*

Context

Augmented accessibility in virtualization and 3D printing of heritage (AA, from now on) is a project and a non-formal strategic alliance between a leading museum in UD, that is, Vilamuseu, the Museum of the City of Villajoyosa/La Vila Joiosa; and a leading professional in 3D technologies applied to heritage, Néstor F. Marqués - Patrimonio Virtual y Divulgación Cultural, now 3D Stoa - Heritage and technology. AA refers to the whole process of improving accessibility and usability of a 3D model or replica.



Image 1.- Façade of Vilamuseu.

The method includes every step, from the selection of the most representative heritage items to planning the model, printing and finishing it, and then exhibiting and communicating it, both by personal (e. g., guides trained in inclusive attention) and non-personal means (e. g., UD based texts, audios, etc.).

AA includes five main processes:

- 1. Selection of key pieces and their adequacy to museum narrative purposes.**
- 2. 3D virtualization via high quality photogrammetry. Post processing, optimization, uploading to Sketchfab.**
- 3. Modify and enhance the 3D models to match AA standards, schematizing or highlighting features for haptic approach. For example, we can highlight some figures painted on a Greek pottery crater.**
- 4. 3D print in the original plus the appropriate scale for AA. FDM 3D printers –layers 80-120 micrometers high– and MSLA –layers 25-50 micrometers high, for finer detail– are used. Finishing processes in Vilamuseu’s laboratory to achieve contrast, secure touch, etc. Test by users.**
- 5. UD based museography. Accessibility chain. Evaluation. Improvements.**

The results are a series of 3D models that serve scientific documentation, preservation analysis and accessibility in dissemination. A case of success at Vilamuseu can be seen [here](http://nestormarques.com/restauracion-virtual-e-impresa-en-3d-el-simpulum-de-vilamuseu/).¹

¹ <http://nestormarques.com/restauracion-virtual-e-impresa-en-3d-el-simpulum-de-vilamuseu/>



Image 2.- Process of virtualization of an Iberian saber, 4th c. AD.

3D printed replicas are the perfect substitutes to fragile original pieces, they are true to the original geometry, low-cost and easily replaceable if damaged. AA is a revolution in inclusive museums, if it follows the principles of UD.

Models are also displayed virtually in Internet, making the museum collections available anywhere in the world, following the Recommendation of the European Commission. Vilamuseu's virtual collection can be seen by clicking here².

15 criteria have been taken into account:

- I. Selection of key museum pieces, not the easiest to digitize. It ensures a sense of global understanding.**
- II. Polyvalent file use. 3D files are the best possible kind of museum documentation and virtual preservation, serve as analytical info for researchers and restorers and as dissemination models via 3D online viewers and 3D printed replicas, fulfilling three main needs of every museum at a minimum cost.**

² ***Recommendation of the European Commission. Vilamuseu's virtual collection can be seen by clicking here <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011H0711>***



Image 3.- Néstor F. Marqués working session in Vilamuseu

III. Sustainability: printing in ecologic PLA, a non-toxic and ecologic material made from potato or beetroot starch. It is a very quick and affordable product, compared to others based on traditional scanning and polyester resin with moulds, etc. Museography in Vilamuseu is also ecological and sustainable.

IV. Explore the best tactile options. Simplify reliefs to make them easier to distinguish; create reliefs from plain decorations by digitally detecting the painting microreliefs; increase sunk reliefs or inscriptions, etc.

V. Final scale accessible to touch: an expanded scale for small objects —an additional 1:1 size replica for real sense of scale— and a reduced one for very large objects, not reachable with both hands.

VI. Safe and aesthetic finish: edge polishing, priming and painting with non-allergic gouache. Safe attachment of the pieces to the table. The finish allows safely sanitize tactile pieces very often.

VII. Accessible finish: we can increase the original colour contrast and take into account Dyschromatopsia.

VIII. Test and evaluation by blind and partially blind people from the ONCE (National Blind Organization), by Talaies Center for Mental

Disabilities, by Fesord (Valencian Association of Deaf People) and many others.



Image 4.- Test visit of COCEMFE in 2018.

IX. Accessible and secure tables or surfaces to display the 3D printed pieces, contrasted with the museum’s walls and floor, so people with visual impairment can easily detect them. Many tables, close to the original pieces, not reduced to isolated “sensorial points”.

