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SUBDIRECCIÓN GENERAL
DE PROYECTOS DE INVESTIGACIÓN

JORNADAS DE SEGUIMIENTO

PROYECTOS EN TECNOLOGÍAS DE LA INFORMACIÓN

DESCRIPCIÓN DE RESULTADOS

Referencia del proyecto: TIC99-1083-C02
Título: Diseño software basado en componentes. Metodología y herramientas para el desarrollo de aplicaciones distribuidas.
Investigador principal: José M. Troya Linero
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Datos sobre el grupo investigador:

¿Se trata de un proyecto coordinado? Sí

Referencia del proyecto: TIC99-1083-C02-01
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Referencia del proyecto: TIC99-1083-C02-02
Investigador principal: Juan Hernández Núñez
Dirección de contacto: Universidad de Extremadura. Escuela Politécnica. Avda. de la Universidad. 1071 Cáceres

1. PROJECT OBJECTIVES

1.1. Background and motivation

This is a coordinated project about Software Architecture (SA), Coordination (C), and Component-based Software Development (CBSD), three topics in which the participant groups initially had some experience. The original goal of the project was to serve as a working framework within which the two groups could collaborate, share their respective experiences, and get a in-depth and hands-on-experience knowledge on these late-breaking topics and technologies. With a staff of 30 researchers (19 from Málaga and 11 from Extremadura), the project started in January 2000 and is expected to continue until December 2002. Three major private companies were originally interested in the project and its potential results.

1.2. Introduction

As stated in the original proposal, the project tries to combine three different approaches to software engineering in open and distributed systems. In the first place, **Software Architecture** concentrates on the specification and design of the system architecture, focusing on the structure of the system in terms of a set of components and the interconnections among them, at a high level of abstraction. Second, the **Coordination** paradigm aims at the separation of the computational and interoperational aspects of components, trying to cope in that way with the complexity of the large open systems and their concurrent, reactive, and distributed nature. Finally, **Component Oriented Programming** has been described as the natural extension to Object Oriented Programming in the realm of open and independently extensible systems.

Although these complementary approaches clearly overlap in many areas, they are usually separately treated when building applications. Therefore, the original plan was to study their potential integration, studying their extensions from a common perspective so they can be combined into a single approach, analysing the problems and limitations that this challenge carries along.

There was also an special emphasis on methodologies, tools, and formalisms to support the construction of complex software applications. First, software models, languages and tools need to be developed for building applications in open systems out of reusable software components. The formal aspects of the design and development of those applications needs to be considered too. In particular, those models and mechanisms that permit reasoning about the properties of a software application directly from the properties of its constituent components and its software architecture.

Two main application domains were selected for evaluating and validating the methodologies, methods, and tools proposed in this project. The first one was concerned with the unified management and integration of heterogeneous data living in the Web. The second one dealt with collaborative CSCW applications, offering a framework for the derivation and implementation of this kind of applications.

The coordination of efforts and resources is another key issue in this project. Although both groups do not have the same degree of participation in all tasks because of their different sizes, backgrounds, and experiences, the common working framework provided by the project aimed at the cross-fertilization of ideas, experiences and results, based on the development of a set common methods and tools—to be shared by all participants in the project—which greatly facilitate the exchange and sharing of information and the comparison analysis of the results and experiences obtained by both groups.

1.3. Project objectives

As mentioned above, the main project objective was the study of the potential integration of three of the existing approaches for the development of software applications based on components.

This main objective was split into the following (more concrete) six sub-objectives:

1. Design and implementation of a common component model, supported by a distributed component platform, which allows the integration of heterogeneous software components. This common model is the one to serve as the base model for the rest of the project activities.
2. Analysis and design of methods and mechanisms for the modular development and customisation of software components, that need to be integrated into open and distributed applications. Special interest deserve the proposals by Gregor Kiczales (based on the separation of “aspects”) and by Gul Agha (based on the addition of modular “properties”).

