Expert system approach to design an Automated guided vehicle

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ABSTRACT

The purpose of this paper is to describe an expert system to design the base of an automated guided vehicle. The components of the expert system include:

- A user-friendly graphic user input interface, where the user can enter specifications – like the environment used, application of the robot, etc.;
- An engine that converts the managerial requirements into technical parameters and designs the robot - initially assuming some parameters and confirming its assumptions during the course of the design; when unable to do so, it iterates with different assumptions until they are met; the code also selects various materials to be used are selected from a corresponding database;
- A database of various materials from their manufacturers/suppliers;
- The output data is interfaced with a CAD engine, which generates a 3-D solid model of the vehicle;
- A "Bill of Materials" file is generated as the output and suggestions for how to assemble them are given.

The method has been tested by designing a small mobile robot. The software provides an excellent tool to develop a mobile robot based on performance specifications. Modeling helps the user understand the constraints on the design of the robot and the bill of materials – along with the vendor address, helps the user buy the components needed to assemble the robot.

Keywords: Expert system, automated design, solid modeling, mobile robots.

1. INTRODUCTION

"Expert system" usually refers to a computer program that works based on a large collection of heuristic rules and widely accepted domain facts and relationships of a technical field. Expert systems are highly useful when the application involves an open-ended space of alternatives and requires the co-ordination of multiple experts.

Conventional mechanical design of industrial robots or automated guided vehicles (AGV), consume a lot of timeis time consuming in the product development stage, causing a long time capital stagnation. . Further, the field of robotics is a multi-disciplinary field that requires a collection of brains expertsexpertised in varying fields, to develop a single product.

Hence, to minimize the product development lead-time and simplify the complexity of the design of the product, an expert system is necessary. Most research in artificial intelligence (AI) hasve been restricted to the area of circuit domain, but off late AI is entering into the fields of mechanical design as well. This paper attempts to extend the frontiers of AI into the design of automated guided vehicles, banking on the experience of the authors in the development of the automated guided vehicle "Bearcat".

The use of expert systems in mechanical design automation has been analyzed and recommended by Siddall. She refers to them as automatic consulting systems to simulate , simulating the role of an expert in solving problems. These expert systems have been successfully used in a number of applications inapplications in the industry to trouble shoot various problems or breakdowns.

Expert systems for selection of materials or design of mechanical components have been in use for quite some time now. N. Ramachandran, et. al., have have analyzed the expert system approach in design of mechanical components. . They have developed a design process that can be summarized as refinement + and constraint propagation and parameter selection.

A kKnowledge- based systems approach to design mechanical springs has been developed by Tai. K. K., et al. Another Other literature that inspired us in our approach was the integrated gearbox design developed by Mehdi. K and Play D. The The decomposition of a mechanical system into manageable units, and later, taking on the design of individual units, is explained by Meunier.

However, the possibilities out of expert systems have been tried and dropped abandoned in various other domains, and this is mainly because of the mismatch of the capabilities of the software with the actual requirement of the market. IOn most incidents, they have been dumped defamed as impractical curiosities that could not be seriously considered, mainly because of the non-availability of the complete database to work on or the non-availability of the correct knowledge of all the design possibilities.

This paper tries to circumvent this anomaly by using only standard off-the-shelf components for the building of the robot and by using various manufacturers' catalogs to select the components. In other words, it was consciously decided that none of the components used in the development of the AGV would be tailor-made or specialized. This eliminated the non-availability of a comprehensive database and also the non-availability of the necessary parameters to be known.

In addition, using off-the market components had a lot of other advantages, for instancelike, the availability of a series of options to choose from, the availability of the various product database needed, low component procurement lead-time, low development cost, readily available drawings and specifications and readily available replacements.

The purpose of this paper is to explain the development of an expert system to design the base, actuator and power units of an automated guided vehicle. The elements of the expert system are explained in section 2. The upper level logic of the program is explained in section 3. The actual design of the robot is explained in section 4. The output of the program is explained in section 5. Conclusions and recommendations are given in section 6.

