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ENGINEERING DESIGN IN INTEGRATED PRODUCT DEVELOPMENT
Design Methods that Work

THE HISTORY OF ONE INDUSTRIAL APPLICATION

J. Pokojski

Institute of Machine Design Fundamentals
Warsaw University of Technology
e-mail: jpo@simr.pw.edu.pl

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Abstract: *Computer support for certain engineering tasks such as modeling, analysis, simulation tends to be integrated into one system where all modules are coherent. Because of that a software should also be capable to provide communication between modules and to include knowledge based approach. This paper presents the history of the development of such an application as an integrated environment.*

1. INTRODUCTION

The paper presents the history of one industrial application development [3, 5, 6, 7, 8]. As an exemplary industrial application a system which supports the design process of a piping system (which was developed by the author as an integrated application) is presented. The specialized system consists of two sub-systems: one models the geometry of the piping system and is connected to a second one which analyzes the fluid flow dynamics problem of fluid in the piping system. The generator of the fluid flow dynamics model is a knowledge based system.

The whole system exists in several configurations (the history of their development is presented in the paper) which are the results of cooperation with industrial and non-industrial partners.

The evolution of the described software took about ten years (1989 – 1999). In the whole development of the presented application we can recognize three stages. The first one concentrated on industrial focus – it was done in the West German software firm: Kerntechnik Entwicklung Dynamik (KED Rodenbach) [1, 4, 5, 6]. The main ideas developed at that time (89-90) were based on the way how German industrial engineers work, how they solve their problems and how they cooperate with each other. The ideas were based on the engineers' level of knowledge and on their basic background assumptions. The second stage (93-94) was a scientific research problem for which the software from the first stage was equipped with a more sophisticated tool: the blackboard architecture [6, 7]. During the third stage (97-99) specialized knowledge based application supporting heating system design for little houses [3] was developed. In the next chapter these three stages are described more detailed.

2. SYSTEM DEVELOPMENT

2.1. First stage (industrial focus) [1, 4, 5, 6]

The whole development was initiated in 1989. The firm KED had own software for the geometric modeling of piping systems (so called isometric modeling [4]). This software was cooperating with different specialized modules like specialized data bases of standard components, costing modules, etc. The software had been developed in cooperation with a small group of customers. The observation of the customers' way of solving problems identified the customers' need for software which could calculate pressure drops in the piping system. It was assumed that a geometry of piping system is given first and later the user can add some physical data and then get the pressure distribution in the piping system.

When the development was initiated it was not clear how to do that. The main goal was known, but not the way how to achieve this goal. Several different formal approaches were considered. But none of them was implemented on computer. Therefore the author of this application decided not to experiment with new approaches, new equations generators, etc. He selected some of the existing software. It was a system for fluid flow dynamics simulation called INES done by D. Babala [1]. The system worked fast and perfectly. It was based on cell formalism.

