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"Hold Your Fire!: Preventing Fratricide in the Dismounted Soldier Domain"

Topics: Collaborative Technologies for Network-Centric Operations (9); Modeling and Simulation (3); Cognitive and Social Issues (4)

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Abstract

Since WWI, an estimated 15% of all soldiers killed in combat are attributed to fratricide, and recent military operations show no decline. A substantial amount concerns fratricide incidents between dismounted soldiers. However, most techniques introduced to prevent fratricide focus on inter-vehicle identification (IFF systems). In this feasibility study, we propose a decision support system that warns a dismounted soldier about to engage when there is a high risk of fratricide. The project has won the 2007 Innovation Game organized by the Dutch Ministry of Defense (MoD).
The system will run on a new platform that is currently in development within the Dutch *Soldier Modernisation Programme*. This platform enables information exchange between soldiers and the Battlefield Management System (BMS), among which up-to-date soldier position information from GPS. Together with terrain information, also available in BMS, these soldier positions are taken into account when deriving an instant risk estimation for fratricide in the current shooting direction. The system is demonstrated using a simulation in which the village of Marnehuizen, built to train Military Operations on Urban Terrain (MOUT), serves as an example. The Dutch army has expressed great interest in the outcome of the study, and is currently investigating possibilities for actual implementation.

Keywords: fratricide, dismounted soldier, warning system, risk analysis, demonstrator.

1. Introduction

Combat identification is the process by which military personnel distinguishes between friend, foe and non-combatants during operations. Combat identification relies on technologies and other measures like Tactics, Techniques, Procedures (TTPs) and training to support situation awareness and target identification. The situational awareness and target identification are intercoupled: a) identification of people and vehicles provides details of the targets, b) information about the situation may provide details about the people and vehicles that are expected at a site. Combat identification is a vital factor in the ability to conduct battles effectively and decisively, with minimum overall casualties.

Effective combat identification is important to reduce the casualties due to fratricide. Analysis of recent wars and training exercises indicate that it is common that about 15% of engagements are against friendly targets. Ground-to-ground friendly firings are most common: approximately 60% of these engagements. The perspective of the dismounted soldier becomes increasingly important as military operations are shifting to urban settings (Urban Operations, UO), where the soldier is dismounted from a ground vehicle.

For vehicles, successful target identification technologies have been deployed in operation (Boyd, 2005). An example is low emissivity thermal tape, which can be detected by infrared cameras. Due to low emissivity, the tape is referred to as passive signaling. An example of active signaling is an infrared strobe or an infrared encoded spectrum flasher. Cooperative target identification techniques form a more advanced branch of target identification. These techniques involve the interrogation of unknown entities. Interrogation systems enable positive identification through ‘the process of query and response’. Technologies include Radio Frequency IDentification tags (RFID tags; communication via radio waves), Radio Based Combat Identification, Identification Friend or Foe (IFF) and Battlefield Target Identification Devices (BTIDs; encrypted communication via electro-magnetic millimeter waves). An entity is usually interrogated by a laser or a radio signal. From a technological perspective BTID, which interrogates targets with a millimeter wave radio signal, is very practical as it allows friendly forces to identify each other from far away, and it does so under any kind of weather conditions, day or night, up to 5.5 kilometers away in less than a second. The gunner in a tank would have instant positive identification of friendly forces through both an auditory and a visual signal, thus providing an alert without having to take their eyes off the battlefield. The interrogation systems have proven to be very useful in combat, where focus has been on identification of airplanes and vehicles.

Unfortunately, the abovementioned interrogation systems are too heavy to be carried by a dismounted soldier. Recent advances make progress in reducing the weight and energy consumption (by a highly directed interrogation beam). Examples include the ICIDS interrogation laser, and the DSID interrogator mounted on the soldier's weapon transmits an encoded laser beam query to the target. Transmitted by radio, the response signal immediately warns the soldier not to fire. However, the size of these systems will remain a challenge, as physical dimensions are largely determined by wavelength (mm) and required spatial resolution (i.e., beam width).

To the best of our knowledge, lightweight, low energy consuming interrogation systems are not operational yet. In addition, although interrogation systems are very effective, they are not conclusive: the unknown entity can only be identified if the entity is in the line-of-sight. For signaling this is obvious; interrogation is directed so the interrogator should know where the entity is. The entity may be obscured by an object that is penetrated easily by firings. Hence, a friendly entity may not be detected, while the risk of fratricide exists.

In this paper, we propose a warning system for the dismounted soldier that indicates the risk of fratricide for the soldier’s current viewing/shooting direction, even when the friendly forces are behind penetrable objects. Furthermore, the warning system can be incorporated in the ongoing Soldier Modernisation Programme (SMP) in the Netherlands, thereby adding no extra weight to the soldier’s equipment. In Section 2, the problem of fratricide is described and we pose the problem statement. Related work is discussed in Section 3. Our solution to the problem at hand is presented in Section 4, which is demonstrated in Section 5. Finally, section 6 presents conclusions.

