Request for Proposal #3

The Can Recycling Machine

Need

A recycling company receives a continuous mixed stream of used and unused cans of different types, and needs to sort these cans, based on their material and other factors.

Goal

Design and manufacture the proof-of-concept prototype of a machine that can separate various cans based on their material and whether they have label or pull tab.

Specifications

The machine is expected to receive a maximum number of 12 randomly mixed cans at each time, loaded simultaneously into a bin by the user, and separate and sort them based on the can material and whether the cans have label or pull tab. The supplied cans are made of aluminum (soda can) or tin-plated steel (tin can), and they are all empty. The size and shape of each type are uniform, i.e., 222-ml beverage can for the aluminum material (different brands) and 284-ml Campbell's® soup can for 330-ml type. All tin can come without a lid. The cans must be separated into four categories: **i)** soda cans with pull tab, **ii)** soda cans without pull tab, **iii)** tin cans with label, and **iv)** tin cans without label. The sorted cans must be delivered to the user in separate, removable designated containers. The entire operation for each loading must take no longer than 3 minutes. The shape and size of the loading bin and containers, as well as methods of loading and unloading are up to the design, but must be convenient for the user, e.g., easily accessible and no need for disassembling any part. It is required that the machine be portable with no need for installations, and as such there are constraints on the overall weight and dimensions of the machine. In addition to sorting and dispensing the cans into the above-mentioned categories, the machine is expected to accept user's instructions through a keypad and LCD for starting/stopping the operation and retrieving the sorting information, including the total number of cans, the number of cans for each category, and the overall time of the operation, per user's request. The menus displayed on the LCD should be self-explanatory and provide easy navigation for users of various skill levels. Also, for safety purposes, the machine must have an easily-accessible emergency STOP switch that stops all the mechanical moving parts immediately. The machine can be plugged into the AC outlet.

Operation

The machine is normally in standby mode. After loading the mixed cans, the user can start the operation by pressing a <*start*> button on the keypad. The entire sorting process must be done autonomously, and must take no longer than 3 minutes. At the end of the operation, the machine must return to the standby mode by displaying a completion or termination message on the LCD, and the containers must be made available for pick-up. The user can then unload the containers and communicate with the machine through the keypad and LCD 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 following section.

Performance Evaluation

The prototype will run two separate but consecutive 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 run is qualified if the machine sorts correctly at least 1 can in each category that is present in the supplied mix within 3 minutes, returns to standby mode so that the containers can be unloaded normally, displays the completion or termination message at the end of its operation, and is able to communicate the operation information.

➢ Each "qualified" run	+1000
➢ Each "complete" run	+500
➢ Each can in the containers correctly sorted	+200
➢ Each can in the containers incorrectly sorted	–200
➢ Each "damaged" can	–200
➢ Each can not in a designated container at the end of the operation	–200
➢ The displayed number of cans for each category is correct.	+200
➢ The displayed number of cans for each category is incorrect.	–200
➢ The displayed total number of cans is correct	+500
➢ The displayed total number of cans is incorrect	–500
➢ The operation time displayed on the display is "correct"	+600
➢ The operation time displayed on the display is "incorrect"	–400
➢ Time penalty:	-10 per second of operation (from start)

Bonus Points for Extra Design Features:

➢ Robustness and Durability	0 to +400
➢ Operability and Sustainability	0 to +400
➢ Elegance and Safety	0 to +400
➢ Dexterity	0 to +800
➢ Extendibility	+700

- Compactness and Portability +700
- Real-time Date/Time Display +300
- Permanent Logs +300
- PC Interface +300

Constraints

a. The entire prototype (including the loading bin when loaded with cans) shall completely fit within a $0.8 \times 0.8 \times 0.8$ m^3 envelope at all operation times (power cable notwithstanding.)
b. The weight of the machine, including the empty bin and containers (without the cans), power cable, etc., shall not exceed 10 kg.
c. The total prototype costs shall not exceed $230 CAD before shipment and taxes. For parts purchased in foreign funds, the exchange rate reported by the Central Bank of Canada at the end of business day on January 9th, 2017, will be considered. The manufacturing labour is not considered on top of the material costs in the prototype, unless a part is manufactured using a 3D-printer or CNC machine. In these case, an additional cost of $5 CAD per manufacturing hour will be assumed. The G-code and exact manufacturing time for such parts must be reported.
d. The machine can be plugged in the AC, 110V-60Hz, 3-pin outlet.
e. The machine must have an easily-accessible emergency STOP switch that stops all the mechanical moving parts immediately.
f. 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 pressing a <*start*> button on the keypad.
g. No installation or instrumentation is allowed in addition to what is devised within the machine.
h. Containers for the sorted cans must be easily removable and clearly identified in the machine.
i. Containers must not contain any power supply, actuator or electronic board or part, such as active sensor, etc.
j. Loading and unloading the cans must be convenient to the user with no need for disassembling any part of the machine.
k. The time required for loading the cans into the machine and starting the operation shall not exceed 1 minute. The type and orientation of the supplied cans must remain undetermined during the loading period, i.e., machine must not pre-orient or sort the cans during the loading period.
l. Each run is considered “complete” when all the cans are sorted into the designated containers and the display shows a message indicating the completion of the process.
m. At the end of each run, the machine display must be on prompt to show the total number of cans, the number of cans for each category, and the overall time of the operation, per user’s request.
n. After the operation and unloading the containers, if any can is deformed or notably scratched (to the referee’s discretion), the can is considered as “damaged.”
o. The machine user interface for both operation and information retrieval shall be self-explanatory, and provide easy navigation for users of various skill levels.
p. The operation time is the duration between when the <*start*> button on the keypad is pressed and when the machine shows the completion or termination message on its LCD. No actuation or sensing must occur in the machine prior to the start of the operation. The operation time shall not exceed 3 minutes.
q. The recorded and displayed operation time is considered “correct” if it equals the time measured by the referee $\pm$ 1 second. Otherwise, it is assumed “incorrect.”
r. Each run is “qualified” for scoring if the machine sorts correctly at least 1 can in each category that is present in the supplied mix within 3 minutes, returns to standby mode so that the containers can be unloaded normally, displays the completion or termination message at the end of its operation, and is able to communicate the operation information.

