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تموضع الأجهزة الطبية وإرسائها باستخدام الواقع المختلط

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الملخص:

شهدت الجراحة الدقيقة والعمليات الطبية في المستشفيات ومراكز الرعاية الطبية تطورات كبيرة بفضل القدرات المتزايدة والدقة التي توفرها الأجهزة الطبية في الخدمات التي تقدمها. ومع ذلك، يواجه الأطباء والموظفون الصحيون تحديات ملحوظة عند التعامل مع تشغيل وضبط وتثبيت هذه الأجهزة، لا سيما في المرافق الطبية الجديدة المنشأة بأحجام ومتطلبات متخصصة متنوعة، مع مراعاة الأبعاد والوزن لبعض الأجهزة. تسعى هذه الدراسة لتقديم حلاً فعّالاً للتعامل وتثبيت الأجهزة الطبية مثل (روبوت دا فينشي، جهاز الرنين المغناطيسي، جهاز C-ARM) داخل بيئات المستشفى. الهدف الأساسي هو عرض نموذج ثلاثي الأبعاد للجهاز الطبي في المساحة المطلوبة باستخدام Microsoft HoloLens 2 ، لتوفير نظرة مسبقة للفريق الطبي على الوعي المكاني. حيث قدم النموذج ثلاثي الأبعاد حلاً لمحاكاة تحركات الأجهزة الطبية الحقيقية وتثبيتها في البيئة الحقيقية. تساعد هذه الطريقة في منع التداخل مع العوائق وتمكين التخطيط الاستراتيجي للمسار الأمثل للتعامل مع الجهاز الطبي الفعلي وتثبيته. على سبيل المثال، تم وضع نموذج ثلاثي الأبعاد لروبوت الجراحة دا فينشي بدقة على الأرض، مع مراعاة العوائق القريبة، وتكرار الأبعاد الدقيقة للجهاز الأصلي (الارتفاع: 175.3 سم، الطول: 127 سم، العرض: 91.5 سم). في هذه الدراسة التحقيقية الأولية، قيمنا فعالية النظام المقدم في إعادة إنتاج الحواجز الحقيقية التي تقيد حركات الجهاز الطبي وقابليته للاستخدام في إدارة النسخة الافتراضية للجهاز.

تاريخ الايداع

تاريخ القبول

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Placing and Docking Medical Devices Using Mixed Reality

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Abstract:

Minimally invasive surgery and medical operations in hospitals and medical centers have seen advancements due to the increased capabilities and precision offered by medical devices in their provided services. Nonetheless, doctors and healthcare staff encounter notable challenges when it comes to operating, configuring, and docking these devices, particularly in newly established medical facilities of varying sizes and specialized requirements, considering the dimensions and weight of certain devices. This study seeks to present an efficient solution for the handling and placing of medical devices such as (Da Vinci Robot, MRI, C-ARM) within hospital environments. The primary objective is to project the 3D model of the medical device into the desired space using Microsoft HoloLens 2, providing the medical team with a preview of spatial awareness. Where the 3D model gave a solution for simulating the real medical devices moving and docking in the real environment. This approach aids in preventing interference with obstacles and allows for strategic planning of the optimal path for handling and docking the actual medical device. For example, the 3D model of the Da Vinci surgical robot was accurately positioned on the floor, considering nearby obstructions, and replicated the precise dimensions of the authentic system (height: 175.3 cm, length: 127 cm, width: 91.5 cm). In this preliminary investigation, we assessed the system's effectiveness in reproducing real barriers that restrict the movements of the medical device and its usability in managing the virtual replica of the device.

1. Introduction:

Since the 1980s, robotic tools and medical devices have played a pivotal role in aiding surgical procedures, leading to the development of various robotic devices for diverse applications (Lanfranco et al. 2004), (Kwoh et al. 1988). The Da Vinci robot, in particular, offers distinct advantages over traditional laparoscopy, including 3D vision, tremor filtering, and intuitive control (Iranmanesh et al. 2010). However, challenges arise due to the device's size and the time required for system configuration between operating rooms, presenting persistent difficulties that may prove formidable to overcome (Iranmanesh et al. 2010).

