Rapid Intelligent Avatar Training System Development

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ABSTRACT

Some of the highest on-going training costs are associated with providing instructors and their support. Training in the Immersive Virtual Environment (IVE) offers the opportunity to replace some of the instructor's tasks with intelligent avatars and tutoring systems, potentially reducing costs. However, traditional Artificial Intelligence (AI) system development can be costly, offsetting the delivery cost advantage. Low cost automated tutors and avatars lack the intelligence to meet the training need. Conventional belief is tutoring systems and avatars that demonstrate the required intelligence are cost prohibitive. This presentation proposes a process for intelligent tutoring and avatar development. We identify specific problems associated with developing intelligent tutors and avatars for high level intercultural skills training. We review approaches for addressing these problems. We apply them in a case study of intelligent tutor/avatar development using a graphics based Subject Matter Expert (SME) knowledge modeling system. We conclude with a Return on Investment (ROI) analysis of the approach and a description of a process going forward for producing an intelligent tutor/avatar based schoolhouse.

ABOUT THE AUTHORS

Dr. Crutchfield has 15+ years as a social science researcher and object-oriented software architect in the simulation industry. He currently serves on the Group Technical Staff at Lockheed Martin Global Training and Logistics. Recent projects include design and testing of training development and delivery systems including an interCultural Readiness Trainer (iCRT), the Cognitive Human Performance Measurement Framework and the Advanced Distributed Learning experiment for Lockheed Martin. Past projects include the Advanced Traffic Management Training Center at Oak Ridge National Laboratory (ORNL) and the UNITES traffic model integrator. Dr. Crutchfield received his PhD and MA in Sociology from Stanford University, his BA from Georgia State University.

Mr. Reginald Price currently works as Chief Engineer on the Irregular Warfare & Stability Ops Campaign at Lockheed Martin GTL. He brings more than 25 years of product development experience in military training simulation field. He developed the CLE PoC system which is a LVC Immersive Trainer that utilizes NxTrain Virtual Environment & IOS, JSAF ClutterSIM, WARSIM and TeamSpeak. Scenarios are incorporated into an established training environment that develops and enhances the trainee's cognitive decision making skills in a bloodless environment. Mr. Price created the BioUnique Enrollment Capture Station and led the TWIC program. As Visual System Lead engineer for the FRIII Subsystem of the CompuScene (CS) II Visual system, contributed to site support in maintaining two (2) Visual Systems in LRAFB, and was Site Lead Engineer at KAFB for seven (7) years leading three (3) FSRs in the Maint and Operation of the system providing 98% system availability for training. In Orlando, worked on one of the first CS 2000 Visual systems developed for TESCO, completed the I&CO of the system in Japan and trained the customer.

Dr. Steven J. Tourville has over 25 years of engineering, research & development, and program management experience across US DoD and International Programs. Dr. Tourville currently serves as a Lockheed Martin (LM) Corporate Engineering & Technology Fellow, as a Distinguished Member of the LM Global Training & Logistics (GTL) Chief Technology Office Staff, and as a Principal Architect on the GTL Human Performance Engineering Staff. Dr. Tourville has operational experience as a former AFSOC Evaluator Navigator and was formerly assigned to the JSOC Staff. Dr. Tourville earned his doctorate from Nova Southeastern University, with a focus on training systems engineering and training and learning technologies. He has conducted post-doctoral applied studies, led advanced research and development programs, and has been recognized for advanced training systems design concepts and performance measurement approaches.

Mr. Hien Pham has over 15 years of engineering in telecommunication and simulation industry. He has served multiple engineering disciplines throughout his career, as software developer, system engineer, software architect, and project engineer. Currently, he serves as a Project Engineer on HoloWall at Lockheed Martin Global Training & Logistics and Software/System engineer for Buffalo Mine Protected Vehicle (MPCV) Simulation Training System, C130 Multi-Function Training Aid (MFTA), Desktop Advanced Gunnery Training System (AGTS), and United Kingdom Combined Arms Tactical Trainer (UK CATT). In his career, Mr. Pham also worked as a software architect for Future Combat System (FCS) Manned Ground Vehicle (MGV), leading development and design for a team of 12 engineers. In addition, he has worked as a System/Project Engineer on VCCT delivered to the U.S. Army and VCOT to the National Guards. He has earned a double Bachelor of Science in Electrical Engineering (B.S.E.E) and Computer Science at the University of Central Florida (UCF).