s. A run is "disqualified" if the machine structurally collapses, falls over, hangs or jams (for more than 3 minutes), or terminates the operation before sorting at least 4 cans, or does not display the termination or completion message on the LCD at the end of operation, or runs longer than 3 minutes before terminating the operation, or takes more than 1 minute to load the cans in the machine and start the operation, 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.

t. Each team will have a period of maximum 2 minutes to set up the machine before it is ready to load the cans for each run. (For the second run, this time is extended to 3 minutes if the first operation is disqualified.) If the preparation time exceeds 2 minutes, the operation is "disqualified."

u. There will be no control over the conditions of the contest environment.

v. The machine must pose no hazard to the users, and shall not be perceived as hazardous (e.g., excessive vibration, noise, sporadic movement, or electric sparks during the operation is perceived as dangerous.)

Extra Design Features

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

- **Robustness and Durability:** Machine is durably constructed, and functions consistently in a wide range of operating environments with a low failure rate.
- **Operability and Sustainability:** Little time/effort is needed to set up and calibrate the machine, and the machine is modular so that parts can be replaced or repaired easily.
- **Elegance and Safety:** Machine looks elegant, and operates quietly and smoothly with little or no sensible noise or vibration.
- **Dexterity:** Machine can perform extra functions, such as separating the pull tabs or labels, neatly stacking or packaging the cans, etc.
- **Extendibility:** Machine can also accept and detect tin cans with lid and collect them in a different container with little or no need for modifications.
- **Compactness and Portability:** The entire prototype weighs not more than 5 kg (i.e., half of the maximum permitted weight,) and fits within a cubic envelope of $0.5 \times 0.5 \times 0.5$ m^3 (i.e., ~60% of that of the maximum allowed envelope.)
- **Real time Date/Time Display:** Date and time of each run are displayed on the LCD in standby mode.
- **Permanent Logs:** Machine stores sorting logs of at least 4 previous runs in permanent (EEPROM) memory.
- **PC Interface:** The operation information, including sorting logs and date/time, can be readily downloaded on a PC.

Expected Outcomes

Design and Construction Process: The team must follow a logical and systematic process in accomplishing their tasks of design, analysis, and fabrication. Conceptual design and system analysis are important steps of this project where the team has to compromise speed, accuracy, reliability, robustness, ease of use, 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: The final report details the entire process of detail-design, analysis, fabrication, and evaluation.

***Final Prototype*:** The final prototype developed by the team should reflect the work presented in the proposal. Any major or significant change in the design of the prototype after submitting the proposal must be agreed upon by the client (instructor) and 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 limitations. Many of the deficiencies of these prototypes can be resolved later in the students' academic career.

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 demonstration. The instructor will enhance the team dynamics by spending some time with the teams examining 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 individual/team has interacted and performed the tasks. Nevertheless, the final product and performance evaluation (demonstration and competition) will maintain their crucial roles in the overall grade.

Statement of Work

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

Processing and Control (Microcontroller)
One student shall be primarily in charge of developing all the software for the system. In addition to combinational and sequential logic required for the algorithms, keypad and display interface with the microcontroller is also part of this assignment. Some extra coding may also be needed for system debugging. Further utilization of the microcontroller may be needed if the team plans to accomplish some of the Extra Design Features, such as Real-time Date/Time Display, Permanent Logs, and PC Interface. For a low-power, high-end microcontroller, the assembly language is the most efficient option for programming. Nevertheless, some cross-assemblers can translate specific C and/or Basic instructions into machine codes resulting in more convenient programming options, albeit likely creating less tractable codes. For the processing hardware, the use of the microcontroller development board in the Project Kit is permitted if budget allows. Otherwise, the microcontroller student has the responsibility of assembling the microcontroller board, e.g., the Simple Configuration Board. It is required that the microcontroller be functional for basic design features and programmable by the Reading Week, so that system integration and testing may begin right after the Reading Week. Often integration requires additional adjustments to the microcontroller hardware and software.

Mechanism and Actuation (Electromechanical)
One student shall be primarily responsible for constructing the containers, structure and frames and incorporating whatever actuators and mechanisms are required in the system. Major components of the Electromechanical subsystem can include: structure and frames, feeding mechanisms, agitators (if needed), sorting mechanisms, containers, and sensor and microcontroller mounts. Some off-the-shelf mechanisms or platforms can be used for the above-mentioned components, but this must be clearly addressed in the proposal and authorized by the instructor. In addition to design and analysis of these components, their fabrication and/or assemblage as well as assigning the locations of the sensors and circuit boards are also parts of the Electromechanical subsystem. 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.

Instrumentation and Interfacing (Circuit)
One student shall construct all the digital and analog interfacing electronics to connect the sensors and actuators to the microcontroller board. This includes motor/solenoid driver circuits. All sensors and input/output signal calibration/protection are also part of this subsystem. 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 member is advised. For the actuator drivers, the use of the driver board in the Project Kit or driver IC’s is permitted if the budget allows, but the Circuit person must design and build at least one “open” circuit for a motor (DC, Stepper or servo) in the system and prove their functionality. Size/weight/material sorting and label/tab detection are major sensory tasks of this subsystem, in addition to the driver circuits and cabling. The Circuit person shall also complete wiring the machine and 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 cans and separating them into 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 final demonstration 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."***