# On the Spot Information in Augmented Reality for Teams in the Security Domain

**Stephan Lukosch**
Delft University of Technology
PO box 5015, 2600 GA Delft
The Netherlands
s.g.lukosch@tudelft.nl

**Heide Lukosch**
Delft University of Technology
PO box 5015, 2600 GA Delft
The Netherlands
h.k.lukosch@tudelft.nl

**Dragoş Datcu**
Delft University of Technology
PO box 5015, 2600 GA Delft
The Netherlands
d.datcu@tudelft.nl

**Marina Cidota**
Delft University of Technology
PO box 5015, 2600 GA Delft
The Netherlands
m.a.cidota@tudelft.nl


*CHI'15 Extended Abstracts*, Apr 18-23, 2015, Seoul, Republic of Korea
ACM 978-1-4503-3146-3/15/04.
http://dx.doi.org/10.1145/2702613.2732879

## Abstract
For operational teams in the security domain it is important to quickly and adequately exchange context-related information. This is necessary to develop distributed situational awareness and facilitate collaboration. Currently, information exchange is mainly based on oral communication. Oral communication can be misunderstood or ambiguous. This paper reports on different scenarios from the security domain in which augmented reality (AR) techniques are used to support information exchange. A combination of quantitative and qualitative evaluation showed that AR can improve the distributed situational awareness of a team.

## Author Keywords
Augmented Reality; Information Exchange; Distributed Situational Awareness; Collaboration Quality

## ACM Classification Keywords
H.5.3 Group and Organization Interfaces; H.5.1 Artificial, augmented, and virtual realities

## Introduction
In the security domain, operational units rely on quick and adequate exchange of context-related information. Currently, this communication is mainly orally and

sometimes accompanied with taken pictures. Communication is often standardized, in order to avoid critical human mistakes [8]. Nevertheless, oral communication, especially under time pressure, can be misunderstood by the different team members [7], resulting in wrong actions. Amongst other fields of application, e.g. in the field of crime scene investigation, Augmented Reality (AR) environments have been used to allow experts to spatially collaborate with others at any other place in the world, thereby creating the experience of being virtually co-located [10]. AR environments have also been used to increase social presence in video-based communication [1] or help in complex assembly tasks [6]. In our study, we explore whether an AR environment can be used to foster distributed situational awareness [4] and thereby facilitate collaboration. This paper reports on the evaluation of an AR environment that is being developed to support interaction of geographically distributed users within the security domain. The next section presents the scenario identification and design for evaluating the effect of the AR environment. Then, the AR environment is described. Based on the evaluation, conclusions are drawn and future work directions are given.

## Scenario Design

In order to investigate the effect of the AR environment on collaboration quality and distributed situational awareness between different teams, scenarios are used. The scenarios are designed in such way that they can be played in two conditions: (1) with AR support for virtual co-location, i.e. one participant uses an optical see-through head mounted device (HMD) with a RGB camera and a remote participant views the HMD camera feed on a laptop, and (2) when using standard equipment following standard procedures.

Based on earlier experiences with operational units in the security domain [9], we used the triadic game design (TGD) approach [5] to design the scenarios. During a half-day workshop, in which 6 members of the Dutch Police, the Netherlands Forensic Institute (NFI) and the fire brigade of the port of Rotterdam participated, 2 different scenarios have been identified.

*Discovery of an Ecstasy Lab*

A team of 2 policemen arrives at an apartment of which a strange chemical smell was reported. The policemen receive information about the location as well as the current inhabitant from a remote colleague. Then, the policemen recognize a strange chemical smell in the house. Within the apartment, they are able to mark suspect objects and take pictures. When they find an ecstasy lab in the kitchen full of chemical bottles, they arrest the inhabitant. The remote policeman calls the fire department for further support. When 2 firemen arrive at the apartment, they get an oral briefing on the situation by the policemen on location. The 2 firemen enter the apartment and perform further investigation in collaboration with a remote colleague. On clearance of the location, the remote fireman contacts the forensic institute. The local firemen brief the arriving forensic investigator orally. After entering the apartment, the forensic investigator analyses the site and sets up a investigation plan in discussion with a remote colleague.

