

UTILIZING DATA MINING TO ESTABLISH KEY SPECIFICATIONS FOR A MECHANICAL ENGINEERING TECHNOLOGY ROBOT DESIGN PROJECT

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Abstract ? Starting a project with a clean sheet of paper can be both refreshing (due to the possibilities) and daunting (due to having to determine the limits). Data mining, which is a technique of new knowledge discovery in databases (KDD), was utilized in a senior-level Mechanical Engineering Technology (MET) course project, MET 499, to resolve disagreements observed at project initiation. The MET 499 course used as a case study here involved the design, analysis, prototyping, and testing of a competitive robot for competition in BattleBot™ tournaments.

This paper details the design, population and subsequent querying of a database and how the results were analyzed to support establishing a suitable project direction. It is interesting that these results differed dramatically from the pre-conceived, “going in” project direction.

Index Terms ? data mining, neural networks, Battlebot™

INTRODUCTION

The MET 499 project described above began with the understanding that the design of a competitive robot involved moderate-to-high complexity work. The BattleBot™ organization holds competitions for various classes of robots at the regional and national levels, with the national level competitions aired by the Comedy Central™ network. The national weight-class winners are awarded the coveted golden nut trophy, which was a major motivator for this MET 499 team. The current Battlebot™ organization homepage is shown in Figure 1 below showing the current champions with their Battlebot™ designs for each of the four weight-classes, which include light weight, middle weight, heavy weight and super heavy weight. The MET 499 project team chose to address the super heavy weight division, even though there was some team dissent with this decision.

The initial, “going in” design had been presented with the project proposal, submitted four months prior to the Fall semester kick-off, for Curriculum Sub-Committee approval. Both this initial design sketch and the final design is shown below in Figure 2. The final design, along with design prototypes, was given a first-place award at the 2002 IL/IN ASEE Sectional Conference.



FIGURE 1

BATTLEBOT™ ORGANIZATION HOMEPAGE (WWW.BATTLEBOT.COM)

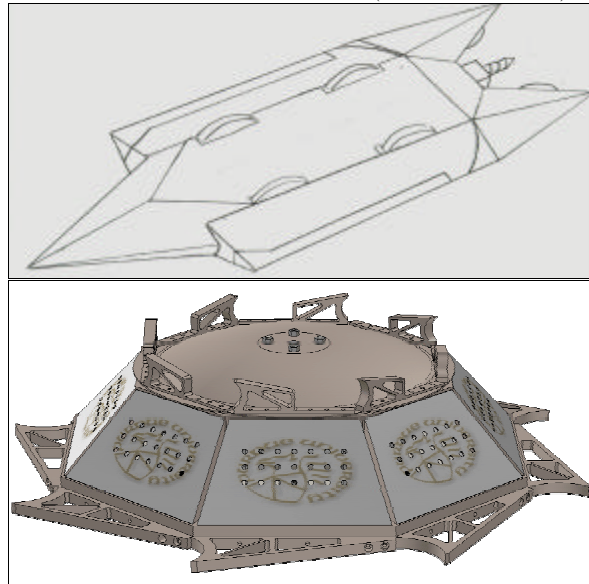


FIGURE 2

INITIAL BATTLEBOT™ CONCEPT SKETCH SUBMITTED WITH MET 499 PROJECT PROPOSAL AND FINAL DESIGN PRESENTED AT ASEE 2002.

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When the major professor questioned the group about which design specifications had led to which features in the above figure, the group was not able to match a specific specification to a specific feature. This led directly to a discussion of what features would be best to design into the competitive robot to assure that the robot would not only be competitive on its own merits, but be superior to already existing BattleBot™ designs.

Shigley, et al [1] and Ullman [2] provide good reference materials for the design process steps. Determining the “need” was a common theme in establishing product design specifications. This paper describes the process of determining these suitable product specifications utilizing data mining techniques.

