Evaluation of interaction methods in augmented reality head-mounted displays for total knee arthroplasty*

Ánxela Pérez Costa[1,*], Anna De Liddo[2], Nieves Pedreira Souto[3] and Florian Michaud[1]

[1]Laboratory of Mechanical Engineering, Centro de Investigación en Tecnologías Navales e Industriales (CITENI), Campus Industrial de Ferrol, Universidade da Coruña, Ferrol, Spain

[2]Knowledge Media Institute (KMi), The Open University, UK

[3]Department of Computer Science and Information Technologies, Faculty of Computer Science, CITIC-Research Center of Information and Communication Technologies, Universidade da Coruna, Biomedical Research Institute of A Coruña (INIBIC), A Coruña, Spain

Abstract

The integration of Augmented Reality (AR) in Total Knee Arthroplasty (TKA) has the potential to enhance surgical precision and improve surgeon performance by providing real-time, three-dimensional visual information directly within the surgeon's field of view. This study evaluates the performance of various interaction methods for AR Head-Mounted Displays (HMDs), focusing on usability, efficiency, and ergonomics within the constraints of the surgical environment. Five interaction methods—head movement, holographic touch, hand gestures, gaze fixation, and a gaze-gesture combination—were assessed based on task completion time, error rates, subjective workload, and user comfort.

Keywords

Augmented reality (AR), head-mounted displays (HMD), total knee arthroplasty (TKA), interaction methods, usability evaluations

1. Introduction

The integration of Augmented Reality (AR) Head-Mounted Displays (HMDs) in Total Knee Arthroplasty (TKA) is transforming surgical practice. By providing real-time, three-dimensional visual information directly within the surgeon's field of view, AR HMDs empower surgeons to perform procedures with greater precision and spatial awareness [1]. This technology supports intraoperative decision-making by overlaying critical data onto the surgical site without requiring surgeons to divert their attention to external monitors. However, despite these advantages, the introduction of AR HMDs into the surgical workflow presents new challenges, particularly concerning human-computer interaction (HCI). These systems demand that surgeons interact with digital interfaces in a dynamic, high-pressure environment, where usability, intuitiveness, and efficiency are essential [2]. Poor interaction design or complex workflows may increase cognitive load, disrupt surgical flow, or even lead to errors [3, 4, 5]. Additionally, the conditions of use must be considered to ensure that interactions are valid, safe, and ergonomically comfortable for surgeons [6]. Therefore, understanding and optimizing the interaction between the surgeon and the AR system is crucial to fully realizing the potential of this technology while ensuring patient safety and surgical efficiency.

The integration of AR in surgical procedures has motivated numerous studies on HCI, particularly focusing on how surgeons interact with AR systems in high-stakes environments. However, while interaction methods in AR have been extensively explored in general contexts, studies specifically addressing the medical field, and more precisely orthopedic surgery, remain limited. Several prior works have evaluated the performance and usability of different interaction techniques in non-medical AR

Interacción '25: XXV International Conference on Human-Computer Interaction, September 03–05, 2025, Valladolid, Spain

*Corresponding author.
anxela.perez@udc.es (Á. P. Costa); anna.deliddo@open.ac.uk (A. D. Liddo); nieves.pedreira@udc.es (N. P. Souto); florian.michaud@udc.es (F. Michaud)
0009-0004-6156-4763 (Á. P. Costa); 0000-0003-0301-1154 (A. D. Liddo); 0000-0002-8122-0886 (N. P. Souto); 0000-0003-2415-4007 (F. Michaud)

applications. For example, Williams et al. [7] compared gesture-based and speech-based interactions, highlighting trade-offs in terms of efficiency and user preference. Similarly, Schön et al. [8] investigated the 'gorilla arm' fatigue phenomenon in mid-air interactions, while Kim et al. [9] studied how users interact with both virtual and physical objects in 3D matching tasks. These studies commonly follow a structured evaluation framework: (1) a pre-evaluation phase, including user training and background data collection, (2) a task execution phase with controlled variables, and (3) post-task questionnaires and feedback collection [8, 10, 11, 12].

