EXPRESSION OF INTEREST

Integrated Project

"BRIDGE"

Diagnosis and Monitoring Complex Systems: Bridging the methodologies of the AI and Control Communities

Prepared by

Louise Travé-Massuyès, LAAS-CNRS, France

(as Chair of the BRIDGE Task Group within the MONET2 NoE (IST-33540))

This Expression of Interest is submitted in response to Call EOI.FP6.2000

1. Aim of the Proposed Work

The aim of this proposal, named, BRIDGE is to mobilise the European scientific expertise in Model Based Control/Monitoring and Diagnosis to provide technological fields designers and users and environmental and medical professionals with relevant, up-to-date methods and tools, bridging the methodologies from the fields of Artificial Intelligence and Automatic Control, for the safe, reliable, more intelligent operation and optimal efficiency of their systems. A sub-goal is to take advantage of the model based approaches bridged over the two fields to define integrated modelling environments, interfacing engineering and knowledge based models for better knowledge management during the systems life-cycle.

The consortium will work along identified research directions and develop at least four industrial challenging applications in different domains. The methods and tools will be demonstrated on the selected applications and evaluation will be performed to outline the advantages and benefits of the “bridge” on industrial relevance basis. The foreseen application fields are among the following : 1)Chemical and petrochemical processes, 2)Space, 3)Transportation, Automotive, 4)Bioprocesses, 5)Environmental systems, 5)Gas turbines, 6)Power Networks, 7)Telecommunication Systems, 8)Civil engineering structures, 9)Health Care.

1.1 Contribution to Priority Thematic Area of Framework 6

The objectives of this proposal undoubtely contribute to the Priority Thematic 1.1.3 iii (New Production processes and Devices) of Framework 6 as aiming to provide the industrial systems of the future with the necessary tools for intelligent, safe and reliable production, improving at the same time the life-cycle design efficiency (diagnosability analysis, control and diagnosis integration, model sharing and reuse).

The objectives of this proposal also contribute to the Priority Thematic Area 1.1.2 ii (Communication, computing and software technologies) in the sense that they aim at consolidating and further developing European strengths in the area of embedded software and systems, and to improve the performance, cost-efficiency, functionality and adaptive capabilities of these systems. Better and more effective diagnostic and control/monitoring systems address major economic challenges, such as reliability and robustness as well as autonomous self-adaptation, and major societal challenges like safety.

1.2 Contribution to the European Research Area

This proposal has a strategic impact on European competitiveness and market opportunities. Control/Monitoring and Diagnosis Model Based Systems which bridge over AI and Control techniques for addressing situation assessement, state tracking, reconfiguration and recovery problems, are definetively a step ahead for handling the complexity of software and hardware embbeded systems, hierarchic and distributed systems and hybrid behavior systems that are encountered in transversal application domains. AI techniques are essential for achieving autonomy and self-adaptativity goals, whereas diagnosis techniques from the Control field are definetively better at the signal level for incipient fault detection and fine fault identification, in statistically characterized noisy environments.
Bridging over the two fields provides the significant advantage to unify through all the system levels (signal, equipment, functional sub-system, whole system). Such a model based Control/Monitoring and Diagnosis system can then in a unified way handle the equipment aspects together with the functional ones and get a global view to perform better state identification. For example, at the two first levels, an alarm on some equipment can as well be the consequence of a fault on another equipment (e.g., cascade effects). The relational analysis leading to the localization of the source cause can only be performed at the functional or even system level.

Merging the model based diagnosis AI and Control technologies leads to unify the modelling process and integrate knowledge management, bridging from the system design to the system maintenance stages and providing considerable benefits.
This is highly relevant in many application domains, in particular those listed in 1.

2. Background to the Proposed Work

Two distinct and parallel research communities concerned with the model based control/monitoring and diagnosis exist. The FDI community has evolved from the Engineering world and uses techniques from control theory and statistical process control. The DX community is more recent. Its foundations have been derived from the fields of Computer Science and Artificial Intelligence. Each community has developed its own tools, techniques and approaches. There are however growing numbers of researchers, in both research communities, who are trying to understand and incorporate the approaches of their parallel research field.

