Defining Spatial Information Requirements for Asymmetric Threat Behaviour in Simulation

Chelsea Kramer
Jordan Miller, David Unrau, Joseph Armstrong
CAE Professional Services
CANADA

chelsea.kramer@cae.com

ABSTRACT

Across NATO, preparing the warfighter to face an asymmetric threat is a significant challenge. Insurgents evolve new tactics, techniques and procedures faster than coalition forces can respond. The current ability of simulation-based training systems to realistically model insurgent threat scenarios is limited by our ability to model relevant human behaviour. Standardization of data, concepts and models is a key enabler to allow human behaviour modelling activities to contribute to a growing, reusable capability, rather than requiring the development of single-point and inflexible solutions. Defining a simulation framework that supports execution of human derived content in simulated environments involves explicit definition of the inputs (observations, knowledge) and outputs (actions) of the human model, which defines the requirements that the cognitive model imposes on a synthetic environment.

This paper presents an analysis of insurgent decision making, focused on deriving the information requirements for a robust model of Improvised Explosive Device (IED) emplacement. These information requirements are grouped into three classes of information. First, spatial information requirements are compared to the information normally found in the synthetic natural environment representation (i.e., terrain database) of a military simulation. Second, the impact of context specific information requirements is outlined. Finally, the requirement for domain knowledge is discussed. Future activities of the project will focus on the use of human factors tools and methods, including Cognitive Task Analysis (CTA) and ontologies to directly configure the execution of human behaviour models.

1.0 INTRODUCTION

In defence simulation, unless every entity (whether blue force, red force or civilian) is controlled by a human operator, the decision-making and activities of humans must be simulated. While the cognitive science domain has developed sophisticated models of aspects of human cognition (e.g., ACT-R[1,2,3], SOAR[4]), these efforts have generally existed in isolation, and been limited in scope. By not informing the development of defence simulation activities in a significant fashion, there remains a significant gap between the human simulation activities encountered in the cognitive science domain and the defence Modelling and Simulation (M&S) domain.[5]

[1] Anderson, J.R. (1990). The Adaptive Character of Thought. Hillsdale, NJ: Erlbaum.

[2] Anderson, J.R. & Lebiere, C. (1998). The Atomic Components of Thought. Mahwah, NJ: Erlbaum.

[3] Anderson, J.R., Bothell, D. Byrne, M. D., Douglass, S., Lebiere, C., & Gin, Y. (2004). An integrated theory of the mind. Psychological Review, 111, 1036-1060.

[4] Laird, John, Rosenbloom, Paul, and Newell, Allen. (1987). Soar: an architecture for general intelligence. Artificial Intelligence, 33: 1-64.

[5] Guo, R. J., Unrau, D., and Armstrong, J. (2010). *Scoping Report: AI Driven Wargame Replicator*. Defence R&D Canada Contractor Report, DRDC CORA.

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14. ABSTRACT
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One obstacle between the cognitive science domain and defence relates to mismatches in conceptual abstraction. Traditionally, Human Factors (HF) combines academic level research with standardized knowledge capture from subject matter experts to understand and predict human performance. The cognitive science requirements to describe human behaviour are naturally phrased in abstract concepts, while the defence M&S requirements to model real-world events lead to more concrete constructs. HF concepts used to describe how human agents interact with the environment can become lost in translation when they are not explicitly and consistently defined for M&S. Consequently, M&S must filter this information to transform abstract concepts into the models that result in simulation.

This observation has motivated the development of techniques to span, or translate, levels of conceptual abstraction to integrate models of different resolutions into federated simulations. This is expected to bring the flexibility of more abstract formulations into the specificity of more concrete applications. Our HF and M&S teams are collaborating under a common research and development initiative to gain a shared understanding and to develop a standardized language. As such, the HF and M&S domains work together to assess captured domain knowledge to select information that is both representative of the problem space, but also technically feasible for simulation. This process allows for more efficient construction of explicit hierarchical data bases (i.e., ontologies) built from the HF products, which feed the eventual model. Compromising a degree of domain specific practice in exchange for enhanced shared understanding facilitates a more rapid, realistic and reusable data integration for the human modelling community.

2.0 KNOWLEDGE CAPTURE OF INFORMATION REQUIREMENTS

A primary focus of this research was to unify the flow of information from knowledge capture into functioning simulations spanning the fields of HF, M&S and Geographic Information Systems (GIS). Our implementation philosophy has been to integrate advantages from existing tools in these domains to produce more capable simulations of human activity. This process translates the means by which objects in the environment influence behaviour into the data elements used to represent those objects in simulation. The work reported in this paper builds on this effort to develop a refinement of HF methodology to produce a more standardized product that functions as an explicit statement of M&S and GIS requirements.

