CONIM - a prototype for integration between design and technical analysis in AEC (Architecture, Engineering and Construction)

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Abstract

The objective of the CONstruction Information Model is to integrate the architectural description of the construction with the technical models used in the engineering analysis. The principle of the solution is to integrate the main components from different aspect models into a common kernel. CONIM is based on a conceptual model, which contains a small product model and a system for assembling aspect models. This makes it possible to join the main components in a convenient logical structure, and allows references to the applications and data in the aspect models.

1 Introduction

During the last years information technology has been used increasingly in the Danish construction industry. For architectural and engineering purposes the applications have mainly been either technical oriented applications, e.g. as programs for frame-analysis, or drawing based CAD-system e.g. AutoCAD. CONIM is an attempt to form a basis for the integration between technical applications and CAD-systems.

The initial goal is a more integrated use of computer applications through neutral databases containing common information. In future developments we can model further areas of information, and include design rules and consistency check in the neutral databases.

2 Status in Denmark

In the Danish construction industry information technology is used either to solve complicated problems or to increase productivity for specific well defined tasks e.g. as standard drawings. Data communication either internally in the firm or externally is limited to CAD-drawings and documents, and do not involve direct access to databases. The reason for this is:

- The nature of the Danish construction sector implies many small and independent firms.
- Lack of general solutions.

As the firms participate in many different collaborations it is difficult to allocate sufficient resources to solve the integration problems. The investment in hard- and software has resulted in many different solutions, and this often makes communication between the many small firms difficult. A more rational exploitation of the information technology will involve the building sector as a whole, and it would be beneficial to agree on a future architecture of the informationsystems. A commonly accepted standard will enable the data exchange between the many different participants.

3 Methods of modelling

3.1 Tools for modelling

We have used IDEF for conceptual modelling of CONIM's functions and informations, see [1]. IDEF has been chosen due to the following reasons:

- Used in international standardization work e.g. STEP.
- A relative high semantic content.
- Suitable for an implementation in a relational database system.

The IDEF-tools do not give the opportunity to model inheritance, methods and messages in opposition to more modern object-oriented modellingsystems, e.g Object Oriented Analysis (OOA) by Yourdon & Coad [2]. IDEF is developed in order to model the reality as entities connected with semantic dataflows. In this context it is important to distinguish between the real objects and the objects in the modelling system. CONIM's point of origin is in the objects of the reality, and e.g. not in geometric entities and in this sense CONIM can be regarded as object-oriented. If CONIM was going to be implemented in an object-oriented database structure, it would have been necessary to model directly in an object-oriented systemplanning tool.

3.2 Aspect models

In the development of CONIM we have realized that, whether we use an object-oriented or a traditional relational database, it is not rational to create a total model of the project which contains all information. From a modelling point of view the principle of aspect models is a fair compromise between one total model and a number of independent informationsmodels for each application. Therefore, CONIM is based on a small common kernel through which the different aspect models communicate.

In opposition to former product models CONIM has primarily focused on the technical applications need for information, and to a lesser degree on visualizing and a "bill of materials" structure. The different aspect models should be able to support the design phase, and not only serve as a final documentation for the project.

A very important feature of aspect models is the ability to use different representations of the physical objects depending on the specific task. Applications, and to a certain degree product models, have often not been offering sufficient flexibility in the choice of representation, see [3].

3.3 Datamanagement

A very important issue of the aspect model principle is to secure that the different aspect models always have access to an updated datastructure. The objective is to automize this consistency procedure as far as possible, and we rely on the computers ability to control large amounts of information, and to search in these information effectively. In the development of CONIM we therefore have created a model for a datamanagement system, which is independent of datatypes used in a specific discipline. In the datamanagement system we find it useful to distinguish between:

- Integration oriented information management (Physical), which is datamanagement between different databases.
- Application oriented information management (Logical), which represents control of where data are used, mutual relations and storing of information.

