THE INTEGRATION OF A RADIATOR NETWORK DIMENSIONING PROGRAM WITH A BUILDING PRODUCT MODEL

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ABSTRACT

Dimensioning programs for heating radiator networks are still today cumbersome to use. This project is trying to develope easy to use and fast calculation methods for the dimensioning and balancing of radiator networks. The main idea is to integrate the dimensioning and balancing program with the CAD software. Objectoriented programming and building product modelling methods are utilized in the prototype program.

1. INTRODUCTION

Nowadays radiator networks are designed mainly with manual calculation methods. In Finland some HVAC-engineering offices have computer programs which are based on computerized manual calculation methods. Such calculation programs are little used in practice because they are yet too difficult and slow to use. The problem is that there is no standard method for transferring CAD designed radiator network models automatically as input data for the dimensioning programs. Therefore designers have to separately input manually the data necessary for constructing the matrices and vectors describing the network in the dimensioning algoritm.

On a more general level it can be noticed that computers are currently used for a large variety of tasks in building design and analysis. Among the basic software types used are 2-D draughting systems, spreadsheet and database programs, technical calculation and simulation software. One of the major drawbacks in today's situation is that almost every program uses a unique internal representation of the relevant data describing the building to be designed or analyzed. Consequently, it is very difficult to exchange data directly between different programs.

In order to exchange data between different application programs it is necessary to develop standard conceptual models structuring the data used in the description of building and its equipment. /1/

2. THE RATAS PRODUCT MODEL

The aim of the RATAS project has been to develop a national Finnish framework for computer-aided design in the construction industry. The system is meant for a situation in which the whole industry uses information technology on a large scale around the turn of the century.

The core of the RATAS system is the description of the building in computerized form - the Building Product Model. The other subprojects in the RATAS project studied general databases, data exchange standards, and changes in design and documentation practice.

The object description of a building is made up of objects and of a network of relationships between these objects. To each object one can associate a number of attributes, which describe the properties of the object in question. Together these constitute a product model of the building.

So far, agreements have only been reached on the general principles of the product model (use of object-oriented concepts, main abstraction hierarachy etc) /2,3/. The detailed definition of object classes, attributes and relationship types remains to be done. The RATAS model defines an abstraction hierarchy tailored to the needs of building designers.

3. THE AIM OF THE PROJECT

In the long term the aim of this project is to promote the development of integrated design environments based on the building product model concept. The RATAS- product data model is based on the assumption that in the future the design information will be stored in product model databases. The design information is accumulated during the design process. It should also be possible to get different views from the database for each building design phase. This project promotes the development of the product data model from the view of designing the radiator network.

In the short term the aim of this project is to develop a prototype program for dimensioning and balancing of a radiator network. The most important part of the project is the integration between the building product data model and the network calculation program.

The building will be modelled in the database using RATAS product modelling principles. In the prototype program the radiator network will be input graphically using a CAD program. The model of the radiator network will be transferred to the building product model database from which the necessary data will be retrieved for the radiator network dimensioning program. The results of the calculation will be returned back to the product model database and to some extent to the CAD program.

A key question to be addressed in the research is how to relate the static attributes of the product model (for example length of a pipe) with the parameters of the dynamic data structures (for example matrices describing network topology) used for dimensioning and balancing a radiator network. The aim is to enable the creation of these calculation objects automatically from the product model data without the need for human judgement. Work has already been done on the description of simulation equation systems as objects by other research teams /4/, while the integration methods with product model data are still largely undefined.

This research project is part of the COMBINE project of EC which aims at developing integrated design software for energy economic design of buildings /5,6/. All together six different prototype programs will be built within the COMBINE-project, one of which by VTT and PI-consulting Ltd.

4. CONCEPTUAL MODELLING WITH NIAM

The future Standard for the Exchange of Product Data (STEP) /7/ serves computer aided design and manufacturing by defining standards for the structuring of product data in CAD program databases and for data exchange between application programs. STEP is a large scale standardization effort undertaken by the International Standardization Organization ISO.

