Virtual Access and Digitization for Unreachable Sites (VADUS)

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The VADUS project, co-financed by ESA (*European Space Agency*) - call *ARTES 20 Applications*[1] - aims to offer the opportunity to enjoy cultural heritage that are not easily accessible through the use of a metaphorical *pass* (i.e., the Latin meaning of the project acronym) of a virtual nature designed to overcome the difficulties associated with their physical access and to facilitate the understanding of those cultural aspects that are difficult to read due to the lack of significant parts (badly preserved, dispersed, allocated in other structures and contexts, or that can only be highlighted by the use of scientific instruments generally used in diagnostics.

A new experience concept for cultural heritage virtual visits is offered by exploiting the convergence among 5G networks, Cloud infrastructure and satellite assets, as well as by developing high-definition SfM 3D models, enriched with scientifically correct multimedia information layers; besides, the most hidden aspects of the art works will be revealed thanks to the mix of the results coming from digital modelling of missing elements merged with captivating storytelling and instrumental diagnostic technologies.

Virtual visits have often proved to be inadequate not only for the technological limits imposed by the viewers and system devices, that strongly affect accuracy and visual quality of offered 3D models, but also for the lack of insertion in their environmental and historical context. Besides many applications have been developed focusing more on a spectacle-tactics than on scientific transparency, historical rigor, authenticity, thus betraying the true essence of a

[1] For more information on the project and the executing consortium: https://business.esa.int/projects/vadus.

cultural visit, and producing "Black Box" effects and many times labelling of “fake visit”(Lercari, 2017, Demetrescu, 2018).

The demonstration sites are the Casa di Diana (Ostia Antica Archaeological Park) (Fig. 1), the Aula Isiaca (inside the Colosseum Archaeological Park in Roma city centre) and the Pastiss Fortress (Civic Museum Pietro Micca in Turin) (Fig. 2). For each of these cultural sites, a specific storytelling virtual reality solution have been identified in line with the purposes of enhancing and managing of the cultural institution.

The innovative aspects characterizing the project are the following:

- Use of satellite services (Galileo and EO) to support the mobility and the virtual visit of tourists and to contextualize the not accessible environment, when required
- Use of advanced diagnostic tools in the field of cultural heritage, developed for conservation and restoration actions, to obtain additional information that can be related to the type of materials used and the state of health of the works. Particularly, fresco decoration and the most interesting areas of masonry are scanned and digitalized with two prototypal remote instruments developed at the ENEA Research Centre of Frascati. The instruments are based on monochromatic laser sources: the RGB-ITR (Red Green Blue - Imaging Topological Radar) and the imaging LIF (Laser Induced Fluorescence) system called FORLAB. Thanks to such prototypes, three elastic channels (at 440, 517 and 661 nm) and fluorescence signals (induced by a laser at 248 nm and collected at eight different significant bands) can be acquired point-to-point with high detail. The RGB-ITR allows for structural and reflectance analysis with sub-millimetric spatial resolution: in this way micro defects and fractures, minimal differences in colour and roughness can be detected and localized from a distance up to 30 m. The LIF apparatus can reveal surface chemical characteristics and produces, in addition to punctual information with a spatial resolution of 5 mm, compositional maps of the studied surface. The integration of the data coming from the two systems allows for the spatial-referencing of the fluorescence results (Fig. 3).
- Creation of accurate and high-definition 3D models which, in addition to being used in the project, thanks to 5G, can support the historical / archaeological and anthropic interpretation of cultural assets (Bedford, 2017), but also the development of new services and products (*virtual tour*, *360°views*, HBIM, *digital twin*).
- Objective visual and dimensional evaluation of produced 3D by structural and non-structural indices (i.e., Mean Absolute Percentage Error (MAPE), the Perception based Image Quality Evaluator (PIQE), the Structural Similarity (SSIM), the Signal to Noise Ratio (SNR), the Peak Signal to Noise Ratio (PSNR) and Mean-Squared Error MSR) typical of the computer vision and medical field already and tested in another project (Pompei et al., 2019). Structural indices suppose that the human visual sys-

tem is highly adapted for extracting structural information from the scene, and therefore a measure of structural similarity can provide a good approximation to perceived image quality (Wang et al., 2003).

- Creation of storytelling characterized by reliable and scientifically correct information contents developed in agreement with the authorities delegated for the management and conservation of cultural heritage. The use of different specific information layers allows a "conscious" visit, enjoyable according to the cultural level and the interests of the tourist through the possibility of accessing graphic, audio, video, and textual information, including those deriving from the diagnostic measurements. Furthermore, the different information layers allow the tourist a vision and a connection between what surrounds him and the content he is viewing, limiting any sensation of "fiction" and "spectacularization". The storytelling is conceived as multilingual and the contents are scalable in terms of time duration and available information, completely at the user's choice.
- Use of Cloud platforms for storing and accessing data and multimedia resources to be shared with the scientific community and stakeholders.
- Use of 5G to stream the virtual tour data to avoid local calculation, long downloads and to permit high-resolution content available with no latency in use.

