

# Stereo depth assessment experiment for microscope-based surgery

R.J. Lapeer<sup>1</sup> A.C. Tan<sup>2</sup> A. Linney<sup>2</sup> G. Alusi<sup>3</sup>

<sup>1</sup>School of Computing Sciences, University of East Anglia, Norwich NR4 7TJ, UK.

<sup>2</sup>Dept.of Med.Physics and Bioengineering, University College London, WC1E 6JA, UK.

<sup>3</sup>St.Bartholomews Hospital, London, UK. - contact first author: rjal@cmp.uea.ac.uk

## Abstract

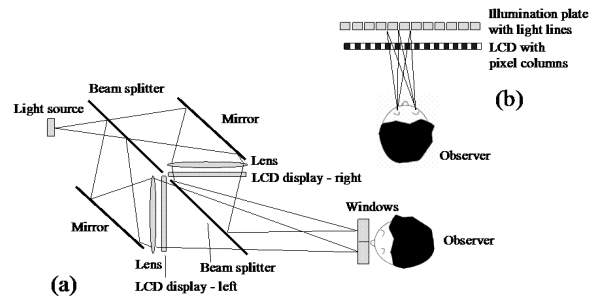
We present experimental data on the use of autostereoscopic displays as complementary visualisation aids to the surgical stereo microscope for augmented reality surgery. Five experts in the use of the microscope, and five non-experts, performed a depth experiment to assess stereo cues as provided by two autostereoscopic displays (DTI 2015XLS Virtual Window and SHARP micro-optic twin), the surgical microscope and the 'naked' eye.

## 1 Introduction

The surgical stereo microscope is used in a number of ENT (Ear, Nose, Throat) and neuro-surgical procedures. Although its capabilities of magnifying the surgical area of interest and providing stereo depth are indispensable to guarantee a successful intervention, it may cause eye strain and, back and cervical complaints, when used for prolonged periods of time. Autostereoscopic displays avoid this ergonomic problem and are therefore an interesting complementary visualisation aid to the surgical microscope. Moreover, when used in the context of computer controlled augmented reality (AR) surgery, they avoid cumbersome adaptations of the optical system of the microscope, thus making it a more general solution which can be used in conjunction with other visual aids (e.g. endoscopes) without significant adaptations. In this paper, we investigate the quality of the stereo depth cue provided by autostereoscopic displays, as compared to the gold standard, being the surgical stereo microscope and the naked eye.

## 2 Autostereoscopic displays

Stereoscopic displays, requiring the user to wear special glasses, have been in use for several years. However, many of these systems suffer from uncomfortable eye-wear, control wires, cross-talk levels up to 10% and other image degrading effects such as image flicker and reduced image brightness [4]. Autostereoscopic displays require no viewing aids and are thus more comfortable to use. They do suf-

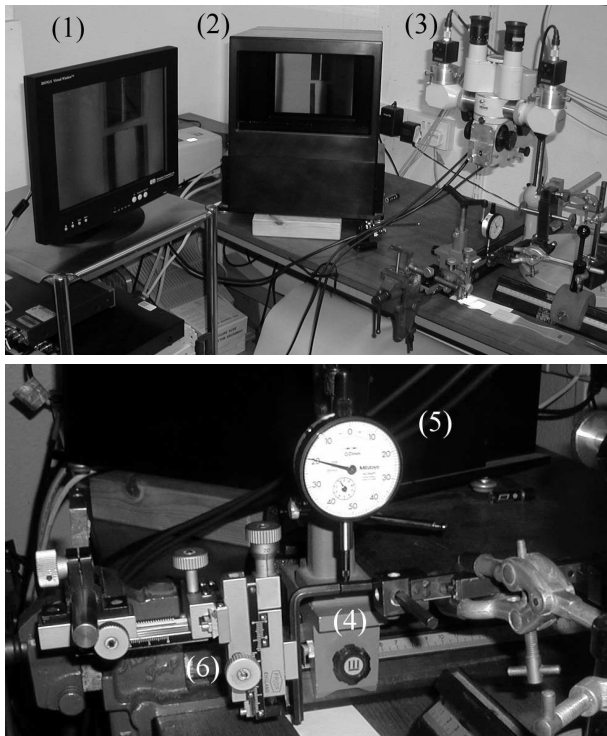


**Figure 1.** (a) The principle of the SHARP micro-optic twin display [2], which employs two mirrors, a beam splitter and a beam combiner to generate a stereo pair of images. Its resolution is 640 x 480 with a pixel pitch of 0.33mm. Its lateral and longitudinal freedom are 480mm and 550-990mm, respectively. (b) The principle of the DTI Virtual Window 2015XLS flat panel display which employs a mask which selects alternate pixel columns for left and right images respectively. Its resolution is 1024(512 per window) x 768. Pixel pitch is 0.297mm; lateral freedom is 150mm; longitudinal viewing is 609-813mm.

fer from limited viewing freedom as compared to shutter-based systems. Their principle of operation is based on optical output producing two 'windows' separated by a plane, allowing the left and right eye to see a different image. Figure 1 shows the principle of the SHARP microtwin LCD display (a) and the DTI 2015XLS Virtual Window (b).

