

The IRIS Rapid Prototyping System Selector for Educational and Manufacturing Users*

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The development of a number of different rapid prototyping (RP) technologies with wide-ranging capabilities, features and applications has created a problem of selecting an appropriate RP system for engineering educational institutions as well as manufacturing organisations intending to adopt this new technology. This paper presents an IRIS Rapid Prototyping System Selector (IRPS) for selection of a rapid prototyping system from among a wide range of RP systems commercially available from the RP manufacturers worldwide. The search routines give access to a large database built on entity relationship techniques to enable fast retrieval of information. The system is designed to be user-friendly, flexible and expandable, and can also be used as an educational tool for RP systems education due to its large information base on each specific RP machine.

INTRODUCTION

RAPID PROTOTYPING (RP) is a new group of manufacturing processes which allows fabrication of physical prototypes of any complexity using a layer-by-layer deposition technique directly from a computer-aided design model without any conventional requirements of process planning, tooling or numerical control programming. The rapid prototyping process greatly reduces the time and cost necessary to bring a new product to market. The prototypes made by these systems are used in a range of industrial applications including design evaluation, verification, testing, and as patterns for casting processes. Rapid prototyping technologies first emerged in 1987 with the advent of Stereolithography, the first commercial RP system, marketed by 3D Systems. Since then, several other companies have joined the market selling different types of rapid prototyping processes. These processes employ a variety of materials and mechanisms to build up the layers to build the part [1, 2]. Engineering educational institutions offering courses in mechanical, manufacturing and materials engineering are introducing this new technology into their engineering curriculum and providing experience and training to their students in this multi-faceted technology.

With the growing proliferation of rapid prototyping (RP) technology, the selection of an appropriate rapid prototyping system is becoming an increasingly difficult task for engineering institutions as well as manufacturing organisations intending to adopt the technology to serve their

specific needs. The choice of a rapid prototyping system depends on a number of factors or selection criteria such as price, accuracy, build envelope, build material, build speed, surface finish and end applications. At present there are around 22 RP vendors around the world, marketing nearly 60 RP systems, with each system having its own strengths, limitations and applications [3]. The selection process is further complicated by a general shortage of benchmark standards and industry experience with most of these systems. Moreover, newer RP systems are regularly appearing on the market.

Recent efforts in the direction of selecting an RP system has been directed to the development of computer-based selector programs. These are aimed at assisting the potential purchaser to select the right RP system to suit the particular needs [2-4]. This normally involves the user providing answers to specific questions or entering the required data. Recommendations and suggestions are displayed on the screen at the end of the program. This provides a quick and interactive way to get a result, rather than reading reports on benchmarking studies and comparing tables and graphs of different systems.

Hornberger *et al.* [4] developed the Rapid Prototyping Program at Santa Clara University in 1993, which was perhaps the first attempt to develop a computer-based program in assisting the selection of an RP system. The program serves as an educational tool to provide general information on RP processes. The program mainly includes RP systems available in 1993, namely, 3D Systems' Stereolithography, Stratasys' 3D Modeler, Cubital's Solider 5600, and Light Sculpting Inc.'s LSI systems. Hans Muller *et al.* [5] at

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Bremen Institute of Industrial Technology and Applied Work Science (BIBA) developed the Rapid Prototyping System Selector in 1995. This program uses the relational database management system MS Access and it can be seen on the BIBA website. This selector program was not aimed at selecting a commercial RP system based on specific selection criteria, but its purpose was to select the best combination of factors like part features (solid, hollow, thin-walled, etc.) and RP processes to fabricate a physical prototype. Darrell Phillipson [6] of Arizona State University developed RP Adviser as part of his Master's thesis in 1996. This program also uses MS Access, and includes six RP systems available from 3D Systems, Stratasys, Helisys, DTM, Schroff Corporation, and Sanders Prototype. The RP Adviser was benchmarked against the Santa Clara University's Rapid Prototyping Program, using the Japanese methodology Quality Function Deployment (QFD), to compare the two selector programs.

This paper presents a Windows-based rapid prototyping selector system developed at Industrial Research Institute Swinburne (IRIS) for the selection of a rapid prototyping system from all the commercial RP systems manufactured in the USA and other countries. The system, called IRIS Rapid Prototyping System Selector (IRPS), is designed to assist novices as well as experienced RP users to quickly select the most appropriate RP system to suit their requirements. The program is also designed to serve as an educational tool in mechanical and manufacturing engineering schools for learning the features and capabilities of all RP systems in a user-friendly interactive style. The program incorporates 57 RP machines from 22 RP vendors available up until December 1999 from the major RP vendors in the USA, Japan, Germany, China, Israel and Singapore. The program allows the user to choose any of the four options, namely *quick selection*, *detailed selection*, *build technology*, and *machine style*, to select the RP system. The system displays the full

specifications of the recommended RP system. The program is designed to be open-ended and can easily incorporate future RP systems.

