Modelling and Simulation of Civilian Group Behaviours in Catastrophic Situations

CAMX Version 1.4

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DRDC CORA TM 2013-089

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Defence R&D Canada

Centre for Operational Research and Analysis

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Abstract

The Civilian Activity Modelling for eXercises and eXperimentation tool (CAMX) was recently upgraded with police-specific features to suit the United States Secret Service. This document discusses in detail the construction of civilian behaviours for both military and police applications. It also discusses all changes since the first publication on CAMX in 2009.

Résumé

L'outil de modélisation d'activité civile pour exercices et expériences (CAMX) a récemment été amélioré avec des ajouts axés sur l'activité policière pour convenir au Service secret américain davantage. Ce document discute en détail de l'élaboration des comportements civils pour les applications militaire et policière. Il discute aussi de tous les changements survenus depuis la publication du premier document CAMX en 2009.

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Executive summary

Modelling and Simulation of Civilian Group Behaviours in Catastrophic Situations: CAMX Version 1.4

François Cazzolato; Jérôme Levesque; DRDC CORA TM 2013-089; Defence R&D Canada – CORA; May 2013.

Introduction or background: The Civilian Activity Modelling for eXercises and eXperimentation (CAMX) tool has seen an array of different users in 2011 and 2012. Besides its normal use within the Canadian Army, Defence Research & Development Canada -- Toronto and the United States Secret Service (USSS) joined the effort to improve the tool by providing critical feedback. The USSS started funding[1] CAMX development in early 2012 in order to make it more suitable for supporting police simulations. Considering that police organizations deal more with civilian populations than military organizations, this collaboration made good sense in terms of knowledge exchange and the pooling of modelling and simulation resources.

As part of the partnership, the USSS requested more research be conducted on civilian behaviours than had been done for the military. For this, all behaviours present in previous CAMX versions were revisited and improved based on the research presented in this paper. New behaviours were added as well, many of which pertaining to police operations. Reference [1] presented a way to extract behaviours from public videos. This technique was once again used after confirmation from subject matter experts[2] that it was sound. In order to enrich current behaviours and better describe them, more videos were studied than in previous investigations. Additionally, interview data from a previous study were also incorporated. These interviews were conducted with Canadian Forces members in 2009 (Annex A) in order to extract typical civilian behaviours for various situations, most of them non-threatening. The interview subjects were all exposed to events involving civilian populations or interacted with them directly during their tours. The results influenced the development of CAMX, though more implicitly than explicitly.

Results: CAMX version 1.4 can support police-specific scenarios such as dignitary protection, mass congregation, and public speeches. It can also support exercises involving the dispersion of toxic gases and their impact on civilian populations, thanks to the Naval Research Laboratory's CT-Analyst tool [2][3]. Moreover, new, more refined civilian behaviours were added while all previous behaviours were improved with the data collected in Annex A and the analysis of new videos. As an example, curiosity now plays a much bigger role in CAMX V1.4 than before, whether it be curiosity about explosions, police arrests, or simply the presence of a motorcade.

Significance: Because CAMX allows a single operator to control hundreds or even thousands of entities, it allows exercise managers to do more with fewer operators. In fact, all civilian activity can now be under the control of a single operator, freeing much needed manpower for other tasks.

[1] Funding for CAMX came through the Technical Support Working Group on behalf of the Department of Homeland Security.
[2] Social scientists from the Canadian Defence Academy (private communications).

Future plans: The civilian component of military simulations will be more prevalent than ever if urban operations become the norm. There is thus a need to focus on features that will enhance the realism of simulations in such environments.

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François Cazzolato; Jérôme Levesque; DRDC CORA TM 2013-089; R & D pour la défense Canada – CARO; mai 2013.

Introduction ou contexte: L'outil de modélisation d'activité civile pour exercices et expériences (CAMX) a été exposé à un grand nombre d'utilisateurs en 2011 et 2012. Mis à part son utilisation normale par les Forces canadiennes terrestres, Recherche et Développement Défense Canada -- Toronto et le Service secret américain (USSS) ont aussi contribué à améliorer l'outil en fournissant des commentaires constructifs. Le Service secret américain a financé[3] CAMX au début de 2012 dans le but de le rendre plus apte à appuyer les simulations policières. Compte tenu que les organisations policières interagissent davantage avec les populations civiles que les organisations militaires, cette collaboration semblait inévitable.

Dans le cadre de ce partenariat, le USSS demanda que plus de recherches soient effectuées sur les comportements civils qu'il n'en avait été fait pour les Forces canadiennes. Pour cela, tous les comportements des versions précédentes de CAMX ont été revisités et améliorés en fonction de la recherche présentée dans ce rapport. Par ailleurs, de nouveaux comportements ont été ajoutés, plusieurs ayant trait aux opérations policières. La référence [1] a présenté une façon d'extraire les comportements d'extraits vidéo publics. Cette technique a été utilisée une fois de plus après confirmation d'experts[4] qu'elle était adéquate. Dans le but d'enrichir les comportements présents et de mieux les définir, plus de vidéos ont cette fois été étudiés. De plus, des entrevues avec des membres des Forces canadiennes ont été conduites en 2009 (Annexe A) dans le but d'extraire des comportements civils typiques pour diverses situations, la plupart non menaçantes. Ces membres ont tous été exposés à des évènements impliquant des populations civiles ou ont interagi avec eux directement durant leurs déploiements. Les résultats de ces entretiens ont été intégrés au travail présent, quoique plus implicitement qu'explicitement.

Résultats: CAMX, présentement à la version 1.4, permet maintenant de jouer des scénarios pertinents pour les opérations policières tels la protection de dignitaire, les congrégations de masse et les discours publics. Il permet aussi de simuler la dispersion de gaz toxiques et leur impact sur la population civile grâce à l'outil CT-Analyst [2][3] du Naval Research Laboratory. De plus, de nouveaux comportements civils, plus raffinés, ont été ajoutés tandis que tous les comportements déjà existants ont été améliorés à l'aide des données collectées en Annexe A et de l'analyse de nouveaux vidéos. Par exemple, la curiosité joue maintenant un rôle plus important dans CAMX V1.4, que ce soit la curiosité liée aux explosions, celle déclenchée par une arrestation policière, ou celle provoquée par la présence d'une escorte de protection motorisée.

[3] Le financement de CAMX fut possible grâce au Technical Support Working Group au nom du Department of Homeland Security.
[4] Communications privées.

Importance: Puisque CAMX permet à un seul opérateur d'être en contrôle de centaines, voire milliers entités, cela permet aux gestionnaires d'exercices de travailler avec moins d'opérateurs, libérant ainsi de la main d'œuvre pour d'autres tâches.

Perspectives: La composante civile des simulations militaires sera plus présente que jamais si les opérations urbaines deviennent la norme. Il faut donc se concentrer sur les caractéristiques qui augmenteront le réalisme des simulations dans de tels environnements.

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Acknowledgements

Many thanks go to the US Secret Service for advancing CAMX's development to new heights.

More importantly, CAMX would not have reached its status without Mr. Janos Martonosi and Mr. Jean-Pierre Cuerrier's devotion to the project. The authors truly felt privileged to have been assigned the smartest coders in town.

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1 Introduction

Simulations are very beneficial since they allow the training of soldiers in controlled conditions at a much lower cost than real life. Civilian behaviour modelling for simulations is important as it gives the ability to represent patterns of life in synthetic environments. In these environments there is no need to hire thousands of players or actors, expend munitions, and run the risk of damaging equipment in order to provide quality training. CAMX, the Civilian Activity Modelling for eXercises and eXperimentation tool, is used to simulate hundreds or thousands of civilians populating urban and rural areas. These extras or background civilians need to do more than just populate the scene; they need to react appropriately to their environment and to events, with focus on military and police operations.

The ease with which CAMX can create and control very large numbers of pedestrians, animals, and vehicles now opens the door to many scenarios that were otherwise impossible without CAMX. Human-controlled enemies can now hide in crowds totally undetected, large numbers of refugees can quickly overwhelm a peace-keeping military force, and demonstrators can hamper police movement. Currently there are no tools that can easily populate exercises with high numbers of agents like CAMX while maintaining control over all of them with the use of a single operator, and allowing real-time modifications if necessary, all of this in a distributed environment.

Although numbers and densities are crucial to represent real-life populations, behaviours are also important. CAMX currently supports behaviours that allow pedestrians, animals and vehicles to react to surrounding events. They range from following an invisible path (a “go to” command) to fleeing explosions. Differences exist between vehicles, pedestrians and animals for almost all behaviours. Gender and age effects are also incorporated as both play a significant part in the differences observed between people.

The CAMX project focuses on short-term behaviours, i.e., behaviours that take place on a short time scale like fleeing a shooter or driving to a location. In its current form, CAMX does not alter behaviours significantly over time. While entities can become more afraid with time based on nearby terrifying event occurrences, they will not become friendlier towards Blue (i.e., Canadian/Coalition Forces) over time if soldiers do good deeds unless the modification is done manually. In any case, military simulations are rarely played continuously over many days. Short vignettes are much more common. Police-related scenarios are even shorter. Therefore it is easy to just set the tone or atmosphere for a given vignette by imposing certain parameters (e.g., attitude towards Blue) based on previous actual or fictitious events. Short-term behaviours are thus quite adequate for the current training realm.

Lack of civilians

Not using civilians in a simulated urban environment when they are required for training purposes, for example, will bring its share of problems. Below are listed some of the main issues:

- Cities are devoid of life. If Red is hiding in town, as soon as movement is observed, Blue knows it must be the enemy and will act accordingly.

    - The detection, recognition, and identification (DRI) process becomes much easier and faster than in real life. The level of uncertainty often associated to DRI disappears almost completely.

- Without CAMX, due to resource constraints civilians are scarcely used and are controlled via more primitive tools. Observing one civilian in the simulation then implies that something is amiss and that the civilian's presence is probably meant to trigger a specific response from the trainee.

    - The trainee can prepare himself upon observing a civilian which will negate any surprise.

- Movement becomes too easy because of the complete absence of traffic.

    - Vehicles going from point A to point B will do so in record time, every single time.

- Civilian casualties are non-existent.

    - Headquarters training might suffer as civilian casualty evacuation is part of normal training in the Canadian Forces (CF).

- If civilians are used and do not react properly to events surrounding them, players might start rejecting the synthetic environment they are in.

    - Keeping players immersed is critical to the success of some exercises or experimentations.

Simulation of behaviours

This paper focuses on civilian behaviours. The aim is to focus on the most representative behaviours that are observed in real life. When people flee an explosion, some run away, some walk away, some are curious and just stare at the event. Normally, there is no need to model the one individual who walks from body to body to steal cash from the victims during the ensuing confusion. This outlying behaviour is not representative of the majority. If it were modelled, it would not add any value to the training of soldiers or policemen. In simulations, the interest is in broad, credible behaviours that look natural so that the trainee stays immersed since immersion is the key element that all simulations thrive for. One must ensure CAMX plays its part, and plays it well.

The difficulty with behaviours is understanding the *why*. While it is intriguing on its own, it is more practical to focus on the *how*, which is easier to tackle. It is not required to fully understand why an individual flees an explosion. In synthetic environments, the interest is on the representation of the behaviour based on real observations. When real-life explosions occur, people flee. The objective is thus the recreation of this behaviour, almost irrespective of the reason why, so that once observed in a synthetic environment, the trainee believes what he sees. That being said, understanding why certain actions are taken indeed facilitates the construction of synthetic behaviours. Some of the explanations were provided by psychologists that were met

throughout the years on the CAMX project. None of these encounters are discussed formally in this paper as many conversations were rather informal. However, they did influence the authors' methodology used to extract behaviours (and validated it as well) and provide explanations for certain actions that seemed counter-intuitive (e.g., running towards an explosion).

Participation of the US Department of Homeland Security

In November 2011, Defence Research & Development Canada – Centre for Operational Research and Analysis received funds from the US Department of Homeland Security through the Technical Support Working Group program, on behalf of the US Secret Service (USSS). As police organizations deal with civilians on a much more frequent basis than the CF, CAMX was deemed extremely relevant to their operations. While this paper often talks about military operations and soldiers, one could at any time replace these terms by police operations and police officers. Some of the new behaviours implemented in CAMX are actually oriented more towards supporting the USSS rather than the Canadian Army. In any case, any addition, irrespective of its target audience, is an enhancement to the tool.

This report is presented as follows: Section 2 provides background on common tools used by the Canadian Army and the USSS as well as the communication protocol used by the simulations to communicate to each other. Section 3 discusses observations made on civilian group behaviours while Section 4 describes their implementation in simulation. Section 5 shows the damage assessment model. Unlike [4], this document is not intended to be used as a user's manual. This document is rather meant as a behind-the-scenes look at CAMX with focus on its behaviours. For a complete overview of CAMX's capabilities, the reader should request a thorough demonstration of the tool. The reader is also encouraged to read the user's manual [5] for more information on how to use the tool. Some technical aspects of CAMX are nonetheless discussed in the main sections of the paper when required.

2 Simulations Description

The Canadian Army employs multiple simulations simultaneously (called federations) for its activities involving synthetic environments. The main simulations, the Joint Conflict and Tactical Simulation (JCATS) and Virtual Battlespace 2 (VBS2), are in use just about every single time an exercise takes place in any of the Canadian simulation sites.[5] Support tools such as network filters, data collection tools, and secondary simulations are used to add very specific features or capabilities to certain exercises. Many are highly specialized and created in-house. CAMX is one of them.

On the USSS side, VBS2 is the main simulation. CAMX and Contaminant Transport Analyst (CT-Analyst) provide additional capabilities and are used only when necessary. This section will discuss the main tools with emphasis on VBS2, and the support tools that are CAMX and CT-Analyst. The Distributed Interactive Simulation (DIS) communication protocol used by simulations to communicate with each other is also discussed as it plays a critical role in any federation.

2.1 VBS2

The Canadian Army, like many armies in the world and high-profile police organizations (USSS and the Federal Bureau of Investigation among others) use VBS2 for training. VBS2 is an immersive, virtual, first-person shooter-type simulation that allows the player to play an avatar and drive vehicles, shoot weapons, and look and move around. Several people can play along, each manning their own station. In the Army, VBS2 is often times used to complement a constructive simulation (i.e., JCATS) and acts as a 3D viewer by playing Unmanned Aerial Vehicles feeding the headquarters. Other times it is used as the primary training tool. Indeed, multiple stations can be used to simulate platoons for dismounted operations or convoy operations with relative ease.

Artificial Intelligence (AI) support is available for just about any role (e.g., driver, gunner, soldier) though it is quite limited compared to human-controlled avatars. While VBS2 is well equipped to represent virtual reality, it is ill-equipped to play civilians controlled by the game's AI. VBS2 civilians display odd behaviours that can quickly annoy human players.[6] Because of this, they are rarely used.

Figure 1 shows a typical VBS2 scene involving soldiers and CAMX civilians in the background.

[5] Canada operates sites at Canadian Forces Base Kingston, Valcartier, Gagetown, Petawawa and Edmonton.
[6] For example, VBS2 civilians do not flee explosions or shooters appropriately or at all. When they do so, they run towards pre-determined zones in single files. They also do not react well to the presence of vehicles, which leads to frequent collisions.

Figure 1: Urban environment in VBS2.

2.2 JCATS

JCATS is a multi-sided, interactive, entity-level constructive simulation utilized by government organizations as a tool for training, analysis, planning, and mission rehearsal. It uses a top-down view for visualization and only units detected by the operators' own force appear on the screen, as well as those coming from other situational awareness means.

JCATS is the workhorse of Canadian simulations when high numbers[7] of units are required. While JCATS operators can control multiple units at once, the amount of operations required for the simplest tasks limits that number. The AI in JCATS is limited to fighting when units detect enemies based on pre-determined rules of engagement. As for movement, units never move on their own to avoid obstacles or other units in the way, nor do they flee from danger. The operator must issue all move orders himself/herself. JCATS civilians thus require constant attention which makes this simulation ill-equipped to play that role.

Figure 2 shows a JCATS scene with four stationary Blue tanks facing east.

[7] Thousands, with averages between 5000 to 10 000.

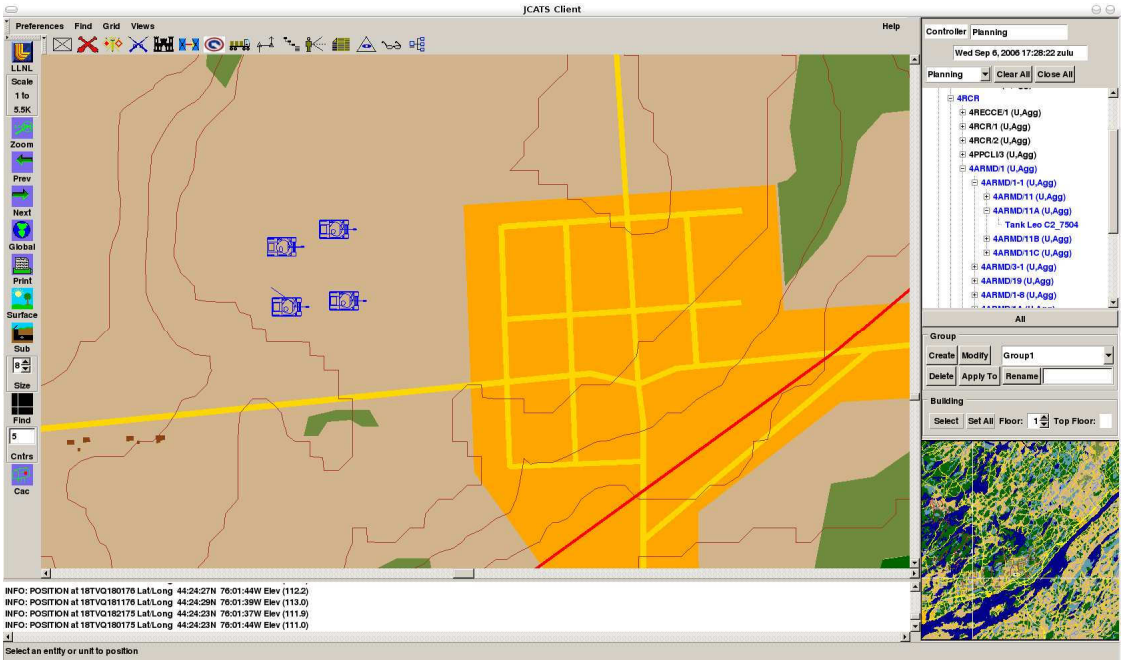

Figure 2: JCATS interface.

2.3 CAMX

CAMX is a civilian population generator that allows a single operator to create and control hundreds or a few thousands of civilians. The operator can decide large crowd movements, crowd layouts and mood changes. Large entity numbers are thus possible because the operator does not have to constantly control them. CAMX entities will react to their surroundings appropriately in accordance with a set of behaviours. Most of these behaviours were developed for environments where troops are deployed so that civilians react appropriately to explosions and shooters. However, with the addition of new users from the police community, new sets of behaviours (discussed in this paper) are required to satisfy domestic operations.

Figure 3 shows the same scene as Figure 1 from CAMX's perspective.

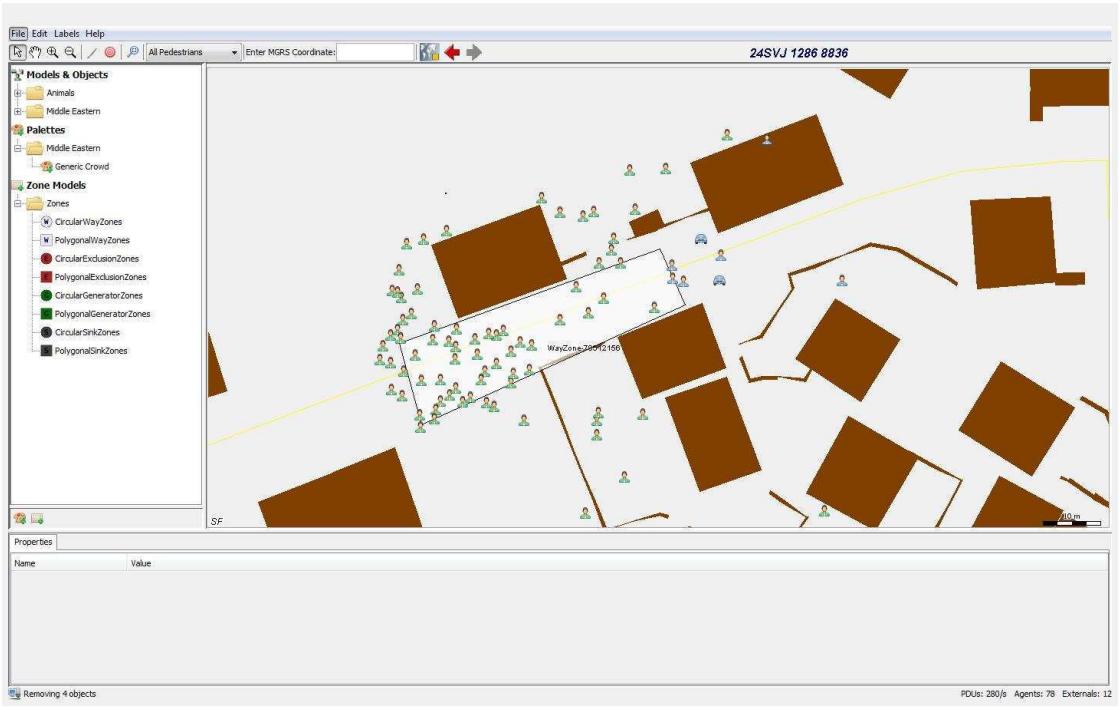

Figure 3: CAMX interface.

CAMX is never used as a stand alone tool. It is always used to support exercises using JCATS or VBS2, the latter being the main recipient by far. This aspect is critical in the conception of the tool as it guides its development. From a simulation standpoint, what is important is the end result in VBS2, not what is seen on the CAMX screen. It is thus paramount to ensure that all actions in CAMX are well displayed in VBS2

2.4 CT-Analyst

The US Naval Research Laboratory CT-Analyst [2][3] is a tool that models plume dispersion based on wind and obstacle location. It also takes into account the intake of toxic gases[8] to determine immediate health effects on humans. The exact methodology used to determine the health effects cannot be disclosed by the US Department of Homeland Security due to the sensitivity of the data. CT-Analyst knows at all times where VBS2 and CAMX entities are located with respect to the fumes, and how much toxicity they are exposed to. When certain thresholds are met, these entities see a change in their health status and display it on screen. If appropriate actions are not taken (e.g., putting on a gas mask or fleeing the area), severe harm can ensue.