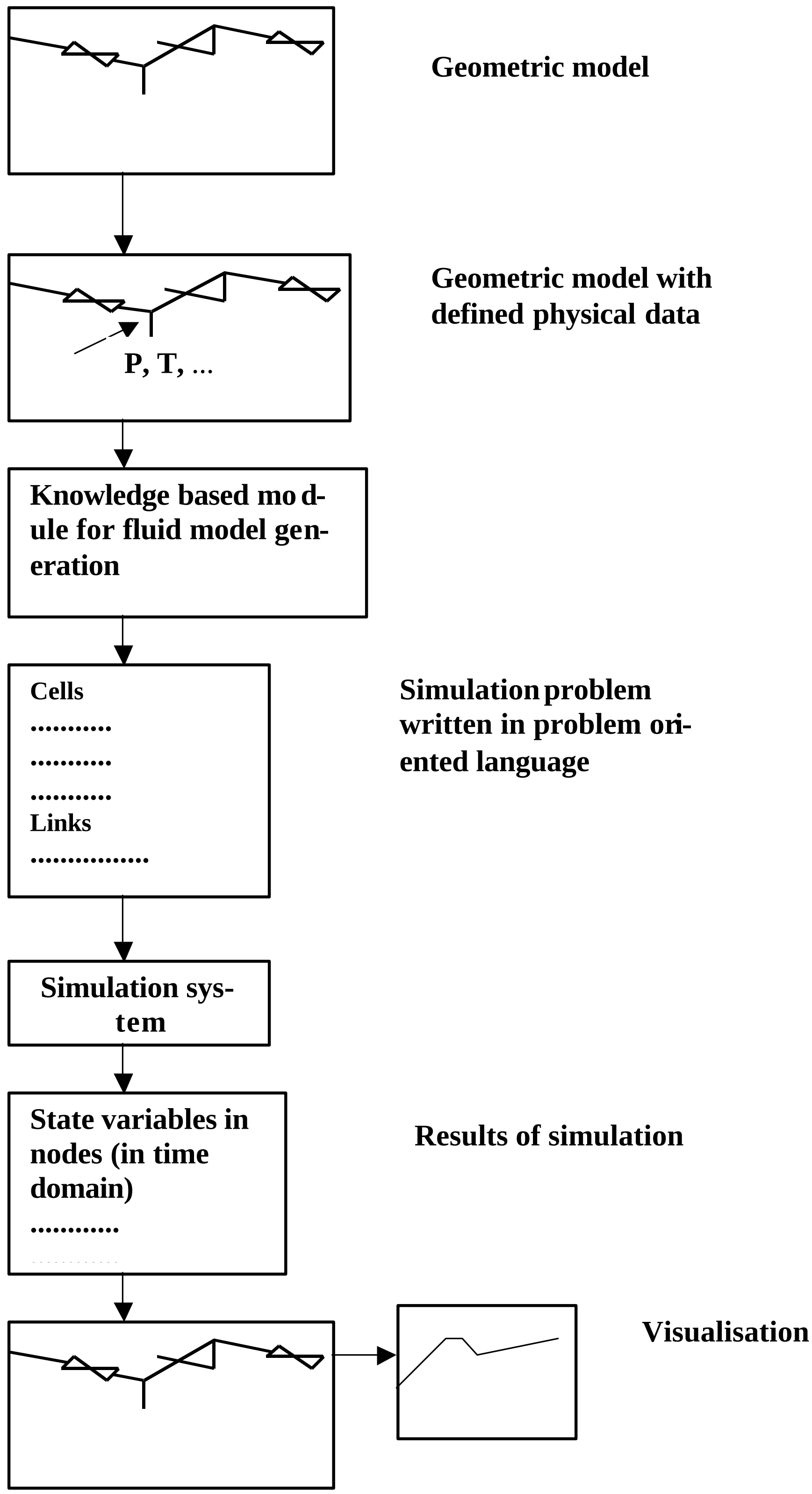

Fig. 1. *First stage (industrial focus) –scheme of processing.*

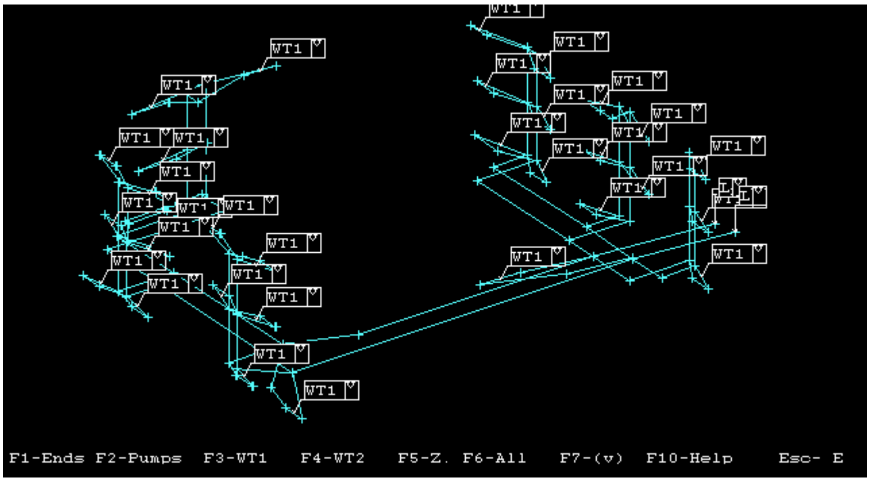

Fig. 2. *Exemplary model of piping system.*

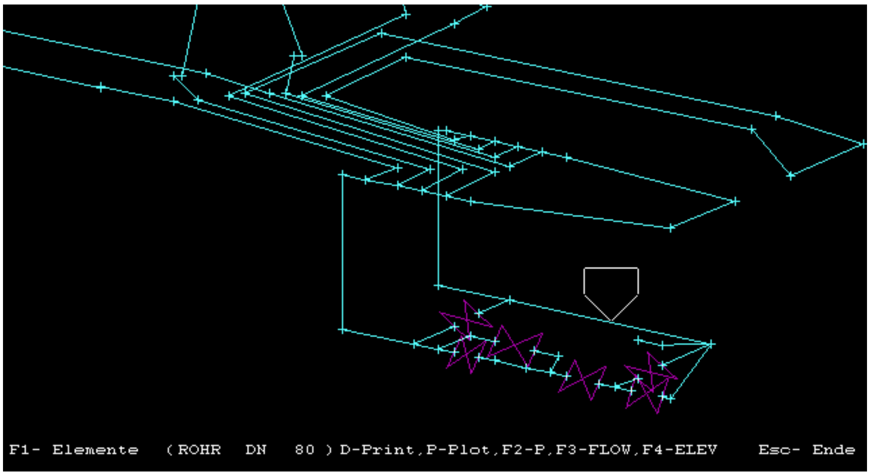

Fig. 3. *Visualisation of results of simulation.*

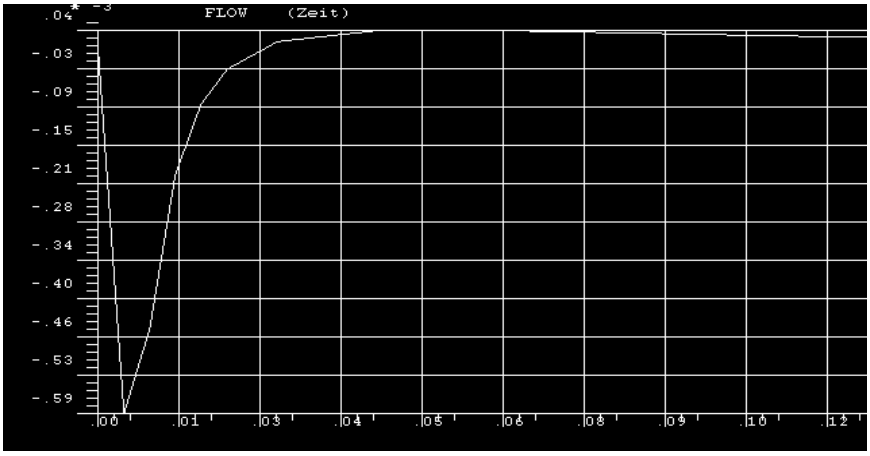

Fig. 4. *Visualisation of flow in time domain (in selected node).*

The fluid was modeled as a net of connected cells and links. The cells were modeling mass, capacity and energy. The links were modeling flow resistance, etc. The system had a special problem oriented language for modeling fluid systems and fluid simulation problems. The system INES analyzed the modeled problem and delivered a huge amount of results in the time domain (for instance fluid flow, pressure in a particular cell, etc). The system was made in fortran.
First the idea was considered that the model of the fluid in the piping system will be created by the user. Then the graphic editor was built where the nodes (cells and links) were shown graphically as an integrated net. The whole model was presented in 2D space. It was possible to add new cells or links and edit an existing net. Every node had a number of numerical parameters, which were achievable via special windows. Special functions supporting modeling branches and special functions for visualization were developed (especially zoom function was very useful). The considered class of models mostly had a size of 100 – 200 nodes. The direct connection between this system and the simulation system INES was done. Separately the module for showing results on graphic way was built.
The prototype version was examined and evaluated by several engineers. The first opinion was that the system is too demanding. The language of the problem taken from the simulation system was much more sophisticated than the language used by an average engineer. Therefore the decision was made that the whole system should be better integrated with the system for geometric modeling and should offer an automatic fluid flow dynamic model generation.
As a result the author of this paper continued this project as a knowledge based application. As a first step an expert system shell (written in fortran) integrated with other considered applications was built. The expert system was filled with the knowledge of how to transform a geometric model with some physical data into a fluid flow dynamics model. About 60 rules which could support model transformation were created. The geometric model additionally had to contain physical