Augmented medical education for explorative and interactive learning

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Abstract

Health care all over the world has problems that are expected to grow, such as rising health care costs, shortages of doctors, shortages medical educators and worries about the skill level of new medical students. New medical students would get less practice based education, and more lecture based education. Current education methods would leave the students not skilled enough, due to the type of education given, or the shorter education hours. In the educational field in general as well, innovative educational methods are needed. Old fashioned learning methods would leave the students uninterested. New educational methods are proposed, such as more explorative learning, or education that makes use of new technology. New technologies such as virtual reality and augmented reality could be useful as an educational method. Augmented reality is a new technological development in the field of visual computing. Although the technique is still in its early stages, it is more and more being used in numerous of different fields. We propose a system that could be a solution to a few of the expected problems in health care and education. We propose an education method that uses augmented reality for medical students. Using the system, the students would be aided in the exploration of the human anatomy and instructed about surgical skills.

Introduction

In today's society proper health care is becoming increasingly important. There are a number of issues in health care. It is estimated that health care costs will keep increasing in the future (Bodenheimer, 2005; Kuttner, 2008) of which some of the causes are: a growing need for longer medical care services (Altman & Levitt, 2003), administrative costs, population growth and the development of new drugs (Congressional Budget Office, 2008). Properly trained medical personnel are harder to come by each year (Aiken, 2002; Ananthakrishnan, 2007). Another concern is the skill level of new medical personnel due new educational methods. Medical students used to study for long hours in an education method that focused on practice rather than instruction. Current educational systems have shorter hours (Taffinder, 1999) and students have less exposure to clinical cases and have to focus more on instructions rather than on practice (Ananthakrishnan, 2007). Changes of the medical education methods have been proposed. The limitation of operating room time, the increase of technical innovation in surgery, greater expectations of patients, cause a need for medical educators and medical students to practice techniques before using them in the operating room (Macintyre & Munro, 1990). Surgical training has undergone many changes, so it has been proposed that surgical training could be performed outside the operating room. Simulation of surgical procedures and human tissue could aid in the training of surgical skills. Examples are artificial tissues, animal models and virtual reality computer simulation (Torkington, Smith, Rees & Darzi, 2000). Another proposed simulation method is augmented reality. It differs from virtual reality in that it mixes real world view with a computer generated view (Van Krevelen & Poelma, 2010). It has the advantage that users of an augmented view can still interact with the real world. If it is used for surgery training, augmented vision could provide a learning environment that is more similar to an actual surgery environment.

The system we propose is an education method that aims at educating medical students about human anatomy and surgical skills. It uses augmented vision to provide the students with the required information or instructions. Generally in the current situation where medical students have to train for surgery, learning is done first from books, and then examination of actual human bodies. Since the actual organs look different from 2D images, students have to adapt to this and this may result in making unnecessary mistakes. With augmented vision, textual information and an immediate vision of the actual organs can be combined into a single process. It would provide for a better understanding of the learning material and is likely to speed up the process. Since there is little time available for the students to practice, this could speed up the learning process. Human anatomy information can instantly be displayed and an overview of the organ in relation to other organs can be given. Our target group are medical students. Novice medical students could use the system to explore the human anatomy, and more advanced students could use it to train surgery skills. The system could allow the students to learn more independently. While this system could not replace the teaching instructor, it could serve as a solution to shortages of medical teaching personnel if less assistance is required. Augmented reality is a booming field and relatively new. By using augmented vision as a training method, we want to introduce an innovative education method. As new technologies are being developed, education methods could make use of those technologies to increase motivation and interest in the subject (Martin-Gutierrez, Contero & Alcaniz Raya, 2010). In the future, augmented vision could be common in daily live, and in it could serve as a common supporting tool in surgery as well.

Related work

Many theories have been developed about education and educational methods, and each field of industry has its own preferred educational methods. As long as there is a need for education, there will be a need for better education techniques. Researchers keep searching for innovation in educational techniques in every branch of industry and in surgery as well (Nandi, Chan, Chan, Chan & Chan, 2000). Training is the process of bringing a person to an agreed standard of proficiency by practice and instruction. Medical personnel used to reach those standards by working for long hours in an education method that focused on practice rather than instruction. New educational systems have shortened hours, which results in the situation that students have less exposure to clinical cases (Ananthakrishnan, 2007). Medical educators are concerned that current teaching methods are insufficient for students to acquire the necessary medical skills. In current education methods, there is less practical training and more lecture based training. But calls for reform are nothing new. Fundamental reforms in medical education have been advocated for 100 years. The complexities of medical care have increased dramatically over the last century, but the methods of teaching medicine have changed little. Teachers need to learn about new and improved techniques and theories medical education. Medical education, as with any other educational program, needs ongoing improvements to meet the changing demands of medical practice in the 21st century (Nandi, et al., 2000).

