Control Module/Interface for Service Robots

Senior Design Team 315

Department of Electrical and Computer Engineering

Team Introduction

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Scope of Presentation

- Problem Statement
- Concept Generation
  - High Fidelity Concepts (3)
- Concept Selection
  - Selected Concepts
  - Models/Diagrams
- Future Work

Problem Statement

- Design control module/interface for service robots
- Enable motorized system to semi-autonomously follow a person

Concept Generation

- Morphological Chart
- Lateral Thinking
- 5 Medium Fidelity Concepts
- 3 High Fidelity Concepts

Concept Generation: Morphological Chart

Components

- User Interface
- Display
- Connectivity
- Cameras/Sensors
- Power Source

User Interface	Display	Connectivity	Cameras/Sensors	Power Source
Touchscreen	LCD	Bluetooth	Lidar	Lithium battery
Voice	LED	WIFI	Digital Camera	AC power
Mobile Application	Smartphone display	Wired Ethernet	Radar	Solar power
Push Buttons	Tablet display	USB	Acoustic sensors	Fuel cell
Keyboard	Computer monitor	Wireless Ethernet	WIFI sensing	DC power
	LEDs	GPS	Laser based sensors	Nuclear power
	HUD	Line Follower	Ultrasonic sensors	
			Photoelectric sensors	

Concept Generation: Lateral Thinking

Components

- Robot
- Control Logic
- Cameras/Sensors
- User Interface
- Power Source
- Multi-Use Applications

High Fidelity Concepts (Part 1 of 3)

- Tablet-like LCD interface on front of robot
- In addition to app, allows the user to switch between semi-autonomous and manual mode
- Employees can interact with the robot
- Keeps track of items placed into cart
  - Suggests other similar items (Ie. BOGOs or similar products)
  - Shows where items are located
  - Automatically processes payment once user leaves store

High Fidelity Concepts (Part 2 of 3)

- Camera mounted electric turning swivel
- Travels to user's last known location
- Continues normal following operation when user is found
- Depends on alternative user location tracking until user is in view

High Fidelity Concepts (Part 3 of 3)

- Additional functionality
  - Out of scope of the project
  - Fully autonomous feature
- Extra button to end user's session
  - Return to cart / charging station
  - Router / GPS module at station to guide it back

Concept Selection

- Power Source
- Display
- Connectivity
- User Interface
- Camera/Sensors

Power Source (Pugh Chart)

	Weight	Lead Acid Battery	Solar Lithium Ion Battery	Nuclear	Fuel Cell
Safety	5	-	-1	-1	-1
Cost	2	-	-1	-1	-1
Lifetime	3	-	+1	+1	+1
Efficiency	3	-	+1	+1	+1
Score		-	-1	-1	-1
Continue?		Yes	No	No	No

Power Source (AHP)

	Safety	Efficiency	Cost	Lifetime	Mean	Weights
Safety	1	2	5	2	2.115	0.450
Efficiency	1/2	1	3	1	1.066	0.228
Cost	1/5	1/3	1	1/3	0.386	0.082
Lifetime	1/2	1	3	1	1.066	0.228

	Weight	Lead Acid Battery	Solar Lithium-Ion Battery	Nuclear Power	Fuel Cell
Safety	0.45	0.40	0.30	0.15	0.15
Efficiency	0.228	0.15	0.20	0.30	0.30
Cost	0.082	0.60	0.10	0.15	0.15
Lifetime	0.228	0.10	0.25	0.25	0.30
Score		0.29	0.23	0.19	0.20
		Winner			

Display (Pugh Chart)

		LCD	LED Screen	Phone	Tablet	Computer Monitor	LEDs	HUD
Ease of Use	1	+1	+1	+1	+1	+1	+1	+1
Comfort	1	+1	+1	+1	+1	+1	+1	-1
Cost	5	-1	-1	+1	-1	-1	+1	-1
Battery Usage	3	-1	-1	+1	-1	-1	+1	-1
Score		-6	-6	10	2	-6	10	-9
Continue?		No	No	Yes	Yes	No	Yes	No

Display (AHP)

	Weights	LCD	LED Screen	Phone	Tablet	Computer Monitor	LEDs	HUD
Ease of Use	.11	.8	.8	.7	.75	.9	.4	.2
Comfortability	.11	.9	.9	1	.9	.1	.8	.05
Cost	.49	.3	.3	1	.1	.01	.95	.3
Battery Usage	.29	.2	.3	.9	.2	.1	.95	.2
Score = $\Sigma a_i \cdot w_i$		.392	.421	.938	.289	.144	.873	.232

Winner

Connectivity (Pugh Chart)

