June 2007

Questions and Issues in Developing a Modular Narrative Learning Environment

Susan EITELMAN[a,1], Brian MAGERKO[b] , and Lisa Scott HOLT[a], Brian STENSRUD[a]

[a]*Soar Technology, Orlando, FL*

[b]*Michigan State University, Games and Entertainment Lab, East Lansing, MI*

Abstract. We are developing an Interactive Story Architecture for Training (ISAT) that combines the user-adaptive features of an intelligent tutoring system with the story management capability of a scenario director to provide a training experience that is tailored to individual trainee needs—both dramatic and pedagogical. Another unique contribution of this effort is the development of an authoring tool that will facilitate the input of dramatic and pedagogical content by a non-programmer. The envisioned result of ISAT is a seamless integration of interactive story and individually-guided instruction. The current ISAT prototype is tightly coupled with the training simulation and the corresponding domain knowledge. This is in contrast to a truly modular architecture design that could accommodate a variety of training needs, domains, and simulations. Therefore, we propose a core architecture that would be supplemented by specialized, modular plug-ins to support unique training-dependent or simulation-dependent needs. In designing this modular architecture, we have identified several basic questions about how to develop the modular architecture so that it appropriately addresses a variety of training contexts and available simulation tools. We present these questions, and our initial considerations of them, in this paper.

Keywords. Interactive narrative, intelligent agents, interactive learning environments, modularity, training system design

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[1] Corresponding Author: Susan Eitelman, Soar Technology, 3361 Rouse Road, Suite 175, Orlando, FL 32817; E-mail: seitelman@gmail.com

Introduction

Social constructivist learning theories argue that knowledge is in part a product of the activity, context, and culture in which it is developed and used [1]. It is therefore important to provide training through realistic scenarios that establish the context critical for robust learning. Military training often utilizes scenario-based approaches where realism and context are a vital part of the training experience. In military training, instructors control the exercise to provide specific training opportunities and to make poignant learning points for trainees. They adaptively control how the scenario unfolds to achieve instructional goals, such as by directing the actions of role-players or simulation entities.

One-on-one human tutoring is the most effective form of instruction [2], but demand for instructors in the military is high, and supply is often strained. Intelligent tutoring systems (ITS) provide a means of effectively adapting computer-based training content to individual trainee needs through automation. The purpose of automating such control functions is *not* to replace the human instructor in the classroom, but to supplement him. ITS technology has been successfully proven in the laboratory and as a valuable addition in real world classrooms [3]. Using ITS technology to control and tailor a training scenario has also been successfully developed for military training in a limited context and with well-constrained scenario variations [4, 5].

For a truly realistic and interactive story to be instructionally effective, a wide range of interactions between the trainee and the scenario must be supported [6]. Trainee actions must realistically affect the outcome of the scenario (maintaining story flow) while at the same time the story must address a pre-established set of training objectives [7]. This can be a challenging balance to achieve [8, 9]. Creating an interactive narrative is an approach that allows users to take part in the direction of the experience [6, 9, 10]. Implemented in an immersive simulation, interactive narrative promises to provide increased realism and training value. Many questions still exist to identify the right way to appropriately create an interactive narrative environment for learning.

Additionally, current approaches are also typically tightly-coupled with the simulation environment and the training context they address. We believe there are a core set of features that can be developed to address a sufficiently wide range of instructional functions and that can be appropriately supplemented (through specialized plug-ins) to address training needs in the context of simulated training environments.

1. Overview of ISAT

We are developing an Interactive Story Architecture for Training (ISAT) that combines the user-adaptive features of an intelligent tutoring system with a the story management capability of a scenario director to provide a training experience that is tailored to individual trainee needs—both dramatic and pedagogical. By adding dramatic control to an ITS approach, the scenario can be controlled to better increase a trainee's engagement. Constructivist learning theories argue that learners must be actively engaged to make cognitive connections between their existing knowledge and the knowledge they are learning [11, 12]. This is a novel approach that combines both pedagogical and dramatic adaptation to create an enhanced training experience.

We envision ISAT as an architecture that can be applied to many training domains and integrated with various simulated environments. The cost and turn-around time to make an ITS for any one specific training context reduces the feasibility of widespread ITS use. By generalizing the ISAT architecture we aim to make individualized training, through interactive stories, more accessible. A critical element of this effort is to provide an authoring tool that enables the instructor, who can not be expected to have significant programming expertise, to author both story and instructional content. By enabling the domain-expert instructor to author content we give him control over the material available to his trainees, thereby supplementing his efforts in the classroom and the field, and reduce the cost and time for developing "hard coded" material.

