

Agent Simulation for Contents Evaluation with User Models for Hierarchical Knowledge Relations

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Abstract—To construct an appropriate e-learning system, it is inevitable to evaluate it by testing it with real human learners, but it naturally implies some sacrifices on the part of learners. To minimize the risk, some computational simulative evaluations are desirable. In this paper, we propose a multi-layered multi-agent simulation model for learner's growth through using an e-learning system. As a typical example of complex learning objects, we employ the task of learning presentation skills for which we are constructing a comprehensive learner support system and learners' data, and the knowledge model and learner growth model are prototypically proposed. By a preparatory experiment, our attempt, though it is still in its fancy, is shown to be on the right track.

Keywords- contents evaluation; agent simulation; multi-layered knowledge model; hierarchical knowledge relations; awareness promotion

I. INTRODUCTION

With more need for customized tutoring or learning support with information and communication technology, more and more e-learning systems have been developed and utilized for various types of topics. They are supposedly developed deliberately with preceding analyses of the topic, the targeted learners, and the expected functions and user interfaces, but their effectiveness has been measured only when they are used by real human learners. It is true that the real value of any system is known only in the real situations, but as much risk of inappropriateness or failure should be avoided as possible, though we admit that the complete displacement of human trials is impossible.

To evaluate e-learning systems without real human learners, it may well be useful to employ an agent simulation. However, we face at least three fundamental issues:

- Knowledge and skill of many complicated, and often very abstract, tasks to be learned by human learners contains different levels of knowledges. Thus modeling such a complex system is not trivial, let alone implementing an agent system.
- Learner's knowledge and skill is in definition incomplete and often contains incorrect parts, which has also to be modeled.

- Learning steps contains continuous revisions, corrections, and refinements of prior knowledge and skill. So adequate model of growth has also to be modeled.

To tackle these issues, we will take a synthetic approach with an inter-related knowledge structure of complex tasks. As a typical example of complex learning objects, we employ the task of learning presentation skills for which we are constructing a comprehensive learner support system and learners' data, and we propose a multi-layered multi-agent simulation model for learner's growth through using an e-learning system. Though our attempt is still in its infancy, a preparatory experiment seems to show our attempt to be on the right track.

The organization of this paper is as follows. In section II, we describe our ongoing project to construct a comprehensive learner support system for English presentation, particularly for the purpose of presenting knowledge models assumed in the system. In section III, we propose a prototypical multi-layered multi-agent simulation model, and in section IV we conduct a preparatory experiment to evaluate our model.

II. PRESENTATION LEARNING SUPPORT

A. Overview of the relevant system

Based on the recognition above, we are currently developing a comprehensive learner support system for basic presentation in English [1]. It consists of several modules including digital contents of preliminary tutorials, an interactive aide for organizing a presentation and its corresponding slides, semi-automatic evaluation estimation, and a online review of recorded presentations, with a multimedia learner corpus of presentation. The overview of our system is shown in Fig.1.

B. Underlying Learner Model

As a learner support system, our system assumes a basic meta-cognitive model of presentation preparation and exercise similar to that of writing process designed by Hayes and Flower [2], and our model is shown in Fig. 2.