In the development of product model standards we need systematic and formal modelling methods. These methods are used for defining product model data and connections between these data and in this way for defining database structures. In the STEP development work NIAM and IDEF1X are used. The formulation of the STEP standard will be done using the EXPRESS data definition language.

The Nijssen Information Analysis method (NIAM) is used to model various universes of discourse using a graphic notation. The NIAM method has two types of objects: Non-Lexical Object Types NOLOTs (those objects which are generic types, not able to have atomic values assigned: pipes, radiators, etc.) and Lexical Object Types (those objects which can be assigned values: mass flow, pressure loss, etc.). /8,9/

With NIAM schemes the information models of the structures of the building and radiator network and their important connections to each other have been described (Figure 2). Objects, classes and relations between objects and attributes which describe the properties of the building components have been modelled with NIAM. The description of the building is an abstraction hierarchy of objects, where the higher level objects are decomposed into objects describing lover level components.

5. THE DIMENSIONING ALGORITM

The dimensioning and balancing of the radiator network will be done using a matrice- based calculation method. A matrice calculation method has been chosen instead of traditional manual calculation methods, because with the matrice method it is possible to calculate different networks (one pipe and two pipe systems together) and in the network there can be many different types of pipelines if necessary.

With the matrice calculation method a network is abstractly described as set of numbered connection points (nodes) and connectors (branches) between connection nodes, for example pipes. The defining data for the networks will be collected from CAD input data. With this information it is possible to describe the construction of the radiator network for the calculation program.

The topology of the network is described by connection and loop matrices. The description of the network with matrices defines how the mass flow balance of different nodepoints are written and if there are closed circuits in a network how the pressure equations of these loops will be written.

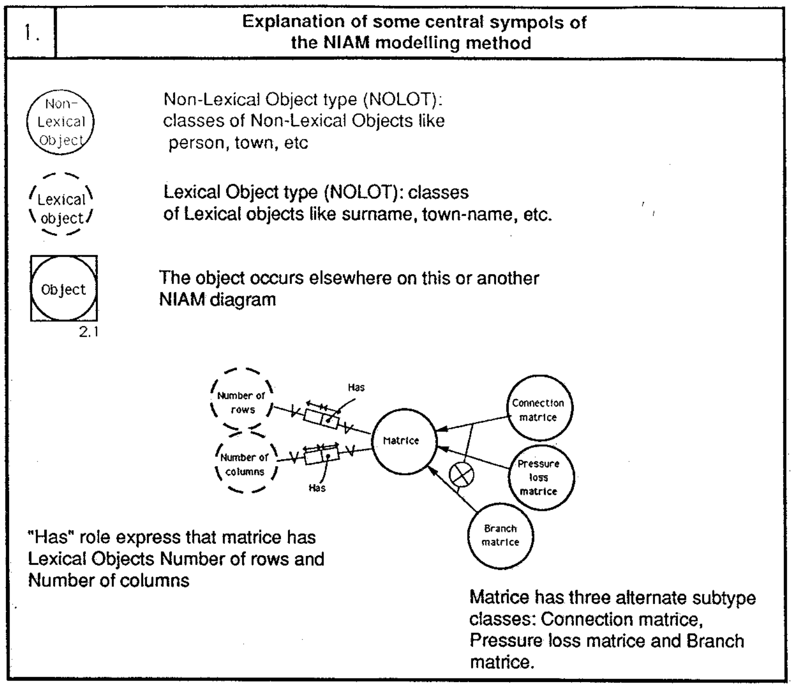


Figure 1. Explanation of some central symbols of the NIAM modelling method.