2.1 Cognitive Tasks Analysis

CAE Professional Services (CAE PS) has been involved in the use of HF tools to drive M&S requirements for domain specific, simulation-based experimentation for over 14 years. Cognitive Task Analysis (CTA) is a well-accepted tool within the HF domain used to describe and explain human activity for the analysis of human performance and in human-centric design. A CTA hierarchically decomposes the skills required, the cognitive demands placed on the operator during the execution of the task, the information requirements required to initiate the task, and the task outputs used by individuals performing the tasks.[6]

While HF experts have long used CTAs as a gold standard for analyzing human behaviour, these tools do not necessarily translate into the appropriate information requirements needed to recreate this behaviour in simulation. The ethnographic nature of knowledge extraction involves observations, interviews and semi-structured questionnaires that are determined by the researcher’s expertise. The knowledge captured during these processes varies by the overall purpose of the CTA, which then can be influenced by numerous factors including job experience, personality, interviewing skills and motivation of the SMEs in question. That said,

[6] Stanton, N.A., Salmon, P.M., Walker, G.H., Baber, C., & Jenkins, D.P. (2005). *Human factors methods: a practical guide for engineering and design.* Great Britain: Ashgate.

variations in the way in which knowledge is extracted from SMEs, and/or the quality of knowledge that is extracted, makes it difficult to build CTAs that are reusable across domains.

To increase the general transferability of CTAs across contexts for the purposes of simulation, we propose to adjust the initial approach of CTA creation. The purpose is not to re-invent how the HF community uses CTAs, but instead to seek task similarities across domains that can be re-purposed into high level descriptions of human behaviour. The process begins with the detailed decomposition of one type of task to extract the high level types of information requirements that will inform each subtask. This method allows similarities in the requirements of other tasks to be drawn from parallel CTAs. As more similarities are identified between types of tasks, we can eventually create the high level classifications of tasks, which become the "task templates" that can be reused in different modelling environments regardless of specific task context. This paper uses Improvised Explosive Device (IED) emplacement as a use case in developing a process to facilitate a more standardized CTA.

2.2 IED Use Case

The IED is an unparalleled strategic weapon employed by insurgents against a stronger military force. IEDs enable small insurgent cells to seize the coalition's initiative by allowing the insurgent to choose when and where the attack will occur.[8] The attempt to model the insurgent's decision making is an immense challenge; however, not one that we believe to be insurmountable. While the IED problem will not be defeated with a single solution, the aim is to counter IED attacks as part of an overarching counterinsurgency to reduce an insurgency's ability to gain strategic advantage with IEDs.[8] For our current research the IED example is a discrete, representative use case around which numerous training scenarios for simulation can be built. Success in modelling this instance will yield the lessons learned necessary to expand the scope of modelled insurgent behaviours.

To begin to describe and explain IED operations, it is necessary to decompose insurgent behaviour into discrete tasks. Our approach involved extensive research into the realm of counter-IED (CIED); we conducted multiple interviews with CIED course instructors, and trained SMEs on the nature of the IED threat. Data collection was supported by training documents used by the Canadian Forces where applicable. The aim was to extract common themes from the various sources in order to expand the depth and breadth of a CTA that could conceivably portray a generic hierarchal structure of IED operations.

From the beginning, it was evident that the world of IED analysis comprises many facets; the motivation of individual members, the means by which individuals are recruited, the operational and strategic goals an IED campaign supports, the social network analysis of an IED network, the attacks themselves, and the logistical supply chains required to sustain an IED campaign are some of the noteworthy elements. [7] For our initial analysis the scope was limited only to IED attacks. IEDs are effective weapon systems because of their ability to detonate in close proximity to a target at a predetermined angle, granting the same effect as a precision-guided weapon.[8] Though developing a Human Behaviour Representation simulation that would encompass the entire CTA scenario is ultimately the goal for this research, our initial focus is route selection; specifically, routes that would affect IED emplacement as a proof of concept. This assumed an availability of resources, and a general plan to conduct the attack.

[7] Weaver, R., Silverman, B.G., Shin, H., Dubois, R. (n.d.). Modeling and simulating terrorist decision-making: a "performance moderator function" approach to generating virtual opponents. University of Pennsylvania, 19104-6315.

[8] Mouton, J. (2009). Rethinking IED strategies: from Iraq to Afghanistan. *Military Review*, July-August.

2.2.1 Route Selection in IED Emplacement

This section describes in detail the domain specific information requirements to consider while simulating insurgent route selection during IED emplacement. The overall process structure is derived from the Drake's model of Terrorist Target Selection (see Figure 1). [10] This model outlines a high level view of various interdependent steps involved in an IED attack, spanning from planning, building, training, moving, caching, and escaping. The point of this reference is not to describe each task in detail, but to illustrate how our focus of route selection fits within a larger system of insurgent activity. As such, the specifics of route selection falls under the categories of moving the IED, placing it, then escaping from the attack site.