DEVELOPMENT OF IRPS SYSTEM

The IRIS Rapid Prototyping System Selector (IRPS) is a stand-alone system which accepts user inputs and commands and produces a search report detailing the most appropriate RP systems based on its search mechanisms. The environment variables, which deal with the system, include the database, where all data is stored, and the user, where operational commands are obtained. The system also interacts with a word processor to produce the final report. The IRPS has strong links with the operating system and uses all Application Interface (API) functionality to communicate with other tasks in the system.

The context diagram of the IRPS is shown in Fig. 1, which shows the environment interactions with the system. The system uses an event-driven design based on object-oriented design methodology. The figure shows that the initiating event of the system always comes from the user by initiating a query or a search for an RP system. The database module shown external to the system is an off-line database that is accessed by the system. This database holds all the relevant data the system needs to answer a search.

More details of the IRPS modules are shown in a Data Flow Diagram (DFD) in Fig. 2. Note that, in the diagram, the dotted lines represent control commands and the solid lines represent data transactions. All processes are represented in elliptic shapes.

Figure 2 shows that the system consists of three main modules: Graphical User Interface (GUI), Report Generator and Search module. A series of command and data transactions occur between these modules to produce the final search results. The database used by the IRPS is a standalone

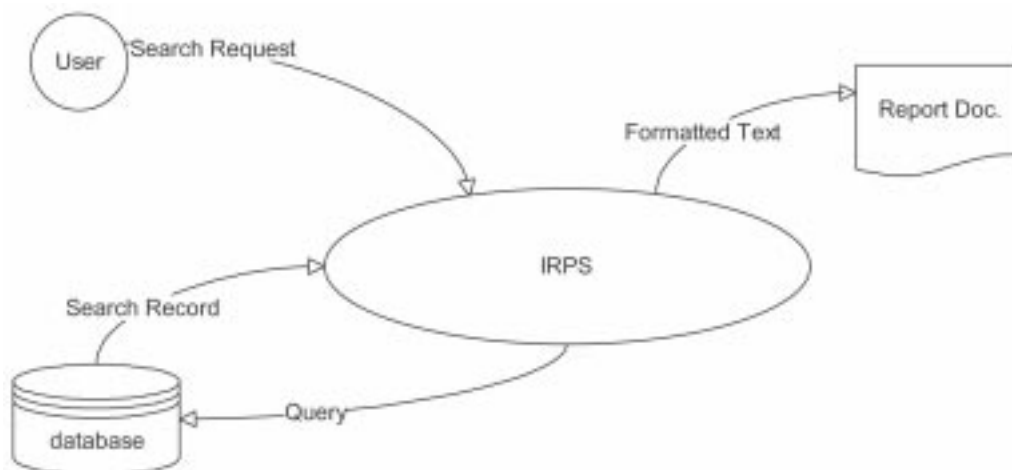


Fig. 1. IRPS Context diagram.

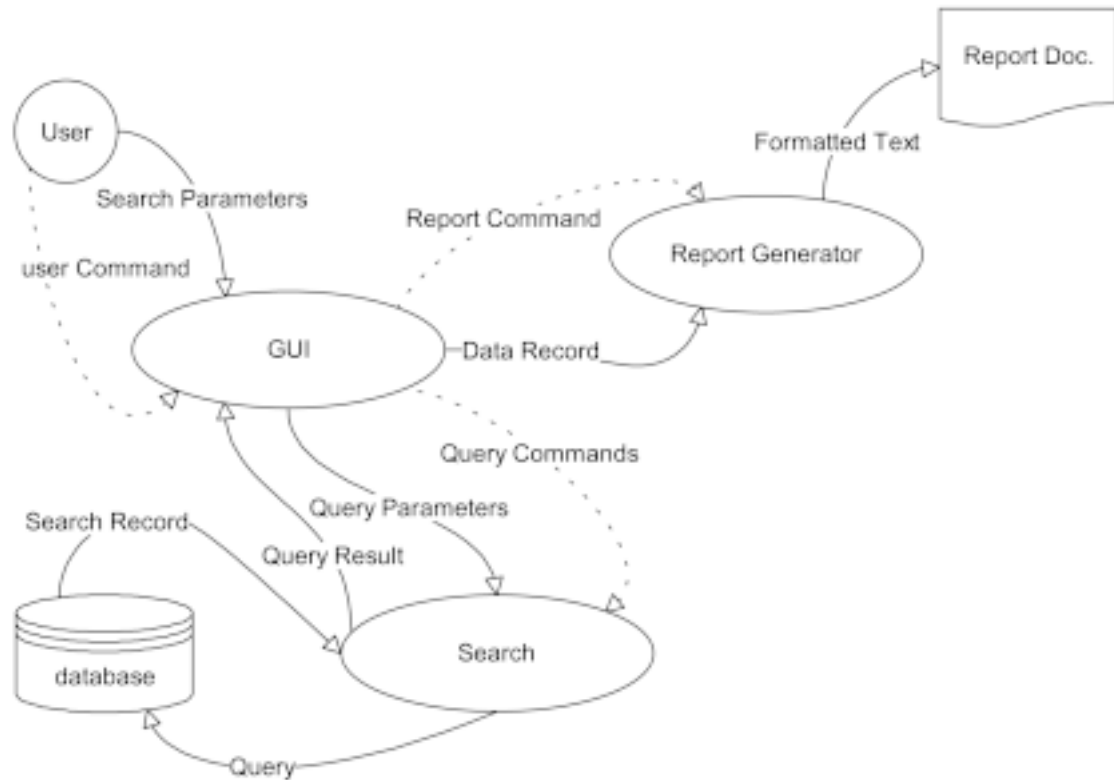


Fig. 2. Level 1 DFD of modules of IRPS.

software package. However, it is still considered as a separate module from the point of view of software design. The database stores the information required for the system in an easy-to-process and accessible format. A full database module design was developed identifying all entities and the relation between them.