Our vision for ISAT is to generalize the architecture by implementing domain-independent and simulation-independent features into a core architecture. This architecture would be tailored to a particular training need and simulation with modular plug-ins. Plug-ins would allow for specialized functions to be included, as needed, for particular training contexts and for use with particular simulations. Shown in Figure 2, the core functions might include general instructional strategies for scene selection and control. Modular plug-ins could then be selected for use to provide a means to author domain-specific story interactions and domain-specific instructional feedback. Some training contexts may involve speech interaction and some may not, so for example, one modular plug-in could be a dialogue authoring tool.

We have identified challenges that must be addressed in order to successfully implement the envisioned generalized architecture. Namely, what are domain- and simulation-agnostic features a core architecture must include and how will domain-specific, story-specific, and instruction-specific content get authored by an instructor and then used by the system? We propose a core architecture that is supplemented by specialized plug-ins that could serve as a generalized approach to uniquely combine interactive story management, adaptive simulation, and authorable training content. In the following sections we provide an overview of the current ISAT system, then propose our generalized architecture, and finally review our preliminary thoughts on the questions that have arisen from this effort.

2. Current state of ISAT

The ISAT architecture (see Figure 1) includes the student, the human trainer who authors the training content (using Scribe [13], the story authoring tool), the virtual simulation environment populated with synthetic or non-player characters (NPCs), and the director agent. The director and Scribe are the central components of the ISAT. Using scenario content authored in Scribe, the director orchestrates a complete training experience. Content is selected and instantiated based on the pedagogical need of the trainee and the dramatic relevance of the content to create a seamless and engaging story. Functionally, the ISAT director operates by inducing behaviors and actions from characters and objects within a training scenario. The director also monitors the trainee's performance in the environment and provides appropriate feedback within the environment when needed (ranging from exaggerated cues in the training environment to explicit spoken feedback from a story character). The director uses pedagogical strategies to decide on what feedback is appropriate (depending on dramatic context and observed trainee aptitude) and then implements this feedback within the context of the ongoing story.

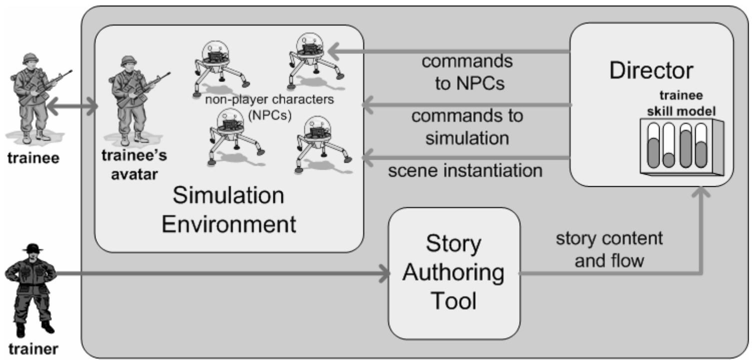

Figure 1. The ISAT architecture

The director is responsible for selecting appropriate story content (called *plot-points*) from a set of pre-authored selections, which provide training opportunities geared for the particular trainee. For example, if the trainee has demonstrated poor proficiency at prioritizing casualties, then the director will choose a plot-point that involves several casualties with differing levels of severity, which requiring the trainee to consider prioritization of casualties.

Once a scenario is selected, the director adapts the environment within each scene to achieve both training and dramatic goals. For example, in the prioritization scenario, if the trainee begins treating a casualty with a less severe injury than another casualty, the director will command the more severely injured casualty to scream louder, providing a subtle environmental cue to the trainee that he inaccurately prioritized the casualties and to increase the dramatic effect of dealing with combat casualties. The director uses information about the trainee's behaviors to make decisions to achieve instructional goals and dramatic effect in both scene selection and environment adaptation.

Our current work developing ISAT focuses on developing a proof-of-concept that demonstrates the feasibility of the ISAT approach. The current instantiation of ISAT is very tightly coupled with both the training domain and the simulation used for the current development. Our long-term aim is to develop a system that can be used with a variety of simulations to meet different training needs of various contexts. Next, we present some of the questions we have identified and must address to evolve our current prototype into an architecture that can support different training contexts through different simulation environments.

3. Core architecture

Modularity is a key theme to support an architecture that can be integrated with different simulations and support multiple training contexts. There are two main factors here: (1) What simulations are available for a given training domain? and, (2) What are the specific training goals and domain content for a particular training context?

