Bidirectional See-Through Displays for Enhanced Interaction in Surveillance Systems

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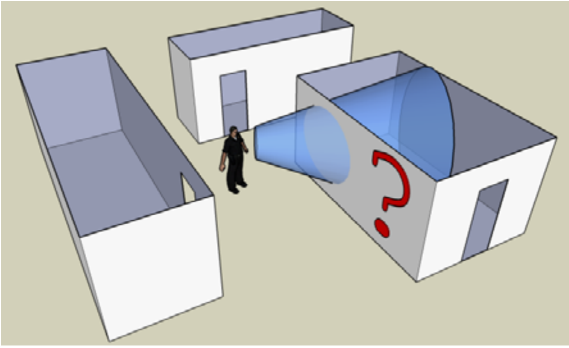
Whenever the design of human machine interfaces is affected, one has to pay attention concerning aspects of usability. Thereby, surveillance specific requirements, such as mobility or – in some cases – soundlessness have to be considered. Furthermore, in many security applications, such as rescue missions, a hands-free and lightweight design is mandatory. Considering these aspects, the four Fraunhofer Institutes IPMS, IOF, IGD and IITB have bundled their skills and expertise in order to develop the iStar-device, where iStar is an acronym for *Interactive See-Through Augmented-Reality*.

1 Introduction

Imagine a security guard is on his nightly patrol on a large industrial property. Using his hands to control his personal transporter, a short text appears about one meter ahead of the guard, sort of hovering in front of him and saying »intrusion detected in sector 5.6«. Right below the text a virtual button appears which is labeled with »map view«. By focusing his gaze on the button for some milliseconds, the text, and the button disappear. Instead a map of the property pops up, with one position in sector 5.6 highlighted. Clearly, the text, the button and the map do not exist in reality. Rather the guard was wearing very special eyeglasses, which are able to display virtual information and simultaneously analyze eye movements for gaze control.



Jump cut to a fireman within a large building positioned in the front of a door. Smoke leaks underneath the door. It is the fireman's and his co-workers mission to rescue a fainted person which is located in the room behind the door. The position of the person is well known, since the person is equipped with a RFID-chip that can be detected. Wherever the fireman is looking at, an arrow in front of him points to the direction, where the person is located. The arrow is created by the same kind of eyeglasses that were described in the previous scenario.

In these two, roughly sketched scenarios an iStar-device comes into operation, which is designed in the manner of see-through eyeglasses. The eyeglasses are able to display information and simultaneously record the user's eye movement via an integrated camera. While the display clearly serves as output device, the integrated camera can be seen as input device, which is controlled via conscious or even unconscious eye movement. In combination, these two features lead to mobile, soundlessness and hands-free interaction with security systems steered by gaze control. Unlike existing see-through head mounted systems, the innovative hardware design leads to a compact device of little weight and small size, which is a basic feature for usability.

In this paper several aspects of the iStar-device are discussed: In the next section a short description of the basic iStar concepts is given. Next, the main technical challenges that had to be solved are described. Finally, potential applications are discussed, future works are presented and a summary of the paper is given.

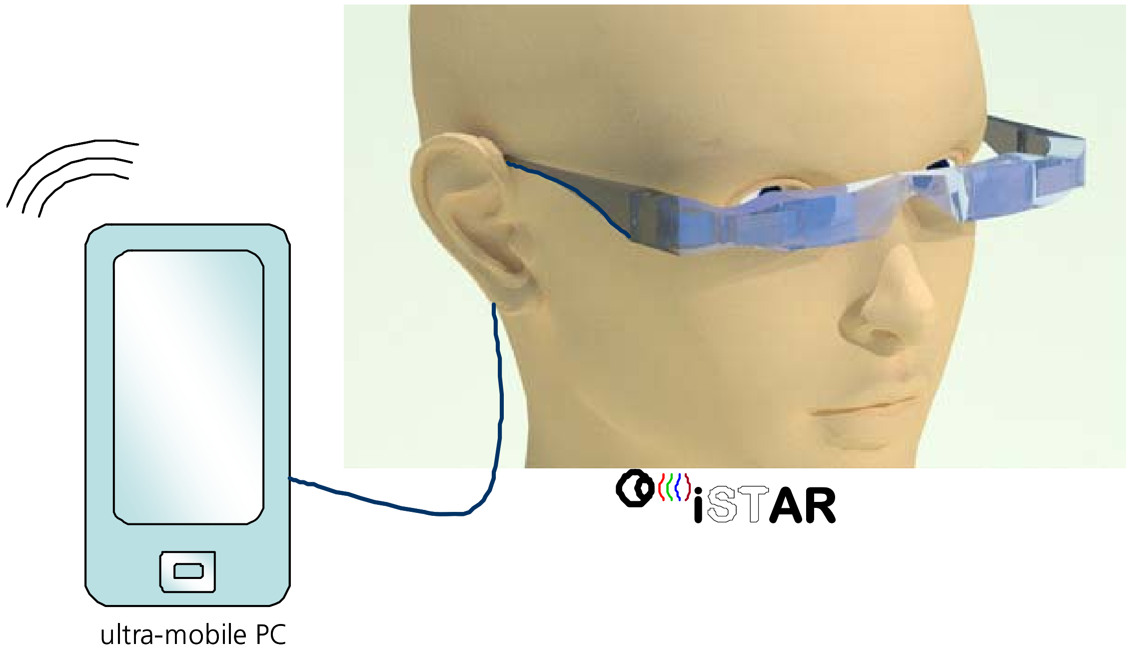


Fig. 1: The hardware of iStar consists of the device itself and an ultra-mobile PC. The latter may communicate with superior systems.

