IMPROVING INTERACTIVE TRAINING THROUGH INDIVIDUALIZED CONTENT AND INCREASED ENGAGEMENT

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ABSTRACT

Simulation-based training offers the potential for relatively low-cost training available at any time and almost any duty station. However, a main drawback of simulation-based training is the lack of oversight in the training process. Simulations often depend on a fixed number of pre-defined training scenarios that are designed to test training objectives but often do not deliver a training experience customized to the specific trainee's current level of skill and understanding. In this paper, we introduce the Interactive Storytelling Architecture for Training (ISAT) which uses an intelligent agent, the director, to assemble training scenarios that test the skill level of individual trainees. The director also acts in the course of the execution of the training scenario to provide indirect feedback about trainee actions, subtly adapting the training environment to stress skills and suggest remediation. This approach results in a training experience that is engaging and specialized to the trainee's individual training needs and, potentially, provides faster development of trainee proficiency and greater trainee engagement in the training process.

ABOUT THE AUTHORS

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Lisa Scott Holt is a Research Scientist at Soar Technology, Inc. During a 9-year tenure in the Center for Innovation in Learning at Carnegie Mellon University, she received her Ph.D. in Cognitive Studies in Education from the University of Pittsburgh in 2001. For her dissertation she designed, implemented and evaluated an interactive tutoring environment for introductory physics. Dr. Holt's current research focus is in the design of technology tools to support learning and the design of interfaces based on an information-processing model of human cognition. She is also interested in assessment methods to reveal what learners actually know and are able to do with their knowledge.

Brian Stensrud received his Ph.D. in computer engineering from the University of Central Florida (2005), and also holds B.S. degrees in mathematics and electrical Engineering from the University of Florida (2001). His doctoral dissertation dealt with learning high-level tactical behavior using a modified neural network architecture. Prior to joining Soar Technology, Brian was involved in a variety of research projects as a member of UCF's Intelligent Systems Laboratory (ISL). These projects involved a broad range of topics including human behavior modeling, neural network and evolutionary programming applications, affective reasoning, and robotic applications of agent-based systems.

INTRODUCTION

Advanced Distance Learning (ADL) technologies are critical for training war fighters in distant locales where access to schoolhouses is limited and resources are scarce. Immersive computer games are increasingly used as an ADL technology because they provide compelling, engaging learning experiences that have been shown to reduce training time and increase training persistence. Game technology also represents a significant step forward in the "train as we fight" vision of effective, anytime, anywhere training. In virtual environments, the realism of the training experience helps trainees obtain a better sense of "how" and "why" they are learning to perform some task, whether it's an urban room clearing exercise, fire training in a shipboard engine room, or an aircraft maintenance scenario.

Human-controlled systems where a trainer actively directs a trainee's experience are usually the preferred training environments. However, human trainers are a costly resource and are usually only available at prescribed times and duty stations. They are often quite constrained in providing individualized training. For example, in the U.S. Army's 91W10 combat medic training, a schoolhouse instructor demonstrates medical procedures (such as applying a tourniquet) to trainees using a dummy to represent an injured person. The instructor typically guides one student through the process hands-on, while the other students in the class observe the target performance. To maximize training effectiveness and persistence, it would be best to give each trainee hands-on experience in each medical procedure. In a schoolhouse situation with limited time and resources, however, hands-on training for all is not practical.

Automated systems, such as virtual reality training systems, address some of the limitations of human-mediated training. They may cost less to operate and can offer individual trainees the experience of performing the trained skills. Computer games are increasingly used as very low-cost virtual training platforms with a computational profile that allows them to be used for ADL, as well as in more direct training situations. Computer games provide somewhat adaptive experiences, by reacting to trainee actions, but, in general, game behaviors are typically only loosely or indirectly coupled to training goals. Thus, while computer games offer "fun" experiences for the trainee, without careful design, the training experience itself can either be lost in the game play or fail to take advantage of the freedom offered by the game environment. Generic training games can result in poor training or training experiences that must be repeated many times to achieve a desired effect. Further, skill assessment (based on behavior) can be difficult and sometimes may also be less precise than most web-based learning environments (where skill is evaluated based on responses to specific questions). Without appropriate oversight, computer games can result in negative training. Unlike the schoolhouse, typically no human trainer is present to guide the trainee and provide the most appropriate experiences. Within the freedom of the game environment, the trainee is able to perform many actions, some of which are appropriate for the training and others that may not be.

