CHANGING TOPICS OF DIALOGUE FOR NATURAL MIXED-INITIATIVE INTERACTION OF CONVERSATIONAL AGENT BASED ON HUMAN COGNITION AND MEMORY

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Keywords: Mixed-initiative interaction, Global workspace, Semantic network, Spreading activation theory.

Abstract: Mixed-initiative interaction (MII) plays an important role in conversation agent. In the former MII research, MII process only static conversation and cannot change the conversation topic dynamically by the system because the agent depends only on the working memory and predefined methodology. In this paper, we propose the mixed-initiative interaction based on human cognitive architecture and memory structure. Based on the global workspace theory, one of the cognitive architecture models, proposed method can change the topic of conversation dynamically according to the long term memory which contains past conversation. We represent the long term memory using semantic network which is a popular representation for storing knowledge in the field of cognitive science, and retrieve the semantic network according to the spreading activation theory which has been proven to be efficient for inferring in semantic networks. Through some dialogue examples, we show the usability of the proposed method.

1 INTRODUCTION

Conversational agent can be classified into user-initiative, system-initiative, and mixed-initiative agent with the subject who plays a leading role when solving problems. In the user-initiative conversational agent, the user takes a leading role when continuing the conversation, requesting necessary information and services to the agent with the web searching engine and question-answer systems. On the other hand, in the system-initiative conversational agent, the agent calls on users to provide information by answering the predefined questions. Although the various conversational agents have been suggested with the user-initiative or system-initiative, these techniques still have significant limitations for efficient problem solving. To overcome their limitations, the mixed-initiative interaction has been discussed extensively.

Mixed-initiative conversational agent is defined as the process the user and system; which both have the initiative; and solve problems effectively by continuing identification of each other's intention through mutual interaction when needed (Hong *et al.*, 2007, Tecuci *et al.*, 2007). Macintosh, Ellis, and Allen (2005) showed that mixed-initiative interaction can provide better satisfaction to the user, comparing system based interface and mixed-initiative interface through ATTAIN (Advanced Traffic and Travel Information System) (Macintosh *et al.*, 2005).

The research to implement mixed-initiative interaction has been studied widely. Hong used hierarchical Bayesian network to embody mixed-initiative interaction (Hong *et al.*, 2007), and Bohus and Rundnicky utilized dialogue stack (Bohus and Rudnicky, 2009). However, these methods, which utilize predefined methodology depending on working memory solely, can process only static conversation and cannot change topics naturally.

In this paper, we focus on the question – how could the conversational agent naturally change the topics of dialogue? We assume that the changed topics in human-human dialogue are related with their own experiences and the semantics which are presented in the current dialogues.

We apply the global workspace theory (GWT) on the process of changing topics. GWT is a simple cognitive architecture that has been developed to account qualitatively for a large set of matched pairs of conscious and unconscious processes. On the view of memory, we define the consiousness part as a working memory where the attended topics on the

Lim S., Oh K. and Cho S. (2010).
CHANGING TOPICS OF DIALOGUE FOR NATURAL MIXED-INITIATIVE INTERACTION OF CONVERSATIONAL AGENT BASED ON HUMAN COGNITION AND MEMORY.
In *Proceedings of the 2nd International Conference on Agents and Artificial Intelligence - Artificial Intelligence*, pages 107-112
DOI: 10.5220/0002733501070112

working memory are candidates of next topics, and the unconsiousness part as a long term memory. By the broadcasting process of GWT, the most related unconsious process is called and becomes a consious process which means one of the candidates of next topics in this paper. We model the unconsiousness part (or long term memory) using semantic network and the boradcating process using the spreading activate theory.

2 RELATED WORKS

2.1 Global Workspace Theory

Global workspace theory models the problem solving cognitive process of the human being. As figure 1 shows, there is independent and different knowledge in the unconscious area. This theory defines the independent knowledge as the processor. Simple work such as listening to the radio is possible in the unconscious but complex work is not possible in the unconscious only. Hence, he calls the necessary processors through the consciousness and solves the faced problem by combining processors (Moura, 2006).

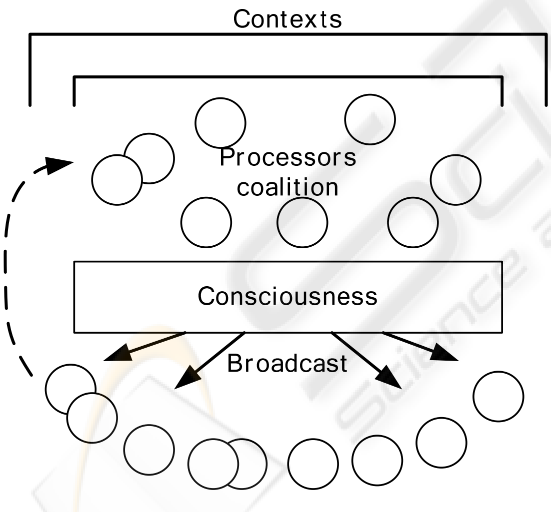

Figure 1: Global workspace theory.

