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Simulating Human Behavior for National Security Human Interactions

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Simulating Human Behavior for National Security Human Interactions

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Cognitive and Exploratory Systems & Simulation

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Intelligent Systems Principles

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Abstract

This 3-year research and development effort focused on what we believe is a significant technical gap in existing modeling and simulation capabilities: the representation of plausible human cognition and behaviors within a dynamic, simulated environment. Specifically, the intent of the *Simulating Human Behavior for National Security Human Interactions* project was to demonstrate initial simulated human modeling capability that realistically represents intra- and inter-group interaction behaviors between simulated humans and human-controlled avatars as they respond to their environment. Significant process was made towards simulating human behaviors through the development of a framework that produces realistic characteristics and movement. The simulated humans were created from models designed to be psychologically plausible by being based on robust psychological research and theory. Progress was also made towards enhancing Sandia National Laboratories' existing cognitive models to support culturally plausible behaviors that are important in representing group interactions. These models were implemented in the modular, interoperable, and commercially supported Umbra® simulation framework.

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Table of Contents

Figures

Nomenclature

DoD	Department of Defense
DOE	Department of Energy
GUI	Graphical User Interface
HI	Simulating Human Behavior for National Security Human Interactions
HLA	High Level Architecture
LDRD	Laboratory Directed Research and Development
M&S	Modeling and Simulation
SCREAM	Sandia Cognitive Runtime Engine with Active Memory
SNL	Sandia National Laboratories

1 Introduction

The primary intent of the *Simulating Human Behavior for National Security Human Interactions* (HI) Laboratory Directed Research and Development (LDRD) project was to develop a human interaction framework that simulates intra- and inter-group interaction behaviors, as well as to demonstrate initial human modeling and simulation capability derived from a psychologically plausible cognitive framework. To achieve this objective, the existing Sandia National Laboratories (SNL) modeling architecture was extended to allow cognitively modeled simulated humans, or “cognitive characters” to interact with each other, their environment, and with actual humans in a behaviorally realistic and psychologically plausible manner. Towards this end, substantial progress was made in simulating human cognition and behaviors in a manner that produces life-like characteristics and movement.

Ultimately, the goal of this effort is to help create the groundwork for human simulation models that can be fielded as next-generation Modeling and Simulation (M&S) training, behavioral forecasting, and tactics development tools. With this purpose in mind, the HI work integrated, and thus leveraged, multi-million dollar past investments that include Umbra and the SNL cognitive modeling architecture. The result of this effort is a M&S capability that will serve as a technical foundation for subsequent national security analysis and security personnel training. Overall, the HI cognitive modeling framework was designed to be an interoperative architecture that can serve several different application areas besides human simulations, such as augmented cognition, robotics, medicine, and educational needs (see Figure 1 below).

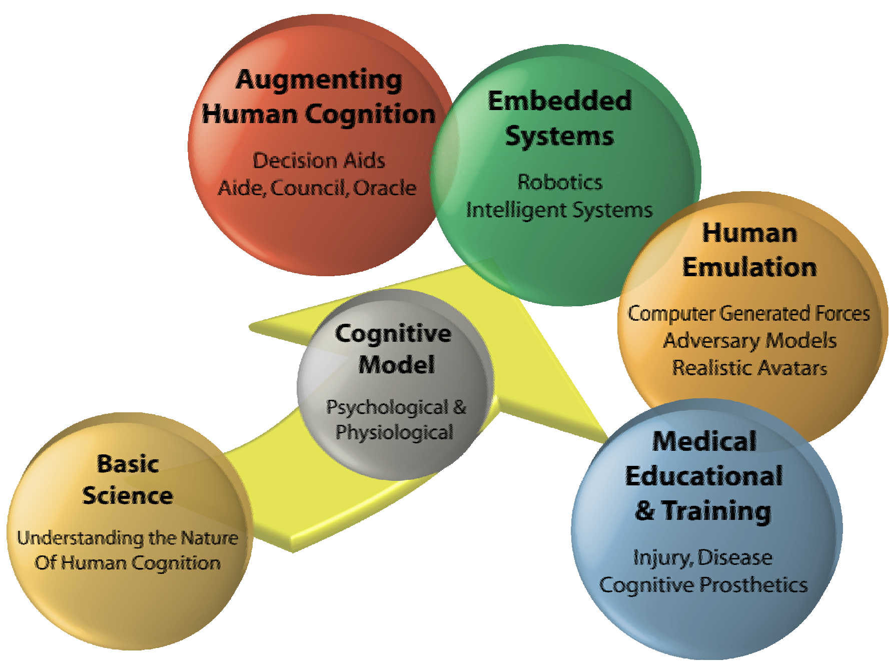

Figure 1. Potential application areas for the SNL cognitive model architecture

1.1 Traditional Modeling Limitations

Using human simulations for training is potentially an effective way to achieve significant reductions in cost and manpower. Current human simulations are appropriate for many domains that are strictly defined. However, when the domain environment is highly dynamic and complex and needs to be realistic, current simulation methods tend to fail. This occurs because training environments involving human simulations presently do not have the resolution and fidelity required to be able to replicate the asymmetries that are often seen in the "real world." Existing simulations also focus almost exclusively on modeling reactive, physical behaviors instead of the underlying cognitive process that actually drive these behaviors. Consequently, simulated human behaviors in current simulations tend to be brittle, especially in changing environments and scenarios. Moreover, players can easily "game the system" after learning its limitations. A potential benefit of using a cognitive model architecture that is both psychologically realistic and flexible is that it could ultimately address the resolution and fidelity problems that face current human simulations. For instance, the existing HI framework can exhibit cognitive characteristics of foreign adversaries, including their basic perceptions, mindset (i.e., context, goals), and the significant physical characteristics and behaviors that are reflective of individuals within a particular country or geographical region.

Advanced cognitive models could eventually provide US governmental agencies with additional tools for dealing with evolving threats through action/counter-action behavior forecasting and simulations. Indeed, using cognitive models for behavior forecasting is a significant long-term goal of this effort. The ability to generate a scalable number of cognitive characters that interact and behave in a culturally and sociologically accurate manner will allow US agencies to play "what if" simulations so as to test different policy and/or military approaches to specific situations. Moreover, they could serve to forecast the movements and general behaviors of large groups of individuals in response to US policy, military actions, and/or critical events that impact the general population (such as terrorist bombings and natural disasters, etc). In fact, the HI framework is currently being applied to the modeling of behaviors and cumulative economic effects on the US population in the aftermath of a simulated natural disaster event (*Cognitive Modeling of Human Behaviors within Socio-Economic Systems* project, LDRD 06-1102, will be further discussed in the potential applications section).

Overall, it is anticipated that the capabilities developed by this LDRD will ultimately provide security enhancements and/or new technologies that will aid in formulating better domestic and foreign security strategies. Moreover, it is expected this project will serve as a technical foundation for next generation training tools for DOE response forces and DoD military personnel.

2 HI Cognitive Modeling Framework

The HI framework is designed to be a psychologically plausible framework of human thought and behavior (see Figure 2). Thus, an important feature of the framework is its primary emphasis on psychological and sociological realism. This includes the need for realism in cognitive functioning of individuals, realism in the sociological behavior of individuals within groups, and realism in the physical responses of individuals to stimuli. In this way the framework is capable of representing different types of individuals (e.g., red/blue forces, instigators, general public, etc.) who may, by and large, be similar to one another but exhibit differences in thoughts and behaviors.

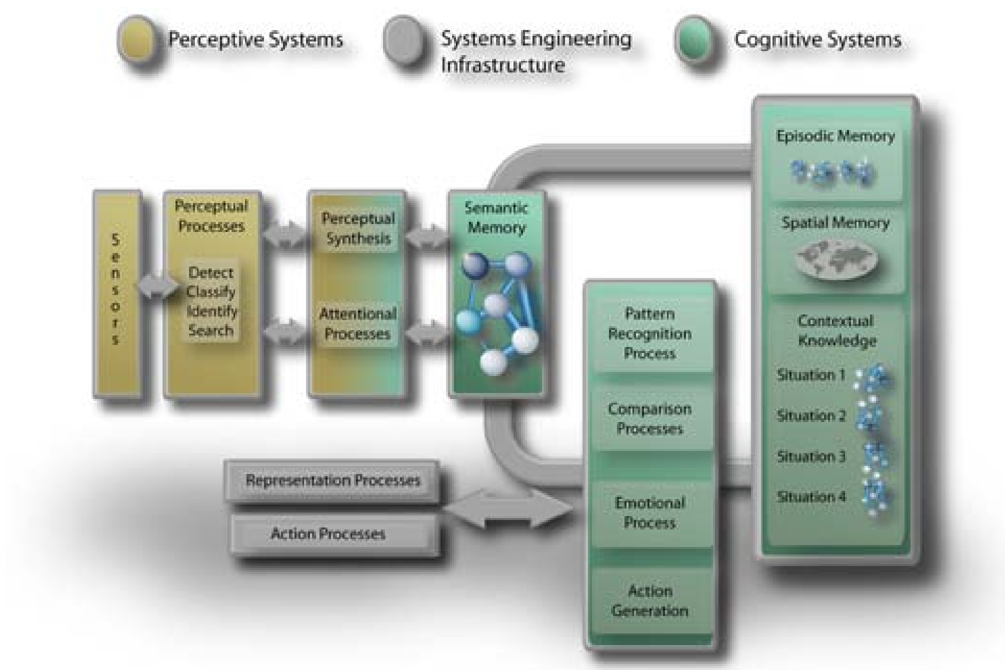

Figure 2. A high level view of the SNL cognitive modeling architecture

2.1 Overview

The HI cognitive framework consists of a human-representative computational model through which a cognitive character recognizes patterns of stimuli in the environment and responds to those stimuli according to current contexts, goals, and emotions. The cognitive characters can sense each other, react to each other, and move about in a simulated 3D environment. Moreover, the cognitive characters have selected spatial capabilities that can interface to future perceptual and motor functions. For example, they can maneuver through a building, perceive and recognize objects (such as other characters) within the buildings, and recall the layout of rooms they entered. In addition, the cognitive characters' emotion states and the actions of other cognitive characters will affect their behaviors. For instance, fearful cognitive character adversaries may find a place to hide or seek to escape a building, whereas cognitive characters in an agitated state may act in an aggressive manner. Collectively, these functions permit a potentially more accurate simulation in which actual humans could interact with them in a manner that more realistically reflects human thoughts and behaviors.

The HI framework is a cognitive structure that is an expansion of the general SNL cognitive architecture. The HI framework sits on top of the Sandia Cognitive Runtime Engine with Active Memory (SCREAM). In this application, SCREAM acts as a general purpose engine that allows the HI-specific framework to operate. The HI framework is implemented in Umbra®, a C++-based, modular simulation framework that is High Level Architecture (HLA) capable (See Gottlieb et al. 2001; Gottlieb et al. 2002; Van Leeuwen et al. 2004). Umbra was designed for modeling complex physical systems and has been used successfully to model systems containing robots, sensors, and non-cognitive, simulated humans.

