IMAGIM+

A knowledge-based system for enterprise modeling

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Abstract

From the beginning of the 80s, several methods for enterprise modelling have been developed, among which the GRAI approach. The GRAI Integrated Methodology (GIM) is one methodology belonging to the GRAI approach, enabling the modelling of the enterprises' physical and informational systems, as well as their decisional system. *Imagim+* is the software support to GIM, providing assistance for the implementation of the approach. *Imagim+* is composed of a set of integrated graphic editors for each formalism used in the GIM methodology (*grids, nets, Idef0 and E/R diagrams*). Besides its graphical capabilities, the software has an expert system to validate and diagnose malfunctions in the models built. This paper presents *Imagim+*, describing its main functionalities and use in enterprise modelling.

Keywords

Enterprise modelling, consistency check, diagnostic, knowledge-based systems, GRAI approach.

1. INTRODUCTION

GIM (GRAI Integrated Methodology) has been conceived with the main goal of providing techniques and flexible tools for enterprise modelling. Having been

inspired on the GRAI approach (Doumeingts 84), GIM has extended it in order to model the totality of the enterprise, instead of focusing only on the decisional subsystem.

The GIM approach is implemented in three main phases: *the modelling phase*, where the initial model of the enterprise is produced; *the inconsistency search*, whose main objective is to detect inconsistencies and weak points in the enterprise studied; *the design phase*, where the design of the new system is elaborated based on the results of the previous phases. The software *Imagim+* has been built in order to support the implementation of GIM through all three phases. The software is composed of four graphic tools for the edition of the graphical formalisms employed, namely: GRAI grids, nets, Idef0 and Entity/Relationship (E/R) diagrams. Besides its graphical capabilities, *Imagim+* incorporates an expert system that validates and diagnoses malfunctions in the models built.

This paper presents the software *Imagim+*, describing its architecture and main functionalities. This paper is organised as follows: Section 2 gives a brief introduction to the formalisms used in GIM; Section 3 presents the architecture of *Imagim+*, outlining the structure and operation of its main components. Section 4 presents a practical example of the use of *Imagim+* in the modelling of an enterprise which manufactures products under demand, in small scale; Section 5 presents some conclusions and directions for future work.

2. THE GIM FORMALISMS

The GIM formalisms have been chosen through a comparative study of different existing methods (Roboam 88). The main criteria used in the selection of each method have been the exactitude of the representation and its ease in interpretation. The formalisms employed in GIM are:

- *Idef0 (ICAM Definition)* - used for the modelling of the enterprise's functions and physical system. This formalism has been developed in the American project ICAM (Integrated Computed Aided Manufacturing), with the goal of representing in a hierarchical fashion and from a static point of view the functionalities of an enterprise. We will focus mainly on the modelling of the physical system. The models highlight the use of physical and human resources, as well as the flow of products (e.g. in case of manufacturing systems). The description of the physical system is initially done from a global level, indicating top-activities and then subdividing each activity to the level of specificity desired.
- the GRAI formalisms (grids and nets): used in the modelling of the enterprise's decisional system. The main advantage of using the two representation mechanisms is that while the grids enable the representation of the global structure of the decisional system, the nets can be used in the representation of the details and internal operation of the components of the decisional system. The grid has a matrix form which determines temporal

and functional aspects of the decisional system. The nets provide a more refined view of the decisional system, detailing the activities defined in the decision centres of the grid.

- *Entity/Relationship*: used in the modelling of the informational system. In the context of a GIM study, this representation mechanism is used mainly for the description of the conceptual and structured information models.

Below, the GRAI grids are further explained, as they are used later to illustrate the modelling of the decisional system of an enterprise. The reader is referred to Zanettin (1994) for a more detailed description of all the formalisms used in GIM.

The GRAI grids have been conceived to describe the global structure of the decisional systems. The horizontal axis of the grid is decomposed in different functions (in the example of figure 1: to manage resources, to plan, etc.), while the vertical axis is divided into two temporal lines: horizon and period. The decisional system is then globally described in the grid by placing decision centres according to their function and to the scope of their decision.

Links between the different decision centres are also described in the grid. Two types of links exist: informational and decisional. The latter is called decision frame and comprises objectives to reach, constraints, decision variables and criteria. In the grid, the decision frame is represented by a framed arrow and the information flow by a simple arrow. The basic structure of a GRAI grid is presented in Figure 1.

Figure 1: The GRAI grid.

3. THE ARCHITECTURE OF IMAGIM+

Figure 2 presents the architecture of Imagim+. The knowledge-based system has been divided into three portions: the editors, the database system and the rule-based system. The next subsections describe each of these components.

