# Remembrance Agent: A New Type of Pedagogical Agent

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**Abstract:** Many pedagogical agents have been designed and successfully applied in educational games, such as learning companions, tutor agents or other kinds of intelligent agents. Most agents work in a traditional way to teach or guide the players by directly transferring knowledge to players. In this paper, we introduce a new type of pedagogical agent: remembrance agent. A remembrance agent records what a player has already explored and provides just-in-time support to him in a new scene. Unlike a tutor agent, the support provided to the player is the description of previous scenes which share similar knowledge of the current scene. The knowledge will not be demonstrated directly. By this way, the player is reminded of and encouraged to find solutions to current situations based on what he already learned. A remembrance agent has been realized in an educational game, *The Chronicles of Singapura*. The agent is designed using Goal Net design tool. The agent received good feedback from players.

## 1 INTRODUCTION

RPG (Role-Player-Game) Video game is a new trend in educational games by providing players virtual world to explore (Dostál, 2009). A virtual word consists of open learning environments. As identified in (Clarebout, Elen, Johnson, & Shaw, 2002), in such an environment, student players are responsible for their own learning and must be able to solve a complex task with help from support tools. In a game, pedagogical agents are animated characters playing the role of instructors for supporting or facilitating learning (W. L. Johnson, Rickel, & Lester, 2000).

Many pedagogical agents are already being used in learning environments to support student learning. Popular agent types are tutor, co-learner, and teachable agent. Tutor is the most common kind of pedagogical agent. It plays the role of a teacher to explain knowledge to players, answer the players' questions, and evaluate how well the players learned. For example, *Adele* is one tutor agent used in web-based educational simulations (Ganeshan, Johnson, Shaw, & Wood, 2000; W. Lewis Johnson, Shaw, & Ganeshan, 1999). A rather new tutor agent was recently reported in (Cheng et al., 2009). The concept of a co-learner agent is proposed in (Chou, Chan, & Lin, 2003). In a research from Stanford, a computer-mediated co-leaner agent resulted in the same positive consequences as human–human interaction (Lee, 2007). The Teachable agent comes from the idea of learning-by-teaching (Biswas, Schwartz, Leelawong, Vye, & Vanderbilt, 2005; Blair, Schwartz, Biswas, & Leelawong, 2006; Brophy, Biswas, Katzlberger, Bransford, & Schwartz, 1999; Leelawong & Biswas, 2008). Students learn by teaching the teachable agent. They evaluate how well the agent learned and modulate how to improve the teaching, through which the students are promoted for deeper learning. A system called Betty's brain is designed to demonstrate the agent. The feedback showed that self-regulated learning feedback better prepared students to learn in new domains. The Teachable agent can also inspire the students to themselves become a teacher in real life.

In this paper, we introduce a new kind of pedagogical agent into educational games: remembrance agent. Remembrance agent provides just-in-time support when the players are facing a new problem. The agent communicates verbally with sound as a supplementary tool. The distinction between a remembrance agent and other agents is that it provides descriptions of experiences of the players in the previous scenes related to the current scene instead of giving direct information of knowledge related to the current problem. The players have to think for themselves to find out the connections between the current problem and the past scenes. This is a strategy proposed for lectures that lead to student engagement: focusing students' attention, elaborating on

material, and requiring students to retrieve and generate answers from memory (deWinstanley & Bjork, Spring, 2002).

As a notion, remembrance agent was first introduced as a tool for just-in-time information retrieval (B.J. Rhodes, 1997; Bradley J. Rhodes, 2003). The remembrance agent is a program that continuously "watches over the shoulder" of the user and provides information relevant to the current context. To use the agent, the user is required to wear a detector. The user's activities on the wearable computer can be sensed. Then the agent automatically displays information that might be relevant in that environment on a head-up display. The agent works by remembering the user's past experiences and associating the user's current situations with the past experiences to augment the user's memory. Our design of the remembrance agent follows with this idea but for a different application.