In the medical domain, research on AR interaction methods has primarily focused on the recognition performance of specific interaction systems rather than a comparative analysis of different interaction modalities. Bautista et al. [13] compared native gestures of the Meta AR glasses with the MYO armband for gesture recognition in an orthopedic surgery application. However, their evaluation was limited to non-overlapping interfaces, leaving unexplored the potential for false gesture recognition during surgery. Similarly, another study [14] examined gesture-based interactions using the Oculus HMD and the MYO armband in an image-guided surgery scenario, but the evaluation was restricted to a pre-operative context, outside the constraints of real-time surgery.

These studies highlight the importance of evaluating interaction methods, but they also reveal a significant gap: limited research systematically compares interaction methods within actual surgical environments, potentially restricting the available interactions. To fill this gap, our work analyzes these environments to define feasible interaction methods for implementation and proposes both objective and subjective evaluations of various interaction techniques used with AR HMDs under recreated surgical conditions. Drawing from existing research frameworks, we adapt evaluation protocols to address the specific needs and constraints of orthopedic surgery, with the goal of identifying the most effective and user-friendly interaction methods to enhance surgical support and assist surgeons in the operating room.

2. Material and methods

2.1. Surgical environment

The surgical environment is a highly controlled, sterile, and dynamic space where precision, safety, and efficiency are paramount. It is typically occupied by a multidisciplinary team, including surgeons, nurses, and anesthesiologists, all operating under strict protocols [15]. The environment is often constrained in terms of physical space and subject to continuous movement, instrument usage, and communication. Background noise from equipment, alarms, and team interactions is common, which can interfere with technologies like voice recognition. Additionally, the presence of blood or bodily fluids on the surgeon's gloves or tools can impair the reliability of gesture recognition or touch-based interactions, especially when systems rely on visual tracking or capacitive sensors. Surgeons must also maintain sterility at all times, limiting the ability to interact directly with hardware interfaces. Lighting conditions, visibility, and the need for uninterrupted focus further complicate the integration of advanced technologies, making human-computer interaction a critical consideration in designing AR HMDs for surgical use.

2.2. Interaction selection

AR HMDs offer a range of interaction methods, each with distinct advantages and limitations in surgical environments. To identify the most suitable interaction techniques for our device and context, we first compiled a list of potential methods. These were then filtered based on their compatibility with the device used in our evaluation —Microsoft HoloLens 2— with a particular focus on methods that did not require additional hardware, ensuring practicality and ease of integration in the operating room. Among the compatible methods, we assessed their feasibility within the surgical environment described in section 2.1.

These interactions can be implemented in a single-modal form, where communication between the user and the system relies on one input channel—such as voice, gestures, or gaze used independently. In contrast, bimodal, or more broadly multimodal, interactions involve the simultaneous use of two or more input modalities. This enables richer, more intuitive, and efficient communication with AR systems [16, 17]. However, studies have shown that while multimodal interactions can reduce errors and cognitive load, they may also increase the time required to complete tasks, and users may report higher perceived effort [18]. These findings suggest that bimodal or multimodal interactions influence AR performance in a task-dependent manner: they often enhance accuracy and user acceptance but may involve trade-offs in speed and perceived workload [16].

Among the interactions allowed by our device, several interaction techniques were excluded from this study based on their suitability for the surgical environment:

- Interactions involving physical contact were ruled out due to the challenges they pose for maintaining sterility in surgical settings. Likewise, techniques requiring the surgeon to make significant movements away from the operating area were dismissed, as such actions could interrupt the continuous visualization of data and disrupt the surgical workflow.
- Body movement —specifically, device movement in space— is incompatible with the surgical workflow due to the constrained operating environment. Surgeons must remain stationary during procedures to maintain precision and avoid disrupting the sterile field, and the limited space, crowded with colleagues and surgical tools, leaves no room for unnecessary movements. Any such displacement could compromise both the surgical procedure and the safety of the patient.
- Spatial Mapping & Anchoring does not detect user intent, as its primary function is limited to providing 3D visualization and ensuring spatial alignment of holograms within the physical environment. It is not designed for interaction or decision-making, but rather to enhance the accuracy of holographic placement relative to real-world objects, thereby supporting contextual awareness during surgery.
- In the case of natural language input versus structured voice commands, natural language was excluded due to the high risk of unintended activations during conversations with other surgical team members. Structured voice commands, in contrast, provide a more deliberate and reliable mode of interaction and could be considered in future works.
- Image-based interactions were also discarded. Since our system already employs ArUco markers for tool recognition[19], adding more visual elements could increase cognitive load and risk confusion—issues previously observed in similar evaluations [19, 20]. Moreover, the presence of blood or bodily fluids during surgery may obscure visual markers, further reducing reliability.

