Jornada de Seguimiento de Proyectos, 2010
Programa Nacional de Tecnologías Informáticas

SOAQTest: Quality in development and test processes in service oriented architectures - TIN2007-67843-C06

Javier Tuya [*] University of Oviedo
Isabel Ramos [**] University of Seville
Mercedes Ruiz [***] University of Cádiz

Abstract

This project is aimed at the research on new methods, techniques and tools, as well as the adaptation of those already existing, in order to improve the quality of software processes and products, paying special attention to the applications based on service oriented architectures. The technologies to develop include new testing approaches and the elaboration of simulation models of both processes and products.
Keywords: Software Testing, Software Process Simulation Modelling, Service Oriented Architectures

1. Project objectives

The global objective of the project is the research and development of new technologies aimed at the improvement of software processes and products quality, paying special attention to the development of applications based on service oriented architectures. The base technologies that will be applied are software testing and simulation as a means of evaluating both products and processes. This general goal is decomposed into the following seven objectives:

O1. To elaborate criteria and specific functional testing techniques for the access to repositories of structured and semi-structured information.
O2. To elaborate criteria and specific techniques of testing and simulation in web service compositions.
O3. To improve requirement models and tests based on metrics and early testing.
O4. To elaborate methods and simulation models oriented towards the improvement of the software processes.
O5. To model and simulate the interactive systems development process under service oriented architectures.
O6. To adapt process assessment and improvement models to software development in small and medium companies.
O7. To develop tools to support the methods and techniques developed and perform technology transfer of the results (shared by all the above).

To achieve these objectives, the project was organized into three subprojects which are enumerated below, with the indication of the University leading each one:

[*] Email: tuya@uniovi.es
[**] Email: iramos@us.es
[***] Email: mercedes.ruiz@uca.es

- UO (University of Oviedo) - *Test4SOA: Techniques for functional testing in service oriented architectures.*
- US (University of Seville) - *QSimTest: Predictable and managed quality by means of simulation and testing techniques at early stages.*
- UC (University of Cádiz) - *SOAQSim: Ontology-based simulation models and software process improvement for SOAs.*

The number of EDPs for each project is 8.5, 8.5 and 12, respectively. Figure 1 depicts the Gantt Chart for the whole project and provides the up to date percentage of completion of each of the ten workpackages and the tasks in which it has been structured.

2. Project achievements

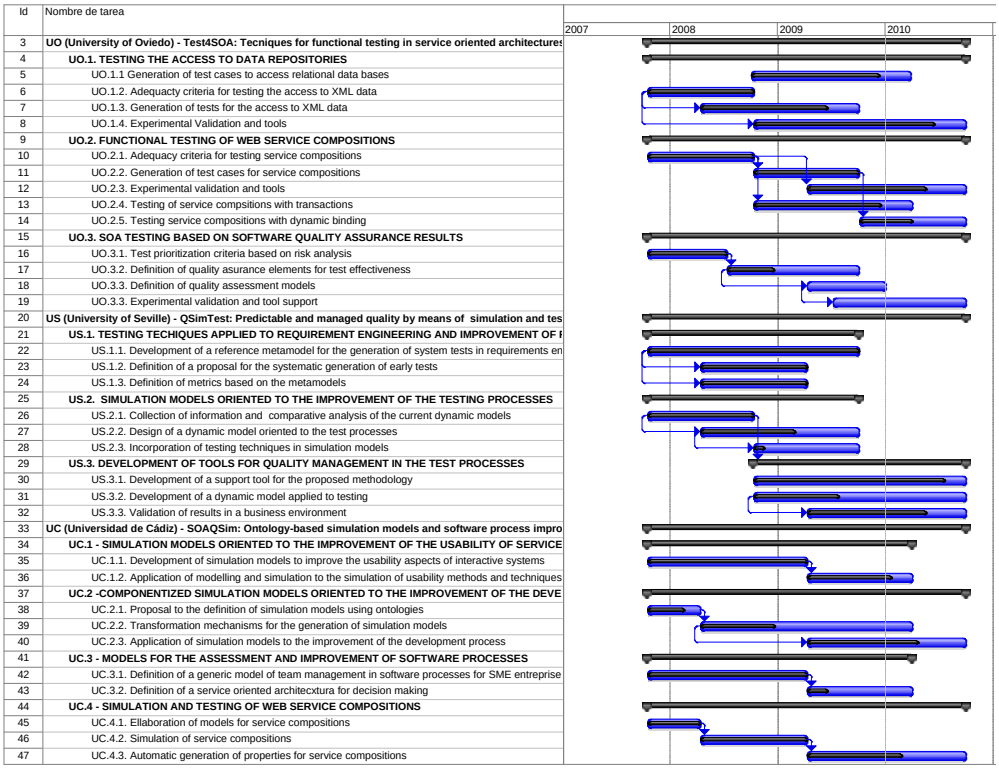
This section describes the activities and achievements of the project related to the aforementioned objectives. Each objective is traced back to the workpackages which allocate the planed tasks intended to accomplish each one. In most cases, a workpackage includes tasks allocated to different subprojects.