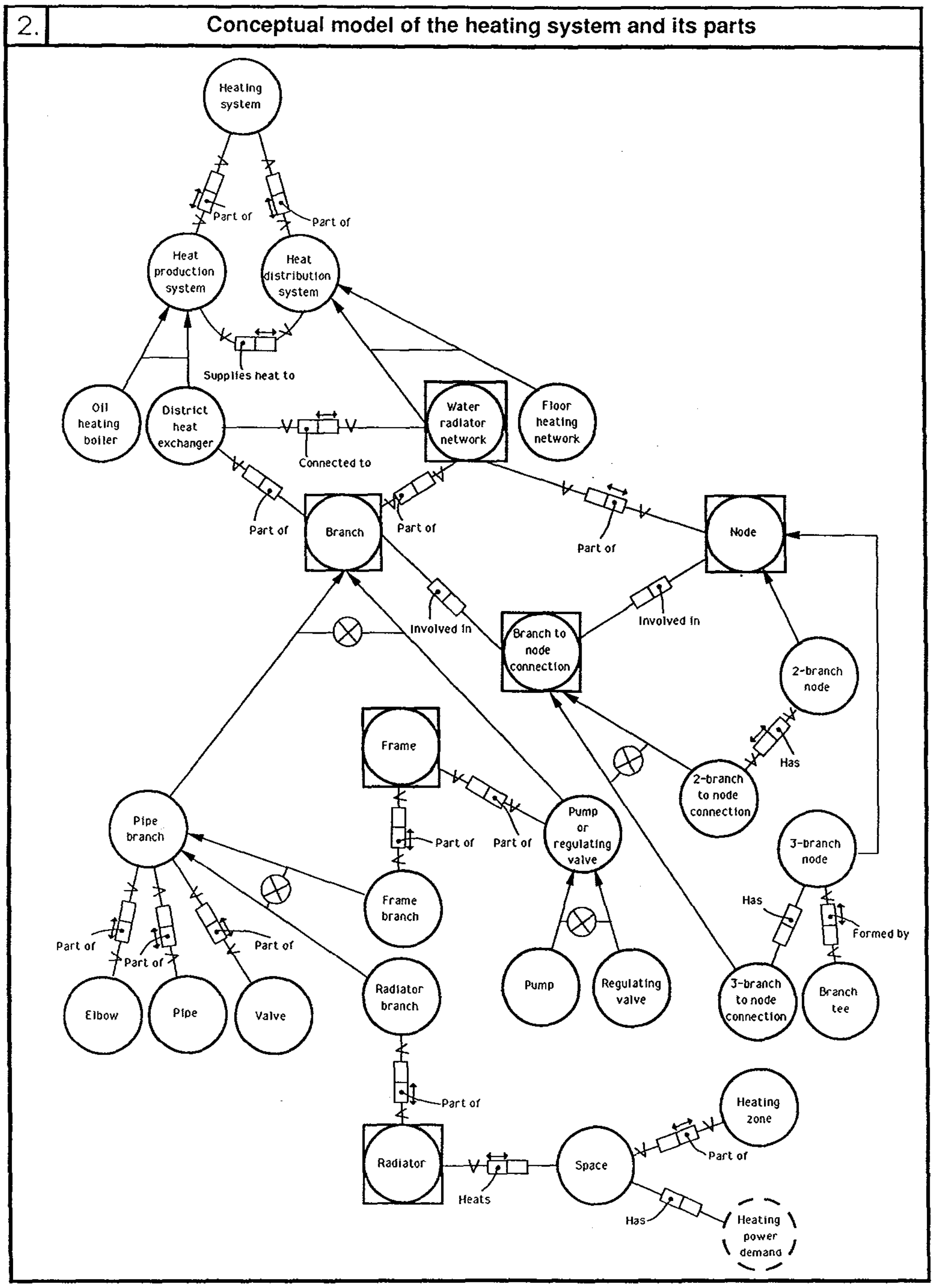


Figure 2. NIAM scheme of radiator network of the building.