Although tangible interactions —such as physical buttons— were excluded due to sterility concerns, their virtual counterparts, namely holographic buttons operated via hand gesture recognition, were considered. These preserve the intuitive familiarity of tactile input while maintaining a sterile, contact-free interaction [21].

To identify effective bimodal interaction strategies, we constructed a matrix cross-referencing all compatible methods. Combinations that could interfere with surgical activities were discarded, and from the remaining options, we selected those that aligned most closely with natural human behaviour, as supported by prior studies. Based on this process, five interaction methods were selected and evaluated in this preliminary study:

1. Head Orientation Selection (HOS): This technique replicates the functionality of the interface evaluated in [20], with the goal of improving it. Horizontal head movements (left or right) are mapped to navigation.
2. Holographic Touch: This method simulates the pressing of a physical button using virtual interface elements. The user extends their hand toward a hologram, triggering the action through proximity and motion—effectively mimicking a touch interaction without contact.

3. Gestures: A simple and low-effort gesture—raising the index finger to the left or right—is used to indicate a selection. This gesture was chosen for its clarity, ease of execution, and minimal physical or cognitive load, requiring no specific positioning relative to the interface.
4. Gaze Fixation: Users select an interface element by looking directly at it. Selection is confirmed by maintaining gaze for a short period, providing a hands-free and intuitive interaction mode.
5. Gaze + Gestures (Bimodal): This combined method uses gaze for targeting an option, followed by a confirming gesture (raising the index finger), enhancing accuracy and reducing the risk of accidental selections.

Preliminary tests were conducted to validate the compatibility of the interactions mentioned above within a simulated surgical environment. Future work will involve more extensive testing under various conditions, such as different glove colours, blood on gloves, tools in hand, and other relevant factors.

2.3. Experimental data collection

2.3.1. Participants

In the preliminary tests, ten voluntary participants were recruited to evaluate the basic compatibility and functionality of the proposed interactions within a simulated environment. The sample included individuals aged between 23 and 46 years, with heights ranging from 163 cm to 188 cm and arm lengths from 50 cm to 60 cm. Six participants had corrected vision impairments and wore their own prescription glasses during the evaluation. In terms of hand dominance, two participants were left-handed, while the remaining eight were right-handed. These initial tests provided valuable insights, but future work will expand the sample size to include a broader range of participants, particularly orthopedic surgeons. By incorporating professionals with expertise in the surgical field, the next phase of testing aims to evaluate the interactions' effectiveness and usability in a more realistic context, ensuring the technology is suitable for actual clinical use.

2.3.2. Experiment and survey

At the start of the evaluation, participants were briefed on the procedure and asked to provide demographic, biometric, and technology usage information. The device was then fitted and calibrated to ensure optimal alignment and comfort. Each interaction method was introduced and demonstrated, after which participants were given time to familiarize themselves with a practice interface until they felt confident using each method.

Evaluations were conducted in a controlled environment designed to closely simulate surgical conditions. Participants wore surgical gowns and gloves to replicate real-world factors that could impact interaction performance. Each participant followed a structured protocol for testing the five interaction methods. For each method, they completed a predefined task using the assigned interaction technique, followed by a brief questionnaire to capture their perceptions and experiences. This cycle was repeated for all five interaction methods. At the end of the session, participants completed a final questionnaire to provide their overall impressions and formally conclude the evaluation.

2.3.3. Task design

Users were asked to perform a menu-driven navigation task designed to simulate the configuration of a device during surgery —such as aligning the system with the preoperative plan or handling any step requiring user input. This task reflects a phase in the surgical procedure where the surgeon's hands are typically free, and the primary focus is on decision-making. However, in future work, we aim to assess whether these interaction methods could interfere with the surgical workflow during other phases.

