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Desarrollo basado en modelos de sistemas Web de tele-educación TIN2006-09678

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Abstract

Model-based development is the suitable paradigm for web systems. Implementation technologies as well as offered functionality are in constant evolution. Abstract web designs are far more stable than the implementations, so it is essential to allow developers to express themselves using problem domain entities so there is an improvement in productivity. However, it must be noticed that web development teams are interdisciplinary groups and each member uses his/her own language (or meta-model) to express solutions to the same problems. This project presents the development of web systems by integrating meta-models pertaining to diverse areas of domain or perspectives. In particular, we intend to develop a framework that combines different specific domain meta-models: application domain meta-models oriented to specialists in that domain and users that in MoDUWEB will be restricted to the e-learning area; and hypermedia/web meta-models that provide the software design context. MoDUWEB will allow each development team member to use tools pertaining to his/hers knowledge domain, so communication might be optimised. At the same time, to guaranty the integrity and consistency of the final design the different perspectives will integrate in a unique formal representation from which code can be generated automatically. Moreover, to improve product quality product metrics and V&V techniques will be included by using widely accepted design patterns so that design knowledge can be reused. V&V as well as the different metrics could activate the redesign process. As design guidelines, patterns and metrics come from different communities. MoDUWEB will help in reusing multidisciplinary knowledge about design. All these theoretical issues will be implemented in a prototype.

1 Project goals

The main goal of this project is developing a meta-modelling framework for web educational systems, which include validation tools and reuse of design knowledge. In particular, we define the following four objectives:

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1. Developing a model-based framework for web educational systems. MoDUWEB attempts to define a multi-perspective framework that favours collaborative work in multi-disciplinary teams through the integration of design models used in different disciplines.

2. Integrating validation and verification techniques for functional and usability requirements by means of design patterns. On top of the unique meta-meta-model we want to include mechanisms for the validation and verification of functional and usability requirements. In particular, we will apply design patterns from the e-learning, usability and hypermedia/web communities to the meta-meta-model and, following a top-down approach, to the domain specific models in order to validate the requirements.

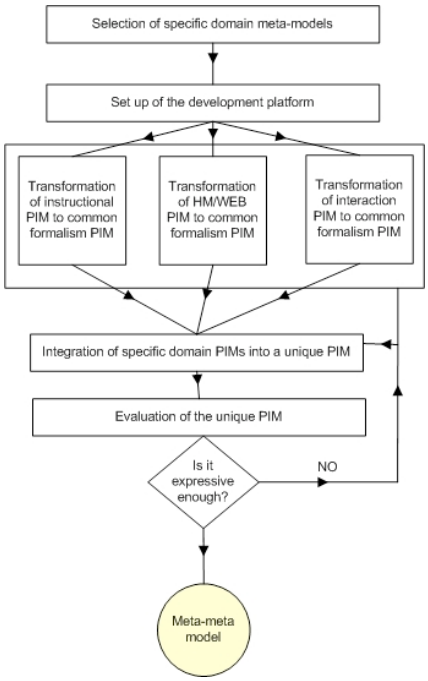
3. Integrating quality metrics and redesign techniques. Redesign rules will be included to reuse knowledge on good practices in the educational, web engineering and usability engineering communities. These rules would be activated either when the requirements are not met, or when detecting invalid threshold values for domain specific metrics (e.g. connectivity in hypermedia nets). The novelty consists on combining product metrics expressed in different abstraction levels with correctness rules expressed as redesigns.

4. Developing a prototype that supports the framework, the validation and verification techniques and the redesigns. Finally, we want to validate the theoretical results obtained by the previous objectives, by developing a prototype that allows a multi-perspective model-based development, and integrates quality metrics, validation and verification through the use of design patterns, and execution of redesigns.

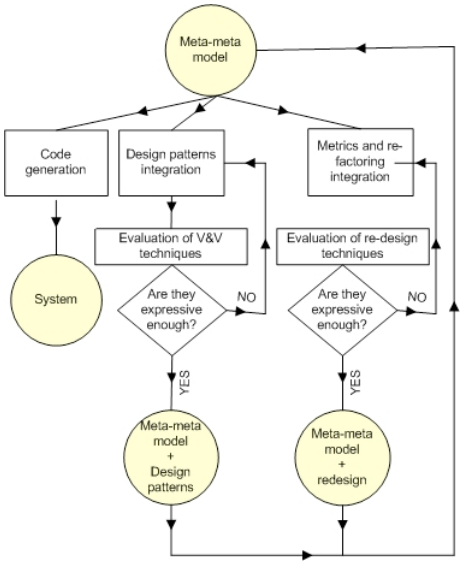
1.1 Project planning

To achieve the project goals we defined the working plan shown in Figures 1.a and 1.b.