2 Basic Concepts of iStar

The basic concepts of the iStar-device concern three aspects, namely the design of *hardware*, the design of *software* and the concepts of *interaction*. In the following, these concepts are addressed, while the iStar specific hardware is discussed in the next section, which is addressing the major technical challenges.

2.1 Hardware Concept: Portability

As sketched in Figure 1, the iStar-device consists of two physical components: the eyeglasses on one side and a mobile processing unit, like an ultra-mobile PC or a PDA on the other side. The latter basically performs three tasks: It is providing an input signal for the see-trough display, the analysis of the eye movement and – whenever the device is connected to a superior system – a high level interface for system communication. In order to stay abreast of the rapid changes of PC technologies, the mobile processing unit itself is not explicitly specified within the iStar-concept.

Instead of specifying a non-generic platform, the software modules are implemented in a highly portable manner and thus are portable onto new off-the-shelf platforms with none or very little effort. In consequence, the performance of iStar will not be limited by the usage of an outdated mobile processing unit, and therefore will be adaptable to upcoming computer technologies.

2.2 Software Concept: Modularity

Due to the concept of portability, it is possible to realize applications with different requirements concerning the hardware resources and featured functionality. In order to additionally enhance the scalability of the system, another concept of iStar is the modularity of the software architecture. Basic graphic and image processing libraries, wrapped with standard interfaces, allow the construction of highly customized applications, which can be completed by standardized hard- and software components.

The advantage of this design concept can be illustrated by the previously introduced scenarios: The watchman will profit from information in different levels of detail, such as low-key alpha-numerical information as default setting and dense data such as AR overlays on demand only. The fireman in contrast will benefit on a robustly determined position of the person to rescue. Thus, in the rescue scenario the main focus has to lie on real-time capability and ergonomic data display.

2.3 Interaction Concept: Gaze Control

Gaze control is not a common way of system interaction yet and still can be seen as object of research. So far two concepts of gaze controlled interaction are distinguished: conscious and unconscious eye movement analysis.

Tracking of conscious eye movement provides interaction concepts that are similar to known human machine interfaces: gazing at a virtual button can be equated with activating a feature by mouse click. On the other hand, despite focusing certain virtual points, there is little potential of interaction concepts by conscious eye movement. Interaction by means of conscious eyelid movement for example, would be technologically realizable, but probably does not lead to ergonomic concepts of interaction.

Instead of demanding conscious eye movement other than gazing, one better will focus on the observation of unconscious eye movement. In combination with a forward directed camera, unconscious eye movement can be used for analyzing human's attention by means of intelligent pattern recognition. Starring on certain objects in the real world, e.g., might be interpreted as focus of interest and therefore might be used as trigger to display context-dependent information. Certainly, this kind of interaction is highly innovative and demands for further research.

Besides the application as method of interaction, tracking of unconscious eye movement can serve as technological input for the iStar-device. An almost self-evident application would be the interpretation of eye movement patterns in order to detect conscious eye movements more robustly. Furthermore, real-time tracking of the line of sight can be used in order to improve the overall comfort of the iStar-device, e.g., by providing an auto-contrast enhancement in the region of the eyes focus or the emulation of a sun shield functionality.

3 Major Technical Challenges

As a major technical highlight, the display and the integrated camera are realized on a single chip, more precisely via OLED micro-displays with embedded CMOS sensors, where the latter are used for the eye monitoring feature. This »two-in-one«-strategy leads to a device, that makes calibration routines almost redundant, since the relative orientation of the sensor and the display is naturally fixed.

Due to this highly innovative duality, challenging research in the field of optics was mandatory. An optical unit had to be designed, which is able to combine two entirely different optical paths in the same optical axis: One path projects a virtual image of the OLED-imager and superposes this to the regular see-through visual perception. The other part images the eye onto the sensor-array. Thereby, the prior mentioned constraints of usability such as low weight and a compact overall size had to be considered. The optimal solution turned out to be a combination of a highly parameterized free form lens combined with an array of micro lenses, where the latter can be seen as an ultra-thin artificial compound eye inspired by insects.

Clearly, the overall hardware design had to be accomplished in close coordination with the research activities concerning the software development for the display technology and the gaze control: While for the functionality of the display aspects like image resolution, system interfaces and luminous intensity had to be considered, the module for gaze control is in dire need of a high frame rate and a good image quality. Since the devices will not be limited to indoor usage, the consortium is about to develop eye tracking algorithms that work robustly under changing conditions of illumination. Thereby, the special design of the chip demands for highly sophisticated algorithms. In the end, expertise concerning augmented reality systems will be required in order to fully exploit the potential of the overall design.

4 Applications

As proof of concept for applicability, the iStar-device will be plugged to the semi-autonomous surveillance system NEST (Network Enabled Surveillance and Tracking), which is installed in the Fraunhofer IITB. The scenario will be similar to the two scenarios, which are sketched in the introduction.

Clearly, there exist many more reasonable applications for civil security and safety than the two preliminary scenarios concerning fire rescue and safeguarding of large properties. Further thinkable applications are the enhancement of existing and upcoming security systems at all kinds of highly frequented public places by equipping security staffs and policemen with iStar-devices.

Even though security applications will highly profit by the iStar-device, its usage is not limited to security systems, which will be demonstrated in industrial and consumer applications by the scientific consortium.

5 Summary and Future Work

For the development of the here described iStar-device, expertise concerning chip design, optics, pattern recognition and computer graphics was bundled. The design leads to a head mounted system for interaction that fulfills many constraints concerning usability, such as low weight and compact design.

In order to shorten the developmental period, the first two demonstrators of iStar consist of reduced functionality and mainly serve as proof of concept and platforms for subsequent work packages, such as pattern analysis and computer graphics. In the near future, the consortium will start manufacturing the first »all-in-one« version of iStar.