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

- SEEKING A LIFE-CYCLE-ORIENTED MODELLING -

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Abstract: International building industry has not still achieved a high degree of integration and automation in the past years. Up to now, the use of Information Technology (IT) in outdoor applications, specially in the building industry and automated construction, should have more attention. For that reason existing architectures and modules from other industrial areas can be adapted to the special requirements of the building industry.

Because the use of standards in the modelling process can help the integration task, a STEP (ISO10303) based platform for integration of applications (SIP toolkit), created by UNINOVA in the ambit of an European project, was developed. Several managerial and engineering applications were already integrated in industrial environments using SIP, including the construction one. Demonstrations are available showing achieved results.

The paper mainly concentrates on the following aspects:

- Discussion about integration of software tools in industrial environments, under standardisation of information modelling.
- Presentation of the internal architecture of the platform, and the global information system architecture implemented.
- Comments about the results and experience acquired during the implementation of SIP in R&D projects and in industrial companies, specially in the European Project for road construction - RoadRobot.

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1. INTRODUCTION

International building 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 some industrial sectors, in the building Industry and automated construction the use of Information Technology (IT) in outdoor applications did not have so much attention.

This lack of integration and automation has resulted in a demand for very flexible and automated heavy-duty machines, and in integrated concepts for automated construction sites.

To study existing architectures and modules from other industrial sectors, trying to bring them to the building industry after adequate adaptation for its special requirements, can be an adequate approach.

Two possible approaches [Camarinha-Matos.92] can be applied in order to go from the scenario found in the company, to the scenario required for that company:

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 an European project, was developed to assist integration of several applications using a unique format.

A proposal intended to contribute to the solution of integration problems for construction industry is presented in this paper. It makes emphasis on integration of commercial tools using UNINOVA's STEP-based Integrated Platform (SIP), as a result of the experience acquired during the implementation of SIP in Research & Development (R&D) projects and in industrial companies. Special emphasis is made on the European Project RoadRobot.

Technical and implementation aspects addressed during the integration process are highlighted.

2. THE ROADROBOT PROJECT

European building industry has not achieved a very high degree of automation in the past years. To remain competitive, enabling manufacturers of heavy-duty building machines to sell their products on the world market, new control concepts for heavy-duty machines have to be developed and brought to a commercial stage.

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 building industry. The second one is the development and implementation of a modular control architecture, and the flexible automation of well-defined sub-units.

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.

2.1 Objectives of project

The objectives of RoadRobot project [J.P.Pimentão.94] are to adapt a generic control architecture to the requirements of the building industry, and to build up and integrate components needed for automated out-door construction purposes.

This will enable Computer Integrated Manufacturing (CIM) techniques to be used in the construction industry, bringing with it the associated benefits of production quality, costs effectiveness and flexibility.

Its main goal is the development of an architecture, which is to be used to design and develop the various modules of an automated construction site. After testing the functionality of these modules, they will be integrated in some example machines (a road paver and an excavator), and at last demonstrated and used at a real building site in France.

RoadRobot's main challenge is the development of an overall concept for the integration of heavy-duty machines into a sophisticated manufacturing environment, tailored for the requirements of construction industry.

Recognising the low level of Information Technology (IT) in building industry, one main point of interest is the development of IT for the specific requirements of this sector. Therefore, it is important that knowledge and experience be brought into the building industry, by manufacturers of heavy-duty building machines, companies with special IT expertise, and Research & Development (R&D) institutes.

