

# Curriculum visualization in 3D

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## ABSTRACT

This paper describes a 3D environment for representing a university undergraduate education programme. More specifically, the curriculum data selected for representation, how they are visualized in the 3D environment, and the process of generating it are detailed. Modules and curricula have been rendered in such a way that many numerical data, such as credits and duration, are translated into a graphical form, resulting in a simple and intuitive overall view. This effective visualization strategy provides added-value in comparison with the more traditional textual presentation. The 3D environment, based on the X3D language, is dynamically generated from a database thanks to an XSLT transformation. The use of a powerful XML based Web publishing tool, i.e. Apache Cocoon, allows this transformation to be easily performed “on the fly”.

## Categories and Subject Descriptors

H.5.2 [Information interfaces and presentation]: User Interfaces – *Graphical user interfaces (GUI)*.

I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism.

J.1 [Computer Applications]: Administrative Data Processing – *education*.

## General Terms

Languages, Design, Human Factors.

## Keywords

X3D, curriculum visualization, dynamic XSLT transformation, city metaphor.

## 1. INTRODUCTION

University web sites usually present their education programme in a textual form, such as lists of course names and descriptions, which difficultly provide an overall picture of what the real training offer is to potential students.

This is the case, for instance, of the University of Applied Sciences of Southern Switzerland (SUPSI), that presents its bachelor and master programmes in a textual form, both on paper in the study guide, and digitally in the Web site. On the Web (<http://www.supsi.ch>), general information is provided through

HTML pages, while additional details about the specific curricula are contained in PDF documents.

Because of the recent re-organization of the European higher education system according to the Bologna model (<http://www.europaeum.org/content/view/58/65/>), a major restructuring of courses and curricula has been undertaken in the SUPSI bachelor programme. There is the need to provide students with a vision that is, at the same time, immediate, clear and complete of the different training possibilities of the education programme.

In order to find alternative and more effective ways of representing the SUPSI curricula on the Web, information visualization techniques have been considered. “Information visualization aims to produce graphical representation of abstract information structure for human users” [Geroimenko and Chen 2003]. Visualization is a representation of some aspects of the underlying information, where the main questions are what to represent and how to represent it [Goguen 2003].

On the basis of this premise, our main objective was to choose which information to consider for representation, and how to represent it, i.e. which spatial metaphor to use in order to make it really meaningful and easy to use.

Polys [2003] discusses general visualization design principles, stating that primary factors in visualization design concern both human factors, e.g. the user’s purpose and expertise, and the data features, e.g. dimensionality, type, scale, range and attributes of interest. Therefore the design choices for the 3D environment derive, on one hand, from the study of target user needs and, on the other hand, from an analysis of data to be represented. The final target users of the SUPSI 3D world are mainly students who are interested to explore and compare the different training offers, and, in smaller part, people responsible for the education system organization who want to check soundness and structuring of the course organization and training offers.

Information of the SUPSI undergraduate education programme is collected in a complete and detailed way, in a large database, born and used mainly for management and administrative purposes. In this dataset, our goal was therefore to identify the most interesting information for students and to find out an appealing and effective way to present it. In the process of mapping data into a visual presentation, the primary concern is to enable the user to detect patterns and relations within the data, minimizing the user cognitive effort. Another concern is reducing the click number, i.e. time, which separates the user from the information he/she is interested in.

From a practical point of view, an important issue was to find the most appropriate technology for visualizing these data on the Web. X3D (Extensible 3D Graphics) has appeared to be a good candidate, being the standard for delivering interactive 3D graphics over the Web [Geroimenko and Chen 2005]. X3D

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(www.web3d.org) is based on the XML language, and represents a universal interchange format for integrated 3D graphics and multimedia. Taken into account our objectives, X3D represented a very valuable choice, above all because it can be dynamically and automatically generated.

Once decided that data had to come from the database and their visualization had to be in X3D, the next step was to define the mapping or transformation process. The choice was to expose data in XML and dynamically transform them to X3D by using an XSLT stylesheet. The XSLT use has demonstrated to be a powerful mechanism to render XML contents on the fly in X3D. An example is the application of a stylesheet to transform a Chemical Markup Language (CML) file of the cholesterol molecule to X3D [Polys 2003]. The chosen visualization in this case is based on a visual representation already used in the chemical domain, therefore intuitive and easily understandable, because there is an analogous counterpart in the real world. In the education domain there is not an obvious spatial mapping for courses and curricula; the goal here is to find a graphical presentation that is representative, intuitive, and corresponded to the real user needs. At the same time the 3D world has to guarantee good performance (e.g. short response times) when the user navigates and interacts with the world objects. An excessively complex and rich 3D world has an impact on the final performance.