CT-Analyst uses a direct link to communicate with VBS2 which allows it to trigger very elaborate animations for affected entities such as holding one's abdomen or putting one's hands to the face. It communicates with CAMX using the DIS standard which greatly limits the

[8] For now, only sarin is modelled.

possibilities.[9] That being said, in a USSS simulation, when CT-Analyst is used, civilians controlled by VBS2 and civilians controlled by CAMX have very distinct roles.

Figure 4 displays a screenshot of CT-Analyst. The source is shown by a star surrounded by a box. The different air toxicity levels are represented by different colors (yellow being more toxic than blue).

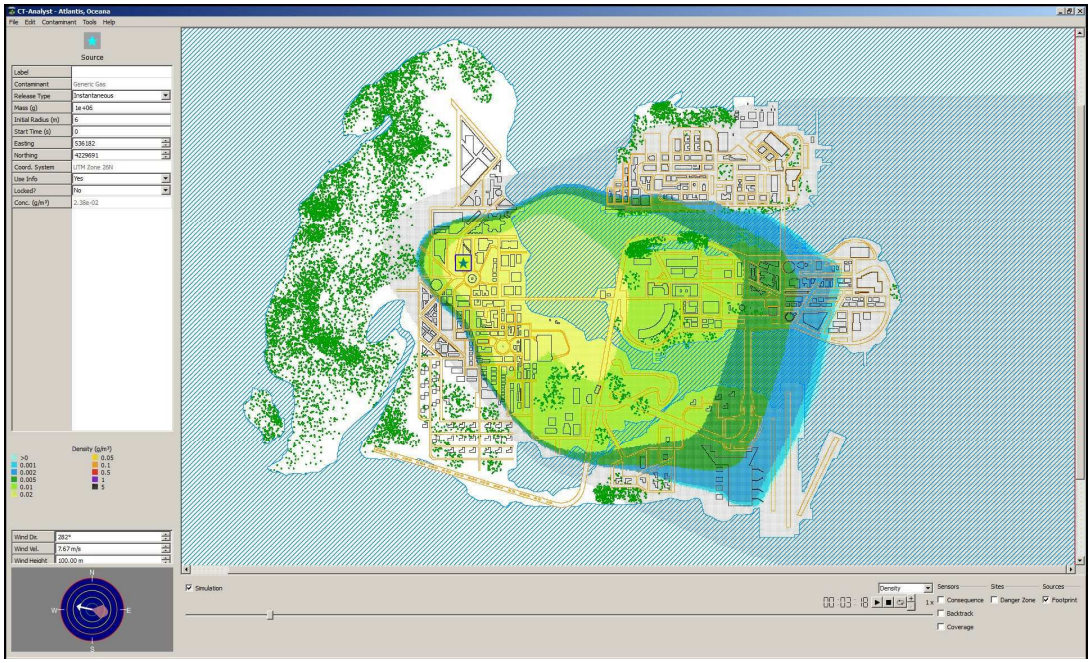

Figure 4: CT-Analyst Interface.

CT-Analyst was never meant to be used with JCATS. Therefore, there is no communication protocol between the two tools.

2.5 DIS

DIS (Distributed Interactive Simulation) is a standard used for interconnecting various simulations across multiple platforms. In a nutshell, it is a language used by simulations to talk to each other and report unit positions and fire events (to name a few). The Canadian Army runs simulations that are DIS-compliant almost exclusively as it requires all federation components to constantly talk to one another.

Figure 5 shows the layout of a federation using CAMX, VBS2, JCATS and CT-Analyst. DIS is shown as the main communication protocol between all elements except for CT-Analyst, which uses a VBS2-specific language to communicate with VBS2. In Canadian Army simulations, CT-

[9] A home-made DIS bridge was added to CT-Analyst so that it can communicate with CAMX. Because it was built in-house for CAMX, it is not fully compatible with other DIS-compliant simulations. CAMX's DIS bridge was modified to communicate to CT-Analyst without interfering with its main DIS bridge.

Analyst is absent as it is a USSS-specific tool. In USSS simulations, JCATS is not used. Note that many more supporting tools typically appearing in Army simulations were omitted from Figure 5. They are of no concern here and are therefore not displayed.

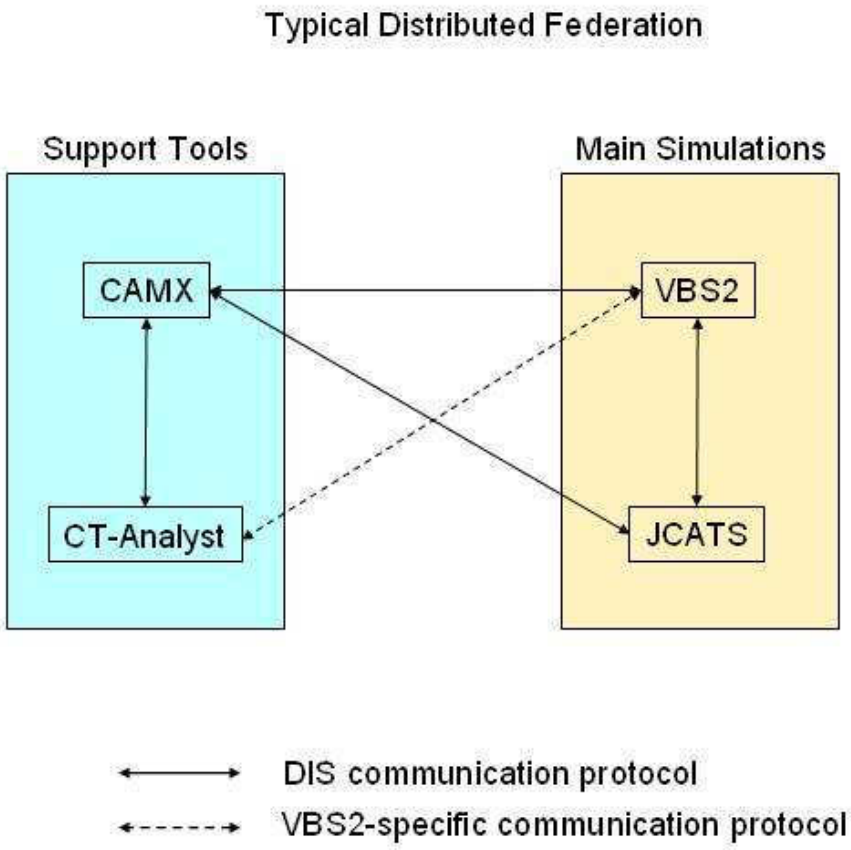

Figure 5: Typical distributed federation.

3 Civilian behaviours: how can they be observed?

The characterisation of human behaviour is a complex task. Even the most basic reactions to events are sometimes counter-intuitive. While one person might flee a shooter, another may actually walk towards him. The goal of this paper is not to fully explain why individuals show certain behaviours but it is rather to ensure that key behaviours are represented in CAMX, irrespective of their rationality. The focus is thus generally on the most representative (i.e., probable) behaviours and some occasional but significant ones. It would be unwise to start characterising every single behaviour, especially if demonstrated only by a single individual and only on rare occasions. Rather, the most representative behaviours are sought after. This surprisingly includes a few irrational ones as demonstrated in the following sections.

For the CAMX project, *action* and *behaviour* were defined as:

- **Action:** A simple act limited in time and space that usually involves movement or stance.
- **Behaviour:** A series of actions in space and time that give rise to a realistic activity.

For example, the *flee shooter* behaviour is composed of multiple actions such as running away, standing still and staring at the event, walking away, depending (among other things) on the distance to the event and the time elapsed since its occurrence.

Behaviours can be obtained in many ways. A few are described below.

3.1 Direct Observation

A direct or live observation is defined here as being able to see the action unfold. Information is obtained from memory recollection of the participant involved in the action or from a witness (an observer). It can be obtained by interviewing the subject/observer or from the literature.

The authors of this paper were not the witness of any event significant enough to be relevant to this paper except for a few mundane behaviours involving populations in peaceful environments (i.e., North America). While CAMX was created to support military exercises in the first place where combat is always a possibility, recent collaborations with police agencies encouraged the CAMX team to start thinking more about North American populations and their behaviours. Timing of that requirement also coincided with the pullback of Canadian troops from Afghanistan. Therefore, the Directorate of Land Synthetic Environments (DLSE) went back to simulations in more generic environments (i.e., less Afghan-like) and now uses generic North American settings on a regular basis. The desire to add a North American flavour to CAMX was thus welcome by both main users.

The advantage of this shift in location is obvious from a behavioural perspective. The authors can now extract civilian behaviours in their daily lives without exposing themselves to danger, at no cost, and without the need to interview anyone for the most common and mundane behaviours. Section 4 describes some of these behaviours observed first-hand in a North American, peaceful environment, relevant to DLSE and USSS simulations.

3.1.1 Participants

Participants can see, hear, smell, and even be injured. One issue associated to live observations arises when the participant's life is in danger. It can potentially negate all the positive aspects of the live observation as the individual will most probably take cover and miss part of the action. He/She runs the chance of having a biased view of the entire event as he/she will only have partial snapshots of the entire scene and be greatly influenced by his/her immediate environment. The chance of missing key events could be significant. Participants of events that are not life-threatening should not be affected by these limitations.

It is rather difficult to find and interview individuals who have lived through dramatic events since it potentially involves travelling to dangerous locations. This means of obtaining data was omitted almost entirely for the CAMX project.[10]

3.1.2 Observers

Observers that were interviewed were people who have seen civilians in conflict areas perform their daily routines and witnessed some dramatic events involving them. The authors used this approach to complement video analysis. To this end, about two dozen people, most from the CF, were interviewed in 2009 and asked specific questions about their daily lives and their interactions with the local populace. These people served across the globe in multiple and very diverse missions. Annex A discusses in detail this approach. Results from the interviews are not discussed explicitly here as they deal more with large-scale behaviours displayed by civilians in their daily lives. Annex A would be more useful to scenario planners that want to know how to tailor civilian activity to suit their exercises. However, its content did influence some of the behaviour descriptions when memory recollection infirmed or confirmed what was observed in the videos.

3.2 Video Clips

Video recordings allow the extraction of numbers like the fraction of people that did a specific action, which are key to the characterisation of behaviours for CAMX. Document [1] discussed the "extraction of civilian behaviours" technique using videos.

Depending on the angle(s) of view, a clear view of the ensemble is sometimes possible, which allows a wider space of observation, rather than the potentially narrower view of live observation. Closed-Circuit Television (CCTV) cameras do not run for cover or hide, and most importantly, keep shooting irrespective of the event unfolding. However, they are usually fixed which is detrimental. It was found that on average CCTV cameras allow a more continuous flow of information unless the action moves out of the field of view or if dust covers the area which is very common for events involving explosions. Cameramen, on the other hand, tend to take cover

[10] Less than a handful of participants were met and interviewed as they were either acquaintances or referred to by other people that were interviewed. Their recollections are not discussed here as notes were not taken during these informal conversations. That being said, most confirmed in one way or another some of the behaviours described in this paper.

if their lives are at stake which often prevents good continuous footage. Still, it is not uncommon that they follow the action accurately.

Youtube and other similar websites were the sole source of videos used to extract behaviours of civilians confronted with dramatic events because of their unclassified nature and their ease of access. Reports of bomb explosions in urban areas are part of the daily news, most of them happening in Iraq, Afghanistan, and Pakistan. Riots and confrontations between police/military forces and civilians were also part of daily events in the spring and summer of 2011 in Northern Africa and the Middle-East. Many videos were produced and distributed by the participants themselves.

Other more isolated events were also studied to extract behaviours. For example, the writing of this paper coincided with the 10th anniversary of the World Trade Center attacks. Several videos related to these attacks were released, many of them showing the population reacting to the events in New York City as they were happening. A few more videos filmed in North America were watched to specifically study panic in large groups in peaceful environments as the majority of videos about shooters and explosions usually involve rather unstable states.

A total of four videos were analyzed in [1] to extract typical actions observed in civilian populations when confronted with dangerous events: three concerning explosions, one concerning a shooting. The most basic actions were found to be the following:

- Run away from event;
- Walk away from event;
- Stand still and watch event;
- Walk towards event and;
- Run towards event.

These five actions alone could describe most of all behaviours observed in the four original videos. The manner in which actions were performed was not discussed at all. For example, running towards an event because a loved one was injured is different from moving towards an event because of curiosity. Also, some people walk away instead of running simply because of physical limitations; this is quite different from people walking away nonchalantly because they are just following the flow of people surrounding them. This paper will thus go slightly deeper and add nuances to the main five actions.

The four original videos were revisited and commented further in this section. Additional videos were also analyzed. Many more were watched but not analyzed since fundamental difficulties prevented that from happening. These issues are:

- **Classification**: Since CAMX in an unclassified project, all videos must be unclassified as well. Many restricted videos filmed by troops deployed in Afghanistan were available to the CAMX team. They were all discarded.

- **Video quality**: Video quality is the main problem with on-line videos. The majority of videos that include civilians in dramatic situations on Youtube are filmed using cell phones equipped with low-end video recording devices. Without good picture quality it is impossible to fully understand the events that are unfolding. Bad video quality alone accounted for most rejections.

- **Bad camera angle; shaky images**: CCTV cameras not pointing towards the action was an issue in many discarded videos. Numerous shaky videos filmed by cameramen that were part of the action were rejected for lack of clarity even though their image quality was excellent.

The videos that were studied and examined are listed below. Actions were extracted in order to build the basis of CAMX behaviours. All behaviours and their specific actions are discussed in detail in Section 4. Here, the area surrounding the events was separated in three zones: *close to the event*, *further away*, and *far away*. The extent of these zones is purposely not defined with exactitude as many times, the location of the trigger (e.g., explosion or shooter) is unknown. Moreover, the extent of these zones seems to be influenced by previous events, the environment (e.g., open space versus closed space), mood of the population, and the presence of protection (e.g., parked cars and buildings). In general, these zones can be defined as the following:

  - *Close to the event*: the event is life-threatening;

  - *Further away*: the event has a low probability of being life-threatening;

  - *Far away*: the event is not life-threatening.

Some of the new videos presented in this paper lasted long enough to see the aftermath of the events. The videos studied in [1] were only a few seconds long and prevented the authors from observing longer-term behaviours.

Note that in the following list, additional notes were given to the location of each event to put the videos in context.

3.2.1 Madrid Train Bombing

Duration: 13s

Location: Madrid, Spain [indoors, train station, crowded environment]

Date: 11 March 2004

Atmosphere:[11] Stability

[11] [1] and Section 4.7 describe the concept of atmosphere in detail. Atmosphere modifies the *fear* level of entities which in turn impacts the probability and magnitude of certain actions. The levels are (from less exposure to dramatic events to more exposure): *peacetime, stability, tension, irregular warfare, wartime*.

Description: The video starts moments after the first bomb explodes further down the platform (top of Figure 6). Screams can be heard which seem to attract attention. A few people can be seen running away from the event (though at this point it is unknown if they are running from the explosion or just in a rush). A few people are curious and stare back at the event as the escalator is moving them away. Some look back as they are climbing the stairs away from the explosion. Many people on the platform are immobile and some even seem unaware of the situation (probably because of the noise of the train engines). However it is obvious that most people are aware that something unusual just happened. Most look in the direction of the event. The majority do not try to get closer to it. Most are leaving the station hence moving away to a "safe" location even though nothing seems to threaten anyone at this point. As displayed in Figure 6, the curiosity shown is quite passive (e.g., most look towards the event without doing much more) as no one really tries to get near the event. In fact, some stronger force (e.g., the desire to leave the station in order to go work/school, etc.) is naturally pulling people away from the station.

Figure 6: View of the people leaving the train station moments before the second bomb explodes.

When the 2nd bomb explodes everyone reacts as this one is nearer. The reaction is instantaneous. People lower their heads for protection almost in unison. A panic sets in, the screams get louder, and everyone runs for their life as fast as traffic allows. In the case at hand, it seems to be barely faster than a brisk walk because of the crowded environment and the fact that people have to climb up stairs.

A third bomb, much closer to the camera this time, only adds to the confusion. The video ends in a cloud of smoke and chaos. This video only depicts one of many attacks.

The coordinated bombings killed a total of 191 people and injured 1800.

Behaviour: Flee Explosion

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away fast (but not maximum speed because of obstacles)
- Further away:
    - Immediate reaction
        - Walk away
        - Run away
    - Delayed reaction
        - Stare at event
- Far away:
    - Immediate reaction
        - Stare at event
        - No reaction (keep current status)

3.2.2 Olympic Park Bombing

Duration: 18s

Location: Atlanta, Georgia, USA [outdoors, city park, crowded environment]

Date: 27 July 1996

Atmosphere: Peacetime

Description: A large crowd gathered at Olympic Park for a concert during the 1996 summer Olympic Games in Atlanta, Georgia. In the video, when the bomb explodes, it is obvious that the

flash and the sound of the explosion are clearly perceived by the crowd as most react physically to the blast by lowering their heads. Some clearly yell in fear (women) and excitement (men).

The first few seconds show that people far from the explosion discard the event as threatening (it could be perceived as a speaker or firework malfunction at this point) as almost all are curious and stare at the event intensely (Figure 7). A few even keep watching the show that is taking place on a stage to the left of the camera view. The cameraman then raises his camera to get a better view of the scene (an obvious sign of curiosity). About 9 seconds after the explosion a significant portion of the crowd starts walking away calmly from the event while a few keep staring without moving. Clearly, the event is not perceived as threatening (far from its origin, at least) as people sound excited as they leave. The contagion of behaviour seems to be in effect here. People closer to the explosion seem to leave the area. As they do so, they "convince" the others, much further away, to leave as well. The wave of fleeing people gets bigger. It would seem that some leave the grounds just because most do so. There is no sign of anyone running in the video though some walk fast, potentially prevented from running because of the crowded environment.

In this video, it is evident after studying the faces of the individuals walking away from the incident (thus facing the camera) that some are clearly excited by the event and display a broad smile while others are clearly calm. Those who are excited walk away fast while the calm individuals walk rather slowly. The difference in speed is significant.

Figure 7: View of the crowd looking towards the explosion. The smoke is visible in the air.

The video stops about 16 seconds after the explosion.

One person was killed directly by the blast while 111 were injured. One more died of a heart attack while fleeing.

Behaviour: Flee Explosion

Typical Actions:

- Very close to the event:
    - Unknown (out of range of camera view)
- Further away:
    - Immediate reaction
        - Stare at event
        - Walk away
    - Delayed reaction
        - Walk away
- Far away:
    - Immediate reaction
        - Stare at event
        - No reaction (keep current status)
    - Delayed reaction
        - Walk away (contagion – large range of speeds)

3.2.3 Karachi Bombing

Duration: 19s

Location: Karachi, Pakistan [outdoors, streets, crowded environment]

Date: 28 December 2009

Atmosphere: Tension

Description: A large bomb explodes from within a crowd of demonstrators. The smoke cloud reaches a few tens of meters in height. Most initially run away from it at speeds barely faster than a brisk walk. Not too many individuals actually try to run fast, even if the way is clear in front of them.

It is obvious that many are not scared much as they quickly stop running and choose to either keep walking or just stop. It would seem that the majority of those who turn a corner (which places a wall between them and the explosion) feel safe and stop fleeing. Not long after the blast a handful of people that were originally further away (and safe) are seen running towards the blast against the flow of the crowd. About 10 seconds after the explosion almost all people who were not too close to the explosion have stopped fleeing and now stare at the event. As time goes on more and more people actually walk towards the blast site instead of moving away from it. The whole time though, those that were near the explosion keep walking away from it. Figure 8 shows the crowd moving away from the explosion. The video stops about 18 seconds after the explosion.

Figure 8: View of the crowd fleeing the explosion (smoke still visible).

Of note in this video is the car that tries to leave the area. The driver does so in a civilised manner, avoiding all pedestrians near him and yielding when necessary.

A total of 43 people died as a result of the explosion.

Behaviour: Flee Explosion

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away (not maximum speed)
    - Delayed reaction
        - Walk away
- Further away:
    - Immediate reaction
        - Walk away
        - Run away (slowly)
    - Delayed reaction
        - Stare at event
        - Walk towards event
- Far away:
    - Immediate reaction
        - Stare at event
        - No reaction (keep current status)
    - Delayed reaction
        - Run towards event (slowly)
        - Walk towards event

Behaviour [vehicle]: Flee Explosion

Typical Action:

- Drive away from event without hitting pedestrians.

3.2.4 Mexico City Metro Shooting

Duration: 1m58s

Location: Mexico City, Mexico [indoors, metro station, crowded environment]

Date: 18 September 2009

Atmosphere: Peacetime

Description: A deranged person starts shooting a policeman at point blank range while surrounded by bystanders about to enter the metro cars. The surrounding crowd clearly hears the gun shots. Some are even pushed by either the killer or the policeman struggling for his life. A few more shots seem to be fired and the surrounding crowd flees the shooter. Some run away as fast as traffic allows (brisk walk at best). Others seem to just walk away very slowly; they look back, torn between curiosity and life preservation (at this points it seems clear that they know someone has a pistol. Yet they do not flee much). A minority do not move at all, and instead stare at the event only a few meters distance from the shooter. Some even walk towards him. One bystander then decides to stop the killer by walking/running at him (Figure 9). In the end, most have fled the area except for a few ultra-curious or heroic bystanders.

It is clear from watching the video that the shooter's gun malfunctions after his first shot. This could explain why many individuals stay close to him and do not flee as the threat level goes down. That being said, this fact might not have been obvious to those around and most probably did not play a role in their behaviour. After the gunner shoots the man who was struggling with him, all bystanders leave the area slowly at walking speeds, some raising their hands in the air as they do so.

Throughout the video, it is clear that all women left very early. The curious (and/or heroic) people that are observed are men exclusively. However, one must be careful with extracting gender data here since the initial crowd near the shooter was almost exclusively composed of men.

Figure 9: Shooter (standing on the left) fighting with an individual (on the ground) while onlookers observe the scene closely.

Behaviour: Flee shooter

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away (low speed; limited by crowded environment)
        - Walk away
        - Stop and stare
    - Delayed reaction
        - Stop the shooter
- Further away:

        - Immediate reaction
            - Walk away
            - Stare at event
- Far away:
        - Immediate reaction
            - Stare at event
            - No reaction (keep current status)
        - Delayed reaction
            - Walk towards event

The defiance showed by the lone man is an outlying behaviour that is not the norm. This however attracted many other individuals towards the shooter, within point blank range. It is suspected that if this man had not struggled with the shooter, many "curious" individuals would have left instead.

