Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 68 (1993)

Artikel: Reconstructing conceptual models of structure

Autor: Gelder, J.T. De / Gorp, L.F.M. Van / Lucardie, G.L.

DOI: https://doi.org/10.5169/seals-51843

Reconstructing Conceptual Models of Structure

Reconstruction des modèles de conception des structures

Zur Rekonstruktion konzeptioneller Modelle aus Bauwerken

J.T. DE GELDER
TNO
Delft, The Netherlands

L.F.M. VAN GORP
TNO
Delft, The Netherlands

G.L. LUCARDIE
TNO
Delft, The Netherlands

SUMMARY

Until now, conceptualization methods applied in the modelling of structures are based on the assumption that, in essence, all attributes for creating a concept are provided initially. Furthermore, it is assumed that the classifications of these attributes are a priori fixed and possess an unconditional status. Recent advances in Artificial Intelligence are stating that relevant descriptive attributes are not necessarily given a priori but should be acquired by reasoning about the goals of classification. A goal-oriented approach initiates a process wherein conditional attributes and dynamic classifications are reconstructed. This paper shows that a conceptual model of a steel structure should take into account the goals of different parties involved in the building and construction industry.

RÉSUMÉ

Jusqu'à nos jours, les méthodes de conception appliquées dans la modélisation des structures étaient fondées sur l'hypothèse que tous les attributs d'élaboration d'un concept étaient déjà fournis au départ et, en outre, que leur classification existait inconditionnellement. Les récents progrès de l'intelligence artificielle montrent toutefois que les attributs descriptifs remarquables ne sont pas donnés à priori, mais que le raisonnement devrait permettre de les déduire des objectifs de classification. Une approche à orientation objective donne naissance à un processus de reconstruction d'attributs conditionnels et de classification dynamique. En s'appuyant sur un exemple de structure métallique, l'article montre comment le modèle associe les objectifs différentiels des intervenants au projet et à la construction.

ZUSAMMENFASSUNG

Ueblicherweise wird bei der Abstraktion von Bauten zum dahinterstehenden Entwurfskonzept unterstellt, dass alle Attribute des Konzepts von Anfang an gegeben sind und ihre Klassifikation bedingungslos feststeht. Jüngere Fortschritte der künstlichen Intelligenz zeigen jedoch, dass dies nicht der Fall sein muss, sondern relevante beschreibende Attribute erst aus dem Nachdenken über die Klassifizierungsziele abgeleitet werden sollten. Durch den zielorientierten Ansatz entsteht ein Prozess zur Rekonstruktion bedingter Attribute und einer dynamischen Klassifikation. Am Beispiel eines Stahlbaus wird gezeigt, wie das konzeptionelle Modell die unterschiedlichen Zielsetzungen der am Entwurf und Bau Beteiligten einbezieht.

1. INTRODUCTION

Conceptual modelling is an essential activity in the development of knowledge based systems. In current practice, conceptual modelling of structures often leads to the development of generic models. Generic models, however, have the problem, that they are not really functional for a specific application. Generic models are the consequence of following a conceptual modelling theory, which we call the theory of extensional classifications. In this paper the limitations of this theory are described and an alternative theory, known as the theory of functional classifications, is proposed. In chapter 2 these two theories on conceptual modelling are described. By giving an example of the modelling of steel structures in chapter 3, it is shown that the theory of functional classifications, is preferable to the theory of extensional classifications. Finally, chapter 4 discusses some advantages of using the theory of functional classifications in conceptual modelling.

2. THEORY

2.1 Knowledge level

In his presidential address for the American Association of Artificial Intelligence (AAAI), Newell introduced a new computer system level: the knowledge level [10]. At this conceptual level knowledge about an application-area is defined [1,2,10]. Modelling at the knowledge level permits the development of implementation independent conceptual models, which better reflect the reality of an application area [2,8,15].

2.2 Conceptual modelling

Conceptual models consist of concepts. The meaning triangle of Ogden en Richards, cited in [14] explains what a concept is (figure 1). A concept refers to a physical object and is symbolized by a symbol. The fact that we symbolize the object which we use to take a seat as "a chair", is because we have an idea of what a chair is. This idea is called a concept.

