PURDUE UNIVERSITY

CAPSTONE/SENIOR DESIGN EXPERIENCE 2016

ASABE Robotics

Agricultural & Biological ENGINEERING

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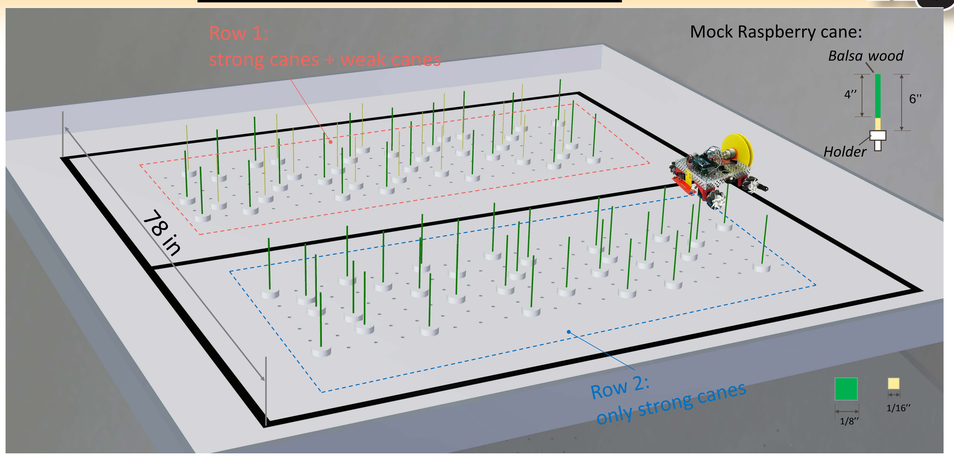
Objective: To develop a robotic solution to the challenge outlined in the 2017 ASABE Robotics competition. This years competition is a simulation of the pruning process of raspberry canes. The robot will need to be able to move around a competition board and identify and cut specific canes based on specified properties. An ideal solution will perform exceptionally at the competition and remain under budget.



Problem Statement & Background

- July 16-19 in Spokane, Washington
- Washington State produces 95% of the domestic raspberry crop
- Selective pruning is vital for raspberry harvesting
- Manual and chemical pruning requires a large amount of labor effort and herbicides
- This year's ASABE Robotics Competition challenge is designed to simulate the pruning process of raspberry canes using autonomous robots
- Two types of canes represented by 6 inch strips of balsa wood:
  - Floricanes (strong, 1/8'', yellow): need to be completely **REMOVED**
  - Primocanes (weak, 1/16'', **green**): need to be **SUPPRESSED**
- Mock canes are randomly distributed on the competition board
- Competition board:
  - 8 x 8 x ¼ foot piece of plywood
  - 6'' wall surrounds the entire board to prevent color interference
  - Two rows each containing 5 zones
  - Row 1 consists of 3-5 strong canes and 1-3 weak canes per zone
  - Row 2 consists of 5-8 strong canes per zone
  - Each zone has 3/8" holes drilled in a grid pattern for cane holders
  - Each cane can be seen from either the left or right side of the row
  - The perimeter of the two rows is surrounded by black electrical tape
- The goal is to remove all floricanes and leave less than 6 primocanes in each zone
- A scoring system is used to evaluate the performance of the robots
- 3 Rounds for execution, highest two scores will be taken

Scoring Rubric

Round __ Team _____		Count		Value		Subtotal
Weak Cane	Full Cut		X	5	=	
	Partial Cut		X	3	=	
	Removed		X	2	=	
Strong Cane	Full Cut		X	10	=	
	Partial Cut		X	6	=	
	Removed		X	4	=	
Number of zones with <6 canes			X	10	=	
Add'l strong canes removed			X	-15	=	
Weak canes left standing			X	-5	=	
Interventions			X	-5	=	
Poster Deductions			X	-25	=	
Time remaining (seconds)			X	1	=	
				Total		

Significant Restrictions

- Robot(s) must be fully autonomous
- Up to 3 robots, but only 2 can cut canes
- Robot must fit in a cubic foot box a the start of the run
- 5 minute time limit
- No rotating blades or cutting chains
- Canes cannot be removed from the holder

Final Design:

Arduino Mega 2560

- Microcontroller for all components
- Selected for ample amount of both analog and digital ports
- Both members had previous experience with Arduino programming

10 AA Battery Pack (Hidden)

- Power supply for robot
- Supported by 3D printed mount on underside of the robot

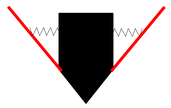
12V Mini DC Motor

- Drives the chain spool
- 60 RPM, High Torque
- Low RPM allows slow control of chain extension
- DC motor was chosen over stepper motor due for smoother operation
- 3D printed motor mount

