IMPLEMENTATION CONCERNS OF PROCESS MODELLING TOOLS

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ABSTRACT

The paper describes on-going development of a generic construction process model for the implementation of process modelling tools. The tools are aimed to support evolutionary construction process modelling and reengineering. Requirements and desirable features of construction process models are presented.

AIM OF THIS STUDY

Vision

The ultimate target is a capability to dynamically integrate the processes of multiple individual participants in construction projects. It is reasonable to assume that in the near future many companies will have a model of their processes in a form which is to some extent computer interpretable. Such models could be imported to a common project model data base and integrated. The integration basically interconnects the 'external links' of company specific process models as illustrated in fig. 1.

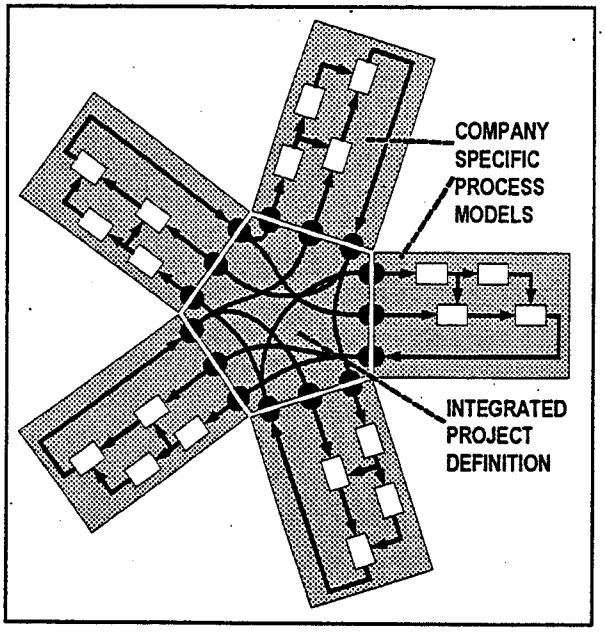

Figure 1. Project integration

Implementation of a process modelling tool

The immediate purpose of this study is to outline the implementation of a prototype process modelling tool within the STAR research program (Hannus 1995) at VTT.

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Formalisation of existing industry standard 'models'

Using the tool a number of existing and industrially applied construction process 'models' will be formalised and integrated. This is expected to support both short term industrial exploitation and continued research on process improvements and reengineering in longer term.

The tool should provide a step forward from today's less formal 'modelling methods'. We plan to use the tool to formalise, store and integrate several national industry standard construction process related models. The primary categories of such models are listed below.

- *Task descriptions*: definitions of the tasks of various design disciplines (SKOL95). These textual descriptions are usually referred to in design contracts.
- *Reference quality systems* for various actors in construction industry. These definitions were compiled collaboratively by the major professional organisations of the Finnish AEC industry in a recent large national research program on quality management in construction. The above task descriptions were strongly influenced by this research.
- *IDEF0 models* from a number of national R&D projects e.g. (Karhu 1995).

Examples ot further common ways of structuring construction projects by practitioners are e.g.

- Division of project life cycle into *stages* (phases).
- Standardised building *classification systems*. In Finland the national system is (TALO90). Classification is oriented towards dividing construction projects into procurable units from a cost point of view.

In general, the above 'models' are not fully consistent, formalised nor integrated. Many models have been made in textual format only. Therefore especially the interrelationships of process items are often poorly defined. Obviously, the theoretical foundation of current models is vague. On the other hand, these models are familiar to and enjoy wide commitment from the industry. We expect to be able to add value to this industry-wide process knowledge by providing a more logical structure.

Naturally, there are also a number of information oriented models from international R&D which need to be considered. A recent overview of several relevant models is given by (Froese 1995).

Process improvements and reengineering

Finally, we expect that a generic construction process model and software implementations of it will provide us tools for systematic process analysis, reengineering and model dissemination in longer term.

BASELINE

As discussed by another paper (Koskela 1995) in this workshop, the fundamental concepts of construction process are not yet established within the international R&D community. We should explore various approaches and need flexible process modelling tools.

In a related field, product modelling, a more solid theoretical basis has already been established by many research groups around the world. We have focused on a generic metamodel of product data. The fundamental idea of this OOCAD model (Serén 1993), and its predecessor the RATAS model (Enkovaara 1988) is that building product data can be represented in a uniform, relatively simple structure; see fig. 4. Concurrently with this study we are also developing some tools e.g. browsers for product modelling.