Database module

The IRPS system's database contains data for more than 50 different commercially available RP systems. A significant effort was needed to compile this database from different sources such as IRIS Intelligent RP System Selector, World Wide Web, manufacturer brochures and catalogues, direct contact with manufacturers and Rapid Prototyping & Tooling State of the Industry Reports, produced by Wohler's Associates.

The initial large pool of data collected was classified into three main groups for the use of the IRPS:

- Database containing technical information about RP machines. This database is the one accessed by the IRPS system search engines and is always subject to continuous updates. MS Access was used as the platform to utilise this data class.
- General vendors information. This class of data is useful for further investigation regarding a vendor and the type of product supported by that firm. This information was hosted by MS

word and utilised in the final report generated by the IRPS.

- Miscellaneous data. These are in the form of images and statistical data utilised in different parts of the IRPS, i.e. report generation, results display and statistical charts.

The first class of data, the database hosted by MS Access, is the most critical part of the database utilised by the system and its search engine to produce the needed recommendation about RP systems according to certain criteria using this data. MS Access was selected because it offers many advantages and features, such as easy availability and ease of use, which made it the most suitable database application for the IRPS. Some of these include:

The database was tabulated into seven different tables with primary keys linking these tables with each other. The database structure was designed so as to simplify the search mechanism and to provide better upgrading and usability of the system database. Figure 3 shows the relational tables used by the system. The software is represented in a relational database model. This model was chosen to accommodate any changes and enhancements that arise in the future, so that different tables and modules could be added into the system without affecting the core of the software.

In the RP_Machine table in Fig. 3, the primary key, machine_key, is used to relate this table with one to many relationships with the junction table Laser/Non-Laser table and one to many

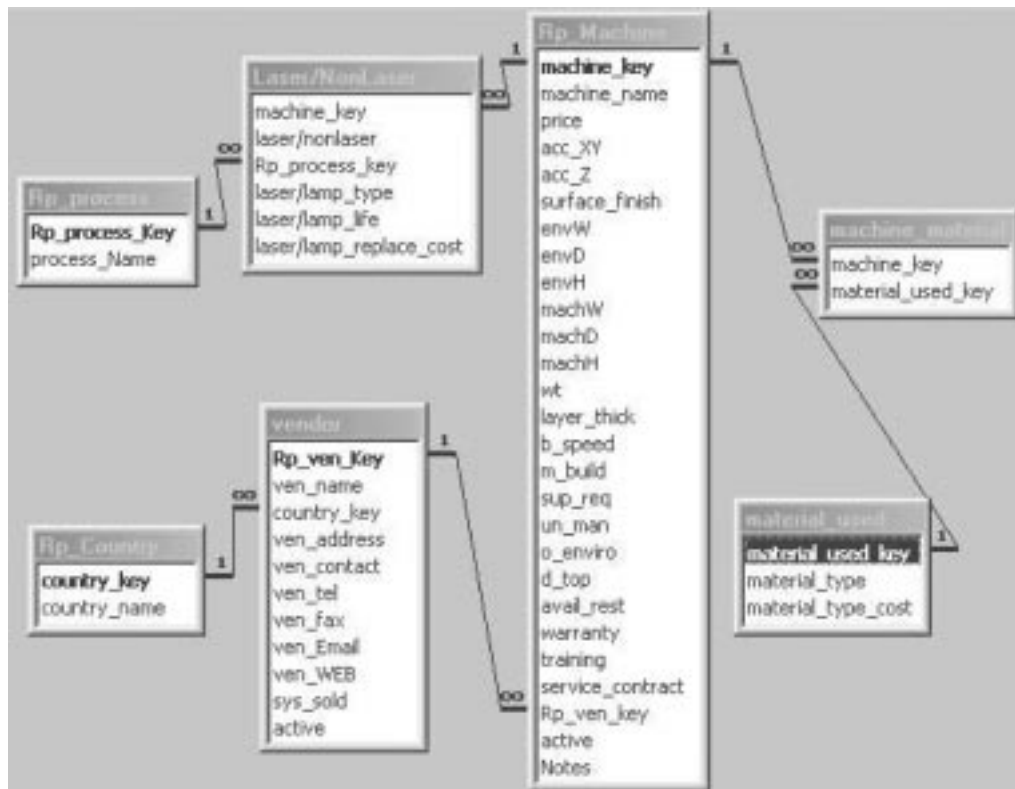


Fig. 3. Entity relationship.

relationships with the junction table machine_material table. The vendor key, Rp_ven_key, is used to relate this table with many to one relationship with the vendor table. The primary key, material_used_key, is used to relate the Material-Used table with one to many relationships with the machine_material junction table. In the Rp-Country table, the primary key, country_key, is used to relate this table with one to many relationships with the vendor table. The primary key, Rp_process_key in the RP_Process table, is used to relate this table with one to many relationships with the Laser/Non-Laser table. The relationships between these tables clearly represent the amount of flexibility that are reflected through these relationships. This flexibility allows future enhancements to the software to be made easily with minimal changes to the core of the system.