3. Design and implementation of a coordination model that serves as the glue that binds together the high-level architectural description of the application and the software components of the base component platform. The target coordination model will try to unify the two coordination models developed by UMA and UEX (named “TCM” and “Coordinated Roles”, respectively).
4. Definition of a language and a methodology for the documentation and customisation of component-based application frameworks. Study of the expressiveness of Architecture Description Languages (ADLs) for these purposes, in particular LEDA—an ADL developed by the Málaga group. Evaluation of the possibility of automatic code generation from the architectural descriptions in LEDA.
5. Design of methods and tools for the formal analysis of component-based applications directly from their architectural description using ADLs. These analyses include component compatibility and replaceability within an open application, abstract interpretation of specifications, and model checking.
6. Validation of the proposal, by identifying two main families of applications in which the proposed methods and tools could be tested: a) those dealing with the unified management and integration of heterogeneous Web-based data, and b) collaborative CSCW applications.

1.4. Work plan and schedule

In order to achieve the 6 previous sub-objectives, all the project tasks and activities were organized in 7 modules. The first one (module 0) was dedicated to project management and coordination only, while the rest of the modules have a direct correspondence to the project sub-objectives. Each module has a coordinator (the task “supervisor”) and is structured into concrete tasks. The following plan describes the modules and tasks that were originally identified.

Module 0: project management and coordination
Supervisor: J.M. Troya (University of Málaga) Participants: Module managers (7).
Objective: project management.
Duration: 36 months.

Module 1: Component models and platforms
Supervisor: A. Vallecillo (University of Málaga) Participants: 6 UMA + 1 UEX.
Objective: Design and development of a common component platform.
- Task 1.1: Design and implementation of a distributed component platform (24 months)
- Task 1.2: Platform refinement, improvement and maintenance (12 months)

Module 2: Designing components for open systems
Supervisor: J. Hernández (University of Extremadura) Participants: 4 UMA + 4 UEX.
Objective: Comparison of two of the approaches used in the modular design of components for open systems: “aspects” and “properties”.
- Task 2.1: Use of aspects in component-based development (24 months)
- Task 2.2: Use of properties in component-based development (24 months)
- Task 2.3: Comparison analysis of both approaches (12 months)

Module 3: Coordination models and languages
Supervisor: B. Rubio (University of Málaga) Participants: 5 UMA + 3 UEX.
Objective: Definition of a coordination model and language for the coordination of software components, based on the models and experiences of both groups.
- Task 3.1: Design and definition of a common coordination model (14 months)
- Task 3.2: Formal definition (10 months)
- Task 3.3: Implementation (12 months)

Module 4: A methodology for the development of component-based software applications
Supervisor: L. Fuentes (University of Málaga) Participants: 6 UMA + 3 UEX.
Objective: Definition of a language and methodology for the development of component-based software applications.
- Task 4.1: Design and definition of a common methodology (12 months)
- Task 4.2: Definition of an ADL (12 months)
- Task 4.3: Implementation of an integrated component-based development environment (18 m)

Module 5: Formal techniques for the verification of component-based systems

Supervisor: M. Gallardo (University of Málaga) Participants: 5 UMA + 3 UEX.

Objective: Study and adaptation of formal techniques for the static and dynamic verification of component-based software systems.

- Task 5.1: Verification of Software Architectures (18 months)
- Task 5.2: Static analysis of specifications (6 months)
- Task 5.3: Implementation of verification tools (18 months)