data like pressure, flow, temperature, etc. A special editor supporting physical data modeling, as values connected with geometric primitives, was developed. Some data were generated on the basis of algorithmic approach, for instance flow resistance calculations for different structures: bending, valves, etc. Rules deciding what is processed in which part of the piping network were created. The expert system shell was fully integrated with the rest of systems. This new developed knowledge based module could create a dynamic model of fluid which was in the geometric model of the piping system. The results of the simulation were presented as diagrams modeled in a geometric model. There were static diagrams of different state variables in any place in the net or diagrams and animations made on some indicated path in the piping system.
The whole newly built system was tested on different examples. The test versions of the system were given to several users. Soon new ideas appeared. Not every simulation was successful. Therefore additionally a module based on some of the rules supporting the process of repeating a simulation was built. The effects of these analysis were presented to the user. Either a place with data error (error had to be corrected by hand) or suggestions of a new simulation with new corrected values of simulation parameters (this possibility could be proceeded automatically) were indicated.
While testing the system we found that the group of potential users was relatively wide and that they had various expectations. Especially, they had many different ideas about the basic set of primitives available in the system. For instance: people coming from chemical industry claimed for objects modeling heat exchange with the atmosphere, people managing water delivery systems had bigger expectations in the field of fast modeling of elevations, etc. So we came to the conclusion that nearly every potential user needs a very customized application. Looking back we can say that it was the claim for feature based application.
The industrial application finished at the level presented above. The system was presented several times for different people from industry. During such presentations numerous problems (not only prepared by the author but given by observing people as well) were solved. At least several times problems which had never been considered before by the author of the system were solved successfully. The knowledge approach proved that it can give good results for a wider class of problems. The implemented knowledge chunks gave more combinations than author had considered. The knowledge was stored in the form of rules: 1) rules transforming geometric model into fluid model, 2) rules finding contradictions and making decisions, 3) rules finding and correcting values of particular parameters. Some rules could activate big parts of codes for finding parameters on algorithmic way.