All fields represented in the database can be updated without affecting the functionality of the IRPS, providing that no tables are deleted, no relations are disabled, and no changes are made to any of fields name in any table. Therefore, a database specialist who understands the integrity of the overall entity relationship of the system should carry out the updating process.

New RP systems can be added and existing RP systems can be removed from the database. To remove a system from the database, the database administrator can either completely delete (not recommended) that system or deactivate it. Activation or deactivation of a record can be done using

the 'active' in the Rp_Machine table. This option is very helpful if the administrator chooses not to show one system in the IRPS program without deleting that system's record.

SEARCH ENGINE

Criteria of search

Generally, the entity relation between the data categories offers a search into four main methods, quick search, detailed selection, build technology and machine style. These methods were chosen to simplify the search, from the user and the system perspectives, and to give more informative guidelines to the user.

The different factors used in the search implement different mechanisms. Some of the data used in the search criteria are dynamically linked to each other, so that only valid data will be used. The relation between these valid inputs is controlled via some Structured Query Language (SQL) scripts, which manipulate the database for this purpose. The user can selectively enter other information. This dynamic relation assignment gives the system better upgradability over other existing systems.

Search parameters

The IRPS utilises many parameters in order to generate professional suggestions for a potential RP buyer. These parameters were identified as the

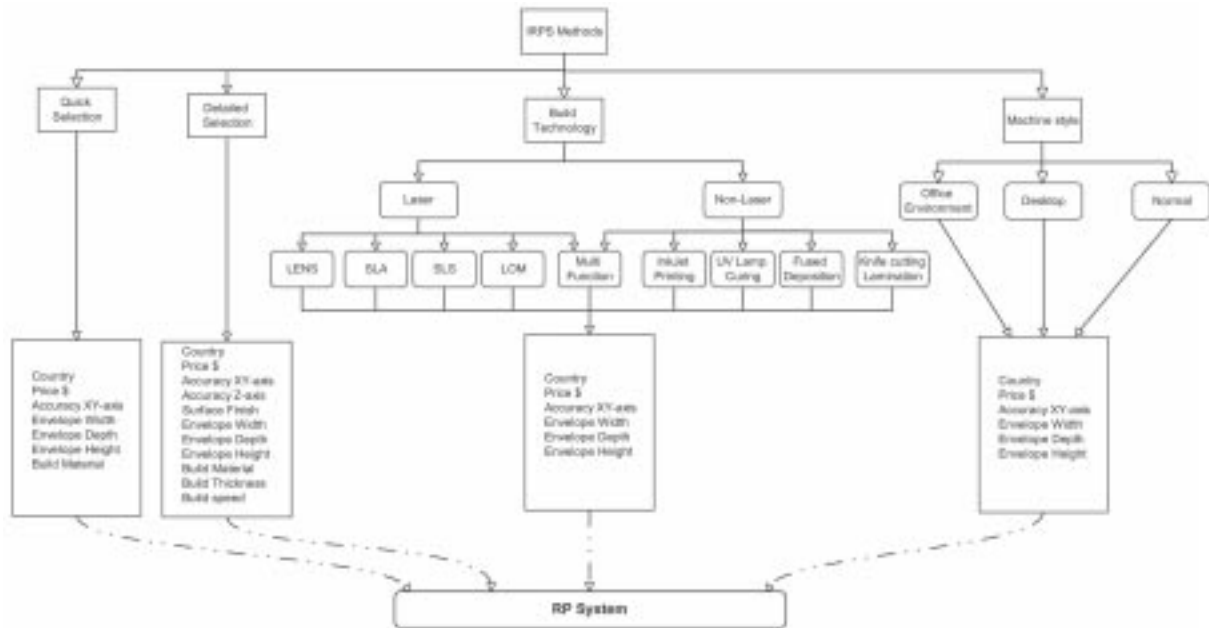


Fig. 4. Search hierarchy.

main factors that can affect the selection of one RP system over another.

