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# Mixed reality application to support infrastructure maintenance

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**Abstract**— This paper presents a mixed reality (MR) application developed for the head-mounted display Microsoft HoloLens that supports infrastructure maintenance works in buildings with complex infrastructure. The solution is intended to help maintenance workers when they need to track and fix part of the infrastructure by revealing hidden infrastructure, displaying additional information and guiding workers in complex tasks. The application has the potential to improve maintenance worker’s tasks as it can help them perform faster and with more accuracy. The work explores the creation of the application and discusses the methodologies used to build an optimal and user-friendly tool. The methodology is based on design science research: an improvement need, and not necessarily a problem, was identified, and from there a solution was conceived. MR has proven to be a major tool for helping in several areas, and this paper can give insights for many future solutions with mixed reality or HoloLens and help them build new and better applications to improve tasks at a job or at home.

**Keywords**— *Building maintenance, facility management, hologram interface, Microsoft HoloLens, mixed reality*

## I. INTRODUCTION

Building maintenance is a part of Facility Management (FM) and comprises all the general repairs and preventive maintenance of systems and equipment that keep a building in the required functional standard. As buildings become more and more complex and the number and complexity of embedded systems grows, the way it is managed and executed however changes too. One of the current possibilities is to improve it with Mixed Reality (MR). Maintenance workers regularly face the situation where they must remove false ceilings or floors to check or fix a faulted infrastructure, for example a pipe, a vent or electric line. These infrastructure components are scattered throughout all buildings and can be hard to locate, especially when the building is not well documented with exact blueprints, which are hard to read and interpret.

The ability to preview the inside of a building before opening a hole in it is what MR can offer if done correctly. The project we propose is to create an application that can be user friendly and extremely accurate, so that it can show a

maintenance worker all the infrastructure in the shape of a hologram as if it is floating right in front of him using the Microsoft HoloLens, a Mixed Reality head-mounted display (HMD) that can read the surrounding environment and display holograms. The solution presented for our problem is to build a program that can accurately detect where the user of HoloLens is in a given virtual 3D building and then show him/her the infrastructure present around him. A different possible solution, is to project an interactive 3D hologram of the building into a flat surface. The user can zoom in and out of it and explore freely to see in detail where everything is. This later solution must also be user-friendly; however, it doesn’t depend on the location of the user as it can be presented independently of the location of the user in relation to the modeled building.

This paper starts with an introduction to the societal problem that gave origin to the research and an argument is made into the working context, main technological issues and the contributions. A review of the very recent developments in the fields of building maintenance and mixed reality follows. Then, the research methodology is explained, and the structure and functions of the application are demonstrated. The final sections contains short remarks on the future work and the path we see for the application of this technology.

### A. Motivation

Creating this MR application involves several different challenges on a technical level. It includes learning new high-end technology, exploring real life problems and test solutions with the hardware of the future, which is holograms. The main investigation questions this paper wishes to answer are:

- Is Microsoft HoloLens’ hardware and software capable of handling the programs and models these building maintenance problems need? What are the limitations of HoloLens?
- How does the application accurately map and identify the user’s real location on a 3D virtual model?
- What is the information necessary for a maintenance worker when fixing infrastructure? What part of it should be displayed on the user interface hologram?

- What is the best solution for our project? Is it to create an interactive fixed projection of the 3D model of the
- campus on a flat surface, or a dynamic hologram that detects the user's location and shows the infrastructure behind the walls?

The challenges discussed can be tested in ISTAR, where all the hardware requirements are met, and a 3D model of the ISCTE-IUL campus already exists. With this technology available, we intend to test it with ISCTE-IUL's internal and external maintenance staff.

### B. Contributions

This paper furthers our knowledge as researchers on Microsoft HoloLens and the potential of MR applications for dealing and helping with old and recent problems today. Concretely, these are the contributions intended after development is finished and documented:

- Extensions to the state of the art in mixed reality for building maintenance (section II), detailed in section III and IV.
- Creation of a new user interface with holograms – aid a new member of ISCTE-IUL explore the campus, allowing him to see useful information with interactive holograms; aid maintenance workers explore the infrastructure and interact with its hologram model.