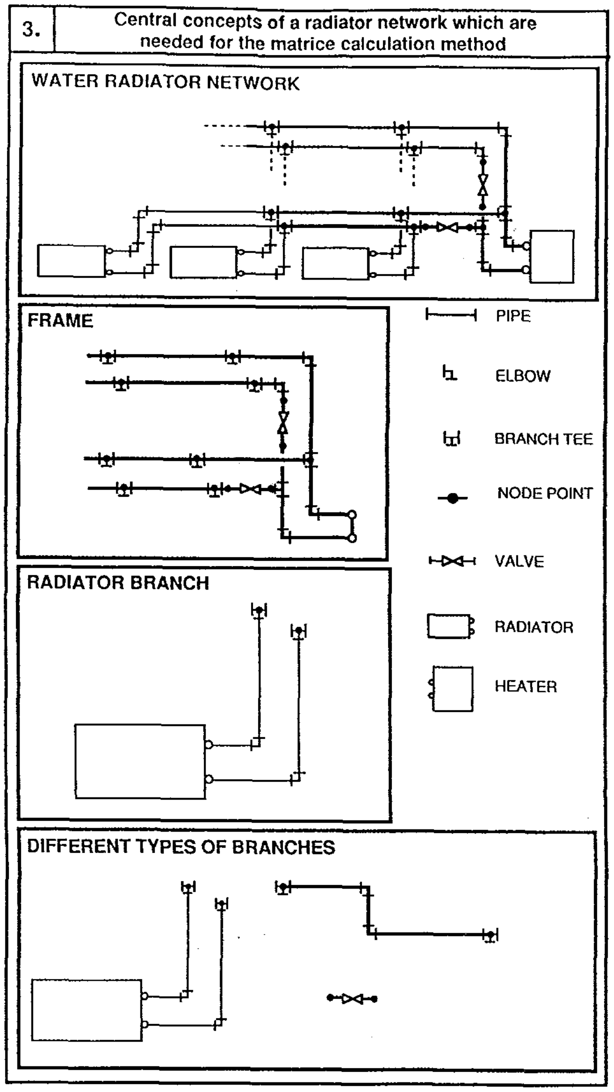


Figure 3. Central concepts of a radiator network which are needed for the matrice calculation method.

As input information the matrice calculation program needs the identifier of each radiator branch, startpoint of the branch, endpoint of the branch, length of the branch, friction coefficients, minimum pressure loss for the farthest radiator and the farthest line regulator valve as well as the measured mass flow for the radiator branches. As output the program calculates unknown pressure losses, mass flows, and sizes of pipes.

6. INTEGRATION BETWEEN THE PRODUCT MODEL AND THE DATASTRUCTURES OF THE CALCULATION MODEL

The product model of the radiator network which has been described with NIAM schemas will be built in the product model database of the building, from where input data for the dimensioning and balancing program of the radiator network will be fetched.

The prototype program will work so that first radiator network is designed with a CAD program on top of CAD drawings of architecture. After the design process has finished the ready drawing files will be transferred to the product model database. From the database the network data will be transferred to the calculation program and the network will be dimensioned and balanced. At the end the calculation results are saved to the database and CAD programs.

The radiator network describtion consists of objects such as pipes, radiators, pipe connectors, valves, pumps et.c. From the CAD-based description of the components of the network a topological graph description is abstracted. A graph consists of nodes (both sides of the pumps and line regulator valves, branching nodes of the network) and branches as connectors between nodes.