The video lasts long enough to see the individual's arrest by the police.

3.2.5 Syrian Protesters 1

Duration: 1m14s

Location: Syria (precise location unknown) [outdoors, streets]

Date: Summer 2011

Atmosphere: Instability

Description: The video shows hundreds of Syrian protesters gathered in broad daylight to confront police or military forces just off the field of view of the camera. The street is surrounded by multi-level buildings and it is obvious that the stores located on the first level are all closed as their "garage doors" are all shut. There are a few parked cars on the street which indicates that people still live or do business in the area. Figure 10 displays a still image of the movie. Note that many more protesters are not displayed in the figure; they are just out of view.

The video seems to show that the crowd is predominantly composed of men. However, when the police force starts shooting at the protesters, women can clearly be heard. Most protesters run away from the shooter(s) as expected, towards the bottom-left of the picture. Some clearly react much faster than others. One individual takes up to 6 seconds before running away as if he were still assessing the situation. He is located close to buildings, less exposed to the police than most protesters, and might therefore not feel as threatened. Other slow-reacting individuals are

standing behind cars right from the start and do not move much or at all during the shooting, again most probably feeling safe and protected.

The video shows that people do not tend to run along specific lines. For example, it does not seem that people avoid running in the middle of the street even if they are fully exposed; they just stay in the street and run. People near buildings at the start of the event ran alongside buildings as well. One location does not seem to attract runners from the other locations.

Figure 10: Syrian protesters. Police forces are located in the upper-right corner out of range of the camera field of view.

Most people are running away without looking back. It appears that only a minority are jogging and looking back on a regular basis. Almost no one is running at maximum speed even if space allows for it. Rather, people tend to run at a pace slightly faster than jogging. Those who walk at first all end up jogging at some point to follow the flow of people. These individuals are mostly located near buildings and were not anywhere close to the police to start with.

During the flight, it appears that a child is trampled. It takes a few seconds before an adult picks him up and runs away. A man closer to the police force is shot right from the beginning. At first almost a dozen individuals gather around him to carry him. As more of the crowd disperses, about half of them just leave for safety. Near the end of the video, only 3 or 4 individuals are trying (and struggling) to carry the injured man to safety. They all take refuge behind a car.

Two outliers then make their moves. First, a man walks out from a side street and stops to have a look at the event. He stands still for about 10 seconds before walking back slowly into the side street, almost as if nothing unusual was happening. At about the same time, a young man who did not appear to be near police forces at the beginning of the video runs against the flow of people

along the parked cars. He finally exposes himself in the centre of the street, picks up an object, most probably a rock, and throws it towards the police. The police then fire upon him immediately.

It would seem that "contagion" affects the decision of certain individuals in this video. As the crowd moves away from the shooter(s), those who are further away, whom did not react immediately after the first shot, finally start reacting as they see the mass of individuals running towards them. It is probable that they feel the need to follow the mass to avoid being alone and fully exposed.

Behaviour: Flee shooter

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away fast (but not maximum speed; not attracted to cover much)
    - Carry injured individuals[12]
- Further away:
    - Immediate reaction
        - Jog away if exposed; look back from time to time
        - Run away fast (but not maximum speed)
        - Jog or walk away if closer to building or any object/terrain feature that offers protection
        - Stare at event
        - Carry injured individuals
    - Delayed reaction (especially if close to protection)
        - Run away
        - Jog away (most walkers will end up jogging as they are taken over by people that are running as if influenced by them).
- Far away[13]:

[12] It is unknown if this action, so close to the shooter(s), is typical or not.

- Defiance: Will run towards event and defy the authority by yelling insults or throwing object(s).

The restricted field of view of the video prevents one from observing where the fleers were actually going, most probably a street perpendicular to the main one to seek cover. It does not show either what individuals far from the event actually did. It would have been enlightening to observe the behaviours of those further away, not really threatened by the event.

3.2.6 Syrian Protesters 2

Duration: 2m11s

Location: Homs, Syria [outdoors, streets]

Date: Summer 2011

Atmosphere: Instability

Description: A crowd of about 200 individuals protest in front of a police (or military) blockade at night. The crowd seems to be mostly composed of men, if not exclusively. The police start shooting at the crowd which flees immediately in silence.[14] Figure 11 displays the demonstration a few seconds before the shooting.

[13] Far away includes those individuals not too far away but did not feel threatened at all by the event because they were fully protected by a wall.
[14] This silence is somewhat unusual. It could be caused by the absence of women (who tend to yell more than men) or the fact that it is night (which could play a role). This is pure speculation though.

Figure 11: Syrian protesters. Police forces are located in the upper-left corner hidden by the TV station logo.

In less than 10 seconds all demonstrators flee the area covered by the camera view. In this video, the camera work is quite shaky when the shooting begins, which prevents one from seeing clearly the events unfolding. It would seem, akin to in the previous movie, that fleers do not attempt to run towards buildings for cover. They just run away from the shooter(s), in the open if necessary.

There are no observable outlier actions in this video. Running is the only visible action. The "flee shooter" behaviour is biased towards those who are near the shots in this case as no individuals far from the shooters are observed.

Behaviour: Flee shooter

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away fast (but not maximum speed).

3.2.7 Indiana Fair Stage Collapse

Duration: 47s

Location: Indianapolis, Indiana, USA [outdoors, park, crowded environment]

Date: 13 August 2011

Atmosphere: Peacetime

Description: A music stage collapses due to high winds in front of a capacity crowd at the Indiana State Fair. This video was shot in high definition. While not being an event involving military or police forces, this video shows a crowd's reaction, in a peaceful environment, towards a tragedy. The collapse killed and injured spectators located near the stage, which was witnessed by thousands. Figure 12 shows the stage at the onset of collapse.

During the collapse, spectators away from the danger zone yell typical phrases showing disbelief or raise their hands to their heads in sign of distress. Most just stare at the event and do nothing.

Of interest in this video are the people who actually act as first responders once the stage has collapsed. They are at first mostly men who were not immediately next to the stage collapse. They were individuals who felt threatened but moved away sufficiently early or far enough to feel safe and stopped running immediately after the collapse. Some of the first responders were also not in danger in the first place, away from the stage before the collapse. The time taken to go from fleer to first responder is in many cases only about two seconds.

Figure 12: Indian Fair stage as it collapses due to high winds.

The number of first responders then grows with time as more women and men gather around to help the injured stuck under the debris. Thousands start to calmly leave the area as the video nears the end though some sense of urgency is still visible (some jump over barriers to cut corners). After the collapse, the need to run away from the event dissipates very quickly. Walking becomes the only option because of the high density of the crowd.

In this video it was clear that there was not much to do after the stage collapsed for those who did not want to help except either stay and watch the rescue effort (i.e., curiosity) or just leave as it was obvious the show was now cancelled. Of note is the obvious absence of danger following the collapse. This might have influenced individuals who would have fled other more dangerous events to go back and help others. While the fraction of rescuers is small, its absolute equivalent is actually quite large. In fact, no other video shows that many rescuers not long after the event. The obvious absence of continuous danger must have played a role.

Behaviour: Flee Danger

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away fast (but not maximum speed) for a short distance
    - Soon after
        - Come back and look for injured
- Further away:
    - Immediate reaction
        - Stare at event
        - Walk away
        - Come back and look for the injured (as fast as 2s after the collapse)
- Far away:
    - Stare at event
    - Walk away

3.2.8 Russian bomb explosion

Duration: 2m20s and 0m33s

Location: Vladikavkaz, North Ossetia, Russia [outdoors, streets]

Date: 9 September 2009

Atmosphere: Stability

Description: In these videos a car bomb explodes near a market, killing and injuring dozens. The explosion is caught by multiple security cameras. Two distinct videos present different angles of the event, the first (Figure 13) being the only one that shows the immediate vicinity of the explosion. The second (Figure 14) rather shows the effect of the explosion on the population located further away.

First Video:

As it is often the case, when the bomb explodes it creates so much dust that the camera is obstructed for a few seconds. Once the dust settles down, panic can be observed among survivors. Casualties can be seen lying on the ground as survivors run or walk past them at a brisk pace in all directions.

One woman walking with a child is caught by the explosion. It is clear that the woman is at most only slightly injured as she runs frantically with the child in her arms and drops him. The child is clearly injured or dazed significantly as he struggles to get up unsuccessfully. After dropping him again in the middle of nowhere she just leaves momentarily only to come back right away to pick him up one more time and flees with him. While part of this behaviour is difficult to explain, unless the woman was dazed and confused, it would seem that her instinct to stay close to the child is strong. Family ties, especially parent-children ones would appear to play a significant role in behaviours.

Another adult is seen later in the video, holding hands with a child and running through the danger zone. The adult most probably reduced its speed to accommodate the child's running speed. At one point the adult falls on the ground. The child immediately stops and waits. The tie between these two individuals is obviously more important than anything else.

While people run or walk in all directions, most still move along the sidewalk or along streets. Those who move more slowly seem to be of older age (unable to run) or just people who were dazed by the explosion. The confusion can be observed for almost an entire minute. It is striking to see the amount of people crossing the danger zone in all directions.

Figure 13: Car bomb (red circle) just about to explode in a market.

Once people stop running, the area near the explosion starts to fill up quickly with individuals, most of them walking, trying to make sense of what happened. Some actively try to help the injured (and the dead) while others seem to be walking randomly in a confused state. The area is still crossed by people who are just passersby. The zone does not appear to stay deserted much after the explosion.

The density of people near the explosion point two minutes after the detonation is about the same as before the explosion. It is obvious that more and more people walk towards the event, most probably out of curiosity. The video does not run long enough to see the arrival of emergency units.

Interestingly, the Youtube description of the video, once translated[15] from Russian to English, states the following:

> "Many were shocked by the behaviour of unknown men and women who engaged in looting a minute after the explosion. They collected the money that fell from the hands of the dead located near the entrance to the market."

It is unclear in the video if this actually happened as the resolution of the image is limited. Individuals are indeed observed to walk towards the dead and seem to look for vital signs. None of them actually does cardiopulmonary resuscitation or moves the bodies. Either they do not possess the necessary skills or it is obvious that these people are dead. One cannot unequivocally conclude that looting takes place. It is possible that some who appear to be good Samaritans in the video might indeed be looters. The video does skip 1 or 2 seconds at the very end when one

[15] Google Translate was used. Editing was necessary to make sense of some sections.

individual leans over a dead body. On the next frame he walks away. It is suspected the video was edited to remove the thief in action before being released to the public.

Second video:

This video contains multiple camera angles (Figure 14 shows one of them). None of them actually catches the immediate area of the explosion. Instead, multiple areas around the explosion are filmed. It thus gives insight to what behaviours civilians display when not in the immediate vicinity of an event. It is estimated that most of these other camera angles filmed the action 25m to 50m from the explosion.

Even if located further away, the reaction to the explosion is instantaneous. People slightly duck to cover their heads and immediately start running (or walking at a brisk pace) away from the event. Most do not bother to look at the event at all. They seem to know the right direction to take. Some stop running early as they take cover inside buildings. Some show curiosity by slowly walking towards the event, though only men seem to exhibit this behaviour.

Figure 14: Explosion of car bomb from further away. The orange glow is visible in the upper-right corner as well as its reflection on the ground. Some individuals clearly react to the sound of the explosion.

The very last camera view, while it only lasts a few frames, clearly shows the explosion from afar.[16] The two most obvious individuals in the picture both stare at the event. One even walks towards it. Dozens of shoppers are seen closer to the explosion in the same frame. Four seconds after the explosion there is still little reaction. Considering that almost all people closer to the explosion reacted instantly, it is possible that these individuals did not feel threatened. They could be assessing the situation (i.e., "should I flee or move closer and have a look?"). The video stops before they make up their minds.

Behaviour: Flee Explosion

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away fast (but not maximum speed)
- Further away:
    - Immediate reaction
        - Walk away
        - Run away
    - Delayed reaction
        - Stare at event
        - Come back and look for the injured
- Far away:
    - Immediate reaction
        - Stare at event
        - No reaction (keep current status)
    - Delayed reaction
        - No reaction
        - Go towards event (curiosity or to help)
- After effects:

[16] While it is difficult to assess, it is believed this location is 50m to 75m from the explosion.

- The explosion zone does not stay deserted for long
    - Starts being filled with helpers or curious individuals
    - Passersby still walk or run through the explosion area

Looting (if present) was decided to be unusual enough to be discarded from the probable actions triggered by explosions.

3.2.9 Quetta Mezan Bomb Blast

Duration: 5m58s

Location: Quetta, Balochistan, Pakistan [outdoors, streets, crowded environment]

Date: 3 September 2010

Atmosphere: Stability

Description: A suicide bomber exploded himself inside a dense crowd. His actions were caught by a CCTV camera. Due to the windy conditions, the dust created by the explosion dissipated very quickly which allowed the analysis of behaviours moments after the blast. Over 73 deaths were reported at this event. Figure 15 shows the crowd shortly before the explosion.

In the video, survivors flee the area as soon as the explosion occurs. Some are running, some are walking; a few injured individuals are crawling. It is obvious that the injury sustained dictated how fleeing took place. Some individuals, too injured, are unable to leave. About 14s after the explosion the first helpers arrive. They go from one body to the other, looking for signs of life. They start dragging the survivors away from the fire caused by the explosion right away. About a dozen individuals are seen helping others 1 minute after the explosion when the video ends. Instants before the explosion, over 100 individuals were present.

Figure 15: Moments before the explosion.

No information can be obtained from this video for the areas further away from the blast as the camera field strictly focuses on the explosion site. Other low quality videos of the event, filmed by survivors within the crowd and close enough to the explosion to be pushed to the ground by the blast, show that while people tried to flee the area, those who were on bicycles or motorcycles left with their transport by pushing them and walking alongside unless they were too badly damaged. Walking away with their belongings seemed more important than fleeing fast. One video also clearly shows that people away from the explosion are walking towards the action as others, initially closer to the blast, flee. Many stand and stare at the event. Others take cover and do not move.

Behaviour: Flee Explosion

Typical Actions:

- Very close to the event:
    - Immediate reaction
        - Run away as fast as possible (limited by injury).
- Further away:
    - Delayed reaction

        - Go towards event and look for the injured.
        - Stare at event.

- After effects:
    - The explosion zone does not stay deserted for long (<15s).
        - Starts being filled with helpers (few).
        - No passersby within the first minute.

4 CAMX behaviours

This section discusses all the behaviours included in CAMX V1.4. The priority of behaviours is also presented as certain behaviours take precedence over others in certain situations.

There are multiple behaviours one could model in CAMX to make civilians livelier. For example, a quick look at any North American street corner will show a significant number of people talking on their cell phone, teenagers texting while walking, pet owners walking their dog, mothers pushing a stroller, boys on skateboards, people riding their bicycles, couples holding hands, etc. While all of these different activities would add realism to CAMX, they are either not required by CAMX users or simply not available in VBS2 to display.[17]

CAMX's main function is to create civilian clutter. Static and moving entities are generally enough to get the effect. When helicopter pilots fly their aircraft during the yearly Winged Warrior exercise[18], they only care about movement on the ground, be it pedestrian, vehicle or animal. When soldiers enter a village or a town known to harbour potential enemies, they tend to focus on the presence (or absence) of people, if they stare at them, where they walk to, and if they keep their distance or not. The USSS has similar needs with emphasis on the constant presence of civilians near the White House or any location visited by VIPs. CAMX is elaborate enough to display all of the above features. For both the CF and the USSS, proper reaction to events triggered by explosions and gun discharges are also essential.

Because movement is involved in just about all behaviours, it is discussed in detail before the other behaviours are introduced.

4.1.1 Movement

Movement is the most basic action in CAMX. Entities either walk or run towards a destination, randomly in a specific zone, or in the entire map. If a destination is selected, it is either a specific zone of interest (of customizable size) or a series of consecutive zones (i.e., an itinerary). In game terms, they are given a *Go-To* command that is always initiated by the CAMX user. The command forces pre-selected entities to reach a pre-determined destination. It can be imposed on the fly anytime during a simulation or upon creation of the entities. Path-finding is done by CAMX's artificial intelligence component called AI.Implant.[19]

Walking: Real-life walking is quite simple. People walk towards a pre-determined location. Some walk fast, some walk slowly. Speeds are affected by gender and age. A plethora of other factors can also play a huge role such as stress (i.e., in a hurry), affiliation to a group, surroundings, etc. Pedestrians usually follow rules at intersections and tend to walk on sidewalks.

[17] VBS2 has a limited number of pedestrian models and an even more limited number of animations that CAMX can tap into through the supported communication protocol used between the simulations. The latter is what limits the amount of animations one can trigger in VBS2 with CAMX. Therefore, CAMX pedestrians are restricted to simple movement and orientation changes as the only actions they can perform.
[18] Exercise Winged Warrior serves as a mission readiness confirmation exercise for the Canadian Helicopter Force Aviation Battalion.
[19] www.presagis.com.

In CAMX:

- Pedestrians and animals will walk towards their destination, avoiding obstacles on the way such as vehicles, other pedestrians, buildings and other impassable terrain features.
- If a specific route must be followed, the operator can give entities waypoints to follow.
- Walking speeds are based on age and gender and are randomly assigned by CAMX.
- The surrounding density of pedestrians will impact their speeds.
- Civilian avatars in VBS2 only have one animation irrespective of the walking speed of the individual. Faster and slower individuals will thus move faster/slower than the animation suggests.
- CAMX pedestrians do not follow sidewalks as they are non-existent in VBS2 or JCATS.[20]

Multiple studies are available on walking speeds at intersections. References [6] and [7] are summaries of studies that focused on the differences between older and younger pedestrians.

A pedestrian in CAMX has an intrinsic walking speed between 1.00 m s^{-1} and 1.70 m s^{-1}. To add diversity, the age and gender of the entity affect its base speed as shown in Table 1.

Table 1: Age and Gender Walking Speed Modifiers.

Age or Gender	**Walking speed modifier (m s^{-1})**
Elder	-0.35
Woman	-0.10
Child	-0.10

The videos have shown that entities often flee a danger zone walking at a faster speed than they would normally in the absence of danger. This "brisk walk" speed bonus is thus added to speeds when entities are fleeing a scene and choose not to run.[21]

[20] CAMX pedestrians can be forced to avoid certain streets by constricting them to sidewalk-like zones, which requires some work from the CAMX operator.
[21] The data for this bonus were influenced by [7] for pedestrians crossing streets at unsignalized crossings.

Table 2: Brisk Walk Speed Bonus.

Type of walk	Bonus (m s^{-1})
Brisk (older population)	+0.16
Brisk (rest of population)	+0.38

Running: Joggers are somewhat common in North America. While both genders run, age does seem to play a role in the demographics of runners, with a bias towards the 20s and 30s. Running is sometimes observed in non-joggers if someone is in a hurry. This typically involves men (women will tend to just walk fast) and age seems to contribute as well (the older you are, the more you are likely to walk fast instead of running). Joggers tend to dress appropriately while those who run when in a hurry are usually not dressed for running (i.e., casual or business dress).

In CAMX:

- There are no joggers.
- Entities do not run because they are "in a hurry".
- Entities can run to a specific location if triggered by the operator.
- Entities will run if their lives are threatened.

Running speeds are randomly set between 4.17 m s^{-1} and 6.94 m s^{-1} with age and gender modifiers shown in Table 3.

Table 3: Age and Gender Running Speed Modifiers.

Age or Gender	Running modifier (m s^{-1})
Elder	-2.22
Woman	-1.67
Child	-1.11

Driving: Cars in North America usually respect speed limits imposed by the streets they drive on and stay on the right-hand side of the roads. They pay attention to pedestrians and other cars as well.

In CAMX:

- CAMX Vehicles drive at constant speeds to reach their destination unless they slow down if their path is blocked or if turning.

- Vehicle speed is not set by the roads. It is rather a global parameter that all vehicles obey and tends to be much slower than real life cars, especially on highways. Speeds range from 5 m s^{-1} to 15 m s^{-1} (i.e., 18 km/h to 54 km/h).

- Vehicles can be tasked to drive randomly on the entire map or a subset of it, or be tasked to drive to a given location (requiring manual input from the operator).

- CAMX cars only stop or slow down at intersections when turning. The map system does not contain information on lights or stop signs.

- Cars in CAMX are good at avoiding other vehicles and pedestrians. See Section 4.2.2.6 for more on their avoidance behaviours.

4.1.2 Special

Curiosity: Curiosity is ubiquitous in everyday life. Drivers slow down to watch accidents on highways, pedestrians stop and stare at accidents, police arrests, the presence of a VIP, or any unusual event. Not everyone displays curiosity. When one does, it can be for a very short time or for the entire length of the event. Busy people tend not to loiter as much as people with loose schedules. Curiosity was observed in almost all videos and reported multiple times in Annex A.

CAMX supports two types of curiosity which affect pedestrians and animals (to a lesser extent). One is passive and will affect entities when certain events happen. For example, explosions will trigger curiosity in certain individuals far away from any danger. The other type is triggered by the operator to force individuals in a very specific zone to exhibit such behaviours. Section 4.2.1 discusses the active curiosity in detail. The passive curiosity is a subset action of more elaborate behaviours discussed in Section 4.2.2.

Gender effects on the probability of actions: It was evident after watching the videos that women and men did not behave the same way when faced with identical incidents. However, the authors are aware that a biased sample of videos was used as there were more men than women in almost all of them. That being said, it was clear that women tended to display curiosity or the desire to help the fallen less often. Private communications with psychologists confirmed this fact.

To this end, the probability of certain actions was varied for women depending on their nature. For example, curiosity-related behaviours were decreased with respect to men while fleeing actions were increased. This ensured differences between the two genders.

4.2 Behaviours Types

There are two types of behaviours in CAMX: objective-based behaviours and event-driven behaviours.

Objective-based behaviours

Objective-based behaviours are behaviours that force or compel an entity to do an action. They are mostly related to movement and orientation. All objective-based behaviours are triggered by the CAMX operator through the graphic user interface.

Event-driven behaviours

Event-driven behaviours are behaviours that are triggered if certain conditions are met or when a peculiar event takes place. They include avoidance and fleeing behaviours. They occur automatically and require minimal or no input from the operator's part.