2. Fratricide

Fratricide literally means the killing of one's brother. In a military context it refers to the unintentional wounding or killing of own or allied personnel. The term Friendly Fire is closely related, although it is more comprehensive, like accidentally hitting own army material. On the occurrence of fratricide multiple estimates exist, depending on the source. 2% of all fatalities was a long-standing figure (Shrader, 1982), but more recently the number is supposed to be higher. In the recent war 'Desert Storm', 35 of the 146 fatalities on US Army side, or 24%, are attributed to fratricide. Although one would expect the percentage to be declining in modern warfare, it is actually rising. A number of factors account for this:

- The pace of warfare increases. Fighter jets and tanks can advance at greater speed, decision making has to be done in less time.

- Modern weaponry has a higher range, higher lethality and misses less often.

- The focus on joint operations is still growing, with a higher coherence between army divisions. Lack of communication and/or errors in communication between divisions increase the risk of fratricide.

- The *Fog of War* is larger, when more operations are Urban Operations (UO, sometimes referred to as Military Operations on Urban Terrain, MOUT).

Two general factors give cause for fratricide incidents:

- Position Errors: when it is not known where own forces are, due to complex or bad maneuvers or insufficient communication; or when this information is not taken into account in the heat of the battle. In such cases, ammunition meant to hit the enemy may accidentally hit own forces.

- Identification Errors: when friendly forces are incorrectly identified as enemies.

2.1 Dismounted soldier domain

Most public attention for fratricide incidents tends to be paid to air-to-air and air-to-ground incidents. The 1994 Black Hawk shootdown incidents (26 deaths) and even more the 2003 US aircraft attack on a British convoy have had an enormous press coverage. Ground-to-ground incidents receive less attention, although during the Gulf War, an estimated 60% of fratricide casualties are attributed to M1A1 tank actions during the 100 hours ground campaign (Armstrong, 1999).

It is even more difficult to find generalities on fratricide in the dismounted soldier domain. In most cases, there are just incident reports. Well known incidents include the, eventually deadly, wounding of general Thomas "Stonewall" Jackson in the US Civil War (1863) and the 1991 Umm Hajul incident that drew a lot of attention in a later stage when it was discovered that high ranking officials had tried to cover-up. Both incidents were due to identification errors. The Umm Hajul incident appears to be *not* so much of an incident when it comes to covering up. This suggests that the estimated percentage of fratricides is still lower than the actual level (Young, 2005).

After the feasibility study that this paper describes was finished, a serious fratricide incident occurred in Afghanistan, involving Dutch and Afghan soldiers. On the night between 12 and 13 January 2008, two Dutch soldiers and two Afghan soldiers were killed, and one Dutch soldier was seriously wounded, in a fratricide incident in the province of Uruzgan, Afghanistan (van Middelkoop, 2008). That night, two companies (the A and C company) had made themselves ready for the night about 800 meters apart. They were involved in operation Kapcha As, aimed at gaining insight in Taliban positions and operations in a certain area of the province. Actually, there were 3 incidents:

1. At about 20.30, the A company observed persons on a building that were thought to be enemy forces. They were given permission to engage. At the same time, the C company reported explosions in which a corporal was killed. Offering first aid to the corporal, a private first class was killed, too. Analysis shows that in the chain of command, uncertainty had arisen about the position of the observed persons. The casualties are ‘most probably’ caused by fratricide.

2. At about 21.00, the C company reported enemy soldiers in the open terrain between the A and C company. The C company was aware of the position of the A company. At the time of engagement, some soldiers of the A company were on the roof of a building. One was accidentally shot in the legs, which had to be amputated. Later analysis has indicated that there was uncertainty of the position of the enemy soldiers, and that the C company had actually observed A company personnel.

3. Shortly after these incidents, the A company came under fire and reports came in that they were surrounded by enemy forces. Later that night Dutch forces opened fire on armed persons disguised by cloths around the head and body, who appeared to be a direct threat. Later, it was discovered that they were Afghan National Army forces, who weren’t recognized as such because of the cloths hiding their military outfit.

We want to stress that the systems described in section 3 and the approach proposed in this paper have been under development for some time, and are not in production state as of yet. For clarity, there is no relation between the incidents and the systems described in this paper.

All three incidents on that night are examples of both position errors and identification errors. Incidents like the ones described show that these two general causes for fratricide often coincide.

Experience gained during training or during actual operations is an important source of information on the topic of fratricide in the dismounted soldier domain. Such information is mostly available in the personal experience and knowledge of individual personnel.

This knowledge is not so much available in the public domain via scientific publications. It is mostly transferred from one generation to the other in military institutions. Apart from that, knowledge on (preventing) fratricide is also implicitly contained in army doctrines and rules of engagement, usually without direct reference. It has been incorporated here through the years, and plays, whether or not labeled as such, an important role in preventing fratricide. This aspect is noteworthy, as rules of engagement and doctrine are 2 of 4 main pillars in the prevention of fratricide (Armstrong, 1999). It is, however, difficult to extract direct knowledge back from unlabeled, long standing best practices.