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OPERATIONAL NEED FOR INTELLIGENT AVATAR BASED TRAINING

Avatars in Training System Design

Military forces need highly skilled warfighters that are able to operate effectively under adverse conditions. Today's military is required to operate in the complex environment of failed or weak nation-states where mastery of the complex and difficult tasks of finding and killing the enemy is insufficient. Our national objectives require skills that address political and social needs in addition to projecting military power. This added dimension to military preparation increases both the cost and time to train to force readiness. Any training approach that reduces these costs will provide value to our defense budget.

Turn-key training solutions will necessarily require multiple training media technologies. Students approach training with variable degrees of expertise. Across the range from novice to practitioner to expert, the learning need changes so that the effectiveness of different training media varies. Our internal research (Tourville, unpublished) has determined that the most effective training media to transition the student practitioner into an expert requires either an interactive virtual environment or live role-player based training. This research found that interactive classroom settings are necessary for the novice; that intermediate learning is most effective using computer-based training techniques or videos; and advanced expert status requires simulation or live training exercises. As a result, the final stages of the most effective training for these required operational skills will require the most expensive training media, live role playing and/or immersive virtual environments. We are presenting a way to meet these training needs, while reducing the cost through the use of intelligent avatars.

Effective avatar design for training systems, though difficult and expensive, has been successfully used in this arena. For example, Alelo and VCom-3D have delivered programs of record. These designs achieve the appearance of Artificial Intelligence (AI) though we believe they have limitations, both in cost and adaptability across cultures and training scenarios.

In this paper, we have taken a different approach by drawing from Identity Theory as the basis for our model. Writing about identity theory, Stets and Burke state, "Most recent conceptions of identity expand on the notion of a correspondence of meaning between identity and behavior and incorporate the idea of a perceptual *control system,* a cybernetic model…" (2003). We will demonstrate that this approach provides a means for achieving a goal based agent (Beckert, 2004) that will permit the rapid development of cultural training avatars.

Intercultural Competence Training Methodology

Learning the amount of knowledge, the breadth of skills and attitudes necessary to navigate through a different culture can be daunting. Organizations have approached the problem through the use of multiple training techniques. Fowler and Blohm (2004) identified eighteen (18) current cultural training methodologies:

Training Method	Employed by DoD	Intelligent Avatar Possible
Lecture	Yes	Yes
Written materials	Yes	No
Computer Based Training	Yes	Yes
Film	Yes	No
Self-assessment	No	No
Case studies	Yes	Yes
Critical incidents	Yes	Yes
Simulations and games	Yes	Yes
Role play	Yes	Yes
Culture Contrast	Yes	Yes
Culture Sensitizer	No	Yes
Culture Analysis	No	Yes
Cross-cultural Dialogues	Yes	Yes
Area Studies	Yes	Yes
Immersion	Yes (at academys)	No
Exercises	Yes	Yes
Visual Imagery	No	Yes
Art and Culture	No	Yes

Our review of TRADOC and PMTRASYS training materials indicates that the DOD currently employs

thirteen (13) of these approaches in various training programs. Most of these require an instructor or trained facilitator and are presented in a classroom context. As such, they represent a substantial training investment. For example, Nicholson, Roby and Bushika (2011) report that PMTRASYS-ABM Support Services invest over $85 Million in role player support per year. Our conclusion is that intelligent avatar based training systems can potentially replace live instructors in as many as fourteen (14) of these training methods. The potential cost savings is substantial.

INTELLIGENT TUTORING AND AVATAR DEVELOPMENT APPROACHES

Intelligent Agents

We begin our analysis by understanding the requirements needed in intelligent agents to provide training avatar control. These agents select behaviors, or "acts" that the avatar expresses. The act selection function, $f()$, of the agent is completely described by:

$$f: P^* \rightarrow A$$

Where P^* is a sequence of preceding perceptual experiences and A is the atomic act that is generated as a result (Beckert, 2004). The realization of the act selection function can vary from simple deterministic cause and effect to more complex functions that arise as a result of the causal interactions of the perceptual experience. Beckert identifies four types of intelligent agent,

- simple reflex agents,
- model based agents,
- goal-based agents, and
- utility-based agents.

Simple reflex agents simply map perceptual inputs to responses. An air-conditioning thermostat would qualify as a reflex agent. Model based agents condition their responses on an internal model of the effect they have on the world. A weapons fire control system that determines distance and speed to "lead" a moving object to get the projectile on target would be this kind of agent. Goal based agents include this modeling capability but select actions on the basis of how they achieve goals. For Bechert, utility based agents select actions on the basis of goals and the anticipated happiness associated with performing the selected action. Beckert's assumption is that utility based agents require human intelligence because it associates affective outcomes with the performance of behaviors, something machine intelligence can only emulate.

