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MIXED REALITY FOR THE MONUMENTAL HERITAGE. A FIRST TEST

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Abstract:

This short paper presents the first results obtained in developing a Mixed Reality application to support maintenance and inspection activities performed in Milan Cathedral building site. Up to now Cultural Heritage applications have been relegated to tourism, leisure, and virtual museums activities, but as it is happening in many other fields, MR could improve building inspectors' workflow allowing for cost reduction and timesaving. Milan Cathedral constitutes an excellent case study, a top example for its periodic maintenance and inspection interventions. MR could potentially give an enormous contribution in terms of exchange and dissemination of information among the many practitioners working on the Cathedral yard. On this line, a prototype is currently being developed to support Milan Cathedral yard activities with some initial positive results.

Keywords: HoloLens, Mixed Reality (MR), cultural heritage, point cloud, industry 4.0

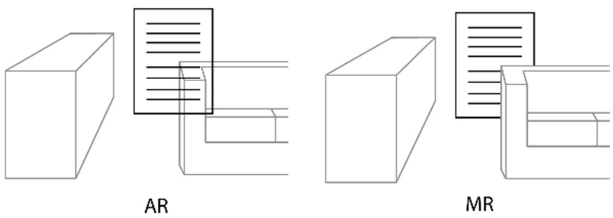
1. Introduction

At the industrial level, the need to have information at disposal in real-time and directly at the production line is spreading the development of technologies related to "smart factories". This need is reshaping how the production process has been intended. Integration among the physical and virtual world, together with widespread connectivity are key points in factories of the future (Culot, Nassimbeni, Orzes, & Sartor, 2020). Augmented Reality (AR) and Mixed Reality (MR) are the leading enabling technologies for this new way of intending the production process inside the new "industry 4.0". They give the possibility to see in the real world all the virtual information related to different aspects of the fabrication process.

This short paper presents some impressive initial results related to the first steps moved toward the use of MR in support of maintenance work inside Milan Cathedral building sites.

2. What is MR

During the last years, the distinction among the terms AR and MR, usually used as synonym of Holographic AR, has become increasingly blurry. The difference between the two words lays in how the augmented content is perceived in relation to real objects. In MR, 3D virtual objects are shown as holograms. These are objects made of light that are displayed and sensed as part of the environment through head-mounted displays (HMD) that can project these holograms into the real world. They enable the user to interact with the holograms using gaze, gestures, and voice commands. Contrary to a standard AR application, it is possible to directly manipulate the 3D virtual objects as well as real objects. A movement through the real world corresponds to the same motion in the digital one (Fig. 1). This blend mixes capabilities of Virtual Reality with those of AR producing an environment where physical and digital coexist (Pedersen, Gale, Mirza-Babaei, & Reid, 2017).



(a) (b)

Figure 1: Virtual object perception difference: a) AR where the virtual content is projected onto the real world; b) MR, real object and virtual ones coexists.

2.1. MR in Cultural Heritage

MR in Cultural Heritage could potentially give an enormous contribution in terms of exchange and dissemination of information among the many practitioners working on a particular case study, from restorers to site managers.

However, nowadays, the uses of AR and MR are relegated mostly to tourism, education and virtual museum (Bekele, Pierdicca, Frontoni, Malinverni, & Gain, 2018) with no example of the use of this technology for

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more professional activities. This could be due to two main reasons: an intrinsic delay of CH in accepting and using new technologies in the daily practice and, the difficulties in producing CH 3D models, a mandatory task for a MR system. Some interesting experiments demonstrated improvements in CH dissemination allowing broader access to knowledge (when physical access is constrained) as well as visitor experience enhancement through exhibition enrichment with virtual content (Andrade & Dias, 2020; Hammady, Ma, & Strathearn, 2020).