Nandi et al. (2000) compared problem-based learning with conventional learning. In problem-based learning, medical science facts were learned concurrently, students actively participated in their own education and they practiced skills to become self-directed learners for the rest of their lives. In conventional learning, teaching is tutor-centred and students passively received information rather than actively acquiring knowledge. Nandi et al. (2000) concluded that students that used the problem-based learning method placed more emphasis on meaning than on memorising, used more varied sources and were more confident in information-seeking. Students using the conventional learning method performed only better in basic science examinations. Binstadt, Walls, White, Nadel, Takayesu, Barker, Nelson and Pozner (2007) tested a new education method for medical students, which was different from the conventional graduate medical education models. They had a complete curriculum redesign in which they applied adult learning principles, medical simulation learning theory, and standardized national curriculum requirements to create an innovative set of simulation-based modules for integration into their emergency medicine residency curriculum. Binstadt et al. (2007) still used traditional lecture and group discussion methods of teaching, but a large part of the program involved a form of experiential learning by using the simulation modules that they developed. Medical simulation allows trainees to experience realistic patient situations without exposing patients to the risks inherent in trainee learning and is adaptable to situations involving widely varying clinical content. Although medical simulation is becoming more widely used in medical education, it is typically used as a complement to existing educational strategies.

Martin-Gutierrez, Contero and Alcaniz Raya (2010) performed an experiment in which they used an educating method that promotes active learning, encourages discovery through interactivity and object manipulation controlled by the students. In the experiment students were educated about geometrical problems. Augmented reality was used as an interactive education method. After the experiment was performed, the spatial abilities of the students were measured. Martin-Gutierrez et al. (2010) concluded that the education method improved the spatial abilities, students had a better understanding of the subject and that the system was ergonomical to use. In their experiments the Magic Book system was used. The Magic Book is an educational application that uses augmented reality (Billinghurst, Kato & Poupyrev, 2001). It is a system built to visualize virtual 3D-models on the pages of a physical book. Without augmented vision, users can turn the pages of the book, look at the pictures, and read the text. If they look at the pages through an augmented display they see 3D virtual models appearing out of the pages. The book acts as a handle for the virtual models. By moving the book, users can move the models and look at them from different viewpoints. The magic book has been used for other applications as well. Klinker, Dutoit, Bauer, Bayer, Novak & Matzke (2002) did a research about the challenges of introducing new applications such as augmented reality to potential users and stakeholders. The nonfunctional requirements of such applications are difficult to assess a priori, and usability issues that the product designers are likely to raise have to be anticipated. They described the technical and human challenges encountered when closely collaborating with the end user in the design of a novel application. They collaborated with an automobile manufacturing company to develop a proof-of-concept augmented reality system for car designers. Other proposed applications for the Magic Book system are the visualization of interactive 3D children stories and geological data, as well as architectural models (Billinghurst, et al., 2001).

Augmented reality systems have been defined as systems that have the characteristics of combining real and virtual, are interactive in real time and are registered in 3-D (Azuma, 1997). It is a visual perception of a physical, real-world environment combined with graphical elements that are generated by computer. Users of augmented reality technology have an enhanced perception of reality, but they still see a real-world environment. This differs from virtual reality in that it doesn't replace the real-world with a simulated world. Virtual reality is being used as well for educational (Ahlberg, Enochsson, Gallagher, Hedman, Hogman, McClusky III, Ramel, Smith & Arvidsson, 2007) and other purposes such as rehabilitation (Guberek, Schneiberg, Sveistrup, McKinley & Levin, 2008; Reger & Gahm, 2008), but differs on a number of aspects. Augmented reality augments a real world scene, in which the user maintains a sense of presence in the real world. A system is needed to combine the virtual and the real world view. Virtual reality provides an immersive environment for the user. The visual senses are being controlled by a system, and sometimes the aural and proprioceptive senses as well (Van Krevelen & Poelma, 2010). Using virtual reality as a simulation education method has a number of disadvantages. There is a trade-off between graphics and fast screen refresh rate. If there is a limited processing power, graphics can be very close to a real world environment, but the refresh rate of the simulation will be much slower. It can result in interaction problems of the user with the system. Such a setting would differ too much from real world settings if timing is essential, and a different reaction would be required. Simulation for education has to be as close to the real world setting as possible, which means that a simulation of audio and haptic stimuli is required as well (Torkington, Smith, Rees & Darzi, 2000). Thomas, John, and Delieu (2010) used a virtual environment as a method of teaching anatomy. They provided their test subjects with simulation for touch as well as sight, by using an interface window which displayed a simulation of the human body. Their goal was to use this system as a viable supplement to traditional cadaver based education. The result of their user study suggests that their test subjects found the system helpful to understand the shape and the location of the organs. Another advantage was that they could use the system at any time and thus it would be invaluable for revision. Time in the dissection room is very scarce and subject to the availability of a cadaver. With some adaptation, their system could also be used to visualize more complex anatomy. They concluded that their system is effective in conveying information about anatomy, is an effective supplement to body dissection, but it is not yet able to fully replace body dissection. Although both visual and tactile representations of anatomy were presented, their system could not reproduce all of the sensations that body dissection can.