	Weight	Bluetooth (Reference)	Wi-Fi	Wired Ethernet	USB	Wireless Ethernet	GPS (Cameras/Sensors)
Accuracy	5	-	0	+1	+1	0	+1
Feasibility	3	-	-1	-1	-1	+1	0
Cost	3	-	0	0	0	-1	-1
Score			-3	2	2	3	2
Continue?		Yes	No	No	No	Yes	No

Connectivity (AHP)

	Connection Accuracy	Feasibility	Cost	Mean	Weights
Connection Accuracy	1	7	3	2.75	0.69
Feasibility	1/7	1	1	0.522	0.13
Cost	1/3	1	1	0.693	0.18

Criteria AHP Chart

	Weight	Bluetooth	Wi-Fi	Wired Ethernet	USB	Wireless Ethernet	GPS
Connection Accuracy	0.69	0.18	0.18	0.24	0.20	0.10	0.10
Feasibility	0.13	0.25	0.20	0.00	0.25	0.20	0.10
Cost	0.18	0.22	0.22	0.10	0.22	0.19	0.05
Score		0.20	0.19	0.18	0.21	0.13	0.091
		Winner					

Alternatives Ranking Table

User Interface (Pugh Chart)

	Weight	Touchscreen (Reference)	Voice	Mobile App	Push Buttons	Keyboard
Ease of Use	5	-	-4	3	3	-1
Comfortability	4	-	4	3	3	-1
Cost	3	-	2	4	2	1
Score			2	39	33	-6
Continue?		No	No	Yes	No	No

User Interface (AHP)

	Ease of Use	Comfortability	Cost	Mean	Weights
Ease of Use	1	3	7	2.756	0.67
Comfortability	1/3	1	3	1	0.24
Cost	1/7	1/3	1	0.362	0.09

Criteria AHP Chart

	Weights	Touchscreen	Voice	Mobile App	Push Buttons	Keyboard
Ease of Use	0.67	0.65	0.07	0.72	0.1	0.34
Comfortability	0.24	0.23	0.22	0.23	0.2	0.15
Cost	0.09	0.12	0.71	0.05	0.7	0.51
Score		0.5	0.16	0.54	0.18	0.31
				Winner		

Alternatives Ranking Table

Camera/Sensors (Pugh Chart)

		Digital Camera (reference)	Lidar	Radar	Acoustic Sensors	WIFI Sensing	Laser Based Sensors	Ultrasonic Sensors	Photelectric sensors
Visual Acuity	5	-	-1	0	0	0	0	0	0
Cost	3	-	+1	+1	+1	-1	-1	-1	-1
Processing Power	2	-	-1	-1	-1	+1	+1	+1	+1
Power Consumption	4	-	+1	+1	+1	+1	-1	-1	-1
Availability	1	-	+1	+1	+1	+1	-1	-1	-1
Score			1	6	6	4	-6	-6	-6
Continue?		Yes	Yes	Yes	Yes	Yes	No	No	No

Camera/Sensors (AHP)

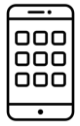
	Visual Acuity	Cost	Processing Power	Power Consumption	Availability	Mean	Weights
Visual Acuity	1	5	5	7	3	3.49	0.51
Cost	1/5	1	7	1/3	9	1.33	0.19
Processing Power	1/5	1/7	1	3	1/5	0.44	0.06
Power Consumption	1/7	3	1/3	1	1/5	0.49	0.07
Availability	1/3	1/9	5	5	1	0.98	0.14

Criteria chart

	Weights	Lidar	Digital Camera	Radar	Acoustic Sensors	WIFI Sensing	Laser Based Sensors	Ultrasonic Sensors	Photoelectric Sensors
Visual Acuity	0.045	0.179	0.107	0.134	0.089	0.170	0.134	0.143	0.045
Cost	0.011	0.220	0.275	0.275	0.055	0.055	0.055	0.055	0.011
Processing Power	0.133	0.167	0.200	0.100	0.100	0.100	0.100	0.100	0.133
Power Consumption	0.114	0.102	0.125	0.170	0.148	0.136	0.114	0.091	0.114
Availability	0.151	0.151	0.151	0.151	0.151	0.146	0.050	0.050	0.151
Score		0.062	0.171	0.149	0.160	0.093	0.133	0.100	0.103
			Winner						

