PLANTWIDE RISK MANAGEMENT USING DISTRIBUTED OBJECTS

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Abstract: Strategic process control is a mostly open issue due in part to the complex nature of large process plants and the lack of precise models for high level decision making in these plants. Research an development in this field has been focused on the exploitation of advanced information processing technologies (artificial intelligence, distributed object systems, advanced user interfaces, etc.) to enhance process operation in near-critical plant situations. This paper comments the objectives of the DIXIT project and specifically the RiskMan application of this technology for integral risk management in a chemical plant.

Keywords: Risk management, distributed control systems, object computing, intelligent control, chemical process control.

1. INTRODUCTION

There is an important need for the enhancement of process operations at plant production management level, because plants must be operated near criticality, i.e. in conditions far from ideal ones from the point of view of control and stability.

Continuous process industries are usually very complex and difficult to model. While plant personnel feel there is a tremendous need for better and more versatile simulation and modeling tools, no product in the market offers the necessary capabilities to deal with the uncertain nature of complex plants.

The industry is well equipped with advanced control systems (ACSs) that process and production engineers use to pilot the process for improving production quality, productivity and reduce costs.

The industry has heavily invested (and still investing) in both ACS and also Management Information Systems (MIS) like MES, R/PE, ERP, SCM or SSM (OMG Manufacturing Domain Task Force, 1998). These investments are in the range of millions of Euro per site. Information systems in plants are hierarchically structured in order to deal with the large collection of functional components.

Advances in computing technology, specially powerful and cheap PCs able to run advanced OSs, advent of Windows NT and wide acceptance of de-facto standards, have led to widespread use of PCs and window-based user interfaces throughout the industry. This trend is accelerating and, while these products offer an impressive potential, care must be taken in their use throughout the plant. Complex software systems tend to be unpredictable and this is not accept-

[1] We acknowledge the support from the Comission of the Eu-

vironments are the common infrastructure for advanced control systems.

Almost everybody recognizes the need for better and more extensive solutions for tackling problems belonging to the *tactical and strategic layers of control*. They also recognize the need for vertical integration of the layers (in terms of flow of information.

This paper does not focus in specific technologies for these topics but in the problems of construction of complex distributed control systems. In relation with SAFEPROCESS, the relevance of this paper is not in the safety topics themselves (FDI or FTC issues are addressed in other papers of the symposium) but in the utilization of CORBA technology to build complex application. A real example for emergency management of chemical plants is commented in more detail.

2. THE DIXIT PROJECT

In search of those solutions at the strategic level, the DIXIT project was partly funded by the Commission of the EU (ESPRIT 22139). The project concluded 31st December 1998 generating two industrial demonstration applications, and four potential commercial products.

2.1 *The DIXIT Framework*

Better automation is a key aspect for improving industrial competitiveness. *Intelligent automation* at management levels —in particular— can play a major role regarding this aspect. DIXIT aim was to help in this improvement by building a distributed and generic software system that addresses decision support for *near critical situation management* in continuous process industries. In particular, assistance, in terms of diagnosis and solutions, is provided to plant staff when situations suitable to be corrected, prevented or enhanced are detected.

Summarizing, DIXIT is a project on distributed software systems for the process industry. The focus is on software architecture for the integration of different software components as well as on the software components themselves. These software components include core modules, user interface modules and problem solving modules.

2.2 *The Objectives*

The objectives of DIXIT project were twofold:

- From the *user point of view*: the implemen-

addresses the problems related to the global management of the plant while taking into account the interrelation of the strategic objectives, such as production, quality, maintenance, safety, efficiency and continuity, as well as problems closer to the process control layer.
- From the *systems integrator point of view*: the development of an open software architecture based on CORBA (OMG, 1998) specification, to allow the construction of distributed intelligent control systems on top of the existing control systems being used in the industrial plants.

  In this sense, it is crucial the development of products (capable to provide decision support solutions such us data mining and analysis, process diagnosis, process simulation, first cause determination, etc.) integrable with existing environments and databases.