In this paper we propose a multiple, competing goal based agent model to produce a machine intelligence that appears, within a limited domain, to use its experience to generate speech, gestures and expressions. We base our approach on social Identity Theory. The proposed avatar design uses social identity images as goals and employs strategies to achieve and protect them. When adapted to specific learning objectives, these identity strategies provide a necessary component of avatar fidelity that has been missing from previous training avatars.

AVATAR INTELLIGENCE FRAMEWORK APPROACH

Identity Theory and Avatars

Identity theory's roots emerged from Symbolic Interactionism theoretical research paradigm proposed by G. H. Mead (1934) at the University of Chicago. This influential approach, also known as the "Chicago School" became the framework for investigation into numerous social psychological theories. From this two identity models emerged, one based on the impingement of social structure on the self and how the resultant structure of the self influences social behavior, and the other concentrates on the internal dynamics of the self and the social situation and how it influences behavior (Stryker & Burke, 2000). Both of these identity theories support a cybernetic model of behavior, but we believe the second approach offers more prospects in the design of a cross-cultural AI model that can be implemented in a system to drive avatar behavior.
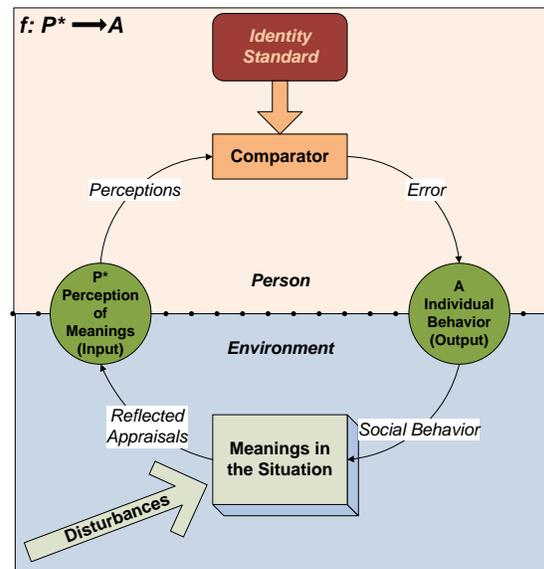

Figure 1. Basic Identity Model (Adapted from Stets & Burke, 2005) fits Beckert's intelligent agent.

According to Burke, the internal Identity model consists of four central components,

- the identity standard which is a set of culturally prescribed meanings which define role responsibilities in a given situation,
- the perceptions of meanings within the situation,
- a comparator or mechanism that relates those situational meanings to those of the standard, and
- the individual behavior or activity which is a function of the difference between perception and the standard (Burke, 1991).

"Behavior, in this model, is organized to change the situation and hence the perceived self-relevant meanings in order to bring them into agreement with those in the identity standard." (Stryker & Burke, 2000).
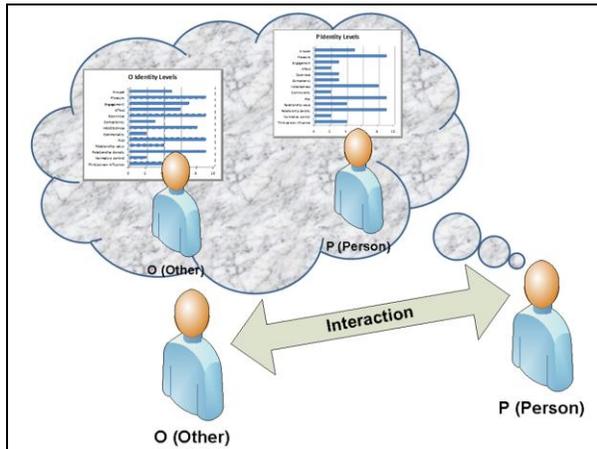

Figure 2. Our self identity as well as our conception of others consists symbols and meanings that evolve through our interactions with others.

We should emphasize here that the cybernetic concepts described in these references are those of these researchers. They were not attempting to describe an intelligent agent, as we use the term today, nor were they considering avatars. These are theoretical models for human behavior that (1) were developed to explain human behavior, (2) have been discussed and debated in one form or another in refereed journals since 1934, (3) have been developed into sophisticated quantified models, (4) seem to have been overlooked by AI research, and (5) include sufficient definition for realization as the intelligence model for avatar development. We extend this theory by actually applying it to produce an avatar intelligence.

As our proposed intelligent agent design is based on an application of this identity theory, some explanation of

the approach is required. Symbols in this behavioral model have defining properties. They indicate the socially recognized existence of an object, the meanings and behaviors associated with that object and the expected attitudes toward it. Identity theory argues that each of us has an internalized **Symbolic Identity Image** made up of a collection of symbols that we have assigned ourselves. These symbol assignments and meanings evolve through social interaction beginning with the parents who apply them to their children.