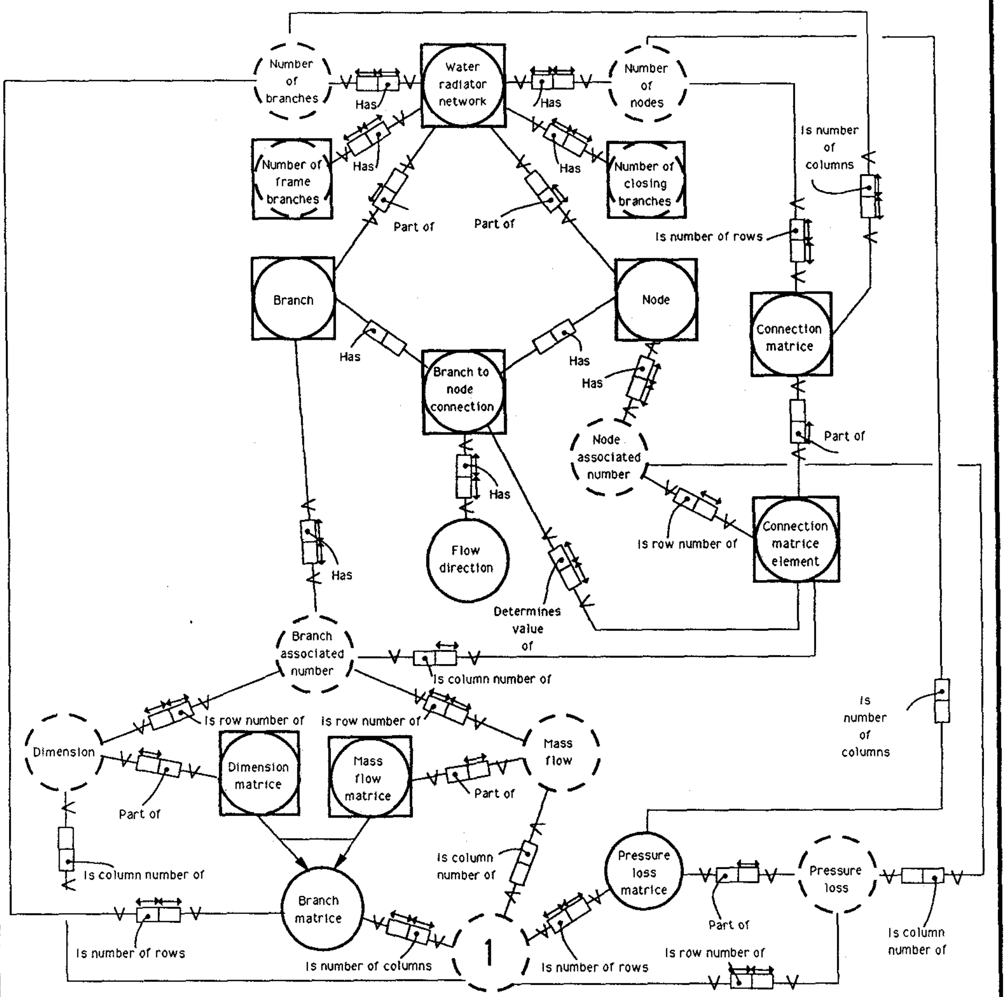
The connection matrice for creating the massflow balance equations and for calculating the unknown mass flows will be formed by translating in the database saved network model for the calculation program. With the connection matrice the branches connected to the nodepoints of the branches will be described and the mass balances of the nodepoints will be defined.

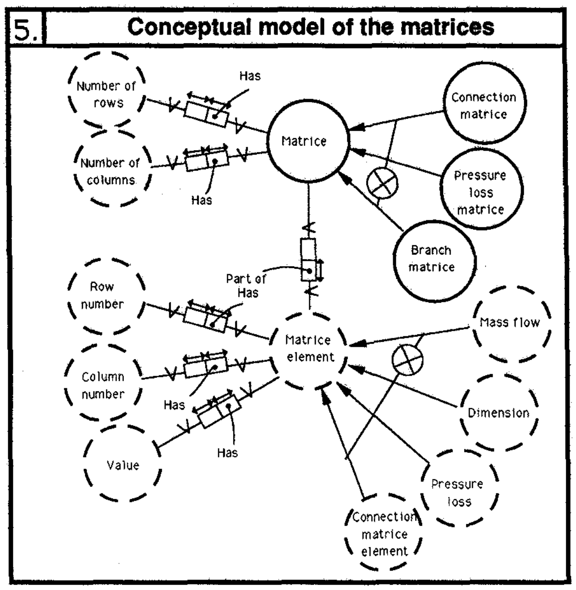
The connection matrice is divided into submatrices, one represents the frame branch matrice and the other closing branch matrice which further are composed of elements of matrices. The elements can get values of 1,0 or -1 based on an interpretation of the network CAD model. The value of the matrice elements will be defined on the basis of numbering of the branches and the nodepoints.