The task design was inspired by an existing commercial solution [22], with the graphical interface remaining unchanged except for the icon representing the current interaction method. To minimize learning effects and reduce bias, the menu text was replaced with ten pairs of generic placeholders

Figure 1: Experimental conditions.

("Option A" and "Option B"), with the order of options randomized across trials. Participants were randomly assigned to consistently select either Option A or Option B throughout the evaluation. Each participant completed all ten tasks using each of the five interaction methods, resulting in a comprehensive and balanced assessment.

2.4. Data analysis

The data collected to evaluate the different interaction methods comprised both objective and subjective measures. Objective data were obtained from measurable performance metrics during task execution, while subjective data were gathered through questionnaires completed by participants after each test.

2.4.1. Objective data

Performance: Task performance was evaluated using two key metrics: task completion time and error rate. Completion time was recorded from the moment the participant activated the start button, with timestamps logged at each placeholder transition. This enabled a detailed analysis of the interaction process and helped identify any issues linked to specific interaction methods or interface screens. Timing concluded once the participant had completed all ten selections. Errors were assessed using a 4-point Likert scale: 0 – correct execution, 1 – near miss, 2 – incorrect execution, and 3 – assistance required[23].

2.4.2. Subjective data

Perceived Workload: After completing each task, participants assessed their cognitive workload using the raw version of the NASA-TLX questionnaire. They rated their mental effort on a 0–20 scale, providing a quantitative measure of the cognitive demands associated with each interaction method [10, 24, 9].

Preferences Questionnaire: Immediately following each task, participants completed a brief two-item questionnaire, rating both the overall effectiveness and perceived comfort of the interaction method on a 0–10 scale [8].

General Preferences: Upon completing all tasks, participants ranked their top three preferred interaction methods. They were also invited to share open-ended feedback, highlighting any challenges they encountered and offering general impressions of the different interaction techniques.

3. Results

Statistical analyses were performed to identify significant differences between the interaction methods. Task completion times followed a normal distribution for all methods except HOS, as determined by the Shapiro-Wilk test. Consequently, the Friedman test was used to analyze task completion time due to the mixed distribution of results. Error rates exhibited a non-normal distribution and were also analyzed using the Friedman test. The significance level was set at 5% ($p < 0.05$), and p-values below this threshold were considered statistically significant. For the preference questionnaire, which is not a standardized instrument, internal consistency was assessed using Cronbach's α to evaluate its reliability.

3.1. Performance

The results of the task completion times reveal significant differences among the interaction methods ($p < 0.001$). Gaze fixation was the fastest method, followed by gaze + gestures (bimodal), which provided a balance of speed and usability. On the other hand, gestures and head orientation selection (HOS) took longer to complete, with holographic touch being the slowest method. While gaze fixation offered the quickest task completion, it had some errors, which suggests that, while efficient, its reliability may need to be improved. Gestures were the most reliable, with no errors or near errors, though they required slightly more time compared to gaze-based methods.

In terms of errors, gestures and head orientation selection (HOS) were error-free, demonstrating their reliability. Gaze fixation and gaze + gestures (bimodal) had some errors and near errors, suggesting that while these methods were effective in terms of task completion time, they introduced some challenges in accuracy. Holographic touch showed moderate reliability with a few errors and near errors. Overall, gestures provided the best balance of reliability and usability, whereas holographic touch and gaze + gestures might require further refinement to reduce errors and improve efficiency, especially in environments where precision is crucial, such as surgery.