The HI framework consists of three primary modules that handle semantic knowledge, pattern recognition, and action generation. The semantic module incorporates an associative network with nodes representing each critical concept or "schema" embodied in each cognitive character. Pattern recognition and comparator modules provide mechanisms for: (1) evaluating the evidence provided by cues favoring or conflicting with each situation, (2) assessing the validity of the current situation, (3) determination of a valid situation when the current situation is judged not to be valid, and (4) implementation of top-down activation.

The HI framework is distinctive in its instantiation of human decision-making, as opposed to more common production rule-based approaches (see Forsythe, Bernard, Xavier, Abbott, Speed, & Brannon, 2002; Forsythe & Raybourn, 2001; Forsythe & Xavier, 2002). That is, instead of using production rules that drive behaviors of cognitive characters, it uses levels of activation for perceptions and states. Behaviors derived from production architectures are guided by strict "if-then" rules, which state that if an objective is to do something and the parameters have been satisfied, then it will perform an operation associated with that objective. Production rules are efficient and appropriate for architectures that are chiefly concerned with behavioral control and predictability. The HI framework seeks predictability as well, but it puts a much greater emphasis on modeling the cognitive processes that ultimately guide the behaviors of cognitive characters. It is asserted that rigorous modeling of cognitive processes will ultimately result in more accurate, predictive behaviors. For example, the HI framework allows for multiple perceptions, goal states, and action intentions which can concurrently have some degree of activation. Once a perception has been activated by cues in the environment, it may trigger a specific, intermediate goal state if that state is consistent with higher-level goals and current environmental conditions. The intermediate goal that is activated will trigger an action intention state. The action intentions that are ultimately chosen will be mediated by current emotion states (i.e., fear, anger) that are affected by what they perceive in their environment.

While comparatively new, it is asserted that the underlying framework emphasizing pattern recognition, integration of perceptual, cognitive and affective processes, including multi-modal memory representations, and other features provides the basis for a substantially more realistic and flexible representation of human cognition. Yet, it is recognized that integration with an abstract decision-based system could provide additional capability for applications that require complex logic, such as inductive, deductive, and abductive reasoning. Implicit to recognition of a situation, there is recognition of goals, or attainable states, and the actions needed to realize those goals, including likely intermediate states. The cognitive subsystem serves in our model as the point where the diverse emotions, stressors, memories, and other factors are all integrated into a decision for action (or inaction) in order for a transition to the next state (or return to the current state).

This human ability to recognize a situation quickly and accurately and respond accordingly, as opposed to a lengthy internal discourse in pros and cons, is one of the differentiating features of SNL's theoretical basis for the cognitive model framework—that is, humans may collectively and instantly react to a situation (such as a cheer when a baseball player hits a homerun) without deliberating with each other. Just as recognition of situations leads to the development of a context and associated expectations, this method of interpreting the world also lends itself to immediate recognition of events or objects that do not fit in the current context. Similarly, events that do not fit in the current context are also immediately noticeable.

Also within the SNL modeling framework, it is recognized that cognitive processes are inseparably interwoven with state and trait emotional processes. The model of human emotion encompasses multiple aspects of emotion. At present, a model with emotions would include surprise-fear and frustration-anger. The choice of emotions was based on a large body of cross-cultural and neuropsychological research (e.g., LeDoux, 1998).

When constructing a model, each concept may be attributed to one or more emotional component that is associated with specific levels of activation. For example, a disliked individual may be represented as a concept for which there is an association with a high level frustration-anger. Activation of a specific concept or situation contributes to the weighted averages that determine the overall activations of associated emotional components. The specific emotion activation levels are converted to fuzzy set (e.g., *high-fear*) representations that are then feed into context recognition patterns. In the near future, emotions will have a reciprocal effect on cognition, causing an increase in concept or situation activation that triggers the emotion and active inhibition of other concepts and situations. In the future, as with the current interactions, emotion and cognition will be consistent with neuropsychological findings and, thus, will allow certain neuropsychological phenomenon to be demonstrated by the framework.

By and large, the HI framework can be viewed as three interconnected, high-level components that basically correspond to "pre-cognitive" (attention), "cognitive" (perceptions, states, goals), and action generation states (motion control). A discussion of each interconnected component and how they relate to actual human psychological processes is presented below.

2.2 Semantic Memory System

Within the HI framework, knowledge and the relatedness of concepts is represented within a semantic memory system. Relatedness refers to the awareness that two concepts are associated with each other by virtue of being members of the same category and operating together. When concepts are extracted via automated knowledge capture techniques, the relationship between concepts is based on a representation of each concept as a vector in a high-dimensional space. The cosine similarity of vectors for a given pair of concepts provides the basis for the strength of the relationship between concepts. The relatedness of concepts derived in this manner then provides a basis for simulating the priming that occurs for a concept in response to the prior presentation of a related concept (Forsythe & Xavier, 2005).

Certain concepts are likely to occur in conjunction with a perceptual context, which forms the basis of an expectation. For example, noticing "potentially hostile people" may prime the expectation of seeing "armed soldier." If the existing pattern of concepts is on the verge of providing enough evidence for this context to be activated, then only a minor amount of evidence that hostile people are in the area is needed to prime the expectation. It also might be that very strong evidence from only a small number of concepts is enough to activate a context. Once a context is activated, the associated concepts are primed so that corresponding sensory inputs produce accelerated and supplemented activations. The semantic memory component thus incorporates an associative network with nodes representing each critical concept known to the particular cognitive character. A pattern recognition component (embedded in SCREAM's ContextRecognizer module) and comparator component (in implementation) also provide mechanisms for evaluating the evidence provided using cues favoring or conflicting with each situation, as well as assessing the validity of the current situation, determination of a valid situation when the current situation is judged not valid, evaluation of unexpected cues, and implementation of top-down activation (Bernard, Xavier Wolfenbarger, Hart, Waymire, Glickman, & Gardner, 2005).

A certain context may also prime humans to continuously attend to specific stimuli in the environment, so long as that context is activated. For example, the context of "being in a dangerous area" may prime a person to hear footsteps behind him or her and see shadows that have the shape of a human. In the HI framework, certain contexts may heighten the activation of specific cues in the environment. This generally occurs when there are contexts with salient cues that indicate danger to the cognitive character.

Concepts can support (positive cues) or oppose (negative cues) the activation of a context. For example, the perception "I am at work" is supported by the positive cue, "in my office" and is opposed by the negative cue, "watching sports on television." The levels of activation are mediated by associated weights. The weights link concepts to contexts and concepts to states in an analogous manner (as distinguished from a purely logical one) for the pattern recognition portion of the model. The weights also indicate their level of significance related to a particular context or state.

2.3 Interaction of Semantic Memory and Pattern (Context) Recognition in SCREAM

2.3.1 Basic Cognitive Elements

A ***concept*** is the most fundamental element of the SNL cognitive architecture. Abstractly, a concept is a representation of known regularity arising from external and/or internal data sources, as well as representations that are based entirely upon associations between other representations and have no specific physical manifestation (e.g., the attributes short, busy, free) and/or elements of other memory systems.

In SCREAM, concepts are elements of semantic memory. For practical purposes, concepts are given names, although the cognitive architecture associates no meaning directly with a name itself (Integration of natural language capabilities with the architecture might create an indirect association). Mapped to English words, some examples of concepts are *bicycle, clown, elephant, popcorn, seal, water, big, gray, wet, free, eats, walks, rides, chases,* and *conceals-from*. Note that for brevity, we will write, e.g., "…the concept *walks*..." instead of "…the concept named '*walks*'…".
Theory linking the psychological to the physiological states that semantic memory processes—such as rise, decay, and spreading activation (or, at least, priming)—involve the activation of localized neural assemblies oscillating in the 10-13Hz bandwidth ("high alpha"). In the simplest view, each concept is represented by a neural assembly and the neural assembly associated with a concept that is "currently used" in cognition will rise above baseline in terms of both frequency and amplitude.

Contexts can be defined as meaningful perceptual representations that are based on recognizable patterns of stimuli, as well as, consistent with situation models, schema and theme-based representations of events. The basic idea is that context activation behavior is governed by pattern recognition applied to the activation trajectories of concepts. A concept that plays a role in the recognition of a context is known as a **cue**. For example, the concepts *bicycle, clown, elephant* and *popcorn* in a cognitive model might be cues whose activations tend to cause activation of the context *circus*. Activation of a context, in turn, can cause top-down activation of priming of its cues.

A context activation (recognition) mechanism has been proposed that builds on weighted summation of concept activations followed by a leaky integrator. According to theory linking the psychological to the physiological, the context recognition process is associated with oscillations in the 4-7Hz bandwidth (i.e., "theta"; see Klimesh, 1996).

Instances provide a means to associate entities in the world (real, perceived or cognitive character) with specific concepts. If we view a concept as a relation, then a complete instance of that concept associates each field (slot) of the relation with an entity. Instances enable cognitive models running in SCREAM to properly keep track of contexts that overlap in terms of concepts even when the entities involved do not overlap.

Abstractly, a **concept instance** maps the slots of a concept to entities. For a practical definition and representation, SCREAM uses **entity identifiers (entity IDs)** in its computational framework. An entity identifier is simply an integer that is associated with an entity at some time. This association may be done by or in collaboration with other components of the system that is part of cognitive model. For example, a perceptual component might associate a new entity identifier with each entity it recognizes as distinct from entities it has encountered before.

In a (running) SCREAM model, a concept instance is uniquely identified by a concept and a vector of entity IDs such that the dimension of the vector matches the arity of the concept. For example, *clown {31}* and *clown {22}* uniquely identify instances of the concept *clown*, and *chases {22, 31}* uniquely identifies an instance of the concept *chase.* Note that we will usually write, e.g., "…the concept instance *clown {22}*…" instead of "…the concept instance identified by *'clown {22}'*…" for brevity.

We similarly build the definition of **context instance** from context so that a context instance is uniquely identified by a context and a vector of entity IDs—for example *PieFight {31, 22}*.

If a concept (context) can apply only to the entire universe of a cognitive model instead of to entities in that universe, then it is appropriate for that concept (context) to have at most, one instance. If there is no entity (physical or abstract) that needs to be associated with the concept, then it is appropriate for the vector of entity IDs for its instance to have dimension zero. *ValentinesDay {}*, for example, is the only possible instance of the concept *ValentinesDay*. However, if there is an entity to be associated with that concept, then its instance should be associated with an entity ID. For example, *WhiteHouse {1600}* or *IndependenceDay{17760704}*.

A *Non-Specific Entity ID* is defined to enable incompletely specified concept instances and context instances. A concept instance whose vector of entity IDs does not have the the *Non-Specific Entity ID* as an element is said to be completely specified.

2.3.2 Context Patterns and Context Instance Instantiation

The Context recognizer currently supports the construction and recognition of two types of patterns, ***cue vector context patterns*** and ***XQ context patterns***.

2.3.2.1 Cue Vector Context Patterns

Cue-vector context patterns are templates for context instances composed from no more than a fixed number of concept instances, usually instances of different concepts.

A context vector cue pattern is a vector $\mathbf{Q} = \{Q_i\}$ of triples $Q_i = (P_i, w_i, \mathbf{m}_i)$, where: P_i is a concept (name); w_i is a weight; and for each j the j^{th} element of integer vector $\mathbf{m}_i$ maps the j^{th} slot of the concept (named) P_i to a slot of the context. We will usually use the notation $\mathbf{Q}^{(X)}$, $Q_i^{(X)}$, $P_i^{(X)}$, etc. when describing the cue pattern for a context X . Note that the dimension of $\mathbf{m}_i$ is equal to the arity of P_i .

