Tactical Optical Information System

– improving the situational awareness inside an APC

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Abstract

Inside armored personnel carriers, APC's, such as e.g. Hägglunds CV90 or Mowag Piranha, the possibilities for looking out are rather limited. That is especially true for the soldiers being transported inside the personnel compartment. Because of this, the soldiers are in effect expected to put themselves into harms way with very limited knowledge of what is happening outside the vehicle. One possible way to improve the situational awareness inside an APC is to have screens showing live images of the outside environment. The current investigation utilizes a set of carefully placed cameras connected to screens streaming live images inside the vehicle. It is found that this will significantly improve the situational awareness of the soldiers inside the APC. Field trials conducted in a realistic environment show that a careful placement of the cameras and the screens will increase the safety, and the efficiency, of the soldiers when they dismount the vehicle.

Introduction

Situation awareness is a relatively new area of research that stems from research concerning the working environment of fighter pilots, and it has found its way into other fields high work load fields such as e.g. air traffic control. There exists several definitions of situational awareness, but put shortly it means knowing what is going on around you [1]. Endsley [2] has defined situation awareness as an understanding of the surroundings and relevant parameters of the system, e.g. a fighter aircraft or an armored combat vehicle. A more formal definition of situation awareness is, according to Endsley [3], *the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future*. Irrespective of which definition is chosen, the level of situation awareness among the soldiers being transported in the personnel compartment of an APC is limited to their interpretation of the spoken information from the vehicle commander.

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Adding large windows to an APC would increase the situation awareness of its passengers significantly, however requirements for ballistic protection limits those possibilities to close to nil with current types of armor glass. Using a set of cameras connected to screens inside the passenger compartment could be a possible alternative to windows. Most armored vehicles, e.g. KMW Leopard 2 or Hägglunds CV90 have cameras coupled to screens inside. Those screens are however used either to help maneuvering the vehicle, e.g. backup cameras, or mainly for the eyes of the vehicle or platoon commanders. Universal Engineering showcased a Ranger vehicle with clusters of cameras which were connected to one screen in the transport compartment, figure 1. The view of one camera was shown as a main picture, and the other cameras were shown as a row of small sub pictures at the bottom of the screen. Because of its size and resolution the view of the screen was limited to the person, or persons, closest to the screen.

Figure 1: Camera system showcased on a Universal Engineering Ranger at the DSEI 2009 exhibition

Rather than just using one screen divided into several smaller screens which are not viewable from more than half a meter away, several larger high resolution screens could be used. Screens showing streamed images from cameras pointing in the same direction as the screens could give the impression of looking out of windows. This could make it possible for the soldiers to get a reasonable view of the surroundings, thus keeping up with the situation outside the vehicle. A possible downside to using cameras is that they might induce nausea. An investigation by Griffin and Newman [4] found that a forward view could be beneficial in reducing the amount of motion sickness depending on the type of view. A clear forward view was found to be beneficial whereas a video view was found to be somewhat detrimental. Whether it was possible to achieve a resistance to the nausea through training or if the amount of nausea was dependent on the frame rate of the cameras was not investigated.

This investigation suggests that the cameras and screens are used to give a certain overview of the surroundings. There is a natural trade off between camera viewing angle and the ability to identify objects, or details of objects on long distances [5]. Thus one can either see details on long distances or have a good overview, e.g. seeing how the terrain looks before dismounting the vehicle or identifying crowds of people which might be a threat when dismounting.

A possibility when using cameras and screens is to overlay information on the images to create a mixed reality. Gustafsson et al. has studied the effect of mixed reality on technical maintenance tasks [6] and found that it could reduce the amount of errors made by the operator, while not necessarily reducing the time to complete a task.

Experimental equipment

For the experiments five uEye RE waterproof digital cameras from IDS Imaging Development Systems GmbH, figure 2 were acquired. The cameras provided a black and white image of 1024 x 768 pixel resolution and a fully digital signal path, see table 1 for technical data. Discussions with researchers at BAE Systems Hägglunds [7] revealed that a fully digital signal path, i.e. digital camera, digital signal transfer, digital signal processing and digital screens, delivers sharper images than if the whole, or parts, of the signal path is analogue. This was provided that the resolution of the shown image was identical to the camera resolution. Their experience also showed that objects could be identified on longer distances if the image was black and white rather than color.

