Dokalman

University of Cincinnati

Intelligent Ground Vehicle Competition 2014

Christopher Crowell   Kenneth Fechter   Patrick Fadden   Xiancheng Yu

CERTIFICATION:
I certify that the engineering design in the vehicle Dokalman (original and changes) by the current student team identified in this Design Report has been significant and equivalent to what might be awarded credit in a senior design course.

Professor Dan Humpert, Advisor

Contents

Introduction

Design Innovations

Design Process and Team Organization

1. Hardware

  - Frame
  - Design of the Bearcat Cub Micro
  - Drivetrain
  - Power System
  - Emergency Stop
  - Motion Controller

2. Electrical and Electronic Systems

  - Laptop
  - Laser Measurement System
  - Global Positioning System (GPS)
  - Cameras
  - Compass

3. Software

  - Mapping
  - Lane Detection Algorithm
  - Path Planning
  - Vector field general theory
  - Modified Vector field Concept
  - Navigation
  - Obstacle Avoidance

Conclusions

References

Appendix A: Bill of Materials

Introduction

Dokalman is a new robotic platform designed for the 22nd Intelligent Ground Vehicle Competition. Dokalman is the result of over a year of planning and design. The new design brings an all new electrical system, as well as new software designed from the ground up. The sections in this report describe in detail the hardware and software platform of Dokalman, as well as its improvements over previous IGVC designs.

Design Innovations

The new design innovations for Dokalman are as follows:

- New software platform written in Java and running on Linux:
    - Three Layer Architecture
    - Intel NUC with Ubuntu
- Waterproofing
    - Lessons learned from previous design iterations
- New electrical system and wiring
- Less proprietary hardware

Design Process and Team Organization

The Dokalman design team consists entirely of undergraduate students. The team members all learned a lot in building an entirely new robotic platform. It was also a more challenging task as this was a completely new design rather than an iteration of a previous platform. The first task for this robot was designing the hardware platform. The software architecture was planned in parallel to the hardware to speed development. The design team is comprised of students from several majors, including Computer Science, Computer Engineering, and Electrical Engineering. Throughout design and building, the team met as a whole on a weekly basis, with members contributing time outside of meetings as well. A critical part of the process for the team was passing on knowledge from the more senior members to the newer members of the team to ensure the future success of the team. The advisor for the team was Professor Dan Humpert, who met with the team during its weekly meetings.

Table 1. Team Organization

Role	*Name*	*Major*	*Year*
Captain	Chris Crowell	Computer Science	2016
Software	Kenneth Fechter	Biomedical Engineering	2016
Software/Hardware	Patrick Fadden	Computer Engineering	2018
Hardware	Xiancheng Yu	Electrical Engineering	2016
Hardware	Brad Becktel	Mechanical Engineering	2017

This report is divided into sections, each explaining the different modules of the robot and categorized as following.

1. **Hardware Design:** This section describes the basic platform along with the hardware components which includes the framework, power system, the emergency stop and the motion control system.
2. **Electrical and Electronics system:** The section lists out in brief the computer system and the various sensors with schematics of its integration.
3. **Software design:** Describes in detail the algorithms used for mapping, lane detection, the vector field approach and path planning.

1. Hardware

Frame

The chassis of Dokalman is comprised of aluminum extrusion. This design was chosen because it is lightweight, strong, and easy to assemble. It also provides the advantage of being modular, which allows easy adaptation for new components and replacement components as the design changes.

Design of Dokalman

Over its history, the University of Cincinnati has had several major design iterations, as well as evolutionary upgrades in the intervening years. Dokalman is the smallest and least expensive the team has fielded yet. Budgetary restrictions have forced the team to explore alternative solutions to the traditional path of very expensive sensors.

The actual frame went through two builds before the final design was settled upon. This kind of evolutionary prototyping and building is simplified through the use of aluminum extrusion. We have plans to build a welded aluminum frame in the future to save weight and increase structural integrity.

Drivetrain

Dokalman has two pairs of wheels, the main drive wheels and two swiveling castor wheels. The main drive wheels are 12 inches in diameter. The wheels are wider, which allows for greater durability in the conditions likely to be seen at the IGVC. The 5½ inch diameter castor wheels provide the stability needed to perform near zero turning radius turns. Two AmpFlow F30-400 Motors provide power to the wheels. each motor has a gearbox with a 7.1:1 ratio. This ratio was chosen to give maximum torque with the motors chosen. Thorough testing has ensured that the robot will easily exceed 1 MPH, without surpassing 10 MPH. Other than the use of the aluminum extrusion, an all new design was chosen for the robot. The robot will include waterproofing, which is a result of lessons learned from the Bearcat Cub. Since this was a new platform, major focus was put on software, hardware, and electrical systems.

Power System

Dokalman is powered by a single 12V deep cycle marine lead acid battery, which provides 1032 watt hours of energy storage. Power from the battery is used to drive an 800 watt inverter, which provides power to the computer, an Intel NUC, as well as a powered USB hub. The rest of the components either draw power directly from the battery through voltage regulators, or get their power via USB. The use of batteries has proved very successful on the Bearcat Cub, so their use is continued into the next generation. One downside to using deep cycle batteries is they require regular maintenance which includes being refilled with distilled water. Failure to perform the routine maintenance can result in the failure of the battery and loss of charge storage capacity. The wiring is modular to provide for easy swapping of batteries. This provides a near-zero downtime.