Example

Suppose a cognitive model has the unary (i.e., arity one) concepts *dominant* and *submissive* and a binary concept *attacks*. Then we can define a binary context *Dominated-by* that has the pattern

Dominated-by 3 submissive 0.4 0 attacks 0.6 1 0 dominant 0.5 1

whose vector of cues $Q^{(\text{Dominated-by})} =$

{ *(submissive, 0.4, {0}), (attacks, 0.6, {1, 0}), (dominant, 0.5, {1})* } .

In our notation, index numbering for elements of a vector begins with 0. The *{0}* in (*submissive, 0.4, {0})* maps slot 0 of *submissive* to slot 0 of *Dominated-by*. The *{1, 0}* in (*attacks, 0.6, {1, 0})* maps slot 0 of *attacks* to slot 1 of *Dominated-by* and slot 1 of *attacks* to slot 0 of *Dominated-by*. Finally, the *{1}* in *(dominant, 0.5, {1})* maps slot 0 of *dominant* to slot 1 of *Dominated-by*.

2.3.2.2 Context Instances

Formally, an instance $\chi = (X, \mathbf{g}, \mathbf{Q}^{(X)}, \mathbf{p}, \sigma)$ of a context X has a tuple $\mathbf{g}$ of entity IDs and a non-empty tuple $\mathbf{p} = \{p_k\}$ of active concept instances that it associates with elements of the pattern vector $\mathbf{Q}^{(X)} = \{Q_i^{(X)}\}$ via the one-to-one map σ from one set of indices to another. $\mathbf{g}$ serves as χ's bindings and has the same arity as X. The concept instances associated with a context instance must simultaneously unify with its pattern under the mapping σ. Note that the *Non-Specific Entity ID* unifies with any entity ID.

Example

Suppose that *attacks(56,13)* and *dominant(56)* are active concept instances. We verify that *(Dominated-by, {13,56},* $Q^{(\text{Dominated-by})}$*, {attacks(56,13), dominant(56)}, {1,2})* , with $Q^{(\text{Dominated-by})}$ = { *(submissive, 0.4, {0}), (attacks, 0.6, {1, 0}), (dominant, 0.5, {1})* }, as above, represents a legal instance of *Dominated-by*.

- *{attacks(56,13), dominant(56)}* is non-empty.
- $P_{\sigma(0)}^{(\text{Dominated-by})} = P_1^{(\text{Dominated-by})}$=*attacks*, and $P_{\sigma(1)}^{(\text{Dominated-by})} = P_2^{(\text{Dominated-by})}$=*dominant*.
- The tuple *{13,56}* has two elements.
- $\mathbf{m}_{\sigma(0)}^{(\text{Dominated-by})} = \mathbf{m}_1^{(\text{Dominated-by})}$=*{1,0}*; $\mathbf{m}_{\sigma(1)}^{(\text{Dominated-by})} = \mathbf{m}_2^{(\text{Dominated-by})}$=*{1}*.
  $\mathbf{g}[\mathbf{m}_{\sigma(0)}^{(\text{Dominated-by})}[0]] = \mathbf{g}[1] = 56 = \mathbf{b}_0[0]$; $\mathbf{g}[\mathbf{m}_{\sigma(0)}^{(\text{Dominated-by})}[1]] = \mathbf{g}[0] = 13 = \mathbf{b}_0[1]$.
  $\mathbf{g}[\mathbf{m}_{\sigma(1)}^{(\text{Dominated-by})}[0]] = \mathbf{g}[1] = 56 = \mathbf{b}_1[0]$, which is consistent.

Note that there is no need for there to be an instance of the concept *submissive*.

The set of context instances is updated as the Context Recognizer learns of changes to the set of active concept instances. The activation level of a context instance is updated at a rate in the 4-7Hz range according to the cognitive framework simulator clock. An instance χ of context X is a member of the set of context instances maintained by the Context Recognizer if and only if there is no way to add an active concept instance to χ's concept instances $\{p_k\}$ and extend its map σ and have the result be a legal context instance. In other words, the set of maintained context instances is the maximal set of context instances such that each member is maximally unified with respect to the set of active concept instances. Intuitively, this means that the Context Recognizer maintains all the context instances that each takes into account all the cues it can without being inconsistent. Since this thoroughness might not be cognitively plausible in light of capacity limitations, the SCREAM Context Recognizer enables limiting output context instances to a specified number of context instances ranked according to activation level.

Inhibitory bias can be specified to be applied in the computation of the activation of instances of a context. Basically, the bias is subtracted from what would otherwise be the immediate activation in computing the activation level of a context instance. Thus, if $\beta^{(X)}$ is the (inhibitive) bias of context X and $\chi = (X, \mathbf{g}, \mathbf{Q}^{(X)}, \{p_k\}, \sigma)$ is an instance of X, the expression for immediate activation of χ is

$$a_{\text{immed}}(\chi) = \max\left(\left(\sum_k w_{\sigma(k)} * a(p_k)\right) - \beta^{(X)}, 0\right),$$

where $a(p_k)$ is the (gross) activation level of concept instance p_k at the time.

Computation of the gross activation level of χ is based on applying an activation function to $a_{\text{immed}}(\chi)$ and then applying a normalized leaky integrator to the result. Note that a normalized leaky integrator is a leaky integrator followed by a scaling factor such that for any given constant input the steady-state output will approach that input.

2.3.2.3 XQ Context Patterns

XQ context patterns are templates for context instances whose immediate activation is based on activations of a variable number of instances of the same concept. The concept instances must have matching values at specified slots. The activation of one of these context instances is computed from the activation of a variable number of instances of a single concept. Because the pattern type is related to existential quantification, we will refer to such patterns as *XQ context patterns*. Similarly, we call a context whose pattern is an XQ context pattern an *XQ context*.

Formally, an XQ context pattern is a triple $Q = (P, w, \mathbf{m})$ where: P is a concept; w is a positive weight; for each j the j^{th} element of integer vector $\mathbf{m}$ maps the j^{th} slot of the concept (named) P to a slot (index) of that context or is the *Non-Specific Entity ID*; and at least one element of $\mathbf{m}$ is the *Non-Specific Entity ID*. Observe that the number of *Non-Specific Entity ID* elements of $\mathbf{m}$ is equal to the reduction in arity from P to Q.

As before, an instance $\chi = (X, \mathbf{g}, Q^{(X)}, \mathbf{p})$ of an XQ context X has a non-empty tuple $\mathbf{p} = \{p_k\}$ of active, completely specified concept instances. $\mathbf{g}$ serves as χ's bindings and has the same arity as X. The concept instances simultaneously unify where constrained to by $\mathbf{m}$: for each k, let $\mathbf{b}_k$ denote the vector (tuple) of Entity IDs associated with p_k;

then, without conflict, for each k, j, if $\mathbf{m}[j] \neq -1$, then $\mathbf{g}[\mathbf{m}[j]] = \mathbf{b}_k[j]$, and $\mathbf{g}[i] = -1$ for i for which no such constraint applies.

If X is a context whose recognition pattern is an XQ context pattern, then an instance χ of X is a member of the set of context instances maintained by the Context Recognizer if and only if there is no way to add an active concept instance meeting the second criterion to χ's concept instances $\{p_k\}$ and have the result meet the last criterion. Intuitively, this again means that the Context Recognizer maintains all the context instances and that each takes into account all the cues it can without being inconsistent.

Example

Let the concept *attacks* be as in the previous examples, and similarly, let *Under-attack* be a unary XQ context having the pattern $Q^{\text{(Under-attack)}}$ = *{attacks,1,{-1,0}}*. Suppose that *attacks(55,13)* and *attacks(56,13)* are active concept instances.

We verify that *{Under-attack, {13},* $Q^{\text{(Under-attack)}}$*, {attacks(55,13),attacks(56,13)} }* is a valid instance of *Under-attack*.

- *{attacks(55,13),attacks(56,13)}* is non-empty;
- *attacks(55,13)* and *attacks(56,13)* are instances of the concept *attacks*;
- *{13}* contains one element, and *Under-attack* is unary
- the *Non-Specific Entity ID (-1)* does not appear in either *attacks(55,13)* or *attacks(56,13)*; and
- $\mathbf{m}$ = *{-1,0}*, and $\mathbf{g}[\mathbf{m}[1]] = \mathbf{g}[0] = 13 = \mathbf{b}_0[1] = \mathbf{b}_1[1]$.

We observe that the slots of P that Q do not map to any slot of X are effectively existentially quantified away. For example, the XQ pattern type enables to us to take the concept "x eats y" and create patterns for "x eats something" and "something eats x."

When the Context Recognizer is updating the activation of an instance χ of a context X, the immediate activation expression including inhibitory bias $\beta^{(X)}$ is

$$a_{\text{immed}}(\chi) = \max\left(\left(\sum_k w * a(p_k)\right) - \beta^{(X)}, 0\right).$$

Bias is particularly useful in supporting XQ patterns that roughly correspond to there being at least a desired number of active instances of a certain concept. For example, if the average activation level of a perceived instance of a given concept is 1, then we can use a weight of 1 and a bias of $m-1$ in the XQ-type context pattern for there being m perceived instances of that concept.

As is the case with cue vector context patterns, computation of the gross activation level of χ is based on applying an activation function to $a_{\text{immed}}(\chi)$ and then applying a normalized leaky integrator to the result.

2.3.3 Multiple Associative and Recognition Layers

For a cognitive model to be psychologically plausible, it must allow recognition of one context to be a cue for recognition of another context. SCREAM includes a mechanism that enables the activation level of a context instance to set the input activation level of a concept instance identified with it (Note that one motivation for the distinction between concepts and contexts is that the processes for context recognition and spreading activation, etc., seem to occur in different frequency bands). This functionality is implemented in the **context concept driver** module. For example, recognition of the context instance *Party {54}* could determine the raw activation level of the concept instance *Party {54}*, which in turn could be a cue for the context *BirthdayParty {54}*. Thus, cognitive models that include hierarchical or cascaded context recognition can be supported. The Semantic Memory and Context Recognition components of a SCREAM model thus can act together as a type of dynamically-structured, multi-layer neural network, where the structure of the network is updated according to instantiations of concepts and contexts.

SCREAM allows a context instance to be tracked when the subset of activated cues (concept instances) for or against it has activation, even when not all of its slots are bound to entity identifiers. Thus, cognitive models in SCREAM can recognize partially formed context instances. Furthermore, SCREAM allows context recognition patterns that are recurrent individually or as a set. Thus, it should be easy to see that SCREAM allows cognitive models with context recognition capability greater than that of multilayer perceptrons.

We note that the psychological plausibility of multiple layers of context recognition and sets of context recognition patterns that include recurrence has not been documented by the psychologists on our team and requires further investigation. It is important to note that while strings in SCREAM representation enable convenient interaction with people and other system components, strings are not fundamental to cognitive processing in SCREAM.