## II. LITERATURE REVIEW

The state of the art in MR is widespread throughout diverse areas such as health, military, education and maintenance. This chapter provides an analysis on the overall context of the state of the art for several of these areas and then details the work that inspires and relates to this paper's application.

### A. Related Mixed Reality Work

The application presented in this paper relies on 3D holographic views of an infrastructure. This infrastructure can be compared with a living organism with veins and arteries, as the one projected in a hologram by researchers at the University of Lübeck [1], as shown in Fig. 1.

Our work's goal is a solution that can project not the organism and its veins and arteries, as represented in [1], but the infrastructure components like wires, pipes and vents. In the area of health, image guided surgery is the state of the art for MR [2], and these visualization techniques are useful when implementing this paper's application as the visualization technique is related.

Xue, H. [3] developed an augmented reality application for military training. He uses markers to better help HoloLens map and track the user's location in the real world. This alternative is to be explored during the implementation of our user interface, as real markers can provide a starting point for HoloLens to start mapping the virtual world around it and from there create its own virtual markers. However, this approach is

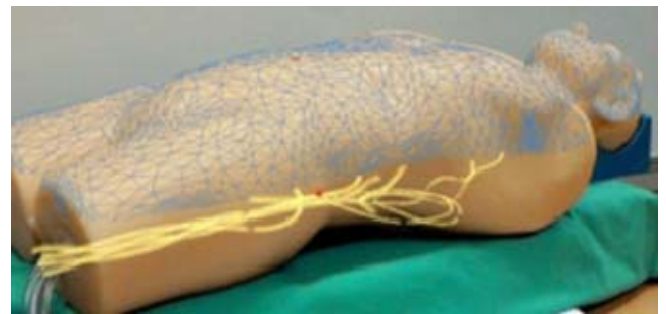


Fig. 1. Holographic view of the interior of a human body replica [1]

not the cleanest, as it involves extra production, and the goal in this paper is to provide a markerless solution.

Fig. 2 shows that the interface can turn out to be quite disorganized, even with markers, and one of this paper's goals is to simplify and make it user-friendly.

In education, MR is very favorable for teaching students and teachers in simulated environments [4]. This virtual platform provides a virtual classroom where the student can connect with avatars which have artificial intelligence commanding their voice and behavior, and learn by interaction. At Aachen University [5], a virtual reality (VR) laboratory is presented in which machines in the real world are synchronized in real time with their corresponding models in the simulated VR lab, as shown in Fig 3. This setup offers the unique ability to remote control the real-world machine, by controlling the virtual ones using a head-mounted display such as Oculus Rift [6].

The overall concept in these education applications is the creation of a virtual environment that, with the use of intelligent avatars and holographic projects, can simulate a real-world classroom scenario. The idea of creating a virtual scenario is also applied in this paper, as the HoloLens can project the 3D model of the university campus in real scale, as if the user is walking in the virtual campus. Once that environment is created, the user can then explore the buildings and infrastructure in the 3D world as he desires, but also seeing infrastructure that is occluded by walls and ceilings.



Fig.2 User interface for military training using markers and HoloLens [1]



Fig.3. Real world setup visualized in a Virtual Reality scenario

In the entertainment industry, mixed reality is especially noticeable for evolving old games and sports into revitalized experiences [7]. This means that simple activities such as coloring books can have a new potential with technology advancements and be a whole new form of entertainment. Basketball can also be upgraded into a power-up game with a virtual playing ball, which intensifies and may improve the experience of the game. This paper takes these transformations in the entertainment industry as inspiration to create the most immersive scenarios possible, as this immersion is what users hope for when using head-mounted display for games and for work. The goal is that the created 3D world feels real and users can interact with it seamlessly, as if holograms were tangible objects.

#### B. Previous Work in Building Maintenance

Regarding previous work in building maintenance with mixed reality, the most relevant case study known at the time of writing this paper is the Thyssenkrupp application that revolutionized the elevator industry with Microsoft HoloLens [8]. In a partnership with Microsoft, Thyssenkrupp created a holographic application to assist elevator maintenance workers with their everyday tasks. This application is extremely relevant for this paper, as some of the main features are similar, except they are applied to building maintenance and not elevators. The core functions the application in this paper will provide, in parallel to Thyssenkrupp's app, are the interactive 3D user interface and interactive 3D models of the object in need of fixing (Fig 4). Their app also offers live Skype calls of workers in need of assistance, and the Skype responder can visualize what the caller is seeing, making it possible to verify or assist the repair work in real time.