- *RP system country of origin.* The IRPS database covers systems from the USA, Japan, Germany, Israel, China and Singapore.
- *The price, in US dollars, which the customer is ready to pay for the RP system.* This also gives an indication of features, build envelope size and complexity of the RP system. The IRPS database includes systems with price ranges starting from US\$10,000.
- *The XY-axis accuracy achieved by certain systems, in millimetres (mm).* The XY-axis accuracy is based on the working envelope dimension and depends on operator experience, skills and other operating factors. The IRPS includes systems starting from as small as 0.05 mm in XY accuracy.
- *The Z-axis accuracy achieved or required by certain systems, in millimetres (mm).* The Z-axis accuracy is based on the working envelope dimensions and depends on operator experience, skills and other operating factors. The IRPS includes systems from as small as 0.05 mm in Z-axis accuracy.
- *The depth of the working envelope, in millimetres.* The IRPS database includes RP systems that range from 100 to 800 mm in envelope depth.
- *The height of the working envelope, in millimetres.* The IRPS database includes RP systems that range from 61 to 700 mm in envelope height.
- *The width of the working envelope, in millimetres.* The IRPS database includes RP systems that range from 100 to 1600 mm in envelope width.
- *The build material used by the RP system to produce parts.* Some RP systems only use proprietary build material. For instance, the RP machine Actua 2100 uses thermoplastics and Actua Sanders ModelMakerII uses Thermoplastic-Modelmaker2. When the user clicks the combo box down arrow, a list of build material for all the systems manufactured by the selected country will be displayed. The build material selection and the country selection are linked, which is why it is highly recommended to select the country first. If the user is uncertain of what value to choose, he/she should select 'Any', which means any available material. This option is available in Quick Selection and Detailed Selection Methods only.
- *The surface finish, which is affected by the post processing finish and build material.* The higher the surface finish, the less work the RP machine should have to do. The surface finish is measured in units of microns. The IRPS database includes systems with surface finish values ranging from 5 to 30 microns.
- *Typical build layer thickness (mm).* Smaller thickness produces a smoother surface but increases build time. The IRPS database includes systems with build thickness ranging from 0.025 to 1 mm.
- *The build speed in cm^3/hour .* This indicates the RP machine ability to cure, sinter, laminate or deposit materials and does not represent build time, which depends on many factors. The IRPS database includes systems of build speeds ranging from 8 to 1575 cm^3/hour .
- *The technology group used by the machine.* The IRPS database includes systems from two technology groups, Laser and Non-Laser. The technology group criteria is dependent on the country of origin. Some countries have only one type, while others may have both

technologies. The build technology group is used only in Build Technology Method.

- *The build process.* This depends upon the technology group and the country selected, so it is highly recommended to choose the country first, followed by the technology group, then the build process.
- *The machine style, which is a country-dependent criteria.* The IRPS database includes systems with Desktop, Office Environment and Normal machine styles. This criteria is only used in the Machine Style Method.

The search engine, according to the search method used, utilises some or all of these parameters. Some methods use less parameters than others and enable a fast search to happen, especially for those expert users who can limit their search to a specific domain. Other methods utilise the full range of parameters for a more accurate and comprehensive search. The hierarchy of the search engine is shown in the flow diagram in Fig. 4.

Search methods

The program provides the user with the option of the following four major methods of selection (Fig. 4): Quick Selection, Detailed Selection, Build Technology and Machine Style.

The *Quick Selection* option selects a system quickly on the basis of price, accuracy in XY-axis, working envelope dimensions and build material.

The *Detailed Selection* option selects a system on the basis of price, accuracy in XY-axis, accuracy in Z-axis, surface finish, working envelope dimensions, build material, build thickness and build speed.

The *Build Technology* option further provides selection on the basis of a Laser or Non-Laser system and specific building process, and then uses the selection criteria of price, accuracy in XY-axis and working envelope dimensions. The options for RP systems with laser-based build technology include Stereolithography (SLA), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM) and Laser Engineering Net Shaping (LENS). The options for RP systems with non-laser based build technology include ink jet printing, UV lamp curing or Slid Ground Curing (SGC), Fused Deposition Modelling (FDM) and knife-cutting lamination. There is also a multi-functional RP system (M-RPMS-II system from China), which offers a combination of laser- and non-laser-based technologies.

The *Machine Style* option includes selection according to whether the RP system is to be of office environment type, desktop type or normal commercial type, and then selects on the same criteria as for the build technology option. The office environment type refers to RP systems which are designed to be used in a design office, the desktop type refers to the small-size portable RP machines which can be mounted on a table.

Search module

The functionality of the search engine in the IRPS includes two main issues: to validate critical user entries and to find suitable RP systems according to user entries. The search rule, in validating the user entries, starts immediately after an entry is made. When the user selects a country from the country list, the search engine immediately performs a search on the database to build the suitable build material selection list. This is performed to reduce the chances of wrong or non-compatible search entries. The search engine also performs the task of finding the appropriate RP system according to the user inputs. It does this by accessing the database tables and cross-referencing the entries with fields in the tables. The search engine in the IRPS, in order to access the database stored in Microsoft access format, uses SQL statements. All tables are linked with foreign and primary keys that help retrieve information from a table according to an entry from another. Once all the data required are ready, the responses are then sent back to the GUI routines to format the display and for further processing by the user. The search engine is also linked to the general help and error protection utilities supported by the IRPS. If an error occurs or data corruption of any kind is detected, an error message will be displayed.

Reports generator module

The user activates this module after having a valid search outcome. The user may choose to produce a full document of the search result. The report generation module utilises the window environment and API functions to format the search results into an MS word format. The module also includes functionality to retrieve a vendor template and RP system images to incorporate them into the final document. Factors such as windows set-up and MS office options can affect the performance of this module. If any incompatibility is detected, the IRPS system will generate an error message advising the user of the reason and suggested solutions.