Table 1: Technical data for uEye RE camera and lens

Vertical resolution	768	pixels
Horizontal resolution	1024	pixels
Frame rate	30	fps
Bandwidth	23	Mbits/s
Interface	USB	2.0
Focal length	3.5	mm
Angle of view	87°	

The cameras could stream images at a 30 frames per second (fps) frame rate via a USB 2.0 interface. This made it possible to stream live images to laptop or hand held computers that could be quite simple to fit inside a vehicle. To mount the cameras on a vehicle small suction cup camera mounts were used.

For the initial field trials a car equipped with two cameras, each connected to one laptop computer, were used. Further field trials were conducted using a VW Transporter van with blanked out windows in the cargo compartment. Four cameras were mounted

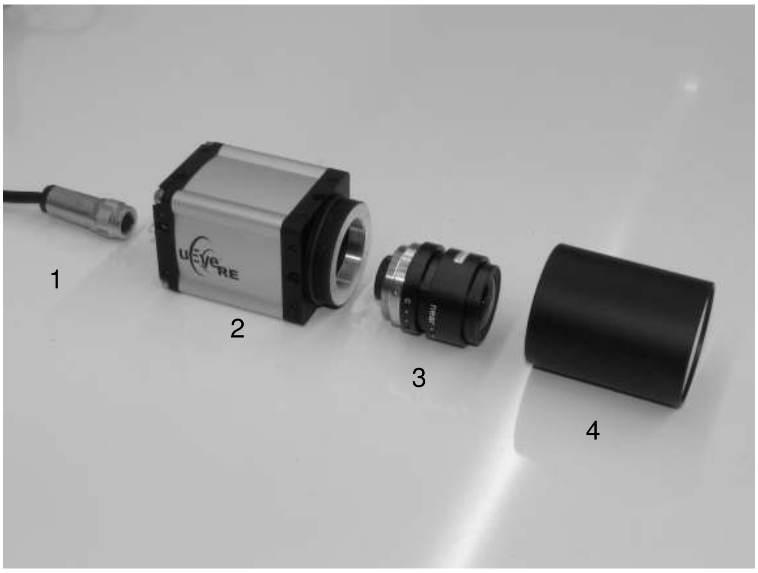

Figure 2: Exploded view of uEye camera; USB cable and connector (1), camera housing (2), lens (3), and lens cover (4)

on the roof of the van, one in each corner of the roof. They were pointed at an angle of about 45° out from the center line of the van. E.g. the camera at the front left corner of the roof was pointed 45° forwards and left of the centerline, whereas the camera in the rear left corner was pointed 45° backwards and left of the center line. The cameras were connected to four computers in the cargo compartment. The screens of the computers were placed in the same direction as the cameras, so that the view on the screens would be somewhat like looking out of a window see figure 3.

Method

Eight persons divided into two groups of four participated in the field trials. The persons participating in the trials were army cadets. Their earlier military experience ranged from fulfilling seven months of conscription to up to seven tours of duty in international task forces. Two scenarios were studied, one scenario (S1) concerned picking up an object at a location, the other scenario (S2) concerned a simulated armed ambush. In both scenarios the participants were transported from a holding area to a task area. Transport from the holding area to the task area was in the back of a van with blanked off windows. During the transport one group was allowed use of the cameras and screens to keep watch of the surroundings, the other group had no view of the surroundings until ordered out of the vehicle at the task area. Which group could use the cameras was switched

Figure 3: Test setup for the field trials. Within the dark circles are two of the four cameras mounted on the roof of the van. Each camera were connected to a laptop computers which were placed in the cargo compartment (grey circles)

between the two scenarios, i.e. the first group could use the cameras in scenario S1 and the second group could use the cameras in scenario S2. Both groups were briefed of the tasks awaiting in the scenarios before entering the vehicle at the holding area. At both scenarios the time from dismounting the vehicle to fulfilling the tasks was timed.

After both scenarios were completed all participants completed a questionnaire containing the following questions.