The next section describes a 3D environment for representing the SUPSI undergraduate education programme.

## 2. THE SUPSI 3D ENVIRONMENT

The idea of representing the SUPSI education programme in 3D derives from a previous work developed in 2003 with Java 3D [Cresta and Giulieri 2003], in which data were taken from an XML file and directly translated to 3D. At that time, the database did not exist; it was successively developed in a SUPSI internal project (ProgettoScuola, 2005), on the basis of a preliminary implementation used for presenting curricula information on the Web in HTML and PDF formats [Cresta 2003]. The graphic visualization with Java 3D were satisfactory, but the performance was poor. As the amount of data to be represented increased, the system was low and heavy to manage, showing interaction drawbacks. The system was not able to load even less than 50 courses.

Due to the Java 3D performance problems, and the limited hardware resources available when the application was developed, the need for a different solution emerged. The X3D language, for the features outlined above, was chosen as the language for formalizing the 3D world.

In this section the data selected to be represented in X3D are firstly presented. Then, how these data are rendered in the 3D environment is described; finally, the process of generating the X3D world is detailed.

### 2.1. The SUPSI undergraduate programmes data

SUPSI is one of the seven Switzerland Universities of Applied Sciences, and hosts about 3000 students, including bachelor and post-graduate and more than 400 employees. It is organized in various departments: DACD (*Dipartimento ambiente, costruzioni e design*), DSAS (*Dipartimento Scienze Aziendali e Sociali*), DTI (*Dipartimento Tecnologie Innovative*) and DSAN (*Dipartimento Sanità*), covering different domains. Each department offers a number of bachelor programmes, called here *curricula*. For

instance, the DTI department provides the *Elettronica, Informatica*, and *Tecnologia delle macchine* curriculum. Each curriculum consists of different modules, for a total of 180 credits (ECTS), leading to three-year bachelor degrees in different areas.

All data concerning departments, staff, curricula and modules are organized and stored in a Oracle relational database.

### 2.2. The SUPSI curricula in 3D

A subset of the data contained in the database are automatically extracted to produce the 3D world. The SUPSI modules are visualized in a virtual environment based on a simple geometric metaphor, a simplification of the city metaphor. Each department is a district (see Figure 1). Each curriculum of a department is a block in the district (see Figure 2), divided in 6 areas, one for each semester (s1..s6). In fact, the bachelor curricula are three year long and are organized in 6 semesters, two per year, the winter and the summer term.

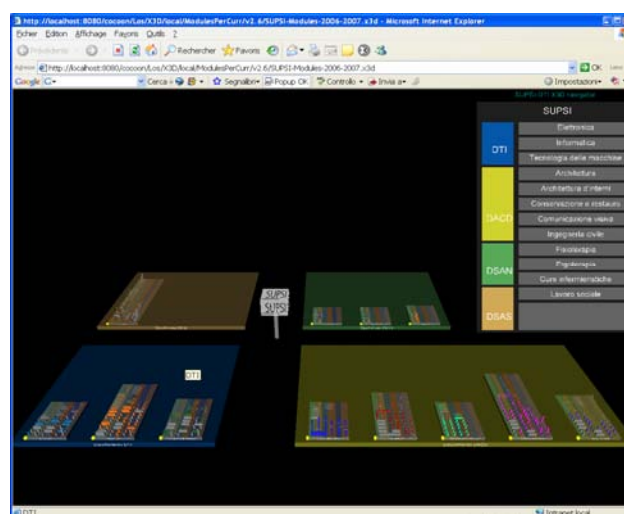


Figure 1. Overview of the SUPSI 3D world with the four department districts.

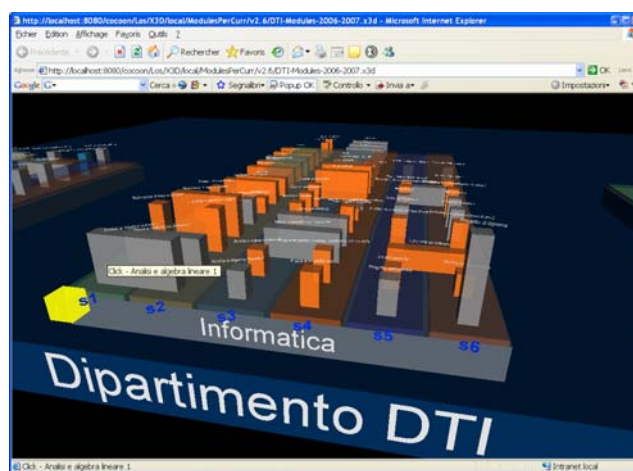


Figure 2. Curriculum block of a department showing modules aligned in semesters.