3.2. Perceived workload

Table 1 presents the results of the NASA-TLX perceived workload analysis for five different interaction methods, assessing mental demand, physical demand, temporal demand, performance, effort, frustration, and the overall mean workload score. The interaction methods evaluated include Head Orientation Selection (HOS), Holographic Touch, Gestures, Gaze Fixation, and Gaze + Gestures (Bimodal). Among the methods, Gaze + Gestures (Bimodal) exhibited the highest overall workload (mean = 26.25), driven by higher scores in mental demand, temporal demand, and frustration. In contrast, Head Orientation Selection (HOS) had the lowest overall workload (mean = 16.08), with the highest physical demand but relatively lower scores in other categories. Gestures ranked similarly with a low overall workload (mean = 16.5), though it showed relatively moderate mental demand and frustration. Gaze Fixation and Holographic Touch exhibited moderate workloads, with Gaze Fixation having a notably higher temporal demand and Holographic Touch reflecting moderate frustration scores. These results provide valuable insight into the perceived workload and usability of each method, highlighting differences in how each interaction type places cognitive and physical demands on users.

3.3. Preferences questionnaire

In the preference questionnaire (Cronbach's $\alpha = 0.903$), participants rated 'Gaze Fixation' the highest, with a mean score of 8.3, which also corresponded to the method's highest comfort score (mean = 8). The second highest-scoring method was 'Head Orientation Selection' (mean score = 8.2), though it received a significantly lower comfort score (mean = 6.7). The remaining methods received the following scores: 'Gestures' (mean score = 7.7; comfort score = 7.3), 'Gaze + Gestures' (mean score = 8; comfort score = 7.56), and 'Holographic Touch' (mean score = 7; comfort score = 6.2).

Table 1
Mean NASA-TLX perceived workload scores across participants for different interaction methods (highest value in bold)

Interaction Method	Mental Demand	Physical Demand	Temporal Demand	Perfor-mance	Effort	Frustration	Workload (%)
Head Orientation Selection (HOS)	2.6	**6.2**	2	2.6	3.3	2.6	16.08
Holographic Touch	3.8	5.3	5.1	4.2	5	**5.8**	24.33
Gestures	3.9	4.2	3.4	1.7	3.7	2.9	16.5
Gaze Fixation	4.3	3	6.5	2.7	3.3	3.5	19.41
Gaze + Gestures (bimodal)	**5.2**	4.2	**6.9**	**5**	**5.2**	5	**26.25**

3.4. General preferences

Regarding participants' rankings of interaction methods based on preference and comfort, gaze fixation and gestures emerged as the top-performing techniques. Each was selected by 90% of participants as one of their top three preferred methods, with gaze fixation also appearing in the top three comfort rankings for 100% of participants. This indicates that these two methods were consistently rated highly across users, both in terms of subjective preference and perceived ease of use. Notably, gaze fixation was the most frequently selected as both the first-choice preference (30%) and for comfort (40%), reinforcing its perceived efficiency and ease of use. Gestures, while slightly less favored as a first choice (30%), had the highest third-choice preference (50%) and mirrored this pattern in the comfort rankings, indicating consistent, if moderate, user satisfaction. Head Orientation Selection was selected by 70% of participants in both categories, suggesting a solid, middle-ground experience. Conversely, gaze gestures received lower overall preference (40%) and comfort (30%) ratings, possibly due to its higher error rates and perceived complexity. Holographic touch was the least favored in both preference and comfort (10% each), highlighting clear user dissatisfaction, likely stemming from its usability limitations in the experimental setup.

4. Discussion and conclusions

Although differences in error rates across interaction methods were not statistically significant, errors remain a critical concern in surgical environments, where even minor mistakes can have serious implications. As such, performance evaluations considered both task completion time and error count, despite statistical significance emerging only for completion time. Among the tested methods, gaze fixation was the fastest and received the highest preference ratings; however, it also produced the most errors, indicating a need for greater precision or enhanced error mitigation strategies. Gaze + gestures offered a balanced performance, combining moderate speed with favourable user evaluations, but its relatively high error rate also calls for caution. In contrast, the gestures method, while slightly slower, stood out as the only technique with zero errors, demonstrating strong reliability and potential for high-risk environments.

Head orientation selection (HOS) was similarly error-free and generally well-received. However, results on comfort were contradictory—despite being rated as the least comfortable on average, it was selected as the most comfortable method by some participants. This discrepancy suggests variability in user preferences, possibly related to individual differences in perception or physical strain. Refinements in tilt sensitivity could improve consistency, though any adjustments must be carefully evaluated to avoid compromising detection accuracy. Holographic touch, although natively supported by the device, consistently underperformed across measures. Users reported frustration due to difficulties in pressing static interface elements, likely caused by a lack of depth cues and spatial flexibility.

