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Closing In On a Human Representation Reference Model

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ABSTRACT: Representing humans in simulation has become a progressively more important consideration in simulation development and execution. In particular, increased emphasis within the Department of Defense on non-kinetic operations has focused attention on the need for kinetic and cognitive representations of individuals and groups.

The past few years has seen the deployment of many game engines that include human representation, as well as the emergence of specialized “people engines”. As these engines have proliferated, so too have the approaches to representing individuals and groups. Today, there is no generally agreed ontology or vocabulary for describing human representation; there is no common point of departure for discussions among kinesthetic and cognitive researchers, simulation developers, and simulation users.

A human representation reference model is an organization of the fundamental elements of human representation, their relationship to human models, and the relation of human models to other represented objects on the simulation. A reference model provides an itemization of human representation elements to focus discussion and interchange, a structure to guide further specification in design, and a foundation for interoperability between human representation implementations.

This paper discusses the purpose of reference models in simulation, the need for a human representation model, and considerations in developing a human representation reference model. A reference model is postulated and described. Finally, the paper discusses applications of a human representation reference model to research and to simulation design and development.

1. Introduction

Today, many diverse simulations incorporate representations of people. As graphics processors become faster, there is more and more scope to visualize people in all their diversity and complexity. At the same time, multi-processors and widespread 64 bit computing hold out the promise of increasingly intensive processing to simulate moving, sensing and thinking. Finally, both the entertainment and military simulation communities are developing software to represent people, individually, and in groups; “people engines” have arrived. (However, in this paper, the authors will use the term “human representation”, to avoid potentially confusing associations with existing simulation capability.)

Soon, human representation will become a mature technology component of virtual worlds. The authors believe there are a number of characteristic elements of maturity:

- A body of applications that have demonstrated utility and verisimilitude.
- A common vocabulary that promotes technical interchange among builders, buyers and users
- Recognition of authoritative sources of representation
- The rough community consensus and running code that underlies representation and interchange standards development.

The focus of this paper is on the second and fourth characteristics; common vocabulary and community consensus for standards development. The diverse background of

the stakeholders creates the need for a common understanding: there are kinesiologyists, cognitive scientists, computer scientists, hardware and software developers, game distributors, commercial and military project managers, and simulation users. Common vocabulary minimizes the misunderstandings that come when different stakeholders use the same term to mean different things. For instance, the terms “modelⁱ” and “cognitiveⁱⁱ” are used quite differently by cognitive scientists and software developers. But beyond terminology, a common set of concepts, commonly organized, allows stakeholders to subdivide the human representation domain into discussion-size topics while keeping a common overall context.

Standards development has become an engine of growth for simulation (as it has for many technologies). Standards often enable a virtuous circle of improvement, where standards foster larger numbers of interoperable tools, simultaneously providing more capability and competition.

The human representation reference model (HRRM) is our enabling contribution to common vocabulary and community consensus. We define a reference model as a diagrammatically based structure that specifies the elements and relationships of a domain. The HRRM is an

organization of the fundamental elements of human representation, their relationship to human models, and the relation of human models to other represented objects on the simulation. The HRRM uses a specific vocabulary to identify the elements, along with text definitions of the vocabulary and descriptions of the elements.

In addition, it may be useful to comment on the limits of applicability of the HRRM. The HRRM is not an architecture; it should not, for instance, be interpreted as prescribing a component-based people-engine, or as prescribing that models of humans be distinct from the system models that represent other objects in a scenario. Rather, the HRRM bears a closer resemblance to platform independent models as they are defined in a model driven architecture. The HRRM should also not be interpreted as prescribing that every human representation model include all the representation elements shown in the HRRM.

2. The Human Representation Reference Model

The HRRM is presented diagrammatically to highlight the relationship between the elements.