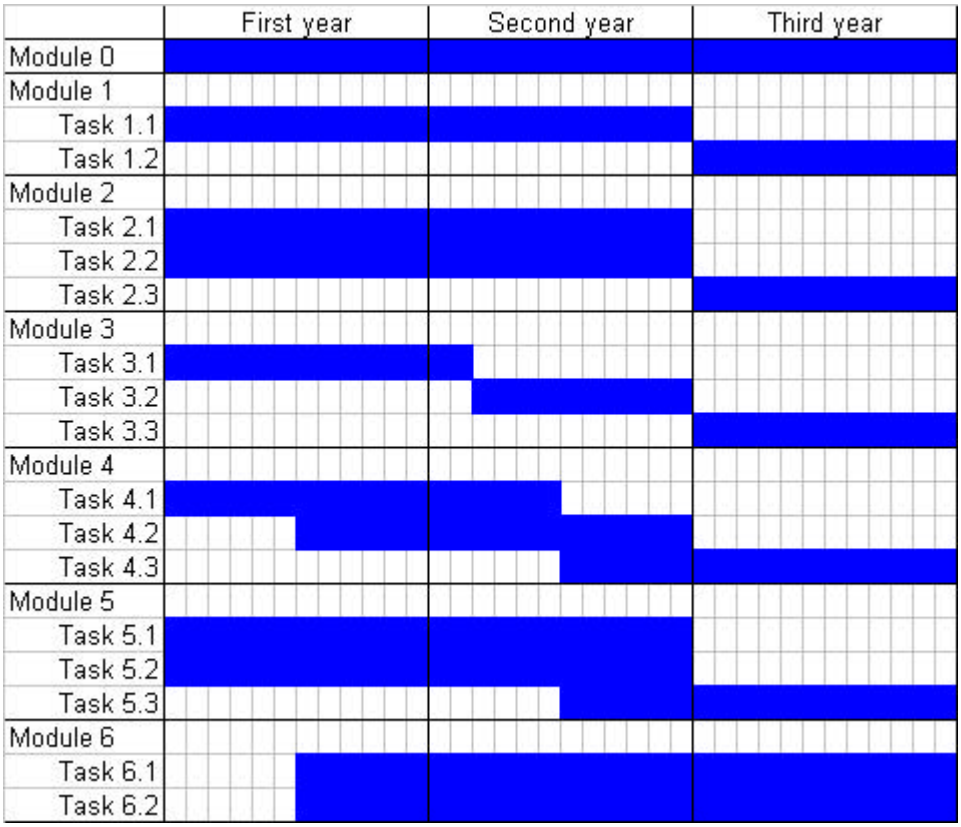
Module 6: Validation with real applications

Supervisor: J. Aldana (University of Málaga) Participants: 8 UMA + 3 UEX.

Objective: Design and implementation of two applications in order to validate the proposed methods and tools.

- Task 6.1: Unified access to heterogeneous web-based information (24 months)
- Task 6.2: A framework for the derivation of CSCW software applications (24 months)

The following table shows the project schedule, based on the previous tasks:



2. LEVEL OF SUCCESS

This section describes the main goals achieved, in terms of the relevant scientific and technological results obtained so far. These results are summarized in the following table, indexed by tasks. References to the main (refereed) publications that endorse and disseminate the results are shown in the last column. Details about these publications can be found in Annex 1.

