



From Multimedia Micro-University to Macro University and beyond

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ABSTRACT

For this special issue of the Journal of Visual Languages and Computing in honor of Prof. Shi-Kuo Chang we review Prof. Chang's research contributions to the field of education. Always visionary and inspirational, these works reflect Prof. Chang's student-centered approach and his interest in building relationships among international educators in order to bring the benefits of such collaborations among educators to the students while keeping in mind the motto "Small is beautiful".

1. Introduction

Prof. Shi-Kuo Chang is best known to the research community for his contributions to the fields of visual language and image database systems – including starting the first scientific conference on visual languages and founding the Journal of Visual Languages and Computing. He has made major contributions to many other areas however, and, in particular, as part of his long career as an educator – more than 35 years as a professor of computer science in U.S. universities including terms of service as Chair of department at both Illinois Institute of Technology and the University of Pittsburgh – education has long been an area of interest. He has performed research with education as the central topic as well as applying his research results from other areas in the education domain. Those of us who have been his students and collaborators know Prof. Chang's passion for education and we might point to his founding of the Knowledge Systems Institute (KSI) as an institution for teaching graduate level computer science using the principles he holds dear – the personal touch and the introduction of students to cutting-edge research, encouraging them to get involved in the same.

In looking at the corpus of Prof. Chang's research in the field of education, a couple of themes shine through – first enabling the means to build international collaborations in teaching and research which will benefit students by exposing them to multiple points of view and emphases from international experts in their chosen field of specialization. This theme, which was evident more than 30 years ago when Prof. Chang brought together a group of researchers from many countries to collaborate in research in visual languages at the early visual languages conferences, is increasingly important in today's diverse and globalized education environments. Second, while wanting to leverage the possi-

bilities brought about by the rise of the Internet and distance education, Prof. Chang has always been concerned not to lose sight of the individual student in this online environment, thus providing a customized and personalized learning experience is necessary in order that the student not be overwhelmed and in order to stick to Prof. Chang's education motto "Small is beautiful". Of course, as one of the pioneers of research in the area of visual languages, the themes of visual interfaces, multimedia, and visual languages and grammars are all interwoven in the research in learning carried out by Prof. Chang.

In the rest of this paper we will provide an overview (not exhaustive) of Prof. Chang's research work in the education area, at times indicating how subsequent developments have vindicated the previous research, while at other times technology has driven practice in somewhat different directions, we will show how the parts fit together, and we will conclude with suggestions for further research in this area inspired by Prof. Chang's work.

2. Multimedia Micro-University

From his earliest research, Prof. Chang has shown an interest in how computer technology can improve education (two of these early efforts are [1,2]). The first of his education research efforts in the modern Internet age concerned what he termed a Multimedia Micro-University (MMU) [3]. The Multimedia Micro-University is built-on the tele-action object (TAO) formalism [4]. TAOs in turn build on the active index formalism [5], where an active index consists of a number of index cells (ICs). The tele-action object formalism is introduced in more detail in Section 3. We will see the active index/index cells used again in the sentient map described in Section 3.1, and also in the research described in Section 6.

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A Micro-university is a teaching or learning environment for an individual teacher/student, designed to optimally serve the needs of that teacher or student. This contrasts with a virtual university which consists of one or more MMUs and embodies a collection of personalized learning environments for a single student interacting with a (virtual) teacher. In the extreme case a virtual university is the same as a single Micro-University, but usually a virtual university contains many Micro-Universities and performs many administrative functions supported by a virtual administration office. The administrative tools include software tools for managing users, curriculum, facilities, resources, plans, etc. Each of the above tools can be used by authorized users.

MMUs can be small, medium or large ranging from a single software module to a complex configuration of software modules. Example MMUs include: Virtual Course-room, Virtual Collaboration Room, Virtual Laboratory, Virtual Library and Virtual Private Office, which operate on a dynamically changing collection of tele-action objects (TAOs) [4].

The Multimedia Micro-University was developed at the Knowledge Systems Institute (KSI) which was founded by Prof. Chang in 1978 to support research and professional education. KSI maintains a limited enrollment and offers courses on evenings and weekends and through distance learning. These characteristics influenced the design of the Micro-University to support KSI's education program and management operations. The components of the multimedia Micro-University consisted of a virtual library, an intelligent distance learning system and visualization and planning tools for the school's operations. The virtual library was implemented with a WYSIWYG paradigm and supported both keyword-based retrieval and visualization of the titles in the (physical) KSI library. The intelligent distance learning system is a complex finite-state machine which uses a knowledge base to model the educational process. It serves as an intelligent communication channel between the author of distance learning materials and the cooperative recipient. Different user roles have different interpretations of the system states, and the system states correspond to four application programs – the Tutor, the Advisor, the Publisher, and the Administrator. The Tutor program provides the course material to the student and then assesses mastery by means of online quizzes. The Advisor facilitates communication between student and teacher. The Administrator mediates and facilitates the logistics of the education process for administrators. The Publisher moves learning materials to a server, updating configuration tables along the way.

