SBD: Robotic Metallic Debris Collector

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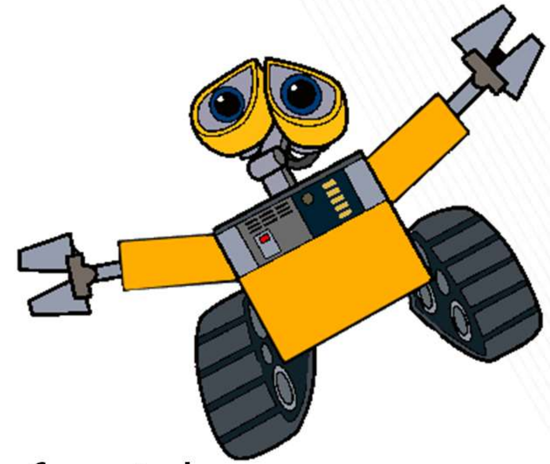
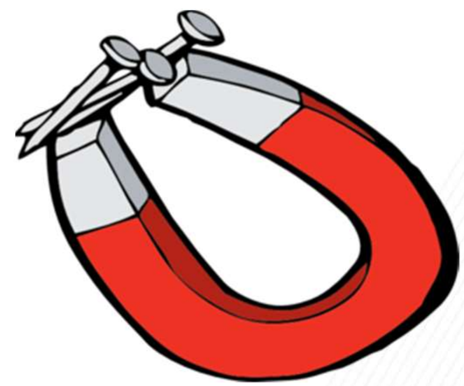
Overview - What is it?

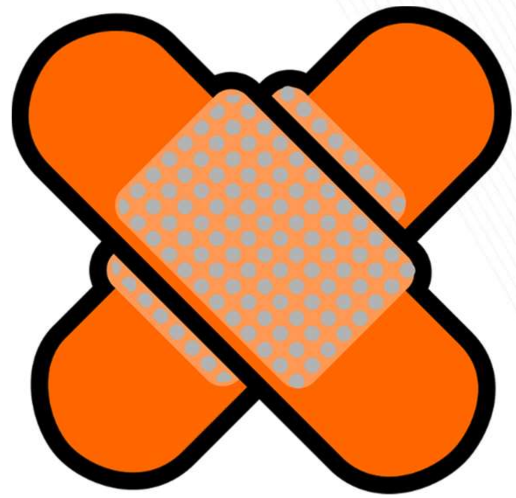
- What it should do:
  - Autonomous navigation
  - Obstacle avoidance
  - Metallic debris collection
    - nails, screws, staples and small scraps of metal
- How it will do it:
  - Ubiquity Robotics Magni Silver
    - built-in sensors
    - Robot Operating System (ROS)
  - Natural magnet
  - Pathfinding algorithm
- Projected Cost
  - $7000

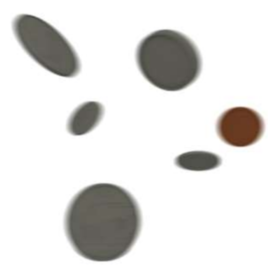




Motivation - Why is it needed?

- Saves time and money...
  - Two types of cleanup:
    i. construction laborers
      - (1-3 hours of labor)
    ii. third-party companies
      - (50 cents/sq ft)
  - Can work unsupervised
- Improves Safety...
  - Tetanus
  - Flesh wounds





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Project Description - Hardware

- Magni Silver (platform)
- Arrays of ultrasonic sensors (feedback)
- Pi camera (localization)
- IMU (navigation)
- Magnet (manipulation)
    - Mounted on the front of the robot
    - Will be attached to a forklift

