PATH TO SUCCESS: AN ANALYSIS OF 2016 INTELLIGENT GROUND VEHICLE COMPETITION (IGVC) AUTONOMOUS VEHICLE DESIGN AND IMPLEMENTATION

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IGVC Competition Purpose

Objective:

The objective of the competition is to challenge students to think creatively as a team about the evolving technologies of vehicle electronic controls, sensors, computer science, robotics, and system integration throughout the design, fabrication, and field testing of autonomous intelligent mobile robots.

Educational Benefits:

This competition has been highly praised by participating faculty advisors as an excellent multi-disciplinary design experience for student teams, and a number of engineering schools give credit in senior design courses for student participation.

Real-world Applications:

To advance and promote intelligent mobility for civilian and military ground vehicle applications. Intelligent mobility will provide the driver aids required for future Automated Highway Systems (AHS) and Intelligent Transportation Systems (ITS). For military systems, autonomous mobility will enable unmanned combat vehicles to perform high risk operations and multiply the force effectiveness of manned systems. IGVC objectives for military applications focus on goals established in the Department of Defense. IGVC promotes core intelligent mobility competencies in perception, planning, actuation and mechatronics.

24 Years and Running

500+ Teams

80+ Universities

7 Countries

2016 Participating Schools

Vehicle	University
Bengal Bot	Louisiana State University
AUTOBEE	Istanbul Technical University
Octagon	Oakland University
Project Wilhelm	Stony Brook University
Betsy	Universite' de Moncton
BigFoot 2	Lawrence Technological University
Sedrica	Indian Institute of Technology Bombay
Apollo II	Bluefield State College
Moroccan Monster	The College of New Jersey
Dokalman	University of Cincinnati
Sparky	University of Colorado Denver
Ohm 4.0	University of Michigan Dearborn
HAL	University of West Florida
Little Jump	Instituto Tecnologico de Estudios Superiores de Monterrey
Cilantro	Old Dominion University
Eklavya 5.0	Indian Institute of Technology Kharagpur
Schildkrote	Oakland University
Z3RO (Ozone)	Embry-Riddle Aeronautical University

Vehicle	University
Jaymi	Georgia Institute of Technology
S & T Pathfinder	Missouri University of Science and Technology
R.E.V.O.	University of Illinois at Chicago
Capra7	Ecole de Technologie Superieure
EulSpill	Lawrence Technological University
Kezia	Bob Jones University
IGGY	United States Military Academy
PabloBot	The Citadel
Linfield Wildcat	Linfield College
Astraeus	Rose-Hulman Institute of Technology
FloridaRAS	Florida Institute of Technology
Taurus	University of Calgary
Netra	California State University Fullerton
Charlie	Michigan Technological University
C.L.O.V.E.R.	Wentworth Institute of Technology
Metaknight	University of Central Florida
Snowstorm	University of British Columbia
EARL	Trinity College

Competition History

1993 - 2012 Autonomous Challenge

1995 Design Competition

1999 – 2000 Road Debris Course

1999 – 2001, 2003 Follower The Leader

2001 – 2012 Navigation Challenge

2006 – 2013 JAUS Challenge

2013 Auto-Nav Challenge

2014 IOP Challenge

2017 Spec 2 Demonstration

ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

Intelligent Ground Vehicle Competition

IGVC 2017 (25th Anniversary)
June 2-5, 2017, Oakland University

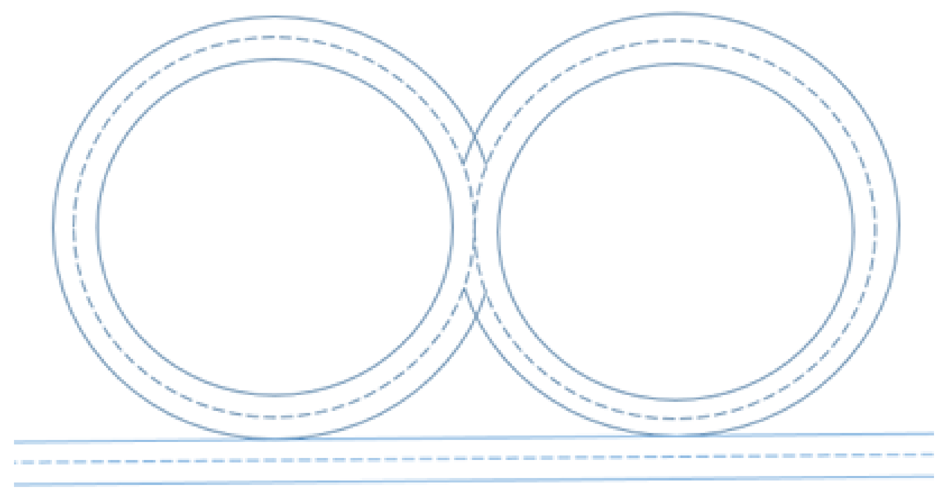
New for 2017
Spec 2 Demonstration at IGVC 2017