Figure 2: The basic architecture of *Imagim+*

3.1. The Editors

The editors of Imagim+ have been organised in three groups, as described below:

- The *Rules editor*, which enables the user to create new rules, to modify or delete them. This editor can also be used to select and mark a set of rules as the active set, which means that when the system activates the rules, these are the only rules of *Rule Base* to be verified.
- The *Context editor* enables the user to create, view and modify the context information. The term *context* is used here to classify the data describing an enterprise, as well as its environment (e.g. the company's type, size, position in the market, etc.). According to the company's type, several other attributes are defined. For instance, for a manufacturing company, the *context* will detail the types of products manufactured, the quality constraints, technology features, etc.
- *Graphic editors*: four graphic editors have been defined in Imagim+, for each of the formalisms of GIM: GRAI grids, GRAI nets, Idef0 and E/R diagrams. The editors enable the user to create new models

and eventually modify them. As the operation of all editors is fairly similar, we present below the main functionalities of the GRAI grid editor.

The *GRAI grid* editor provides flexible tools for the construction of a grid. Figure 3 shows an initial empty grid created by the editor.

Functions	External Info.	Function	Function	Function	Internal Info.
Horizon Period Process Unit 10					
Horizon Period Process Unit 20					
Horizon Period Process Unit 30					

Figure 3: The GRAI grid editor.

When creating a new grid, the editor provides a grid skeleton which is filled-out by the user with the appropriate information. By using the buttons shown in the tool-bar, he may select elements of the grid, add functions, add levels, delete functions or levels, add informational or decisional flows. By clicking on the elements displayed on the grid, the user may also change the information shown. For example, if the user wants to change the first couple horizon/period of the grid, by clicking on the corresponding square, a dialogue box is displayed where the user enters the new information (figure 4).

The screenshot shows a dialog box titled "Level" with a close button (X) in the top right corner. The dialog contains several input fields and buttons:

- Number_Level**: A text box containing the value "10".
- Horizon**: A text box containing "1", followed by a dropdown menu currently showing "Year(s)", and a "Wording" button.
- Period**: A text box containing "1", followed by a dropdown menu currently showing "Month(s)", and a "Wording" button.
- Processing_Unit**: A text box containing "1", followed by a dropdown menu currently showing "Week(s)", and a "Wording" button.
- Driven Activities**: A text box containing "0", followed by a dropdown menu currently showing "Week(s)".
- Comments**: A large, empty text area at the bottom.
- Buttons**: "OK" and "Cancel" buttons are located on the right side of the dialog.

Figure 4: Changing the information of a decision center.

3.2. The Database system

The database system is responsible for the storage of the "environment of a GIM study", ie. the models built, as well as the rules and the context data. Each study has thus a particular database where all this information is stored.

The part of the database concerning the rules contains some essential knowledge that is always delivered with the system. This knowledge can be later adjusted by the user according to his needs, through the addition of new rules, the activation and switching-off of certain rule-sets. The structure of the Rule-Based system is presented next.

3.3. The Rule-Based system

The Rule-Based System has the goal of identifying inconsistencies and malfunctions in the models built by the user, according to the models themselves and some further information about the enterprises (the context). Figure 5 shows the four main components of the Rule-based system.

Figure 5: The detailed architecture of the Rule-based system

- The *Rules manager* makes sure new rules entered in the system will not conflict with already existing rules. The rules consistency is managed by the *Rules manager* in two aspects: static and dynamic. The former deals with the consistency of rules taking into account only the rules described in the *Rule base*, without considering the facts contained in the *Fact base* (systems such as COVADIS (Rousset 88) and INDE (Pipard 88) are based on this approach too). The inconsistencies that may be found at this level concern redundancy, contradiction and cycles. The redundancy of rules happens when two or more rules are identical (same conditions and conclusions); the contradiction, when the rules have the same conditions but different conclusions; and the cycles when there is a chain of rules in the *Rule base* where the first rule has a condition A and the last has a conclusion A, thus forming an endless loop. The consistency in the dynamic level concerns both the facts stored in the *Fact base*, and the rules themselves (systems such as TMS (Doyle 79) and ATMS (De Kleer 86) are based on this approach as well). At this level, the consistency is verified at all times. When the conditions which have conducted to the deduction of a fact are no longer valid, this fact is removed from the *Fact base*. Therefore, there is no risk that another rule takes into account this inconsistent fact.
- The *Context data manager* makes available to the *Rule-based system* all sorts of information about the enterprise studied (the context).
- The *Main Core* is further divided into three components.
 - ⇒ The *Rule Base* is composed by the rule sets which have been selected by the user.
 - ⇒ The *Fact Base* stores the facts used to test the condition parts of the rules. Two types of data are kept in the base: *facts from the user's models* (grids, nets, Idef0 and E/R diagrams), and from the enterprise context.
 - ⇒ The *Inference Engine* accesses the *Rule Base* to obtain the rules selected for the current study. The *Fact Base* (context data and user's models) are

also checked in order to identify true statements in the condition part of the existing rules.

