A FRAMEWORK FOR INTEGRATION OF SUPPLY CHAIN MANAGEMENT APPLICATIONS BASED ON THE IAI/IFC MODEL

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Abstract: At the present time, electronic data exchange in construction industry is mainly used for the exchange of information related to technical design, most of the time using proprietary data formats from the CAD systems in use. Planning, control and management activities are very often not supported automatically, and standard models to enable their automatic data exchange are just now coming from the research stage. The European project SUMMIT – Supply Chain Management In Construction Industry, is a end-user driven project which envisages to create, implement, test and evaluate an EDI, STEP and IAI/IFC based communication infrastructure on a specific project of building prefabricated houses, connecting project manager, contractor and suppliers. This paper presents the framework developed for SUMMIT for integration of supply chain management applications based on the IAI/IFC model.

Keywords: Integration, Interoperability, Standards, IAI/IFC, Supply Chain Management.

1. INTRODUCTION

Although there is already a large portfolio of Information Technology (IT) Research & Development (R&D) and commercial solutions for the exchange of information in the building industry, there are very few examples of real-world implementations [1]. A major technological hindering factor is the lack of integration between R&D developments and commercial applications, leading to a delay in terms of the implementation of the newest and most advanced technologies, like e.g. Internet, Workflow, STEP/EDI Standards, Procurement Systems [2]. In order to overcome this situation, the ESPRIT 25559 Project, Supply Chain Management in Construction Industry – SUMMIT, created, implemented, tested and evaluated an Electronic Data Interchange (EDI)-based communication infrastructure between the various partners involved in the manufacturing and construction of prefabricated houses, using a pragmatic approach to combine both commercial / real-world systems and new technologies [3][4].

SUMMIT developed a framework to automate the tendering, ordering, delivery, invoicing and payment processes of house systems, equipment and services in its supply chain, whose members have different levels regarding Information and Communication Technologies (ICT).

The adopted methodology focuses on the analysis of the current business processes information infrastructure and grounded on the possibility of integration to support new business processes. SUMMIT is dedicated to the exploitation of potentials of both EDIFACT and IFC approaches to product and process data communication, by a concept of combining the complementary nature (business versus technical data) of both approaches. This, together with an EDI system based on an inter-organizational workflow system, enables a better co-ordination between the companies on the supply chain, from the client's representative (project manager), to the contractor, and suppliers. Major results by SUMMIT are:

- A procurement process model exploiting the potential of pure digital data exchange and system interoperability

- EDIFACT messages sub-sets for the procurement of house systems and equipment
- IFC product/process model enabling the representation of project management data for prefab houses
- An EDI communication infrastructure featuring secure and compatible information exchange for the entire production process
- A distributed information flow component based on EDI and inter-organizational workflow infrastructure, supporting process definition and process execution in the boundaries of autonomous organizations
- Use of commercial application for fast-track implementation of the ICT infrastructure, and linkage to widely used commercial and technical applications.

1.1 EDIFACT and Project management data in the SUMMIT project

There are about 200 UN/EDIFACT internationally agreed messages at various stages of development available. However, EDIFACT standards themselves do not lead necessarily to a plug and play solution for inter-organizational EDI connections, particularly in construction [1]. The message content and the meaning of data within the message structure have to be agreed by the interacting partners. SUMMIT detailed the content of the most important EDIFACT messages for the supply chain for prefab house systems, connecting the project manager (or others client's representative), the contractor / manufacturer, and suppliers/subcontractors. Thus, construction firms aiming to implement an EDI-based information flow will only require to specify concrete instances of the detailed defined messages. Description of SUMMIT results regarding EDI and EDIFACT can be found elsewhere [1][2][4].

Based on the pragmatic philosophy in which SUMMIT was grounded, i.e. development of a solution that can deliver real world results in the short term, it was decided to complement the need of exchanging commercial and administrative data using EDIFACT standards, with the exchange of project management data using a more adequate standard for the exchange of product and process data. Although there was an EDIFACT message specific for project scheduling and resources data exchange – PROTAP, it was decided that EDIFACT structure is not adequate to support the exchange of this type of data [2]. Initially the developments in the Building Construction Core Model (BCCM) were the adopted solution. The idea was to complement EDIFACT files with product/process data in standard format, i.e. embed the EDIFACT data structure with STEP structure. However, the analysis into this standardization area demonstrated that very few developments were made regarding project management data, and that current state-of-the-art would not support a pragmatic approach, a requisite for the user-driven type of project.