The intent of the 2017 Spec 2 Demonstration Meet is to define a feasible competition for 2018. In order to better understand our customer (university & schools) and sponsor interest, the 2017 SPEC 2 Demo/Meet will be demonstration/meet oriented. A freelance event and nominal awards given to the 1st-3rd place performance based on performing the following actions: Lane Keeping, Lane switch, Merging, Avoiding crossing obstacles (simulated pedestrians - cardboard boxes)

Vehicle Details:

- FMVSS-500 Vehicle equipped with automotive systems drive-by-wire
- Roll bar, seat belts and occupant protection doors or door strapping for Safety driver
- Fire extinguisher mounted near safety driver
- External kill switches both sides of vehicle
- E-Stop kill 200ft

Sensor Details: Automotive ADAS sensors, Navigation sensor



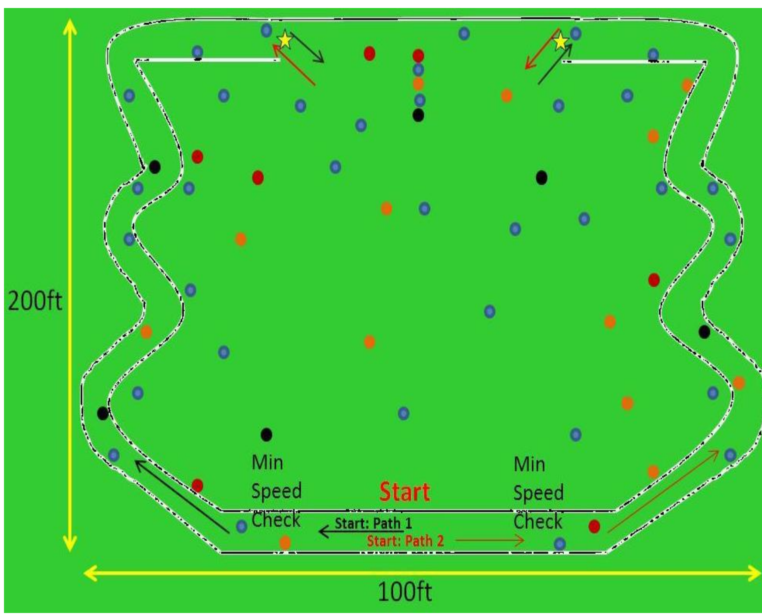
Auto-Nav Challenge

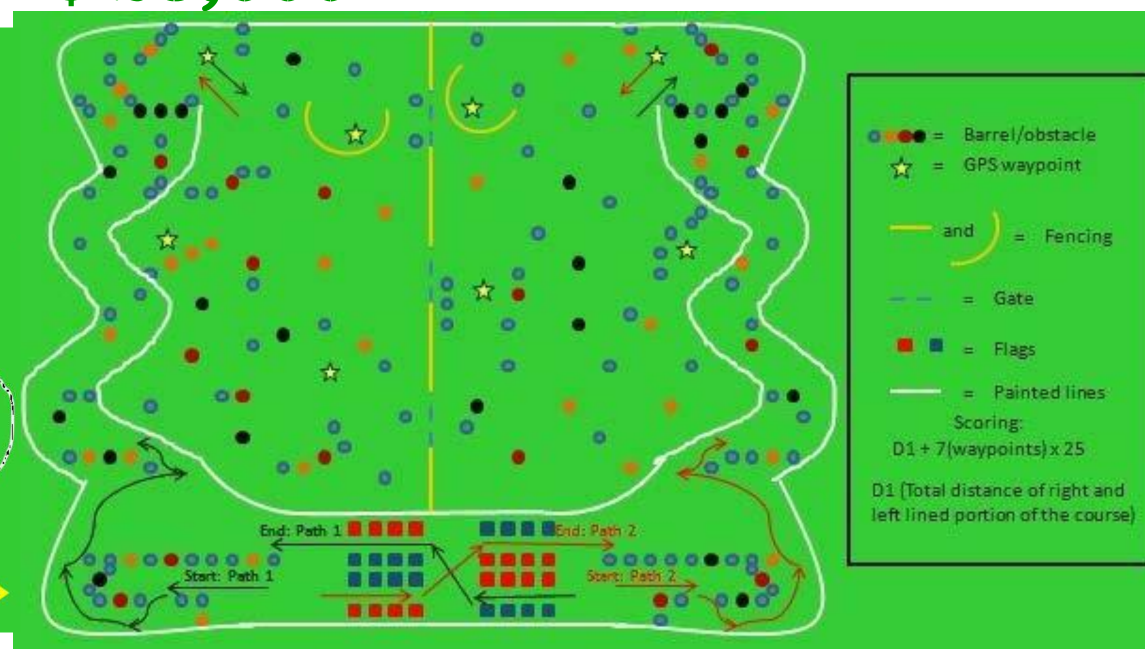
A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while staying within the 5 mph speed limit, and avoiding the obstacles on the track.