DETAILS ON DATA MINING

The common definition of data mining is the process of finding hidden data, relationships, and/or information from large stores of information, typically in a database or a data warehouse. Data mining is a knowledge discovery process that typically requires computational tools to find this hidden information where simple observation or high-level analysis will not suffice. This paper shows how a database was established and data mined using an artificial neural network program. Details of the steps have been presented, allowing other teams to replicate these results.

DETAILS ON ASSEMBLING THE DATABASE

The Battlebot™ website provides a wealth of data about the robot designs that have competed at the national competitive level. An example of the type of data availability is shown below with top-level information shown in Figure 3 and more specific detail data in Figure 4.



FIGURE 3
COLLECTION OF BATTLEBOT™ INFORMATION ON INTERNET



FIGURE 4
DETAIL ROBOT SPECIFICATIONS ON INTERNET

The first step in the creation of a relational database in Microsoft Access™ [3] is to create a table and define the metadata. The creation of the table is illustrated step by step in Figure 5.

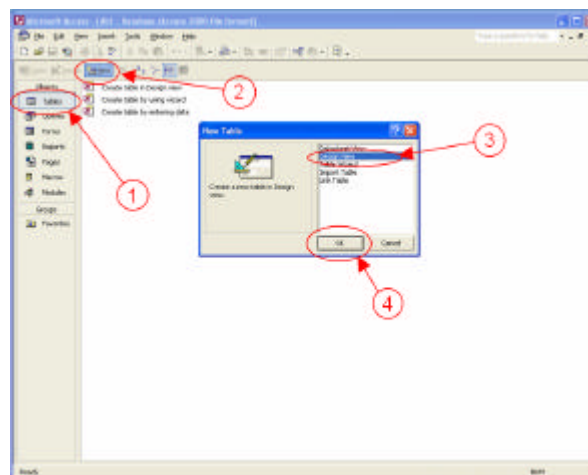


FIGURE 5
CREATION OF DATA TABLES USING THE METHODOLOGY OF:
1) CLICK TABLES, 2) CLICK NEW, 3) SELECT DESIGN VIEW, 4) CLICK OK.

The design view, as shown in Figure 6, is displayed on the screen. Population of the table's metadata includes entering an appropriate field name, selecting a data type which supports the dataset, enter an optional description for

reference, repeat for all the data fields, save the table, and click the Design View button. When the table is saved the table definition is written to the database and the table is created for data entry.

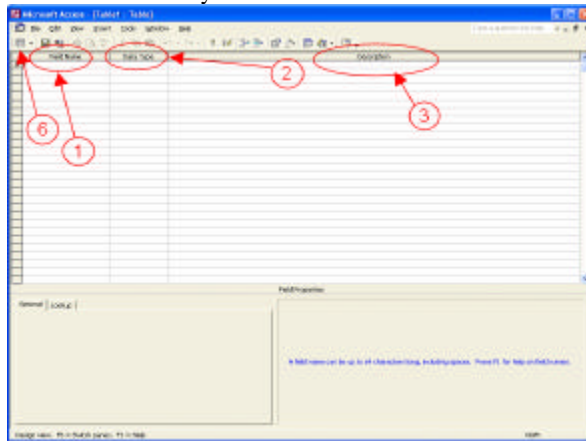


FIGURE 6

POPULATION OF TABLE METADATA METHODOLOGY: 1) ENTER APPROPRIATE FIELD NAME, 2) SELECT DATA TYPE WHICH SUPPORTS DATASET, 3) ENTER OPTIONAL DESCRIPTION FOR REFERENCE, 4) CONTINUE FOR ALL DATA FIELDS, 5) SAVE TABLE, 6) CLICK DESIGN VIEW BUTTON.

The completed metadata for the Battlebot™ comparison is illustrated below in Figure 7. The fields, as specified in this table, define how the table will contain the relevant information regarding a single row of information.

