CONTS

An e-learning platform for the domain of Mathematics and Sciences.

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A mathematics and science domain e-learning platform IWT based.

Abstract

This paper has the purpose to introduce an e-learning platform specially tailored for the Mathematics and Science domain.
The starting point for the realisation of the domain platform is IWT (Intelligent Web Teacher), an e-learning platform designed to be easily extensible both for contents and services.
The Mathematics and Science platform provides the users with a flexible tool for teaching and learning in the fields of mathematics and science. For the realisation of such features, we have equipped IWT with tools useful to data presentation and data processing of mathematical-scientific data type.

1. Introduction

The experience acquired in the field of e-learning suggests us that to be able to offer a high quality didactical support in the field of Mathematics and Science, it seems not enough offering some good contents via web, but it is necessary to translate tools and methods characterising that particular domain within a new didactical context.

To meet this requirement, and all the matters connected to it, it has been designed an e-learning platform : IWT [CRMPA White Paper, 2002], which realises a modular and extensible software architecture so to be taken as the basis for the construction of a virtually infinite set of e-learning applications, both traditional and innovative.

The strategy we have followed for the realisation of the Mathematics and Science domain platform, from hereinafter called *Math-IWT*, has seen, as its first step, the individualisation of an initial set of tools to integrate in the platform as a support for the formative process. After a first analysis of the software and tools supporting the mathematical and scientific subjects we have decided to initially integrate inside the platform the WebMathematica engines for numerical and symbolic calculation, the optimization software XPress-MP and the NAG software libraries for mathematical software.

The following step has been that of specialising the *Math-IWT* with applications able to facilitate the learning process. For this purpose, the platform allows the user to easily manage objects containing mathematical formulas. All the IWT communication channels between teacher and learner (messages, chat, forum, etc.) have been extended in order to allow the editing of formulas by MathML or TeX standards and the visualisation of mathematical expressions in a symbolic way.

2. What is IWT

IWT is a distance learning platform for the learning personalisation in according to the user's real needs and preferences, which also guarantees extensibility and flexibility features not only at the content level, but also for the functionalities and, mainly, at a higher level, for strategies and models.

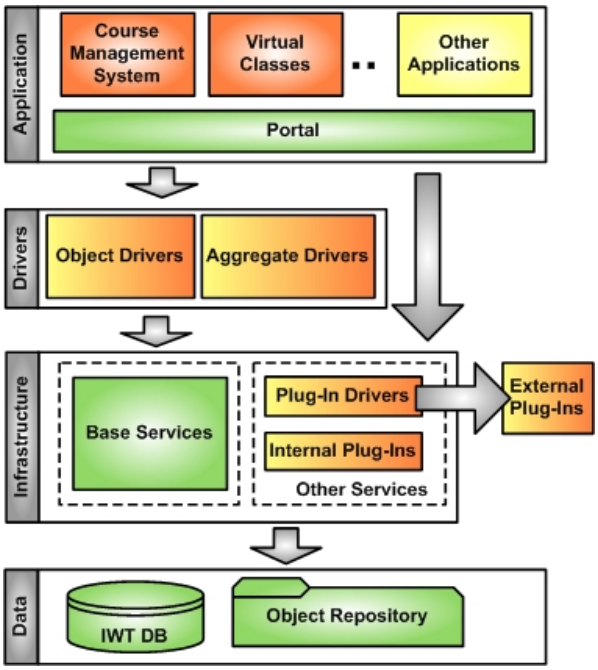

Figure 1: IWT Logical Architecture

IWT is a very complex platform, in this paragraph, besides a short description of its fundamental modules, we will describe in detail all the components involved in the base platform specialization process towards the *Math-IWT* domain platform.

The logical architecture of IWT is subdivided into four layers, as reported in the figure 1.