2.4 Modeling Emotion, Attitudes, and Culture

Converging lines of research suggest that a person's attitude (which is a general opinion towards a person, object, or concept) influences their behavior. A general theory supporting this research, *theory of planned behavior*, proposes that behaviors are influenced by attitudes towards a specific behavior, the subjective norms associated with acting out that behavior, and the perception that this behavior is within a person's control. This forms an action intention state, which then typically drives that person's actual behavior (Ajzen & Madden, 1986; Fishbein & Stasson, 1990; Madden, Ellen, & Ajzen, 1992). For example, if one has the attitude that being a suicide bomber will ultimately help the community and thus is a good thing, believing the community treats suicide bombers as heroes, and believing he or she can perform the act of being a suicide bomber, then that person is more likely to form the intent to be a suicide bomber. Whether one actually becomes a suicide bomber depends on several environmental and psychological factors, such as any intervening events (e.g., police detecting the bomb, etc) and the person's emotion state at the time.

A person's emotional state often plays a large role in a determining the ultimate behavior of the individual. According to the research by Berkowitz (1993) and others, certain experiences may create general negative affects (such as the fight or flight impulse when a threat is perceived), which then may stimulate associations linked to fear and anger. How people ultimately respond can be a result of both goal- or moral-related decisions and their perceived emotion state. As mentioned above, assessments of a person's environment and the potential outcome can also temper their behaviors. Consequently, an angry person might refrain from being aggressive if this aggression conflicts with their goals or moral values. Accordingly, they may choose other behaviors that more closely align with their goals or values (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Huesmann, 1988). Using the example above, a person may want to explode a bomb on a bus. If the ticket agent for the bus angers him, he has a choice; either expresses his anger or control himself and board the bus. Normally his goal might be to express his anger, but today his higher-level goal is to avoid drawing attention to himself before he boards the bus. Therefore, the person recognizes and suppresses his anger before proceeding to board the bus. A large amount of research supports the notion that attitudes, norms, emotions, goals, and the perception of control helps drive actual behaviors. In fact, the theories that support this research have been successfully used to predict a wide range of behaviors, such as voting, shoplifting, gun-related violent acts, and other moral and ethical decisions (Kurland, 1995; Sheppard, Hartwick, & Warshaw, 1988).

The HI framework corresponds to the theories and supporting research mentioned above. As a cognitive character perceives his or her environment, their perceptions in the form of contexts are influenced by a hierarchy of higher-level goals or moral states. For example, one goal may be to protect his family, while a lower-level goal may be to work hard to buy new clothing. Supporting the higher-level goals are the intermediate goal states. Intermediate goals help support the higher-level goals by breaking down the goals into discrete-level tasks. As a consequence, the intended actions are a product of both the intermediate goals and the current emotional state of the simulated human. This emotional state may dynamically change—for example from very low to very high levels of anger—if the perceptions change.

Continuing with the previous example, the cognitive character may see a western woman without a veil (hijab), which perturbs his emotional state toward increased anger. He may also see a police officer, which increases his fear. When the police officer leaves, his level of fear may subside due to the removal of his perceived source of fear. However, depending on the salience or emotional relevance, the cognitive character may stay angry due to the presence of the western woman. Having a high level of anger may increase the likelihood of carrying out the goal of bombing a bus. Conversely, having a high amount of fear of getting caught by the police officer may cause the simulated human to postpone his actions. The actions that are ultimately chosen stem from his current emotional state and their correspondence to the actions that contribute to his most important goals.

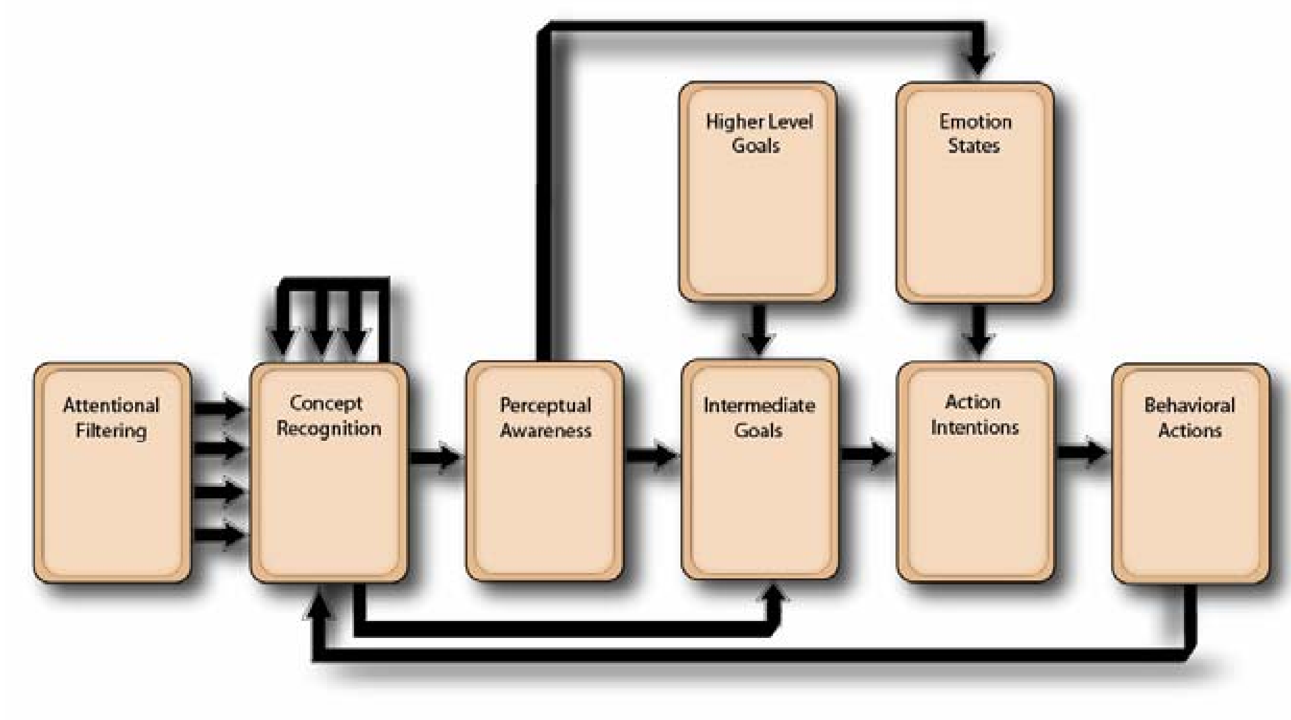

Figure 3. The process diagram of the cognitive actions within the HI framework

In the HI framework, an impression of culture can be generated by varying a simulated human's emotional response to particular perceptions, such as the above example where a women wearing a somewhat revealing, western-style outfit might stimulate a more intense anger response in certain cultures. Cultures also exhibit variations within their high-level and intermediate goals. As a result, their intended and actual behaviors will show cultural uniqueness (see Figure 3). The result is a complex set of behaviors that have certain emergent properties that are common to a particular group. As noted, these behaviors are not programmed directly, but develop as a result of the inter-relationships between the perceptions and goals of the cultural group being modeled. Thus, simulated Americans (or any nationality or ethnic group) could perceive, think, and act with a similarity corresponding to a common "culture." Consequently, a simulated American will act and "think" differently than another simulated nationality under similar conditions.

2.5 Dynamic Emotion States

2.5.1 Scientific Basis for Direct Route

Research has shown that early in stimulus processing, the fear/surprise emotional centers of the brain (amygdala) receive direct input about the potential significance of a stimulus (Anderson & Phelps, 2001; Cacioppo & Gardner, 1999; LeDoux, 1996). The "direct route" conveys a fast, rough impression of the situation because it uses a sub-cortical pathway in which no high-level cognition is involved. At the same time, stimulus information is processed via another information pathway to allow for a deeper, cognitive assessment of this information. This "indirect route" allows for more deliberate assessments of the situation. The multiple pathways enable both an initial, fast response as well as the integration of emotion with higher-level recognition and understanding. The memory process output is appraised for its emotional meaning through which a behavioral assessment is made (Phelps, 1996).

One useful way to think about direct types of responses is that they are action tendencies that have evolved to make it possible to deal more effectively with prototypic situations. A negative affect such as fear has evolved to mobilize the physiological resources necessary to make a quick and effective behavioral response to a perceived threat. This is opposed to "feelings," which are the subjective awareness of an emotional response (the presence of an action tendency). Conversely, "emotion" does not necessarily involve an awareness of such an action tendency. Fear, as an action tendency that has evolved to deal with threat, is often useful in mobilizing the body to deal with a perceived threat.

Evidence for a direct pathway has been found by Pare, Quirk, & LeDoux, 2004; and others (e.g., Marsh, Fuzessery, Grose, & Wenstrup, 2002), by injecting anterograde and retrograde tracers in animals at physiologically defined sites within the amygdala to view axon pathways. The results provide evidence of a rapid thalamo-amygdalocollicular feedback circuit that imposes emotional content onto the processing of sensory stimuli at a direct pathway level— permitting a human to respond to potentially harmful stimuli before it is fully assessed (LeDoux, 1996). Other evidence supporting the conclusion that emotional information is separate from semantic information is the finding that perceptual representations of objects, and the evaluation of their emotional significance, are separately processed by the brain. In fact, brain damaged people often lose the ability to appraise the emotional significance of certain stimuli without loss of the ability to perceive the same stimuli as objects (Phelps, 2006).

As with humans, cognitive models should incorporate the ability to react quickly to certain stimuli without the need first to deliberate the degree of threat. In the HI framework, this psychological phenomenon was modeled such that the cognitive characters exhibit defensive reactions of fear in response to perceived stimuli that represent potential dangers and/or anger towards certain perceived events or actions. Specifically, the cognitive characters have responses representing the direct route, in that it essentially represents the reflexive thalamo-amygdala pathway that bypasses the cortex. This pathway exhibits fear and defensive reactions, but not other emotions such as happiness. Other emotions and aspects of the indirect route will be modeled in the very near future.

2.5.2 Model of Emotional Processes in SCREAM and the HI Framework

A basic capability for modeling emotional processes in cognition has been implemented in SCREAM. SCREAM continuously updates the level of activation of each emotion based on concept activation levels. While a concept is directly activated by perception as a result of much semantic processing, a concept may be specified to influence emotional state. The HI framework converts emotion levels into fuzzy-set representations that control cues in context-recognition patterns to influence context (pattern) recognition. This permits cognitive models with emotions to affect behavior of a range of semantic processing involved. A minimal amount of semantic processing, rather than no semantic processing, is required for emotional processes to influence behavior in the present implementation. This is because the input of the Emotional Processes Module is the Semantic Memory output, and because action generation requires context recognition.

Specifically, emotional processes parameters enable each concept to be associated with a level of activation and a weight for each emotion. For example, in an emotional parameters file, the line

```
cee clown 2 fear 0.700 .7 anger 0.100 .9
```

specifies that concept *clown* influences two emotions. It tends to push the activation level of *fear* to 0.700 with a weight of 0.7 times the activation level of *clown* and the level of *anger* to 0.100 with a weight of 0.9 times the activation level of *clown*.

In computing the overall emotional state for the model, the emotional processes module takes as input the overall activation levels of all concepts. For each concept the net weight of its effect on the level of an emotion is the product of that concept's activation and its weight coefficient for that emotion. In the updated emotion state, the activation level of an emotion is the centroid (weighted average) for that emotion computed from the net weights and emotion activation levels associated with each concept and that emotion.

