Continuous assessment of presence in stereoscopic displays

adequately explained by rescaling to match the effective visual disparities. Although there was a strong linear correlation between naturalness and quality ($r = 0.96$), a small but systematic deviation could be observed. This deviation was best modelled by a linear quality model that incorporates both naturalness and depth.

◆ **Illusory contours do not capture stereopsis—they just constrain the depth spreading**
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If vertical cut-out sectors defining a Kanizsa square are given crossed disparity, the illusory figure appears in depth. Such an illusory figure can pull the background pattern inside the illusory figure to the same depth. It has been assumed that illusory contours are necessary for this phenomenon, which is called stereo capture (Ramachandran, 1986 *Perception & Psychophysics* **39** 361 – 373). However, we noticed that the vertical cut-out sectors of the inducing figures ('pacmen') are not the only structures that can capture the background texture. The rows of background dots that are enclosed between the disparate vertical cut-out sectors also have unambiguous stereoscopic depth. Thus it might be possible that the disparate rows alone capture the background texture. To investigate our hypothesis we created a stereogram in which the inducing figures were removed. It consisted of a dotted background texture and four areas devoid of dots. The dotless areas corresponded to the areas which were occluded by the original inducing figures. Because of this, the top and bottom rows inside the central area were in crossed disparity.

According to our results (a) depth capture also occurred without illusory contours; (b) when illusory contours were not present, the depth of the disparate rows spread more often to other areas. Usually the depth spread first to the central area of the figure and after that horizontally to other areas of the figure. Therefore, we conclude that illusory contours do not capture stereopsis—they just constrain the depth spreading.

◆ **Effects of stereo and motion manipulations on measured presence in stereoscopic displays**
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Methods of assessing presence, a sense of 'being there' within a displayed virtual environment, include post-test subjective measures, discrimination tests, and monitoring reflexive responses. Each is limited—either they do not provide a measure of temporal variation, are not feasible with current display technology or are overly content-specific.

A measure of presence derived from the method of continuous evaluation (ITU-R, Recommendation BT.500-7, revised, "Methodology for the subjective assessment of the quality of television pictures", 1995) has been used to overcome these limitations. The results of two experiments are presented. Those of the first experiment established that the methodology is usable under the optimal viewing conditions for the 20 inch stereoscopic TV display upon which our stimuli were presented. It compares within-subject variation on continuous TV picture quality ratings under two viewing conditions—at six picture heights in the light (standard for quality evaluations) and at two picture heights in the dark (optimal stereo TV viewing). The second experiment investigated the effects of manipulations of the visual parameters of stereo, scene motion, and observer-based motion on participants' presence evaluations within edited sections of a stereoscopic film. The results provide support for theories predicting that the extent of sensory information available to a participant is one of the factors determining presence.

◆ **Continuous assessment of presence in stereoscopic displays**
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Presence, a sense of 'being there' evoked by a display, can be regarded as a concept of central importance in the evaluation of broadcasting and entertainment services in general and virtual reality applications in particular. Subjective methods of assessing presence that have either been used or proposed to date do not provide a measure of temporal variation in observers' presence. To overcome this limitation, we have applied the method of continuous assessment (ITU-R, BT 500-7) to the measurement of presence. Thirty observers (twelve at IPO, eighteen at UoE) with normal

or corrected-to-normal vision and good stereo-acuity viewed a stereoscopic film. While watching, observers were asked to continuously rate their perceptions of depth, naturalness and presence. The stimulus material varied considerably in the amount and strength of the visual cues presented over time. This enabled us to investigate whether the extent of sensory information presented to an observer was a determinant of presence, as proposed by Sheridan [1992 *Presence: Teleoperators and Virtual Environments* **1**(1) 120 – 125].

The results, which were very similar across two independent laboratories, suggested that continuous assessment provides a promising methodology for the subjective assessment of temporal variation in the observer's sense of presence. Further, increasing the extent of sensory information presented to an observer may enhance the sense of presence, provided the depth cues introduced are consistent and within natural bounds. [*Note*: First and second author in arbitrary order.]

◆ **Completion under isoluminance**

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It is known that monocular depth cues become much less effective under isoluminance. One of these depth cues, occlusion, gives rise to surface completion. A study is reported in which the loss of completion under isoluminance was tested.

A pair of horizontally aligned bars of different lengths is detected automatically in a display filled with pairs of bars of the same length. The pair is detected serially, when vertical bars are placed over the gaps between the pairs. Because the vertical bars are occluders, and the pairs of horizontal bars are aligned, completion behind the vertical bars takes place and the two parts together behave perceptually as a single bar.

We used this knowledge to measure completion under isoluminance. When occlusion is lost under isoluminance, we expect that an occluding surface, isoluminant with the background, will not lead to object completion and as a consequence, the pair with unequal lengths of the parts will pop out. Using this procedure we have demonstrated that completion is lost under isoluminance.

◆ **The impact of 3-D video endoscopy on binocular perception and visually guided manipulation**

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Monocular video endoscopic systems are established in the clinical routine of surgical endoscopy. The introduction of 3-D video systems could improve visualisation of the intracorporal operating site because of the stereoscopic depth information. The goal of our investigations has been to quantify the influence of this visualisation technology on visual perception, on visually controlled endoscopic manipulations, and on the intraoperative performance, including ergonomic and psychophysical aspects. These results are used to define guidelines for improvement and for the integration of such systems into clinical routine so as to achieve optimal support of the medical team.

The comparison of 2-D and 3-D video endoscopic systems showed a general improvement in the performance of endoscopic procedures. However, 30% – 50% of the users had perceptive problems with 3-D endoscopy. To study the problems quantitatively, we compared the case of stereoscopic visualisation with the real situation of direct view onto the specific objects. The users with problems had insufficient binocular depth perception of stereoscopic images for visual discrimination tasks, although their depth perception of real objects was good. Analysis of their eye movements showed significant differences compared with those of users with good binocular depth perception of stereo images. In particular, there were differences in the relation of vergence movements and accommodation. When we compared visually guided manipulations under stereoscopic video sight and direct view, we found the overall manipulative performance of all users to be the same, but the users with problems showed a lower performance in general.

The experimental design and the results are discussed in detail.

◆ **Effects of position and contour blurring of cast shadow on depth perception**

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Shadows are known as a qualitative depth cue. Moreover, dynamic changes of shadow position were recently reported to lead to the perception of a looming object, suggesting that shadows