S-MADE: Interactive Storytelling Architecture Through Goal Execution and Decomposition

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Abstract

Interactive storytelling, emerging with virtual reality technology, has attracted a lot of research interests in recent years. In order to bridge the gap between story generation and story presentation, some hybrid narrative models are raised. In this paper, we propose a new hybrid interactive storytelling architecture S-MADE. It combines the story plot generation and character performance through goal execution and decomposition mechanism. Fuzzy Cognitive Goal Net (FCGN) is a goal modeling tool for modeling the story scenario and character behaviors. The goal decomposition algorithm enables for director agent to dispatch acts to characters easily. With this system, dynamic storylines as well as character behaviors are created in real time simultaneously, which is hard to be achieved in traditional approaches. Audiences are able to experience different perspectives through interactions with director and characters.

Introduction

Interactive storytelling in the virtual environment gets more and more concerns in the prosperous game and education industry. It allows to create a personalized story according to user interactions. As a mixture of storytelling, virtual reality and user interactions, interactive storytelling provides audiences the capability to interact with the storyteller and the characters in realtime, so that dynamic and personalized storylines can be generated.

Currently there are two main research directions of interactive storytelling/narrative: plot-based interactive story authoring and character-based interactive story presentation. Plot-based storytelling focuses on dynamic storyline authoring for the story director/drama manager, e.g., (Magerko & Laird 2003; Young *et al.* 2004). On the other hand, character-based interactive storytelling concerns the implementation of believable behaviors, e.g., OZ project by Mateas et al. (Mateas 1997), Character-Based Interactive Storytelling by Cavazza (2001; 2002). In order to combine the story plot control as well as character development, some hybrid architectures are raised, e.g. Façade (Mateas & Stern 2003). However, as most approaches implement the characters or director agents in the view of tasks or roles, the agents are not equipped with intelligence of goal autonomy at story generation. Moreover, there is a lack of research about realtime story authoring and story presentation simultaneously. Some tools are created to facilitate interactive storytelling scenario implementation for novice designers, e.g. Alice (Kelleher 2006). However, the tools still have limitations at creating complex story scenes.

This paper introduces a goal-oriented hybrid architecture, namely S-MADE (Multi-Agent Development Environment for Storytelling), that combines plot-based story authoring and character-based behavior modeling through the goal execution and decomposition of agents. Fuzzy Cognitive Goal Net (FCGN) is employed to model the goals of involved agents, in which the temporal causal relationships of the scenes and behaviors, as well as the reasoning of the context and user interactions, are clearly defined. With the hybrid architecture, audiences are able to experience storytelling through various levels of interactions, with great degree of freedom.

A Goal-Oriented Hybrid Interactive Storytelling Architecture

In order to bridge the gap between the plot-based approach and character-based approach for interactive storytelling, hybrid approaches are adopted by researchers. To model the storytelling in the view of entities in the storytelling (i.e. director, characters), a new hybrid architecture is proposed, namely S-MADE (Multi-Agent Development Environment for Storytelling). The interactive storytelling process is viewed as the goal execution of the agents (i.e director agent and character agents), which will be illustrated in details in the next section.

Interactive Storytelling Process

A typical hybrid storytelling process is shown as the following four steps:

Story Authoring A scriptwriter creates the story plot which contains multiple storylines. Then the story plot is sent to a director agent for execution.

Story Executing/Selection The director agent selects only one storyline based on the user interactions or context changes in realtime. Scene selection is done through fuzzy cognitive reasoning mechanism, which will be explained in details in the next section.

Scene Dispatching Each scene of the plot involves a number of characters and events, so that the director agent distributes the scene to relevant characters dynamically. The director agent interprets the scene, assigns them to characters as behaviors accordingly. The story plot modeling and behavior dispatching process are described in details in the next section.

Character Performing The characters perform the behaviors assigned by director in the chronological sequence. The composite behavior can be further decomposed to atomic behaviors. Based on the user interactions and context changes, the characters select most appropriate behavior to execute.