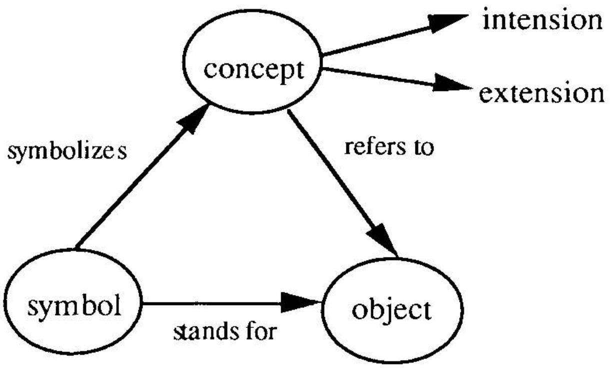


Fig. 1 Meaning triangle

Conceptualization involves reconstruction of the meaning of concepts. Each concept has an intension, also called an object-type, and an extension. The intension of a concept is a set of requirements, which should be met by an object in order to belong to the class covered by the concept. The intension of the concept "chair", for instance, could be the existence of a seat, a back and at least one leg. The extension of a concept is a set of objects, satisfying the intension. So, in the example, all objects having a seat, a back and at least one leg are classified as chairs.

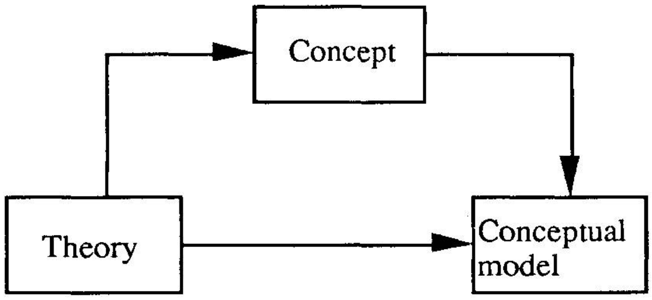


Fig. 2 Conceptual modelling using a theory

For reconstructing the meaning of concepts a theory about concepts is required, that prescribes how the meaning of concepts should be reconstructed (figure 2). There are several theories dealing with the reconstruction of concepts. Two of them are of special interest and will be described below.

2.3 Theory of extensional classifications

In practice the theory of extensional classifications is often applied, in many cases implicitly. In this theory a conceptual model is developed by analysing the objects in reality which have to be modelled [3,18]. For instance, a conceptual model for a chair is developed by analysing the common properties of chairs. In fact the intension of a concept is reconstructed by analysing extensions of the concept.

2.4 Theory of functional classifications

2.4.1 Goal-oriented

In contrast with the theory of extensional classifications, the theory of functional classifications [5,11,12,13], reconstructs the intension of a concept by following a goal-oriented approach. The theory of functional classifications states that the decision on which attributes and constraints to reconstruct for the intension of a concept totally depends on the goal of classification. Having a goal or a function, one has to find out which knowledge is required to reach that goal or to perform that function.

2.4.2 Functional equivalent object-types

In reconstructing the intension of a concept by following a goal-oriented approach functional equivalent object-types are reconstructed. In reality there are often several ways to reach a certain goal or to perform a certain function. If a concept is symbolized by "chair" and the only requirement is that someone should be able to take a seat, a table meets this requirement too. So, a table is functional equivalent to a chair if the function is "taking a seat". In the theory of extensional classifications a table and a chair would have been modelled differently, because different properties are recognized. But, applying the theory of functional classifications most of these properties won't be modeled, since they are irrelevant to perform the function "taking a seat".

2.4.3 Context dependency

Another essential aspect in the theory of functional classification is the relevance of a context. The reconstruction of concepts is also directed by a context. The meaning of the concept "good football player", for instance, totally depends on the context in which this concept has to be reconstructed. In the context of a local club team this concept has a completely different meaning than in the context of a world class team. More precisely, a good football player in a local club team has completely different properties than a good football player in a world class team. This aspect is illustrated by figure 3.