However, looking at CH substantial necessities for maintenance and restoration planning and interventions, it is possible to see that in many cases the building site of a monumental heritage architecture is as alive as that of new construction and although different, some needs are similar for the two worlds even those that can be solved with dedicated Mixed Reality systems. For example, the combination of BIM (Building Information Modelling) and MR can improve building inspectors' workflow allowing for cost reduction and time savings. Overlaying the architectural model to the real world, filling the inspection form and assigning damage reports with attached photographs and audio record proved successful in building an effective workflow (Brito, Alves, Magalhaes, & Guevara, 2019). MR can allow for multi-dimensional exploration of technical documents projecting them directly on the reality, visualizing hidden objects and details, wall thicknesses, allowing to check planarity and verticality, to count objects (e.g. statutes or marble blocks) and to inspect far and near objects at the highest resolution (Pratt et al., 2018). Furthermore, the possibility to share info in a real-time multiuser experience is another essential feature of the system that could facilitate the exchange of information between actors in the maintenance process (Brun et al., 2019) as in the new construction design activities.

3. From Survey to Holograms: the Milan Cathedral prototype

Milan Cathedral can be an exceptional case study concerning this topic for its periodic maintenance and inspection activities, for the number of different actors working for its conservation that need to access and share all different type of data, and the amount of technical and historical documents that constitute the cognitive patrimony of the whole cathedral. A MR system could help under so many aspects of the Cathedral activity. Moreover, thanks to previous research activities, there is at disposal the complete point cloud model of the cathedral. It is "only" a matter of solving the problem of how to model a complex and extensive monument like this or better to choose what kind of model is possible to be used to speed up the process, minimize costs and maintain a high degree of metric accuracy. A reality-based 3D surface or parametric model of complex CH usually is not easy to be produced, and to be used in real conservation activities. The modelling phase is time-consuming, uneconomical, introducing an unsupervised degree of subjectivity and lowering the initial metric content of the survey. For all these reasons, the main research idea aims at using the 3D point cloud models (produced during survey activities) directly, skipping this unproductive modelling phase. This can be done preparing the point cloud to use it as a real 3D model segmented in its constitutive parts, assigning semantics and structure to the whole model. Milan Cathedral point-cloud dataset has been classified at different resolutions, following the procedure presented in (Teruggi, Grilli, Russo, Fassi, & Remondino, 2020) and finally used as 3D on which to build the Mixed Reality System.

3.1. The prototype

The prototype is being developed for HoloLens 2 (Microsoft, 2020), a Head-Mounted Display (HMD) that through a pair of transparent glasses allows the user to see and manipulate 3D models as holograms in the real world. The software environment is Unity 3D (Unity3D, 2020) using the MRTK v2 (MRTK, 2020) package as the interface that allows communicating with the physical device.

However powerful, it is essential to remember that the HoloLens 2 is a portable device and, therefore, it has computational as well as battery life limits to be considered. To cope with these problems, it is necessary to use different resolution point models: the same that were used during the classification process (Teruggi, Grilli, Russo, Fassi, & Remondino, 2020). Lower resolution 3D point models can correctly display objects seen from a bigger distance retaining a good visualization quality: the resolution increase as the distance from the object decreases. Full resolution point models (0.5 cm) are used only to display single instances of detail objects (e.g. statues, ornaments). This is necessary to ease the computational requirements to which the device is subjected, thus increasing battery life, and keeping the application above 60 frames per seconds (necessary to display the holograms correctly).

The HoloLens 2 device works on the possibility to recognize hand gestures as well as gaze direction and voice inputs. When device's cameras detect a hand present inside the rendering area, a white dashed line is projected in the direction to which the hand is pointing. Four primary types of hand gestures are used to interact with holograms: hand ray or touch for far and near interaction, air tap to select and air tap and hold to grab and drag holograms. These gestures have been used ad hoc to give the user the possibility to navigate through the structured point cloud. It can be orbited, navigated, moved, and scaled depending on user necessities.