Agents and Goals in Storytelling

Agents are goal-oriented, autonomous objects, which work in specific context. Agent technology facilitates to model intelligent and believable storyteller and characters. The process of storytelling is the process of pursuing goals for involved agents in the storytelling. In a storytelling, the goals of agents can be viewed in Table 1.

	Director	**Character**
Goal	Story plot	Scene act
Atomic Goal	Story Scene	State in act
Role	Plot planning	Behavior planning
Transition	Scene Transition	State Transition
Knowledge	Global	Local

Table 1: Goals of Agents in Storytelling

Fuzzy Cognitive Goal Net (FCGN)

An efficient model/language is required for the communication between the director and characters, in order to achieve the autonomy of story generation and story performing. In our hybrid architecture, Fuzzy Cognitive Goal Net (FCGN) (2006) is used to model story plots for director and behaviors for characters respectively. Through the behavior dispatching mechanism, the director assigns the behaviors for the characters involved in story scenes dynamically. In (Cai *et al.* 2006), FCGN has been used to model the story plot for single director to narrate an interactive story.

Structure of FCGN

As shown in Figure 1, FCGN is composed of *goals* and *transitions*. *Goals*, represented by circles, are used to represent the goals that an agent needs to pursue in order to achieve final goal. *Transitions*, represented by arcs and vertical bars, connect from the a goal to a output goal, specifying the relationship between the two goals. Each transition is associated with a task list which defines the possible tasks that the agent needs to perform in order to transit from the input goal to the output goal.

In FCGN, an *atomic goal* represents a primitive state which cannot be further divided, while a *composite goal* can be split into goals connected via transitions. Therefore, a complex goal can be recursively decomposed into sub-goals and sub goal nets. The hierarchical structure simplifies the goal modeling process with different levels of abstraction. There

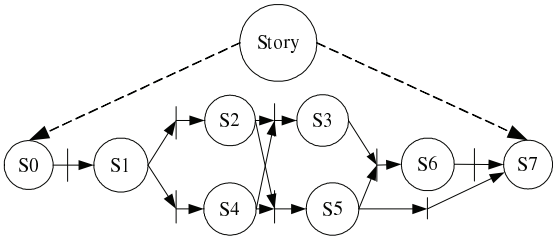


Figure 1: Goal Net with the Alternative Storylines

are four types of transitions:*sequence*, *choice*, *concurrency* and *synchronization*. A very complex goal can be represented with atomic goals and combination of transitions.

In FCGN, Fuzzy Cognitive Maps (FCMs) is adopted as the inference mechanism for goal selection and task selection. Fuzzy Cognitive Maps is a qualitative modeling tool proposed by Kosko (1986). By modeling the fuzzy causal relationships among concepts in a system, FCMs enables to model complex system evolution in short run and long run, which provides a more sophisticated result over one-step if-then inference. A more detailed description of FCGN can be found in (Cai *et al.* 2006).

Director: Plot Planning with FCGN

FCGN is a very expressive and efficient tool to model the story plot. The scenes are related in chronological sequence. In the model, each scene S_i is represented as a goal, the causal relationship between scene S_i and S_{i+1} is represented with transition T_i. As shown in Figure 1, multiple storylines are available due to user interactions or context changes. Different storyline can be achieved by director with 'Choice' mechanism. For example, after scene S1, the director would decide whether next scene is S2 or S4 based on selection criteria. The FCGN represents the goals of the director agent, i.e, story scenes. A complex scene is represented as a composite goal, and a simple scene is represented as an atomic goal. A complex scene is split into small scenes for story narrative.

The *transitions* of goal net are capable of describing different relationships between story scenes in storytelling. The *sequence* transition is used when two scenes has temporal causal relationships. The *concurrency* transition is used when two scenes are independent, such that the presentation order is not important. The *choice* transition is the most important to the user interaction and context variables change, as it might lead to different scene after the current scene. The *synchronization* transition is needed for the concurrent scenes, such that the next scene can be achieved only after the concurrent scenes are achieved. Moreover, the combination of *transitions* allows to model complicated relationships among scenes, thus it is able to model a very complex storytelling.

