Multiple Representation Approach in Multimedia based Intelligent Educational Systems

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Abstract: The paper describes the Multiple Representation approach for presenting multimedia technology within intelligent educational systems. The implementation of the approach is dependent on the adopted educational framework. In this paper, it is discussed for systems using cognitive apprenticeship framework for task oriented disciplines where the major focus remains on cognitive skills acquisition. The paper describes the application of the approach in the design of InterSim system, which provides learning of structure and functionality of the human ear.

1. Introduction

This paper demonstrates the Multiple Representation (MR) approach to present multimedia objects (such as audio, pictures, animations) into a multimedia interface world where the relationships of the objects to the world are governed by the educational framework. Learners are provided with various forms of interactivity to suit the pedagogical goals of the intelligent educational systems. This approach ensures the suitable domain content presentation by guiding the multimedia objects selection, navigational objects selection, and integration of multimedia objects to suit different learner needs.

The next section of the paper discusses the application of multimedia technology for acquisition of cognitive skills under cognitive apprenticeship framework. Then the paper presents the Multiple Representation approach for cognitive apprenticeship framework. Rest of the paper discusses the implementation of Multiple Representation approach in the InterSim system which aims to provide adequate cognitive skills in the human ear domain while adapting content/information selection and presentation to learners needs..

2. Multimedia and cognitive skills

The use of multimedia objects in educational systems can enhance their efficacy to a great extent in facilitating cognitive skills besides other components of domain competence. However, just the collection of multimedia objects does not guarantee proper learning [15]. Another important aspect is the proper interaction of the learner with the interface components, specially when learning is recognised as a complex activity (or process) combining various factors such as information retrieval, navigation, and memorisation [5].

In the area of cognitive skills, the use of various multimedia objects in a suitable educational framework may satisfy different learning needs which arise at different stages of cognitive skills acquisition. Cognitive Apprenticeship framework [4] provides one such effective path [13].

The first step of cognitive apprenticeship is the observation phase where the learner receptively explores the task pattern of an expert. Within a system, receptive exploration is possible through text reading, watching a picture, listening audio and observing a video or animation [12]. After basic understanding the system can provide advanced observation through image maps, interactive videos and pictorial virtual reality.

After the observation phase, the learner is required to imitate the observed tasks to acquire skills. Simulations and interactive flowcharts can provide an adaptive environment where the learner can imitate the tasks under system guidance. The progress in skill development and retention can then be measured in problem solving and assessment scenarios where different multimedia objects would play different roles. After acquiring basic skills, the learner can achieve competence through repetitive training using practice simulations and flowcharts in different contextual scenarios. Table 1 gives few examples of multimedia objects suitable for different tasks under cognitive apprenticeship framework.

Table 1. Tasks in cognitive skills acquisition and related multimedia objects

Requirement	*Example of suitable multimedia objects*
Observation (receptive)	Text, Static pictures, Animations, Video, Audio
Observation (active)	Image maps, Textual links, Interactive videos, pictorial VR
Exploration (Imitation)	Simulations, Flowcharts
Feedback (immediate)	All above components in problem solving
Evaluation (delayed feedback)	All above components in assessment mode
Practice (repetition)	Practice simulations and flowcharts for different scenarios
Transfer in real life	Authoring tools using various multimedia objects
Co-operation in work context	Authoring and communication tools using various multimedia objects

It is not an easy task to select adequate multimedia objects in a particular context, specially when there is a need to integrate various objects, or the objects need to act as navigational aids. The proposed Multiple Representation approach provides guidelines for multimedia objects manipulation according to the adopted educational framework.

3. The Multiple Representation approach

Learners with different domain competence levels require different explanations and representations of domain content. Multiple Representation (MR) approach tackles the domain content presentation in three ways: multimedia object selection; navigational object selection; and integration of multimedia objects.

3.1. Multimedia object selection

Various recommendations for domain content presentation according to the MR approach are described below.

3.1.1. Task specificity and learner's competence

MR approach suggests the selection of multimedia objects to be based on their suitability for the tasks to be carried out, for example, [2] suggested that audio is good to stimulate imagination, video clips for action information, text to convey details whereas learner's domain competence and consequently the curriculum should follow a granular structure to allow its measurement at individual units level [1]. Table 2 shows the selection of multimedia objects for cognitive apprenticeship framework.