The probability and magnitude of some actions are modified by past events and the atmosphere of the scenario or vignette being played. All entities are tagged with a parameter called *fear*. Fear modifies the probability and magnitude of actions. It is affected by events and its baseline is set by the atmosphere. Videos from [1] and this paper, and interviews from Annex A showed that populations react differently to similar events based on their knowledge and their feeling of safety. In a peaceful environment, people tend to react less to explosions. The presence or absence of fear ensures behavioural differences exist between different populations. In game terms, fear goes up when entities are confronted with life-threatening events. Subsequent similar events will thus provoke bigger reactions. Fear never goes down as scenarios rarely play for long periods. Instead the operator can just set the atmosphere to a new, more appropriate, level, or change the fear level of his entities manually. Section 4.7 discusses atmosphere and fear in more detail.

Figure 16 displays all the behaviours supported by CAMX. The left column displays human behaviours. The right column pertains to animal and car behaviours.

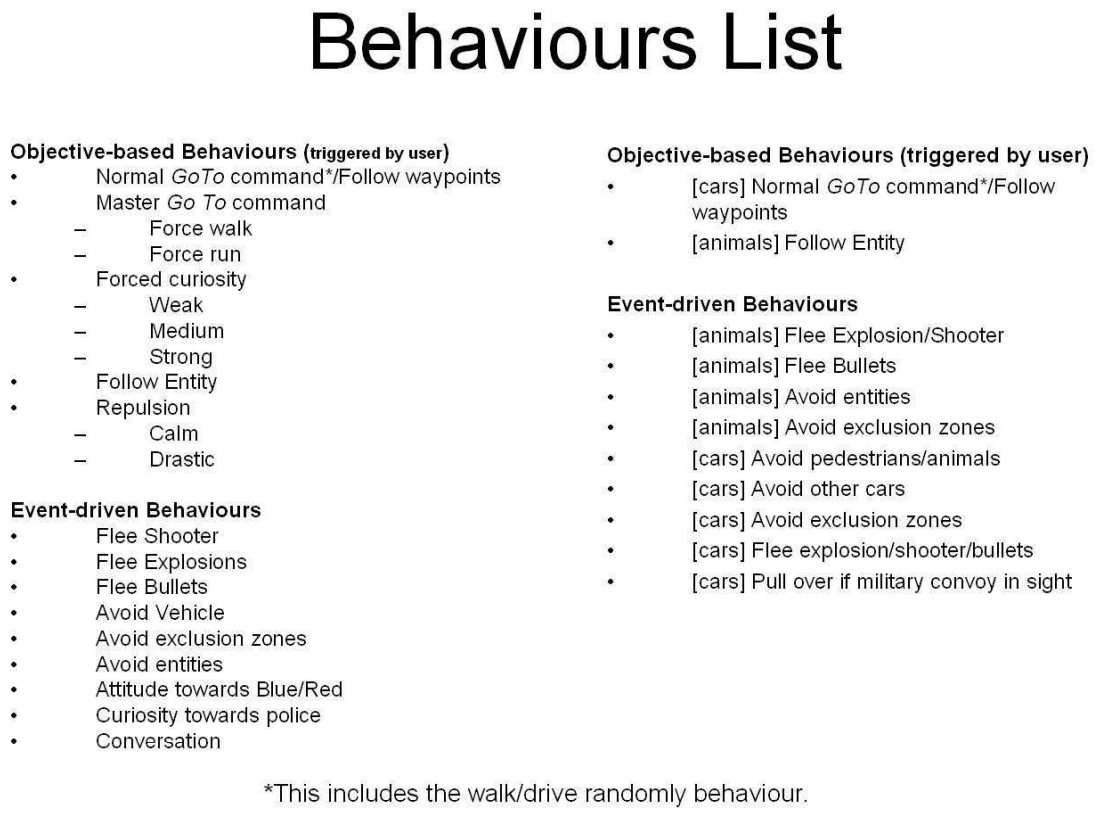

Figure 16: Behaviours list

CAMX behaviours are discussed thoroughly below. First they are summarized in order to give an idea of what is expected. This is followed by a more technical description that introduces numerical values, ranges, thresholds, etc., which are essential. In its current version (V1.4), only a few numerical values are customizable in CAMX. Future versions will feature more customizable parameters.

The five simple actions discussed in [1] are still omnipresent, but subtleties were introduced such as durations, gender differences, and the impact of fear.

It is important to note that none of the behaviours have been validated. That being said, they were based on sound observations, though somewhat biased towards what data were accessible at the unclassified level. However, if the behaviour looks good on the screen and feels real, unless training truly depends on it, then it is considered appropriate. The intended purpose here is to increase realism, not to mimic life to perfection. Since training objectives never fully depend on simulated civilians and their behaviours, CAMX behaviours are deemed more than adequate.

The videos under study were used to obtain a sense of what actions are performed and the fraction of people performing those actions. The diversity displayed from one video to the next clearly showed that location plays a huge role in the types of actions observed, their magnitude, and the fraction of individuals performing them. One should thus see the numbers in this paper as

representative of the average civilian reaction without any statistical studies to support them. If better figures are available, default values can be changed easily.

4.2.1 Objective-based Behaviours

- **Normal Go To:** The entity walks towards a specific location (i.e., zone). Once the zone is reached, the entity will start walking randomly within its border according to the zone's parameters. If an event occurs, the entity will react appropriately. This behaviour applies to pedestrians, animals, and vehicles. When triggered by the operator, the entity will completely forgo its current behaviour and obey the operator's command. It will however react to any ensuing event of higher priority.[22]

- **Master Go To:** The entity walks or runs towards a specific location (i.e., zone) depending on which command is given: *force walk* or *force run*. If an event occurs during movement, the entity will *not* react. This behaviour is used to ensure entities reach their destination irrespective of surrounding events. Once the zone is reached, the entity will start walking randomly within its border according to the zone's parameters. While artificial, this operation allows operators to move entities under all circumstances. All other parameters are equal to that of a *normal go to* command. This behaviour only applies to pedestrians and animals.

- **Forced Curiosity:** The entities are attracted towards another entity (internal or external to CAMX), an object, or a location. The operator selects the location of attraction and a fraction of the pre-selected entities are subject to its power.
    - Weak curiosity
        - Curiosity that affects only a few individuals that observed a strange event, object or person.
        - Effect Radius (ER): 25 m.
        - Probability of curiosity: From 35% @ 0 m to 0% @ ER.
        - Effect: Agents stare at the specific entity, object, or location for up to 1 minute.
        - Example of use: A suspicious bag on the ground; a VBS2 avatar that threw rocks at the police.

    - Medium curiosity
        - Curiosity that affects many individuals that observed an interesting event.
        - Effect Radius: 35 m.
        - Probability of curiosity: From 35% @ 0 m to 0% @ ER.
        - Effect: Agents stare at event for up to 2 minutes; some might even walk towards it.
            - Probability of movement: 0% if within 5 m to 20% @ 35 m.
            - Movement is 0 m @ 5 m and reaches 10 m @ 35 m.
            - Agents within 5 m of the curiosity centre move away slightly and then turn around. This repulsion is 100% effective.

[22] Section 4.3 discusses priorities at length.

        - Example of use: Police arrest.
        - Special: The temporary repulsion of 5m ensures no one gets too close to the event.

    - Strong curiosity
        - Curiosity that affects many individuals that observed an interesting event.
        - Effect Radius: 50 m.
        - Probability of curiosity: From 50% @ 0 m to 0% @ ER.
        - Effect: Agents stare at event for up to 5 minutes; some might even walk towards it.
            - Probability of movement: 0% if within 5 m to 30% @ 50 m.
            - Movement is 0 m @ 5 m and reaches 15 m @ 50 m.
            - Agents within 5 m of the curiosity centre move away slightly and then turn around. This repulsion is 100% effective.
        - Example of use: VIP appearance; vehicle in flames.
        - Special: The temporary repulsion of 5 m ensures no one gets too close to the event.

    All probability decays based on range are linear. At the onset of curiosity, a zone extending to the effect radius appears on the screen. The curiosity behaviour can be stopped abruptly upon deletion of this zone.

- **Follow Entity:** The CAMX entities will follow another CAMX entity or an external entity around and face it when stationary. It is available to both pedestrians and animals. This behaviour mimics the impact of crowd leaders or goat herders when used with animals.

    The selected entities will try to stay within 50m of the target entity. If it moves away, they will move in order to be within the threshold distance. Once inside, there is an 80% probability that they will face their target.

- **Repulsion:** The CAMX entities will feel compelled to leave an area. Its effect is only temporary. Two subsets of this behaviour exist:

    - Calm:

        - Effect radius: 25 m

        - Effect: Entities within the radius will leave the zone walking and stay away from the centre for 5 minutes.

        - Example: A small threat was discovered.

    - Drastic:

        - Effect radius: 50 m

- Effect: Entities within the radius will leave the zone running and stay away from the centre for 5 minutes.

- Example: The discovery of an unexploded bomb; a weapon was drawn.

Individuals within the effect radius will be affected by the repulsion and leave. Entities that started just outside of a repulsion zone will be prevented from going in (similar in this case to an exclusion zone[23]).

4.2.2 Event-driven Behaviours

Event-driven behaviours pertaining to munition events (e.g., shooter or explosion) make use of the following three parameters: Fear, Trigger Radius (TR), and Flee Radius (FR). They are defined as:

Fear: As described in [1], fear influences the probability and magnitude of certain behaviours. It increases the probabilities of actions related to flight and decreases those related to curiosity. As for the magnitude, it extends the distance entities walk or run before they feel less threatened by an event. Fear levels go from -2 for the less fearful entities to +2 for the easily frightened ones. Dramatic events usually raise fear by 1 or 2 levels and affect subsequent behaviours. The conflict intensity, or atmosphere (see Section 4.7), also plays a crucial role as it sets the baseline fear level for all entities. Gender and age however play no role.

Trigger Radius: It is the radius of the area perceived as dangerous by CAMX entities. It is munition dependant (based on calibre mostly). The radii are defined in Annex B and Annex C. TR is dynamic as it is affected by fear as shown in Eqn. (1).

$$TR' = TR + (FEAR * TR) \text{ for fear} \geq 0 \quad (1)$$

where *TR'* is the *TR* felt by an entity while *TR* is the intrinsic *TR* of a munition. *FEAR* is the fear level of the entity. *TR'* is strictly equal to *TR* for $FEAR < 0$.

Flee Radius: It is the distance from the event at which CAMX entities feel less threatened. FR is always 2x TR.

Many complex event-driven behaviours are described using flow charts. Flow charts are composed of four distinct columns that indicate the distance to the event. The first column corresponds to a distance equivalent to the one called "Very close to the event" used to describe videos. The second column corresponds to the case "further away". The third and forth columns correspond to the case "far away". Distances are dynamic based on TR which itself is based on the nature and calibre of the munitions and the fear level of the entities. Therefore, no absolute distances are ever given for complex behaviours that require charts.

[23] Exclusion zones are similar to repulsion zones except that they are permanent features (unless deleted by the operator) and they do not force entities to leave when they are superimposed onto them. For a complete understanding of CAMX's features, the reader is encouraged to read the CAMX user's manual [7].

The terminology used in these charts is described as follows:

- **Run away:** The entity runs away from the event in a straight line. If blocked by an obstacle (building, exclusion/repulsion zone, other entities), it will go around. It stops once FR is reached (with slight random variations).

- **Walk away:** The entity quickly walks away (i.e., brisk walk) from the event in a straight line unless blocked by an obstacle (similar to *Run away*). It stops once FR is reached (with slight random variations).

- **Stop & stare**: The entity stops walking/running and turns to face the event**.**

    - During this action, the entity enters a light random walk pattern where it picks a random direction and then slowly walks 1 m to 5 m followed by a pause of 10 to 60 seconds while keeping its orientation towards the event.

- **Move closer and watch**: The entity will slowly walk a distance anywhere between 0 m and up to the intrinsic TR of the munition used.[24]

- **Go help**: The entity will walk towards the event, enter the intrinsic TR of the event and walk towards injured or dead entities if present. It will then stand next to them for 10 to 60 seconds.

- **No reaction:** The entity keeps or returns to its original behaviour (i.e., the one prior to the event).

- **Assess situation:** The entity pauses for 2 to 6 seconds before a check is made to determine the next course of action. While doing so, it faces the event.

- **Situation returning to "normal"**: After 5+*fear* minutes, the entity will either go home or resume its previous behaviour.

- **Resume previous behaviour**: The entity will resume its previous behaviour (i.e., the one prior to the event).

- **Go home**: The entity will walk away from the event for 5 minutes.

4.2.2.1 Flee Shooter

The videos showed an array of different circumstances where individuals fled one or several shooters. In some instances, people just fled, especially during demonstrations. The Mexico metro event rather showed a lack of protective measures for many individuals. It may be that the gunner was alone, not part of a regular force, or that the atmosphere was rather peaceful. The fact that one individual fought with the shooter might have influenced a few other individuals as well. Moreover, the gun malfunction might have been noticed by close bystanders, making the scene feel less threatening. It is doubtful that this video showed the norm but rather the exception.

[24] Here the intrinsic TR is used to avoid the effect of *fear* which would increase it dramatically.

Therefore, all excessive curiosity and the desire to fight with the shooter were omitted from the behaviour construction.

In general, it seems that if a shooter is present, armed and ready to shoot again, the threat is perceived as continuous. Curiosity is then not that prevalent.

The flee shooter behaviour does not discriminate between a lone gunner and a fully armed squad. While it does appear to impact civilians differently, the gain in realism was not deemed essential. All events involving shooters thus fall under this one behaviour.

Figure 17 shows the *Flee Shooter* behaviour chart.

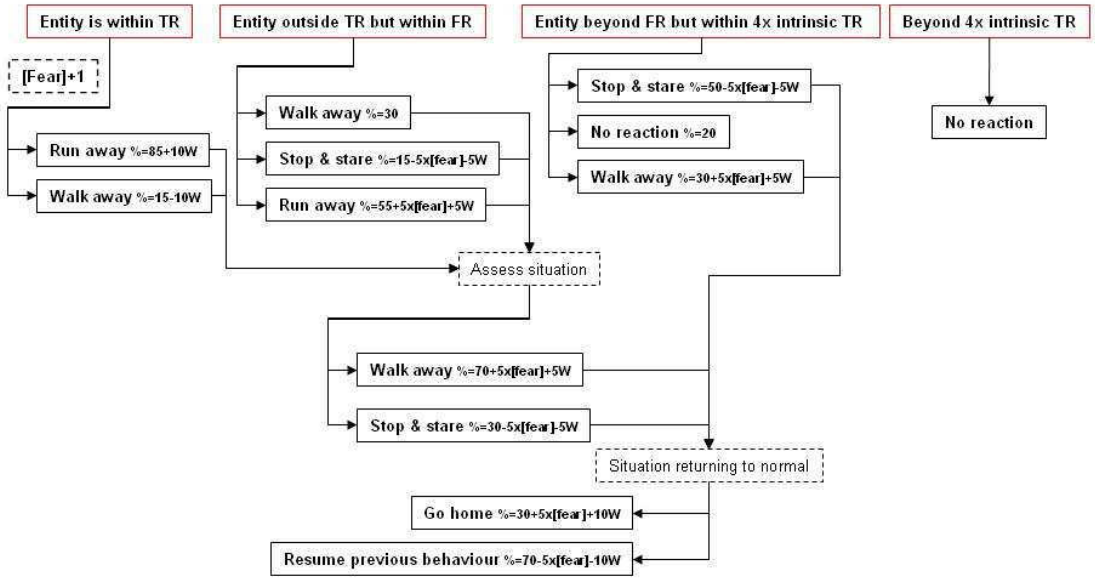

Figure 17: Flee Shooter Chart.

The individual actions performed by the CAMX entities are shown by the complete boxes of the figure. Decision nodes are shown by dashed-line boxes, except for the one involving fear. This box indicates that entities within the TR will have their fear level increased by one by the event. The probability of occurrence for all actions is shown within the boxes, with the effect of fear and gender displayed explicitly. The modifier for women is indicated by the letter W. All arrows are one way arrows. Entities cannot revert back to a previous action within a given behaviour. Of note in the flee shooter behaviour is the increase of fear limited to entities near the shooter.

4.2.2.2 Flee Explosions

This behaviour is similar to the flee shooter behaviour. However, curiosity is much more prevalent as if people knew the danger was contained to this single event. The actions displayed by individuals after explosions were more homogeneous than when shooters were involved without much variation from one video to the next. The one exception would be the explosion in

Atlanta. It is believed that the atmosphere (i.e., peaceful), the setting (a rock concert during festivities), the possible presence of alcohol, and most especially the relative small size of the explosion all played a critical role in the absence of panic. Otherwise, all videos showed about the same reactions, whether it be fleeing actions of curiosity patterns.

In all cases, the explosion did not completely empty its surrounding. Within a minute or two, the place filled up with helpers, curious people, and passers by.

Figure 18 shows the *Flee Explosion* behaviour chart.

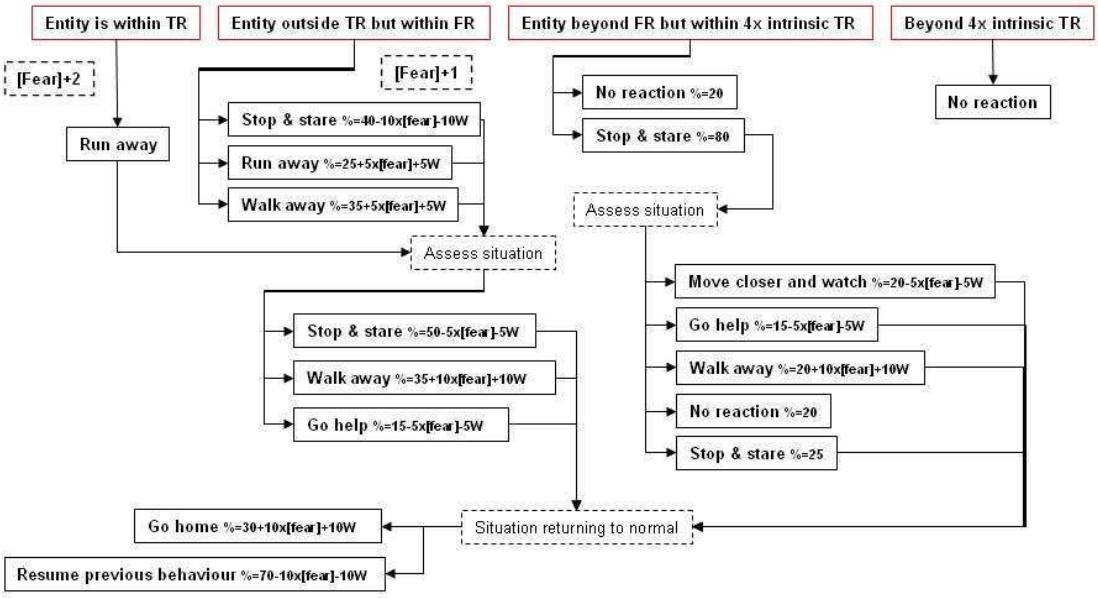

Figure 18: Flee Explosion Chart.

4.2.2.3 Flee Bullets

None of the videos showed the psychological impact of bullets landing near civilians. This behaviour is thus somewhat arbitrary as no data were used to support it.

In CAMX, pedestrians and animals always flee away from the shooter's location if located within 300 m. Beyond that threshold they flee the bullet impact location itself. The flee bullet behaviour is only triggered when:

1. The shooter is too far away to react to him directly[25] and;

2. A bullet lands near an entity.

[25] This distance depends on the intrinsic TR of the munition fired and the fear level of the entity.

Since echo is not supported by any of the simulations, CAMX entities always locate the shooter with pinpoint accuracy if within 300 m. Beyond that threshold the localization is impossible hence why they flee the bullet impact location.

Figure 19 shows the *Flee Bullet* behaviour chart.

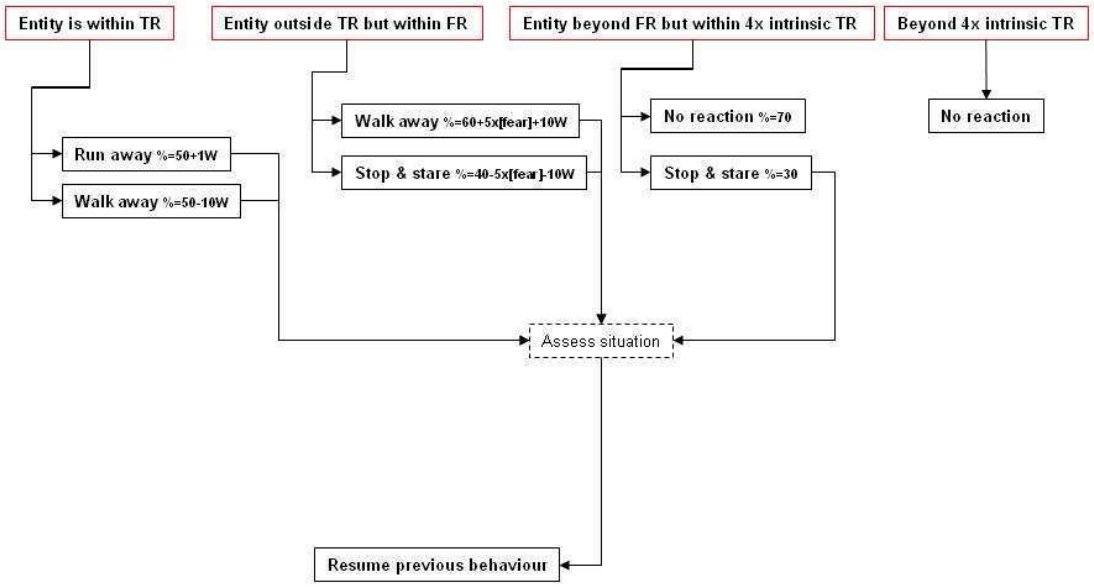

Figure 19: Flee Bullet Chart.

4.2.2.4 Avoid Vehicle

Pedestrians move away from vehicle traffic, but only from vehicles external to CAMX.[26] This ensures collisions are rare but still remain a possibility. CAMX entities are "intelligent" enough to know when to walk or run out of the way. Annex D depicts the algorithm used by pedestrians to avoid collisions with external vehicles.

4.2.2.5 Avoid Exclusion Zones & [cars] Avoid Exclusion zones & [animals] Avoid Exclusion Zones

Exclusion zones are areas that CAMX entities are prevented from entering. They are placed by the operator to prevent traffic in very specific areas such as known mine fields the population would avoid at all cost, terrain features not displayed on the CAMX screen, or zones where civilians are kept off by local authorities.