We have applied the planned method but there is a slight delay in the schedule due to the fact that two members of the team left the project as formally notified.



a. Objective 1



b. Objectives 2, 3 and 4

Figure 1. Project work plan

2 Level of achievement

2.1 Developing a model-based framework for web educational systems

In order to support a multi-perspective and meta-modelling environment for the development of web educational systems, we follow an approach that allows each designer to use her meta-model and relies on meta-modelling techniques to create a common design. It combines two different modelling environments:

- one oriented towards educational designers, where the design is specified in terms of units of learning, educational competence, evaluations, etc.
- a second one oriented towards web designers, where the system is defined in terms of navigational nodes and tools, contents, events, etc.

In both cases, existing domain specific languages are used for educational and web design so that each expert can use the language she is proficient in. Meta-modelling and model transformations are applied to create a common meta-model integrating the two perspectives, where a number of validation and verification rules are applied to guarantee completeness, consistency and integrity of the specification.

IMS LD [1] has been selected for educational design. LD specifies a language for describing learning activities. It is based on the Open University of the Netherlands Educational Modelling Language, and provides the means to describe the roles and activities carried out by the different participants on the course of a learning process. The LD specification defines three levels of implementation and compliance. Level A contains the core of the LD, providing a vocabulary to specify a sequence of activities to be carried out by the learners and teachers who take part on the learning process, while Levels B and C allow the designers to define a more elaborated sequencing of the process. A *Unit of Learning* (UoL) is obtained when a description of a LD is included in a content package. The UoL encapsulates all the information required to go through the learning process, including both pedagogical information and information needed to locate and use the required resources. Using the appropriate elements, the designers of the learning process specify the different roles that each of the participants of the learning experience can play. In order to attain a particular set of learning objectives, the participants will carry out diverse learning activities and support activities organized in different structures. It is possible to specify a collection of learning objects and services necessary for the participants to successfully complete the proposed activity. In order to obtain an effective prototype, we started working just on level A, and the extension to levels B and C was left as future work.
The meta-models of the ADM method [2] have been used for web design. These allow the specification of the logic structure, navigation, presentation, interaction, behaviour and security characteristics of the system. It is the only web design method including all these perspectives, which promoted its election for web design.

In order to capture the relationships between these two meta-models, we have made use of a meta-model triple. This structure allows capturing the relations between the meta-models of two different languages through a third correspondence meta-model, whose nodes represent morphisms to the nodes or relations of the other two. Figure 1 depicts the meta-model triple developed for the integration between LD and the ADM meta-models. The LD meta-model and the ADM meta-model are shown in the left side and right side of the figure, respectively. Although the real meta-model triple contains the complete definition of both meta-models, for legibility reasons, only the elements for which a correspondence has been defined are shown. The correspondence meta-model is shown in the middle part of the figure and defines the relationships between the other two meta-models. This way, it is possible to integrate the two different languages while preserving their original definition and without including externals elements. Therefore, the integration is completely transparent to the users of the modelling languages, this is, the designers of the web application for e-learning.