With this background it seems rational to adopt the available product modelling tools to process modelling. Other obvious boundary conditions are compatibility with the few de-facto standard (construction) process modelling approaches such as IDEF0, CPM (Critical Path Method) and the implicit models of popular project planning tools.

REQUIREMENTS

Generic requirements to construction process modelling methods are presented by (Koskela 1995) in this workshop. This paper presents implementation aspects of these requirements.

Decision support

Models should provide relevant information about processes for decision making. Typical questions which a model is expected to answer are(Laurikka 1995) e.g.:

- *Why* is it done?
- *What* are the objectives, incentives & constraints?
- *Why* did something happen?
- *What* is done?
- *What* is the result?
- *What* is the performance of the process?
- *How much* does it cost?
- *How* is it done?
- *Who* does it?
- *Who* is responsible?
- *Where* is it done?
- *When* is it done?

Existing modelling methodologies provide answers to some these questions only. For instance, IDEF0 is focused on some aspects of *why* (control), *what* (input–activity–output), *who* (mechanism) & *how* (activity decomposition, control).

Construction peculiarities

The process modelling methodology should cope with construction peculiarities.

One-of-a-kindness of construction projects makes it specially difficult to model reusable knowledge about processes. The sequences of activities, roles of actors, time schedules, etc. are all subject to project specific alterations.

Temporary organisations - There is a special need to define roles of individual actors and coordinate boundaries of responsibilities between them.

Site work - The location of building parts, mobile workers, machines, materials and other resources is a key issue.

Multiple views - There is typically no single 'owner' of a construction project. Different actors have specific views of the whole process.

Several kinds of subprocesses need to be considered e.g.:

- design / production,
- primary value adding / supporting processes,
- information / material processes.

MODELLING FRAMEWORK

Process models can be divided into layers e.g. as shown in fig. 2. The triangular form indicates that a higher level generic model can be specialised into several lower level more specific models. The figure also shows our approach to define these models.

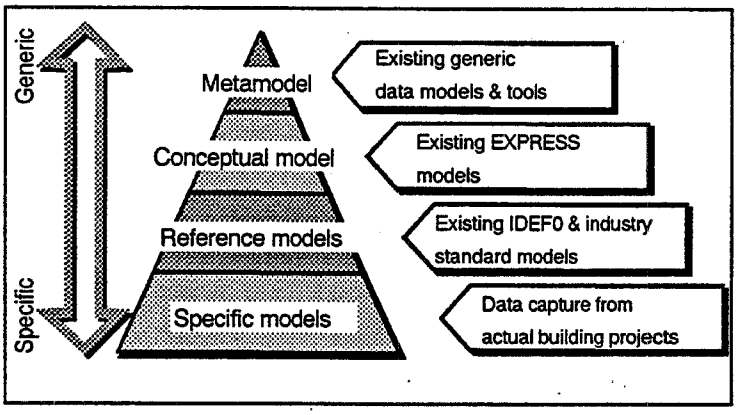

Figure 2. Layered process modelling approach

Metamodel

This layer defines the 'modelling language' for conceptual models including generic modelling constructs such as objects and classes, inheritance, decomposition and other relationship types, attributes etc.

We are now trying to define a metamodel of construction process which would allow us to implement generic process modelling tools. The motivation of metamodelling is easy incorporation of new concepts into (process) models without necessity to modify modelling tools. Instead of implementing the tool based on a conceptual model, the conceptual model itself will be regarded as data. It is expected that the metamodels for product modelling e.g. (Serén 1993) can be adopted, with some enhancements, for this purpose.

Conceptual model

This layer defines the application i.e. construction specific concepts e.g. activity, actor etc. These concepts are instanciated on the levels of reference and specific models.

A lot of recent research, see e.g. (Froese 1995), is focused on the definition of conceptual models of construction process (information). Conceptual models are typically represented in EXPRESS language.

Reference models

We call description of a typical although not actual process a reference model. A reference model can define several aspects of construction process only as suggestive examples which are ultimately definable at the specific layer only e.g. sequence of activities, time, roles of individual actors etc. Knowledge of construction process can be reused primarily via reference models.

Many process models are on the 'reference layer' and are often represented with IDEF0 methodology, which indeed does not allow inclusion of specific aspects such as sequences or occurrence times of activities.

Specific models

By specific model we here mean information about an actual process e.g. a specific construction project.

Project planning and the perception of construction process by practitioners is mostly on the specific layer. Models at this layer are obviously limited to unique process occurrences. While only specific construction processes may be observed in the real world, models on higher abstraction levels are needed for knowledge development and sharing. For process reengineering studies and demonstrations we are now capturing detailed data of an ongoing construction project.

