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Effective close-range accuracy comparison of Microsoft HoloLens Generation one and two using Vuforia ImageTargets

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Abstract

This paper analyzes the effective accuracy for close-range operations for the first and the second generation of Microsoft HoloLens in combination with Vuforia Image Targets in a black-box approach. The implementation of Augmented Reality (AR) on optical see-through (OST), head-mounted devices (HMDs) has been proven viable for a variety of tasks, such as assembly, maintenance, or educational purposes. For most of these applications, minor localization errors are tolerated since no accurate alignment between the artificial and the real parts is required. For other potential applications, these accuracy errors represent a major obstacle. The "realistically achievable" accuracy remains largely unknown for close-range usages (e.g. within "arms-reach" of a user) for both generations of Microsoft HoloLens.

Thus, the authors developed a method to benchmark and compare the applicability of these devices for tasks that demand a higher accuracy like composite manufacturing or medical surgery assistance. Furthermore, the method can be used for a broad variety of devices, establishing a platform for bench-marking and comparing these and future devices. This paper analyzes the performance of test users, which were asked to pinpoint the perceived location of holographic cones. The image recognition software package "Vuforia" was used to determine the spatial transform of the predefined ImageTarget. By comparing the user-markings with the algorithmic locations, a mean deviation of 2.59 $\pm$1.79 [mm] (HL 1) and 1.11 $\pm$0.98 [mm] (HL 2) has been found, which means that the mean accuracy improved by 57.1% and precision by 45.4%. The highest mean accuracy of a single test user has been measured with 0.47 $\pm$1.683 [mm] (HL 1) and 0.085 $\pm$ 0.567 [mm] (HL 2).

Index Terms: Human-centered computing— Human computer interaction (HCI)—Interaction paradigms — Mixed / augmented reality; Human-centered computing—Visualization—Empirical studies in visualization

1 Introduction

The development of Augmented Reality (AR) optical see-through (OST) devices has encouraged companies to request AR solutions for an increasing amount of applications. In the manufacturing industry, the implementation of AR for visual guidance has been proven useful for manual assembly and repair operations [1, 4, 7].

Different tasks require different capabilities of AR HMDs. For some tasks, like repair instructions, the human operator only relies on indications on how to execute the next step. But for tasks like manual composite manufacturing (specifically "lay-up"), the operator needs AR guidance for a correct and high precision alignment [3, 8]. Whereas most repair instruction applications use human experience and knowledge of the context for exact alignment, the operator in manual composite lay-up needs to fully rely on the visual guidance in his high precision alignment task, and any defect can result in millions of financial losses for the product/company. Therefore, for this specific application, the visual guidance displayed by the AR HMD needs a high precision close-range usages as well. Naturally, this varies from person to person and from task to task. The developers of such applications would start with a trade-off between various different devices depending on the specific requirements. However, for many devices, the effective accuracy can only be estimated, meaning that an adequate comparison is widely based on gut-feeling or loosely comparable results. This research was initiated based on this need. In our case, the application requirements for composites manufacturing only allowed an absolute deviation of 3mm. For this, not sufficient information was available for a suitable trade-off.

This study aims to deliver measured results for the short-range accuracy of the HoloLens (HL1 and HL2). This short-range accuracy required for e.g. manual composite manufacturing, where the space of operation shall not exceed the maximum reach of a human body [$d_{max} = 500mm$]. In addition, with the results at hand, both generations of HoloLens will be compared with each other.

1.1 Related Work

Due to the design of optical see-through (OST) HMDs it is rarely, if ever, possible to fully eliminate projection errors [6]. Hence, for potential Augmented Reality solutions, the close-up accuracy of holographic content needs to be estimated. The typical distance between test subject and projection shall remain in a user-comfortable distance of 500mm.

Studies for comparable situations [5] indicated a static deviation of $\pm$ 1.92mm, using image recognition algorithms. Others found a deviation error of $\pm$ 5mm over a distance of 50cm [2] or of 5.81mm $\pm$ 0.51mm at 95% confidence level [9].

2 Method

This study only focuses on the measured achievable accuracy by test subjects. rather than establishing an accurate mathematical approach.A software application was designed, which places three holographic markers in reference to an ImageTarget known as the Vuforia based vision system. These holographic markers have an identical shape and size but differ in their respective color (red (hex: FF0000), green (hex: 00FF00), blue (hex: 0000FF).

The participants (20 for HL1 and 22 for HL2) were wearing a HoloLens, and have been tasked to first calibrate the device and pinpoint as accurately as possible where they perceived the holographic markers by shifting predefined crosses on a monitor using the arrow keys. By using algorithmic analysis, the marked location was compared with the intended location defined in the holographic application, providing insight into divergences. The collected data was then analyzed utilizing statistical tools to determine the average perceived location and the spray of the individual markings. The resultant values provide insight into achievable accuracy.

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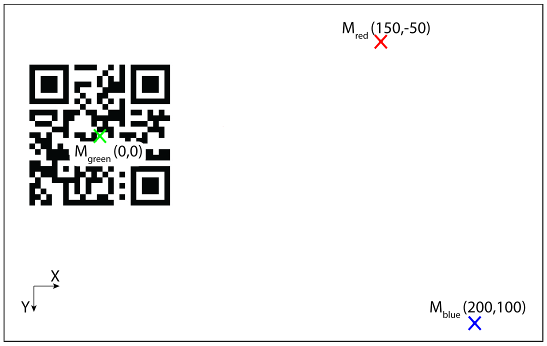
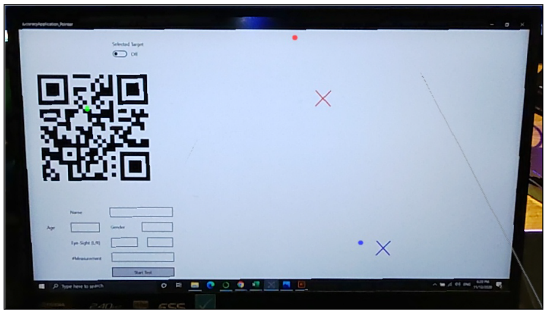