Our approach to interactive training, the Interactive Storytelling Architecture for Training (ISAT), is designed to address the limitations of computer games for ADL outlined above and to fully realize the potential of games as engaging, individualized, and training-focused environments. To accomplish these goals, ISAT introduces an intelligent software agent into the training environment. This agent, which we call the "director," serves a role similar to the schoolhouse trainer. The director chooses and customizes training scenarios based on a trainee's skill level and previous experiences. The director also subtly guides the trainee thru a scene by dynamically adapting the environment to the dramatic needs of the scene and the learning needs of trainee. Unlike the schoolhouse trainer, the director acts "behind the scenes" and is imperceptible to the trainee, which allows the training experience to remain immersive and engaging. This approach applies earlier work on interactive storytelling, the Interactive Drama Architecture (IDA) (Magerko, 2005; Magerko and Laird, 2004), to the interactive training domain. ISAT extends IDA to the requirements of training systems, including a skill model that the director uses to evaluate the proficiency of a trainee with respect to training objectives and to tailor training scenarios to exercise specific skills. This paper will present ISAT's design, including both the design implemented in our prototype system as well as the approaches to be explored in full implementation.

Requirements for an Interactive Trainer

Before describing ISAT's design and initial implementation, we should first address the design requirements used to guide its design and development. Requirements for an interactive training architecture include:

1. *Training Effectiveness*. A training system should effectively train the desired skill set. This requirement subsumes all others in that the end measure of a training system is how accurately and efficiently that system can be used for training.
2. *Engaging Experiences*. Engaging systems have a greater likelihood of providing persistent and efficient training. A system is more engaging if it provides some secondary motivation for a trainee in addition to it being "required training," such as interesting gameplay or a compelling narrative. An important requirement for engagement is that the situation in which the trainee learns be believable and realistic. Believability does not necessarily imply high fidelity models of the environment and actors in it (Wray & Laird, 2003), but rather trainee observations and experience should be consistent with the experiences one would encounter in a real situation.
3. *Individualized Training*. In order to maximize effectiveness, a training process should adapt content to fit the particular needs of individual trainees. Computer-based training technologies should support scaffolding (providing guidance and support to the trainee early in learning) and fading (gradually removing or reducing scaffolding to ensure the trainee self-reliance). These approaches should be used to tailor the system's guidance and feedback in accordance with the trainee's performance.
4. *Generality*. Any architectural approach to interactive training should be explored as one that could be applied across domains and training environments. A specialized trainer that does well in a single domain but not others is certainly useful, but does not have the utility of an approach that can be applied in many different domains.

Previous Approaches

Pedagogical software agents have in recent years been implemented in interactive learning environments to individualize the learning experience, providing learners with needed support (scaffolding). Users learn and practice new skills in a virtual world, and the instructional system adapts to individual learners through the use of artificial intelligence. Intelligent agents can interact with the learner directly (e.g., as a coach or learning companion) or indirectly by altering the environment.

Agent-based technologies have been used to realize a range of support and guidance in educational technology systems. A software agent is simply a software system designed to interact (perceive and act) within an environment, which could be a physical environment (i.e., a robot) or a virtual environment (e.g., a computer game "bot"). Pedagogical agents have been developed to provide explicit tutorial guidance in training systems (Rickel and Johnson, 1997), and these developments have demonstrated the power of using software agents in knowledge-based learning environments (Johnson, Rickel, and Lester, 2000; Moreno, Mayer, and Lester, 2000; Lester, et. al, 1997a; and Lester, et. al, 1997b). In most cases, pedagogical agents have been represented explicitly in the simulation environment as an animated virtual instructor that is always present. The explicit representation of a director may be appropriate for some training, but it also has the serious drawback of compromising the realism of the training scenario (see Requirement 2).

Our work builds on the notion of a pedagogical agent that guides user experience, but makes the agent implicit rather than explicit. An implicit pedagogical agent does not provide direct guidance but rather structures the environment to give the trainee appropriate experiences (ones tailored to needs and skill level). Because the agent is not represented explicitly, the trainee's sense of engagement and responsibility for making decisions is naturally and effectively supported. As the trainee's skills deepen, the pedagogical agent takes fewer and less frequent remediation actions, providing a natural implementation of fading. Pedagogical agents that directly support remediation and storytelling should efficiently support a large numbers of users, individualize training, and provide simulated experiences that can transfer to improved performance in the real world.