An easy way to understand about GWT is in terms of a “theatre metaphor”. In the “theatre of consciousness” a “spotlight of selective attention” shines a bright spot on stage. The bright spot reveals the contents of consciousness, actors moving in and out, making speeches or interacting with each other. In this paper, the bright spot could be interpreted as current topic of dialogue, the dark part on the stage as the candidate topics of next dialogue, and the outside of the stage represents the unconsciousness part (long term memory).

2.2 Structure of Human Memory and Semantic Network

Figure 2 shows the structure of human memory. Sensory memory receives the information or stimuli from the outside environment, and the working memory solves problems with the received information. The working memory cannot contain the received memory in the long term since it store the information only when the sensory memory is in the cognition process of the present information. Hence, the working memory calls the necessary information from the long term memory when the additional memory needed (Atkinson and Shiffrin, 1968).

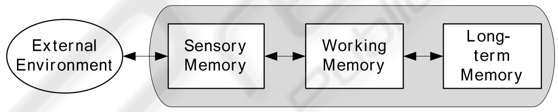

Figure 2: Human memory structure.

The long term memory of human can be classified into non-declarative memory which cannot be described with a certain language and declarative memory which can be. In the conversation agent, we deal the declarative memory and construct the declarative memory in the long term memory. The declarative memory is divided into semantic memory and episodic memory. Semantic memory is the independent data which contain only the relationship, and episodic memory is the part which stores data related with a certain event (Squire and Zola-Morgan, 1991).

In this research, for the domain conversation, we transfer the needed keywords and the past conversation record to semantic memory and episodic memory respectively, and express descriptive memory as semantic network. In the field of cognitive science, semantic network is a popular representation for storing knowledge in long term memory (Anderson, 1976). Semantic network is the directional graph which consists of nodes connected with edges. Each node represents the concept, and the edge represents the relationship between concepts the nodes mean. Semantic network is mainly used as a form for knowledge symbol, and it is simple, natural, clear, and significant (Sowa, 1992). Semantic network is utilized to measure the relationship between the created keywords during the present conversation and the past conversation, and generate system-initiative interaction when the past conversation with the significant level of relationship is discovered.

2.3 Spreading Activation Theory

Spreading activation serves as a fundamental retrieval mechanism across a wide variety of cognitive tasks (Anderson, 1983). It could be applied as a method for searching semantic networks. In the spreading activation theory, the activation value of each and every node spreads to its neighbouring nodes. As the first step of the search process, a set of source nodes (e.g. concepts in a semantic network) is labelled with weights or activation values and then iteratively propagating or spreading that activation out to other nodes linked to the source nodes.

3 CHANGING TOPICS IN CONVERSATIONAL AGENT

3.1 System Overview

In this paper, we proposed a method for changing topic of dialogue in conversational agent. Figure 3 represents the overview of proposed method adapting memory structure of human and global workspace theory.

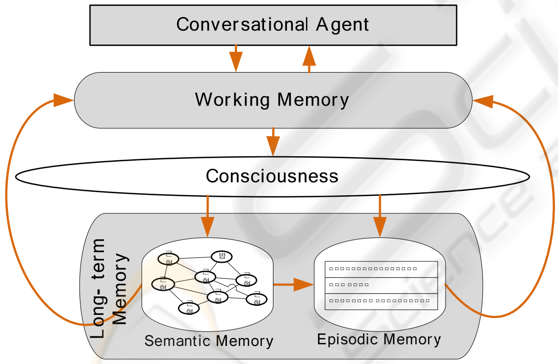

Figure 3: Overview of proposed method.

In the working memory, the information needed to process the present conversation and the candidates of next topics of dialogues are stored. Long term memory is composed of semantic memory and episodic memory. Semantic memory expresses the relationship between important keywords in the conversation, and episodic memory stores the past conversation which is not completed. The proposed method is to represent such two types of memory into be a semantic network.

Conversation agent process the current dialogue using the information in working memory. When the current dialogue is ended, it selects some candidates of next topics in the long term memory by broadcasting using spreading activation. If there are some topics which have more activation value than threshold, they are called and become candidates of next topics. Finally, the conversational agent selects the most proper topics from the candidate topics.

