A web-based learning tool for applied mathematics disciplines

Francesco Giannino[a], Mario Rosario Guarracino[b], Valeria Marina Monetti[a], Loredana Randazzo[a], Gerardo Toraldo[a]

[a] University of Naples Federico II, Napoli, Italy
[b] Italian National Research Council, Napoli, Italy

Abstract

Recently, many efforts have been devoted to the implementation of web based learning tools, that have found widespread diffusion in high schools, graduate and undergraduate universities classes. They enable the fruition of educational materials through a web used user interface and they often implement the same cognitive model that is beyond a traditional course. The aim of this work is to present SIRMM (Searchable Information Repository of Mathematical Models), an interactive environment for mathematical teaching and learning within scientific disciplines.

Keywords: Learning Environments; architectures for educational technology systems; teaching/learning strategies; improving classroom teaching.

1. Introduction

A large amount of projects and material is nowadays accessible online aimed to redesign the educational process throughout the integration of computer and communications technologies (Avgeriou et al., 2001a, b). Nevertheless, the heterogeneity of the different projects around and the lack of portability and adaptability of the developed systems to different educational scenarios are serious drawbacks to achievement of such ambitious goal.

The aim of this work is to present SIRMM (a Searchable Information Repository of Mathematical Models), a new interactive environment for mathematical teaching and learning within scientific disciplines. The goal of the SIRMM project is to provide a mathematical common and unifying framework to teach scientific and technical disciplines such as physics, engineering, biology and finance, in which mathematical modeling and data analysis play a major role. On the other way around, SIRMM might be used in teaching and learning mathematics through real world applications (Greer, 1993; Greer, 1997). SIRMM is not supposed to be a simple collection of problems, rather it is an adaptable Learning Environment (LE) to be used in a wide range of courses.

2. SIRMM conceptual architecture

SIRMM proposes a conceptual framework (Giannino et al., 2004) for the development of a problem solving-oriented learning system for applied science disciplines, in which the main mathematical concepts involved in real word applications are supplied in a unified, flexible and collaborative framework.

SIRMM database contains objects of different types usable in frontal and distance learning processes within standard learning paths. SIRMM has the ambitious goal to support different learning paths for different types of students and subjects field. It implements a learn-by-doing approach, thus yielding the greatest educational benefit. In contrast to traditional science, students are presented with a LE in which they have the option to dynamically create their own study path. Furthermore, students have also the chance of accessing additional information and tools as need arises, stimulating a flow of knowledge.

SIRMM let people solve problems step by step from the easiest level to the most difficult one and provides the possibility of building various modules of information related to every specific issue, and different educational paths; Figure 1 presents two alternative paths. The first one focuses on mathematical issues (calculus and numerical analysis and computational techniques), by integrating application problems in the learning path, whilst in the second one the mathematical concepts support the formalization and the problem solving stage in a technical discipline.

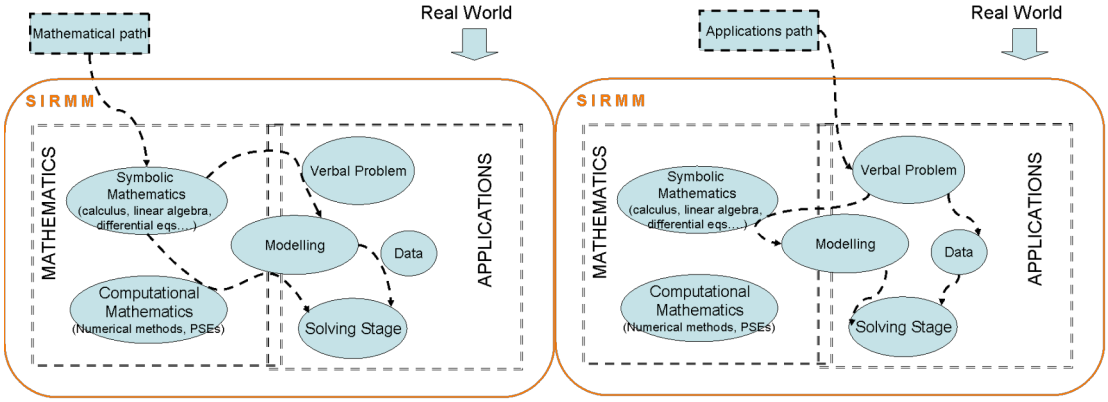

Figure 1. Example of learning paths supported by SIRMM.