Drake's model represents highly complex, yet ambiguous tasks relationships that tend to be captured when conducting interviews with SMEs. Figure 1 depicts numerous intertwined activities within IED operation, but is not clear on the order or importance of the overall system. The level of complexity associated with knowledge capture coupled with lack of hierarchical organization makes systematic analysis difficult. The task relationships are difficult to relate directly or expand to other domains. Therefore, modified Drake's model using TaskArchitect Pro2to build our own CTA of the IED operation (see Figure 2). [9] By organizing the tasks in a hierarchical structure – we can see commonalities among various tasks, which can later be grouped and simplified into the previously discussed task templates.

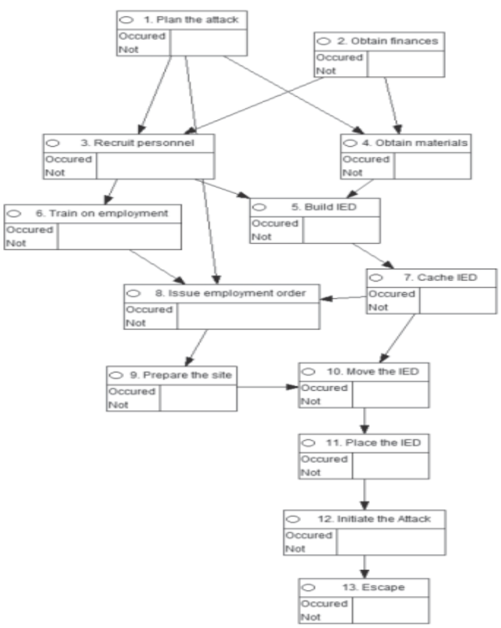

Figure 1: Drake's Model of IED operations[10].

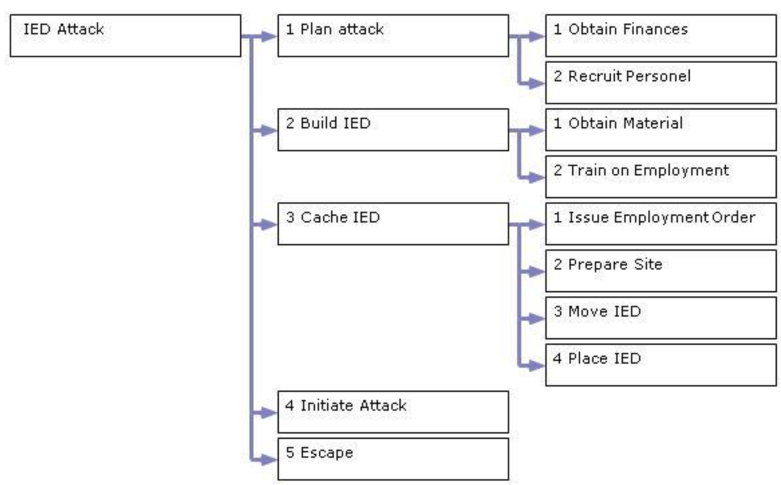

Figure 2: HTA of Drake IED Operations.

Nevertheless, the high level information captured within TaskArchitect is still just an outline. A hierarchical decomposition of tasks does not provide enough detail to be considered a CTA. To build a more complete CTA, we captured information on insurgent motivation from SME interviews, supported by procedures taught in CIED training. We began this process by choosing an initial subset of human behaviour to expand upon as

[9] Task Architect (2010). http://taskarchitect.com/index.html.

[10] Drake, C.J.M. (1998). Terrorists' Target Selection. New York: St Martin's Press.

a proof of concept for the remaining CTA. As a result, we selected navigation within a hostile environment because it reoccurs within this domain within IED emplacement, and could apply to other domains, such as Close Quarters Battle. Generally speaking, in any hostile environment where there is constant enemy surveillance, the insurgent seeks to carry out a goal without getting caught. Initiative is ideally maintained through fast and undetected movement. Conceptually, we understand this type of route selection based on the level of *concealment* (i.e., how visible are you to the enemy) as well as its *tempo* (i.e., how fast you can move through the environment).

The following section describes the explicit navigation portion of the IED operation. Route selection for IED emplacement is discussed from the SME perspective in terms of the *ingress*, *attack*, and *egress* actions of the insurgent, highlighting how various factors in the environment affect concealment and tempo. In the subsequent sections, these rich descriptions are then parsed into the more explicit information requirements used to build the models and simulations representing this knowledge. By attempting to better appreciate reasons why insurgents make decisions, we can build better models of insurgent behaviour in order to enhance training fidelity against this type of asymmetric threat.