Through the maturation process, humans learn that symbols have social consequences. A common symbol consequence, you may remember from childhood, is "Bad" children do not get dessert. Children and adults seek through interactions with others to avoid symbols that block their desires and instead obtain the symbol assignments that will enable things they want. People also learn, through interaction, that they are able to assign collections of symbols to others and influence their behavior. Adults also learn to assign collections of symbols to generalized others (Mead's concept) whom they have not personally met but that enable them to anticipate others' behavior.
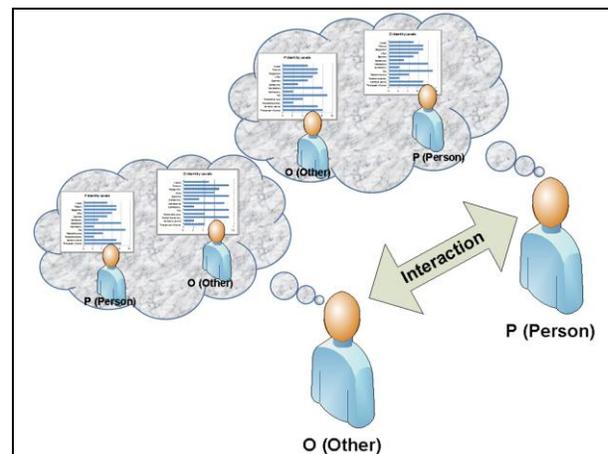

Figure 3. Interaction includes the joint negotiation of both self and other identities.

Much of human interaction is negotiation of these personal symbol set assignments. In addition, there are socially defined rules for how that is accomplished. We call these "strategies". For example, there is a strategy known as the norm of reciprocity. If someone gives us something, we owe something in return. The power of this norm is in its impact on our social identity and we can both manipulate, and be manipulated by it.

Another example of the impact of identity can be drawn from social distance theory. How we understand socially defined groups, or people we define as belonging to some classification, can be explained as a set of socially shared symbols we have assigned to

people of these classifications. For example, we apply this to create expected behaviors from people who come from different regions of the country. We informally construct personal strategies to deal with people like these.

Another understanding of behavior comes from Role theory, where we explain behavior by the roles they perform. This can be resolved as an application of identity theory in that roles represent symbolic collections that define the role behaviors and attitudes. Social norms associated with roles are shared rules about the behaviors associated with roles. These can be collected into behavior strategies.

Adapting these differing research paradigms into identity theory by describing them as strategies gives us an approach for constructing a cybernetic or multiple "goal oriented" model that can be expressed in machine business logic.

We observe that people use different identity strategies under different conditions. Consequently, higher avatar fidelity requires us to support multiple interaction strategies. Additionally, the interaction identity strategy in use by someone at any point in an interaction may change. We assume that people choose strategies based on what worked in the past, socio-structural constraints such as power differences in an interaction and what they want to get out of the interaction.

This can become overly complex. For training purposes, the avatar is not required to emulate the full richness of human interaction. We can use this approach, however, to give the avatar enough fidelity to support specific learning objectives in specific domain situations.

Structural Design

In order to translate these concepts into machine logic, we must first simplify the model. We begin by referring to the identity symbol sets as identity "images." We make the simplifying assumption that when we engage in interactions with others we maintain four internal identity images.

- An image of ourselves
- An image of the other
- An image of what we think the other has of us
- An image of what we want the other to become

For this study (and in figures 2-3) we assume that each identity image consists of fourteen attributes:

- Arousal
- Pleasure
- Engagement
- Affect
- Trust

- Openness
- Competency
- Indebtedness
- Commonality
- Risk
- Relationship value
- Relationship density
- Normative control
- Third person influence

These attributes describe the person in a specific relationship at a single point in time. They change as the interaction proceeds. For example, "arousal" describes the degree of physical reaction to the interaction at a given point in time. "Pleasure" describes the enjoyment or lack of enjoyment in the experience. High arousal and low pleasure could exemplify elements of an angry identity. "Engagement" describes how attentive the person is to the interaction. "Affect" describes various levels of liking or disliking. High engagement and low affect could also be associated with an angry identity.

"Trust" describes the sense of predictability expected from each other and "openness" describes a willingness to share. Both of these could also accompany the angry person identity. "Competency" describes relative expected capability with regard to some aspect of the interaction. "Indebtedness" and "commonality" are also relative values. "Risk" describes the sense of potential loss from the interaction. High relative self competency, imbalanced indebtedness and low commonality and high risk identity elements can all lead to acceptance of the angry person identity.

