Transparent Cockpit Using Telexistence

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Abstract

We propose an indirect-vision, video-see-through augmented reality (AR) cockpit that uses telexistence technology to provide an AR enriched, virtually transparent view of the surroundings through monitors instead of windows. Such a virtual view has the potential to enhance driving performance and experience above conventional glass as well as head-up display equipped cockpits by combining AR overlays with images obtained by future image sensors that are superior to human eyes. As a proof of concept, we replaced the front windshield of an experimental car by a large stereoscopic monitor. A robotic stereo camera pair that mimics the driver's head motions provides stereoscopic images with seamless motion parallax to the monitor. Initial driving tests at moderate speeds on roads within our research facility confirmed the illusion of transparency. We will conduct human factors evaluations after implementing AR functions in order to show whether it is possible to achieve an overall benefit over conventional cockpits in spite of possible conceptual issues like latency, shift of viewpoint and short distance between driver and display.

Keywords: Augmented Reality, Telexistence, Virtual Reality.

Index Terms: Computer graphics—Graphics systems and interfaces—Mixed / augmented reality.

1 Introduction

Drivers obtain up to 90% of information necessary for driving through the visual channel [1]. Unfortunately, visual information is often incomplete, for example due to occlusion, darkness or weather conditions. Human processing of the visual channel is also sequential, so drivers might miss information while their attention is focused on something else.

Augmented Reality has the potential to enhance driver's perception and understanding of the surroundings. Past examples include letting drivers virtually see through occluders, warning drivers by marking obstacles like pedestrians and providing riving cues like safe distances or navigational guidance within the main field of view [2,3]. Such automotive AR systems are mostly either video see-through using a small display with below-unity magnification or optical see-through HUDs. Both types of systems have conceptual limitations: The former requires the driver to look at yet another display while driving, whereas perfectly registering and matching AR overlays to appear three dimensional and real is difficult for the latter.

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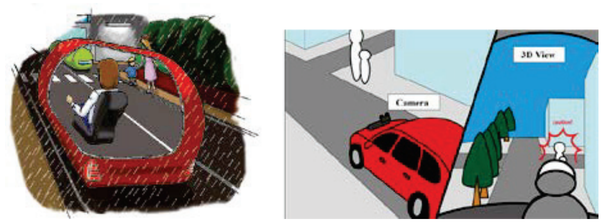

Figure 1: Transparent Cockpit concept aims to provide a clear view of the surroundings even under bad environmental conditions that can further be augmented to provide visual cues.

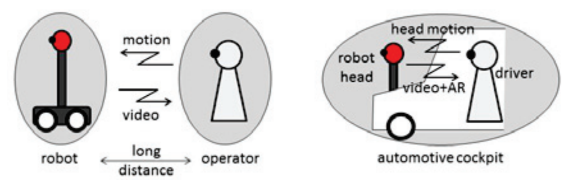

Figure 2: Left: Telexistence. Right:: Augmented transparent cockpit using telexistence technology.

A different problem is solved by indirect vision systems for driving. Well known examples are night vision enhancement systems (NVES) for civilian vehicles which show the monochromatic live image of a forward looking infrared camera on a small LCD display on the dashboard and indirect vision systems that provide external views to the occupants of a window-less armored vehicle. Human factors evaluations mostly agree in the potential of NVESs to increase detection distances, but are divided about their effect on workload. Unity magnification seems best for distance judgment and speed control, although magnification of less than 1 may help with overall orientation in navigation tasks at the cost of causing slower driving speeds (due to decreased speed perception) and higher workload [4,5]. In general, driver task performance increases with driving time, indicating that there are some limitations that drivers need to get used to. Opinions differ about the presence and amount of discomfort and contributing factors like motion sickness. While most systems are monocular, a few researchers have investigated stereoscopic systems (without motion parallax) and concluded that stereoscopic systems have an advantage in depth perception resulting in higher task performance, while having no significant effect in reducing motion sickness [6]. We confirmed in a preliminary driving simulator study that providing motion parallax, i.e. correctly changing the viewpoint of the displayed image depending on head position is important to reduce motion sickness.

The aim of our current work is to show the effectiveness of replicating motion parallax to reduce visual discomfort in indirect vision cockpits using telexistence technology [7,8,9]. At this moment, the indirect vision system has been implemented and a formal evaluation is planned for the near future. Once that step is done, we will be able to use the system as a basis to implement a transparent full-size video see-through AR cockpit.

2 Motion Parallax Indirect Vision System

We used a Nissan NV200 minivan as our experimental vehicle. The front windshield has been removed and a large, stereo-capable 60 inch LCD display (Manufacturer: Sharp) was mounted on top of the firewall and protected by aluminum panels that are lined in black cloth on the inside to shut out sunlight and eliminate reflections. (Figure 3)

There are two main approaches to produce seamless motion parallax video. The option we chose is a multiple DOF robot camera that exactly tracks the head motion of the driver. Alternatively, a multiple camera array could be used to interpolate images for arbitrary viewpoints within the array.

The robotic head system consists of a XY robot (Model: IAI LSA-S6SS, LSA-S8HS series) and a custom made 3 DOF robotic head. We decided not to implement Z motion because the driver's head does not move much in the vertical direction and a preliminary driving simulator experiment showed that ignoring Z motion did not have a significant effect. The head uses two web cameras fitted with 128.5 degrees wide angle lenses as a stereo camera pair placed 65mm apart so that it matches the average human Inter-Pupillary distance (IPD) in order to create correct distance and depth perception. The completed robot, placed in front of the backside of the display and above the engine hood, can be seen in Figure 4. In order to generate control commands for the robot, the driver's head motion is captured by a motion tracking system (Model: OptiTrack Duo).