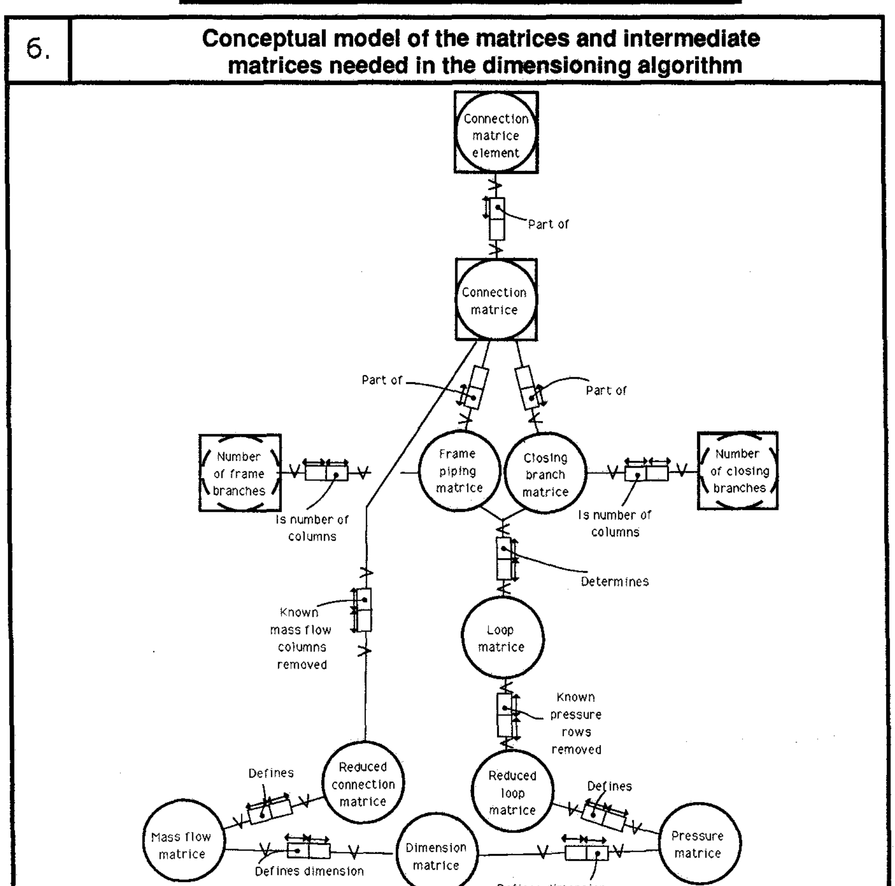
The value of the matrice elements which differ from zero are solved so that the flow direction towards the nodepoint is negative and direction away from the nodepoint is positive. In the connection matrice the branches are described on horizontal lines and nodes on vertical lines.

Another matrice which is necessary for the description of the network is the loop matrice. The loop is created by adding to the tree of the network one closing branch. The loop can contain only one such branch. In the loop matrices the branch numbers are on the horizontal lines and loop numbers on the vertical lines. The loopmatrice can be divided submatrices containing frame branches and closing branches. With the loop matrice it is possible to write pressure condition equations for solving the unknown pressure differences.

4.	**Conceptual model of the topology of the heating system and the description using calculation matrices**







Figures 4,5 and 6. NIAM schema of the connection between the static network model and the dynamic matrice datastructure model.

7. CONCLUSIONS

The main aim of the project was to extend the data structures of building product model from the view of dimensioning and balancing of a radiator network. In this project we have developed a conceptual model for the data used in the area of radiator network design. As conclusions can be said that NIAM modelling is worth doing before the programming work because NIAM schemes offer exactly defined base for the object oriented programming and building product modelling. The principles of the integration will be tested with a prototype program. This project will finish at the end of the year 1992.

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