The scalar representation of the activation level of emotion is translated into membership levels in fuzzy sets to enable emotional state to influence context recognition using the cue-pattern mechanism. For example, the activation level of the emotion *anger* can be represented by membership levels in the three fuzzy sets *lowAnger*, *medAnger*, and *highAnger* that cover the range of *anger* activation levels. In the current HI Framework implementation where emotions have a range of [0,1], Gaussian fuzzy set representations are used. For example, an *anger* level of 0.25 translates to membership levels of 0.468 *lowAnger*, 0.468 *medAnger*, and 0.063 *highAnger*. These membership levels are fed back into SCREAM to control the activation levels of the concept instances *lowAnger*, *medAnger*, and *highAnger*, which can be used as cues in context (pattern) recognition.

The HI project created SCREAM's emotional state computational capability to model the direct route emotions of *fear* and *anger*. Concepts in the HI framework's Cognitive Perception category influence emotional state. Contexts in the HI framework's Action-Intent category include emotion-driven cues in their recognition patterns.

In addition, the HI framework includes an Emotion Regulator Graphical User Interface (GUI) that enables a user to directly control (increase or decrease) the emotional state of a cognitive character, overriding SCREAM's emotional state computation. Thus, if a user is interested in examining the behaviors of a specific cognitive character as a result of that character becoming rapidly more (or less) fearful or angry he or she can do so. This allows users to initiate simple "what-if" scenarios related to specific situation events. The image shown in Figure 4, depicts the emotion GUI where the user can control the emotion state of a particular cognitive character. In the GUI, fear and anger values are shown in percentages (i.e., 25 corresponds to 0.25), and scalar values from the GUI for the emotions are translated into fuzzy set values described above.

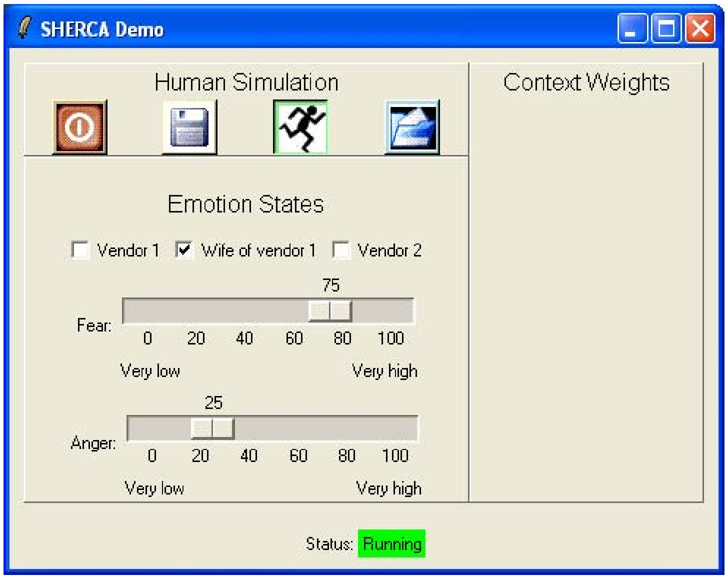

Figure 4. The Emotion Regulator GUI

3 Modeling Visual, Spatial, and Motor Functioning

In addition to semantic functioning, the SNL cognitive framework includes elements of spatial, visual representation, and motor functions. These functions permit a much more accurate M&S and training environment in that actual humans could conceivably train against (or with) cognitive characters via augmented reality and virtual reality environments, as well as in highly realistic simulated environments.

3.1 Visual Representation Simulation

In humans, representations of visual information are rapidly constructed in a hierarchical sequence of processing levels. Processing begins with features, such as edges, colors, textures, and their relations. This feature information is then bound together into meaningful composite proto-object entities, such as objects and surfaces. These entities can then be collapsed into larger scene entities, forming object groups and relations between objects and surfaces (Zeki, 1993). A representation of a scene is subsequently formed and quickly becomes symbolic (within semantic memory). As a result, scene representations are, by and large, accurate abstractions of the environment within semantic memory (Sanocki, 2003). The visual information is then split into two independent processing streams. One stream manages perception of “things,” while the other manages visuomotor actions (Rensink, 2000).

In the HI framework, cognitive characters are able to perceive visual stimuli from their environment. As the scene changes so do their perceptions regarding that environment (and consequently their behavior). This capability roughly corresponds to the assessment of abstract visual representations, described above. Specifically, in the HI framework visual perception produces semantic and spatial information that is used as input to subsequent stages of the cognitive model. Visual perception is currently fairly straightforward in that it is based on robotic sensor simulation and computer game techniques. Future implementations could be based on detailed simulation of human visual perception—when that modeling capability becomes sufficiently fast and is needed.

Concept instances whose raw activation is driven by perception are used as cues to recognize contexts that cognitive characters can understand. Spatial information is used to help navigate and establish the location of objects or characters within their environment. The simulated process of “visual perception” and subsequent “attention” to environmental cues includes recognizing objects, properties and relationships, including what direction other cognitive characters are gazing. The simulated visual perception builds upon the visual sensor modeling framework previously existing in the Umbra Packages sensor library. In the current HI implementation, a viewer can only access descriptor tags of a target entity if viewing frustum and line-of-sight criteria are met. While the current gaze estimation mechanism relies on a symbolic “gazes at” relational tag, better fidelity in modeling the eye and head motions of cognitive characters would enable us to pursue a more geometry-based model incorporating viewing distance, visual angle, and how long the observed gazer is in the modeled character’s visual frustum.

A proposed performance optimization to this latter model (written but untested software) uses a specialized visual property descriptor to model what a character might appear to be gazing at or scanning. This will reduce the work that an observer's visual perception module must do to compute plausible targets—e.g., estimate what is in the actor's foveal region. Thus, by using inputs from cognitive character visual sensors, cognitive characters can recognize what room they are in, where it is located relative to other rooms, the layout of each room, and generally react to stimuli in the environment that they see. In addition, if an entity's perception can tell what concept an object is associated with, their Object Recognition system will allow new concepts to be created. For example, an entity can recognize a chair and that it belongs in a specific room.

3.2 Role of Spatial Memory and Awareness

Carrying out certain behaviors, such as finding a bus terminal, requires spatial situation awareness. Spatial situation awareness is achieved via several visuo-spatial systems. According to current models of human visuo-spatial cognition, once visual information is acquired it is sent to both egocentric and allocentric reference systems. The egocentric system remembers the relative position (body or head) of the observer as that person navigates through his/her environment (e.g., remembering the path to your car). The allocentric system, on the other hand, remembers the position of objects with respect to other objects irrespective of an observer (for example, remembering that a book is on a table in the other room). The allocentric system selects particular, environmentally-defined references in which object positions are remembered partly in terms of larger spatial groupings or regions. These groupings are usually defined by the relations among a number of different objects. Spatial relations are coded in terms of vectors indicating the relative direction and distance between locations (Werner & Schmidt, 2000).

Egocentric and allocentric reference systems may be used at different levels of spatial memory. According to Sholl (1995), spatial information is stored in an allocentric reference system. The information is then retrieved by superimposing an egocentric reference system depending on the position that is physically or mentally taken by the observer (Werner & Schmidt, 2000).

Spatial representations are partially hierarchical in nature. That is, spatial relations are encoded between locations in different regions of an environment according to a graph-theoretic tree. Partially hierarchical representations contain redundancy such that many spatial relations will be stored explicitly. The principal advantage of this redundancy is the increased speed and accuracy with which certain spatial judgments can be performed. The advantage follows from the assumption that, at least in many cases, knowledge encoded in memory can be retrieved faster and more accurately than the same knowledge could be inferred from other knowledge in memory (evidence from spatial relationship errors). For example, people often erroneously believe Reno is further east than San Diego (McNamara, 1986).

Evidence supporting the partially hierarchical structure is the finding that locations in the same region prime each other more than locations in different regions. This indicates that locations in the same region were "closer" in the subjects' memories than locations in different regions, regardless of the actual Euclidean distance. This backs the idea that different regions of an environment are stored in different branches of a partially hierarchical mental representation. People also use regional information (category knowledge) to judge relative position when that knowledge is available and useful (McNamara, 1986; McNamara, Hardy, & Hirtle, 1989).

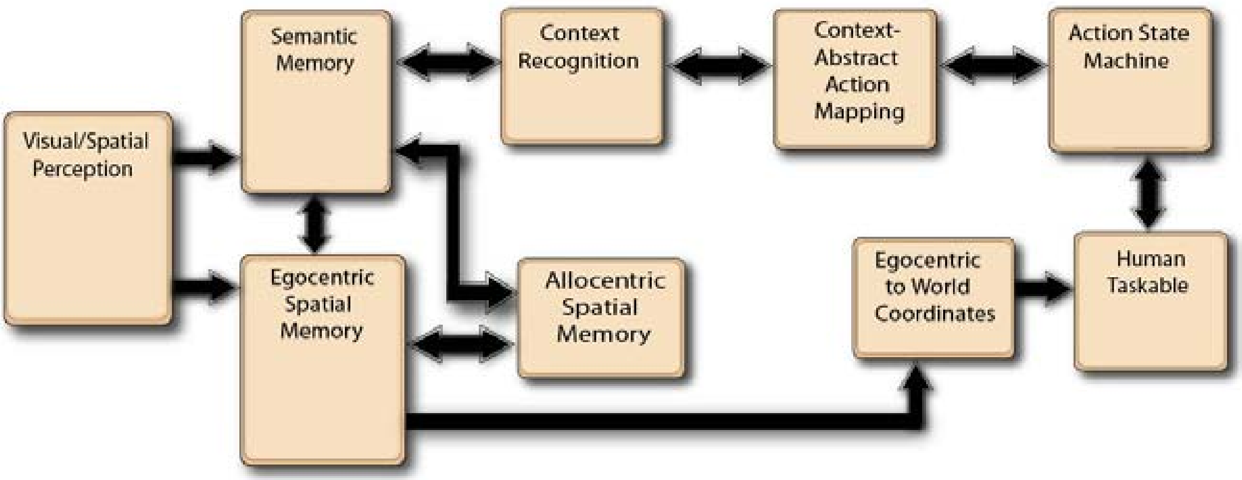

Figure 5. A diagram of spatial functioning in the HI framework

In the HI framework, spatial knowledge draws upon spatial memory to help determine the most efficient path a cognitive character should take in order to move from point A to point B (see Figure 5). The spatial knowledge/memory component consists of egocentric (body centered) and allocentric (global) spatial memory, cognitive mapping of the environment, and memory representation of objects in the environment. The current model assumes perceptual synthesis of large spaces such as rooms. The spatial system integrates these spaces into a hierarchical representation indicating adjacent rooms and their contents. Perceiving and moving about the environment thus builds up the spatial knowledge and awareness, which includes the current location and velocity of the cognitive entity and of perceived items. The Spatial system then uses that location, along with the stored hierarchy and cognitive map, to establish paths to given objectives. For example, in Figure 6 the spatial system perceives items that are represented by blue and red boxes. The blue boxes indicate a perceived medium to low level of interest. The red boxes indicate a perceived high level of interest.

