Visualization of Environment-related Information in Augmented Reality: Analysis of User Needs

Kateřina Chmelařová, Čeněk Šašinka and Zdeněk Stachoň

Abstract The main motivation for this study was to enable paragliding pilots to use Augmented Reality features during flight. For orientation in the air, paragliding pilots use a map as the main source of information. It is therefore important that the information is presented in the most easily accessible way. The aim of the present study was to investigate the needs of paragliding pilots with respect to maps and the way maps provide them with information about the environment. The participants were three professional paragliding instructors with different amounts of experience. The methods employed involved a semi-structured interview and a practical, real-flight test involving AR glasses; the test was done by only one of the pilots. Two categories of data were identified, with the first involving data related to geographical terrain and the other to the pilot's immediate surroundings. Our results suggest that an optical see-through display would be more suitable for use in the air than the video-based glasses we utilized. If an optical see-through display were used, the terrain could be seen through the glasses, with terrain-related information displayed in the map. AR could be used to present flight-related information as well. Our findings suggest that the way in which information is presented to pilots should be chosen based on the category of the information, namely, whether it is terrain-related or flight-related. In addition, it was found that the small display in the right corner of the pilot's field of view is rather distractive and insufficient to fulfill the pilots' needs. Our results also showed that future AR applications should be designed to be transferable between different platforms: glasses, mobile phones, and tablets.

K. Chmelařová (✉) · Č. Šašinka
Department of Psychology, Center for Experimental Psychology and Cognitive Sciences, Masaryk University, Brno, Czech Republic
e-mail: sprinarova.katka@gmail.com

Č. Šašinka
e-mail: ceneksasinka@gmail.com

Z. Stachoň
Laboratory of Geoinformatics and Cartography, Department of Geography, Masaryk University, Brno, Czech Republic
e-mail: zstachon@geogr.muni.cz

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1 Introduction

The importance of maps is constantly increasing. In cartography, more and more Information and Communication Technologies (ICT), including Geographical Information Systems (GIS) and Global Positioning Systems (GPS), are utilized. In addition, Inertial Measurement Units (IMUs), such as accelerometers, gyroscopes and magnetometers are employed in outdoor environments to track the position and rotation of a body.

AR glasses determine their position according to GPS and IMUs (Barbour and Schnidt 2001; Bichler et al. 2012; Elarebi et al. 2016). The challenge is in selecting an appropriate information visualization method for the user.

Our research aims to establish the most effective ways of presenting the information contained in a map by means of Augmented Reality (AR) glasses. AR glasses are a type of Head-mounted Display (HMD), a device that is worn on the head. It utilizes a small screen to present images or videos. Augmented reality is achieved through overlaying real-world elements with computer-generated sensory input. The information is presented in 2D; alternatively, it is presented as a 3D image that can be studied from multiple directions. AR is a technology that superimposes a computer-generated input on a users' view of the real world, thus providing a composite view.

Several studies are available in which AR is used in the context of cartography and environmental information representation (Behzadan et al. 2015; Chung et al. 2016; Fajnerova et al. 2016); however, in most of them, AR systems are used on the ground. The system we used in our study aims to enhance the pilots' view of the environment during a paragliding flight.

The objective of the present study is twofold: first, it is to gather information about what data are available to paragliding pilots before and in-flight; second, it is to determine what information is needed and what the limitations of currently used systems are.

