From Construction Product Information to Consistent Project Documentation: the CONDOR Approach

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Abstract:
The paper gives a comprehensive overview of the European Esprit Condor project. The project aims at bridging the gap between current information systems and future ones, and provides a migration path from document-based to model-based approaches to information representation and structuring. After a brief overview of the project's aims and objectives, the paper gives the state of the art of electronic document management (EDM) systems in the construction industry, followed by a description of the three legacy EDM systems used within the Condor project. A Strategy towards the integration of these systems is then given. Finally, the paper presents the overall Condor system architecture. The project is ongoing and supported by a user interest group, which involves representatives from a variety of non-construction industry companies all over Europe.

Keywords:
Computer Integrated Construction, Electronic Document Management, Distributed Objects Technology.

1. Introduction

Industrial processes are characterised by the intensive use and production of knowledge and information. Most of this knowledge and information, even when produced using computers, is still exchanged and conveyed on a paper based medium. This can be viewed as a limitation to potential opportunities for construction process innovation as information is constrained by what can be achieved using paper. In fact, the format and layout of most documents was shaped before the proliferation of personal computers, and has not yet changed in response to more recent IT developments. There is a growing demand on flexible information systems that are flexible enough to accommodate continuous business process improvements. These systems must support the complexity needed for increasingly finer levels of granularity of information context, content and structure. However, even if many international standards have been developed to solve information problems within separate business sectors (STEP: ISO 10303 and SGML: ISO 8879), the problems of enterprise-wide information compatibility remain.

In the construction process, diverse and complex information flows (using documents) between actors. These documents need to be highly consistent in order to provide a reliable basis for actors to perform their design, construction and maintenance activities. Document management has become a crucial issue within modern construction companies. The various solutions proposed by some software vendors revealed to be unsatisfactory, to a point where many leading construction organizations, with an advanced IT department, have undertaken the development of their own tools and solutions to support the production and maintenance of project documents. Even though such proprietary tools provide many helpful facilities, including support for document storage, retrieval, versioning and approval, they don't handle any semantics of the information being processed and therefore remain limited in their support of the end-user. In fact, construction project data and documentation (including full specification

documents) constitute two fragmented information sectors where compatibility and interoperability are mostly needed. Moving these pseudo-sectors closer together to support construction project documentation as part of the life-cycle of the building product is becoming an actual and urgent topic for standard bodies and industry alike.

In order to pioneer a solution, the European ESPRIT Condor project, which involves a consortium driven by construction end-users, is investigating a new model-based - as opposed to file-based - approach to document production and management, based on recent IT developments. One aim is to demonstrate the genericity of the approach, and its applicability across industries. The consortium is aware of the fact that it is not possible to develop a unique document management solution for all the members, because of their investment in proprietary systems. The Consortium is promoting the use of the various existing systems, as described in section 4, by the development of extensions which comply with the proposed approach. These extensions will enable all systems to communicate, and have access to advanced Condor functionality, through a dedicated Application Programming Interface (API) being developed within the project.

The paper presents a means of bridging the gap between the traditional document-centred and the proposed (model-based) approaches to project information structuring and representation. Robust models supporting this transition are being developed, together with a prototype implementation which demonstrates a pro-active use of document management and information management techniques in a collaborative multi-actor environment.

2. The European ESPRIT Condor project

The construction industry needs information structures which will give construction project participants increased access to consistent project information. This requires an infrastructure which brings together information processing, information storage and retrieval, information transmission and the information content itself. In order to address this wide scope, the Condor project is driven by the needs of users and the market, through the expertise of Kvaerner Construction, JM Bygg, Derbi and CAP GEMINI, and benefits from the combined expertise of the other project partners (University of Salford, CSTB and KTH). The main project's objectives are summarised below:

- Provide opportunities for new processes and new forms of project organisations to be used on construction projects.
- Improve document quality and consistency throughout ongoing projects.
- Increase accessibility of project information to all participants in the process, and allow small to medium sized enterprises to be more closely integrated into construction projects.
- Define the process changes required in order to realise the benefits of integrated document management.
- Identify organisational and cultural issues impacting on the adoption of integrated document management and propose ways of addressing these.
- Integrate document-based ("black-box") and model-based approaches to project information management.
- Provide a migration path and strategy for moving from document-based to model-based approaches.
- Integrate more closely document types and representation (e.g. text and drawing).