3.2 Conversational Agent

In this paper, we adjust and adapt the conversation agent using CAML (Conversational Agent Markup Language) to our experiment (Lim and Cho, 2007). CAML has designed in order to reduce efforts on system construction when applying the conversation interface to a certain domain. It helps set up the conversation interface easily by building several necessary functions of domain services and designing the conversation scripts without modifying the source codes of conversational agent. The agent using CAML works as following.

1) Analyze the user's answers and choose the scripts to handle them
2) Confirm the necessary factors to offer service which is provided by the chosen scripts. (If there is no information of the factors, system asks the user about them.)
3) Provide services

This agent use both stack and queue of the conversation topics to manage the stream of conversation, and provide different actions to the identical input by the faced situation. System initiative conversation with working memory is already constructed; we focus on the system initiative conversation using long term memory.

3.3 Semantic Networks and Spreading Activation

Figure 4 shows the structure of semantic network we used in this research. The internal nodes in the network consist of semantic memories, the leaf nodes episodic memories, and the edges show the intensity of connections.

Formally, a semantic networks model can be defined as a structure

$$N = (C, R, \delta, W)$$

consisting of

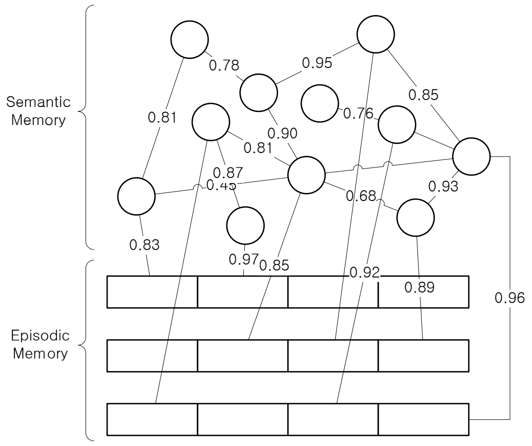

Figure 4: Semantic networks.

- A set of concepts $C = \{C_s, C_e\}$ which represents the semantics of keywords and episodic memory respectively,
- A set of semantic relation $R = \{R_{s \to s}, R_{s \to e}\}$ which represents the semantic relations between keyword and keyword, and between keyword and episodic memory respectively,
- A function δ: $C \times C \rightarrow R$, which associates a pair of concepts with a particular semantic relation,
- A set of weight functions $W = \{W_c(c_x), W_r(c_x, c_y)\}$which assign weights to concepts and relations respectively.

The past conversation stored in episodic memory C_e goes up to working memory by broadcasting, and we customize this process with applying spreading activation theory. Searching network is done by BFS (breath first search) algorithm using priority queue, and calculates the level of relationship between the corresponding node and the working memory when searching from the node to the next node. Finally, it calculates the level of relationship of episodic memory, the leaf node, and if it has relationship over a certain level, corresponding information goes up to working memory.

Figure 5 shows the pseudo code of Semantic network searching process. For the first stage of spreading activation, it gets the initial semantics which is appeared keywords in the current dialogue.

The activation values for these concepts are set 1. Then the activation values are spread through the semantic relations. The spreading values are calculated as follow:

$$c_y.value = c_x.value * W_r(c_x,c_y) * W_c(c_y)$$

```
procedure SpreadingActivation
  input:  Cs  // a set of semantics
                 in working memory
  output: E // a set of episodic
               memory
begin
  Q.clear() // Q = priority queue
  for each cx in Cs
    Q.push(cx)
  end for
  while Q is not Empty
    cx = Q.pop()
    for each linked concept cy with cx
      cy.value =
        cx.value*Wr(cx,cy)*Wc(cy)
      if cy.value < threshold1
      then continue
      if isVisitedConcept(cy) is false
      then Q.push(cy)
      if cy is episodic memory
      then E.insert(cy)
    end for
  end while
end proc
```

Figure 5: Pseudo code for Spreading Activation.

The weight function $W_c(c_x)$ returns 1 when $c_x \in C_s$, and returns the priority of episodic memory when $c_x \in C_e$.

Figure 6 represents a flow chart of the conversation process in conversation agents. In this paper, we use the 2 level of the threshold values. If the level of relationship is over the threshold value 1, the information has a significant link. If the level is over the threshold value 2, it means that it has both a significant link and urgency. If there is episodic memory over the threshold value 2, the agent stops the current conversation to deal the past conversation. And if there is episodic memory with only threshold value 1, the agent waits the current conversation to be finished and then it precedes the past conversation.