2 Background

Kraak and Brown (2003) describe a cartographic visualization process as a translation or conversion of geospatial data from a database into maps and map-like graphics. Geospatial data handling consists of the acquisition, storage, manipulation and visualization of geospatial data in the context of particular applications. According to Larkin and Simon (1987), two types of equivalence of visual representations can be distinguished: informational and computational. When two visual representations are informationally equivalent, all of the information contained in one of them can be drawn from the other, and vice versa. Computational equivalence, then, refers to the fact that the same amount of 'computation' (i.e., effort) is needed to extract the information given explicitly in each of two informationally equivalent representations. In earlier surveys on AR, many types of AR displays were identified (Azuma 1997; Billinghurst et al. 2015). Military aircraft and helicopters use head-up displays (HUD) and helmet-mounted displays (HMD) to present graphic without requiring the users to divert their attention from their usual viewpoint. For working with maps, two types of displays can be used: video see-through AR displays and optical see-through AR displays. Video see-through displays combine closed-view HMD with one or two head-mounted cameras; they are limited by the camera(s)' frame rate(s). Optical see-through HMDs work similarly to HUDs, but they employ an optical combiner attached to the head. Optical combiners typically reduce the amount of light that the user sees from the real-world environment. The displaying capabilities of devices with optical combiners are not limited by the properties of the video cameras employed. One of the advantages of AR HMDs consists in allowing communication between multiple users. According to Ellis et al. (1991), collaborative interaction can take place either at the same time/in the same place, or in different times/at different places; thus, in accordance with Table 1, meeting room technologies and wall projectors would fall into the top left category, real-time document editors and video conferencing into the bottom left category, group calendars into the top right category, and emails and blogs into the bottom right category.

A number of projects have focused on virtual space collaboration. One of these was WearCom, a project presented by Billinghurst and Kato (1999), which set out to explore the possibility of using wearable computers in remote collaboration. Using fiducial markers, the authors of the project succeeded in making a remote call through audio-visual connection. Hölleler et al. (1999) developed a system enabling to connect indoor and outdoor AR devices. Any action performed by an indoor device was captured by the outdoor device; therefore, the system could be used as a navigation device. Poelman et al. (2012) presented an AR system that allows remote crime scene investigation. The project consisted of the following phases: (1) establishing the requirements for supporting crime scene analysis; (2) creating a mock-up design; (3) mock-up design evaluation; (4) designing a mediated reality system; and (5) evaluation of the mediated reality system. The above project served as an inspiration for the present study, with the initial part of the project being reproduced in detail.

Table 1 Time space matrix (Ellis et al. 1991)

	Same time	Different times
Same place	Face-to-face interaction	Asynchronous interaction
Different places	Synchronous distributed interaction	Asynchronous distributed interaction

Kamilakis et al. (2016) used two-dimensional zoomable maps to visualize points of interest in close surroundings of the user. Their results suggest that most participants spent more time attending to the mobile AR environment than to the map interface. The authors emphasized that the above should be interpreted as a sign of experimentation with an unfamiliar environment, rather than an indication of user preferences.

The present study aims to understand paragliding pilots' informational needs as well as their operational environment, and to investigate the limitations of currently used systems.

3 Methods

Our research sample consisted of three professional paragliding instructors with different amounts of experience. All of them had an instructor's license. Pilot 1 had three years experience; pilot 2 and pilot 3 had above 15 years of experience.

First, a semi-structured interview focusing on AR visualization possibilities was administered. In addition to involving a predefined set of questions, the interview allowed the pilots to talk freely about their paragliding experience and to identify the difficulties they faced.

Second, a user test involving the Vuzix M100 AR glasses was conducted in real-flight conditions. After the paragliding flight, the pilots were asked about how the flight differed from their usual flying conditions. Vuzix M100 Smart Glasses have a small video see-through display in the upper right corner of the right eye. The display is opaque, with only the video camera's image of the real world shown. The device has an aspect ratio of 4:3, with a field-of-view of 15°, which is equivalent to looking at a 4-inch display from the viewing distance around 35 cm. An integrated head-tracker allows 3 Degrees-of-Freedom (3 DOF) head-tracking; in addition, the system is equipped with a 3 DOF gesture engine. Three means of control are available: button control (via dedicated buttons on the glasses), voice control and two-dimensional gesture control.

Finally, the pilots were asked to provide feedback on the AR glasses and suggestions concerning the use of AR during a paragliding flight.

4 Results

In the first subsection, a brief overview of general information related to paragliding is included. The information was provided by three paragliding pilots comprising our sample. The second subsection contains results of the semi-structured interview; the third subsection deals with the results of the user test. Only one of the pilots underwent the user test.

