INTEGRATING APPLICATIONS FOR THE CONSTRUCTION INDUSTRY USING A STEP-BASED INTEGRATION PLATFORM (SIP)

- IMPROVEMENTS AND RESULTS ACHIEVED SINCE CIB '95 -

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Abstract: International construction industry has not still achieved a high degree of integration and automation in the past years. The European ESPRIT III project number 6660, RoadRobot (Operator Assisted Mobile Road Robot For Heavy Duty Civil Engineering Applications) intends to design and to implement an architecture to support the integration and automation tasks in that domain. To aid the implementation of the architecture, a STEP-based (ISO 10303) platform for integration of applications (SIP toolkit), was developed by UNINOVA. The general purpose of SIP is to assist the achievement of standardised Computer Integrated Manufacturing (CIM) environments, providing a set of development system tools. Last year, during CIB W78 and TG10 held at the University of Stanford - California (USA), SIP and the aim of the RoadRobot project were presented. During the CIB'96, the RoadRobot architecture and its achieved results will be shown, as well as the improvements of SIP made in order to meet the project requirements. Special care will be taken concerning the problems found and the solutions adopted.

KEYWORDS: STEP, Integration, Information System, Modelling, Automation, Heterogeneous Systems

1. INTRODUCTION

International construction industry has not still achieved a high degree of integration and automation in the past years. Up to now, in opposite of what is happening in other industrial sectors, the use of Information Technology (IT), in outdoor construction applications, did not have much attention.

This lack of integration and automation has resulted in a demand for very flexible and automated architectures which can be achieved studying the already existing ones from other industrial sectors. This approach, after adequate adaptation for the special requirements of the construction industry, resulted in the RoadRobot project's architecture and intends to contribute to a solution for the integration problems within the construction industry.

To implement the designed architecture, two possible approaches could be followed (Camarinha-Matos.92):

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1- Build a new system, strongly integrated, where each system tool shares the same (distributed or not) physical data structure.

2- Integrate already developed tools into the system by using a specific data protocol.

The second approach has being better accepted by industry because it maintains the same environment with minimal software acquisition and training costs, enabling it to take the benefits of an integrated company.

Because company’s software tools are modelled in different ways, and have different Import/Export data format, data communication between them is an arduous task to carry out. To make easier this task, a unique interface for data interchange might be defined. Adopting a standard format will enable that, in future, to integrate new tools in the system can be effortless.

The increasing number of different standards, mainly for representation of information produced by CAD systems (H.J.Helpenstein.91), and the growing needs for product representation (besides its geometric representation) (U.Rembold.86) caused that ISO, in 1984, created the sub-committee SC4 with the following objective: “...to specify a form for the unambiguous representation and exchange of computer interpretable product information throughout the life of a product...”(ISO1.92). This standard was called ISO 10303, or STEP (STandard for the Exchange of Product model data).

Provide a set of mechanisms that speed up the integrator’s tasks, facilitating the generation of interfaces and avoiding development errors, becomes essential to achieve integration results in competitive times. The use of standards in the modelling processes avoids the high number of required interfaces, and automatically code generation reduce errors during development.

A STEP (ISO10303) standard based platform for integration of applications (SIP toolkit)(Jardim-Gonçalves.94), created by UNINOVA in the ambit of a European project, was developed to assist the integration of several applications using a unique format.

This paper describes the designed and implemented RoadRobot’s architecture, using the UNINOVA’s STEP-based Integrated Platform (SIP), making emphasis on the work developed since CIB’95 (Jardim-Gonçalves.95).

2. THE STEP-BASED INTEGRATION PLATFORM - SIP TOOLKIT

During last years the scientific community has recognised that several of the main problems that exist within industrial environments are related with the integration process (PRATT.93). Some of them are connected with shortening of product life cycles, reduction of manual operations and activities, and decrease input data errors, system maintenance and upgrade efforts.

To aid to solve these problems, the use of an integration platform based on a standard should be considered. This platform will allow an integrated sector oriented solutions and it will facilitate the information management, bringing productivity, flexibility and quality improvements. For this purpose UNINOVA, in the framework of the European BRITE/EURAM CIMTOFI (CIM sysTems with improved capabilities fOr Furniture Industry) project (Jardim-Gonçalves.93), developed a STEP (ISO10303) standard based platform for integration of applications - SIP - Toolkit.