The architecture currently involves two main components, the director agent and the authoring tool, Scribe. We pose that these two components will serve as the foundation of the envisioned core generalized architecture. Specialized plug-ins will serve as domain- and simulation-specific modules to transform the generic architecture into a full system for a particular training need to be addressed in a chosen simulation. The overall system, including the two core components and any plug-ins, must work together as well as with an independent third-party simulation environment to provide and manage a robust learning environment that appropriately supports training.

Figure 2 illustrates the vision for ISAT, a generalized, modular architecture. In the figure, the director is represented by a box titled "Intelligent Controller(s)". The purpose for abstracting the name 'director' into 'intelligent controller' is that the component that is currently the director may work with other intelligent control components. For the remainder of the paper, we will continue to use the term 'director' to refer to any intelligent control functions, as we still have not determined how the core architecture will address various aspects of intelligent control. Other components of the ISAT vision are Scribe (the authoring tool) and the various plug-ins. We initially envision the plug-ins as supplementing either the director component or authoring component, however, it may prove more valuable to have domain-dependent components that each plug into both the director and the authoring tool.

The modularity of ISAT would support integrating generalized instructional and dramatic aspects of the system with a variety of already available simulated environments. Many simulations and games are currently available commercially off-the-shelf (COTS) that are appropriate for training, when properly controlled and utilized. To name a few: Flight Gear is a commercially available PC-based flight simulator used, in conjunction with an intelligent instructional control component, for training Air Force pilots in radio communications [14]; a version of the commercially available game, Operation Flashpoint, known as VBS-1, has been used by the Marine Corps for training team coordination and communication for fire-teams and squads; the America's Army game has both a commercial and military version, and has been used for training [15]. For convenience, both 'simulations' and 'games' will be referred to simply as simulations for the rest of the present discussion, where we mean tools that involve a computer-based simulated virtual environment.

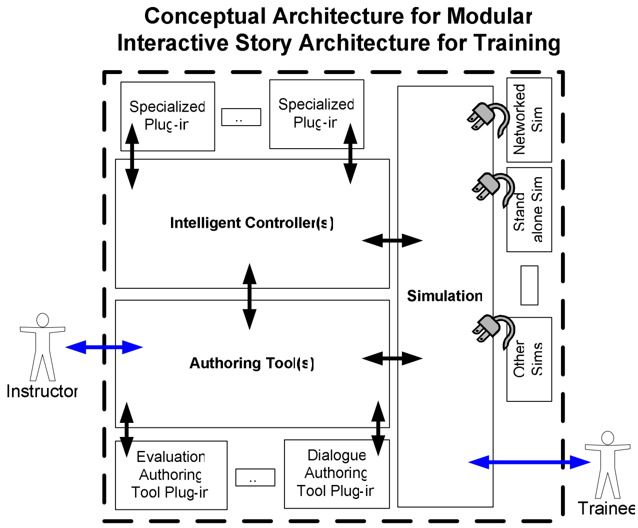

Figure 2. Conceptual, Modular Architecture for ISAT

Some simulations may be more appropriate for training in certain contexts than others. However, there is not necessarily a one-to-one mapping between the type of simulation and the training context. In our vision, a modular ISAT architecture would be agnostic to the simulation selected for a particular training need and would generalized to support a variety of training contexts.

The first question that we have identified, then, is:

1. *Which simulations area appropriate for which training contexts?*

There are a myriad of simulations available currently, and more currently under production, that are appropriate for training in various domains. We need to identify those simulations that will be most useful for their targeted training audiences, as well as which simulations may be most widely useful to multiple training audiences. The first attempt at answering this question may involve identifying a small set of simulations, and their associated training contexts, to identify those simulations and training contexts that present a representative cross-section of the types of training and simulations ISAT would be appropriate to integrate. For example, we would not want to consider only ground-based combat medic training contexts, nor do we want to limit ourselves to considering first-person-shooter simulations. From such an analysis we can prioritize those simulations which will be most useful for supporting identification of common integration needs for the generalized ISAT architecture. Similarly, it may be prudent to begin identifying solution gaps in the available simulation technology to identify probable future simulation capabilities. By identifying both current and probable future simulation capabilities, we can position the system to successfully generalize across simulations and training contexts both now and for the future. This leads us to our second question:

2. *What are the general functions that are appropriate to include in the core architecture?*

The general functions will span both pedagogical control and dramatic control. ISAT currently includes examples of both. The ISAT director performs scene selection and real-time instructional control, which we have labeled skill-based direction and reactive direction, to achieve pedagogical control. These instructional strategies are described in [16]. Dramatic control is primarily achieved through story direction. The instructional functions we have already identified are appropriate in many training contexts. We must, then, continue to identify other instructional functions that are appropriate across training contexts and include them in the development of the core architecture.