One of the aspects of the MR application in this paper is its ability to see behind walls with hologram representations of the occult. Researchers at DAQRI [9] have created an augmented reality (AR) helmet which has this exact ability. Their purpose is to aid in construction management and inspection, as they allow the user to see exactly what infrastructure components are behind a wall or ceiling. The experience these workers have is a fraction of the experience this paper wishes to provide, as it doesn't contemplate interaction with the 3D holograms, which HoloLens can offer.



Fig. 4. Visual representatio of workers' view [8]

Researchers of the French Institute for Research in Computer Science and Automation (INRIA) described a relevant and interesting ecosystem that helps the transition of complete physical activities to its virtual opposites [10]. This system directly applies to most maintenance MR applications, since all tasks were purely physical in the past and are now transitioning to its virtual form. The current solutions for MR in maintenance can be described as hybrid systems, since they don't rely only on physical or virtual, but on both environments.

#### C. HoloLens Specific Work

One of the topics explored for developing the MR application is the choice of the toolkit used to develop the application, as there are several options in the market for developing MR for the HoloLens. Vuforia [11] seems to be the optimal choice and will be used in the implementation stage, as it offers object recognition features with a great maximum capturing distance of 1.2 meters, and most of all it is already supported and easily integrated with HoloLens.

The state of the art for HoloLens and MR is well explored by Coppens [12]. This author described several of the most recent applications that use HoloLens (Fig 5) as well as its most powerful features - "being able to see the real world through autonomous glasses capable of superimposing holograms anchored in the environment (occluding the models if necessary thanks to the spatial mapping capabilities) had never been achieved before".

Known limitations of HoloLens [12] are its short field of view and social acceptance issues due to its bulk size, which can, in the future, be solved through improved technology, e.g. retinal displays.

### III. METHOD

The investigation approach in this paper is of objective-centered solution, since, instead of a problem, we identified a possible improvement that originated the idea for this project. The idea and its motivations were previously detailed in section I and II, as well as a definition of the objectives and questions to investigate in development.



Fig. 5. HoloLens application example in building visualization [12]

In this section we will demonstrate the design steps for the application and aspects of development that have been made so far, as followed by the Design Science Research Model (DSRM) methodology. The results and discussion sections describe and justify the objectives fulfilled and their evaluations so far, according to the tests that will take place after the solution is complete.

#### A. Setup

When designing the solution for the project and thinking of ways to build and develop it, the initial setup was mounted as advised by Microsoft [13]. The setup (Fig 6) consists of Revit [14], a software for modelling buildings and infrastructures, Unity3D [15], a game engine, Visual Studio [16], an Integrated Development Environment (IDE) software for programming in C# language and Microsoft HoloLens itself.

The intent is to adapt this setup while implementing the solution. Unforeseeable obstacles and requirements will appear, which we will need to overcome either by adapting the setup, adding new components to it or simply circumvent them with data manipulation.

#### B. Initial Development

Even though the designed solution isn't completed at the time of writing, one of the objectives is to explore HoloLens, its capabilities to solve our needs and its limitations. In this sense several small projects using the full integrated framework of Unity, Microsoft Visual Studio and HoloLens have been developed, as represented in Fig 6.

The basic hologram design which fully integrates all the framework components together and is a solid start for the project consists of:

- Exporting of the 3D geometry of the BIM model produced in Revit to the FBX format;
- Exporting of alphanumeric information regarding building components contained in the BIM model to XML format via the scripting language Dynamo for Revit
- Integration of the FBX and XML files from Revit into Unity and matching of the geometric and alphanumeric information;
- Unity development to adjust the 3D model and interface;
- Visual Studio development to compile the executable program that uses the models created with Unity;
- HoloLens emulation with Visual Studio;
- Final utilization with a real HoloLens

The above development steps have already been prototyped and are the same as the final solution, the only change being the model to be used (ISCTE-IUL campus).