O1. Functional testing of the access to data repositories (workpackage UO.1). We defined a number of test adequacy criteria, by refining and completing previous work on multiple condition [51] and the first empirical study aimed at assessing the effectiveness of using these criteria compared with conventional approaches [53]. Based on the feedback obtained, we created a novel criterion called Full Predicate Coverage [56] which is based on masking Modified Condition/Decision Coverage (MCDC) specifically tailored for database queries and fully supported by the SQLFpc tool. Additionally, new capabilities have been added to the SQLMutation mutation system to support more query features and to detect more equivalent mutants. These works lead to the definition of a standard set of benchmarks and enabling tools for the assessment of research in testing database applications [55] developed as a join work with the Polytechnic University of New York. Starting from the SQLFpc criterion, two additional as well as complementary directions have been taken: the automation of the generation of test data starting from a blank database [51] and the reduction of the test database starting from a previously populated database, supported by the QAShrink tool [54]. Regarding to the testing of non relational data, the test data generation has been addressed for testing XML repositories using ToXgene [33]. We have also begun to address the oracle problem [34][35].

O2. Testing and simulation of web service compositions (workpackages UO.2, UC.4). Metaheuristic techniques for test data generation have been developed based on Tabu Search [9] and Scatter Search [7] as well as their particularization for the web service compositions [6]. Due to the nature of web service compositions two other important issues have been studied: the first one is the problem of testing the composition of services with long running web transactions. A risk-based approach is used to determine the test situations to be exercised [8]. The second one is the problem of testing web service compositions with dynamic binding [22]. Currently we are undertaking a systematic review of the works published so far, whose results reveal a number of potential areas for future research.

A complementary approach to the testing of service compositions is the generation of dynamic invariants from the execution of the compositions which allows inferring properties in the service composition using Daikon [50]. This approach is integrated in the Takuan tool which has further been enhanced to analyze more complex compositions with non-scalar variable content, despite the limitations of the dynamic invariant generator used [49]. The Daikon invariant generator has

Figure 1: Gantt Chart of the Project



Id	Nombre de tarea
3	**UO (University of Oviedo) - Test4SOA: Tecniques for functional testing in service oriented architectures**
4	**UO.1. TESTING THE ACCESS TO DATA REPOSITORIES**
5	UO.1.1 Generation of test cases to access relational data bases
6	UO.1.2. Adequacty criteria for testing the access to XML data
7	UO.1.3. Generation of tests for the access to XML data
8	UO.1.4. Experimental Validation and tools
9	**UO.2. FUNCTIONAL TESTING OF WEB SERVICE COMPOSITIONS**
10	UO.2.1. Adequacy criteria for testing service compositions
11	UO.2.2. Generation of test cases for service compositions
12	UO.2.3. Experimental validation and tools
13	UO.2.4. Testing of service compsitions with transactions
14	UO.2.5. Testing service compositions with dynamic binding
15	**UO.3. SOA TESTING BASED ON SOFTWARE QUALITY ASSURANCE RESULTS**
16	UO.3.1. Test prioritization criteria based on risk analysis
17	UO.3.2. Definition of quality asurance elements for test effectiveness
18	UO.3.3. Definition of quality assessment models
19	UO.3.3. Experimental validation and tool support
20	**US (University of Seville) - QSimTest: Predictable and managed quality by means of simulation and tes**
21	**US.1. TESTING TECHIQUES APPLIED TO REQUIREMENT ENGINEERING AND IMPROVEMENT OF I**
22	US.1.1. Development of a reference metamodel for the generation of system tests in requirements en
23	US.1.2. Definition of a proposal for the systematic generation of early tests
24	US.1.3. Definition of metrics based on the metamodels
25	**US.2. SIMULATION MODELS ORIENTED TO THE IMPROVEMENT OF THE TESTING PROCESSES**
26	US.2.1. Collection of information and comparative analysis of the current dynamic models
27	US.2.2. Design of a dynamic model oriented to the test processes
28	US.2.3. Incorporation of testing techniques in simulation models
29	**US.3. DEVELOPMENT OF TOOLS FOR QUALITY MANAGEMENT IN THE TEST PROCESSES**
30	US.3.1. Development of a support tool for the proposed methodology
31	US.3.2. Development of a dynamic model applied to testing
32	US.3.3. Validation of results in a business environment
33	**UC (Universidad de Cádiz) - SOAQSim: Ontology-based simulation models and software process impro**
34	**UC.1 - SIMULATION MODELS ORIENTED TO THE IMPROVEMENT OF THE USABILITY OF SERVICE**
35	UC.1.1. Development of simulation models to improve the usability aspects of interactive systems
36	UC.1.2. Application of modelling and simulation to the simulation of usability methods and techniques
37	**UC.2 -COMPONENTIZED SIMULATION MODELS ORIENTED TO THE IMPROVEMENT OF THE DEVE**
38	UC.2.1. Proposal to the definition of simulation models using ontologies
39	UC.2.2. Transformation mechanisms for the generation of simulation models
40	UC.2.3. Application of simulation models to the improvement of the development process
41	**UC.3 - MODELS FOR THE ASSESSMENT AND IMPROVEMENT OF SOFTWARE PROCESSES**
42	UC.3.1. Definition of a generic model of team management in software processes for SME entreprise
43	UC.3.2. Definition of a service oriented architecxtura for decision making
44	**UC.4 - SIMULATION AND TESTING OF WEB SERVICE COMPOSITIONS**
45	UC.4.1. Ellaboration of models for service compositions
46	UC.4.2. Simulation of service compositions
47	UC.4.3. Automatic generation of properties for service compositions

also been modified to not infer as invariants the properties enforced by the XML Schema definition [48].

In order to allow experimentation in this field two different directions have been taken. The first one is the elaboration of a set of mutation operators for WS-BPEL 2.0 language covering the spectrum of features of the OASIS standard [19]. Besides, a framework for automatic mutant generation for the WS-BPEL language has also been designed [11]. A mutant generator, together with an analyzer and a system that executes and evaluates the mutants integrate the core of the tool GAmera, which generates automatically a subset of high quality mutants for WS-BPEL compositions and is able to detect potentially equivalent mutants allowing improve the quality of the test suite [10]. The second direction is addressed towards the construction of a repository of available web services compositions.

