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A Knowledge-Based Industrial Robot Selection System for Manufacturing Industries

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Abstract – *Nowadays, robots can be used for different applications and environment. The capabilities and specification of the robot will determine its usage. The large number of the robot in the market has made the selection of the suitable robot becoming difficult. This paper presents the development of knowledge-based system for robot selection using expert system shell. The aim of the work is to select the suitable industry robot for manufacturing industry. The selection criteria are based upon application, payload, maximum reach, number of axes, repeatability and mounting position.*
The system consists of several modules such as knowledge acquisition module, inference engine module and user interface module. The development system helps the industrial engineers to select the most appropriate robot for an application.

***Keywords**: Expert System, Industrial Robot Selection, Manufacturing Industry*

I. Introduction

The International Standards Organization (ISO) define the industrial robot is a machine consist of arm mechanism to hold a tool or work piece. The robot is able to memorize the program and it will receive the feedback from the sensor to decide the next action. The robot can be carried out the repetitive action or control by human or autonomous function. The demand of the industrial robot is increasing due to the high labor cost and shorter time to market [1].

To select a suitable industrial robot, a manufacturing engineer need to consider various condition such as production demands, manufacturing systems design and economic impact.

This consideration will influence the robot attributes such as pay load, accuracy requirement and control system. Many studied have been reported on robot selection research and development. Kamali et al. [2] developed a system to select a robot based on production requirement such as manual or hard automation. Offodile et al. [3] studied on the database that based on robot characteristics with the used of economic modeling approach.

Agrawal et al. [4] presented computer software to assist the industry to select the right robot based on the multiple attribute decision-making methodology. Tang et al. [5] developed an industrial robot selection system using C++ language.

The developed system considered six robot specifications such as applications, payload, repeatability, reach and velocity.

II. Development of Knowledge-Based Industrial Robot Selection System

The development of Knowledge-Based Industrial Robot Selection System (KIRSS) need to perform number of steps before the final program delivers to the user.

The development process is consist of the user interface design, compilation of robot specification information, determination of robot selection criteria, define the program tree structure, program writing and coding, program test run and validation.

The developed KIRSS uses Kappa-PC expert system shell [6]. Various researches [7]-[13] have been conducted by using rule-based approach. The KIRSS consists of the knowledge base system, the inference engine as well as the user interface. Fig. 1 shows general configuration of the proposed system. The knowledge to be input to the system are the application type, the payload, maximum reach, number of axes, repeatability and mounting position.

All information regarding the robot specification is stored in knowledge base. An inference engine run through this storage by Kappa-PC tool kit applying 'if-then-rules' to find the appropriate solutions to the problem.

The inference engine interacts with the knowledge base in forward reasoning mechanism to give the best possible answers. The program handles the user input, identifies the rules, searching for right data and then gives an answer. Fig. 1 shows an example of inference browser of robot types for the proposed system.

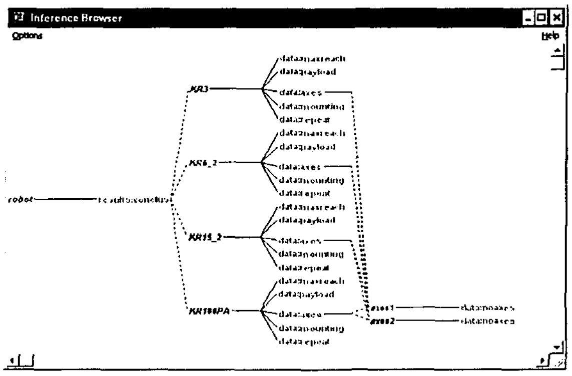

Fig. 1. The inference browser of the industrial robot type

III. System Description

The Knowledge-Based System for Industrial Robot Selection System is developed based on heuristic rules and the expert experience. The selection classification and reasoning of industrial robot is using a rule-based system approach. The developed knowledge-based system includes knowledge acquisition, selection criteria definition, selection of user interface, knowledge hierarchy, programming, program validation and testing as well as documentation and maintenance. The development of KIRSS involves 4 major phases.

Phase 1: Knowledge Acquisition

The KIRSS requires selecting the industrial robot to the specific process. The expert knowledge is heuristic and need some effort to gather it. The dominant source of knowledge is the domain expert. The expert is consisting of manufacturer, robot programmer, operator and user.

