A System for Enhanced Situation Awareness with Outdoor Augmented Reality

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Abstract. Augmented Reality (AR) is an upcoming technology focusing on the enrichment of the user's natural view by integration of text and interactive objects in real time. While indoor AR may rely on stable environment conditions and sensitive tracking devices, high-precision outdoor AR faces more challenging requirements and is thus less spread. Furthermore, constantly changing environment outdoor conditions require a robust system capable to offer different views with appropriate information density, especially in stressful situations. In this case, the correct choice of colors, text size and mark-up style may be critical for the performance of the interactive system. A concept for a new, video-based and compact Augmented Reality vision system, based on Differential-GPS, is presented. Results of a preliminary study on two different approaches for position and object pinpointing give valuable cues for interface design with optimized situation awareness.

Keywords: Outdoor Augmented Reality, Situation Awareness.

1 Introduction

1.1 Augmented Reality

Augmented Reality (AR) has been identified as an upcoming technology with many different areas of application. Many have been identified, which range from in-situ visualization of wind tunnel data [1] to industrial robot programming [2]. They have in common that cognition and productivity can be increased by enriching the human's natural view with usually invisible information. Other commonalities are constant and stable environment conditions which facilitate realization and implementation. The foremost problem of AR is accurate spatial matching of reality and virtual objects. Real-time tracking of the camera's or the human eye's transformation in 3D space is necessary for correct virtual object placement. Tracking availability, accuracy and reliability are usually the most prevailing reasons for the yet humble expansion of mobile Augmented Reality. Thus, examples for mobile AR with high accuracy can rarely be found. One of the few properly working examples is indoor commissioning [3].

In facts, problems accumulate when going outdoors. The user will mostly not come across stable surrounding conditions, but power supply is limited, temperatures as well as light conditions are constantly changing and all technical devices need

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protection against rough weather and agitation. Demonstrators for outdoor Augmented Reality like ARVISCOPE [4] or TINMITH [5] use the Global Positioning System (short: GPS), combined with additional sensors like inertia, laser distance measuring etc. for localization. This leads to compromises in accuracy and speed. Another disadvantage is the high ergonomic impact on the user wearing a helmet and carrying a backpack for all equipment. This narrows down capacities for mission-related accouterments.

Especially for soldiers, firemen, rescuing personnel and comparable occupational groups, this not acceptable because the informational advantage is compensated by an excessive additional physical load. As this is an obvious caveat, a hand-held solution has been developed in VIDENTE [6]. Since VIDENTE focuses on underground engineering, still no emphasis has been put on situation awareness, especially under stressful circumstances.

1.2 Research Goals

As primary target group, the infantryman/-woman of the future has been selected as a professional group with outstanding requirements for an outdoor Augmented Reality system. Reliability and simplicity of use are foremost requirements. Especially in confusing situations, the system must support situation awareness by augmenting the soldier's view with important, mission-relevant information into the spatial context of the situation at hand. Our research aims at developing a mobile system for three major benefits: At first sight to increase leadership by augmented situation awareness. Secondly, support of mobility by intelligent assistance in orientation and navigation. And thirdly, enhanced survivability through threat recognition at the earliest possible stage and so risk avoidance. Of course, the system shall not significantly impact the soldier's mobility. Consequently, size, weight, power consumption etc. must be taken into account carefully. Common approaches to model situation awareness like that by Endsley [7] differentiate between phases of perception of the current situation, followed by comprehension, succeeded by projection into the future as a basic for reasonable decision-making. Thus, one of the foremost requirements for the Augmented Reality display as well as the design and the amount of all displayed information is the possibility to adapt to different operating conditions (change daytime, activity status etc). Consequently, the aim of the approach is to provide an optimized situational awareness which comprises to get the most important information in shortest time, ideally at a glance.

2 Mobile Outdoor Augmented Reality System

The components of a conceptual functional demonstrator are presented in this section. Basis of an Augmented Reality system is a computer to render artificial content like text, symbols and graphics. For mobile Augmented Reality, a portable, small-scaled, lightweight computer is essential. Its power consumption must be low to grant a maximum of operating time and a minimum of cooling effort. Generally, the emission of heat, light, noise and movement must be avoided wherever possible for operation safety reasons. Thus, an ultra-mobile fit-PC2i [8] with passive cooling serves as platform. Its power consumption is 8 Watts and its dimensions are 115 x 101 x 27 mm only. It runs standard Windows 7, so no special embedded software development is needed. It is powered by a redundant power supply, consisting of three independent batteries where each can be exchanged during run-time. Any high resolution USB web camera can be attached to the computer; a LifeCam Cinema [9] is used here. To provide outdoor tracking accuracy in centimeter range in real time, the Differential-GPS device GRS-1 [10] tells about the translation of the system. The GRS-1 receives both the American GPS as well as the Russian GLONASS signals. Beside the standard frequency L1, the additional frequency L2 can be processed with an external antenna attached. The GRS-1 uses a real time correction data stream by SAPOS [11], a local German correction service. The suitability of this solution in fields of research has already been proven by Letsch & Kircher [12]. For rotation (azimuth, roll, pitch), the 3DOF InertiaCube3 [13] is employed. All components are integrated in one "stack" (Figure 1 left). The output display can be, for example, an ocular display attached to the stack for safe operation in unsafe regions (Fig. 1 right).