O3. Early testing (workpackages US.1, US.3, UO.3). Our original approach, NDT was improved with new ideas oriented to test generation [13]. Its metamodel was extended with test support and its associated tool (NDT-Tool) was evolved with a set of tools to support these improvements [27]. This new tool environment, named NDT-Suite is composed now by five tools that helps in NDT application and supports the test phase [14]. Nowadays, this environment is being used by several companies. NDT was also improved with some new aspects developed in collaboration with the UC group aimed at the improvement of NDT with some processes of ISO 12207 [1].

Other additional work was directed towards the evaluation of UML driven test cases [20] and a survey on testing practices used by practitioners in Spain [21].

O4. Methods and simulation models oriented towards the improvement of software processes (workpackages US.2, UC.2). A prototype model to hybrid simulation for software production in a multiproject environment was developed [41]. This prototype captures two software process characteristics: continuous and discrete and lets to hierarchically decompose the multiproject problem, generate plans in terms of limited resources and dealing with risk and uncertainty of these projects [40][42]. In order to offer a suitable support to analyze results obtained with the use of our dynamic models, a method to obtain association rules mainly oriented to project management in software projects was presented [39]. The model is composed by a set of association rules and allows simultaneous estimates of the variables to optimize, which represents an advantage over other estimation techniques in which only can make a personalized estimate of each variable. Also a segmented software cost estimation based on fuzzy clustering [5] obtains mathematic models which are different for each cluster and, thus, each project in the historical database can participate in more than one cluster. This allows solving some problems detected in the use of segmented combined models proposed by other authors, which each concrete project belongs to a submodel with a concrete grade of belongings.

In order to analyze how service-oriented development can benefit from simulation, the different applications of simulation modelling in support of service-oriented development have been first identified and categorized [47]. An in-depth study of the fields of application of simulation modelling in the area of service management, having ITIL as a reference, has also been developed [46]. After these studies, two simulation models have been built. The first one is useful at the service strategy process [44] and the second one is useful at the service capacity management process [45][43]. With the aim of building a tool for automatic mapping BPMN models to the notation of simulation models, two studies have also been developed. The first one explores the possibilities of an ontology-driven mapping and proposes a domain ontology for the transformation of BPMN to the System Dynamics simulation approach [28]. The second study analyzes Model Driven Engineering as an alternative to automate the transformation [29].

O5. Simulation modeling of the interactive systems development process (workpackage UC.1). We have built a simulation model that helps to experiment the effects that key usability aspects have upon the UCD process evolution and behaviour [30]. A simulation model to simulate the behaviour of the usability problem detection phase using the heuristic evaluation method has been also developed. It helps to analyze how the three key areas, namely cost, time and quality, are affected by changes in the number and expertise of evaluators [28]. This simulation model has also been enhanced to simulate the effect of the evaluators' dedication to the evaluation sessions [29]. As far as we know, the application of simulation modelling in the field of usability evaluation and UCD is original since no other similar results have been found in the available specialized literature.

O6. Adaptation of process assessment and improvement models (workpackage UC.3). Firstly, a mapping between the ISO/IEC 15504 best practices and the teamwork key factors was performed [37]. Secondly, a set of teamwork best practices that could be used by a software company to assess software development teams was defined [4]. With the interest of focusing on teamwork aspects in future software process improvement initiatives, Team SPICE, a SPICE-based Teamwork Assessment Model for software projects, was developed [2]. Finally, this Teamwork Assessment Model was applied to eight software teams. The experiences of the implementation of ISO/IEC 15504 are published in [38]. Lessons learned from the application of Team SPICE to these software teams are expected to be published in [3].

O7. Support Tools & technology transfer (all workpackages). In addition to the aforementioned accomplished activities, a set of support tools have been developed. The tools have been mentioned when applicable and they are listed in Section 3.4 along with a short description and the URL from which they can be accessed. Technology transfer is detailed in Section 3.5.

3. Results indicators

This section presents both quantitative and qualitative result indicators of the project and separate information about each subproject. Table 1 summarizes the main quantitative indicators of the project and subprojects. When two numbers appear in the form *a*+*b*, it means that *a* refers to a published or accepted item and *b* to a submitted or planned item (from now to the end of the project). The most relevant publications are cited in this report and referenced at last section.

Table 1. Summary of the results indicators

Indicator-Subproject	Test4SOA	QSimTest	SOAQSim	Total
Int. Journals (SCI)	5+3	8+2	0+3	13+8
Int. Journals (no SCI)	4	2	2	8
Int. Conference/Workshop	10+5	17+4	16+2	43+11
Nat. Journals		5+3	1	6+4
Nat. Conference/Workshop	7+2	7	15	29+2
PhD Thesis	1	1+2	2+2	4+4
Research Stays	2+1	5+3	5	12+4
Tools (publically available)	5	5	2	12
Related projects (Number)	2	5	1	8
Related projects (Budget)	248,315.00 €	837,206.26 €	8,800.00 €	1,094,321.26 €

The following subsections provide further qualitative details about the results. When appropriate, the identification of the subproject is indicated by means of the name or the acronym (UO, US, UC) of the University leading the subproject.