We applied the idea of remembrance agent in an education game, *The Chronicles of Singapura*. The remembrance agent is designed using Goal Net design tool. Goal Net (Shen, Li, Miao, & Gay, 2005) is a model to design agents. A Goal Net consists of goals which are organized in logical orders. In a remembrance agent, this kind of hierarchy is used to represent the storyline of the educational game. To find related scenes is to search the Goal Net to find previously accomplished goals (scenes). A remembrance agent designed in *The Chronicles of Singapura* for learning transport in plants is shown in this paper. The feedback from players showed that it was helpful.

The paper is organized as follows. We will first introduce the remembrance agent model. Then we explain the Goal net model in section 3. In section 4, the detailed design and implementation of remembrance agent in *The Chronicles of Singapura* is explained. The demonstration and feedbacks are shown in section 5. Finally, a conclusion is given.

## 2 REMEMBRANCE AGENT

As we described in last section, a remembrance agent has three basic functions: recording, analyzing and displaying. A basic model for remembrance agent is shown in (Figure 1). The arrows in the figure show dataflow in the agent. The information about scenes which players have already visited will be collected by the agent and saved in the case base. If a player is in a new scene, the agent will do some online reasoning to get the related scenes from the case base. The related scenes should contain knowledge that can be applied to solve the problem in the current scene. Then the previous scenes are described to the player to help him recall what he visited. The objective is to help the player to connect the previous scenes with the new scene, and solve the problem with the help of the knowledge learned in the previous scenes.

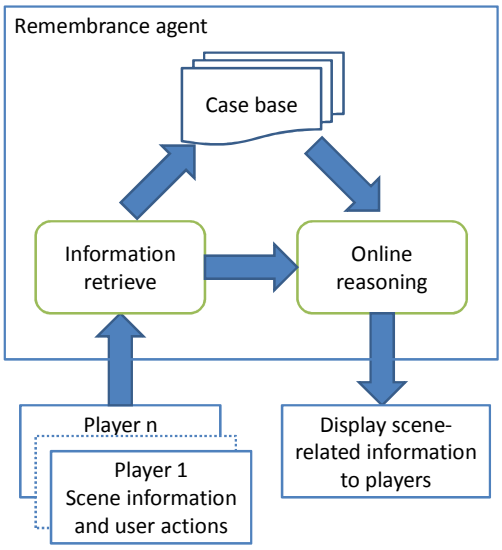


**Figure 1:** Remembrance agent model.

In a multi-player game, the case base may be shared among team members and a player may get help from other players' experiences. This way of distributed cognition strengthens the ability of a remembrance agent and thus the game experience for players.

In the following, we will show the design of remembrance agent in a specific game, *The Chronicles of Singapura*. We apply Goal Net model to keep the scene information in the game. A description of Goal Net model is given in next section.

## 3 GOAL NET MODEL

In previous researches, a Goal Net model (Shen et al., 2005) has been proposed based on the goal-oriented methodology (Lamsweerde, 2001). A Goal Net is a composite goal hierarchy which is composed of goals and transitions.

Before describing the design of a Goal Net agent, we give the following definitions:

- GOAL is a collection of all possible goals in the agent.
- ACTION is a collection of all actions the agent can perform.

A Goal Net consists of the goals and the transitions among them. In normal cases, a serial of intermediary goals can be identified before an ultimate goal can be accomplished. All the goals are linked together by the transition relations between them to make a hierarchical goal network. A Goal Net can be defined as $GNet = <G, T, g_s, g_e>$, where:

- $G$ is a set of goals. $G = \{g_1, \ldots, g_n\} \subset$ GOAL. A goal $g_i$ is either atomic or composite. A composite goal can be decomposed to a sub Goal Net. An atomic goal cannot be split anymore. A goal is atomic if it can be achieved by executing an atomic action.
- $T$ is a set of transitions. $T = \{t_1, \ldots, t_m\}$.
- $g_s \in G$, $g_s$ is the starting goal of this Goal Net. $g_s$ is atomic. Each Goal Net has only one $g_s$.
- $g_e \in G$, $g_e$ is the ending goal of this Goal Net. $g_e$ is atomic. Each Goal Net has only one $g_e$.