2.2. Second stage (scientific approach) [6,7,8]

The next stage of the system development was based on a more scientific approach. The author found it interesting to develop a module which searches for the reasons of simulation failures. A module which analyzed the whole trace file from the simulation was developed. Distributions of different variables, their mid-values and variances were calculated. Knowledge dealing with phenomena patterns in the whole piping net was acquired. The considered knowledge dealt with basic values and calculated functions based on these values. In the case of failure the system suggested changes in the parameters and the repetition of the simulation. The system used the trace file with the results of the simulation as a source of information. The content of the file was filtered. The values of state variables were classified. New measures of distribution were calculated. These data were placed in the blackboard on its lowest level. The different knowledge sources i.e. expert systems were connected to the blackboard. There were two classes of knowledge sources: 1) analyzing separately single variables like: elevation, pressure, temperature, mass flow, energy flow , heat energy flow, 2) analyzing "abstractions" resulting from different kinds of variables and suggesting model corrections. The first type of knowledge source analyzed for instance the temperature over the range of time for every node. It looked for especially prepared and remembered patterns for every node and couples of nodes. Information resulting from this process was placed on a higher level of the blackboard. Knowledge sources analyzing "abstractions" looked for some known phenomena on the basis of information from the first and the second level of the blackboard. Their conclusions were the basis for model corrections and next, new simulation. The knowledge sources triggering conditions were based on the maximal ranges of state variables. The echo of the blackboard inferencing process was shown on the screen in an alphanumeric way. Only the final suggestions: placing of error, sensed phenomena, suggested action were presented in graphic way. They could be accepted or corrected by the user.