The SIP requirements were:

- Support the integration (data exchange) of all existing and future activity tools, which are heterogeneous by nature;
- Offer the possibility of product data exchange between different sites;
- Provide a good approach for data modelling at all levels, preferentially using a standard;
- Be reliable and efficient;
- Enable the management of expertise knowledge related to specific activities, using a standard interface;
- Allow interfacing to different standard languages (e.g. C, C++, Object Oriented Data Bases and Relational Data Bases).

2.1 Architecture of SIP

The architecture of SIP (Figure 1) is fundamentally constituted of an Information Management System (IMS), an Information System Access Protocol (ISAP) and a Development System Tool Set. (DSTS).

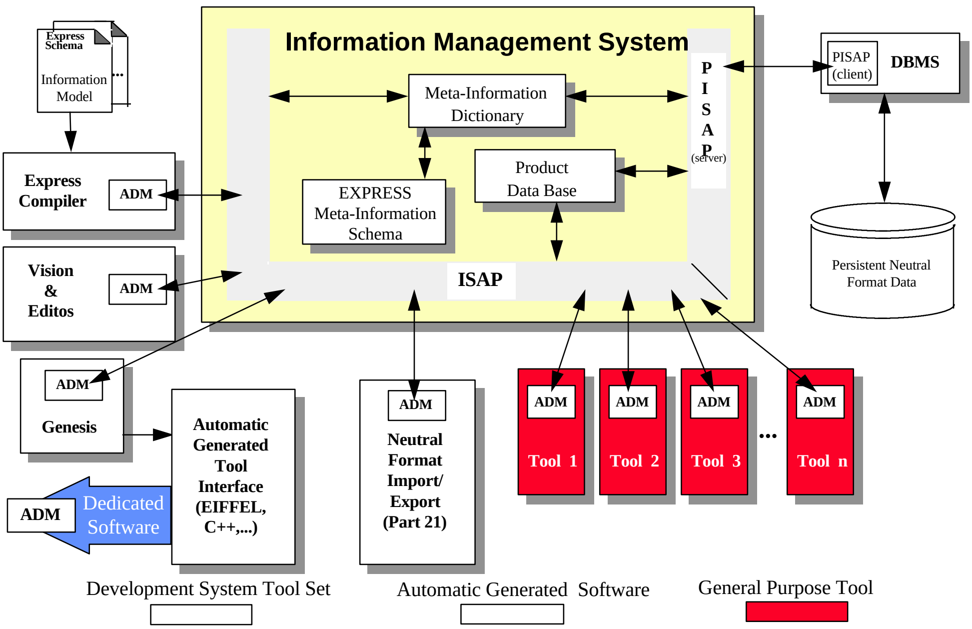

Figure 1. Architecture of SIP

The IMS handles the information based on a model (EXPRESS schema), elaborated previously, and it is constituted by: PISAP - Persistence Driver; MID - Meta-Information Dictionary; PDB - Product Data Base and EXPRESS MIS - EXPRESS Meta-Information Schema. ISAP is the communication protocol, that establishes the interface between external tools and IMS, allowing data exchange in a distributed way.

The architecture incorporates many of the concepts of Computer Integrated Manufacturing (CIM) to bring productivity, flexibility and quality improvements. A suitable object-oriented approaches for the design of the architecture, allows a gradual integration of automated functions as they become available.

The IS offers the local and remote capability of communication. In the local approach, the IS is directly linked to external systems, which means that the client and the server parts are linked together generating one unique application.

In the remote approach, the RPC (Remote Procedure Calls) service of TCP/IP (Transmission Control Protocol / Internet Protocol) is used. Client and server are remote processes that can be running in different computers.

The communication protocols consist of libraries of functions that supply the capability of local and remote communication between the Information System and the external systems (EXPRESS Compiler, CIM tools and DBMSs).

In order to be able to maintain flexibility, SIP runs on several platforms (IBM PC compatible, IBM RISC 6000 and SUN), and uses TCP/IP as the communication protocol.

In (Jardim-Gonçalves.95) SIP is presented in detail.

3. THE ROADROBOT PROJECT

Started in 1992, the RoadRobot project - Operator Assisted Mobile Road Robot For Heavy Duty Civil Engineering Applications - is a four years ESPRIT III European project, with seven partners coming from different countries and areas of expertise.