Graphical user interface

All user interaction with the IRPS happens via the GUI module, which is linked to all other modules in the system. The IRPS utilises the full power of a windows-based application system in its graphical user interface design. The IRPS GUI is used for the system's interactions with the user. GUI is used for data entry, search method selection, results display and report display. The search method windows, where the user is able to enter the search parameters, perform the IRPS system data entry and selection functions. These data entry modules are linked to the IRPS database, where search parameters might be verified with the database entries. The results window is used to display all information related to a particular search result. The result window will provide

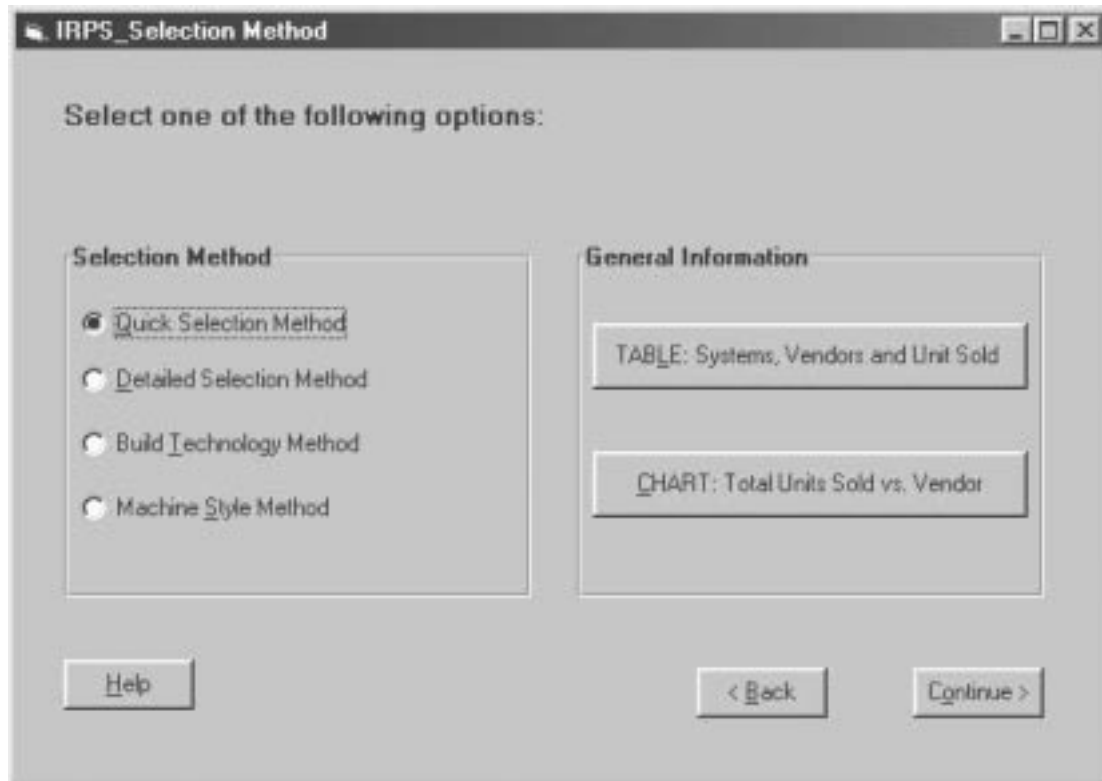


Fig. 5. IRPS method selection window.

the user with easy-to-access screen display of the selected RP systems. Full reports can be displayed using the linking facilities provided by the GUI to MS word application. The document will be formatted and presented to the user in an editable format. Both the keyboard and mouse pointer and clicks can be used to activate different options on the GUI.

RUNNING THE PROGRAM

The IRPS system is designed to run a Pentium-based PC running on a Windows 95/98 operating system with Microsoft Word 8 or MS Office 97. The minimum RAM required is 16MB and a hard drive space of 20 MB is recommended. Once the system is started, after the initial introductory window, the method selection window appears, as shown in Fig. 5. The window gives the user the option of selecting any of the four selection method or access to general information about any RP system.

The general information frame provides the user with two options: 'TABLE' for the vendors' listing of RP systems, and 'CHART' for statistical information on the number of units sold worldwide. Clicking on TABLE will show a table displaying the RP systems along with vendors' names and the number of RP systems sold up until December 1998. Clicking on CHART will show a chart of the total RP units sold by each vendor. The chart gives the reader an idea as to which systems are the

market leaders in the RP industry. This general information will provide an overall picture of the RP market to the potential user and will help make a more informal decision on the RP system selection. This information is based on the Wohler's Report [3].

We will illustrate the running of the program by detailed discussion on the Quick Selection Method. The detailed procedures of other three selection methods are much more elaborate and can be found in Al-Alawi [7].