Figure 1. Fratricide incident in the exercise village Marnehuizen. This is a screenshot from the logfile player. A blue soldier (small circle at the far end of the line) detects movements from an unknown soldier on the edge of the woods in the foreground. He expects enemies at that location, which is too far of to get a clear view – and thereby a positive enemy id. The red soldiers (diamonds) are actually only in and around the village, in the middle of the picture.

During the feasibility study that this paper presents, we have been guests at the Marnehuizen exercise facility in the Netherlands. Marnehuizen is the biggest European facility for training Urban Operations (UO). Movements and actions are logged in a central database in a high level of detail. This facilitates analysis and debriefing afterwards. Logfiles of recent exercises show that there is hardly a day *without* a blue-on-blue incident. In a recent 5-day practice by the Dutch Marine Corps, 100 blue on blue incidents occurred, 20 of which were 'lethal' dismounted soldier-to-dismounted soldier incidents. One may argue that the training exercises are extreme in their intensity; lethal reports may not have been lethal in actual operations; the soldiers exercising were still in training and therefore less-experienced. Be that as it is, it does show the high risk of fratricide in UO, which has not been gainsaid by any officer we have spoken to.

Incidents reported at the Marnehuizen training site show the same causes as fratricide incidents in other army divisions: position and identification (see figure 1). Factors influencing fratricide occurring in UO are:

- UO is what is sometimes called ‘the corporal’s war’. Small battle groups swiftly move from one location to the other. No or tardy synchronization of position information between battle groups is a potential cause of fratricide.
- Identification Friend or Foe (IFF) systems that are or become common on larger platforms like tanks and fighter jets, are not carried around by soldiers; technical solutions to prevent friendly fire among dismounted soldiers are still largely in development, and not widespread in use.
- Information devices to enhance the soldier’s situational awareness are seldom looked upon in the heat of a battle. As a recent study to the added value of such systems show (Spaans et al., 2006), those systems can only be used before the first enemy contact. During enemy contact, the soldiers need their senses to look at the environment.
- The ‘Fog of War’ is very much present in UO. E.g., friendly shots nearby are very easily confused with enemy fire.

2.2 Problem statement

The problem of fratricide currently receives a lot of attention on the solution side, as shown by this excerpt from Atkinson (1993, pp. 314-317), taken from McDaniel (2001):

> *“Spurred by the Marine deaths [...] during the battle of Khafji, the Joint Chiefs ordered a review of on-the-shelf technologies in hopes of finding a device that would enable gunners and pilots to distinguish friend from foe. The Defense Advanced Research Projects Agency (DARPA) began to evaluate sixty proposals sorted into five categories: thermal imagery, infrared imagery, lasers, special radio frequencies, and visual devices. At the Yuma Proving Ground in Arizona on February 15, only six days before the scheduled ground offensive, DARPA started testing the most promising techniques. The crash effort was belated and futile, attempting in a week’s time to solve a mystery that had plagued warriors for thousands of years. Scientists [...] cobbled together a battery-powered beacon that could be seen through night-vision goggles five miles away. A few of those beacons arrived in the theater on February 26, by which time the friendly fire toll had tripled.”*

The next section presents a number of technical approaches to preventing fratricide. As the excerpt shows, fratricide is a long-standing problem that will not be solved by technology alone. Armstrong (1999) shows that 4 pillars are important in the prevention of fratricide:

- Doctrine,
- Rules of Engagement,
- Training,

- *and* Technical Solutions.

Each of these should receive equal attention. Our approach, therefore, is not a silver bullet to solve the problem of fratricide, nor will it work when not brought into harmony with the other 3 pillars, especially training.

The goal we have set for ourselves in this study is to help prevent fratricide by (1) increasing an individual soldier's situational awareness with respect to other blue forces and (2) warning the individual soldier when he is about to engage with a high risk of fratricide. To do so, we have restricted ourselves by only using electronic devices that belong to the outfit of Dutch military personnel, currently or in the near future.

3. Related work

No silver bullets yet exist to eliminate fratricide. Experts believe that a combination of new technology and modifications to training and procedures lead to significant improvements in combat ID. Recently, the focus of combat ID has shifted towards increased situational awareness, that is, what and who is where in the mission site, beyond the line of sight, and with semantic information about the operation and the mission site. Hereby, the objective is to provide the soldiers with sufficient information to facilitate decision-making (Levchuk, 2007), reasoning about positions of the enemy (Brynielsson, 2005), and reducing errors including fratricide (Ceralde, 2005).

3.1 Situational awareness

Situational awareness aims at a timely dissemination of the 'operating picture' (Boyd, 2005), including combat identification information, across the combat force. These integrate a variety of identification technologies in order to provide information to users in a suitable format. Many of these systems display location and command and control information on a digital map in near-real time. Architectural options can be found in the range from distributing data and merging it at the shooting platform to centralized data merging and distributing the ID declaration (Defense board, 1996).