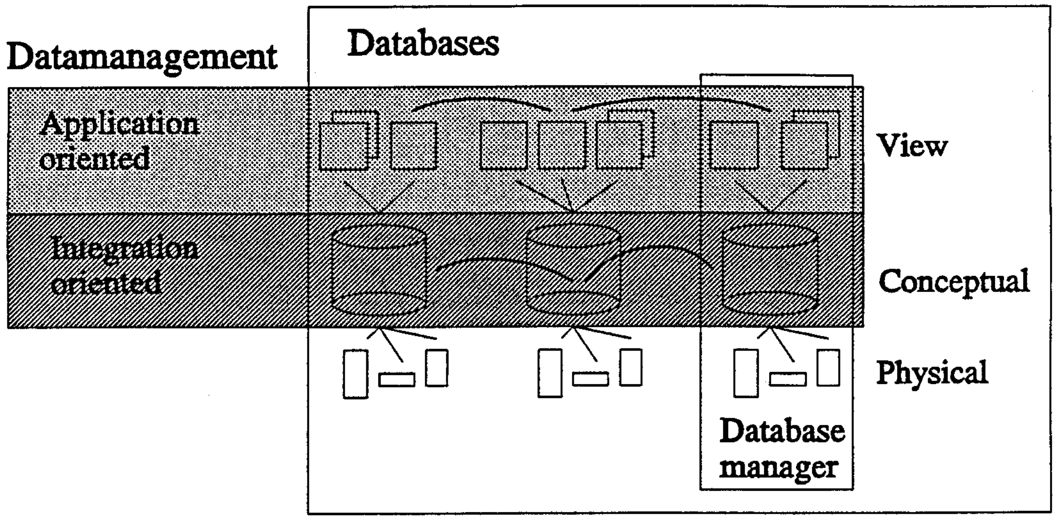

Fig. 1 Different levels of Datamanagement systems.

CONIM uses an application oriented datamanagement system, and the integrated oriented datamanagement is done by the different database system through standard procedures, see fig. 1.

By means of an independent datamanagement system the modelling process to a higher degree can be concentrated on the discipline oriented problems. As the fundamental application oriented problems are solved generally, the expert in the specific fields can contribute more directly to the solution, and the final model will hopefully both be better and demand fewer resources.

4 International Standards

In the field of standardization we observe a continuous evolution which, on a long term basis, can solve some of the integration problems in the construction sector. The ISO classification project and STEP's product models seem to be the most promising standards for a conceptual modelling of the technical applications. For future developments it is important that the technical oriented application models are coordinated with the standards for financial transactions, e.g. Electronic Data Interchange For Administration, Commerce and Transport (EDIFACT) and methods for project management.

4.1 STEP

CONIM's geometry- and materialmodels are elaborated on the basis of the preliminary results of the STEP-standard, see [4]. CONIM's material model only contains a fraction of STEP's, as it is very comprehensive, and has a deep hierarchical structure. The future ISO STEP-standard will probably contain a large number of technical attributes, which can be used by the different aspect models.

STEP's long period of implementation has implied, that product models developed today have to be able to function without STEP. This may very well result in a number of different structures and exchange formats similar to STEP, but not identical, and the different structures will probably not be compatible to each other. A preliminary edition of the STEP-standard with a more pragmatic aim would therefore have a great influence on today's product modelling and data exchange.

4.2 Classification

Product models in the construction sector are primarily used in order to use modern information technology effectively. The product models generate a need for subdivision of components into different classes, and describe the different classes through attributes. This subject has been the main topic for construction classification through the last 40 years, and therefore, it is from a product model point of view, interesting to see how the construction classification deals with these problems.

ISO's preliminary report "Classification of the construction process", see [5], from september 1991, identifies the future demands for classification, and also gives some proposals for solutions. The objects of the construction process are divided into 7 groups: Buildings/facilities, Spaces, Elements, Work sections, Products, Plants and Attributes. The main objects are described by attributes which are controlled through datamanagement.