Adler, Salah, Mecke, Rose and Preim (2010) described the requirements needed to simulate visual stimuli. They developed a virtual education method that supports apprenticeship and training of surgeons through interaction with a simulated intervention. The method was also useful for the training of medical images interpretation, because the anatomical data and the related images could be explored without any risk to the patient. In their system, patient specific anatomical image data over geometric models was integrated into a surgery simulation. The image data was used to plan the next steps within the simulated surgery procedure. The virtual image was displayed in different points of view. The orthogonal view displayed an overview over the operational field and the user could explore the anatomical structures for the current point of view. The plane parallel view was used to recognize changes of tissue in the direction of infiltration to avoid injuries during interaction. While Adler, et al. (2010) concluded that their system was useful for the training of surgery students, they noticed some issues. Advanced rendering techniques were required, even though no lighting computation was needed in their system and no additional computation time was required during rendering. For simulation in surgery it was required that their presented method was of high performance**.** The majority of the computation had to be used for complex dynamics simulation, which is essential for the tissue behavior. When an organ is cut during an operation, it changes shape. Surgery simulation has to accurately simulate the dynamics of soft-tissue. Images of organs should be deformed in relation to the deformation of soft-tissue. Even if only visual stimuli were simulated, this would require much more effort to resemble a real world setting than by using augmented reality.

Augmented reality already has various implementations in a number of different fields. Augmented reality techniques have been used in marketing to provide customers with product information and services. E-commerce based augmented reality was developed to provide shopping assistance and personalized advertising. Geographical information has been presented in augmented view for landscape visualization and for enhanced location based services for urban navigation and way finding (Liarokapis, Brujic-Okretic & Papakonstantinou, 2007). In architecture and interior design augmented reality was used for constructing collaborative design applications. It was used to explore relationships between perceived architectural space and the structural systems so that methods for the construction, inspection, and renovation of architectural structures could be improved. Augmented reality systems have been proposed to provide navigation guidance. Users of such an application can see virtual signs anchored to the physical world. Similar to a compass, the signs indicate the correct direction regardless of the device's orientation. Such an application could be used to guide tourists in a city, visitors inside a museum or soldiers in an unfamiliar environment (Costanza, Kunz & Fjeld, 2009). In military training augmented reality can support in the planning of military training. It can be used to display a real battlefield scene and augment it with annotation information, such as coordinates, distance measurements and known sources of danger (Yu, Jin, Luo, Lai & Huang, 2010). In robotics based augmented reality can be useful for human-robot collaboration. Robots can present complex information by using augmented reality technique for communicating information to humans (Yu, et al., 2010).

In the medical field, augmented reality has been used for image guided surgery, pre-operative imaging training and education. Several applications have been used, in combination with wearable devices such as head mounted displays, and augmented optics or non-wearable devices such as an augmented reality windows for monitoring (Sielhorst, Feuerstein & Navab, 2008). The difficulties of using surgical monitors have been pointed out by Yamaguchi, Outani, Yatani, and Soumura (2009). Computer-assisted navigation systems have been developed to realize safe and precise surgery. In conventional systems, surgeons feel anxious intra-operatively because they have to watch a surgical monitor while operating instruments in the oral cavity. Yamaguchi et al. (2009) developed a dental implant navigation system by combining a retinal projection head mounted display and augmented reality techniques. The augmented vision can directly overlay pre-operative simulation images onto the real view of the surgeon. They performed an image overlay procedure and verified the accuracy of the system. They concluded that their procedure could be performed as a real-time image overlay. For the use of the system as a clinical application, they will evaluate the size of markers, image overlay accuracy, measurable range, and light conditions.

Methods: Interaction Design

The system aims to aid medical students in learning about human anatomy training of surgery skills. When the medical students are exploring the human body and the various organs, they should be informed about what organ it is and if needed, more in-depth information should be presented. More advanced medical students should be instructed about how surgical operations are performed. The students can view this information through augmented display. The flowchart (Fig.1) displays the interaction of the student with the system. The input modalities are visual (images of the real world and user's gestures) and audio (voice commands). The output modalities are visual: layers of augmented information. To use the system, the user puts on the HMD glasses, microphone head set and switches the system on. The system presents the student with voice calibration instructions. After these have been performed, the system presents a menu in which the student can make a selection from 4 layers:

- identify organs
- in-depth information
- 3D-models
- surgery instructions

Interaction such as navigation, selection and controlling of the augmented display items can be performed by 2 methods. The student can either speak voice commands (registered by microphone) or use hand gestures (registered by camera). By using a voiced based controller, students can use both hands to focus on the operating tasks and not use it for other tasks such as controlling additional equipment. Moreover, the training process is more similar to actual surgery procedures. Medical personnel need both of their hands to operate and are not allowed to touch any non-sterile objects. Voice commands are pre-defined, such as "select identify organs" to select the identify organs layer. Hand gestures are pre-defined as well. After the selection has been made for 1 of the 4 layers by voice command or hand gesture, the system displays this layer on the augmented display. Voice commands and hand gestures can be used as well to interact with information from the layers, such as selecting subjects and scrolling through text in the in-depth information layer, and turning the 3D-model in the 3D-model layer. After a layer is displayed, the student can return to menu to select another layer.

