

# Contextual In-Situ Visualization for Port Placement in Keyhole Surgery: Evaluation of Three Target Applications by Two Surgeons and Eighteen Medical Trainees

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## ABSTRACT

Port position in minimally invasive surgeries is chosen to minimize the lesion of tissue and maximize the movability for endoscopic instruments. In this study, we present an evaluation of the potential of a 3D contextual in-situ visualization of the anatomic target region to help surgeons for three different surgical procedures decide where best to create ports and incisions to enable the insertion of a specific set of instruments.

**Index Terms:** K.3.1 [Computer Uses in Education]; H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities

## 1 INTRODUCTION

This paper addresses the navigational and instructional benefits of Augmented Reality (AR) based *contextual in-situ visualization* [4]. The position of the port has to cause as few lesions as possible and provide maximal access for the instruments to reach the site of operation. This study aims to measure firstly the potential of using an AR system to assist placing ports for an operation correctly and secondly its potential as an educational training tool. For evaluating port placements defined by the candidates in our experiment, we chose three minimally invasive operations: Pelvis (one entry port), Thoracic spine (cloud of ports) and Lumbar spine (skin incision) listed in order of increasing level of difficulty.

The literature proposes several methods that use 3D visualization to help with the positioning of ports as well as automatic computation of optimal access points for surgical instruments [1, 2, 5]. AR supported port placement has also been proposed by Feuerstein et al. [3].

## 2 METHOD

### 2.1 Contextual In-Situ Visualization

For detailed information on the employed AR system and the rendering pipeline for contextual in-situ visualization, we refer to Kutter et al. [4]. Instead of the head mounted display (HMD) described by Sauer et al. [6, 4], the HMD used is an NVIS NVisor SX with a 1280x1064, 24-bit color, 60Hz display. Two PTGrey Flea color cameras with a resolution of 1024x780 capture the view in front of the HMD and these images are displayed in the HMD simulating the view from a user's eyes. The HMD is tracked using both an

inside-out tracking system (a black and white 640x480 resolution PTGrey Flea camera attached to the HMD tracks a set of infrared markers fixed to an arc) as well as an outside-in tracking system from A.R.T. GmbH, Germany. Two tracking systems are used because the inside-out tracking setup provides higher rotational accuracy but the tracking camera must have the infrared markers in its line of sight [6, 4]. Therefore the outside-in tracking is used to allow the user to move completely freely around the AR scene. For our experiment, we augmented a Visible Korean Human Phantom, a rapid prototyped life-size manikin of a Korean, with the CT data from the phantom itself using the method described by Kutter et al. [4](see Fig. 1).

### 2.2 Experiment Setup

We invited 20 candidates to partake (2 surgeons and 18 medical trainees; female/male: 7/13; average age: 26.1; spectacle wearers: 6; two had experience from 11 to 20 endoscopic interventions and 18 had no previous experience in the surgical operations used in the study). We conducted the experiment as follows:

1. **Learning Part 1:** Candidates were provided with information about three operations from a surgeon who assisted us in the experiment. This included a text with illustrations, a life size skeleton model and other plastic bone models relevant to the operations.
2. **Port Placement Part 1 (PPP1):** Applying the information given to them in Learning Part 1, candidates pointed with a tracked hand held target to port positions on the skin surface of the manikin.
3. **Stereo Vision Test 1 & HMD Setup:** By checking if a candidate could see a pre-created Random-Dot-Stereogram, we ensured that the HMD was being worn correctly.
4. **Port Placement Part 2 (PPP2):** Candidates wore the HMD and adapted themselves to the augmented view inside the manikin. When they felt comfortable, they started to point again with a tracked hand held target to define the same set of port positions but now using an augmented CT dataset.
5. **Learning Part 2:** Candidates viewed their defined port positions from PPP1, their port positions from PPP2 and also the port positions from an expert surgeon, which were previously saved.
6. **Stereo Vision Test 2:** To test the ability of candidates to see in stereo, a Random-Dot-Stereogram similar to the standard Lang-Test was used.
7. **Port Placement Part 3 (PPP3):** Candidates placed the ports again without the use of the HMD.
8. **Questionnaire:** For the assessment of the subjective psychological state of each subject before and after the experiment, we used a psychological mental state test and further questions were posed to assess the quality of the AR system and the experiment.

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### 3 RESULTS

In the Stereo Vision test, all candidates except for one passed the test.