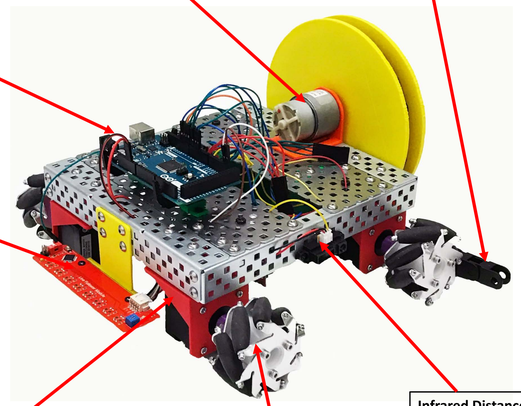
IGUS Micro E-Chain

- Provides horizontal reach into the zones
- 24 inch length
- Designed to transport wires
- Stiff enough not to flex while travelling through zones
- Mounted to 3D printed spool

Breaking Mechanism (In Progress)



- The graphic above represents the top view of the current cane breaking design.
- The black piece represents a 3D printed cart structure that will have a wheel underneath. - This cart will me attached to the end of the chain.
- The two red lines represent thin metal bars that will make contact with the canes as the cart travels through the zones.
- The bars will be stiff enough to break the weak canes, but not stiff enough to break the strong canes
- This design allows the breaking process to be passive and would not require any sensors or other electronics



QTR-8RC Reflectance Sensor

- Function: Line Following
- Combined with PID logic allows robot to remain centered along a line
- 3D printed sensor mount

Stepper Motor Driver (Hidden)

- Controls voltage to stepper motor from fixed voltage power supply
- Mounted on underside of chassis

Bipolar Stepper Motor

- Drives Mecanum Wheels
- Chosen over DC motor for ease of control for fixed distances
- 40 mm motor
- 200 steps per revolution
- 3D printed motor mount

Mecanum Wheels

- Standard 4 wheel design
- 60 mm diameter
- Rollers set at 45 degree angle
- Allows motion in all directions without rotating the robot
- Attached with custom 3D printed wheel hubs
- Chosen over standard wheels due to their flexibility

Infrared Distance Sensor

- Used to identify when robot is aligned with a cane
- Offers significantly more precision than standard sonar distance sensors

Costs:

Item	Qty.	Unit Price	Total
Vex Chassis Kit	1	$18.99	$18.99
Vex Metal Plate	2	$3.99	$7.98
60mm Mecanum Wheels Kit	1	$68.00	$68.00
Nema 17 Stepper Motor	4	$12.99	$51.96
Stepper Motor Driver	4	$6.36	$25.44
QTR-8RC Reflectance Sensor	1	$15.99	$15.99
Infrared Distance Sensor	1	$9.95	$9.95
IGUS Micro E-Chain	1	$12.99	$12.99
Arduino Mega 2560	1	$45.95	$45.95
12 Mini DC Motor	1	$11.98	$11.98
Rechargeable Batteries Pack	1	$20.98	$20.98
Cables & Wires	1	$9.98	$9.98
3D Printing Material	1	$29.00	$29.00
Total			$329.29

Impact & Sustainability

- Unlikely that any of the competition robots could function well in a real environment, this competition is based on the real pruning process of raspberry canes.
- The execution logic on simulating board is the same as the real field. All the software can be directly applied to real world application.
- This platform offers a much more accessible way to test new and innovative ideas for tackling some today's toughest agricultural problems.
- The scale is such that there is a relatively small financial barrier of entry so new minds can develop solutions to problems they would otherwise not be able to solve.
- It is possible that one of the innovative solutions from the competition can be scaled up to function in the real world.
- This can save companies a lot of money on research and provides a free source of new ideas.
- Any environmental impact from the robot is insignificant. All components are electric so there are no emissions.

Alternative Solutions

Cane Identification

Color Sensor

- Distinguish small or weak canes based on color
- Lacked precision for smaller canes
- Required perfect alignment

Precision Force Sensor

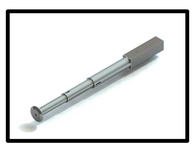
- Distinguish small or weak canes based on their response to a force
- Barely precise enough to measure weak canes
- Required a linear actuator to apply a force
- Required perfect alignment

Both of these solutions required perfect alignment and wiring run through the length of the chain. The final solution is passive and requires cane identification at all.

Zone Movement

Collapsible Robotic Arm

- Provide horizontal and vertical movement control
- Could easily remove cut canes from the zone for bonus points
- Complex control programming
- Very expensive for pre-built options
- Limited reach
- Too large



Telescoping Linear Actuator

- Straight forward controls
- Extremely limited options for such a small size
- Would require custom fabrication
- Awkward wiring to the end of the actuator
- Slow movement compared to other options
- Can be expensive depending on model
- Limited reach

Both of these options suffered from one major downfall. Many of the market options were too large to fit within one cubic foot. They also had limited reach and would not be able to reach all of the canes. Our final chain design has much more range, is more cost-effective, and has more simple controls.

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