

Knowledge-based system for the choice of rapid prototyping process

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ABSTRACT

This paper introduces a knowledge-based system for the choice of rapid product development processes.

Rapid product development processes are not limited to layer-manufacturing machines, but they also integrate CAD, reverse engineering, indirect methods for metallic and plastic part manufacturing, etc...

Due to short delays, people have no time to test and compare different solutions of rapid product development processes. Even if people have time, tests are time and money consuming. It is also very difficult for somebody to know all about industrial technologies, and to be able to evaluate a multi-criteria choice in a short time.

The aim of the proposed knowledge-based system is to generate, from the specification of parts or tools, different alternatives of rapid product development processes, which can be discriminated and optimized when considering a combination of the different specification criteria (cost, quality, delay, etc...).

Keywords : knowledge-based system, rapid prototyping process, optimization

1. INTRODUCTION

The evolution of layer-manufacturing techniques (Bernard and al, 1998) (AFPR, 1998), during the last ten years, and the development of new applications show that rapid prototyping, and more recently rapid tooling and rapid manufacturing (Wohlers, 1999) (SME, 1999), are new ways for industrial production tools. Nowadays, it is possible to obtain, in a very short time, good quality and low price prototype parts or tools. This is due the development of various kinds of technologies, but also thanks to the different materials transformed on the layer-manufacturing machines. Of course, the development and the integration of numerical environments (systems and interfaces) have favored the efficiency of such processes.

But, due to the large number of possible combinations of technologies (from 3D digitizing and reverse engineering (Bernard, 1999) (Zhang and al, 1995) (Varady and al, 1997) to mass production thanks to metallic tools), industrial companies are not able to capitalize realistic knowledge in order to choose the optimal process for a given specifications, even if they have a long experience in rapid prototyping. More over, the evolution of technologies and their strategic aspect make it important to be able to classify rapid product development processes with regards to real efficiency and reliability.

Life cycle of products is very short. So, companies have to adapt their development and industrialization organization in order to reduce time-to-market, based on numerical information that has become the reference for the product. In fact, new challenges concern the capability to manufacture the just necessary number of products. The main consequence is flexibility for tool manufacturing with low-price and consumable tools, instead of very cost-consuming tools. This is possible because of numerical information, used along the complete development of the product, and due to new materials. But, consequently, it is necessary to validate product and process concepts very early during design stage. Some recent developments in rapid manufacturing allow such possibilities.

These examples show that the dynamic evolution of technologies is not easy to take into account in real time. This is why it is strategic to find the just necessary process for given specifications.

What is proposed in this paper is an approach for knowledge and know-how capitalization, and for computer-aided process planning (CAPP) from given specifications (type of part, material, delay, quality, color, etc...).

In the following paragraphs, the proposed solutions in terms of modeling and process-planning alternatives and choices are developed.

2. RAPID PRODUCT DEVELOPMENT PROCESS

The experience shows that quite all industrial products are concerned by rapid product development technologies. It is mainly due to the variety of technologies and more especially of materials. As said before, there are various fields of applications to favor less time consuming for product development.

The other main evolution is related to the integration of layer-manufacturing technologies with CAD and numeric models. Such CAD systems and environment are not so expensive and are more user-friendly. So, the exploitation of known processes in other application fields is possible for new users. Due to the stability of the technologies, the results are really 3D images of CAD models of parts or tools, more functional and accurate, in many different materials.

In spite of last arguments in favor of the use of rapid product development processes, this domain has a permanent evolution. It is very difficult to appreciate all the real capabilities offered for industrial applications. But it is really more and more interesting to use such means because the number of parts that have to be manufactured at one time seems to be lower and lower. This fact induces a new tendency and favors the development of rapid tooling technologies, in order to obtain some real industrial processes which are alternatives to actual traditional processes. The main originality is to develop materials and technologies that allow obtaining economical and consumable tools which life time is limited. And due to the integration of CAD reference models with these new processes, it is possible to produce as many economical tools as needed, even if this is in one, ten years or more.