A main focus of situational awareness systems is to keep track of blue and red forces (Ceralde, 2005). A promising, hand-held system is the Dismounted Intelligence Situational Mapboard (DISM; Coffey, 2007), where blue forces are indicated by symbols (special symbols indicate where visual information from imagery is available), the mission plan is sketched and terrain types are displayed. Terrain information can be extracted from the Digital Terrain Elevation Database (DTED; Ceralde 2005).Information about the positions of blue forces is provided by Global Positioning System (GPS) data. Additional information can be exchanged between multiple systems (Coffey, 2007). Figure 2 depicts the DISM display of a battlefield situation.

DISM User Interface

Figure 2. Example of user interface of situational awareness system DISM. Courtesy of (Coffey, 2007).

Similar systems to DISM have been developed. We mention some examples. VISA (Firey, 2007) has the useful property that it plots the situational information onto a Google Earth map, such that terrain data is provided by actual satellite images (rather than artificial terrain images). In the FBCB2 system (Barry, 2004), the situational awareness system is based on a fully distributed network. Client systems are distributed among airplanes, helicopters, vehicles and soldiers, which are able to share information. A very interesting and useful tool of the FBCB2 system is the circular line-of-sight indicator (for examples see Ceralde, 2005). For a given position, the system determines the extent of the line of sight for each direction. I.e., it takes objects that block line-of-sight, like constructions and vegetation, into account. An annotated map with altitudes and positions of objects is required to determine the circular line-of-sight. The tool indicates quickly what can be seen from a position, and which objects are within the shooting range from that position; an illustration can be seen in Figure 3.

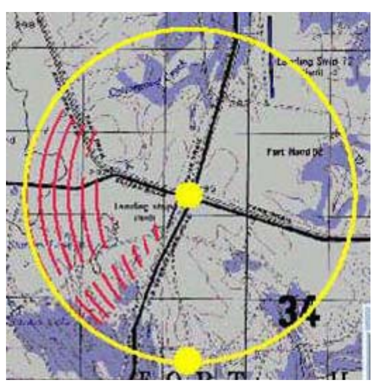

Figure 3. The circular line-of-sight tool that is incorporated into FBCB2. (Courtesy of S. Srolovitz, Office of the Program Manager-FBCB2, 12 March 2004.)

The C2 Support Center (C2SC) has developed the Battlefield Management System (BMS) for use in the mobile domain (Louw, 2007). Within the currently running Soldier Modernisation Programme, run by the Ministry of Defense of the Netherlands, a prototype of the Communication and Information Module (CIM) has been developed by

Thales and TNO in co-operation with C2SC. The CIM system incorporates a lightweight version of a BMS terminal, basically a tablet PC providing a gateway into the BMS system.
The CIM user interface is provided by the SMMI, a handheld device integrating high quality display, controls and a Digital Magnetic Compass (DMC). The display shows a map and plotted geo-referenced objects, together building a situation awareness picture.

Figure 4. On the left, the hardware equipment CIM providing the situational awareness. On the right, a detailed image of the SMMI, a convenient interface of CIM.

3.2 Uncertainty in situational information

The discussed situational awareness systems extract the positions of blue forces from GPS coordinates. The use of GPS data has a number of disadvantages however: GPS coordinates are accurate up to 0.3 meter at best, while coordination errors may vary up to 15 meters. This is mainly due to atmospheric effects and timing errors between satellite and the GPS device. Another disadvantage is that the GPS device may not receive data from the satellite when the GPS device is inside a construction. Even if the GPS coordinates are accurate, the radio connection that communicates the GPS coordinates to other troops involves delays or can be lost.

In the CIM system (Louw, 2007), it is indicated in the interface if a position is not updated for a long time, such that the position is no longer reliable. The position is then indicated by an increasing vague color of the symbol, to denote that the position is not reliable but that no better estimation is available.

To deal with the inaccuracy of GPS coordinates, Brynielsson (2005) proposed an algorithm to determine the likelihood that an entity is at a certain position, given that coordinates are inaccurate. A maximum likelihood indicates where the entity is hypothesized to be.

3.3 The contribution of this paper

Although the systems discussed above indicate the tracks of blue forces, none of the systems indicates *explicitly* the risk at fratricide. In this paper, we propose a system to compute the risk of fratricide for every viewing or shooting direction from the soldier that is carrying the hand-held device.

We build upon the strong points of the systems discussed above. That is, to determine the positions of blue forces, we adopt GPS coordinates, where we take their uncertainty and last update into account. From the CIM system, we adopt the potential of communicating red force information by the data-exchange network. We consider an interface that is very similar to the circular line-of-sight display from Figure 2, including terrain information, but with the extension of indicating the fratricide chance for every viewing/shooting direction on the circle. The objective of this study is to deliver a fratricide-warning demonstrator, which can be validated by lab and field experimentation.

4. GPS-based determination of risk of fratricide

To determine the probability of fratricide for each viewing direction, the following inputs and functionalities are required.