## 3 Experimental setup

The experiment aims to test depth perception. Therefore in-plane cues based on scale and focus should be eliminated. The setup is shown in Figure 2. Figure 2 shows the two displays and the surgical microscope equipped with two CCD cameras to capture and magnify the area underneath. The captured area is a setup of two Allen keys which can be adjusted in three dimensions with an accuracy of 0.05mm. Before the experiments starts, an operator levels the two Allen keys using a dial indicator (Figure 2(b)). He/she writes down the current setting as given by the mi-



**Figure 2.** Top: Experimental setup with DTI (1), SHARP (2) and microscope with mounted cameras (3). The Allen keys - which are visualised on the displays in top view - have to be set level by the subject using the stereoscopic parallax cue only; Bottom: Micrometers for depth measurement, Allen keys (4) and dial indicator (5) to set ground truth. The movable Allen key (centre left) is changed in z-level by the micrometer device's z-adjustment (6).

rometer scale which becomes the reference value. He/she then moves the keys apart and the subject tries to level them using one of the four visual aids: the surgical microscope, the SHARP display, the DTI display and the naked eye. The naked eye implies just using normal eyesight. For each device, six trials per subject were conducted. Five experts in the use of the surgical microscope and five non-experts performed the experiment.

#### 4 Experimental results

Table 1 shows the results for both the experts (E) and non-experts (NE) group (the latter being used as a control). Note that paired t-tests were performed to compare the individual visualisation aids within one group and to compare across groups for the same device.

#### 5 Discussion and Conclusion

Due to lack of space, a more in depth coverage and discussion on this experiment can be found in [2].

The performance on the DTI was significantly less than on the microscope ( $p=0.05$ ), for the experts group. It also took most subjects longer to complete the trials on the DTI dis-

Device		DTI	SHARP	Micro	eye
E	ave(mm)	0.298	0.203	0.115	0.211
	std(mm)	0.169	0.251	0.098	0.040
NE	ave(mm)	0.286	0.160	0.490	0.237
	std(mm)	0.172	0.107	0.398	0.135
E	ave(min)	11.2	4.8	5.8	3.3
	std(min)	5.4	2.0	2.3	1.6
NE	ave(min)	11.2	5.6	7.2	5.0
	std(min)	4.0	2.0	2.3	1.4

**Table 1.** The first four rows show mean and standard deviation of the depth error for experts (rows 1,2) and non-experts (rows 3,4)-  $n=5$  for both groups - for each of the four visualisation aids. The next four rows show mean and standard deviation of time (in minutes) needed to complete six trials for experts (row 5,6) and non-experts (row 7,8).

play though this may well be because it was the first device to be tested, so part of the time needed may be due to getting used to the protocol. In future experiments, the trials should be randomised to avoid this problem [3]. The performance on the SHARP display was not significantly less than on the microscope, for the experts group. This finding strengthens the argument of using autostereoscopic displays as a complementary device to the microscope. The SHARP display was tested in the operating theatre in the past [1]. Though it was considered to be a useful visualisation aid, its weight and dimensions made it cumbersome to reposition during the intervention. The DTI display's performance varied amongst users so testing it in the operating theatre at this stage would be too early. Its advantages are being light-weight and small, and its relatively low purchase cost. Further fine-tuning of the intrinsic camera parameters, to which it appears to be sensitive, may allow us to introduce it in the operating theatre in the near future.

#### References

- [1] P. Chios. *The Design Process of an Autostereoscopic Viewing Interface for Computer-Assisted Microsurgery*. PhD thesis, University College London, August 2002.
- [2] R. J. Lapeer. *Computer Assisted Surgery, Simulation and Planning using Augmented Reality (CASSPAR): visualisation and calibration*. Technical report, School of Computing Sciences, University of East Anglia, UK, 2003.
- [3] J. P. Rolland, C. Meyer, K. Arthur, and E. Rinalducci. Method of adjustments versus method of constant stimuli in the quantification of accuracy and precision of rendered depth in head-mounted displays. *Presence: Teleoperators and Virtual Environments*, 11(6):610-625, 2002.
- [4] G. Woodgate, D. Ezra, et al. Autostereoscopic 3D display systems with observer tracking. *Signal Processing: Image Communication*, 14:131-145, 1998.