Hence, SUMMIT focused on the developments on the Industry Foundation Classes (IFC) within the work of the International Alliance for Interoperability (IAI) [5]. SUMMIT worked in the Project Management Domain, in particularly in the Domain project PM-1 Scheduling, in co-operation with current IFC 3.0 Release working groups on that area. However, for the implementation, it was used the IFC 2.0 Release Specifications, issued in April 1999, which incorporated much of the work being developed for the IFC 3.0 Release.

According to the IFC Specifications, the construction scheduling process creates a construction schedule using the objects across the IFC Model. In general, construction schedules will be developed through analyzing the Task objects and Resource Use objects created when developing the Cost Estimating, and aggregating them into Construction tasks at the appropriate level for scheduling. However, this process must consider the size and complexity of the model. In situations when there was no cost estimating, construction scheduling process will be different, implying a querying to the shared project model, and the objects found will be used as the basis for developing construction tasks. In both situations, time duration of the tasks will be estimated and construction sequences will be identified. The construction schedule is then created and analyzed, and after completion of the schedule, dates will be embedded in the IFC Model.

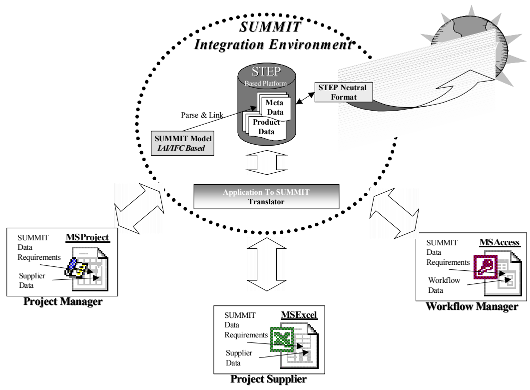

Figure 1 – SUMMIT's IFC-based approach for the exchange of schedules.

Developments in the IFC/IAI are aimed essentially for the future design and engineering of new software for the construction industry. But the aim of SUMMIT was to deliver a solution that would not imply major software developments, rather that would enable integration of existing commercial systems with minimal programming. The adopted approach (depicted in Figure 1) is grounded on the concept that scheduling applications are linked through ODBC (or other dynamic link) to an IFC scheduling database. The format of the database is based on current specifications of IFC 2.0 Release. Because there are no IFC compliant scheduling applications, on top of the database an IFC interface (combined with an editor/browser) simulates a future IFC compliant project management application.

Within the SUMMIT project, the IFC and EDIFACT information is combined in a common communication infrastructure defined by an Internet-based inter-organisational workflow system, that co-ordinates the business and management information flows between project manager, contractors and suppliers in the various stages of building prefab wood houses. A simple example is the dynamic integration between the dates present in the scheduling applications and IFC database and the issuing and deliver dates of orders, coordinated by the inter-organisational workflow system.

2. IAI/IFC-BASED SUMMIT MODEL

The model used in the SUMMIT project to support the integration of supply chain management applications, is based on an extended view of the IAI/IFC model – release 2.0 [3]. This extension was developed to cover the project requirements and sometimes to simplify the way IAI/IFC does concerning the project aims.

The *view* from the IAI/IFC, includes the classes devoted to the definition of the information manipulated by the translator, such as:

- planning activities
- tasks in each plan
- schedule of different task
- resource and materials used to complete the tasks
- information related to the delivery of goods

The IAI/IFC model defines classes with the intent to cover many of the activities related with the Building and Construction industry. To face the SUMMIT implementation requirements, a subset of the IAI/IFC was used, where some extensions were made as a proposal that intends to get a model, functional in terms of implementation, providing the missing structures necessary to SUMMIT.

The additional classes included in the extended model give, for example, the possibility to associate tasks with “consumed” resources and materials, and to describe the sequence of task’s execution.

