Authoring Goal Oriented Educational Game in Virtual Learning Environment

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Abstract. This paper uses learning goal as a continuous thread to organize the educational game authoring process in order to smoothly integrate learning contents into the game designing process. The proposed authoring system has been used in a practical virtual learning environment Virtual Singapora. This goal oriented system can not only facilitate game designers during the authoring process, but also provide students with personalized control of their own learning progress.

Keywords: Authoring Tools, Learning Goals, Virtual Learning Environment.

1 Introduction

In this day and age, virtual communities become very popular among young generations. Through internet, they communicate with each other, share information, and play cyber games, spending a lot of time. To adapt this emerging life style of young people, various researches integrate educational features into virtual games to attract student via promoting the immersive learning experiences, such as "teleporting" students into a plant to see how a water molecule is absorbed[1]. However, this "fancy" technology also potentially entails some unfavorable outcomes such as the colorful scenarios and competitive mechanism may distract students from their learning materials, and the complex game control may bring students more unnecessary anxiety and uncertain feelings[2].

In order to solve these problems, we need to analyze the authoring process of educational games. To design an educational game, the first task is to identify the learning objectives, which answers the question *what to learn*; then according to the identified learning objectives, we conceive the learning interventions and design the concrete game scenarios, to answer *how to learn* [3]. These two processes must tightly integrate with each other so that the game scenarios can specifically serve the learning objective, and the learning objectives can be fully covered by scenarios. All these aim to make sure that the students can have a clear mind of their learning purpose so as to avoid the unnecessary distraction, and the playing experience can really help them to obtain a deep understanding and a long lasting retention of the related knowledge. How can we achieve this objective? In our opinion, it can be

realized through the setting of learning goals for game scenarios. Learning goals are used for specifying the knowledge or the understandings that students are able to obtain by the end of a learning process [4]. A clear setting of learning goals contributes to a well-defined game structure since it works as a map that tells developers what contents should be involved, and indicates students where the game is going. The goal oriented structure will bring students a pre-mindset on what they need to learn. This pre-mindset will assist students to concentrate on learning materials and meanwhile reduce their uncertain feeling about the game flow.

The setting of learning goals needs the help from both computer developers and the pedagogical researchers. So we need an easy-to-use tool to encapsulate the programming features and hide them from those educational experts to allow them to concentrate on the learning goal settings and other pedagogical features. To this end, we will be seeking an authoring tool that can meet these demands. In the field of intelligent tutoring systems, authoring tools are widely used. According to [5], the authoring tools can be divided into seven categories, which include the tools used for curriculum sequencing and planning [6], tutoring strategies [7], device simulation and equipment training [8], domain expert system[9], multiple knowledge types [10], special purpose [11], and intelligent hypermedia [12]. In order to author learning goals, our attention narrows down to the use of curriculum planning and work-flow management. To achieve this, the system should support two main tasks, which are supporting authors to identify domain knowledge and designing pedagogical strategies with practical scenarios [5].

Several researches [6, 10, 13] have focused on this perspective, but they have two common drawbacks. One is applying very constrained settings for data entry, and the other is deploying a tiresomely long dialog to create a course such as sequentially asking what the learning focus are for all different sections. To improve these limitations, we propose to use an interactive authoring tool with explicit presentations to set and organize learning goals and meanwhile provide students with choices to control their learning progress and to work at their own pace. In this way, the duty of game designers is to bring students learning materials with corresponding learning goals and the students can perform as co-constructors to decide the game flow and take the responsibility of learning.

2 Goal Net as an Authoring Tool

In this paper, we propose to use Goal Net to author and model learning goals. Goal Net [14] is a composite goal hierarchy which is composed of goals and transitions. The goals, represented by node, are used to depict the goals that an agent needs to go through in order to achieve its final goal. The transitions, represented by arc, connect one goal to anther specifying the relationship between goals it joins. From the representation of Goal Net modeling, it is tailored for Goal Net to model learning goals and the relations between them.

