CHAPTER 1

Introduction

The emerging field, E-Learning, is based on a wide range of literatures such as information and communication technology (ICT), educational theory, instructional design, media comparison study, multimedia technology, and computer-assisted learning. We observe that the field has faced the difficult choice between *to improve learners' learning achievements* and *to enhance reusability and availability etc. (i.e., 'ilities') of learning materials*. Since the underlying philosophy of these two considerations is quite different, bridging the gap between the two in practice has become a challenging task to practitioners of the field.

Many works have been endeavored to promote and develop the framework of Learning Objects (LO) to increase 'ilities' of learning materials recently. Relatively speaking, in most current E-Learning systems, the task of improving learners' learning achievements seems to rely *only* and *heavily* on the design of learning materials. Besides learning materials, other essential elements of effective learning such as learning context, leaning guidance, interactivity and adaptivity are not systematically considered in typical E-Learning. Or more precisely, learners' learning achievements are considered only *locally* (i.e., depending on learning material) instead of *globally* (i.e., system-level consideration) in most E-Learning today. In our opinion, learning materials are important but cannot take all the responsibility of improving learners' learning effects. Just like that we cannot expect that every student would learn a new topic well by reading books (i.e., learning materials) herself/himself when the book is inappropriate for her/him.

We recognize that it is necessary to investigate how to design both content and system architecture to enhance learners' learning outcomes under the E-Learning paradigm. It is emphasized that the design of system architecture should support pedagogical concerns of the learning domains, not merely play the role of management. We propose the "Media and Method" (M&M) concerns based on educational media studies to enhance learning. The media concern refers to *cognitive media*, which aims at designing appropriate type of media representation of learning materials as the best means to deliver ease-of-understand presentation of particular domain knowledge to learners [56]. That is, we aim at using computer multimedia appropriately based on cognitive and educational theories. The method concern refers to *intelligent tutoring and adaptivity*, which proposes an appropriate system architecture to import methods from the Intelligent Tutoring Systems (ITS) field (e.g., student modeling) as well as to realize adaptive techniques proposed by the Adaptive Hypermedia (AH) field (e.g., *adaptive presentation* and *adaptive navigation support*). It has been a trend that learners associated with distinct information such as different knowledge, interests, cognitive/learning styles and preferences etc., should be treated adaptively in educational settings for better learning effects. This scenario has been observed by researchers on investigating the effects of human tutoring [19]. Till now it has been known and proved empirically that, human tutoring could be the most effective way to learn. Most practitioners of education would acknowledge that the effect of human tutoring largely comes from its characteristic of adaptivity. By all the endeavors upon ITS and AH, the goal is clearly to improve learners' learning effects. In this research, the purpose of the consideration of intelligent tutoring is to offer learners personalized, tailored learning experience in light of the ongoing adaptive philosophy of education.

The term "intelligent media" is intended to be used in this study to highlight the "Media and Method" concern proposed and employed by this research. By taking advantages of computers' capabilities of computing, computer-based educational system could interact with learners, observe her/his behavior pattern, induce learners' knowledge status, arrange the instructional plan, and adapt the content, presentation, types of media representation to fit to learners' needs further. Since media and method are designed to be integrated meaningfully and compactly, we could use "intelligent media" to describe this kind of integration well. Typical terms like "interactive media" and "computational media" [27] seems to describe this type of human-computer interaction just partially. Whereas it is intended to reveal the implicit

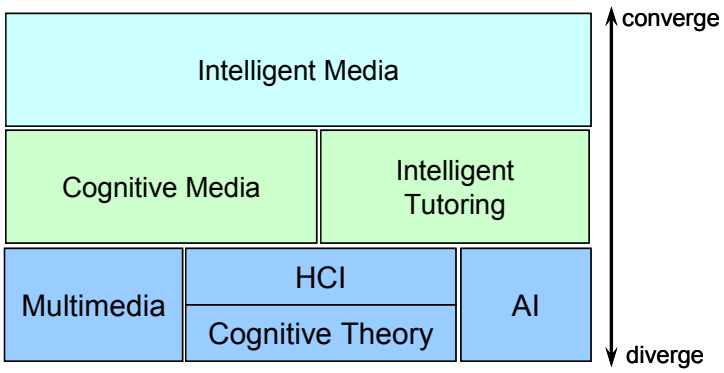

Figure 1. 1: The concept of intelligent media for effective learning

meaning of knowledge communication activities such as user modeling, content adaptation between human and computer systems by using the term, *intelligent media*. The conception of intelligent media is illustrated in Figure 1.1. In our view, the core value of an intelligent media system in education should be the convergence of media representation and intelligent tutoring method which addresses different facets of the needs of effective learning. In this thesis, we use the topic of spatial geometrics as an example domain to demonstrate how to transfer such conceptual convergence into a practical system.

