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A Non-Contact Measurement Method based on HoloLens

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Abstract

In this paper, a non-contact measurement method with interactive functions is proposed based on the HoloLens, a mixed-reality product by Microsoft. By scanning the measurement space using the depth camera on the HoloLens, and by determining the measurement points using the Gaze and Gesture functions, this method enables non-contact measurement and automatic calculation of the distance, area and volume between the target points. Furthermore, it supports speech recognition for interaction. Compared with traditional measurement tools, the interactive measurement tool developed in this paper allows its users to take measurements in a more natural, contact-free way. Its broader measurement range, automatic calculation of area and volume while measuring distances, and the ability to measure places that are difficult for the traditional measuring tape, show its good application value.

Keywords: HoloLens; MR technology; non-contact measurement

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1. Introduction

Mixed Reality (MR) is proposed by Steve Mann, a professor at the University of Toronto, who is widely regarded as “The Father of Wearable Computing”. MR uses the technologies of computer graphics and visualization to produce virtual objects that do not exist in the physical world and overlays them in a real environment via sensing technology, thus displaying the real environment together with the virtual objects in the same picture or space. Hence, users can experience a new make-believe environment with the help of a display device. The multiple state-of-the-art computer application technologies encompassed in MR, including computer vision, computer graphics, multimedia, and network technology, depict our spaces and enable us to interact with the objects or pictures, which is, ultimately, interacting with the virtual world. [1,2,4,5,6,9]

There are many real-life occasions where we need to measure distance and calculate the volume of certain fields. The obstacles on the sites, however, deter us from directly measuring the distance, let alone automatically calculating the area and volume. Thanks to the advancement of cutting edge technologies such as mixed reality, which bring us awesome experiences, these problems can now be solved.

In this paper, an interactive non-contact measurement method based on mixed reality is proposed. Backed by the spatial scanning function of the depth camera of HoloLens helmet, a mixed-reality product of Microsoft, this method is able to determine the measurement points of the scene through the user’s visual measurement and gestures, so as to automatically calculate the distance, area and volume between target points using self-developed software. It also supports speech recognition for interaction. Compared to traditional measurement tools, the interactive measurement tool developed in this paper enables people to perform interactive non-contact measurement in a natural, hands-free way. Moreover, it supports a broader measurement range and automatic calculation of area and volume. Places that are inconvenient to measure for a ruler can be completed with ease using this non-contact measurement tool.

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2. Technical Principles of HoloLens

On January 22, 2015, Microsoft officially launched the HoloLens virtual helmet, a mixed-reality product it developed, as shown in Figure 1 [7].

Figure 1. HoloLens

Users wearing the HoloLens helmet are immersed in a world where physical and digital objects co-exist and interact in real time. The HoloLens is equipped with multiple sensors, including an inertial measurement unit, an ambient light sensor, four environment-sensing cameras, and a depth camera, as shown in Figure 2. These facilities allow HoloLens to depict the current space and scan the environment in real time. At the center of the HoloLens spatial coordinate system is the depth camera, with X being the horizontal axis; Y the vertical axis; and Z the third dimension of depth. See Figure 3. Consequently, the HoloLens is able to identify relatively large objects in the environment - such as planes, walls, and desktops – and supports tracking, spatial anchors and other functions. The holographic processing unit (HPU) developed and deployed by Microsoft on the HoloLens can be used for real-time scanning and processing of huge volumes of data [3].