3.1 Objectives of project

The main objective of the RoadRobot project is to adapt a generic control architecture to fit the requirements of the construction industry and perform its validation. The RoadRobot generic architecture should be seen as a "template" to be used within real construction site systems. It defines entities (objects and categories) that may exist within a general construction site, and the relationships that they share. The achieved architecture is a result of detailed analysis of different real sites making special focus on the planning, scheduling, and the control procedures. The adoption of RoadRobot architecture in constructions' sites will optimise the use of construction applications towards automation (J.P.Pimentão.94). This fact will enable to introduce Computer Integrated Manufacturing (CIM) techniques in the construction industry, bringing with it the associated benefits (e.g. production quality, cost effectiveness and flexibility)(GUINDY.89) (PRATT.93).

The automation of several tasks and heavy-duty construction machines will increase quality, safety and give a better control of the machines concerning operators and other workers. Due to the complexity of the problem, the general aim can be achieved in two steps. The first step is the definition of needs correlating to the demands of construction industry. The second one is the development and implementation of a modular control architecture, and the flexible automation of well-defined sub-units.

3.2 Technical aims of the project

The specific technical aims of the project are:

- Development of a multi-purpose architecture for mobile platforms in heavy-duty applications;
- Demonstration of the modularity of the developed architecture, as well as of its components;
- Development of a general control system, with a dedicated man-machine interface;
- Development of process control component's applications for automated road paving machines, and for automated excavators.

In order to reach an international standardisation of the architecture, the information models were described in STEP/EXPRESS (ISO11.91)(ISO21.92). In this way, an overall use of the developed parts brings world industry the possibility to transfer and to expand the results of the project RoadRobot.

4. THE ROADROBOT'S ARCHITECTURE (LOGICAL LEVELS)

The RoadRobot's architecture is defined and implemented in four logical levels. Each level is co-ordinated by a dedicated controller and it has associated an intelligent planner/scheduler system working on the results produced by a Decision Support System (DSS).

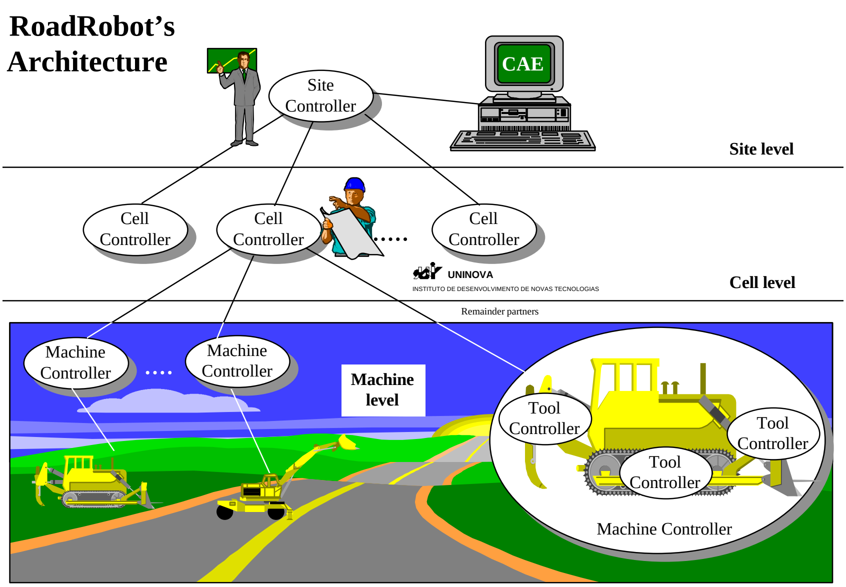

Figure 2. Architecture of RoadRobot project - Logical levels

Tasks are automatically generated by the DSS on base of the data and knowledge acquired and stored by the system. Each level is assisted by an Operator interface system enabling the user for corrective actions on the automatic generated plans.

Deliberately, each level share with the others the relevant features. Figure 2 depicts the logical levels of the RoadRobot's architecture.

4.1 Site level

The site level is the architecture's top level and behaviours like an effective system controller. This level is responsible to produce the geometric description of the construction site, to identify tasks, assign them to the lowers levels and control its execution towards the final goal (e.g., construction of a road junction).

Figure 3 shows the site level's data flow diagram.