Field Name	Data Type	Description
Robot_Name	Text	Designated Robot Name
Visuals	Hyperlink	Visuals for Robot
Picture	OLE Object	Embedded Picture
Classification	Text	Registered Weight Class
Special_Features	Text	Special Features
Trak_Open/Close	Text	Robot is capable of track based operation
Drive_Type	Text	Type of Drive Mechanism
Drive_Power	Text	Type of Power Source Used for Drive
Weapon	Text	Primary Weapon
Weapon_Power	Text	Type of Power Source Used for Primary Weapon
Weapon_Category	Text	Primary Weapon Type Classification
Weapon_Motion	Text	Primary Weapon Motion Type
Weapon_Direction	Text	Primary Weapon Rotationally Mounted
Weapon_Int_Ext	Text	Primary Weapon Internally/Externally Mounted
Attack_Surface	Text	Attack Surface on Internal Components
No_Wins	Number	Number of Wins

FIGURE 7

COMPLETED METADATA FOR BATTLEBOT™ DESIGNS

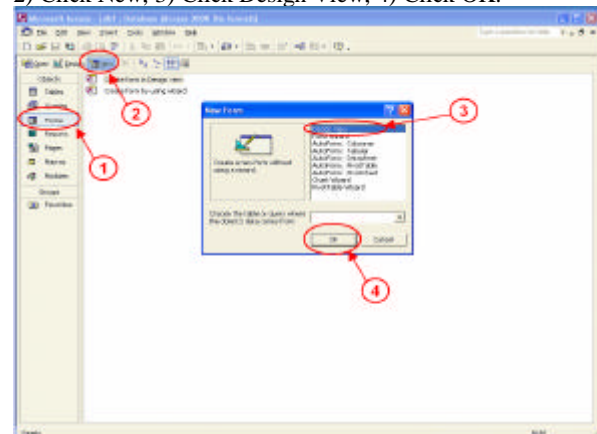
After the table has been successfully created in the database and the data view has been selected, it is now possible to enter data for each entity being cataloged. Figure 8 displays the data table after the analysis team successfully

entered 118 robots. A distinct advantage of utilizing relational database technology is the ability for multiple individuals to add, modify, and simultaneously query. This is a significant enhancement over other indexing software packages, such as Microsoft Excel™.

FIGURE 8

TABLE POPULATED WITH COMPARITIVE DATA

The data in the table data view is not logically grouped and presented in a visually aesthetic manner, as seen in Figure 9. The data view can be enhanced by utilizing a form. A form is a tool to add graphical formatting to enhance the appearance of the data, logically group related data fields, and add features which aid in data entry and data manipulation. Figure 7 illustrates the method to follow in the creation of a form in Microsoft Access: 1) Click Forms, 2) Click New, 3) Click Design View, 4) Click OK.

FIGURE 9
CREATION OF FORM VIEW

Upon successful creation of the form the form design view will be displayed on the screen. The steps

necessary to link the data from the data table to the form as shown in Figure 10: 1) Right Click in box at the intersection of the two rulers, 2) Selection Properties, 3) Set the Record Source Property equal to the name of the data table, 4) Drag the necessary fields from the field viewer onto the form.

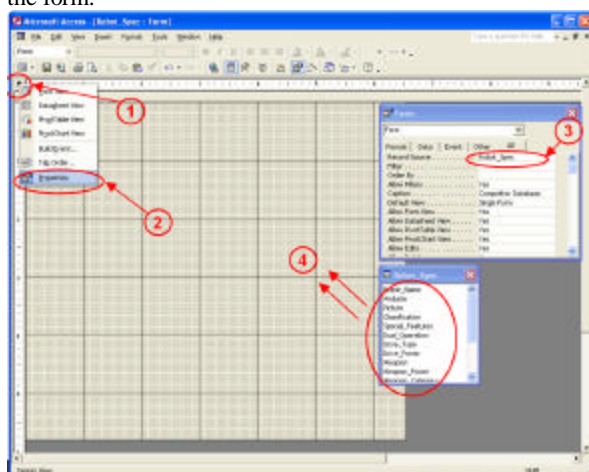


FIGURE 10
ADDING DATA ELEMENTS TO FORM

After the data elements have been added to the form, logically group the data fields and use the visualization tools provided in the form design view to create a logically grouped and aesthetically appropriate layout. The layout used in the Battlebot competition analysis database can be seen in the design view in Figure 11 and in the form view in Figure 12.