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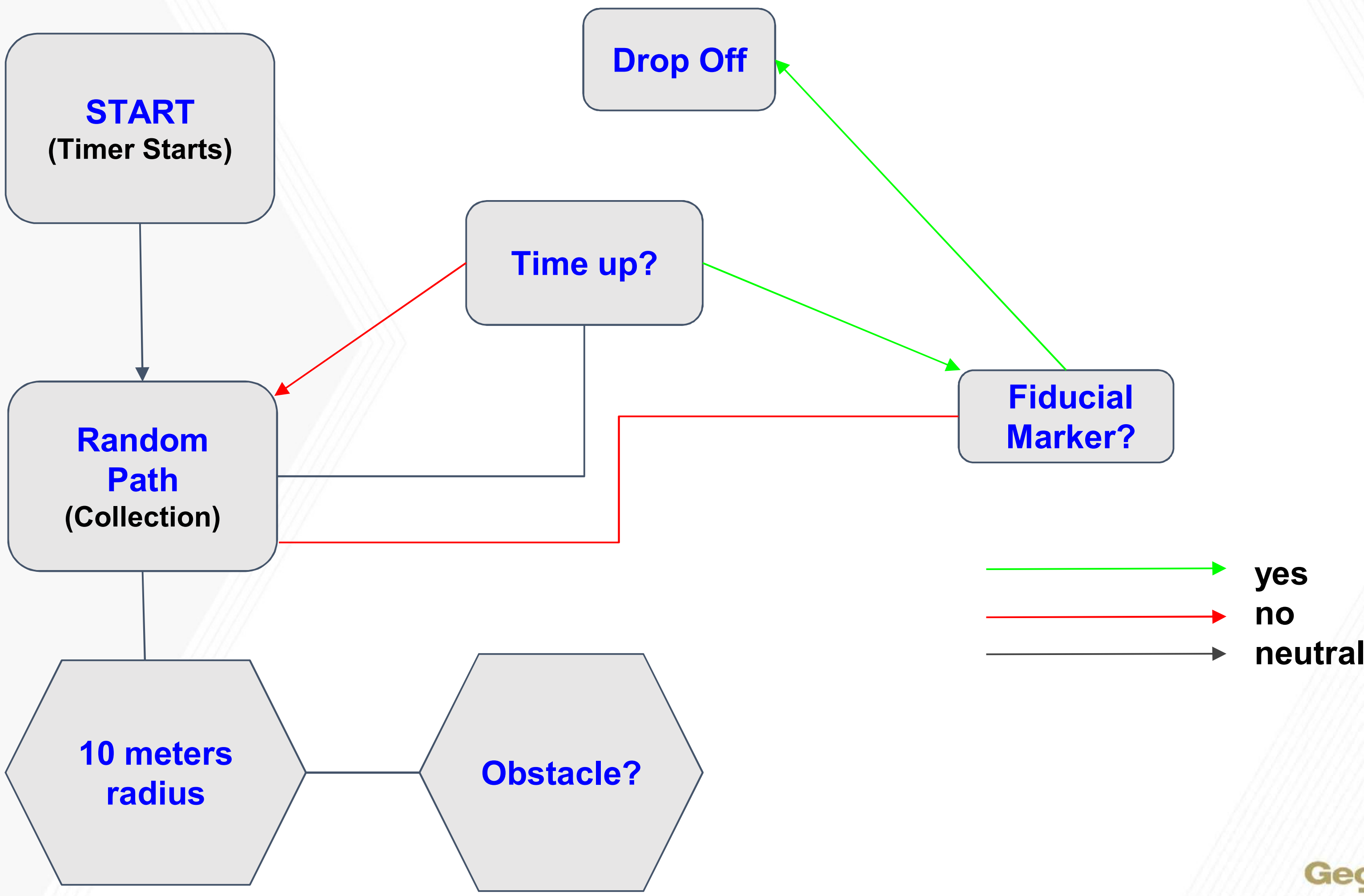
Project Description - Software

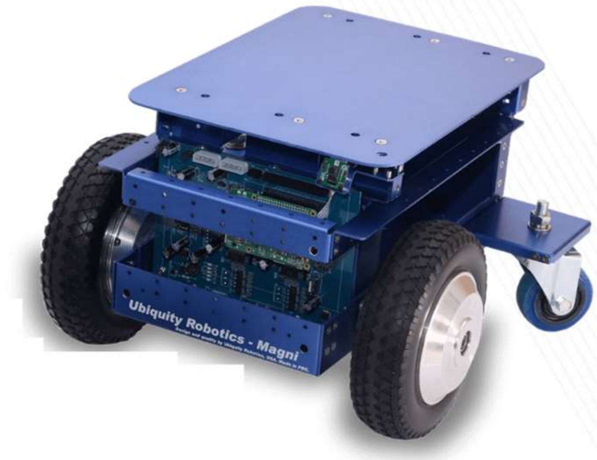


Goals and Add-Ons

- Current Goals:
  - Patrol the unbounded area of the worksite.
  - Avoid collision and collect small metallic debris on the ground.
  - Deliver the debris to a designated, static drop zone.