- Investigate the distribution of documents using different levels of network capability.
- Demonstrate the integrated use of existing standards for messaging, product modelling, etc.

In order to tackle these objectives effectively, a number of well defined research topics are being addressed, these include:

- Development of a highly generic Condor information management model which handles various issues including object versioning, actor's rights and responsibilities, and change notification.
- Development of techniques to define the semantic links across the various forms of document and model-based information.
- Gaining understanding of the organisational and cultural aspects of introducing the document production and management proposed approach, into small, medium sized and large industries and organisations.

The Condor project objectives are roughly addressed through five complementary topics, from which the structure of the technical work breakdown is derived. These topics comprise: document management, migration strategy to the model-based approach, business process re-engineering with respect to the changes introduced by the proposed approach, specifications and delivery mechanisms, generalisation of the approach to other industries and results dissemination.

3. State of the art of electronic document management in the construction industry

The background to document management can be roughly summarised according to the two following approaches:

- The integrated document management approach (Bjoerk et al. 1993) in which documents are treated as black-boxes, and the aim of computer-support is to enable easy document storage, retrieval (using reference information), versioning and approval. This approach is becoming best practice due to the proliferation of EDM systems.
- The model-based approach (Rezgui 1995) in which the information traditionally contained in drawings and text documents is described and represented through an object model, and is contained in integrated databases. These databases are then used as a basis for the production and authoring of project documents.

The three EDM systems that exist within collaborating companies fall within the integrated document management approach. Dispersed across Europe, these companies (Derbi/OTH, JM Bygg and Kvaerner Construction) specialise in various sectors of the industry, including housing, high grade commercial offices through to the development of industrial projects. Existing EDM systems operate under different regimes, codes of practice, different computer platforms and adhere to various formulate standards. They provide a varying degree of document management services, in terms of both complexity and variety. A brief profile of these is presented below.

OTH (France)

OTH group is a major French engineering firm, who have been working on the crucial problem of electronic document management from the mid-eighties. OTH uses a system called SGT (SystËme de Gestion Technique de donnÈes), which provides various basic

functionality for storing, archiving and exchanging various documents, including drawings and written documents, in a structured manner. This EDM system also offers a number of advanced services, including a function to co-ordinate the approval process of documents; a change request management service; an advanced construction specific financial tool; and a subsystem (GPP) that is dedicated to the production and management of drawings in a multi-actor environment. GPP uses the concept of layer as a basis for structuring CAD document-based information. Each actor has specific rights over the different set of layers that constitute a drawing. Each layer describes a specific building element (beam, wall, door, etc.). Similar work is undergoing within ISO (the layering standard proposal), which, in a sense, falls between the two approaches described above. The purpose of ISO TC10/SC8/WG13 (ISO CAD layers standard) is to establish an agreed common basis for organising construction data in CAD systems (ISO 1995).

JM Bygg (Sweden)
JM Bygg is the fifth largest construction firm in Sweden and one of the larger property management companies in the country. They use a project management system called Eureka!Filebase that enables the input and retrieval of information (regardless of its format), including text and drawing documents. Eureka supports document history, administers the maintenance of file revisions and stores documents according to a unique registration. This is just a sample of services provided by this pure reference retrieval system.

Kvaerner Construction (UK)
Kvaerner Construction is a world-wide engineering and construction service supplier. One of its subsidiaries, Kvaerner Trollope & Colls (KT&C), is a London based construction main contractor who specialises in high quality office and commercial property development, and the installation of high quality interiors. They use a document controller to set up an electronic hub for all parties to manipulate, pass and distribute documentation. The document hub provides a collection of services. For instance, it maintains some form of drawing control that keeps track of drawing information, complemented with various functions, including, approval, receipt acknowledgement, and document distribution. The hub also manages correspondence (which handles incoming and outgoing mail) and an information control service (which handles information requests from the system).

Alongside these EDM systems, the CD-Reef (developed and published by CSTB) is a full text documentary base, on CD-Rom, comprising all technical rules (around 20 000 pages) relevant for building works in France. The documents have been processed according to the SGML standard. The software includes multi-criteria search functions (using both human and automatic indexing of documents), and hypertext navigation functions. References to building technical rules are also accessible through the Minitel (a French dedicated on-line information access service). The use of Minitel (compared to the Internet) is decreasing in France due to its limitations in terms of interactivity and human machine interface.