Below, is presented an extract of the extension of the IAI/IFC model adopted and implemented in the SUMMIT project, to support the requirements in terms of scheduling and relationship between tasks. Note that *ITALIC* means extension/modification made on the IAI/IFC model.

```
TYPE IfcWorkTaskTypeEnum = ENUMERATION OF (
  Fixed_duration, Fixed_units, NotDefined);
END_TYPE;
TYPE IfcConstrainEnum = ENUMERATION OF (
   As_Soon_As_Possible, As_Late_As_Possible
      ,Finish_No_Earlier_Than, Finish_No_Late_Than
      ,Must_Finish_On, Must_Start_On
      ,Start_No_Earlier_Than, Start_No_Late_Than);
END_TYPE;
ENTITY IfcConstrainTask;
     constrainType          : IfcConstrainEnum;
     constrainDate          : IfcDateTimeSelect;
END_ENTITY;
ENTITY IfcMeasureWithUnit;
     measure  : REAL;
     unit     : STRING;
END_ENTITY;
```

The following IAI/IFC ENTITIES were partially modified:

```
ENTITY IfcRelProcessOperatesOn
  SUBTYPE OF (IfcRelationship);
    RelatingProcess   : IfcProcess;
    RelatedObject     : IfcObject;
    OperationType     : STRING;
    OperationQuantity : IfcMeasureWithUnit;
END_ENTITY;
ENTITY IfcWorkTask
  SUBTYPE OF (IfcProcess);
    WorkTaskID          : STRING;
    WorkTaskName        : STRING;
    Description         : OPTIONAL STRING;
    WBSCode             : LIST [0:?] OF STRING;
    WBSSource           : LIST [0:?] OF STRING;
    Status              : IfcWorkTaskStatusEnum;
    Milestones          :SET [0:?] OF
IfcWorkTaskMilestoneEnum;
    WorkMethod          : OPTIONAL STRING;
    WorkTaskType        : IfcWorkTaskTypeEnum;
    Contrains           : IfcConstrainTask;
    Responsible         : LIST [1:?] OF STRING;
  INVERSE
              ScheduleElements  :  SET  [0:?]  OF
IfcWorkScheduleElement FOR WorkTask;
    WorkPlans:SET[0:?] OF IfcWorkPlan FOR Tasks;
END_ENTITY;
```

3. THE SUMMIT PLATFORM

The aim of the SUMMIT platform is to establish and provide the mechanisms to link the partner’s applications running in their sites and using proprietary data format, with a STEP Neutral Data format [6] communication channel based on the SUMMIT model [3].

Since those applications chosen for the demonstration of this platform were MsEXCEL, MsProject and MsAccess, the main tasks of this translator are to convert bi-directionally STEP data into CSV or Microsoft Access data (data formats already supported by these applications).

Figure 2 depicts the architecture of the SUMMIT platform. The STEP-based platform is set-up having as input the SUMMIT model, as an extended view of the IAI/IFC models to cover the SUMMIT requirements. A Parser and Linker compile this model and store in the platform's repository their meta-data. This data dictionary will be used afterwards for syntax and semantic data exchange check and validation, and also to generate automatically code that will be part of the translator, using the GENESIS toolkit [7][8].

The front-end for the data represented in Neutral Format repository is the Standard Data Access Interface (SDAI), as described in Part 22 of the ISO10303 Standard [6][9][10].

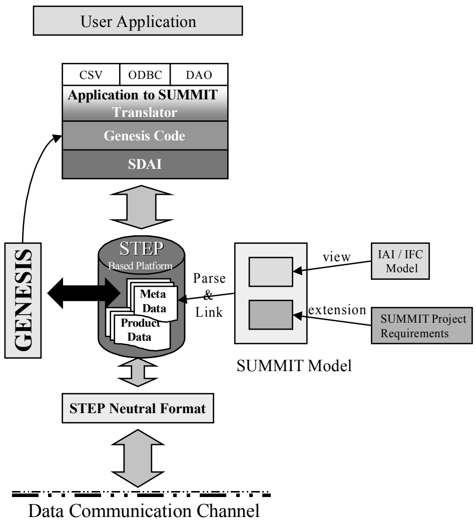

Figure 2. Architecture of the SUMMIT platform

On top of the SDAI it is linked the code generated automatically by the GENESIS toolkit. This code provides a high-level interface, described as a set of C++ classes with functionalities that makes easier the access and generation of the data in Neutral Format based on the EXPRESS model already compiled and stored in the meta-data repository.