In particular, a Task Group called BRIDGE has been created within the European Network of Excellence MONET I (http://monet.aber.ac.uk) (now over) and is an important feature in the actual FP5 MONET II Network (IST 33540). The MONET-BRIDGE Task Group has developped its activity over the last year and created the opportunity to initiate the exchanges at an international level (invited session, workshop). In the next two years, the MONET-BRIDGE Task Group will work to deliver the following deliverables:

- A Special issue in IEEE SMC and an invited session at DX/Safeprocess 2003 and associated report;
- A Common Diagnostic Framework specification document;
- A report describing a collection of industrial reference problems;
- A report on evaluation of solutions to selected problems of industrial relevance;
- A set of introductory articles and tutorials to cross-link methods and techniques to facilitate industrial uptake of the technologies;
- Technological Roadmap for DX/FDI integration.

This project is proposed as natural extention of the MONET-BRIDGE Task Group activities, whose achievements will be taken as a starting point for the deeper developments proposed here. Indeed, this proposal can be viewed as aiming to use the scientific analysis performed by the MONET-BRIDGE Task Group for effectively producing innovative Control/Monitoring and Diagnosis methods bridging over FDI and DX and their corresponding software prototypes together with at least four demonstrated applications in different industrial fields. The collection of industrial reference problems and corresponding evaluation of solutions will be used to select the best appropriate application fields and define the applications (which may scaled up reference problems).

4. Activities to Achieve the Proposed Objectives

The work will require two main activities. Integration activities will be needed to integrated the diverse range of skills needed to achieve the objectives of the work. When these skills are integrated joint research activities will be undertaken using the integrated areas of excellence.

4.1 Integration Activities

The integration activities can be summarised as follows:

1. Training for all partners the state of the art of the individual scientific fields;
2. Workshops on the definition of the project integrated approach, the possible mechanisms which could be used to interface the different fields and options on how to proceed;
3. Workshops on the interfaces between the different research topics;
4. Joint research studies associated to mobility of personnel;
5. Workshops for each selected application field and establishment of a shared database for each application; interfaces between the selected application fields;
6. Establishment of a shared website.

4.2 Research Activities

From the scientific expertise point of view, the goal is to put together an expert team from both the DX and the FDI fields, as well as researchers that already have initiated an experience in the BRIDGE area. The main joint research activities required to achieve the objectives in bridging FDI and DX methodologies can be summarised by the following list of problems, ranked in priority order:

1) Dynamic systems/Controlled systems monitoring and diagnosis; coupling of fault detection and fault isolation; control and diagnosis integration, temporal aspects of diagnosis.
2) Integrated modelling environments, model management/maintenance, interfaces between engineering and knowledge based models (e.g Matlab/Simulink to qualitative modelling tools), self-explanatory simulators, training systems for operators.
3) On-board diagnosis (signal preprocessing, real-time diagnosis, failure propagation analysis...)
4) Automated generation of numerical/qualitative simulation models, model structure and parameter identification.
5) Diagnosability analysis; fault observability; sensor placement; redundancy degree analysis; observability-redundancy-reliability links.
6) Hybrid (mixed continuous-discrete) systems monitoring and diagnosis; unknown fault mode identification.
7) Fault-tolerant control systems; reconfiguration, fault compensation and accomodation; controllability analysis; reconfigurable control schemes; self-maintenance.
8) Modeling, monitoring, and diagnosis of distributed systems; distributed observations and multiple observers in diagnostic tasks; optimization techniques for distributed diagnosis.

The research activities will be performed in coordination with the activities of the Networks of Excellence of relevant scope in place, for instance the DEDALS (Design of Dependable and Reliable Systems) NoE which is also an Expression of Interest proposal.

5. Expertise Needed to Achieve Objectives

5.1 Critical Mass Required and Multidisciplinary Skills

The Core of the BRIDGE project members should be of two types: research members and industry members. The first type is expected to work towards the research objectives of the project and to be involved in the application work. The second type includes suppliers and end users in the selected application areas which have extensive knowledge of their application area and are experts of the selected applications. Appendix 1 provides a list of organisations which manisfested their interest in the topics of this EoI and provided input (members of the actual MONET2 Bridge Task Group are mark with a *). The research members skills are summarised below:

- they have extensive and acknowledged backgrounds in diagnosis,
- they have published diagnostic survey and terminology papers,
- they are prominent in their fields, and
- their membership to FDI and DX organising committees places them in a unique position from which to prosecute the development of a common diagnosis framework.

All of the research participants have made substantial contributions (through involvement in the listed projects of Appendix 2) to the model based control/monitoring and diagnosis. Some have already work for bridging the DX and FDI methodologies.