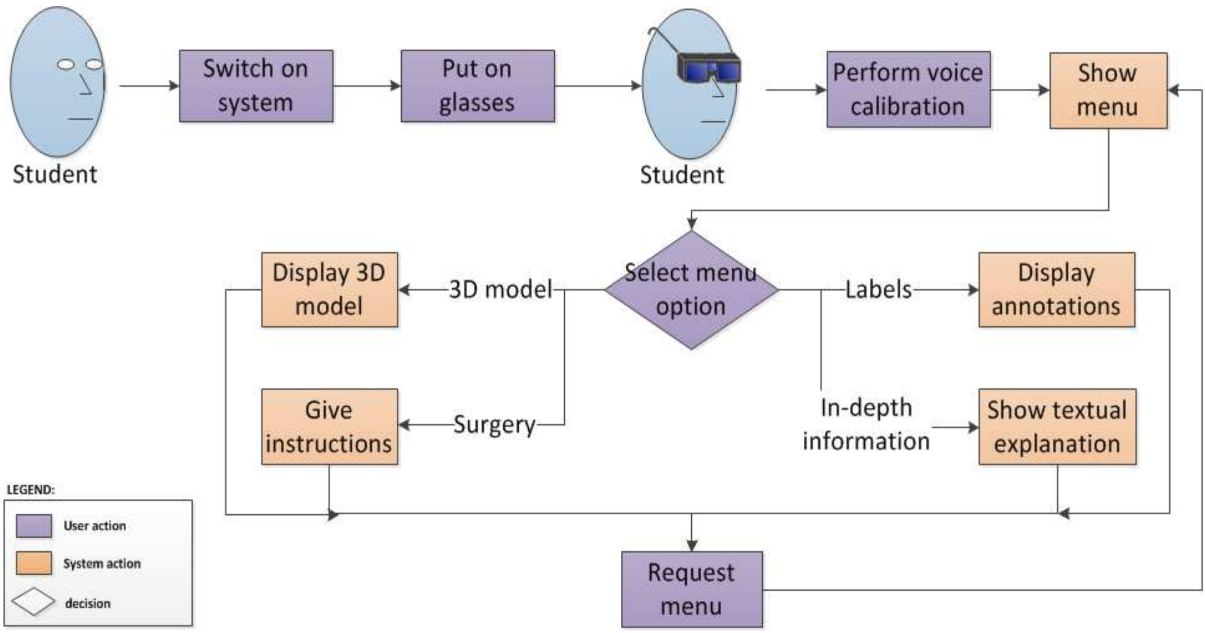

Figure 1: Interaction between the user and the system.

Task scenarios

We developed a few scenarios in which users perform a task using the system. Each scenario describes a different user and a different task and describes how the user interacts with the system.

Scenario 1: A medical student wants to explore human anatomy

A first year medical student wants to learn about the human body. She is interested in a general exploration of the body. She doesn't want to learn in-depth information about the organs, but she just wants to know where the most important organs lie and what they look like different from the organs displayed in a book. When entering the dissection room, a body is prepared for examination. The student is free to explore and dissect the body. She puts on the augmented glasses and microphone head set and switches the system on. After voice calibration, she selects the 'identify organs' layer. She starts dissecting the body, by cutting open an area that she is interested in. The camera is sending images of the body and organs to the system, so that it can detect the organs. The system identifies the organs that come into view and displays the appropriate label to it (Figure 2). The student reads the labels, sees what the organs actually look like, and learns about other organs that she didn't know about.

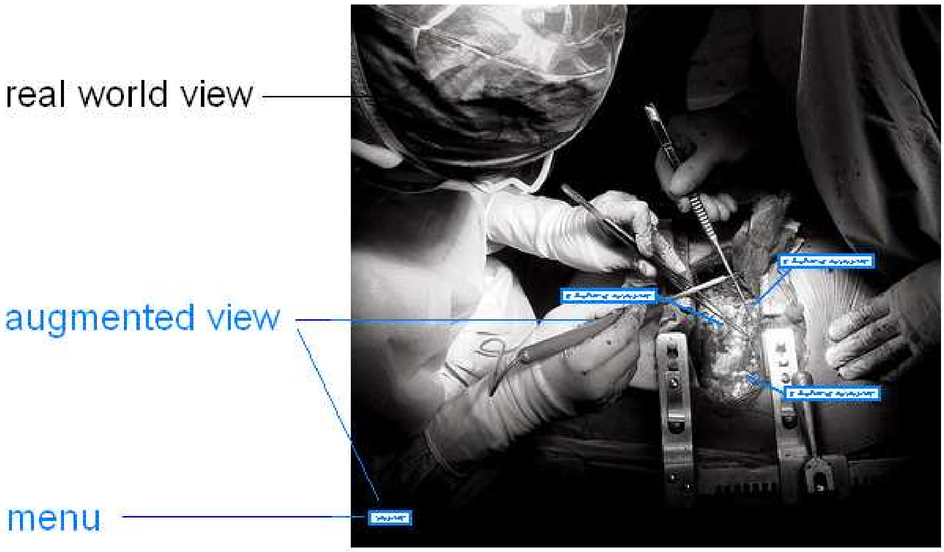

Figure 2. User interface of the 'identify organs' layer. The labels next to the organ identify the organ. The Augmented vision is displayed in blue, over the real world view, displayed in black and white.