4.1 Functional input and pre-processing

To keep track of blue forces, the GPS coordinates from the CIM clients are taken, while the central collection of coordinates is taken from the CIM radio-based network infrastructure, illustrated in Figure 5. Timings of the coordinate updates are needed to determine reliability of the coordinates, which are also stored in the underlying network.

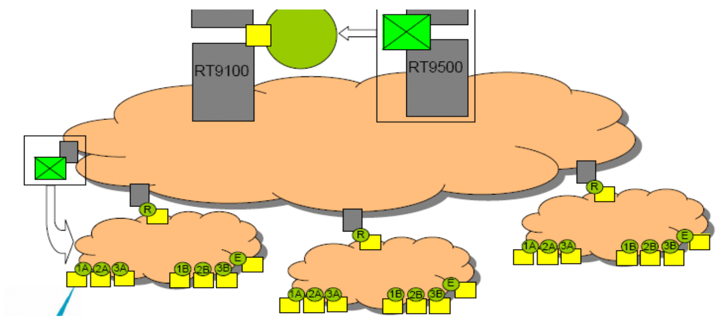

Figure 5. Network topology of transmission of GPS coordinates. The lower layer depicts groups, whereas the upper layer denotes the platoon.

Maps are taken from satellite image recordings, such as displayed in Figure 6 on the left. We have taken the original image and created a schematic vector-based image including annotations of foliage, roads, water, etc. The image is segmented into a number of patches. We have indicated whether the segmentation delivers a suitable number of patches and what types of terrain they convey. The result is depicted in Figure 6 on the right.

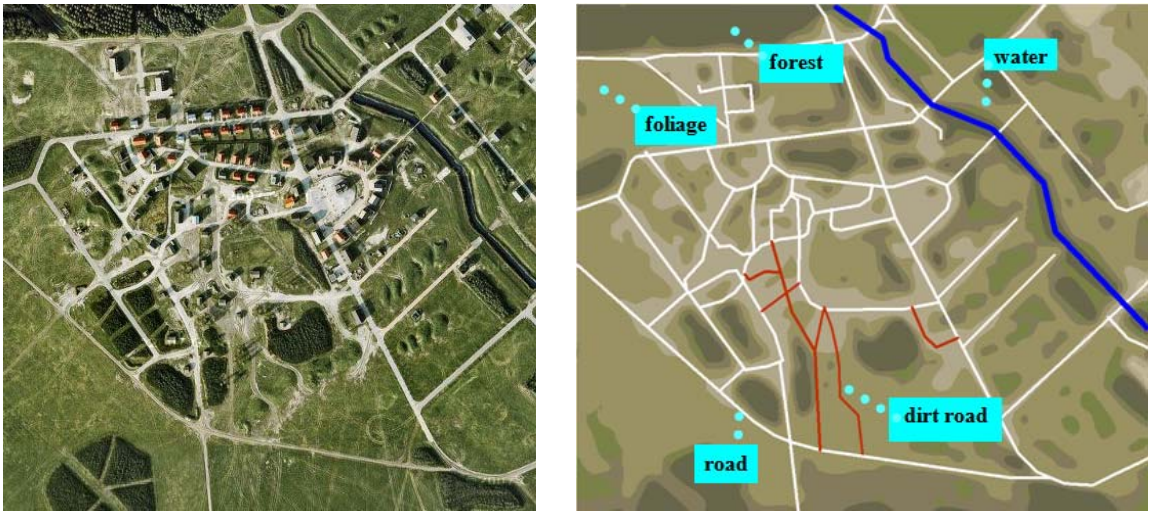

Figure 6. (Left) Terrain image of the training field for military operation in urban environments. Marnehuizen, The Netherlands. (Right) Parsed terrain map, semi-automatically derived from the left image. Details are lost, but important terrain information is maintained. Important objects, like houses and bushes, are stored separately in the system. They can be made (in)visible at will (see also fig. 8), and their features can be used in computations, as described in section 4.2.

4.2 Fratricide risk computation

We use a geometric approach to model the presence of blue forces and to determine which forces are in the line-of-sight. The uncertainty of an entity's position depends on distance and on the last update. If the period since the last update was longer than 30 seconds, the entity remains at its last position, which is subsequently marked by a gray color. For example, this can happen when a soldier is inside a building. If the soldier gets out of the building, the position information is updated and the gray symbol is removed. For soldiers that are further away, the update rate may be less (in CIM, a few seconds). The uncertainty increases for slower coordinate update rates; this is incorporated in the model.

Figure 7 illustrates the presence of soldiers and the uncertainty in their position (the cyan circles). That is, the cyan circles indicate where the soldier *is hypothesized to be.* The circles are determined such that physical limitations, e.g. speed of a running soldier, are taken into account, in combination with the update frequency of the GPS positions. In this illustration, the uncertainty is identical for all soldiers, as their update rates are identical. The uncertainty has its influence on the computation of the risk for the current soldier (the cyan dashed lines).
The projection of the cyan dashed lines on the current soldier (indicated by the yellow symbol) results in a high chance on fratricide, which is indicated by red regions on the yellow indication circle displayed around the current soldier. For the current soldier's viewing direction (the red dashed line), the chance on fratricide is high due to presence of a soldier in the line-of-sight, as indicated additionally by the red block below the image area.