"Relationship Value" is the degree of importance associated with continued and future interactions with the other, where "relationship density" describes the numbers and variation in relationship roles. "Normative control" suggests the degree to which behavior is socio-structurally constrained, where "third person influence" suggests a level of localized behavioral constraint. Relationship value and density combined with normative and third person control can mitigate the performance of the angry person identity or even comprise the characteristics of a righteous indignation to justify and stabilize the angry person identity.

Every behavior can be classified into how it will affect each of these attributes in both actors. So when one actor performs a behavior, images of both actors held by both actors (four images) are modified as a result. Actors choose actions they believe will change these images in both parties to match the image standard they are seeking. This implies that interaction strategies most consist of target images for both parties. By initializing the starting and target images to be used by an avatar

with the values needed for a desired training mission, we have defined the goal seeking targets to be used by the avatar in its interaction with the trainee.

Ideally, we would define behavior based value shift functions for every possible behavior along each of the four identities. In order to reduce setup and operation time, we simply associate deltas for each of the fourteen image attributes. We provide for further simplification by assigning these deltas to sets of behaviors, rather than each behavior individually. This limits the number of deltas whose definitions are required in our interaction database. By doing so, it allows us to set up general behavior classifications that are culturally independent. It is the content of behavior that is culturally specific.

Determination of these behavior classifications and their deltas are the product of a one-time research exercise. This should be accomplished using an interview schedule with a culturally diverse panel of respondents. It is expected that these deltas are fairly universal between cultures. The cultural variation will be found in the kinds of behaviors possible and how they are assigned to behavior classifications.

A Subject Matter Expert is required to list all of the behaviors associated with a given set of learning objectives. These are then categorized into behavior classifications that pre-set the identity attribute deltas.

Once a set of images states and goals have been defined, we require business logic to apply the behaviors to reach the goal. The simplest model is to apply logic select the behavior with the deltas that will achieve the goal. However, interaction protocols often prohibit that direct approach. For example, all cultures require a greeting sequence as the first action. It can be as simple as a single "hello" statement, or more complex, involving bowing and other gestures. Most cultures also require a certain amount of ancillary conversation to precede any serious business discussion. Consequently, a larger strategy is required to navigate even a simple conversation.

These strategies are also cross-cultural, only the content and numbers of associated acts for each strategic phase are required. Computer algorithms to support this logic are not unlike those used to accommodate movement behavior. Existing avatar movement behavior includes logic to avoid virtual objects and other obstructions when moving from one location to another. Complex gaming logic even includes avoiding adversary fields of view or quickly traversing fields of fire. Interaction behavior requires similar logic in navigating the "social" environment.

Fortunately, identity theory applies to interaction strategies, as we described above. The current state of the software engineering science provides means to graphically express strategies in a business logic modeler and editor. Because this is done using a graphical editor, it can be accomplished with little direct input from a software engineer. This allows us to add a behavioral scientist to the team to define cross-cultural strategy logic.

One concern is that differences in culture can lead to differences in thinking, so that one cognitive model may not be appropriate for all situations. This comes from the Sapir-Whorf Hypothesis which assumes language determines thought. It claims that if people do not have a word for something, they cannot even think about it. Munger found in laboratory studies, however, where subjects were shown sets of oddly shaped images that did not correspond to existing objects, they were able to classify them based on similarities in shapes. He concluded that "…although language does influence thought, its influence isn't immutable. Just as we can learn a new language, we can learn to have thoughts that aren't expressible in any language." (Munger, 2008)

Our work addresses the issue by assuming that most of those differences are minor and that our theory based strategies are sufficiently general. Moreover since we are not attempting to create a generalized intelligence, we can create reasonable representations of the relevant characteristics of an avatar needed for a given learning objective. Where cognitive processing differences are significant, the business logic modeler provides the necessary capability to accommodate those differences.

By creating a standardized framework with known identity deltas, and theoretically defined strategies, we produce an intelligent avatar system that can be quickly and cost effectively applied to different tasks in different cultures. We eliminate the need to define a complicated interaction behavior tree (BT) structure, allowing the goal-seeking process and the identity deltas to provide behavior selection for us.