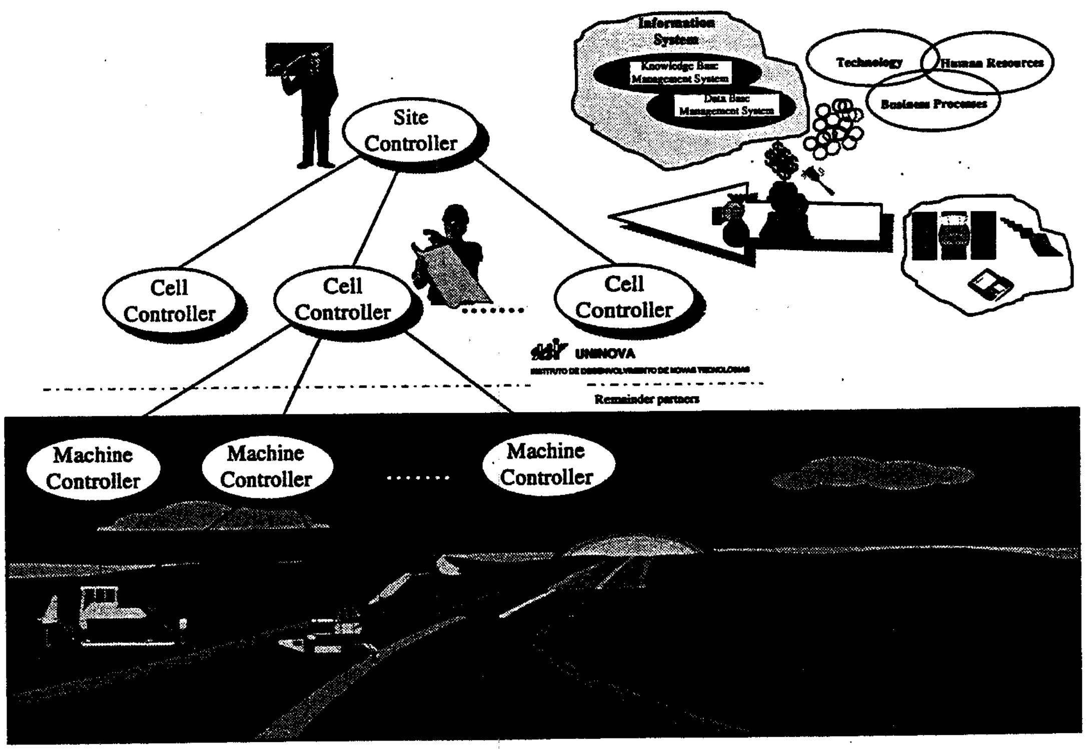

Figure 1. Architecture of RoadRobot project

Figure 1 depicts the architecture of RoadRobot project. The development of this generic control architecture is expected to be used at other similar construction sites. In this way, the planned system can be exchanged or expanded by other machines or applications.

In order to reach as far as possible international standardisation, the information models are 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.

2.2 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.

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.

3. THE STEP-BASED INTEGRATION PLATFORM - SIP TOOLKIT

A STEP (ISO10303) standard based platform for integration of applications - SIP - Toolkit, was developed by UNINOVA in the framework of the European BRITE/EURAM CIMTOFI (CIM sysTems with improved capabilities fOr Furniture Industry) project[Jardim-Gonçalves.93].

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 modeling 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++, EIFFEL, Object Oriented Data Bases and Relational Data Bases).

3.1 Requirements of SIP

To use an integration platform based on a standard is related to problems like the following:

- Shortening product life cycles;
- Reduction of manual operations;
- Allow integrated sector oriented solutions;
- Facilitated information management.

These aspects reduce system maintenance and upgrade efforts. To avoid a high number of required interfaces, a unique neutral data format should be used in the integration process

In order to understand the company's information system and the life cycle of its components, the use of structured planning and analysis techniques is quite helpful.

3.2 Architecture of SIP

SIP is fundamentally constituted of an Information Management System (IMS), an Information System Access Protocol (ISAP) and a Development System Tool Set. (DSTS) Figure 2 shows the 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 related to the communication protocol. It constitutes 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. In order to realise this, we have adopted the suitable object-oriented approach for the design of the architecture, which allows a gradual integration of automated functions as they become available.