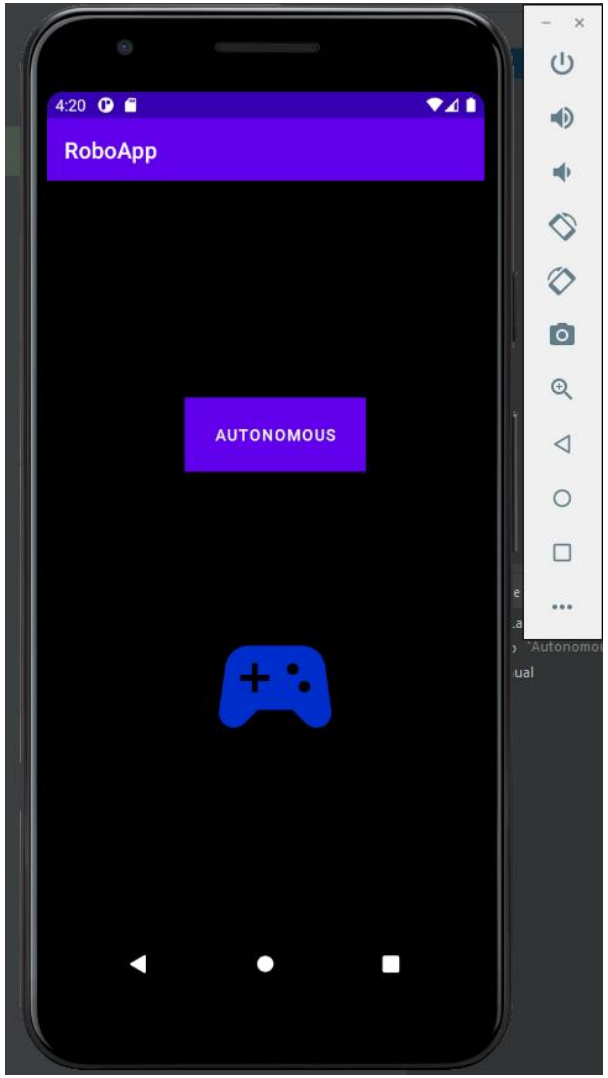
Alternatives Chart

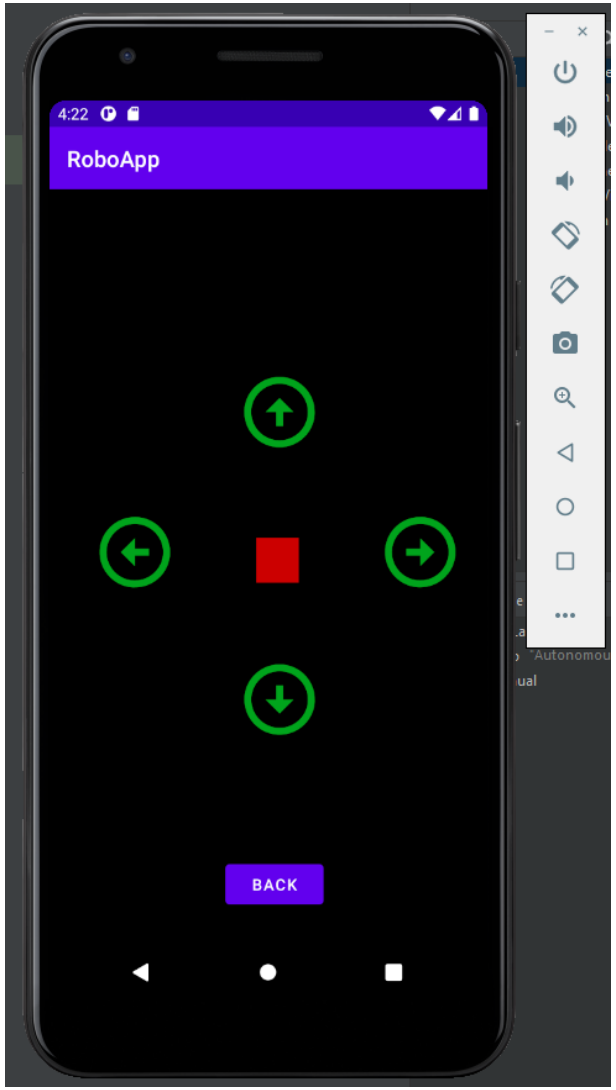
Final Selections

- Power Source – Lead Acid Battery 
- Display – Smartphone Display 
- Connectivity – Bluetooth 
- User Interface – Mobile Application 
- Camera/Sensors – Digital Camera 