3.1. Publications

The results of the project have been published in the following JCR journals (SCI impact factor included in brackets): (UO) Software Testing, Verification and Reliability (1.053), Information and Software Technology (1.200), Journal of Universal Computer Science (0.488), Computers & Operations Research (1.366), (US) IEEE Transaction on Software Engineering (2.132), Journal of Systems and Software (1.241), Journal of Engineering Applications of Artificial Intelligence (1.397), Journal of Hydroinformatics (0.681), Expert systems with applications 2.596), Journal of Hazardous Materials (2.975), Advances in Engineering Software (0.431), and the following currently under review: (UC) Information and Software Technology (1.200), Software Quality Journal (0.974).

Other non indexed publications are: (UO) European Journal for the Informatics Professional, IEEE Latin America Transactions, (US) International Journal of Computer Applications in Technology, Advances in Information Systems Development, Handbook of Research on Web Information Systems Quality, (UC) European Journal for the Informatics Professional, International Journal of Software Engineering.

Regarding to international conferences and workshops, the project results have been presented at: (UO) TAIC-PART 2008, 2009, DBTest 2009, ICWE 2009, SBST 2009, STV 2008, WTST 2008,

EuroSPI 2009, (US) RCIS 2008, 2009, 2010, WEBIST 2008, 2010, ICEIS 2008, EISWT 2008, EATIS 2008, 2009, MoDEL 2008, ICSoft 2009, ICSP 2009, (UC) SOSE 2008, SOFSEM 2009, ECOWS 2008, 2009, ICWE 2009, INTERACT 2009, I3E 2009, EuroSPI 2008, 2009, SPICE 2009.

In the national scope, diverse results of the several subprojects have been published at several related journals, conferences and workshops, such as the following. Journals: NOVATICA, REICIS. Conferences and Workshops: JISBD 2008, 2009, JSWEB 2008, ESTYLF 2010, PRIS 2008, 2009, ADIS 2008, 2009, PNIS 2009.

3.2. Participation in research events

The members of the team have organized JISBD/PROLE 2008, JICS 2008, 2009 the PRIS workshop (2008, 2009) and the IWSM-Mensura 2007. They have also participated in the organizing committee of ESEM 2007 and participated as program committee members or reviewers in several journals, conferences and workshops that are enumerated below:

- Review activities in international journals: (UO) IEEE Transactions on Software Engineering, Software Testing, Verification and Reliability, Journal of Systems and Software, Information and Software Technology, International Journal of Agent-Oriented Software Engineering, Software Quality Journal, (US) ACM Transactions on Software Engineering and Methodology, Journal of Web Engineering, Journal of Systems and Software, (UC) International Journal of Software Engineering, Revista Ibérica de Sistemas y Tecnologías de la Información.
- Program committee members and reviewers in international conferences and workshops: (UO) SBST 2009, ATSE 2009, ICSEA 2008, 2009, 2010, CAST 2008, 2009, FIE 2008, CIINDET 2008, CISTI 2010, INTENSIVE 2009, 2010, IMETI 2008, 2009, 2010, ICSOFT 2008, 2009, 2010, (US) ISD (MDE track manager), CECIIS 2008, EATIS 2008, ECWEB 2008, ICCES 2008, ISD 2008, RCIS 2008, ICADIWT 2009, ICEES 2009, ICNM 2009, ICWE 2009, MDWE 2009, ISD 2009, RCIS 2009, (UC) ISWM-Mensura 2007, IWSP 2008, 2009, 2010, CISTI 2008, 2009, 2010, SELSC 2008, 2009, KREAM 2010.
- Program committee members and journal review (national): JISBD, JICS, PRIS, ADIS, expo:QA, REICIS.

3.3. Collaboration with other research groups

University of Oviedo. As a consequence of this project, the UO team has initiated the following collaboration relationships:

- Polytechnic University of New York (USA): Collaboration with Phyllis Frankl in the assessment of the effectiveness of database application testing by integrating their tool (JDAMA) with the mutants generated by our tool (SQLMutation). Additionally, a joint paper on testing benchmarks in this field has been prepared [55].
- University of Victoria (Canada): Collaboration with Daniel Hoffman to integrate our work on XML data generation with their work on XPath-based data generation grammars and a stay of Claudio de la Riva agreed for summer 2010.
- School of Technology at Oxford Brookes University (UK): Collaboration with Muhammad Younas to work on testing of long-term web transactions, materialized with a stay of the FPI fellow that has started in January 2010.
- University of Castilla-La Mancha: The group is also involved in a project of their Regional Plan: PRALIN: Software Product Line Testing (PAC-08-121-1374) as a subproject.

In addition, the UO group leaded the coordination of the RePRIS Network (TIN2007-30391-E) and participates in other networks and platforms such as the INES platform (Spanish Initiative for Software and Services) and their SEA and IS groups, the CEPIS European SIN on Software Quality as well as other networks: RedBD: National Network of excellence in databases (TIN2005-

24802-E) and its continuation: Data Management Network (TIN2008-04453-E), HEUR: Spanish Red of Metaheuristics Procedures (TIC2002-10886-E, TIN2004 -20061-E), and DQNet: Network for the Promotion of Data Quality in Business Information Systems (TIN2008-04951-E/TIN).

University of Seville. During the project, some researchers have completed the following research stays:

- Javier Jesús Gutiérrez at the University of Montpellier (France).
- María José Escalona at the University of Varazdin (Croatia), Politecnico di Milano (Italy), Ludwig Maximiliam Universitat (Munich, Germany).
- Francisco J. Domínguez at the University of Lille (France).