Our approach of altering the trainee's experience is similar to that used in intelligent tutoring systems (ITSs). The defining feature of an ITS is that it carefully oversees a learner's work to provide needed guidance. ITSs incorporate a rule-based expert model of the target skill that is used to monitor and guide novice learners as they engage in the new activity. The intent of an ITS is to model the actions and interventions of a human tutor which is the most effective means of instruction (Bloom, 1984). ITSs identify the need for instructional interventions by comparing a model of expert performance with a model of the learner's performance (Corbett, 2001). However, the pedagogical nature of these instructional interventions is quite limited in nature (see Requirement 3). Model-tracing methods force the learner to proceed in steps of a specified grain size (corresponding to the underlying rules) that constrains the progression of the learner's actions. The information processing approach is useful in domains where the representation of domain knowledge has a significant rule component such as algebra, physics, or even language (Johnson, et. al, 2004) (see Requirements 1 and 4).

THE INTERACTIVE STORYTELLING ARCHITECTURE FOR TRAINING

ISAT is designed to provide individualized training through the *real-time adaptation of stories*. We are developing general techniques and components (an architecture) that can extend existing and new training systems to provide greater trainee engagement and dynamic adaptation of content to support both engagement and training goals. The ISAT architecture is focused on an internal and imperceptible agent, the *director*, in a constructive simulation environment. To explain how ISAT works and to test its operation, we will describe ISAT in the context of a specific example training system. However, ISAT is designed as a general capability, rather than a component in a single training application (see Requirement 4). Our future plans include integration of ISAT with several additional training domains. Multiple, successful integrations will provide empirical evidence of what is now only a claim with respect to generality in design.

ARCHITECTURAL DESIGN

ISAT is heavily influenced by the aforementioned Interactive Drama Architecture (IDA), which employed an intelligent director agent to mediate between story content, synthetic character behavior, and the player's actions in the game environment (Magerko, 2005; Magerko and Laird 2004). ISAT's design, shown in Figure 1, considers the virtual environment (e.g. the TC3 trainer), the trainee (e.g. the medic character controlled in the TC3), a human trainer who authors training content, the synthetic or "non-player characters" (NPCs) characters that populate the game environment, and the director agent. The director is responsible for managing the trainee's experience in response to the training scenario content, the trainee's actions in the world, and the director's skill model of the trainee, which tracks his aptitude across a set of domain skills. The director can affect the trainee's experience by giving the synthetic characters certain actions (e.g. a squad leader orders the trainee to treat a specific casualty), by altering the environment (e.g. spawning characters, items, or environmental sounds), or through the selection and instantiation of scenario content.

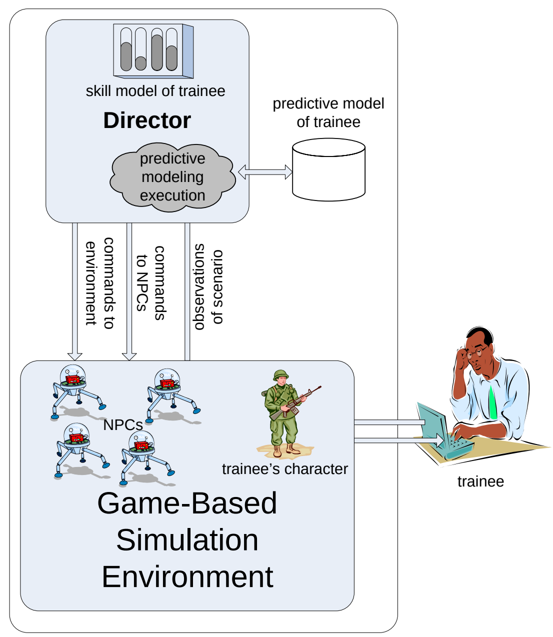

Figure 1. Components of the Interactive Storytelling Architecture for Training.

Environment

Our current prototype system, shown in Figure 2 below, is implemented in the 91W10 TC3 trainer, a training system under development by Engineering and Computing Simulations, Inc. (ECS) for the training of combat medics. The TC3 trainer combines advanced interactive training techniques with distance learning technologies and immersive 3D simulations to provide the knowledge, skills and practice necessary to significantly improve the performance of combat medics. The courseware is based on the same systematic approach for Basic and Advanced Trauma Life Support (BTLS, ATLS) that is used to train Emergency Medical Technicians (EMTs). However, it requires students to demonstrate an ability to perform these tasks in tactical situations that are dictated by the principles of Tactical Combat Casualty Care.