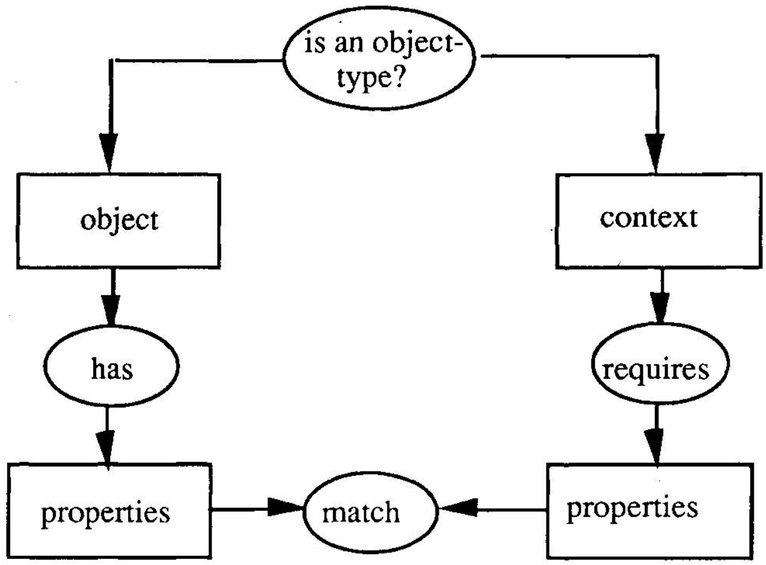


Fig. 3 Context dependency in conceptual modelling

A specific context requires specific properties. An object defined by attributes and constraints is an object-type of the conceptual model if and only if the properties of the object-type defined by attributes and constraints match the properties required by the context.

For the reconstruction of a conceptual model formal techniques are essential. In conceptual modelling work performed by using the theory of extensional classification, often a data modelling technique, like NIAM [18] or IDEF1x [3] is applied. These techniques are not goal-oriented and don't support the reconstruction of functional equivalent object-types. For this reason data modelling techniques are not very useful, if conceptual modelling is performed by using the theory of functional classifications. In the next chapter decision table techniques are applied for conceptual modelling of steel structures using the theory of functional classifications.

3. CONCEPTUAL MODELLING OF STEEL STRUCTURES

3.1 Realisation of steel structures

The process of realizing steel structures can be split into three sub processes, design, detailing and manufacturing.

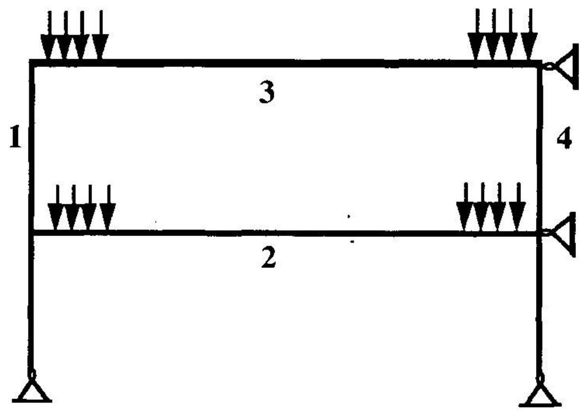


Fig. 4 Portal structure with loads

Starting point in the design process is the design of the topology. Figure 4 displays the topology of a portal structure. The portal structure consists of two columns and two beams.

The topology of the portal structure and the loads are the basis for designing the profiles and calculating the required capacity of the connections. Figure 5 displays the portal structure again at the end of the design process, which is the start of the detailing process. At this moment the required capacities of the connections are known.

