Multimodal Medical Consultation for Improved Patient Education

Patrick Wucherer[1], Christoph Bichlmeier[1], Maximilian Eder[2], Laszlo Kovacs[2], Nassir Navab[1]

[1]Chair for Computer Aided Medical Procedures & Augmented Reality, Computer Science Department, TUM, Germany
[2]Department of Plastic and Reconstructive Surgery, Klinikum rechts der Isar, TUM, Germany
p.wucherer@mytum.de

Abstract. Augmented reality (AR) being applied for preoperative patient education can become a major feature of new communication standards in medical consultation. We have analyzed the current workflow of patient education with respect to breast reconstruction in plastic surgery. According to the gathered information, we developed a concept for an AR supported patient education system and present first implemented components of this system. In addition, we summarize the qualitative feedback from interviews with surgeons.

1 Introduction

The majority of recent publications in the field of medical augmented reality (AR) preferably proposes this technology to intraoperatively support surgical procedures. Authors suggest this technology for example to reduce the focuses of attention e.g. in surgical navigation and to facilitate the mental mapping of imaging data onto the patient [1, 2]. We started an interdisciplinary collaboration between computer scientists and plastic surgeons in order to develop an AR system to support physicians to explain patients the limitations, risks and potentials of an intervention, the surgical procedure itself, potential complications, and prescription for preventive and postoperative behavior, treatment and medicamentation. It is necessary for a patient to completely understand the treatment to consider and communicate the personal value they place on the benefits versus the harms [3].

Today's standard media providing the patient with such information is a printed brochure. Both, the physician and the patient review together the items of this brochure. An example of such brochures being used in Germany are the information and consent sheets of the company proCompliance (Thieme Compliance GmbH) or Perimed (perimed Fachbuch Verlag). In fact in many cases time is scheduled too shortly to ensure a complete, informative conversation and information is often too complex for the standard patient.

This work proposes a multi-modal communication tool for patient education that includes AR visualization.

2 Method

Our target system for patient education illustrated in Fig. 1(a, b) is a digital mirror having also been introduced as “magic mirrors” [4, 5] or virtual mirrors. Such mirrors usually consist of a projection screen and a video camera attached to the screen. The video data showing the environment in front of the screen is then projected onto the screen to create a mirror effect. Virtual objects can be registered with a person standing in front of the screen.

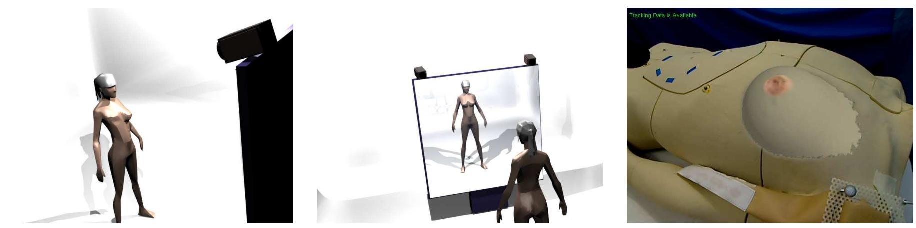
The system focuses on supporting the first and the second stage of the therapy workflow, when the patient has to understand complex information, decides on the procedure and gives the surgeon the approval of being aware of all legal information. We believe that the transfer of complex information and communication barriers caused by medical terminology being usually not familiar to the standard patient can be better managed when the briefing procedure currently performed with conventional spoken, written and 2D illustrated explication is augmented with information presented in-situ on the patient’s body.

Our expandable software framework provides features for interaction, multimodal communication and virtual breast augmentation. In our preliminary version of registering the virtual breast and further virtual objects with patient’s anatomy, the patient wears an optical tracking target on her shoulder, which is located with the SmartTrack system of A.R.T. Weilheim GmbH. Markerless tracking of the patient’s upper body will be addressed in future stages of the project.

Since the system wants to augment but not replace traditional methods of patient education, conventional media presenting instructional information such as as text and illustration can be displayed on the screen next to the AR scene.

The interaction of the system is based on a tracked remote mouse controller. Voice recognition (Microsoft Speech SDK) is used as an alternative interactive input option. The remote mouse controller also serves as a virtual 3D marker to distinguish specific regions on the patient’s skin.

The augmentation of the patient with a virtual breast model (Fig. 1(c)) currently involves three major features, which are the approximation of the biomechanical breast deformation, the composition of the virtual breast and the video



(a) Patient in front of the digital mirror. (b) Virtually reconstructed breast. (c) Breast with blended border.

Fig. 1. Augmenting the patient with instructional information.

and the realistic texturing of the breast. The first step of the breast augmentation pipeline is the acquisition of a 3D data set of the patient's existing breast with a 3D scanner (Minolta VI-900). The scan is taken from a frontal position and another two profile positions by turning the patient to the right and to the left, 30 degrees each as proposed by Kovacs et al. [6]. Then the data is processed to generate a watertight breast volume for its tetrahedralization. The resulting model can be mirrored to obtain the breast to be reconstructed. We use Tetgen (http://tetgen.berlios.de/) to generate a volumetric mesh consisting of tetrahedral elements.

