

# Methods and tools for Component- and Aspect-based software development

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### Abstract

Component-oriented Programming (COP) and Aspect-oriented Programming (AOP) are two of the cornerstone paradigms for the development of complex open distributed applications. Based on them, Component-based Software Development (CBSD) and Aspect-Oriented Software Development (AOSD) constitute two technologies that separately address some of the issues for which traditional Software Engineering techniques have shown to be insufficient. CBSD heavily relies on pre-fabricated components for building software applications, while DSOA extends AOP trying to use separation of concerns in all phases of the software development lifecycle. Both emerging technologies are starting to show their benefits, and even moving to other important fields of application in Software Engineering, such as embedded systems and scientific computing, for which “componentization” and “separation of concerns” were alien concepts. This project focuses on the use of both CBSD and AOSD technologies for the development of software applications, trying to combine both approaches in such way that they can naturally co-exist, and that their separate benefits (such as modularity and separation of concerns) can be joined together. A project goal is the definition of a methodology for the joint usage of both approaches. Then, the appropriate models, languages, and tools will also be specified and built in order to support that methodology and facilitate its practice. In addition, three large applications will be built using the methods and tools proposed. They belong to three different domains (virtual collaborative environments, domotic, and scientific computing), and will serve to show, evaluate, and validate the project’s results by means of real and concrete applications.

**Keywords:** Component-based software development; Aspect oriented software development.

## 1 Project Objectives

### 1.1 Background and motivation

This is a coordinated project about Component-based Software Development (CBSD) and Aspect-Oriented Software Development (AOSD), two fields in which the participant groups had some initial experience. The goal of this project was on the use of both CBSD and AOSD technologies for the development of software applications, trying to combine both approaches in such way that they can naturally co-exist, and that their separate benefits (such as modularity and separation of

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concerns) can be joined together. Besides, the project also aimed at serving as a working framework within which the two groups could collaborate, share their respective experiences, and get an in-depth and hands-on-experience knowledge on these late-breaking topics and technologies. With a staff of 32 researchers (21 from Málaga, and 11 from Extremadura), the project started in January 2003 and is expected to continue until December 2005. Three major private companies were originally interested in the project and its potential results.

## 1.2 Introduction

As stated in the original project proposal, Component-based Software Development (CBSD) and Aspect-Oriented Software Development (AOSD) constitute two technologies that separately address some of the issues for which traditional Software Engineering techniques have shown to be insufficient. CBSD heavily relies on pre-fabricated components for building software applications, while DSOA extends AOP trying to use separation of concerns in all phases of the software development lifecycle. Both emerging technologies are starting to show their benefits, and even moving to other important fields of application in Software Engineering, such as embedded systems and scientific computing, for which “componentization” and “separation of concerns” were alien concepts. This project focuses on the use of both CBSD and AOSD technologies for the development of software applications, trying to combine both approaches.

In addition, the definition of a methodology for the joint usage of both approaches is the main goal of the project. The appropriate models, languages, and tools will be specified and built in order to support that methodology and facilitate its practice. Furthermore, three large applications will be built using the methods and tools proposed. They belong to three different domains (virtual collaborative environments, domestic, and scientific computation), and will serve to show and validate the project’s results by means of real and concrete 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 aims 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 stated above, the main goal of the project is the study of the potential combination of two major approaches for the development of software applications: components and aspects. This main objective was split into the following five sub-objectives:

1. Design and implementation of a component- and aspect-based model for the development of large distributed applications, together with a middleware platform based on such a model.
2. Analysis of the potential combined application of component- and aspect-based methodologies and techniques for the design and development of embedded systems.
3. Analysis of the impact of commercial off-the-shelf (COTS) components in the development of distributed applications, and definition of proposal that integrates such kind of components into the development lifecycle of open applications in a natural way.

4. Definition of a common methodology for the modular design and development of distributed applications, that naturally uses component- and aspect-oriented concepts and mechanisms. Such a methodology will be supported by the corresponding languages, formalisms and tools (as defined in the different project packages) in order to enable the construction of distributed applications following the methodology.
5. Development of three large applications, from three different application domains, that will help refine and validate the proposal.