Character: Behavior Planning with FCGN

In the same way, FCGN is also used as goal model of virtual characters, i.e to model the acts that characters need to perform. In interactive storytelling, the acts for a single character are not linear in response to user interactions, which is same as story plot. Here, the goals of character are the acts/behaviors assigned by the director. The characters perform the scene according to the chronological order of the acts. Different transitions imply the different causal relationships for the acts. As a believably entity, character also monitors user interactions and relevant context changes, to make reasonable act.

Behavior Dispatching

By using the same goal model, the director is able to dispatch the scenes to virtual characters seamlessly, through the goal decomposition algorithm. Therefore, both the story authoring autonomy and character behavior autonomy can be achieved. Behavior dispatching is an important step wherein the director agent assigns the behaviors to different characters in a scene autonomously and dynamically. Director agent will decompose a scene into sub-scenes in parallel for characters which are involved. An algorithm for scene dispatching is shown as

```
Given: Scene $S = [$AC_1, ... $AC_n, $B, $C]

IF $S is Composite
$Q <= Child(S)
While ($Q is not empty)
    $S_t <= $Q
    For i = 1 to n do
        $B_i = Find ($S_t, $B, $AC_i, $C)
        $AC_i <= $B_i
    End
End

Function: $B_i= Find ($S_t, $B, $AC_i, $C)
FOR $AC_i IN $S
IF $B_i is independent \%parallel
    RETURN $B_i
ELSE IF $B_i is dependent of $B_j
    IF $B_j is done
        RETURN $B_i
    ELSE
        RETURN IDLE
ELSE
    RETURN IDLE
```

As shown in the algorithm, independent acts for characters can be performed by characters at the same time, e.g. two characters walk to each other. If there is interaction between the two characters, a synchronization is required to synchronize the acts, i.e, characters wait until dependent acts finish. Characters might call its own act performance with respect to typical act assigned by director agent, so that it can be modeled to handle user interactions.

Reasoning Mechanism using Fuzzy Cognitive Maps

To allow an engaging experience for users, the director and characters need to react intelligently to user interactions and context changes. Such dynamic storyline selection for director agent and dynamic behavior selection for character agents are achieved by reasoning mechanism in a goal net. In FCGN, Fuzzy Cognitive Maps is able to model the dynamic evolution of context changes as well as user interactions, provides basis for goal selection and action selection. Different from other reasoning mechanism, e.g rule-based engine, it is able to work with incomplete information, thus it is helpful for reasoning with different number of factors. With FCM inference, it is able to achieve a sophisticated decision in the case that there is a loop among the causal relationships, which can't be achieved for simple if-then rules. A small comparison of FCM with Hierarchical Task Network (HTN) is shown in Table 2. It shows that FCGN empowers HTN with abilities of goal abstracting, which provides a better modeling to increase agent intelligence.

	FCGN	**HTN**
Structure	Tree	Tree
Purpose	Goal Planning	Task Planning
Selection Mechanism	Fuzzy Cognitive Maps	Precondition
Re-plan	No	Yes

Table 2: Comparison between FCGN and HTN

Case Study: "Mystery Illness Investigation at Nanyang Town"

Story Implementation

A story, namely "Mystery Illness Investigation at Nanyang Town", was implemented using the hybrid approach. The story is about a group of visitors explore the virtual town and investigate the mystery illness. By communicating with virtual characters, or conducting lab experiments, the protagonists find the causes of the mystery disease, and prevent a disaster successfully .