Judges will rank the entries that complete the course based on shortest adjusted time taken. In the event that a vehicle does not finish the course, the judges will rank the entry based on longest adjusted distance traveled. Adjusted time and distance are the net scores given by judges after taking penalties, incurred from obstacle collisions, pothole hits, and boundary crossings, into consideration.

AWARD MONEY:

$ 25,000





2016 Auto-Nav Challenge Results
Basic Course

1. Bluefield State College — Team: Apollo II
Distance: 614ft (completed course)
Time: 4:01
Award: $2,500

2. Lawrence Technological University — Team: Bigfoot 2
Distance: 614ft (completed course)
Time: 4:25
Award: $2,000

3. University of Michigan, Dearborn — Team: OHM 4.0
Distance: 614ft (completed course)
Time: 4:34
Award: $1,500

4. Indian Institute of Technology, Bombay — Team: Sedrica
Distance: 598ft
Award: $1,000

5. Bob Jones University — Team: Kezia
Distance: 484ft
Award: $750

6. Ecole de Technologie Superieure — Team: CAPRA7
Distance: 335ft
Award: $500

7. Embry-Riddle Aeronautical University — Team: Z3RO (“Ozone”)
Distance: 315ft
Time: 4:12

8. University of Calgary — Team: Taurus
Distance: 306ft
Time: 3:11

9. The Citadel — Team: PabloBot
Distance: 46ft

2016 Auto-Nav Challenge Results
Advanced Course

1. Lawrence Technological University — Team: Bigfoot 2
Distance: 457ft
Award: $2,000
Grand Award Points: 24

2. University of Michigan, Dearborn — Team: OHM 4.0
Distance: 447ft
Award: $1,500
Grand Award Points: 20

3. Bob Jones University — Team: Kezia
Distance: 202ft
Award: $1,000
Grand Award Points: 16

4. Bluefield State College — Team: Apollo II
Distance: 168ft
Award: $750
Grand Award Points: 12

5. Indian Institute of Technology, Bombay — Team: Sedrica
Distance: 115ft
Award: $500
Grand Award Points: 8

Design Competition

Although the ability of the vehicles to negotiate the competition courses is the ultimate measure of product quality, the officials are also interested in the design strategy and process that engineering teams follow to produce their vehicles. Design judging will be by a panel of expert judges and will be conducted separate from and without regard to vehicle performance on the test course. Judging will be based on a written report, an oral presentation and examination of the vehicle.

Design innovation is a primary objective of this competition. Two forms of innovation will be judged: First will be a technology (hardware or software) that is new to this competition; and Second will be a substantial subsystem or software upgrade to a vehicle previously entered in the competition. In both cases the innovation needs to be documented, as an innovation, clearly in the written report and emphasized in the oral presentation. Either, or both, forms of innovation will be included in the judges' consideration.