- The *Glossary* is the component of the system that enables the user to use the vocabulary of his choice when describing the models created. The glossary translates the expressions commonly used into standard terms which have a particular "meaning" to the system.

The rules stored in the *Rule Base* have been organised in a hierarchical structure as shown below:

Figure 6: The hierarchy of rules

- **Modelling rules:** ensure that the models built do not present inconsistencies. They have been divided into:
 - **GRAI syntax rules:** concern the detection of inconsistencies related to the syntax defined for each formalism. Eg.: *"for a given level, the horizon of decision-making must have at least five periods for reviewing the decisions"*
 - **Integrity rules:** detect inconsistencies in the models of a given system. The aim of these rules is to ensure a global coherence among the models. Eg.: *"all the information contained in a GRAI grid must appear explicitly in the GRAI net"*

Dividing the modelling rules into two distinct sub-sets, helps the user to understand the inconsistencies detected. Furthermore, it gives the user the opportunity to enable or disable a whole set of rules, which may be wanted in some circumstances (e.g. enabling only the syntax, or only the integrity rules).
- **Diagnostic rules:** have as a main goal to identify inconsistencies in the studied enterprise at the semantic level. The inconsistencies are observed both in the models built, taking into account the context of the company. The diagnostic rules have been divided into three sub-sets:
 - Rules regarding the operating of the enterprise (GRAI rules): they are characterised by being independent of the context;
 - Rules which are inherent to the type of enterprise studied (one-of-a-kind, discrete production or continuous production.);

- Rules linked to a specific domain (Chemicals, Weapons, Spaceship components.)

The different classes of rules are applied in a specific order, according to their type and the GIM phase in which they are used. The *syntax rules* have to be taken into consideration in the modelling and design phases. In fact, these rules are used in real-time during the construction of the model. The *integrity rules* are triggered after the completion of each model, their goal being to check the models' consistency. Regarding the inter-model *consistency rules*, they are applied after the *integrity rules*, when all the models of the different views are produced. Concerning the diagnosis rules, they are verified, beginning with the GRAI rules and then applying the rules inherent to the type of enterprise, followed by the domain specific rules. This progressive approach allow the users to analyse with efficiency their models, avoiding, for instance, to check the GRAI rules on inconsistent models.

4 A PRACTICAL EXAMPLE: MODELLING A MANUFACTURING COMPANY WITH IMAGIM+

IMAGIM+ gives support to the users in all phases of the GIM approach. Figure 7 shows the list of all models constructed during the *modelling phase* of a particular enterprise.

Figure 7: The models of a particular GIM study

Figure 9: The problems identified in the grid

The problems identified guide the analysts in the improvement of the models. The final conception grid designed for the manufacturing system studied, according to goals established and eliminating the inconsistencies detected is presented in figure 10.

Figure 10: The conception grid

This grid gives priority to the production planning aspects that were lacking in the existing decision system. In fact, the number of decisions levels has been reduced (from 5 to 4) and the values associated to the couples Horizon/Period have been recalculated to allow an efficient synchronisation according to the GRAI rules. Concerning the other components of the grid, decision centres have been added for the function *To plan*: Strategic (Business Plan), *Tactical* (Master Production Scheduling and Capacity Plan) and *Operational* (Scheduling).

5. CONCLUSIONS AND FUTURE WORK

At present, IMAGIM+ is in the beta-test stage and is being used by several consulting companies in Europe, for manufacturing systems design and diagnosis of problems.

We are starting to work on the development of a complementary tool which uses Case-Based Reasoning (CBR) techniques to enable the re-use of design solutions created with *Imagim+*. The new system will be capable of finding previous cases that may help the user to model the enterprise analysed, and to identify weak points in the solution proposed. The idea of using CBR in enterprise

modelling is innovative and can be justified for several reasons. Firstly, modifying a solution that has been successfully used in the past is certainly less complicated than building a solution from scratch (Kolodner 93). Secondly, users are usually more willing to accept solutions provided by concrete cases than solutions that are ready-made (Georgin et al. 94). Such a tool should provide further assistance in the modelling of enterprises with GIM.

IMAGIM+ gives now a real support to the use of GIM. It was the computerized tool we were waiting for giving a strong development to the GRAI Approach.

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7. BIOGRAPHY

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