In terms of perceived workload, NASA-TLX results indicated that gaze-based methods were associated with heightened temporal demand. Users reported feeling rushed, as visual confirmation of selection increased the pressure to act swiftly. This aligns with the notion that while gaze interactions are fast, they may induce cognitive strain. Introducing alternative confirmation cues may help mitigate this issue. Physical demand was notably high in the head tilt method, with some users expressing discomfort due to repetitive or exaggerated head movements, while others appreciated the lower angle detection threshold. This variation suggests that ergonomic adjustments could improve usability. Lastly, holographic touch elicited high frustration levels, primarily due to inconsistent recognition, reinforcing the importance of responsive and adaptable interface design in constrained environments like surgery.

Future work should aim to refine these preliminary observations through more ecologically valid simulations that account for the physical constraints of surgery —particularly scenarios where the surgeon's hands are occupied with instruments or the patient's body. Incorporating such conditions could provide deeper insight into the practical usability and limitations of each interaction method under real-world operating room demands.

Acknowledgments

Ánxela Pérez Costa and Florian Michaud would like to acknowledge the support of the Galician Government and the Ferrol Industrial Campus by means of her predoctoral research contract 2023/CP/209 and his postdoctoral research contract 2022/CP/048.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

References

[1] S. Pokhrel, A. Alsadoon, P. W. Prasad, M. Paul, A novel augmented reality (ar) scheme for knee replacement surgery by considering cutting error accuracy, International Journal of Medical Robotics and Computer Assisted Surgery 15 (2019). doi:10.1002/rcs.1958.

[2] S. P. Canton, C. N. Austin, F. Steuer, S. Dadi, N. Sharma, N. M. Kass, D. Fogg, E. Clayton, O. Cunningham, D. Scott, D. LaBaze, E. G. Andrews, J. T. Biehl, M. C. V. Hogan, Feasibility and usability of augmented reality technology in the orthopaedic operating room, Current Reviews in Musculoskeletal Medicine 17 (2024) 117–128. doi:10.1007/s12178-024-09888-w.

[3] J. Buchner, K. Buntins, M. Kerres, The impact of augmented reality on cognitive load and performance: A systematic review, 2022. doi:10.1111/jcal.12617.

[4] T. Schneider, T. Cetin, S. Uppenkamp, D. Weyhe, T. Muender, A. V. Reinschluessel, D. Salzmann, V. Uslar, Measuring bound attention during complex liver surgery planning: Feasibility study, JMIR Formative Research 9 (2025). doi:10.2196/62740.

[5] E. J. Brown, K. Fujimoto, B. Blumenkopf, A. S. Kim, K. L. Kontson, H. L. Benz, Usability assessments for augmented reality head-mounted displays in open surgery and interventional procedures: A systematic review, 2023. doi:10.3390/mti7050049.

[6] M. Birlo, P. J. Edwards, M. Clarkson, D. Stoyanov, Utility of optical see-through head mounted displays in augmented reality-assisted surgery: A systematic review, Medical image analysis 77 (2022). URL: https://pubmed.ncbi.nlm.nih.gov/35168103/. doi:10.1016/J.MEDIA.2022.102361.

[7] A. S. Williams, F. R. Ortega, Understanding gesture and speech multimodal interactions for manipulation tasks in augmented reality using unconstrained elicitation, Proceedings of the ACM on Human-Computer Interaction 4 (2020). doi:10.1145/3427330.