2.2.1.1 Ingress

The ingress portion of an attack is the route an insurgent selects to move from a safe area to the target area. During this move the IED cell will be carrying the device, small arms such as automatic rifles and rocket propelled grenade launchers or recoilless rifles, communications equipment, and sustainment items such as food, water or additional ammunition. The ideal ingress route balances concealment and tempo; it will minimize the risk of detection by coalition or security forces, while maximizing speed of transit. When there is a conflict between the two, insurgents will generally opt for minimizing detection over speed of transit. This is done to maintain operational security, and to avoid surprise.

A desirable ingress route is a combined function of terrain that protects the insurgent from observation by security and coalition forces, and desirable human geography that is more likely to enable their movements than hinder them. The topographic requirements of the terrain will ideally be closed, and facilitate movement. This includes canyons, roadways with high embankments, underground passageways, and areas that are obscured by vegetation. This could also include movement in a non-descript vehicle that would allow the insurgent to blend with the normal pattern of life.

At this juncture the human geographical issue of *population alignment* becomes important. Population alignment refers to the degree of support from the local inhabitants within a given environment. This can be measured on a spectrum of allegiance, meaning the degree to which the locals either support the coalition, the insurgents, or remain neutral to both parties. Support may be moral, material, financial, or information about the enemy. If an insurgent knows there is either the passive support (failure to report to authorities) of the population, or the active support of the population (willingness to provide food, shelter, storage areas, and possibly a recruitment base), routes are considered more desirable. Even if security or coalition forces are nearby, a population aligned with the insurgent will not inform on their whereabouts, and may actively stifle attempts by security forces to detect the insurgents. The strength of the support may also differ depending on whether it is given willingly or under duress. Two key factors that can influence population alignment are the religion and income of the local population. Greater religious allegiance between the locals and insurgents means a better likelihood of local support. In addition, locals with lower revenue are more likely to cooperate with insurgents for bulk payments, for example, getting hired to dig IEDs into the road side.

Conversely, if the population is not aligned with the insurgents (e.g., different tribe, harsh reprisals dealt to the population, political disagreement on end-state, an economically prosperous area with more pressing interests, etc.), they may be willing to inform security and coalition forces of insurgent movements in the area. For the insurgent, if they understand that the population in one area is not aligned with them, no matter how physically desirable the terrain is, the risk of being informed upon may exceed the route desirability. Likewise, any route that brings the insurgent close to security or coalition forces would be undesirable. Examples of this are police checkpoint or roadblocks, impromptu checkpoints, vehicle leaguers or fuelling points, forward operating bases or any other piece of mobile or stationary infrastructure. Contact with either security or coalition forces will be aggressively avoided by the insurgent up to the point of attack.

2.2.1.2 Kill Zone

The kill zone (i.e., target area) is the final destination of the ingress route. Insurgents will transit until they are at the predetermined attack point that was chosen in the planning stage.. The basic criteria for a desirable attack point is an area that gives the target minimum fields of view, gives the triggerman optimal view of the approach of the target into the kill zone, and gives the IED cell a desirable egress route. The kill zone will most likely be along a roadway that the target (coalition or security force vehicles) is known to travel with some frequency. The device will be emplaced directly in the roadway, or in a culvert or pipe running under the road to minimize the amount of digging required, as well as evidence that a device was emplaced.

Like the choice of routes, the target area gives the insurgent maximum cover from view. The insurgent's strength lies in remaining unseen, which annuls the significant advantage that NATO militaries possess over an insurgent force in firepower and armour. Accordingly, the insurgent will not pick a target location that allows a coalition weapon system (e.g., call-sign) to bring their full power to bear on them. When the target is in range all members of the IED cell will prepare for combat, with emphasis on the triggerman aligning the target on some kind of aiming point. Depending on the skill of the insurgent and the speed of movement of the target, the insurgent may detonate the device with a specific intent such as killing the driver by timing the detonation of the device to explode under the front of the vehicle, or target the crew by aiming for the centre-rear of the vehicle. If the terrain permits, the insurgent may also sight an anti-armour weapon or machine gun to engage any survivors of the IED blast.

One factor that can affect the choice of kill zone is *attack history*, which refers to the past activity and success held by the enemy in a particular area. In short, past success is related to higher likelihood of re-targeting the same area. Areas with high levels of successful attacks will have consistent elements of terrain that is considered optimal to conduct such attacks, such as visible line of sight to the enemy. It is also important to note the context under which IED attacks are carried out. If, for example, an IED cell has been particularly successful at using remote control IEDs to target armoured vehicles in the middle of the day, they will continue to do so. Presume that the IED cell picks the time they do because they know they cannot see aircraft in the area at that time, and they often see a small, relatively vulnerable convoy passing by that route. The location is chosen because the routes in are well hidden from observation, virtually ensuring their movement to the target area undetected. Insurgents are adaptive, but they no reason to adapt if their enemy continues to behave in a predictable manner.