The existing TC3 proof-of-concept implementation highlights "Tactical Field Care," which means that the medic is out of direct fire, but threat has not been defeated (as opposed to "Care Under Fire," where the medic is under direct fire). Currently, TC3 development is focusing on situations where the trainee provides care under fire. After an initial introduction, the trainee is placed in a simulated environment with a first-person point of view holding his rifle. The trainee may then survey the situation and move around the environment, a 100 ft. radius circle of terrain representing a courtyard in an Afghani village. Trainee actions include slinging the rifle, manipulating casualties, and accessing items in the medical bag to assess casualties, prioritize treatment, and treat injuries.

Figure 2. Screenshot from prototype ISAT implementation in 91W10 TC3 Trainer.

Skill Model

The director keeps track of the trainee's aptitude in the skills to be trained by the system. As the trainee executes actions in the environment, the director relies on knowledge that indicates when a trainee is performing well or poorly in a particular skill. For example, if the trainee applies a tourniquet to a trainee, but does so too far up from the wound to be effective, then the director would mark down the "apply tourniquet" skill. The set of target skills used in the TC3 trainer is shown in Table 1. The current ISAT prototype employs a simple, qualitative skill model. Developing more fine-grained, multi-dimensional skill models will be explored in future work.

Director Actions

The director is responsible for managing the training environment (e.g. coordinating synthetic characters), hypothesizing about the trainee's aptitude in the tested skills, and selecting training content. How the director actually affects the world in response to these roles can be described in the various actions the director can execute in the environment.

Table 1. Target skills used by ISAT director in the 91W10 TC3 Trainer.

Skills	Description
Care Under Fire	In a hot zone situation, return fire and help secure the area before attempting treatment or extraction.
Find Temporary Fighting positions	Minimize exposure to fire by staying low to ground and using objects in the environment.
Prioritize casualties	Decide the order in which patients should receive care.
Secure casualty	Make sure the casualty poses/can pose no threat.
Check vitals	Check casualty's breathing, heart beat, and skin color.
Apply tourniquet	Decide when a casualty/situation requires a tourniquet and apply the tourniquet.
Manage airway	Open airway if the patient's breathing is labored.
Manage chest wound	Take correct steps to treat a casualty with a chest wound.
Monitor	Monitor casualty until evacuation
Extraction	Properly extract a casualty from a hot zone.

Scene Choice

A scenario is defined as a partially-ordered collection of scenes. Each scenario is authored by a human trainer and encapsulates a single training experience. Scenes in a scenario are temporally-ordered to maintain consistency in the training content, akin to the temporal ordering used in planning languages. Once all of a given scene's parents have been performed, then that scene can be also considered for performance. We use standard languages and representations developed by artificial intelligence researchers to represent dependencies and interactions among scenes.

A scene is defined by a set of skills associated with abstract plot content. Each scene denotes the set of skills that it could possibly test. The abstract content authored in each scene is intended to describe the basic situation, leaving the specifics to be instantiated by the director at run-time. This provides the trainer a means to specify scenario content at an abstract level, offering both more possibilities of experiences as well as training scenarios that are more tailored to the trainee's needs (see Requirement 3). How the director chooses to instantiate abstract content is discussed below.

The director is capable of selecting the next training scene based on both pedagogical and dramatic reasons (see Requirements 2 and 3). The director compares the trainee's current skill model with the available scenes and the skills associated with those scenes in order to decide which scene should come next. The skill model represents the set of skills that the system is supposed to be training as well as the trainee's demonstrated proficiency in those skills. As the trainee progresses, the director agent updates the skill model, noting at which skills the player is good or poor. After the completion of a scene, the director compares the trainee's skill model with the available scenes that could logically come next. The director looks at skills in which the trainee is poor or untested and chooses the next scene that would best test those skills. Next, the director instantiates the abstract scene in the context of both the current state of the world and the subset of skills that specifically applies to the skill model's current state.