The KSI distance learning system was supplemented with multimedia e-books incorporating multimedia elements such as audio and video as well as interactivity.

The administration functions for KSI were facilitated by Multimedia Micro-Universities as well, in the form of visualization tools which give an overview of the school's current status. The whole system is developed using HTML, Java applets and CGI programs.

Planning support is provided through a structured collection of knowledge tables [6] representing goals, plans, expected outcomes, status, and related plans. The knowledge tables are continuously created, updated, evaluated, and revised by key administrators. A tool called the Knowledge Table Editor supports knowledge-table-based planning and evaluation.

The Micro-University was designed, implemented and evaluated by careful measurement of graduate student academic achievement. This achievement was measured quantitatively as part of a preliminary assessment which demonstrated that the Micro-University components already implemented contributed to the learning process at KSI.

It can be seen that much of the functionality of the Multimedia Micro-University has been implemented in Learning Management Systems (LMSs) such as Blackboard Learn and Moodle which have been developed since the research described in this section was carried out. However, it can also be seen that several features of the multimedia Micro-University concept are either lacking or implemented in

different manner in existing LMSs. First, the administrative functions of the Micro-University are often incorporated in separate software tools, while in the research described they are developed on the same Micro-University paradigm. The research also incorporates knowledge through the TAO and knowledge table paradigms which allows for personalized learning experiences which supports the “Small is beautiful” paradigm which is often missing in today's gigantic online distance learning classes. The incorporated knowledge structures also support planning in a unified and organic manner.

3. Macro University

Following the successful introduction of the Multimedia Micro-University, the vision was extended from a single institution to a federation of universities in order to provide the best opportunities for learning and research for students by exposing them to an international array of experts.

Technical and financial considerations in the late 1990s led many academic institutions to set up a web site and start a distance learning program on the Internet. Coupled with a digital library, many academic institutions experimented with the concept of a virtual university. In some countries the local government takes the initiative to form a consortium of universities offering online courses from each institution. These consortia are sometimes called a virtual university or virtual campus. Thus the term “virtual university” sometimes means the distance learning courses of a single academic program, at other times to the distance learning program of an academic institution, and still others to a consortium of distance learning programs.

In [7], the authors argue that establishment of such programs can give administrators of academic institutions unrealistic expectations. Some administrators believe once they have a virtual university, they can greatly reduce the number of instructors and thus become more cost effective. However, they fail to realize the importance of providing an effective learning environment on the Internet, which is not an easy task. Just hosting some courses on the Internet does not provide a learning environment. The students can easily get confused and disoriented, if left alone on the Internet. Beneath the virtual university, there needs to be another layer, offering a student a personalized learning environment. This is where the previously developed concept of the Multimedia Micro-University becomes important.

At the same time, many visionaries have hinted at the possibility of combining the educational resources of a large number of academic institutions, thus creating a super rich learning environment. Without losing sight of the individual student's micro-universe, it is hoped that the coupling and coalition of numerous academic institutions will constitute a macro-universe for the students.

Based on these concepts, Chang and his colleagues introduced a new framework for distance learning consisting of three layers: the Micro-University, the virtual university, and lastly the Macro University. A Micro-University, as described in the previous section, is a self-contained learning environment, usually on a single PC (or notebook, tablet, smartphone, etc.), for a single student interacting with a (virtual) teacher. A Micro-University is designed to serve a single student, but many instances of the same Micro-University can be instantiated to serve many students. A virtual university is a collection of personalized learning environments so that students can engage in learning activities from home, remote locations, etc. A virtual university is usually owned and operated by an academic institution and therefore has more administrative functions than a Micro-University. The Macro University was developed to be a framework such that multiple virtual universities could pool their resources together, thus creating a very rich learning environment for a large number of students worldwide [7]. Macro University was an international consortium of virtual universities. As such there was a wide variety of computational platforms used by students of Macro University. In order to minimize the problems associated with exchange of data in a

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