DECISION SUPPORT SYSTEM IN RAPID PROTOTYPING TECHNOLOGY

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Abstract*: Article describes building a base system as a supporting tool in rapid prototyping (RP) technology. The main task of this system is a supporting in decision making of choosing right technology for build a prototype. The base system means a initial structure of system which contains a particular technical values for each RP process and used materials. The operator can use them for initial selection of technology which is the best choice for projected and generated CAM model. It is a base for further developing in this topic.*

Keywords*: Decision supporting, Rapid prototyping.*

ACM Classification Keywords*: A.0 General Literature - Conference proceedings, I. Computing Methodologies, I.2.1 Applications and Expert Systems, J. Computer Applications.*

Introduction

Rapid Prototyping technology is a part of the computer-aided design (CAD). It is usually associated with modelling of machine parts. It is commonly accepted to call this type of production – 3D printing. This name is associated with the method used in this process of the incremental construction of the designed detail.

Undoubtedly, it is one of the fastest methods of creating machine parts. Manufactured parts can be used in different ways. Models can have a demonstrative character and have the presentation role. They can also be fully functional elements of short batches of products used in greater mechanisms. Such manufacturing is expensive, hence this method is not used in the mass production.

The way of manufacturing the detail in a 3D printer is only based on the data included in the CAD file. The direct data file for the printer is the export called STL in the file. There are also used other formats of exports. Designed models are made with specific techniques and using materials described for the given method. Therefore, they have predetermined properties imposed by the manufacturing technology. The main advantage of the production of models using the RP technique is the possibility to omit the tedious stage of preparation of the detail production obtaining it directly after the design process. This allows the client to present the part, which he is interested in. The fact, which is also important, is that thanks to the development of the prototype it is possible to notice the construction errors at the machine design stage. In each of these cases we gain both time and money. Also the scientific aspect is also important involving the possibilities of the analysis of the implemented machine parts in terms of structure and durability. Studies on prototypes allow to determine the features of final items and technology, which will be optimal for the production of parts in the high volume production

Rapid Prototyping Technology (RP)

A set of methods for producing prototypes of machine parts connected with RP is very rich. However, it is possible to determine the classical division of technology taking into account both the material, from which the prototype is made, and the way of its use and binding. In [Budzik 2011] particular methods have been thoroughly characterised, from which the basis group is:

- **Stereolithography (SLA) -** that is hardening with laser the successive layers of liquid resin in accordance with the prototype model. Hardening takes place only in the particular place, hence high accuracy of this method.

- **Selective Laser Sintering (SLS) -** In this technique, successive layers of material are applied by the machine and then the laser hardens the selected points. Unhardened powder is then removed and a finished item is received. The process must take place in the vacuum.
- **Electron Beam Melting (EBM) -** The model production method using the electron beam melting metal powders. Each of the model layers is made by melting the next cross-section of the model according to data from the control file.
- **Laminated Object Manufacturing LOM -** is the creation of the model of thin paper layers, most often adhesive, forming layers of another plane creating the given prototype. Thus created forms are easily workable and machined and can serve as project verification – they do not have limitation regarding the complexity of the detail. They can serve as models for making forms.
- **Fused Deposition Modelling FDM -** Fused deposition modelling. It involves the placement of the model material by the head (e.g. ABS) according to successive horizontal sections based on the 3D model. The ready made design is practically ready for use after its creation.
- **Digital Light Processing 3D printing (DLP) -** It hardens the liquid polymer using the laser beam.
- **Three Dimensional Printing (3DP) -** This method uses powders: ceramic, polymer or metal. Powders are bonded with an adhesive, which connects them together layer by layer of the model. After creation, the model is subjected to annealing and next layers are connected together by forming, and as a result the adhesive disappears.
- **PolyJet -** The object is constructed on a special tray over which the moving heads (like in an inkjet printer) place the photopolymer. After each application, the UV rays harden the layer. Thus, there is no need to use the additional finishing of the model.

RP Decision Support System

The task of the decision support system in Rapid Prototyping is gathering the expert knowledge and using it in the selection of optimal technology to create the designed part based on the multi-criteria query of the operator. The complexity of the query depends on the references regarding the prototype. It concerns such basic parameters like: dimensions of the manufactured element, which determine the machine on which the given detail can be made as well as the material, from which it will be created. Classification also concerns more advanced requirements like the purpose of the prototype indicating the precision of mapping the details of the designed part or a complex as well as the features, like the physical-chemical properties extremely important in prototype research.