Table 2. Multimedia objects selection for cognitive apprenticeship framework

Domain competence level	*Task*	*Examples of multimedia objects*
Novice in both in knowledge and skills	Direct instruction for knowledge	Text, pictures, audio, animations
Intermediate in knowledge, novice in skills	Direct instruction for skills with little exploration possibilities	Animations, videos, textual links, sensitive parts in static pictures
Intermediate in both knowledge and skills (Ready for problem solving)	Learning by problem solving for both skills and knowledge	Pictorial VR (e.g. asking correct position of a part in structure), Flowchart (e.g. asking a decision point)
Expert in knowledge, intermediate in skills	Advance exploration possibilities	Flowcharts, user controlled animations, simulations
Intermediate in knowledge, expert in skills	Advance active observations	User controlled animations, advance Pictorial VR
Expert in both knowledge and skills	Practice required for achieving mastery	Advance user controlled animations, advance simulations

3.1.2. Reference & revisits of already learned domain content

In learning process it is sometimes necessary to refer already learned domain content in different contexts [17]. The MR approach favours these revisits in different contexts as it enforces links between concepts, enhances the mental model of previously learnt concept, helps in generalising its applicability in multiple situated scenarios and provides ease in learning current concept by making familiarisation with past learning experiences.

3.1.3. Use of multi-sensory channels

The selection of objects should adequately use the visual, aural and tactile senses of the learner. The reception by the learner enhances if the representation of domain content involves all relevant sensory channels (chances of getting distraction due to an unused channel should be minimised).

3.1.4. Context based selection of multimedia objects

When there are more than one multimedia objects available for representation of same task or concept, the domain presentation should use the most suitable object in that particular context.

3.2. Navigational object selection

The navigation in educational systems takes place through various links provided in the system. The learner's expectations of outcome while activating a link should be properly matched with the presentation of actual resulting interface. The MR approach therefore examines the suitability of various types of links and favours both *interaction* objects (e. g. push buttons, radio buttons, check boxes) and *interactive* objects (e.g. text, pictures) [3] to provide navigation. Interaction objects provide transition from one part of the system to another on learner's explicit initiative, whereas interactive objects facilitate a system recommended contextual transfer. Six types of navigational links are identified.

a) *Direct successor link* leading to the successive domain unit in knowledge hierarchy. Such transfer arises from current context such as link in text or message after fulfilling learning criteria of current domain unit.
b) *Parallel concept link*, leading to the analogous domain unit for comparative learning or to the unit related to another aspect of the currently being learnt domain content.
c) *Fine grained unit link*, leading to the fine details of the domain content after identification of some missing or mis-conceptions [11]. These transfers are very contextual and therefore interactive objects such as image maps are suitable for such transfers where the fine grained unit would be explanatory unit of the object clicked in the picture.
d) *Glossary link*, leading to a pop-up "spring loaded" module [10] available only as long as learner is interested in it and is explicitly doing something to keep it active (such as pressing the mouse button).
e) *Excursion link*, leading to a learning unit outside the current context, to learn about an external concept in view of current conceptual unit [7]. Excursion links are used to provide related learning of current context which would generally be a description or a phrase which links current unit to the excursion unit.
f) *Problem links*, leading to the problems related to current learning unit. Transfer to problems is a result of system's suggestion of doing so after learning criteria fulfilment of a learning unit.

Table 3 presents examples of multimedia objects used as navigational links.

Table 3. Types of multimedia objects as navigational links and recommended uses

Examples	*Recommended uses*
Textual links from main text *(Interactive object)*	* transfer to successor unit * transfer to excursion * transfer to glossary pop-up
Textual links from messages *(Interactive object)*	* transfer to successor unit * transfer to excursion * transfer to problems
Sensitive parts of static pictures (image maps) *(Interactive object)*	* transfer to fine grained unit
Push buttons *(Interaction objects)*	* transfer to successor unit * transfer to another learning unit on learner's explicit request * transfer to another aspect of same learning unit * transfer from message (e. g., arrow button in message)
Pop-up menu items *(Interaction objects)*	* transfer to another learning unit on learner's explicit request

3.3. Integration of multimedia objects

In many situations, the domain content presentation requires use of more than one multimedia objects. Learning improves as complementary stimuli and cognitive resources used to present learning content include relevant coding (text, graphics, tables etc.) and relevant modalities (visual, auditive senses) [14]. Following are some recommendations on how best to combine multiple multimedia objects.

- There should be no more than one active multimedia object at a time on the screen. For example, a screen with two animations showing two different aspects of same domain content would demand high cognitive load on the user (with exception of comparative study of two actions).