During the project they have collaborated with several national and international universities resulting in joint papers (already published or under review):

- International: University of Galway (Ireland): A paper is submitted with Michael Lang to Information Software and Technology. University of Paris (France): A paper was published with Gerard Kubryk [36]. University of Sao Paulo (Brasil): A paper was published in ICEIS [17]. University of Montpellier (France): A paper was published in Models with Clementine Nebut [27]. Ludwig Maximiliam Universitat (Germany): A paper was published in LNBS with Nora Koch [16]. University of La Plata (Argentina): A paper was submitted to ICSoft written with Gustavo Rossi.
- National: University of Alcalá de Henares: A paper was submitted to SQM 2010 (Software Quality Management Conference) and other was published in the Journal of Systems and Software [5]. University of Málaga: A paper was published in EATIS with Antonio Guevara [15]. University of Huelva: several publications were published with researchers in other groups [25][32][31][26]. University of Salamanca: A paper was published in the Expert Systems with Applications Journal [39].

Additionally they also had special collaboration with other networks: The RePRIS Network (TIN2007-30391-E), DSDM: National Network of Model-Driven Engineering (TIN2008-00889-E).

University of Cádiz. The members of the team have completed the following research stays:

- Antonia Estero, Inmaculada Medina and Francisco Palomo made a research stay in 2009 at the Software Engineering Group headed by Mark Harman at King's College of London. The topics of collaboration have been Mutation Testing and Optimization Algorithms.
- Manuel Palomo made also a research stay in 2009 at the Moscow Linguistic University. The topic of collaboration was white box testing for WS-BPEL compositions.
- Mercedes Ruiz made a research stay in 2008 at the Adaptive Distributed Systems and Educational Technology leaded by Jorge Torres at the Tecnológico de Monterrey (Campus of Querétaro). During this stay, different approaches of simulation and learning technologies in the context of distributed systems were analyzed.

The UC group also maintains other collaboration relationships with the Computing Department of the Open University (UK), the Alarcos Research Group (University of Castilla-La Mancha) and the University of Alcala. They have also participated in the RePRIS Network (TIN2007-30391-E).

3.4. Tools

This section enumerates the tools developed in the scope of this project:

- SQLMutation (maintenance) (UO): New features for the mutation system for SQL queries (http://in2test.lsi.uniovi.es/sqlmutation/).
- SQLFpc (UO): Generates coverage rules to assess the test data adequacy using a Full Predicate or masking MCDC coverage criterion (http://in2test.lsi.uniovi.es/sqlfpc/).

- SQLRules (UO): Evaluates test data adequacy by running mutants and coverage rules against the database (http://in2test.lsi.uniovi.es/sqltools/sqlrules/).
- QAShrink (UO): Reduction of the size for test databases while preserving the SQLFpc coverage (http://in2test.lsi.uniovi.es/sqltools/qashrink/).
- AGAPE (UO): Eclipse plug-in for test case generation based on UML activity diagrams (http://esp.uem.es/aquabus/index.htm).
- NDT Suite (US): NDT-Profile, NDT-Quality, NDT-Driver, NDT-Report, NDT-Glossary (www.iwt2.org) were registered and now, they are been used by private and public companies.
- Takuan (UC): A dynamic invariant generator for web service compositions written in WS-BPEL (http://neptuno.uca.es/redmine/projects/show/takuan-website).
- Gamera (UC): A mutation testing framework for web service compositions written in WS-BPEL (http://neptuno.uca.es/redmine/projects/show/gamera).

3.5. Technology transfer and social impact

Regarding the involvement of the group in the industrial sector and the technology transfer of the project results, the activities carried out are described below:

University of Oviedo. In addition to participation in forums such as the Working Group IT Sector which works on the Strategy for the Development of Information Society in Asturias, and the coordination of the network RePRIS, involving a significant number of companies, the main researcher of this project is the coordinator of the AENOR Working Group AEN/CTN71/SC7/GT26 Software Testing which works on the development of the future ISO standard ISO/IEC 29119 Software Testing Standard. At an international level he is also a member of the ISO international working group ISO/IEC JTC1/SC7 Working Group 26 and the Association for Software Testing (AST), promoted by Cem Kaner.

In particular, in the field of technology transfer, the project MPPP: Improvement of Software Testing Processes (CN-07-168/08-073) has resulted in the development of a testing methodology for the Principality of Asturias (which is an EPO of the project), named METESPA, complementing other existing management, systems and development methodologies. The implementation of the methodology is currently being undertaken through dissemination activities, training and the use of contractors and staff in the first projects. The other result of this project was the assessment of the SOAQTest project results in the Principality corporate applications (in the fields of database testing and web services compositions), obtaining interesting conclusions that helped to assess the usefulness of these results in an industrial environment and provided valuable feedback on the research. This work will continue within further projects.

University of Seville. Research results obtained in the project have motivated their application in the enterprise environment, by mean of the following technology transfer projects:

- WiTLE2. To develop technologies and tools to make easier the implantation of 4G networks. In collaboration with SADIEL and partially granted by CDTI.
- HEMPIC2: Integrated management tool, in collaboration with Guadaltel to develop a management tool that supports software project needs.
- Development of a Quality Office for Cultural Administration Information Systems in collaboration with Andalusian Culture Government.
- Management of a Technical Office for AQUA project in collaboration with Emasesa Company, the University of Málaga, Everis and Novasoft.
- Definition of a methodological environment for the Diraya project, in collaboration with the Health Andalusian Service.