- Extra Features:
  - Detection and collection of non-ferrous metallic debris.
  - Integration of Robotic arm for bigger debris collection.
  - Dynamic drop zone without the need for fiducial markers.
  - More robust collection routine and pattern.

Technical Specifications



Magni Silver Platform	
Feature	**Technical Specification**
Payload	100kg
Odometry	Hall sensor odometry (accurate to 2mm)
Software	Ubuntu 16.04, ROS Kinetic + Core Magni Packages
Computer	Raspberry Pi
Camera	Single upward facing
Navigation	Ceiling fiducial-based navigation
Included sensor package	Sonar array

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Technical Specifications

Forklift	
Feature	**Technical Specifications**
Payload	At least 20 kg
Height off the ground for collecting debris	2 cm minimum distance off the ground
Servo	12 V power rating

Operational Specs	
Feature	**Technical Specifications**
Bounded Area	10 meter diameter radius
Size of Debris	Under 5 inches in length and 200 grams in weight

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Design Approach - Hardware

Modified Magni Silver controlled by Raspberry Pi3 A+:

- The RasPi runs ROS Kinetic operating system on Ubuntu 16.04.
- Responsible for controlling both 200 W hub motors, with course-correction via Hall sensors and onboard sonar.
  - Cheap, spinning lidar sensor on loan from SBD.
  - SLAM packages available for Magni Silver (ROS).
- Can output 5V or 12V DC power at 7A for peripherals not included in the package (i.e. IMU, metal detector).
- Collection system will consist of natural magnet attached to a solenoid with a thin, plastic sheet under the magnet.

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Design Approach - Software

ROS (Robot Operating System):

- Infrastructure nodes control hardware.
- Capability nodes deal with data (i.e. sonar).
- Action nodes run algorithms.

Plan:

- Roomba-like random walk algorithm is most efficient (with smallest development time). Enhanced with odometry, IMU.
  - Robot will navigate max. 10m away from start for demo.
- Obstacle avoidance via sonar suite and possibly Pi camera.
- Returns debris to start (i.e. drop zone) by following odometry or via SLAM algorithm.
- Unbounded area - consider geofencing, lidar, or SLAM.

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Codes and Standards

- C++ and Python programming standards (set by ISO/IEC 14882:2017 and PEP 8, respectively).
  - Ubuntu Linux is built upon C++ and Python.
- Raspberry Pi3 A+ with ARM A9 core uses ARMv7-A microarchitecture.

(NOTE: ROS is not an OS -- it is middleware -- thus it does not have specific codes or standards associated with it.)

Alternatives and Tradeoffs

Navigation:

- Hall Sensor Odometry - least accurate, but can chart the path of the robot since start.
- Ceiling Fiducial Markers - recognition algorithms widely available, but many, markers needed for accuracy.
    - *DECISION: use both! Odometry to keep precise track of current location, and ceiling markers to correct errors.*

Obstacle Avoidance:

- Sonar - familiarity, limited field-of-view, slower (sound).
- Lidar (SLAM) - 360 degree field-of-view, much faster (light). Provided test unit is cheap and buggy, however.
    - *DECISION: test Lidar unit, but build algorithm based on Sonar just in case.*

Tasks and Schedule

We have divided our team into two sub-team:

1. Hardware team:

   Yee Aung (leader), Christian Brice, Nam Igwe

1. Software Team:

   Tyler Brown(leader), mohammad karim, Ying Ying Choi.

Following Table contains a list of all of the tasks and corresponding leader. The goal of this project is to finish the design portion before March 2019 and then conduct hardware tests and software debugging throughout March and April (until April 20th).

