# VesARlius: An Augmented Reality System for Large-Group Co-Located Anatomy Learning

Felix Bork*
Chair for Computer Aided Medical Procedures
Technische Universität München
Munich, Germany

Alexander Lehner†
Chair for Computer Aided Medical Procedures
Technische Universität München
Munich, Germany

Daniela Kugelmann‡
Chair for Vegetative Anatomy
Ludwig-Maximilians Universität
Munich, Germany

Ulrich Eck§
Chair for Computer Aided Medical Procedures
Technische Universität München
Munich, Germany

Jens Waschke¶
Chair for Vegetative Anatomy
Ludwig-Maximilians Universität
Munich, Germany

Nassir Navab‖
Chair for Computer Aided Medical Procedures
Technische Universität München
Munich, Germany

## Abstract

Interactive educational environments are one of the prime applications for the use of Augmented Reality (AR). A large variety of such systems has been proposed in the past for various areas of education. However, in most cases the number of users these AR systems can support is limited. Only few systems have been developed that support a large number of co-located users to jointly collaborate in a dynamic and interactive learning environment. Multi-user AR collaboration presents a unique setting with distinct challenges and requirements for user interaction and information sharing. In this paper, we present VesARlius, a novel AR system for collaborative and interactive anatomy learning in a large group of co-located users. Our system employs a set of multi-user collaboration paradigms allowing users to engage in an interactive AR learning environment. We evaluated the collaborative features of our system in a user study with 16 medical students. Results demonstrate the potential of the VesARlius system to be used effectively for large-group AR anatomy learning. From our lessons learned, we provide a set of design guidelines for developing similar AR systems to enable large-group collaboration in other application domains.

**Index Terms:** Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / Augmented Reality; Applied Computing—Education—Interactive Learning Environments

## 1 Introduction

Augmented Reality (AR) allows users to view and interact seamlessly with virtual content that is integrated into the real world. While single user AR has been employed for a large variety of applications with great success over the last decades, one of the most fundamental use cases of AR is enabling multiple users to jointly interact with virtual content through collaborative AR interfaces [2]. There are two main types of AR collaboration scenarios that can be classified according to the spatial location of collaborators: *remote* collaboration creates the illusion that two or more distributed users share the same physical space by means of telepresence. On the other hand, *co-located* AR collaboration augments a shared physical workspace such that users can still directly see each other during collaboration. Interactive educational environments historically have been one of the first application scenarios for collaborative AR systems. Such systems proved to be an effective tool for enhancing the learning outcome in various different areas of education [1]. While several AR systems employing remote collaboration have been proposed in the past, co-located AR collaboration offers a set of distinct benefits when used in the context of interactive AR learning environments. Prior research in educational science has shown that joint learning in groups (peer-learning) enhances students generation of knowledge and results in a deeper understanding of the learned topics. Especially in medicine, peer-learning is a well established practice that is used effectively by many students. Collaborative AR systems for multiple co-located users offer the potential to combine the benefits of peer-learning and interactive AR learning environments. In this work we present VesARlius, a novel AR anatomy learning system that has been specifically designed for this purpose. VesARlius can be used effectively by a large number of co-located users (10+) and employs a series of multi-user paradigms to enable collaboration. In the rest of this paper, we provide a short overview of the system and present the results of a user study which evaluated the collaborative features of VesARlius with a total of 16 medical students.

*e-mail: felix.bork@tum.de
†e-mail: alexander.lehner@tum.de
‡e-mail: daniela.kugelmann@med.uni-muenchen.de
§e-mail: ulrich.eck@tum.de
¶e-mail: jens.waschke@med.uni-muenchen.de
‖e-mail: nassir.navab@tum.de

## 2 The VesARlius Anatomy Teaching System

In the 16th century, the anatomist Andreas Vesalius initiated one of the most impactful paradigm shifts in modern anatomy. Through his disruptive cadaveric dissections of the human body, he shifted the focus away from purely theoretical studies towards direct hands-on observations. Today, a similar paradigm shift in the context of anatomy teaching is taking place. Novel technologies such as AR encourage interactive and student-centered exploratory learning in favor of passive, teacher-centered and delivery-based learning. With VesARlius, we propose a novel AR system that aims to take the former learning approach one step further. The system was developed to enable collaborative anatomy learning for large groups of co-located students. Specifically, it was designed as a supplementary teaching tool for enhancing cadaveric dissection courses, which form an essential part of today's medical curricula worldwide. The dissection of cadavers is an inherently collaborative learning experience with up to 12 students working closely together. VesARlius provides students with the possibility to explore a virtual 3D model of the human body, including annotated structures and multimodal section images such as CT and MRI. Additionally, we integrated a set of functionalities specifically aimed at facilitating the collaboration between students during joint learning sessions. In the following paragraphs, we present a short description for each of these features. A general overview of the system is provided in Figure 1.