In virtual learning environment, the learning materials are mainly delivered by the non-player characters (NPCs) or agents [15]. However, the concept of “agent” does not merely refer to NPC, instead it can be any learning objects with visible or invisible formalization. For example, the interface of game authoring can be an

intelligent agent system which senses the input from game designers and acts on it with the pursuit of its own agenda such as generating a course. Goal Net as an agent modeling approach can support both designing and implementing processes on the platform of Multi-Agent Development Environment (MADE) [16]. MADE has two main parts. The Goal Net Designer is used to do the agent modeling, and the MADE Runtime is to facilitate the design and implementation of agent system. With these two parts, the agent-mediated authoring tool can use its Goal Net to do goal selections and finally achieve the goal through subsequent behavior selections. The detailed description of Goal Net and MADE system appears elsewhere in [16, 17].

Authoring learning goals with Goal Net includes two aspects of work. The first is identifying learning goals. We define two ways to capture learning goals from domain knowledge, which are from **learning level** and from **learning topic**. Learning level refers to the difficulty of a learning content which divides learning materials into different teaching sequence, such as concepts, examples, transferred situations, etc. Learning topic refers to the knowledge correlation which divides learning materials into subjects and themes. Each learning level or learning topic is a learning goal which serves the overall goal, the learning purpose of the whole game. All the learning **goals** are represented as **nodes** in Goal Net. If a learning goal has sub-components, it can be modeled as a **composite goal** with sub-goals. Otherwise, it is modeled as an **atomic goal**. In a Goal Net structure, all the lower level goals serve their higher level goals.

After identifying learning goals, it comes to the second task, designing game scenarios. The detailed scenario implementation still highly depends on the game engine program, but with the help of Goal Net, educational experts can set the scenario plots and manage the game progress by designating the actions within Goal Net **transition**. The transitions of Goal Net are used for depicting the relationships between goals. Each transition is associated with a **task list** which defines the possible tasks that the system needs to perform in order to transit from the input goal to the output goal. Game authors can set the tasks or actions within transitions to design the game scenarios.

```
Require: Root Goal G
Push G into Goal Queue Q
while Q is not empty do
    Pop goal g from Q
    Percept Environment e
    if g requires e then
        if g is Atomic then
            Get action A from g
            Execute action A
        else
            Get Sub-goals g1, g2, ...
            Push Sub-goals g1, g2, ... into Goal Queue Q
        end if
    end if
end while
```

With all these settings authored by game designers, the hierarchical Goal Net algorithm will run as the above pseudo code.

3 Case Study in Virtual Singapora Project

Virtual Singapora (VS) project [1] aims to build a 3D virtual learning environment which provides secondary school students in Singapore a culturally familiar environment to learn secondary science lessons (especially the knowledge about transport in living things). Instead of an illustrated picture describing how water molecules can be transported from the roots to the leaves of a plant, VS project brings students an exciting view as water molecules to exploit the root of banana tree. During this adventure, students can also do sequences of experiments, learn basic concepts, and even perform in the role as a tutor to teach an avatar[18].

3.1 Authoring with Goal Net

In this section, we will use VS project as a prototype to illustrate the learning goal authoring process. First, to identify learning goals the system will begin from defining learning topics. Here, Goal Net is performed as a drawing tool for game designers. They can edit the topics through dragging nodes and linking nodes with arcs on the Goal Net Designer client. In VS the domain knowledge focuses on a specific subject, transport in plants for secondary science. As the nodes with number 89, 82, and 83in Fig. 1, VS has three learning topics: the **Xylem and Phloem of Root, Stem and Leaf** (the cross section and functionalities of xylem and phloem inside the plant), the **Osmosis and Diffusion** (different movement patterns of the water and mineral molecules), and **Photosynthesis** (the way how the energy and oxygen are generated inside the leaf with water, light and carbon-dioxide).