A transition is defined as $t = <G_i, G_o, r, A>$, where:

- $G_i \subset G$, $G_i$ is a set of input goals of this transition.
- $G_o \subset G$, $G_o$ is a set of output goals of this transition. $G_i \cap G_o = \Phi$ .
- $r \in R$. $R$ is the library of relationships among the goals.
- $A \subset$ ACTION. This defines the actions to realize the transitions. After the action of a transition is executed, the output goals of the transition are expected to be achieved. *null* action is defined for a composite output goal.

Three kinds of relationship are defined. $R = \{choice, concurrency, synchronization\}$.

- *Choice* relation means a selective connection from one input goal to any one of the output goals. $|G_i| = 1$, $|G_o| \geq 1$, $|A| = |G_o|$. This relation is defined because the output goals may be conflicted or just one of them needs to be accomplished after the input goal is accomplished. The actions defined are associated with each output goal. It is noted here that if $|G_o| = 1$, this can be seen as a *sequence* relation.
- *Concurrency* relation has one input goal but more than one output goals. This means that the output goals can be achieved at the same time if this transition is made: $|G_i| = 1$, $|G_o| > 1$, $|A| = 1$. The action defined is to accomplish all the output goals together.
- *Synchronization* relation specifies a synchronization point from different input goals to a single output goal. This is useful to represent the scenario where there are several goals and all need to be achieved first in order to reach the next goal. $|G_i| > 1$, $|G_o| = 1$, $|A| = |G_i|$. The actions defined are associated with each input goal. Several actions may be required to run in parallel to achieve the input goals.

The three kinds of relation can be used in various combinations in a Goal Net. This enables Goal Net to support a wide range of complicated temporal differences among goals. Examples of Goal Nets and relationships can be seen in (Figure 2).

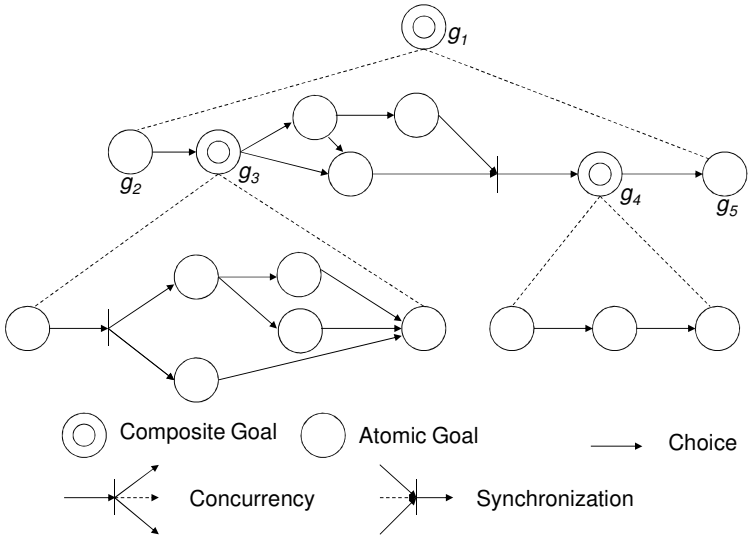


**Figure 2:** Example Goal Nets.

Composite goals in a Goal Net will be decomposed and replaced by sub Goal Nets. The decomposition process continues until there is no composite goal. Finally, a *refined* Goal Net consisting of atomic goals for the original Goal Net is gotten. The agent's ultimate goal can be achieved by completing intermediate goals in the *refined* Goal Net. The action plan of the agent consists of the actions to make the transitions between goals. Because there are unique $g_s$ and $g_e$ for any Goal Net, the transitions to or from a composite goal can be linked to the starting or ending goal of the decomposed sub Goal Net. The output goals of an original transition, $t$, to a composite goal, $g$, will be modified as: $t.G_o = t.G_o - \{g\} \cup \{GNet_c.g_s\}$, where $GNet_c$ is the sub Goal Net by decomposing $g$. Similarly, for a transit, $t$, which starts from $g$, $t.G_i = t.G_i - \{g\} \cup \{GNet_c.g_e\}$.