[8] D. Schön, T. Kosch, F. Müller, M. Schmitz, S. Günther, L. Bommhardt, M. Mühlhäuser, Tailor twist: Assessing rotational mid-air interactions for augmented reality, in: Conference on Human Factors in Computing Systems - Proceedings, Association for Computing Machinery, 2023. doi:10.1145/3544548.3581461.
[9] M. Kim, S. H. Choi, K. B. Park, J. Y. Lee, User interactions for augmented reality smart glasses: A comparative evaluation of visual contexts and interaction gestures, Applied Sciences (Switzerland) 9 (2019). doi:10.3390/app9153171.
[10] K. Kia, J. Hwang, I. S. Kim, H. Ishak, J. H. Kim, The effects of target size and error rate on the cognitive demand and stress during augmented reality interactions, Applied Ergonomics 97 (2021). doi:10.1016/j.apergo.2021.103502.
[11] A. M. Bernardos, L. Bergesio, J. Besada, J. Casar, Evaluation of a multimodal interaction system for big displays, in: ACM International Conference Proceeding Series, Association for Computing Machinery, 2023. doi:10.1145/3605390.3605411.
[12] L. Cao, H. Zhang, C. Peng, J. T. Hansberger, Real-time multimodal interaction in virtual reality - a case study with a large virtual interface, Multimedia Tools and Applications 82 (2023) 25427–25448. doi:10.1007/s11042-023-14381-6.
[13] L. E. Bautista, F. G. Maradei, G. F. Pedraza, Augmented reality user interaction to computer assisted orthopedic surgery system, in: ACM International Conference Proceeding Series, Association for Computing Machinery, 2018. doi:10.1145/3293578.3293590.
[14] L. T. D. Paolis, S. T. Vite, M. Ángel Padilla Castañeda, C. F. D. Velasco, S. Muscatello, A. F. H. Valencia, An augmented reality platform with hand gestures-based navigation for applications in image-guided surgery: Prospective concept evaluation by surgeons, International Journal of Human-Computer Interaction 38 (2022) 131–143. doi:10.1080/10447318.2021.1926116.
[15] M. G. Goldenberg, D. Elterman, From box ticking to the black box: the evolution of operating room safety, World Journal of Urology 38 (2020) 1369–1372. doi:10.1007/s00345-019-02886-5.
[16] K. A. Satriadi, 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), IEEE, 2019.
[17] S. Irawati, S. Green, M. Billinghurst, A. Duenser, H. Ko, An evaluation of an augmented reality multimodal interface using speech and paddle gestures, in: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), volume 4282 LNCS, Springer Verlag, 2006, pp. 272–283. doi:10.1007/11941354_28.
[18] A. S. Williams, J. Garcia, F. Ortega, Understanding multimodal user gesture and speech behavior for object manipulation in augmented reality using elicitation, IEEE Transactions on Visualization and Computer Graphics 26 (2020) 3479–3489. doi:10.1109/TVCG.2020.3023566.
[19] S. Garrido-Jurado, R. Muñoz-Salinas, F. J. Madrid-Cuevas, M. J. Marín-Jiménez, Automatic generation and detection of highly reliable fiducial markers under occlusion, Pattern Recognition 47 (2014) 2280–2292. doi:10.1016/j.patcog.2014.01.005.
[20] Ánxela Pérez Costa, A. D. Liddo, F. Wild, N. P. Souto, F. Michaud, How can the augmented reality experience for surgeons be improved during total knee arthroplasty?, in: VII Congreso XoveTIC: impulsando el talento científico, Servizo de Publicacións. Universidade da Coruña, 2024, pp. 277–284. URL: http://hdl.handle.net/2183/41087. doi:10.17979/spudc.9788497498913.39.
[21] C. Dennler, D. E. Bauer, A. G. Scheibler, J. Spirig, T. Götschi, P. Fürnstahl, M. Farshad, Augmented reality in the operating room: a clinical feasibility study, BMC Musculoskeletal Disorders 22 (2021). doi:10.1186/s12891-021-04339-w.
[22] P. Medical, Pixee medical – a new vision for orthopedic surgery, ???? URL: https://www.pixee-medical.com.
[23] P. Kourtesis, S. Vizcay, M. Marchal, C. Pacchierotti, F. Argelaguet, Action-specific perception & performance on a fitts's law task in virtual reality: The role of haptic feedback, IEEE Transactions on Visualization and Computer Graphics 28 (2022) 3715–3726. doi:10.1109/TVCG.2022.3203003.
[24] L. R. Murthy, Multimodal interaction for real and virtual environments, in: International Conference on Intelligent User Interfaces, Proceedings IUI, Association for Computing Machinery, 2020, pp. 29–30. doi:10.1145/3379336.3381506.