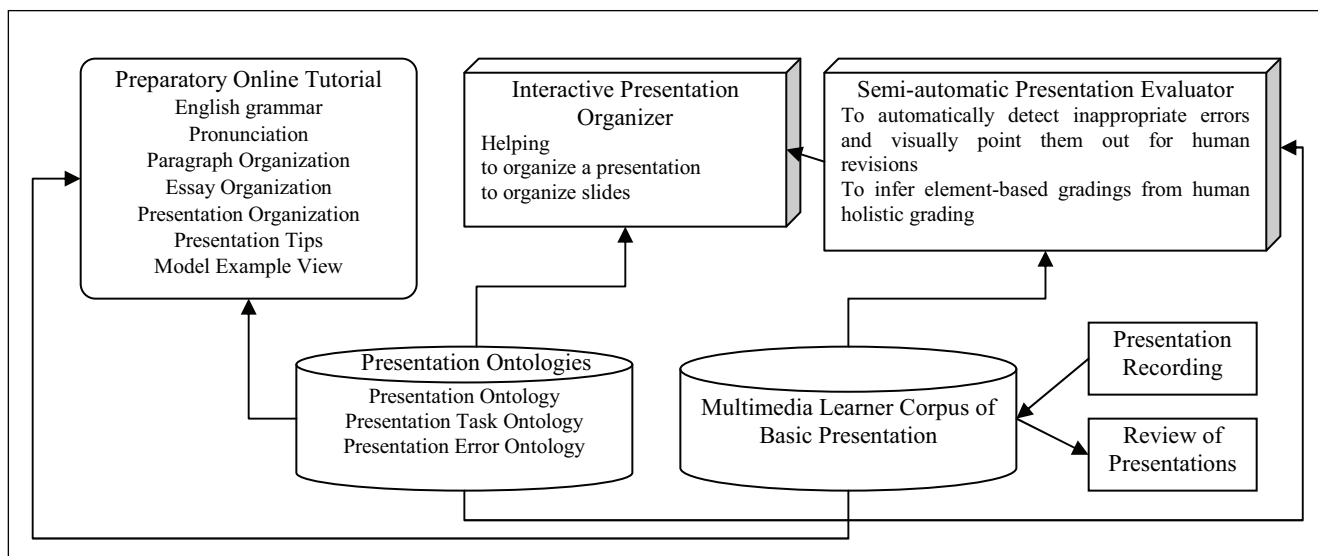


Figure.1 Overview of our prototypical learning support system of Basic Presentation

Based on the Hayes and Flower model, we added a performance section and clarified the status of strategies in the long-term memory. With this model, what any learner support system for presentation should promote is clear. In order for learners to acquire presentation strategies in their long-term memory, the skill choosing the proper writing style, speaking style, visual aids, and performance style, together with the

feature of the chosen topic and the tendency of the audience, should be fostered in the way to stimulate their self-awareness. When preparing the presentation itself, three processes are to be effectively supported again by letting them be aware of what they are doing and what are to be improved.

C. Presentation Style Factors

Presentation, whether it is oral or written, is delivered for a particular communicative purpose, which is to determine what and how to be delivered—content and style. A communicative purpose can be analyzed into different aspects. Let us call these aspects style factors. As each style factor affects what and how to be delivered, they have to be deliberately considered. Numerous books on presentation preparation emphasize the consideration of style factors, though each calls style factors differently, and we classify them as in Table 1.

With the decisions on style factors, oral and slide contents are to be made not only on what to be delivered but also how to

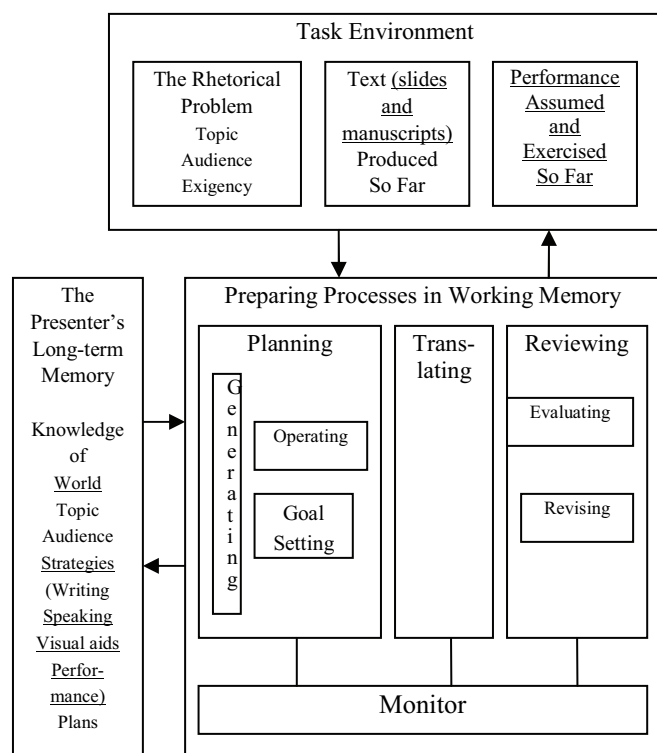


Figure 2 Our tentative model of the presentation preparation process

TABLE 1 STYLE FACTORS

Factors	Examples
Topical (Genre)	inorganic chemistry, English literature ... (Note that the topical factor can be very much specific.)
Media	newspaper, textbook, oral presentation...
Targeted reader/audience	laypeople, professionals ...
Purpose	persuasion, explanation ...
Intention	formal, informal or friendly ...
Time	the length of presentation

deliver it. Preparation for discussion is also affected. In other words, all the other aspects of presentation preparation and delivery are decided along the line of the choices of the appropriate style factors for the presentation. Particularly, all the linguistic style elements like shown in Figure 3 which manifest the choices are heavily affected.