In order to be able to decide what is the best process at a time, taking into account the industrial context and the particular specifications of the product, it is strategic to capitalize the knowledge related to all the technologies. If so, it would be possible to distribute this knowledge to all the services which need it (design, manufacturing, industrialization, control, ...). Of course, the volume and the dynamic aspect of this knowledge have to be taken into account when choosing conceptual models for data modeling and data processing. One of the main difficulties is that data will be related to both knowledge and know-how.

All these arguments show the necessity of a computer environment dedicated to CAPP for rapid product development. This system will allow to obtain alternatives of rapid product development processes and also to choose the best one optimized from multi-criteria or based on a particular main criterion.

The interest for a large company to use such environment is to allow all the services having the global technological information at the same time. According to us, it should also be a tool for general knowledge capitalization.

Concerning a small or medium company, this information system has a strategic interest because this environment should be accessed through a Web application ; in particular, that will allow evaluating alternatives of processes based on real means and companies (subcontractors and all their technologies, their capabilities in terms of cost, delay, quality, etc...).

The last aspect is of course that this system will also contribute to help training sessions in order to highlight technologies and the main choice criteria between technologies and more generally between rapid product development processes.

3. PROPOSED SOLUTIONS FOR KNOWLEDGE AND KNOW-HOW CAPITALIZATION

After the analysis of the problem, it has been decided to model a set of generic objects in order to represent the information related to generic knowledge and know-how in rapid product development domain.