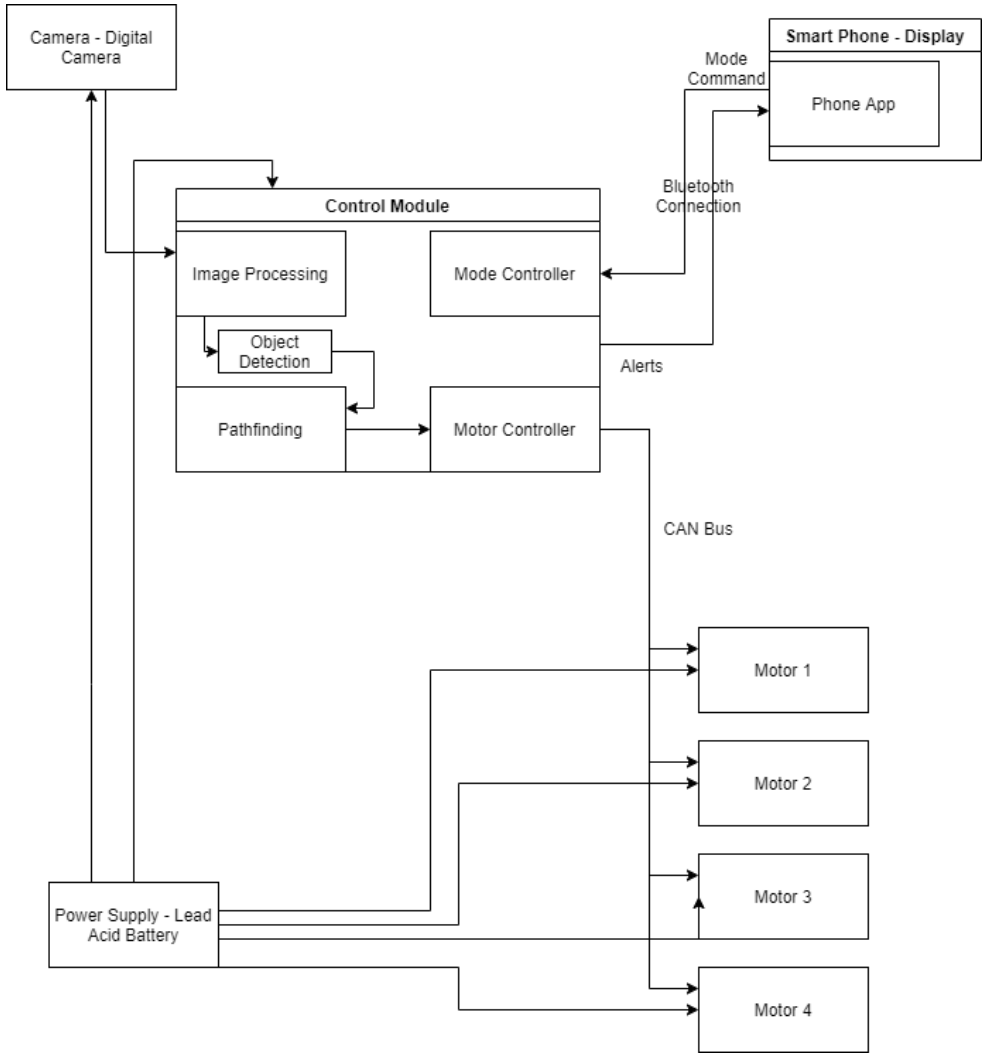
App Connectivity

```java
public class MainActivity extends AppCompatActivity {

    Button auto;
    ImageButton manual;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);

        auto = findViewById(R.id.btnAuto);
        manual = findViewById(R.id.btnManual);

        manual.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                Intent manualMode = new Intent(getApplicationContext(), ControlActivity.class);
                startActivity(manualMode);
            }
        });
    }
```





System Diagram



Future Work

- Power Source – Lead acid battery integration
- Display – Phone application interface
- Connectivity – Bluetooth with module and app
- User Interface – App development
- Camera/Sensors – Digital camera integration

Questions

Robot (1 of 5)

- Dual cameras front and back of robot
- Dual lidar tracking front and back
- Dual sonar tracking front and back
- Multiple channels for output to each motor
- Blackbox recording of all actions taken by the robot
- Regenerative breaking for the motors

Robot (2 of 5)

- Automatic calibration for speeds and breaking distances for different operating platforms
- Kid cart foam around sides
- Omnidirectional wheels
- Bat-like sonar
- Roller skate wheels
- LCD screen on cart

Robot (3 of 5)

- LED screen
- Tablet display
- Computer monitor
- Color LEDs
- HUD
- Pushbuttons

Robot (4 of 5)

- Grocery cart size
- Rideable for kids
- Broom bristles under cart
- Plasma screen control module
- Uses one of previous Senior Design projects as a motorized cart
- Use a shopping cart and put an electric motor on it

Robot (5 of 5)