The information granularity behind SIRMM substitutes the traditional structure of knowledge arranged in a rigid form, overcoming knowledge separation and obstacles in multidisciplinary approaches. Users identify and browse the Learning Objects (LO) that characterize the steps of a specific learning path as components which may be reused in the comprehension of other problems. Fine-grained modules are reusable for different courses and disciplines, facing the needs of an educator to teach the desired course and convert a module already developed into another one. SIRMM is flexible enough to address changing user requirements and knowledge, and is usable in a variety of contexts.

2.1. SIRMM platform

SIRMM platform is accessible through a web browser (http://www.sirmm.unina.it) that integrates different scientific applied problems. It provides, for each problem:

1. a clear description of the phenomena,
2. a model definition (data, relations, parameters) with the analysis of the mathematical issues,
3. a numerical-computational approach,
4. case studies with analysis and interpretation of the results,
5. links to additional source of information.

2.2. Model database

SIRMM is composed of a set of entities interacting at different levels. In this section a model for those entities and their relationships is given. The design of the learning management system will be derived from this analysis.

Figure 2 provides an Entity-Relationship model. The entity DISCIPLINE describes the scientific area of interest, that is the fields in which the contents of SIRMM are catalogued. Each discipline includes several PROBLEMs, that are identified by a name and a short description. A problem is formulated as a MODEL (possibly more than one), composed, according to Von Neumann, of equations and a description in natural language of what it represents in that context. Each MODEL is identified by its name, and it can be related to different PROBLEMs. The following step concerns the computational solving stage, which involves a SOFTWARE which implements a suitable

solving method for the MODEL, and input DATA. Each SOFTWARE can be either a code (specifically created for SIRMM) or a link to some external PSE or library. Input DATA are given in a format(s) suitable for related SOFTWARE. A specific instance of a problem can be described in natural language and becomes a CASE STUDY. Finally, each of those entities is related to one or more RESOURCEs (i.e. book, article, …), to provide further reading on the topic.

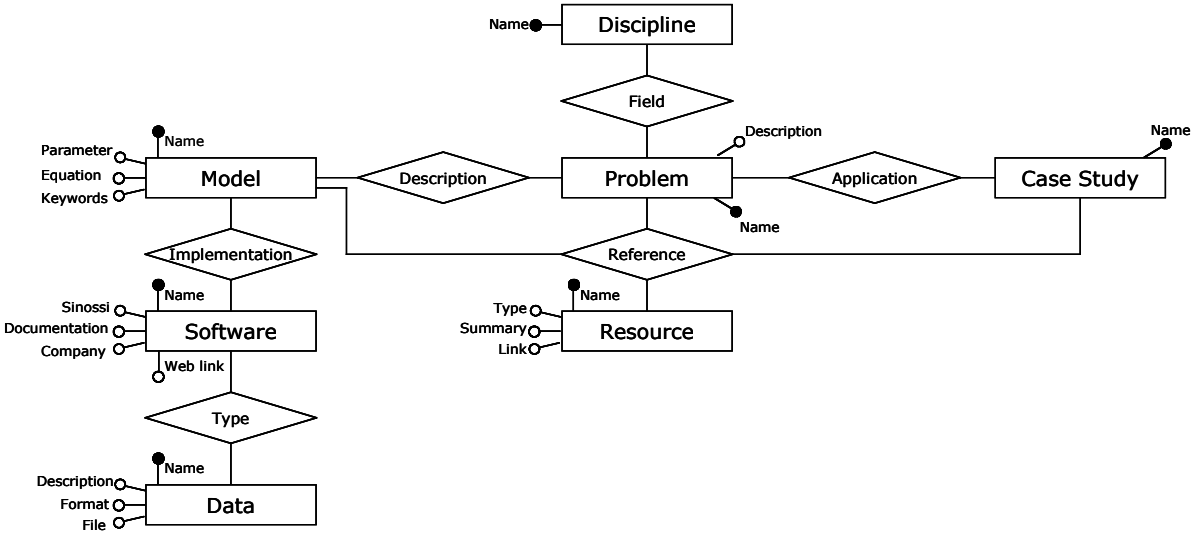

Figure 2. Entity-Relationship diagram.