Starting from the bottom the first layer is the Data, which provides all the mechanism necessary to persistently store the learning resources. It is constituted by two memory tools, the first one, named Object Repository is a file system used to storage all the information and data of to a given user. Each user registered within the platform obtains the access permission for reading and writing the folders he has been assigned. All the learning material is stored inside the Object Repository as file and folder. The second storage mechanism is a relational database named IWT DB. The data of the account of single users, user groups and all the information necessary to indexing (metadata) the learning material inside the Object Repository are stored here.

The second layer is the Infrastructure, which, besides offering a set of base services for the higher layers, also provides the capability to extend the set of base services with other services (Other Services). Among the base services there are also those relating to the management of the access to the portal areas (roles) and of some collaboration aspects. Among the latter, in particular, the following areas are available:

Discussion Forums. This area allows the users to exchange prearranged discussions. Each user may add an “entry” to the forum or add comments and replies to the “entry” already inserted by other users. A forum can be connected to a system group and be accessible, for instance, by all the students of a course or only by intra-course and inter-course working groups.

Messaging Management. It is a messaging system inside the platform which allows the system users to send private messages to other users or, by broadcasting, to system groups. The user has at his disposal various management possibilities in his message box (read, reply, delete, send, etc.).

News Management. It allows to manage a sort of information showcase available for the system users and the visitors.

Chat. It allows the synchronous collaboration between the system users that are contemporarily connected. The chat is divided into “rooms” and to each “room”, a system group corresponds.

In IWT, the Other Services are represented as Plug-Ins. A Plug-In is an additional module which once installed inside the platform provides new services having a general purpose or depending on a particular didactical domain. The Plug-Ins can be of two types: Internal Plug-In and External Plug-In. The first type does not need external resources to provide its services to the higher layers, while the second one needs the functionalities offered by a component which is external to the platform to realise the required services. In this second case the Plug-In is composed of the Plug-In Driver/External Plug-In couple, where the Plug-In Driver allows the higher layers to access to the functionalities of the external component analogously to the internal services.

The third layer of the architecture are the *Drivers*. The components of such layer manage different kinds of didactical material that can be used in IWT. Also the Drivers level can be extended to manage new typologies of teaching objects

(Learning Object LO) thanks to the installation of suitable modules named Object Drivers. In order to manage the new LO the Object Driver exploits all the services at the infrastructure level. Besides the Object Driver in the Drivers layer, also the Aggregate Drivers can be installed, through these latter it is possible to manage complex didactical objects deriving from the aggregation of more LOs.

The highest layer of the architecture is the Application, in which there are the specific applications we want to realise in the IWT platform (for instance Courses Management System, Virtual Classrooms, etc.).

3. Extension of functionalities and typologies of the IWT contents

The extensibility at the functionality level is realised using the *Plug-in / Plug-in Driver* couple which allows the tools *wrapping* for the scientific calculation of third parties making their functionalities accessible to IWT as services. Besides the functions of communications interpreting and managing between IWT platform and calculation engine, the *Plug-in /Plug-in Driver* couple, when necessary, also foresees additional functionalities for the management of the calculation software database or, more in general, of data which it will access to in the processing phase.

The integration of the calculation engines in IWT has the main purpose of supplying new LOs to be used in the teaching of Mathematics and Sciences. From the IWT viewpoint a LO is a complex object stored in the database (IWT DB + Object Repository) of the platform in which, by simplifying, there are some “data” and “meta-data” for the description of “data”. In particular (just as it happens for WebMathematica) the area “data” usually contains the necessary information for the processing the calculation engine carries out.

The integration of a new system with the IWT platform, generally allows new types of LOs that make use of specific functionalities added to the platform. In IWT this is possible by extending the contents typologies managed by the platform through the definition of a new LOs typology (for example, referring to the specific case of WebMathamatica, the WM-LO typology) and the construction of suitable *Object Drivers* responsible for the creation, presentation and management of the designed resource. The *Object Driver* works well in this operation since it is able to communicate both with the *Plug-in Driver* (in general also with more than one) which makes it able to use the new functionalities offered by the calculation engine, and with the services provided by the platform for the LOs management.