978-1-7281-4765-9/19/$31.00 ©2019 IEEE
DOI 10.1109/ISMAR-Adjunct.2019.00-66

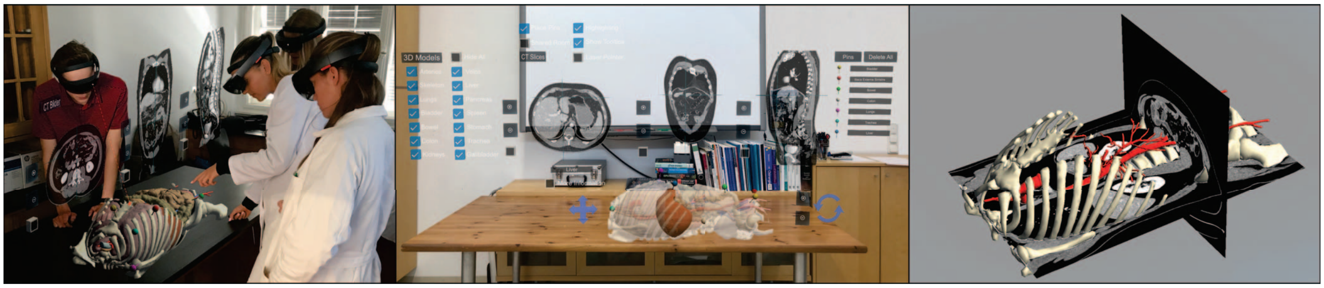

Figure 1: Overview of the VesARlius anatomy learning system. **Left:** Four medical students use the system in a synchronized room. Colored pins are placed on the virtual 3D model to highlight different structures of interest. The CT images correspond to the position of the last placed pin. A dotted red line indicates the laser pointer functionality. **Middle:** The different components of the VesARlius user interface: *left)* a menu for showing and hiding anatomical structures in the 3D model; *center)* 2D section panels for axial, coronal and sagittal slices; *bottom)* 3D model reconstructed from above section images including colored pins and highlighted organ (liver); *top)* menu for various VesARlius options; *right)* pin menu displaying all currently active pins and the names of the corresponding structures. **Right:** Close-up view of the 3D model with skeleton and arteries. The axial and coronal slice are displayed at the exact place they coincide with the model to help students get a better spatial understanding of CT images.

**Synchronized Rooms**: The main feature to enable collaborative learning in VesARlius are synchronized rooms. For all users inside the same room, the entire state of the application is synchronized in real-time. This applies to all functionalities of the application, such as rotation of the 3D model, selection of individual anatomical structures or image sections, as well as updates to the user interface. At all time, users are free to enter existing rooms, switch between them, or create new ones.

**Individual Content Placement**: The only setting that is excluded from the above room synchronization is the position of the system's virtual content (i.e. user interface & 3D model). All users can freely choose to position their individual copy of the application in the environment. While this positional synchronization could easily be achieved using marker-tracking, it severely limits the number of users that can observe a specific virtual object from a given position. Especially when working in large groups of co-located users or in restricted environments with limited space, students can thus position their individual copy such that they can comfortably move around it without disturbing other users.

**Laser Pointer**: To direct the focus of users to a specific object of interest, we implemented a virtual laser pointer. A small red circle is displayed at the location where the gaze direction vector of the currently active *presenter* intersects with a virtual object. There can be one presenter for each synchronized room and all users can take over the laser pointer to facilitate communication between them.

**Colored Pins**: A more permanent focus on structures can be achieved by placing colored pins on the surface of the 3D model. Within a synchronized room, the position of these pins is synchronized and every user has the ability to manipulate the pins. Additionally, a list of all active pins including the name of the associated anatomical structure is part of the VesARlius user interface.

## 3 User Study

We conducted a user study with a total of 16 first-year medical students (5 male, 11 female, mean age 21.00±2.94 years) to investigate the potential of our VesARlius system for large-group collaborative anatomy learning. The Microsoft HoloLens was employed as the AR display during our study. After a short tutorial introducing the system's functionalities, two same-sized groups with 8 students each worked with the VesARlius system for a total of two hours. During the first hour, all students were required to work together inside one synchronized room. For the second hour, students were free to choose their own rooms such that working individually or in subgroups was allowed. Following the two hour learning session, all participants were asked to fill out a System Usability Scale (SUS) survey, a mental effort test according to Paas [3], as well as a short questionnaire on the collaborative features of the VesARlius system based on a 7-point Likert Scale. While the first two are standardized evaluation methods, the latter was comprised of the following three questions: ***Q1:*** I found the collaborative features useful; ***Q2:*** I think the collaborative features were sufficient; ***Q3:*** I found the collaborative features disturbing.

## 4 Results

Overall, students provided a very positive feedback of the VesARlius system with an average SUS score of 80.00±13.90. Mental effort was considered rather high with a Paas score of 5.13±2.45. In terms of the collaborative features of VesARlius, students considered them as useful (***Q1***, 5.63±1.36) and not disturbing the learning session (***Q3***, 2.00±1.37). They also found these features to be sufficient for enabling collaborative learning in large groups (***Q2***, 5.44±1.31).

## 5 Design Guidelines

From the observations obtained during our user study, we derived the following three design guidelines for large-group collaborative AR learning systems: *1) Individual placement of virtual content is superior to synchronized positioning*. It allows all users to take the same viewpoint by individually positioning a local copy of the application, even with limited space. *2) Both short-term and permanent synchronization methods should be available*. Students valued having both options in the form of a laser pointer and pins to quickly direct attention towards a structure with the former and to start longer discussions with the latter. *3) Synchronized rooms are an efficient method for co-located learning in various sized groups*. During the second part of the user study, three types of learning configurations were used effectively: the majority of students remained in the same synchronized room with three students switching to individual rooms and two students creating another shared room for themselves.

## 6 Conclusion

We presented VesARlius, a novel AR system for AR anatomy learning in large groups of co-located users. During a user study with medical students, the collaborative features of the system were evaluated and found to enable efficient collaboration between users. The lessons learned allowed us to propose a set of design guidelines for developing similar AR systems in other application domains.

## References


[1] M. Akçayır and G. Akçayır. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20:1–11, 2017.

[2] M. Billinghurst and H. Kato. Collaborative augmented reality. *Communications of the ACM*, 45(7):64–70, 2002.

[3] F. G. Paas. Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of educational psychology*, 84(4):429, 1992.