Emergency Stop

Dokalman has a manual e-stop button, located more than two feet off the ground, that cuts power to the drive system, halting the robot. A wireless E-stop can also perform the same action from a distance of >100 feet. The wireless remote is from 3Built LLC.

2. Electrical and Electronic Systems

Dokalman's electrical systems are comprised of a Sabertooth Dual 60A motor driver and Kangaroo X2 motion controller, 2 1080p Web Cameras (Logitech C920), GPS units, a compass and accelerometer, motor encoders, wireless and physical emergency stop, as well as two AmpFlow F30-400 Brushed DC motors. Power is fed from the inverter to the Intel NUC as well as the USB hub. most sensors are driven by either 5 or 12 volts, so they pull power from USB, or directly from the battery with regulators for protection. It is extremely modular, and allows for any combination of hardware and sensors with no changes to the power systems.

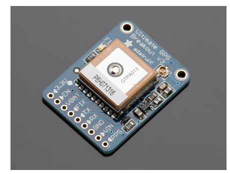
Computer

An Intel NUC (Next Unit of Computing) acts as the central processing unit for Dokalman. It is powered by a 1.8GHz Intel dual core processor with 8GB RAM. It processes data from the laser scanner, GPS, motion control system and image processing system. The software is written in java and uses the Open Computer Vision library to process image data. The software runs on the Linux Operating System.

Laser Measurement Systems

The Sick LMS 200 scans a 2-dimensional plane of 180 degrees and returns obstacle distance measurements for up to 8.191 meters with an infrared laser beam (835 nm wavelength) based on its time of flight. The resolution of scan is 1 degree. It is communicating with the computer using a RS 232 ports with a data transfer rate of 38,400 bauds.

Global Positioning System (GPS)



Due to the prohibitive cost of a professional GPS system, three *Ultimate GPS* units from *Adafruit* are being used in place of a single more precise GPS unit. The *Ultimate GPS* units have an accuracy of 1.8m each. Through trilateration we are able to achieve submeter accuracy.

Cameras

Two Logitech C920 HD webcams provide image data for line and obstacle detection and avoidance. This data is processed using the Open Computer Vision (OpenCV) library.

Compass

The *LSM303* is a 3-axis tilt compensated compass with a built-in gyroscope. It has single degree accuracy, and will not output erroneous data if the robot is jostled or on an incline.

3. Software

Mapping

Dokalman performs SLAM (Simultaneous Localization And Mapping) using the data pulled in from its sensors. Each sensor has a thread running on the NUC receiving data, which are used to create the map. The map is then used to determine what path the robot should take.

Line Detection Algorithm

Lines are treated as obstacles by the robot. In order to detect lines an algorithm is performed on each frame received from the cameras. Based on the 'whiteness' of each pixel and it's surrounding pixels a line is either identified or not.

Path Planning

Using SLAM, Dokalman is able to create a map of it's environment, and choose the optimal path. The primary sensors feeding into the SLAM algorithm are the LIDAR and cameras, but movement data from the motor encoders and accelerometer is important for Dokalman to know where it should be in relation to it's previous location as well. After initially creating the map, the robot then constantly updates and improves the map. SLAM allows Dokalman to find the optimal path with the least amount of obstacles.

Navigation

A Kalman Filter is used to aid location accuracy. The trilaterized data from the GPS units, along with the compass, accelerometer, and motor encoder data are all fed into the filter. The Kalman Filter helps improve location accuracy and remove noise from the system.

Obstacle Avoidance

Dokalman employs a SLAM algorithm which creates a map of the robots environment using data from the LIDAR and cameras. Both lines and physical objects are treated as obstacles. Using the created map, Dokalman is able to navigate through the optimal path.

Conclusions

Dokalman is the first entirely new robot the team has built in several years. None of the current team members were at the university when the last new robot was built. As such, it was quite a challenge. Because of these factors we spent a very long time (over a year) planning and preparing before diving in and getting to work. We have learned several lessons from working with our existing robots, and carefully planned how the components would interact. We hope that Dokalman carries on the strong tradition The UC Robotics Team has of competing in the IGVC

Appendix A: Bill of Materials

Part	Manufacturer	Model No	Quantity	Unit Price	Total
Frame	80/20 Inc.	Custom design	1	$950	$950
Batteries	U.S. Battery	US 36DCXC	1	$135	$135
Motors	AmpFlow	F30-400 w/ Gearbox	2	$200	$400
Motor Driver	Sabertooth	TE-091-260	1	$190	$190
Lidar	Sick	LMS-200	1	$6500	$6500
Computer	Intel	DC3217BY NUC	1	$400	$400
Cameras	Logitech	C920	2	$100	$200
Wireless Estop	3built	RES12VU	1	$70	$70
Motion controller	Kangaroo	X2	1	$28	$28
GPS	Adafruit	Ultimate breakout w/ active antenna	3	$53	$159
Inverter		800W	1	$80	$80
Encoders	Sparkfun	COM-10932	2	$40	$80
				Total	$9192

Acknowledgements

We would like to thank our advisor Professor Dan Humpert, our unofficial advisor Professor Paul Talaga, our outreach and public relations chair Byron Hutchins, and the University of Cincinnati, without all of whom none of this would be possible.