The last problem to take into account in the design of the *Plug-in Driver* and the *Object Driver* is that of the Front End towards the final user. Generally, every tool for the scientific calculation offers its own GUIs (Graphics User Interface) for the interaction with the user. The GUIs can reach different complexity levels passing from simple visualization tools to more complex software able to catch and manage events generated by the user by means of his keyboard, mouse etc. Normally the GUIs and the calculation engine communicate through their own protocol. In the calculation engine integration with IWT we do not only need to transfer the GUIs essential features of that particular calculation software towards the final user, we also need that all things are suitable with the IWT *Delivery* features. In IWT the GUI is obtained through the construction of panels or *UserControl* supplied by the *ObjectDriver* and by the *Plug-in Driver*.

The GUI necessary to the creation, editing, presentation and management of LOs is supplied by the *Object Driver* which returns to the portal a UserControl according to the specific operation we want to accomplish. In generating the interface, the *Object Driver* can require the support of the services provided by the *Plug-in Driver*.

Instead, the GUI necessary to the management and control of the *Plug-in* and its specific functionalities is supplied by *Plug-in Driver* through a set of panels.

4. The Math-IWT domain platform

The domain platforms are based on the general platform and offer a series of resources depending on the disciplinary domain we choose or on the considered contents typology.

The Domain Platform for Mathematics and Science gives a set of specific functionalities with regards to the IWT general Platform, so to make the overall environment suitable for the development of applications in the mathematical and scientific domain. It represents a tool for the support of either the setting and creation of LOs (teacher side) or the fruition of the LOs (student side). Practically this platform carries out an important role in the relationship teacher/student, allowing the first to personalise lessons and exercises already available in the repository and /or to create some new ones, and the second to learn theoretical concepts and to practice/learn through specific study sessions for the didactical context of Mathematics and Science.

Math-IWT differs from the IWT general Platform not only for the integration of third party products and the management of additional Learning Object (LO) typologies specialised for the domain of Mathematics and Science, but also for the capability given to the user to manage in a simple way objects containing mathematical formulas.

The list below reports the functionalities / services integrated in the Math-IWT Platform, followed by the features description and, whereas necessary, the interfacing modes:

- Mathematical formulas manager
- WebMathematica: mathematical Software for the symbolic calculation
- XpressMP: linear optimization Software
- NAG: set of algorithms and procedures for the numeric calculation.

5. Mathematical formulas manager

An essential component characterising the Mathematics and Science domain in general, is the massive use of symbolic representations through formulas.

The problem of writing and visualising mathematical formulas lies not only at a LOs level, but it also influences all the communication tools, synchronous and asynchronous, through which the learning platform users may interact.

Math-IWT offers to the users the possibility to insert as a text within the LOs and communication services, objects written in TeX/LaTeX or MathML and to visualize formulas and expressions described in them in a symbolic manner. In particular, also the messaging both synchronous and asynchronous (chat, forum, etc.) has been designed and realised so to allow the users to communicate each other using mathematical and scientific expressions under a symbolic shape.

MathML is a mark-up mathematical language which allows the mathematical formulas representation in hypertexts. Today and already available there are various plug-ins or applets for editing and visualising the formulas inside the browser, among them we have taken into account the Techexplorer by IBM because it seems to be the most complete from many points of view. The ActiveX Techexplorer by IBM allows, besides the visualization and the writing of formulas according to the MathML standard, also the visualization of documents written in LaTeX and TeX which are currently the most used and widespread languages by scientific community for editing an authoring of documents and scientific works.