The knowledge can be acquired by interview with experts, design guidelines and robot operation manual.

i) Interview with expert

The domain experts for industry robot are manufacturing engineer, robotic engineer, technician, supplier, contractor and operator. The knowledge was documented with interview approach.

ii) Design guidelines

The design guidelines of the industry robot will provide the specification of the industry robot such as dimensions, payload and limitation.

iii) Robot operation manual

The robot operation manual mainly related to the standard operation procedure of the industry robot. In addition, the safety procedure is one of the important information to be input to the developed system.

Phase 2: Design

In the second phase, the task is to define the right knowledge representation technique and control strategy.

A prototype system is developed as shown in Fig. 2.

The prototype system will be tested and validated.

i) Selection of the development tool is based on certain criteria in order to save time and effort in fulfilling its objective. In this project, Kappa-PC expert system shell has been selected to develop KIRSS.
ii) In this stage, a knowledge representation technique that best matches the way the expert models of the industry selection was required. Therefore, a rule-based system was chosen to design the KBS, and the following approach was applied:

$$If(X)\ Then\ (Y)$$

iii) The backward chaining methods was used in this project due to the expert is considered some conclusions and then attempts to prove it by searching for supporting information. The expert is mainly concerned with proving some hypothesis or recommendations.

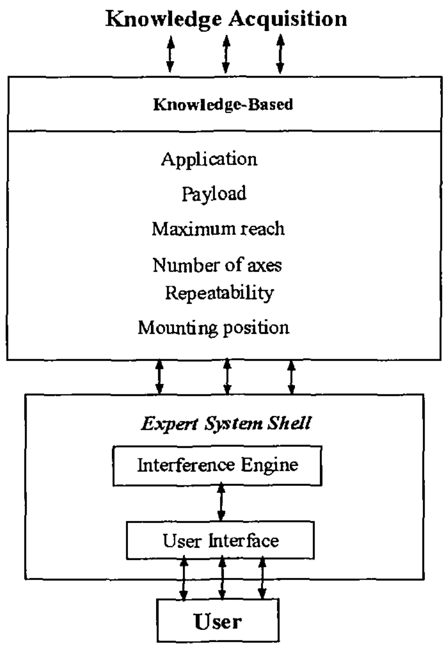

Fig. 2. The configuration of the developed system

Phase 3: Testing and Validation

The developed expert system is tested and evaluated to ensure the software performance is converging towards established goals. The evaluation process is ensuring the proposed system is able to satisfy the requirements as well as fulfill the user-system interaction. User acceptance efforts are concerned with issues impacting how well the system addresses the needs of the user.

i) Preliminary testing

The testing is to evaluate the KIRSS prototype at the early phase. The developed system was tested separately based on the module.

ii) Field testing

The developed system, KIRSS is validated in the manufacturing environment and exposed to robot selection problem. A few personnel are requested to try on the expert system.

The objective of the test is to determine whether the developed system able to meet its original goals.

Phase 4: Documentation

The documentation serves as the diary of the project. It contains all the material collected during the project and used as reference. The information is needs to be retained and recorded in the documentation. The user interface of the proposed system is shown in Fig. 3.

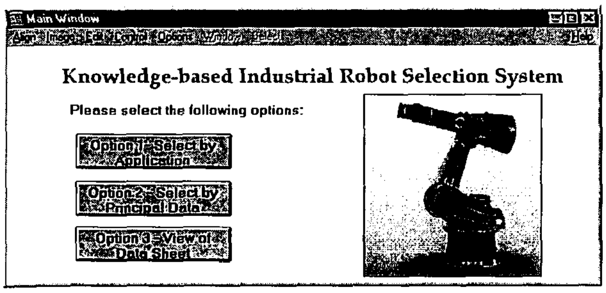

Fig. 3. The main window

The system provides three options in selecting a robot based on:

1) *Option 1: Select By Application*– the users have to input the application of the robot such as spot welding to determine the robot types/configuration. The flow chart of *Option 1* is shown in. Fig. 4. The window of *Option 1* is shown in Fig. 5.