5.2 Proposed Consortium

A consortium could be easily organised from the organisation list of Appendix 1 along the selected application domains. Every selected application domain should be covered by a sub-consortium including two to three research members, one supplier and one end user.

6. Promotion of Results Outside of the Consortium

The promotion of the results outside the consortium will be considered as essential.

The professional research organisation will disseminate the results of this work by standard approaches, primarily through scientific publications in the main conferences and journals of the field, organisation of invited sessions in targetted conferences, and further industrial projects.
For dissemination, the consortium will produce a case study of the model based control/monitoring and diagnosis systems per application. This will clearly illustrate the needs and problems of the users, the role of the model based diagnosis system in addressing those, and the benefits that have resulted from merging FDI and DX methods. In addition, the consortium will produce a glossy brochure explaining the model based DX/FDI diagnosis aspects and its industrial relevance and benefit. Also, a dedicated web site will be created and provide an excellent way to disseminate the results of the work.

A round of publicity is planned to the major vertical trade magazines for the approached industrial sectors, as well as major conferences. The target audience will primarily be suppliers to industry rather than the end users themselves. Therefore 'industry' will be looked at as a two layer target. In the technical area it will be companies who have the potential to adopt this advanced technology and propose it to their end users.
The technical achievements of merging DX and FDI model based diagnosis techniques for industrial applications will be broadcast through the Networks of Excellence in place, for instance the DEDALS (Design of Dependable and Reliable Systems) NoE which is an Expression of Interest proposal.

7. The Role of SMEs in the Proposed Work

The role of SMEs in the proposed work is of primary importance. Indeed, we believe that the way to look at industry is as a two layer target and that the way to transfer the technology is by approaching the suppliers to industry (like Intelligent Applications Ltd (UK) an OCC'M (G) which are among the core members). The consortium is hence organised along the selected applications. For each applications, we plan a end user, a supplier (SME) and two research organisations (one from DX, one from FDI).

SME should play a fundamental role in the project, serving as an intermediary between the end user and the dedicated research team.

8. How the Project will be Managed

The project management will be done using a project manager directing a project management board. In addition there will be as many Application Committees as applications addressed. Every Application Committee will be chaired by an Application Chair. Finally, there will be a Research Committee and a reasearch Chair in charge of supervising the reasearch activities within the project.
The project leader will chair the project board which will include the Research Chair, the Application Chairs and one representative of each of the core partners, if not already represented. They will meet formally at 3 month intervals to review all aspects of the project, its plans and progress, and will make the final decision in any disputes.

On a monthly basis, the Research Chair and each Application Chair will produce a progress report and the project manager will individually review the progress of research and by each application group and the overall plan to ensure that progress is satisfactory.
The project will have a kick-off meeting as soon after the project start date as possible and a final workshop meeting at the end of the project.

The project will conduct a formal progress review with the CEC.