Figure 2. HoloLens Configuration

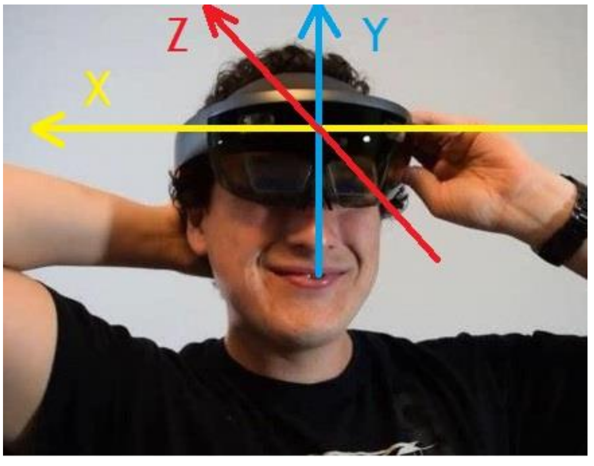

Figure 3. HoloLens Spatial Coordinate System

The HoloLens also has four built-in microphones for voice playback and detection of user voice commands, as well as for ambient noise filtering. Its optical lenses merely consist of a chip for a small projector and some lenses. The projection principle of the HoloLens is the same as that of a normal projector, but it uses a diffractive display rather than a reflective display. That is, the combiners in the head-up display (HUD) are no longer coated flat glasses, but holographic lenses made of (double) curved glass with small etching lines. Consequently, the light is not reflected, but diffracted into the eyes (hence diffractive HUD is also known as holographic HUD). Meanwhile, the holographic lenses also filter out non-visible light, resulting in brighter images and a larger instantaneous field of view. The HoloLens mixes the light from the outside world with the light displayed by the lenses, equally allocating the total 240 frames per second to its four color layers. Therefore, the refresh rate of the overlapped color layers is only60 FPS [8]. The principle of diffraction is shown in Figure 4.

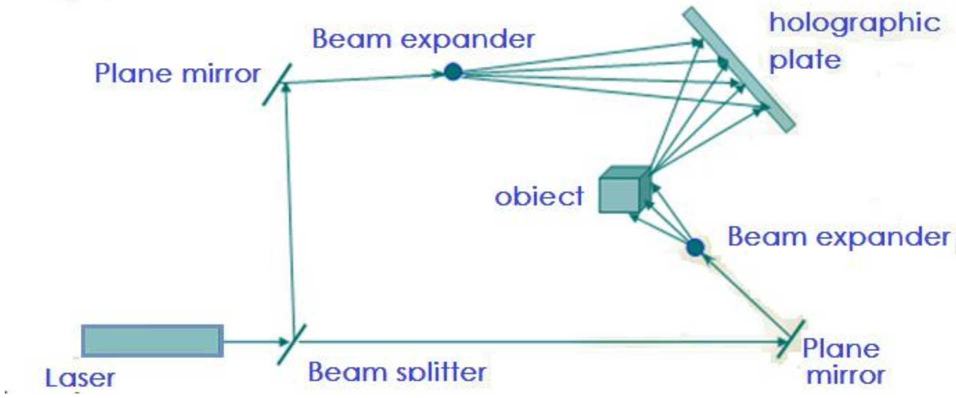

Figure 4. Principle of Diffraction

Currently, there are only three ways for users to interact with the HoloLens: Gaze, Gesture and Voice. The Gaze function is achieved by casting a ray, the direction of which can be controlled by the head movements of the helmet wearer, from the sensor on the HoloLens to identify the object that the ray intercepts in front of the user. Once the intercepted object is detected, there will be a small dot cursor telling the user that an object has been detected and that related operations can be performed. The HoloLens uses four front cameras to identify the gestures of the user's hands. It currently provides users with two kinds of gestures: Air Tap and Bloom. Among them, the former is for confirmation and the latter for return or cancellation. To perform the Air Tap gesture, raise your hand and stretch out your pointer finger and thumb before bringing them together for the HoloLens to recognize your confirmation command. Examples of the Gaze and Gesture are given in Figure 5.

a) Gaze b) Gesture

Figure 5. Examples of Gaze and Gesture

3. Technical Principles of HoloLens

3.1. Project Development Process

The interactive measurement system developed in this paper is composed of the HoloLens hardware and My Tool software. The in-house developed system software My Tool was implemented using the Unity game engine and Visual Studio C# scripts. Then, the software was imported into and installed on the HoloLens via a LAN connection for testing and modification. Now, users wearing the HoloLens helmet are capable of measuring the data of their surrounding spaces. The whole project development process is shown in Figure 6.

