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VALET: VAriable Location Electronic Transport

1 Introduction

VALET: VAriable **L**ocation **E**lectronic **T**ransport. The Global Positioning System (GPS) has been a world changing innovation. Most travel requires GPS usage, and unmanned travel is almost completely reliant on it. However, GPS has its limitations. Factors such as local topography, receiver quality, and atmospheric conditions all detract from GPS' accuracy. For example, GPS enabled smartphones are typically accurate to about 4.9m. VALET seeks to address this issue by integrating other sensors that account for local obstructions (e.g. walls, people, animals). For now, these include LiDAR, an optical sensor (camera), and Bluetooth — all of which would integrate with the GPS system to provide end-to-end travel with increased accuracy and object avoidance.

We will demonstrate this system using an unmanned ground vehicle, but once the concept is proven, the system could be converted to any transport vehicle with understanding of said transport vehicle's control systems (e.g. drones, boats).

2 Problem Description

Amazon made a huge splash when it announced it was investigating the use of drones to deliver packages directly to customers doorsteps a couple of years ago. Kiwibot also has a ground-based delivery solution, targeted primarily at delivering food on college campuses. Drones usurping the UPS man once seemed like something out of *The Jetsons*, but the autonomous vehicle industry has demonstrated through several partnerships (e.g Nuro and Dominos, Waymo and Walmart) that the prospect and viability of unmanned food, grocery, and package delivery is becoming more real every day.

Autonomous travel has several unique technical challenges, including inaccurate GPS navigation, sensing obstacles, negotiating these obstacles, and choosing the appropriate delivery point for a person or parcel.

Once inexpensive, effective, and accurate methods of doing so are implemented, a tremendous proliferation in automated deliveries will take place. The financial upside of automated deliveries is tremendous — there is no labor overhead, these vehicles will navigate with more efficiency and fewer accidents than their human counterparts, and can run all day without tiring (within their battery constraints).

3 Proposed Solution

We aim to develop and design a vehicle capable of implementing the challenge laid out in (2), ultimately safely delivering a package to a GPS-determined location. With redundant sensing, including GPS, LiDAR, optical, and Bluetooth, VALET would have the ability to navigate to an ultimate GPS location, sense objects that are obstructing its path there, pick up predetermined targets and navigate to those as well, and communicate with smart devices while doing so.

More specifically, VALET will tackle the challenges laid out in (2) with the features of:

1. Object Detection/Avoidance
2. GPS Path Following
3. Bluetooth Communication with Smart Devices

Ultimately, a sensor suite and basic controls schema will navigate VALET to the desired drop off location.

4 Demonstrated Features

The VALET delivery system will be used for variable-location delivery. It will be designed to address the accuracy of shortcomings of solely GPS-based delivery systems. With this system, we intend to demonstrate:

1. Summon Feature: Directs car to predetermined GPS location. In order to implement this feature, VALET needs to be capable of receiving a Bluetooth or WiFi signal from an external transmitter. This would simulate a delivery company inputting a unique address or objective for each delivery
2. Communication with a Smart Device: Relevant for summon feature, Bluetooth pinging
3. GPS Path Following: VALET will follow GPS paths to its final objective

4. Object Detection/Avoidance: VALET will detect and avoid obstructions to its path, while ultimately navigating closer to its objective
5. Target Identification: With the ultimate goal of a seamless delivery process, VALET with use GPS data and computer-vision based target recognition to finish the delivery process. This could include the user showing a QR code to VALET, to release whatever parcel is being carried and finish the delivery.

5 Available Technologies

Vehicle and Drivetrain

As this is an electrical engineering project, we have a desire to purchase as much of the mechanical components of our design as possible in order to avoid wasting time and energy focusing on the mechanical aspect of our design:

- **4 Wheels Scout Platform Robot Kit**
  - Price: $169.99
  - Manufacturer: ServoCity
  - Description:
    - 7.5"x10.5" Chassis
    - 4.3" Off Road Chassis
    - Planetary Motors
    - 3-12 VDC motors
    - 624 RPM,
    - 19:1 gear ratio
  - If cost becomes an issue, motors can easily be bought individually and rudimentary chassis constructed in order to save money. A tracked vehicle could also be advantageous as it only requires a dual motor system.
- **Motor Driver:** The motor driver accepts an input signal from the microcontroller and sources the correct amount of current/voltage to accurately supply the motor.
  - H-Bridge Motor Driver With Integrated Current Sense and Regulation
    - Manufacturer: Texas Instruments
    - Model: DRV8876
    - Price: $1.24(x2-x4)

Controllers/Processing

- **Raspberry Pi:** In order to perform image processing, the increased processing power and interfacing capability of the Raspberry Pi is necessary. It also provides WiFi and

Bluetooth support for free. This will allow our vehicle to be summoned remotely, send data, and potentially implement proximity sensing via Bluetooth.