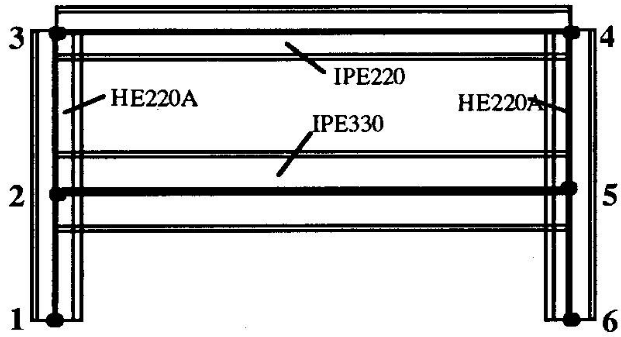


Fig. 5 Portal structure with profiles

In the example only the moment capacity, which is an indication of the strength of the connection, is considered. In the detailing process connections have to be designed, which meet the required moment capacity.

The example concentrates on node 2 and an end plate connection is detailed for it. In column to beam end plate connections, the actual joint between the column and the beam is provided by an end plate, that is welded to the beam and bolted to the column. It is calculated that the required moment capacity in node 2 is 60 kNm.

3.2 Modelling steel structures using the theory of functional classifications

The process to detail the connection at node 2 is displayed by the decision table in figure 6. The decision table is made using DTSS (Decision Table System Shell), an interactive graphic tool to define and consult knowledge in a decision table [7].

A decision table consists of two parts, a condition part and an action part. The condition part defines the conditions in which a specific action has to be performed.

The decision table technique supports a goal-oriented modelling approach. In figure 6 the modelling goal is defined by action A1 "good connection". To detail a good connection 5 conditions are evaluated. In reality more conditions are relevant, like, for instance, bolts and welds, but these are ignored in the example.

The decision table shows that a connection is good only if the condition moment capacity is greater than or equal to 60. The moment capacity is the result of a calculation done by a connection analysis program. So, after each detailing step the moment capacity is calculated and compared to 60. If the calculated value is less than 60, the actions A2 to A6 are performed. The actions A2 to A5 set values for the next detailing step. Action A6 actually activates the next detailing step. If the calculated moment capacity is greater than or equal to 60 only action A1 is performed and the detailing process is finished.

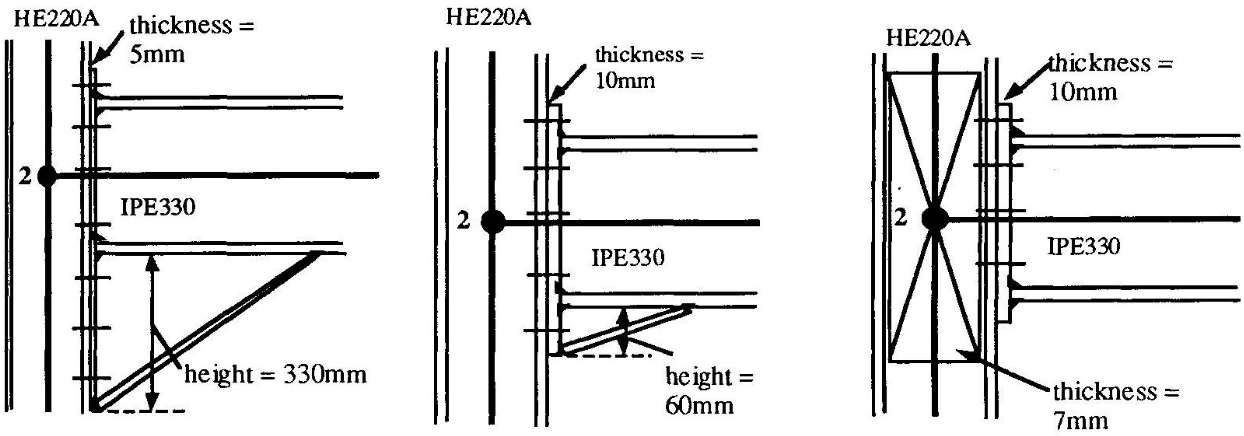
If the moment capacity is less than 60, the detailed connection is not good yet and has to be strengthened by increasing the dimensions of elements or including new elements, like a haunch or a web plate [17]. The decision on which dimensions to increase or which new elements to include depends on the determining collapse mechanism of the connection (condition C1). Like the moment capacity, the determining collapse mechanism is also the result of a calculation done by a connection analysis program. In the example only the collapse mechanisms "yielding of the end plate" and "shear of the column web" are considered.