2.2.1.3 Egress

The egress portion of the attack is roughly the reverse of the ingress; insurgents seek to transit from the target area as fast as possible while maintaining security and evading detection. The differentiator between the ingress and egress is that there is far greater risk of detection during the egress. During the ingress the insurgent is moving according to his own initiative and timeline. An IED attack raises significant attention at security and coalition headquarters. An IED attack will likely bring air assets (helicopters, Unmanned Aerial Vehicles, fixed wing strike aircraft) or a land-based Quick Reaction Force to investigate. As the insurgent no longer controls the initiative during the egress, the emphasis shifts to distancing from the target area, with acceptable compromises to concealment until they perceive themselves to be far enough away to avoid detection and identification. This, again, is a terrain and human geography function. On the egress the insurgent may be slightly more willing to cross through territory whose population is not aligned, but the preference is to travel through an aligned area.

2.2.2 Extracting Knowledge Requirements from CTA

Initially, Drake's model provided an outline for the task network involved in IED operations. However, this outline was unclear on task sequence and priority, and lacked detail necessary to translate into simulation. We remedied this issue by restructuring the tasks in a hierarchical fashion, and then integrated SME knowledge to support the task detail. In Figure 3, TaskArchitect was used to outline the level of task detail that will be used to develop a complete CTA. The aim is to explicitly link the interdependence of tasks and knowledge to decision making. In order for a route to be chosen, variables such as population alignment and terrain tempo/concealment are considered. By simply decomposing tasks a few steps further, we can already see consistencies that can be integrated into modelling.

At this point, we have used the process of building a CTA to sift and identify the most relevant tasks and knowledge elements (from our SME knowledge and research) that should to be considered when representing insurgent decision making for IED emplacement. These concepts of concealment, tempo and human geography are still abstract and the relationships are only meaningful to the SME and the HF team who captured them. The resulting CTA will guide the M&S side on which relevant information to extract to meet the requirements to build a realistic modelling environment. The next steps involve arranging the concepts extracted from the CTA into properties that are currently possible within a simulated environment, and those that the M&S must create to enhance the realism of the defence environment. The following section explicitly links the HF concepts involved in route selection to spatial information requirements for a terrain database in simulation.

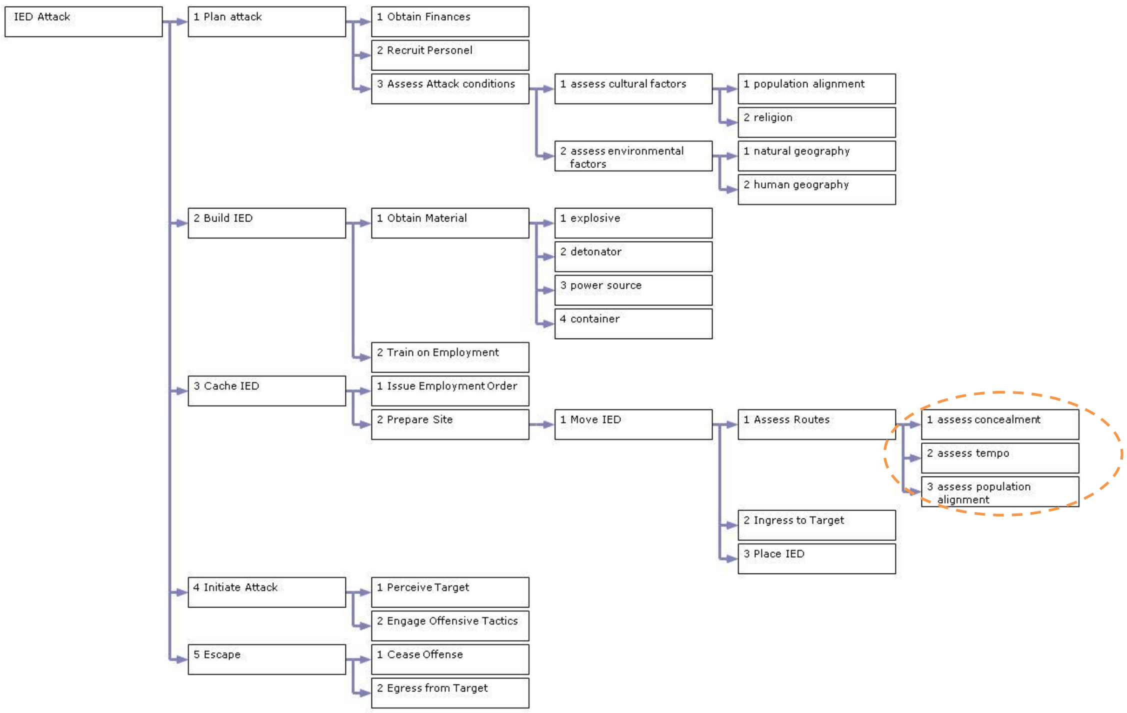

Figure 3: Evolved CTA of IED Operations.