While the above describes a method for selecting scenes based purely on pedagogical motivations, it does not address any motivations concerning engagement. A modification we are considering to this approach, which will be explored in the full TC3 trainer implementation, is the use of a scene choice heuristic that takes both the skill model and a model of dramatic progression. This approach is akin to the use of heuristics for plot content choice in interactive storytelling systems (Mateas and Stern, 2002; Weyhrauch, 1997; Magerko and Laird, 2004). This method requires the annotation of scenes along a series of author-defined dimensions (e.g. "tension" or "interest"). As the trainee experiences the scenario, a set of scenes would be initially selected based on the skills tested, as described above. Within this candidate set, a scene would be selected based on the candidates' dramatic ratings. A sensible, straightforward heuristic that could be used by the trainer would choose scenes in terms of tension along a traditional Aristotelian arc (e.g. an introduction with rising tension up to a climax, followed by a resolution). At the beginning of the scenario, less tense scenes would be chosen, followed by more tense scenes to lead up to a climax, etc. This approach provides a two-tiered method of scene selection that puts a premium on training value during selection, but does so with a dramatic and narrative goals considered as well.

Story Direction

We define "direction" to be any actions that the director executes in the training environment. This may include instantiating synthetic characters or objects, giving commands to synthetic characters (e.g. new goals or knowledge), and altering the environment itself (e.g. creating an ambient sound). *Story direction* is specifically an action taken by the director agent to fulfill plot content. For example, if the ambush scene involves the trainee's platoon leader yelling "Take cover!" that dialogue action would be sent to the platoon leader character as a command from the director. ISAT does not require strongly autonomous agents (i.e. agents that rely on their own goals while interacting with the trainee & the environment) for populating the world (see Mateas and Stern, 2002, for a discussion of the weaknesses of strongly autonomous agents in interactive storytelling systems).

Skill Direction

S*kill direction* indirectly guides the player in performing a particular targeted skill. If a player has not been tested in a given skill, such as "prioritize casualties," or has already shown to be particularly bad at this skill, then the director will give explicit in-game advice to the trainee (e.g. director will cause the CO to give a direct order to the trainee, such as "Be sure to attend to the casualties in critical condition first!"). As the trainee shows aptitude at this given skill, the director's guidance will fade. The director will use progressively less explicit strategies when guiding the trainee (e.g. the most critical patient may gasp several times to get the trainee's attention instead of being directed by the platoon leader). In this manner, ISAT directly supports the notion of fading. Fading of guidance in skill direction is a direct way for the system to adapt the training world to the trainee's needs within a particular skill across the duration of the training (see Requirements 1 and 3).

Reactive Direction

Reactive direction is a technique used in interactive storytelling systems to prevent player actions from moving the experience outside of what is covered by the story content (Magerko and

Laird, 2004; Young, et. al, 2004). Authors for interactive stories create "story spaces" (Magerko, 2005) when authoring plot content for an interactive story, such as character behaviors, rules for generating dramatic situations, or plot points. If a player executes an action that takes the story outside of that story space (e.g. shooting a character that is important to future plot developments), then the system executes reactive direction to modify the world to keep the player's experience within the story space (e.g. making the gun misfire or jam).

ISAT applies this approach in response to the highly interactive nature of the environments it is designed for. The more interactive a world is (i.e., the more possible actions in and interactions with the world), the more possibilities exist that could result in the trainee executing an action that prevents the logical continuation of the story. For example, getting lost in the environment is completely irrelevant to the training of a combat medic but would harm the trainee's progression through the training scenario. It is the director's role to execute direction in the world, such as noticing when the player is getting away from his squad and having a fellow soldier fall back to help guide him, when such a problem arises. This approach helps address the problems that can arise in an interactive environment without relying on the standard, less believable techniques used in commercial computer games, such as disallowing the player from executing any action that isn't the "right" one (see Requirement 2).

STORYBOARD

This section describes an example storyboard to be used for our future implementation in the 91W10 TC3 trainer. Rather than conveying specific details, the goal of this section is to provide a concrete sense of the kinds of scenarios and actions ISAT will be able to support by the conclusion of implementation. For the storyboard, which outlines the director's actions in one training scenario, we focus on showing the director's decisions and actions with respect to the proficiency of a skill. Initially, we have chosen a simple, qualitative model of proficiency: untested, bad, fair, neutral, good and very good. In future work, we will develop richer models of proficiency. For example, if a trainee demonstrated "very good" proficiency on a skill in a training session over a month previous, then the director might choose to test that skill's persistence in the trainee. Therefore, below is an example training experience. The skill model uses the skills listed previously in Table 1.

Scene 1: Bombing in a Marketplace

The initial scene takes place in a village market in Afghanistan. The trainee arrives on the scene of a bomb explosion in a marketplace as part of a quick response force (QRF). There are only civilian casualties, mainly in a store open to the market. The rest of the squad quickly secures a perimeter as the trainee is ordered to tend to the wounded in the store. There are several casualties motionless on the ground, and three wounded, obviously alive and injured. It is only a matter of time before an ambush, like others that have occurred, could happen. The trainee needs to quickly prioritize, diagnose, treat, and then secure the patients.