An initial calibration is used to match the default head position of the driver to the default position of the robot. After the calibration, the x, y position as well as pan, tilt and roll of the robotic head is moved so that the stereo camera pair maintains constant relative position and direction to the drivers head. The XY robot and the head communicate at 200Hz cycle speed after filtering rugged motion with a digital low pass filter.

The stereo image pair is mapped onto a virtual projection screen and the resulting image is shown to the driver wearing an active shutter 3D glass to which retro-reflective markers for the motion tracking system were added. Therefore, when the driver moves in x, y direction as well as pan, tilt, roll the robotic head in front of him moves accordingly to give the exact same Point of Vision.

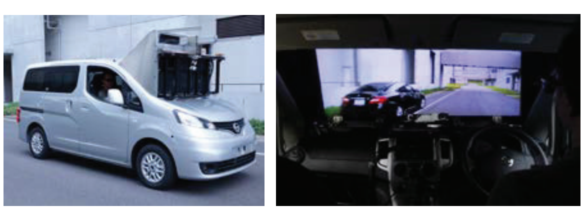

Figure 3: The windshield of the prototype car was replaced by a large 3D monitor and enclosed inside a hood to block sunlight.

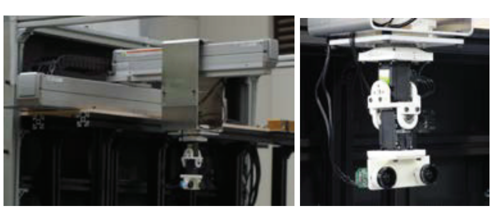

Figure 4: Completed robot camera with the 2 DoF linear servos above the 3 DoF robot head with the stereo camera.

3 Conclusion

We proposed a fully enclosed, windowless, indirect vision, video see-through AR cockpit as a solution for providing superior situation awareness by combining advanced image sensors and AR. We believe that motion parallax is essential for illusion of transparency and implemented a prototype car that replaces the front windshield by a 5 DoF robotic stereo camera, a head tracking system and a large stereo display. Initial results of driving it on roads within our research facility have been promising and further evaluations are planned for the near future.

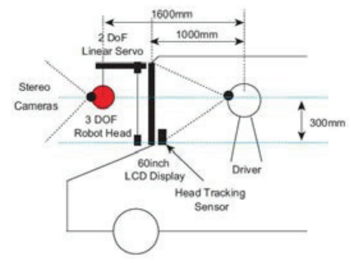

Figure 5: Layout of indirect vision system

References

[1] A. Cohen, R. Hirsig, "Zur Bedeutung des fovealen Sehens fuer die Informationsaufnahme bei hoher Beanspruchung," *Sicht und Sicherheit im Strassenverkehr,* Verlag TUV Rheinland, Koeln, 1990.

[2] U. Bergmeier, C. Lange, "Acceptance of augmented reality for driver assistance information," *Proceedings 2nd International Conference on Applied Human Factors and Ergonomics,* Las Vegas, 2008.

[3] W. Narzt, G. Pomberger, A. Ferscha, D. Kolb, R. Mueller, J. Wieghards, H. Hoertner, C. Lindiger, "Augmented reality navigation systems," *Universal Access in the Information Society* 4, 2006, 177–187.

[4] S. Mahlke, D. Roesler, K. Seifert, J.F. Krems, M. Thuering, "Evaluation of six night vision enhancement systems: Qualitative and quantitative support for intelligent image processing", *Human Factors,* 49, 518-531, 2007.

[5] C. Smyth, G. Gombash, P. Burcham. "Indirect Vision Driving With Fixed Flat Panel Displays for Near-Unity, Wide and Extended Fields of Camera View,". *Tech. rep., Army Research Laboratory,* Aberdeen Proving Ground, MD, June 2001.

[6] J. Chen, R. Oden, C. Kenny, J. Merrit. "Effectiveness of Stereoscopic Displays for Indirect-Vision Driving and Robot Teleoperation," *Tech. rep., Army Research Laboratory,* Aberdeen Proving Ground, MD, August 2010.

[7] Susumu Tachi, Kouta Minamizawa, Masahiko Furukawa and Charith Lasantha Fernando: "Telexistence - from 1980 to 2012," *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2012),* pp.5440-5441, Vilamoura, Algarve, Portugal (2012.10)

[8] Takumi Yoshida, Kensei Jo, Kouta Minamizawa, Hideaki Nii, Naoki Kawakami and Susumu Tachi, "Transparent Cockpit: Visual Assistance System for Vehicle using Retro-reflective Projection Technology," *Proceedings of the IEEE Virtual Reality 2008,* pp. 185-188, Reno, USA (2008.3)

[9] Charith Lasantha Fernando, Masahiro Furukawa, Tadatoshi Kurogi, Sho Kamuro, Katsunari Sato, Kouta Minamizawa and Susumu Tachi, "Design of TELESAR V for Transferring Bodily Consciousness in Telexistence," *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2012),* pp.5112-5118, Vilamoura, Algarve, Portugal (2012.10)