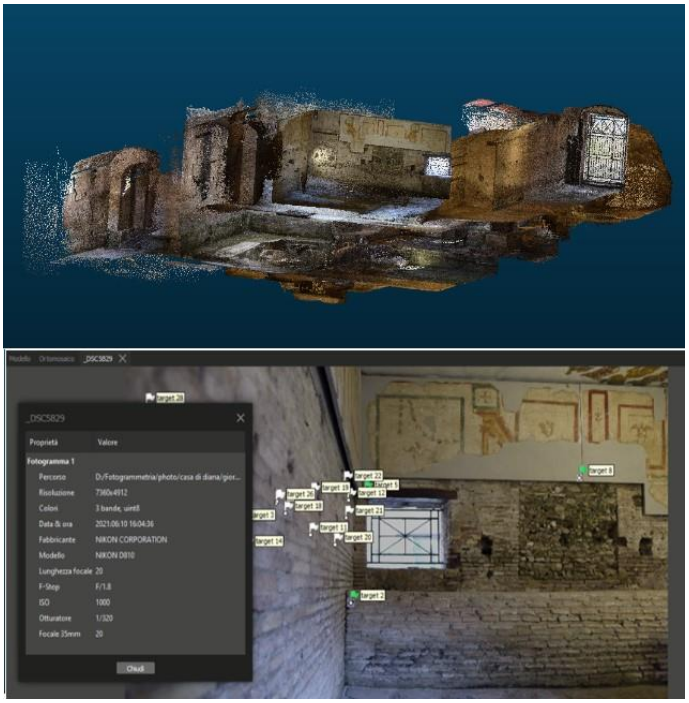

Fig. 1. Screenshot of reconstructured model with texture information of the Casa di Diana in Ostia Antica Archaeological Park based on 800 million points (© Sapienza University of Rome).

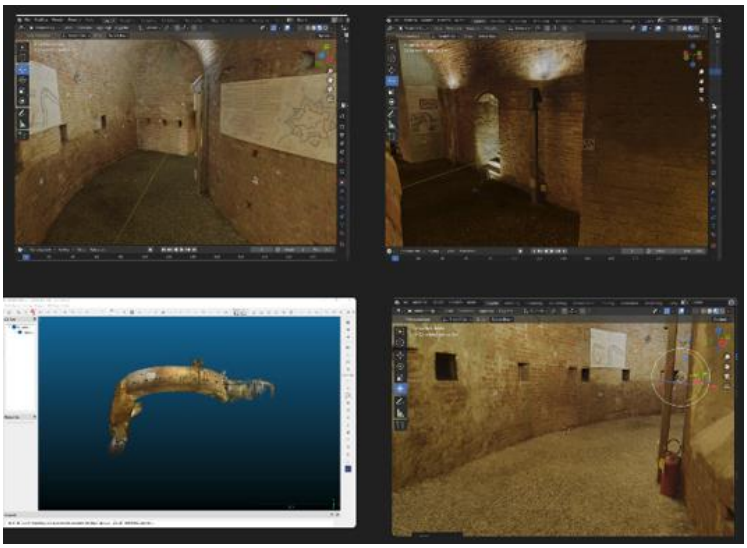

Fig. 2. Screenshot of reconstructured model with texture information of the Pastiss Fortress in Turin based on 600 million points (© Sapienza University of Rome).

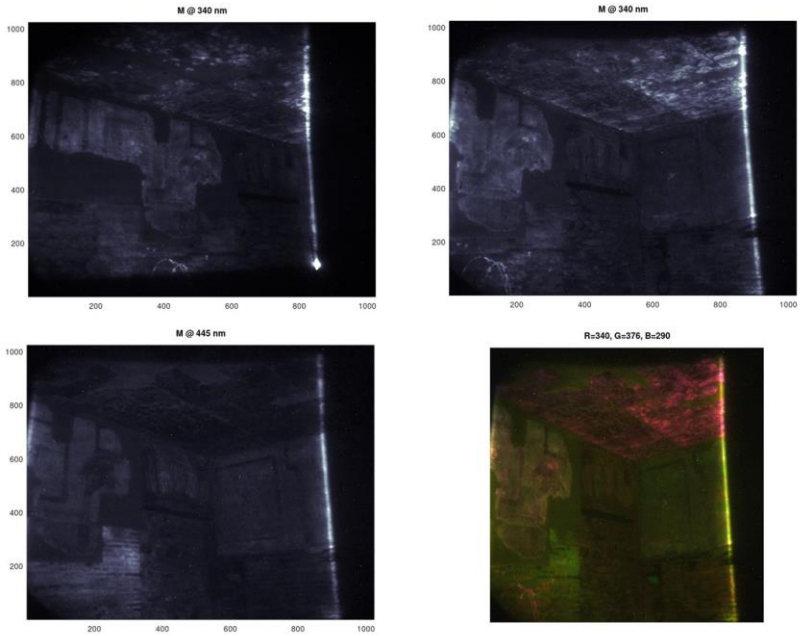

Fig. 3. In the figure above an example of the LIF results is reported. Two fluorescence map, at 340 and 445 nm, are shown. The processing of the data collected at all the 8 different wavelengths leads to images that can put in evidence just one specific material of more then 1, as in the false color map presented: here every color represents the distribution of a different material on the surface (for example modern synthetic acrylic consolidants in magenta neances). (© ENEA).

Author Contributions

Please list the contributions of the project participants here, according to the CRediT system. See specific descriptions of the role here: (http://credit.niso.org/). **Please omit non-applicable roles**.

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Writing – review & editing: <Sara Marino, Luca Gugliermetti, Valeria Spizzichino>

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