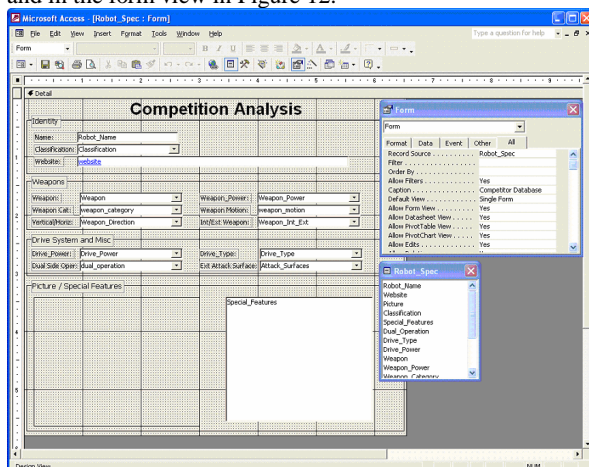


FIGURE 11
COMPLETED FORM IN DESIGN VIEW

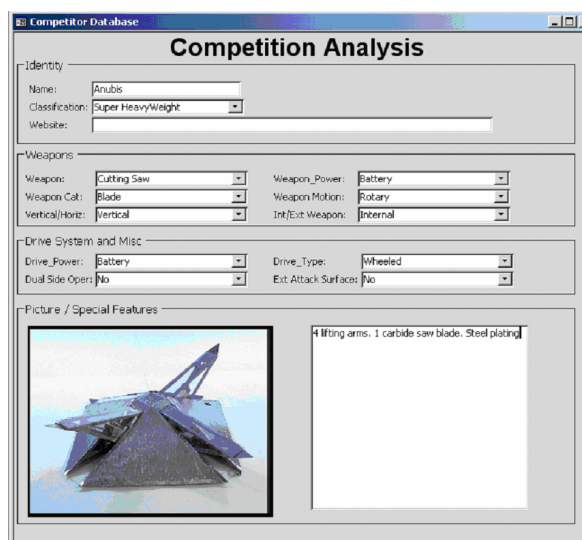


FIGURE 12
COMPLETE FORM IN FORM VIEW

Once the representative data set is contained in a table in the database, a query can be utilized to perform analytical evaluation of the data. One particular question which needed to be answered regarding the Battlebot™ competition was which category of weapon was used in the majority of the wins. Figures 13 illustrates the creation of this query in the following steps: 1) Click Queries, 2) Click New, 3) Click Design View, 4) Click OK.

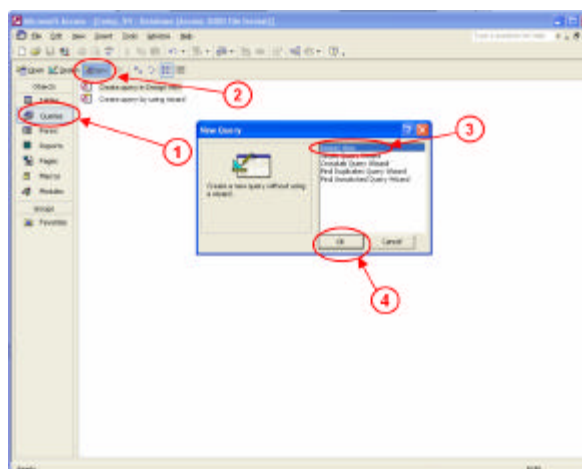


FIGURE 13
CREATION OF QUERY

The next step to create the query is adding a table which the data to be analyzed is contained. In Figure 14 the

query creation is continued: 5) Click the table to add, 6) Click the Add button, 7) Click the close button.

