Request for Proposal #3

The Ball Sorter Machine

Need

A sport utility retailer needs to sort out various types of balls based on their type and colour.

Goal

Design and manufacture the prototype of a machine that can separate different balls based on their type and colour.

Specifications

The machine is plugged into the AC outlet. It receives a maximum number of 20 balls at each time, and must finish separating them in no longer than 2 minutes, based on their type and colour. The possible types of balls are tennis, ping-pong, golf, and squash. The ping-pong balls can be white or orange. All other types have uniform colour (for each type). Balls may be from various brands. They are loaded by the user, and they must be separated into 5 categories: **i)** tennis, **ii)** golf, **iii)** squash, **iv)** white ping-pong, and **v)** orange ping-pong. Samples can be acquired from the client. In addition to separating the balls into the above-mentioned categories, the machine is expected to inform the user about the sorting statistics (the total number of balls, the number in each category, overall time of the operation, etc.) per user's request.

Operation

The machine is normally in the standby mode. After loading the balls, the user can start the operation by pressing a button on a keypad. At the end of the operation, the user can communicate with the machine through a keypad and a display to retrieve the sorting log.

Depending on the operation time and accuracy of the classification results, the performance of the machine will be evaluated as detailed in the sequel.

Performance Evaluation

The prototype will run two separate but consequent operations and the total time and accuracy of these operations are measured. Reward and Penalty points will be given to the prototype performance according to the following scheme. Each operation is qualified if the machine sorts at least 3 balls.

➢ Each ball located in the correct category	+100
➢ Each ball located in the wrong category	-50
➢ All balls are located in different sorting locations	+500
➢ The sorting log asked by the user is “correct”	+500
➢ The operation time displayed on the display is “correct”	+100
➢ The operation time displayed on the display is “incorrect”	-100
➢ Time penalty:	-5 per second of operation
➢ Each disqualified run	-700

Additional points, called Extra Design Points, of up to 1000 will also be awarded to each machine by the judges for extra design functionality/capability features including extendibility, maintenance, installation, robustness, and performance repeatability.

Limitations and Constraints

a. The entire prototype (including the loading bin when loaded by the balls) shall completely fit within a $1.5 \times 1.5 \times 1.5\ m^3$ envelope.
b. The weight of the machine (without the balls) shall not exceed 10 kg.
c. The total product costs shall not exceed $200CDN.
d. The machine must be plugged in the AC, 110V-60Hz, 3-pin outlet.
e. The machine must be fully autonomous, and no interaction with an external PC or remote control is permitted during the operation. The operation must start by hitting a <*start*> button on the keypad.
f. The locations for the sorted balls must be specified in the machine clearly.
g. Dispensing the sorted balls must be quite easy with no need to disassemble any part of the machine.
h. At the end of each run, the machine display must be on prompt to show the number of balls sorted in each category, the total number of balls, and the overall time, per user’s request.
i. The operation time is considered “correct” if it equals the time measured by the referee ± 5%. Otherwise, it is assumed “incorrect.”
j. Each run is considered “finished” when all balls are positioned in the sorting locations and/or the display shows a message indicating the completion of the process. The run is not complete but disqualified if the machine hangs or jams unpredictably with no completion message on the display.
k. There will be no control on the conditions of the contest environment.
l. Each team will have a period of maximum *2* minutes to set up the machine before each run. If the preparation time exceeds 2 minutes, the run is disqualified.
m. A run is disqualified if the machine structurally collapses, falls over, hangs or jams (for more than 2 minutes), or the team declares the termination. If any of the above happens to the first run, the team will have 3 minutes to fix the system and run for the next time, if they wish. However, a run is qualified for scoring if the machine sorts at least 3 balls within the specified time (2 minutes) and then stops (for any reasons), displays the completion message and prompts for the sorting information.
n. The machine must pose no hazard to the users, and shall not be perceived as hazardous (e.x., too much vibration or noise or frequent spike during the operation is perceived as dangerous.)

Extra Features

The following features would enhance the machine performance, and increase the Extra Design Points:

- Machine has an emergency STOP button.
- Little time is needed to set up (or calibrate) the machine on the scene.
- More than 20 balls can be loaded into the machine and sorted with no modifications.
- Machine display can hold a longer log (of the previous operations) with more information.
- Machine has a backup power source for holding the information on the processor and communicating with the user when it is unplugged.
- Balls are sorted neatly and in an order suitable for packaging.
- Machine works robustly under different indoor and outdoor conditions.
- Machine operates quietly and smoothly (less sensible noise or vibration.)
- Machine looks elegant.

Expected Outcomes

Design and Construction Process: The team must follow a logical and systematic process in accomplishing their tasks of design, analysis, and construction. Conceptual design and system analysis are important steps of this project where the team has to compromise speed, accuracy, and cost. The detailed process must be reflected in the final report submitted by the team.