The basic classification concerning dimensions of the constructed objects and declarations of the material for the construction is made based on data included in technical descriptions. Technical specifications of machines introduced to the structure of the service database concern information both about the selection of machines compare the operator's requirements with the dimensions of the machine's working space. Each machine is at the same time associated with the group or family of materials related to the technology, in which the details are made. Hence the basic criterion is determined by dimensions of the objects indicates the range of available methods and determines the material. Designer of parts is therefore able to state at an early stage of design whether he is able to make the selected prototype according to the preferences. Technical data of materials used in RP and selected by the system indicate also the potential purpose of the created prototype as, e.g., the work part of the research subject [Sobolak Budzik 2008, Oleksy at al. 2010, Grzelka at al. 2012], or the review mock for the presentation [Budzik, 2011, Budz at al. 2013].

Precise classification, concerning the expert knowledge in the field of selection of RP techniques requires the possession of extensive information reaching beyond the framework of catalogue technical data. Response of the service to the detail query of the type: “with what method and what kind of material can we make the object characterised by the selected hardness, with holes with the selected diameter and carrying the determined loads” requires resorting to additional data obtained from research. Preliminary tests for particular RP technologies connected with the description of accuracy of the description, load characteristics and suitability for the manufactured prototypes are a must. Writing down the achieved results as information in the service in a way which enables the reference to them in the query requires the development of database with proper structure. This design is to provide not only the present use but is to become the good base for the further development of the system. The extended part of the service however is the future. The current state of the system of the RP support covers the basic catalogue data and on their basis the selections of machine lists.

RP Information Store

Database according to the rules, which determine the relational structures of data stores is divided into several basic sets. This structure is created by tables defining the information of the elementary nature. The system of tables is presented n fig.1.

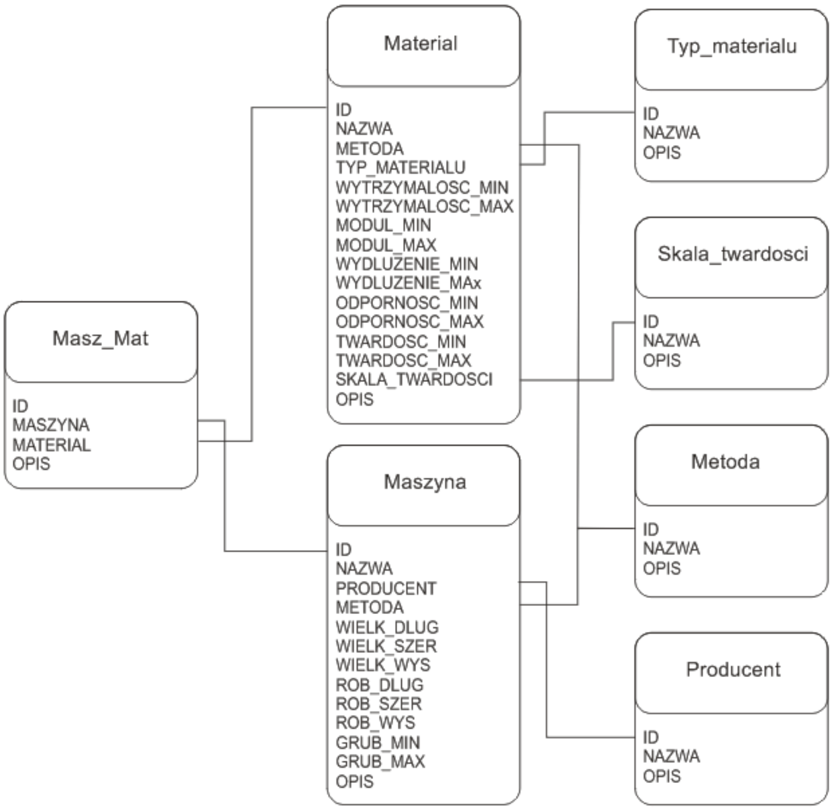

Figure 1. The system of tables in the RP support system

Basic dictionary data are included in the tables Material_type, Harndness_scale, Method and Manufacturer. They contain information which are the complement of the fields of the main selection forms for the service. Main forms supplement the Material and Machine tables with necessary data. They are main containers of data with the characteristic of the material and the machine. Data in both tables are described by the method in order to clarify the information included in them.