Despite some minor differences, the EDM systems described above offer similarities across organisational boundaries. An example of this exists in document categorisation, archiving, retrieval, versioning and approval. The services provided by these EDM systems will be used as a basis to define the API that will support inter-working between these legacy applications.

4. Strategy towards the Integration of existing EDM systems within the Condor project

The nature of the construction industry is such that virtual teams are often brought together for projects before being broken apart again on completion. Organisations and individuals participating in a team bring their own unique skills and resources, which may include proprietary applications and data. The software applications used may vary from one construction project to another, depending on the nature and complexity (in terms of project type, size, number of actors involved, etc.) of the project. These applications include software for managing electronic and paper-based documents; financial and project planning tools; CAD applications; and various advanced software used in the area of thermal analysis and main frame structural behaviour simulation. It is not unreasonable to describe most existing construction industry software packages as monolithic legacy applications. A general survey reveals that organizations are reluctant to use proprietary systems developed by other companies, within projects. That is due mainly to their investment in their own system (as described earlier) and also to the impact of the adoption of these software in terms of training and cultural change within their organization, which reveals to be a costly and time-consuming process. Therefore, for the Condor system to be effective, it should be open enough to coexist and inter-operate with construction legacy applications, as with other existing and emerging distributed components, in a seamless way. These legacy applications could then, in turn, take advantage of the generic, and construction specific, Condor advanced functionality, described in section 5.

This approach adheres to the principles of distributed object technology. In fact, each legacy application can emulate a distributed component by means of an object wrapper. The latter will provide an interface to the application's services. Instead of integration being achieved through static models that define the structure of shared information (in the form of files or databases), we advocate that integration should be made through frameworks which define semantic relationships between the interfaces of separate components. There are currently two major emerging standards for distributed objects, Microsoft's Distributed Common Object Management (DCOM) (Orfali et al. 1996) and the Object Management Group's Common Object Request Broker Architecture (CORBA) (OMG, 1996). The CORBA architecture provides these frameworks through business object facilities (also known as vertical common facilities) and distinguishes them from basic services (such as naming, persistence, transactions, etc.) and horizontal common facilities (such as user interfaces and system management). Business object facilities are already under development for several business areas, including computer integrated manufacturing and banking. We argue that the adoption of the distributed-component approach within the Condor project, will enable monolithic construction legacy applications (which embed a great deal of construction organizations' cultural and technical expertise) to inter-work between each other and coexist with emerging software components.

5. The Condor system architecture

This section describes a proposed architecture for the CONDOR system. It does not define the functional specification for the system because that will be determined from requirements emerging from the process modelling activities currently undertaken by the end-users (Kvaerner Construction, Derbi and JM Bygg).

As mentioned in section 4, the emphasis of the approach taken here is one of inter-working between dissimilar systems rather than sharing of common data structures. This is in line with current developments in software technology, which are based on object-oriented client-server approaches. The approach also recognizes the need to allow the vendors of specific document management systems to make their own decisions on internal data structures and local functionality. One might argue that a pure component-based approach would rather tackle finer levels of granularity of information. The focus would then be on the document rather than the EDM system that manages it. Furthermore, the document would become a self-managing component with a set of public interfaces that provide similar services to the existing EDM systems. That is, in fact, supported by the Condor approach. It is part of its strategy to migrate to emerging component-based technology.

The CONDOR system architecture and functionality will be defined in a manner that is independent of any particular object inter-working technology or standards, but may be mapped into the OMG's CORBA and Microsoft's DCOM architecture for demonstration purposes.

5.1. The Overall Architecture

The core of the CONDOR architecture is the CONDOR API. It defines the services to allow on the one hand, inter-working between the project's legacy EDM systems, and on the other, semantic linking between different documents and between documents and other information objects. The precise services that are provided will be largely determined from the results of the analysis being presently conducted by the end-users.