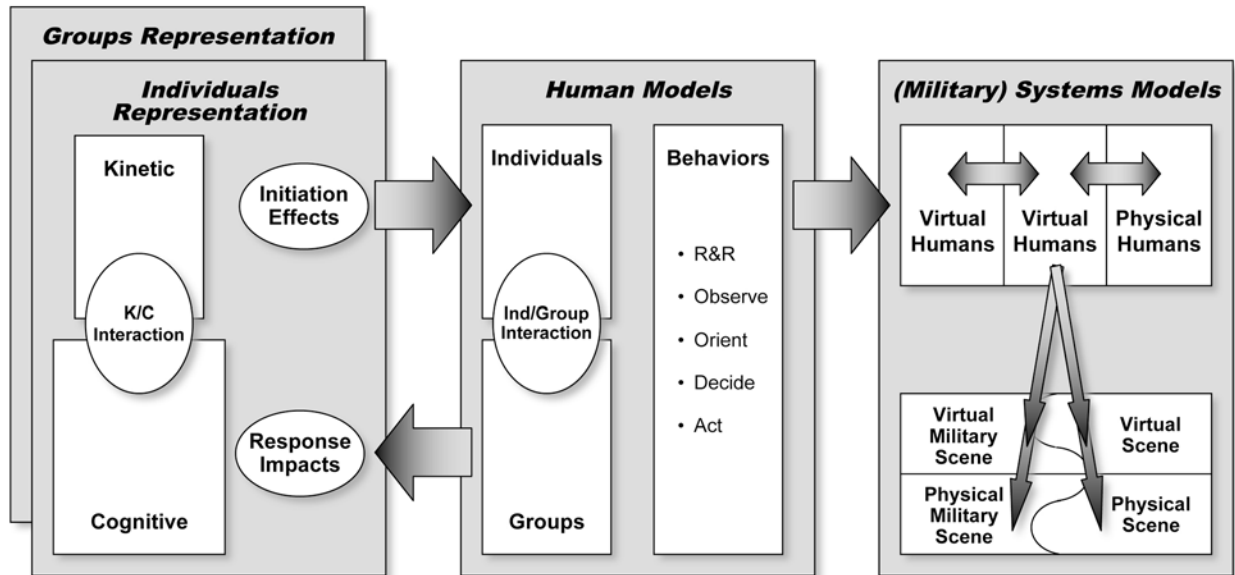


Figure 1. Human Representation Reference Model

Humans exhibit diverse and complex behaviors and interactions. They perform tasks, communicate with others, and operate equipment. They engage in mental behavior such as decision making that may be rational, emotional or volitional. Humans also have behaviors directed to self-preservation: eating, sleeping, sensing and playing.

Human carry out their behaviors either alone or with other individuals. Is there a way to classify or group the various human behaviors that enhances understanding of human behaviors and supports the incorporation of human behavior models into simulations?

2.1 Representing Individuals and Groups

The human behaviors listed in the above paragraph are neither extensive nor detailed. Before adding more human behaviors to the list, consider what is common in the behaviors already named. Each human behavior is either physical, mental or some combination of both. Here physical behavior refers to observable activityⁱⁱⁱ, while mental behavior refers to unobservable processes^{iv} associated with the mind or intellect. Many human behaviors are described as purely physical when they are really a mixture of both physical and mental. For example, ask someone how to drive a car. The person will describe how to turn on the engine, to release the safety brake, and to use the accelerator, turn signals, lights, brakes and steering wheel. Rarely will the person describe the intricate mental processes that are involved in operating a car. Yet teaching someone to drive a car safely requires that the person be trained in the mental as well as the physical behaviors involved. Thus, even classifying a human behavior as physical, mental or some combination of both requires careful consideration. Nearly all human behaviors can be classified as physical, mental or, more commonly, some combination of both.^v

In this paper, we are developing human representations reference model for military non-kinetic operations as opposed to traditional kinetic operations. The latter are munitions-based with the object of inflicting physical damage to targets while the former are information-based and directed to results other than physical damage. Information-based operations obviously involve mental processes with the emphasis on cognitive or information processing. The cognitive processes are sometimes considered to be purely rational, that is, to preclude emotions and volition. However, for non-kinetic operations, it is critical to understand and incorporate the ways that cognitive behaviors are affected by emotions and volitions.

Dividing military operations into kinetic and non-kinetic may appear to eliminate the need for kinetic representation of human behavior. However, this is not true as non-kinetic operations can involve kinetic behaviors just as kinetic operations can involve non-kinetic behaviors. The cognitive processes are involved in decision-making with the result that some response will be selected and executed. The response execution may be purely mental but more commonly involves some type of action or kinetic behavior. In addition, the initiation of cognitive processes involved in decision-making can be linked to kinetic behaviors. The cognitive process of perception involves processing the initiation effects or information cues received through the senses. In using their senses to optimum effect, humans will move into position. For example, in using vision, a human may turn his head to better view a computer screen or may move from behind a

building to assess the movements of other operatives. Thus, the cognitive process of perception can involve kinetic behavior of the human engaged but the actions of other operatives being perceived can be represented as purely kinetic behavior.

For kinetic operations in general, humans are treated as acting individually or in a group. Group behavior is used when the actions of the individuals need not be considered. For example, consider a scenario with a unit of Marines making a beach landing and moving into the shelter of nearby hills. For many applications, the individual behaviors of the Marines in the unit are not relevant. It is the group behavior of landing and moving into the hills that is important to the problem. Thus, for kinetic operations, group behavior designates the common or shared behaviors of the members of the group. On the other hand, it is possible that both group behavior and individual behavior may need to be considered. That unit of Marines making the beach landing may allot different responsibilities to members of the units such as removing equipment from the landing craft or stowing the craft for return. The group movement of the unit into the hills may be affected by the individual effort in removing a given piece of equipment.