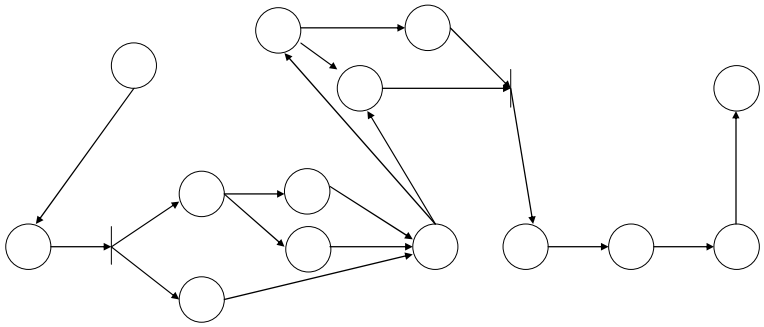

**Figure 3:** Refined Goal Net for the composite goal $g_1$.

For example, the composite goal $g_1$ in (Figure 2) can be decomposed to a refined Goal Net as shown in (Figure 3). In the remembrance agent, we will use *refined* Goal Net to keep the storyline of the game. Each scene is represented as a goal. Then the related scenes can be found by searching the Goal Net. A recursive searching algorithm can be found in (Zhang, Shen, & Miao, 2009).

## 4 REMEMBRANCE AGENT IN *THE CHRONICLES OF SINGAPURA*

*The Chronicles of Singapura* is an educational game in the form of 3D RPG (Role-Player-Game) game. The game is realized based on Torque Game Engine Advanced (TGEA) developed by GarageGames (http://www.garagegames.com/). In the game, a 3D virtual world is created based on the map of Singapore. Student players from junior school play roles as explorers. The players interact with NPCs (Non-Player-Character) to get tasks and try to solve them. Knowledge can be learned during the process to accomplish the tasks. In the current game, the knowledge of transport in plants will be learned. A game screenshot is shown in (Figure 4), in which a player is communicating with Uncle Ben (a NPC) to get a task to save a banana tree. Various kinds of agents are realized in this game to support learning, including tutor agent, teachable agent and remembrance agent. In this paper, we just focus on the remembrance agent.


**Figure 4:** *The Chronicles of Singapura* screenshot.

The remembrance agent is constructed based on BDI (Belief-Desire-Intention) model (Rao & Georgeff, 1995; Zhang & Huang, 2008) as shown in (Figure 5). Before the agent is run in a game, a Goal Net is designed according to the storyline of the game using the Goal Net design tool and kept in the database. The agent works in a serial loop: detect, process and display. The information received in detection is the name of a scene in the game. Then the agent process to keep the new information and retrieve related scenes. Finally the descriptions of the related scenes are displayed to the player.

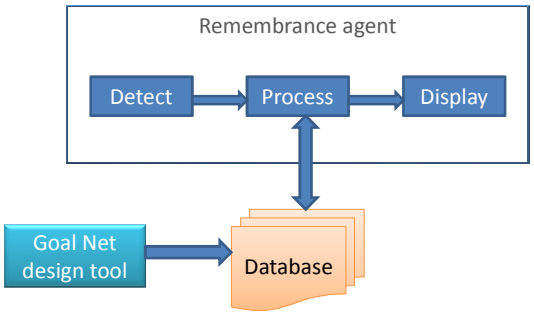


**Figure 5:** Remembrance agent.

| Name | Description |
|---|---|
| **Goal Net tables** | Tables used to save Goal Net information |
| **Scene** | Basic scene information |
| **Knowledge** | All knowledge which can be learned in the game |
| **Hints** | The information displayed to players |

**Table 1:** Tables in the database.

The database consists of several tables as shown in (Table 1: Tables in the database.). Goal Net tables are used by Goal Net design tool to store information of Goal Nets. Their structures are not discussed in this paper.

A record in *scene* table consists of *scene name*, *scene ID* and *activation point* where the scene is activated. For example, the current game consists of 20 scenes. The game storyline is shown in (Figure 6) and the corresponding Goal Net is shown in (Figure 7). The relationships between scenes are realized by the relationships in Goal Net. A player's objective is to achieve the ending goal by experiencing all the scenes in the game. By searching the Goal Net, given a scene, all the previous scenes the player visited can be found.