The mesh is animated using a GPU-computed mass-spring model [7]. For the integration step, we added artificial damping to enlarge the time step in order to guarantee the stability of the system. In addition, the early-z culling using a depth buffer is replaced by a texture lookup in the pixel shader during the force calculation to avoid processing unbound vertices.

The mass-spring system can be stimulated by the moving patient. The tracking target on the patient's shoulder provides 3D pose and acceleration data to deform the virtual breast. In a future version, the tetrahedral elements shall be parameterized using biomechanical parameters, e.g. proposed by Bianchi et al. [8]. The current version still uses dummy deformation properties for elements of the mass-spring system.

The breast model is colored with a skin texture generated with Adobe Photoshop. First an image of the whole upper body of the patient is loaded into the program. Then the existing breast is cut out of the image without the shaded regions. The mamilla is cut out and stored to a separate image layer. The mamilla image layer is moved by hand to its designated position in texture space. Finding this position currently bases on experience values. The border of the mamilla layer is blurred for a more smooth transition between skin texture and mamilla. The automatic generation of a breast texture including the mamilla is part of future work. The mapping of the texture onto the breast model bases on the projection from view uv unwrapping texture coordinates calculation done by Blender (blender.org). The uv-coordinates are drawn from the same point of view as the surface vertex coordinates of the 3D breast model.

For superimposing the virtual breast onto the patient's body we propose a processing pipeline for composition that exploits vertex buffer objects (VBOs), color buffer objects (CBOs) and frame buffer objects (FBOs).

The vertices, normals and and colors of the surface of the breast model are stored to an index array defining a triangle structure. Each of these three items feeds one of three textures (VTex, NTex, CTex) of a FBO while the pixel index of each of the texture defines the correlation of the data in those textures.

In the first step, the normals of NTex belonging to the concave side of the breast shape are determined. Here, we assume that the model is positioned parallel to the xy-plane. For this reason, all normals on the surface of the 3D model are compared with a vector parallel to the z axis. Colors in CTex are then used to label corresponding normals in NTex and vertices in VTex by indexes when normals have an acute angle with the mentioned vector (Step: Mark Vertices).

In the second step, the VTex and CTex of the FBO are used as VBO and as CBO respectively. Because of drawing only labeled vertices the resulting texture shows only the concave region of the breast surface.

After that, the edge of the concave surface is detected using a Sobel Filter and the border of the surface is extended by a dilation. Then the border is blurred to create a smooth blending mask between a texture sample taken of the video frame and the video frame itself.

A pointer based registration procedure finds the correspondence of four spots on the patient's skin and four positions in the volumetric mesh [9]. While the positions on the skin are selected during the consultation with a tracked remote mouse controller, the four positions in the volumetric mesh can be selected in a previous stage when the breast model is being prepared. The order of selecting the positions has to be the same for both resources.

3 Results

The feedback of five interviewed surgeons indicates that there is a demand for advanced communication tools for patient education. All surgeons mentioned the patient's major interest in the risks and consequences of the therapy. The combination of text, images of the patient herself and the virtual breast augmentation in one system would cover every aspect of patient education. Different communication strategies and levels of detail can be achieved to individualize the information to be transfered.

Surgeons favored the tracked mouse controller serving as a virtual pen to interactively augment the patient with virtual 3D sketches. The virtual sketches can be used to explain the procedure and its consequences, for instance scars that may occur, but also to extend the documentation of the clinical workflow and to measure anatomic distances.

Most of the surgeons would like to use this system to present the outcome of the surgery, provided that the prediction is realistic. This also involves breast reconstruction as well as breast augmentation in aesthetic surgery. However, the realistic prediction strongly relates to the exact simulation of the biomechanical parameters of the breast tissue, which is still subject of ongoing research. However, surgeons mention that they would already use the system for patients having small breasts with less deformation.

Along with the desire to provide only information that is honest and ethically correct, some surgeons have recommended to display the anatomy rather with an abstract than realistic visualization.

4 Discussion

We presented the concept and first setup of a novel communication tool that augments the current media standard for patient education. According to feedback from interviewed medical partners the system can be useful to explain the limitations, risks, the surgical procedure itself, potential complications and postoperative scars, preventive information and prescription for postoperative behavior, treatment and medicamentation. We plan to replace the optical tracking system with a TOF (Time of flight) camera to enable interaction as well as anatomy registration and increase the usability of the system.

In addition, biomechanical information for realistic deformation has to be integrated once research has progressed in this area. For more realistic simulation of soft tissue, an advanced deformation model has to be applied that that for example may be based on the Finite Element Method proposed by Bianchi et al. [8]. Future work also includes an advanced method of composing the virtual breast and the patient. We currently plan to do early patient studies in order to better understand further requirements of the system.

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