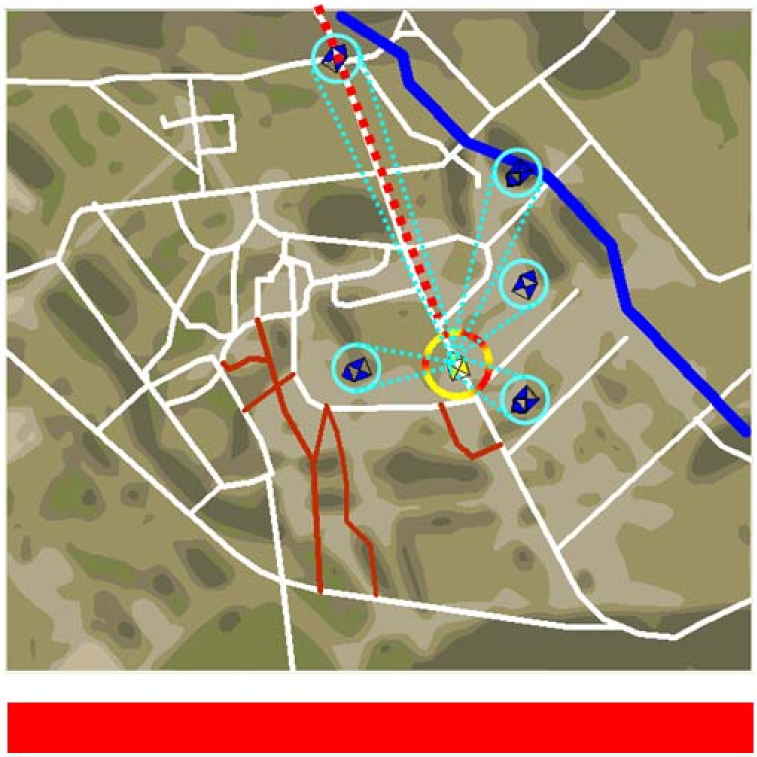

Figure 7. Computation of fratricide probability for all directions. In the shooting direction, indicated by the red dashed line, the probability of fratricide is high due to presence of a soldier in the line-of-sight.

This example is a very simplified one; it lacks buildings, hills, etc., which were temporarily removed from the model for illustrative purposes. In the next example, the original model is shown; including the buildings, hills, etc. As a consequence, the surface of the terrain is not flat. For simplicity, we reduce the range of heights of terrain objects to two classes: heights smaller than and heights higher than the average length of a soldier. This simplifies the determination of obscurance of soldiers by buildings, hills, etc. In order to obtain a map with height information, the user is queried which terrain objects have a large height; other objects are simplified such that they are considered to be flat. Additionally, the user is queried which objects are non-penetrable, for example, buildings or hills. For our purpose, the height information is used in the computation of the probabilities of fratricide. Note that, as a secondary purpose, the terrain information can be used in the briefing stage.

Figure 8 illustrates the terrain types that have extensive height. Contrary to Figure 7, the map of Figure 8 contains buildings (red blocks) and dense forest and hills (dark green). They obscure some of the soldiers as viewed from the current soldier (yellow). Hence, the probability of fratricide for the obscured soldiers is reduced, which is depicted by smaller (partially visible soldiers) or absent red regions (soldiers obscured by a non-penetrable object) on the yellow indication circle around the current soldier.