The Quick Selection Method

The Quick Selection Method starts with the input data window shown in Fig. 6. When the user selects this option in the selection window (Fig. 5), the program runs the SQL (Structured Query Language) statement automatically to select the available countries in the table Rp_Country and add an All Countries statement to the list. The purpose of running the SQL is to force the user to select the country first, as the build technology depends on the country selected. Then the user has to select the price, accuracy in X and Y directions, and work envelope dimensions from the list available or by typing in the proper value. These are not selected from the database, as most of them have different ranges to cover all the RP machines/systems available. Other reasons are to reduce the load on the program by running so many SQLs and also to give the user a wide range to select from instead of only one value or two.

The screenshot shows a software window titled "IRPS_Quick Selection". Inside the window, there is a section titled "QUICK SELECTION METHOD". Below this title, there are seven rows, each with a label and a dropdown menu. The labels are: "Country:", "Price (US\$):", "Accuracy XY (mm):", "Envelope Width (mm):", "Envelope Depth (mm):", "Envelope Height (mm):", and "Build Material:". The dropdown menus contain the following text: "Select Country", "Select Price in US\$", "Select Accuracy XY-axis", "Select Envelope Width", "Select Envelope Depth", "Select Envelope Height", and "Select Material Type Used". At the bottom of the window, there are four buttons: "Help", "Exit", "< Back", and "Run".

Fig. 6. Quick Selection Method input window.

Once the user clicks the Build Material combo box then another SQL is run to select all build materials available for the selected country. If the user selects 'All Countries', the 'Build Material' will show all the build materials available in the database. As soon the user clicks the Run button, the main SQL statement is activated to select the available system or systems and its properties from all the tables available in the database. If there is no RP system available to satisfy the selected parameters, a message will appear showing that no result is available and the user will be asked to return to modify the selection parameters or exit the program.

The quick selection window, as shown in Fig. 6, requires the user to fill in the following fields:

- *Country*. This field refers to the country of origin of the intended RP machine. Extra care should be taken in this field because it affects other fields, i.e. Build Material.
- *Price (US\$)*. The price is an indication of features, build envelope size and complexity of the machine. The user can either manually enter a price or select a range from the three predetermined options in the combo box list. There are three pre determined price ranges in the field list: less than 100,000 ('< 100,000'), 'between 100,000 and 400,000', more than 400,000 ('> 400,000'), and 'ANY'. ANY means the price criteria are not included in this selection. All prices are in US dollars.
- *Accuracy XY (mm)*. The RP machine accuracy

in X and Y directions. This is based on the maximum working envelope dimension, and often depends on operator experience, skills and other operating factors. The user can either manually enter an accuracy range from 0 to 3 mm or select from the default list ranges in the combo box. The default ranges are: less than 0.15 mm ('< 0.15'), 'between 0.15 and 0.25', greater than 0.25 ('> 0.25') and 'ANY'. ANY means that the accuracy at XY-axis criterion is not included in this selection. All values are in millimetres.

- *Envelope width (mm)*. This refers to the working envelope width dimensions. A larger value is desirable but it may increase the machine cost. The user can either manually enter the width range from 0 to 3000 mm or select from the default values in the combo box list. The default values are: less than 250 ('< 250'), 'between 250 and 400', greater than 400 ('> 400') and 'ANY'. ANY means that the envelope width criteria are not included in this selection. All values are in millimetres.
- *Envelope depth (mm)*. This refers to the working envelope depth dimensions. Larger is desirable, but it increases the machine cost. The user can either manually enter the depth range from 0 to 3000 mm or select from the default values in the combo box list. The default values are: less than 250 ('< 250'), 'between 250 and 400', greater than 400 ('> 400') and 'ANY'. ANY means that the envelope depth criteria are not included in this selection. All values are in millimetres.

Fig. 7. Selecting the parameters.

- *Envelope height (mm)*. This refers to the working envelope height dimension. Larger is desirable but increases the machine cost. The user can either manually enter the height range from 0 to 3000 mm or select from the default values in the combo box list. The default values are: less than 250 ('< 250'), 'between 250 and 400', greater than 400 ('> 400') and 'ANY'. ANY means that the envelope height criteria are not included in this selection. All values are in millimetres.
- *Build material*. This refers to the build material used by the desired machine. Some machines can only use proprietary build material. This field is dependent upon the country of origin of the machine. The user will be provided with a list of all the build material (All Build material) available in the selected country to choose from. Also, the user can select ANY from the list to exclude the build material from the selection criteria.

Figure 7 shows an example of the input window after selecting the appropriate parameters in the Quick Selection Method.

Having entered all the search criteria, the system will automatically implement the criteria. The result screen will display the details of the selection results. Figure 8 shows that the selection criteria resulted in six systems that meet the criteria specified by the user as shown in Fig. 7. Clicking the arrow bar at the bottom of the screen will display the picture and the details of each of the six

recommended RP systems one by one. Pressing the Show Report button will start the formatting of the report. The report will be formatted as a word document. The report starts with a list of the selection parameters used and the values used in the fields, and gives a full description of the RP system selected by the user from the list of systems recommended by the IRPS system.

FEATURES OF THE IRPS SYSTEM

Knowledge base range

The IRPS covers all available RP systems in the market up to December 1999. There are more than 56 different systems included in the database from more than six countries. The database holds all possible details of each particular system, details of manufacturers, vendors, material type and all technical features. The database also includes a close estimate of the cost in dollars of each RP system. In other words, the database contains all possible information required by the user to select the appropriate RP machine within the budget range assigned. This feature gives the IRPS the potential to be a very successful commercial tool.