Task	Relevant scientific and technological results achieved so far	Main references
1.1	• A first implementation of the SC component model is available. • An Integrated Development Environment (IDE) for building applications using the SC component model is also available	[Troya y Vallecillo, 2001]
2.1	• A visual tool (called Visual Disguise) for building applications through the composition of functional and non-functional properties (synchronization and distribution) is currently available. • It has been shown how to build distributed applications abstracting away the "distribution" aspect (i.e. independently of the distribution protocol used). Tests with CORBA and RMI components have been successfully conducted. • Crosscutting occurs in all phases of the software life cycle. In particular, crosscutting is explicit in UML interaction diagrams. It has been shown how some aspects can also be captured with UML in the design phase of applications. • The semantics of UML has been extended with new stereotypes to describe and model the aspects of synchronization, distribution and replication. • It has been shown how component-based systems can be developed in principle without crosscutting using AOP concepts.	[Sánchez et al., 2000] [Sánchez et al., 2001a] [Herrero et al., 2000a] [Herrero et al., 2000a] [Herrero et al., 2001a] [Herrero et al., 2000b] [Navasa et al., 2001a]
2.2	• It has been shown how to specify and implement some Quality of Service properties of components, namely independence, integrity, adaptability, and self-protection. • A beta release of the implementation framework for adding these properties to components has been built (within Visual SC). • New controllers (implementing new requirements) can be easily specified, defined and implemented in Visual SC.	[Troya y Vallecillo, 2001]
3.1	• It has been shown that endogenous coordination models and languages are suitable for integrating task and data parallelism, but that they may not be suitable in general for coordinating software components in open systems. In particular, the endogenous coordination model TCM developed by the UMA team has revealed as a suitable model for high-performance computing. • It has been shown that exogenous coordination models and languages allow the separation of the computational and interoperational aspects of components. • An Integrated Development Environment for the development of coordinated applications following the Coordinated Roles model has been developed.	[Diaz et al., 2001a] [Díaz et al., 2001b] [Murillo, 2001]
3.2	• It has been shown how applications developed using "Coordinated Roles" may also be formally specified using a formal notation such as Maude. This provides a mechanism for applications' quick prototyping using the Maude execution environment.	[Sánchez et al. 2000] [Sánchez et al., 2001b]
4.1	• It has been shown how UML Profiles can be successfully used for framework documentation.	[Fuentes y Vallecillo, 2001]
4.2	• A new ADL (called LEDA) has been designed and developed, that fulfils the requirements expressed in the project original plans.	[Canal 2001] [Canal et al. 2001]
5.1	• It has been shown how protocol interoperability among CORBA components can be specified and verified using the pi-calculus. • It has been shown how Maude specifications may seamlessly coexist with CORBA and SOAP objects, providing a smooth connection between both worlds.	[Canal et al., 2001b] [Albarrán et al., 2001a] [Albarrán et al., 2001b] [Albarrán et al., 2001c].

Task	Relevant scientific and technological results achieved so far	Main references
5.2	• A semantic framework for Promela model have been defined.	[Gallardo Merino,2000a] [Gallardo Merino,2000b] [Gallardo et al. 2000]
6.1	• A reference architecture for the semantic integration of heterogeneous data sources is being developed.	[Aldana et al., 2001a] [Aldana et al., 2001b] [Fernandez et al., 2001].
6.2	• It has been shown how Aspect-oriented frameworks (AOF) can be a promising alternative to aspect-oriented languages (AOL): they provide the architectural and dynamic information missing in AOLs. • Some aspects, such as coordination, persistence, awareness, authentication, or multiple views, have been successfully identified in the collaborative virtual environment domains.	[Pinto et al., 2001a] [Pinto et al., 2001b] [Pinto et al., 2001c]

2.1. Problems during the project development (Arial 10 ptos.)

We have found no major problems during the project development so far, at least no one that could not be solved or circumvented. Basically, every planned task is being developed according its initial schedule. The only issue is about the application in task 6. Due to the rapid changes in Web technologies, this task had to be re-oriented in order to take into account the latest technologies and developments. However, this change will not have a string impact in the global schedule.

3. RESULTS (Arial 10 ptos.)

The main results achieved during the first two years of the project are as follows.

3.1. PhD theses

- Javier López. "Diseño de una estructura de notarización para comercio electrónico". Depto. Lenguajes y Ciencias de la Computación. Universidad de Málaga. Noviembre 2000. Director: José M. Troya.
- Carlos Canal. "Un lenguaje para la especificación y validación de arquitecturas de software". Depto. Lenguajes y Ciencias de la Computación. Universidad de Málaga. Febrero 2001. Directores: José M. Troya y Ernesto Pimentel.
- Enrique Soler. "Un lenguaje de coordinación para la resolución de problemas basados en descomposición de dominios". Depto. Lenguajes y Ciencias de la Computación. Universidad de Málaga. Septiembre 2001. Directores: José M. Troya y Juan I. Ramos.
- Juan Manuel Murillo. "Coordinated Roles: Un Modelo de Coordinación de Objetos Activos. Tesis Doctoral. Dpto. Informática, Universidad de Extremadura, Junio 2001. Director: Juan Hernández.
- Fernando Sánchez. "Modelo de disfraces: hacia la adaptabilidad de restricciones de sincronización en lenguajes concurrentes orientados a objeto". Tesis Doctoral. Dpto. Informática, Universidad de Extremadura, 1999. Director: Juan Hernández.