Figure 1 shows the basic architecture of CONDOR. The major components of the

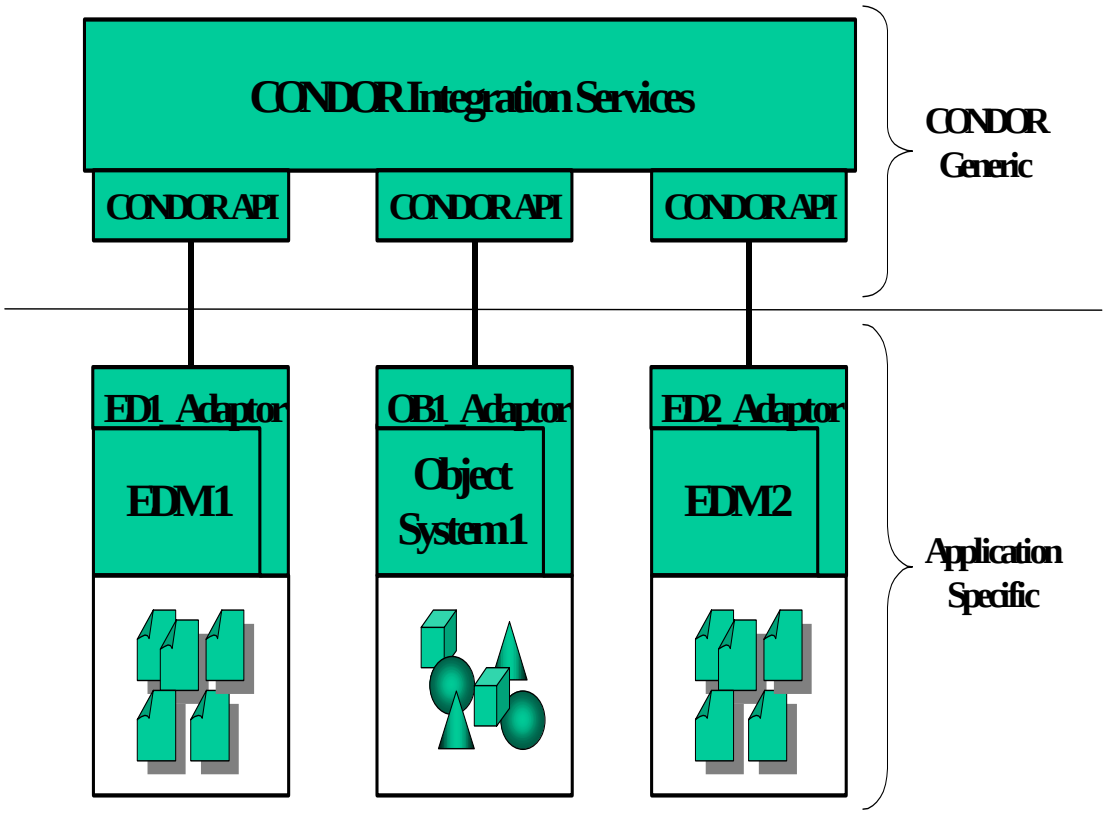

Fig.1. The CONDOR Basic Architecture

architecture are:

- the *CONDOR Integration Services* (implemented as a class library in the demonstrator);
- the *CONDOR API*, which defines the interface to the integration services;
- the *Adaptors*, which provide the mapping between the CONDOR API and each of the document and object management systems to be integrated.

The architecture will be designed to keep the size of the adaptors as small as possible, and this will be facilitated by means of a third set of API services: the CONDOR Mapping Services. The CONDOR Mapping Services will provide interfaces to a number of component objects that will aid in the creation of adaptors, thereby minimizing the code that will be required to implement adaptors.

The approach taken will ensure that generic CONDOR functionality will be implemented only once in the CONDOR system, whilst the functionality that is specific to a particular document or object management system will be implemented separately from the CONDOR system. It is worth mentioning that much of the functionality of the CONDOR API can be provided directly by making use of CORBA horizontal services. A more limited subset of the functionality can be provided from within the Microsoft Distributed COM proprietary standard. It is proposed that a binding of the CONDOR API be provided to define a CORBA (and possibly DCOM) implementation.

5.2. Condor Integration Services

These will be determined primarily from the process modelling carried out by the project end users. Condor will provide services concerned with the sharing of information across partners. The full sets of facilities provided by a document management system do not fall within the scope of these services. The Condor integration services are primarily provided in two areas:

- Semantic linking between different documents and between documents and other information objects.
- Inter-working between different electronic document management (EDM) systems and between EDM and object management systems.