For each participant, we measured one port for the Pelvis surgery, three ports for the Thoracic spine surgery and two points defining an incision for the Lumbar spine surgery. Port positions



(a) Defining the ports for thoracic spine surgery (b) With AR vision (c) Reviewing the ports for lumbar spine surgery

Figure 1: One of 20 candidates performs port placement.

were evaluated quantitatively as well as qualitatively. An expert surgeon assessed qualitatively the participants' ports positioning (**QualPos**) and their arrangement (**QualArr**), both on a scale from 1-3 (1 is optimal, 2 possible for surgery, 3 is impossible). We consider the qualitative evaluation of the port positions as more important than the quantitative evaluation since multiple port configurations are possible for the operations.

For the pelvis surgery neither a benefit from the contextual in-situ visualization nor a learning effect could be shown in our experiment.

For the thoracic spine surgery three ports form a triangle. We computed the similarity of the centroid (**Centroid**), the distance of centroid to the operation site (**PathLen**), the grad parallelism of the normal of the triangle and the vector centroid to operation site. Since the ports should ideally be arranged as an equal-sided triangle we used the measure grad parallelism to assess the quality of the ports defined. The measured results indicate that contextual in-situ visualization helps with positioning the ports because the distance of the triangle centroid reduced. Results also improved for **PPP3** after learning from the expert's port sets.

**QualPos** and **QualArr** showed steady improvement in both categories from **PPP1** to **PPP3**.

	<b>Centroid [mm]</b>	<b>PathLen [mm]</b>	<b>QualPos</b>	<b>QualArr</b>
PPP1	91,98(43,41)	6,09(5,09)	2,40(0,75)	2,25(0,71)
PPP2	68,45(34,97)	7,74(4,60)	1,80(0,83)	2,05(0,82)
PPP3	50,25(22,60)	3,49(2,30)	1,55(0,61)	1,70(0,66)

Table 1: Thoracic Spine Surgery: values are given as AVG(STD) rounded to 2 decimals

For the lumbar spine surgery, we compared expert's and candidates' cuts for parallelism, similarity in length, distance between the centroids (**CutCent**) and the distance of the centroids to the operation site (**PathLen**). The results indicate that the proposed contextual in-situ visualization helped to optimize the position of skin incision. A learning effect could be observed for positioning, length and orientation of the incision. **QualPos** and **QualArr** showed steady improvement in both categories from **PPP1** to **PPP3**.

	<b>CutCent [mm]</b>	<b>PathLen [mm]</b>	<b>QualPos</b>	<b>QualArr</b>
PPP1	40,73(20,82)	24,44(10,82)	1,85(0,81)	1,55(0,68)
PPP2	34,48(25,54)	21,11(14,91)	1,65(0,81)	1,60(0,60)
PPP3	28,29(26,48)	19,15(13,94)	1,50(0,76)	1,20(0,52)

Table 2: Lumbar Spine Surgery: values are given as AVG(STD) rounded to two decimals

### 4 DISCUSSION

Since the Korean phantom manikin consists of rigid material, the ability to touch and feel anatomic structures such as the ribs or the pelvis was reduced. However, the available tactile shape of the hip and the chest as well as a life-size human skeleton model placed nearby could be used by the candidates to help with placing the ports without AR vision. The evaluation of the learning effect requires further studies to distinguish the benefit of contextual in-situ visualization. In a subsequent experiment, candidates will learn how to place ports with a longer training period where they can familiarize themselves with the AR vision. Time is required to explain the complex technology and for them to begin to immerse themselves in the AR scene to take full advantage of the technology. We also plan to introduce a control group and include the angle of instrument incision in the analysis.

### 5 CONCLUSION

In this paper, we present a first evaluation of the navigational and instructional benefit of contextual in-situ visualization. The results of our experiment show that the augmented view into the patient can help with positioning and arranging ports for three different minimally invasive interventions. Augmentation of palpable information of the anatomy close to the patient's skin surface with visual information from deep seated anatomy can enhance the mental model for planning the instrument position and orientation. Furthermore, we extended the AR scene with expert ports collocated with candidates' earlier defined ports and found a positive learning effect from the resulting combination of sensory information. Feedback from our questionnaire and discussion with surgeons and medical students after the experiment encourages us to introduce an AR system for further instructional tasks in the medical field such as surgical simulation and teaching anatomy.

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