Another PhD thesis is about to be defended:

- Luis Llopis. "Integracion de analisis de tiempo real y tecnicas de diseño en el desarrollo de sistemas empotrados con SDL". Directores: José M. Troya y Manuel Díaz.

3.2. Publications (2000-2001)

The following list shows the number of refereed publications that disseminate the project results so far. A complete listing of these publications is included in Annex 1.

Books (edited)	1	
Book chapters	3	(published by Springer, Addison-Wesley)
Articles in International Journals	7	(all included in the SCI)
Papers in International Conferences	16	(published in LNCS, LNAI, IEEE CS Press)
Papers in International Workshops	15	
Papers in National Conferences	18	

3.3. Technolgy transfer. Participation in other national and international projects

Closely related to this project, some members of this group have participated in an integrated action with the University of Pisa, Italy: "Lenguajes y Modelos para la Interacción de Componentes Software" (1998 a 2000). Basically, this action aimed at the study of how coordination could be used in component-based software environments, in which components are black-boxes, instead of the white-box entities that the traditional coordination languages usually handle.

In addition, two new integrated actions have been submitted and are currently being evaluated. One is with the University of Pisa, in order to continue the work stated by the previous integrated action. The second is with the University of Lisbon, Portugal, and focuses on the possibility of using dynamic types for specifying component protocols, instead of process algebras.

3.4. Collaboration with other research groups

During the development of the project, four researchers visited foreign Universities in Europe and USA:

Researcher: José M. Álvarez Palomo
Dates: September 2000 – November 2000 (3 months)
Location: Dept. of Computer Science, University of York (UK).
Foreign contact: Dr. Andy Evans

Researcher: Mónica Pinto
Dates: June 2000 – September 2000 (3 months)
Location: Dept. of Computer Science and Engineering, University of Nebraska-Lincoln (USA)
Foreign contact: Dr. Mohamed Fayad

Researcher: Mónica Pinto
Dates: May 2001 – October 2001 (6 months)
Location: Dept. of Computer Science and Engineering, University of Nebraska-Lincoln (USA)
Foreign contact: Dr. Mohamed Fayad

Researcher: Carlos Canal
Dates: September 2001 – December 2001 (3 months)
Location: Dept. of Computer Science, University of Pisa (Italia)
Foreign contact: Dr. Antonio Brogi

3.5. Other Activities

The following workshops and events have been jointly organized by the project participants:

- One international Workshop:
  -- WOI'00, in conjunction with ECOOP 2000, Cannes, France, June 2000.
- Two national workshops:
  -- IscDIS'00, in conjunction with JISBD'00, Valladolid, November 2000.
  -- IscDIS'01, in conjunction with JISBD'01, Almagro, November 2001.

The following events will be organized:

- ECOOP 2002: The 16th "European Conference on Object-Oriented Programming" will be held in Málaga, June 12-14, 2002, and co-organized by the two groups.

In addition, four project follow-up meetings have been held for coordination purposes, where participants of the two groups met. The first meeting was held in June 2000, and three meetings have happened in 2001 (February, June, and November).

4. CONCLUSIONS

So far, the project is performing in time, according to the initial plan and schedule. The project is expected to be finished by the end of the next year, where the initial goals will probably be achieved if the scheduled tasks for the last year conclude in time. The only deviation has occurred in task 6.1, that has been re-oriented in order to adapt to the latest emerging technologies in the Web arena, such as the new standards based on XML.

With regard to the results obtained so far, we have shown in the previous sections how the project has achieved not only theoretical results but also some prototypes, which allow the validation of the different proposals and the conduction of concrete experiments with industrial technologies.

We would like to highlight the high degree of collaboration between the two groups involved in the project, mainly among those researchers participating in the same modules. This collaboration in a project in which the tasks are closely inter-related is very positive, not only for the achievement of the project goals, but also for the people involved in it. Moreover, the good relationships between the two groups has resulted in four R&D events jointly organized.