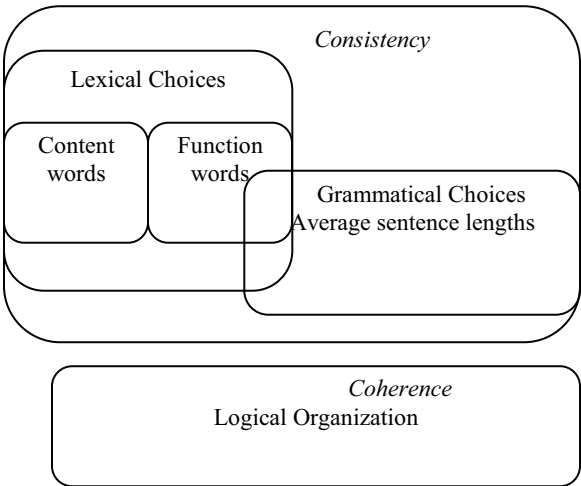


Figure 3 Linguistic Style Elements

D. Rhetorical Structure

The actual content of a presentation is then represented as a series of spoken sentences constituting a logical organization. One of the best known logical organization is that of paragraph, but a more fine-grained relation between sentences is needed, and a number of theories and frameworks have been proposed [4], of which Rhetorical Structure Theory, originally proposed by Mann and Thompson [5-9] is the most popular.

In the RST framework, the discourse structure of a text is considered to be coherent and thus capable of being be basically represented as a single-rooted tree with a set of directed graphs. Each directed graph is labeled for its

rhetorical relation. Originally 23 relations were proposed [10], but the exact number proposed varies among researchers. Based on various proposals, we constructed a revised rhetorical relations of RST for presentation as shown in Table 2 [11].

It is important to note that the adequate sequence of rhetorical relations varies according to the purpose, targeted audience, and intention of the presentation. So, though it is difficult at this stage to reveal an quantitative correspondence between them, styles factors and rhetorical relations are related.

E. Learners’ Presentation Samples

We have been constructing a multimedia learner corpus of English basic presentation (MLCP), part of which is to be employed as learning data in this paper. MLCP contains more than three hundred English presentations by learners [12]. The collected presentations vary in topic and in purpose, but all have common structure of five paragraphs, and common targeted audience, i.e. peer learners. The common structure is schematized as in Fig. 4, which is originally hinted by the idea of basic five paragraph essays. As shown, each slide roughly corresponds to a paragraph.

- Title and its corresponding slide
- Introduction and its corresponding slide
- Three supports and their corresponding slide
- Conclusion and its corresponding slide

As learning data for the experiment to be described later, we manually tagged rhetorical structure relations to the transcribed oral speech for 100 presentations. To facilitate the experiment, however, we manually added the style factors to them, which is not included in MLCP.

MLCP contains human evaluations of each presentations, which is considered to represent the growth level of the presenter.

TABLE 2 OUR REVISED RHETORICAL RELATIONS OF RST

EDU(Elementary Discourse Unit): Semantically clausal segments

A rhetorical relation is basically based on the surface structure and is assigned 0 or 1 according to the logical validity.