In addition to general instructional functions, we must also include those functions that affect the dramatic value of the training experience. There are several aspects to controlling the dramatic affect of a scenario. Further, dramatic control must not interfere with training value – actually, dramatic control should *enhance* training value. Thus, we must craft the director to recognize when and how to appropriately control dramatic affect to support the overall training value within a scene as well as across multiple scenes within a whole story.

So far we have begun to address the issue of what functions should be included in the core architecture for both the director and the authoring tool. Naturally, then, the next question addresses the plug-ins that will supplement the core architecture. Our third question is:

3. *What functions should be off-loaded into plug-ins?*

Knowledge-based agents are designed to handle symbolic, qualitative, data and are not well-suited for heavy computation on large amounts of quantitative data. In a flight-simulation, a director would need to recognize when aircraft are inside or outside of pre-defined volumes in the defined airspace. The computation involved to do this is highly quantitative where distances and angles must be continuously computed. The director agent is implemented with a knowledge-based Soar agent. In an automated air-traffic control example, also developed with a knowledge-based Soar agent, the quantitative computations were outsourced to a spatial computer for this very reason [17]. A knowledge-based agent performs better by monitoring symbolic data of the situation such as "in" or "out" of a volume, where an external spatial computing component would perform the continuous, quantitative computation and report back as needed to the director. Spatial reasoning is one example of computationally-heavy calculation that is appropriate to outsource; temporal computation might be another example as well as natural language processing. We need to identify other functions that are required for supporting the identified simulations and training contexts and that are appropriate for off-loading from the director into a specialized plug-in.

There are several ways that are reasonable for organizing the plug-ins, such as by functions (e.g., spatial reasoning, language reasoning) or by domain (e.g., urban versus rural terrains, maintenance versus distributed operations training). Another aspect is the instructional context, such as new training and instruction versus refresher training. So, the scope of the specialized plug-ins could be vast and we need a way to systematically organize and develop these components. So our next main question is:

4. *What is a useful organizational framework for the plug-ins?*

We do not yet know the answer to this question. However, we do have some thoughts about the different possible factors that may drive the plug-ins we choose to develop and thus inform the design of a useful organizational framework. The main reason for this question is that we probably will not be able to identify ahead of time all of the plug-ins that may be worthwhile to develop. So, if we can develop a reasonable framework for categorizing the different kinds of plug-ins we may want to develop, we can set a more solid foundation for modular extensibility of ISAT. We present three of these considerations next.

One, we must consider the needs of the instructor that will be met through the authoring tool. The director needs to know the goals of the training experience from the instructor. These goals are provided to the director through the story authoring tool. Some core characteristics of the authoring tool have already been identified in [13]. These include: usability, capability to preview and debug a scenario, representation of the simulation environment, and ability to define and manage pacing and timing. Other capabilities may include aspects such as definition of performance metrics and modification of instructional feedback. Depending upon the simulation and the training context, different functions may be necessary to support authoring of a realistic and effective training scenario. Thus, one aspect to an organizational framework is the set of needs that must be met for the instructor through the authoring tool.

Two, there are obvious constraints in modality of trainee interaction depending upon simulation environment used. For example, if a simulation provides speech generation, then the authoring tool should provide the instructor ways to define speech acts in the story. So, another aspect of an organizational framework of the plug-ins is the simulation interaction modality, which has implications for both the director and the authoring tool.

Three, another probable organizational factor reflects the relationship between the trainee, the instructor, and the training tool. Does the instructor intend for the student to use the tool elsewhere and return with a summary report of their experience and performance with the tool? Does the instructor want to watch the trainee interact with the tool, say in a classroom setting where an instructor monitors many trainees at once? Does the instructor want to be able to "jump in" and override the director on the fly? What level of interaction might the instructor want to have *during* the scenario that he might plan for in the authoring process? There are a lot of questions here that depend upon the particular problem being solved. So, our organizational framework for the plug-ins should probably reflect in some way the differing forms of interaction between: the instructor and the trainee before, during, and after the interactive story; between the instructor and the system before (authoring), during (real-time control), and after (after-action review) the interactive story.