In Europe product classification will be based on the European Product Information Co-operation (EPIC) classification work, see [6]. In EPIC, products are classified according to 3 criteria, which describes shape, primary function and material. ISO, see [5], expects that EPIC's product classification on long term will become an ISO standard.

A classification, according to the structural characteristics, can be found in CIB's master list, see [7]. The list only contains the general concepts, which can help to create a logical structure of the information. It is expected, that a coming ISO grouping of structural attributes will be based on a revised CIB master list.

4.3 Product models and standards

In general there is not yet a fully understanding of the relations between product models, classification and STEP. Some product models as e.g. the swedish "Neutral building product model", see [8], are directly based on a classification system, while others as e.g. GARM, see [9], uses classification to add keys to components and attributes.

In ISO's classification project the future expectations to computers are described, but not how classification and product modelling should be unified. The objectives of classification are, according to ISO's own report, to secure a future common language for the construction area, and this is similar for the STEP standardization work.

The relations between STEP and present/future classification systems are to our knowledge not clearly defined yet. STEP's definition of technical attributes has a level of detailing, which the classification systems do not achieve, but groups of attributes will have a close relationship with CIB's master list. Similar conditions will be true for STEP's collections of components. It would be very unfortunate for the future, if the different definitions would not be able to coexist within the common framework of product models and classification.

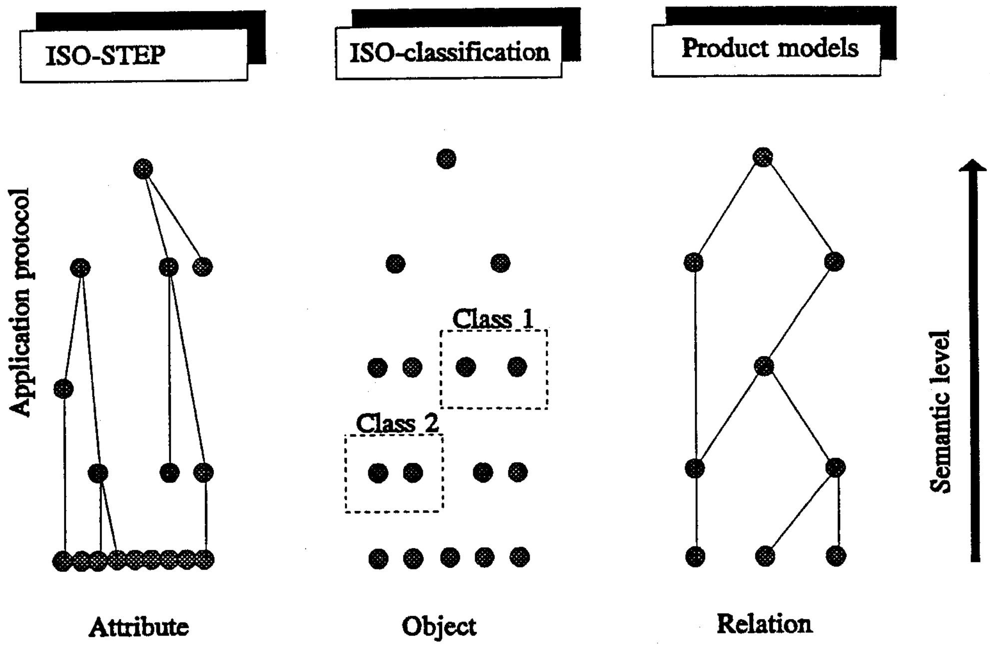

Fig. 2 Relation between classification, STEP and productmodelling.

In fig. 2 we show a proposal for a general understanding of the relation between product models and standards. STEP primarily defines the attributes of the model, the classificationsystems make proposals for classes, and the product models creates relations between attributes and entities/classes.