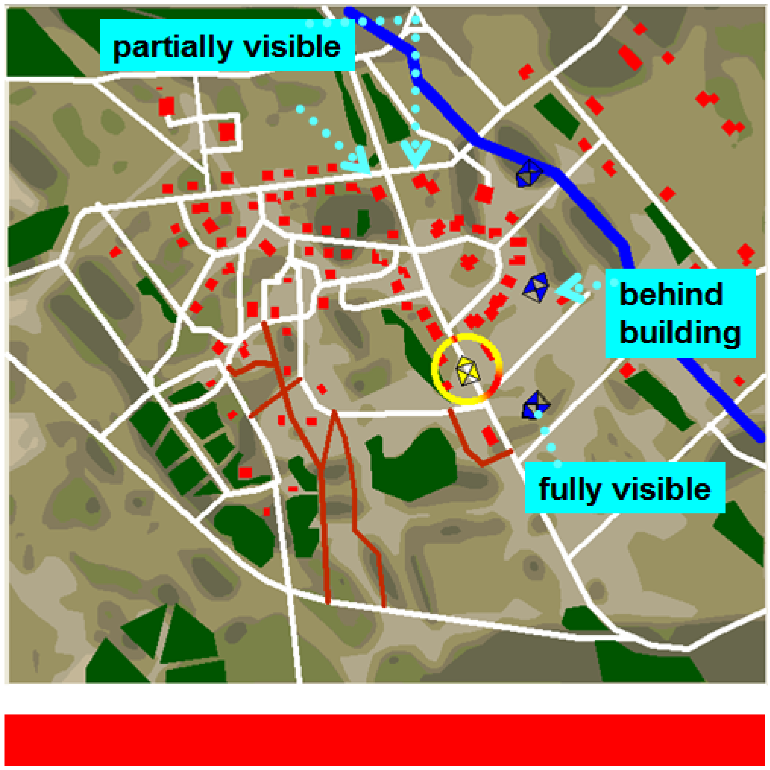

Figure 8. Computation of fratricide risk for all directions, incorporating the position and heights of terrain objects. Buildings (red blocks) and dense forest / hills (dark green) obscure some of the soldiers, reducing the risk of fratricide as viewed from the current soldier (yellow).

5. Demonstrator

Figures 6 (right) to 8 are actually screenshots from a demonstrator program that has been developed during this study. Figure 9 shows a complete screenshot of the demonstrator. We have used the Marnehuizen village as an example of UO, but the underlying map could be anything. The 'own' soldier is depicted in the middle of the picture, and can be operated using a joystick. Other soldiers walk randomly along a set of (invisible) paths, staying very close to buildings and vegetation, as in reality.

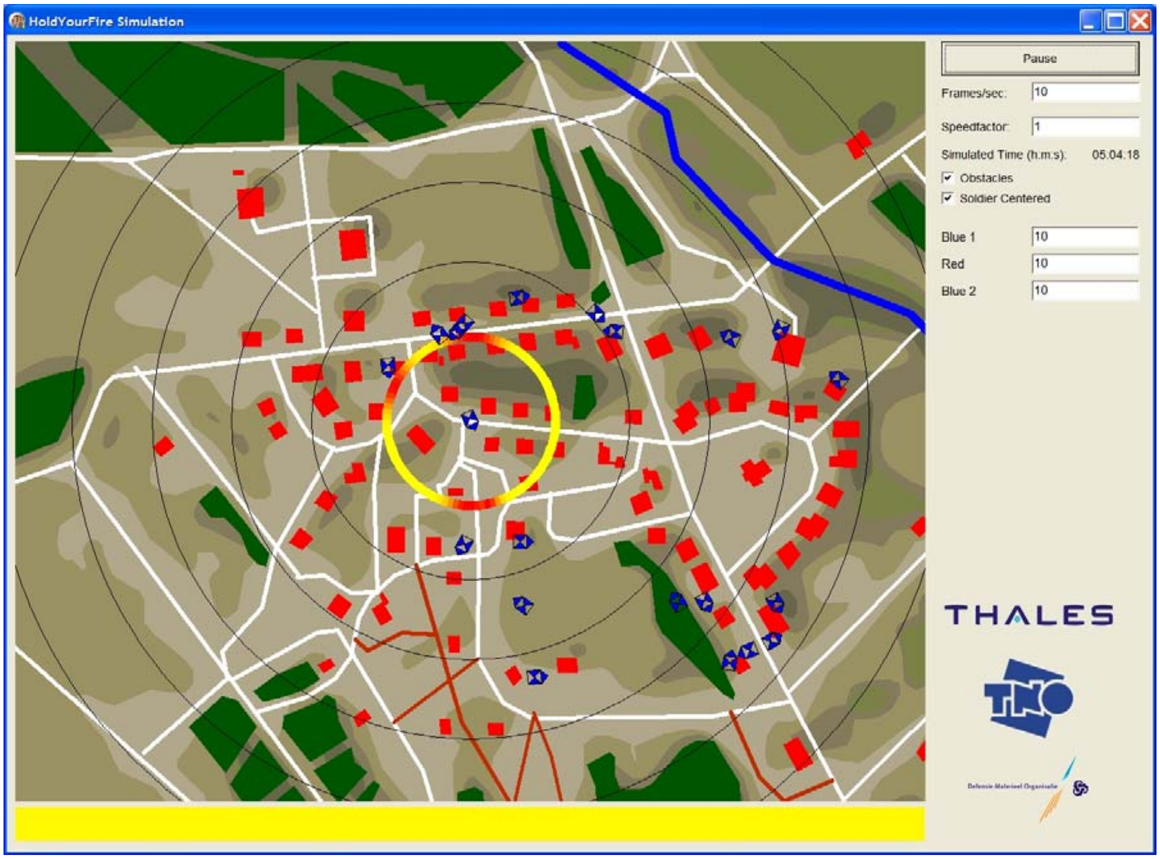

Figure 9: Screenshot of the Hold Your Fire Demonstrator.