Connection design

C1	collapse mechanism	yielding endplate					shear column				
C2	thickness end plate	x =< {old thickness end plate}			x > {old thickness end plate}		-				
C3	thickness web plate	-			-		x =< {old thickness web plate}			x > {old thickness web plate}	
C4	height haunch	x =< {old height haunch}	x > {old height haunch}		-		x =< {old height haunch}	x > {old height haunch}		-	
C5	moment capacity	-	x < 60	x >= 60	x < 60	x >= 60	-	x < 60	x >= 60	x < 60	x >= 60
A1	good connection	No	No	Yes	No	Yes	No	No	Yes	No	Yes
A2	old thickness end plate	{thickness end plate}	{thickness end plate}	-	{thickness end plate}	-	-	-	-	-	-
A3	old thickness web plate	-	-	-	-	-	{thickness web plate}	{thickness web plate}	-	{thickness web plate}	-
A4	old height haunch	{height haunch}	{height haunch}	-	{height haunch}	-	{height haunch}	{height haunch}	-	{height haunch}	-
A5	COMMAND reset(['collapse mechanism','thickness end plate','thickness web plate','height haunch','moment capacity'])	X	X	-	X	-	X	X	-	X	-
A6	COMMAND repeat_table	X	X	-	X	-	X	X	-	X	-
		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10

Fig. 6 Decision Table "Connection design"

In a situation where yielding of the end plate is the determining collapse mechanism there are two alternatives to increase the moment capacity of the connection. One can choose to include a thicker end plate or to include a (higher) haunch. Including a (thicker) web plate doesn't have an impact on the moment capacity in this situation.
In a situation where shear of the column web is the determining collapse mechanism there are also two alternatives to increase the moment capacity of the connection. One can choose to include a (thicker) web plate or to include a (higher) haunch. Including a thicker end plate doesn't have an impact on the moment capacity in this situation.



Moment capacity = 60kNm   Moment capacity = 66kNm   Moment capacity = 82kNm

Fig. 7 Functional equivalent connections

It can be concluded from the decision table that there are several alternative ways to reach the goal "good connection" [4]. Figure 7 displays three alternative connections, which are all good considering the goal "good connection", which actually means moment capacity greater than or equal to 60 kNm. Considering this goal these three geometrically different connections are functional equivalent.

Following a goal-oriented approach by analysing the decision process of a connection detailer trying to reach a specific goal, it is demonstrated that functional equivalent object-types are reconstructed. These functional equivalent object-types reveal that the attributes of these object-types can't be provided initially, because they are dynamic and conditional. They can only be acquired by reasoning about the goals of classification.

To demonstrate the relevance of the context in which a concept is reconstructed, figure 8 displays the concept "portal structure" in the context of a designer and in the context of a manufacturer.

A designer designs profiles and details connections between these profiles. A manufacturer manufactures assemblies, which generally consist of a profile and all the elements welded to the profile.

This example demonstrates that the reconstruction of concepts to define object-types, in this case the object-type "portal structure" depends on the context in which the concept is reconstructed. The relevant properties of a portal structure in a manufacturing context reasonably differ from the relevant properties in a design context. So, it is very important to define the context in which concepts are reconstructed.