The Set of Rhetorical Relations for our purpose

Name	Description	Order of N&S
Background	Satellite provides background information to the nucleus	S before N
Contrast	Applies to two nuclei that contrast each other	
Elaboration	Satellite elaborates the information in the nucleus	N before S
*Elaborative Example	Satellite exemplifies the information in the nucleus	N before S
Enablement	Information in the satellite enables the audience to perform action in nucleus	N before S
Evidence	Satellite provides evidence to the statement in the nucleus	N before S
Justify	Satellite justifies the nucleus	
Motivation	Satellites motivates the reader to perform the action in the nucleus	
List	Listed nuclei	S before N
Sequence	Multiple nuclei that follow each other in sequence	
Solutionhood	Satellite is the problem; Nucleus provides the solution.	N before S
Summary	Short summary or paraphrase of the previous span	
*Supra-textual Cue	Cue for an action on the part of the audience.	
Orphaned	Any other orphaned nucleus, to be connected to the nearest dominating nucleus (indicates that the item is newly introduced here)	

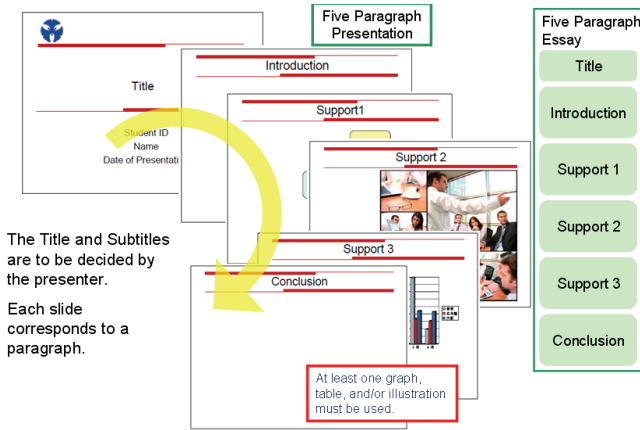


Figure 4 Correspondence between presentation slides and basic five paragraph essay

III. MULTI-LAYERED MULTI-AGENT MODEL OF LEARNER

According to our developing e-learning system for English presentation and learners' data described in the previous section, we constructed a multi-layered multi-agent model of learner in learning English presentation skills.

A. A Multi-Layered Model of Relevant Knowledges

When preparing a presentation, one should first analyze and determine style factors. According to style factors, he constructs what is to be presented, i.e. contents, and it is constructed as oral speech and slides. As noted previously, style factors do affect contents. For example, if the topic is technical while the audience is assumed to have little prior knowledge on the topic, then it should be supposed that the contents should contain comprehensible definitions and a fair amount of examples for easy understanding. Then, the actual speech and slides reflects the determination of style factors and the construction of contents. It is difficult to make a rigorous model for this kind of relationship, but a restricted part of the relationship can be stated fairly simply. In this paper, as a prototypical restricted model, we prepared a set of simple relations between the technical complexity of topics and the knowledge level of the targeted audience like the following.

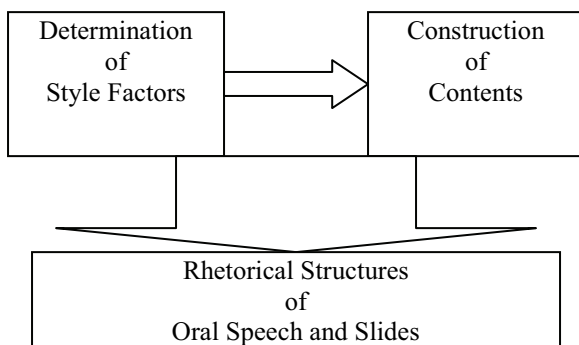


Figure 5 Primitive Multi-Layered Model

- The more technical the topic is, the more comprehensible definitions and examples (including metaphorical ones) are needed.
- The more abstract the topic is, the more metaphorical elaborations are needed.
- If the targeted audience have some prior knowledge, then the definitions usually come first. On the contrary, if not, then they may not.

At the same time, some style factors like purpose and intention both directly and indirectly (i.e., through the determination of contents) affect the sequence of rhetorical relations.

Note here that humans have each knowledge on style factors, contents, and rhetorical relations at different levels, and have additional knowledge on relations among them, which is why the model adopted here, roughly shown in Fig. 5, is called a multi-layered model of relevant knowledges.

B. A Multi-Agent Model

Each pieces of knowledges in the multi-layered model can be considered to an agent with a limited knowledge and reasoning rules. In other words, The body of knowledges of a human can be considered to a set of agents.