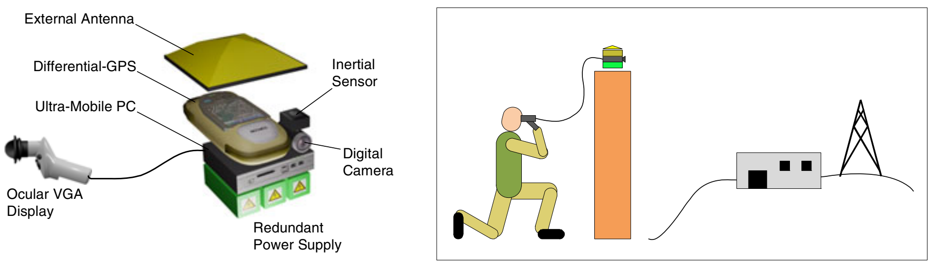

Fig. 1. Augmented Reality system components (left) and example of safe usage (right)

The Augmented Reality application basically grabs a live video stream from the USB camera and sets it as background for OpenGL renderings. According to the research aims (chapter 1.2), our research focuses on the design of the artificial elements augmenting the scene for best situation awareness. For this, one main function is to graphically pinpoint a location and to give information related to it. An empirical study with a desktop-based setup has been conducted. Its design and results are presented in the following chapter.

3 Empirical Study on Situation Awareness

Safety-critical situations leave narrow margins of time because decisions may have to be taken within seconds. This is why situation awareness of a soldier using a vision system is of crucial importance for the total system design. Pinpointing a certain location or object visible or concealed in the soldier's field of view should be one of the major functions of an Augmented Reality system. With respect to the high importance of an undisturbed view of what is going on around a leader's squad, a basic question must be brought forward: should the graphical mark-ups be drawn directly into the augmented view or rather at the views borders? What are the benefits of an in-view mark-up (e.g. with a rectangle) compared to a mark-up at the image's border (e.g. with arrows)?

3.1 Experimental Setup

A sample of ten participants (five female, five male) with an age, according to the future system's target group, between nineteen and forty years volunteered for the experiment. All participants had a minimum viewing acuity of 80% and passed Ishihara's [14] color perception test. They participated in a coincidental sequence. For this, they sat down in front of a standard laptop PC (Fig. 2 a), with an eye-to-display distance of 500mm in average. A string of four lowercase random letters were shown to them once with a request to keep those four letters in mind.

Then, controlled by the experiment's supervisor, a random sequence of twenty images of an exiguously cultivated landscape was shown for two seconds plus half a second for fading in and out (to generate temporal stress). Overall, one out of ten possible locations (Fig. 2 b) was marked on each image either by two arrows at the border of the image (left or right and top or bottom, depending on the location's image position; see Fig. 2 c) or by a rectangle marking the location directly (Fig. 2 d). Additionally, a random string consisting of four lowercase letters was shown either next to the top or lower arrow or above the rectangle respectively. Actually, only ten different locations were marked, so each location was marked with arrows on one image and with a rectangle on another so that mark-up type (arrows or rectangle) was balanced. As the human eye's sensitivity in the fovea is best at a light wavelength of 530 nm [15], green has been chosen as mark-up color and text color while the landscape was grayscale. The images' size on the screen was 330x220mm, the arrows' length and the rectangles' edge length was 25mm. The arrows' line width was 4mm, the rectangles' line width 2mm on the display and the font size of the letters was 22pt.

As a main task, the participants marked the pinpointed location on a slide placed on a printout of the landscape with a cross just after an image had faded out. There was no time limitation for this main task. As a side task, based on Sternberg's memory test [16], the participants decided whether one or more of the letters shown initially to the participant occurred in the last mark-up's string. If so, the subject had to write down the letter “j” at the slides upper right corner, if not, the letter “n” had to be written down. Overall, when categorizing situation awareness measuring into explicit questioning (mid-run or post-run), implicit measuring (e.g. task performance analysis) and subjective methods (e. g. self-rating), those two tasks can be seen as a combination of explicit and implicit measuring. For each image, a new slide was used. On average, the experiment took ten minutes per participant.

For the main task, the type of mark-up (arrows vs. rectangle) and the ten uniformly distributed locations' were the two independent variables and the individual error of a checked location to its true position on the image was the dependent variable. For the side task, the randomly generated string was the independent variable and the answer if one or more of the given letters was included in the string was the dependent variable.