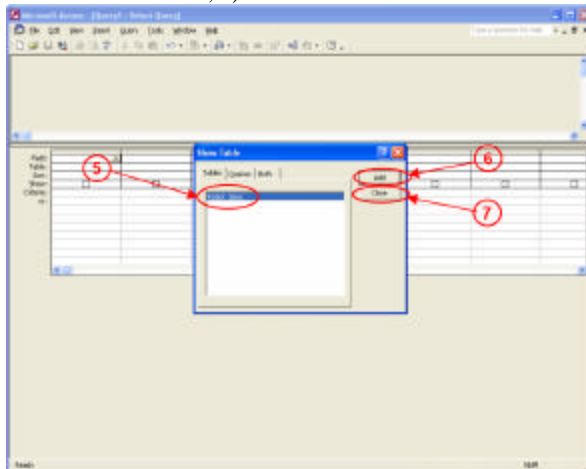


FIGURE 14
ADDING TABLE TO QUERY

Now that the data source for the query has been established it is necessary to describe the actual elements of the query. Illustrated in Figure 15 the appropriate columns are added to the query and their properties established in the following steps: 1) Click the Totals button, 2) Drag Weapon_Category into data grid, 3) Drag Weapon_Category into data grid again and change total property to count, 4) Drag No_Wins into the data grid and change the total property to sum, 5) Click the exclamation mark to execute the query.

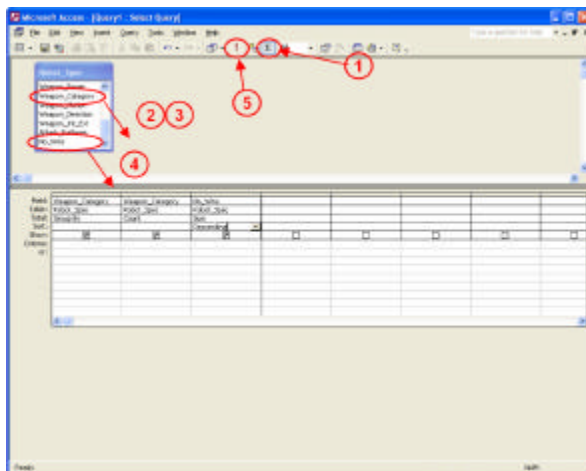


FIGURE 15
ADD FIELDS AND DEFINING QUERY PROPERTIES

As seen in Figure 16, the results clearly indicate that the Blade, Lifter, and Momentum type weapons had the most number of wins. There was a general correlation between the number of wins for the top weapons and the number of robots which had the superior types. After reviewing the results the team decided that the best course of action was to combine the blade and momentum type weapon in the same robot. By spinning in one direction the robot would become a large spinning blade. By reversing the direction, the robot would use the opposite end of the dual-purpose weapon to provide the momentum action.

Weapon_Category	CountOfWeapon_Category	SumOfNo_Wins
Blade	20	21
Momentum	20	21
Lifter	14	21
Blade	12	9
Blade	5	1
Blade	1	0

FIGURE 16
QUERY RESULTS

DETAILS ON ARTIFICIAL NEURAL NETWORKS

The queries from the database were exported to a comma-separated value (CSV) document for subsequent analysis by an artificial neural network (ANN) analysis program from Ward Systems called NeuroShell Predictor™ [4]. While it is not within the scope of this paper to discuss the theory behind ANN, it is clearly shown in the literature that neural networks are useful for constructing models from multi-dimensional data sets [5]. The CSV file is on each specific Battlebot™ in each of the subsequent rows.