With these projects, the group got an amount of 837,206.26 euro as a result of research transference. Besides, these transfer activities have originated some publications and papers in collaboration with companies [15][12][18].
Besides, there are a relevant participation of US researchers in other groups such as the AENOR AEN/CTN71/SC7/GT26 Software Testing workgroup, and the Spanish platform of Software and Services (INES) in Quality aspects.

University of Cádiz. The main technology transfer activities are carried on in the project: "Software Process Assessment and Improvement according to ISO/IEC 15504", whose goal is to lead a Software Process Improvement Programme according to ISO/IEC 15504. Within this programme the Teamwork Assessment Model has been applied to eight software teams. This project is supported by TurisTEC, a cluster of small and medium software companies in the Balearic Islands.

3.6. Impact on Human capital

The following four PhD theses related to the project were defended over the two years:

- Raquel Blanco (UO): *Scatter search for automatic generation of software test cases* (2008).
- Javier Navascués (US): *A hybrid model for dynamic simulation of custom software project in a multiproject environment* (2008).
- Esperança Amengual (UC): *A software project teamwork assessment model* (2009).
- Juan José Domínguez (UC): *Methods of global optimization and combinatorial optimization based on genetic search* (2009)

The PhD Thesis of Mª José Suárez-Cabal (UO) obtained the Doctoral Dissertation Award in 2007. Four other PhD theses are scheduled for 2010: Javier Gutiérrez (US): *Functional tests generation from functional requirements*, Antonia Reina (US): *Advanced separation of concerns and model-driven development applied to web systems*, Elena Orta (UC): *System Dynamics Simulation Models applied to the SOA field* and Nuria Hurtado (UC): *Applications of Simulation Modeling to Usability Engineering.*

Additionally, during the project period the following four DEAs have been obtained by members of the project: Arturo Torres (US), Nuria Hurtado (UC), Elena Orta (UC), María Teresa García (UC), and four other are planned for 2010: José Ponce (US), Rubén Casado (UO), Dae Sung Kim Park (UO) and Marcos Palacios (UO).

Related to the incorporation of human resources to the project, in 2009, Rubén Casado joined the project with an FPI Grant, as well as Dae Sung Kim Park and Marcos Palacios with a Severo Ochoa Grant (regional). They had previously joined the project as hired software engineers in the UO team. In 2008, four new novel researchers were included in the US team. During the project, three software engineers have also worked as hired personnel.

3.7. Project Management

The project is currently on schedule. The only significant deviations from the plan are in workpackage UO.3 which is behind schedule and task UC.3.2 whose scope has been changed.

The issues addressed by the project are based on two different but complementary technologies: testing and simulation. The different background of the teams that compose each subproject made the coordination essential and its results very fruitful. The UO team provided the general background in software testing, the US team its experience in project simulation techniques oriented to management process and early testing approaches; and the UC team in simulation and process improvement. A particularity of the project was that, although the general research lines were a continuation of previous ones, 52% of members of the project team did not participated in the previous National R&D projects. After the seven new incorporations (four faculty members in the US project and three fellows in the UO project) this figure rises to 61%. Therefore, the

participation of these novel researchers in a larger team strongly contributed to their learning. Other important additional results of the coordination activities are two co-supervised PhD Theses, the participation in the RePRIS network and the joint works on WS-BPEL mutants and on the relationships between NDT and the ISO/IEC 12207 standard [2].

The coordination mechanisms that have been used ranged from twice-a-year leader meetings, to team member monographic meetings and continuous interaction to deal with specific issues via e-mail and other channels of communication. A critical factor to achieve the cohesion of the whole team is the visibility of the project results by all members, which is of particular interest for novel researchers. Every year a formal project meeting was held (Seville 2007, Cádiz 2008, San Sebastián 2009). The next one will take place in 2010. All team members attended these workshop-like meetings and made presentations of their work, which are published in the project's intranet, followed with a discussion about the current and future works and planning. Most of the members have also arranged coordination meetings during the JISBD week.

4. References

[1] Amengual E, Mas A, Escalona MJ, Ramos I, Ruiz M. Correspondencia de procesos de la metodología NDT con el estándar ISO 12207. Revista Española de Innovación, Calidad en Ingeniería del Software. REICIS. España 2009.Vol. 5(1), 6-19,

[2] Amengual E, Mas A. La Gestión del Trabajo en Equipo para la Mejora de la Calidad y los Procesos de Desarrollo de Software. Novática. Revista de la Asociación de Técnicos en Informática, 2009; 200: 32-38.

[3] Amengual E, Mas A. Team SPICE: A SPICE-based Teamwork Assessment Model. Software Process Improvement and Capability Determination. 10th International Conference (SPICE), 2010. (Submitted, under review).

[4] Amengual E, Mas A. Teamwork Best Practices in ISO/IEC 15504. Software Process Improvement and Capability Determination. 9th International Conference (SPICE), 2009; 106-112.

[5] Aroba J, Cuadrado JJ, Sicilia MA, Ramos I, Barriocanal E. Segmented Software Cost Estimation Models based on Fuzzy Clustering. Journal of Systems and Software, 2008.

[6] Blanco R, García-Fanjul J, Tuya J. A first approach to test case generation for BPEL compositions of web services using scatter search. 2nd International Workshop on Search-Based Software Testing (SBST), 2009b.

[7] Blanco R, Tuya J, Adenso-Díaz B. Automated test data generation using a Scatter Search approach. Information and Software Technology 2009; 51 (4): 708-720.

[8] Casado R, Tuya J. Testing transactions in service oriented architectures. International Conference on Web Engineering (ICWE) - Doctoral Consortium, 2009.