Scenario 2: A medical student wants to learn more about a specific organ

A second year medical student wants to know more about a specific organ and is looking for textual background information and 3D models about the organ, such as the blood vessels and internal structure of the organs. When entering the dissection room, a body is prepared for examination. The student is free to explore and dissect the body. He puts on the augmented glasses and microphone head set and switches the system on. After voice calibration, he selects the 'in-depth information' layer. He dissects the body, by cutting in the area of the organ that he is interested in. The camera is sending images of the body and organs to the system, so that it can detect the organs. In the in-depth information layer, the student can specify which organ he is interested in. If he knows which organ it is, he can use voice commands to name it. If he doesn't know the organ, he can use hand gestures to point to the specific organ. The system identifies the specific organ and displays a list of subjects about the organ. Due to the large amount of information about an organ, in-depth information is divided into subjects. The text display is large enough for the user to be able to properly read through the text, but small enough so that it doesn't block the user too much from the real world view. The student selects the subject he is interested in, after which textual information about the organ is displayed (Figure 3). Voice commands or hand gestures can be used to scroll through the text.

After he is done reading, he wants to see more of the internal structure of the organ. From the menu, he selects the '3D-model layer'. In the 3D-model layer, the student can specify which organ he is interested in. Then he can select the type of 3D-model he is interested in:

- 3D model of the organ
- 3D-model with connections to other organs
- 3D-model (transparent) with internal structure of the organs
- 3D-model (transparent) of the blood vessels in the organ
- 3D-model (transparent) of the nerve fibers in the organ

The student selects the type of 3D-model he is interested in and a standard 3D-model for the organ is displayed (Figure 4). The 3D-models can be turned and enlarged to have a clear understanding of how the organ works.

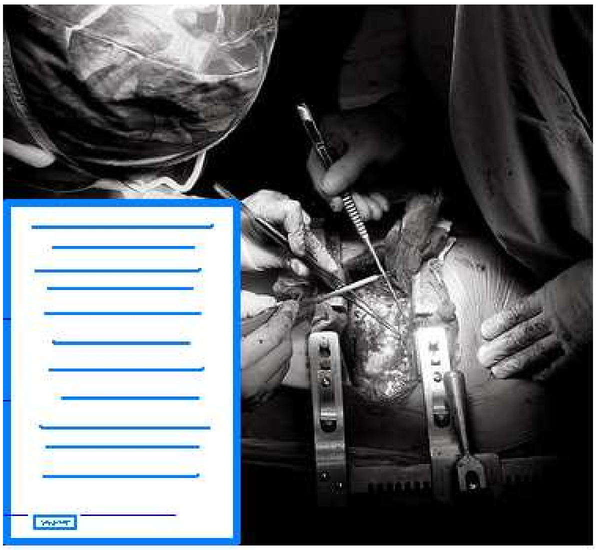

Figure 3. User interface of the 'in-depth information' layer. The textual information about an organ is displayed.

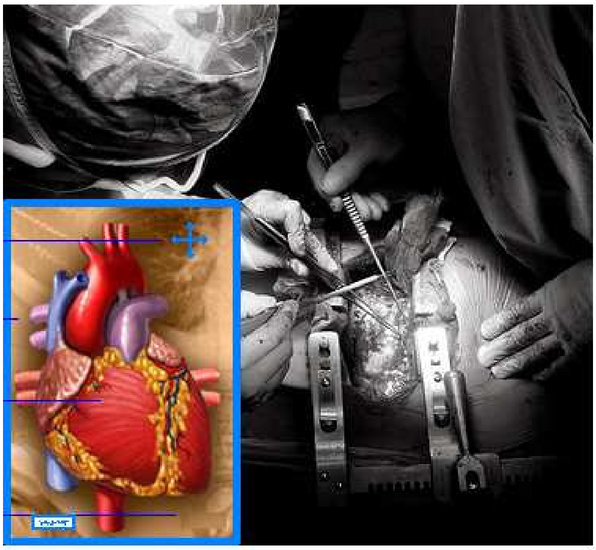

Figure 4. User interface of the '3D-model' layer.The 3D-model of the organ is displayed.

Scenario 3: A medical student wants to learn about practicing surgery

An advanced medical student, specialized in surgery, wants to learn about practicing surgery. He wants to know how to properly perform a surgical procedure, at which areas he can safely cut into an organ, and in which areas he should be cautious for vulnerability of the organ. When entering the dissection room, a body is prepared for examination. The student is free to explore and dissect the body. He puts on the augmented glasses and microphone head set and switches the system on. After voice calibration, he selects the 'surgery instructions' information layer. In the surgery instructions layer, the student can specify which organ he is interested in. If he knows which organ it is, he can use voice commands to name it. If he doesn't know the organ, he can use hand gestures to point to the specific organ. The camera is sending images of the body and organs to the system, so that it can detect the organs. After the organ has been specified, the student can select a procedure that he wants to train. The system displays the surgical instructions for the organ (Figure 5). The student dissects the body, and performs the procedure according to the instructions. Voice commands or hand gestures can be used to scroll through the various surgery instructions.