#### 1.4. Work plan and schedule

In order to achieve the five previous sub-objectives, all the project tasks and activities were organized in 6 work packages (or *modules*). The first one (module 0) was dedicated to project management and coordination only, while the rest of the modules have a direct correspondence with 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- and aspect-based models and platforms**

Supervisor: L. Fuentes (University of Málaga)      Participants: 4 UMA + 2 UEX.  
Objective: Design and development of a common component and aspect platform.  
- Task 1.1: Design of a component and aspect model (12 months)  
- Task 1.2: Development of the platform (18 months)  
- Task 1.3: Design and development of a set of common services (18 months)

##### **Module 2: Components for embedded systems**

Supervisor: M. Díaz (University of Málaga)      Participants: 5 UMA.  
Objective: Combine AOSD and CBSD technologies for the development of embedded system.  
- Task 2.1: Extra-functional properties compositionality analysis (12 months)  
- Task 2.2: Design of a component and aspect platform for embedded systems (9 months)  
- Task 2.3: Design of components for embedded systems (9 months)  
- Task 2.4: Development of analysis tools (18 months)

##### **Module 3: Basis for COTS-based software development**

Supervisor: A. Vallecillo (University of Málaga)      Participants: 3 UMA + 4 UEX.  
Objective: Analysis of the impact of the use COTS components in large distributed applications.  
- Task 3.1: COTS components evaluation and selection (24 months)  
- Task 3.2: COTS components adaptation (24 months)  
- Task 3.3: COTS components trading in open systems (24 months)  
- Task 3.3: A methodology for COTS-based software development (24 months)

**Module 4: Modelling and designing component- and aspect-based applications**

Supervisors: F. Sánchez, J.M. Murillo (University of Extremadura) Participants: 3 UMA + 4 UEX.  
Objective: Definition of languages and models for the specification and design of component- and aspect-based software applications.

- Task 4.1: Software architecture specification using aspects (36 months)
- Task 4.2: UML extensions for aspect-oriented design and development (36 months)

**Module 5: Applications**

Supervisor: J. Hernández (University of Extremadura) Participants: 6 UMA + 3 UEX.  
Objective: Design and implementation of three applications in order to validate the proposal.

- Task 5.1: Collaborative Virtual environments (24 months)
- Task 5.2: Domotic (24 months)
- Task 5.3: Scientific computing (24 months)

Table 1 shows the project schedule, based on the previous tasks:

**Table 1.** Project schedule.

	First year	Second year	Third year
Module 0			
Module 1			
Task 1.1			
Task 1.2			
Task 1.3			
Module 2			
Task 2.1			
Task 2.2			
Task 2.3			
Task 2.4			
Module 3			
Task 3.1			
Task 3.2			
Task 3.3			
Task 3.4			
Module 4			
Task 4.1			
Task 4.2			
Module 5			
Task 5.1			
Task 5.2			
Task 5.3			

## 2 Level of success

### 2.1. Project scientific and technological results

The main project results are summarized in the following table, indexed by the tasks described in Section 1.4. 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 Section 4.

Task	Relevant scientific and technological results achieved so far	Main references
1.1	The "CAM" model successfully defined	[Pinto et al, 2003a]
1.2	The "DAOP" middleware platform designed and implemented Extensions to CCM to deal with aspects defined	[Pinto, 2004] [Clemente et al, 2003a-b]
2.1	Generic model for embedded systems' components defined	[Diaz et al, 2003a] [Diaz et al, 2003c]
2.2	Component platform for embedded systems designed and implemented on TAO Real-time CORBA platform	[Diaz et al, 2004a]
2.3	Embedded components for nuclear power plants simulators designed and implemented Component integration in full scope simulator for CN Trillo	[Diaz et al, 2003b] [Diaz et al, 2004b] [Diaz y Garrido, 2004a] [Diaz y Garrido, 2004b]]
2.4	Model checking and performance analysis tools developed  Real-time Analysis Model for SDL defined. This model is used as metainformation in components with real-time constraints	[GMP 04; GMMP 04]  [Alvarez et al. 2003]
3.1	Quality model for software components Usability metrics for software components	[Bertoa et al, 2003a] [Bertoa et al, 2004]
3.2	Semi-automated generation of software adaptors	[Canal et al, 2004a-c]
3.3	A COTS trader for open systems designed and implemented	[Iribarne et al, 2004a]
3.4	A methodology for COTS-based software development has been defined.  Extensions to WSDL to add non-functional properties to web services have been proposed Extensions to WSDL for web services composition (Choreographies and Orquestations) using aspect-orientation have been designed.	[Iribarne, 2004] [Iribarne et al, 2004a-d] [Pérez et al, 2004]  [Ortiz et al., 2004a]  [Ortiz et al., 2004b-c]
4.1	Aspects have been successfully integrated in two current ADLS: LEDA and Rapide  Formal specification of aspects at architecture level have been proposed	[Navasa et al, 2003] [Navasa et al., 2004] [Murillo et al., 2004]  [Sanchez et al, 2003] [Sanchez, 2004]