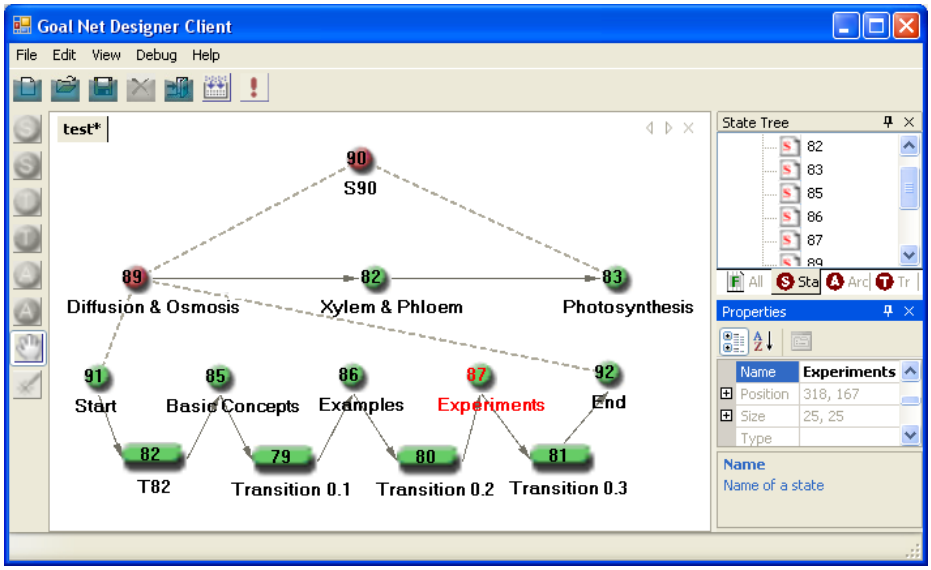

Fig. 1. Editing learning goals with Goal Net

Next, for each learning topic, designers can edit its sub-goals according to the learning levels. Taking the sub-goal "Diffusion and Osmosis" in Figure 1 as an example, the designers set four different learning levels for this goal which are

learning basic concepts, obtaining concrete understandings, and doing experiments respectively which are shown as the nodes 85, 86, and 87. Once the setting from both learning topic and learning level has been finished, the system will provide the option to add "details", which comes to the next step for designing game scenarios.

Fig. 2. The screenshot of experiment of osmosis in Virtual Singapora

As mentioned before, the scenario design is encapsulated in the transitions of Goal Net. The duty of game authors is to define the task list in transitions. Taking the sub-goal "87 Experiment" in Figure 1 as an example, designers need to set the "details" of the "experiments about diffusion and osmosis" as a list of tasks. This scenario has been designed as an osmosis experiment in a laboratory in virtual world (Fig. 2). The task list in Goal Net transition includes four tasks:

1) Come to the place (the third experiment desk)
2) Trigger the corresponding task (the third experiment)
3) Check whether the task is successfully completed
4) Display the learning goal setting page

The descriptions in task list should begin with a verb, and all these tasks in transition are organized in a task library in game engine side. The developers will do the program based the task lists to realize the game scenario in 3D virtual world. The build-in tasks will be recorded in the task library, and prepare for the reusing in the future. By repeating above learning goal settings and scenario settings, the skeleton of the whole educational game can be established.

3.2 User Customization

Now, we have introduced how to use Goal Net to identify learning goals and design game scenarios, but it is not the end of the story. We have mentioned that this system tries to provide students with the capability of controlling their learning progress. We aim to encourage students get rid of the habit of relying on the decisions made by external authorities such as teachers and parents. The first step is to allow students to control their learning pace and take the responsibility of playing this educational game. We believe that asking students to select learning goals and game flows can relieve them from the feeling of anxiety and uncertainty, and further enhance their motivation of learning. Therefore, our authoring system provides students the capability to select learning goals from the "learning goal pool" which has been set by game authors. When students begin to play the game, the system will allow students

to select one learning goal or arrange all the learning goals by dragging the Goal Net nodes to the goal setting interface. Through assembling these learning goals, students can decide and monitor their learning progress, as the Goal Net will run based on new ordered flow.