9. Appendix 1: List of organisations

	Organisation	Chief Scientist	email address	Country	Org. Type
1*	LAAS-CNRS	Dr. L. Travé-Massuyès	louise@laas.fr	France	A
2*	IRISA	Pr. M.O. Cordier	Marie-Odile.Cordier@irisa.fr	France	A
3*	LAIL	Pr. M. Staroswiecki	marcel.staroswiecki@univ-lille1.fr	France	A
4	CRAN, Institut National Polytechnique de Lorraine	Pr. J. RAGOT	jragot@ensem.inpl-nancy.fr	France	A
5	Heudiasyc, Université de Technologie de Compiègne	Dr. A. Charara Dr. B. Dubuisson	ali.charara@utc.fr Bernard.Dubuisson@utc.fr	France	A
6*	LIPN, Université Paris 13	Pr. P. Dague Pr. F. Levy	dague@lipn.univ-paris13.fr francois.levy@lipn.univ-paris13.fr	France	A
7	LAG, Institut National Polytechnique de grenoble	Pr. S. Gentil	sylviane.gentil@inpg.fr	France	A
8	Ecole des Mines d'Alès / Commissariat à l'Energie Atomique	Dr. J. Montmain	Jacky.Montmain@ema.fr	France	A
9	INRIA Sophia Antipolis	Dr. J.L. Gouzé	Jean-Luc.Gouze@sophia.inria.fr	France	A
10	LAP, UMR 5131 CNRS, Université Bordeaux I	Pr. A. Zolghadri	zolghadri@lap.u-bordeaux.fr	France	A
11	Université de Valenciennes	Dr. S. Piechowiak	sylvain.piechowiak@univ-valenciennes.fr	France	A
12	CEDRAT TECHNOLOGIES SA	Dr. F. Claeyssen	frank.claeyssen@cedrat.com	France	I
13	Institut Français du Pétrole	Dr. B. Braunschweig	Bertrand.BRAUNSCHWEIG@ifp.fr	France	I
14*	France Telecom R&D	Dr. C. Dousson		France	I
15	THALES Airborne Systems	Dr. P. Taillibert	patrick.taillibert@fr.thalesgroup.com	France	I
16*	Università del Piemonte Orientale	Dr. D. Theseider Dupre	dtd@mfn.unipmn.it	Italy	A
17*	Universita'degli studi di Torino	Pr. L. Console	luca.console@di.unito.it	Italy	A
18*	Universita' di Brescia	Dr. G. Lamperti	lamperti@bsing.ing.unibs.it	Italy	A
19	IMATI-CNR, Pavia	Dr. L. Ironi	liliana@supers1.ian.pv.cnr.it	Italy	A
20*	Ruhr-University Bochum	Dr. J. Lunze	lunze@esr.ruhr-uni-bochum.de	Germany	A
21	Technische Universitaet Berlin	Pr. R. King	Rudibert.King@tu-berlin.de	Germany	A
22*	OCC'M & Univ. of Technology Munich	Pr. P. Struss	struss@informatik.tu-muenchen.de	Germany	I A

23*	UWA	Pr. G. Coghill	gmc@aber.ac.uk	UK	A
24	Department of Engineering, University of Hull	Pr. R. J Patton	R.J.Patton@Hull.ac.uk	UK	A
25	Loughborough University	Pr. P. W. H. Chung	P.W.H.Chung@lboro.ac.uk	UK	A
26*	Intelligent Applications	Dr. R. Milne	rmilne@cix.co.uk	UK	I
27	British Maritime Technology	Dr. F. Caldeira-Saraiva	fernando@bmtech.co.uk	UK	I
28	ATKINS	Dr J. T. Gierlinski	Jacek.Gierlinski@atkinsglobal.com	UK	I
29*	Universidad de Valladolid	Pr. C. Alonso Gonzales	calonso@infor.uva.es	Spain	A
30	Universitat Polytecnica de Catalunya - ESAII	Pr. J. Quevedo	joseba@esaii.upc.es	Spain	A
31	Universitat de Girona - MICE	Pr. J. Vehi	vehi@silver.udg.es	Spain	A
32	CARTIF	Dr. A. Gallego	magal@cartif.es	Spain	A
33	Universidad Pontificia Comillas	Dr. M. A. Sanz Bobi	masanz@iit.upco.es	Spain	A
34	Delft University of Technology	Pr. T. Tomiyama	tomiyama@race.u-tokyo.ac.jp	The Netherlands	A
35*	EPFL - Swiss Federal Institute of Technology in Lausanne	Dr. I. Smith	Ian.Smith@epfl.ch	Switzerland	A
36*	Technische Universität Graz	Dr. B. Rinner Dr. M. Hofbaur	rinner@iti.tu-graz.ac.at hofbaur@irt.tu-graz.ac.at	Austria	A
37	Austrian Research Institute for Artificial Intelligence (OFAI)	Pr. W. Horn	werner@ai.univie.ac.at	Austria	A
38*	Linköping University	Dr. M. Nyberg	matny@isy.liu.se	Sweden	A
39	University of Ljubljana - AI Laboratory	Pr. I. Bratko	ivan.bratko@fri.uni-lj.si	Slovenia	A
40	ULB	Pr. M. Kinnaert	kinnaert@labauto.ulb.ac.be	Belgium	A
41	Fundamental Technological Research, Smart-Technology Centre	Pr. J. Holnicki-Szulc	holnicki@ippt.gov.pl	Poland	A
42	University of Zielona Gora	Pr. J. Korbicz	j.korbicz@issi.uz.zgora.pl	Poland	A

10. Appendix 2: List of projects

- ***Vehicle subsystems**:* **VMBD** (*Vehicle Model-Based Diagnosis*) (1996-1998), European Brite Euram project for the design and implementation of off-board and on-board diagnostic systems for vehicles; **IDD** (*Integrated Design for on-board Diagnosis*) (2000-2002), European project for the design and development of an integrated model-based environment for design, diagnosability, on-board diagnosis and FMEA for vehicle subsystems. **AGENDA**: French project ACTIA/LAAS-CNRS/LIPN, automatic interval model-based generation of optimal diagnosis trees.
- ***Telecommunication networks**:* **GASPAR** aand **MAGDA**, France Telecom project, model based diagnosis technology applied to the supervision of telecommunication networks.