The story plot is modeled as shown in Figure 2, in which the investigators have different choices in the investigation. For example, he/she can go to either the hospital or the clinic to check the symptoms of the mystery illness and how widely the illness has spread. Depending on the availability of the officer in health ministry, the investigators can check differences of diseases from government officer, or from library books. The director agent selects a storyline dynamically

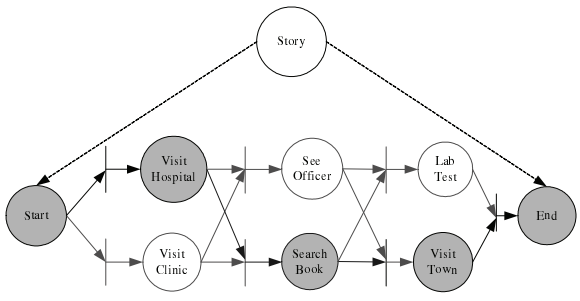


Figure 2: Fuzzy Cognitive Goal Net for Illness Investigation Story

based on the user interactions and the current context. A selected storyline for one investigator is shown in Figure 2 with goals shaded, in which the investigator first visited the hospital for illness symptoms, then went to query about the differences of the illnesses from books, lastly went to visit the town to confirm the conclusion. Figure 3 shows a

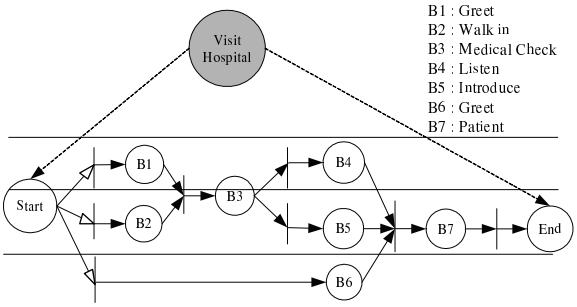
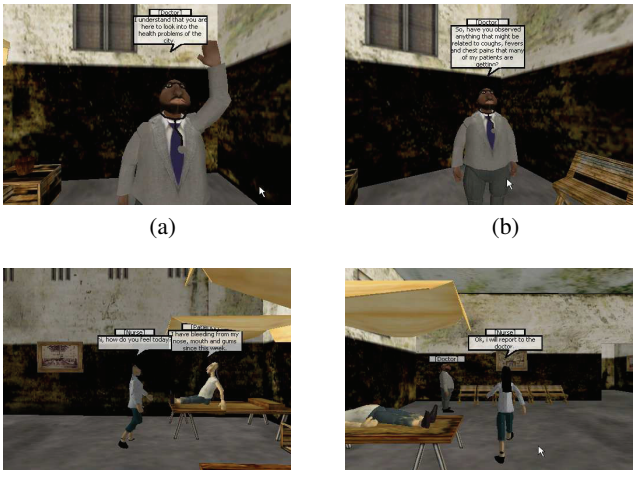


Figure 3: "Visit Hospital Scene" for Doctor Agent

detailed design of scene "visit the hospital". The scene involves three characters: an investigator, a doctor and a nurse, and the behaviors of whom are shown vertically separated by lines respectively. The director agent dispatches the behaviors to characters through behavior dispatching mechanism. The visualization engine is ActiveWorlds 3-D virtual environment powered by Renderware. Some snapshots are shown in Figure 4, in which characters perform the behaviors assigned by the director at different stages.



(a) (b) (c) (d)

Figure 4: Snapshots for (a) talking to the doctor at the first time as protagonist (b) talking to the doctor at the second time (c) nurse visiting the patient (d) nurse reporting to doctor

Results

In the implementation, story plot and character behaviors are generated in real-time with respect to user interactions. The director has high-level abstraction over the story scenes and characters have low-level abstraction over detailed scene acts. In the storytelling process, the audiences are able to affect the decision of director as well as single character, which promotes the engaging and immersive experience.

Conclusions

In this paper, we propose a goal-oriented hybrid interactive storytelling architecture, namely S-MADE, to achieve the storytelling through goal execution and decomposition. Fuzzy Cognitive Goal Net (FCGN) is used to model story plots as well as character behaviors for director and characters respectively. The director agent and character agents are connected seamlessly through goal decomposition algorithm. As a result, story authoring autonomy and character behavior generation autonomy are achieved. Audiences are able to make the interactions at different levels of authoring and storytelling.

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