GENERIC MODELLING CONSTRUCTS

Decomposition, modularity and reuse

Decomposition serves two main purposes in modelling: ease of modelling and reuse. In IDEF0, for instance, activities may be decomposed into more detailed level.

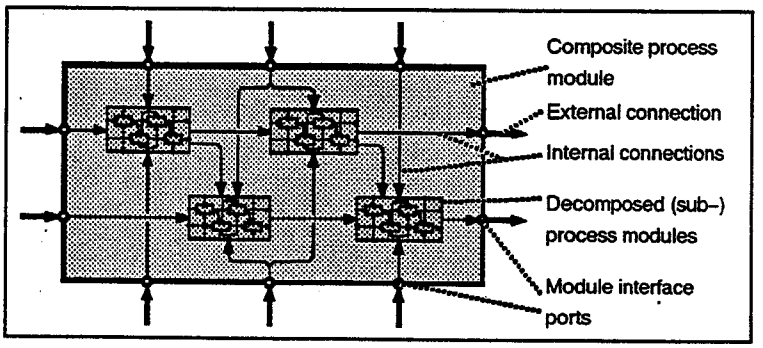

Figure 3. Modularity of process models

The modelling methodology should support definition of subprocess modules with clear interfaces. For instance, reusability of IDEF0 models is limited by poor modularity caused by complex interconnections between subprocesses. Software tools can implement reuse by reference to library modules instead of duplication of data.

To support common perception of decomposition we couple it with existence-dependency: if the composite entity is deleted then its subentities are deleted as well.

Classification / categorisation / grouping

Classification is another popular 'modelling' construct which is widely used by the building industry. It is also a traditional target for standardisation. Classification is applied to categorise items according to some common aspect such as function of building parts, production method or source of procurement. However, the theoretical basis of classification is usually undefined. In the OOCAD model (Serén 1993) we formalised classification into a generic grouping construct: entities may belong to any number of groups; see fig. 4.

Multiple views – integrated models or view conversions?

The fundamentals and importance of multiple views are not yet properly understood by model developers. The trend is to standardise data structures such as integrated product-process data models and building classification tables. Basically a single view is being enforced rather than supporting multiple views. It also seems that the current modelling focus on relationships between project entities neglets the problems of multiple views.

In practice project information is created by a partner based on his/her view while considering the needs of potential users. When information is handed over to other partners they extract selected portions of it and/or reorganise it into a new structure of their view. The reorganisation is based on available 'hooks' in the received information structure, miscellaneous criteria, knowledge and preferences. The rules of view conversions are not available as formalised knowledge.

Our conclusion so far is to support view conversions as follows:

- Decomposition (coupled with existence-dependency) is the primary data structure in a single view but is usually not shareable between several views.
- Grouping is the primary mechanism to support reorganisation of data into other and incompletely known views. Standardised groupings allow (semi)automatic translation of a view specific decomposition to another.
- Attributes of project entities are shareable and also provide additional important 'hooks' for view conversions. Attribute definitions should be a primary target for modelling (and standardisation).
- Many relationships between project entities are not shareable between views - new relationships are derived from other data as part of view conversions.

Generalisation / specialisation

Class inheritance in object oriented modelling provides a method to define more generic or specific data types by means of other types. The supertype/subtype

constructs in EXPRESS language provide a similar (more complex) capability. These are, however, primarily definition methods and do not necessarily influence a (non-object-oriented) implementation.

Generic, specific and occurrence definitions

In product modelling (Gielingh 1988) introduced the concepts: *generic* product definition (~ product properties with unassigned values), *specific* product definition (~ product with assigned property values, no location), *occurrence* definition (~ location of a specific product).

We employed somewhat similar concepts called *object* class, *type* object, *occurrence* object in the OOCAD model (Serén 1993). Any type object may be composed of occurrences of (other) types which have a relative position with respect to the composite type object. An occurrence may also have other attributes like (occurrence) quantity etc.

It seems quite obvious now to enhance this model to process modelling by simply adding the attribute (relative) time to an occurrence of a generic project entity.

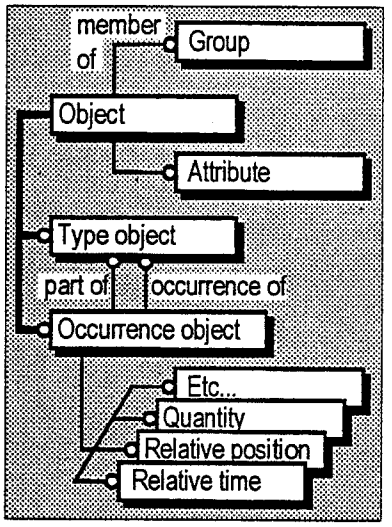

Figure 4. Simplified OOCAD model

Concretisation

Also introduced by (Gielingh 1988) are the (product) life cycle definitions: as-required, as-designed, as-planned etc. The relevance of these concepts for the implementation of software tools is still unclear to us: the latter definitions are derived from previous ones and are usually not stored in the same database.