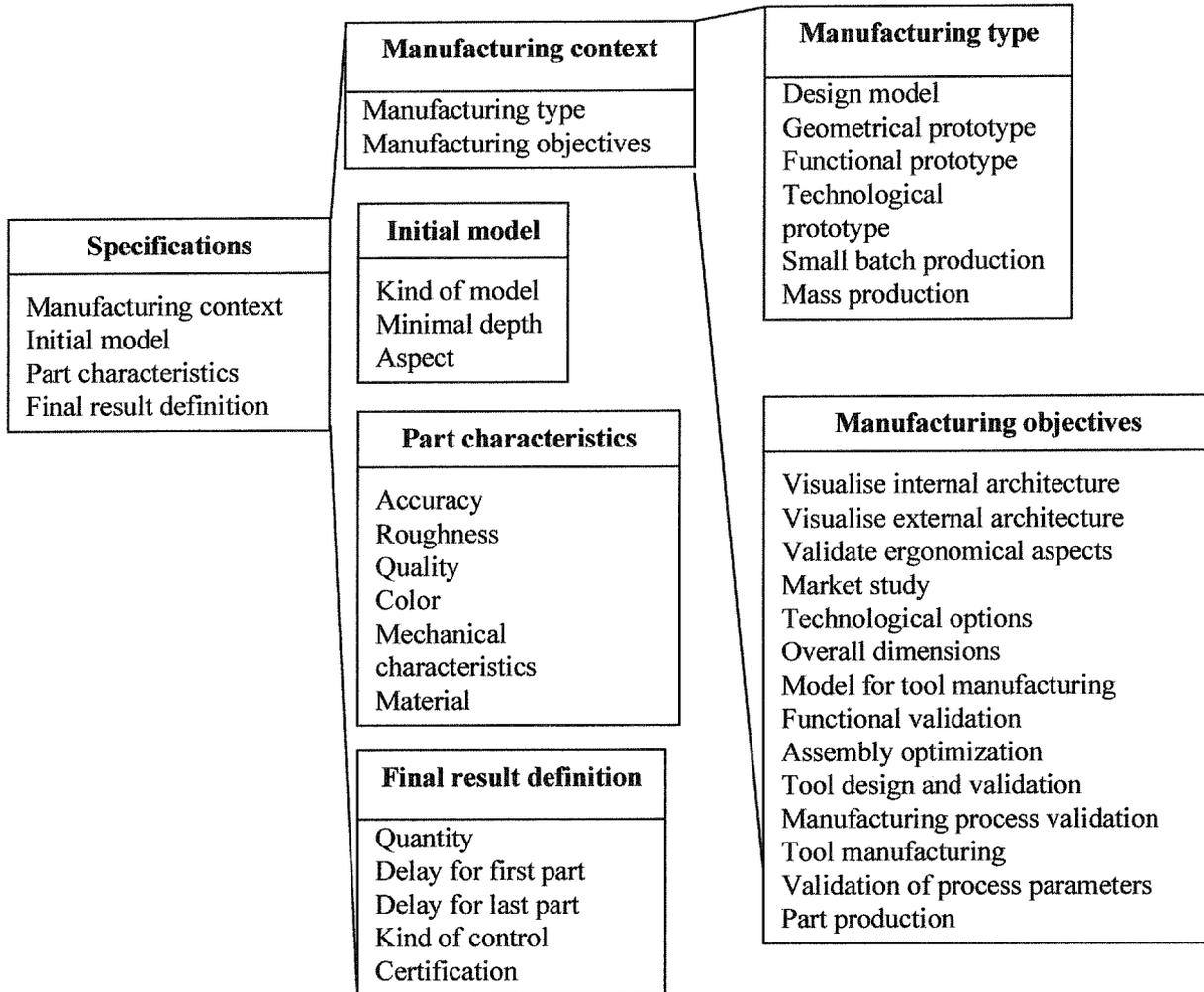


Figure 1. Some elements of specifications decomposition

These objects are classified into six main classes:

- knowledge of the specifications:
this is the starting point of the process, because this is what is given by the client to his subcontractor ;
- knowledge of the different technologies and processes:
it is of course necessary to model all the technologies and the main choice criteria, and the knowledge is obtained from documents, experiences and interviews of experts ;
- knowledge of case studies:
this is necessary because the case studies are the image of what is really feasible (success) or not feasible (failure) ;
- global knowledge of rapid industrialization:
this is related to the different technologies and to all application fields, in order to define precisely the limits of the domain ;
- knowledge related to process choice:
this more especially concerns to the formalization of choice criteria and to their representation ;
- knowledge of computing methods:

the final objective is the final reasoning in order to generate different rapid product development processes, and to choose between these processes in order to find the optimal one.

The entry point of a CAPP system is the definition of the specifications related to the product that has to be manufactured. Figure 1 shows the decomposition of the specifications, which is modeled for each capitalized case study. The main attributes are related to manufacturing context (manufacturing type and context), initial model (more especially STL file, CAD file, physical object, drawings, minimum depth, aspect), final result definition (quantity, delay, certification and control) and part characteristics (material, quality, accuracy, roughness, color, mechanical and physical characteristics).