[9] Díaz E, Tuya J, Blanco R, Dolado J. A tabu search algorithm for Structural Software Testing. Computers & Operations Research (focus issue on Search-Based Software Engineering) 2008; 35(10): 3049-3392.

[10] Domínguez JJ, Estero A, García A, Medina I. GAmera: An Automatic Mutant Generation System for WS-BPEL Compositions. 7th IEEE European Conference on WEB Services (ECOWS), 2009; 97-106.

[11] Domínguez JJ, Estero A, Medina I. A framework for mutant genetic generation for WS-BPEL. Lecture Notes in Computer Science. 35th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM) 2009; Vol. 5404, 229-240.

[12] Escalona MJ, Parra CL, Martín FM, Nieto J, Llergó, A, Pérez F. A Practical Example of Model-Driven Web Engineering. Advanced in Engineering software. Springer Verlag; USA (2008). Vol. 1.

[13] Escalona MJ, Aragón G. NDT: A Model Driven Approach for Web Requirements. IEEE Transaction on Software Engineering. United States. 2008-05. IEEE. Vol.: 34 (3), 377-390.

[14] Escalona MJ, Aragón G. The use of metamodels in Web Requirements to assure the consistence. Handbook of Research on Web Information Systems Quality. Spain, 2008. IGI Global 21, 356-370.

[15] Escalona MJ, Gutiérrez JJ, Rodríguez-Catalán L, Guevara A. Model-driven in reverse. The practical experience of the AQUA Project. Proceeding of the Euro American Conference on Telematics and Information Systems. EATIS 2009; Czech Republic (2009). 90-95.

[16] Escalona MJ, Koch, N. Metamodelling the Requirements of Web Systems. Lecture Notes in Business Information Process. Web Information Systems and Technologies: Int. Conferences WEBIST. Springer Verlag; USA (2007). Vol. 1, 267-288.
[17] Escalona MJ, Torres J, A.H,Gutiérrez JJ,Martins, E, Torres R.S, Cecilia M, Baranauskas C. A Development Process for Web Geographic Information System A Case of Study. ICEIS 2008. International Conference on Enterprise Information System; Spain (2008). Vol. HCI, 112-117.
[18] Escalona, MJ, Gutiérrez, JJ, Morero, F, Parra, CL, Nieto, J, Pérez, F, Martín, FM, Llergó, A. A Practical Environment to Apply Model Driven Web Engineering. Advances in Engineering Software. Springer Verlag. Spain 2009. 249-257.
[19] Estero A, Palomo F, Medina I. Mutation Operators for WS-BPEL 2.0. 21st International Conference on Software & Systems Engeneering and their Applications (ICSSEA), 2008. Proceedings on CD-ROM.
[20] Fernández-Sanz L, Lara PJ. Test case generation, UML and Eclipse. DrDobbs Journal 2008; 415: 49-52.
[21] Fernández-Sanz L, Villalba MT, Hilera JR, Lacuesta R. Factors with Negative Influence on Software Testing Practice in Spain: A Survey. European Software Process Improvement Conference (EuroSPI), 2009; 1-12.
[22] García-Fanjul J, Palacios M, Tuya J, de la Riva C. Methods for Testing Web Service Compositions. The European Journal for the Informatics Professional 2009; 10(5): 62-66.
[23] García MT, Ruiz M. Dos alternativas para la transformación de modelos de negocio a modelos de simulación: ontologías o MDE. II Taller de Procesos de Negocio e Ingeniería de Servicios. San Sebastián, 2009. 83-89.
[24] García MT, Ruiz M. Propuesta de Esquema de Transformación de Modelos de Negocio a Modelos de Simulación usando Ontologías. 4ª Conferencia Ibérica de Sistemas E Tecnologias de Información. Póvoa de Varzim, Portugal, 2009. 85-90.
[25] Gegundez ME, Aroba J, Bravo JM. Dentification of Piecewise Affine Systems by means of Fuzzy Clustering and Competitive Learning. Journal of Engineering Applications of Artificial Intelligence, 2008.
[26] Grande JA, Andújar JM, Aroba J, De la Torre ML. Presence of As in the fluvial network due to A.M.D. Processes in the Riotinto Mining Area (Sw Spain). A fuzzy logic qualitative model. Journal of Hazardous Materials, DOI: 10.1016/ j.jhazmat 2009.11.043.
[27] Gutiérrez JJ, Nebut C, Escalona, MJ, Mejías M, Ramos I. Visualization of use cases through automatically generated activity diagrams. LNCS. Springer Verlag. USA, 2008. Vol.: 5301, 83-96.
[28] Hurtado N, Ruiz M, Toro M. Using a Dynamic Model to Simulate the Heuristic Evaluation of Usability. 12th IFIP TC 13 International Conference on Human Computer Interaction (INTERACT 2009). Uppsala, Suecia, 2009. 912-915.
[29] Hurtado N, Ruiz M, Torres J. Ayuda a la Toma de Decisiones en la Evaluación de la Usabilidad mediante Simulación. X Congreso Internacional de Interacción Persona Ordenador (Interacción 2009), Barcelona, 2009. Proceedings on CD-ROM.
[30] Hurtado N, Ruiz M, Torres J. Improving the Usability Evaluation Process Using Simulation Modeling. Journal of Software Quality, 2010. (paper submitted, currently under review)
[31] Jiménez A, Aroba J, Grande J.A, Andújar JM, De la Torre ML. Model of behaviour of conductivity versus pH in acid mine drainage water based on fuzzy logic and data mining techniques. Journal of Hydroinformatic, 2009.
[32] Jimenez A, Aroba J, Grande JA,Andújar JM, de la Torre ML. Model of behaviour of conductivity versus pH in Acid Mine Drainage water, based on Fuzzy Logic and Data Mining techniques. Journal of Hydroinformatics, 2008.
[33] Kim-Park DS, de la Riva C, Tuya J, García-Fanjul, J. Generating Input Documents for Testing XML Queries with ToXgene. Testing: Academic and Industrial Conference - Practice and Research Techniques (TAIC-PART), 2008.
[34] Kim-Park DS, de la Riva C, Tuya J. An Approach to a Test Oracle for XML Query Testing. International Conference on Web Engineering (ICWE) - Doctoral Consortium, 2009.
[35] Kim-Park DS, de la Riva C, Tuya J. A Partial Test Oracle for XML Query Testing. Testing: Academic and Industrial Conference - Practice and Research Techniques (TAIC-PART), 2009.