5.2.1. Condor Semantic Linking Services

These services describe the semantic links between documents, between sections of documents, and between documents (or sections of documents) and the instances of an object model describing the construction project. Semantic links will be represented by means of objects. In cases where objects already exist, those objects will be used. Where objects do not already exist, for example in relation to documents and to STEP entities, new objects will need to be created, which will act as wrappers providing an object-oriented interface. Object-oriented versions of some STEP entity types will be created for demonstration purposes, and it is proposed that these objects make use of SDAI (Standard Data Access Interface) to access the data in either STEP physical files or any dedicated database.

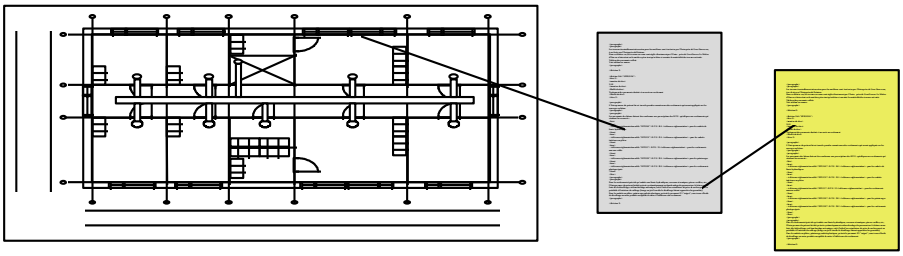

Fig.2. Semantic Linking between documents

5.2.2. Condor Inter-Working Services

Inter-working between applications is achieved by means of requests to the CONDOR API, which are ultimately mapped into the native functionality of the various EDM systems or Object Management systems.

For example, suppose a document (Document 1), stored and managed under EDM 1 needs to be made available to other software systems such as EDM 2. The first step will be for EDM 1 to register the document with the CONDOR system using a suitable API call. This will result in a CONDOR object identifier being created, which is mapped into a local document ID within the EDM1 Adaptor. This adaptor will be responsible for maintaining the mapping between CONDOR specific concepts and EDM1 specific concepts, but will make use of the mapping services, which are also provided through the CONDOR API. The CONDOR system will maintain a limited amount of information about the registered document (or object) for the purposes of identification and searching. EDM2 can make requests against the CONDOR API to obtain lists of documents, retrieve documents, perform searches, etc., as required. Typical services that might be offered to EDM2 in respect of Document 1 might include: "Get Current Version", "Get Date Last Modified", etc. It will also be possible for the CONDOR registered document to be mapped into a local identifier within the EDM2 adaptor in order to make access to CONDOR documents as transparent as possible. Whilst this is primarily a local client issue, it will be necessary for certain guarantees to be made by the CONDOR API to enable CONDOR clients to implement such features with confidence.

6. Conclusion

This paper presented the European Esprit Condor project. The Condor project is specifically concerned with defining the working practices, processes, techniques, tools and technical infrastructure to allow the construction industry to *progress from its current position* towards a large scale, computer integrated approach. All partners in the project are well aware that moving from processes based on the current document-based approach to processes based on a pro-active model-based approach is the key issue in facing the ever-growing complexity of construction projects. They all acknowledge that most of today's commercially available solutions are considered to be unsuitable for the particular requirements of their industry.

The integrated project database will take many years to develop, but one of the first problems to be overcome is the change of culture. The document model-based approach, supported by information technology, can provide a powerful lever for change. It can not however produce the benefits alone. The organisation and processes of construction projects must change in order to deliver the benefits. Therefore, the construction project

lifecycle, from concept development to demolition and recycling, need to be examined and re-engineered. In that respect, the Condor consortium is analysing and modelling the business processes within the project end-users. Managing technically linked change calls for the total integration of the human, organisational and technical elements of the change throughout the project. The Condor project will also provide metrics to evaluate business systems responsiveness towards meeting business objectives, and will analyse the technological and socio-economic impact of the proposed approach.

This project is ongoing and supported by a user interest group, which involves representatives from a variety of non-construction industry companies. It is hoped that the latter will help to ensure that the results of the project are sufficiently generic to be transferred to industries other than construction, and to assist in the wider dissemination of results. It is expected that some of these companies will be interested in exploiting the CONDOR project results within their own organizations

7. Acknowledgements

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