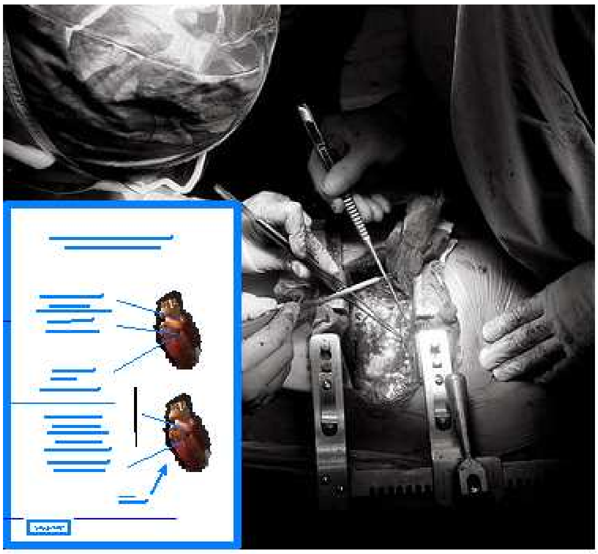

Figure 5. User interface of the 'surgery instructions' layer. The instructions to perform a surgery procedure are displayed.

Scenario 4: A medical student is using the system but encounters an error

A medical student is using the system to get more information about a specific organ. She has selected the 'in-depth information' layer. The camera is sending images of the body and organs to the system and it should properly detect the organs, but she is very sure that the system misidentified the organ. She doesn't know the name of the organ, but does know that the identification of the organ is not correct. The student selects a 'determine organ' option from the menu. Before determining the organ, she is presented with some instructions that could improve the system organ detection, such as adjustment of luminosity in the room, or removing any tissue or other objects that could be in front of the organ and prevent a correct detection. Then she is presented with a determination menu from which she can step wise determine what organ it is.

Interface design

For the interface design, we had to balance between a clear readable presentation of the information, and minimal blocking of the real world view. A lot of text had to be displayed, and minimal blocking of real world view would be by presenting the augmented text directly over the real world view. But due to the large amount of information to be displayed and the contrast issues between text and real world view, we decided to present the text on a non-transparent background. The contrast settings can be optimal, which makes it easier to read for the students. The augmented layers can be switched off quickly at any time, for a full world view. The augmented information is consistently presented in the left corner for minimal obstruction of the real world view, except for the labels from the 'identify organ layer'. In this layer the only augmented information is provided by small identification labels (Fig. 2). The labels are not displayed directly over the organ, but next to it, or it would block the student from a proper view of the organ. The amount of augmented information is minimal where possible. The various menu options are only visible when the menu is selected.

Methods: System Description

The system requires the following components:

Input/Output devices:
1. Head-mounted display (HMD) glasses
2. Camera
3. Microphone

Other equipment:
4. Personal Computer
5. Wireless data transfer

1. HMD glasses

A head mounted device (HMD) is a display device in which the display optics use semi-transparent mirrors to show computer generated images (CGI) over a real world view, similar to a HUD (heads-up display) used in simulators and video gaming (Costanza, Kunz & Fjeld, 2009). It has a small display optic in front of one (monocular HMD) or both eyes (binocular HMD). It can be worn on the head or attached to the glasses (Fig. 6).

2. Camera

A small digital camera is used to record the same view of the user is looking at. Images from organs and hand gestures of the user have to be recorded and send to the computer for further processing of the images. The digital camera can be mounted to the glasses, so that it is pointed in the same direction as direction that the user is viewing.

3. Microphone

For user input such as controlling of the augmented display, the user speaks voice commands into the microphone. A microphone converts an audio signal into an electrical signal. Data from the microphone is send to the computer for further processing of the voice command. Similar to the HMD glasses, the microphone can be mounted to the user's head so it is not required to manually operate it (Fig. 6).

4. Personal Computer

A computer with high processing power (CPU) is required for high performance tasks such as image processing and voice command processing. After processing of the input data, the required output data is selected and send to the display of the HMD glasses. The database with models of the organs and other data such as surgery instructions and textual information has to be stored onto a hard disk drive.

5. Wireless data transfer

The input/output equipment is mounted to the users head, but the processing of data has to be performed by a personal computer. Data from the camera and microphone have to be transferred to the computer, and data from the computer have to be transferred to the HMD glasses. Since it is very inconvenient to the user to connect the head mounted devices to the computer by wires, wireless data transfer is needed.

Figure 6. HMD-glasses and microphone.

System processes

The input data comes from voice capturing (registered by microphone) and image capturing (digital camera). This data is send to the computer for processing. After the input is processed, the output data is displayed on the HMD glasses. An overview of the system processes is displayed in Figure 7.