Presently, the process of operating large devices outside their designated rooms and connecting them to new locations of varying sizes and specialties still heavily relies on manual intervention. The success of this undertaking significantly depends on the user's skill and spatial awareness. In this initial study, we propose a digital approach to enhance the initial manipulation and docking of the Da Vinci surgical robot within the operating room. This entails incorporating a virtual representation of the robot into the actual operating room, eliminating the necessity for physical relocation or transfer of the device between different rooms.

2. Literature Review:

On the contrary, in 2010, Iranmanesh et al. engaged a team of trained nurses in the setup and docking of the robot, with the assistant surgeon guiding a scrub nurse in positioning the robot before the actual docking at the patient's side (Iranmanesh et al. 2010).

In 2020, Schans et al. tackled these challenges by implementing a 6-week training program for professional nurses and surgeons, streamlining the draping process to 5 minutes and the docking process to 7 minutes (van der Schans et al. 2020).

A separate study conducted by Hoang et al. (2022) utilized augmented reality through HoloLens to create a robot model featuring two types of Virtual Barriers for safety: a Virtual Person Barrier that surrounds and tracks the user, preventing collisions with the robot, and Virtual Obstacle Barriers that users can establish to safeguard specific areas from robot entry. The barrier is positioned at the HoloLens headset's location and is monitored using the AR headset's internal sensors, ensuring user protection by moving along with the user's headset during workspace navigation. To avoid user distraction during tasks, the person barrier is depicted with spherical markers of low opacity, outlining the barrier (Hoang et al. 2022).

Cogurcu et al. (2022) proposed a solution for visualizing a robotic arm using HoloLens 2 (HL2). The hologram remained fixed in its position and could detect the safe zone of users within the workspace. To achieve this, they employed scenarios involving Speed and Separation Monitoring (SSM) and integrated the Augmented Reality (AR) system with the SSM calculations. The robot arm was presented with a 3D cylinder or cube representing the safe zone (Cogurcu and Maddock 2023).

3. Material and Methods:

3.1 Unity 3d Implementation

Unity3D, a game engine, was employed to create an MR environment. MR systems necessitate users to carry a computer and/or a Head-Mounted Display (HMD). These systems encompass MARS (Mobile Augmented Reality Systems), which are portable setups combining a computer with 3D graphics acceleration, GPS and/or indoor localization, a transparent head-mounted display, wireless LAN, and other components (Kim and Suk 2014).

The first step involved configuring the Unity3D environment to incorporate Mixed Reality (MR) tools. This was accomplished by importing several packages, including the MR Toolkit Foundation, Standard Assets for scene construction, and the MR OpenXR Plugin, which aided in deploying t0 the HL2 model. The HoloLens 2, a Microsoft-designed and produced head-mounted display (HMD), offers an immersive experience, enabling users to engage with the environment using holograms and activating their senses in the process (Palumbo 2022). HoloLens 2 visualized the 3D hologram of the medical devices in real demotions to help the user dock it in the required position considering the obstacles. We integrated the 3D model of the robot and two medical devices (MRI and C-Arm) with some features provided by Unity 3D to provide a realistic experience of the robot's mobility. For example, to secure the model to the floor, we implemented the gravity option by incorporating the "Rigidbod" component. For configuring, relocating, and securely docking the model in the designated space, we activated both the "ObjectManipulator" and "NearInteractionGrabbable" components. To ensure the device doesn't collide with nearby obstacles, we enabled spatial awareness within the scene, making the 3D model aware of all mesh lines generated by other objects in the environment, including walls, ceilings, doors, and medical equipment typically found in operating rooms.