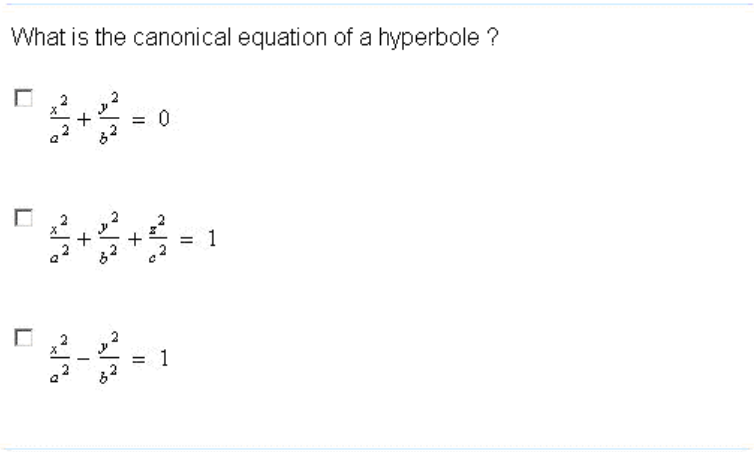

Figure 2: Example of MCT.

An example of LO allowing the mathematical formulas editing in MathML or TeX and their visualization in a symbolic manner, is the Multiple Choice Test (MCT) a didactical resource which allows to assess the student's preparation on a given subject. In its original version the LO does not allow to use any mathematical symbolism, while in the case of Math-IWT it has been made specially tailored to allow the teacher to build some MCT such as that reported in figure 2.

The inclusion of symbolic formulas inside the Math-IWT happens through an initial choice of the type of writing mode (Math-ML, TeX/LaTeX or Normal Text) to be inserted into the text field assigned to the data input. Once the user has chosen a writing mode, he will textually insert inside the field, the mark-up language code or the normal text. In case he chooses the Math-ML or TeX/LaTeX the inserted text will

constitute the input for the ActiveX which will allow their visualization inside the platform panels.

6. WebMathematica, XPress and NAG in Math-IWT

The integration of WebMathematica and XPress, the two calculation engines, has allowed to directly extend both the functionalities and the contents typology that are managed inside the Math-IWT domain platform. Indeed, besides the realization of the Plug-In Driver/External Plug-In couples permitting to exploit the external functionalities offered by the calculation engines as services inside the IWT, also the Object Drivers and the Aggregate Drivers have been implemented, able to manage the LOs using the new services offered by the domain platform.