2. ELEMENTS OF THE EXPERT SYSTEM

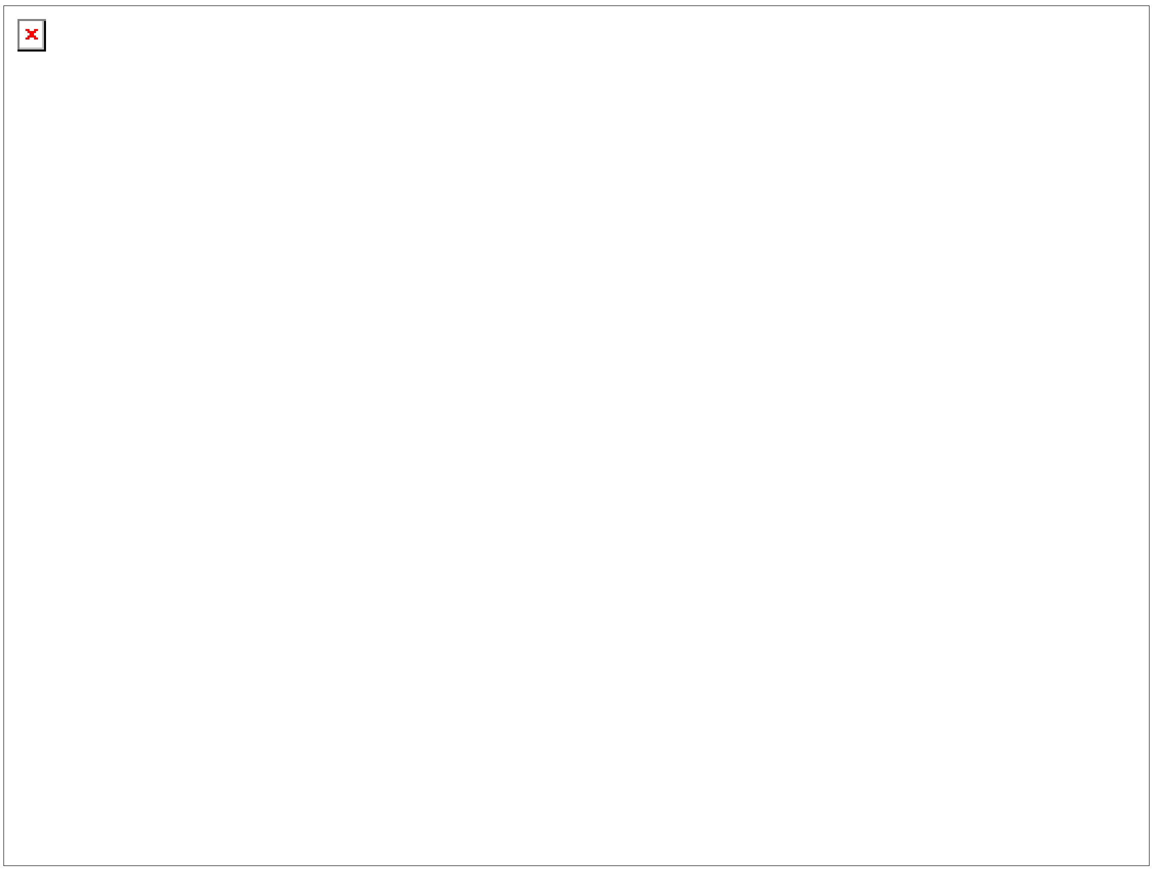
The expert system obtains the specification requirements for the robot - the input from the user - using simple English. An inference engine converts the text answers into engineering parameters. These parameters are then used to develop various design constraints and selection factors, which are used to select the appropriate components from its corresponding manufacturer or supplier's catalog. Thus, the expert system can be broadly broken down into the following elements:.

2.1 User interface

The user interface is the feature that effects knowledge acquisition for the expert system by facilitating the user to influence the design flow. Visual Basic 4.0 (VB) was chosen to develop the interface because of the simplicity with which various forms could be created and the compatibility of VB with Windows NT. VB Forms create a comfortable environment to the user with on line help, context- based help, facilitating ease of navigation and operation.

These forms were used to put forth seemingly non-technical English questions, and the results were converted to technical parameters using heuristic approximations. These technical parameters were used in the design calculations to select components for the robot.

An example screen shot. Figure 2.0



2.2 Knowledge base:

The knowledge base is the main repository for domain-specific heuristics. These are the design logic, various domain facts, inter-relationships, approximations, already evolved algorithms and ideas that could be used to support the flow of the design. Our experience and the design documentation of Bearcat I is were the main contributor for this knowledge base.

2.3 Database / catalog collection

This is a collection of manufacturers' product catalogs, for every component of the robot. These include the product numbers, specification, design parameters to be known, selection procedure, product drawings, approximate price, vendor name, number and address.

About 93 different components were used in the robot and the number of components within the scope of the paper was about 70. Data was collected and compiled for an array of every product type, in all possible variations made by the manufacturer. These were used as master databases, to choose the right component from the design parameter in hand.