Moreover, a user interface has been added to help the user to choose which device wants to see first, or to visualize all the device together at the same time. by adding 3 buttons in the scene where the user is able to see those buttons once he looks to his left-hand palm as the HoloLens 2 has the ability to track the hand

3.2 Deploying the project into HoloLens 2

Our design was implemented on HoloLens 2 to visualize and interact with the robot within a real-world setting. The tool we developed allows users to view a 3D model of the devices, enabling them to position and manipulate them in all directions on the floor, except for movement along the axis perpendicular to the floor (the y-axis in Unity 3D). Users can grasp the hologram using two fingers (thumb and forefinger) and move it, except when obstacles are obstructing its path in the environment. These obstacles prevent the hologram from crossing them because the HoloLens 2 utilizes spatial mapping to generate a grid mesh that defines the boundaries of the environment. The experiment commenced when users initiated the application on HoloLens 2, and their initial observation was the creation of a grid mesh covering the environment through the HoloLens 2.

3.3 Testing the Models

We conducted various tests on the 3D model to assess its capabilities and movement across diverse environments, including a corridor, hall, and room. Users were invited to evaluate the surgical cart model within these settings. Utilizing HL2, they immersed themselves in the visualization and interaction with the 3D model of the Da Vinci robot, simulating its movements and interactions with the surroundings.

The application initiated the process by scanning the environment in HL2 and creating a grid mesh to cover it, enabling the identification of the floor. Subsequently, the virtual Da Vinci model was positioned in a space that accommodated its dimensions without overlapping with nearby objects. The grid mesh lines facilitated the recognition of obstacles, as depicted in Figure (1) and Figure (2). Users had the flexibility to view the model from any angle, allowing interaction by moving it to various positions on the floor through a drag-and-drop action with two fingers or rotating it around the y-axis.

The application imposed restrictions on moving the model along the y-axis and rotating it around the x-z axis. Moreover, when the 3D model encountered barriers or walls, it came to a halt. Attempts to push it against obstacles resulted in the 3D model tilting on its side, as illustrated in Figure (3), serving as a clear warning of a hazardous situation

4. Results and Discussion:

The HL2 successfully generated a grid mesh with the capability to encompass the majority of objects in the environment. For instance, barriers comprised of boxes were strategically positioned on the ground and reconstructed, as illustrated in Figure 1.

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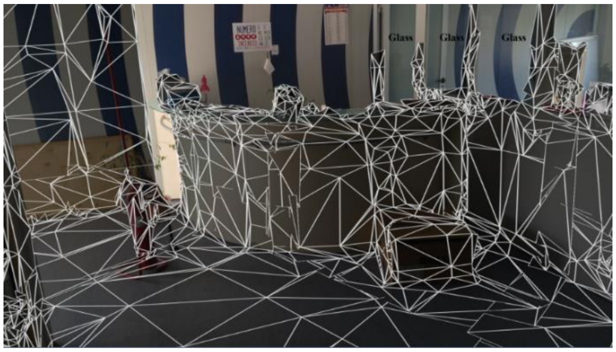

Figure 1 - Barriers and mesh grid in the environment

After the grid mesh was created using HL2, users had the capability to observe the 3D model of the robot as it landed on the ground, allowing them to view it from different angles. Furthermore, they noticed that when the robot was pushed toward obstacles, it would tilt or start to lean on its side, simulating a realistic response to a precarious situation, as depicted in Figure 2 and Figure 3.

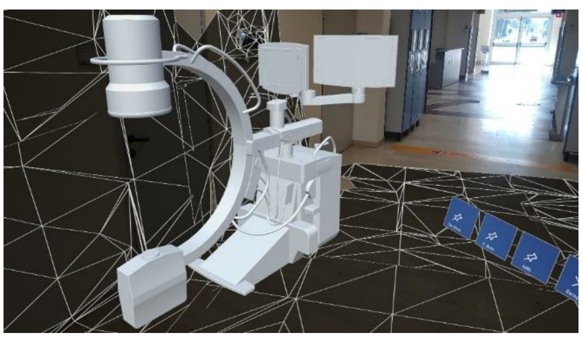

Figure 2.A - Dogging C-Arm on the ground

Figure 2.B – Dogging Da Vinci and MRI.