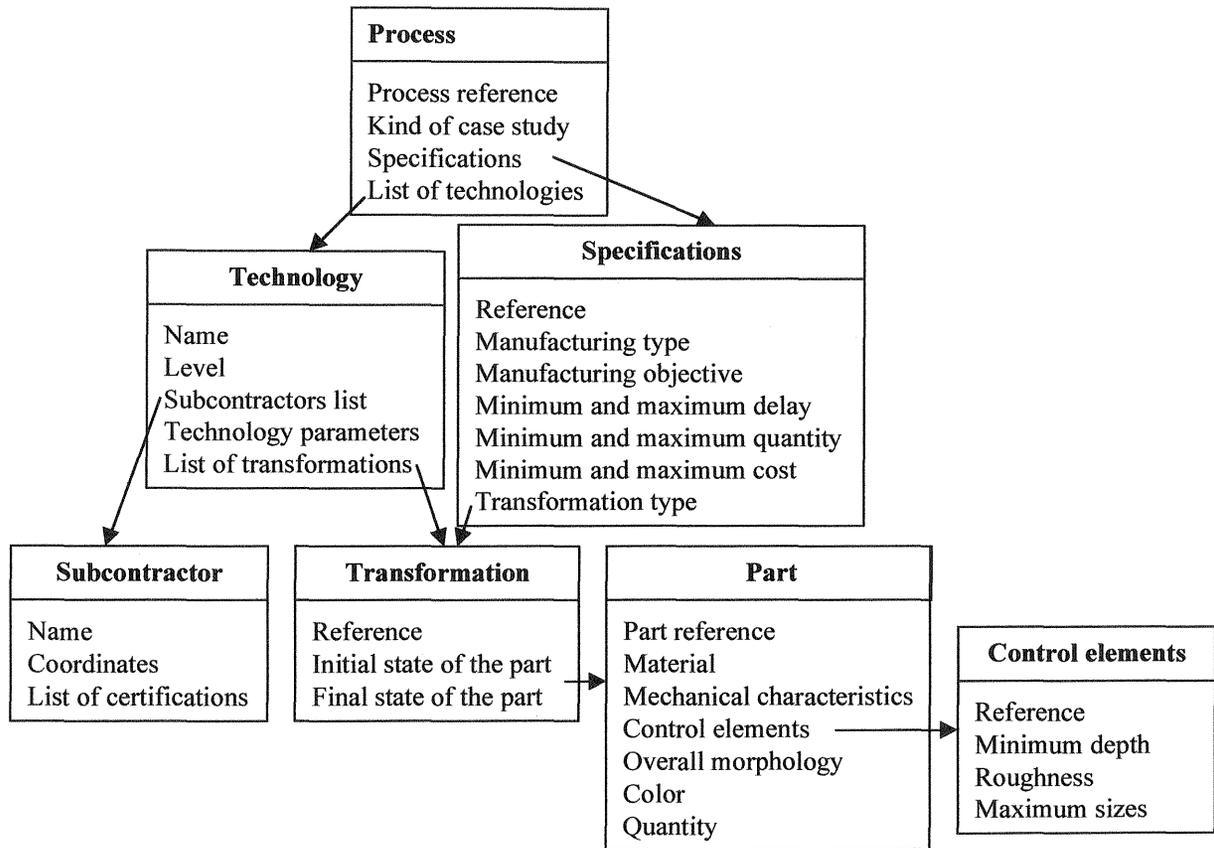


Figure 2. Some elements of semantic net

From a given specification, the system extracts the processes from the knowledge database. This is possible because each technology and each rapid product development process have also been individually modeled, with all their features and fundamentals. Thanks to this structure and based on conceptual models (figure 2), reasoning is computed in order to generate alternatives of rapid product development processes.

Because of the necessity of evolution, the proposed system has different functionalities in order to introduce knowledge elements based on the specifications corresponding to the different alternatives of rapid prototyping processes. Some of these functionalities have been integrated in the user module of the system.

The first one is the capability to specify the specifications of the part that has to be manufactured. This module is necessary in order to help the user to define his needs.

The second one is to select a process from the knowledge database. This is the basic functionality that allows the generation of all the different possible processes.

The third one is to generate all the processes, which correspond to the defined specifications.

The fourth one is necessary for the selection of the best process, with regards to the specifications constraints, as quality, aspect, cost, delay, reliability, etc...

The fifth one is to generate new processes when introducing new technologies. This functionality is based on the state notion. The idea is simple. A technology transforms a part from an initial state to a final state. The introduction of a new given technology consists in finding the other technologies, which deliver final states that correspond to the initial state of this given technology. It is also necessary to identify the technologies that need an initial state, which corresponds to the final state of this given technology. Consequently, the immediate consequence is the existence of new process alternatives.