4.2	UML profiles for the distribution, synchronization, notification and replication aspects successfully defined.  New stereotypes to deal with aspects in CCM have been defined Hypermedia patterns and web business process modelling through aspect-orientation have been proposed Aspect-reverse engineering mechanisms have been designed	[Herrero, 2003] [Conejero et al., 2004]  [Clemente et al., 2003e] [Rodriguez et al., 2003] [Rodriguez et al., 2004] [Pedrero et al., 2003a]
5.1	Some initial results on the development of CVE applications using our proposal already achieved	[Amor et al, 2004a-c] [Fuentes, 2004]
5.2	Two initial applications have been successfully developed	[CRM 04] [Conejero et al, 2003-04]
5.3	The “SBASCO” environment for scientific computing successfully implemented.  A new model integrating aspects in SBASCO is defined	[Diaz et al, 2004c]  [Diaz et al, 2005]

## 2.2. Problems found during the project

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.

## 3 Achievement indicators

### 3.1 PhD theses

- Mónica Pinto. “CAM/DAOP: Modelo y Plataforma Basados en Componentes y Aspectos”. Dpto. Lenguajes y Ciencias de la Computación. Universidad de Málaga. Septiembre 2003. Directores: José M. Troya y Lidia Fuentes
- Jose L. Herrero. “Propuesta de una plataforma, lenguaje y diseño para el desarrollo de aplicaciones orientadas a aspectos”. Dpto. Informática. Universidad de Extremadura. Febrero 2003. Directores: Fernando Sánchez y Miguel Toro.
- Luis Iribarne. “Un modelo de mediación para el desarrollo de software basado en componentes COTS”. Depto. Informática. Universidad de Almería, Julio 2003. Directores: José M. Troya y Antonio Vallecillo.
- M. Soledad Sánchez-Alonso. “COFRE: entorno formal para la especificación, validación y desarrollo en sistemas coordinados”. Dpto. Informática. Universidad de Extremadura. Julio 2004. Director: Juan Manuel Murillo
- Mercedes Macías. “KAI: Kit de accesibilidad a Internet para personas con discapacidad visual”. Dpto. Informática. Universidad de Extremadura. Julio 2004. Director: Fernando Sánchez.

Three more PhD thesis are about to be defended:

- Pedro Clemente. “Aspect-Component based Software Engineering: metodología de desarrollo de software basado en componentes y aspectos”. Director: Juan Hernández

- Mercedes Amor. “Desarrollo de Sistemas basados en Agentes usando Componentes y Aspectos”. Directores: José M. Troya y Lidia Fuentes.
- Daniel Garrido. “Desarrollo de Sistemas Empotrados Distribuidos basado en Componentes”. Director: Manuel Díaz Rodríguez.

### 3.2 Publications (2003-2004)

The following is a summary of the 95 publications obtained during the first 2 years of the project. The complete listing of these publications is included in section 4.

Books (edited)	4	
Book chapters	6	(published by Springer, Addison-Wesley, etc.)
Articles in International Journals	20	(13 of them included in the JCR)
Papers in International Conferences	26	(published in LNCS, LNAI, IEEE CS Press, etc.)
Papers in International Workshops	21	
Papers in National Conferences	19	

### 3.3 Technology transfer. Participation in other national and international projects

The two groups involved in this coordinated project have participated in the following international projects:

- European Network of Excellence on “Aspect-Oriented Software Development” (AOSD Europe). EU Framework Programme (FP6) (Ref.: FP6-IST-004349). Nine centers, 84 researchers. 2004-2009.
- CYTED Project “WEST: Web-Oriented Software Technology” (CYTED subyoyecto VII, codigo VII.18). July 2000 – July 2003.
- European Integrated Action “Typing the Behavior of CORBA Objects” (HP2001-0077), with the University of Lisbon, Portugal. 2002-2003.
- Edition of ISO/IEC International Standard 19793, ITU-T X.906: “Use of UML for specification of ODP systems”. Joint project ISO/IEC and ITU-T, 2003-2006.
- ISO/IEC Study Group on the revision of the RM-ODP. 2004-2005.
- CDTI Industrial Research Project: Modernization of Simulation Technology at Tecnatom (*MOTESI*).
- JAVI: Real-time Visualization Tool of Nuclear Power Plant Models. Tecnatom S. A. 2003-2004.
- TEAMLOGIC: A Real-time Logic and Control Simulator for Nuclear Power Plant Models”. Tecnatom S. A. 2004-2005.
- PREJAVI: Thermohydraulic Model Generation for TRAC. Tecnatom S. A. 2004-2005.
- Software Process Improvement in Tecnatom. 2002-2004.