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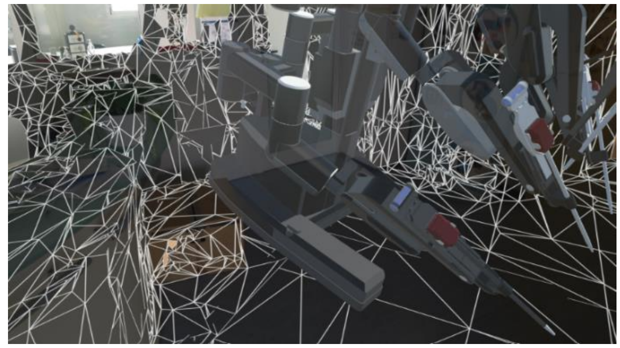

Figure 3 - Blocking the Da Vinci by a barrier

Figures 2.a and 2.B also show the user interface as 4 pressable buttons that can be seen once the user looks to his palm.

The system demonstrated the ability to detect both solid objects and smaller items (e.g., tubes, bars, sockets) measuring at least 5 cm within the designated space, as illustrated in Figure 4. Additionally, we verified that the 3D models could effectively interact with these objects. The HL2 efficiently regenerated the grid mesh when users shifted their head position to an uncovered area, but there was an extended processing time to recognize tubes or bars in space. Unfortunately, it was incapable of reconstructing transparent surfaces such as glass windows, as depicted in Figure 1.

When the robot reached the boundary of the scanned area and encountered user-induced pushing, it descended into empty space. This necessitated subsequent movement toward the unexplored region and a brief waiting period for the HL2 to regenerate a grid mesh, considering its capacity to cover an approximate radius of 5-6 meters

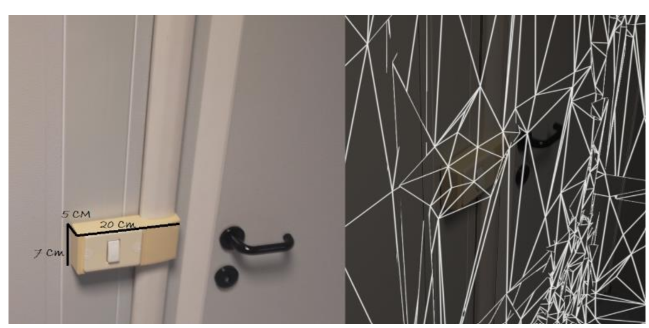

Figure 4 – Rebuilding of small objects by HL2

Table 1 - Users Responses to Likert Questionnaire

Users	Questionnaire categories		
	Visualization	Usability and Interactions	Mesh Generating
User 1	4.5	4	4
User 2	5	5	3.5
User 3	5	4.5	4
User 4	5	4.5	5
User 5	4.5	4.5	4
User 6	3.5	3.5	4
User 7	4.5	4.5	4
User 8	4	3	4.5
User 9	5	3.5	3.5
User 10	4	4.5	4
Median	**4.5**	**4.25**	**4**
IQR	**0.87**	**0.87**	**0**

Table 1 showcases the users' responses to the questionnaire. To begin with, we computed the median of the responses and documented them in the relevant category columns. Following that, we determined the median for each column and presented it in the Median field. The interquartile range (IQR) for each category is also included. Table 1 exhibits the users' responses to the questionnaire. Where, according to the survey results, the "Visualization" aspect received predominantly positive feedback, with a majority of users expressing high satisfaction with the 3D model. More than half of the responses scored above 4.5 on the scale, indicating strong agreement. The relatively narrow interquartile range (IQR) of 0.875 suggests that responses were closely clustered around the 4.5 mark, reflecting a consistent level of satisfaction.