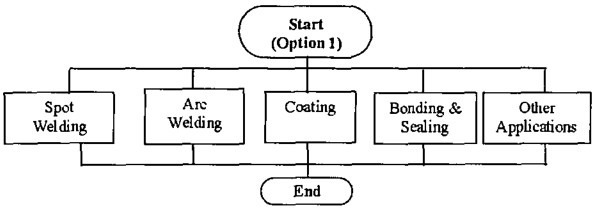

Fig. 4. Flow chart for Option 1

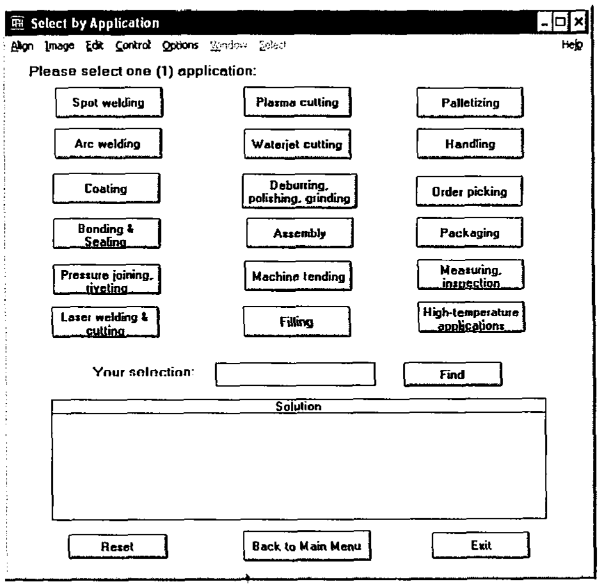

Fig. 5. The window of "select by application

2) *Option 2: By Principal Data*–the system will recommend a robot type based on principal data such as application, payload, maximum reach, number of axes, repeatability, and mounting position was considered. Fig. 6 shows the Flow chart of *Option 2* and Fig. 7 shows the window of *Option 2*.
3) *Option 3: View of Data Sheet*– the user can view the complete data sheet of the robot to select the suitable robot type. Fig. 8 shows the flow chart of *Option 3*.

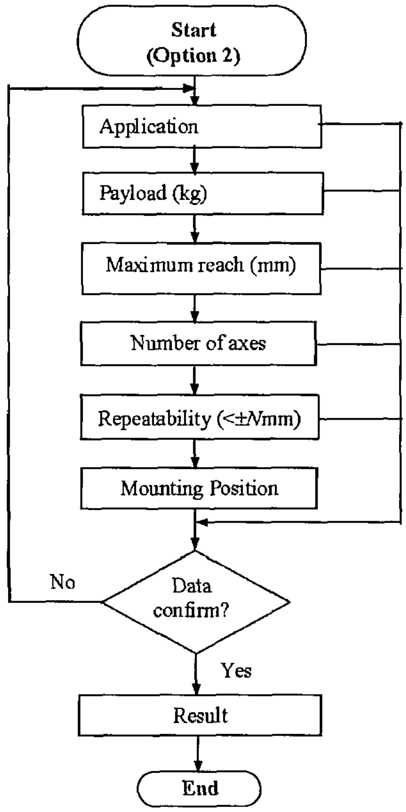

Fig. 6. Flow chart for Option 2

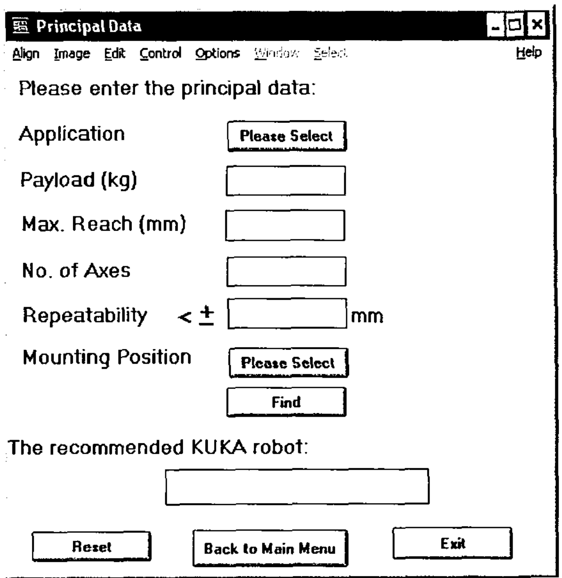

Fig. 7. The window for Option 2

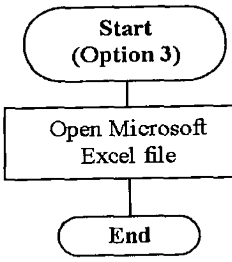

Fig. 8. Flow chart for Option 3

IV. Result and Discussions

A prototype knowledge-based system for robot selection was developed and tested. The proposed system can select type of robot based on applications, principal data and view of the robot data sheet.

The related attribute such as performance, work envelope, environmental conditions, weight of robot and cost are not considered at the moment. The database of the proposed system can be changed and upgraded by user easily. Currently, the proposed system interprets 21 rules before giving an answer and only KUKA robots are available in the database. The developed KIRSS was validated with different scenarios. The developed system equipped with the capability to alert the user with an error massage when he/she make a mistake during data entering. In order to validate the proposed system, two case studies were used to validate the capability of the developed system.