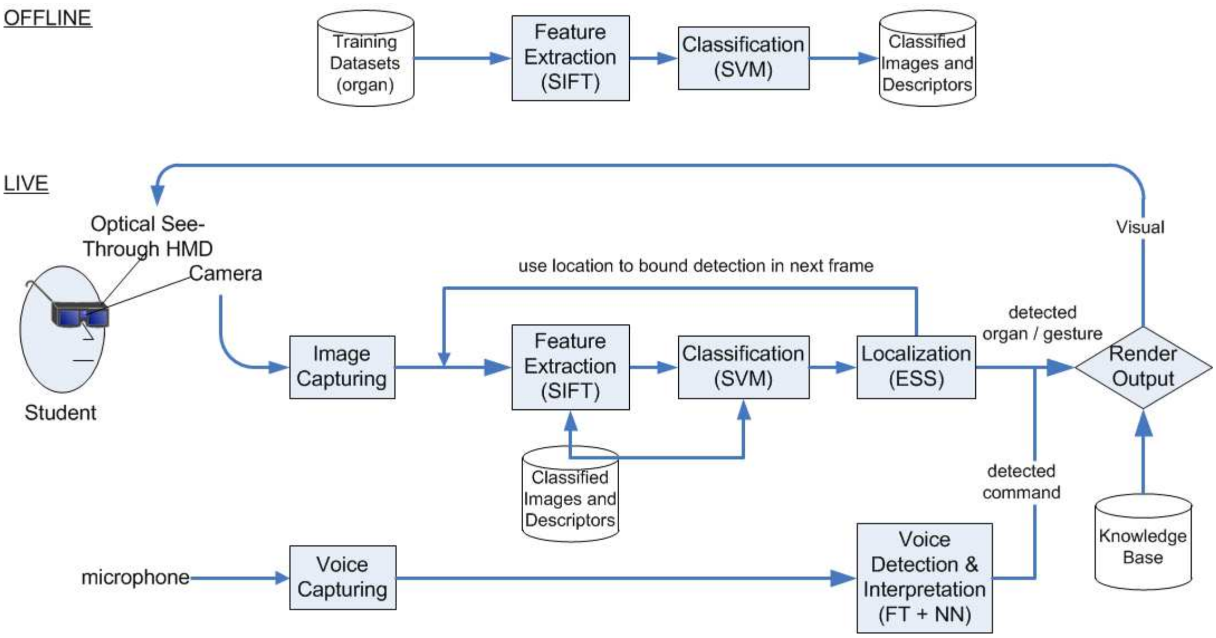

Figure 7. Overview of the system processes.

Image processing

The digital camera is used to capture the image of hand gestures (for selection, control and navigation of items from the augmented display) and organs. Hand gestures are pre-defined, so that the system can distinguish between gestures meant for control of the system, and normal hand movement. To prevent that the computer registers a hand position from other students or the dissected body, the user has to show the hand gestures in a straight position in front of the camera. To select an item from the augmented menu, the user has to perform a 'select gesture' and point it to the augmented item. For control of an augmented item a 'control gesture' has to be performed and for navigation a 'navigation gesture'.

The detection of hand gestures and organs starts with the capture of their images by the digital camera. The camera receives video signals as RGB images. These image are used for feature extraction, using the Scale-Invariant Feature Transform (SIFT) algorithm. For the SIFT algorithm, first a database is created. From many sample images (1000+) of hand gestures and organs, each slightly varying in illumination, point of view, shape, and size, SIFT features are extracted. They are transformed into local feature coordinates that are invariant to translation, rotation, scale, and other imaging parameters. The extracted features are used to train a classifier. A multi class classification method is used. Support vector machines (SVM) is used for classification. SVM are a set of related supervised learning methods that analyze data and recognize patterns. It classifies each organ, compares each image of the organ to the classes and then assigns to the class which has the most similarities. The classified extracted features are stored in a database of classified images and descriptors. The new RGB image of an organ or a hand gesture is then matched by individually comparing each feature from the new image to the images from the classified images and descriptors database and a key is selected with matching features based on Euclidean distance of their feature vectors (Lowe, D.G. (2004). Since SVM can't determine where an organ is located and at what scale, Efficient Subwindow Search (ESS) is used. EES relies on a branch-and-bound scheme to find the global optimum of the quality function over all possible subimages, (Lampert, Blaschko & Hofmann, 2008). After this procedure, the system has detected the organ or hand gesture, and localized where it is. The requested output is shown on the augmented display.

Speech recognition

The microphone receives the user input for voice commands. All voice commands are pre-defined, so that there is only a limited amount of words that the system has to recognize and it will be less prone to errors. Speech recognition is a technology that converts spoken words to text. Fast Fourier Transformation will be used to transform the audio signal from the microphone to a sequence of numbers, based on the distribution of the audio frequencies. The sequence of numbers is processed by a neural network, which is composed of a large number of interconnected processing elements (neurones) working in unison to identify the sequence of numbers (Ramakrishnan, Schmidt-Nielsen, Turicchia & Sarpeshkar, 2010). After this procedure, the system has detected the voice command of the user. The requested output is shown on the augmented display.

Discussion

We presented an augmented education system that can be used for learning about human anatomy and surgery skills. The proposed system was designed in such a way that it would be an effective and usable teaching method for medical students. While we found solutions and adapted our system accordingly for the problems we encountered, we would outline some of the issues that occurred and other problems that might occur for users of the system. As a teaching method, the student relies on the information of the system. Any of the educational information has to be thoroughly checked for correctness. However, not all of the information given can be checked beforehand. Organs have to be detected in real-time. It might be possible that because of an obstructed view or due to an unusual shape of the organ, that it can't be properly detected or that it is misidentified. If an organ differs too much from the representative classification model, because of a radically different colour, shape or size, then errors might occur. In the occasion that the student knows that the system has incorrectly identified an organ, there is an option for the student make corrections by specifying his own input to the system. If the identity is unknown to the user, a determination system can be used. Based on input of the user, the organ can then be correctly identified. The determination system can be used as well when the system can't detect an organ, and the user's input is required to determine the organ. Another issue is luminance. While the organ detect process is invariant to luminance, very bright or very dark luminance can still cause the system to fail to detect organs. For the best performance, an equal luminosity in the body dissect room is required.