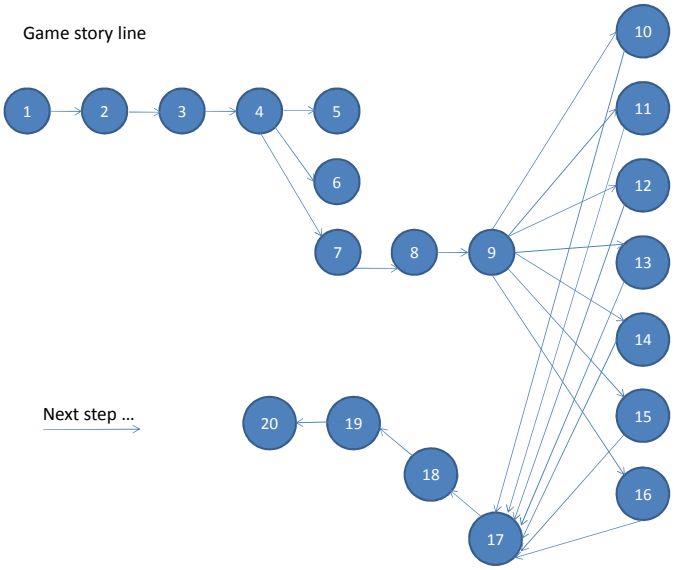


**Figure 6:** Storyline of the game.

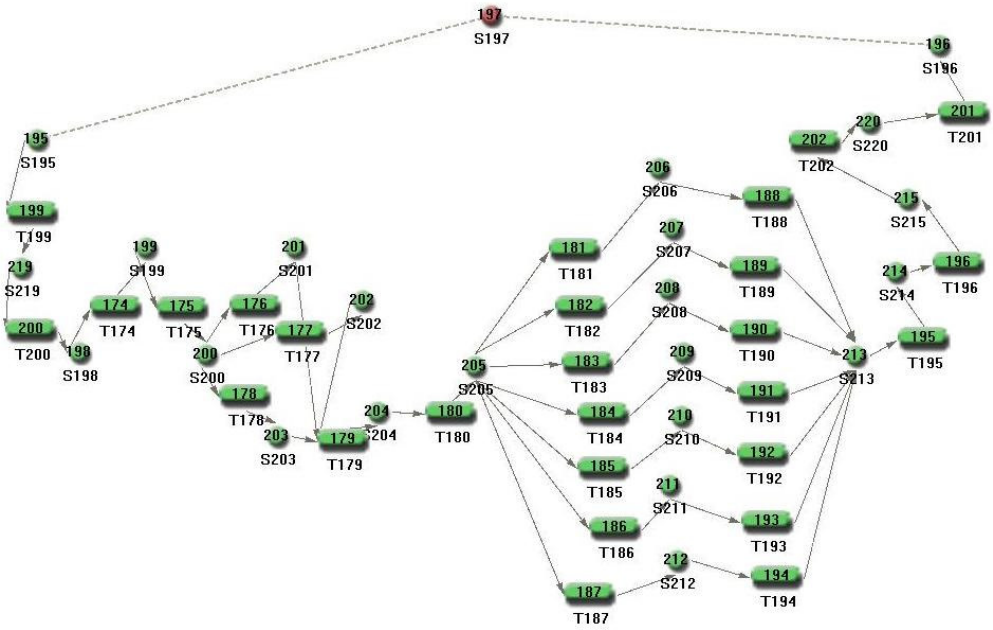


**Figure 7:** Corresponding Goal Net.

After the game scenes are decided, all knowledge points which can be learned through the game can be concluded. The information of the knowledge points is kept in *knowledge* table. A record of *knowledge* table consists of no of the *knowledge point (KID)*, *knowledge description* and the *ID of the earliest scene* in which the knowledge point is introduced. The *ID of the earliest scene* is used to decide when the hints about this knowledge can be displayed. Some knowledge points in the game are shown in (Table 2).

| KID | Knowledge description | ID of the earliest scene |
|---|---|---|
| 1 | Diffusion (Passive transport) | 1 |
| 2 | Osmosis | 2 |
| 3 | Partially permeable membrane | 1 |
| 4 | Facilitated diffusion (Passive transport) | 5 |
| 5 | Active transport | 2 |
| 6 | Absorption of mineral salts | 3 |