- ***Gas turbines:*** **TIGER** *(Real Time Situation Assessment of Dynamic, Hard to Measure Systems):* European project (1992-1995) devoted to design and implementation of a monitoring and diagnosis system for gas turbines. Main partner: Intelligent Applications Ltd (UK). Partnership of LAAS-CNRS. **TIGER SHEBA** *(SHEBA TIGER Model Based Diagnosis)* European Trial Applications project (1998-2000), following the TIGER project, with aim to fully integrate the model-based module Ca-En into the TIGER system for diagnosis of gas turbines. Same partnership.
- ***Power Networks****:* **AUSTRAL** project from EDF, France.
- ***Process industry:*** **CHEM** *(Advanced Decision Support Systems for Chemical/Petrochemical Manufacturing Processes):* GROWTH Project. **DIAMOND** (*Distributed Architecture for Monitoring and Diagnosis*): European project (1998-2001) aiming at increasing the availability and safety of industrial installations. **HINT**, Esprit #6447, for Heterogeneous Integration Architecture for Intelligent Control Systems. **DAMADICS**: European FP5 Project (Development and Application of Methods for Actuator Diagnosis in Industrial Control Systems). **STOPHAZ** (1993-1997): ESPRIT project focused on developing methodologies and software tools for identifying hazards in process plants.
- ***Space:*** **KOALA** is a project (on-going) from the French Space Agency, CNES and ASTRIUM, France in collaboration with LAAS-CNRS and LIPN which aims at applying hybrid model based diagnosis techniques for autonomous satellites. The KOALA prototype is to be tested on the CNES test bench for autonomous satellites. "**Autonomy Requirements and Technologies for Future Constellations of Satellites**" (2000-2001) is an ESA project leaded by ASTRIUM and in which LAAS-CNRS and LIPN delt with the diagnosis issue.
- ***Civil and mechanical structures***: **PIEZODIAGNOSTICS** (*Smart Structural Diagnostics using Piezo-Generated Elastic Waves*) (2002-2005), GROWTH European project; **CONVIB** (*Innovative Control Technologies for Vibration Sensitive Civil Engineering Structures)* (2002-2005): European Science Foundation (ESF) Project. **SAMCO** (*Structural Assessment, Monitoring and Control*): GROWTH Thematic Network.
- ***Environemental Systems:*** Several French project for water and air management in collaboration with IRH (*Institut de Recherdche en Hydrogéologie*, Vandoeuvre les Nancy), GEMCEA et *Communauté Urbaine du Grand Nancy,* AIRLOR, AERFOM et Région lorraine, PFR *Eau et environnement.*
- *Bioprocesses:* **TELEMAC** (*Telemonitoring and advanced telecontrol of high yield wastewater treatment plants*) European project.
- ***Health Care:*** **GAMES I and II** European Project (General Architecture for Medical Expert Systems) within the framework AIM (Advanced Informatics in Medicine) (1990-1995) to design and implement a knowledge-based framework for medical diagnosis, therapy planning and monitoring. **CASIS**: Italian C.N.R. Special Project (Cooperative Agents in a Health Information System) (1996-1998) to develop problem-solvers for the representation and identification of nonlinear dynamical systems.
- ***Basic research projects***: **COSY**: European Science Foundation Project (1993-1999) concerned with the fault-tolerant control of complex systems. **IMALAIA**: French project supported by the French CNRS Programs on Automatic Control and Artificial Intelligence as well as AFIA Group, aims to provide a unifying framework for FDI and DX techniques. "**Analysis of Data, Signals and Patterns"** Italian C.N.R. National Project within "Applications of Mathematics to Technology and Society"(1994) to design and implement methods for the quantitative and qualitative signal analysis. **Safe design of computer controlled plants** (1997-1999): a project funded by the UK Engineering and Physical Sciences Research Council which looked into the safety aspects of computer control.