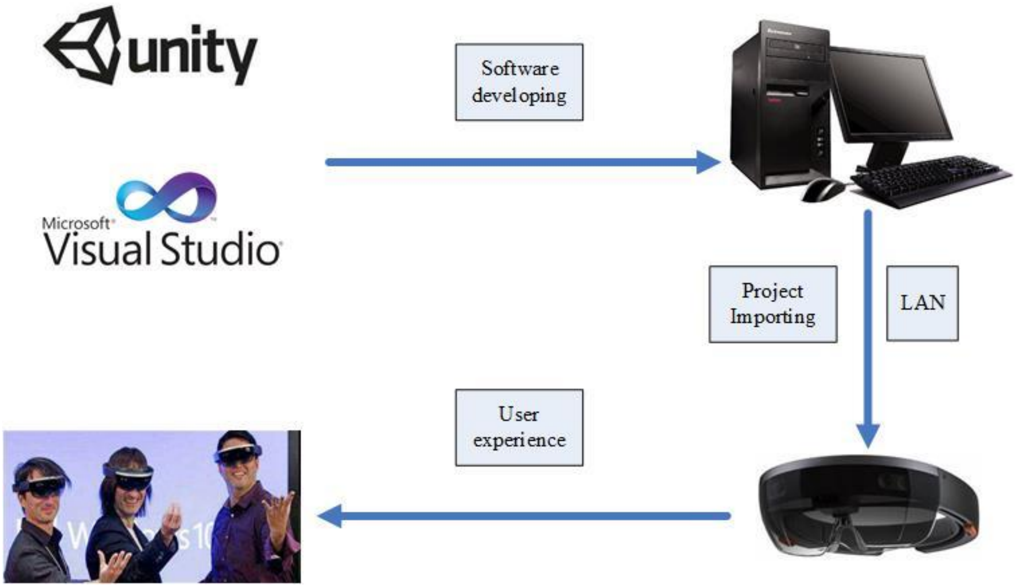

Figure 6. Project Development Process

3.2. Software Design

The system uses the Gaze and Gesture functions of the HoloLens to obtain the measurement points, and then the software automatically calculates the distance, area and volume between these spatial points in accordance with math formulas.

Let's assume that the coordinates of the spatial measurement points in the scene are $(x_1, y_1, z_1), (x_2, y_2, z_2), \cdots (x_n, y_n, z_n)$; according to the principles of plane and space analytic geometry, the formulas of D2, S3, and V4 – which stand for the distance between two points, the area between three points, and the volume of four points - are shown in Formulas (1) ~ (3) below. When calculating the area between four points, the quadrilateral can be divided into two triangles whose areas are then added up.

$$D_2 = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad (1)$$

$$\begin{aligned} S_3 &= \sqrt{p(p-a)(p-b)(p-c)} \\ wherein,\ p &= \frac{1}{2}(a+b+c) \\ a &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \\ b &= \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2 + (z_3 - z_1)^2} \\ c &= \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2 + (z_3 - z_2)^2} \end{aligned} \quad (2)$$

$$V_4 = \frac{1}{6}\begin{bmatrix} (x_2 - x_1)(y_3 - y_1)(z_4 - z_1) + (x_3 - x_1)(y_4 - y_1)(z_2 - z_1) + (x_4 - x_1)(y_2 - y_1)(z_3 - z_1) \\ -(x_4 - x_1)(y_3 - y_1)(z_2 - z_1) - (x_3 - x_1)(y_2 - y_1)(z_4 - z_1) - (x_2 - x_1)(y_4 - y_1)(z_3 - z_1) \end{bmatrix} \quad (3)$$

Once the gesture of the user, who wears the helmet and gazes at the target points, is confirmed, the target points are also determined. Then, the calculation starts and the results are given based on the location and number of the target points. Figure 7 describes the software design process.