#### IV. RESULTS AND CONCLUSIONS

The results presented are what it is intended and expected to be the final product of this paper's proposed solution. The final project will consist in one or even two concretizations of the following concepts. The first concept is partially developed and displayed in Fig 7: a holographic projection over a fixed flat surface of the 3D model the user needs to maintain: a building, a town, a car or any other type of infrastructure. In the demo, a user successfully explores around and inside the model.

The interface to move the model, place it on a flat surface and zoom using gestures is partially completed and under testing. The coding in Unity and Visual Studio for the creation of the interactive interface, including choosing which elements

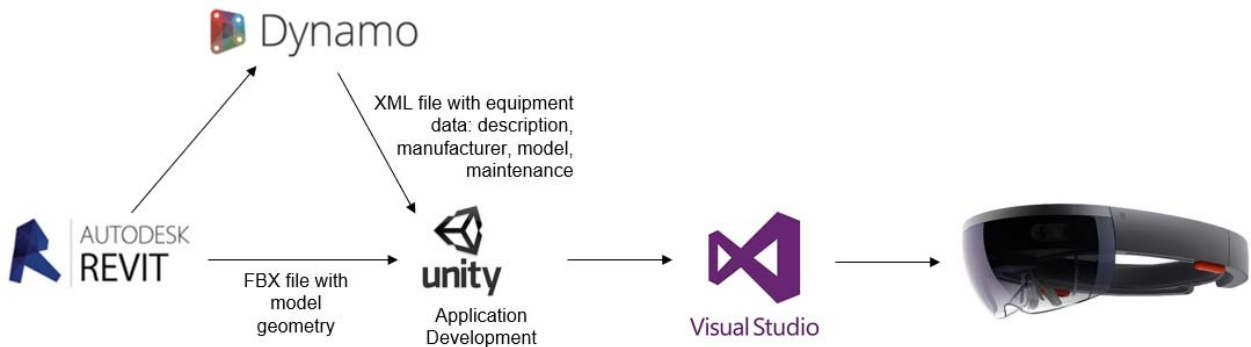


Fig. 6. Development setup

should be displayed and hidden to facilitate visualization, displaying of written information about equipment are already developed.

The second concept is a dynamic projection of the infrastructure that can be queried for diverse information: e.g. function, materials, repair and maintenance instructions. In our case, most infrastructure is occluded behind walls, floor and ceilings rendering the HoloLens particularly useful. The solution for the 3D interface will be similar to the UI portrayed in Fig. 8 as it gives a fair amount of information without being disorganized and provides simple and clear instructions to help the worker in his task.

A practical and similar example of the ideal solution can be seen on this video of the HoloGarage from Yamagata Corp [17].

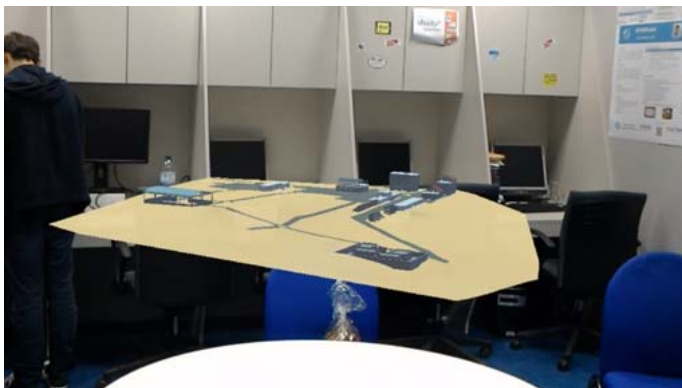


Fig. 7. Building complex tridimensional model presented above a table in the ISTAR-IUL laboratory



Fig. 8. Interactive 3D interface to aid maintenance repairs [8]

Currently there are still little concrete and final results to discuss, however it is intended that the end solution will clearly demonstrate the project defined in this introduction and answer the investigation questions proposed. There is still work in progress, this paper presents a foundation to the dissertation in mixed reality to support building maintenance with HoloLens.

The objectives are defined, the capabilities of HoloLens are being tested, namely its capability to store geometrical information about a large indoor space, as per questioned in the first section of the paper. The conclusion to this project will demonstrate a new approach to building inspection and maintenance and present new ways of designing an interactive 3D interface for maintenance workers.

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