The presentation of information that has to be displayed lead to a usability issue. A lot of information has to be presented to the student, such as in-depth information about the organ, its structure, surgery methods, etc. The most comprehensible formats to show this information would be in audio, textual or graphical format. Audio format has the advantage that it is an information type that is transferred to the ears and would limit the amount of visual information to be displayed. The student would have a clearer, unobstructed view of the real world objects, and less visual information has to be processed by the student. But there is a major usability issue with the audio format. Audio information can only be presented in a linear format. The student would be restricted to listen to the information from start to end. Navigation for a specific kind of information is difficult, since each section has to be listened to before it can be determined if the type of information is useful or not. A difficult text can quickly be re-read, but for audio information this is more difficult. The user has to interrupt the audio information, estimate to what point to rewind to and rewind to that point, and then replay it. There are too much extra actions required to interact with an audio information format, which would distract too much from the educational purposes of this system. Information can be presented in a graphical format as well, but there is only a limited amount of information that can be displays in graphics. For example, surgery instructions contain in-depth information about cutting areas and vulnerable areas, which can't be presented by graphics only. Textual information can be easily navigated through. The user can select a particular section of the text in which he is interested, and can easily re-read any of the difficult parts. A disadvantage of textual information is that any augmented visual information that has to be displayed, obstructs the user from viewing real world objects. Since a lot of information has to be displayed, a large part of the real world view could be covered by textual information. To counter this problem, students have the option to quickly switch off the augmented layer at any time. Therefore a combination of textual and graphical information would be the most useful format for this system. For the processing of visual data, a large amount of computations would be needed. The amount of computations requires that very powerful computers with lots of CPU power are needed for this system. Although the system is wireless connected, powerful computers would have to be available and close to the system.

There are general issues in the field of augmented reality as well. While augmented reality has a lot of benefits and a widespread use, there are some issues. There are a number of demanding technological requirements needed for its implementation. The display technology used to present augmented vision has to visualize digital objects at high resolution and high contrast. Another challenge is precise position tracking. Users need to perceive the augmented vision as if the virtual objects are located at fixed physical positions or attached to the physical items. In order to achieve this, the system must know the position of relevant physical objects relative to the display system. The user's point of view (their position and the direction of their gaze) is also of interest. Most of the augmented reality technologies require the system to know the location of the objects relative to the location of the display. Both the position and the orientation of the display in all 6 degrees of freedom are needed. In some situations, the tracking system can be physically attached to the display, and so the user wearing such a display can also be tracked. (Costanza, et al., 2009). Moving objects may separate and merge due to partial occlusion or image noise, and object appearance may also change due to difference in lumination. Augmented reality enables users to manipulate digital objects by physical tools or by hand. Some issues with this kind of manipulation is that it is relatively difficult to tell the state of the digital data associated with physical tools, the visual cues conveyed by tangible interfaces are sparse and 3D imagery in a tangible setting can be problematic as it is dependent on a physical display surface. Most systems also have usability issues. Physically, the design of the system is often cumbersome, leading to discomfort for the user (Zhou, Duh & Billinghurst, 2008).

Another issue is the educators need confirmation that augmented education works better than the method that they currently use. Most studies of simulation are surveys that report the enthusiastic and appreciative reviews of learners. True validation studies are needed (Lammers, 2007). In the experiment of Martin-Gutierrez et al. (2010), where augmented reality was used as a new education method to improve spatial ability, the control group received no spatial ability training at all. It can be expected that the level of spatial ability would improve by using any education method about spatial ability. For proper validity testing the control group should be trained with the current education method. A comparison with the test group would show if the augmented education method is significantly better method. The usability evaluation of their system was merely based on the opinions of the test subjects, rather than by usability testing.

Conclusion

Augmented vision as an education system can be an improvement of the current education methods. As explained in previous sections, augmented vision can be used in many different areas. An education system as we proposed could be used in areas with a similar setting, such as mechanics, where students learn how to build a car or plane, or in completely different areas, such as a training system for jet fighter pilots.

For our proposed system, numerous of extensions are possible. The system could be modified and used specifically for education with audio lectures. The students would explore the body while listening to an audio lecture. This could serve as a solution for a shortage of medical educators. The system could be modified to keep track of the progress made by the student, and evaluate the performance of the student. While it is highly difficult, the surgery skills of a student could be evaluated to determine the progress. Multiple cameras would be needed to register if cuts have been made at the right places, and surrounding organs have not been damaged. A group based application would be a modification of the system so that it could interact with the other systems. The majority of current body dissection classes are already performed in groups, so it would benefit students if information could be transferred from one system to the other. Students can compare their performances, show each other recorded images and teachers can directly evaluate their progress. Medical instructors could easily explain to a group of students any specific information they wants to share and highlight anything important through interaction via a shared augmented vision with the group.

More technical improvements would benefit the system. The processing of video images requires a lot of CPU power, installed in large (non-wearable) computers. If the calculation could be improved or the required hardware has become so powerful yet light and small enough that it would be wearable, then it could be mounted on the HMD glasses. A wireless connection to powerful personal computers in the vicinity for data processing wouldn't be required anymore.

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