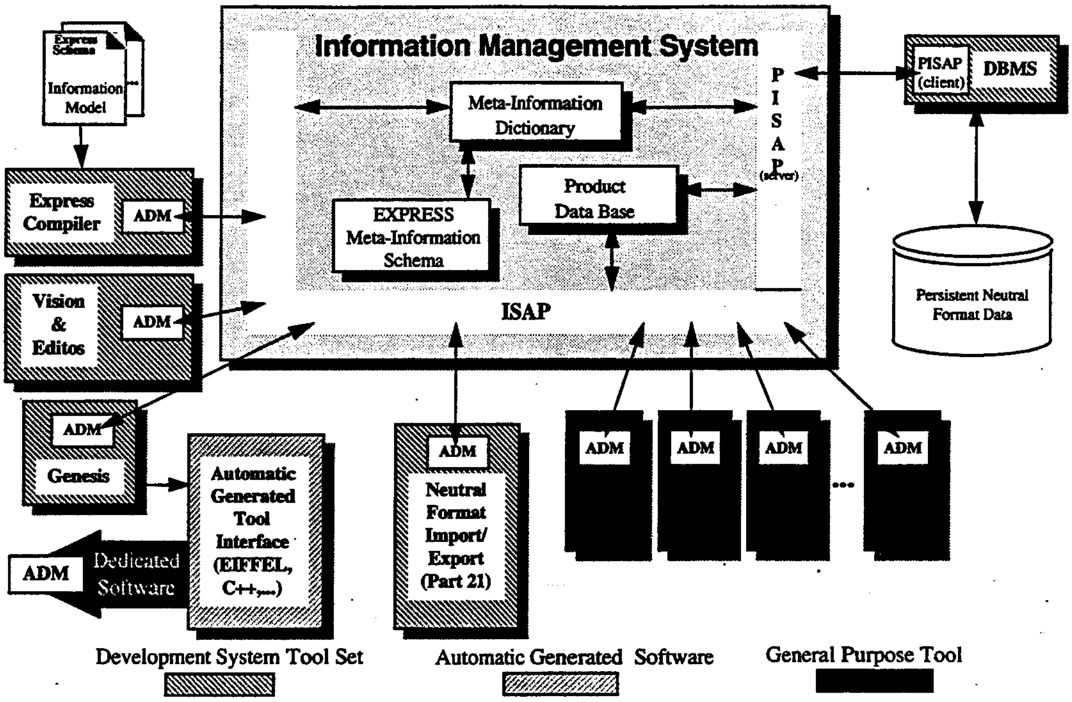

Figure 2. Architecture of SIP

3.2.1 SIP's Development System Tool Set components

The SIP's Development System Tool Set components are:

- An *EXPRESS compiler* (modelled himself in EXPRESS), that has the responsibility of processing Express schemata, checking for lexical, syntactic and semantic errors, generating the equivalent meta-information representation structure, and updating the meta-information dictionary inside SIP.
- *Vision* and *Editus,* that allow edition and navigation through the STEP-based Information System.
- *Genesis,* a tool that generates automatically the front end for several programming languages. Every time it is necessary to integrate a new tool, a dedicated Application Dependent Module (ADM) has to be developed. The DSTS *Genesis* tool helps this task, generating code automatically. This code stands for a complete implementation of all entities described in Express schemata, generating automatically access primitives for the entities (for example those that make the data transference from/to SIP using ISAP). Front ends to C, C++ and ONTOS (Object oriented data base) are already done, Relational Databases access languages (SQL is now in test), and EIFFEL front-ends are being considered.
- Import/Export data tool. This tool uses neutral format (Part 21) to change date.

3.2.2 *Inside IMS*

The EXPRESS Meta-Information schema represents the meta-information model and data. This schema is loaded in the meta-information dictionary at initialisation time of IMS.

Private, Public and External objects are supported by clusters. This feature is very important when we are working in industrial environments. A data exchange typically contains the model representation of an individual existing part. In industrial applications there is a need for a mechanism to cope with complex model structures where dependent structures are stored in individual physical clusters. It is therefore necessary to access data from external entities (for example, a solid model may have components 'shared' by other solid models).

3.2.3 *Connection with external systems*

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).

Relating to the communication protocol, two distinct parts can be identified:

- *Server*. The IS plays the server part, supplying access to the data produced and consumed by external systems. It has a library of functions linked to the IS code, which manage the communication between the client part of the protocol and the IS.
- *Client*. Tools play the role of clients. There is a library of functions, to be linked with the code of the external systems, to allow the communication between tools, the clients, and the server.

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

4. INTEGRATING TOOLS USING SIP

When we have a large set of tools, coming from different places (in RoadRobot project they are Site and Cell Controller tools and Machine Controller), and an integration process is being considered, the design of a global Information System is a necessity.

One advantage of this approach is to put available to the system the information owned by a specific tool, in an automatic way (automatic data import/export), allowing an indirect consolidation of the global system.

To fulfil these requirements, a detailed data analysis of each tool should be performed, finding which data must be shared by other tools. After the conclusion of this work, a consolidated Schema (described in EXPRESS, as in the RoadRobot case) must represent the data structure of the global transfer necessities among system tools. Therefore, the import/export data flowing through the system is defined, and it will be physically represented using the STEP neutral format, supported by the Express schema to impose the rules of data transference.