DIXIT follows the conceptual structure of most distributed control systems, that is a hierarchical and multilayered structure, similar to a pyramid. Abstraction and complexity of the control mechanism increases in higher layers. All the basic functionalities of the system are grouped into problem solving components that work in a cooperative way to find a solution to the plant problems or to optimize the plant objectives.

As an application of this technology, two demonstrators have been built and installed in a petrochemical plant owned by Repsol Química (Tarragona, Spain) and a cement plant owned by Lafarge Ciments (Contes, France). These applications include the following functionalities at the different control layers:

Strategic layer: Management of global objectives of the plant and their interrelation. For example, management of maintenance operations, incident prevention, assessment of production costs in real time, quality deviation detection and alarm management.

Tactical layer: Assistance through the problem lifespan, including process failure prevention, detection and diagnosis.

Operational layer: Tasks such as filtering and validation of plant data, variable estimation and trend forecasting.

2.3 *The Technical Approach*

Full life cycle reuse is hardly achievable in broad and evolutionary domains like the intelligent control domain. The DIXIT approach tries to provide reusability in the broadest sense for the cations. Object technology is one of the cornerstones of this approach (Guttman and Matthews, 1995). Reusability can be done at any stage in the life cycle: from requirements elicitation to commissioning or maintenance. Two phases of special importance have been addressed in DIXIT: design and implementation. Design patterns technology (Sanz *et al.*, 1999) tries to provide reuse at the design level, while the agent programming model tries to provide reusability at the implementation level.

The DIXIT approach to reusability is based on the availability of *design patterns* and *reusable component implementations* with few design compromises. These implementations are flexible enough to be adapted or modified to fit new requirements with little effort. Agent based development and integration middleware concepts provide the basis for this DIXIT reusability .

In DIXIT we have developed components for artificial neural network based prediction, user interfacing, rule-based diagnosis, fuzzy filtering, database wrapping, etc.

Following task-oriented functional criteria, preexistent code or tools are encapsulated using object wrappers and all new code is developed with the DIXIT agency model as its basic guideline. The customized components (agents) are integrated in a global architecture using a real-time integration middleware. This middleware is based in the CORBA specification, incorporating extensions to make possible its use in real-time applications. This facilitates the easy reuse of components and even the reuse of the global application architecture because run-time components can be easily changed without affecting other components behaviour.

Having a technology like DIXIT middleware makes really possible the use of previous designs or components in new control systems. Legacy system wrapping is an effective way to integration and deployment over "*old-fashioned working systems*".

The reusability of the approach comes from the implementation of a forest of behaviour inheriting agents. The base nodes of the trees in this forest compose what are called ICa Generic Agents. They are agents with different levels of behaviour completion, adapted to specific tasks in an intelligent control domain.

In DIXIT we have demonstrated the reusability based on object wrapping of legacy systems. For example, we have used previous developments in fuzzy systems to build fuzzy components in the DIXIT way (Sanz *et al.*, 1998). An agent inheritance tree is used to manage specific interfaces mented as a C++ framework for POSIX/ISO C++ machines.

2.4 *The Results*

The main results from the DIXIT project are the following:

(1) RiskMan demonstrator installed in the petrochemical plant owned by Repsol Química and sited at Tarragona, Spain. This application is explained in section 3 of this paper.
(2) PIKMAC demonstrator installed in the cement plant owned by Lafarge Ciments SA and sited at Contes, France.
(3) ZINK product developed by IIC.
(4) POEM product developed by DaCapo.
(5) ICa framework developed by UPM-DISAM.
(6) MIMER product developed by Rambøll.

This paper focus on one of the demonstration applications: DIXT RiskMan.

3. RISKMAN

Petrochemical plants are very large, continuous and with several-thousand variables. They are potentially hazardous plants that must operate in 365×24 regimes. They employ DCSs (like TDC-3000 in the case of Repsol plant or PROTOP in the case of Lafarge's) to control and operate the plants using human operators to supervise the process.

3.1 *RiskMan Objectives*

The Tarragona petrochemical complex of Repsol Química extends over an area of approximately 150 hectares and comprises a refinery and a chemical complex.

The DIXIT project is dealing only with the chemical complex, which is composed by nine plants grouped into three geographical zones.