1. Rank your level of nausea during transport with cameras.
2. Rank your level of nausea during transport without cameras.
3. Rank the difference between using cameras and not using cameras.
4. Rank the level of difficulty of the tasks at the scenarios.
5. How much did the use of cameras affect the difficulty of the tasks.
6. Did the camera image of the scenario match the scenario when dismounting vehicle.
7. Was it easier to do the tasks with the help of cameras?

8. Was it possible to identify people along the road?

9. Was it better to use cameras during transport?

10. Was it possible to identify objects along the road using the cameras?

The first six items should be ranked on a scale from 1 – 3, where 1 was little or none, 2 was intermediate or some, and 3 was significantly or much. The last four questions should be answered with yes or no. As a last item the persons were asked if they had any further comments.

Field trials

In order to get acquainted with the workings of the system a couple of initial field trails were conducted. During these field trials the author's car was equipped with two cameras, figure 4. The cameras were mounted in the upper rear corner of the side windows of the car using suction cup camera mounts. The cameras were connected to two laptop computers which were placed in front of the front passenger seat, for the passenger to use. The velocity of the vehicle was in the range between 30 km/h and 60 km/h, the environment was inside a city and in the country side.

Figure 4: uEye cameras mounted on each side window of test vehicle during initial field trials.

The main field trials were conducted at the exercise grounds of Göta Engineers, Ing2, with the help of personnel and cadets from the Engineering School. In both scenarios the groups were transported from the holding area to the task area in the cargo compartment of a VW Transporter van. There was no possibility to look out from the cargo compartment during transport. Exit and entry of the van was through the rear cargo doors.

In scenario S1 the group was transported along a gravel road for about 3 km, with vehicle speeds ranging between 30 and 50 km/h. Soldiers dressed in camouflage fatigues were placed at four locations along the road between the holding area and the task area to find out if it was possible to see and identify the soldiers. At the task area the group was to dismount the vehicle, locate one orange traffic cone which was placed at the corner of one of two barn sized buildings, pick it up, and bring it to the vehicle. The distance from the cone to where the vehicle was stopped was about 30 m. When entering the area between the two buildings the van was parked so that it obscured the view of the cone, thus making it necessary for the groups to scout the area to find the cone.

In scenario S2 the group was transported at vehicle speeds between 30 and 50 km/h along a gravel road which ran on a rise in the terrain. The distance between the holding area and the task area was about 1 km. At the task area the van was subjected to a simulated armed assault. An explosive charge was detonated some distance away from the road. At the same time soldiers hidden in the terrain by the road opened fire with automatic rifles loaded with blanks. When the explosive charge was detonated the car was stopped and the group was ordered out of the car and into cover. Because the road ran on a rise it was equally natural to seek cover on both sides of the road. The groups had to choose which side of the road to take cover without any information given by the driver.

Results

The initial field trials showed that pointing the cameras sideways at about 45° angle to the moving direction of the car provided an image that was easier to watch than when the cameras were pointed at a 90° angle. Because of the finite frame rate of the cameras, about 30 fps, the latter resulted in staggering images, which was found to be greatly reduced when pointing the cameras at a 45° angle.

Watching through two computer screens gave a reasonable overview of the surroundings, it was possible to identify people playing football at a distance of about 200 m as people running around. The ball itself was impossible to see. Making accurate estimates of distance through the screens was difficult compared to looking through the windows, objects seemed much further away on the screen than they were in reality.

In the final field trials the time to complete the tasks were timed. The timing was started when the group opened the cargo doors of the van, and it was stopped when the task was completed. In scenario S1 the task was finished when the group had brought the traffic cone back to the van and entered the cargo compartment. In scenario S2 the task was completed when the group considered that they had taken cover.

In scenario S1 the group that could use cameras took 25.8 s to complete the task, and the group that could not use cameras took 23.3 s to complete the same task. Because of weather conditions, light rain, the lens cover of the camera pointing in the direction of where the traffic cone was placed was obscured by rain drops. Thus the group could not see the traffic cone before they exited the van. Therefore, both groups had more or less the same conditions which resulted in little difference in time to complete the task.