The translator module is the responsible to establish the data format transformations between the application's proprietary data format and the SUMMIT one.

This transformation of data is done based on a mapping table, as described in the section below, and provides the description of the data transformation as it is handled in one application to another, having as an intermediate point of access the Neutral Format. Are through these mapping tables that is specified the association between the models representative of the application's data and the SUMMIT's model that rule the translation process.

The access to the proprietary data format is done in this case using the CSV (Comma Separated Value), ODBC (Open DataBase Connectivity) or DAO (Data Access Objects) mechanisms, and managed directly by the user applications.

The SUMMIT platform can be remotely or locally installed in the different partners involved in the project, and is the responsible for the generation and handling of the STEP Neutral Format and for the data exchange among the applications using this Neutral Format.

4. THE MAPPING BETWEEN APPLICATION'S DATA MODELS

The exchange of data between applications relies on a mapping between its data models, to keep the semantics of the data when transferred from one application to the other.

There are several possibilities to describe the mapping functionalities between two data models, depending on the complexity and extension of the mapping task.

One possibility is to use a mapping table, describing the transformation functions for each attribute in each entity. These functions could be defined in most of the cases of type:

App1.EntA.AttribX =
funcTransfOf(App2.EntK.Att1, App2.EntL.Att4,….)

The simplest case is when it is used the Identity Function, i.e., I( ), between two attributes of two entities in two applications, where the mapping functions are represented by a direct assignment operation.

Another possibility is to use a more complex language to describe the transformations required for the mapping. The EXPRESS-X language [6] is an example of such language. This approach, although more powerful and flexible, implies in most of the cases the use of a complex interpreter.

The realization of the mapping rules for implementation can be early or late binding. In the early binding case, the mapping table is compiled and hard-coded, to be linked with the translator's code.

In the late binding code, the interpreter of the mapping language is linked with translator's code, and the mapping description is used as on-line input for the translator. This case provides a flexible approach, since the translator supports automatically changes in the mapping rules without any further procedure, although a complete interpreter for the mapping language needs to be included in the translator's code.

CSV Field	***IFC Class***	***IFC Attribute***
Project	IfcWorkSchedule	WorkScheduleName
Created	IfcWorkSchedule	CreationDate
ID	IfcWorkTask	WorkTaskID
Task_Name	IfcWorkTask	WorkTaskName
Duration	IfcScheduleTimeControl	ScheduleDuration
Type	IfcWorkTask	WorkTaskType (*Attribute added to IFC*)
Outline_Level	IfcWorkTask	WBSSource

Predecessors	IfcRelSequence	RelatingProcess + SequenceType {FF, SF, ...}

Table 1. Extract of the SUMMIT's mapping table.

In the early binding case, every time the mapping rules change, new code needs to be generated and linked with the translator. In this case the code is only the required to support the specified mapping rules.

The case of the SUMMIT project, it was adopted the representation of the mapping rules using a mapping table, with early binding implementation.

Table 1 gives an overview of the mapping table used in SUMMIT, and Figure 3 depicts the framework implemented to support the mapping of data models between the SUMMIT applications, with the objective to exchange the information between the applications, each one with its own data format.

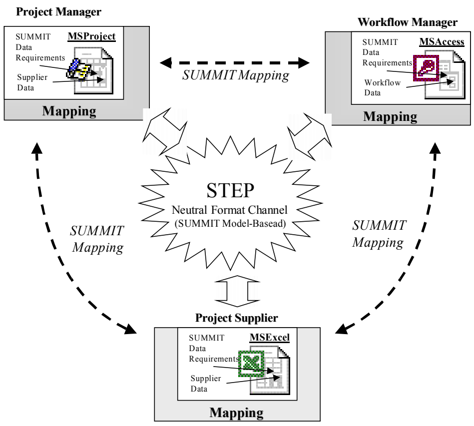

Figure 3. Approach for mapping between the applications used in the SUMMIT project.

The mapping layer was developed based on the mapping table description, and linked with the application's translator, that was used as the interface to an intermediate Neutral Format data representation, based on the SUMMIT data model, virtualizing the direct data exchange between the applications (dashed line).