- The integration of multimedia objects should be complimentary and should be synchronised. For example, audio narration along with a diagram should direct the learner towards the salient parts of the diagram [16]. Care should also be taken not to present the same material with more than one multimedia object (such as audio transmission of the text presented on the screen).
- Decision intensive objects such as flowcharts demand high cognitive loading. Therefore integration of such objects with any other multimedia object is not recommended.
- To avoid confusions different multimedia objects not initially distinguishable should not be put together. For example, pictures and image maps initially look static. similarly, user controlled animations and automatic animations initially have similar dynamic look.
- Integration of dynamic observation objects (e.g. animations) with static observation objects (e.g. text) should not use the same sensory channel at the same time. For example, learner should not be forced to read text while watching the animation.

4. The InterSim System

The InterSim system facilitates conceptual knowledge and cognitive skills of the human ear domain. A detailed description of the system architecture is available in [8]. The system has three main functional states: learning, assessment and case authoring. The learning and assessment states are for the learner whereas the case authoring is for teachers to add real cases of the domain into the system. The learning state is further sub-divided: (a) coarse grained instruction dominated learning; (b) fine grained knowledge construction; (c) cognitive skills development; and (d) application of the acquired knowledge and skills.

4.1. The Multiple Representation approach in the InterSim system

4.1.1. Multimedia object selection

Table 4 examines the educational objectives of various parts of InterSim system under cognitive apprenticeship framework. Various multimedia objects are then selected on the basis of table 1 and 4. Following section describes the rationale of using these objects.

a) The receptive and active observation of the subject domain starts with the help of static pictures along with corresponding text. Three types of static pictures are used: normal static pictures, static pictures with sensitive parts (similar to image maps), and static pictures with semi-sensitive parts.

Table 4. Educational objectives of various states and sub-processes in the InterSim system

States and sub-processes	*Educational objective*
Learning state: coarse grained instruction dominated learning	* Receptive and active observation of healthy ear structure and functionality * Observation of simple physics related to the auditory system * Observation of graphs and diagrams related to the auditory system
Learning state: fine grained knowledge construction	* Exploration of structure and functionality of the healthy ear * Excursions to auditory system related topics in physics of sound and audiometric measurements * Observation of diseases of the ear
Learning state: cognitive skills development	* Exploration and diagnosis of diseases of the ear * Interpretation of graphs and diagrams related to the auditory system
Learning state: application of the acquired knowledge and skills	* Learning by problem solving of the healthy ear and diseases of the ear * Repetitive training by practice in multiple contexts

Case authoring state	* Addition of various real cases of the domain to be used in advanced exploration of diseases of the ear for acquiring context based cognitive skills

Normal static pictures are used for receptive observations whereas static pictures with sensitive and semi-sensitive parts are used for active observations. Sensitive parts in the pictures represent domain objects in current domain hierarchy. On such objects, mouse over shows the boundary and name of the part; single click highlights the whole part and gives a short textual/audio description; and double click transfers the learner to the fine grained learning unit. Semi-sensitive parts do not belong to the current domain hierarchy and they react only to the double click mouse actions to provide information about how to change the current domain hierarchy.

b) The next stage in the receptive observation deals with the dynamic/functional behaviour of ear parts, and animations are found suitable for this purpose [18]. Three types of animations are used: *automatic animations* run in continuous loop without any learner intervention; *user controlled animations* allow the learners to see a continuous action, and a particular event can be generated by some explicit actions (e.g., pressing a button); and *user initiated animations* are used where learners can explicitly run the initially stopped animation to see the complete process.

c) After the observation phase, simulations are used for acquiring skills. Simulations are important because learner's first active participation in learning process starts with simulations. They help learners in achieving mastery by providing virtually unlimited practice situations without incurring costs of real work environment [18].

d) To provide more realistic learning environment, pictorial virtual reality (VR) are used which allow manipulation of three dimensional objects and scenes.

e) Even more realistic cases are provided by videos to show the actual world phenomena.

f) Decision making skills are provided by flowcharts as they graphically represent the sequencing, options and conditions affecting the domain content representation [9].

Table 5 shows how the system supports the student by providing timely recommendations and updating the student model, while not hindering the student to access any such part of the domain which would not cause unnecessary cognitive overload on the user. The table shows a typical learner-system interaction sequence for learning of acute otitis media disease when the learner tries to access the disease from the Eustachian Tube learning unit in the healthy ear part of the system.