For non-kinetic operations, the key aspect of group behavior is not that they *act* in the same way but that they *think* in the same way. Suppose several individuals are provided with the same information and, after processing that information, reach identical conclusions. Then the cognitive behavior for the group can be represented by the cognitive behavior of one individual in that group. There is no diversity in their thinking. In reality, individuals usually have some differences in their conclusions, even when provided with identical information. These differences can be resolved either among the individuals or by a leader making the final decision with the result that the group behavior again is in effect. As will be discussed in the following section, a critical part of non-kinetic operations is the understanding of factors affect the determination of group behavior.

In summary, human behaviors in non-kinetic operations are categorized as individual or group and as cognitive or kinetic with interactions between individual and group and between cognitive and kinetic being recognized. What other facets of non-kinetic operations need to be considered? First, the human behaviors are stimulated by outside influences designated as the Initiation Effects. The stimulated human behaviors result in actions, designated as Response Impacts, which, in turn, alter the outside influences present. So, the additional facets of non-kinetic operations that must be included are the initiation effects and the response impacts as shown in Figure 1 in the left hand panel.

tions and the values that the decision maker has. Consider again the driver passing the school ground. A dog dashes into the street in front of the car. What are the options? The driver can do nothing, brake, swerve to the left or right or brake and swerve. What are the risks? What are the values? Most drivers in the US value dogs and so will try to avoid hitting the dog by braking and swerving to the left or right. If the driver swerves to the left, he may hit an oncoming car. If the driver swerves to the right, he may hit a schoolchild following the dog into the street. On the other hand, some drivers in the United States of America place no value whatsoever on the life of a dog. The point here is that the Response Selection does not depend just on the Analysis but on ancillary information that stored in memory and that relates to emotions and volitions. Whatever Response Selection is made will result in an action or Response Execution that impacts the outside world or Scene.

At the end of the mental processing, a decision is made, Response Selection, and executed, Response Execution. Such responses obviously will alter or impact, Response Impacts, the physical world. Thus, the original Scene Present becomes the Scene Past and a new Scene Present is established by the Response Impacts. The previous Scene Present, which started the cycle, is now the immediate Scene Past, which enters into the Working Memory Cognition. The new Scene Present provides new Initiation Effects to start the decision making cycle again.

The main steps in the decision-making process are shown in the four boxes along the bottom of the diagram in Figure 2: Perception, Analysis, Response Selection and Response Execution. These steps may be more familiar in the military world as Observe, Orient, Decide and Act. As illustrated in the preceding discussion, these four terms are a very compact description of the human behavior in non-kinetic operations. Each step may be expanded into more detailed steps and the feedbacks among the various steps can be quite detailed, depending on the human behavior/performance model being used. However, the most general description of the behaviors can be distilled to the four steps of Observe, Orient, Decide and Act with one addition. As discussed earlier, Perception is influenced by the physical and mental condition of the observer or individual. Therefore, an additional behavior, which may need to be incorporated into the human models, is that of Rest & Relaxation or R&R. These behaviors are listed on the in the second panel, Human Models, in Figure 1.

The human decision making process depicted in Figure 2 (orange boxes) is referred to as a cognitive or information processing model. However, as discussed in the previous section, the Perception step (Orient) can involve both cognitive and kinetic behaviors on the part of the human. Further, the Response Execution step (Act) almost cer-

tainly involves some type of kinetic behavior to carry out the selected response (Decide).

This detailed discussion of the human decision making process highlights key factors other than the Scene Present that can affect the thinking and actions of humans. The human memory is filled with information about general education, specific training, cultural background, religious experiences, and ethical and moral values. If this information is widely different for two individuals, then they may make different decisions and actions, even when faced with identical circumstances or Scene Present. If, however, individuals share a common background, training, and experiences, they may tend to reach the same decisions and actions when placed in the same Scene Present. This commonality among the individuals means that the individual behaviors can be replaced with a group behavior model.

Group behavior can be both a strength and a weakness. Group behavior is a strength because the individuals in a group can anticipate to a degree how the other individuals within the group will think and act in a given situation or Scene Present. However, if two groups have different backgrounds, training and experiences, then they will not necessarily make the same decisions and actions for the same Scene Present. If group A is unaware of the relevant background, training and experiences that shape the memories of Group B, then group A may be unable to anticipate, understand, and influence the thinking and actions of Group B. If Group B, however, is aware of the relevant background of Group A, then Group B will have a decided advantage in anticipating, understanding and influencing the thinking and actions of Group A.

In non-kinetic operations, it is imperative to understand group behavior, both within one's own group and within the other groups involved, whether the other groups are on the same or opposing sides of the operations.