System Architecture

Typical intelligent avatar architectures involve the software definition of intelligent agents. This is done in conjunction with subject matter experts to produce a behavioral response logic built on a BT diagram. The result is a mapping of input behaviors to response behaviors to form an Input-Process-Output (I-P-O) model that executes expected behaviors. This development process may be enhanced with a cognitive model that attaches affective states to the behaviors to give the impression of an intelligent agent.
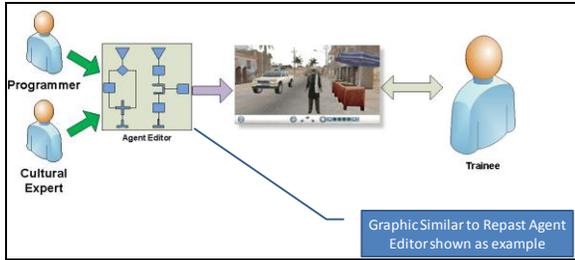
Figure 4. Typical design of intelligent agents for cultural training requires collaboration of programmer and culture expert over lifetime of development.

This approach has drawbacks. First, to be effective, it requires an extensive list of behaviors and a complex system to relate them to perceptual inputs. Since this list is typically limited, the result is an avatar with a perceivable level of predictability that impedes the fidelity of the model. Second, generating this list and especially the causal structure is costly and time consuming and it has to be repeated for every new venue. Third, it requires the programmer to work with the cultural expert to produce every new training model, since the causal structure resides in the rule system used by the software to operate behaviors. This adds risk to the project as additional program code carries with it additional likelihood of imbedded error. In general, as the model becomes more complex to meet new training needs, the chances of failing to identify these errors before release to the users becomes greater.
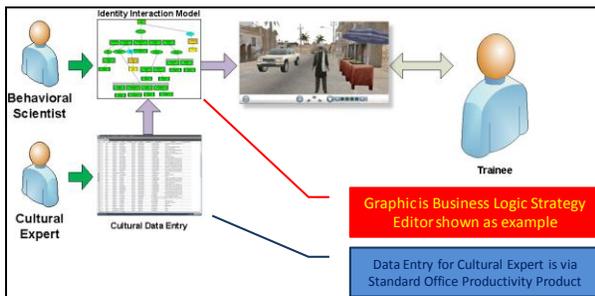

Figure 5. Behavioral scientist defines cognitive strategy model while cultural expert defines content.

Our approach is to engineer a simple AI support structure whose reliability can be established early on. We use two independent knowledge systems, one for capturing behavior strategies and the other for capturing cultural data. Our business logic modeler provides a graphical tool for capturing behavior strategies. The behavioral scientist applies this easy to use tool. Through this approach, we produce the business logic associated with the strategies that apply identity theory. These strategies are complied into a tokenized module that is executed by a Business Logic Interpreter (BLI).

We use Microsoft Office products, specifically Excel spreadsheets, to capture specific training information, in this case cultural information, provided by a subject matter expert. We import these data into a database accessible by the business logic interpreter.

Model re-use and increased affordability

The software engineer and the behavioral scientist is only necessary for initial development of the model. The role of the software engineer becomes redirected toward providing elements of the virtual environment. Similarly, the role of the behavioral scientist becomes necessary only when training elements require new behavioral strategies. We anticipate these theoretically based strategies, or goal models will apply in most cultural training situations, so the role of the behavioral scientist becomes less necessary over each new application. The subject matter expert is the only development role necessary for every new training application.

Increased affordability and reduced development time is achieved in developing each new application. Consequently greater cost reduction is obtained by applying avatar based training to as many of the training methodologies identified earlier as possible.

PROTOTYPE SYSTEM DEVELOPMENT

The prototype system developed for testing this approach consists of a sensor array, an integration processor, an avatar intelligence model processor, and a display system.
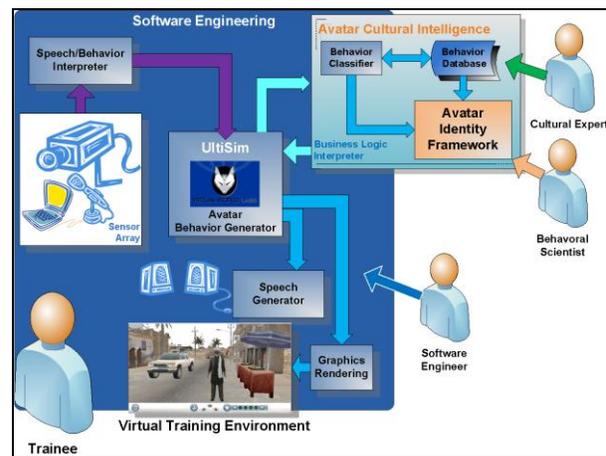

Figure 6. The prototype avatar intelligent agent system.