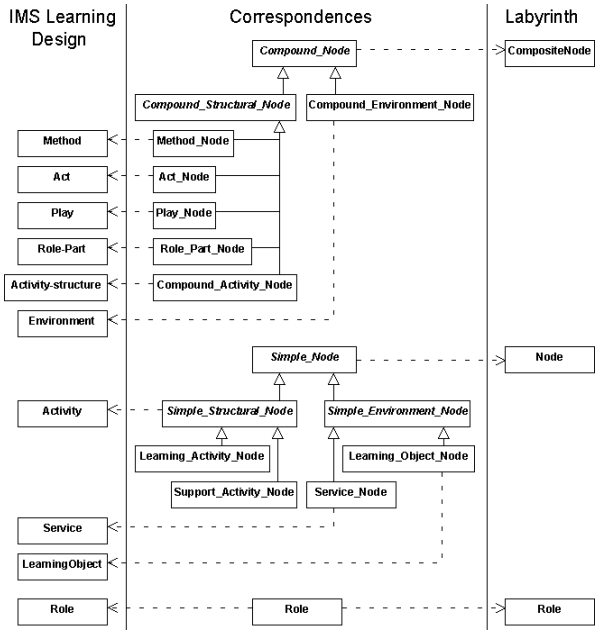


Figure 2. Integration through meta-model triple

In addition, we have defined a transformation that translates parts of the instructive model into the web design perspective. This facilitates the automatic integration of the different perspectives in a consistent way. For instance, the creation of a new method in the instructive model fires the search of a composite node with the same identifier in the web model. If such node exists, then a correspondence node relating the method and the node is automatically created. Otherwise, a new composite node is created with the same identifier as the method, and related to it.

2.2 Integrating V&V techniques for functional and usability requirements by means of design patterns

A formal notion of design pattern grounded in category theory has been developed. In this formalization, patterns are seen as formed of: i) a vocabulary of roles; ii) a collection of diagrams, possibly in different modelling languages, defining cardinalities and associations between roles, and supplemented with indications of variable regions; iii) a collection of interfaces between these diagrams, to identify roles across different diagrams. Novel in this formalization proposal is the possibility of describing (nested) variable submodels, as well as inter-pattern synchronization across several diagrams (e.g. class and sequence diagrams for UML design patterns).
However, we were also aware that using patterns is not so easy, specially finding the pattern you need to solve your problem. For that reason we started a research line on

exploring the strategies users apply when browsing patterns catalogues with view to developing useful tools meeting their needs. In this sense, several studies were conducted in Penn State University and Universidad Carlos III de Madrid to analyse the browsing strategies of users. Also we have developed a first prototype supporting goal-oriented browsing strategies whose interface is shown in Figure 3. The prototype, called VEISIG makes use of the concept of soft-goal graphs [3] that have been enhanced making them interactive and visually enhanced to help users realise the utility and trade-offs of design patterns.

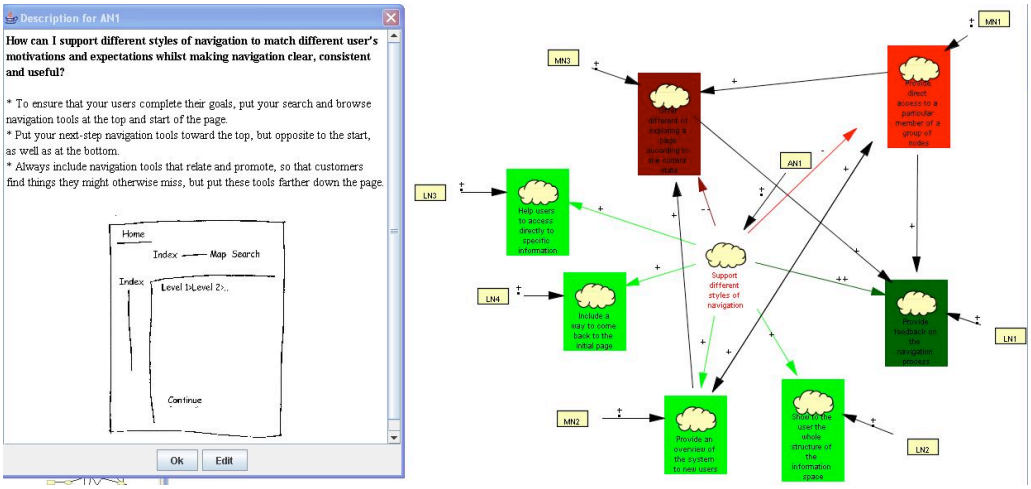


Figure 3. VEISIG interface for goal-oriented navigation in design patterns catalogues

