An Agent-Supported Multimodal Scaffolding Infrastructure

M. Brian Blake and Jerome Butcher-Green
Georgetown University
Washington, DC
{mb7,jdb52}@georgetown.edu

Jayfus T. Doswell
Juxtopia, LLC
Baltimore, Md
juxtopia@hotmail.com

Abstract

Scaffolding is a well-established instructional approach that facilitates learning by incrementally removing training aids as the learner progresses. By combining multiple training aids (i.e. multimodal interfaces), a trainer, either human or virtual, must make real-time decisions about which aids to remove throughout the training scenario. A significant problem occurs in implementing scaffolding techniques since the speed and choice of removing training aids must be strongly correlated to the individual traits of a specific trainee. We detail an agent-based infrastructure that supports the customization of scaffolding routines per individual user. We describe the integration of this agent-based approach into a simulated augmented reality (AR) environment

1. Introduction

Learning by scaffolding [5] is an advantageous training approach since the learners can actively participate and clearly see their progress. Another advantage is that the learner is able to receive individualized treatment based on his/her training needs. This individualization, however, is also perhaps the biggest problem for the teacher since developing personalized supports and *scaffolded* lessons would be significantly time-consuming [7]. Furthermore, this problem is exacerbated if you consider a large number of trainees across multiple training scenarios. Another problem occurs considering the personality of the teacher. A proper scaffolding session requires that the teacher give up some of the control and allow the students to make errors [7]. Some conscientious teachers may find this difficult to do effectively. As a final problem, traditional manuals and guides in a learning environment do not include scaffolding instruction although the notion of scaffolding is independent of the actual training material.

In this paper, we proposed the use of intelligent software mechanisms or *intelligent agents* to help mitigate the impact of the aforementioned problems. Agents are software entities that have the knowledge of their environment and the innate capability to learn and adapt to their context given external stimuli. These aspects are similar to the traditional definitions of agents [3]. Agents are particularly well equipped in this domain because their operations are based on rules. As a learner performs within a scaffolded routine, agents can observe response times and errors and automatically reconfigure training routines to the respond to the individual learner. In addition, agents do not have the burden of human emotions. An agent can consistently mandate a training routine without the barriers imposed by empathy (as with human instructors) when learners make mistakes.

Probably the most significant benefit of using agents for scaffolding is the fact that agents can facilitate the separation of the concerns of training material versus training tactics. Typical training evaluation materials have problem sets combined with the corresponding *hints*. Without reconstructing this evaluative material, intelligent agents can control the delivery of hints and ultimately transform traditional training material into a scaffolded approach. To deliver these hints, we propose a scaffolding agent that controls hints over multimodal interfaces (i.e. graphical, textual and audible). In addition, we believe that by having multiple agents controlling various training tasks that an organization-wide scaffolding profile can be created.

The paper proceeds in the following section with a discussion of the related work. In Section 3, the design intelligent scaffolding agent is described. In Section 4, we describe the implementation the agent as a part of a simulated augmented reality (AR) environment.

2. Related Work

Separately the notion of scaffolding and multimodal training have been favorably investigated in many research projects [1][2][5][4][8]. However, as a combined approach these two techniques are suspiciously not well reported in published works. We believe these two approaches are quite compatible when considering the environment of computer-based training and training over some electronic medium. Multimodal approaches are excellent for providing hints that overlay regular, domain-specific instructions. Aist et. al. [1] used multimodal scaffolding approaches for training, but their focus was on the incorporation of emotions into training feedback. Several interesting results show the impact of emotions in their sessions. In comparison, we propose an adaptive approach for creating scaffolding lesson plans in real-time that incorporate the results of many prior learners.

3. An Intelligent Scaffolding Agent

A scaffolding agent can be defined as an intelligent software mechanism that uses the knowledge of its environment to reactively and proactively assist a human user with regards to incrementally learning a particular task or process. The scaffolding agent is composed of four high-level components, the *agent control component*, the *data management component*, the *rule engine component*, and the *multimodal interface component*. This logical architecture is illustrated in Figure 1. The agent control component executes the instructions that mandate the actions of the agent. The data management component contains the agent training-specific instructions as stored in an *agent knowledge base*. The agent knowledge base is a data repository that stores both the schema of the training tasks in addition to historical performance information of users that have completed the specific training routines. As the agent perceives a positive correlation in the way users respond to a particular scaffolding instruction, then a rule is stored in the *personal learning rule base* by the rule engine component. The agent control component manages the delivery of instructions using the multimodal interface component.