3.0 SPATIAL INFORMATION REQUIREMENTS WITHIN A TERRAIN DATABASE FOR MILITARY SIMULATION

The spatial information requirements for realistic human behaviour may differ from those found in typical synthetic environments. Generally, a military terrain database contains representations of physical properties and objects in the environment, such as road outlines, land types (i.e., grass, sand, water, pavement etc.), building locations and dimensions and other features such as trees and fences. In the simulation of human behaviour, this representation of the world must satisfy the information requirements of the behaviour model. If a real human acts on an aspect of the world that is not represented in the simulation, this aspect of human behaviour cannot be simulated.

Thus far, we have used navigation within IED emplacement to illustrate route selection in hostile environments. Conceptually, route selection is based on concealment and tempo. Although we extend these concepts as spatial properties, neither concealment nor tempo is represented in a typical terrain database. Therefore, we must translate these conceptual representations of the environment into a representation amenable to simulation. Our process decomposes this translation into three kinds of relationships. First, some physical features or properties have a simple, or fixed, relationship to the HF concepts. Second, some features have a relationship that is variable, depending on the context of the scenario or domain, or an effect that is moderating depending on context. Finally, we recognize that some aspects of the world are related to behaviour by the domain knowledge held by the entity to be simulated. These divisions allow us to understand the significance of information typically represented in simulation environments, and to specify the additional information requirements to enhance the simulation realism.

3.1 Fixed Spatial Properties

The HF concepts of tempo and concealment relate to certain concrete spatial properties in a consistent, invariant fashion. We refer to these relationships as being "fixed", in that they represent permanence within the context of the environment. In terms of concealment, physical objects provide concealment by obstructing *line of sight*, whether it is lateral (concealment behind), vertical (concealment under) or complete (concealment within). An analysis of the features used for concealment in the real world provides a direct specification of the features required in the simulation environment.

Similarly, fixed factors also relate tempo to the objects in the environment. Features act as obstacles and affect the time required to cross a given terrain. Two factors that we considered to interact with tempo are the surface terrain that is travelled on, and any objects that must be travelled around. Individually, the terrain's surface material affects the speed of navigation, such as slower movement on sand than on pavement. Objects in the environment also decrease tempo, such as a city's housing infrastructure. Generally, open, rural areas can be thought of as being faster to travel through than crowded, urban areas. However, these two properties interact to create a range of route desirability. For example, depending on a higher need for tempo or concealment, a cluttered route on a slow surface may be more desirable than an open, hard surface. Ultimately, surface terrain and fixed objects need to be considered together as different combination of natural landscape and man-made objects will affect route selection.

The specification of fixed factors defines fixed relationships between physical features and behavioural properties. This enables traceability between the specification of behaviour and the specification of terrain database contents. Further, it allows the behaviour model to be phrased in generalizations such as tempo and concealment, and for these generalizations to be produced from information contained in a terrain database.

3.2 Contextual Properties

3.2.1 Variable Factors

Some properties of the environment affect concepts like concealment with *variable* relationships that can change the desired properties of a location minute by minute, scenario by scenario or domain by domain. In contrast to the fixed relationship between objects and concealment based on obstruction, variable factors affect visibility along the *line of perception*. Line of perception differs from line of sight in that an object may or may not be recognized or noticed, even though it is within the line of sight. This definition was derived from the concept of *inattentional blindness*[11] - the phenomenon of not perceiving a stimulus in plain sight. For example, blending occurs when an object is able to be seen, but is not recognized as a threat, such as the case of using common commercially available products (e.g., radios, cell phones) to build IEDs, in order to hide them in plain sight. Similarly, camouflage may occur when an insurgent mimics the visual properties of their environment, such as the military uniforms that match natural terrain.

Another example is concealment within the environment's normal activity, such as blending into the crowd – which may be difficult to visually detect. This type of blending can be representing using *population density*, that is, the number of people that need concealment to the number of other people in environment. A low ratio, such as one person hiding in crowd, facilitates concealment. Thus, population density *varies* the concealment offered by a location.

[11] Simons, D. J. Chabris, C. F. (1999). Gorillas in our midst: sustained inattentional blindness for dynamic events. Perception, 28, 1059–1074.