(a) ImageTarget and hologram constellation, coordinates in *mm*



(b) User perspective (user experience differs)

Figure 1: Accuracy test application; ImageTarget and holographic content constellation and user perspective

3 Results

For all test subjects, the geometrical center point of the marked locations was determined. With this center-point [*CP*] the absolute deviation in *x*- and *y*- direction (CPD_X, CPD_Y) and the total magnitude of deviation (CPD_{mag}) was calculated. Furthermore, the spray radius around the center-point [*SCP*], as indicated in Figure 2, was determined. The CPD_{mag} of each individual serves as an approximation of the accuracy of the perceived content, while the spray radius approximates the precision.

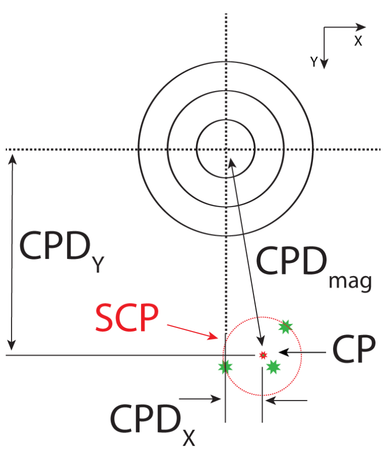


Figure 2: Accuracy Test Terminology; CPD_X, CPD_Y, CPD_{mag}, SCP

This test is designed to measure the horizontal and vertical divergence, not the depth since minor errors along the gaze of the user are tolerable for the use-case this test was conducted for. The measured results are presented in Table 1. Using the mean values of

Property	HL1	HL2	Change [%]	p
CPDx_red	0.560	0.324	42.14	0.001
CPDy_red	-1.579	-0.148	90.6	< 0.001
SCP_red	1.560	0.889	43.05	< 0.001
CPDmag_red	2.390	0.811	66.07	< 0.001
CPDx_blue	1.447	0.795	45.06	< 0.001
CPDy_blue	0.401	0.896	-123.44	< 0.001
SCP_blue	2.019	1.066	47.23	< 0.001
CPDmag_blue	2.804	1.418	49.43	< 0.001
SCP_avr	1.790	0.977	45.41	< 0.001
CPD_avr	2.597	1.114	57.09	< 0.001

Table 1: Accuracy Test, HL1 vs. HL2 Summary with p(HL2<HL1). (Length in [mm])

all measurements per device, a CPD magnitude of 2.59 [mm] and an SCP of 1.79 [mm] was found for the first generation of HoloLens. In comparison, the second generation a CPD magnitude of 1.11 [mm] and an SCP of 0.98 [mm] were found. Using a T-test, the first generation was hypothesized to result in equal or greater mean deviations (and mean spray) than the second generation. The found difference was significant, with $p < 0.0001$ for each test.

4 Conclusion

Using this method, we could justify recommending the MS HoloLens 2 yet not the first generation since a direct trade-off was possible. Hence by using this method, different AR devices can be compared and recommendations are given based on measured data rather than assumptions or educated guesses.

References

[1] D. Aschenbrenner, F. Leutert, A. Çençen, J. Verlinden, K. Schilling, M. Latoschik, and S. Lukosch. Comparing human factors for augmented reality supported single-user and collaborative repair operations of industrial robots. *Frontiers in Robotics and AI*, 6:37, 2019. doi: 10.3389/frobt.2019.00037

[2] S. Condino, G. Turini, P. Parchi, R. Viglialoro, N. Piolanti, M. Gesi, M. Ferrari, and V. Ferrari. How to build a patient-specific hybrid simulator for orthopaedic open surgery: Benefits and limits of mixed-reality using the microsoft hololens. *Journal of Healthcare Engineering*, 2018:1–12, 11 2018. doi: 10.1155/2018/5435097

[3] M. Elkington, D. Bloom, C. Ward, A. Chatzimichali, and K. Potter. Hand layup: understanding the manual process. *Advanced Manufacturing: Polymer & Composites Science*, 1(3):138–151, 2015. doi: 10.1080/20550340.2015.1114801

[4] M. Fiorentino, A. Uva, M. Gattullo, S. Debernardis, and G. Monno. Augmented reality on large screen for interactive maintenance instructions. *Computers in Industry*, 65, 01 2013. doi: 10.1016/j.compind.2013.11.004

[5] T. Frantz, B. Jansen, J. Duerinck, and J. Vandemeulebroucke. Augmenting microsoft's hololens with vuforia tracking for neuronavigation. *Healthcare Technology Letters*, 5, 09 2018. doi: 10.1049/htl.2018.5079

[6] J. Grubert, Y. Itoh, K. Moser, and J. E. Swan. A survey of calibration methods for optical see-through head-mounted displays. *IEEE Transactions on Visualization and Computer Graphics*, 24(9):2649–2662, Sep. 2018. doi: 10.1109/TVCG.2017.2754257

[7] M. R. Marner, A. Irlitti, and B. H. Thomas. Improving procedural task performance with augmented reality annotations. In *2013 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 39–48, Oct 2013. doi: 10.1109/ISMAR.2013.6671762

[8] R. Nijssen. *Composite Materials : An Introduction*. Inholland University of Applied Sciences, Rotterdam, 2015.

[9] R. Vassallo, A. Rankin, E. Chen, and T. Peters. Hologram stability evaluation for microsoft (r) hololens tm. p. 1013614, 03 2017. doi: 10.1117/12.2255831