4.1 General Background

The highest reported altitude for paragliding was approx. three kilometers (around 10,000 feet), the average altitude being approx. 6,500 feet. Paragliding pilots use a radio for communication. Typically, the radio is attached to the harness shoulder strap in order to decrease the influence of aerodynamic noise. Below is a list of the necessary instrumentation and information the pilots need in flight:

- Map + GPS
- Forward speed
- Gliding angle (+ distance)
- Vario (rate of climb and descent indicator)
- Altitude (a paraglider's height over sea level)

One of the paragliding pilots from our sample provided the following comment:

- *"The most important information to know in flight includes current altitude, whether I am ascending or descending, and forward speed."*

4.2 Areas of Application of Augmented Reality in Paragliding

In the semi-structured interview, several areas of application of AR glasses in paragliding were identified by the paragliding pilots:

1. Performance flying
2. Training
3. Safety purposes

The use of AR glasses during performance flying and competition flying will provide the pilots with georeferenced information, thus giving them an edge over other pilots. Another possible area of application is "air caching," a game where the players follow a pre-defined set of geographical points.

Of particular interest would be the application of AR glasses in paragliding training. The three professional instructors in our sample suggested they would find it useful to be able to distinguish "their" group from other paragliding pilots. One of the pilots provided the following comment:

- *"I want to know where the other people are."*

AR would allow paragliding beginners to locate the other trainees and to collaborate with them. Information about latitude and longitude will help the trainee to

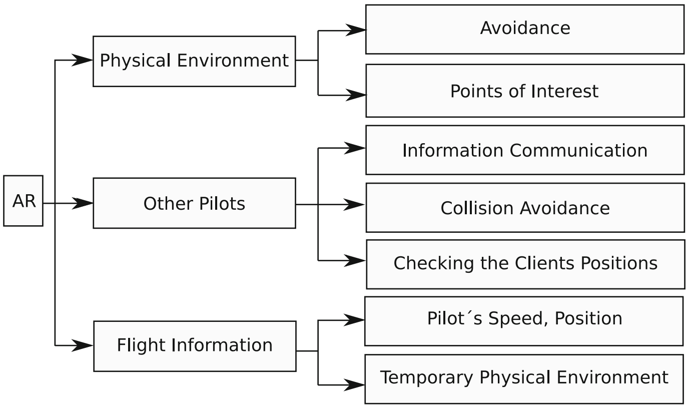

Fig. 1 Benefits of AR in paragliding

determine their own position, too. Another useful feature would be flight-path/altitude tracking, which would make it possible to:

- Watch the other people in training
- Locate people quickly (for the instructor)
- Provide help in unexpected situations

In order to serve the above purposes, the tracking would obviously need to be operative during the entire flight of each of the trainees.

Of the three areas of application listed above, safety reasons are the most important. Safety in paragliding includes avoiding dangerous (or potentially dangerous) objects such as high-voltage power lines, wind plants and chimneys.

An overview of the benefits of AR use in paragliding is presented in Fig. 1.

In the semi-structured interviews, three categories of information were identified that could be presented through augmented reality:

- Static/dynamic information
- Textual/graphical information
- Non-interactive/interactive visualization

While static information (e.g., the position of turning points) is available pre-flight, dynamic information includes flight-related data such as current position, weather and communication with other paragliding pilots.

Textual information is used where precise numerical/textual values are needed, whereas graphics may serve the purpose of representing real-world objects.

Non-interactive presentation of information is suitable for when the information is needed to solve a particular task but the pilot does not have free hands to interact with the device. Interactive presentation, on the other hand, is needed for interaction with AR glasses.