2.4 Inference engine

This is the main computation engine that controls the flow of design based on the algorithm in the knowledge base and the input from the user through the user interface, making assumptions, selecting the components, verifying the assumptions and making inferences from the data in hand. This is an inherent part of the control code and this regulates the design sequence. The inference engine studies the individual rules, exceptions, inter-relationships and guides the code accordingly to select the right component out ofin the database.

2.5 Cad extension

Once a product is selected, the Cad extension retrieves the drawings of the component from the database file, and modifies it to suit the current design specification based on the requirement specification presented by the inference engine.

2.6 Output

The output of the expert system is a comprehensive bill of material listing and accompanying drawings of all the components that haves been selected. The list also includes,includes the vendor name, address, contact numbers, approximate cost and instructions to assemble the product to make the system.

3. STRUCTURE OF THE PROBLEM

3.1 Problem decomposition

The autonomous mobile robot is a complex, computer- controlled, and intelligent system. The design of a complex mechanical system like an automated guided vehicle must be done by hierarchical decomposition of the design problem into simpler units and continue this breakdown until the units reach individual component levels. These components then can be easily designed, integrated to form major sub-units and then, on further integration, would lead to the whole system.

3.1 Decomposition of the system: The main difficulty in this approach is properly identifying the unit groups and isolating them. One logical approach is to define the boundaries of the units in such a way that they would have minimal causal effect on other units. That is, the demarcation needs to be done in such a way that the dependency of the parameters of one unit with other units should be minimal.

Our vehicle can broadly be decomposed into the following major sub-systems:

- The Robot Base
- The Vision System
- The Sonar System
- The Motion control System
- The Control Logic
- The Safety and Braking System

Of these, the scope of this paper restricts itself to the algorithm to develop the base, the power units and the transmission of the robot. The components that fall within the scope of the paper can be further simplified into major sub-units, such as:

- The cage of the robot,
- The power units,
- The actuators,
- The transmission system,
- The component positioning logistics,
- Accommodation for safety and braking,

- Allowances for expansion or modifications and
- The skin of the robot

3.2 Sub-classification to component level: These major units can be simplified into component level units that can be designed with the help of standard design procedures and can be selected from the corresponding manufacturers' catalog.

For example: The transmission unit can be simplified as:

- motor to gearbox coupling
- motor to gearbox coupling key
- gearbox
- gearbox base
- gearbox base bolts and nuts
- gearbox to Wheel shaft coupling
- gearbox to wheel shaft coupling key
- wheel shaft
- Wheel - wheel shaft key
- Wheel shaft supporting bearing blocks
- Wheel shaft supporting bearing blocks bolts.
- Gearbox-bearing block spacers
- Bearing-block wheel spacers.
- Wheel bolts.

Thus, a comprehensive list of components can be made and the design or selection of each material can be done depending on the specification.

3.3 Identification of design parameters: The next most important step is, to identify the parameters that need to be known to select these components. These parameters can be classified as two types:

1. Causal parameters

2. Specification parameters

Causal parameters: These are the parameters of a component, which directly depend on a parameter of another component either within the unit, or in the sub-system or the system as a whole. The main idea of the approach is to make the system identify all the casual parameters and make the most of this dependency. The aim is to achieve the design of the robot with minimum minimal questionings offrom the user.

Example of causally dependent parameter:

At the unit level:

The inner dia. (i.d.). of the wheel = outer dia. (o.d) of the shaft = i.d. of the bearings = i.d. of the spacers = i.d. of one end of gearbox shaft coupling.

At the sub-system level:

The o.d. of the motor shaft = i.d. of the gearbox-motor coupling top end.

At the system level:

The weight of all the components + payload = load on the motor.

Specification parameter: These are the user-input parameters. They can be further classified into two groups viz., functional specifications and non-functional specification. For example: The color of the robot skin is a non-functional specification and the required speed of the robot is a functional specification parameter.

These parameters are fed into the logic system by the user through the VB interface.

3.4 Product selection: Once all the required parameters are determined, either by questioning the user or through causal relationships, the corresponding manufacturer's database is searched on the primary specification needs and the matching product is selected. If no such product is found, the iterations are repeated with a different set of assumptions.

Once the product is selected, the factors initially assumed on the product initially are verified and, if they do not match, the assumptions are changed in the subsequent direction and the design is repeated. However, this time, the user is not prompted for data input and the existing data set IDid is re-used. However, a counter is incremented each time the design is iterated due to wrong assumptions, and if the counter reaches 40, the user is prompted to enter a different set of data set, prompting him that the given data is unusable.