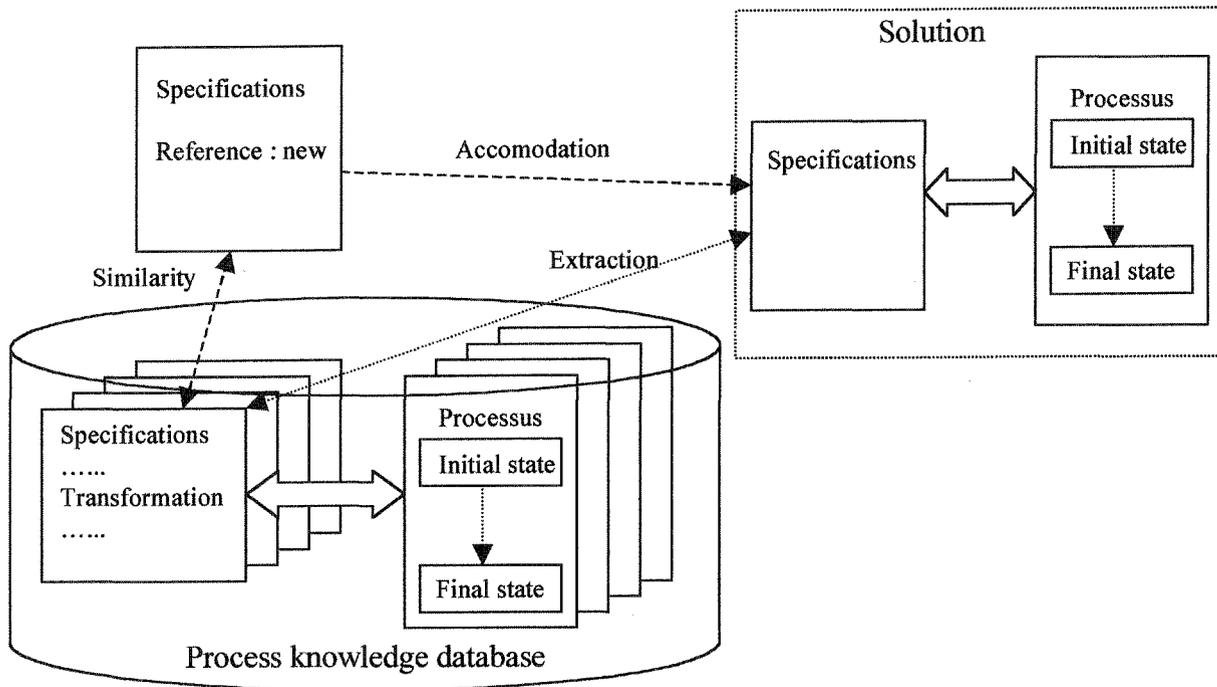


Figure 3. Extraction of a process from the knowledge database

4. EXPERIMENTATION

The experimentation module has been developed from the initial analysis work of A. Deglin (Deglin, 1998). This first approach was oriented to a graph representation of all the processes. Afterwards, V. Trousselard (Trousselard, 1999) tried to generalize this approach and began testing case-based reasoning approach (Pankakosky and al, 1998) instead of graph analysis. He also used a very specific approach specially dedicated to knowledge capitalization, from Kade-Tech company.

The present version of the environment is mainly dedicated to plastic parts. All the technologies and about eighty different processes have been modeled. The chosen compatible database is Oracle. Some industrial specifications have been entered for test in order to verify the efficiency of reasoning rules. The first results are very positive and the next version should take into account many other processes, especially for metallic parts and economical tools.

The current step of the work is the capitalization of all metallic part processes, and some complementary elements on plastic parts. Of course, due to new technologies and new needs, all technology evolutions are memorized and possible processes are extended, more especially for ceramics.

The system will also take into account specifications for tools instead of parts. Of course, tools processes are already integrated in global process generation for parts. In the figure 4, one should understand technology as one single technology (as stereolithography) or as a subprocess (a sequence of technologies, like stereolithography and vacuum casting).

Based on such approach, all the possible processes, which allow obtaining the final part from the initial model (part initial state), are selected and presented to the user. Then, the final step is the selection of the best process by taking into account mono or multi-criteria optimization. It is important to remind that each

technology represented in the database corresponds to an effective machine and company, with actual delays, costs, quality, etc...