Tempo is similarly affected by variable factors. The same population density that allows an insurgent to blend in, can also constrain their ability to travel quickly. For example, during weekdays, routes along downtown business cores are highly populated. Those same routes after working hours or on the weekends may be virtually vacant and again affect route selection. In addition, such variable factors such as religious holidays, ceremonies or other events that create non-routine human and vehicle traffic need to be considered. For instance, a route that is typically deserted on a Saturday afternoon may be flooded with foot traffic in the event of a wedding or funeral. The tempo afforded by a location is varied by population density. Further, this example outlines how *local knowledge* might also be related to the assessment of the impact of this variable factor on route selection. This implication is discussed further in the domain knowledge section.

3.2.2 Moderating Factors

The aforesaid spatial information requirements form the core of the simulated environment, but are not yet complete for defence modelling. Accordingly, we imposed a further layer of contextual meaning onto the physical object and terrain data. This defined layer moderates and agent's decision making based on different conditions within the same environment –stemming from properties associated with the terrain. While there are understandably countless variables that could be considered, for the scope and purpose of this work, we have focused on defining a finite number of variables related to *human geography* and *climate* that would affect the human behaviour in a military simulation.

Here, we refer to human geography as intangible properties that can be attributed to objects in the physical terrain that serve to moderate the overall desirability of route selection despite other fixed and variable factors. In addition to physical features and topography, we considered population alignment and attack history as two characteristics of human geography that could interact with the physical terrain and affect human behaviour. For example, while a crowded area may distort the enemy's line of visual perception, the target may still avoid that area if the crowd population does not support the target's political objectives – the crowd may report the target, removing the perceptual concealment. Similarly, a route that appears less desirable physically, such as having low concealment, may also have previous attack success. For less obvious reasons such as frequency of travel by the coalition due to a forced choke point, the target area remains attractive to the insurgent.

Climate consists of *time of day* and *weather conditions*, which are can moderate the effects of concealment. These factors interact with the fixed terrain properties to either enhance or reduce the current level of concealment offered by physical objects in the environment. Specifically, objects are easier to see during a clear bright day, and more difficult to see through atmospheric particulation (i.e., fog, smoke, precipitation) or at night. Furthermore, when considering how these two factors interact, it is easier to see on a clear night than a cloudy day, and difficult to see at both dusk and dawn. Linking back to the fixed and variable properties, light and/or weather has the potential to change the overall concealment, and therefore desirability of a route over and above its physically-based characteristics. Overall, to maintain simulation realism, it is important to consider how the interaction of fixed and variable factors can affect the concealment, tempo and ultimately choice of route in any given context.

3.3 Domain Specific Properties

Domain specific information requirements are the knowledge or awareness that an agent must possess in order to complete the task in question, and may not transfer to other domains. For instance, whether a target is considered *in range* varies depending on insurgent's knowledge and skill with the weapon in question. While it is important when building a complete decision making model to include this granularity of knowledge, the examples outlined in this paper do not explore this level of abstraction in detail. Nevertheless, to properly represent knowledge for realistic simulation, the following section outlines some domain knowledge aspects of IED operations, which will more directly influence our future modelling process.

Domain specific variables can be the agent's experience and knowledge about that particular task that would influence the quality of decision making. For instance, to execute any type of attack a team of insurgents must possess some level of tactical knowledge about weaponry, blast radius and enemy reconnaissance. To illustrate how tactical expertise can affect decision making, suppose that a coalition convoy employs electronic counter measures, also known as 'jammers', to negate the insurgent's ability to use remote control devices. The IED cell may then switch to a pressure plate device that will be triggered when the target vehicle drives over it; such a device is not susceptible to jamming. However, suppose that a civilian vehicle or a vehicle carrying an insurgent drives over and detonates the device. In the attempt to defeat coalition counter-measures, the insurgents have destroyed something other than their target. Reasonably, the insurgents would then shift to a closed circuit command wire IED, which are not susceptible to jamming, and also allow them to discern targets to avoid detonating something that is not a target.

Insurgencies are Darwinian in many ways; those who lead adaptation will be more difficult to kill or capture that those who cannot adapt in the face of more effective counter-measures. The context under which insurgents operate will drive the micro elements of their application, though their macro requirements remains the same. When considering how this applies to a CTA, the high level tasks will not change for insurgent operations, but the sub-tasks will change drastically based on the specifics of the context.