Proposal: Each team must work together to generate a proposal documentation on the design. The design proposal should reflect the conceptual design phase, team and project management with the scheduling, the steps to be taken for the detailed design and prototype fabrication, and the methods of manufacturing, integration and debugging to be followed in building the prototype.

Final Report: This report details the entire process of design, analysis, fabrication, and evaluation.

Final Prototype**:** The final prototype developed by the team should reflect the work presented in the proposal. Any significant changes in the design of the prototype must be justified in the final report. The quality of the prototype may vary widely depending on the background of the team, the difficulty of the concept, and other constraints. Many of the deficiencies of these products can be resolved later in the students' academic career. For this reason, a smaller portion of the student grade is allotted to the prototype construction and performance.

Team Dynamics: The team must propose a solution and the plan in the proposal, and remain *loyal* to the proposal during the entire process. Hence, a close interaction between members of the team is required initially to be able to "*plan ahead*." Early team dynamics may be strained, but interaction increases as the construction and integration of the machine proceed. Maximum team interaction occurs during the system integration, test and competition. The instructor will enhance the team dynamics by spending some time with the teams evaluating the process. In many cases students remember this team experience (including their teammates) when they are seniors, or even when they are returning alumni. Professional and humane characters are expected in all team activities.

Grade evaluation will be heavily weighted to the generated design concepts, proposal, final report, and the way each team has interacted and followed the tasks. The final product and performance evaluation (competition) will have less influence on the overall grade.

Statement of Work

Each team is composed of three students. Conceptual design, system analysis, and project planning must be performed through a close interaction of all members of the team. However, for the implementation, tasks can be broken into the following categories:

Processing and Control (Microcontroller)

One student shall program all the software for the system. In addition to combinational and sequential logic required for the algorithm, keypad and display interface with the microcontroller is also part of this assignment. Some extra coding may also be needed for system debugging. The software may be written in whatever language the group elects to use. However, for a low-power, high-end microcontroller, the assembly language would be the most efficient option. Some cross-assemblers can translate C++ and/or Basic into machine code resulting in a less efficient code. The microcontroller student also has the responsibility of assembling (if needed) and programming the system processor. It is required that the processor be functional and programmable by the end of the fall term, so that subsystem integration and testing may begin early in the spring term. Often integration requires additional minor adjustments to the computer hardware and software. In addition, in the winter term, the person responsible for microcontroller shall effectively assist the Electromechanical subsystem with duplication or fabrication of components and subassemblies. The division of Electromechanical tasks between the two members (Microcontroller and Electromechanical) must be identified clearly in the project proposal.

Mechanism and Actuation (Electromechanical)

One student shall be primarily responsible for constructing the structure and incorporating whatever actuators and mechanisms are required in the system. Nonetheless, for the second half of the project (winter term), the Microcontroller student will join the Electromechanical student for completing the tasks, according to the plan specified in the proposal. Major subsystems of the Electromechanical category can include: frame and structure, dispensing mechanisms, agitators (if needed), and stocking mechanisms. Some off-the-shelf mechanisms or platforms can be used for the above-mentioned subsystems, but this must be clearly addressed in the proposal and authorized by the instructor. In addition to design and analysis of these subsystems, their fabrication and/or assemblage as well as assigning the locations of the sensors and boards are also parts of the Electromechanical category. Although integration of the entire system might seem as a “mechanical” task by nature, all members of the team should equally and effectively take part in the integration process.

Sensor and Interfacing (Circuit)

One student shall construct all the digital and analog interfacing electronics to connect the sensors and actuators to the computer interface card. This includes motor/solenoid driver circuits. All sensors and input/output signal calibration/protection are also part of this category. In those situations where the primary calibration for a transducer is positional in nature, such as a stop switch, the task is still part of Circuit subsystem, but consultation with the Electromechanical person(s) is advised. For the actuator drivers, the use of driver IC’s is permitted, but the Circuit person must design and build at least one “open” circuit for each type of driver (DC, Stepper, Solenoid, etc.) in the system. Size/weight sorting and colour detection are major sensory tasks of this category. The circuit person shall also acquire suitable power supplies for the actuators, circuits, sensors, and the microcontroller.

Discussion

In this design, speed, accuracy and budget are competing factors. Designers should first analyze the performance criteria to specify the level of acceptable compromise in each of the above factors.

A variety of solutions can be proposed for sorting the batteries and separating them in different locations. Power consumption can become critical in this design. Hence, a careful analysis of the force and power required for the operation is important.

Students might encounter problems with construction of the product. With limited experience in shop practices, final prototypes may not always work as anticipated. This can be frustrating to the students. As with any life experience, the product building will improve as the students gain maturity, not only in shop practice, but also in improved engineering science background. The contest session provides proof of the paper design. It also demonstrates to students that in real life the result does not always follow the prediction of theory. This is a good time to remind the students that ***"an ounce of application is worth a ton of abstraction."***