2.3 Integrating quality metrics and redesign techniques

In order to integrate metrics and redesigns in the process of web educational systems design, an evaluation model has been developed. The model is general, i.e. it is not tied to a specific design language, educational domain or quality model; it provides adaptability should the compliance rules change, or should new evaluation objectives, criteria, measures or redesigns are to be considered; and it can be used for the automatic generation of computer-supported evaluation systems (see subsection 2.4).
The evaluation model defines the information that conducts the evaluation process. In this model, the evaluation process is guided by a set of *Objectives* which are subject of the evaluation, and that can be organized in tree structures. Each objective is realized by a set of *Criteria* corresponding to quality characteristics of the didactic material. In its turn, each criterion is decomposed into *Parameters* or quality aspects, which are measured in order to assist the evaluation. In particular, each parameter has associated a set of *Measures* that can contribute to a certain extent to the parameter's conformance. Measures may include information about *Threshold* values or intervals pointing to desirable or undesirable values, depending on their attribute *valid*, in the measurement scale. This way, a measure contributes to the parameter's conformance

if the measurement result is among its valid thresholds and not among the invalid ones. Finally, the model allows associating *Redesigns* to ranges of parameter's conformance so that applying the redesign can help to improve such conformance degree.

Currently, we are working on the identification of specific criteria, measures, redesigns and their relations to support an effective evaluation of web educational systems designs. With respect to the redesigns, we are currently considering simple actions to be performed on the design components, although some work has been done in rewriting design patterns for web educational systems. A report about existent design patterns for this kind of systems has been elaborated for the "Centro Nacional de Información y Comunicación Educativa del Ministerio de Educación y Ciencia", thus acquiring knowledge in order to incorporate this kind of patterns in the development process.

Finally, we have implemented a development framework that supports the evolution model and allows generating evaluation tools based on it, as next subsection explains.

2.4 Developing a prototype

Two prototypes are under development. The first one implements the mechanisms for integrating the different perspectives of web educational system designs (objective 1), whereas the second one implements a development framework of evaluation tools for educational systems (objective 3). Next, both prototypes are briefly presented.

The front-end of the first prototype provides two client design applications: a visual editor for IMS LD level A designs, and the AriadneTool [4] toolkit for the specification of web designs based on the ADM method [2]. The former allows designing educational processes, while the latter supports hypermedia authoring processes (i.e. modelling hypermedia applications, validating the design, and generating XML + SMIL implementation templates). On the other hand, the back-end provides services to store the different models and meta-models, to translate the information between them and validate their consistency, and to automatically generate the final system using different technologies (web/Java, web/PHP, e-learning/SCORM, etc.).

By using the prototype, the creation of a web educational system is as follows. The pedagogical expert uses the IMS LD visual editor for designing a learning process, and a transformation module translates the IMS LD manifest into Labyrinth by generating an AriadneTool project. Then, the hypermedia expert adapts the Ariadne design in order to produce an application that responds to the requirements of visualization, accessibility and usability specific for that learning process. A validation process is launched in order to check the compliance of the final design with the initial IMS LD specification. For this purpose, an ontology that describes the model in a complete, comprehensible and formal manner is used. Finally, from the validated Ariadne model, code is synthesized for the final application.

The second prototype attempts to facilitate the generation and adaptation of evaluation tools that can be easily integrated in the didactic material creation process. It has been implemented as a generic development framework that realizes the evaluation model obtained as result of objective 3. The framework automates the aggregation rules for calculating the conformance of quality criteria, and proposes appropriate redesigns to improve such quality criteria. The framework is being instantiated to work on top of the AriadneTool toolkit to validate web educational systems designs.

Figure 4 sketches the evaluation of web educational systems designs by using evaluation tools generated with the framework. The didactic designer selects the objective of the evaluation, which states which criteria and quality parameters use in order to determine whether the design conforms to the selected objective. In order to estimate the conformance degree of each parameter, the tool uses different sets of measures to be used as indicators. A measurement tool calculates such measures on the input didactic material. Then, a reasoner uses the obtained results, together with aggregation rules specified by the quality model, in order to assess the conformance level of the objective's criteria, and therefore the objective conformance. If some parameter is not met, the tool suggests redesigns to improve its conformance degree.