4.3 User Test

After the real flight with AR glasses, one of the pilots from our sample was asked to answer several questions. The first question concerned the pilot's opinion on the use of AR in a paragliding flight. *"The glasses were not helpful in any respect. Wearing them during the flight was aggravating. It was left to my imagination what benefits the glasses might actually bring."*

Then, the pilot was asked to suggest any improvements that would make the glasses more amenable with a paragliding pilot's needs. *"Rather than a display in front of the glasses, I would appreciate a see-through display so that I could see the terrain, overlaid with terrain-related data."*

Another question concerned possible uses of AR in paragliding. "*For me, the only reason to look at the display instead of the environment would be to acquire important data that would help me in tactical decision making; this contributes to better quality as well as higher safety of the flight. What I find especially attractive is that by rotating my head I could see the terrain behind the glasses. As regards information related to my air surroundings, I would prefer having it displayed in front of me; however, I would need to try this in practice to be able to decide for sure."*

Then, the pilot was asked about his experience with the M100 glasses during the paragliding flight. His task was to evaluate the glasses from the viewpoint of a Subject Matter Expert (SME) who needs to reach a given destination. AR should be able to make it easy.

"The glasses that I tried are not suitable either for sport or flying; they are too light and unstable. They cannot be used with any of the helmets paragliding pilots use. Also, the display is too small; I had to focus a lot when searching for a particular content. The display took up a major portion of my field of view. Yet, sight is the main sense in flying. The small display attracted my attention more than I would wish. This can be a very dangerous distraction, especially when several paragliding wings are rotating in a thermal. However, when exploiting lifts, we typically have 5–10 min to correct our decisions, so attending to the display was not a problem."

The last question was related to interaction with the AR map layer. *"Since we are flying with our gloves on, controlling the device would be difficult. The system settings should be set up prior to the actual flight. In the air, only the screen switch should be used. The button for switching between displays should be attached to the driving rope or to the helmet."*

The above suggests that it might be useful to create a visualization system that would be compatible not only with AR glasses, but also with mobile phones and tablets so that those not having (or not willing to wear) AR glasses could make use of the enhanced view capabilities.

5 Discussion

Our findings suggest that it might be useful to create a universal visualization system that would be compatible not only with AR glasses, but also with smart-phones or similar devices. The main conclusion that follows from the user test in the real environment is that the information that will be presented in AR should be divided as follows:

- The information that is better to visualize in relation to terrain
- The information that are visualized in relation to pilot (data important for tactical decisions)

One of the possible explanations for the above findings is that paragliding pilots need to be thoroughly familiar with flight-related information; in addition, they need to understand how these characteristics are changing towards the environment.

If the Vuzix M100 AR glasses are not suitable to be used in paragliding, a question remains of what glasses *are* suitable. A plausible alternative might be the use of binocular glasses capable of displaying flight-related as well as environment-related information. For safety reasons, it is essential that the device can be switched off when need be.

6 Conclusions

The results of our study showed that there are multiple ways to investigate, calculate and visualize data in AR. The semi-structured interview we used revealed several concepts that would be worth exploring in future research. In our study, three possible areas of application of AR in paragliding were identified: performance flying, paragliding training (e.g., aiding location of the trainees both in the air and on the ground); and safety reasons (e.g., helping the pilots to avoid trees, chimneys, wind power plants and high-voltage lines).

Our results also showed that AR can be used to display several different types (modes) of information:

- Static versus dynamic
- Text versus graphics
- Information visualization only versus information visualization with interaction

The user test results indicate a need for developing a universal system for both AR glasses and mobile phones. The need stems from the fact that all paragliding pilots cannot be expected to be equipped with AR glasses; therefore, mobile phones could be used instead, providing these are able to present the same amount of information. However, an in-depth research is needed here. The pilots we interviewed reported that a significant drawback of mobile phones when it comes to AR and other systems, e.g., GPS, is their low battery power.

The results of the user test indicate poor suitability of the Vuzix M100 AR glasses for the purposes of either sport or flight (where the user is attending to a map). The glasses are too fragile to be used in changeable environmental conditions. Finding a suitable alternative is the objective of future research.

Terrain-related information should be presented depending on changes in the altitude of the terrain. It is important that the displayed information is highly accurate and not prone to changes due to head movement. The results of our research indicate the necessity to choose an appropriate way of data visualization, based on whether the information to be presented is terrain-related or flight-related.

Following where we left off, future research could focus, for instance, on evaluating the suitability of different types of AR glasses with an optical-see through technology for paragliding purposes. Also, using a larger sample of participants would be advisable, along with testing the resulting data for statistical significance.

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