The logical model of entities and relations induces a model in the navigation of the information stored in the system. Since each entity is in relation with one or more entities, it is possible to start the navigation from each of them. For example, a student can have some data, and he might want to discover which are the software that can accept them as input. As another example, one could start from a particular problem, then studying the available models. For one model one can be interested in a software that implements an algorithm that can solve the model for given data. For each model auxiliary information can be accessed, such as references, slides, books, for a better understanding of the topic.

3. Using the system

SIRMM includes three types of users, with different roles, and therefore authorization levels: *consumer/student*, *producer/teacher* and *administrator*. The *consumer* is a user that navigates the system, he can read all records/forms of the database, search information and download files; he is in general a student that uses SIRMM as an interactive learning system, and he does not necessarily need to be authenticated by system. The *producer* is a user that can add information and data in the SIRMM database; usually he is a teacher who wants to insert and share (LO) and therefore needs to be authenticated from the system. Obviously a producer can modify only the LO that he has previously inserted. In addition, using the data of SIRMM the producer can build his own e-learning course. Finally, the *administrator* is in charge of all system management tasks, such as the authentication requests.

This structure has be implemented into SIRMM through three main sections: *Navigate*, *Contribute* and *Course*; any LO in SIRMM system can be accessed by the consumer (*Navigate* section), inserted and modified by the producer (*Contribute* Section). The producer can also produce an e-learning course, through a logical path which includes LO belonging either to SIRMM or to the external world (*Course* section). Figure 3 shows the flow of information and activities into SIRMM, with the roles of the different kind of users.

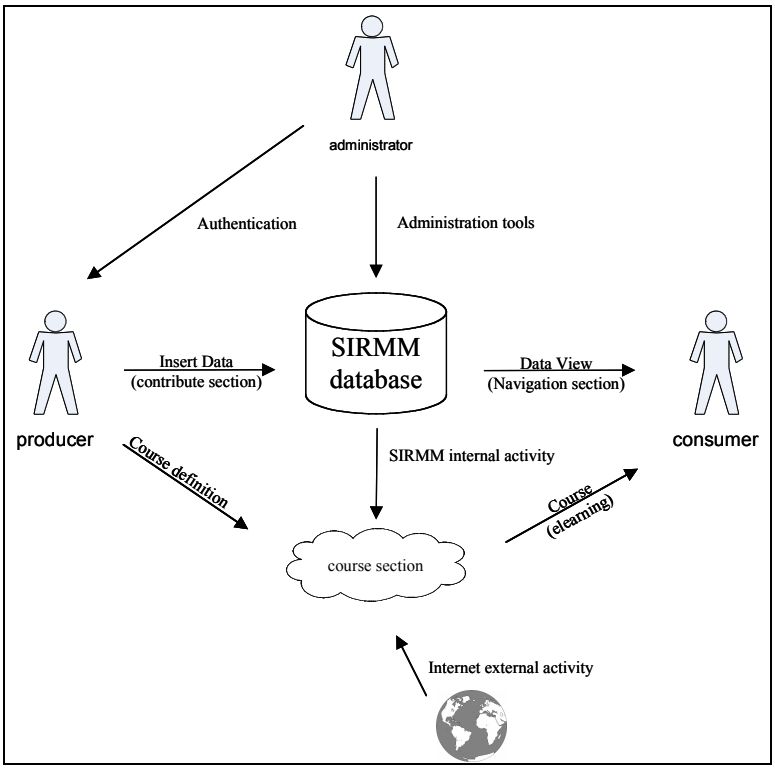

Figure 3. SIRMM using interfacing structure.

