On designing a global infrastructure for content sharing in mathematics education

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Abstract

This paper describes a set of new technologies, tools, paradigms and infrastructures that have been developed and studied by the KMR group. Based on the emerging next-generation World Wide Web, the so-called Semantic Web, these developments rely on international learning technology standards to support the sharing of digital content for learning and the building of virtual learning communities, especially in mathematics.

1. Introduction

The use of online digital learning resources is a relatively new trend in mathematics education, made possible by the World Wide Web and the availability of many widely supported formats and tools for content creation. The next generation WWW, the so-called *Semantic Web* [2], promises a quantum leap in the usability of such material as it enables advanced computer support for finding, combining and personalizing digital resources.

The KMR group is developing and studying supporting technologies for e-learning on the Semantic Web, and we have applied them to the use of digital learning components for mathematics and to the design of virtual learning communities in mathematics. These tools are specifically aimed at support the sharing and reuse of learning content on a global scale. In this paper, we will try to describe how some of these tools and technologies try to achieve that goal, and some of the potential significance to mathematics education.

2. Background

The fundamental notion that our work rests on is the notion of a *learning component* (sometimes called *learning objects*). Learning components form one kind of digital replacements for – and extensions of – mathematical textbooks, and as such they can be used as base material for

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1 http://kmr.nada.kth.se

creating mathematics courses and curricula. But they have important differences to traditional text book formats. Well-designed learning components, as described in [17], are

- flexible – by allowing many different kinds of learning modules (courses etc.) to be created using the same material.
- reusable – by allowing the same content to be moved and used in many different contexts.
- modularized – by allowing the reuse of small components of the material without requiring all the surrounding material.
- decontextualized – by containing as few assumptions as possible about the pedagogical contexts that the material will be used in[2].

The notion of learning components has become the center of attention for much of the recent developments in e-learning. While there are many kinds of motives behind this movement[3], it remains a challenging hypothesis that the use of learning components can help educators build more flexible learning environments, with more choices for teachers and learners, better personalization features, more complete sources of information, etc.

In our work, we are experimenting with mathematical learning components of at least the following forms:

- Animations showing dynamic mathematics (See Illustration 1).
- Somewhat more interactive material in the form of small computer programs (sometimes called "applets") (See Illustration 2).
- Highly interactive material using sophisticated software that allows interactive real-time manipulation of mathematical relations (See Illustration 3).
- Mathematical texts in various digital forms.

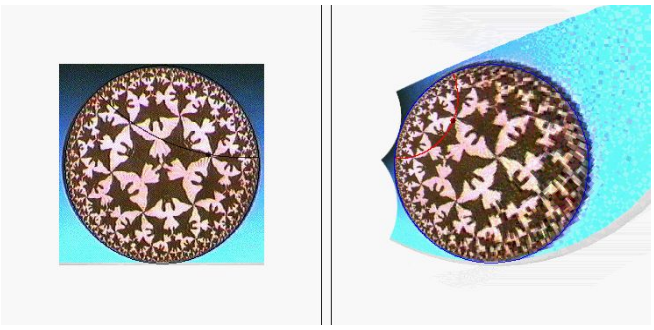

Illustration 1: A one-parameter family of isometries in the Poincaré disc model of the Hyperbolic plane. This is an example of an advanced subject with a strong appeal to students of any age – for its strong aesthetic appeal as well as for its historical importance and its profound philosophical consequences.

2 thus allowing for *recontextualization* into different contexts

3 hopes of large savings in educational expenses, or of diminishing the need for live teachers, are prominent examples.

An important feature of e-learning systems based on learning components is that both teachers and learners can become active producers of educational content. Tools for high-quality content-creation are readily available, and anyone with enough inspiration can compete in quality (but perhaps not in completeness) with traditional publishers. While this has still to work in practice, it has the potential to transform the whole idea of educational content, shifting the power into the hands of the practitioners. At the KMR group, we are actively trying to design our tools in order to support such a development towards what we call *open content*[4].