*Home visit by a VIP*

A VIP plans a home visit. Just before the visit, a reconnaissance team receives information on the address as well as the person living in the apartment that must be checked for safety. One member of the reconnaissance team investigates the location. After arrival, detected dangerous objects are discussed and checked with the person living in the apartment. Pictures are being taken to allow the identification of changes when visiting the apartment with the VIP. When the apartment is declared safe, the reconnaissance team orally briefs the personal protection unit using the pictures that have been taken during the investigation. At a later time, one member of the personal protection unit arrives at the apartment together with the VIP. The member of the personal protection unit discovers a suspect change in the apartment and decides to abort the visit. Based on information about possible evacuation routes provided by the remote colleague, the VIP and the local member of the personal protection unit leave the apartment. In the following section, we describe the AR environment that is used to run through the scenarios.

## DistributEd CoLlaborative Augmented Reality Environment (DECLARE)

DECLARE is based on a centralized architecture for data communication to support virtual co-location of users. Within DECLARE, user interfaces are developed with the Unity 3D game engine.

Figure 1 shows the four major DECLARE components. The local user AR support is developed for a local user wearing an optical see-through HMD. The video captured by the HMD camera is sent to the other components of DECLARE. Based on the hand detection and tracking, a local user interacts with DECLARE through a 3D user interface.

DECLARE supports remote user AR displayed on a desktop computer or laptop. The user interface shows the video stream from the local user. Via the user interface, a remote user can augment the environment of the local user using a keyboard and a standard mouse device.

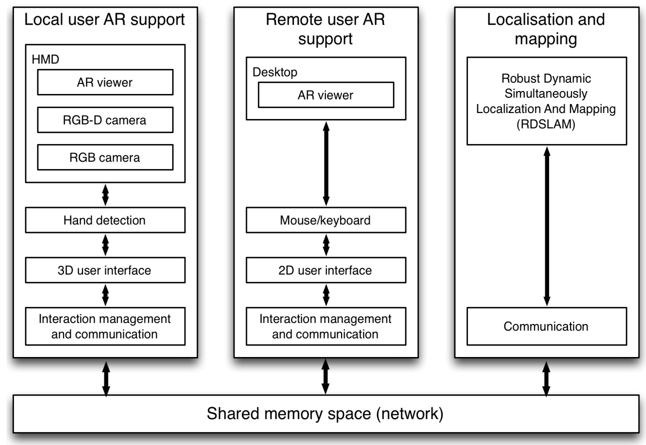


**Figure 1** DECLARE system architecture

The localization and mapping component is based on an implementation of RDSLAM (Robust Dynamic Simultaneously Localization And Mapping) [11]. RDSLAM tracks the position and orientation of the HMD camera. It further identifies a sparse cloud of 3D points to allow augmentation of the local environment.

The shared memory space allows all DECLARE components to communicate with each other and share information, such as the 3D positions of virtual objects used for augmenting the local environment.

**Figure 2** Screenshot of the user interface for a remote investigator in the ecstasy lab scenario

**Figure 3** Simulation of the user interface for a fireman in the ecstasy lab scenario

## Experiments

13 participants in total took part in the experiment. All participants were male, with an age from 25-54 years (M=37.8, SD=10.0). All had a minimum of 2 years experience in their recent professional function. 3 participants were forensic researchers from the Netherlands Forensic Institute (NFI), 3 were firemen from fire brigade of the port of Rotterdam, 3 were policemen from the Dutch Police in North-Holland, 2 were from a close protection team of the Dutch police, and 2 were from a reconnaissance team of the Royal Netherlands Marechaussee (RNLM). All experiments took place indoor in a training environment set up as a real apartment at the Netherlands Forensic Institute (NFI). The whole tests altogether lasted one day.