Table 5. Typical system-learner interaction with adaptive system behaviour

Domain content representation on screen	*Student model (major changes)*	*System recommendation*	*Actual student action*
Eustachian tube closure - **Animation** (Simple observation)	*Update:* eustachian tube closure knowledge exposed	Go to observation of diagnosis (animations)	Rejects system recommendation, goes to exploration of diagnosis
Diagnosis - **User controlled animation** (Exploration)	*Update:* diagnosis knowledge exposed	Go to advanced exploration of diagnosis (simulations)	Rejects system recommendation, goes to problem solving
Problem - **Simulation** for diagnosis (covering observation and exploration of diagnosis)	*Partial success update:* eustachian tube closure knowledge grasped, diagnosis tried but not grasped	Need more learning, go to advanced exploration of diagnosis (simulations)	Rejects system recommendation, goes to development of acute otitis media

Development of acute otitis media - **Animation** (Observation)	*update:* development of acute otitis media knowledge exposed	Problem solving	Accepts system recommendation
Problem - **Flowchart** related to diagnosis of eustachian tube closure and initial development of acute otitis media	*Full success* *update:* eustachian tube closure fully grasped, initial acute otitis media knowledge grasped	Go for advanced exploration of acute otitis media development (simulations)	(some action from user in continuing the learning process)

4.1.2. Navigational object selection

In InterSim system the navigation methods are selected following MR approach. For example, in the partial screen of the Ossicle Chain learning unit in figure 1, navigation panel on the left side provides various combo boxes for explicit navigation among various learning units. The ossicle chain picture on right behaves as image map to allow navigation to successor units. The textual links pop-up glossary window explaining the terms.

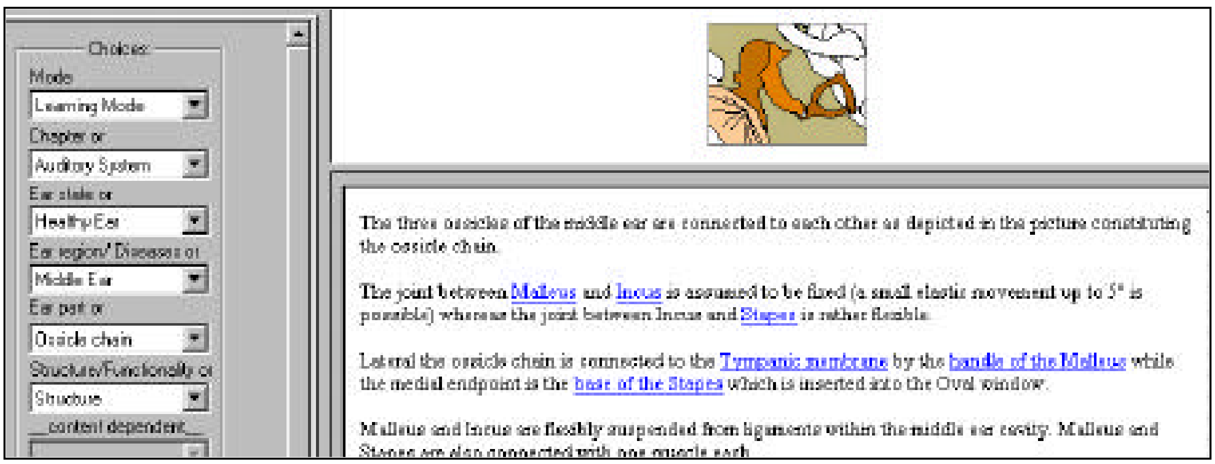

Figure 1. Screen-shot of simulation for Acute Otitis Media in InterSim ear system

4.1.3. Integration of multimedia objects

The InterSim system follows MR approach in integrating multimedia objects for domain content representation. For example, the concept of "appropriate sound energy routing " is presented by two comparative animations. On another occasion, structure of ossicles required representation both as static picture and pictorial VR. Since both multimedia objects have similar initial visual states, not recommended by MR approach for simultaneous use, they are used alternative to each other and the learner can explicitly switch between the two without being confused due to their initial similar states.

5. Discussion and future plans

The use of multimedia technology in educational systems has not been considered much from the view of educational theories. This paper proposed such a consideration in the form of Multiple Representation (MR) approach. The approach has been implemented in the InterSim system using cognitive apprenticeship framework.

There are many areas in which the research demands further consideration. Currently the MR approach is applied only to the disciplines with focus on cognitive skills. The requirements of other types of disciplines and educational scenarios demand different frameworks to work with (for example, Socratic dialogues is one such framework, guided discovery another) and the implementation of Multiple Representation approach would also need to adapt to such requirements.

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