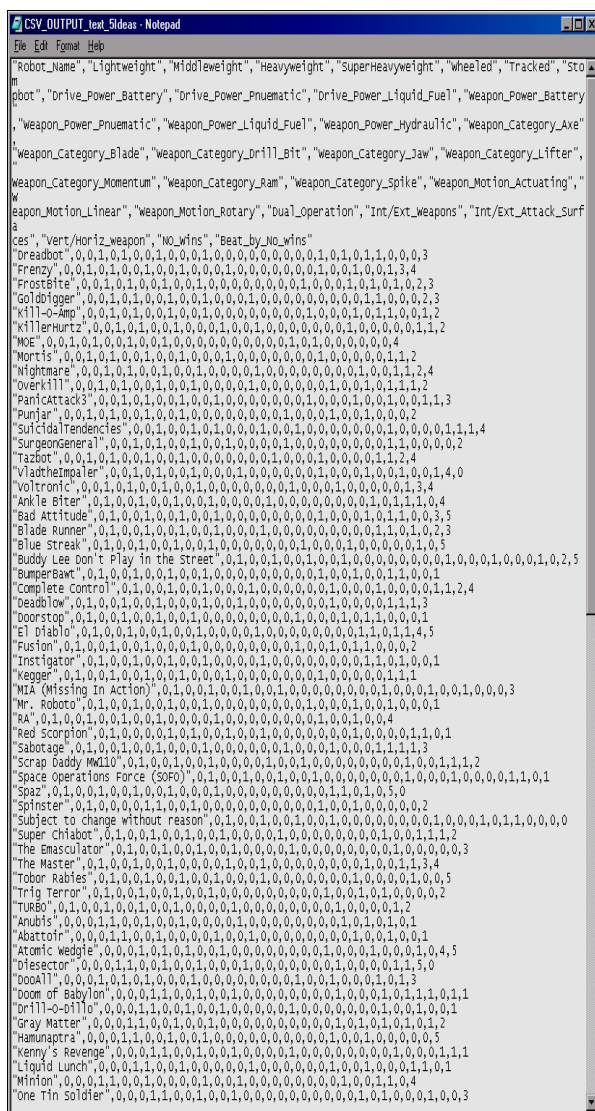


FIGURE 17
COMMA-SEPARATED VARIABLE (CSV) FILE AS INPUT TO
ARTIFICIAL NEURAL NETWORK

The corresponding inputs to and outputs from the ANN are selected as shown below in Figure 18. The goal here was to find the most significant characteristics of the historical winning Battlebots™ and to utilize this data to guide the initial product development direction. It is seen from the ANN output that the most significant features lead to the conclusion that a rotational weapon architecture was suitable for the team's design.

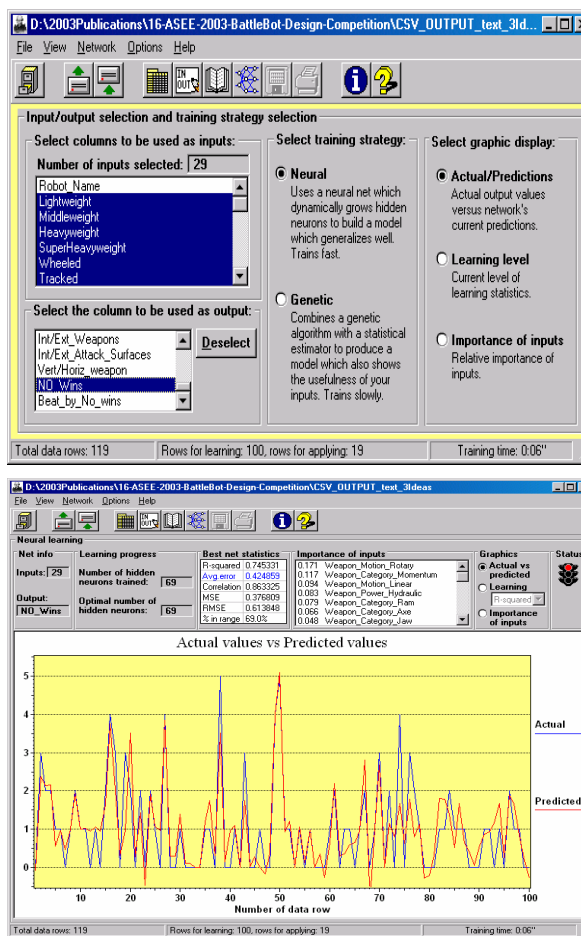


FIGURE 18
INPUT and OUTPUT OF ARTIFICIAL NEURAL NETWORK

RESULTS

In the case of the Battlebot™ design project in MET 499, this input proved invaluable as seen in the progression of design directions as seen in Figure 19 below. This progression is dramatic and surprising; a result that would not have been achieved without utilization of data mining techniques.