For the visual display system, we use a projection system to produce life-sized characters. The sensor array includes a microphone, camera, proximity and motion sensors as well as standard computer interfaces, i.e. keyboard and mouse. UltiSim (visual 3D scene

generator and simulation application) provides a common integrator interface that assembles inputs to the avatar intelligence model, the BLI. The BLI provides the artificial intelligence of the avatar. UltiSim also receives outputs from the BLI and converts that into behaviors that drive both the speech generation system and the avatar graphics rendering.

UltiSim provides additional functionality. When the user is beyond perceptual range of the avatar, UltiSim will assign it a random "fidgeting" and model animations. This allows us to create a virtual world expressing characters with variable levels of cognitive fidelity. As the trainee moves through the world, the avatar BLI need be awakened and assigned to drive only the avatar that is near to the trainee. As the trainee leaves the perceptual field of the avatar, its intelligence can drop back to a lower level of cognitive fidelity, and UltiSim again assigns a fidgeting model. This allows the system to support a large virtual training environment that only needs a limited number of concurrent BLIs for high fidelity operation.

Development Plan

Initial development and testing of the system proceeded in two phases.

In Phase I, we created a simple stimulus-response avatar that would recognize simple phrases and respond appropriately. The objective was to stand up a prototype system with all of the operational components present.

Phase II incorporates necessary modifications identified in Phase I and extends the model to include an informant interview using strategies from the identity theory model in a goal based system. At the conclusion of this phase, an estimate of the ongoing Return On Investment (ROI) of maintaining the model and applying it to future systems will be completed.

Future development will incorporate modifications identified in Phase II. Concurrent graphical model and animation development will include extension of the behavior sets through each phase and the fidelity of expression rendering. Speech recognition and generation will require continuous development.

Phase I System Evaluation Approach

The system structure was evaluated using an adaptation of training materials for an earlier project. The earlier training task consisted of an interview with an indigenous informant in an Afghan town in order to gain intelligence about insurgent activities. In this configuration, the "informant" was a role player in front of a green screen. This enabled placement in the virtual environment. The need to move beyond role players was discussed above, but we used this to demonstrate

the plausibility of using life-sized avatars for intercultural skills development.

Figure 7. Avatar in virtual environment recognizes presence and addresses trainee.

The script was adapted for performance by the avatar. This included a process of listing all the behaviors observed in the prior test in a spreadsheet and linking behavioral inputs to output responses. The implementation of strategies follows in phase II. This functionally tests the hardware and interfaces.

The original script was slightly extended by the subject matter expert to allow a greater range of inputs and responses. The initial BLI, including behavior recognition and interfacing with UltiSim took approximately four man-weeks to produce. This included time spent by the behavioral scientist learning to operate the business logic editor.

Our initial implementation used the BLI to do a simple I-P-O model. On initialization, the BLI loads the database and prepares its behavior recognition framework. It then goes into a sleep mode. The recognition framework is used to identify and classify what behaviors are being received by the system. Proximity data from UltiSim awakens the avatar from its sleep mode and the avatar begins to respond to inputs from the trainee. In the initial test, speech recognition was limited to a few phrases.

With the modifications implemented, the avatar represents a local tribal leader who is a point of contact for activities involving the local virtual villagers. The graphical visual database includes 3D scene representing streets, buildings, compounds, and life forms simulating a realistic Afghanistan village environment. A behavior-dynamics graphical model rendering provides for the natural movement of the avatar.

The behavior library incorporated in UltiSim to support the avatar included the simple expressions of smiling, frowning and puzzlement. We added puzzlement early on to provide an appropriate response when

unrecognized inputs are received. We included simple gestures like polite bow, touching the chest, and shaking the head. Movements like turning to face the user were also included. These are examples were used in the prototype, but the graphic artist and SME can enhance the application to provide additional behaviors to meet the training needs.

Speech generation used the Microsoft "Anna" voice interface provided with Microsoft Windows 7®. The avatar interface provided for the expression of recorded sound bites so that some Pashto phrases could also be included, but these were not implemented in initial testing. Visual representation of behavior associated with speaking, bobbing head, moving lips and jaw, is also coordinated with the speech generator.

Speech recognition was divided into three sub-systems. The first is the actual speech-to-text converter based on the existing Windows® speech recognition Application Program Interface (API). It provided recognition of a limited set of words (dictionary) defined by the user in the voice recognition application. It also provided a second system for compiling lists of words into phrases to be passed into the avatar intelligence. The third system is the behavior recognition framework implemented in the BLI. It employs a mapping scheme to identify the behavior most likely to have been received by the speech recognition interface. If the intelligence is unable to recognize the perceived behavior, it responds with a puzzled look and an apology for not being able to understand the speaker. Otherwise, appropriate BLI responses are generated.