We used a pre-questionnaire to collect data with regard to the participants' background, their experience in the domain and with AR technology, and their expectations towards the experiment. For the first run through the scenario, participants were only allowed to use currently available technology like their standard equipment for audio communication and a camera.

For the second run, one local participant used the AR support as described earlier in order to establish virtual co-location with a remote colleague. We further changed the scenario in the second run slightly by exchanging deviant objects the participants had to detect. Doing so, we tried to minimize the sequence effect within the experiment as far as possible. When using AR support, participants also used their standard equipment for audio communication. The remote colleague was physically separated from the apartment by walls and doors so that remote and local participants could only interact via the available technology.

After both rounds, a questionnaire was provided to the participants to assess the quality of collaboration [2] and the individual situational awareness, using the standardized SART questionnaire [12]. Finally, after each experiment a structured de-briefing was conducted to further investigate the experiences of the participants.

Figure 2 shows a screenshot of the user interface for a remote user in the 'Discovery of an Ecstacy Lab' scenario. The user interface includes buttons to create virtual objects and augment the view of the local user. In Figure 2, the local scene is augmented with a red sphere, a 3D text message, a fingerprint symbol and a hazard symbol. Also, taking, saving and loading pictures is possible using the HMD camera of the local user. 3D text messages and pictures can be either displayed in a fixed position on the screen or linked to the 3D points of the tracking system. The user interfaces for the local users offer the same functionality as for the remote user but are adapted to one of the 3 roles: policeman, fireman (see Figure 3) and forensic investigator. Within the scenario 'Home visit by a VIP', a user interface for local reconnaissance team members was added. This user interface allowed to view taken pictures at the position where they were taken. This was to support the comparison of the current real world situation with an earlier taken picture to identify possible suspect changes. Figure 4 shows a person marking an object using the 3D user interface.

## Results

The results of the SART questionnaire for the ecstasy lab scenario indicate the level of arousal is lower (Mdn=5, IQR=2) when using the AR system compared to the standard approach with no AR for both local and

**Figure 4** Picture taken during the home visit by a VIP experiments

remote user (Mdn=6, IQR=1.5) ($p$=0.02). Both local and remote users using the AR system focused on lower number of aspects (Mdn=5, IQR=2) than in the standard procedure that involves no AR (Mdn=6, IQR=0.5), ($p$=0.01). Additionally, the concentration of attention for the user wearing an HMD was lower (Mdn=3.5, IQR=3), compared to the standard approach without AR (Mdn=6, IQR=0.5), ($p$=0.001). The division of attention was lower (Mdn=4, IQR=3) for the local user wearing the HMD during the ecstasy lab discovery scenario, as compared to using no AR support at all (Mdn=6, IQR=3), ($p$=0.047). The highest average overall SART score was 19.50 for the remote users using AR support in the ecstasy lab scenario. The lowest average overall SART score was 10.17 for the local using the AR HMD in the ecstasy lab scenario.

The de-briefing of the scenarios without the use of AR technology showed that the participants value their current technology as sufficient in the first instance. Nevertheless, they also experience clear limitations of the current technology. There were two main issues, which were raised within the de-briefing of the scenarios with the use of AR. The first one was that the majority of the participants mentioned especially the role of the remote person as valuable. The possibility of sharing the local view of the scene, to add information immediately and to take pictures of the scene that can be used later on, were seen as an important added value of the new technology. The advantage of the remote user in the AR scenario was summarized as an advisory one, but not as having an important role in the decision-making and action taking process on the spot. The second issue targets the distributed awareness of the whole process directly. When one participant stated that by participating in the experiment "you are getting more aware of the other parties involved in the whole process and that your actions do have consequences for their work", the other participants agreed that the experiment increased their awareness for the process as a whole, and their own role in it. The majority of the participants agreed to the observation of one participant that the AR technology introduces a higher workload, which could lead to a distraction from the crucial tasks within such a situation. One solution to this challenge discussed by the participants was that a new role could be introduced, like an AR expert, who accompanies the regular security team and handles the HMD-driven data collection on the spot.