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Schedule Table

Tasks

Name	Begin date	End date
Hardware	11/5/18	3/4/19
Tasks dealing with the hardware of the robot.		
Deciding on Hardware	11/5/18	11/19/18
Examining specific hardware components for the harware element of the design.		
Research BeagleBone	11/5/18	11/19/18
Christian		
Research Sensors, Motors, Batteries and IMUs	11/5/18	11/19/18
Looking at different operating voltages. Nam		
Research Robotic Arms	11/5/18	11/19/18
Integrating the robotic arm with an electromagnet. Specifications for the arm. Yee		
Prototype Test Platform	11/20/18	12/4/18
Using rudimentary hardware.		
Assembling the Robot	11/20/18	12/4/18
Putting together all the pieces.		
Secure Hardware Funding	1/7/19	1/11/19
Ordering Parts	1/14/19	1/18/19
Order the parts we need.		
Testing Ordered Parts	2/14/19	2/18/19
-Yee: test the robotic arm and electromagnet *-Nam: test different motors speed, battery stress test, sensors inputs/outputs* *-Christian: more stress test on microcontroller*		
Building the Platform	2/19/19	3/4/19
3D Printing Peripheral Mounts	2/19/19	2/22/19
Integrating Peripherals	2/25/19	3/4/19
Software	12/5/18	3/5/19
Prototype Pathfinding Algorithms	12/5/18	12/13/18
Writing the algorithms to patrol the area.		
Configuring Hardware APIs	1/21/19	2/4/19
Refining Pathfinding Algorithm	1/14/19	1/28/19
Debris Detection and Collection Algorithm Development	2/19/19	3/5/19
Delivery Algorithm Development	1/29/19	2/11/19

Tasks

Name	Begin date	End date
Project Proposal Paper	11/20/18	12/5/18
Trial Demo/Experimenting	3/6/19	4/1/19
Pathfinding/Navigation Debugging	3/6/19	3/13/19
Metallic Debris Detection Debugging	3/12/19	3/19/19
Pick Up/Drop Off Debugging	3/20/19	4/1/19

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Task Distribution and Level of Importance

Task	Task Lead	Other Members	Importance
Secure Hardware Funding	CB	YA, MK, NI	*Medium*
Ordering Parts	YA	MK, CB	*Medium*
Testing Ordered Parts	NI	CB, MK, YA	*Low*
Prototyping Path Finding Algorithm	TB	YC, MK	*Medium*
Configuring API	MK	TB, YC, CB	*Medium*
Refining Pathfinding Algorithm	TB	MK, YC	*Medium*
Debris Detection and Collection Algorithm Development	YC	MK, TB	*Medium*
Collision Detection and Avoidance Algorithm	MK	TB, YC	*Medium*
Delivery Algorithm Development	CB	MK, YC, TB, YA, NI	*High*
Project Proposal Paper	CB	YA, MK, TB, YC, NI	*Medium*
Trial Demo/Experiment/Debugging	CB	MK, TB, YC, YA, NI	*High*

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Project Demonstration

- Demo Details:
  - Indoors.
  - Smooth and even terrain.
  - Area will be randomly littered with metallic debris.
    - 10m radius around the start position
  - Artificial obstacles within the 10 meter radius.
  - Fiducial markers will be place strategically on the ceiling to help the robot navigate back to the drop off area.
  - The robot collection algorithm will be initiated at a predetermined spot with the internal timer set to three minutes.

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Project Demonstration Goals

- Successful completion of the demo:
  - Robot navigated through the area autonomously...
    - avoided obstacles
    - successfully collected 80% of the metallic debris
    - was able to navigate to drop off location
    - was able to dump the metallic debris at the drop-off location

- Extra features that can be tested:
  - Relocating the drop off location halfway through the demo.
  - People moving through the demo area.
  - Collection of larger metallic debris and non-ferrous metallic objects.

Market Analysis

- Main competition: hiring a cleaning company to clean the construction site.
- One-time payments ***vs.*** reusability.
  - More cost-effective to use a robot if multiple sites need to be cleaned or a site is cleaned multiple times.

Cost to Clean a Construction Site			
National Average	Typical Range	Low End	High end
$442	$275 - 656	$150	$1000

Cost Analysis

Expense of Income Component	Amount
Parts Cost	$2,233.92
Assembly Cost	$20.00
Testing Labor	$10.00
Fringe Benefits	$9.00
Subtotal	**$2,272.92**
Overhead	$2,727.50
Input Costs Subtotal	**$5,000.42**
Sales Expense	$500.04
Amortized Development Costs	$50.00
Subtotal, All Costs	**$5,550.46**
Profit	$1,449.54
Selling Price (Per Unit)	**$7,000.00**
Development Costs	**$85,083.09**

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Current Status

- We have the following:
  - Magni Silver robotic platform, sonar suite (included with the platform), spinning lidar.
- Plan to talk to ECE "parts guy" to check his stockpile (magnet, metal and plastic sheets, motors for the lift mechanism).
  - If not, we will fill out an order sheet ASAP.