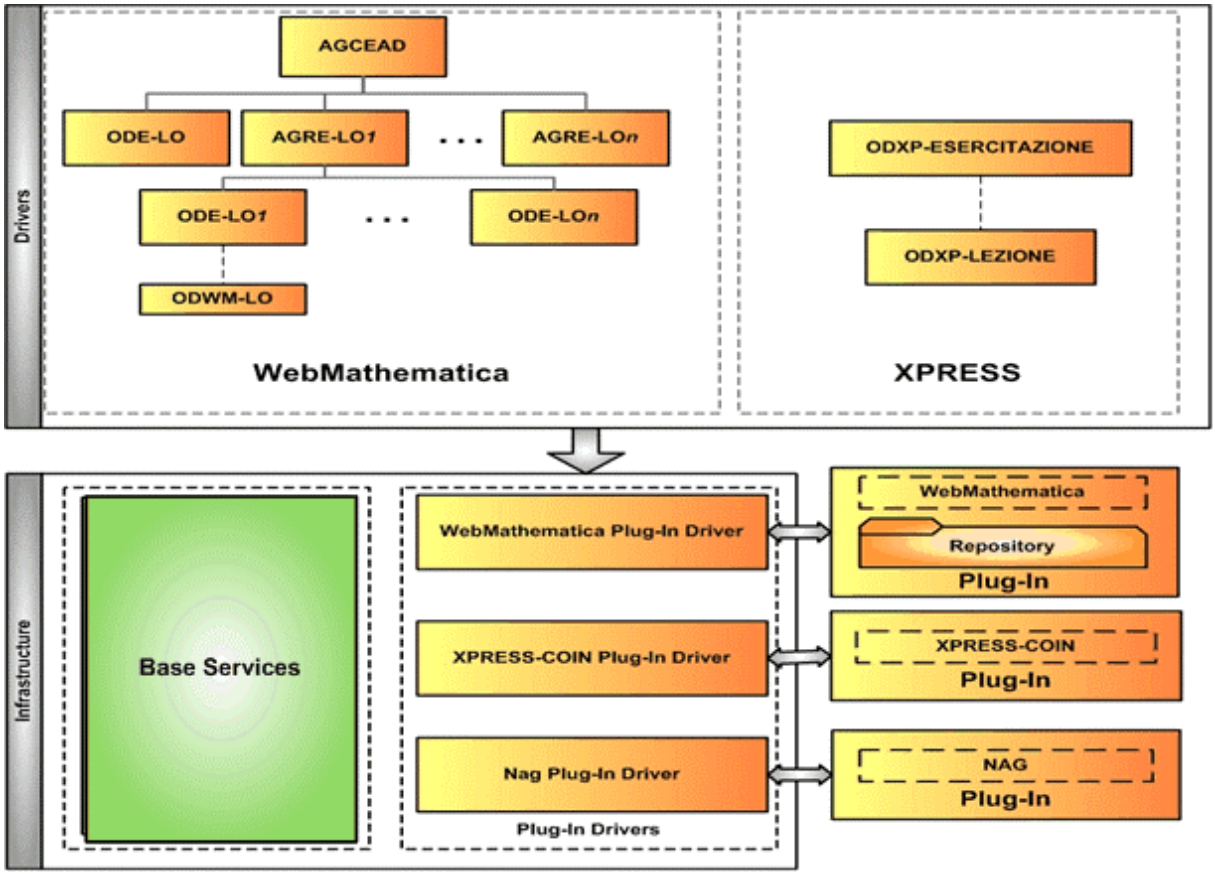

Figure 3: Driver e Plug-In di Math-IWT

Instead for NAG library, only the Plug-In Driver/External Plug-In couple has been realised to enable the components internal to the Driver layer to access to the services offered by the functions of mathematical calculation available inside the library.

6.1 Integration of WebMathematica

The WebMathematica calculation engine allows to transport via web all the mathematical computations realised through Mathematica. It makes use of specific web pages (MSP pages) that have recourse to particular instructions, the Mathlet, which are carried out on the server by the WebMathematica and allow to communicate with the Mathematica kernel. The kernel is able to access to the data sent through a post operation with the MSP page and dynamically construct the output html page containing the calculation results.

The WM-LO are managed by the Object Driver ODWM-LO (Object Driver webMathematica Learning Object). In the creation phase of a new didactical ODWM-LO type resource, the teacher proceeds with uploading all the files necessary to the mathematical computations (Mathematica package) and the formatting of html data (MSP page). Moreover, always in the creation phase, the teacher also fill in the metadata fields for the LOs description. In the delivery phase the student has the access to the didactical resource and uses it as it were an ordinary object generated by the WebMathematica.

The Object Drivers, besides exploiting the services of the infrastructure layer, can also access to the functionalities directly implemented in other Object Drivers. The Learning Objects exercises (E-LO) have been created just following this philosophy. The Object Drivers managing these LOs (ODE-LO) exploit the ODWM-LO functionalities for the realization of interactive exercises in the field of limits, derivatives and linear algebra. With respect to the simpler WM-LOs the E-LOs, in the resource creation phase, allow the teacher to choose a set of macro functionalities already implemented in terms of Mathematica package and MSP pages for the realisation of exercises connected to the subjects previously listed.

In the delivery phase the student using an E-LO is placed in front of an interactive exercise of mathematics subdivided into steps. The students is stimulated to solve all the steps of the exercise and whereas he could not manage with it he can access to the solution of any step and of the global exercise.