Each of the basic questions we have posed here lead to many other, more specific questions. Most of the more detailed questions will depend on what training context is being addressed and what simulation tool is available to use. For our own development, answering these questions helps provide a framework for identifying the functional needs of the core architecture and separate functions that would supplement core architecture across training contexts and simulation tools. Thus, we can develop a system that can be re-used and evolved, through modular plug-ins, for a variety of training needs and for use with any number of simulations.

4. Summary

We are developing an Interactive Story Architecture for Training (ISAT) that combines the user-adaptive features of an intelligent tutoring system with a the story management capability of a scenario director to provide a training experience that is tailored to individual trainee needs—both dramatic and pedagogical. The envisioned result of ISAT is a seamless integration of interactive story and individually-guided instruction. The current ISAT prototype is tightly coupled with the training simulation and the corresponding domain knowledge. This is in contrast to a truly modular architecture design that could accommodate a variety of training needs, domains, and simulations. Therefore, we propose a core architecture that would be supplemented by specialized, modular plug-ins to support unique training-dependent or simulation-dependent needs. In designing this modular architecture, we have identified four basic questions about how to develop the architecture to appropriately address a variety of training contexts and available simulation tools: 1) What is a useful set of simulations and training contexts to use as a baseline for defining core and supplemental functions? 2) What functions are most appropriate to be included in the core director and the core authoring tool? 3) What functions should be implemented in the plug-ins? 4) What is a useful organizational framework for the plug-ins?

References

[1] J. S. Brown, A. Collins, and P. Duguid, "Situated cognition and the culture of learning," *Educational Researcher*, vol. 18, pp. 32-42, 1989.

[2] B. S. Bloom, "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-on-One Tutoring," *Educational Researcher*, vol. 13, pp. 4-16, 1984.

[3] T. Murray, "Authoring Intelligent Tutoring Systems: An analysis of the state of the art," *International Journal of Artificial Intelligence in Education*, vol. 10, pp. 98-129, 1999.

[4] R. Stottler and S. Pachinas, "A New Generation of Tactical Action Officer Intelligent Tutoring System (ITS)," presented at Interservice/Industrial Training, Simulation, Education Conference, Orlando, FL, 2006.

[5] W. L. Johnson, J. W. Rickel, and J. C. Lester, "Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments," *International Journal of Artificial Intelligence in Education*, vol. 11, pp. 47-78, 2000.

[6] B. Magerko, "Evaluating Preemptive Story Direction in the Interactive Drama Architecture," *Journal of Game Development*, vol. 3, pp. in press, 2007.

[7] M. O. Riedl, C. J. Saretto, and R. M. Young, "Managing interaction between users and agents in a multi-agent storytelling environment," presented at Autonomous Agent and Multi Agent Systems (AAMAS '03), Melbourne, Australia, 2003.

[8] B. Magerko and J. E. Laird, "Mediating the Tension Between Plot and Interaction," presented at AAAI Workshop Series: Challenges in Game Artificial Intelligence, San Jose, CA, 2004.

[9] M. Mateas and A. Stern, "Facade: An Experiment in Building a Fully-Realized Interactive Drama," presented at Game Developer's Conference, San Francisco, CA, 2003.

[10] M. O. Riedl, A. Stern, and D. Dini, "Mixing story and simulation in interactive narrative," presented at AIIDE, 2006.

[11] S. Papert, *The children's machine: Rethinking school in the age of the computer*. New York: Basic Books, 1993.

[12] J. Piaget, "The construction of reality in the child," Basic Books, 1954.

[13] B. Medler and B. Magerko, "Scribe: A tool for authoring event driven interactive drama," presented at 3rd International Conference on Technologies for Interactive Digital Storytelling and Entertainment, Darmstadt, Germany, 2006.

[14] S. Eitelman, J. Ryder, M. Szczepkowski, and T. Santarelli, "Using agents to enhance performance assessment of team communications," presented at Behavior Representation In Modeling and Simulation (BRIMS), Baltimore, MD, 2006.

[15] D. B. Nieborg, "America's Army: more than a game?," in *Transforming Knowledge into Action through Gaming and Simulation*. Munchen: International Simulation & Gaming Association, 2004.

[16] B. Stensrud, L. S. Holt, and B. Magerko, "Intelligent Story Architecture for Training (ISAT)," presented at Artificial Intelligence and Interactive Digital Entertainment (AIIDE), Stanford, CA, 2007.

[17] G. Taylor, B. Stensrud, S. Eitelman, C. Dunham, and E. Harger, "Toward automating airspace management," presented at Computational Intelligence for Security and Defense Applications (CISDA '07), Honolulu, HI, 2007.