As it has been detailed in the previous section in relation to the aim of the whole DIXIT project and in particular to the strategic objective definition, the *safety and maintenance* objectives have been the cornerstone of the Repsol demonstrator.

The safety objective that has been demonstrated at Repsol plant can be further decomposed in two major sub-objectives.

(1) The first one deals with intelligent process control to prevent from happening situations that can derive into an emergency, or to correct these situations once they occur

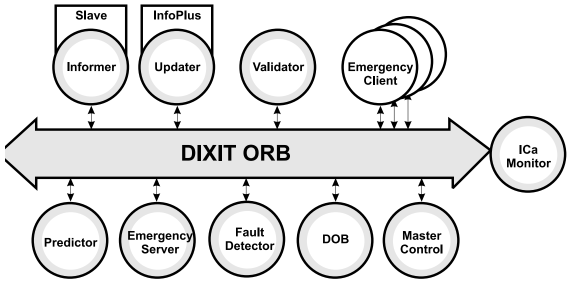

Fig. 1. RiskMan Application structure as a collection of interacting CORBA objects. The figure shows the base middleware (ICa) and the objects that implement system functionality.

(2) The second sub-objective deals with situations that have already reached the emergency state. It consists of implementing the existing Repsol's emergency plan in a distributed computing environment in order to improve and enhance the performance of the human team participating in an emergency situation.

3.2 *RiskMan Structure*

RiskMan has been implemented as a solution to the problems outlined above by means of several subsystems that coexist and iteroperate. The basic subsystems are the ”Emergency Manager”, the ”Preventive System” and the ”WorkPermit Manager”; all they have been impemented using CORBA objects over an integration middleware specifically developed for the process industry (see Figure 3.2.

The **Emergency Manager** deals with the management of emergencies and implementation of the plant safety plan following the already established policies for dealing with emergencies. Safety protocols are very complex because they involve safety regulations from the European Union, Spanish laws, Catalan laws, Tarragona's chemical sector plans (PLASEQTA) and Repsol's own policies. This includes the elaboration of the *emergency organization chart*, *i.e.* The human organization structure to deal with the emergency, under the constraints posed by the emergency as well as the communication of the actuation procedures to the personnel involved in the emergency.

Once the emergency is declared, the system automatically handles all issues related to the organization chart elaboration and information management.

The technologies used in this application are:

- Rule based systems for fault detection and

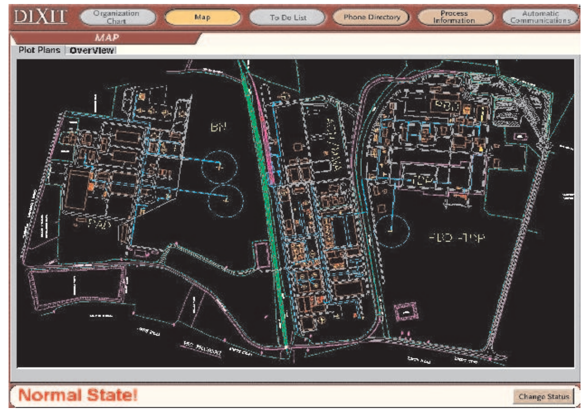

Fig. 2. RiskMan Emergency manager user interface. The figure shows the navigation map used to focus on specific areas of the complex.

- Fuzzy systems for data validation and basic control.
- Neural systems for subsystem behaviour prediction.
- User interfaces.
- Shared object management.
- Ad-hoc components: Conventional simulation and calculus, filters, database wrappers, special equipment managers, etc. ·

The **Preventive System** monitors the state of a subsystem detecting abnormal situations before they reach a critical stage. This component is only applied to a set of selected equipment in order to fully test its suitability and correctness. A complete implementation, i.e. covering the whole complex, was out of the scope of the project. A rule-based approach is utilized in this software module.

The nature of the tasks involved in an industrial process and the potential danger of the raw materials and output products used in it, makes necessary an analysis of the impact of all maintenance operations before their performance.

At Repsol plant, the impact of all maintenance activities is carefully evaluated in all aspects and more when their execution is considered as very dangerous under some operating conditions.