3.5 Bill of material generation: This selection procedure is repeated for all the components, and when done, a comprehensive bill of material list is generated. Supporting drawings, supplier details, cost, assembly suggestions are also generated.

4.0 ABSTRACT ALGORITHM OF THE DESIGN

The seed of the logic was the based on our development of an AGV for the "Automated Unmanned Vehicle System competition, 1998". The robot was made as an Industrial robotic kit with the buy-only mantra ideas behind it, as the time we had to complete the robot was very shortlimited. The design calculations were encoded in Mathcad 6.0, so that many iterations could be done with different data sets as per our requirement. The logic used and the design process was then analyzed and encoded into a computer system. The abstract logic is given below.

1. Initialize the assumption variables
2. Get the area of operation - μ - The co-efficient of friction between the surface of operation and the type of wheel to be used
3. Get the speedmax. – This is the maximum speed at which the vehicle should move. Usually not more than 10mph
4. Get the payload – The maximum load the robot may be carrying other than its' self-weight.
5. Get the hours required to move around without recharging. This is useful to determine the capacity of the battery.
6. Ask the user...whether he needs 12v or 6v battery (If the user does not know use 12v). Estimate the weight of the batteries.
7. Ask him how many cameras he may use. Default = 2. Estimate the weight of the cameras.
8. How many monitors the user needs? Estimate the weight of the monitors.
9. How many sonars the user needs?
10. Is the user going to use a laptop/palmtop/desktop? This converts itself to the corresponding load on the machine
11. What is the factor of safety to use? Use 150% as default.
12. Calculate total mass = known mass + payload * factor of safety. (Assume no. of batteries). Use the steel cage to be 200 lbs.
13. Thus the total mass of the robot is estimated by
14. Ask the user the type of the wheel to use
15. Ask for clearance (ground clearance)
16. The wheel dia. cannot exceed dia. 12-24 inches dia.
17. Ask the user whether to use rubber wheels/iron wheels/plastic?
18. Ask the user, the application environment and decide the width of the robot.

19. Select wheel from the catalog for the specification and to carry half the load.

20. Check weight assumptions – check the selected wheel.

21. Get r2, r3 – the inner diameters of the rim and the wheel

22. Calculate in revolutions/minute the speedmax, for the dia. of the wheel from

and where, $D._o$ is the dia. and $S._v$ is the speedmax.

23. get jrim Where, $\rho ._1$, $h._1$ and $R._1$ and $R._2$ are the density, width and radii at the rim

24. Similarly,

25. And

26.

27. Find force to overcome self-weight – use the static friction co-efficient.

28. Find the torque

29. Ask for acceleration required? Convert this to the corresponding angular acceleration needed

Where a is the acceleration

30. Determine the inertial torque required, required through the gear train

Where, and floor = lower round off of the argument.

31. Determine gear ratio, i

32. Check for worm and wheel specifications and check weight assumptions

33. Determine torque to overcome static frictional force. Where, T_{ftom} = frictional torque of motor

    Total torque the motor needs to overcome.

34. Find in the motor manufacturer catalog - choose motor

35. Choose corresponding amplifier (12V),

36. Check assumption regarding the weight of the motor

37. Ask can he use an inverter?

38. If yes...choose an inverter. From from 12V or 6V DC to motor input voltage from the catalog. Check weight assumptions.