X. UD based information: contrasted macro-type interpretive information in Spanish, Valencian (local language) and English; texts in easy reading and pictograms of augmentative communication; sign language videos and 3 language subtitles in audio-visuals, etc. Some of them are provided via a self-managed webApp, no downloading needed, accessible via QR code. High-speed free WiFi in the whole Vilamuseu.

XI. Search of safe options to handle tactile devices in the context of the post-COVID19: washable and sanitizable finish and clear cleaning protocols, security information along the museum, hydro alcoholic gel in tactile areas, gloves at disposal –ultra thin high-density polypropylene (HDPE), latex and protein free to avoid allergies, for ambidextrous and embossed to maintain the feeling of touch—, etc.



Image 5.- Detail of a Greek crater, 5th c. AD. Note the bas-relief, limited to the main figures to make the tactile exploration easier. The virtualization process allows us automatically to identify the micro-relief of the painted surfaces and convert it into a bas-relief.

XII. Personal information (guides) trained in audio-descriptive techniques.

XIII. Online availability of the 3D Digitized pieces, optimizing its loading speed and quality to make sure they are viewable by all devices, not only by most expensive ones³.

XIV. Accessibility chain in the museum, natural or cultural heritage place: museography, paths, wayfinding, public spaces, website, visitor inclusive service, etc.

XV. Work in collaboration with other museums and first-rated professionals in the world (see below).

Vilamuseu's team is fully involved in the project: A. Marcos an D. Ruiz, chief curator and archaeologist, select the pieces and provides cultural information; the director, A. Espinosa, and museologist C. Bonmatí study the accessible furniture and the exhibition presentation; the restorer, M. J. Velázquez, directs the processes of imprimation and finish of 3D printed pieces; finally, Néstor F. Marqués creates the

³ See: <https://sketchfab.com/vilamuseu>

virtual models, 3D prints the objects and develops new ways to augment accessibility.

A number of experts are often consulted: the Provincial Direction of ONCE; Mrs. Begoña Consuegra, one of the main specialists in tactile heritage; Viviane Sarraf, manager of Museus Acessíveis (Sao Paulo, Brazil); the Museo Tattile Statale Omero in Ancona (Italy); Gabriela Aidar, Chief of the Education Department in the Pinacoteca de Sao Paulo, etc. Many final users and experts on other disabilities are consulted and participate in evaluation.



Image 6.- The replica in front of its non-tactile original.

3D pieces are included in exhibitions planned following aspects of human diversity: age, sex, sexual orientation, cultural background and interests, physical and mental capabilities, pregnancy and maternity, etc. The project takes into account criteria of respect for human diversity, safety, health, functionality, ease of understanding, appeal (aesthetics), affordability, ecology and sustainability.

Some examples are:

- **Age is taken into account for example in macro types for interpretive labels and panels for elder people; in pictograms (suitable for children under 7, not only for people with mental disabilities); in easy-reading texts (especially interesting for children between 7 and 12 years); devices for kids so they can reach the tactile pieces, etc.**
- **Sex is always a crucial perspective in the discourse of every exhibition in Vilamuseu (also in non-sexist language). Sexual orientation is always considered (e. g., our last main exhibition is named Slaves to Beauty, in Spanish Esclavxs de la Belleza, where the "x" refers to sexual diversity, present along the visit).**
- **Cultural background is taken into account when writing exhibition texts according to the principles of heritage interpretation, to make them entertainable, short, clear, interesting, easy-to-understand, interesting to different publics. Language diversity refers to the use of Valencian/Catalan, Spanish and English everywhere, even social media (e. g. see @Vilamuseu on Facebook).**
- **Physical and mental capabilities: museographic furniture (for example, the tables on which the 3D printed pieces are displayed are accessible to wheelchairs), texts in easy-reading and pictograms, enough light in every hall, wide walking spaces, etc.**
- **Pregnancy and maternity have a reflect in the pieces chosen for the project: e. g., Phoenician amulets to protect pregnant women. As for the facilities, Vilamuseu has a fully equipped comfortable lactation room and every detail in the building is designed following accessible criteria.**



Image 7.- A good example of augmentation of visual accessibility: Phoenician flask nr. 022158. See the original in figure 8.