Each module of a curriculum is a building of the block, temporally located on the appropriate semester area, and labelled on top with the module name. It is represented as a box, whose sizes depend on some module attributes. The module height is proportional to the number of credits, while its width depends on the module duration, i.e. how many semesters it covers. In addition, modules are active objects; their activation, with a mouse click, shows an information panel above them that provide additional information: exact duration, credits, curricula to which the module belongs, courses, etc. (see Figure 3).

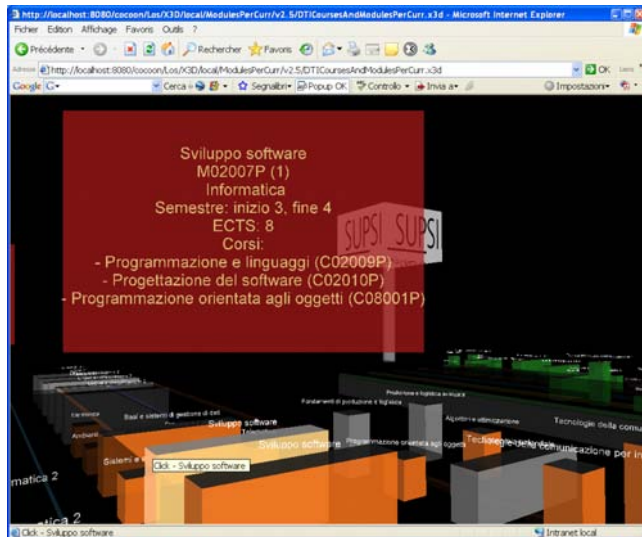


Figure 3. Visualization of module details in the information panel.

The spatial location of modules on the curriculum platforms also allows interesting comparisons to be made between modules in the same curriculum or in different curricula. For instance, it is immediate to know which modules last for more semesters, which curriculum has more modules, etc.

The choice of colours in this virtual environment aims to provide supplementary clues, in addition to those given by textual information, to retrieve and recognize modules in the city. Each department identity is characterized by a particular colour (e.g. blue for DTI, light green for DSAN, etc.), inheriting the colours already used in the SUPSI web site. These colours are used in the 3D environment for the department platforms. Moreover, the different semester areas are also distinguished by different colours, using warm colours for summer semesters and cold colours for winter semesters.

Modules belonging to the same curriculum have the same colour. An exception is represented by those modules that are shared among different curricula, which are distinguished in grey. In addition, in the information panel the list of curricula which the module belongs to is reported.

Although text and colours represent useful orientation and navigation clues, sometimes it may be still difficult to localize or retrieve a specific module in a world which contains more than 500 modules, or even in a small curriculum of about 50. Therefore other alternative navigation mechanisms are provided. Firstly, a navigation menu with the list of all curricula organized by departments is always visible. This tool has been added to

meet a fundamental user need: students are primarily interested to see the bachelor programmes, i.e. curricula SUPSI offers. Therefore the primary access key has to be the curriculum. The navigation menu is implemented as a head-up display (HUD), i.e. is a semi-transparent object always located in front of the user and within his/her field of view (see Figure 4).

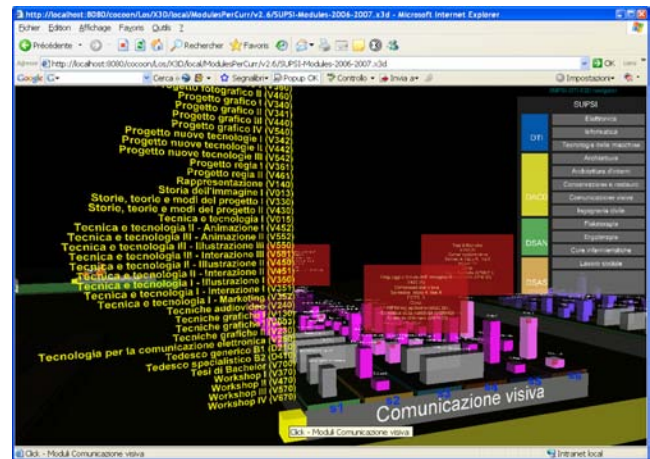


Figure 4. HUD and active list of curriculum modules.

Navigation is mainly based on viewpoints defined for departments, curricula, and modules. It is worth noting that almost all objects in the world are made active. The platforms of both departments and curricula, labelled with the corresponding names, are buttons which, activated, allow the user to navigate towards the corresponding object. In order to make the access to single modules easier, in addition to the spatial navigation provided by the 3D world browser, a more direct way has been given through an active textual list of the module names and IDs. Clicking on a yellow box button located on the curriculum platform opens the whole module list of that curriculum (see Figure 4).