*Limitations of the study*

The introduction of such a new technology like an AR environment including a hands free gesture based interface means that the novelty of the approach may influence the results in a strong way. Furthermore, generalizable conclusions are difficult to draw, as the sample size within the experiments is very small. This is due to the fact that only a very limited number of experts in the field of our investigations is available for such experiments. Nevertheless, we underpinned the quantitative measures with qualitative data, especially from the de-briefing. The results indicate that the AR technology has added value for developing distributed situational awareness and fostering collaboration amongst the team members and teams.

## Conclusions and Future Work

The experiment indicates that the major advantage of the AR environment is the possibility to establish virtual co-location of a remote user with a local user. The data from the SA rating and the de-briefing show that the remote user provides the highest value to the distributed SA of the team. Related to the three stages of SA as proposed by Endsley [3], we can conclude that the AR technology introduced in the experiments was able to support the perception of the crime scene, especially for the remote user, leading to better comprehension and prediction of the situation by both local and remote user. Thus, we were able to find implications that the AR technology can lead to a higher distributed SA. Despite the current limitations of AR technology it still offers added value to the security domain. It offers strong possibilities for further development as a tool for advice and support in stressful situations. We take into account the findings of the current studies for planning the roadmap for future work, in preparing the next version of the AR environment.

## Acknowledgment
This study is part of a joint project with the Dutch Police and the Netherlands Forensic Institute (NFI) sponsored by the National Coordinator for Security and Counterterrorism (NCTV) of the Netherlands.

## References
[1] Almeida, I. de S. et al. 2012. AR-based Video-Mediated Communication: A Social Presence Enhancing Experience. *14th Symposium on Virtual and Augmented Reality, SVR 2012* (2012), 125–130.

[2] Burkhardt, J.-M. et al. 2009. An approach to assess the quality of collaboration in technology-mediated design situations. *European Conference on Cognitive Ergonomics: Designing beyond the Product — Understanding Activity and User Experience in Ubiquitous Environments* (Helsinki, Finland, 2009), 30:1–30:9.

[3] Endsley, M.R. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. 37, (1995), 32–64.

[4] Gross, T. 2013. Supporting Effortless Coordination: 25 Years of Awareness Research. *Computer Supported Cooperative Work (CSCW)*. 22, 4-6 (2013), 425–474.

[5] Harteveld, C. 2011. *Triadic Game Design: Balancing Reality, Meaning and Play*. Springer, Berlin.

[6] Huang, W. et al. 2013. HandsIn3D: Supporting Remote Guidance with Immersive Virtual Environments. *Human-Computer Interaction - INTERACT 2013* (2013), 70–77.

[7] Van Knippenberg, D. et al. 2004. Work Group Diversity and Group Performance: An Integrative Model and Research Agenda. *Journal of Applied Psychology*. 89, 6 (2004), 1008–1022.

[8] Leonard, M. et al. 2004. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Quality and Safety Health Care*. 13, (2004), i85–i90.

[9] Lukosch, H. et al. 2014. Building a Virtual World for Team Work Improvement. *Frontiers in Gaming Simulation* (2014), 60–68.

[10] Poelman, R. et al. 2012. As if Being There: Mediated Reality for Crime Scene Investigation. *CSCW '12: Proceedings of the 2012 ACM conference on Computer Supported Cooperative Work* (2012), 1267–1276.

[11] Tan, W. et al. 2013. Robust monocular SLAM in dynamic environments. *Mixed and Augmented Reality (ISMAR), 2013 IEEE International Symposium on* (Oct. 2013), 209–218.

[12] Taylor, R.M. 1990. Situational awareness rating technique (SART): The development of a tool for aircrew systems design. *Proceedings of the Symposium on Situational Awareness in Aerospace Operations (AGARD-CP-478)* (1990), 3/1 – 3/17.