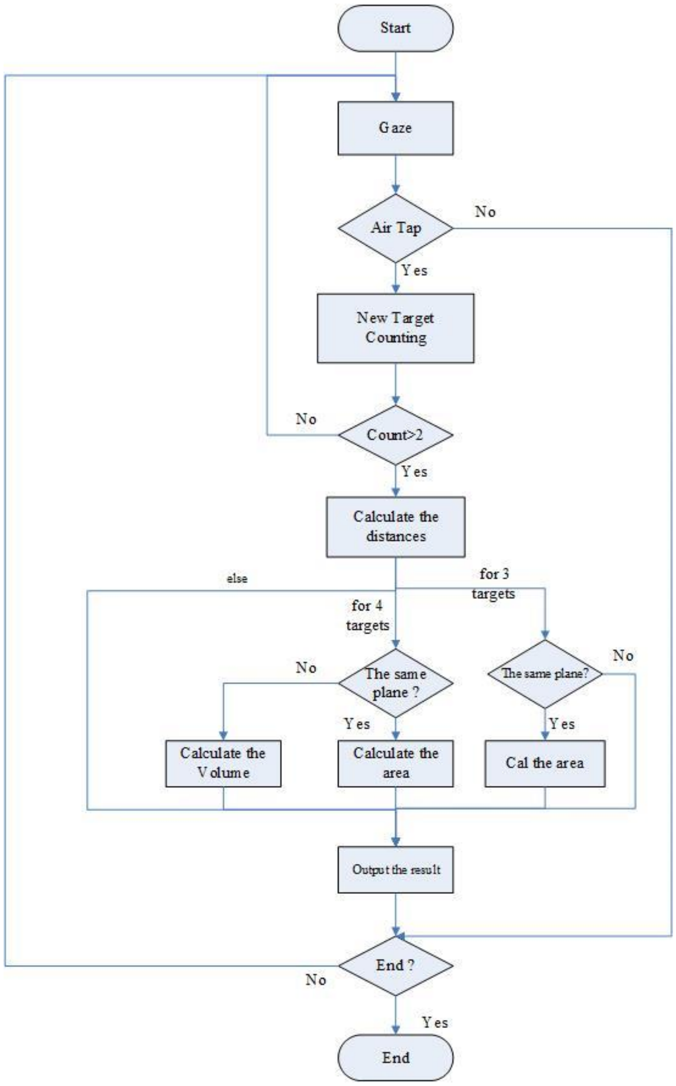

Figure 7. Software Design Process

4. Testing and Effect Analysis

A few measurement examples using the HoloLens helmet are given in Figures 8-11, where the units for the measurement of distance, area and volume are m, m2 and m3 respectively. The triangular grids in the figures were automatically generated during the measurement of the surrounding space and environment when wearing the helmet. The measurement results of this method and of the traditional measuring tape were analyzed and compared in Table 1, with each distance data taking the average value of two measurements. The result shows that the data repeatability of the two measurements using the method in this paper is as high as 99.99%, with a 0.01 meters margin of error compared to the results of a traditional measurement tape. In Table 2, while measuring the height for the same user, the user height value is measured with the different distance between the Hololens helmet and the tested users. The error range can be seen in the millimeter scale.

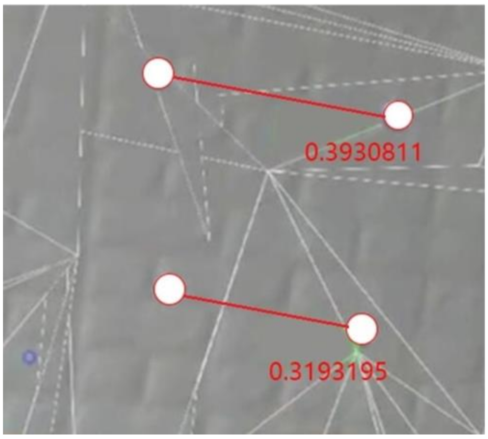

Figure 8. Distance Measurement Between 2 Points out of 4

Figure 9. User Height Measurement (Actual Height: 1.78 m)

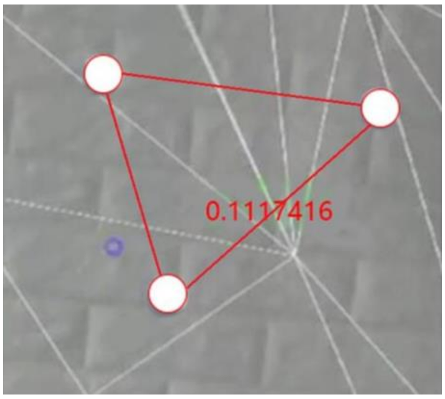

Figure 10. Area Measurement Between 3 Points

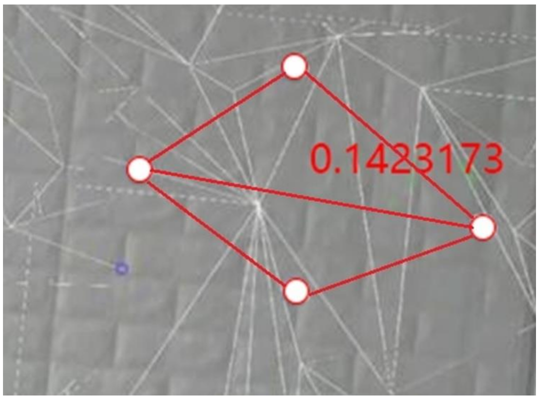

Figure 11. Volume Measurement Between 4 Points

Table 1. Measurement Result Comparison between This Method and the Traditional Measuring Tape