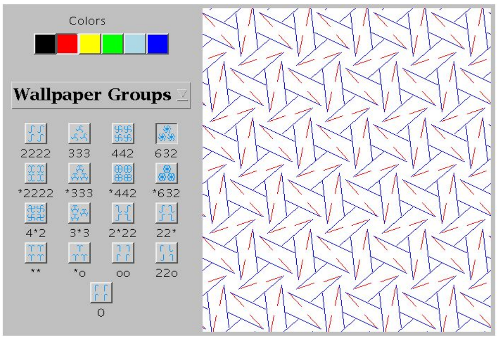

Illustration 2: The JavaKali applet from the Geometry Centre: http://www.geom.umn.edu

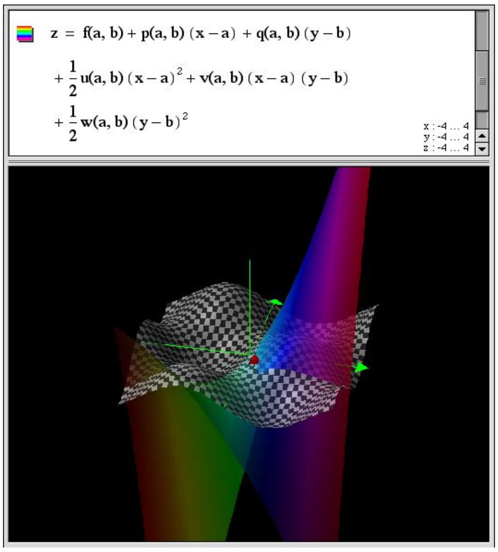

Illustration 3: A session with the Graphing Calculator, playing with Taylor expansions

There are already large sources of freely available material available online. This material is of varying quality, is dealing with various subjects and is available at various costs. One of the central problems when trying to use learning components in a practical setting, is the problem of actually finding relevant material[5].

In order to implement the ideas of sharing and reusing of learning components, a number of technical systems has been proposed as a foundation for what we have called a *public e-learning platform* [8]. These systems are of at least three kinds (taken from [13]):

- *Archives* or *repositories* of learning components, that offer the most fundamental access to and management of learning components
- *Infrastructures*, that makes many archives work together for search, retrieval, and use of the learning components

4 in symmetry to *open source*, i.e. content with a licence allowing for free use and redistribution

5 not to mention all the licensing issues related to *using* the material.

- *Environments*, that bring the low-level technology together into a coherent experience for the teachers and learners. These often combine learning components with collaborative tools like chats, message boards, shared whiteboards and much more.

The rest of this article will describe how the Semantic Web-based archives, infrastructures and environments developed by the KMR group contribute to a global infrastructure for content sharing in mathematics education.

3. Archives – the SCAM repository and portfolio

In cooperation with the Swedish National Agency for Education[6], the KMR group is developing a content archiving system called SCAM [14], which is designed for use in many kinds of situations where an archive of learning components is called for. SCAM is presently being used by the Swedish Educational Broadcasting Company (UR) as the basis for their online digital media library[7]. This archive will contain information about all of the more than 2000 (radio and TV) educational programs produced by UR each year. Moreover, as many as possible of these programs will be accessible online, free of charge.

SCAM is also being used by NoTnavet[8], a project at the Swedish National Agency for Education that provides an online resource for teachers in science and technology. It contains an archive of links to innovative pedagogical ideas in the form of experiments, animations, tests, etc. that can be searched by subject, audience and so on.

The SCAM archive is also being used as the basis for a digital *learning portfolio* system developed under the coordination of the KMR group. Such portfolios can be useful for learning purposes in many ways [3]. The central hypothesis behind their use is that they encourage meta-cognitive activities, which allow the learners to become more aware of their learning progress. SCAM has been used as an experimental web-based digital portfolio system in the teacher education program at Uppsala University as well as in the media technology program at the Royal Institute of Technology[9].