  - Raspberry Pi 3 Model A+
  - Price: $19.99
  - Dedicated CSI camera connection
  - 40 pin GPIO
  - 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2/BLE

- **Microcontroller:** The microcontroller will be responsible for motor control and the processing of sensor inputs. The dsPIC33 was chosen for its unique PWM motor control hardware, I2C/UART/SPI support, and our familiarity with the platform. It will interface with the Raspberry Pi via USB/UART.
  - Model: dsPIC33
  - Price: <$5
  - Manufacturer: Microchip
  - Important Features: Built in PWM motor control support for controlling the BDC motors of our vehicle. It also includes feedback to enable motor speed/position control.
- **Board:** We will have a custom PCB for this application, with the dsPIC33 microcontroller:
  - Price: ~ $50

Sensors

- **GPS**
  - TESEO-LIV3F - Tiny GPS Module
    - Price: $14.22
    - Manufacturer: STMicroelectronics
    - -163 dBm tracking sensitivity
    - 2.1 V to 4.3 V supply voltage range
    - Supports GPS, GLONASS, BeiDou, and Galileo
    - UART and I2C interfaces
- **Magnetometer and Accelerometer**
  - FXOS8700CQR1
    - Price: $4.72
    - Manufacturer: NXP
    - Interface: I2C
    - Description: This magnetometer and accelerometer combination package is incredibly useful for orientation towards waypoint, or maintaining directional heading when GPS signal is spotty.

- **LiDAR:** Technology for measuring the distance to an object via laser light. Extremely useful for object and objective distance detection.
    - LIDAR-Lite v4 LED Rangefinder
        - Price: $59.99
        - Manufacturer: Garmin
        - Communication: I2C or ANT; user configurable for SPI using the Nordic SDK
        - Input Voltage: 5V
        - Range 10m
    - Many LiDAR systems are prohibitively expensive. This sensor provides relatively simple functionality but is cost effective and comes with quality component support (many cheaper LiDAR systems are from Chinese manufacturers with little documentation).
- **Camera:**
    - Raspberry Pi Camera Module V2
    - Price: $24.83
    - 8 MP
    - 1080P video
    - Unique CSI communication with Raspberry Pi
- **UWB**
    - DWM1001C Module
    - Price: $14.95
    - Utilizing two modules, one could be mounted to the AV and the other could act as a beacon providing precise close in position sensing

Power Control System

- **Battery:** The battery will have to have great enough capacity to power all of VALET's electronics, and motor controller for an extended amount of time (~10 mins). It also has to supply up to 12 V to the motor and a significant amount of current (up to 4.5A) to power the motors. It is possible that there may be one we can acquire from a previous project or from a professor/lab that may suit our needs.
    - Tracer Lithium Polymer Battery Pack
    - Voltage: 12V
    - Capacity: 4Ah, 48Wh
    - 20 A peak current
    - 4 A continuous

6 Engineering Content

- Design and construction of the drivetrain
  - Our team must buy electric motors and design a model car that can effectively hold the necessary sensors and payload to accomplish our objectives.
  - This also includes designing a system that can communicate its speed and acceleration with the user.
  - Also need to integrate the microcontroller with the electric motor so we can vary the speed and control direction/motion.
- Design and integration of the Raspberry Pi and Microcontroller to use the camera, Wifi, and Bluetooth capabilities
  - Our group must properly connect the Raspberry Pi to the camera so we can process images
  - Also, our group needs to connect the Raspberry Pi to WiFi and Bluetooth so the VALET system can accurately determine the drop-off location and communicate wirelessly.
  - Integrate the Raspberry Pi with a microcontroller for handling motion and sensor control/communication. This will be accomplished via UART.
- Design of GPS and Path following
  - A gps is needed so the location of the VALET system is known
  - GPS will also be used so the VALET system knows the most efficient path to the destination.
- LiDAR sensor construction and Object avoidance
  - Program the light sensor so the vehicle understands when there is an obstacle within its path of motion.
  - The LiDAR can also help with path following and lane assistance technologies

In summary, this project will require the integration of several functional blocks:

1. Power System
2. dsPIC33
   a. Sensor Suite
   b. Motion Control
   c. Primary Logic Device
3. Raspberry Pi
   a. Computer Vision
   b. Wireless Module
4. Drivetrain

The greatest engineering challenge will result from the integration of all of these different components.

7 Conclusions

This system offers a wide variety of practical applications. Here are some of the general use cases that could be implemented by this system:

1. Unmanned Delivery: Drone delivery is emerging as a potentially legitimate alternative to human delivery people. One limitation of this issue is the accuracy offered by GPS. In more suburban areas, our system would provide a way to deposit packages in closed off areas such as backyards or balconies. This would decrease the number of packages stolen by miscreants. In urban areas, packages could be delivered to the rooftops via drones, offering an additional benefit of removing some street traffic.
2. Farms/Farming Industries: Recently, farms are getting larger and larger as the industry gets more consolidated. The increased level of automation has reduced the number of workers required for the operations of these farms. With that framing, imagine a worker has to travel a distance to fix a fence or other common issue on the fringe of the farm and realizes they need a tool from the toolshed. Instead of needing to travel back to the tool shed, they could just summon an unmanned ground vehicle with the tool and specify where in the field they want the vehicle to stop in order to avoid crop damage or any other potential issues.
3. Industrial Usage: Tesla's Gigafactory is 5.5 million square feet. Fiat Chrysler Automobiles' world headquarters is 5.4 million square feet. Delivery of parcels and packages in large, indoor environments such as this eliminate losses in productivity by reducing the number of nonessential tasks for employees.
4. Military usage: This system could be used to deliver supplies into difficult environments with decreased chances of detection.

All of these cases depend on a more accurate method of destination location then currently available. VALET is our solution to these issues and we believe that it would be a worthwhile Senior Design Project. There is tremendous transfer between this project and the growing industry of autonomous vehicles and unmanned delivery.