Once in the store, the trainee quickly checks the pulse and breathing of all of the casualties. He checks the worst-looking casualty first, which yields no pulse or breath (director: increase in skill *check vitals*, decrease in *secure casualty*). He moves on to the next casualty, who has a leg blown away, without doing any more (director: increase in *prioritize*). He checks this casualty's vitals (director: increase in *check vitals*, decrease in *secure casualty*) and sees that he is still alive. He quickly applies a tourniquet, but too high up from the wound and without removing minimal clothing (director: decrease in *apply tourniquet*).

He moves on to the next casualty, who has a chest wound from shrapnel (director: increase in *prioritize*). He checks for weapons and then checks the casualty's breathing, which is labored but existent (director: increase in *check vitals;* increase in *secure casualty*). The trainee removes clothing to bandage the entry wound (director: increase in skill *manage chest wound*), sits the casualty up (director: increase in skill *manage chest wound*), and bandages the exit wound (director: increase in skill *manage chest wound*).

The trainee moves on to the last casualty, who is already dead from loss of limb (director: increase in *prioritize*). He forgets to check for vital signs (director: decrease in *check vitals*). As he begins treatment, the director moves on to a new scene. The first scene is represented as ending either when 12 minutes have gone by or when the trainee is attending to the last casualty (director: begin next scene). Scene 2 is authored to be an ambush on the quick response team. The particular details of the attack are dependent on the trainee's skill model. At this point, the director's assessment of the trainee's skills would be:

- *check vitals*: fair
- *prioritize*: very good
- *stay covered*: untested
- *secure casualty*: neutral
- *apply tourniquet*: fair
- *extraction*: untested
- *manage airway*: untested
- *manage chest wound*: very good
- *monitor*: untested
- *soldier first*: untested

Scene 2: Ambush of Quick Reaction Force

The director will have the ability to map a scene description to an instantiation that matches this particular trainee's needs (i.e. test untested / less than good skills). Therefore, in preparing the next scene, the director will:

1. Choose the scene which can test *stay covered*, *extraction*, *monitor*, *soldier first*, *secure casualty*, *apply tourniquet*, and *check vitals*.
2. Spawn the ambushers with an RPG and small weapons (a combat situation will test *stay covered* and *soldier first*)
3. Give the enemy a goal of firing on the trainee when he appears from the store (test *stay covered*)
4. Give the enemy a goal of hitting at least one soldier with the RPG, and hitting at least 3 people total (injuries mean *check vitals* is tested and possibly *monitor* and *extraction*)
5. Give the injured soldier the feature of being hysterical after being hit (tests *check secured*)

While the trainee is attending to the third patient in the store, shooting begins outside and there is a loud explosion. The trainee continues checking the dead amputee for vitals (director: decrease *soldier first*). A US soldier yells "medic!" The trainee rushes outside and then pauses/hesitates to take in the situation (director: decrease *stay covered*). The ambushers direct their fire towards the trainee, which causes him to crouch low and move toward the burning Humvee parked near the store. The trainee surveys the situation as weapons fire continues coming from several directions across the square outside the bombed store. Within a few yards are two wounded soldiers. One is lying motionless on the ground, while the other is screaming for a medic. The trainee moves immediately to the screaming soldier (director: decrease *soldier first*). The director reactively directs by playing an animation of the platoon leader yelling at the medic: "We need some more firepower". The trainee unshoulders his weapon and begins returning fire.

After a few minutes, shooting subsides and then stops. The response team moves out in a mop up operation. There are 2 casualties visible to the trainee, the two wounded soldiers. There is also a third casualty that the trainee cannot see, on the other side of the Humvee. The trainee moves to the soldier who had been screaming and checks his vitals. The soldier has received multiple gun shot wounds and is incoherent / hysterical, but his vitals are stable. The trainee begins to apply pressure to the wounds to stem the bleeding (director: decrease *prioritize*, decrease *secure casualty* -- he should have safetied the hysterical soldier's weapon).

The trainee moves next to the unmoving soldier. His vitals are erratic and barely perceptible (director: increase in *check vitals*). The trainee suspects a chest wound and begins to remove clothing from the soldier. He finds the wound and immediately begins to bandage it (director: decrease *sucking chest wound*, should also test for exit wound).