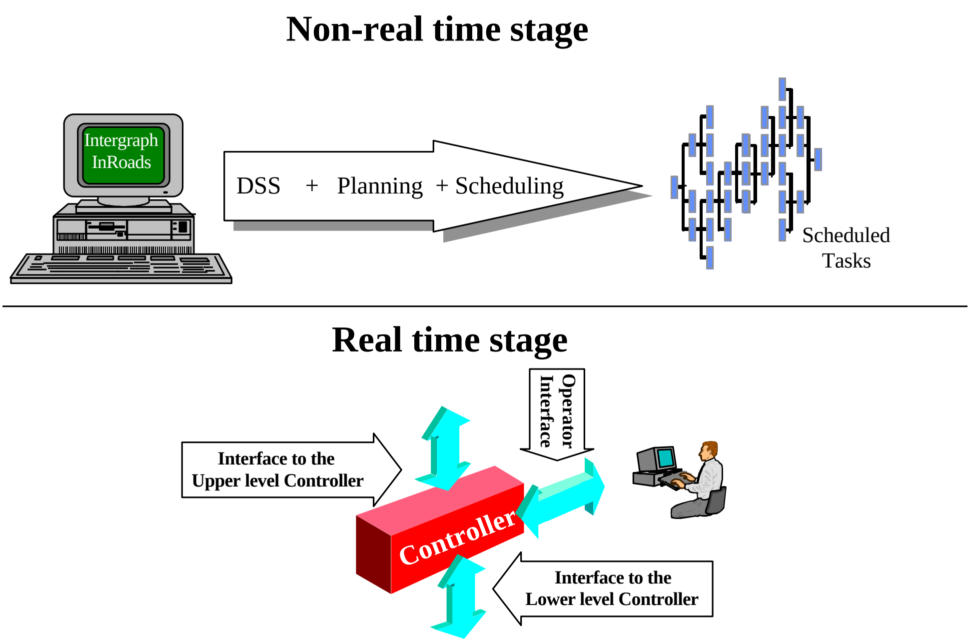

Figure 3. Site level's data flow diagram

In this level two different time stages are identified: the non-real time stage and the real time stage.

The non-real time stage includes the CAD representation of the construction site, that describes the work to be executed and the geologic layers affected by the construction. Then the DSS identifies the tasks, generating the data to be imported by the planner and by the scheduler in order to produce the scheduled tasks.

The real-time stage includes the control of the scheduled tasks, that is made monitoring all active cell's controllers (below level). Thus, this stage is able to detect cell problems related to tasks behind time scheduling, controlling and generating new rescheduled tasks scenery. In this case the overall plan may be non-optimal until a complete non-real time planning is carried out.

4.2 Cell level

The cell level is responsible for the control execution of one task by a cell. Tasks are dispatched by the site level and this level is concerned in the execution of one “single task”. This level only exists during the task execution, becoming “non-existent” afterwards.

Like in the site level, it is possible to identify two stages in this level. The non-real time stage is where tasks are sub-divided (via DSS), planned and scheduled to be performed by one machine. The biggest difference is that it is strongly conditioned by the start and finish times already assigned to the global task execution and it is itself part of the site real-time stage. Therefore the use of several pre-planned templates should be used trying to speed up the process. The real-time stage monitories and controls the execution of tasks which in this case is a synonym of heavy-duty machine monitoring.

The cell level resources (e.g., worker, paver, excavator) are assigned by the site level. The proposed architecture allows the existence of shared resources by several cells granting a more flexible overall plans. A typical RoadRobot’s cell contains one road paver, accompanying machines, workers, operators and the asphalt to lay a specified strip of road.

4.3 Machine level

The system’s low control is started by the machine level. To co-ordinate the work each machine has a controller that receives the assigned tasks, and uses the local knowledge to execute them.

The machine controller has the responsibility to produce the plan. In this level, real-time related problems are not so much important when the vehicles involved are slow motion machines (e.g., road pavers). This level is also responsible to incorporate the tool sensors and to process the collected data into suitable information.

4.4 Tool level

The tool level is the lowest and the most real-time sensitive in the generic architecture. Tools have their own tool controller to co-ordinate their actions. Examples of possible tool levels are: motion base, excavator arm, asphalt conveyor.

5. NEW FEATURES OF SIP SINCE CIB’95

During last year, the use of SIP in several projects shown that two more features might be added to the platform in order to fulfil the requirements of the projects.

Therefore, the following functionalities are being developed:

1. Messaging - A mechanism that allows message flowing among tools inside the system. This mechanism will allow signalling of events in the Information System.