The web interfaces provided by SIRMM have a rather simple full-screen menu structure (Figure 4), that includes:

- The *Horizontal menu* at the top of the screen which offers access to the functions that allow to use the system: starting from here, the user can either *Browse* through the system by accessing to information repository, or to *Contribute* with a new record or new *Courses*. In addition, the *Download* of external resources is allowed.
- The *Side menu* enhances the system navigation. It works dynamically and, at each moment shows only the entities that are related to the record of database that is currently displayed. For instance, if the user is accessing the information about a specific *Model*, then only *Problem*s, *Resource*s and *Software* links.
- The *Page content,* i.e. the area of the graphical user interface in which records are displayed.
- *Bottom bar* contains links to the Site Map and to the Contact us section. If the user has logged in as an authorized producer, it will display links to change user settings and to logout.

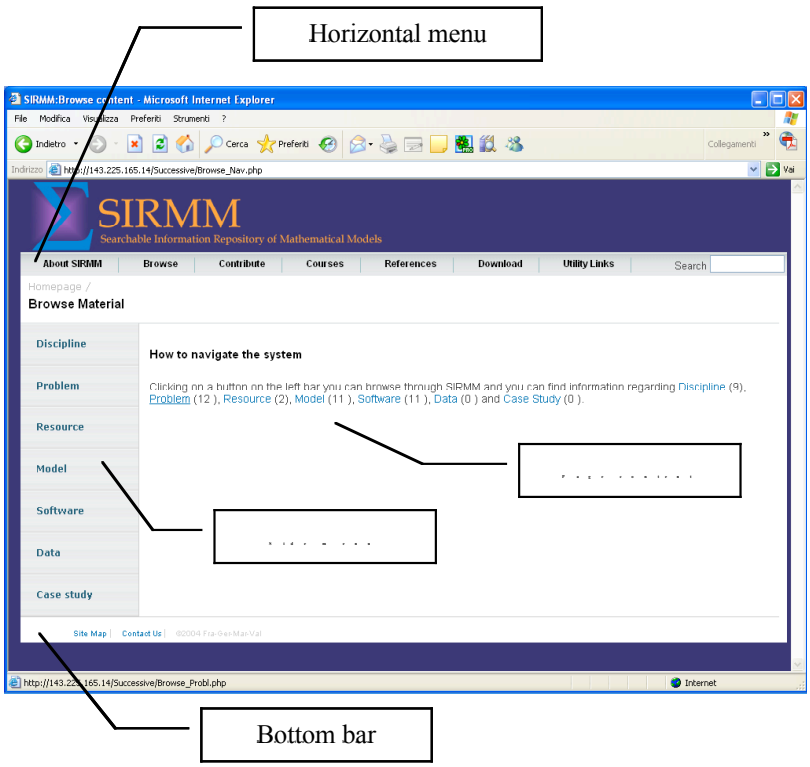

Figure 4. SIRMM user interface.

3.1 Navigate Section

The navigate section allows to browse all elements of the SIRMM data base. It is possible to navigate the system using the side menu (discipline, problem, resource, model, software, data, case study). When a specific instance is chosen the names of all related instances are shown, and the user can access their information. Figure 5 shows a software instance (SIMILE, for system dynamics problems), in which it is possible to see the hypermedia web page with text, images and mathematical formulas. Moreover the side menu links directly to LO related to such instance, so to enhance possible interactive educational paths to the users.

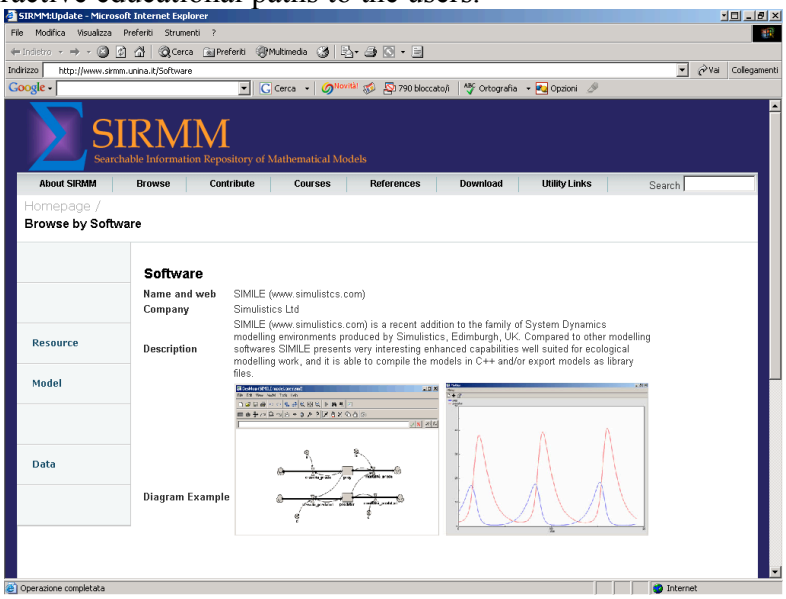

Figure 5. SIRMM software instance.