5.1 Enhanced SMMI

The various circles correspond to 50-meter distances. This view is very similar to the view that the SMMI (figure 4) presents, except for the inner circle, which we have replaced by the ‘warning circle’. The algorithmic effort to draw this warning circle (section 4) is comparatively low. The input for the algorithm will be available when the Soldier Modernization Programme (SMP) is rolled out (section 3.1). Therefore, the possibility to enhance the SMMI with this warning circle, thus providing the soldier with a very quick situational awareness with respect to the risk of fratricide, is a quick win of this study.

5.2 Actual scenarios, use in debriefings

Mr. Peter Söderström, from Saab Training Systems, provided us with a number of ‘fratricide incidents’ from the Marnehuizen logfiles. These scenarios are reflections of training exercises, with soldiers at different training stages. Therefore, the quantity and exact details of those incidents may not be representative for actual fratricide incidents, but for our purposes, they are very realistic. With little effort, these scenarios could be imported into our demonstrator, thereby checking the system’s performance in realistic scenarios. One of those scenarios is shown in figure 1. Figure 10 shows a screenshot of the demonstrator with the same scenario, looking from the north as in figure 1. In the simulation, blue and red soldiers are walking around at the same locations as in the original scenario. Although the shooting angle for a 'successful' blue on blue is very small, the warning circle is correctly indicating red in the current shooting direction, as is the colored bar below the picture.

Figure 10. Demonstrator view of the figure 1 blue-on-blue scenario.

As actual Marnehuizen data can easily be transferred to this demonstrator, the Dutch Army has expressed interest in the demonstrator *as such*, for usage in debriefing situations. It provides an easy walk-through, and presents the viewer with potential dangerous situations and makes it possible to alter positions to find out how those situations could have been avoided.

5.3 An actual warning system

When a soldier is about to engage, he is probably not looking into situational awareness increasing devices like the SMMI. The bar below the picture in figure 10 indicates the danger in the current shooting direction. When there is no known danger, the color yellow is displayed. It is important that this color is not green: the system can never guarantee complete and accurate knowledge, as the previous sections stress. There is a gradual change from yellow to red. To inform the soldier of the *redness* in the current shooting direction, we need to obtain accurate directional information from the soldier's rifle, as well as a means to communicate it to the soldier.

Directional information from the rifle can be obtained by very light-weight sensors on the gun. This will probably be some combination of an electronic compass and inertial sensors (solid state gyro), as they are widely commercially available, relatively easy to implement, and with a very low energy footprint. This directional information is then wirelessly communicated to the Soldier Digital Assistant, a processing unit that provides the SMMI with its current view, and also calculates the warning circle.

Communication to the soldier is a more delicate issue. A few options have been proposed, each with its own strong points and weaknesses. Those options include a warning light on the rifle itself, or a tactile vest that vibrates when danger increases. The most favorable option, however, is an auditive signal:

- Soldiers will be wearing a headphone (on one ear) for communication when the Soldier Modernisation Programme is implemented.
- Auditive signals are noticed under great stress, as hearing is one of the primary human warning systems for danger.
- There is already a wide body of research on how to give auditive warnings, via various tones of different pitch, volume and intervals (Brewster, 1995).
- The infrastructure for giving auditive signals is already there.

An instantaneous warning prior to shooting is a topic of follow-up research.

Conclusion

Fratricide is an actual problem, in particular for dismounted soldiers who carry no active signaling or interrogation systems to identify blue forces. The perspective of the dismounted soldier becomes increasingly important as military operations are more often situated in urban settings, where the soldier is often dismounted from a ground vehicle. To reduce the risk of fratricide for the dismounted soldiers, we propose a warning system that provides a real-time risk estimation for fratricide in the current viewing or shooting direction.

The article discusses causes for fratricide, specifically focusing on the dismounted soldier domain. We show that getting a positive enemy ID is a very difficult task, where current systems exhibit a trade off between portability and performance. The system proposed in this article enables a high performance even when the footprint, in terms of weight and energy usage, is low. Furthermore, it is built upon successes of other technologies (CIM). These technologies do more than just giving positive friend ID, they facilitate a comprehensive Situational Awareness. This makes implementation of our system feasible. A demonstrator we have developed illustrates the correct indication of fratricide risks for realistic scenarios taken from the training field. Hence, the demonstrator has proven the system’s ability to help prevent fratricide.

6.1 Future work

We stress that the proposed fratricide warning system should be validated in a field test. Firstly, field tests are required to validate the practical use of the fratricide warning system. Secondly, the system’s parameters need to be fine-tuned, such as the amount of uncertainty, the extent of information sharing, etc. Thirdly, probably more information is required to guarantee optimal functioning of the fratricide warning system, such as the incorporation of gun information to indicate its shooting distance, and the distinction into more than two height levels of terrain objects.

Future work includes the development of an instantaneous warning system, as section 5.3 discusses. When such a system is actually implemented and tested, other factors should be considered as well. Training is a very important issue, as the soldier cannot put his complete trust into such a system, nor ignore it completely. Changes in soldier behavior after successful usage of such a system may very well have its effects on Doctrine and might even influence on Rules of Engagements as well.

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