He goes behind the Humvee and finds another US casualty. The trainee checks vitals, which are reasonably good (director: increase *check-vitals*). The soldier has lost the lower part of his left forearm in the RPG explosion against the Humvee. He cuts away the soldier's uniform from the wound and applies a tourniquet, close to the wound (director: increase *apply-tourniquet*).

With the situation secure and the patients mobilized, the trainee calls for an evac to extract the wounded soldiers (director: increase *extraction*). He continues to monitor the vitals of each patient periodically while awaiting the ambulance (director: increase *monitoring*).

At the conclusion of Scene 2, the skill model would approximately be:

- *check vitals*: very good
- *prioritize*: fair
- *stay covered*: bad
- *secure casualty*: bad
- *apply tourniquet*: fair
- *extraction*: good
- *manage airway*: untested
- *manage chest wound*: fair
- *monitor*: good
- *soldier first*: bad

When the director considers how to construct Scene 3, soldiering skills and the need to secure casualties will be high priorities to exercise. The director also notes the trainee has not yet been in a situation where *manage airway* has been tested, and will choose a casualty injury to test that skill.

Scene 3: Offensive Infantry Operations

Based on the current skill assessment, for scene 3 the director will:

1. Choose this scene as next because it can possibly *test prioritize*, *soldier first*, *manage airway*, *manage chest wound*, *apply tourniquet*, *secure casualty*, and *prioritize*
2. Firefight will naturally test stay covered (bad), and soldier first (bad)
3. Create enemy squad in firefight sequence to use rifles (tests manage airway, because skill is untested)
4. Leave behind a "civilian casualty" who is booby-trapped (tests secure casualty, because skill is bad)
5. Make sure one of the soldiers is shot in the throat (tests manage airway)

The medic has been called to join the patrol that has gone in the direction of the ambushers. After joining the patrol, a firefight breaks out in the streets. The trainee takes cover in a nearby doorway (director: increase *stay covered*). One of the soldiers nearby goes down from a rifle shot to the neck. The trainee sees what happens, but continues to return fire without risking extraction (director: increase *soldier first*, increase *prioritize* – a throat hit is a low-casualty injury not worth the risk of extraction to a warm zone).

After the fire has cleared there are two casualties, the injured soldier and a civilian. The civilian is lying motionless, so the trainee attends to the soldier first (director: increase *prioritize*). The soldier is having trouble breathing, so the medic first checks his vitals (director: increase *check vitals*), executes a jaw thrust maneuver, and then intubates the soldier (director: increase *manage airway*). The trainee then moves to the civilian.

The civilian is dressed in a burkha and is lying face down in the dusty road. The trainee moves to the civilian and rolls "her" over (director: decrease *secure casualty*). The "woman" is actually an insurgent laying on an AK-47, which he pulls up and fires on the trainee from point blank. This is the end of the training experience. The resulting skill model is:

- *check vitals*: excellent
- *prioritize*: good
- *stay covered*: fair
- *secure casualty*: very bad
- *apply tourniquet*: fair
- *extraction*: good
- *manage airway*: good
- *manage chest wound*: fair
- *monitor*: good
- *soldier first*: fair

DISCUSSION

ISAT addresses the requirements laid out for an interactive training system. *Engagement* (Requirement 2) is addressed by both the use of an immersive, 3D game environment as well as by the heuristic selection of training content. *Individualization* (Requirement 3) of the training experience is achieved through the various roles played by the director agent, such as the use of skill direction, scene selection, and the instantiation of scene content. *Generality* (Requirement 4) has been a guiding concern throughout ISAT's design, but has yet to be shown. ISAT, because of its attention to the larger-grained size of real-world actions, seems specifically suitable for more skill-based domains, such as training medics, versus more cognitive-based domains, such as language training (Johnson, et. al, 2004) Future work will entail using ISAT in several environments to show the applicability of this approach across domains. However, there is no aspect of ISAT that specifically depends on the domain that we have selected as our first environment.

Effectiveness (Requirement 1) should be at least as good as the underlying training system. The suggestion from training literature that both engagement and individualized training improve training effectiveness indirectly suggests ISAT should improve effectiveness given that it incorporates both of these properties. However, the actual impact of ISAT on training effectiveness has not yet been investigated. As ISAT is more fully instantiated in the TC3 simulation, we plan to perform user tests to evaluate the role of ISAT in improving training effectiveness.