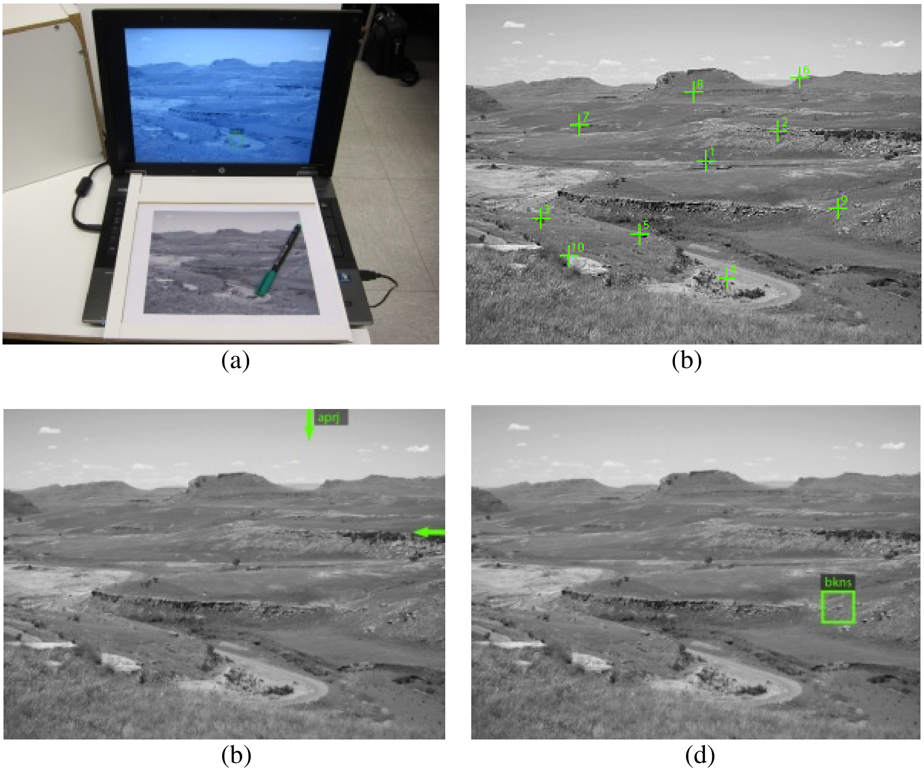

Fig. 2. Setup (a), different locations (b), arrow mark-up (c) and rectangle mark-up (d)

3.2 Results

Table 1 shows the mean, the standard deviation and the difference of means (short: DOM, difference between arrow mean and rectangle mean) of the error between manually checked locations and originally marked locations in millimeters. The Kolmogorov-Smirnov test indicates only for two of the ten locations a normally distributed error for both the arrow mark-up and the rectangle mark-up. Thus, statistically founded comparison of means requires analysis with a nonparametric test, e.g. the Wilcoxon signed-rank test.

As highlighted (white letters on black background) in the table, the difference of means is statistically significant for six locations. In these cases, the rectangle mark-up led to significantly more reliable location identification in comparison to the arrow-based mark-up. The strongest difference turned out for location number one which was coincidently exactly in the center of the image. On the other hand, the sample size is not sufficient to show that reliability of the rectangle-based solution is constantly higher for locations in the image's center: location number two, for example, where the arrows mark-up leads to slightly better results, was nearly as close to the image center as location number one.

Table 1. Means (M), standard deviations (SD) and difference of means (DOM) in millimeters for the arrows mark-up and the rectangle mark-up over all ten locations; the z-values and effect sizes are for $p < 0.05$

Location	1	2	3	4	5	6	7	8	9	10
Arrows M	11.5	6.6	5.3	6.6	11.2	4.2	6.8	9.4	9.9	5.0
Arrows SD	7.71	4.95	3.27	4.45	7.98	3.82	7.05	4.79	5.9	2.45
Rect. M	3.9	7.7	1.3	5.4	2.9	1.8	2.4	3.4	7.9	2.0
Rect. SD	5.43	5.89	0.82	3.53	2.6	0.79	0.7	2.37	5.8	1.56
DOM	7.6	-1.1	4.0	1.2	8.3	2.4	4.4	6.0	2.0	3.0
z-Value	-2.25		-2.71		-2.68		-2.38	-2.61		-2.41
Effect Size	-0.5		-0.6		-0.6		-0.53	-0.58		-0.54

Table 2 shows that the amount of errors for the string memory side task. While the overall rating is fairly balanced for the arrows and the rectangle mark-up, there is an irregular appearance of outliers for certain locations: When position ten was marked with arrows, three subjects gave a wrong answer to the string memory test and when positions seven and nine were marked with a rectangle, at least three subjects failed.

Table 2. Total number of errors done for each location in the side task

Location	1	2	3	4	5	6	7	8	9	10
Arrows	0	2	2	2	0	0	1	0	0	3
Rectangle	0	1	0	0	0	1	4	1	3	1

4 Conclusions

The fields of application for high-precision outdoor Augmented Reality are manifold. But the design of the system's user interface needs the same amount of care and consideration like choice and composition the hardware parts, especially when optimized situation awareness is required. The results of an empirical study shows that generally a clear preference towards an in-sight position and object marking should be followed. The rectangle used for marking always had the same size, shape etc, so future research will focus on variation of symbolism, colors etc. for better recognition. Results also show that textual information transmittance can be deficient, especially in mentally demanding and hectic situations. Alternatively, multimodal approaches, e.g. situation-related combinations of shapes, symbols, colors, text and sound need further investigation for better situation awareness and increased information perception.

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