Ontological Support for Dynamic Adaptation in Educational Games

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Educational games bear a close resemblance to Intelligent Tutoring Systems and narrative centered learning environments since they all use technology to enhance learning, and deliver instructional material to students by leveraging the attractive features of computers, software, and mobile devices. However many DGBL environments fail to balance the game (learning) challenges to the skill level of the student [1]. The difficulty in this adaptation is brought about by the wide variations in the "frustration or patience" level of students; some are frustrated easily and others need more challenges. The insufficient balance between challenges and skill levels exists because of the lack of player profiling from an instructional perspective and also because of the absence of semantic descriptions which give insight into the meaning and usage of the game assets in educational games. [2]. In educational games, players are often modelled from a gaming viewpoint where data is recorded about game events relevant to the players such as points collected, completed levels and rewards found. This information is valuable and makes the game experience more believable; however (educational game) players are for the most part students. Consequently, equal emphasis must be placed on modelling the students' knowledge, their instructional goals, and overall learning achievements. In addition, since all of the learning activities are featured in an educational game as one or more game assets, these activities not only have a pedagogical context but also a gaming context. Therefore, a proper understanding of what the game assets mean and how they fit into the game world along with a detailed student/player model enables the selection of learning activities that are appropriate for use in the game. By using an ontological approach for representing the gaming context in educational games, the relationships between the instructional and gaming roles of the game assets become clearly defined.

Few examples of ontologies specifically designed for use in educational games have been described in the literature ([1], [3]). By selecting and combining some of the pure 'gaming' concepts and some of the pure 'instructional' concepts from these ontologies, the game ontology shown in Figure 1 below was developed. The ontology features concepts which describe the gaming environment and the player because in order to adapt the challenges of the game to the player's skill level, a record of the game state that concerns the player must be kept. When a player gives a response to a learning exercise, the solution for the exercise can be compared to the player's response. If the response is

incorrect, then a game hint that involves game characters associated with the learning exercise can be selected and presented to the player since every learning exercise is essentially a game activity and by extension, a game event. The student's mastery of the topic for the learning exercise is then adjusted such that a different learning exercise which still relates to the gaming activity that the player is currently engaged in is presented as feedback.
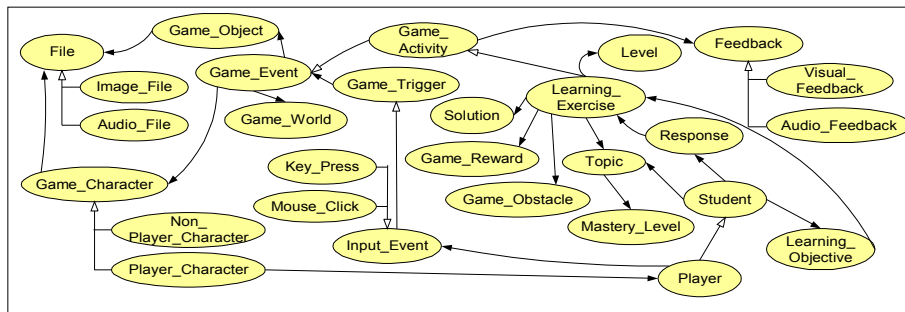

Fig. 1. A diagram of the concepts and relationships in the educational game ontology

An initial prototype of an educational problem-solving game, *Baking Trays*, was designed and developed for teaching undergraduate computer science how to program arrays using Java. The game dynamically adapts the problems presented to the players based on their knowledge level in specific topics related to arrays such as declaration and initialization, insertion and deletion of elements, traversal and sorting. Each topic has an associated set of learning activities ranging in difficulty from beginner to intermediate to advanced. *Baking Trays* has been fully developed using Java based tools and the game architecture has its foundations rooted in traditional ITS style. Pedagogical and game character agents, built using the JADE multi-agent platform, are featured in the game and adapt the gameplay using JESS rules which operate on data that reflects the taxonomy of the game ontology's concept hierarchy. The rules select exercises at run time based on their semantic relationships to the concepts game ontology. Presently, the game is in its early stages and future work remains to be done on integrating the game exercises designed for teaching the intermediate and advanced array topics such as traversal and sorting.

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