In the "Usability and Interaction" category, participants strongly agreed on the smooth movement and easy control of the hologram. However, there was a slight decline in satisfaction related to mesh generation. It took approximately 2-3 seconds to cover a 6-meter radius area, and users needed to move forward to expand coverage for manipulating Da Vinci's 3D model in new spaces..

While graphs have their numbers, description and reference (if needed) under the figure, in bold size 10 font, as shown in figure 1:

5. Conclusion:

To enhance medical procedures in the hospitals and address challenges associated with the transfer of big devices, it is crucial to develop a solution that facilitates efficient docking and seamless transitions between surgical rooms. This approach aims to minimize time consumption and potential complications linked to physically relocating of those devices.

In this study, we propose a solution involving a 3D hologram model created with HL2. The precise virtual representation of the medical device allows users to manipulate its position within the current room, considering physical barriers as realistic obstacles in the simulation. It's noteworthy that the system currently lacks the ability to reconstruct glass panels, although these are typically limited in surgical rooms. Further validation through tests in real environments during routine clinical practice is imperative. Our tests focused on a virtual replica of the patient cart, but the integration of the console and vision cart is also feasible.

We believe that the surgical room layout can be efficiently planned using MR visualization due to its intuitiveness, providing immediate spatial understanding and awareness of the work environment. This aids in determining if there is sufficient space for robots, machinery, and humans. The intuitive interaction and safe movement of the virtual robot through the MR application can streamline the physical placement of the new element in the surgical room, preventing errors and time loss. It also highlights the challenges that medical staff may encounter when translating the 3D model into reality

6. Acknowledgement:

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7. References:

1- Cogurcu, Yunus Emre, and Steve Maddock. 2023. “Augmented Reality Safety Zone Configurations in Human-Robot Collaboration: A

User Study.” *ACM/IEEE International Conference on Human-Robot Interaction*: 360–63.

2- Hoang, Khoa C. et al. 2022. “Virtual Barriers in Augmented Reality for Safe and Effective Human-Robot Cooperation in Manufacturing.” *RO-MAN 2022 - 31st IEEE International Conference on Robot and Human Interactive Communication: Social, Asocial, and Antisocial Robots*: 1174–80.

3- Iranmanesh, Pouya et al. 2010. “Set-up and Docking of the Da VinciÂ® Surgical System: Prospective Analysis of Initial Experience.” *JSLS : Journal of the Society of Laparoendoscopic Surgeons* 10(Jul-Sep): 317–320.

4- Kim, Sung Lae, and Hae Jung Suk. 2014. “Using Unity 3D to Facilitate Mobile Augmented Reality Game Development.” *2014 IEEE World Forum on Internet of Things (WF-IoT)*: 21–26.

5- Kwoh, Yik San, Joahin Hou, Edmond A. Jonckheere, and Samad Hayati. 1988. “A Robot with Improved Absolute Positioning Accuracy for CT Guided Stereotactic Brain Surgery.” *IEEE Transactions on Biomedical Engineering* 35(2): 153–60.

6- Lanfranco, Anthony R., Andres E. Castellanos, Jaydev P. Desai, and William C. Meyers. 2004. “Robotic Surgery: A Current Perspective.” *Annals of Surgery* 239(1): 14–21.

7- Palumbo, Arrigo. 2022. “Microsoft HoloLens 2 in Medical and Healthcare Context : State of the Art and Future Prospects.”

8- van der Schans, Emma M., Marijn A.J. Hiep, Esther C.J. Consten, and Ivo A.M.J. Broeders. 2020. “From Da Vinci Si to Da Vinci Xi: Realistic Times in Draping and Docking the Robot.” *Journal of Robotic Surgery* 14(6): 835–39. https://doi.org/10.1007/s11701-020-01057-8.