From the structure point of view there was a plurality of similar knowledge bases which dealt with different physical phenomena. As a tool for the integration of multi knowledge sources the blackboard architecture was used. The queue functioned as a control mechanism. The software was based on two expert system shells. One was to control, the second was to activate actually used knowledge source.

Experiments done with this software proved that blackboard architecture has a very useful open structure. The main problem was to acquire knowledge. The author had problems with finding people who felt these phenomena well and were willing to devote their time for building knowledge bases. Some knowledge bases contained knowledge from the first stage of development. As a consequence the development based on blackboard architecture was stopped.

2.3. Third stage (customized approach) [3]

At the end of the nineties a scientific project was done at the Polish Academy of Science which dealt with intelligent design techniques in civil engineering. The author of this paper, together with two research students, participated in the project. As a result a software for intelligent support for heating system design for little houses was built. A specialized editor for modeling houses in 2D (with possibility of transforming it to 3D) was added to the software which had been developed earlier. The module for the modeling of houses allowed to add a module for heating system installation modeling. A set of objects typical for heating installations was created.

We developed software modules which correspond to the following activities: selection of type of heating system, configuration of heating system components, estimation of energy transfer through the building, simulation and evaluation of newly created design. First a specially developed control module had to identify the preferences of the future user of the heating system. According to the identified preferences this module activated other modules for a more detailed and specific dialogue. After that a control module created a sequence of simulation problems. The results could be interesting for a particular user with a particular profile of using the heating system, in a particular house and in a particular place with the particular correctness of calculations. Finally a process of simulation was conducted. The results of the simulation were stored. Later another module supported the process of estimation of the simulation results.

The module for the simulation of flow and heat phenomena in the heating installation had as an input data about the geometric description of the heating system and the physical aspect of a particular simulation. As a result we could get the temperature of every room and the energy flow in the time domain.

The system was tested on several examples. Even three level houses were considered. The results were positive. But the created models needed a lot of data. With such software we came to engineers who were doing such projects, who were designing heat installations. Looking closer how these people do their job we noticed that they mostly use software delivered by heat components producers. This software is relatively simple and it doesn't consider dynamic problems. It is based on rough rules. But the designers regarded our approach as too complicated and evaluated it as suitable for a more advanced expertise.

3. CONCLUSION

The first stage of the system development was based on a very industrial and practical focus. People who decided about the methodology and form of the software had experience and contacts with industrial users. They knew their needs, their abilities and their way of solving problems. From this point of view the scenario of cooperation with the system was very