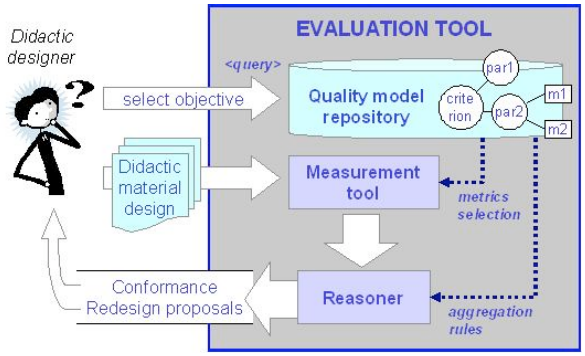


Figure 4: Evaluation tool

3. Project indicators

3.1 Personnel in training

The following two thesis have been developed in the scope of MoDUWEB:

- Esther Guerra Sánchez (December 2007): "Especificación, análisis y generación de entornos para lenguajes visuales de dominio específico". Universidad Autónoma de Madrid. Supervisors: Juan de Lara Jaramillo and Paloma Díaz Pérez.
- Telmo Zarraonandia Ayo (July 2007): "Adaptaciones de unidades de aprendizaje en tiempo de ejecución". Universidad Carlos III de Madrid. Supervisors: Camino Fernández and Juan Manuel Dodero.

The following two thesis are currently under development:

- Carmen L. Padrón Nápoles: “Desarrollo de materiales didácticos desde una perspectiva basada en modelos”. Supervisor: Paloma Díaz Pérez.
- David Díez Cebollero: “La aplicación del Análisis de Dominios al Desarrollo de Sistemas de Aprendizaje Asistido por Ordenador”. Supervisors: Camino Fernández and Ignacio Aedo.

3.2 Publications

JOURNALS

- Paloma Díaz, Esther Guerra, Telmo Zarraonandia, Ignacio Aedo. A meta-modeling based approach for the multi-disciplinary design of web educational systems. 2009. To be published in Journal of Universal Computer Science, special issue on Computers in Education: Advances in Software Technology (selected papers from SIIE'2008)
- Esther Guerra, Juan de Lara, Paloma Díaz. Visual Specification of Measurements and Redesigns for Domain Specific Visual Languages. 2008. Journal of Visual Languages and Computing (Elsevier). Vol 19(3), 399-425.
- Esther Guerra, Juan de Lara, Alessio Malizia, Paloma Díaz. Supporting user-oriented analysis for multi-view domain-specific visual languages. 2008. Accepted in Information & Software Technology (Elsevier).
- Paolo Bottoni, Esther Guerra, Juan de Lara. Enforced generative patterns for the specification of the syntax and semantics of visual languages. 2008. Journal of Visual Languages and Computing (Elsevier), Volume 19, Issue 4. pp.: 429-455. Selected papers from VL/HCC'2007.
- Paloma Díaz, Ignacio Aedo. Towards efficient web engineering approaches trough flexible process models. Journal of Systems and Software. 80 (8). 1375-1389. Agosto, 2007.
- David Díez, Camino Fernández, Juan Manuel Dodero. A Systems Engineering Analysis Method for the Development of Reusable Computer-Supported Learning Systems. Interdisciplinary Journal of Knowledge and Learning Objects. Vol 4, 2008, 243-257.
- Juan Manuel Dodero Salvador, Sánchez-Alonso, Dirk Frosch-Wilke. Generative Instructional Engineering of Competence Development Programmes. Journal of Universal Computer Science. 13(9).
- Esther Guerra, Paloma Díaz, Juan de Lara. Generación de entornos de modelado avanzados mediante técnicas de transformación de grafos. IEEE América Latina. 4(2). 2006.

- Esther Guerra, Juan de Lara. Event-driven grammars: Relating abstract and concrete levels of visual languages. 2007. Software and Systems Modeling (Springer), special section on ICGT'2004, Volume 6, Issue 3. pp.: 317-347.
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- Telmo Zarraonandia, Juan Manuel Dodero, Camino Fernández. Crosscutting Runtime Adaptations of LD Execution. Educational Technology & Society, ISSN 1176-3647, vol 9(1), pp. 123-137, 2006.

BOOKS

- Susana Montero, Telmo Zarraonadía, Paloma Díaz, Ignacio Aedo. Patrones de diseño aplicados al desarrollo de ODEs y entornos educativos basados en TIC. Centro Nacional de Información y Comunicación Educativa. Ministerio de Educación y Ciencia. In press.