3.4 HF and M&S Information Relationships

This paper has described challenges of translating HF concepts into M&S information requirements. We focused on various factors that can affect route selection in a during IED operations that were based on knowledge capture from SMEs and training documents. This process has two key characteristics. First, the information requirements must be traceable to the behavioural requirements. As such, we used a tailored CTA process to hierarchically arrange information. This process identified key concepts that influence behaviour, such as concealment, tempo and population alignment. Second, the explicit relationships must allow the behaviour model to be formulated in terms of generic characteristics, and a translation layer that relates the behaviour model to a specific simulated environment. The subject matter expert information was used to explicitly relate key concepts to information items that can be represented in simulation environments. Table 1 summarizes the analysis structure relating the HF concepts to physical characteristics that appear in the simulation environments, and example comparisons. These interactions can influence how an insurgent views the desirability of a given route, and therefore sway their decision making processes.

Table 1: Summary of HF and M&S Information Relationships.

HF Concept	Spatial Properties	Effect		Example Relationship
Fixed Factors		Concealment	Tempo	
Line of Sight/ Fixed Clutter	**Man-made Structures:** buildings, houses, shops	X	X	Urban more covered than rural
	Landscape/Vegetation: trees, shrubs, rocks, hills, ditches, berms	X	X	Forest more covered than field
	Surface Terrain: grass, sand, water, pavement, gravel	X	X	Sand slower than pavement
Contextual Factors				
Line of Perception/ Variable Clutter	**Population Density**: crowds, foot/vehicle traffic	X	X	Crowded more covered than empty; Crowded slower than empty
Human Geography	**Population Alignment:** money, material, moral, religious	X	X	Positive/Neutral support more desirable than negative support
	Attack History: success, failure, no history	X	X	Success more appealing than failure
Climate	**Weather:** rain, snow, fog, sleet, clear	X		Fog more covered than clear
	Time of Day: night, day, dusk, dawn	X		Night more covered than day
Domain Specific				
Knowledge/ Experience	**Weaponry:** skills, blast radius, training; **Reconnaissance:** enemy location, tactical evolution	TBD	TBD	Skilled insurgents should choose better routes

4.0 CONCLUSION

This paper reported on the collaboration of HF and M&S fields at CAE PS to develop shared tools for integration into defence modelling and simulation. The use of simulation to enhance team preparedness for deployments into hostile areas requires the development of realistic models of insurgent behaviour. We outlined a process that bridges the gap between HF knowledge acquisition and M&S implementation. As such, this work defined aspects of the information requirements for asymmetric threats encountered by CIED teams as its use-case. A CTA was used to outline a hierarchy of knowledge and relationships between behaviour and physical characteristics that can be more efficiently implemented into simulation. We decomposed insurgent decision making to simulate route selection during IED emplacement. The context of the methodology undertaken by our team supports the need to incorporate a higher level of simulation fidelity to support training in respect to the evolution of the nature of the threat faced by NATO forces.

5.0 FUTURE DIRECTIONS

Cognitive architectures and modelling and simulation components (such as terrain databases) both deal with concepts. A task analysis for IED emplacement may deal with abstract concepts such as concealment or tempo, while a terrain database deals with physical concepts such as labels on a segment or vertex. A challenge to improving current human behaviour representation is integrating the two different representations of the world. We propose the development of a semantic ontology-based translation layer that maps between the different conceptual representations.

Semantic ontologies are structured representations of knowledge. An ontology will typically contain a hierarchical scheme to classify objects using an 'is-a' relationship. Additional relationships between classes of objects are defined to fully represent the knowledge. Logical axioms can then be applied to the classes and relationships to fully capture the semantics and meaning of the knowledge being represented. The power of ontologies comes from the ability to use an inference engine to draw logical conclusion from a set of data, assertions and axioms. These inferences can lead to new assertions about the data or can provide more information in the presence of incomplete data. [12]

The implementation of such a translation layer will allow a generic behaviour model to integrate into a specific simulation environment. For instance, a behaviour model can query the translation layer for concealment; the translation layer can encapsulate the relationships that have been defined in this paper between physical objects and this abstract concept, and the behaviour model can act appropriately without an explicit understanding of the technical details of the terrain database and/or simulation infrastructure. This process will enable the re-use of behaviour models across scenarios and simulation technologies.

The ontology will focus on the three target areas discussed in this paper; the enemy's ingress to the target area, emplacing and employing the device, and egressing from the target area. The ontology will explicitly define the relationships among the environment's spatial properties that will affect the desirability of route. Future work will focus on explicitly stating and constraining the characteristics of route selection from the position of a subject matter expert, and then translating those characteristics into the common terms to build a functional ontology.

[12] Franken, P, Harrison, A.J., Holton, J.J., Macfarlan, L., Wowczuk, Z.S., Capshaw, N.C. Williams, R.W. & Russomanno, D.J. (2009). Development of an Ontology-Based Tool to Support the Test and Evaluation Process for Rapid Acquisition of IED Detection Capabilities. ITEA Journal. 30(2). Pp305.