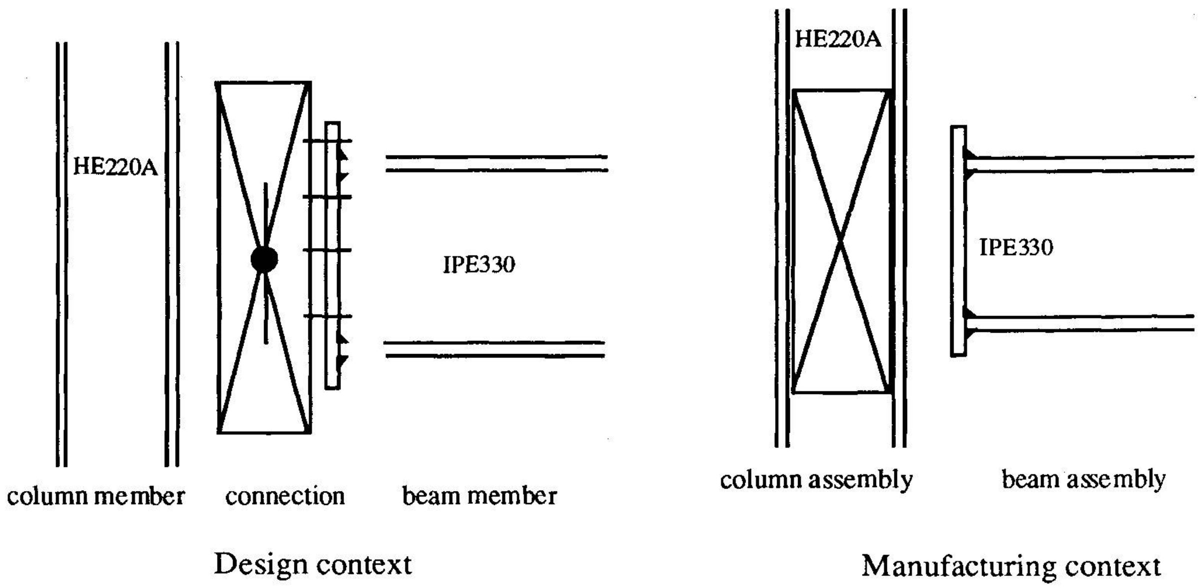


Fig. 8 Context dependent classifications of portal structure

3.3 Modelling steel structures using the theory of extensional classifications

In the theory of extensional classifications a conceptual model is developed by analysing the objects in reality which have to be modelled. Usually a data modelling technique like NIAM or IDEF1x is applied. In the IDEF1x-model developed within Eureka project EU130 "CIMSTEEL" [3] a connection is modelled as displayed in figure 9.

This model defines that a connection requires part-joints. And each part-joint connects two parts. In the first place this definition is rather generic. No difference is made between parts, like end plates, haunches and web plates. In the second place this definition is rather static. The model doesn't include information on the conditions in which a specific element is a part of the connection. The model doesn't include knowledge on functionally equivalent connections either. In reality a connection is a very heterogeneous object-type. The occurrence of elements is not static and can't be defined initially. Therefore it's very hard to describe connections by static and unconditional object-types and attributes. In the extensional approach this problem is bypassed by defining a generic model. The only general statement about connections is that they consist of an arbitrary number of joined parts. Consequently this is the only knowledge in the model.

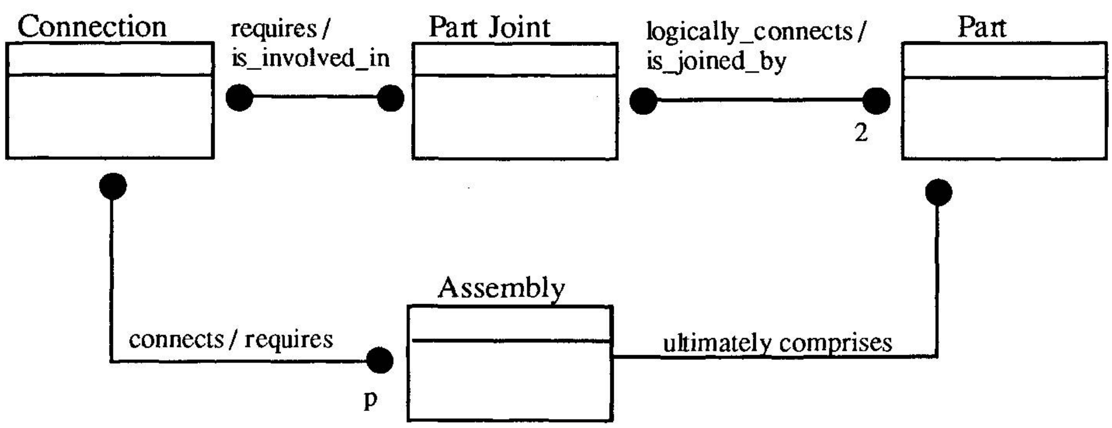


Fig.9 Fraction of CIMSTEEL product model

Concerning the design and manufacturing context, the CIMSTEEL model tries to combine these into one model. This is also shown in figure 9. A connection connects assemblies. An assembly comprises parts.
This combining of contexts shows that the existence of different contexts was recognized, but in order to be able to exchange information between different contexts one generic model was developed including aspects of both contexts. This makes the model rather ambiguous.