BOOK CHAPTERS

- E. Guerra, J. de Lara, P. Díaz. Integrating Measurements and Redesigns in the Definition of Domain Specific Visual Languages. In Model-Driven Software Development: Integrating Quality Assurance. Idea Group. 2007
- T. Zarraonandia, J. M. Dodero, C. Fernández, I. Aedo, P. Díaz. Interactive design of learning processes. In Computers and Education- from theory to practice. Kluwer Academic Press. 163-178. 2007

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- Paloma Díaz, Mary Beth Rosson, Ignacio Aedo and Jack Carroll. “Web Design Patterns: Investigating User Goals and Browsing Strategies”. 2009. Accepted for the Second International Symposium on End User Development.
- Padrón, C. L., Zarraonandía, T., Díaz, P., Aedo, I. (2008) "The evaluation within the development and deployment of IMS LD-based didactic materials: The MD2 + runtime adaptation approach". 8th IEEE International Conference on Advanced Learning Technologies (ICALT08)
- Padrón, C. L., Díaz, P., Aedo, I. (2008) "The automatic generation of semantic annotations for didactic materials and the use of models in the material development to improve its reusability". 8th IEEE International Conference on Advanced Learning Technologies (ICALT08)
- Telmo Zarraonandia, Paloma Díaz, Ignacio Aedo, Camino Fernández, Juan Manuel Dodero. “Evaluating the runtime adaptation of EML-described learning processes" - The 6th IEEE International Conference on Advanced Learning Technologies (ICALT 08), 2008.
- José Eduardo Rivera, Esther Guerra, Juan de Lara and Antonio Vallecillo. “Analyzing rule-based behavioural semantics of visual modeling languages with

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- David Díez, Paloma Díaz, Ignacio Aedo, Camino Fernández. "DEI-CHECK. Automating the assessment process to improve the informative feedback". 2008. 38th Annual Frontiers in Education (FIE08)
- Paolo Bottoni, Esther Guerra and Juan de Lara. "Formal foundation for pattern-based modelling". 2009. To be presented at FASE'09: Fundamental Approaches to Software Engineering.
- Paloma Díaz, Ignacio Aedo and Mary Beth Rosson. "Visual representation of web design patterns for end-users". 2008. Proc. of AVI 2008. pp. 408-411.
- David Díez, Camino Fernández, Juan Manuel Dodero, Paloma Díaz, Ignacio Aedo. "Instructional Domain Analysis: A methodological approach to Service-Oriented Learning". 2008. Actas de 8th IEEE International Conference on Advanced Learning Technologies (ICALT08)
- Jordi Cabot, Robert Clarisó, Esther Guerra and Juan de Lara. "An invariant-based method for the analysis of declarative model-to-model transformations". 2008. Lecture Notes in Computer Science 5301, Springer. pp.: 37-52. Presented at MODELS'08: ACM/IEEE 11th International Conference on Model Driven Engineering Languages and Systems.
- David Díez, Ignacio Aedo, Paloma Díaz. "DEI-ED. Una experiencia de uso de software educativo en asignaturas de programación de computadores". 2008. X Simposio Internacional Informática Educativa (SIIE08)
- Jordi Cabot, Robert Clarisó, Esther Guerra and Juan de Lara. "Analysing graph transformation rules through OCL". 2008. Lecture Notes in Computer Science 5063, Springer. pp.: 229-244. Presented at ICMT'08: International Conference on Model Transformation.
- David Díez, Camino Fernández, Juan Manuel Dodero, Paloma Díaz, Ignacio Aedo. "Instructional Software Analysis: Lessons from Software Development Process Improvement". 7th IEEE International Conference on Advanced Learning Technologies (ICALT07)
- David Díez, Camino Fernández, Juan Manuel Dodero. "An Effective Analysis Method for Computer-Supported Learning Systems Reusability". Actas de IV Simposio Pluridisciplinar sobre Diseño, Evaluación y Desarrollo de Contenidos Educativos Reutilizables (SPDECE07)
- Esther Guerra, Daniel Sanz, Paloma Díaz and Ignacio Aedo. "A transformation-driven approach to the verification of security policies in web designs". 2007. Lecture Notes in Computer Science 4607, Springer. pp. 269-284. ICWE'07: 7th International Conference on Web Engineering.
- Esther Guerra and Juan de Lara. "Adding recursion to graph transformation". 2007. Presented at GTVMT'07: 6th International Workshop on Graph

Transformation and Visual Modeling Techniques (satellite event of ETAPS'07). Proceedings published as Vol. 6 (2007) of Electronic Communications of the EASST.