As for the relationship between style factors and contents, we only focus on the degree of necessity of definitions and examples, and the *style factor agents* are supposed to have one reasoning that require the corresponding construction of contents. Because it is beyond the scope of this paper, we assume that the construction of contents is the mere reflection of the determination by style factor agents; in other words, we do not deal with the actual contents, and the construction of contents is a set of the number of words (expressions, to be more exact) with definitions and the number of examples, both of which are determined by style factor agents, together with some other pieces of contents like causes and conclusions.

As for the rhetorical relations, we assume each rhetorical relation is implemented as an agent with simple reasoning of the order between nucleus and satellites.

C. A Learner Model Reflecting Growth Stages

The two notions of “multi-layered” and “multi-agent” are considered to constitute a human knowledge of a complex skill, and if they are constructed idealistically, it is a model of the perfected body of related knowledges. We assume as a zero hypothesis that the perfected body of related knowledges can in fact be constructed for some types of e-learning systems including that for English presentation, though we admit that it is not the case with every kind of possible e-learning systems. If we have a perfected body of related knowledges, then *a learner model at a particular growth stage* is to be constructed as an imperfect, often incorrect, body of related knowledges, and let's suppose so.

Then, a model for a particular growth stage constitute a set of agents at multi-layers whose reasoning is unstably probabilistic or just inert as shown in Fig. 6.

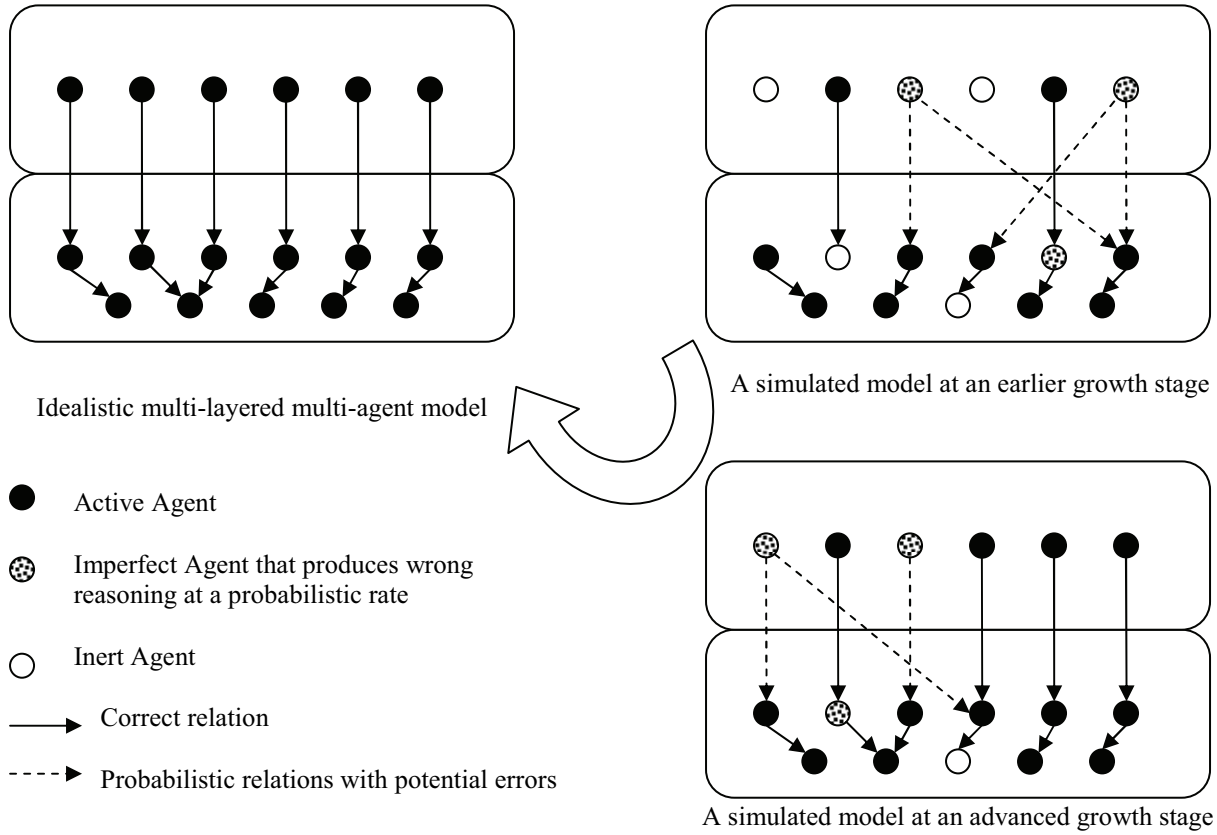


Figure 6 A Multi-Layered Multi-Agent Learner Model at Different Growth Stages

For convenience, each agent belongs to one of the two layers in Fig. 6, and in learner's model, agents are categorized as one of the three conditions.