During the simulated assault in scenario S2 the group that could use the cameras immediately saw the smoke from the explosive charge by the road, and therefore chose the safe side of the road to take cover. The group that could not use cameras did not detect the explosion. When they were ordered out of the van and into cover they chose to take cover by the van in the line of fire. The group that could use cameras took 6.6 s to take cover, and the group that could not use cameras took 8.3 s. In the debriefing afterwords the group that could use cameras said that they felt secure because they knew how the terrain looked and where to find cover in addition to knowing from which side the assault came before they exited the van.

None of the participants felt nauseous when the cameras were used, whereas one participant felt a slight nausea without the use of cameras. All participants felt that there was a big difference between using and not using cameras. They also felt that it was better to use cameras both to help solve the task and during the transport. Two participants felt that the tasks were somewhat difficult, the remaining six felt that the tasks were easy. The view of how the use of cameras affected the level of difficulty of the tasks was quite divergent. Two participants felt the cameras made a big difference, three felt it made some difference, and three felt it made little difference. On average the participants felt that the image presented by the cameras agreed reasonably well with the actual environment outside. It was found possible to see specific objects and people along the road during transport, but it was not possible to identify the persons.

Discussion and conclusion

Even though the cameras were waterproof they were found to be sensitive to rain. Raindrops stuck on the lens covers and obscured the image. Adding some kind of coating to the lens covers should reduce this problem.

The system that was used could only stream images to a computer screen, saving movies proved difficult because of the high requirements for bandwidth. A 30 fps stream of uncompressed images required a bandwidth of about 23 Mbits per second, which is quite close to the practical limit of USB 2.0. Saving movies would require either very large hard disks or a computer powerful enough to compress movies in realtime. Compressing the movies might however reduce the image quality and make the movie difficult to interpret.

The initial field trials were conducted to get to know the system and try to solve initial quirks which always appear in practical tests. They showed that pointing the cameras directly sideways in relation to the direction of motion was not a good idea. The resulting image became staggering which made the image difficult to watch. Pointing the cameras about 45° out from the line of motion was found to be significantly better. This was thus how the cameras were mounted for the final field trials. Because the amount of cameras were limited to four, it was chosen to mount the cameras diagonally on the roof of the car rather pointing one camera forwards, one backwards and one to each side.

The final field trials showed that cameras connected to screens in the personnel compartment can improve the situational awareness of soldiers transported in e.g. armored personnel carriers. All the participants were positive to the cameras and felt that they gave important information. None of the participants felt nauseous when using the cameras, but this can be partly attributed to the relatively short transport distance. Positioning the screens coaxially with the cameras, and keeping the time lag between camera and screen to an absolute minimum, might also have contributed to limit the level of motion sickness since the motion of the image coincides with the actual motion of the car.

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References

[1] O. Straeter, W.S.M. Woldring, M. Barbarino, A. Skoniezki, and W. Philipp. The development of situation awareness measures in atm systems. Technical report, EATMP Infocentre, Eurocontrol Headquarters, Brussels, Belgium, 2003.

[2] M.R. Endsley. Measurement of situation awareness in dynamic systems. *Human Factors*, 37(1):65–84, 1995.

[3] M.R. Endsley. Design and evaluation for situation awareness enhancement. In *Proceedings of the Human Factors Society 32nd Annual Meeting*, pages 97–101, Santa Monica, USA, 1995. Human Factors Society.

[4] M.J. Griffin and M.M. Newman. Visual field effect on motion sickness in cars. *Aviation, Space, and Environmental Medicine*, 75(9):739–748, 2004.

[5] S. Sandberg. Identifiering med sikteskamera. Technical report, Department of Command and Control Systems, FOI, Defence Research Agency, Linköping, Sweden, 2002.

[6] T. Gustafsson, P. Carleberg, P. Svensson, Susanna Nilsson, and Åke Sivertun. Mixed reality systems for technical maintenance and gaze-controlled interaction. Technical report, Department of Sensor Technology, FOI, Defence Research Agency, Linköping, Sweden, 2005.

[7] Personal communication with Lindell, Mannelqvist, and Norlin at BAE Systems Hägglunds, 2009.