- Esther Guerra, Juan de Lara and Alessio Malizia. "Model-driven development of digital libraries: Validation, analysis and code generation". 2007. Proceedings of WEBIST'07: 3rd International Conference on Web Systems and Technologies. Lecture Notes in Business Information Processing (Springer), vol 8, 169-183.
- Esther Guerra, Telmo Zarraonandia, Paloma Díaz and Ignacio Aedo. “Integrando perspectivas de diseño para el desarrollo de sistemas Web de tele-educación”. 2008. Proceedings of SIIE'08: X Simposio Internacional de Informática Educativa.
- Juan de Lara, Esther Guerra and Paolo Bottoni. "Triple patterns: Compact specification for the generation of operational triple graph grammar rules". 2007. Presented at GTVMT'07: 6th International Workshop on Graph Transformation and Visual Modeling Techniques (satellite event of ETAPS'07).
- Juan de Lara and Esther Guerra. “Pattern-based model-to-model transformation ”. 2008. Lecture Notes in Computer Science 5214, Springer. pp.: 426-441. Presented at ICGT'08: 4th International Conference on Graph Transformation. EASST award for the Best Software Science Paper.
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- Francisco Pérez, Juan de Lara and Esther Guerra. "Domain specific languages with graphical and textual views". 2007. Proceedings of AGTIVE'07: 3rd International Workshop on Applications of Graph Transformation with Industrial Relevance. pp.: 79-94.

3.3 Technology transfer

The acquired abilities and knowledge in meta-modelling techniques have been used in an agreement with the Amper Sistemas company for developing a domain specific language (DSL) in the control of frontiers domain.

In addition, the book ”Patrones de diseño aplicado al desarrollo de ODEs y entornos educativos basados en TIC” has been published, for the “Centro Nacional de Información y Comunicación Educativa”. The book analyses existent design patterns for e-learning, as well as other kinds of patterns that can be useful for reusing expert knowledge in the development of this kind of systems.

3.4 Cooperation with other groups

In this project we have collaborated with the Open University of the Netherlands, more in detail with Prof. Kopper, researching in meta-modelling environments for IMS-LD. The collaboration started in 2006 with the stay of Prof. Juan Manuel Dodero, and it has continued since then.

In the meta-modelling area we have a close collaboration with Prof. Juan de Lara from the Universidad Autónoma of Madrid, and with Paolo Bottoni from Sapienza Universitá di Roma as it can be seen in the number of contributions done in cooperation with both researchers.

We also collaborate with the Laboratory for Computer-Supported Collaborative Work and Learning from the Information Science and Technology College, Penn State University, leaded by Prof. John Carroll and Mary Beth Rosson. The main researcher of the project spent one year in this University, collaborating in performing empirical studies concerning the usability of design patterns, as well as in the use of visual notations for their representation.

The team is involved in the IEEE Technical Committee of Learning Technologies, and the main researcher is one of its vice-chairs. The profuse amount of works on educational technologies presented in different related conferences and workshops, made possible the election of the team as organizer of one of the bigger international conferences in this domain: ICALT'2008.

Members of the group also take part in different research networks including:

- Network: RED CESEI (Extension of TIN2005-25886-E)
  Duration: 1/1/20008-1/11/2010
  PI: Antonio Vallecillo
- Network: Red Temática del Capítulo Español de la Sociedad de la Educación de IEEE (Extension of TSI2005-24068E)
  Duration: 1/1/20008-1/11/2010
  PI: Martín Llamas
- Network: RED OBER-Objetos educativos reutilizables (TSI2007-31091-E)
  Duration: 1 /6/ 2008 – 31/5/2009
  PI: Manuel Castro

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[3] Chung, L., Nixon, B. A., Yu, A. and Mylopoulos, J. 2000. Non-Functional Requirements in Software Engineering. Kluwer Academic Publishers.

[4] Susana Montero, Paloma Díaz, Juan Manuel Dodero, Ignacio Aedo (2004): “AriadneTool: A design toolkit for hypermedia applications”. Journal of Digital Information. In press.