The Egocentric Reference System (ERS) component takes inputs from visual/spatial perception and identifies which perceptions correspond to items already in egocentric spatial memory. Any corresponding spatial records are updated with velocity estimates and are available for export to situational awareness or other higher functions. Items not found in the egocentric spatial memory are added to it. The entire set of objects that was originally fed in from perception is then sent out to the Allocentric Reference System (ARS) which looks at each to see if there is a matching concept instance. The ARS module then creates spatial records for any items which have only concept instances but not spatial records (Concept instances and spatial records are linked so ARS can always find one from the other). The ARS then updates the location of any spatial objects which have moved with respect to fixed coordinates, and exports the updated items to ERS for the next round.

Currently, the concepts of 'adjacent' and 'contained' are implemented. Likewise, new structures such as 'left of' would be relatively easy to add. Work needs to be done in modeling how humans determine weak adjacency (e.g., table and chair), rather than topological adjacency (e.g., room, portal, room). Other problems include modeling how a human looks into a building and recognizes whether he has been in it before, or how to recognize regions demarked by features rather than walls, etc. This would entail modeling the dynamic creation of frames from the landmarks within a region of the environment rather than relying upon the frames being a part of the environment model itself, or being generated by an external perceptual synthesis component.

Updates to the simulation infrastructure are not currently compatible with the previously implemented Egocentric Spatial Memory and Allocentric Spatial Memory modules. Efforts are underway to re-integrate them with the updated simulation infrastructure. The current demonstrations use a spatial memory capability that is based on maps for robotics and embodied-agent simulations. This spatial memory supports many key capabilities of the combined Egocentric and Allocentric Spatial Memories, but it currently makes no effort to be psychologically-plausible. Using outputs from modules simulating visual sensing and perception, our cognitive character humans can recognize or recall the room in which they are located; where that room is located relative to other rooms; layout of each room; and generally react to stimuli in the environment that they see. Concept instances can be recognized if an entity's perception can tell which concept an object is associated with. The cognitive character humans can also approximate body location and recognize objects as types and recall them from previous encounters if they are known and recognized perceptually. General distance, direction, and orientation can also be determined. Robot planning and simulation software enables the characters to navigate to desired locations without collisions. Once updated, the Egocentric and Allocentric Spatial Memory modules can serve as a foundation for psychologically plausible models of the following:

- Spatiotopic Mapping – Allows cognitive characters to approximate body location, recognize objects as types, and spontaneously recall them from previous encounters if they are known.
- Categorical Relations – Allows cognitive characters to relate a landmark to where they are relative to the landmark (For example, I see the fire extinguisher and I know it is in the hallway in a particular building, so I must be in the hallway in that building).
- Coordinate Relations – Allows cognitive characters to compute their general distance, direction, and orientation.
- Spatial Associative Memory – Allows cognitive characters to match stored information about the location, name, and function of other object(s) in the visual scene in terms of partial hierarchies (For example, the knowledge that a particular room is in a particular building).
- Path planning – Uses a combination of semantic, topological and metric information from the spatial memory model to generate path plans in terms of a combination of semantic, topological and metric information.

Figure 6. A representation of the spatial perception of the HI cognitive models

4 Modeling Motion Control

Generally, in humans stimuli are first identified either visually or through various other senses. The information associated with the stimuli is quickly identified via an automatic process. Once there is identification, a specific response is selected (in approximately 300ms). The selected motor response (which is often a chunked series of motor movements) is then enacted. This entire process typically takes approximately 500ms (Schmidt & Wrisberg, 2004). Within the HI framework, a cognitive character's actions and the behavior of others will feed back into its environmental perceptions. These, in turn, will be fed back into the framework for processing and actions.

The sub-framework that integrates semantic processing with simulated physical action generation is described below (Recall the diagram in Figure 3). The Behavioral Actions module in the HI framework uses SCREAM's Context Recognizer to compute activation levels of instances of SCREAM contexts that are associated with action scripts. The Context to Abstract Action module updates the action script selection based on the activation levels of these context instances, with the constraint that the action script can be instantiated. Currently, this means that the Semantic and Spatial Memory modules must contain concept instance and entity information that satisfies the script. Script instantiation can include requirements for specific concept instances, partially instantiated concepts, or any instance of particular concepts.

Behaviors to carry out instantiated action scripts are controlled by a hierarchical state machine (Action State Machine). When a new action script instance is selected, the start state of the state machine program corresponding to the script is instantiated with the appropriate data and run on the state machine. State machine programs include commands that interface with the Cognitive Model and with the Human Taskable subsystem. This subsystem integrates the simulated human sensing and perception model with path control and the simulated physical human model. The current simulated physical human model is based on Boston Dynamics' DI Guy®, which combines robot-like control with a motion-loop manager and a library of captured motions to generate realistic-looking motion. Thus, the Action State Machine corresponds to Executive Motor Functioning, while the Human Taskable handles Effector Motor Functioning.

Currently, the physical behaviors of the cognitive characters are initially created by motion capture tools that allow them to move and react in a manner that is generally realistic. Their actions are, in turn, strung together and run by a motion loop manager. Scheduled improvements to the HI framework will include modeling and simulating the effects of physical fatigue on the cognitive character human's actions, as well as implementing accurate reaction times in response to stimuli.

5 Development of Cognitive Characters

To create a specific cognitive character, both the stimuli (environmental cues) and contextual associations (perceptions, activations, and states (shown in Figure 3) need to be composed. This is done by first cataloging a series of low-level environmental cues that the cognitive character might perceive in a given scenario (see Appendix A). As with humans, certain concepts may prime other concepts. To specify priming in the framework, the modeler generates a series of cue-to-cue relationships with a certain degree of activation—i.e., activation from Cue1 primes Cue2 with a weight of 0.8.

In addition, the modeler may compose perception-to-cue priming (discussed below) with a specified degree of activation using the same procedure as cue-to-cue priming. When a certain number of cues that fall within a pre-defined cluster are activated, a context associated with that cluster is activated. A context is used to describe the "mental" processes that occur when we try to make sense of, and interact with, our environment. These processes can be broken down into perceptional context or "perception" and "goal" states.

A specific perception that is active at any given time is the result of a particular pattern of concepts (i.e., cues) that are activated. Perceptions seek to "clarify" a current situation. (For example, "One soldier is moving near me for a purpose other than to buy my merchandise"; see Appendix B). To create a perception, the modeler lists a series of concepts associated with a particular perception, as well as the degree of activation. The result of an activated perception is the priming of a series of potential intermediate-goal states.

The intermediate, sub-goal state(s) that are primed will become activated if they are relevant to the current environmental situation (see Appendix C). Accordingly, to activate the intermediate goals, pre-determined cues from the environment must be present. To accomplish this, the modeler creates a list of intermediate-goal states. Each intermediate goal state is associated with environmental cues and its level of cue activation. If the cues that are present in the environment do not match up with the pre-determined cue set, then the primed intermediate goal will not become activated.

As noted, each intermediate-goal state is associated with a hierarchy of increasingly abstract-level goals (such as "protect family," being the highest of the goals). If two or more primed goal-states are active, the highest of these states will be chosen. The sub-goal that is selected will activate a corresponding action intention state. Action intentions bind emotional affect with behaviors. In the HI framework, there are currently two emotions that are exhibited, fear and anger. Both emotions can vary in intensity from very high to medium to very low. This is done by assigning a fear and anger value to each perception that the cognitive character might encounter (see Appendix D). Thus the degree and type of emotion state that is exhibited will be dynamic, resulting in what a cognitive character perceives at any given moment (see section 2.5). Currently, emotions directly effect only the selection of behavior (The next iteration of the framework will have emotions dynamically affect the context of the simulated human).

The next step for the modeler is to assign an action appropriate to the various levels of fear and anger (high, medium, or low) that a cognitive character experiences as a result of its perceived context (see Appendix E). For example, if a character is very angry it will select a behavior associated with being very angry. If the cognitive character is both very angry and very fearful it may select another action. The resulting combination produces a particular action script for this emotion state. Each action script consists of a coded sequence of behaviors (see Appendix F). After the behaviors are played out the character will reassess the environment and follow new behaviors based on new perceptions.

The entering of cues, perceptions, and states are typically done manually, often through manual knowledge elicitation. Thus, if a modeler seeks to have a cognitive character that represents a particular culture or region, then he or she may simply interview someone from that culture or region and have them assign values to the cues, perceptions, and states. Another method of knowledge capture that is being pioneered at SNL is the use of automatic knowledge capture techniques. While still in its infancy, SNL is developing ways to automatically capture information via text and mass media to populate aspects of a cognitive model without human intervention.

Additional work is required to convert the received information into models that can be used by SCREAM. This work includes determining the slot structure (roles of entities) within concepts and contexts; the cognitive process of recognizing cues (e.g., Cue1,…, Cue50) from concept instances directly activated by, for example, visual perception, which is modeled by additional concepts and contexts. Moreover, in other stages of the framework, what appear to be simple patterns for recognition in the model are decomposed into several layers of pattern recognition where tuning of parameters is required, and if implemented state-machine programs ("motion control") matching the high-level descriptions are not available, they need to be written. This need should decrease as the library of action programs grows.

6 Display and Example of Cognitive Functions

One of the capabilities produced by the HI LDRD is the ability to dynamically display the recognized cues, their general perceptions associated with those cues, high- and intermediate-goal states, emotion states, action intentions, and the final actions of the cognitive characters. This permits easier software and modeling bug corrections as well as allowing participants to observe what each cognitive character "perceives" and "thinks." As a cognitive character perceives or thinks about the events occurring in its environment, this process is visualized in the Visualization Graphical User Interface (GUI; see Figure 7).