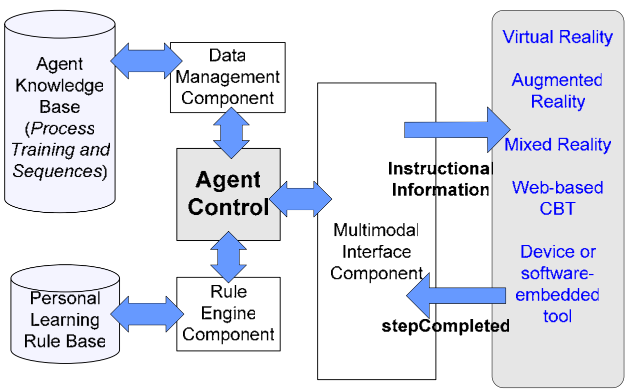

Figure 1. Architecture of an Intelligent Scaffolding Agent.

3.2. Generating a Scaffolded Training Scheme

In generating a scaffolded training scheme, the metrics of multiple users are recorded using a straightforward equation. Weights are assigned to instructions based on the provided multimodal type, textual, t, verbal, v, and graphical, g. The completion time, Ct_i, that a user finishes a step, S_i, is also recorded given a specific number, i, of training process steps. A baseline time, Bt_i, represents the best possible time of completing a particular step based on measuring an expert user that knows the training case. Therefore, the training performance, TP_c, of a particular training case, c, is represented by

$$TP_c = \sum_{i=0}^{numSteps} \left(\frac{(t \cdot v \cdot g)Ct_i}{Bt_i} \right)$$

The reader should note that when all multimodal instructions are removed then the overall performance is equal to the optimal performance, OP_c (i.e. this is numerically equivalent to the total number of steps). The training performance equation takes into account the fact that some steps will take longer than other steps depending on the training case.

The agent attempts to map a user's performance to a specific scaffolding profile. The scaffolding profile is the most effective curve (i.e. minimizing user errors) for moving from the current training performance measure to the optimal performance measure. The agent randomly removes the multimodal instructions to target a training performance time that matches a time in the scaffolding profile. As the user learns the training case, eventually there will be steps that do not contain any training aids. An *incremental* learner progresses in a consistent, almost straight-line manner, the *fast initial* learner moves quickly, at first, but learns much slower once training aids are removed and a *slow initial* learner has a difficult time grasping the task at first, even with aids, but later starts learning more quickly with experience. Several example scaffolding profiles are shown in Figure 3.

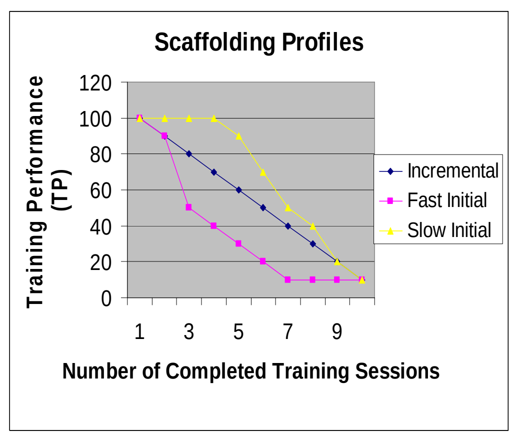

Figure 3. Sample Scaffolding Profiles.

4. Simulated Augmented Reality: A Proof of Concept System

The scaffolding agent was designed to be integrated with augmented reality headsets to provide advanced pedagogical support using multimodal instructions as delivered by the headsets. The agents provide enhanced human learning. As a first step, we have developed an emulated augmented reality approach. Using the Java programming language, we developed an application that trains a user how to complete a jigsaw puzzle with the assistance of various multimodal instructions. The jigsaw puzzle is connected to and controlled by our scaffolding agent. Users have the ability to drag pieces to a specific location, and the puzzle will lock the piece in place as the conclusion of the step.

At the initiation of the puzzle and at the completion of each step, the user is receives some combination of text instructions, visual instructions (represented by a dynamic arrow), and voice instructions. The illustration in Figure 4 shows a user in the process of placing piece, *S4,* in the second step while receiving voice and textual instructions. The rectangle having points P1 through P4 is the boundary of the puzzle. Table 1 shows a sample of data captured for the prior completed step for the puzzle piece, *S4*.