[26] CAMX pedestrians do not avoid CAMX cars since CAMX cars will always stop for CAMX pedestrians. This however causes frequent traffic jams when pedestrians walk in the streets. This issue will be tackled in a future CAMX release.

CAMX entities are prevented from entering these zones at all times. Entities that need to cross these zones will simply go around. When these zones are superimposed onto existing entities, these entities will not leave the zone at once unlike the temporary *repulsion* behaviour, though once an entity leaves an exclusion zone (due to its movement [e.g., random walk]), it will not go back in. Exclusion zones are permanent (until deleted by the operator).

4.2.2.6 Avoid Entities & [cars] Avoid Pedestrians/Animals & [cars] Avoid Other Cars

CAMX entities try to keep a reasonable distance from each other in order to prevent collisions. This is managed by AI.Implant and acts as an omniscient brain in control of all movements by taking into account the size and velocity[27] of all CAMX entities. Since AI.Implant manages all path findings, it will always ensure collisions do not occur between its entities by altering their velocity within certain limits. If acceleration or deceleration is not enough, a change in orientation will be applied. This works well with internal entities.

However, when external entities are present, AI.Implant can only modify the behaviour of the CAMX entities. It cannot predict the other unit's movement with pinpoint accuracy. It is thus necessary to introduce additional behaviours to ensure collisions are avoided. This explains why the *avoid vehicle* behaviour is required.

This intrinsic avoidance behaviour is at the core of the CAMX engine and can only be altered minimally.[28]

4.2.2.7 Attitude Towards Blue/Red

This behaviour ensures a distance is kept between civilians and Blue soldiers, Blue vehicles, Red soldiers, and Red vehicles respectively. A low value indicates the civilian will tolerate that unit's presence up to within a distance equal to its value (in meters). If a Blue or Red unit comes within that distance, the CAMX entity will move away from it. Four different values can be entered, one for each category.

This behaviour allows Red units to hide in a pro-Red civilian crowd if a low value is used. Blue units can see they are not welcome in a village if all civilians move away form them (i.e., large value). This behaviour also ensures civilians do not stand too close to stationary (i.e., parked) Blue and Red vehicles (vehicles on the move will trigger the *avoid vehicle* behaviour which is more elaborate).

Some interviewees reported in Annex A that the stance adopted by soldiers greatly influences the attitude of the local population towards them. Unfortunately, the attitude parameter in CAMX is static and does not fluctuate depending on Blue or Red's actions unless changed manually.

[27] The word *velocity* implies a direction and a magnitude.
[28] Changes to acceleration and deceleration factors are possible, but values must be kept within the realm of reality.

4.2.2.8 Curiosity Towards Military/Police Units and VIPs

Police/Military units and police/military vehicles often attract the attention of surrounding individuals, especially when emergency lights are turned on, or when the siren is in use (for police cruisers). This passive curiosity is universal and affects pedestrians. The USSS requested this behaviour be present in CAMX to ensure its entities would mimic what is observed in every-day situations.

The behaviour here only concerns the temporary passive (i.e., not triggered by the operator) curiosity triggered by the mere presence of police/military units, police/military vehicles, and VIPs near CAMX pedestrians. For specific police activities (i.e., arrest), the *forced curiosity* behaviour should be used. Note that VIPs must be identified as such by the CAMX operator by simply attaching a VIP tag onto the target entities. This can be attached to both internal and external agents of any type (animal, pedestrian, or vehicle).

- Condition: VIP nearby
- Effect Radius: 35 m
- Probability of curiosity: From 35% @ 0 m to 0% @ 35 m (linear decrease)
- Effect: Pedestrians will turn their bodies towards the specific entity for up to 30 seconds

If multiple triggers are present (e.g., multiple VIPs), only the closest one will trigger the behaviour. If a new VIP gets closer or the former one moves away so that a new VIP is closer, the check for curiosity will be done again.

The parameters of this behaviour are not based on any scientific observation. They are merely based on USSS observations shared with the authors and statements from Annex A regarding the curiosity and indifference observed in conflict areas.

4.2.2.9 [animals] Flee Explosion/Shooter

Many animals seem to be startled by sound. Explosions and gun shots thus have an impact on their behaviour.

Animals were given similar *flee explosion/flee shooter* behaviours as pedestrians with the exception that they do not exhibit any curiosity behaviours. They only run or walk away from events. Animals do not have a fear level either so their reactions are always the same. In no case do they "assess the situation" either. Note that animals never return to their original location after such an event. They remain scattered and automatically enter a random walk mode after the event.

Figure 20 shows the *Animal Flee Explosion/Shooter* behaviour chart.

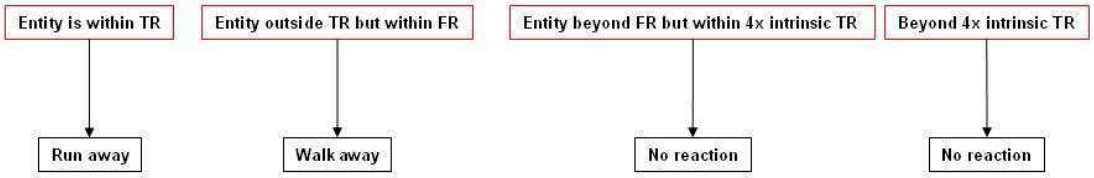

Figure 20: Animal Flee Explosion/Shooter Chart.

4.2.2.10 [animals] Flee Bullets

Animals were given a *flee bullet* behaviour similar to that of pedestrians with the exception that they do not exhibit any curiosity behaviours and the magnitude of their actions is much diminished. They only walk away slightly from events. Animals do not have a fear level either so their reactions are always the same. In no case do they "assess the situation" either. Animals never return to their original location after a nearby bullet impact. They remain scattered.

Figure 21 shows the *Animal Fleet Bullet* Behaviour chart.

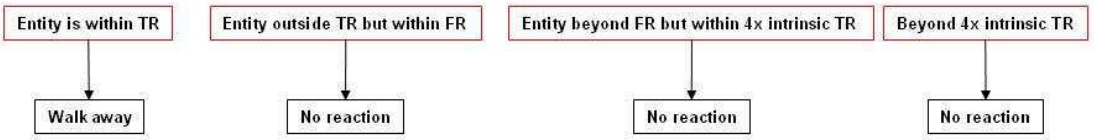

Figure 21: Animal Flee Bullet Chart.

4.2.2.11 [animals] Avoid Entities

This behaviour is controlled by CAMX's AI.Implant brain and is similar to the a*void entities* behaviour.

Not much effort was put into animal behaviours as animals do not play a significant role in military and police simulations. That being said, DLSE once had explicit requirements for goat behaviours for a given exercise. Since animals were originally created with human behaviours, they moved out of the way of vehicles. One vignette called for an ambush where a convoy had to be stopped by a herd of goats. Goats (and all other animals[29]) were thus made unafraid of being hit by vehicles and therefore do not move out of the way. While vehicle horns should have an impact on animals, they currently do not.[30]

[29] All animals share the same behaviours.

[30] Ultimately, one would tie the horn of VBS2 vehicles to invisible and non-lethal "munitions" when activated. These munition events would be received by CAMX through standard communication protocols between simulations and trigger the dispersal of animals startled by the sound. There is no existing direct mechanism right now to send the information from VBS2 to CAMX other than using these fake munition signals to trigger a behaviour. Incidentally, this method is used by CT-Analyst to communicate with CAMX.

4.2.2.12 [cars] Flee Explosions/Shooters/Bullets

Only one video clearly showed a car in movement and its reaction to an explosion. It drove away without hitting pedestrians. It seemed to go as fast as traffic allowed.

In CAMX, drivers will react if a shooter is nearby, if their vehicle is hit by bullets, or if a nearby explosion occurs. Note that bullet impacts around them will not trigger the behaviour. Only direct hits will.

- Trigger Radius**:** TR of the munition
- Flee Radius**:** Depends on the munition
- Effect**:** Cars will leave the area

4.2.2.13 [cars] Pull Over if Military Convoy in Sight

This behaviour was requested by DLSE to fully mimic North Atlantic Treaty Organization-imposed behaviours for Afghan drivers. When a military convoy is in sight, drivers must pull over temporarily to let it pass. They can in no circumstances overtake a convoy either.

- Trigger Distance**:** 200 m
- Effect**:** Car slows down, pulls over and stops until the convoy is more than 200 m away

4.2.2.14 Conversation

When two CAMX entities end their movement near one another, there is a possibility that they will face each other in order to simulate a conversation. Otherwise, they just chose a random orientation. This behaviour is overridden by almost all other behaviours in order to ensure it only happens if the entities do not have anything else worth doing.

When one entity ends its random movement within 2 m of another entity, there is a chance they will both turn towards another.

- Range: 2 m
- Probability: 15% per individual
- Conversation time: Until one of the entities decides to move to a new location[31]

[31] If the entity was walking randomly within a zone, its conversation time is set by a zone parameter. If the entity was walking randomly on the entire map, its conversation time is set by a global parameter. These time delays typically range from a few seconds to (but not limited to) 60 seconds.

4.3 Priority of Action

Behaviours and actions within behaviours need to be prioritized. Some behaviours are important on some occasions and not at all on others. For example, while a pedestrian will most probably check for cars before crossing a street in every-day life, if he is running for his life because of a nearby shooter (*flee shooter* behaviour), he will not bother checking both sides of the street (*avoid car* behaviour) anymore before crossing it. The relative importance of the *avoid car* behaviour thus depends on current events.

In essence, CAMX entities react to the most dangerous event based on the nature of the event and quite significantly on the distance to the event.

Table 4 shows all pedestrian behaviours in order of priority. Here, a high priority means a low number. Thus the behaviours set at priority level one will never be interrupted by any other behaviour. The behaviour at the bottom of the table (low priority, high number) will always be interrupted if a new behaviour is triggered.

For complex behaviours that affect people differently based on distance, each portion of the behaviour is given a different priority. This is required as, for example, people close to an explosion would run away without paying attention to cars while those further away, curious about the event, would pay attention to cars before crossing a street to get a better vantage point.

The nomenclature used for complex behaviours to set the different priorities is as follows: *behaviour 1st column* is for the entities closest to the event (i.e., the first column of a behaviour chart), *behaviour 2nd column* is for the next closest, up to *behaviour 3rd column* for the further ones. The 4th column of complex behaviours is always *no reaction* and is therefore not ranked.

If a priority *x+n* behaviour (where *x* is the priority rank and *n >= 1*) is triggered while entities are performing a priority *x* behaviour, there will be no change in behaviour. If a priority *x-n* behaviour is triggered, the entities will act upon it and will cancel their previous behaviour permanently or temporarily depending on the nature of the original behaviour.

Table 4: Prioritization of Pedestrian Behaviours.

Behaviour	Priority
Avoid exclusion zones	1
Master Go To: *Run*	2
Master Go To: *Walk*	3
Flee Shooter 1st column	4
Flee Explosion 1st column	5

Behaviour	Priority
Flee Bullets 1st column	6
Avoid oncoming cars	7
Repulsion	8
Flee Shooter 2nd column	9
Flee Bullets 2nd column	10
Flee Explosion 2nd column	11
Attitude towards Blue/Red	12
Forced curiosity: *Strong*	13
Forced curiosity: *Medium*	14
Forced curiosity: *Weak*	15
Flee Shooter 3rd column	16
Flee Bullets 3rd column	17
Flee Explosion 3rd column	18
Follow Entity	19
Curiosity Towards Police	20
Normal Go To	21
Conversation	22
Wander in World/Zone	23

Of note in Table 4:

- The multiple appearance of *Flee Shooter/Explosion/Bullets* because of their complexity.

- *Flee Explosion* and *Flee Bullets* switch positions for low-threat levels. Bullets imply an active shooter (i.e., continuous threat). Explosions are rather discrete events. At close range explosions have a much bigger psychological impact, hence their higher priority.

- Exclusion zones are respected at all times because they sometimes represent impassable terrain features that were not originally present on the terrain and had to be added manually by the CAMX operator. This also applies to cars and animals (see tables below).

- When a Go To command is triggered by the operator (master or normal), its priority is temporarily set to 1 to ensure the command is obeyed. It then drops to its intrinsic priority immediately after the order.

Table 5 shows the prioritization of vehicle behaviours.

Table 5: Prioritization of Vehicle Behaviours.

Behaviour	Priority
Avoid Exclusion Zone	1
Avoid Pedestrians	2
Avoid other cars	3
Flee Explosion/Shooter/Bullets	4
Pull over if military convoy in sight	5
Normal Go To	21
Wander in World/Zone	23

Table 6 shows the prioritization of animal behaviours.

Table 6: Prioritization of animal behaviours.

Behaviour	Priority
Avoid Exclusion Zone	1
Master Go To: *Run*	2

Behaviour	Priority
Master Go To: *Walk*	3
Flee Explosion/Shooter	4
Flee Bullet	5
Forced curiosity: *Strong*	13
Forced curiosity: *Medium*	14
Forced curiosity: *Weak*	15
Follow Entity	19
Normal Go To	21
Wander in World/Zone	23

As with pedestrians, the Normal and Master Go To commands have their priorities temporarily set to 1 to ensure the commands are obeyed before they drop to their intrinsic priorities.

4.4 Atmosphere

The videos tended to show that an *atmosphere* characterizes the general state of mind (i.e., the overall mood) of civilians. In a peacetime environment, people tend to react less to explosions or shootings when they first occur. They seem more likely to be curious and just stand and stare at the event as shown clearly by the Olympic Park Bombing. Only people very close to the actual event seem to react strongly and flee.

CAMX allows the user to set the overall atmosphere, or conflict intensity, of the scenario about to be played. This has a direct impact on the probability of occurrence of certain actions. For example, curiosity is much more prevalent in a peacetime environment. During wartime, it is potentially rare at best. Five levels of atmospheres are thus used. Each level impacts civilian emotions which in turn modifies the probability of occurrence of certain actions. The only emotion currently in CAMX is *fear*. A high fear level makes entities more susceptible to fleeing dramatic events (and with increased magnitude) and also less susceptible to curiosity towards these events by increasing or decreasing probabilities appropriately. For example, entities that are fearful are not only more prone to running, they also run farther than those who are not fearful. The CAMX fear level will thus increase the probability of the *run away* action and make the entity run a longer distance. The behaviour charts of Section 4.2 show the impact of fear

explicitly. The fear level of a given entity is limited to -2 for the low end (i.e., less scared) and +2 for the high end (i.e., easily scared).

The atmosphere allows the CAMX controller to modify the mood of all entities at once. This is a global setting that affects all entities equally and is usually set at the very beginning of a simulation (and is rarely changed during one). Table 7 shows the five atmospheres and their associated initial fear levels.

Table 7: Atmosphere initial fear levels.

Atmosphere	**Emotion**
	Fear
Peacetime (similar to Canada)	-2
Stability	-1
Tension/Instability (similar to Israel or Pakistan)	0
Irregular Warfare (similar to Afghanistan)	+1
Wartime	+2

The atmosphere could potentially affect multiple emotions which would all impact behaviours in CAMX. Fear was the most obvious first choice hence explaining why it was selected. One must be careful not incorporate too many emotions without an appropriate level of research, since the end result could be unexpected or exaggerated, especially if modifiers tend to cancel each other out or if they all "push" in one direction. It would also make management of behaviours more difficult. The primary objective is to represent relevant *collective* behaviours, not individual emotions.

4.5 Missing Behaviours

There are many more behaviours that would make civilian activity more realistic in simulations than those described in this paper. Many reasons explain their omission, though technical difficulties explain the majority of them. One must keep in mind that CAMX entities are kept as dumb as possible to allow for a large number of entities being simulated at the same time. While many more behaviours could be implemented, one must not forget that high population numbers and densities are crucial. For this reason, some noteworthy behaviours were discarded on purpose because they were deemed too resource-hungry or it was determined that they would require too much effort to implement compared to the benefits they provide. Only those deemed important are discussed in this section. The list is mostly based on past requests from users but also on the

universality of the behaviour. Behaviours that are not location or culture dependant are usually deemed important enough to be included as they could potentially benefit many users. The following behaviours are not currently in CAMX but might be implemented in the future because of their significance. They are discussed in alphabetical order.

Contagion: In some videos it was observed that some individuals would mimic the behaviours of the surrounding crowd. This behaviour was quite obvious when a wave of people moved in unison; those caught by the wave would just follow it and make it bigger. While contagion of behaviours is a known reality, it is quite a challenge to code efficiently without stealing precious computing cycles. For this reason, it was decided not to implement contagion in CAMX. Therefore, entities in CAMX do not influence surrounding entities in any way behaviour-wise, except for path finding and collision avoidance.

Enhanced curiosity (children): Annex A reports that children of all cultures are quite curious about foreign armies. Staring at a distance is ubiquitous, as is following the soldiers around, especially if they are known to carry candies (which was sometimes the case in Afghanistan). CAMX children do not exhibit this curiosity.

Family/Group ties: People that know each other or are part of a specific affiliation tend to react as a group. This link is particularly strong when children and adults are involved; adults do not leave injured children behind. In CAMX, all entities are independent. Therefore, children that are injured are not saved nor carried by relatives as they have none. This behaviour was discarded since there are currently no animations for tending the injured or for carrying fallen comrades. This alone limits the benefits of this behaviour. However, the effect of group ties is visible in other more mundane actions or events like walking to a preset destination as a group. In this case, a group tie would be observed readily among the entities. Combined with an improved chance of conversation within the group, the effect would convey a sense of relationship between the entities. This has not been implemented yet.

Go prone: While going prone is a typical soldier's reaction to gun shots and explosions, it is not at all inherent to civilians. None of the videos showed this action, nor was it ever witnessed by soldiers interviewed in Annex A.

Reaction to drawn weapons: CAMX entities do not react to the exposure of weapons, even those aimed right at them. If deemed necessary by the users' community, the appropriate behaviour could be added in the future.

Running (children): Children are commonly seen running in just about all cultures. This behaviour is absent in CAMX even though it is universal.

Take cover: CAMX entities do not look for cover to protect themselves from danger. While cars and buildings are omnipresent in military simulations (especially in urban environments where civilians are ubiquitous), they are not recognized as beneficial to CAMX entities. It was found that "looking for cover" would be a somewhat resource-hungry operation. Moreover, the entities would have to be "intelligent" enough to use cover properly (by positioning themselves away from the danger on the right side of the cover). Additionally, some covers are shorter than

individuals and CAMX entities cannot crouch properly.[32] While the *take cover* behaviour would greatly enhance CAMX, it was left aside until it becomes a necessity.

In its absence, CAMX entities behind cover will not react less to some events contrary to what was shown in some videos. Without the perception of cover, all entities within a given radius react about the same, even if intervening objects offer total protection.

Walk on sidewalks: Surprisingly, CAMX entities do not recognize sidewalks as they were never present on any map used in the early days of CAMX. For years, most of the training took place in synthetic environments similar to Afghanistan where sidewalks were the exception rather than the norm. There was thus no requirement for this capability. With the USSS involved, it might become essential as training is done exclusively in well-built urban environments. If so, a new behaviour will need to be created as long as sidewalks can be added to CAMX maps and recognized as special features to interact with. Until then, objective zones can be used to restrict civilian movements if shaped appropriately.

4.6 Missing Visual Cues

Nearly all videos showed that people tend to lower their head and sometimes cover it with their arms when explosions or gun shots are heard. It would seem to be instinctive, irrespective of culture, age or gender.

Unfortunately, these animations cannot be triggered through DIS. They do not exist in VBS2 either. It is thus impossible to recreate them with CAMX entities. Listed below are some animations that would enhance civilian activity if they existed and could be triggered. Disclosing this limitation is mandatory to ensure proper use. They are discussed here either because users have requested them or they were observed regularly in the videos of Section 3.2 or reported in Annex A.

Duck while running: There is only one way to run in VBS2: head-up. It is simply impossible to have entities run with their heads down or with their arms protecting their head for extra protection.

Hands to the head or to the mouth: CAMX entities cannot put their hands to their head to display shock or disbelief when confronted to dramatic events, or to their mouth to show disbelief, despair, or sadness.

Hold family member: CAMX entities cannot hug each other to display affection or the protection instinct of adults towards children when danger arises.

Hold hands: CAMX entities to do not hold hands to show relationships between individuals.

Raise fist in the air: CAMX entities cannot raise their fists to show defiance.

[32] This limitation is imposed by VBS2 and only affects civilians external to VBS2 like those from CAMX.

Raise hands: CAMX entities cannot raise their hands in the air to show compliance to a shooter. This behaviour was displayed by a few individuals in the Mexico Metro shooting instead of fleeing the shooter.

Tending the injured: Most videos showed that the injured are tended to very quickly, sometimes instantly when children and parents are involved. Though this action exists with VBS2 players, it is not possible with CAMX as there is no way one can trigger the animation through DIS. While CAMX entities can walk or run towards the injured, they cannot tend to them or pick them up to move them to safety.

Throw rocks: In VBS2, if a player plays the role of a civilian, he can throw rocks to show discontent. CAMX entities cannot throw rocks as this action cannot be triggered through DIS.

4.7 Sounds

In addition to images, sound can play a crucial role in immersing a player. VBS2 is fully equipped to play sounds related to military assets such as gun shots and vehicle engines, but also crowds of people to an extent. The only sound pertaining to civilians is that of an angry crowd which works great for demonstrators. There are unfortunately no sounds to support fleeing crowds or just casual conversations.

Videos of civilians fleeing dangerous events all showed that people tend to scream in fear or disbelief, sometimes rage. The collapse of the Indiana State Fair stage and the World Trade Center tower collapses (not discussed in this paper) clearly showed individuals yelling and screaming in disbelief. It would appear that when women are present, a lot more screams can be heard if panic takes place.

The Syrian videos showed similar results. Some crowds composed of men exclusively (based on initial pre-shooting screams) fled in total silence when confronted to danger. However, these videos involved shooters instead of an explosion which could explain the difference.

Sounds should be used and linked to certain behaviours to enhance their realism. Unfortunately, it is not possible to trigger sounds in VBS2 through DIS from CAMX. There is thus no way to enhance the realism of the simulation using sounds typical of civilian crowds, unless a protest is simulated. Until it is feasible, this aspect will not be investigated further. CAMX civilians will thus always flee in silence.

The impact of this is of course negligible for drivers and helicopter pilots, who are enclosed in a noisy environment masking outside crowd noises.