As a final consideration, it has been noticed that in some cases the global vision of all the curricula of all the departments may not be necessary, because the user is only interested in the curricula of one department. In this case it is possible to load in the page only data related to the selected department, enhancing the response time focusing on a reduced complexity world. This is obtained thanks to the pipeline mechanism of the Cocoon tool, described in the next section.

### 2.3. The process of generating the 3D environment

The 3D environment is directly generated from the database in a two-step process (see Figure 5). Firstly, data are extracted from the Oracle database and converted into an XML document. Secondly, an XSLT transformation takes the XML document as input and produces an X3D file.



Figure 5. From the database to the 3D file.

The XSLT stylesheet contains template rules that match the different XML elements, and consists of about 1000 lines. It is quite complex, because it contains most of the logic of the X3D generation, leaving the process of data extraction from the database simple. The XSLT stylesheet includes recursive functions and scripts to deal with the need of the 3D world.

It is worth noting that the same XSLT stylesheet is used, through parameter passing, to transform data of a single department and of all the departments. The resulting X3D file, which includes all the departments, is heavy to visualize (2 MB) compared to those produced for the single departments.

Concerning the X3D source, the declared profile is *immersive*, i.e. with support to full navigation and environmental sensor controls, and the specified X3D version is 3.1. This file contains the geometry objects of the 3D world, such as boxes corresponding to modules, curriculum, etc. In addition, the X3D event model is exploited in order to provide interactivity by means of scripts in ECMAScript language, and scene behaviours via routing of events (<ROUTE>).

The X3D file is visualized in a browser. Thanks to SAI (Scene Access Interface), which specifies a standard set of services that are made available by a browser, an author can access the scene graph while it is running. Such access is designed to support interaction with, and modification of the scene-graph, and it is exploited in our world to produce scene changes and interactivity. Due to the limited support for the X3D standard by Web browser X3D plugins, it was not possible to exploit some of the X3D features, such as new geometry generation for the module information panel display.

The two step process is managed using Apache Cocoon (<http://cocoon.apache.org>). This tool allows dynamic on the fly generation of X3D files serving them on http as “model/x3d+xml” mime type upon user requests. The cocoon pipeline for this process is summarized by the following procedure.

1. the server receives from the end user’s client the http request for data about a single department or all the departments, also specifying the academic year;
2. the server extracts from the database data of the selected department or extracts and aggregates data of all the departments, according to the client’s request;
3. the server performs a transformation by applying an XSLT stylesheet to the extracted data, producing the X3D scene;
4. the server performs an XML serialization, returning the X3D file to the client, via the http response.

The procedure adopted in Cocoon is an easy and efficient way of separating the data layer (i.e. the Oracle database) from the logic (XSLT transformation) and the presentation (X3D) layers, and producing a 3-tiered Web distributed application.

### 3. CONCLUSIONS

In this paper our experience of visualizing SUPSI bachelor programmes in 3D, using the X3D language, has been described. Modules and curricula have been rendered in such a way that many numerical data (e.g. number of credits, duration, etc.) are translated into a graphical and visual form, resulting in a simple, effective and intuitive interface. This effective visualization strategy provides added-value in comparison with the more

traditional textual presentation, by highlighting a comprehensive overview of our world.

A remarkable aspect is that the 3D environment is not statically created, but it is dynamically generated, starting from real time data, thanks to the application of an XSLT stylesheet providing an always updated view. The separation of content from presentation provides a great deal of flexibility in re-organizing and re-publishing data. In addition, the use of a Web publishing tool such as Cocoon allows transformations to be performed “on the fly”. Whenever data in the database are updated, their 3D visualization is automatically modified.

A preliminary evaluation was conducted by two usability experts who judged the environment on the basis of some heuristics: content, navigation, interface design and technological aspects. The results indicate that most of the relevant contents are presented and some further details may be added, e.g. lecturers, course syllabus, etc. Concerning navigation, it is quite intuitive to know navigation directions to reach a specific place in the world, but sometimes it is not obvious how to use the X3D navigation functionalities, because commands and shortcuts are dependent on the specific X3D player plugin. An unfamiliar user may easily get lost or find him/herself far from the desired place. The interface design appears to be simple and intuitive, even if sometimes information is not easily readable. This is also supported by the fact that the system does not require particular instructions to be used and the learning time for using it is very low. The use of a lot of active objects helps in this task and provides self discoverable functionalities, such as getting closer to a department platform by simply clicking on any part of it. Finally, it has been noticed that the system requires a considerable time to load information, but it is quite robust and error free.

In the future the 3D environment will be evaluated by real users (empirical evaluation), who will provide feedback and suggestions for improvements and future developments.

In order to better exploit the potential of the graphical visualization environment, increasing its usefulness, some new features are envisaged: for instance the possibility to graphically link modules which are shared among curricula, or highlight modules which are propaedeutic to the currently selected module.

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