Some recent examples of the project's impact are:

- Since 2018 more than 20.000 people with accessibility needs a year, most of them belonging to several programs for elder people or associations of people with disabilities (COCEMFE, Fesord, ONCE, etc.) have enjoyed Vilamuseu's tactile pieces.
- On February 20, 2018, the Tourism Bureau of the Regional Government and Predif organized a course in Vilamuseu on accessibility to tourism, in which the product was tested.
- On October 18, 2018, the Agencia Valenciana del Turisme and Predif organized a blogtrip to two important international disabled people, Martyn Sibley⁴, from Cambridge, deemed the most influential disabled person in UK in 2017 and Núria Azanza⁵. They were explained the project and spread it in their blogs. Martyn wrote, referring to the whole blogtrip along all the Valencian Region: "Afterwards we headed

⁴Martyn Sibley <http://martynsibley.com/2018/11/accessible-valencia/>

⁵ Blogtrip-Sixsense travel <https://blog.sixsense.travel/tag/vilamuseu/>

to the amazing Vilamuseu. Probably my best moment of the whole trip”.

- On December 10 and 11, 2018 Vilamuseu was invited to open the sessions of the Working Group Barrier Free City for All of Eurocities in Berlin’s Senate, as key speaker. The project was presented to specialists from some of the main European cities.
- On January 14 and 21, 2019 the Course “Museums for all people: planning, inclusive services and Universal Design” was organized by Vilamuseu and the Valencian Regional Government. It was a great success, with 90 participants from 34 museums.
- From 2019 to 2022 several visits from professional teams from different museums: Elche, Mahón, Manacor, Chile, Valencia and many others visited Vilamuseu to know more about our AA Project. Some of them have replicated the model.
- In 2019, Vilamuseu has been invited to a number of round tables, lectures, master classes, etc. in which the project has been presented, invited by the Ministry for Tourism, the Valencian Region Government or the Cátedra de Responsabilidad Social of the University of Alicante, among many others.
- Vilamuseu coordinates the Accessibility Group of the Valencian Network of Smart Tourist Destinations.
- Vilamuseu belongs to the Permanent Bureau of the International Congress on Accessibility in Museums and Heritage. The last edition was held in Sao Paulo, Brazil, on November 2019.
- Also, the project was presented at the 13th Meeting of Managers of the World Heritage Sites in Spain, held in November 6-8, 2019, been the director of Vilamuseu invited by the Ministry for Culture to give a lecture on “Accessibility and communication of heritage to all publics”. AA Project has also been presented in the 2nd International Congress Tur4All (2020); the Smart Talk of the 7th Fitur Know-How & Export Meeting (2019), among others.

- In 2022, Vilamuseu is one of the 21 Spanish and international tourist destinations included by Segittur (Sociedad Estatal Española para la Gestión de la Innovación y las Tecnologías Turísticas) in the "Guía de buenas prácticas en accesibilidad para Destinos Turísticos Inteligentes. 21 actuaciones destacadas en accesibilidad turística en destinos nacionales e internacionales". Vilamuseu is one of the three tourist destinations that take part as examples in the Webinar in which the Guide is officially presented (14/12/2022).



Image 8.- The original piece 022158. The 3D printed and painted piece in figure 7 is much more accessible and understandable by all people, not only blind.

AA Project has been awarded with the 2020 Design for all Foundation Best Practices Award and the 2020 International Association for Universal Design IAUD Silver Award, among other recent awards. All of them highlight the potential and interesting development of this union of accessibility and technology.

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Silvio Sagramola is President of Design for All Luxembourg.

After having led an institution for persons with diverse disabilities from 1982 to 1993, Silvio Sagramola became the director of Luxembourg's "National disability information and meeting center – Info-Handicap" since its creation in April 1993. His position allowed him to take influence on the implementation of accessibility and Design for All in many aspects of community living in Luxembourg and he initiated the national accessibility labelling system.

In 1999 he became the coordinator of EuCAN, the "European Concept for Accessibility Network" and was responsible for the publication and was co-author of ECA 2003 – Technical assistance manual, ECA 2008 - ECA for administrations, ECA 2013 – Design for All in practice and ECA 2017 – Destinations for All. All ECA documents have been translated from English into various languages in order to serve as guidance documents on national and international levels.

Other related activities: Coordinator of the EU funded project "Build for All" (2004-2006), Member of the European Jury of the EU Commission's "Access City Award" (2010-2013), Expert for the Council of Europe and co-author of the CoE publications "Major hazards and people with disabilities" (2014) and "Major hazards and people with disabilities – A toolkit for good practice" (2015).

Just before his retirement in May 2017, he created the non-profit organization Design for All Luxembourg asbl with the aim to continue

promoting Design for All in Luxembourg and since September 2018 he chairs the DFA-based project "Erliefnis Baggerweier" (experience dredging pond) in Remerschen/Schengen, which opened its doors in January 2020.