39. Find total power required, choose battery from catalog on the specifications

40. Find number of battery required.

41. Check if the selected parameters match with the assumptions

42. Design bearing block to hold shearing load on the eyes of the base, axial and radial load on the inner race.

43. Make use of all causal parameters and select the bearing blocks. Check assumptions

44. Design the two types of couplings on shear, crushing and compressive strengths. And check assumptions

45. Check the shaft on the basis shear, crushing and compressive loads and check the assumptions.

46. Ask the number of castors to be used Use 1 as default.

47. Ask whether the user wants castor wheel rubber or iron?

48. From ground clearance, choose castors...check assumptions

49. Calculate component lengths.

50. Input into the Cad engine and develop the component drawings

51. Add a factor and find the lengths of the 80-20 stuff. Use the logic of 80-20 library.

52. Add fastener, ends, joiners etc., Check the load assumptions.

53. Choose i-scan.

54. Ask for parameters to choose sonars and select sonar kits.

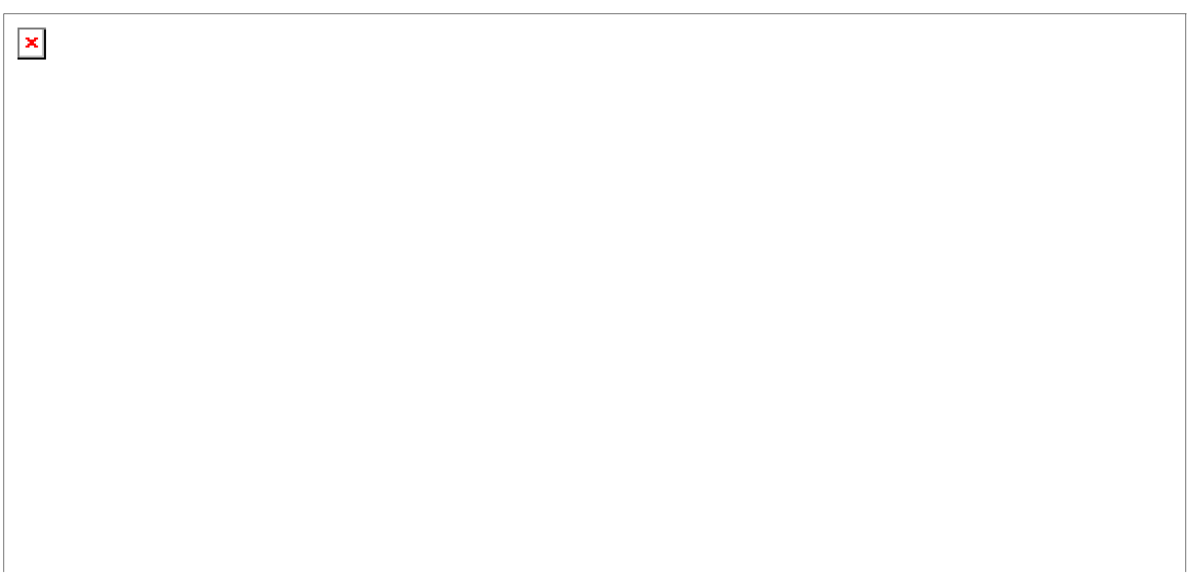
55. Select galil motion controller.
56. Ask for appearance requirements of the user.
57. Cchoose plexi-glass.
58. Give the list.

5.0 RESULTS

After an extensive testing of the code in the module level, the program was integrated with the Cad engine to develop the product. Sample data was fed in, simulating the requirement of a user for an industrial robot.

1. The expert system gave out a comprehensive list of "Bill of Material" (BOM) along with the manufacturer's details and contact numbers. The program gave produced data files, which when incorporated into the Cad engine, gave outproduced the drawings.
2. The robot was fed with tested data, like that of Bearcat. Tand the program output the list and drawings with 91% accuracy. About 73 different components were listed in the BOM and an assembled drawing was generated.
3. Modifications and extensions in the code were made to make the logic more rugged to variations and during the testing of the same, the code was broken into modules and each module output was found to match with the expectations.
4. A sample output drawing is shown in figure 4.0, in the next page.

Figure 4.0



6.0 CONCLUSION AND RECOMMENDATIONS

An expert system to design the base of a robotics vehicle similar to Bearcat II has been designed. The software should be useful to the decision-makers, the managers, to perceive the and analyze the automation before investing in it.

The comprehensive Bill of materials with approximate costs and the supplier addresses will be very useful for making investment decisions. Thus, the robot- making technology can be brought down from R & D rooms to the shop-floor decision-makersmanagement.

Some of the enhancements that could be made in this program are to make it more versatile in order to handle all types of land robots, like tracked vehicles or pneumatically levitated vehicles. The parametric modeler interface could be improved to effect real-time variations on the screen.

The experience in developing this software was an excellent learning experience and it is the first step aimed towards bridging the gap between R&D and shop floor.

ACKNOLWEDGEMENTS

This effort is an extension of the work of various students who have worked on BEARCAT I and BEARCAT II robotic vehicles, at the University of Cincinnati. This work could not have been realized without the hands of previous team members in, David Perdue, Bradley Matthews, Tayib Samu, Alan Lewis, Malik Spencer, Sanjeev Gupta, Todd Brehem, Randy Smith, Rob Hick, Kalyan Kolli, Wen Chiang and Nathan Mundhenk, Nikhil Kelkar, Raymond Ande and Krishna Mohan Kola. The authors also wish to thank all the companies that supported us with their catalogs and especially the 80-20 Structural Kit for their AutoCAD library without which the robot would not have come through. We also wish to thank our sponsors whose contributions enabled us to build the new robot.

REFERENCES