RESULTS

Phase I findings are grouped into three categories, system stability, cognitive design, and culture editing.

System stability

The findings were favorable to justify further development of the system. The BMI was found to be quite robust and stable. We let it run for more than a week and it continued to respond to inputs. This stability encouraged us to add the development of a database "reload" capability to enable refreshing of the behavior-response matrix without completely halting the BLI process.

Cognitive Design

The use of a graphical business logic editor to develop cognitive models was found to be effective. The editor provides a means to represent problem solving strategies as a knowledge hierarchy. The business logic Modeler presents the knowledge hierarchy graphically,

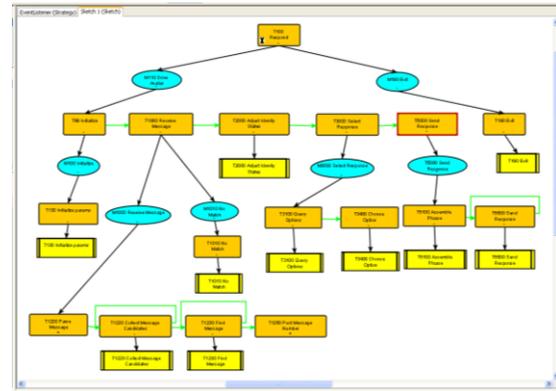much like a flow chart or a Uniform Modeling Language (UML) diagram, but much simpler.

Figure 8. Graphical editing of interaction strategies.

We found the business logic modeler to be intuitive to use. It enables a non-technical, non-programmer user, such as a behavioral scientist to apply the model to describe cognitive function. As a result, the time required for the scientist to create a functional agent without the assistance of a software engineer was very reasonable.

Linking the BLI to UltiSim involved calls to externally complied Java executable libraries. These provided communications through the Java Messaging Service (JMS). Only two functions were required, "wait" and "send". The BLI natively supports multiple threads and these are initiated by calls to "blackboard" variables. Blackboard variables are BLI data structures shared between strategies. The API permits reading and writing to these variables externally by the Java library on receipt of JMS messages. Strategy triggers are associated with these variables so that when a call is made to the BLI API to write to a blackboard variable, it also initiates execution of the strategy. When the strategy completes execution, it makes "send" calls to send behavioral commands back to the JMS. Through the use of the JMS, the system is loosely coupled, allowing the avatar AI model to wait indefinitely in the background and operate only when needed.

The BLI is limited to generating what we might refer to as intentional, self identity image based interaction behavior. This is mostly speech with some gestural and emotion expression animation actions intended to communicate. This is separated from the animation behavior UltiSim generates to give the avatar an animated life-like appearance.

In execution, we determined BLI processing was sufficiently quick. Responses to actions were given immediately, suggesting the need for an artificial

"thinking time" parameter to its responses. As the identity model strategy base is expanded, this time will necessarily be used by the system to do its own processing, but at this stage, the model responds faster than humans do, actually lowering the cognitive fidelity.

Culture Editing

Since culture editing was accomplished using a standard Microsoft Office tool, there was no time required to learn its use. The initial behavior script was transcribed into tabular format. The resulting table was reviewed by the behavioral scientist. Extensions to the script were recommended which were reviewed by both the subject matter expert and the behavioral scientist to ensure authenticity.

We developed a relational database structure to support the identity theory models required for subsequent phases, but in Phase I, only the behavior table was used.

Phase II Development

Phase II applied modifications of the system identified in the Phase I findings. The database structure required some extension to support the identity model, one user and the same "informant" avatar. As a tribal leader, this avatar has goals of personal security and support from the military presence. His conversation also supports an issue regarding the killing of a goat owned by one of his villagers. Thus, he is performing a simple negotiation on behalf of this villager. Much of that capability had already been included, but additional strategy development was required. As part of strategy enhancement, we improve realism by including random variation in both input behavior identification and response selection.

Conclusion

Identity theory provides an established and well researched cybernetic behavior model that to date has not been exploited in avatar design. We argued for the use of this theoretical model in an intelligent agent model for avatar behavior. We demonstrate that it provides for a goal-seeking system applicable for a cultural training avatar. We demonstrate a process that enables cultural training without the need for an extensive BT network of behaviors and responses. The result is an avatar system that is adaptable across cultures and across training situations.

We constructed a system capable of using this model whose primary components were comprised of UltiSim, BLI cognitive models, a database, and supporting systems. We exercised the system and found it to be capable of providing the environment for the testing of the identity theory model.

Avatar based training offers an open ended source of learning solutions that are ultimately cost effective and adaptable to many training needs. They are particularly suited to intercultural training applications.

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