The concept of Spatial Geometric Transformation (or SGT for short) is an important foundation for students to learn advanced computer graphics topics. A syllabus survey in computer graphics education [76] shows that geometric transformations including 2D and 3D are the major topics that most computer graphics educators care about. From the view of learning, this topic possesses two unique attributes:

(1) Spatial reasoning is required. To learn complex geometric transformation (e.g. a series of rotations respect to several axes), learners must construct mental images of spatial relations in their mind, and subsequently manipulate the mental images to assist thinking. Theoretically it is observed that such task is related to each individual's spatial ability. Specifically, instructors also face the problem that it is difficult to clearly describe these abstract concepts without suitable communication tools.

(2) Multiple media representation is needed. For in-depth understanding of this topic,

mathematical descriptions are inevitable. So for clear description of these concepts, *multi-symbol systems* (i.e., multiple representations) are required inherently. At least, the mathematical matrix representation, text-based description and the diagram-based representation are all required.

The requirements of these two attributes (or criteria) may not be easily met by conventional classroom-based lecturing without suitable pedagogical tools. It is also considered that different learners would possess different spatial reasoning skills. But it is neither easy to differentiate learners' subtle variation on spatial skills, nor trivial to personalize the content and styles of the lecture in the scenario of classroom. By the points illustrated above, it is proposed that an adaptive Web-based tutoring system with intelligent media could nicely support learners to learn the concepts of SGT well. Furthermore, this research suggests that M&M concern should be a main basis for better knowledge delivery in Web-based learning environments (WBLE).

From the media aspect of the M&M concern, computer graphics techniques could benefit SGT learning. For abstract concepts that are better to be explained through instantiation and visualization with examples in SGT, text books and typical Web pages tend to clarify them by pictorial diagrams. However, when the concepts imply dynamic processes, what the best text books could offer is only a series of static frames. The difficulty could be nicely solved by employing 3D computer graphics as educational media because of their capabilities of describing spatial concepts and facilitating specific instructional designs. Graphics may have greatly impact on human's perception. Though it is recognized that most students prefer pictorial visual experience rather than typical text medium empirically, we cannot ignore the potential of text, mathematical symbols in learning SGT and other science contexts. Reading, writing, and thinking in these symbol systems are fundamental skills that students should have. Web-based learning should provide appropriate scaffold for students to acquire these skills. We propose to incorporate suitable interactivity between different media in the learning environment for better integration of multiple media representations.

From the method aspect of the M&M concern, as we have mentioned, for effective knowledge acquisition, students associated with distinct information should receive fit-to-size learning materials, including documents, examples and questions. It is specifically noted that

in the task of SGT learning, students with different spatial reasoning and mental visualization skills should be treated adaptively. That is, we import the concern of learners' *spatial ability* and *learning styles* into this research. Adequate adaptive mechanism that can address such a concern is presented here.

Spatial ability is an important factor of human intelligence that is essential to engineering activities and scientific thoughts [53]. Studies in engineering education also indicate that spatial ability might be affected by spatial experiences [3]. Researchers are interested in what kind of activities or instructional design will enhance spatial ability. We have conducted experiments to evaluate the effectiveness of using interactive 3D media to enhance spatial ability. Spatial ability is also a feature to be modeled by the system as well. By employing this feature, the system could adapt and choose suitable media representations to fit to different learner's spatial reasoning skills.

The contributions of this research are:

(1) an explorative notion of using intelligent media based on the Media and Method (M&M) concern for effective Web-based learning,
(2) an architecture for realizing the integration of adaptive mechanism and interactive 3D visualization for learning spatial concepts,
(3) an empirical evaluation to address the relation between 3D media and spatial ability, and
(4) an empirical evaluation on the effectiveness of adaptation based on learners' traits.

This rest part of this thesis is structured in following chapters to elaborate our concepts. In Chapter 2, we review the literature, including both educational and technical aspects. In Chapter 3, the Web-based tutoring system featuring intelligent media, CooTutor, is described. We will describe the overall architecture, the design of its modules and the adaptive mechanism. After describing the system design, in Chapter 4 and Chapter 5, we will present the result of our empirical studies. Two distinct experiments were conducted to evaluate CooTutor from the media representation and the adaptive method aspects. At the end, in Chapter 6, the conclusion and future works are described as a summarization of this research.