5 Injury and Damage Assessment

CAMX pedestrians, animals, and vehicles can be injured or damaged multiple ways. They can be targeted by VBS2 or JCATS shooters or be the victim of collateral damage. Pedestrians and animals can also be injured or killed if hit by vehicles. To follow usage in simulation terminology, the term "damage" will now be used to refer to injuries, material damage or death indiscriminately.

In a DIS federation, the simulation from which the shot originates is always in charge of determining the probability of hit (PH). It then passes the hit information to the simulation that owns the target to let it apply damage. Simulations like CAMX, VBS2 and JCATS are therefore always in control of their entities when it comes to assigning damage. Since CAMX is never on the shooting end, it strictly waits for incoming munition events (i.e., hits). These events contain information on the munition, the location of the hit (on the map), and the shooter's location among many things. CAMX uses this information to trigger behaviours and assign damage.

The following subsections discuss how CAMX applies damage resulting from combat (direct or indirect fires), from collisions involving vehicles, from toxic gases, and how this damage is displayed on the screen.

5.1 Combat damage

5.1.1 Direct Fires

The probability of kill (PK) associated to direct-fire munitions is based on the work already done for JCATS, summarized in [8]. Munitions are assigned a "calibre" (small, medium, or large) that determines their psychological impact when used near civilians, as well as a PK against vehicles and pedestrians.[33] The list of munitions and their parameters appears in Annex B.

For simplicity, all munitions grouped within a given calibre class share the same PK against pedestrians and cars respectively.

The PK values are all 100% against civilians. Injury or death will occur automatically given a hit. Against vehicles, PK values are lower, especially for small-calibre bullets (anything below 12.7 mm).[34] Multiple shots are therefore required in order to disable civilian cars with high probabilities. Also, all PKs are based on hits aimed at the center of a target which explains furthermore some low PK values (e.g., key zones like tires or the engine are not aimed at

[33] Animals fall under the pedestrian category as far as damage is concerned.
[34] PK in CAMX is based on single shots. While 100% compatible with VBS2, it is not fully compatible with JCATS, which fires bursts. If ammunitions consumption studies are ever conducted in JCATS with CAMX civilians as targets, results will be skewed towards high consumption (i.e., a burst would be fired but the PK of a single shot would be applied).

specifically).[35] Note that CAMX does not differentiate between vehicle models, types or size for the damage model. All vehicles make use of the same probabilities.

Finally, if PK is successful (i.e., damage is dealt), the resulting damage is either a mobility kill (MK) or a catastrophic kill (KK) irrespective of the munition.[36] MK and KK were set arbitrarily to 70% and 30% respectively for all CAMX entities (cars, pedestrians and animals). These states are defined in Section 5.3.2. Hits on an entity already suffering from an MK will not automatically cause a KK. Damage assessment does not depend on the current health status of the target.

Direct-fire munitions are presented in Annex B. They are an updated version of what was presented in [4].

5.1.2 Indirect Fires

The lethality associated to indirect-fire munitions is based on the work done for JCATS [9].

The indirect-fire munitions were arbitrarily grouped into 3 categories (small, medium, and large) for the psychological impact (i.e., behaviours) and damage. While the psychological effects and damage most often use the exact same category, some munitions use two distinct ones. For example, a grenade has a Medium psychological impact but has a Small damage category.

As with direct-fire munitions, damage is the same irrespective of the munition and the target (pedestrian, animal, and vehicle). It is arbitrarily set to 70% MK and 30% KK. These states are defined in Section 5.3.2. As with direct-fire munitions, the previous health state of a target has no impact on the next given a hit.

Indirect-fire munitions are presented in Annex C. They are an updated version of what was presented in [4].

5.2 Vehicle-Vehicle Casualty Model

This section discusses the casualty model that involves the collision of CAMX vehicles with JCATS or VBS2 vehicles, as a function of the vehicles' relative speed at impact. While the AI driving CAMX vehicles will avoid collisions at all cost (within realistic physical limits), it cannot predict the behaviour of external vehicles. Collisions with external vehicles are thus a possibility. However, collisions between two CAMX vehicles are not possible as the path finding algorithm in charge of CAMX vehicles will always ensure a collision free environment.

When collisions happen with an external vehicle:

[35] The aim of VBS2 players plays no role in the damage assessment part in CAMX as hit location on a target is not communicated by DIS.
[36] The terms mobility kill and catastrophic kill are ubiquitous to all military simulations. While the terms are used mostly for military vehicles they also apply to living entities.

1. CAMX vehicles will only sustain an MK if they are hit by an external vehicle. KKs were removed from the possible outcomes as the vehicles would show up in flames in VBS2 every time. This was not deemed representative of standard collisions.

2. VBS2 and JCATS decide on the damage outcome of their own vehicle if hit by a CAMX vehicle as the simulation that owns the victim always decide of its fate. The CAMX collision model plays no role at all.

3. The collision model does not take into account the weight and shape of the vehicles involved.

4. The collision model does not take into account the angle of collision. Front, rear and side hits all have the same damage probability and outcome for a given relative speed.

The probability of sustaining damage is only a function of the relative speed of the vehicles. They are presented in Table 8.

Table 8: CAMX vehicle damage model

Relative Speed (km/h)	Damage Probability
0-30	0%
31-40	20%
41-50	40%
51-60	60%
61-70	80%
70 +	100%

The current collision model for CAMX vehicles is quite crude as vehicles were never a priority in military simulations. The data in Table 8 are not based on any real statistics and are pure speculation by the authors. They do however give the desired in-game effect. Note that as with any other CAMX features, the speeds and probabilities can be changed if better data are obtained.

5.3 Vehicle-Pedestrian Casualty Model

In a typical simulation, players expect that CAMX entities will react appropriately to military and police forces and to other civilians as well. For example, pedestrians are expected to avoid vehicles when they cross the streets. Similarly, cars are expected not to hit pedestrians that are in

their way, and to avoid hitting other vehicles as well.[37] JCATS/VBS2 vehicles can hit CAMX pedestrians since the driver, played by a human, can always intentionally direct his vehicle towards CAMX pedestrians.

The following subsections describe the vehicle-pedestrian casualty model in detail when CAMX pedestrians are hit by external vehicles.

5.3.1 Pedestrian Survivability

When a pedestrian is hit by a car, CAMX must determine if the pedestrian was injured.

There is only one condition that establishes if a physical interaction between a pedestrian and a car actually qualifies as a collision:

1. The vehicle must be moving.

A few parameters are not taken into account in the collision model. They are:

1. The mass of the vehicle
2. The shape of the vehicle
3. Gender, age and shape of the pedestrian
4. Angle of collision

From a pedestrian safety strategy point of view, mass (point #1) and shape (point #2) are irrelevant compared to vehicle speed in casualty counts. Speed limits are much easier to impose than a country/province-wide vehicle shape and vehicle mass regulation. Studies [10] and [11] (and references therein) did not record the mass and the shape of the vehicles involved in collisions to derive injury statistics. Point #3 was also rejected since it was not seen as relevant enough in the context that CAMX is expected to be used.

Point #4 will undoubtedly increase the number of fatalities for pedestrians that are sideswiped. This approach is much easier to implement in CAMX. Vehicle speed is thus critical in all impacts since it alone is used to determine the probability of survival, injury, or death.

It is important to note here that CAMX is mostly used in military simulations and that the average mass of military vehicles is much higher than that of a typical civilian car. Any data extracted from collisions involving civilian cars might not be appropriate for military simulation though they might be adequate for civilian applications (i.e., USSS). However, CAMX's role is not to model traffic accidents accurately. Unless military JCATS/VBS2 players drive over pedestrians

[37] As noted earlier, collisions between CAMX entities are impossible as the path finding algorithm will always prevent it. As a result, CAMX vehicles will never hit CAMX pedestrians. On top of the path finding, CAMX vehicles and pedestrians are provided with the *avoid pedestrians* and *avoid cars* behaviours respectively against external entities to ensure realistic avoidance behaviours if a collision were to involve a CAMX car and a VBS2/JCATS unit.

on purpose, one should expect collisions to be somewhat rare. That being said, collisions must be implemented as their absence contributes significantly to the loss of the immersion feeling of the trainee.

5.3.2 Health status of CAMX entities and its real-world counterpart

The United Kingdom (UK) Government uses three states to characterize injuries to pedestrians after a collision with a vehicle. They are (taken directly from [10]):

Slight Injuries

- Sprains;
- Neck whiplash;
- Bruises;
- Slight cuts;
- Slight shock.

Serious Injuries

- Fracture of bone;
- Internal injury;
- Severe cuts;
- Concussions;
- Severe shock.

Fatal Injuries

- Include all deaths that happen within 30 days of a collision.

Three health states are possible for CAMX pedestrians and animals.

1. **Healthy**: The entity is alive and able to move on its own. It can suffer from light injuries that do not affect its mobility and its ability to sense its environment.
2. **Mobility Kill (MK)**: The entity suffers from injuries that prevent it from moving on its own. It could be due to injuries to its legs, head, or some serious injury to other body parts that cause enough pain to warrant immobilization.
3. **Catastrophic Kill (KK)**: The entity is dead or severely wounded.

CAMX's three health states were thus associated to the UK Government's three states on a one-to-one basis because of their resemblance. Section 5.5 shows a visual representation of these health states.

5.3.3 Probability of injury

Table 9 shows the probability of injury as a function of impact speed. All three types of injuries are shown. It is clear that low impact speeds (< 20 km/h) result in slight injuries almost exclusively. At high velocities (> 60 km/h), fatality is almost certain.

Table 9: Probability of injury function of speed

	Injury Type (%)		
Speed (km/h)[a]	**Slight/Healthy**	**Serious/MK**	**Fatal/KK**
0-10	100	0	0
11-20	92	8	0
21-30	75	23	2
31-40	33	63	4
41-50	20	70	10
51-60	10	50	40
61-70	0	5	95
71+	0	0	100

[a] Reference [10] has data up to 80 km/h. Since 100% fatality was reached before those speeds, for CAMX purposes, 100% is used for all collisions beyond 71 km/h.

Unlike in the real world, impact speeds in a simulation can be obtained with high precision. Real-world impact speeds are approximate at best since often times they are estimated from witness accounts, brake marks (if present) and other less-than-ideal means [10]. Because of the aforementioned reasons, it is quite probable that speeds found in [10] are inaccurate. They are however adequate for CAMX's purposes.

During a collision, CAMX will read the vehicle's speed and use the probabilities of Table 9 to determine randomly which injury is applied. Note that JCATS and VBS2 have their own collision model when their pedestrians are hit by vehicles or when their vehicles hit CAMX pedestrians.

5.4 Health effects due to toxic gases

All health effects due to toxic gases are managed by the Naval Research Lab's CT-Analyst tool. In a nutshell, CT-Analyst mimics the effect of plume dispersion in the synthetic environment based on wind currents and obstacle location, as well as determining the intake of toxic gases for all CAMX-controlled entities (pedestrians, animals, vehicles [i.e., drivers]). When CT-Analyst determines that CAMX civilians are exposed to threshold doses, it sends CAMX commands to trigger health effects. The data used to drive CT-Analyst are not disclosed because of their sensitive nature. Because of the limited health states supported by CAMX (and the inability to trigger appropriate animations in VBS2 through DIS), CAMX acts as a high-density, low-fidelity civilian generator when running with CT-Analyst.

The possible health states are presented in Table 10.

Table 10: CAMX health states

Health State	Animation
Alive	Upright (walking, running, standing still or on the ground, head up, no blood showing)
Affected by gases	On the ground*, head still up; blood showing.
Unconscious/dead	On the ground, head down; blood showing.

*Except children: there is no animation for injured/affected children in VBS2. They thus stay upright with blood on their clothes.

5.5 Display of health state

DIS, the language used to communicate fire events and damage states (among many things) between simulations, only supports a limited number of damage states. Additionally, VBS2 has a limited number of animations for damaged entities. Therefore, when CAMX civilians are injured, their avatar, as seen in VBS2, becomes that of a bloodied downed civilian with their head up. Dead entities are similar but heads down. Blood is always present for injured and dead entities irrespective of the cause of death or injury. There is no animation for injured entities still standing up. Figure 22 shows an example of all three states (dead, injured, and alive).

Figure 22: DIS-supported health statuses. From left to right: dead, injured, alive and well.

Unfortunately, the situation is worse for children and animals. Animations do not exist for injured children and injured animals. These entities, when injured, just stand up, indistinguishable from healthy ones, except for the blood stains and the fact that they do not move at all (Figure 23). The total lack of movement is regrettable as they look alive from a distance and often trigger questioning as to why they do not react to surrounding events.

Figure 23: Two children. The one on the left is injured while the one on the right is healthy.

The different health statuses for cars are quite obvious. Vehicles that suffer a KK catch on fire. Vehicles that suffer an MK get darker and stop. Undamaged vehicles have their full color. Figure 24 shows the three states supported by CAMX.

Figure 24: DIS-supported health statuses. From left to right: KK,MK, undamaged.

5.6 Discussion

The damage model used for CAMX, though limited, is adequate for purpose. Even though collisions, inhalation of toxic gases, and the targeting of civilians with military weapons usually do not play a critical role in simulations, appropriate outcomes are essential since non realistic events will distract the trainee, which must be avoided as much as possible.

When injuries are possible, the players' behaviours change. For example, with collisions enabled, human drivers tend to be more careful during their training in virtual urban environments, potentially as careful as they would if operating the same vehicles in real life. This enhances the realism of simulations and forces drivers to avoid collateral damage.

6 Discussion and Conclusion

This paper presented the procedures used to construct CAMX behaviours in a military context that is also relevant to police forces. This document takes precedence over all previous CAMX documents ([1] and [4]) and should be seen as representative of the inner workings of the tool. While numerical values might be subject to change, the layout of behaviours, or any other algorithm will not vary significantly.

Army requirements -- training

CAMX was built with focus on civilian reactions to battlefield events and the presence of Blue and Red forces. Nowadays, focus has shifted to non descript locations with mass movement of refugees, often times involving generic crowds. CAMX is perfectly suited for these settings.

Future improvements to CAMX will most probably involve time-based behaviours that characterize common routines such as civilians leaving their homes in the morning to go to work and returning in the evening. CAMX in its current state is actually ready for the implementation of such behaviours as generator zones and objective zones already exist. Only the time parameter would need to be implemented.

Army requirements -- experimentation

CAMX is perfectly suited for adding civilian clutter when lively environments are required, such as markets and dense city streets. It is quite appropriate for experiments that require continuous distractions that hamper the detection, recognition, and identification process that soldiers are familiar with. In March 2012, the Army Experimentation Centre at Canadian Forces Base Kingston hosted the Networked Soldier System Project experiment (NSSP) [12]. CAMX was critical to the NSSP experiment as future Blue positional awareness and Blue identification tools were tested. Without the elaborate civilian activity that CAMX permitted (i.e., means to distract the trainee), the scope of the activity would have been greatly limited.

USSS requirements

The training context of the USSS is significantly different than the Army's. Initial interest was mostly in civilian reactions to toxic gases. While CAMX only plays a low-fidelity crowd, it plays enough civilians to bring the population to realistic densities or numbers during typical USSS scenarios. CAMX definitely brought new capabilities to the USSS as it can now generate realistic population numbers around protective sites in order to enhance the realism of scenarios and vignettes. Densely populated urban scenes with dynamic pedestrian behaviour are now possible.

Validation of CAMX

A comprehensive way to validate CAMX would be to recreate, in a synthetic environment, some of the videos that were analysed. The two videos discussed in Sections 3.2.5 and 3.2.6 (Syrian protests) seem simple enough to re-create. However, a single activity would not be enough. The tool needs to be validated from many perspectives. This undertaking might require some effort that is not currently possible.

A simpler way to validate CAMX is to arrange for subject matter experts to evaluate the tool directly and provide recommendations for improvement. During the NSSP experiment, soldiers were asked to try new devices that would enhance their situational awareness on the battlefield, mostly urban environments in this case. CAMX was used to populate towns with pedestrians, animals and cars where roads were present. Many times firefights and explosions erupted. The soldiers, many of whom had completed at least one tour in Afghanistan, commented that civilians fled "as expected", so much in fact that they used their behaviours to help them locate the enemy when possible. Since none of them complained about the other civilian behaviours throughout the activity, it also contributed in validating CAMX as an appropriate tool for simulating simple civilian activity for military and security applications.

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Annex A Civilian Activity

A.1 Introduction

From March to May 2009, interviews were conducted with CF officers to gather their observations of civilian populations in various theatres of operation. The activity, which began as an exploratory exercise consisting of unstructured interviews with a couple of officers, progressed beyond the researcher's expectations. The selection of additional candidates was made through word of mouth: at the end of a discussion, participants would often recommend some of their colleagues having had other experiences. A total of 15 officers, in service or retired, were interviewed, ranking from Corporal to Lieutenant-Colonel in the Land and Air Forces.

Table 11 shows the countries discussed in the course of the interviews, and how many participants provided significant comments on each. Figure A-25 displays the same information on a world map.

Table 11: Areas of the world discussed in the interviews. Each number shows how many of the 15 participants provided significant comments on each area.

Areas	No. of participants
Afghanistan	9
Bosnia and Herzegovina	6
Haiti	3
Canada	2
Democratic Republic of the Congo	1
Cyprus	1
Golan Heights	1
Honduras	1
Iraq	1
Pakistan	1
Sierra Leone	1

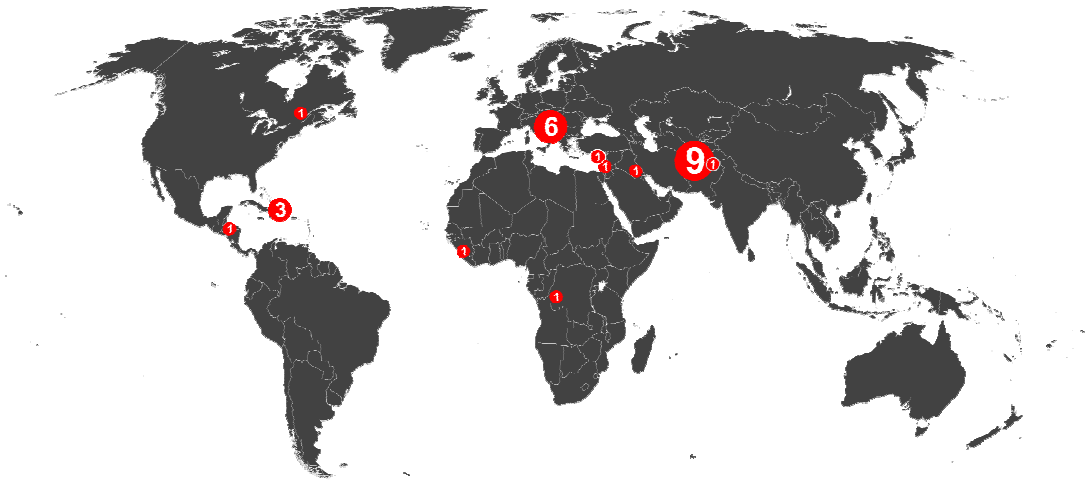

Figure A-25: World map showing the areas discussed in the interviews. The circles are proportional to how many participants provided significant comments on each location.

In general, participants' experiences were naturally biased towards the most recent operational deployments of the CF, including Afghanistan, Haïti and the Balkans. Several interview participants had also participated in various peace support and other observation missions, which expanded the number of countries covered.

The reason for adopting an unstructured approach in interviews was the undefined nature of the problem at the onset. The interest was in improving models of civilian activity for the purpose of military simulation. However it was not known in what ways civilian activity could concretely influence military decision-making, and on what scale or by what means civilian activity was assessed by officers in the field. With such an open question, deciding on a given interview framework appeared too arbitrary.

If unstructured interviews can provide more latitude at the time of collecting information, the analysis phase in counterpart requires additional effort in order to synthesize the content in a useful structure. Following iterated readings of the interview transcripts, several unifying themes appeared to dominate the material. These themes and their relative importance in terms of volume of transcribed material are summarized in Figure A-26. These themes are addressed in individual sections of this Annex.

The themes presented in Figure A-26 are shown as non-overlapping. This structure reflects how much source material went into building each separate section of this Annex. These themes however overlap conceptually. In a way this overlap is mostly addressed in the section on Civilian Activity Patterns, which integrate elements from all other sections and vignettes that were recurrent throughout the interviews. Whenever some remarks were of a general nature and not attached to the description of a specific pattern, they were grouped together to be used for dedicated sections.

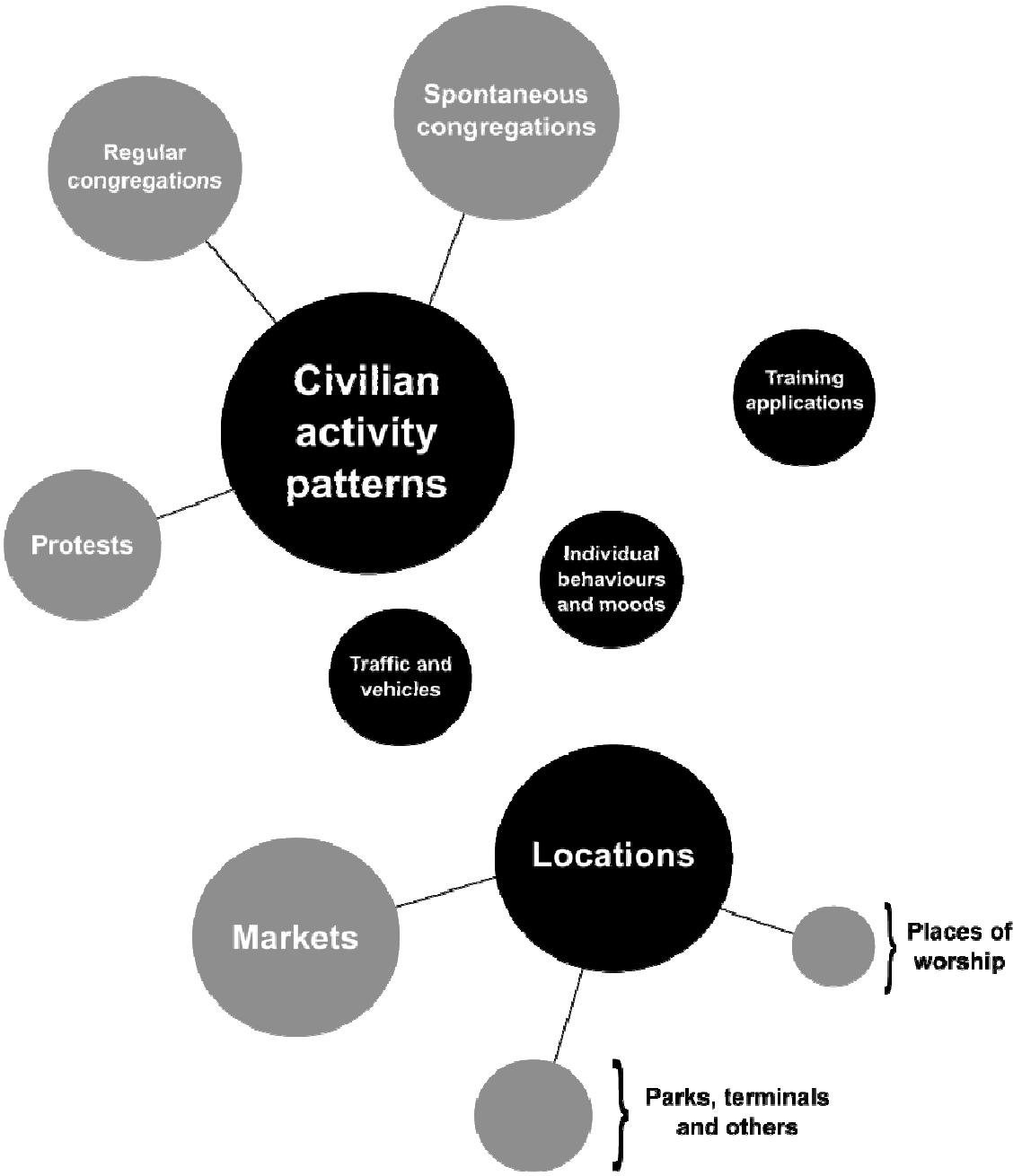

Figure A-26: Segmentation of the interview data in themes. Black circles represent the main themes. The most prominent of these are further expanded in sub-themes (grey circles). The circles' areas are proportional to the volume of transcribed discussions that covered each topic.