In the development of product models it can be appropriate to use the groups of a classificationsystem as a starting point, but on the other hand a product model should never depend on a specific classification.

5 Prerequisites for AEC

5.1 Common structure of information

It is necessary to define a common principle for the decomposition of the construction into smaller units in order to be able to integrate information from different disciplines.

In CONIM a construction element is chosen to be the smallest logical unit, and for a building it could e.g be a roof, a wall or a sink. A construction element contains all the information/demands that is relevant including both "real" data e.g. geometry and logical data, e.g. relations to other elements. Data for a construction element evolve during the construction process starting with the architects initial sketches to the engineers calculations and the final drawings. Data for a construction element can be regarded as composed of two. The first, is denoted construction part, and describes the physical properties of the element, which e.g. enable the contractor to build the structure. The second contain all the logical information including demands to the structure. The concept of construction element and construction part can be used to make a clear distinction between the demands and a specific solution. Thereby, we get a opportunity to evaluate alternatives in a more easy way, and this could e.g. be useful, if the contractor offers another and cheaper solution.

The construction elements are the major part of CONIM's kernel, and this allows the different participants to extract textual or geometric information from a common database. Analysis models and technical descriptions are only stored in the different aspect models, as they have no common interest, and furthermore would complicate the modelling.

5.2 Design rules

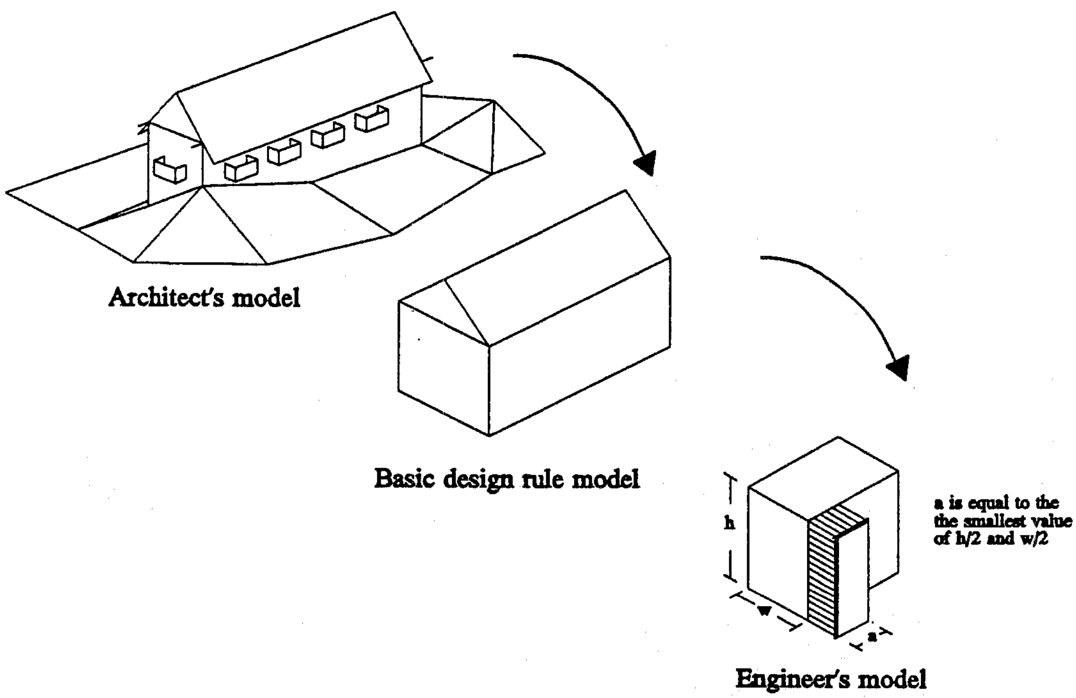

Fig. 3 A simple design rule but a complex solution.