Once an E-LO has been constructed, the following step has been that of aggregating more E-LOs in order to present to the student a real mathematical exercises book. The aggregation has occurred by levels. At a first level various E-LOs have been integrated to create a set of exercises from which, at the student's demand and by random, one of them is chosen to be solved. Such LO is the E-LO random (RE-LO). The Aggregate Driver assumed to managed such didactical resource is the AGRE-LO. In the LOs creation phase the teacher chooses the exercises to aggregate and gives the set of exercises a name (for example Advanced Limits). In the delivery phase when the student selects by random that particular set of exercises he will be proposed that exercises to be solved. The second aggregation level allows to aggregate E-LOs and RE-LOs and to propose them to the student by grouping them according to the subject (for instance Limits, Derivatives, Functions, etc.). In this case the Driver which manages the new aggregate (CEAD) is the Course Driver AGCEAD.

6.2 Integration of XPress-MP

XPress-MP is a product employed to solve problems of linear and global linear optimization. Given a problem model in input according a standard, for instance the LP-file standard, it provides its solution with a text file as optimum for the objective function and function solution in correspondence of the optimum. A LP-file is a standard used by the Operational Research to describe a problem of optimization in terms of problem constraints, expressed as linear equations, and limits for variables.

For integrating the XPress-MP optimization software, we have realised a couple Plug-In Driver/External Plug-In and two Object Drivers managing two new LOs.

The XP-Lezione type LOs, are used through the ODXP-Lezione Object Drivers. In the creation phase of a new didactical resource of XP-Lezione type, the teacher carries out the model upload, that is a text file written according the LP file, which is analysed by the platform and visualised with an easily manageable format through panels and buttons in Math-IWT. Besides, always in the creation phase, the teacher defines the limitations on the model, the tuning values by the solver and fills in the metadata fields for the LOs description. In the delivery phase, the student accesses to the didactical resource and makes use of it according to the limitations imposed by the teacher in the LOs creation phase. In particular if the teacher sets the restrictive constraints so that they can reject any modifications to the model, the student will only obtain the solution of the problem by the solver.

The XP-Esercitazione type LOs, are managed by the ODXP-Esercitazione Object Driver and use the services offered by the ODXP-Lezione Object Driver. In the creation phase of a new didactical ODXP-Esercitazione type resource, the teacher carries out the upload of a file containing an exercise relating to an optimization problem. Also in this case, in the creation phase, the teacher fills in also the metadata fields for the LOs description. In the delivery phase the student accesses to the problem description and creates the model (Lp file) to submit to the solver. The solver receives the data and provides the solution to that problem.

6.3 Integration of NAGs

The integration of the NAG libraries in Math-IWT adds powerful functionalities of numerical calculation useful to the development of richer and more complex LOs.

The NAG library is a complete collection of procedures for the numerical and statistical problem resolution. The library is developed into several programming languages. We have used, in our specific case, the version in C. Inside the NAG library of algorithms of numerical calculation, a function is identified by a name and a type. An example of NAG function is the following:

void **nag_name_of_function**(*Integer n, double a*[]*, NagError *err*)

The Plug-In Driver/External Plug-In couple realised for the integration of NAG software libraries inside the domain platform, not only guarantees the access to all

the NAG functions, but also the call of every single function, type and value of input and output parameters. Of course also the result (or results) of the call are returned under the XML format.

7. Conclusions

In this work, we have described the Domain Platform for the Mathematics and Science based on IWT. Thanks to the integration inside the platform of standard tools characterising this domain, it is possible to increasingly exploit the contribution that the e-learning is able to provide to the learning process starting from the construction of didactical resources by the teacher and ending with the fruition of contents by the student.

In the future we reserve the possibility to integrate further resources inside the Math-IWT and to realise a tool (ActiveX) able to allow both the visualisation and the writing of mathematical formulas in a symbolic way in all the components characterising the domain platform.

8. References

IWT: Intelligent Web Teacher. White Paper. CRMPA. 2002.