4. DISCUSSION

The paper introduced the theory of functional classifications as a basis for modelling steel structures. Usually the theory of extensional classifications is applied in this area. It was demonstrated by modelling a portal structure in steel that the theory of functional classifications should be preferred to the theory of extensional classifications, because:

- the goals of classification significantly influence the reconstruction of concepts
- only by reasoning about the goals of classification functionally equivalent object-types can be identified
- the context in which concepts are reconstructed has a significant influence on the classification process

By using the theory of functional classifications conceptual models are developed which contain knowledge directed towards goals of parties operating in the application area. The example demonstrated that the application area of structures is rather heterogeneous. Attributes are not static and unconditional, but dynamic and conditional. Dynamics and conditions can only be identified by following a goal oriented approach.

The theory of functional classifications used to develop conceptual models including knowledge of the application area, contributes to solutions in a number of research areas. These will be discussed now.

4.1 Conflicting goals

In the building and construction industry many parties are involved in the realisation of a building. Each party has its own goal and depending on that goal the party is only interested in a part of the building or in some aspects of a building. The occurrence of parties with different goals may easily lead to conflicts. It could happen, for instance, that environment requirements are in conflict with fire-safety requirements. Of course these conflicts can't be solved by an information system, but by following a goal-oriented approach in conceptual modelling it's possible to recognize these conflicts in an early stage. By developing goal-oriented models, both for environment and fire-safety, attributes occurring in both models with conflicting values can be recognized. By following a goal-oriented approach it could, for instance, be concluded that the material of a wall is an important attribute for the object-type 'wall' in both the environment model and the fire-safety model. If for fire-safety reasons a wall should be fabricated from material x and for environment reasons from material y, a conflict exists. The decision which material to choose can't be made of course by the system, but the system can report that a conflict exists, that has to be resolved.

This example also demonstrates the relevance of a context. With respect to fire-safety a wall of material x is classified as a good wall. With respect to environment a wall of material x is classified as unacceptable. This proves that the statement "good wall" is context-dependent.

4.2 Evaluation of representation formalisms

In chapter 3 a conceptual modelling approach was described, that can be used at the knowledge level. The knowledge level only consists of functional aspects of a system. Implementation aspects are not considered. Implementation aspects are considered at, what Newell calls, the symbol level [10]. At the symbol level object-types, reconstructed at the knowledge level are reduced to representation formalisms.

According to Newell:

Representation = Knowledge + Access

A representation formalism consists of structures to store knowledge and data and access mechanisms to operate on knowledge and data.
The conceptual model, developed at the knowledge level, can be used to evaluate representation formalisms [4]. Depending on the contents of the conceptual model, the most suitable representation formalism can be selected for implementation of the system.

Well known representation formalisms are record-based systems, and rule-based systems. A record-based system stores knowledge and data in records, which can be manipulated by a query language. A rule-based system stores knowledge and data in production rules, which can be manipulated by an inference mechanism, like forward chaining or backward chaining.

4.3 Integration of knowledge and databases

A great deal of research directed towards the integration of knowledge and databases, concentrates on the transfer of data structures and operations on data structures. In the past the statement could be heard: data is static and can be stored in records, knowledge is dynamic and should therefore be stored in production rules. Later it was realised that data is not always static, but sometimes dynamic and knowledge is not always dynamic, but sometimes static. One tried to solve this problem by using records to store production rules [6] or adding an inference mechanism to a database [16]. These are examples of symbol level integration of knowledge and databases.