2.3 Human Models and Systems Models

Human models are used most often to represent more than one human in a scene. In these instances, the human model may interact with other virtual humans, or it may interact with physical humans. When virtual humans interact there is a need to define a set of actions that can be recognized by virtual humans, and a set of responses that can be performed by virtual humans. Depending upon the objectives of the representation, these virtual human interactions can be simplistic or complex; but they need not be recognizable by physical humans. (For instance, a state table may be queried and modified, without any physically observable effect in the rendered scene.) When physical humans and virtual humans interact, however, the characteristics of action and response may be differ-

ent. In this instance, virtual humans must perform actions that can be recognized and properly identified by physical humans (the more subtle the action, the greater the representation challenge). For virtual humans to recognize responses from their physical counterparts, the physical response must be translated to the virtual environment through some form of human-machine interface, and then represented in the virtual world as a recognizable event, as shown in Figure 1, right hand panel. As a result, human-machine interface characteristics should be considered as a human representation component whenever physical humans wish to interact with any of the virtual humans in a virtual world. When designing virtual human representations, the interaction capability may be considered in terms of the observe-orient-decide-act sequence described earlier.

Virtual (or physical) humans may interact with other components of the virtual (or physical world). In addition to cases of physical humans interacting with either the physical or virtual world, the HRRM identifies interactions between virtual humans and virtual world objects, and virtual humans and real-world components. When virtual human representations interact with other objects within their environment (through the observe-orient-decide-act sequence), the human and object states provide the basis for interactions. However, when virtual humans must interact with objects in the physical world, then there is a need to translate the virtual action into a physical action through some form of an actuator interface. Again, the actuator characteristics should be considered as a human representation component.

As a result of the foregoing discussion, it becomes apparent that human representation may involve the specification and construction of translator interfaces between physical and virtual humans, and actuator interfaces between virtual humans and the physical world. Thus, hardware engineers might be added to the list of human representation stakeholders for certain applications. Indeed, for certain training applications or augmented reality applications, translator/actuator interface hardware might be the critical element of the human representation implementation process.

3. Applications of Human Representation Reference Models

The preceding description of the HRRM has focused on the vocabulary and structure of human representation. In this discussion we turn from description to application, and describe some uses for HRRM. We'll discuss three example HRRM applications: (1) The HRRM as an ele-

ment of human representation research and technology development, (2) the HRRM as a tool to support simulation federation design and implementation, and (3) the HRRM's role in verification, validation, and accreditation (VV&A) activities.

There is a considerable and growing body of research in human kinetics and cognitive processes. The HRRM provides a roadmap that may indicate the application usefulness of research in developing human representations. Research might be categorized into areas corresponding to the elements of the HRRM, and then cataloged for use by human representation developers. If issues in a particular HRRM element are not addressed by existing work, the community may wish to solicit further research on a particular topic. (For instance, additional research regarding the interplay of individual and group behaviors may help developers specify that interaction when designing mixed individual/group people engines.

When designing and implementing systems, the HRRM serves as a valuable diagrammatic checklist of considerations. For instance in the HLA Federation Development and Execution Process, Perform Conceptual Analysis (step 2) and Design Federation (step 3), can benefit by using the HRRM for developing requirement and in developing the federation concept model. As another example, human representations being developed as part of a Department of Defense Architecture Framework implementation. These might benefit by using the HRRM to develop operational views for high level operational concepts (OV-1), operational node connectivity (OV-2), organizational relationships (OV-4) and operational state transition (OV-6b). Finally, the HRRM has application in the development of platform independent models as part of Model Driven Architecture implementation.

The HRRM is also a useful check for assessing the completeness of federation test criteria. In this application the HRRM is can be viewed as validation tool, when one needs to assess whether the implemented human representation reflects all characteristics needed for its intended use.

4. Conclusion

Summarizing, the HRRM is a multipurpose tool to encourage communication, completeness and effective validation in human representation implementations. The authors have postulated a human representation vocabulary and ontology. We hope that the resulting reference model is a step towards a more mature, standards-based human representation implementation process.

5. References

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ⁱ In this paper, we define models as explicit representational descriptions that are amenable to machine processing. This definition is more restrictive than a broader definition, where a model can be any structured description of an object, condition, or process.

ⁱⁱ In this paper, we define cognition as including volition and emotion, in addition to logical mental processes. This definition accords with current usage in the simulation community.

ⁱⁱⁱ We define activity as a process, function, or task that occurs over time and has recognizable results.

^{iv} Brain activity has been measured while certain types of mental processes are carried out but no one has yet developed an experimental technique to measure thinking.

^v The authors have not located an exception but would appreciate information to the contrary.

^{vi} Many of the feedback loops are not shown.

^{vii} Decision-making is based on cognitive or information processing but includes emotional and volitional processes as well.

^{viii} This figure is adapted from Figure 3 in Reference [1] and Figure 8.1 in Reference [3].