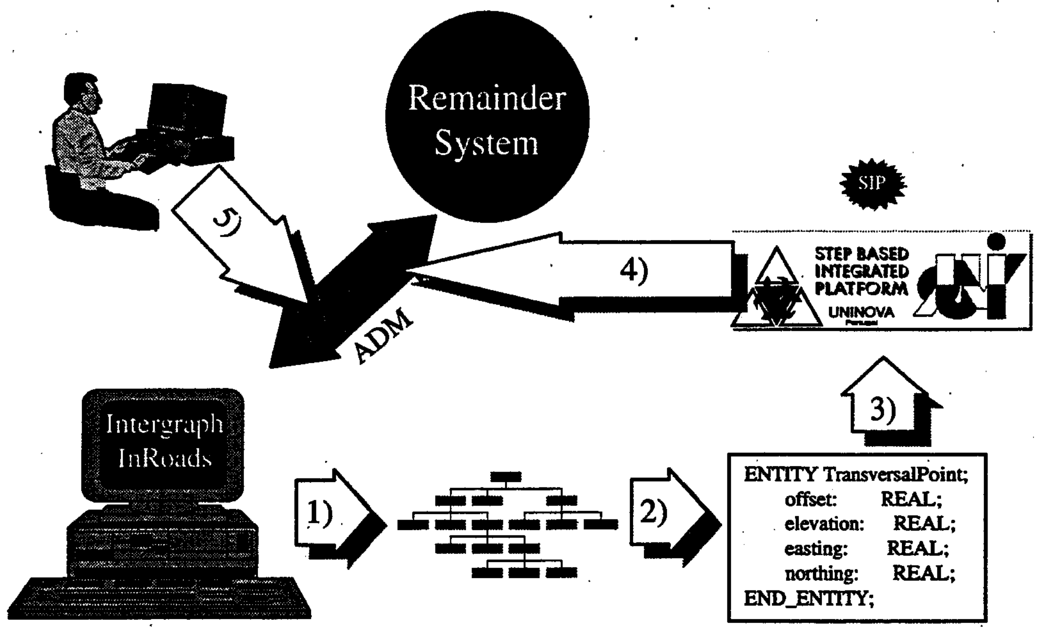

Figure 3. Steps to integrate a tool using UNINOVA's SIP

4.1 A short example in the road construction context

When we want to integrate a tool using SIP, the following steps should be executed (Figure 3):

1) Study the tool to be integrated in industrial system context, to understand very well which data must be imported/exported

   - Let us consider we want to integrate the InRoads Intergraph system, concerning import/export cross section data.

2) Model these data using ISO 10303/11 EXPRESS.

- Using EXPRESS we can model a TransversalPoint in the following way:

```
ENTITY TransversalPoint;
    offset:        REAL;  -- from road alignment, metres
    elevation:     REAL;  -- z-coordinate, high, metres
    easting:       REAL;  -- x-coordinate, metres
    northing:      REAL;  -- y-coordinate, metres
END_ENTITY;
```

3) Compile the EXPRESS model using SIP's EXPRESS compiler.

- This action will store the model as meta-information data inside the integration system, allowing its use by SIP toolkit.

4) Generate the Application Dependent Module (ADM) for tool. ADM will be the piece of software that establishes the connection between tool and the remainder system.

- Let us consider to use C++ language for this purpose. Hence, using SIP's Genesis tool we can automatically generate this interface. Next frame shows the resultant class description.

```
class TRANSVERSALPOINT : public UNI_Object {
private:
UNI_DoubleIs*   OFFSET;
UNI_DoubleIs*   ELEVATION;
UNI_DoubleIs*   EASTING;
UNI_DoubleIs*   NORTHING;
public:
    resultado readIs(void*,void*,int);
    resultado writeIs(void*,void*,int);
    TRANSVERSALPOINT();
    virtual classType isA()const ;
    virtual char* nameOf() const;
    virtual hashValueType hashValue() const;
    virtual int isEqual(const UNI_Object& o) const;
    virtual void printOn(ostream& oS) const;
    virtual void printOn(fstream& oS) const;
    void putOFFSET(UNI_DoubleIs* OFFSETIn );
    UNI_DoubleIs*   getOFFSET();
    void putELEVATION(UNI_DoubleIs*   ELEVATIONIn );
    UNI_DoubleIs*   getELEVATION();
    void putEASTING(UNI_DoubleIs*   EASTINGIn );
    UNI_DoubleIs*   getEASTING();
    void putNORTHING(UNI_DoubleIs*   NORTHINGIn );
    UNI_DoubleIs*   getNORTHING();
};
```

- The generated class provide us with a set of access methods virtualizing the low level integration aspects.

5) Integrate the generated ADM interface within tool and remainder system.

- Because the class generated virtualize integration aspects, to export data, the programmer needs to create a class instance (a TRANSVERSALPOINT object), fill it using the adequate methods, and call the *writeIs* method on it. To import data, the programmer needs to create an instance of this class, call the *readIs* method, and to use the convenient access methods to access the attribute data.

- A library of classes is released with SIP, allowing easy manipulation of non C++ standard data-structures, like aggregates.

4.2 Industrial applications integrated using SIP

A set of industrial applications was already integrated successfully using SIP [Jardim-Gonçalves.93][J.P.Pimentão.94][Jardim-Gonçalves.95].

We highlight the IBM CAD system CATIA, the Intergraph CAD system I/EMS, CNC machines, an Expert System for furniture industry, an Expert System Shell (NExpert from Neuron Data) and a Data Base Management System (Object Oriented DataBase Management System ONTOS), the Intergraph product InRoads [J.P.Pimentão.93] (A design system for road construction purposes), a Scheduler Interface, a Planner, a CAPP (Computer Aided Process Planning) and a MRPII (Manufacturing Resource Planning), a User Interface and Heavy Machinery working on the field.

5. CONCLUSIONS AND ACHIEVED RESULTS

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, with encouraging results[Jardim-Gonçalves.93].

Several managerial and engineering applications were integrated in other industrial environments using SIP. Demonstrations are available showing the results.

As a result of our experience under RoadRobot project, SIP seems to be an adequate proposal solving industrial integration problems for road construction industry.

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