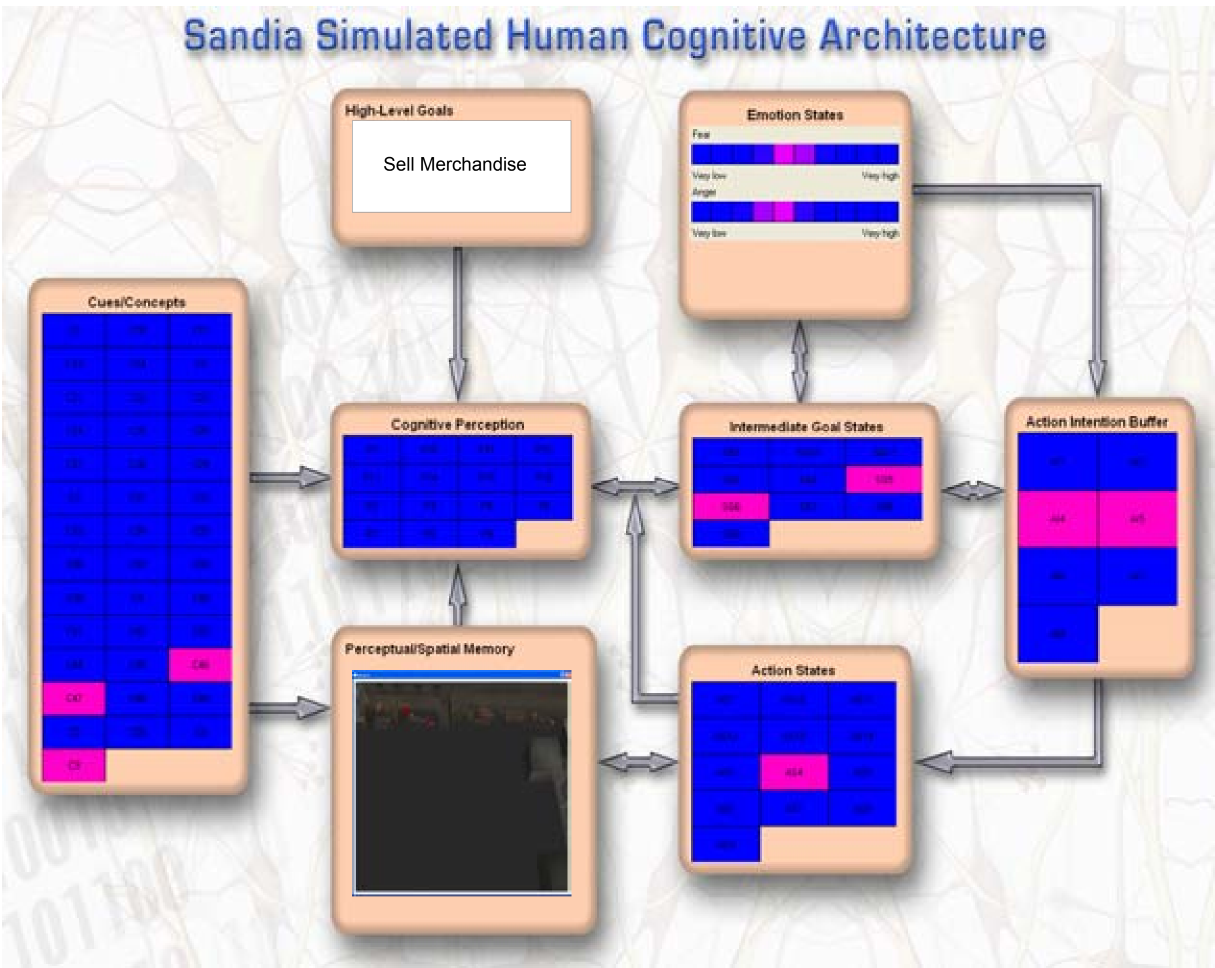

Figure 7. SNL cognitive model process Visualization GUI Display

In this GUI, non-activated states are expressed in blue. As each concept, goal, or state becomes more active the color shifts from a blue state to a red state, depending on its level of activation. Each of the concept, goal, or state elements has an assigned number which are associated with a particular activation description. For example, within the Cues/Concepts box, C47 is associated with the concept *that no US soldier is currently seen* (see Appendix A). Within the Intermediate Goal State box, SG5 is associated with the intermediate goal of *conversing with a nearby person* (see Appendix C). Moreover, as the cognitive characters perceive stimuli from the environment they will have dynamic emotion states of both fear and anger. The Visualization GUI will display both those emotion states as they occur in real-time. These cognitive processes are also expressed in the scenario's display that exhibits the final cognitive character behaviors (see Figure 8). In this display, players can indirectly interact with the cognitive characters by means of manipulating the actions of non-cognitive characters via voice commands. The scenario environment can be dynamic in that multiple, non-cognitive characters can have different interactions with the cognitive characters depending on the player commands as well on as actions of other non-cognitive entities (e.g., automated, semi-random pedestrian behaviors).

6.1 Scenario Example

The HI project produced two main demonstrations of its capabilities. The scenario for the first demo pertained to an office environment in which three cognitive characters attempted to steal documents from a file locked in a safe. The second demo pertained to a marketplace environment in which three cognitive characters interact with solders controlled by players. The second demo is substantially more complex than the first and is discussed below.

In the second demo, player encounters a scene containing a busy marketplace in Iraqi town filled with shoppers, cars, and a small team of US soldiers patrolling on foot (see Figure 8). The behaviors of the soldiers are controlled by a player and can be manipulated via voice and/or joystick commands.

Figure 8. An example of the scenario environment (scenario environment courtesy of Lockheed Martin Corporation)

In the scenario, a player commands a group of soldiers to search for a suspected weapons cache near one of the market stands. The soldiers are essentially scripted entities with some low-level behavior control. A player can order by name one, several, or all of his or her troops to investigate a particular vender stand. Near one of the stands is a 58-year old vender owner and his 28-year old nephew. The vender is a cognitive character in which his “cognition” and behaviors are controlled by a cognitive model that will enable him to respond dynamically to the actions of the soldiers. The number of soldiers, their behaviors, and their gender will affect the vender’s behaviors. For example, if the vender feels threatened (i.e., receives cues that form the perception of being threatened) then he may become aggressive or flee. If he is angered, he may become confrontational and very angry. This will result if his current perceptions are associated with a high-level anger emotion. If he is both fearful and angry he may respond with a different behavior. Factors that determine the vender’s behavior are both the perceived context and the degree and type of emotion that is currently active (which is dynamically generated by what stimuli are perceived from the environment). In addition, automobiles and pedestrians moving about in the marketplace can passively affect the ongoing situation to a certain extent.

In the scenario the vender is hiding a weapons cache under his merchandise. The nearness of the US soldiers and how they behave toward the vender will generally determine his actions. For instance, if the US soldiers move near the weapons cache and are threatening the vender, he will signal his nephew to fire on the US soldiers (see Figure 9).

Figure 9. An example of a cognitive character (blue shirt in the background) and a non-cognitive character (soldier).

Near another stand, two cognitive characters, a husband and wife vender, are also trying to sell their merchandise. Both of these characters are generally hospitable. The male vender is most intent on selling his merchandise by vigorously calling people to come see his wares. The wife is more intent on talking with her female friend (who is a non-cognitive character) than seeking to sell their merchandise (see Figure 10). As the two venders see the US soldiers they become more distressed. This may be exhibited by the female vender ending her conversation with her friend and the male vender becoming more formal. How the soldiers interact with the venders will determine how successful they are in interrogating them to determine if the venders are actually hiding weapons. That is, like actual humans, the cognitive characters respond very well to culturally appropriate gestures and greetings. If the soldiers give the proper greeting, exchange pleasantries, and follow social norms when speaking to the male and female pair (i.e., generating socially positive cues), then the venders will become more relaxed (i.e., low level of anger/fear).

Moreover, since the players playing the role of the soldiers may want to question both the male and female vender, a way to do this without offending the their culture (i.e., generating socially negative cues) would be to have a male soldier ask the male vender for permission to have a female soldier to speak to his wife. If cultural norms are followed, the soldier will receive all the information they need. If some or none of the cultural rules are followed, then the soldiers will receive little or none of the information they seek. The need to be culturally appropriate with respect to genders also applies to the first, 58 year-old vender. That is, if the female soldier interrogates this vender he will be especially angry because of his perception of a violation of gender roles. This perceived insult will increase the likelihood of him behaving in a more aggressive manner.

Figure 10. Vender wife cognitive character (on right)

Throughout the demo, players are able to affect the potential actions of the cognitive characters by making specific decision choices for the soldiers. As discussed above, the makeup of the group and how the soldiers interact with the venders will affect the outcome of the interrogation. Currently, work is being done to increase the complexity of this demo by adding the number of decision points a player must make, as well as increasing the number of environmental variables that impacts both the soldiers and the venders. In addition, a greater range of verbal communications between the soldiers and the venders is being added to increase the demo's realism.

7 Applications and Future Directions

The benefits of using this framework are: 1) that it produces a psychologically and sociologically reasonable computational framework of human behavior, 2) each cognitive model can be tailored to specific individuals, 3) the cognitive characters operate autonomously and do not require human operators to run the simulation, and 4) it is interoperable in larger M&S portfolios for systems studies and experimentation.

7.1 Potential Applications

As discussed, there are many potential application areas for the HI framework. One of the more obvious areas is training. As stated in the magazine, *Simulation & Training*, "combat scenarios today are highly complex, and [simulations] must reflect how political, military and economic developments can shape a conflict" (2005, p. 47). Consequently, a potential benefit of using a training simulation with the HI framework is greater psychological realism. The cognitive characters could incorporate cognitive models of foreign adversaries, including the mindset, behaviors, and training typical of a particular country or regional area. In addition models of adversaries could be created from domain experts, thereby increasing the realism and effectiveness of the training. Since the HI models do not require an actual human to drive their behaviors, participants may repeatedly train at little cost per training exercise. Furthermore, for training applications the level of trainee understanding could be assessed by automatically generating a mental model of the student as he/she trains against the cognitive character. Trainers could compare/contrast this model with a domain expert's mental model of the most efficient/appropriate means to complete the task.

Other application areas include Concept of Operations (ConOps) and tactics development. The use of HI models could provide forces with additional tools for dealing with an evolving threat through action/counter-action forward simulations. Cognitive characters could be created that simulates friendly/adversarial behaviors. For example, there could be a situation that threatens the security of the facility (such as an angry protest crowd—possibly like the US Embassy in Iran, circa 1979). The response force could use the potential tactics development capability to help predict tactical behaviors several generations before they occur. This would provide an environment to evolve new threat understandings and to provide red/blue-force reasoning engine.

Other applications involve developing population models. The HI models could forward simulate the movements and general behaviors of large groups of individuals in response to US soldier actions, etc. This would be useful in helping predict population responses to the transportation and/or protecting of sensitive materiel. In addition, HI models could help predict the cumulative economic effect on people resulting from natural disasters or terrorist events (further discussed in future research directions below). Related to this is the area of behavior forecasting. While this is a long-term goal, one could imagine that in the future cognitive characters will have the psychological, sociological, and cultural similarity to humans so as to fairly accurately forecast specific human perceptions, attitudes, and behaviors within changing environments. To accomplish this, both the depth and breadth of human modeling fidelity would need to be substantially increased, along with framework modifications to enable scaling to very large populations.

7.2 Future Research Directions

The HI LDRD effort served as the impetus for greater R&D work in the area of human modeling. However, this effort should only be considered a first step in a long trek. Multiple projects are currently underway that support and extend the human modeling work. One of these efforts, the *Human Memory and Reasoning for Scientific Study* LDRD (07-0610), is working to improve and extend the current framework by supporting further work in modeling memory, information conceptualization, and emotion, as well as including aspects of human reasoning by FY2009. Assisting in this effort are leading experts in the field of psychology, neuroscience, and computational fields of intelligence. Their role is to help integrate the latest research and robust theories of memory, emotion, concept formation, and reasoning into a single computational architecture. Specifically, the framework will integrate semantic (facts-based) and episodic (event-based) memories, as well as basic emotion (state and trait) and reasoning (deductive, inductive, and abductive—i.e., hypothesis generation) in a single architecture. Research and experiments will be conducted to empirically validate both the psychological architecture and theories behind the architecture, while highlighting future enhancement opportunities.

In addition, the LDRD project, *Cognitive Modeling of Human Behaviors within Socio-Economic Systems* (06-1102), is working to scale the number of cognitive characters to at least 10,000 entities, along with modeling economic, cultural, and stress-induced behaviors by FY2008. The goal of this project is to develop a science-based cognitive modeling framework of the individual-level economic decision-making that is critical to national economic security. Specifically, this project is developing a defensible neuroeconomic and cognitive science-based model of economic decision making before, during, and after "extreme events" such as acts of terrorism or natural disasters. By expanding the current state-of-the-art in modeling and simulating them in large-scale computing clusters SNL is working to produce high-fidelity, internally consistent analysis of these types of events on the economy and public confidence.