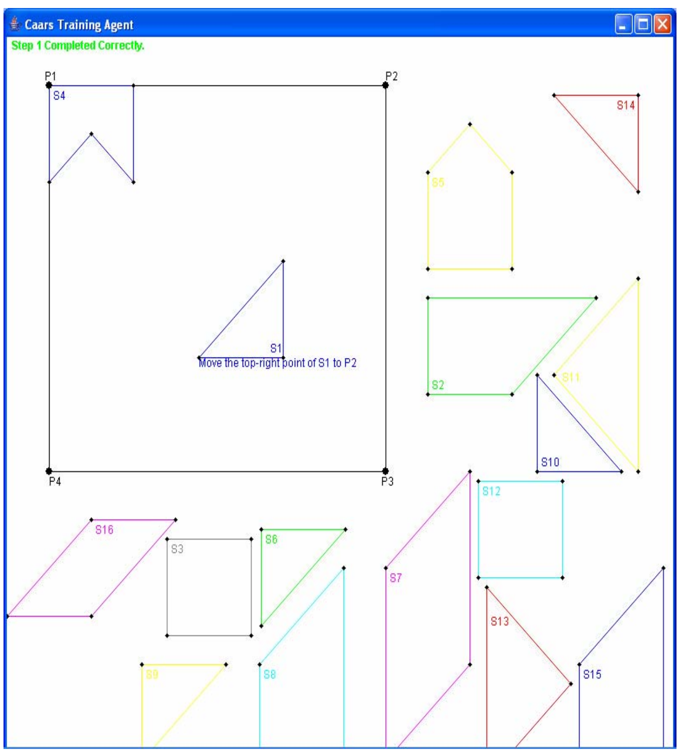

Figure 4. Simulated Augmented Reality Environment with Multimodal Instructions.

5. Conclusion

This paper contributes an infrastructure that supports the integration of multimodal instructions and scaffolding generation techniques using intelligent agents. This approach has been customized to the manufacturing domain with multimodal instructions being delivered within an augmented reality environment. This is one of few studies that combine this set of technologies for the advancement of human performance in learning. In future work, we are currently implementing an experiment to understand what scaffolding profiles are most effective across various demographics (age, race, sex, and subject of academic study). We believe results from this future work will impact how scaffolding schemes are created in variety of settings (e.g. the classroom (K-12 or college), the industry setting, or even for elderly care).

6. Acknowledgements

The authors acknowledge conversations with Charles Griffin, Ojai Mallory, and Finny Mlemchkuwu. This work was funded by the National Science Foundation under award number 0512610.

7. References

[1] Aist, G., Kort, B.,Reilly, R.,Mostow, J., and Picard, R. “Experimentally augmenting an intelligent tutoring system with human-supplied capabilities: adding human-provided emotional scaffolding to an automated reading tutor that listens” *4th IEEE International Conference on Multimodal Interfaces*, pp 483-490, October 2002

[2] Chen-Chung Liu, Ping-Hsing Don, Kun-Lin Chen, and Baw-Jhiune Liu “Reusing web learning portfolios by case-based reasoning technology to scaffold problem solving” *IEEE International Conference on Computers and Education,* pp1216-1217, Dec 2002

[3] Jennings N.R., Sycara K.P., Wooldridge M., “A Roadmap of Agent Research and Development” *Journal of Autonomous Agents and Multi-Agent Systems.* 1(1): 7–36

[4] Kuei-Ping Shih, Chih-Yung Chang, Hung-Chang Chen, and Sheng-Shih Wang “A self-regulated learning system with scaffolding support for self-regulated e/m-learning”, *3rd IEEE International Conference on Information Technology: Research and Education*, pp 30-34, June 2005

[5] Quintana, C., Krajcik, J. and Soloway, E. “Issues and methods for evaluating learner-centered scaffolding” *IEEE International Conference on Advanced Learning Technologies (ICALT 2001)*, pp 353 – 356, Aug 2001

[6] SCORM Overview (2006): http://www.rhassociates.com/scorm.htm

[7] Van Der Stuyf, R.R., “Scaffolding as a Teaching Strategy” Accessed on 2005, http://condor.admin.ccny.cuny.edu/~group4/

[8] Vincent, J.T. (2005) *Computer mediated multimodal text production: Ten-year-olds crossing semiotic boundaries*. PhD thesis, Faculty of Education, University of Melbourne