- Active Agent
- Imperfect Agent that produces wrong reasoning at a probabilistic rate
- Inert Agent

Active agents requires other agents related to it to make a particular action, while imperfect agents may or may not do so to other agents that may or may not be related to it. Inert Agent does nothing. Then growth is considered to have more active agents than the previous stage.

IV. PROTOTYPICAL EXPERIMENT

Based on the model we described in the previous section, we conducted a prototypical experiment to evaluate our model.

Each agent has a set of two rules, one of which is inherent reasoning and the other of which is the request to other agents to a particular action. At the rhetorical relation layer, actions are categorized into the following two actions:

- To require another rhetorical relation agent to follow
- To require a particular type of sentence.

The experiment consists of two phases. The first phase is the stage to statistically learn the condition of each agent and the relations between agents from the data that represent a particular growth stage. A growth stage is judged with the evaluation value of presentations in MLCP. In this paper, we set four growth stages according to the evaluation value. So we will obtain (at least) four models each of which represents one of the four growth stage. Let us call each g_1, g_2, g_3, g_4 . The second phase is the stage in which the set of agents whose conditions are learned for a particular growth stage re-learn for the next growth stage. Let us call each g_i^{i+1} . Then compare g_i^{i+1} with g_{i+1} . If g_i^{i+1} is the same or very similar to g_{i+1} , then it may well be considered that our model represents a growth stage from which it can learn to the next stage.

In average, each presentation consists of 15 sentences, and each learning set consists of 50 presentations. We admit that this size of the learning sets is not so large, and so we employed an SVM method, due to its perseverance to the small size of learning data sets.

As for style factor agents, we just implemented four, each of which may send their requests to the rhetorical relation layer. In this paper, we skipped the contents layer, simply because there is no data dedicated to the contents layer in the current MLCP while the data of learner's speeches can be considered to

be the result of the construction of the contents at least for our experiment here.

Each style factor agents get an input from the meta data of each presentation whether its targeted audience is prepared or not, and whether the topic is technical or not. Then they may make inherent reasoning to send the preset request, and look for another agent to receive their request.

As for rhetorical relation agents, we just picked up four: background, elaboration, elaborative example, and solutionhood. Because the prepared style factor agents have to do with background and elaborative example, the expected result is that only the relations between style factor agents and *background* and *elaborative example* rhetorical relation agents are related.

The learning process has two stages: one for distinguishing the existence of relations from no relation, which distinguishes active and imperfect agents from inert agents, and the other for distinguishing the high probability of relations and the low probability of relations, which distinguishes active from imperfect agents.

The results of the second phase is shown in Table 3.

TABLE 3 THE RESULTS OF THE SECOND PHASE LEARNING RATE

	○ v. ●	○ v. ●	● v. ●
g_1^2 v. g_2	83.4%	75.8%	82.3%
g_2^3 v. g_3	52%	37.4%	64.7%
g_3^4 v. g_4	91.2%	62.3%	86.1%

As Table 3 shows, the comparison between g_2^3 and g_3 is low. This is because the third level is inherently intermediate and such an intermediate level of learners have relatively unstable conditions with unstable tendencies to use correct patterns. However, the comparisons between g_1^2 and g_2 and between g_3^4 and g_4 are relatively high, which indicates that our multi-layered multi-agent learner model can represent growth stages.

V. CONCLUDING REMARKS

In this paper, for the purpose of computational evaluation of e-learning systems for complex skills, we proposed a multi-layered multi-agent learner model which can trace growth stages. The result of the prototypical experiment indicates that our model in fact represents growth stages. It is quite primitive, but this model opens up a possibility to computational learner simulation, and it leads to minimize the risk of learner's sacrifice to be exposed to imperfect e-learning systems.

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