Unit: meter

Distance Measured	Our Method	Traditional Measuring Tape
Distance 1	0.39±0.005	0.39±0.005
Distance 2	0.32±0.003	0.32±0.005
Distance 3	1.78±0.01	1.78±0.01
Distance 4	2.15±0.009	2.16±0.01
Distance 5	5.60±0.01	5.60±0.01

Table 2. Comparison between the results of distance adjustment between the user and the measured object

Unit: meter

The disdance between the user and the measrued object	Our Method	Traditional Measuring Tape
1	1．78569	1.78
2.4	1.782625	1.78
4.6	1.78688	1.78
5.4	1.786194	1.78
7.8	1.786868	1.78

5. Conclusions

The traditional method can only directly measure the length; if other data is desired, the user has to calculate it using math functions. The interactive measurement tool in this paper, however, uses the HoloLens helmet as a carrier and therefore, features its interactive functions, enabling the user to not only measure the distance between two points, but also obtain the area and volume data between the target points. Its margin of error is within 0.01 meters and, under certain circumstances, the HoloLens helmet can eliminate the measurement errors caused by blocked objects, something the traditional measuring tape will need to bypass, or have to measure something else with the same length. But for the interactive measurement tool developed in this paper, once the small confirmation dot for the measuring target has been generated, the coordinates of the dot will be recorded and retained. Thus, the user does not need to bypass or touch anything during the measurement, freeing both hands for something else. Due to the novelty of the technologies and products used in this paper, as well as insufficient development resources, this method does have a few shortcomings. For example, the high-priced HoloLens headset features a depth camera that only covers a range of 30 meters; it only scans relatively large objects like walls, floors and desktops, and measures points on them; it cannot measure spatial floating points. These downsides, hopefully, will be overcome in the near future.

Acknowledgements

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References

1. “Applications of HoloLens Glasses: Exploring the Surface of Mars” [J]. Information Technology and Informatization, 2016,(12):17. [2017-08-07]. (in Chinese)
2. Baoquan Chen, and Xueying Qin. “Composition of Virtual-Real Worlds and Intelligence Integration of Human-Computer in Mixed Reality” [J].SCIENTIA SINICA Informationis, 2016,46(12):1737-1747.[2017-08-07].(in Chinese)
3. Abhijit Ghosh, A K Nirala. “Formation of Uniform Fringe Pattern Free from Diffraction Noise at LDA Measurement Volume Using Holographic Imaging Configuration” [J].Measurement Science and Technology,2016,27(5).
4. “HoloLens: Microsoft’s “Black Technology””, Virtual Imaging Heading for the Future [J]. Information Technology and Informatization, 2015,(06):16. [2017-08-07]. (in Chinese)
5. Jin Huang, Dongqi Han, Yi’neng Chen, Feng Tian, Hong’an Wang, and Guozhong Dai. “A Survey on Human-Computer Interaction in Mixed Reality” [J]. Journal of Computer Aided Design & Computer Graphics, 2016, 28(06):869-880. [2017-08-07]. (in Chinese)
6. Tongxin Qian. “HoloLens: Breaking the Boundary betweenVirtuality and Reality” [N]. First Financial Daily, 2016-06-03(A08).
7. Scott. “Microsoft Demos Its Virtual Reality Glasses HoloLens, Builds Castles out of Thin Air” [J]. ElectronicsToday, 2015,(07):25. [2017-08-07]. (in Chinese)
8. A. Z. Syed, A. Zakaria,S.Lozanoff. “Dark Room to Augmented Reality:Application of HoloLens Technology for Oral Radiological Diagnosis” [J]. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology,2017,124(1).
9. Yang Zhang. “Research and Design of a Human-Computer Interaction Hardware and Software System Based on Mixed Reality” [D].East China Normal University, 2014. (in Chinese)

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