Search methods

The IRPS incorporates detailed search methods covering different criteria. The IRPS has the potential to be useful for people ranging from

Fig. 8. The Quick Selection Result window.

students to engineers, including the executives who need to make the final commercial decision to buy an RP system. The four different search methods follow a very simplified algorithm, which relies on the concepts of an entity relationship database. This utilisation of modern database concepts enables the IRPS to produce the correct results without extensive calculations.

Reusability

The IRPS was developed using the modern concept of object-oriented design recently implemented in most advanced software packages. The IRPS is a set of individual modules integrated with each other using clearly defined data transactions. This construction makes the IRPS modules easy to adapt for any further development of the systems without needing to rebuild it from the beginning. This can be achieved by incorporating as many basic routines as required into the new system. This advantage is missing in most available RP selection systems, as most of them were designed to serve a particular purpose and were developed on the basis of limited technologies.

Upgradability

The IRPS is very easy to upgrade. As in the case of most RP selection systems, the critical part of the upgradability is the database upgrading. The IRPS utilises the power of Microsoft access, which is the most commercially used database system for medium and small databases. The IRPS can access an MS Access file and retrieve the required information. Thus, to upgrade the database, the only

requirement is to edit the MS Access file. New RP systems can be added and old systems can be removed from the database as required. The specific fields' data can also be modified with ease. This upgradability feature and the utilisation of MS Access give the IRPS the advantage over other systems and provide a more appealing feature to use on a continual basis. Moreover, the modular concept used in the IRPS allows the IRPS to be modified to include new information or to perform some functions differently. Moreover, modification to some modules can be isolated without affecting other modules.

User-friendliness

The IRPS is an interactive, user-friendly RP selection program. It requires minimal computer literacy to run. It is very simple to install and operate and has many advantages. It also protects the user from making mistakes, to a certain extent. The system is equipped with very reasonable error detection and data validation routines that will prompt the user whenever any unaccepted set of data is passed to the system. The same error message utility is also used to inform the user when anything goes wrong functionally. The system is equipped with a very powerful help utility that can be used by a user to get more help on the system. The help utility covers all aspects of the system, as well as some trouble-shooting suggestions. Last but not least, the system is Windows-based, which is a very strong feature, considering the vast range of Windows users and the amount of development put into it to make it suitable for

everyone. The IRPS enjoys all the Windows features normally available in any Windows-based system.

Documentation

The IRPS has a unique feature that enables it to generate a full report about a particular range of machines from different vendors. The report is produced in a word document and thus design engineers can utilise the resultant report in supporting their decision or to produce documents for their project resources. The report includes sufficient information and is supported with a range of images describing systems details.

User range

The IRPS is designed to be of benefit to a wide range of users. Since its advent over a decade ago, rapid prototyping technology is being introduced into the design and manufacturing processes curriculum at engineering schools. The parts made from an RP machine are used for design verification and prototype development as well as as a pattern for many casting and moulding processes. The IRPS system can be used not only to make a proper selection in purchasing an RP system by an engineering school possible, but also as an educational and tutorial tool for teaching the capabilities and features of different RP systems. It will serve as a professional technical selection tool for design engineers and as an advisory tool for decision-making by executives. Most other available RP selection systems are limited in their user base.

Limitations

The IRPS system is believed to be the most comprehensive selector program developed to date in terms of the number of RP machines included in the program, yet it is not without limitations. The program is limited to the information and data about the RP systems available at the time of writing the program. There is a constant need to check and update the information to ensure that the data in the program is accurate and current as RP system manufacturers continually improve and upgrade their systems. So the

IRPS system also needs continual updating and upgrading. Obtaining up-to-date, accurate and realistic data for each new RP machine from each RP vendor in the world is not easy, if not impossible. Moreover, there is a problem of a lack of standard terminology used by the RP vendors in providing their specifications. For example, 'built accuracy' can be confused with 'positional accuracy', 'repeatability' and 'resolution'. The accuracy values used in the program are taken over the maximum working envelope. This also poses a problem when comparing accuracy with smaller-sized RP machines. The IRPS system can be further improved by including other secondary selection criteria, such as material cost, running cost, maintenance cost and the total build time.

CONCLUSION

The IRPS system for RP system selection discussed in this paper is an interactive program designed to help a potential purchaser select an RP system from a wide range of choices of commercially available RP systems and using a number of different selection criteria to suit specific requirements. The program's database also includes full specifications for each RP machine, which is displayed whenever the program recommends the specific RP machine. The program is designed to be comprehensive yet user-friendly with on-line help and use of graphics, pictures, images, animation and charts. The user can therefore use the program to compare specifications and applications of different RP systems in making a final informed selection. The package has an up-to-date database and allows modification and upgrading of the database without accessing the program. The system can also be used as an educational tool to train students in system selection exercises based on factors like cost and system capabilities.

Note. The authors apologise for any inadvertent omission of any commercial RP system during the development of this selection program.

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