3.2 Contribute section

The Contribute section of the system provides forms to insert or update elements in the system database. Once the user has been authenticated, he can add records to any entity in the database. He can use an improved version of the rich text format editor of the Wikipedia project (http://www.wikipedia.org/) to edit text, images and formulas. Formulas are inserted in the Latex mathematical environment syntax. They are then stored in the database and displayed either as gif images, or as MathML formulas, depending on the browser functionality. Moreover it is also implemented a *formula preview* window (Figure 6).

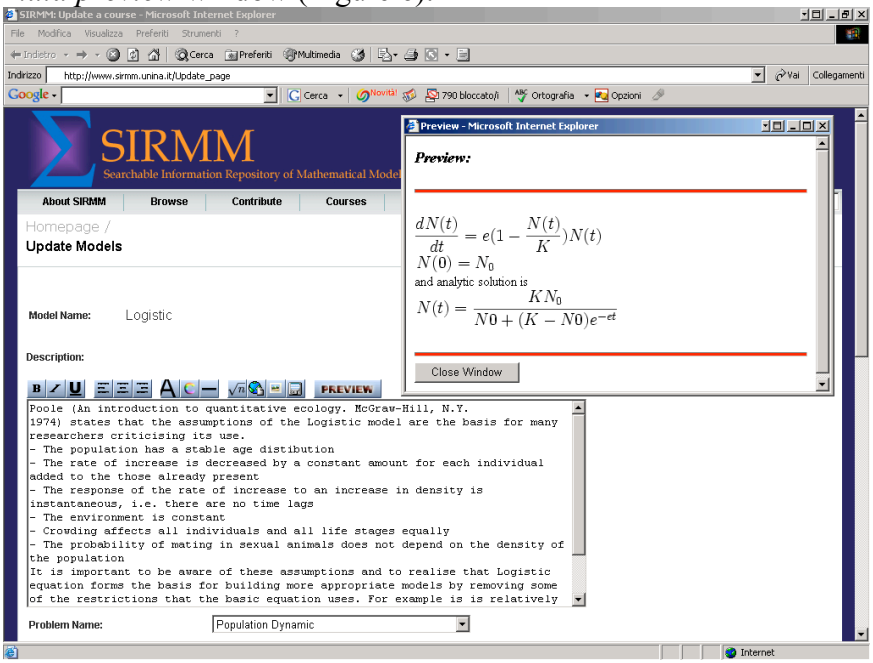

Figure 6. Update page of Contribute section.

3.3 Course section

The *Course section* allows the consumer to access a course which has been already implemented in the SIRMM framework, while the producer can either modify his own course, or build a new course, possibly a modification of an already existing e-learning course. A SIRMM course is composed of two parts: a web page of information (name, teacher, schedule, credits, faculty, …) and a list of activities. Any activity is a link to a web page: an internal link to LO of the SIRMM database or an external link to other www pages.

4. Conclusions and future work

Making easy a mathematical modeling approach to scientific disciplines at every educational level is a goal to be pursued in a modern scientific and technological education process, in which students are required to incorporate applied mathematics and computational tools in their learning process. In this paper we presented the main ideas behind the SIRMM project, aimed to supply a mathematical modeling framework for teaching technical disciplines. SIRMM is still at a prototype stage, and there is still much work to be done, both in terms of system development and database feeding, in order to improve user interface, level of functionality and possibility to implement real courses. However we strongly believe that the project is worth to be carried on, in order to match the needs of the technologically advanced world demands people able to use technological and computational tools, to correctly analyze data, to efficiently support sustainable decisions, to test conjectures, and to develop scenarios of complex systems through a process of modeling and synthesis of the real world.

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