ISAT's design, while implemented in a prototype system, has several facets that have yet to fully mature. We intend to refine design ideas introduced in this paper and in the prototype system to produce a more thorough ISAT design and implementation. The next step in implementation work is to extend the director's role in the 91W10 TC3 trainer to support the capabilities described in the storyboard described above.

Skill Model Refinement

The skill model used for the ISAT TC3 prototype is simple. While it does show the benefits of using a skill model (e.g. skill direction and choice), it does not detail how the skill model should be precisely defined in our full implementation. How to represent the decay of skills over time, to interpret how often a skill has been tested, and to encode "getting better" or "getting worse" at a skill will all be examined in our more rigorous implementation and research efforts.

Scene Instantiation

After selecting a scene based on its pedagogical and dramatic content, the director must instantiate the scene's abstract content. As mentioned above, a scene is partially defined by an abstract description of a scene, such as "the trainee's squad is ambushed by local insurgents." How this content is instantiated by the director depends again on the trainee skill model. The director applies a transition function that translates between the abstract content, such as an ambush, the current state of the game (e.g. they are in a town square), and the player's skill model. If the player is particularly bad at applying tourniquets, for example, then this ambush scene would be instantiated to include an enemy fighter than has a rocket-propelled grenade, which is a weapon that can cause injuries requiring the application of a tourniquet. This transition function must include mappings from skill model to instantiated content as well as from abstract content to the environment (e.g. what it means to create an ambush). The instantiation of scene content is part of ISAT's design, though not yet used in the prototype. Our future work story representation work will be heavily focused on refining this approach.

Predictive Direction

One role of the director that has yet to be explored is suggested by our work done in IDA (Magerko and Laird, 2004). The use of *predictive direction* has been shown to be a more subtle and believable alternative to reactive direction. As opposed to waiting for problematic actions to occur, the director attempts to predict the player's actions in the near future. If that prediction reliably shows a conflict with story content, then the director can employ strategies that are subtler than those used in reactive direction. How to incorporate this approach into ISAT, as well as what defines a good predictive model for a given training domain, is a focus of our future research.

CONCLUSIONS

We have developed and refined the conceptual framework for ISAT and applied its concepts to a specific training system, the 91W10 Tactical Combat Casualty Care Simulation. ISAT suggests engagement and pedagogically-motivated direction can improve training experiences.

ISAT offers a number of distinct advantages over traditional intelligent tutoring systems and constructive simulation technology. Most importantly, ISAT integrates the advantages of these previously distinct approaches to educational technology. ITSs offer explicit pedagogical guidance, building on a cognitive user model to understand and guide a trainee's learning (although ISAT uses a simpler behavioral skill model to provide guidance). Virtual and constructive training offer the experience of learning by doing, of being in the actual environment (or a close approximation of it) in which real-world performance will occur. ISAT includes pedagogical support but offers it in the context of the actual environment. Rather than explicit pedagogical direction, the trainee receives subtle cues and feedback that do not break the "spell" of engagement in the experience.

ISAT also offers the potential to increase training effectiveness by drawing on important elements of interactive storytelling—instantiation of abstract plot content and heuristic scene choice. Because the training experience is designed to be engaging, training goals are reinforced and those skills that most require attention drive scene selection and instantiation. The result should be that trainees get more direct exposure to the skills that need the most work, naturally speeding the training process. Because the experience is engaging and (as a result) enjoyable, trainees may participate in training more often and voluntarily, resulting in additional training speed-up. Engagement also potentially leads to memorable experiences, facilitating in-the-field recall of prior training experiences and thus possibly leading to greater persistence in the training experiences.

Another potential benefit of ISAT is that it supports scaffolding and fading in a realistic setting. The director will take action to aid a student in the execution of the task by providing feedback (e.g., in the form of utterances by other actors). However, because the trainee is not aware of the director during execution of the training scenario, the director can easily "disappear" as the trainee becomes more skilled and requires less feedback. The director's guidance strategies will become more and more subtle until the director is not intervening at all. While there is growing consensus in the educational technology field to use these technologies, scaffolding and fading were not explicit goals of ISAT. Instead, they result from the primary goals of providing realistic, engaging experiences tailored to the needs and requirements of individual trainees. Having completed an initial feasibility demonstration, we are continuing to test these ideas via further exploration and development in the 91W10 Tactical Combat Casualty Care Simulation. Ultimately, our goal is to show the generality of ISAT as an architectural plug-in for training systems and to provide it as a cost-effective component for more effective trainers.

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