Case study 1: By Application

Once the user select the option 1, by application in main menu, the *Option 1- select by application* dialog box will be prompted to user, as in Fig. 9. The user must select one application, such as "spot welding". After the selection was confirmed, the selecting process began.

The system then recommends robot types for the application. In this case study, the recommended robots are R125/2, KR150/2, KR200/2, KR150, KR180, KR210, KR350/2, KR350/3, KR500/1, KR125W/2, KR60P/2, KR100P/2, KR150K, KR180K, KR210K, and KL1500. The output result for the system can be saved in text file format.

Case study 2: By Principal Data

When using this option, users have to key in the specification data into the dialog box such as application, payload, maximum reach, number of axes and repeatability and mounting position (either on floor, wall, variable and floor/ceiling).

Fig. 10 shows the dialog box for *principle data.* If the user were to find the recommended KUKA robot for all data input such in Fig. 10 and the robot application is arc welding, the output result is "*KR 6/2*". This result can be validated by checking the actual data base on the above robot.

The principal data of 'KR6/2' as shown in Table I.

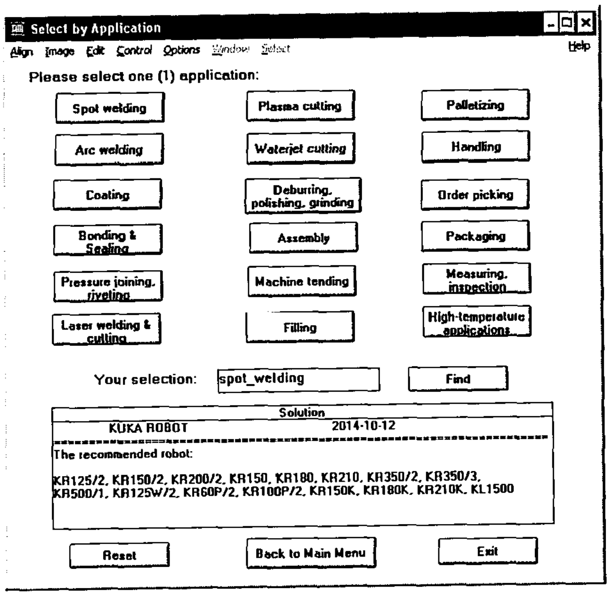

Fig. 9. User interface of Option 1 and recommended robot types

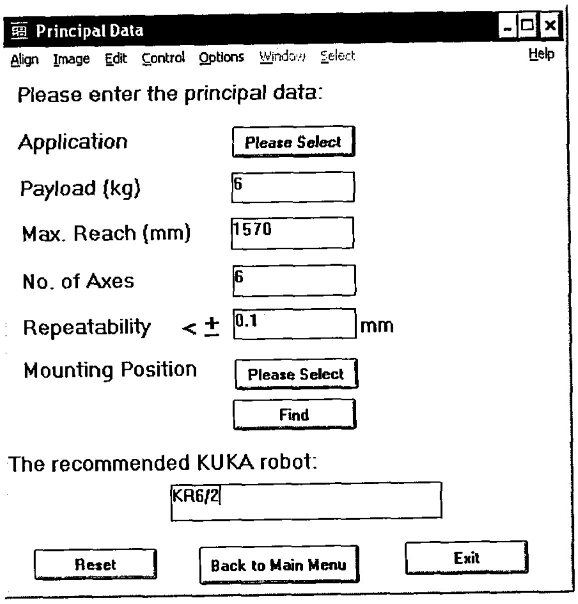

Fig. 10. Dialog box for option 2 - principal data

TABLE I
THE PRINCIPAL DATA OF KR6/2

Type	Applications	Payload	Max. Reach	No. of axes	Repeatability	Mounting position
KR 6/2	arc welding, coating, bounding and sealing, plasma cutting, assembly, machine tending, filling, palletizing, handling, order picking, packaging, measuring and inspection	6 kg	1570 mm	6	<± 0.1 mm	Variable

V. Conclusion

A knowledge-based industry robot selection system has been proposed to overcome the problem in the manufacturing industry. The developed KIRSS consists of a select-by-application module, select-by-principal data module, view-of-data sheet module, a knowledge-based system and a user interface.

The proposed system is enable the user to identify the suitable robot type based on application, principal data and data sheet of the robot type. A user friendly interface consisting of images, menu and buttons was achieved for providing user with easily input data to the system and complete results. The prototype system was based on KUKA robot types. The system was flexible and modular type where the database such as manufacturer, degree-of-freedom, control system, drive of the robot can be upgraded to make the system more comprehensive.

Acknowledgements

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