A great number of high-quality papers and publications have been obtained as a result of the research carried out within the project: a total of 62 papers and 1 book have been published. In addition, 5 PhD thesis have been defended and one is expected to be read during the next year.

So far, the relationship with the private companies endorsing the project has been scarce, basically because during the first two years of the project we have concentrated in setting up the common environment and obtaining the first results. During the last year of the project we expect to have running prototypes of the applications built with our technologies, that can be shown to the interested companies. It is important to mention here the contacts that have already started with the Fundación Retevisión, which is very interested in the results that can be obtained in task 6.2. We have also started contacts with Banesto and Tecnatom, which may use in the future part of the ideas and methods developed here in their applications. Finally, Teleserver in Extremadura is still very interested in the use of aspects for the development of their applications, as a mechanism for abstracting away the distribution aspect of components.

Finally, we would also like to mention the number of hot issues and interesting research areas that the project is uncovering. Although we strongly try to concentrate on the original plan and minimize the number of possible deviations, there are many open issues that deserve further investigation, and that we plan to address separately. As a matter of fact, the two integrated actions currently submitted try to deal with a couple of issues found during the development of the project, that required special treatment. In this sense, we feel as a very positive result that the project is opening a number of very interesting research areas and challenges.

ANEXO 1 – Project Publications

[Albarrán et al., 2001a] A. Albarrán, F. Durán, A. Vallecillo. On the Smooth Implementation of Component-based System Specifications. In *Proc. of the 6th ECOOP Workshop on Component-Oriented Programming (WCOP'01)*. Hungary, June 2001.

[Albarrán et al., 2001b] A. Albarrán, F. Durán, A. Vallecillo. Maude meets CORBA. In *Proc. of ASSE'01*, Argentina, September 2001.

[Albarrán et al., 2001c] A. Albarrán, F. Durán, A. Vallecillo. From Maude Specifications to SOAP Distributed Implementations: A Smooth Transition. In *Proc. of JISBD'2001*, Almagro, Ciudad Real (Spain), November 2001.

[Aldana et al., 2001a] J. F. Aldana, M. M. Roldan, A. Gomez. Información semántica para la integración de servicios de datos sobre la Web. In *Proc of V International Conference Society for Knowledge Organization, Capítulo Español*. ISKO-España. 2001.

[Aldana et al., 2001b] J. F. Aldana, M. M. Roldan, A .Gomez, M.I.Yagüe. Un framework para la consulta e integración de fuentes de datos heterogéneas y distribuidas sobre la Web. In *Proc of IV Workshop Iberoamericano de Ingeniería de Requisitos y Ambientes Software (IDEAS)*, 2001.

[Alvarez et al., 2001a] J. M. Álvarez, M. Díaz, L. Llopis, E. Pimentel, J. M. Troya. Deriving Real Time System Implementations directly from SDL specifications. In *Proc of the 9th International Symposium on Hardware/Software Codesign*. Copenhagen, Denmark, April 2001.

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[Alvarez et al., 2001d] J. M. Álvarez, M. Díaz, L. Llopis, E. Pimentel, J. M. Troya. Integrating Schedulability Analysis and Design Techniques in SDL. To appear in *The Real Time Systems Journal* (accepted Feb 2001).

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[Canal et al., 2000] C. Canal, L. Fuentes, J.M. Troya, A. Vallecillo. Adding Protocol Information to CORBA IDLs. In *Object-Oriented Technology - ECOOP 2000 Workshop Reader*, LNCS No. 1964, pages 260—261, Springer, 2000.

[Canal et al., 2000a] C. Canal, L. Fuentes, E. Pimentel, J.M. Troya. Coordinación de Componentes Distribuidos. Un Enfoque Generativo Basado en Arquitectura del Software. En Actas de JISBD'99, páginas 443-454, Cáceres, Noviembre 1999.

[Canal et al., 2000b] C. Canal, L. Fuentes, J.M. Troya, A. Vallecillo. Extending CORBA Interfaces with pi-calculus for Protocol Compatibility. In Proc. of TOOLS Europe'2000, pages 208-225, France, June 2000. IEEE Press.

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