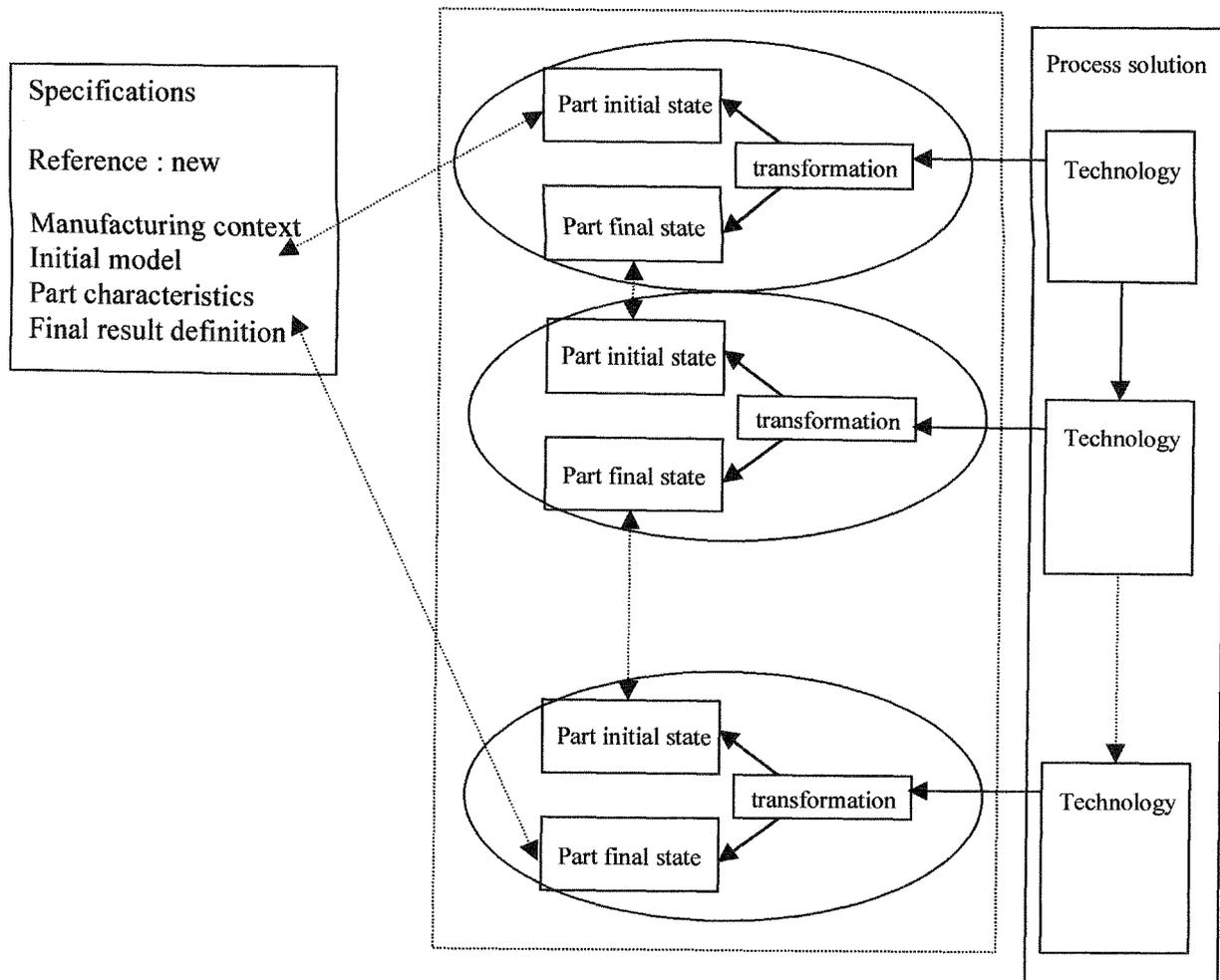


Figure 4. Elements of representation of the chosen process

5. CONCLUSION

The objective of the proposed knowledge-based environment is to capitalize knowledge and know-how on rapid product development processes (Bernard (coordinator), 1998). The first step is to model the state of the art, thanks to bibliography and to interviews of different experts (users, researchers, service bureaus, independent experts, etc...).

As mentioned before, such a system should be generalized for all the technologies used by a company and not only rapid prototyping processes. Before this project, the experience in CRAN laboratory was mainly oriented to computer-aided process planning for milling (2 ½, 3 and 5 axis), and the graph analysis algorithms have already been used. Case-based reasoning is being tested for rapid product development application. It is not sure that it will be the final choice for alternative process generation. During the next months, other approaches will be tested in order to optimize computing time.

Another important aspect will be the possibility to interface web sites of subcontractors and cost evaluation applications for all the modeled technologies, in order to be able to generate realistic costs and delays, for a given specifications. This will be proposed to different companies and service bureaus. The first operational version should be presented on July 2000.

6. ACKNOWLEDGEMENTS

The author would like to acknowledge different persons. T. Fouquerel (from Aérospatiale) for the industrial validation of the idea. The two students who work on this project, A. Deglin and V. Trousselard. The different experts (especially T. Deschamps from Resine Technologie and Y. Seeleuthner from Ateliers Cini) for their availability during the interviews. Finally, Kade-Tech company for their help in Kadviser (Knowledge based system) use.

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