Furthermore, the LDRD project, *Game Technology Enhanced Simulation for Homeland Security Training* (07-1219), is working to attach a gaming interface to the current framework. This will allow a player to play through an adaptive scenario from multiple perspectives, with realistic cognitive characters representing the other players. This project is intended to provide trainees with an immersive environment that transforms their intellectual knowledge into concrete experience that reinforces key learning objectives: situational awareness, logic validity, and decision optimality. This project will be finished in FY2009.

Finally, other R&D projects (e.g., *The Effects of Angry and Fearful Emotion States on Decision-Making* LDRD, 06-1831; and *The Role of Emotion and Emotion Regulation in Decision Making and Action in Critical Situations* project) are providing support to the human modeling effort by funding behavioral and neuroimaging research experiments that support the development of accurate human models of human memory, decision making, culture, and emotions, as well as funding GUI development and cognitive model development. This type of basic research, which supports the framework construction, will continue into the foreseeable future.

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Appendix A: Concept Examples

C1	US soldier is seen
C2	Two or more US soldiers are seen
C3	One or more US soldier is moving directly towards me
C4	US soldier has not gazed upon me fovelally
C5	One or more US soldier is keeping a gaze directed toward me
C8	An Iraqi person is standing nearby (one meter away)
C9	Iraqi people are within view
C10	US soldier is standing very near me (one meter away)
C11	US soldier is talking to me
C12	US soldier is asking me questions
C14	US soldier is communicating back to others regarding questioning me
C21	US soldier is gazing at merchandise
C22	US soldier is walking from vender stand to vender stand
C23	US soldier is in a searching posture
C24	US soldier are holding a rifle in a military stance
C25	US soldier is asking detailed questions
C26	US soldier is scanning people
C27	US soldier is looking at the Iraqi women
C28	US soldier is very direct
C29	US soldier is standing at a distance from me (3 meters away)
C31	US soldier is looking around my merchandise
C32	US soldier is moving around my merchandise
C33	US soldier asked my permission to look at my merchandise
C34	US soldier asked my permission to move around my merchandise
C35	US soldier gave traditional greeting
C36	US soldier took off his sun glasses
C37	US male soldier is looking at my wife
C38	US male soldier is talking to my wife
C39	my wife is loudly fussing at the male soldier
C40	my wife is using angry gestures
C41	I feel myself getting angry
C42	female soldier is near me
C43	female soldier is talking to me
C44	female soldier is talking to my wife
C45	soldier asked permission to talk to me
C46	No soldiers are seen
C47	I don't feel any great threat
C48	US soldier is looking near my weapons cache
C49	Male US soldier is asking permission to talk to my wife
C50	Female US soldier is asking permission to talk to my wife
C51	US soldier is aiming his rifle directly at me
C52	US soldier is in direct path of me
C53	US soldier moving directly towards me
C54	Female Iraqi is seen
C55	Female Iraqi is talking
C56	Female is near me
C57	My spouse is near by
C58	My friend is near by

Appendix B: Perception Examples

P1	One soldier is moving near me for purpose other than to buy merchandise
P2	One soldier is not searching for anyone
P3	Western military forces not perceived to be in area
P4	Two or more soldiers are moving near me for purpose other than to buy merchandise
P5	Two or more soldiers are not searching for anyone
P6	Soldier is interrogating me and may suspect me of hiding something, but is not offensive
P7	Soldier is interrogating me and may suspect me of hiding something and is offensive
P8	One or more US soldier is engaging in actives other than military operations
P9	One or more US soldier is engaging behaviors typical for military operations
P10	US soldier is friendly, asking detailed questions, but is sensitive to my culture
P11	US soldier is using mannerisms that offend my culture
P12	US soldier is not making any move to arrest me
P13	US soldier is looking and moving around my merchandise without my permission
P14	US soldier is looking and moving around my merchandise with my permission
P15	US soldier is not interested in buying my merchandise
P16	US soldier gave the proper greeting
P17	My wife's honor is offended
P18	US soldier is asking my wife questions with my permission
P19	Female soldier is asking my wife questions
P20	US soldier is ready to shoot me
P21	US soldier can block my escape
P22	Soldier is offending my honor
P23	Soldier talking to me is the appropriate sex and respectful
P24	No soldiers are near by
P25	A female friend is nearby
P26	I am protected by family/friends
P27	US soldier looks threatening
P28	US soldier is violating my personal space
P29	I feel threatened

Appendix C: Intermediate Sub Goal State Examples*

VENDER ONE – INTERMEDIATE GOAL STATES

```
SG2   I seek not to be apprehended
SG3   I seek to look innocent/friendly
SG4   I seek to sell my merchandise, but I am nervous
SG5   I seek to converse with a nearby person
SG6   I seek to sell my merchandise
SG7   I seek to comply with the US soldier's demands and questions
SG8   I seek to defend my honor but not be arrested
SG9   I seek to appease the soldier, but he is suspicious
SG10  I seek to show the soldier my anger
```

WIFE OF VENDER ONE - INTERMEDATE GOAL STATES

```
SG3   I seek to look innocent/friendly
SG4   I seek to sell my merchandise, but I am nervous
SG5   I seek to converse with a nearby person
SG6   I seek to sell my merchandise
SG7   I seek to comply with the US soldier's demands and questions
SG8   I seek to defend my honor but not be arrested
SG9   I seek to appease the soldier, but he is suspicious
SG10  I seek to show the soldier my anger
SG11  I seek to watch the soldier
SG12  I seek to stare at the soldier
```

VENDER TWO - INTERMEDIATE GOAL STATES

```
SG1   I seek not to be detected
SG2   I seek not to be apprehended
SG3   I seek to look innocent/friendly
SG4   I seek to sell my merchandise, but I am nervous
SG5   I seek to converse with a nearby person
SG6   I seek to sell my merchandise
SG7   I seek to comply with the US soldier's demands and questions
SG8   I seek to defend my honor but not be arrested
SG9   I seek to appease the soldier, but he is suspicious
SG10  I seek to show the soldier my anger
SG11  I seek to protect my weapons at all cost
SG12  I seek not to be shot
SG13  I seek to find another escape path
```

*Note: Some of the Intermediate Sub Goals have been removed from the original list.

Appendix D: Perception-Emotion Examples

VENDER ONE - PERCEPTION AND EMOTION BINDINGS

P1 = F(.5), A(.1)
P2 = F(.1), A(.1)
P3 = F(.0), A(.0)
P4 = F(.6), A(.1)
P5 = F(.1), A(.1)
P6 = F(.7), A(.2)
P7 = F(.8), A(.9)
P8 = F(.1), A(.1)
P9 = F(.6), A(.2)
P10 = F(.2), A(.0)
P11 = F(.5), A(.10)
P12 = F(.3), A(.1)
P13 = F(.4), A(.6)
P14 = F(.2), A(.0)
P15 = F(.2), A(.1)
P16 = F(.1), A(-.4)
P17 = F(.1), A(.10)
P18 = F(.2), A(.2)
P19 = F(.2), A(.1)

WIFE OF VENDER ONE - PERCEPTION AND EMOTION BINDINGS

P1 = F(.6), A(.10)
P2 = F(.1), A(.-2)
P3 = F(.-1), A(.-6)
P4 = F(.2), A(.1)

VENDER TWO - PERCEPTION AND EMOTION BINDINGS

P1 = F(.7), A(.2)
P2 = F(.2), A(.2)
P3 = F(.1), A(.1)
P4 = F(.7), A(.4)
P5 = F(.2), A(.2)
P6 = F(.8), A(.2)
P7 = F(.8), A(.9)
P8 = F(.2), A(.2)
P9 = F(.6), A(.5)
P10 = F(.6), A(.1)
P11 = F(.6), A(.9)
P12 = F(.4), A(.2)
P13 = F(.6), A(.6)
P14 = F(.6), A(.3)
P15 = F(.3), A(.3)
P16 = F(.2), A(0)
P17 = F(.10), A(.8)

Appendix E: Possible Action Intention State Examples

VENDER ONE - ACTION INTENTION AND EMOTION BINDING

```
AI1   I intend to position myself so that I am not seen
AI2   I intend to fight, hide, or kill in order not to be apprehended
AI3   I intend to look innocent by doing non-threatening things
AI4   I intend to sell my merchandise and fit in to the crowd
AI5   I intend to walk near and discuss things with my nearby friend
AI6   I intend to answer the soldier's questions and do what he wants
      as long as it doesn't neg. affect me.
AI7   I intend to show how angry I am towards the soldiers
```

WIFE OF VENDER ONE - ACTION INTENTION AND EMOTION BINDING

```
AI3   I intend to look innocent by doing non-threatening things
AI4   I intend to sell my merchandise and fit in to the crowd
AI5   I intend to walk near and discuss things with my nearby friend
AI6   I intend to answer the soldier's questions and do what he wants
      as long as it doesn't neg. affect me.
AI7   I intend to show how angry I am towards the soldiers
```

VENDER TWO - ACTION INTENTION AND EMOTION BINDING

```
AI1   I intend to position myself so that I am not seen
AI2   I intend to fight, hide, or kill in order not to be apprehended
AI3   I intend to look innocent by doing non-threatening things
AI4   I intend to sell my merchandise and fit in to the crowd
AI5   I intend to walk near and discuss things with my nearby friend
AI6   I intend to answer the soldier's questions and do what he wants
      as long as it doesn't neg. affect me.
AI7   I intend to show how angry I am towards the soldiers
AI8   I intend to do what ever it takes to stop the soldiers from
      taking my weapons.
AI9   I intend to surrender
AI10  I intend to run in another direction
```

Appendix F: Possible Action Script Examples*

VENDER ONE - ACTION SCRIPTS

AS1 run away
AS2 hide under vender stand
AS4 smiles and nods at soldier
AS5 nods at soldier script
AS6 smiles and gestures for the soldier to come and look at his merchandise
AS7 calls for people in general to look at his merchandise
AS8 walks over to a person near by to talk to him
AS9 looks at soldier only
AS10 ignore soldier
AS11 stands and answers question
AS12 screams at soldier and curses him

WIFE OF VENDER ONE - ACTION SCRIPTS

AS4 smiles and nods at soldier
AS5 nods at soldier
AS6 smiles and gestures for the soldier to come and look at merchandise
AS7 calls for people in general to look at merchandise
AS8 walks over to a person near by to talk to him
AS9 looks at soldier only
AS10 ignores soldier
AS11 stands and answers question
AS12 screams at soldier and curses him

VENDER TWO - ACTION SCRIPTS

AS1 run away
AS2 hide under vender stand
AS3 shoots soldier
AS4 smiles and nods at soldier
AS5 nods at soldier
AS6 smiles and gestures for the soldier to come and look at his merchandise
AS7 calls for people in general to look at his merchandise
AS8 walks over to a person near by to talk to him
AS9 looks at soldier only
AS10 ignores soldier
AS11 stands and answers question
AS12 screams at soldier and curses him
AS13 signals for nephew to fire upon the soldiers
AS14 tries to cover the weapons cache
AS15 no change in behavior
AS16 raise hands to surrender
AS17 run away from soldier OR run in a different direction from soldier

*Note: Some of the Action Scripts have been removed from the original list.

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