We have not included design rules in CONIM, because it would add to the models complexity, and the practical value of design rules are not known. Restrictive design rules can reduce the freedom in the creative design process, and thereby reduce the effectivity. For practical applications it is important that design rules are flexible, and do not make the design work troublesome or result in long responstimes due to processing of large datastructures and complicated calculations. Furthermore, design rules could give conflicts between different aspect models, if they were mutual dependent. In CONIM, instead of design rules, we have concentrated on an effective datamanagement tool, which continuously can inform the users of changes in the common kernel.

It is not possible to maintain full control over all the data, when the model is composed of a number of aspect models. Therefore, it is difficult to ensure that correct information are transmitted to a design rule check. As an example, we can imagine an architects geometry model of a building, which we want to perform an analysis of wind on the structure, see fig. 3. The engineer makes a simplified model of the building, and uses a building code to give the actual wind load, which e.g. depend on the geometry of the building in a complicated non-algorithmic way. The simplification of the model and the evaluation of wind-load are procedures, which are very hard to automize, or even to describe in a rational way, and therefore it is difficult to imagine an automatic design rule check for just a little more complicated design rule.

5.3 Technical applications

We have tried to develop CONIM's structural analysis part on realistic expectations to future technical applications. We have been dealing with a mixture of Finite Element Based Model (FEM) and more simple beammodels. It is not appropriate to allow only one general method such as FEM, as it in many cases would make the analysis unnecessarily complicated. The number of manual calculations will probably decline drastically in the future, but it should still be possible to store the results in the projectdatabase. Furthermore, it should be possible to use the datamanagement system to register changes in the projectmaterial, and thereby secure that manual calculations are updated. In a system development it is important to have a continuous transition from a semi-manual system to a fully computerized system, as we otherwise would have hard to implement the approach in practice.

The need for integration of different analysis programs is illustrated by an example in fig. 4. The example deals with a building with two floors, where we want to dimension the different elements. The main structure is derived from the architects geometry model, and based on that, a structural analysis is performed. The results from the structural analysis are the basis for the design of the individual components. The geometry of the components are partly controlled by the main structures geometry, and the components depend on each other. The connections between the components depend geometrically on the adjacent components and the strength is governed by the structural analysis. Today, it is often only possible to register relations between components in a single programsystem, and therefore, it is very difficult to secure that changes in design are consistently updated in all the design data. The demand for future integrated designsystems must be, that central information are stored in a database, which can be accessed from all programs.