A first ad-hoc application was developed to test the point cloud visualization on a MR system and the use in the real vast environment of the Milan cathedral interiors. Starting the app, the device presents the spectator with the low-resolution point cloud (10 cm) of the concerned sector. Due to the low resolution, the model is zoomed out so that it is wholly contained in the HoloLens 2 field of view. Side by side with the model, there is a small navigation menu that allows performing some operations on the object. The model is divided into its constituent architectonic macro-elements (e.g. pillars, vaults) only touching the holographic "split" button on the main menu. At this stage point cloud resolution does not change since all elements are still contemporary visible. Through the hand ray gesture, it is possible to highlight distinct elements that, when touched, will be selected and isolated displaying the correspondent higher resolution version (5 cm) with all related information attached. Iteratively the user could split through the corresponding menu button the isolated macro element in its constituting architectural elements.

These objects can be highlighted and touched as well as isolated and displayed at a higher resolution (2 cm).

The last step is to split the architectural element in objects (e.g. statues, decoration) that highlighted and isolated will be displayed at full resolution (0.5 cm) or in their 3D mesh model version in those situations where a modelling phase is still mandatory (e.g. marble blocks) (Fig. 2). The possibility to display different types of models is useful to complement already existing 3D mesh models with those parts too complex to model speeding up the implementation process without wasting energy on the modelling phase itself.

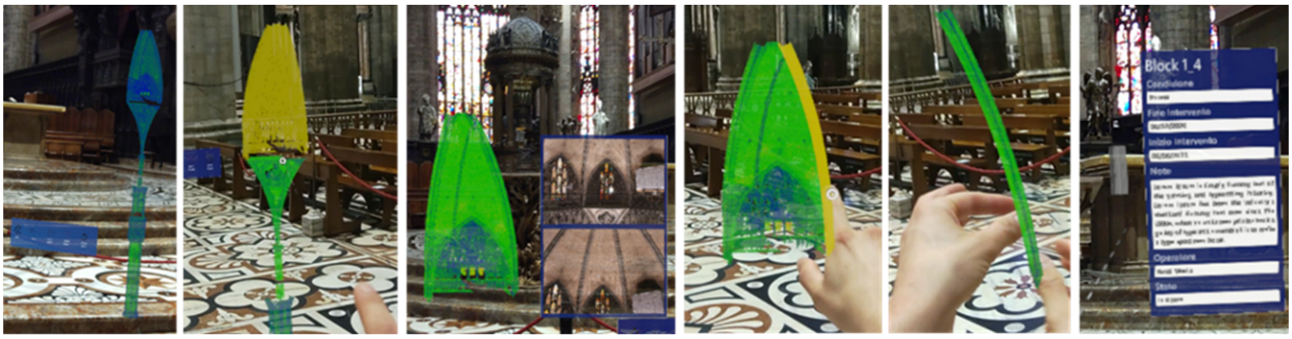

Figure 2: MR point cloud model interaction example. From the first low resolution point cloud it is possible to navigate through sequential increasing resolution point clouds reaching the 3D model of the marble block. Information could be attached at each step.

Finally, the first test of superimposition of the point model at 1:1 scale to the real object has been performed. Holograms have been placed manually, but the visualization quality and their spatial persistence have proved satisfactory (see Teruggi, S., & Fassi, F. 2020).

4. Conclusions

A first MR prototype that uses a vast point cloud model of a very complex monumental heritage has been presented. Through the dedicated developed application, it is possible to navigate the 3D point model of one portion of the crossing of Milan Cathedral. The manual modelling phase has been totally avoided since different resolution point clouds are used depending on the dimension of the visualized element as well as on the detail to be displayed on these elements.

Many are aspects that need further research: from the automatic superimposition of virtual content on the real object to database connection and real-time retrieval of stored information to the possibility in updating this information from the building site to the capability of having real-time multiuser experiences. So, the road to a truly usable system during construction activities is still very long; nonetheless, the prototype assessed the feasibility of the research project and showed positive initial results.

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