4 DIALOGUE EXAMPLES

We use the scheduling program domain to test the utility of the proposed method. Agent needs 4 factors: the type of schedule, subject, time and location. It leaves the conversation unhandled if the factors are unknown because of user's situation. Hence, Semantic network for this scheduling conversation agent have 4 types of internal nodes of in the network: the type of schedule, subject, time, location. The leaf nodes have episodes with 4 values.

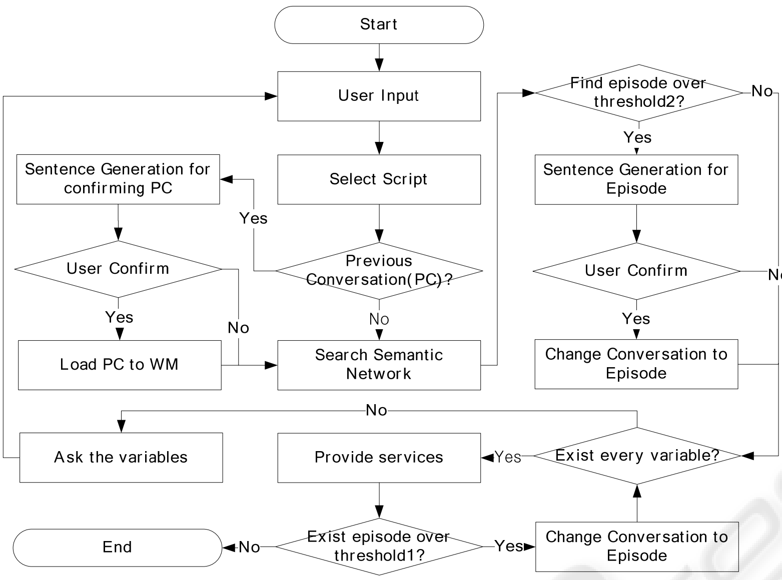

Figure 6: Flow chart of the conversation process.

In this paper, we show how the scheduling program works on 4 situations, when the episodic memory is constructed.

The First scenario shows the general schedule registration process. The agent asks the necessary information and registers the corresponding schedule when all information is obtained. The second scenario shows the past schedule reprocessing. Whenever the schedule information gathered, the agent confirms that there is any correspondence, and continue the past conversation if there is the same data as showed in the scenario. In the third scenario, there exists related conversation which has activation value between threshold value 1 and threshold value 2, so that the agent continues the related conversation after the present conversation had finished. If the activation value of related conversation is bigger than threshold value 2, it stops the present conversation and process the past conversation ahead because it means the related conversation has high priority.

1) Register the schedule

U: I got a dinner appointment.
A: Who will you meet?
U: I'm going to meet Gina.
A: What time will you meet her?
U: At 7 P.M.
A: Where do you meet her?
U: We decided to meet at Yeouido.
A: Okay. The new dinner schedule had registered.

2) Register unprocessed schedule

U: I got a meeting appointment with Jaenam.
A: Is that a dinner appointment at Shinchon you told me on June 13.
U: Yes, that's right.
A: Did you arrange the time to meet?
U: Yes. I decided to meet him at 6 P.M.
A: Okay. The dinner schedule had registered.

3) Process the related conversation

U: I and Kangseok will go out to drink.
A: What time will you meet him?
U: Tomorrow. At 8 P.M.
A: Where do you meet him?
U: At Apgujeong.
A: Okay. The new schedule had registered. Did you arrange the place of tomorrow's dinner with Gina?
U: Not yet. I'll tell you when I decide.
A: Okay.

4) Process the related conversation 2

U: I will study with Gina on this weekend.
A: Did you decide where you and Gina have dinner tonight?
U: Oh! Let it be Shinchon.
A: Okay. The location had registered. When do you study?
U: At 2 P.M.
A: Where do you study?
U: At Gongdeok.
A: Okay. The study schedule had registered.

5 CONCLUSIONS

Former conversation agent provides mixed-initiative conversation according to the predefined methodology and it only depends on the working memory so that only static conversation can be processed. Hence, in this research, we have studied to give an active function to conversational agent that can change the topic of dialogues. The proposed method models the declarative memory of long term memory with the semantic network, and implements the broadcasting process in global workspace theory using spreading activation. By searching relevant episode memory with current dialogue, the conversational agent can change the topic of dialogue naturally.

As showed in the dialogue examples, the proposed method works according to the relationship between the present conversation and long term memory so that the various mixed initiative conversation can be occurred.

Hereafter, it is necessary to form the semantic network automatically by using the frequency of appeared keywords during the conversation and coherence of keywords. Also, the adaptation of memory reduction function is required to calculate the relationship smoothly.

ACKNOWLEDGEMENTS

This research was supported by the Conversing Research Center Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2009-0093676).

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