Object orientation

Object orientation in some form is widely adopted in product modelling and seems suitable for process modelling as well. Especially, the rules how a process module behaves under different boundary conditions could be encapsulated in an object oriented model. In this way modelling the endless variation possibilities in project execution could be simplified.

Compatibility issues

In order to support evolutionary development, compatibility with currently used approaches is desirable; examples: IDEF0 modelling method, Critical Path Method (CPM), implicit models of popular project planning tools, standardised building classification tables, etc.

BASIC CONCEPTS

Here we present on overview of the proposed main conceptual entities for construction process modelling. In fig. 5 we have arranged them into four groups corresponding to the main views on a construction project.

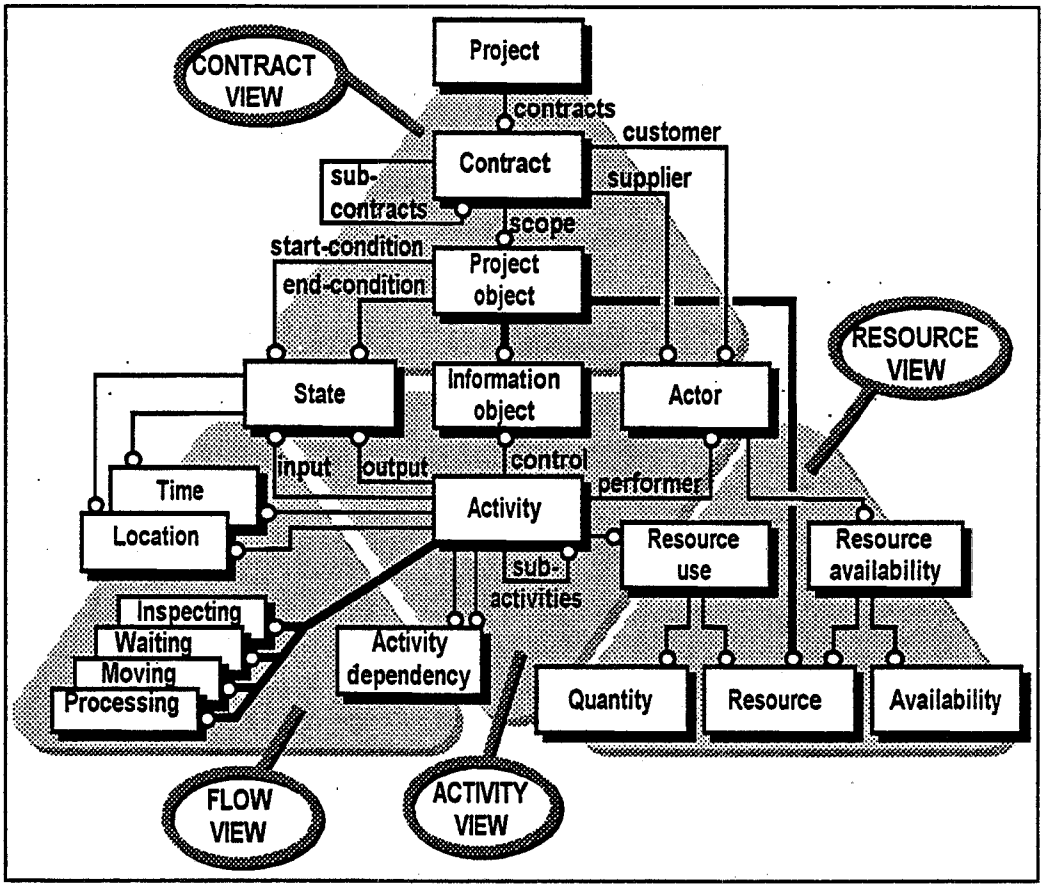

Figure 5. Proposed key conceptual entities for construction process modelling

Contract view describes customer-supplier relationships and main responsibilities of participating actors. The scope of a contract can be defined in terms of start- and end-conditions of project-objects (a generic supertype of many things). A project consists of contracts.