- Bluetooth and WIFI for external devices
- Allows usage with other carts - dynamic
- Use microprocessor to connect to motors
- Use pre-existing system
- Require USB type c input and output

Control Logic (1 of 7)

- Combine camera and lidar feed for tracking
- Combine camera and sonar feed for tracking
- Combine lidar and sonar feed for tracking
- Collect GPS data from user's phone to aid tracking around corners
- Robot returns to charging station automatically after use
- Artificial intelligence for path finding and motor control
- Emergency break when obstacle appears in front of the robot

Control Logic (2 of 7)

- Ignore unsafe commands entered into the robot by users in manual mode
- Robot makes an alert sound through a speaker when stopping or ignoring unsafe commands
- Follows a black line on the floor
- WIFI sensing data collected by module and plans route to follow user
- Radar observes environment for objects and uses camera recognition to find user and determine path to follow

Control Logic (3 of 7)

- Navigation capabilities using AI – able to find unknown locations (solving a maze)
- Use distance from multiple strategically placed routers for robot positioning
- Lead mode – robot knows locations of items in the store that user can follow it to
- Hazard communication between modules
- Premapped area known by robot
- Save paths traveled by robot to create map of area

Control Logic (4 of 7)

- Auto path, after saving path, reuse to move robot without direct user input
- Cart knows geographical location of other carts
- Bots in vicinity to each other connect to avoid collision with one another
- Multiple robots can follow a single user with all following the same route as the lead robot in a single file line
- Cart semiautonomous mode only within premapped area

Control Logic (5 of 7)

- Cart scans person to know who to focus on
- Deciphers between people, objects, structures
- Determines whether it is safe to proceed
- Will stop if unsafe to proceed
- Response time?
- Control module has maximum dimensions of 8”x4”x4”

Control Logic (6 of 7)

- Follow user outside of predefined area?
- Follow user unless physically uncapable
- User has joystick that detaches from cart and can move robot around manually
- Payment processes once cart leaves store, recognizes what items are in cart

Control Logic (7 of 7)

- If a user likes a specific item, the cart will show them multiple items they may like in relation
  - Related items
  - On-sale, BOGOs
- If person is in path, robot asks person to move and get out the way in a kind and polite, yet firm manner
- Uses machine learning to learn the store it’s in

Cameras/Sensors (1 of 3)

- Temporary facial recognition to keep track of current user
- Simple motor control based on camera feed (no AI)
- Multiple cameras?
- Support for minimum of one camera up to n number of cameras
- What kind of cameras?
- User gestures towards camera for robot to follow

Cameras/Sensors (2 of 3)

- Camera mounted on electric swivel so can turn on its own
- 360 degree camera for monitoring most of environment at once
- WIFI sensing to detect changes in environment
- Acoustic sensors
- Laser based sensors
- Ultrasonic sensors
- Photoelectric sensors

Cameras/Sensors (3 of 3)

- Line follower
- Lidar

User Interface (1 of 5)

- Bluetooth ping user's phone for location data
- Voice activated commands in manual mode or to switch between modes
- Assisted power steering when users push the cart
- Manual instructions for motors sent through an app connected through Bluetooth
- Switch between modes using an app connected to the module
- Push notification if trouble occurs
- Push notification to support employee

User Interface (2 of 5)

- Admin app login in allows for monitoring of all robot locations
- Admin app login allows for overriding of user control
- Mode switch button on cart
- Cart LED lights up if in stop mode

User Interface (3 of 5)

- Follow user
  - Via App
    - User inputs commands for robot to switch to autonomous or manual
    - User can control robot moving around via commands
  - User can voice commands
  - Robot will disobey commands if unsafe
  - Walk in front of user (“repelling magnet”)
  - Follows user to car
    - Follows route back inside store navigating safe zones in parking lot
    - Goes in cart section and charges itself

User Interface (4 of 5)

- Touchscreen HUD on cart for the user to interact with
- Provides user bags to put items in
- Can take items of shelf (particularly high shelves for shorter people) and places in cart
- Keyboard input to select modes and configure robot
- Pushbutton selections to change modes
- Voice commands on mobile application to operate robot

User Interface (5 of 5)

- Cart goes home with user and takes items to front door of apartment, navigates back to store via flight
- Removes process of lugging groceries upstairs or elevator

Power Source

- Solar powered robot
- Nuclear - Fusion
- Battery
- AC/DC
- Fuel cell

Multi-Source Applications

- Golf caddy
  - Keeps track of score for user
  - Makes slight noises when competitors are teeing off to get them to shank
- Construction cart
  - Carries equipment
  - Heavy load capacity
  - Moves through rough terrain
  - Can scale walls