[36] Kubryk G. Kubryk M, Escalona MJ. Use of ants to learn users' Web preferences. International Conference on Enterprise Information System and Web Technologies; USA (2008), 97-107.
[37] Mas A, Amengual E. Using ISO/IEC 15504 to Validate a Set of Teamwork Factors. European Software Process Improvement Conference (EuroSPI), 2008; 25-34.
[38] Mas A, Fluxà B, Amengual E. Lessons learned from an ISO/IEC 15504 SPI Programme in a Company,. European Systems & Software Process Improvement and Innovation Conference (EuroSPI) 2009;13-18.
[39] Moreno MN, Ramos I, García FJ, Toro M. An association rule mining method for estimating the impact of project management policies on software quality, development time and effort. Expert systems with applications, January 2008. Vol.: 34, 522-529.
[40] Navascués J, Ramos I, Toro M. Simulación de políticas de asignación de recursos en proyectos software: estado del arte. Construction and Engineering Project Management International Workshop. Valladolid, 2008. 157-162.
[41] Navascués J, Ramos I. A hybrid model for dynamic simulation of custom software project in a multiproject environment. International Conference on Software Process (ICSP), Vancouver (Canada), 2009. Vol. 5543, 173-185.
[42] Navascués, J, Ramos I, Toro M. Una propuesta de aplicación de métodos heurísticos para la programación de proyectos a la producción de software a medida. Construction and Engineering Project Management International Workshop. Valladolid, 2008. 163-170.
[43] Orta E, Ruiz M, Toro M. A System Dynamics Approach to Web Service Capacity Management. 7th IEEE European Conference on Web Services (ECOWS 2009). Eindhoven, Holanda. 2009. 109-117.
[44] Orta E, Ruiz M, Toro M. Analyzing Strategic Business Rules through Simulation Modeling. 9th IFIP Conference on E-Business, E-Services and E-Society (I3E 2009). Nancy, Francia, 2009. 357-368.
[45] Orta E, Ruiz M, Toro M. Aplicación de las Técnicas de Modelado y Simulación en la Gestión de la Capacidad de los Servicios TI. XIII Jornadas de Ingeniería del Software y Bases de Datos (JISBD 2008). Gijón, 2008. 299-310.
[46] Orta E, Ruiz M, Toro M. Aplicación de las Técnicas de Modelado y Simulación en la Gestión de Servicios TI. Taller de Apoyo a la Decisión en Ingeniería del Software (ADIS 2009), San Sebastián. 2009. 81-92.
[47] Orta E, Ruiz M, Toro M. Simulation Modeling for Service-Oriented Development. International Journal of Software Engineering. International Journal of Software Engineering, 2008. Vol. 1, 5-18.
[48] Palomo M, García A, Medina I. Enhacing WS-BPEL dynamic invariant generation using XML schema and XPath information. Lecture Notes in Computer Science. 9th International Conference on WEB Engineering (ICWE). 2009; Vol. 5648, 469-472.
[49] Palomo M, García A, Medina I. Improving Takuan to analyze a meta-search engine WS-BPEL composition. 4th IEEE International Symposium on Service-Oriented System Engineering (SOSE), 2008; 215-220.
[50] Palomo M, García A, Medina I. Takuan: A dynamic invariant generation system for WS-BPEL Compositions. 6th IEEE European Conference on Web Services (ECOWS), 2008; 63-72.
[51] Suárez-Cabal MJ, de la Riva C, Tuya J. Generación de Pruebas Basada en Restricciones para Consultas SQL. XIV Jornadas de Ingeniería del Software y Bases de Datos (JISBD). San Sebastián, 2009; 9-20.
[52] Suárez-Cabal MJ, Tuya J. Structural coverage criteria for testing SQL queries. Journal of Universal Computer Science 2009a; 15(3): 584-619.
[53] Tuya J, Dolado J, Suárez-Cabal MJ, de la Riva C. A controlled experiment on white-box database testing. ACM SIGSOFT Software Engineering Notes 2008; 33 (1): 1-6.
[54] Tuya J, Suárez-Cabal MJ, de la Riva C. Query-aware shrinking test databases. 2nd International Workshop on Testing Database Systems (DBTest). 2009.
[55] Tuya J, Suárez-Cabal MJ, de la Riva C, Frankl P, Zhou C. Benchmarks for database application testing. Submitted to: Second Software Testing Benchmark Workshop (TestBench). Paris, 2010.
[56] Tuya J, Suárez-Cabal MJ, de la Riva C. Full Predicate Coverage for testing SQL database queries. Software Testing, Verification and Reliability. Accepted to publication in 2009. In press 2010.