We try to provide students a learning goal setting interface which can customize the Goal Net structure by dragging learning goal nodes from both the learning topic category and the learning level category. Through previous authoring process of game designers and the detail scenario programming by developers, the system has obtained all the learning goals and corresponding transition functions. Students can work on assembling these components into a goal hierarchy to customize their unique game flows. Figure 3 shows samples of student generated Goal Net structures for VS project.

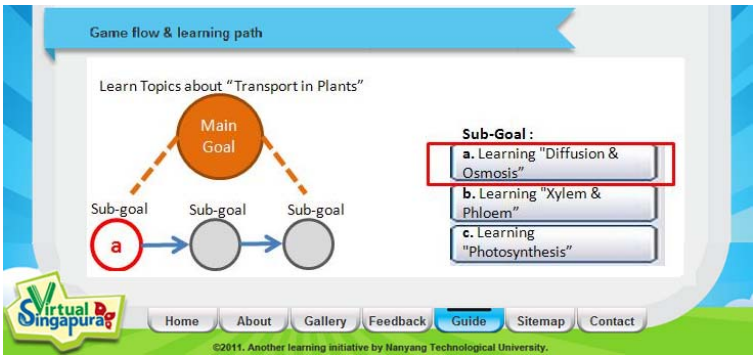

Fig. 3. Sample of a student's learning goal setting interface

In Figure 3, the available learning goals sorted by topics are listed on the right side, and students can drag their preferred goals (the rectangles) to the round blanks. Similar to the process of designing learning goals by game designers, the assembling of learning goals by users also include two steps, 1) choosing learning topic and 2) choosing learning levels. Once the two step selections are complete the system will teleport the user directly to the corresponding areas in the virtual learning environment to do the game tasks.

Table 1. The summary of authoring processes for both designers and users.

Authoring Processes	***Educational Designer***	***Program Developer***	***Student***
	1. Identify learning goals (first by topic, then by difficulty level) 2. Define task list in transitions	Program task functions for game scenarios based on the task list in transitions	Customize game flow by assembling learning goals
System	Generate goal net structure to depict learning materials	Merge the transition functions into game system	Connect the user interface with goal net and trigger game

To summarize, the authoring processes involve three stages: the educational designers identify learning goals and define tasks in transitions between goals; the

program developers realize the tasks in transitions via editing transition functions; and the students customize their learning path through selecting existing learning goals in the system at the beginning of each game scenario.

4 Discussion and Conclusion

The prototype of VS project has been deployed in the Catholic High School in Singapore in last August. The field study included two groups. The treatment group had 38 students who used our prototypes to learn diffusion and osmosis through two separated sessions of forty-five minutes each. The 38 control group students learnt the same topic on standard school classes with the same learning time. Both groups conducted a post-test with four discussion questions related to diffusion and osmosis. The treatment group also took a questionnaire of six rating questions on the scale from 1 (strongly disagree) to 7 (strongly agree) to evaluate the system. We also applied open ended question survey to collect students' comments and suggestions for this game.

After analyzing the feedbacks from students, we found many students argued that the open exploration in the virtual world made them feel uncertain and had difficulty to link the game exploration with learning materials. In order to solve these practical problems, we developed this new version of VS with learning goals authoring. For the time being, this version has not been tested in school. However, during the design and development process several informal tests among game researchers, school teachers, and young students have been conducted, and have received positive feedbacks.

The key feature of this paper is using Goal Net to tightly integrate the domain knowledge with the game scenarios. Learning goal as a continuous thread runs through the game authoring process has four perspective benefits. First, authoring learning goals for educational games can help game authors to design game scenarios centered on the corresponding learning contents. Next, learning goals can be a useful tool for game designers to depict their purpose and effectively interact with colleagues so as to ensure the educational ideas deliverable. Besides, learning goal setting can provide students a pre-mindset of the learning progress and assist them to understand the logic between game tasks and the domain of learning. Furthermore, the explicit representation of learning goals can bring students a feeling that they are following the logic of the course. This type of ownership of learning will highly motivate students to be engaged in the learning process [19]. Therefore, learning goal setting is a powerful underpinning to structure the entire game and form the education skeleton.