2. EMDI - E-Mail Data Interchange using neutral format (ISO 10303-21) to allow data transfer world-wide (for instance data exchange between the headquarters in Europe and the sub-offices world-spread);

5.1.1 Messaging

The RoadRobot project has shown that system's applications need synchronised actions (e.g. one application has to wait for another to modify particular data before continue). So far, our solution for that problem was to create a mailbox of events shared by the whole system and accessed by continuous pooling. That solution has had negative results due to the huge CPU time usage and non admissible network's bottlenecks. To solve that problem an interruptable-based messaging system was implemented.

This messaging system holds an individual and group management, allowing message interchange between application-to-application or application-to-group. When required, a application can suspend itself until receive one message from another application.

5.1.2 E-Mail Data Interchange - EMDI

The geographically distributed configuration of some companies, and the need of data exchange between its production plants across the world, shows that a system based on on-line transactions can become very expensive and slow. The internet support to data sharing seems to be the most appropriate solution for this problem.

Therefore, clusters of standardised data exchanged via E-mail allows the communication between applications from different sites in a batch way. Figure 4 exemplifies data exchange between Lisbon (EUROPE) and West Perth (Australia), using SIP, where E-mail import/export functionalities are based in STEP neutral format - part 21.

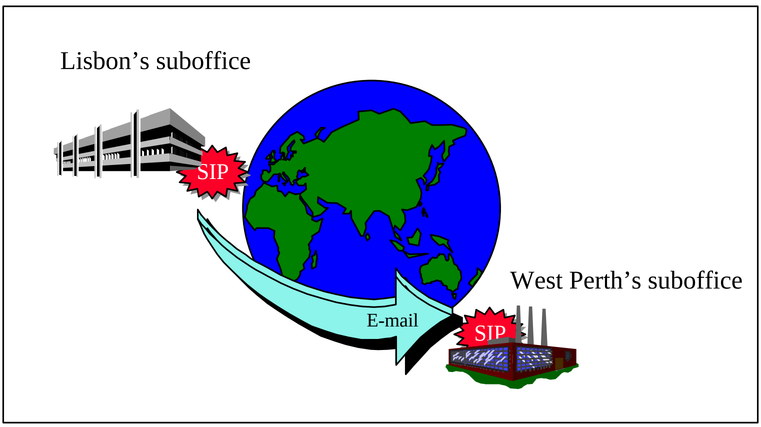

Figure 4 - **STEP-based world-wide data exchange, using E-mail facilities**

The platform (SIP) will be the gate to the outside world via E-mail. When a application performs a write operation on a distant system, SIP handles all the inside details to convert the information to the neutral format and sends the messages to the destination address. At the destination site, there will be an E-mail manager (acting as a SIP's tool) that receives the data and creates a new STEP neutral format cluster in the local system.

Even when the remote system does not use the SIP platform, the received clusters can always be retrieved from the E-mail handler and used by any other STEP-based tool, as long as both ends know the application protocol (AP) used.

6. CONCLUSIONS AND RESULTS ACHIEVED

One of the problems of construction information systems concerns the representation of the information to be accessed by the different agents of a process. This requires the definition of common models for shared concepts in order to support an effective exchange of information.

To assist information exchange among tools, UNINOVA developed a STEP-based Integration Platform - SIP. SIP is a set of tools that allows to integrate several applications using a unique neutral data format (ISO 10303). The goals will be reached by adapting existing applications selected in the market, and integrating product models, processes and resources in a global and standard information system.

In the ESPRIT RoadRobot project, for road construction industry, SIP toolkit is being used in integration tasks (Jardim-Gonçalves.93)(Jardim-Gonçalves.95).

The RoadRobot generic architecture should be seen as a "template" to be used within real construction site systems. The RoadRobot's architecture is defined and implemented in four logical levels (site level, cell level, machine level and tool level). Each level is co-ordinated by a dedicated controller and it has associated an intelligent planner/scheduler system working on the results produced by a Decision Support System (DSS).

During last year, the use of SIP in several projects shown that Messaging and EMDI - E-Mail Data Interchange using neutral format (ISO 10303-21) - might be added to the platform in order to fulfil the requirements of the projects.

A formal demonstration of the RoadRobot project will be held on 26th June 1996, in Aachen - Germany, at the Vögele's site.

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