### 3.4 Collaboration with other research groups

This project has greatly helped establishing strong links with other research groups. These links have materialized on joint publications (see Section 4), joint organization of workshops and other events (Section 3.5), and joint projects (Section 3.4). The following is a list of the main researchers and groups with which we are currently closely collaborating:

- Mehmet Aksit. University of Twente, The Netherlands.
- Jean Bézibin, Ecole de Mines de Nantes, France
- Antonio Brogi. Univ. Pisa, Italy.
- Andy Evans. Univ. of York. UK.
- Nora Kotch, LMU, Munich, Germany
- Lea Kutvonen, Univ. of Helsinki, Finland
- Peter Linington, Univ. of Kent at Canterbury, UK
- Ana Moreira, Univ. Nova de Lisboa. Portugal.
- Pascal Poizat, University of Evry, France.
- Awais Rachid, Univ. of Lancaster, UK.
- Vasco Vasconcelos. Fac. Ciencias, Univ. Lisboa. Portugal.

The following visits and stays have happened or are already scheduled.

- José M. Alvarez visited Prof. Andy Evans at the Univ. of York, for one month in 2003.
- Carlos Canal visited Prof. Brogi at the Univ. of Pisa, one month in 2003 (September), and one month in 2004 (September).
- Jose M. Conejero will visit Prof. Mehmet Aksit, Dept. of Computer Science, University of Twente (The Netherlands) from January 2005 to June 2005 (6 months).
- Jose Luis Pastrana visited Miguel Katrib at the Universidad de la Habana, one month in september 2004.

### 3.5 Other Activities

The following events have been organized to disseminate some of the project results:

- International Workshop on ODP for Enterprise Computing (WODPEC 2004), in conjunction with EDOC 2004, Monterey, CA, 20 September 2004
- Normalización y Calidad en la Ingeniería del Software, Taller asociado a las IX Jornadas de Ingeniería del Software y Bases de Datos (JISBD04) Málaga, 9 Noviembre 2004
- Desarrollo de Software dirigido por modelos. MDA y Aplicaciones, Taller asociado a las IX Jornadas de Ingeniería del Software y Bases de Datos (JISBD04) Málaga, 9 Noviembre 2004
- ISO/IEC JTC1 SC7 Working Group 19 Meeting, Málaga, 22-26 Noviembre 2004.
- Tutorial “Using MDA for Designing and Implementing Web-based Applications”, by N. Moreno and A. Vallecillo at the International Conference on Web Engineering (ICWE 2004), Munich, Germany, July 2004
- A. Vallecillo. “Servicios Web y MDA”. Invited talk at Universidad de Extremadura. May 2003.
- J. Hernández. Casas Inteligentes: Mito o Realidad, Invited talk at Universidad de Málaga, December 2003
- J. Hernández, J. M. Murillo. AspectJ: una perspectiva práctica del Desarrollo de Software Orientado a Objetos, Tutorial at VIII Jornadas de Ingeniería de Software y Bases de Datos, JISBD'2003, Alicante, November 2003.



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

- Four international Workshops:
  - WACT'04, in conjunction with ECOOP 2004, Oslo, Norway, June 2004.
  - DSOA'03, in conjunction with JISBD'03, Alicante, November 2003.
  - DSOA'04, in conjunction with JISBD'04, Málaga, November 2004.
  - VII Jornadas de Tiempo Real, Málaga, February 2004.
- One national Conference:
  - IX Jornadas de Ingeniería del Software y Bases de Datos, JISBD'04, Málaga, November 2004.

Apart from individual short visits between Málaga and Extremadura, two major project follow-up meetings have been held for coordination purposes, where participants of the two groups met (May and December 2003). The next meeting is scheduled on November 2004, in conjunction with JISBD'2004.

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