The essence of learning is not from the uncritical acceptance of knowledge. So we try to encourage students to critically analyze the learning materials and further establish their own knowledge structures and sense of understandings. This internalization process is what developmental theorists call self-authorship [20], or "the capacity to define one's beliefs, identity, and social relations" [19]. The attempt of offering students capability to arrange game flow in a certain degree is the first step to practice the self-authorship. The idea of involving students as co-constructors of educational game enables students to set their own learning goals based on the

structure of Goal Net. It will motivate them to take on the learning responsibilities and build up their self-esteem.

In the future, we plan to add a new perspective—learning tasks—to specify the learning goals for the sake of providing students a view from game tasks. With the three type of organization (learning topic, learning level, and learning tasks) of Goal Net, we will conduct the formal school test in this summer.

References

1. Virtual Singapora. In: http://www.youtube.com/watch?v=aD6A8lX_oZk&feature=related (ed.). Nanyang Technological University (2011)
2. Dillenbourg, P., Schneider, D.K., Synteta, P.: Virtual learning environments. (2002)
3. Wenger, E.: Artificial intelligence and tutoring systems. International Journal of Artificial Intelligence in Education 14 (2004) 39-65
4. What are learning goals. In: http://teaching.berkeley.edu/establishinglearninggoals.html (ed.). UC Berkeley Teaching, Learning, Academic Planning and Facilities (2009)
5. Murray, T.: Authoring intelligent tutoring systems: An analysis of the state of the art. International Journal of Artificial Intelligence in Education 10 (1999) 98-129
6. Merrill, M.D.: ID Expert: A second generation Instructional Development System. Instructional Science 26 (1998) 243-262
7. Murray, T.: Authoring knowledge-based tutors: Tools for content, instructional strategy, student model, and interface design. The journal of the learning sciences 7 (1998) 5-64
8. Towne, D.M.: Approximate reasoning techniques for intelligent diagnostic instruction. International Journal of Artificial Intelligence in Education (IJAIED) 8 (1997) 262-283
9. Blessing, S., Gilbert, S.: Evaluating an authoring tool for model-tracing intelligent tutoring systems. Springer (2008) 204-215
10. Shute, V., Torreano, L., Willis, R.: DNA--uncorking the Bottleneck in Knowledge Elicitation and Organization. Springer (1998) 146-155
11. Murray, T., Blessing, S., Ainsworth, S.: Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptive, interactive, and intelligent educational software. Springer Netherlands (2003)
12. Kiyama, M., Ishiuchi, S., Ikeda, K., Tsujimoto, M., Fukuhara, Y.: Authoring methods for the Web-based intelligent CAI system CALAT and its application to telecommunications service. (1997)
13. Jones, M., Wipond, K.: Intelligent environments for curriculum and course development. Teaching knowledge and intelligent tutoring (1991) 379-395
14. Zhiqi, S.: Goal-oriented Modeling for Intelligent Agents and their Applications. Nanyang Technological University (2005)
15. Cavazza, M., Charles, F., Mead, S.J.: Interacting with virtual characters in interactive storytelling. ACM (2002) 318-325
16. Shen, Z., Miao, C., Gay, R., Li, D.: Goal-oriented methodology for agent system development. IEICE Transactions on Information and Systems 89 (2006) 1413
17. Yu, H., Shen, Z., Miao, C.: A goal-oriented development tool to automate the incorporation of intelligent agents into interactive digital media applications. Computers in Entertainment (CIE) 6 (2008) 1-15
18. Ailiya., Zhiqi, S., Chunyan, M.: Goal Oriented Affective Teachable Agent in Virtual Learnnig Environment. International Conference on Advanced Learning Technology (2011)
19. Hodge, D.C., Magolda, M.B.B., Haynes, C.A.: Engaged Learning: Enabling Self-Authorship and Effective Practice. Liberal Education 95 (2009) 8
20. Magolda, M.B.: Making their own way: Narratives for transforming higher education to promote self-development. Stylus Pub Llc (2004)