The danger of these approaches is that the integration is realised without having a fundamental understanding of knowledge and data at the knowledge level. If only the functional structure of knowledge and data is considered, as worked out in chapter 3 for modelling of structures at the knowledge level, there is no clear distinction between knowledge and data. By following a goal-oriented approach using the theory of functional classifications, object-types consisting of attributes and constraints are reconstructed. These object-types consist of both knowledge and data and at that stage there is no need to bother about how to implement this, in a data-based system, a knowledge-based system or a combination of these. If in conceptual modelling too much attention is paid to representation formalisms, the functionality of the system can easily be adapted to the limitations of these formalisms. Consequently this leads to information systems, which are not really functional.

5. REFERENCES

1. BERG-CROSS, G. & PRICE, M.E., Acquiring and Managing Knowledge Using a Conceptual Structures Approach: Introduction and Framework; IEEE Transactions on Systems, Man and Cybernetics 19, pp. 513-527, 1989.

2. BRACHMAN, R.J. & LEVESQUE, H.J., What Makes a Knowledge Base Knowledgeable? A View of Databases from the Knowledge Level; Expert Database Systems, Kerschberg, L. (ed.), Benjamin/Cummings, Menlo Park, pp. 69-78, 1986.

3. CROWLEY, A.J., A "Walk-through" the LPM version 3.2, CIMSTEEL, EU130.2/LU/TP4, September 1992.

4. GELDER, J.T. DE & LUCARDIE G.L., Knowledge and Data Modelling in CAD/CAM-applications; Design and Decision Support Systems in Architecture and Urban Planning, to be published, 1993.

5. HENDRIKS, P.H.J., De Relationele Definitie van Begrippen: Een Relationeel Realistische Visie op het Operationaliseren en Representeren van Begrippen; Dissertation, Faculty of Policy Sciences, University of Nijmegen, 1986.

6. HERWIJNEN, J. VAN, HOUTEN, G. VAN, HOUTSMA, M. & ROMKEMA H., Implementatie van een regel-gebaseerd kennissysteem in een relationele database-omgeving; Informatie, Vol. 32, pp. 14-21, 1990.

7. HUIJSING, A.P., Een Expert System Shell voor Beslissingstabellen; TNO-rapport BI-92-156, October 1992.

8. LEVESQUE, H.J., Foundations of a Functional Approach to Knowledge Representation; Artificial Intelligence 23; pp. 155-212, 1984.

9. LUCARDIE, G.L., A Functional Approach to Realizing Decision Support Systems in Technical Regulation Management for Design and Construction; Design and Decision Support Systems in Architecture and Urban Planning, to be published, 1993.

10. NEWELL, A., The Knowledge Level; AI Magazine 2, pp. 1-20, 1981.

11. REITSMA, R.F., Functional Classification of Space: Aspects of Site Suitability Assesment in a Decision Support Environment; Dissertation, International Institute for Applied Systems Analysis, Laxenburg, Austria / Faculty of Policy Sciences, University of Nijmegen, 1990.

12. SMAGT, A.G.M. VAN DER, Definiëren en Relateren in Sociaal-Wetenschappelijk Onderzoek; Dissertation, Faculty of Policy Sciences, University of Nijmegen, 1985.

13. SMAGT, A.G.M. VAN DER & LUCARDIE, G.L., Decision Making under not Well Defined Conditions: From Data Processing to Logical Modelling; TESG 82, pp. 295-304, 1991.

14. SOWA, J.F., Conceptual Structures: Information Processing in Mind and Machine, Addison-Wesley, Reading etc, 1984.

15. STEELS, L., Kennissystemen; Addison-Wesley, 1992.

16. STONEBRAKER, M., Adding Semantic Knowledge to a Relational Database System, On Conceptual Modelling, Eds.: M. Brodie, J. Mylopoulos & J.W. Schmidt, Springer-Verlag, 1984.

17. STEENHUIS, C.M. & DOL, C., Geboute kopplaatverbindingen. Gebruik van NEN 6772 tijdens het ontwerpproces van een staalconstructie; Bouwen met Staal 103, pp. 3-7, 1991.

18. WAARD, M. DE, Computer Aided Conformance Checking; Dissertation, Delft University, 1992.