The transaction table and at the same time the element binding all collected data is the Masz_Mat. It includes the compositions of the Machine and Material on the basis of sets. Data included in it are used by the form of the main query in the service.

Characteristics of data in the table Material in addition to classification for the method of a particular material also concerns the numerical limit values within the scope of:

- material strength in [MPa],
- Young elastic module [MPa],
- elongation [%],
- resistance to impact [J/m2],
- hardness – as an extension there was provided the hardness scale.

Characteristics of Machines described in the service concerns, as in the case of materials, the determination of the RP method and manufacturer, as well as the numerical limit values in the scope of:

- Dimensions of the machine: length, width and height.
- Dimensions of the workplace: length, width and height.
- Limit values connected with the accuracy of the detail performance.

It should be noted that for particular machines the accuracy of the prototype performance depends on the adopted material and the next layer of reproduction, which is connected with the RP technology. In other words, it can be assumed that the used material determines the accuracy of the performance and the machine placing next layers builds the appropriately detailed prototype. Of course, at this stage of design, in CAD programs there are defined the details of the prototype and its accurate dimensions, however the finally adopted RP method allows to map the construction of the detail in the appropriate way and possible to achieve in reality (characteristic for the technology of prototype creation). This is of particular importance in case of details with a complex structure, and especially in case of such, in which there can be observed holes as elements of cooperation with other details, e.g., sliding bearing. In case of making prototypes with the purpose of review models it does not matter, however the cooperation of imprecisely made details manifests itself in the form of, e.g., vibrations. In case of prototypes which are the useful parts of machines, the quality of performance is definitely important and influences the resulting nature of the detail classifying it directly for use or the finishing. This gives it the final dimensions and the form compatible with the CAD design.

The Query of the RP Support Service

The possibility to use the collected information in the service database is the basic task of the RP support system. It essentially contains the core idea of the system. Complete data placed in tables and organised in the above-mentioned way allow to filter data placed in the form of the basic query. Here we use the classic approach of selection using the conditional instructions if…else…

The query determines such basic data like dimensions of the designed detail, which initially estimate the list of machines, which meet the requirements of the designer. At this stage it is possible to decide also what kind of material will be used for "printing" of the object. This is the basic stage, in which the query defines the criteria regarding the Machine table. In case of the determination of the Material field, the query is expanded also with the Material table. Fields of the form of the basic query within dimensions are required.

The next stage for the system is the precision of properties of requirements concerning the physical properties of the detail. This concerns the arrangement of details regarding the resistance of the parts to loads, its elastic module, elongation, resistance to impacts and hardness. These are the features of the material of which the prototype will be built and they correspond to entries to the Material table.

In case of the absence of numerical values in the form fields of the second part – "advanced" – no criteria regarding the material requirements are determined.

Supplementing the above-described steps results in the list of machines, on which there can be performed the designed part or detail. The list of proposals contains links to the models selected by the system, which are the photographic examples of what the parts manufactured in the selected technology look like.

The Evolution of the System

The above-described scenarios concerns the basic form of decision support in the RP process.

The current activity of the system consists of the catalogue data, which are given by the material and machine manufacturers. These are real data, but their theoretical nature allows only the simple qualification of machines and materials in the design.

The evolution of the system assumes the empirical approach to the mentioned classification and basing the conclusions about the selection of RP technologies on the laboratory data. This type of task requires the use of a fairly complex approach to the problem because the characteristics of details made in RP is extremely difficult. The spectrum of parts obtained thanks to 3D printing is basically unlimited, however, the requirements posed to them are connected with specific needs. These depend on properties of the material selected for the product.

Conclusion

The currently performed system is the output element for further works within the RP decision support. It serves as the dictionary base for embedding empirical data, which in the further stage of the analysis of the RP process will be acquired through experiences. The system will be developed so that in the final form it will allow the most precise mapping of the needs of the operator designing the product into a prototype made with the right technology.

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