Besides, although some operations may be harmless by themselves, their combination in time and geographical area can be very dangerous. Last but not least, maintenance operations are often necessary in order to correct equipment malfunctions and therefore preventing these equipment from reaching hazardous situations that would compromise the safety of the plant.

The acceptance or not of certain maintenance activities and their performance depends on the result of this evaluation. It was estimated that au-

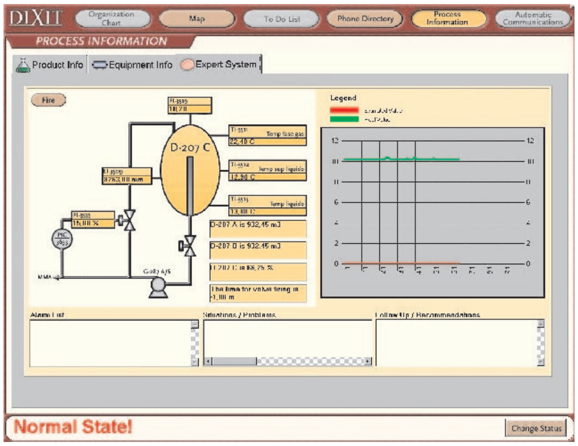

Fig. 3. Emergency management interface for one of the ammonia tanks in the Repsol complex.

save a lot of time and reduce the risk of accident in the maintenance operations.

All these considerations have resulted in the definition and implementation of the **Workpermit Manager**, an application that helps Repsol personnel in the management of the protocols for the authorization and control of these maintenance operations. In order to do so, the application automates many of the procedures that are currently done by hand with the subsequent loss of time and increase of risk. The application helps the user by considering relevant on-line process information that should be taken into account for the authorization and execution of such maintenance operations.

3.3 *Results achieved*

Some of the results achieved by RiskMan demonstrator are the integrated exploitation of a collection of heterogeneous technologies for the prevention of anomalous situations related to the safety of an industrial complex and the suitability of CORBA-based development for integrated control systems construction.

The gathering and compilation of all the information necessary for the implementation of the Emergency Manager has produced as a side accomplishment a greater familiarity with the safety procedures by part of the Repsol personnel which, in the medium run, has yielded a finer tuning of these procedures. This is a classical effect of knowledge based system development.

Another side accomplishment of the system from the users point of view is that it has allowed the integration of the preventive and corrective aspects of safety, which were dealt, until this moment, in a separate way.

Another advantage of great importance arises able to take into account automatically the constraints posed by the *current plant situation* and the ongoing maintenance operations; therefore, the system relieves the operator from these routine but risky tasks when elaborating a new workpermit with the subsequent reduction of the risk of human mistake.

4. CONCLUSIONS

From the project output viewpoint, the results achieved (described in previous chapters) are considered as being of good quality. This statement is based on two reasons:

(1) The two demonstrators have been designed according to real plant requirements with a large involvement of plant staff. At present, both applications are installed and under operation after a period of user validation and evaluation.
(2) The three generic products constructed within the project are truly reusable and exploitable components.

As stated by many relevant projects, artificial intelligence technologies can increase systems autonomy. And as this project demonstrates, this type of advanced control technology can be modularized, deployed and integrated with legacy control systems, progressing effectively toward complete automatic operation.

CORBA technology has demonstrated the capabilities needed to advance in this direction for process industry.

5. REFERENCES

Guttman, Michael and Jason R. Matthews (1995). *The Object Revolution*. Wiley. New York.

OMG (1998). Common object request broker architecture and specification. Technical Report 2.2. Object Management Group.

OMG Manufacturing Domain Task Force (1998). Corba-based machine control white paper. Technical Report mfg/98-03-10. Object Management Group. Framingham, MA. Version 0.14.

Sanz, Ricardo, Angel de Antonio, Miguel Segarra, Fernando Matía, Agustín Jiménez and Ramón Galán (1999). Patterns for for intelligent control systems. In: *14th IFAC World Congress*. Beijing, China.

Sanz, Ricardo, Fernando Matía, Angel de Antonio and Miguel Segarra (1998). Fuzzy agents for ICa. In: *Proceedings of FUZZY-IEEE 98*. Anchorage, USA.