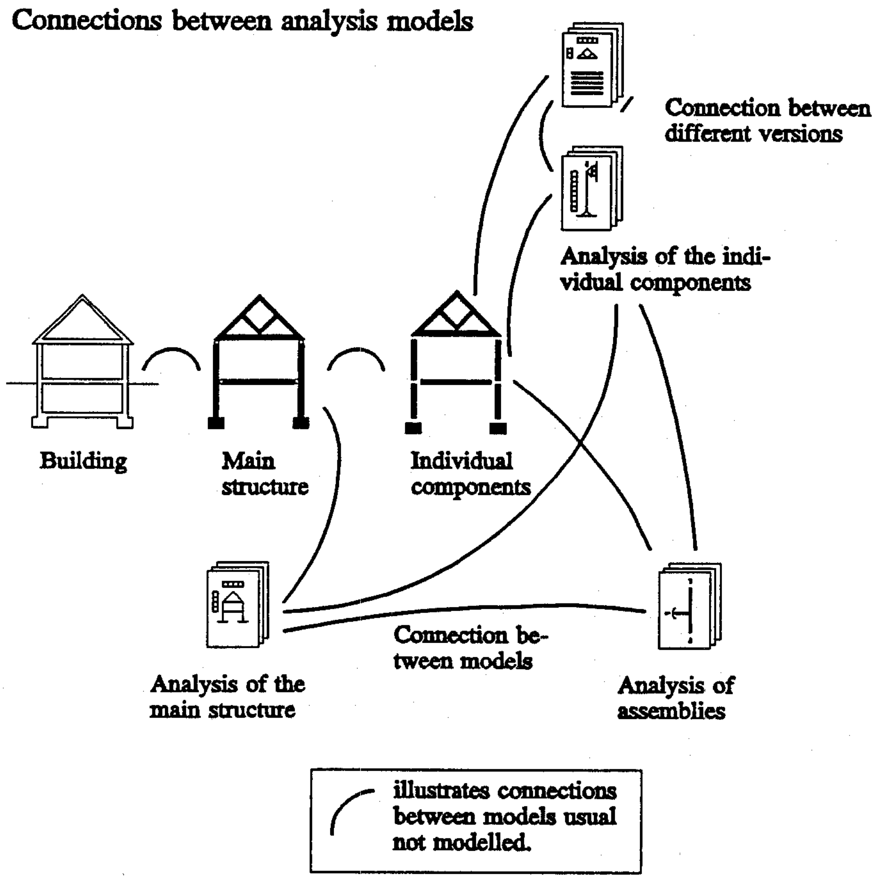

Fig. 4 Connections between analysis models.

6 CONIM

6.1 Objective of CONIM

CONIM can be viewed as a passive system, and it will not generate new data. CONIM's main objective is to assist the users in building a model of the construction with a small common kernel supplemented by a number of aspect models. All the different models can use the same data, but the architecture of the model do not secure consistency at every stage in the design process.

Experience from Denmark shows that introduction of CAD-systems demand an education of the users and a gradual introduction of more complex systems. Therefore, it is difficult during a short period of time to introduce systems with a very high degree of abstraction. CONIM's structure do allow a gradual implementation and to take more and more aspect models into account.

6.2 Product model

The product model is based on construction elements, e.g. rooms and walls, and contains basic information about product structures, location in the building etc. The product model allows several levels of information to be stored, as an example, it is possible to make references to both drawings/geometric models and descriptions of the geometric entities in a CAD dependent or independent format. CONIM is today developed to handle the most common geometric models and structural elements. Great emphasis has been put on the use of different representations and to join different construction elements into groups.

The product model is developed in a way, that it can contain several geometric representations of the same element in order to satisfy demands from different tasks. It is possible to use both 2D and 3D drawings/models for geometry models and to create references to manually produced drawings. Even in the future, we must expect manually prepared drawings, e.g. in connection with sketches or with solutions of details on the site.

The technical oriented aspect models contain a number of different analysis models, which can be coupled to specific construction elements in the central kernel. Due to the technical analysis we have included the possibility, that the product model contains projectspecific material values and models. Through the coupling of analysis models to the central kernel it is possible from the technical aspect models directly to detect changes in the assumptions for the analysis.

6.3 Prototype

In addition to the kernel, we have implemented models for static analysis, which is a typical engineering field and an important part of almost all construction projects. The architects descriptions of the geometry and material are stored in the common kernel, and the technical aspects models can access these data and add extra data. The different construction elements can be related to each other, and they can be part of several technical systems.

After a test of the principles in the model for static analysis, we will revise the model and try to test it into other technical areas. One obstacle in testing the model, in connection with other programs, is problems in reading directly in the database. It is therefore necessary to write modules which translate from the database to the specific program.

7 Conclusion

An effective use of information technology in the construction sector demands integration of information from different areas. CONIM is an attempt to establish a passive integration tool, which primary objective is to secure the user has access to correct and updated information. The datamanagement system is a key point in establishing an integrated construction design system.

Constructions should be modelled as aspect models due to the very complex information structure, and due to the fact, that the users individual tasks do not demand access to all information at the same time. CONIM's concept therefore consist of a small common kernel, and the technical applications are modelled individually through aspect models. The concept has resulted in a model, which compared with practice, gives a better picture of the relations between construction elements and technical models, and the functional demands to the elements are separated clearly. The proposed model gives a number of advantages which should give the engineer a higher efficiency and the construction a better quality.

8 References

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