As a footnote, the MET 499 team won a 1st place award in the 2002 IL/IN ASEE Sectional Conference Student Design Competition, which required the team to submit a written abstract, prepare a poster and prototype presentation, and make a presentation to each judge. A photo of winning team along with the team mentor is shown in Figure 20. [6]

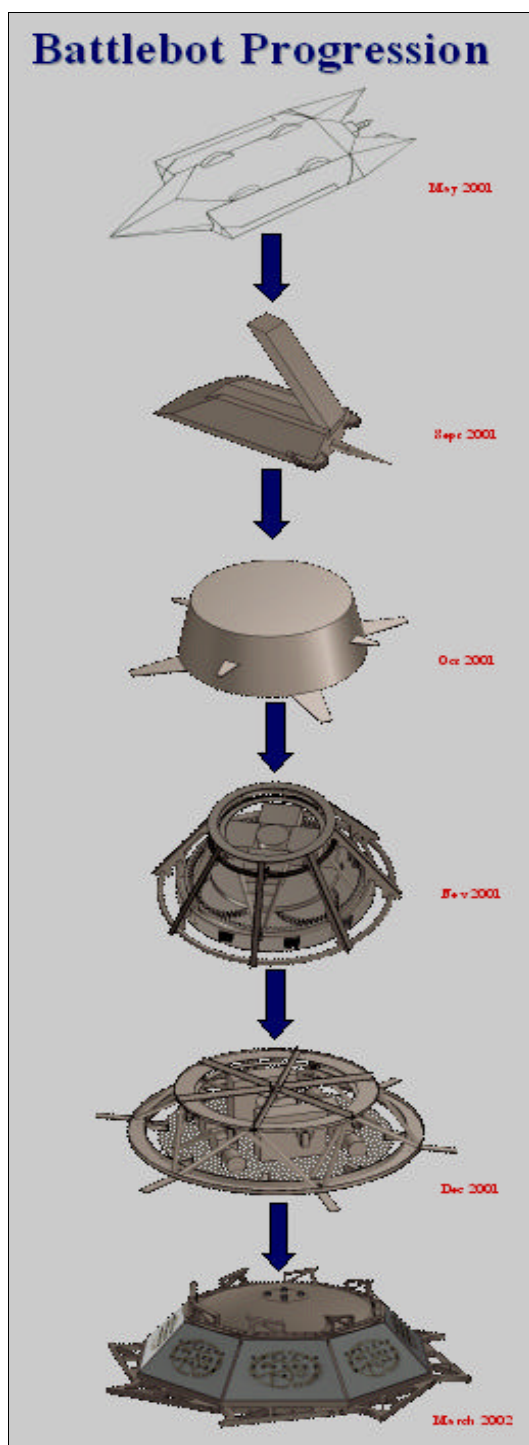


FIGURE 19
PROGRESSION OF BATTLEBOT™ DESIGN USING DATA MINING



FIGURE 20
MET 499 BATTLEBOT™ TEAM WITH 1ST PLACE AWARDS IN IL/IN
ASEE 2002 STUDENT DESIGN COMPETITION. FROM LEFT TO
RIGHT: KRAIG STRANGE, STEPHEN LAAPER, ZACHARY
MILLIKAN, PROFESSOR WILLIAM SZAROLETTA

CONCLUSIONS

This paper has showed a process by which database and artificial neural network technologies can be applied to establishing a design direction at the beginning of a project. Data mining helped the team efficiently sift through a number of often conflicting data elements to provide a direction that was significantly different from the initial, pre-conceived ideas of project direction as evidenced by Figure 19 above. Data mining involves a tangible set of tools that were shown in this paper to help resolve team conflicts about key product specifications. Details of the steps have been presented, allowing other teams to replicate these results.

The literature shows examples of how data mining could be also applied during the design process to support design decisions made “along the way”. [7] The MET 499 team did not utilize data mining in this manner, but in subsequent MET 499 projects this methodology will be applied whenever high importance design decisions are required.

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BIOGRAPHY:

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