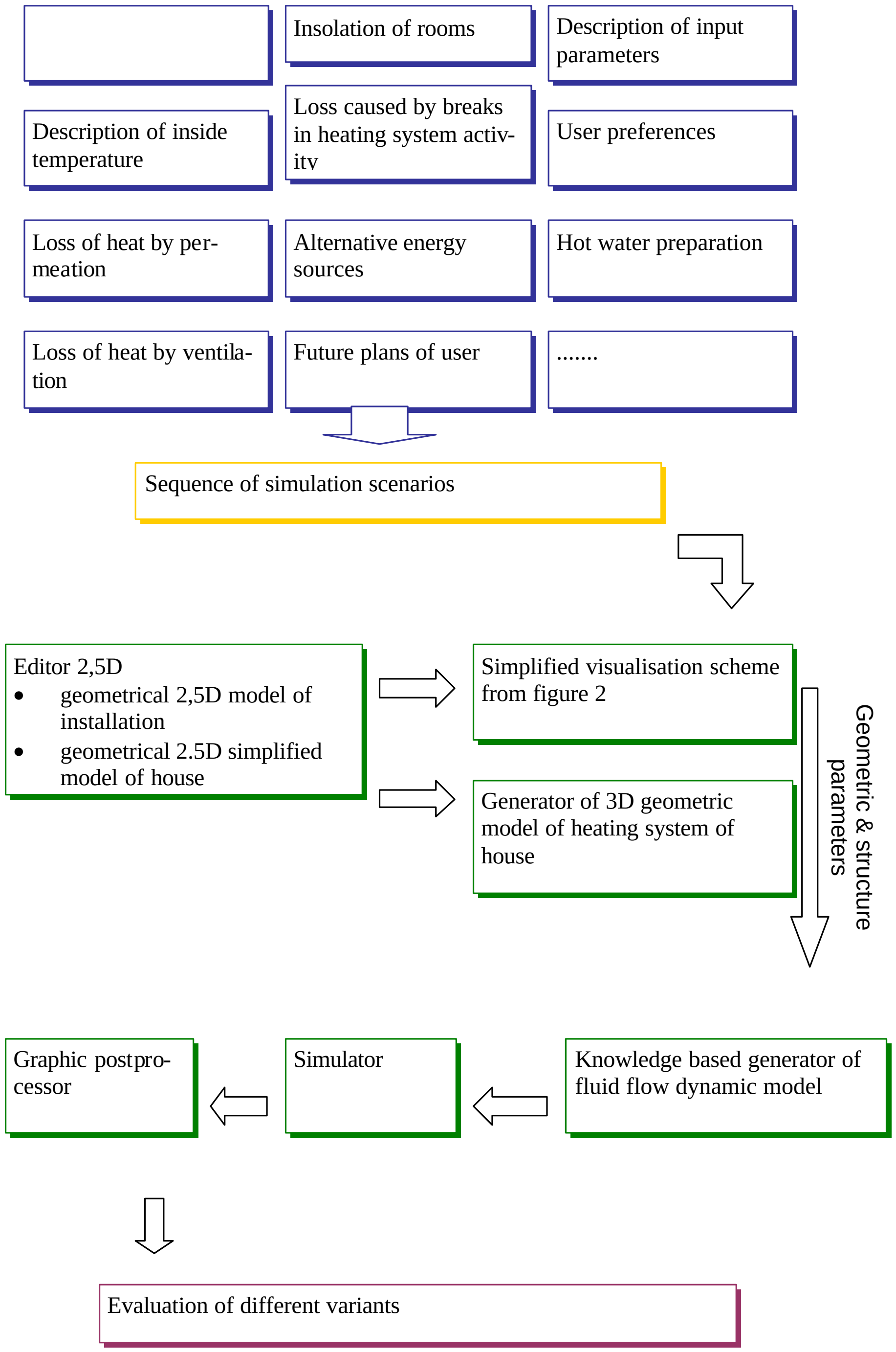

Fig. 5. *Scheme of heating system design support [3].*

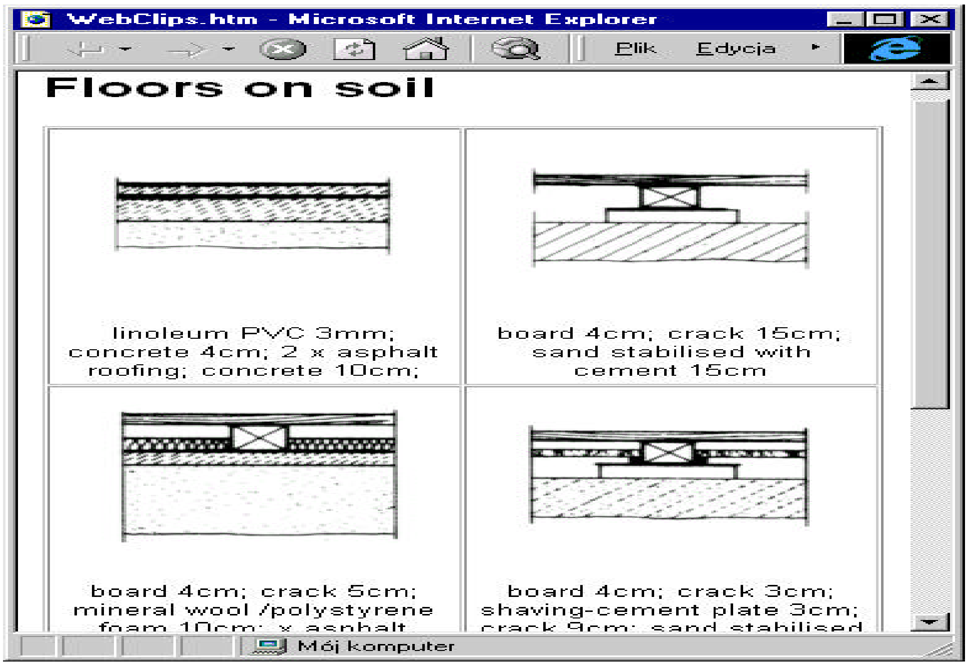

Fig. 6. *Heating system design support. One of the expert systems – dialogue window.*

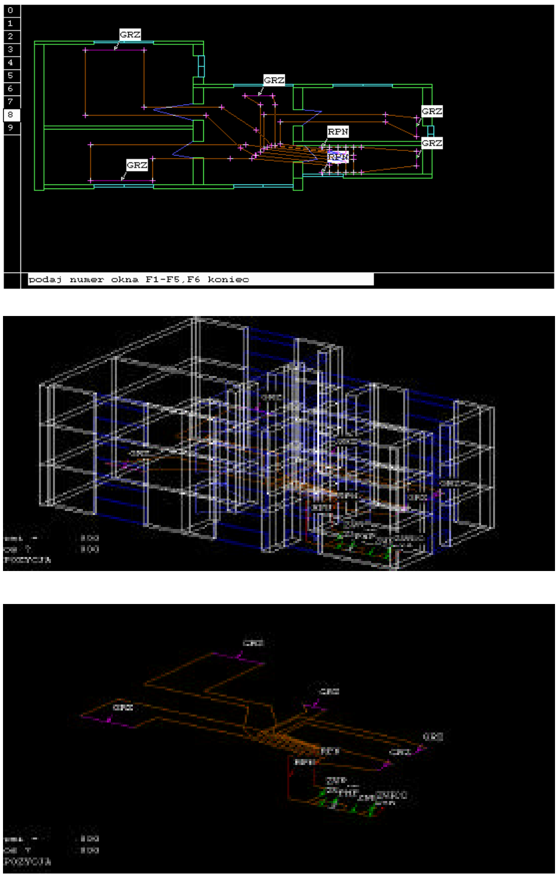

Fig. 7. *Heating system design support – modelling of installation.*

well considered. Many little details – the effect of large industrial experience - were corrected. There were many relatively simple changes, making something more clear, removing some not always accepted units, trying to access some data indirectly, etc. There was also a strong influence of engineer profile connected with some particular industry at some stage of the development. The basic problems solved by these engineers were considered as test examples. It is very important to have a relatively detailed profile picture of the potential users. Their knowledge, their customs, their level in the field of computer technologies are of great importance.

The next stage of the development was the domination of expert system technology. Blackboard architecture was developed with relatively big effort, but it was never fully finished. Somehow it was the result of the industrial stage, because the engineering knowledge in this field had a structure, a form of knowledge management and there was always a kind of context knowledge. Blackboard architecture gave some clear frames. There were knowledge sources reflecting these aspects. The aspects could be activated, controlled or removed. And it was noticeable that a meta- knowledge exists in industry. This stage of application was done in the years 94-95. It was difficult to implement it. Meantime we can observe slow coming of blackboard architecture to every day practice.

The application for supporting heating system design was much more advanced than applications used by an average engineer. Therefore the creating of templates with pre-fixed models and pre-fixed process scenarios for particular problems was considered.

We come to the conclusion that the first stage of the whole application development where everything was well adjusted to the reality was the most successful. The stage of blackboard architecture reflected reality – existing knowledge forms, but it was too complicated from the point of view of knowledge acquisition and knowledge control. People were not used to software with multi-attitude possibilities and with knowledge management tools. The last stage – heating system design – did not fit to the software being actually in use. It indicated the need to use feature based modeling.

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