Caveats

This Annex should not be used as a reference on CF's Standard Operating Procedures (SOPs) or on Tactics, Techniques and Procedures (TTPs). SOPs were not surveyed in this study and

participants were not asked to frame their answers according to them. Similarly, TTPs were not explored. Moreover, the range of individual experiences surveyed covered a period from the early nineteen-nineties to the end of the last decade. While some CF SOPs have changed significantly during that period, the participants' remarks were not kept chronological. Overall, the interest was in the commonalities and differences in civilian activity across cultures and places, not in military rules and conventions.

The detail of some civilian activity features differ from one geographic area to another. For example, the ratio of men and women observed in public places can vary in some countries. Several demographic factors can also vary significantly across nations, as well as the way individuals dress for example. A decision was made not to emphasize such "geospecific" features - to borrow from the language of geographers - but rather to concentrate on common, or "geotypical", features. The possibility of geospecific variations will be mentioned where they seem important, but the detail of each exception will not be discussed. Please note however that in simulation applications such specificities often remain crucial for attaining the necessary realism. However it is believed that it is more effective to investigate them on an ad-hoc basis, for the needs of each specific application.

Finally, it is important to note that the trends highlighted in the interviews constitute probable occurrences of civilian activity, not rigid rules. Critical decision making often happens at times when exceptions occur and normalcy is broken. Examples of exceptional circumstances, such as unannounced violent demonstrations or traffic accidents involving military vehicles, came up in the interviews. When appropriate, these examples were included in the text. However, exceptions are by definition difficult to predict. In simulation-based training and experimentation, a pro-active attitude in generating "what-if" scenarios for each specific application seems a safer approach than to rely on records of past events.

A.2 Results

A.2.1 Civilian Activity Patterns

In the course of the interviews, participants described their experience of civilian activity most often through small vignettes, either detailing specific events or synthesizing their experience of certain environments, for example public markets. From one participant to another, these vignettes often had several aspects in common. Some categories were therefore identified. The description of how civilians act in each generic type of situation was synthesized in individual civilian activity patterns. These patterns put group behaviours in context. As such they offer a more useful description than a list of what could be thought as elementary group behaviours. Patterns also provide information on how group behaviours can be correlated in some common situations.

More precisely, we define civilian activity patterns as an assembly of individual and collective behaviours that recur in a specific context, including elements like place, time of occurrence, duration or triggering event. In absence of a more rigid definition, we hope that the synthesis presented here will provide enough clarity. One thing is certain: these civilian activity patterns emerged repeatedly in our discussions with military subject matter experts and therefore seem to

constitute a natural way of describing similarities in civilian activity across various cultures and geographies.

Civilian activity patterns synthesized from the interviews were divided into three categories: regular congregations, spontaneous congregations, and protests. "Congregation" is meant as a gathering or collection of people, without implying any religious motivation. Examples of regular congregations are daily gatherings in public places (markets, churches), or groups of children playing together. Spontaneous congregations are typically triggered by an event, for example the arrival of a military unit in a populated area or a road accident. Civilian protests were the subject of enough remarks by participants that a separate section was dedicated to that topic.

A.2.2 Regular congregations

Regular congregations are expected sights in populated areas that do not depend on a specific trigger but usually occur in specific public places and at a certain time of day.

Secular gatherings

Because places of worship usually occupy a central location in populated areas, groups are often gathered around mosques, churches and other temples even outside religious services. Other central buildings are also points of convergence. In hot weather, people will preferentially stand in the shade of buildings and trees.

Sporting events were mentioned in the interviews but major congregations at sporting events were rarely observed and had no impact on operations.

Religious gatherings

Religious gatherings were a regular sight in most regions visited by the participants we interviewed. Everywhere, there are usually noticeable variations in traffic at the time of important religious services. In some predominantly Muslim countries for example, city streets are less busy on Fridays. The way people dress also changes. The change in the quality of clothing on these days is even the more visible in poorer countries in which religious devotion is high.

Groups of children

Interview participants repeatedly mentioned groups of children as regular sights on deployment. From their descriptions, children appear to be more active than adults and therefore more noticeable. One participant with experience in Haiti, Bosnia and Afghanistan indicated a common trend:

> "Children up to 12 years old, they act the same in every country you go. [...] They're thinking outside the box; they're not living the war. They act differently from teenagers and adults. [Whether it's] Haiti or Bosnia [or Afghanistan], if you [offer them something], they come to you."

When observed, groups of children seem to be expected in the usual public locations such as parks, central courtyards and public places.

The frequency of groups of children at play during the day varies significantly from one region to another, depending on how many children have access to schools, or are employed at various tasks (subsistence farming in poor areas, for example). It is common in poorer regions to observe groups of children, some orphans, spending the day outside together. One participant with experience in the Balkans indicated that during his deployment in the nineteen-nineties he had constantly observed 60 to 100 children hanging out at the entry of his camp, with about half of them staying there permanently.

The behaviour of groups of children is also briefly discussed in the section A.2.3.

Nomads along roads in Kandahar Province

Several participants with experience in Kandahar Province, Afghanistan, mentioned the sight of nomadic camps visible from the roads. They were typically composed of 30-40 tents along the roads, spanning a few kilometres with 50 m to 100 m between each tent and extending 300 m to 800 m deep off-road. Sheep, goats and camels were observed around the camp, with animals grazing as far as 1 km to 2 km away from the camp. No comparison was possible with other nomadic herders in the world.

A.2.3 Spontaneous congregations

Unplanned congregations are triggered when an unexpected event draws individuals nearby to gather around the site of that event. At the individual level this could result from a natural degree of curiosity or from the desire to emulate others. As one participant with experience in Pakistan explained:

> "That's a thing that people fail to realize: it doesn't take much for a crowd to gather. Like anything, the curiosity factor is phenomenal."

An interpretation founded in the literature on human psychology has not been pursued at this point because the focus of this research was to discover and describe the most prominent patterns, not to formulate their causes at the individual level.

Gathering at the arrival of military patrols and convoys

Civilians gathering at the arrival of military units is one of the most frequent patterns described by interview participants. Several factors influence the size of the crowd, and the rate at which it gathers. In general, inhabitants of rural areas exhibit more curiosity than those of urban areas. Groups of children are also noticeably more curious than adults, and will approach closer. Another important element is the novelty of the military presence and how accustomed local civilians are to seeing military units come by. Remarks related to this aspect are treated separately in the section on individual behaviours and moods.

Most of the examples provided by participants concerned the arrival of a military vehicle or convoy in a populated area. As a rule of thumb derived from several accounts, is seems that in a typical rural town one could observe 20 to 50 people on arrival and that 30 minutes later there could be a few hundred people gathered. One participant with experience in Afghanistan described such situations as "you arrive and all of a sudden – Oh my God, I'm surrounded".

Children seem to gather more quickly than adults, with 20 to 50 children suddenly swarming the vehicles of a military patrol. Children are also more persistent in following vehicles. In rural Afghanistan, one participant explained that "it was not rare to see a group of kids [about 5 to 6] follow a patrol from almost start to finish" while another explained that in a refugee camp in the Middle-East, 10 to 15 children would run alongside the vehicles, yelling, as they rolled through the camp.

Some participants also commented on the same pattern for foot patrols. Because of the increased proximity, the expressed level of discomfort when having to deal with sudden congregations was higher. One participant with experience in Pakistan explained:

> "They try to [prepare you for spontaneous, hostile swarmings] on peace support training [...] . [But] until you've experienced it... it's a really odd feeling"

The same participant explained how a group of military personnel, including women in uniform, were surrounded when entering a refugee camp in the North-West Frontier Province: "In 30 seconds there was 500 men around us [...] we were surrounded". The same type of situation was described by another participant with experience in Afghanistan. When stopping to speak with a town local, "[one is] surrounded by hundreds of people".

One participant explained how the posture adopted by a foot patrol (relaxed vs. defensive) will influence the level of interaction with civilians, in a market place for example. Adopting a defensive posture in a market will result in civilians stopping their interactions with the military.

Distribution of food and other goods

Several situations described by participants regarded the distribution of various goods. The crowd dynamics described in each instance were often quite varied. In one instance, an Army officer described the distribution of radio receivers to an initial group of 30-40 people in Afghanistan. Within 20 to 30 minutes, he described, it was as if the military were being "almost like rampaged, ripped apart". Another officer described an unplanned water distribution event in South America during a humanitarian relief operation. The crowd behaved in an orderly and calm fashion. Another officer with experience in South Asia explained that "if you want to see people congregate real fast, [give money] to somebody. Within 10 seconds you've got 25 children there".

Gatherings following road incidents

Participants made their observations of civilian populations most often in the context of patrols, convoys and other operations conducted mainly on roads. Several road incidents, such as road accidents, were described throughout the interviews.

Typically, road incidents will prompt a patrol or convoy to halt at least temporarily. Some soldiers will most often dismount to manage the situation, unless the ambient security threat precludes it. This creates a point of focus that can attract bystanders. One officer gave a general description of the convergence of pedestrians towards an accident site: "[...] all of a sudden you get groupings at locations, maybe a kilometre and a half away, starting to move towards a specific site". An example was provided of a girl hit by a United Nation vehicle in a rural area of Sierra Leone, gathering a crowd of 20 to 30 people.

Another participant described an argument between two drivers following a small traffic accident in Pakistan:

> "Suddenly you've got this crowd of 25 people standing around [arguing about responsibility for the accident]. This takes 10 to 15 minutes until [an arrangement is found] or a policeman comes along and disperses the crowd."

There is a risk of spontaneous unrest at the site of traffic accidents. As a participant with experience in Afghanistan and Bosnia indicated about road incidents:

> "The mood of the crowd can swing very quickly [...]. If it's somebody hurt or killed the mood of the crowd can shift very quickly to very hostile."

An interesting example was given of a pedestrian hit by civilian traffic in Haiti. The victim was attended to by nearby military personnel on patrol who were not directly involved in the incident. Curious pedestrians arrived on site subsequently, resulting in a dense crowd, "shoulder to shoulder, packed. [...] Any place there was a place to stand somebody was standing for maybe 50 meters out". Some of the comers to the scene erroneously concluded from the proximity of the military that they must have been responsible for the incident, resulting in verbal hostility from the crowd. No confrontation occurred however. According to one officer involved, a factor that reduced physical pressure from the crowd was the number of immobilized vehicles around the victim, which impeded the flow of pedestrians.

A.2.4 Protests

Protests can be planned or spontaneous, but seem to exhibit a few common features. Overt violence such as projectile throwing has been observed but is uncommon and temporary, usually the matter of one day in a given area. According to participants, organized protests were very rare incidents in the theatres they were deployed in; only a few participants had observed one in the course of their careers. For those participants who had experienced them however, these events were the focus of several remarks and appear to have been critical experiences.

Three examples of violent organized protests were given in the entire series of interviews. One was in a small town of Bosnia-Herzegovina and involved 300 to 500 participants. Another, in Kinshasa (Democratic Republic of the Congo), had involved about 2000 protesters. Both of these protests lasted for about 3 hours. In another incident, civilians in Port-au-Prince (Haiti) ambushed soldiers patrolling by foot at night. An estimate of the number of participants to this incident was not provided.

The onset of violent, reactionary protests appears to be unpredictable. The officer who had observed the violent protest in Kinshasa explained that one day prior to the incident, civilians were looking at him with a unprecedented hostility. Such non-verbal hostility has been the subject of several observations by other interviewed participants however, and in most cases were not been followed by violent protests. Remarks related to the perception of civilian moods are further covered in Section A.3. In the Port-au-Prince ambush, only at the last minute, as they were walking down the street, did soldiers notice the unusual absence of civilians.

The likelihood of protests might vary across cultures. For example, one participant with experience in Afghanistan and Haiti indicated that a spontaneous protest in Afghanistan would be unlikely, "there would have to be an agitator".

The crowds that participate in an organized protest sometimes arrange so that the group facing the security forces will be mostly children and women. This observation has been made by interview participants having had experience with protests in Canada as well as in Haiti. This phenomenon has also been reported in the literature for crowds in Somalia in the nineteen-nineties [13].

The issue of crowd leaders and agitators has also been raised by a few interviewed participants. These individuals are often visible in the crowd because they participate less directly in the protest and that there is an increased level of activity observable around them.

A.3 General remarks on behaviours and moods

A.3.1 Resiliency of civilian activity in situations of conflict

An important question is how the heightened levels of threat and risk in situations of conflict impact on the daily behaviour of civilians. From the interviews, it appears that civilian populations can get accustomed to relatively high levels of threat and risk. Commenting on the daily civilian activity in Bosnia-Herzegovina during the civil war in the nineteen-nineties, a former soldier explained:

> "Even if they're [in a] war [...] they still do what they normally do, [shopping and travelling around town]. [...] They mind their own business."

Another participant, with more recent experience in Haiti and Afghanistan provided a similar description of civilians' reaction to the passage of foreign military troops, emphasizing that most people show indifference: "All they want is for the army guys to get out of the way so they can carry with their business". A participant who had the opportunity to observe civilian behaviours in rural Afghanistan from aerial cameras offered a balanced view, confirming that while indifference towards military convoys was regularly observed, curiosity was also a common sight.

This increased resilience and indifference of civilians seems observable even in the most violent contexts. The same participant with experience in Bosnia-Herzegovina quoted above commented on the dynamics following a shell landing in the middle of a city: "There's a moment of panic, and then things go back to normal again." In these instances, it was observed that immediately after the attack people naturally seek the cover of buildings for protection. The same participant indicated that typically, injured people are then helped almost immediately by some of the people unharmed in the attack. This phenomenon has also been observed independently in videos of terrorist explosions in public places (Section 3.2).

Of course no conclusion can be drawn from such remarks alone on the levels of stress endured by individuals in situations of conflict. The observations reported here, as in other sections, only pertain to what's visible of civilians' actions and does not provide evidence related to individuals' emotions and psychological state.

A.3.2 Perception of civilian moods

A question often asked to interview participants was on how civilians' moods could be perceived. Aside from the rare instances in which overt signs of hostility were displayed (covered in Section A.2.4), participants mostly mentioned facial expressions and other indicators related to physical posture. One officer commented about his tour in Afghanistan: "We got everything from curious looks to looks that look less than happy". Another provided an example in which he had wandered in a public market in Bosnia-Herzegovina in combat uniform and suddenly noticed hostility from the crowd: "It was a dear in the headlights look from women, and the steely gaze of the men. No smiles".

While the assessment of a crowd's mood through facial expressions was generally non-ambiguous for the participants interviewed, facial expressions and subtle body postures are notoriously difficult to represent in simulation because of the limitations of 3D models and the resolution of computer monitors. While this report's focus is not on addressing potential gaps in simulation, the approach of using text cues could be one way to remedy to the problem.

A.4 General remarks on vehicles and traffic

Most of the material collected in the interviews about vehicle traffic was related to interactions between vehicles and pedestrians. Several of these interactions, in particular those involving military vehicles, were covered in Section A.2.3. In this short section we present a few extra facts of a more general nature.

In densely populated areas in the developing world, busy streets are often difficult to circulate on not only because of the high number of vehicles, but also because of the dense pedestrian traffic overflowing on the street. This is true in particular in areas where market stalls line the street sides, and unless the traffic is jammed, a typical traffic speed in such areas was given as 10 to 15 km/h by one participant with driving experience in Afghanistan. Some participants explained that pedestrians typically spread away when vehicles come by. Others mentioned that it is often necessary for drivers to go around pedestrians, which results in a traffic flow that deviates from prescribed lanes and can spread wider than the road if space allows.

As a result of dense urban traffic, it was mentioned that one can try secondary streets but then risks getting stuck because of parked vehicles in narrower streets. In the field, tactics are often adapted to that reality. One non-commissioned officer explained: "Our tactics took [traffic] into consideration. We tried to go through Kandahar City at night because we knew that if we went at rush hour it would be a huge issue".

There appears to be a few constants related to vehicle traffic across developing countries. In general, the driving style is less bound by traffic rules. One reason could be that traffic rules are not enforced as strongly (participants offered examples for Afghanistan and Syria). Making a comparison with Canada, one participant mentioned that "[drivers] are probably a little bit more aggressive [in Afghanistan]."

Several observations were collected for Haiti and Afghanistan indicating that vehicles in these countries are in general travelling over-capacity, both in terms of passengers and cargo. "It

wouldn't be unusual to see up to eight people in [a single car]", explained one participant. Another indicated that he "never really saw [a vehicle] with one [occupant]". In Afghanistan, the sight of a vehicle with only the driver and no passengers was exceptional enough to be mentioned as potential threat indicator.

A.5 General remarks on types of locations

The previous sections presented a summary of the participants' observations on collective civilian behaviours in contexts relevant to military operations in populated areas. Interviewed military officers also provided observations about specific types of places that were commonly observed through their tours overseas. Several common aspects have arisen from these observations and are summarized here. Of all the types of public places described, markets were largely predominant with about three quarters of all the material collected on public places. The remaining quarter contained some indications on places of worship, parks and transportation hubs.

A.5.1 Markets

The public areas most often described by interviewees were markets. While open air markets do not seem prominent in Canada or the U.S., their frequent occurrence in interview comments indicate that they are an expected sight in several areas of the world, including but not limited to developing countries.

Physical description

Two generic types of markets were described by interview participants. In one type, a market area is made of independently owned shops lining the sides of a frequented artery, often focussed at an intersection and expanding along the intersecting street as well, in the pattern of a "+". Because of the interface with the street, these markets are characterized by the constant interaction between pedestrians and vehicles. This type of market was the one most often described for developing countries of Africa (DRC, Sierra Leone), Asia (Afghanistan, Pakistan), the Caribbean (Haiti) and the Mediterranean (Cyprus, Syria). No observations were made regarding South American markets.

In comparison, the markets observed in the Balkans were closer to the public markets sometimes organized around Canadian or U.S. towns, where a specific rectangular land area has been reserved for sellers to setup their stalls and only pedestrian traffic is allowed through.

The possible predominance of one type of market versus another in some areas, as induced from the interviews, is of course a trend and cannot be considered a strict rule. The two types of markets highlighted above are most likely found all around the world. For instance, a rectangular pedestrian-only market was described in Freetown, Sierra Leone, besides the more common street markets observed there.

Markets setup along streets show a wide range of variations, often depending on how wide the streets are. The descriptions of Afghan markets indicated relatively wide streets, offering enough space for a steady flow of traffic (10-15 km/h average speed according to one observer). The traffic slowdowns that can occur as a result of market occupancy were said to affect traffic

several blocks away from a market. Telling about his driving experience in a Cypriot street market, one participant described: "Everybody was pouring and crossing the road [...], vehicles were everywhere, it was a mess". A different dynamic was associated to markets setup along very narrow streets in densely built old cities, such as Mediterranean souks. These instances often approached pedestrian-only markets. Small vehicles such as bicycles and tuk-tuks however were said to still make it through the narrow streets, inching their way despite the crowds and the constrained space. A market of that kind was also described for Peshawar, Pakistan.

Interview participants indicated that in large enough markets, shops offering similar merchandise or services are often clustered together (seen in Afghanistan and Africa). One observer described the phenomenon in detail:

> "[...] you'll get an area that is the meat market. [...] You'll get the [areas for] vegetables, plumbing, car repair, brick making, building materials, lumber [...]."

In the poorest regions (examples given for Haiti and the DRC) markets can be less organized and the merchandises offered more disparate and fluctuating. Some stalls appear and disappear. "There will be a stall [in one place] for four weeks and then nothing", described an officer with experience in Sierra Leone.

The size and frequency of markets varied whether participant described street markets (linear) or area markets (covering a 2-dimensional area). One market per village or one per 3-4 city blocks was given as a rule of thumb by one participant. The same participant indicated that larger markets are sometimes found on the outskirts of larger towns (example given for Afghanistan). A 2-4 square kilometre area was given as a typical size for these. A pedestrian market in a dedicated area of a small town in Bosnia Herzegovina was described as occupying a rectangle of 300 m by 50 m. In developing countries, street markets in small towns were described as sometimes occupying the whole length of the main street. As one observer indicated: "[...] in a lot of these countries the market is just the main street".

Level of occupancy

The density of crowds in market areas naturally depends on the population density and on how constrained is the market area. In one extreme, such as souks, one respondent indicated that "you have to inch your way through people" and "anywhere in the market it's elbow-to-shoulder [...] you'd have just a mass of humanity in a marketplace". The same kind of pedestrian density was described for some busy streets in Kinshasa, DRC. In other, less densely populated areas a regular vehicle traffic flow was said to be possible. One participant with experience in Afghanistan compared the daily pedestrian density at markets and around mosques to Christmas shopping time in Canadian malls. The conditions will therefore change depending on the exact geographic location and the level of occupancy of markets must be determined independently for each specific case, depending on the exact context.