5. THE TRANSLATOR MANAGER

The Translator Manager is a Windows application developed to support the Local and Remote management of the translation activities within the SUMMIT environment. Figure 4 shows a snapshot of its main window.

The translator's parameters are divided in the following distinct areas: *Translation Type*, *Input/Output Data*, *STEP Platform*, *Translation Site*, and the command area: *Translate* or *Exit*.

- Translation Type - Indicates the type of data translation to be done between the applications and the STEP platform. E.g., Translation from data in Microsoft Excel format to SUMMIT Neutral Format.

- Input/Output Data - The path and name of the input/output data file. If the data conversion is STEP format data to application's native format data, then the information in this field works as output file. In the reverse, the information in this field works as the input file, which should contain all the input data necessary for the translation process.

- STEP Platform - Defines the configuration and identification of the STEP platform and data repository used for data translation and exchange between applications.

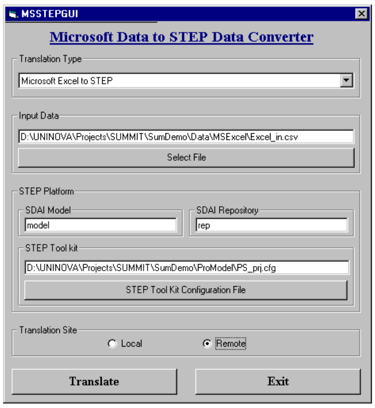

Figure 4. Translator in GUI mode

- *SDAI Repository* - name of the SDAI repository where STEP data is or will be stored.

- *SDAI Model* - name of the SDAI model where STEP data is or will be stored.

- *Configuration file* – file that contains the settings of the STEP repository in the STEP platform.

- Translation Site - Indicates where the translation results are stored. If it is local, then the STEP data is or will be saved in the local computer where the application is executed. Otherwise, the STEP data will be sent and saved in a remote compute, using the ftp protocol.

- *Local* – the application runs with local data.

- *Remote* – it is asked to the user the information to connect to a remote computer through the ftp protocol to handle the STEP data remotely. Figure 5 presents the user interface referent to the server information.

5.1 The Remote Server

The Remote Server enables STEP data to be exchanged anywhere in a network, e.g., using the Internet. It enables the users to access data from any place, though there is a network connection to the STEP data server.

Using this facility, the users of the applications can connect to this server, and work and exchange data from distinct geographical places keeping the same interface.

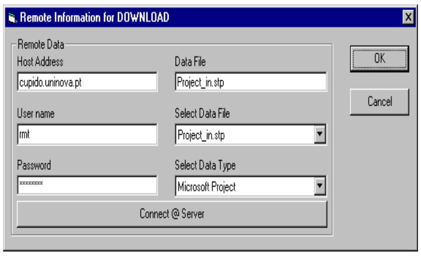

Figure 5 – STEP Server information

This possibility is very important when the users move very often from place to place, and have the need to exchange data between applications frequently. With this possibility, though they have access to Internet, they are always automatically integrated in the system, and, consequently, in contact with the global system, using the same working environment without additional effort.

6. CONCLUSIONS AND FUTURE WORK

The general aim of the ESPRIT 25559 Project, Supply Chain Management in Construction Industry – SUMMIT, is to create, implement, test and evaluate an Electronic Data Interchange (EDI)-based communication infrastructure between the various partners involved in the manufacturing and construction of prefabricated houses.

An extended subset of the IAI/IFC models was used to support the integration of supply chain management application operating in the Building and Construction field in the scope of SUMMIT.

To implement that, a platform was developed and tested, providing the mechanisms to link the partner's applications using a Standard-based data exchange channel, in this case the STEP Neutral Format.

To keep conformity and semantics during the data translation and exchange, mapping procedures were developed and implemented.

Data exchange is handled by the Translator Manager, that allows local and remote management of the data on a network, using ftp.

For future work, it has been considered to link the SUMMIT model with the ISO13584-PLib (Parts Library) standard [6], for representation of the library of resources to be used in the supply chain tasks. Also, a front-end for internet browsing has been developed, providing a general interface for the services described in this paper, for any user with internet access and browsing facilities.

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