At the KMR group, we have started to build an experimental SCAM-

6 nowadays with the newly formed Swedish National Agency for School Improvement
7 http://www.ur.se => “Sök i mediebiblioteket”.
8 http://www.skolverket.se/notnavet
9 as part of the FolioThinking project [3]

based archive of mathematical learning components[10] of the kinds outlined in the previous section. This archive will be used to support experimental course structures and conceptual learning environments in mathematics. These environments will then be used as testbeds in order to evaluate both technical and pedagogical aspects of the e-learning architectures and tools that we have developed.

4. Infrastructure – the Edutella network

As the number of available repositories increases, the problem of finding relevant sources becomes central to using learning components in practical situations. Not surprisingly, experience has shown that using Internet search engines to find specialized material for a given subject can be time-consuming and is often unsuccessful.

This area has been one of the first to be addressed by international standardization organizations. In this context, the so-called *metadata* standards are the most important. These involve a common *resource description language* suitable for describing learning components, something that has recently been realized in the form of the metadata language RDF[11] as part of the Semantic Web. The Semantic Web represents an important step towards more precise search engines, more intelligent software agents, more cognitively profiled websites that improve accessibility, support for distributed communities and much more [2]. The possibilities for e-learning are intriguing, and remain largely unexplored.

At the KMR group, we are trying to utilize Semantic Web technologies as a way of introducing knowledge management functionality into the design of all our e-learning tools. We have started the international development[12] of a rapidly growing infrastructure called Edutella [12], which is a loosely coupled network of learning component archives, all using Semantic Web metadata. Edutella is a so-called peer-to-peer network, which means that there is no central server where the information is stored. Edutella makes it possible to perform cross-searching of many archives simultaneously, without having to search through each one individually. By encouraging sharing among many small-scale content repositories, anyone can participate in the exchange and, not the least, *annotation* of e-learning

10 available from http://www.nada.kth.se/~amb
11 Resource Description Framework
12 in cooperation with research teams at the Universities of Hannover, Karlsruhe and Stanford

resources. By allowing anyone to participate, even individuals, the learners can be given more control over their learning process, leading us in the direction of a more learner-centric educational architecture.

5. Environments

While the technical infrastructures presented above are very important, they do not in themselves directly influence the learning experience. Within the KMR group, we are developing and researching tools that try to bring together the distributed learning components into flexible interactive learning environments [8]. Such environments may be of very different kinds, but they will all build on the same knowledge management architecture – the Semantic Web.

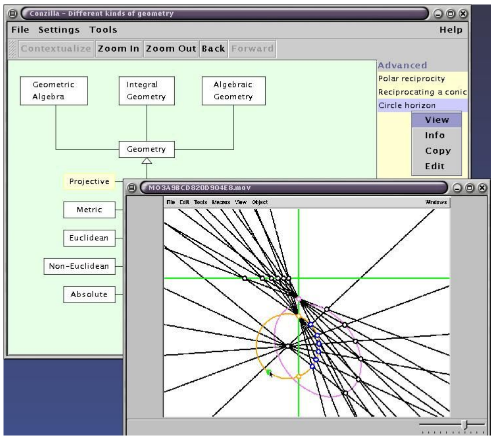

Illustration 4: Conzilla overview of different kinds of geometry, where the present focus is on studying the content component called "Circle horizon" contained in the concept projective geometry

The environments Conzilla – a platform for conceptual browsing [5], CyberMath, a virtual collaborative 3D-space for mathematics education [16], and VWE, the virtual workspace environment [8] are all being integrated into the overarching pedagogical framework of the knowledge manifold [6]. This is more closely described in [9].

Illustration 5: The main exposition hall in Cybermath, displaying a transformation experiment and more

6. Conclusions

The technologies we have described for supporting content sharing in mathematics have only recently started to be usable enough to be tested in real world, not to mention being used on a large scale. However, these technologies, being built on international standards for (machine) knowledge representation, open up fundamentally new possibilities for interaction and content creation on a global scale. With some luck, they might create a foundation for global cooperation on content and curriculum creation on a scale that physical content never could.

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