Regarding the variation of market occupancy throughout the day, several factors can be at play which, again, can make every situation unique. Most of the comments on that aspect were given in relation to Afghan markets. In city markets, daily variations in civilian activity were less visible than in rural areas. One officer said of Afghan markets: "It's like it's busy all the time. Dawn until Dusk". Another confirmed that "as soon as first light is on, [the market] starts".

Fridays were also said to be less busy in Afghan markets because it is a holy day in the Muslim tradition. Some participants noted a minor decrease in activity in markets around the noon hour, in the hot hours of the day. That decrease due to hot temperature was not confirmed by all who were asked however. An officer with experience in the Balkans indicated that the level of activity downtown is typically matched with store opening hours.While in some cities of developing countries the activity was said to never cease (an example was given of Freetown, Sierra Leone), in Afghanistan activity in markets and cities in general completely ceased at night.

A.5.2 Places of worship

Because places of worship are most often centrally located, they are usually the site of small crowds throughout the day, outside of ceremony hours. In Afghanistan for example, an interview participant indicated that mosques are "[...] so central, there's always people around sitting outside, women and men".

At times of worship, in areas where religion is widely practiced, there can be a noticeable change in the level of activity in non-religious public places. Sundays are remarkable in that sense where the Christian religion is dominant (example given for Haiti). These periods of course will vary from one religion to another and from one culture to another. A participant explained, speaking of Afghanistan, that "it will be tens and hundreds [...] that may want to converge on a specific [mosque]". Similarly, it was said that in Haiti several hundred people can occupy a single church on Sundays.

A.5.3 Parks and terminals

Parks in developing countries have been described as relatively bare, with only a few or no play structures for children. Nonetheless, children are typically present in parks. Describing an Afghan city park, one officer said: "Most of the kids are out there playing soccer, or just chasing each other around."

In larger towns and in cities, transportation hubs are often the sites of diversified civilian activity, not limited to transport only. For example, an area comprising several bus terminals in the outskirts of Kandahar was said to be complemented by taxi areas and mosques. The bus traffic was described as continuous. In another area of the world, a train station in a large city was described as a hub for prostitution at night. The same train station was used as shelter by a homeless family.

A.6 Conclusion

These interviews gave the CAMX team insights on some common behaviours observed in conflict areas across the globe. Obviously, these punctual glimpses of life do not offer a global view; they nonetheless offer a way to achieve one goal: the description and characterization of some common behaviours.

The work presented in this annex is not discussed item by item in the main core of the paper as the videos were. It mostly served as a way to understand the context of some of the scenes that were observed in the videos.

Annex B Direct-fire Munitions and their effect in CAMX

Data presented here are an updated version of what was presented in [4]. Table 12 shows the munitions supported by CAMX, their calibre (used to determine the psychological impact) and their PK. The naming convention follows that of the PH/PK Calculator input files [14] which provides PH/PK data for JCATS.

The PK used in CAMX is that of a single shot. If a burst is fired, PK will be calculated multiple consecutive times. Note that as long as the target survives a hit, it suffers no ill-effect (i.e., its structural integrity does not decrease at all).

Table 12: List of direct-fire weapons/munitions supported by CAMX and their respective probability of kill.

Weapon/Munition	Calibre	PK vs Pedestrians	PK vs Vehicles
5.45mm	S	1	0.0425
5.45mm RPK74	S	1	0.0425
5.56mm C7	S	1	0.0425
5.56mm C9	S	1	0.0425
7.62mm C6	S	1	0.0425
7.62mm PKM	S	1	0.0425
Sniper 7.62mm	S	1	0.0425
Sniper 8.6mm	S	1	0.0425
9mm pistol	S	1	0.0425
12.7mm	M	1	0.29
12.7mm Helo	M	1	0.29
14.5mm	M	1	0.29
23mm MIG21	M	1	0.29

Weapon/Munition	Calibre	PK vs Pedestrians	PK vs Vehicles
23mm quad ADA	M	1	0.29
23mm twin ADA	M	1	0.29
25mm APFSDS	M	1	0.29
25mm FAPDS	M	1	0.29
25mm HEI	M	1	0.29
30mm 2s6	M	1	0.29
30mm air A-10	M	1	0.29
30mm BMP2 APDS	M	1	0.29
30mm HEDP	M	1	0.29
30mm SCHEI	M	1	0.29
35mm ADA	M	1	0.29
35mm HE	M	1	0.29
40mm AP	M	1	0.29
40mm HE (grenade)	M	1	0.29
100mm AP T12	L	1	0.29
100mm APFSDS	L	1	0.29
105mm APFSDS Leo C2	L	1	0.725
105mm APFSDS M60A1	L	1	0.725
115mm APFSDS	L	1	0.725

Weapon/Munition	Calibre	PK vs Pedestrians	PK vs Vehicles
120mm APFSDS	L	1	0.725
125mm APFSDS T-72	L	1	0.725
125mm APFSDS T-80/90	L	1	0.725

Calibre is used to determine the behavioural impact (i.e., flee and trigger radii). Three distinct levels are used: small (S), medium (M), and large (L), all proportional to a munition's lethality. Munitions not recognized by CAMX are considered small (S) for flee behaviour and damage purposes. It is believed that most unrecognized munitions (caused by DIS configuration issues, a common problem when running multiple simulations together) will be of small calibres because of their commonality and diversity on the battlefield (and thus in simulations).

The following munitions were used to determine PK against vehicles for all small (S), medium (M), and large (L) munitions respectively.

- 5.56 mm
- 25 mm APFSDS
- 105 mm APFSDS

The *flee shooter* trigger radii associated to direct-fire munitions against pedestrians, animals, and cars are as follow:

- Small: 25 m
- Medium: 50 m
- Large: 75 m

Their respective *flee bullet* trigger radii against pedestrians and animals are as follow:

- Small: 5 m
- Medium: 15 m
- Large: 20 m

The PKs used to fill Table 12 are an average of the head-on and flank PK. The lethality of the 5.56 mm munition, the lightest of the three core munitions, is barely impacted by range against vehicles and pedestrians. Range dependence is thus totally irrelevant for all munitions.

The PK and calibre values can be changed by modifying the appropriate configuration file. New munitions can be added as well if required.

Annex C Indirect-fire Munitions and their effects in CAMX

Annex C presents the list of indirect-fire munitions supported by CAMX and their respective categories for both the psychological impact (i.e., Explosion Size) and the damage output (i.e., Lethal Radius Size). If a munition is not recognized, CAMX will use a small kinetic round by default and warn the user.[38] New munitions can be added to CAMX in order to update the database. The data presented here are an updated version of what was presented in [4]. The naming convention follows that of the PH/PK Calculator input files [14] which provides PH/PK data for JCATS.

Table 13: List of indirect-fire weapons/munitions supported by CAMX and their respective explosion size and lethal radius size.

Munition	Explosion Size	Lethal Radius Size
Grenade M67	M	S
Grenade 30mm AGS-17	M	S
Grenade 40mm GP-30	M	S
Grenade 40mm M-19	M	S
Grenade 40mm M203	M	S
25mm HEI-T	S	S
30mm HEI-T	S	S
30mm HEPD	S	S
Rocket 2.75in	M	M
Rocket 57mm	M	M

[38]All unidentified munitions are handled as small kinetic munitions for behaviour and PK purposes. A kinetic round is used since there is no way to discriminate kinetic-energy rounds from chemical-energy rounds when a munition is unknown. Experience shows that in a typical simulation, unknown munitions have a high probability of being small kinetic-energy rounds.

Munition	Explosion Size	Lethal Radius Size
Rocket CRV-7	M	M
RPG-16	M	S
RPG-27	M	S
LAW	M	S
60mm HE	M	M
81mm HE	M	M
82mm HE	M	M
105mm HEAT M60a1	M	M
105mm HESH Leo C2	M	M
107mm HE	M	M
84mm HEAT CarlG	M	M
AT-10 Stabber	M	S
AT-7 Saxhorn	M	S
RPG-18	M	S
RPG-7	M	S
SA-18	M	M
SA-7	M	M
Stinger	M	M
115mm HE-Frag	L	L

Munition	Explosion Size	Lethal Radius Size
115mm HEAT	L	M
120mm HEAT	L	M
122mm HE	L	L
122mm Rkt HE	L	L
125mm HE-Frag	L	L
125mm HEAT T-72	L	M
125mm HEAT T-80/90	L	M
130mm HE	L	L
140mm Rkt HE	L	L
152mm HE	L	L
152mm HE 2a65	L	L
152mm HE 2s3	L	L
152mm HE 2s19	L	L
155mm Excalibur HE	L	L
155mm HE	L	L
155mm HE AS-90	L	L
155mm HE M109a6	L	L
155mm HE M777A1	L	L
180mm HE	L	L

Munition	Explosion Size	Lethal Radius Size
203mm HE	L	L
220mm Rkt HE	L	L
240mm HE mortar	L	L
120mm HE mortar	L	L
120mm heat mortar	L	L
160mm mortar	L	L
227mm MLRS	L	L
ADATS	L	L
AIM-9	L	L
AT-11 Sniper	L	M
AT-12 Swinger	L	M
AT-13 Metis	L	M
AT-14 Kornet	L	M
AT-2 Swatter	L	M
AT-3 Sagger	L	M
AT-4 Javelin	L	M
AT-4 Spigot	L	M
AT-5 Spandrel	L	M
AT-5 BRDM-S	L	M

Munition	Explosion Size	Lethal Radius Size
AT-6 Spiral	L	M
AT-8 Songster	M	S
ERYX	L	M
HARM	L	L
HELLFIRE	L	L
HOT-3	L	L
Maverick	L	L
Milan	L	M
RPO-A Thermobaric	L	L
SA-11	L	L
SA-13	L	L
SA-15	L	L
SA-19	L	L
SA-8	L	L
SA-9	L	L
Tow IIb	L	M
SM 2MR	L	L
Mk82 500lbs	L	L

The damage associated to each Lethal Radius Size is typical of the M67 grenade (S), the M720 60 mm HE mortar (M) and the M107 155 mm HE artillery shell (L) against unarmoured, exposed pedestrians and civilian cars [9]. The values are not shown for security reasons.

Since the data in CAMX were originally produced for the JCATS PH and PK database, its combat model is analogous. Given an explosion, the PK is given by:

$$PK = e^{-\left(\frac{x}{LR}\right)^2}, \tag{C.1}$$

where *LR* is the lethal radius and *x* the distance to the explosion (from the explosion center to the center of the CAMX entity).

The *flee explosion* trigger radii associated to indirect-fire munitions against pedestrians, animals, and cars are as follow:

- Small: 25 m
- Medium: 50 m
- Large: 75 m

Their respective *flee shooter* trigger radii against pedestrians, animals and cars are as follow:

- Small: 50 m
- Medium: 60 m
- Large: 75 m

Note that if a CAMX entity is hit directly by an indirect-fire munition, it will automatically suffer consequences (i.e., 100% probability of damage) as eqn. C.1 clearly shows that PK reaches 100% when the distance *x* is 0 m. While this has no impact on pedestrians and animals (both suffer 100% PK against all munitions already), vehicles will be more prone to damage than expected, especially against the lower-calibre high explosive incendiary (HEI) munitions like the 25 mm HEI since damage will be sustained after the very first hit. However, since military weapons are rarely used against civilian vehicles in Army simulations, these events will be exceptional.

Annex D Vehicle Avoidance Model

Whenever possible, behaviour models in CAMX should be based on the reasoning of individual agents (as opposed to heuristics). The vehicle avoidance behaviour was based on a simple logic that can be summarized by straightforward narrative. The following description only pertains to potential collisions between external vehicles and CAMX pedestrians as CAMX vehicles will never hit CAMX pedestrians thanks to AI. Implant's pathfinding algorithm.

A pedestrian who perceives to be in the way of an oncoming vehicle should disregard the vehicle until a certain discomfort level is reached. This discomfort can be quantified as the expected time-to-collision. The pedestrian will get out of the vehicle's expected trajectory while minimizing his/her running or walking distance. The pedestrian would also try to reach a safety distance Δ_{dist} away from the vehicle's expected trajectory, which would be greater if the vehicle travels at a higher speed.

In CAMX, agents have a perfect perception of the velocity of oncoming vehicles. Figure A-27 shows a simple representation of such an escape situation. A vehicle of width *W* and length *L* is oncoming at velocity $\vec{V}$ towards a pedestrian (yellow dot). The relative position of the pedestrian with respect to the center of the front of the vehicle (point $\vec{O}$) is given by the vector $\vec{r}$. Two unit vectors $\vec{i}$ and $\vec{j}$ are respectively perpendicular and parallel to $\vec{V}$. The pedestrian attempts to escape the perceived trajectory of the vehicle with the assumption that the vehicle will continue with a constant velocity $\vec{V}$. He/She escapes with velocity $\vec{v}_{escape}$ in a direction perpendicular to the vehicle's trajectory.

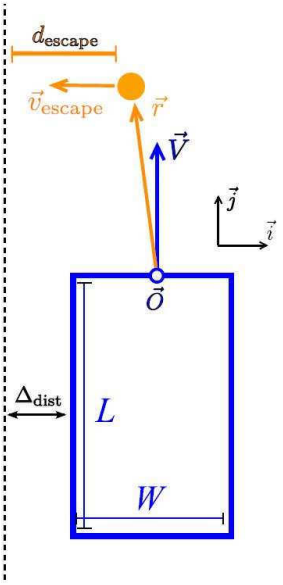

Figure A-27: Collision avoidance.

Avoiding a collision by walking or running in a direction perpendicular to the vehicle's trajectory minimizes the effort by the agent. That simple rule however does not take into account special cases in which the agent is so close to a collision that, while an escape is possible, only a non-perpendicular trajectory would allow it. That development involves some extra arithmetic that might hurt the computational performance of the model. For that reason it is kept as simple as possible, assuming special cases of close-encounters will be the exception.

Agents only start to move out of the way if the time-to-collision becomes shorter than a certain threshold Δ_t. The model then boils down to checking an inequality that compares the escape time to the time-to-collision:

$$t_{escape} \geq t_c + \Delta_t, \tag{D.2}$$

where t_{escape} is the escape time, t_c is the time-to-collision and Δ_t is a constant giving the level of tolerance of pedestrians for t_c. Both t_{escape} and t_c can be expressed in terms of the basic variables found in Figure A-28.

$$t_{escape} = \frac{W/2 + \Delta_{dist} - |\vec{r} \cdot \vec{i}|}{|\vec{v}_{escape}|}, \tag{D.3}$$

$$t_c = \frac{|\vec{r} \cdot \vec{j}|}{|\vec{V}|}. \tag{D.4}$$

A constant value for Δ_{dist} in the current model does not give a visually realistic representation since the pedestrian crowd forms a perfect line along the vehicle's path. To correct the problem one must unfortunately revert to heuristics and include some randomness in Δ_{dist}. To simplify computations a triangular probability density distribution dP/dx centered on $\overline{\Delta}_{dist}$, going to zero at the vehicle's edge is used (see Figure A-28). The value of $\overline{\Delta}_{dist}$, and how it should vary with $\vec{V}$, can only be guessed[39].

[39] A more elegant alternative would involve a force model similar to the ones used by [15], [16], and [17]. The addition of physical and social forces would naturally result in a spread of the crowd on the road side, without the recourse to heuristics.

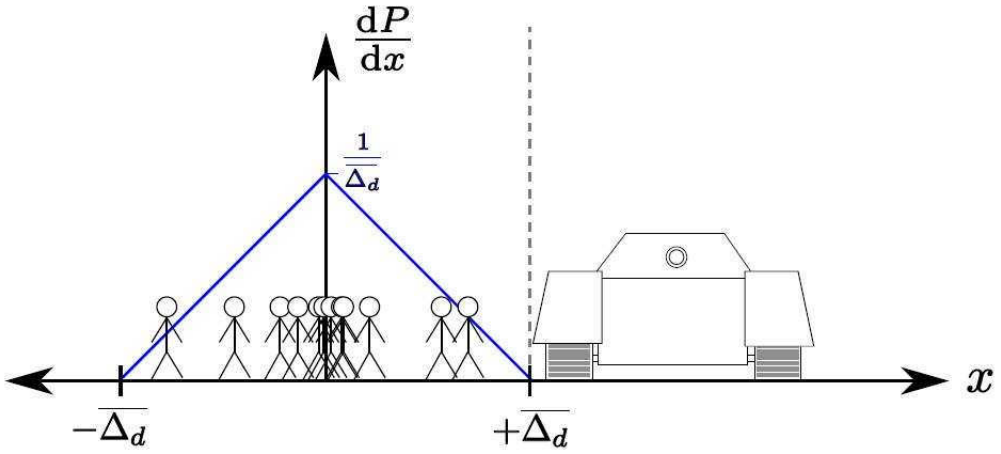

Figure A-28: Applying a triangle probability density to Δ_{dist} to make the pedestrian distribution more natural.

By introducing the definitions of Equations D.3 and D.4 in the inequality of Equation D.2 we get:

$$\frac{W/2 + \Delta_{dist} - |\vec{r} \cdot \vec{i}|}{\vec{v}_{escape}} \geq \frac{|\vec{r} \cdot \vec{j}|}{|\vec{V}|} + \Delta_t . \tag{D.5}$$

This inequality defines three regions in the space in front of the vehicle. These are depicted in Figure A-29 where agents are shown in three different colours. The ones in green are outside of the "discomfort" zone and are thus disregarding the oncoming vehicle. The agents in yellow are in an area for which Equation D.5 is verified and thus attempt to escape the vehicle. A smaller zone, right in front of the vehicle and containing a red agent, represents the "fatal area" from which it is impossible to escape, corresponding to the more simple inequality:

$$t_{escape} \leq t_c \tag{D.6}$$

which can be expressed in terms of Equations D.3 and D.4 as:

$$\frac{W/2 + \Delta_{dist} - |\vec{r} \cdot \vec{i}|}{|\vec{v}_{escape}|} \leq \frac{|\vec{r} \cdot \vec{j}|}{|\vec{V}|} . \tag{D.7}$$

If an agent has multiple possible velocities then more escape regions will be found in front of the vehicle. It is simply a matter of checking for the slowest velocity first and in increasing order after that. The "fatal area" is only shown here for the sake of explanation. A casualty only occurs

if the pedestrian is actually run over by the vehicle, not from the simple fact of being in the fatal area. Restricting escapes to perpendicular trajectories artificially enlarges that region. That discrepancy however remains on the safe side with regards to training, since it requires slightly more conservative driving to avoid running pedestrians over.

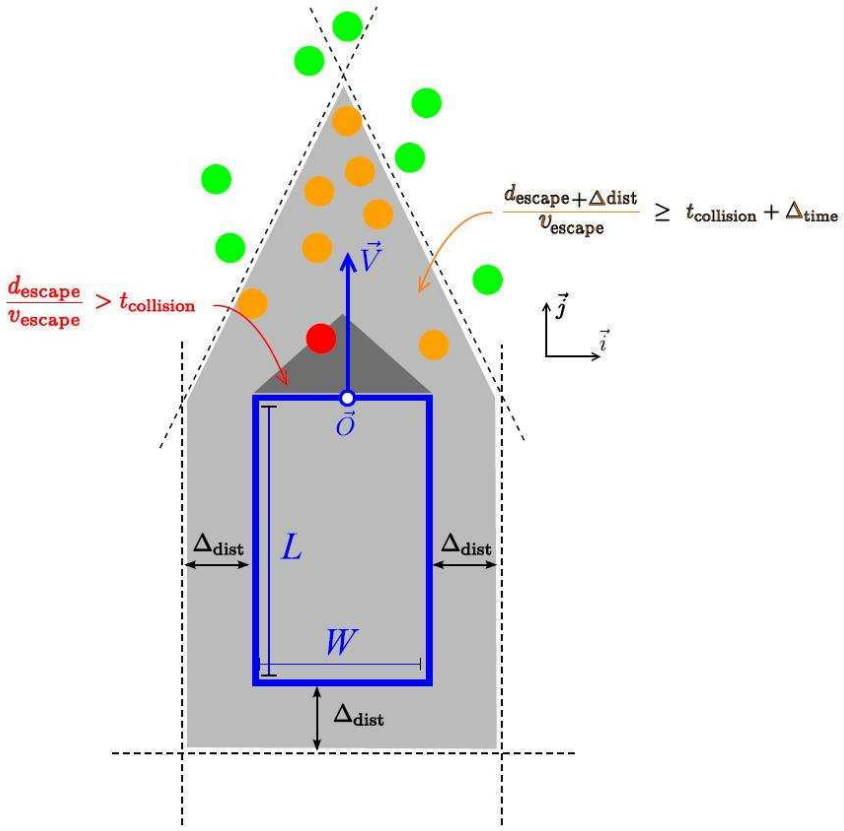

Figure A-29: The inequalities in Equations D.2 and D.6 define triangular areas for which the pedestrians respectively attempt to escape the vehicle trajectory (light gray) and for which no escape is possible (dark grey).

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List of symbols/abbreviations/acronyms/initialisms

AI	Artificial Intelligence
CAMX	Civilian Activity Modelling for eXercises and eXperimentation
CCTV	Closed-circuit Television
CF	Canadian Forces
CPR	Cardiopulmonary Resuscitation
CPU	Central Processing Unit
DIS	Distributed Interactive Simulation
DLSE	Directorate of Land Synthetic Environments
DND	Department of National Defence
DRC	Democratic Republic of Congo
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
DRI	Detection, Recognition, Identification
ER	Effect Radius
FBI	Federal Bureau of Investigation
FR	Flee Radius
HEI	High Explosive Incendiary
HQ	Headquarters
JCATS	Joint Conflict and Tactical Simulation
KK	Catastrophic Kill
MK	Mobility Kill
NSSP	Networked Soldier System Project
PH	Probability of Hit
PK	Probability of Kill
R&D	Research & Development
SOP	Standard Operating Procedures
TR	Trigger Radius
TTP	Tactics, Techniques and Procedures
UAV	Unmanned Aerial Vehicle

USSS	United States Secret Service
VBS2	Virtual Battle Space 2
VIP	Very Important Person

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The Civilian Activity Modelling for eXercises and eXperimentation tool (CAMX) was recently upgraded with police-specific features to suit the United States Secret Service. This document discusses in detail the construction of civilian behaviours for both military and police applications. It also discusses all changes since the first publication on CAMX in 2009.

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CAMX; Civilian Activity; Civilian Behaviours; Crowd Simulation; CT-Analyst; JCATS; Simulations; VBS2

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