Activity view describes the necessary activities to fulfil project contracts. The main linking entity is the state of project-object. Activities are controlled / constrained by information-objects, a subtype of project-object (e.g. design or planning information). The entity activity has been designed trying to establish near compatibility with the popular IDEF0 method.

Resource view supports cost planning and allocation of resources: actors posses resources which can be available in specified quantities for use by activities.

Flow view supports scheduling, logistics, work planning, and process performance evaluation by provision of activity-dependencies, time and location.

CONCLUSIONS

The presented process modelling concepts are still under development. Issues for further refinements are: links between the various modelling layers, feedback and learning mechanisms; built-in control mechanisms: incentives, performance metrics & indicators; relationship of product model and process model; multiple views etc.

The main concern, however, is avoiding laborious implementation of modelling tools due to a complex conceptual process model. We aim at simple solutions by developing a generic process metamodel based on the ideas presented in this paper.

ACKNOWLEDGEMENT

The development described in this paper is part of the on-going research program 'Systems Engineering in Construction' (STAR) at VTT. STAR is developing models and tools for the improvement and re-engineering of construction process. The program is now (Aug. 1995) in the midterm of its 3 year duration. STAR consists of four development projects focusing on: (1) construction process models, (2) customer oriented design methods, (3) methods for the improvement of constructability, design for construction, (4) integrated information management.

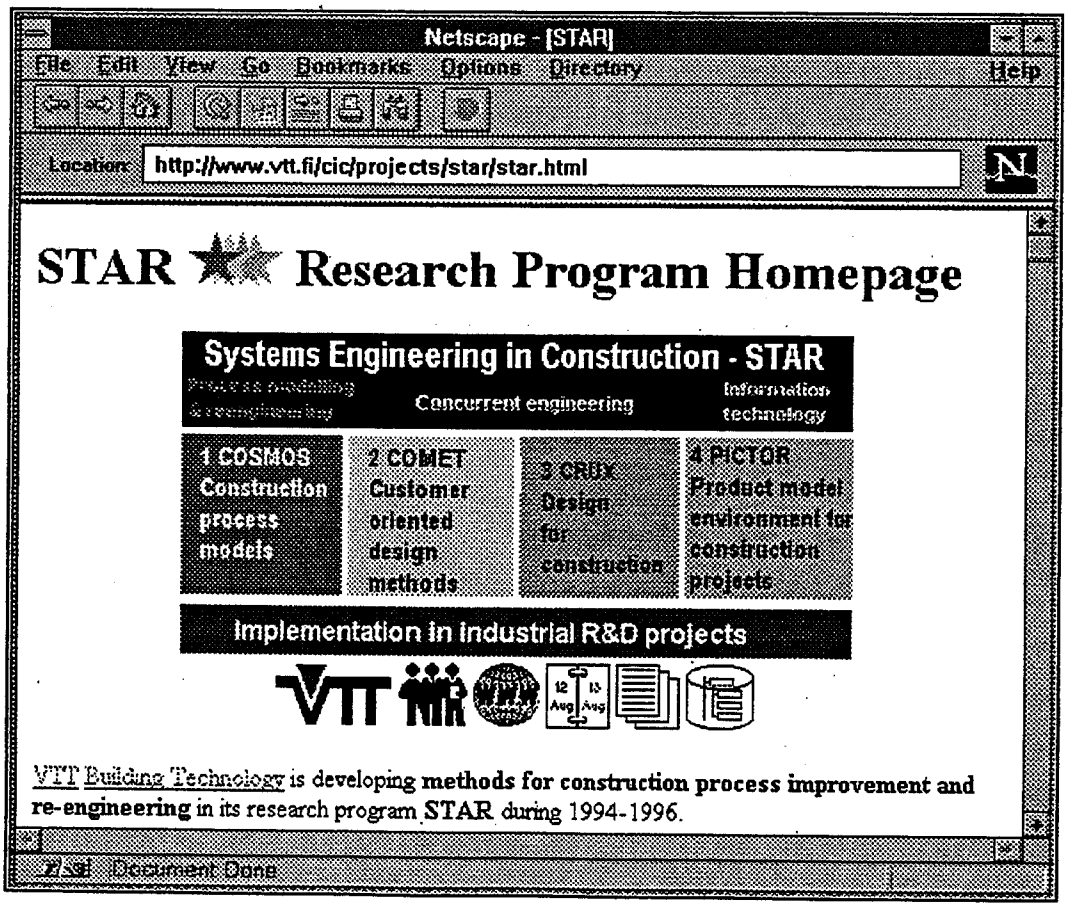

Figure 6. STAR research program is extensively described in the World Wide Web

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