**Table 2.** Some knowledge points.

Finally it is the *hints* table. The attributes in a hint is summarized in (Table 3). There might be several knowledge points which can be learned in a scene. An example of hints from the game is shown in (Table 4). In this scene numbered by 4, two knowledge points can be learned.

| Name | Description |
|---|---|
| **Scene ID** | The scene which generates the hint |
| **Knowledge ID** | The knowledge which can be learned in the scene |
| **Hint to be displayed** | A description of the scene to help player recall the knowledge |

**Table 3.** Attributes of a hint.

| ID | Scene name | Activation point | KID | Hint to be displayed in future related scene(s) |
|---|---|---|---|---|
| 4 | Absorption_1 | Mineral salts try to enter a plant through diffusion | 1 | Mineral salts fail to enter plant through diffusion |
| | | | 6 | |

**Table 4.** Hint designed for a scene about absorption.

Currently the descriptions of the hints are written by the game developers. An application will be provided to the teachers in the school where the game is used to support education. The teachers can edit the hints based on their understandings of the knowledge points. It is also a way to control how much help will be provided to the student players.

## 5 DEMONSTRATION AND FEEDBACKS

This game has been realized and demonstrated to 40 students from a junior school in Singapore. A game screenshot of the remembrance agent is shown in (Figure 8). In this scene, the remembrance agent describes some previous scenes to help the player answer the question asked by the water molecule.

The idea of remembrance agent was welcomed by the students and teachers. A photo of students playing the game is shown in (Figure 9). Most students (80%) think that the agent is interesting and helpful to solve problems. The hints will help them review the knowledge they just learned in previous scenes. At the same time, the knowledge is related to the facing problem and can help solve the problem. They are encouraged to use what they learned to solve new problems. A few students (10%) think that it is a little verbose. They may not pay attention to the hints due to the limited time in class. This might be due to the amateur writing of the scene descriptions from the game developers. More detailed surveys will be designed and performed in our future demonstrations.

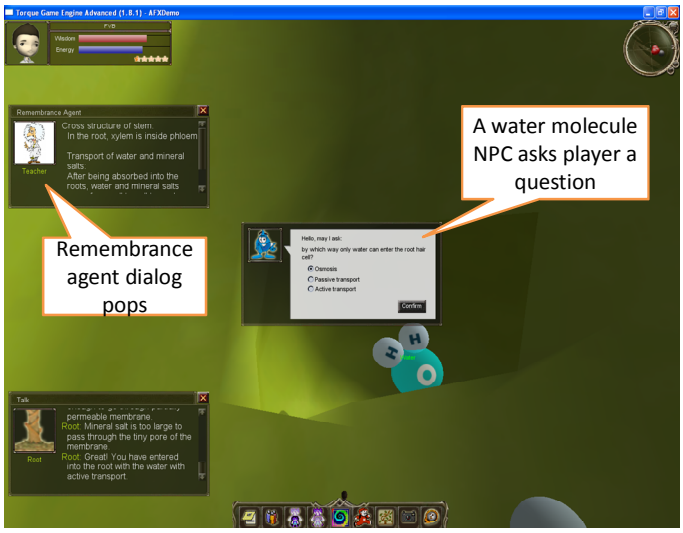


**Figure 8:** Game screenshot of remembrance agent.

**Figure 9:** Students playing the game.

## 6 CONCLUSIONS

In this paper, a new kind of pedagogical agent, remembrance agent, is proposed. A remembrance agent can help student recall and apply knowledge learned previously to solve new problem. The difference between remembrance agent and traditional tutor agents is that the just-in-time hints provided by remembrance agent are not the knowledge explanation that helps to solve the facing problem. Instead, the previous scenes, which contain the same knowledge that will be applied to solve the current problem, are found and described to the player. So to some extent, remembrance agent is still a kind of tutor agent. But this tutor does not teach. It just tries to inspire the players to recall the knowledge learned before. It is a more natural way to encourage players to adopt the strategy of active learning.

A remembrance agent has been implemented in an educational game, *The Chronicles of Singapura*. The agent was realized by using Goal Net model to represent the game storyline. In the paper, the detailed design is described. The feedback from student players showed that remembrance agent is helpful for learning in open environments.


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