AWARD MONEY:

$ 7,500

2016 Design Competition Results

1. Embry-Riddle Aeronautical University — Team: Z3RO ("Ozone")
Score: 437/480
Award: $3000 (qualified)
Grand Award Points: 24

2. Bluefield State College — Team: Apollo II
Score: 412.22/480
Award: $2000 (qualified)
Grand Award Points: 20

3. Michigan Technological University — Team: Charlie
Score: 407.11/480
Award: $400 (did not qualify)
Grand Award Points: 8

4. University of Central Florida — Team: Metaknight
Score: 401.78/480
Award: $300 (did not qualify)
Grand Award Points: 6

5. University of British Columbia — Team: Snowstorm
Score: 370.56/480
Award: $200 (did not qualify)
Grand Award Points: 4

6. Ecole de Technologie Superieure — Team: CAPRA7
Score: 356.56/480
Award: $250 (qualified)
Grand Award Points: 2

IOP Challenge

The Interoperability Profile (IOP) Challenge verifies that teams are using a standardized message suitable for controlling all types of unmanned systems, and is the SAE-AS4 unmanned systems standard, commonly known as JAUS. Teams that completed the challenge will send a request for identification to the Common Operating Picture (COP) once every 5 seconds. The COP will respond with the appropriate informative message and request identification in return from the team's JAUS interface. After the identification report from the COP, the team entry will stop repeating the request. This transaction will serve as the discovery between the OCU via an RF data link and the vehicle. The vehicle that travels the farthest on the course, or completes the course in the shortest time wins.

AWARD MONEY:

$ 7,500

2016 IOP Challenge Results

1. Lawrence Technological University — Team: Bigfoot 2
Award: $3000 (qualified)
Grand Award Points: 24

2. Embry-Riddle Aeronautical University — Team: Z3RO ("Ozone")
Award: $2000 (qualified)
Grand Award Points: 10

3. Ecole de Technologie Superieure — Team: CAPRA7
Award: $1000 (qualified)
Grand Award Points: 8

4. Trinity College — Team: EARL
Award: $300 (did not qualify)
Grand Award Points: 6

4. Bob Jones University — Team: Kezia
Award: $750 (qualified)
Grand Award Points: 6

Rookie-of-the-Year

The Rookie-of-the-Year Award will be given out to a team from a new school competing for the first time ever or a school that has not participated in the last five competitions. To win the Rookie-of-the-Year Award the team must be the best of the eligible teams competing and perform to the minimum standards of the following events. In the Design Competition you must pass Qualification, in the AUTO-NAV Challenge you must pass the Rookie Barrel. 2016 IGVC winner was University of Calgary.

AWARD MONEY:

$1,000

2016 Grand Award Results

1. Lawrence Technological University — Team: Bigfoot 2
Grand Award Points: 68
Award: Lescoe Cup

2. Bluefield State College — Team: Apollo II
Grand Award Points: 56
Award: Lescoe Trophy

3. University of Michigan, Dearborn — Team: OHM 4.0
Grand Award Points: 36
Award: Lescoe Award

4. Embry Riddle Aeronautical University — Team: Z3RO (“Ozone”)
Grand Award Points: 34

5. Bob Jones University — Team: Kezia
Grand Award Points: 26

6. Indian Institute of Technology, Bombay — Team: Sedrica
Points: 14

7. Ecole de Technologie Superieure — Team: CAPRA7
Points: 12

8. Michigan Technological University — Team: Charlie
Points: 8

9. University of Central Florida — Team: Metaknight
Points: 6

9. Trinity College — Team: EARL
Points: 6

11. University of British Columbia — Team: Snowstorm
Points: 4

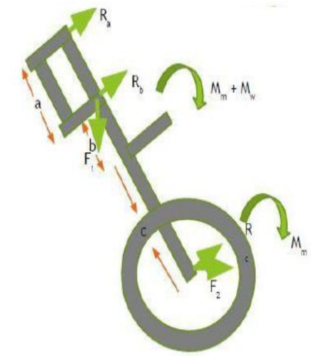
IGVC Puts Students to the Test

-Control theory
-Power requirements/distribution (battery selection, etc.)
-Cognition
-Machine vision (visual/stereo cameras, LIDAR, etc.)
-Vehicle electronics
-Mobile platform fundamentals
-Vehicle electronics
-Sensors
-Systems integration
-Vehicle steering
-Fault tolerance/redundancy
-Noise filtering
-PCB design/analysis/selection
-Vehicle engineering analysis
-Design, fabrication, field testing
-Lane-following
-Avoiding obstacles
-Operation without human intervention
-Detection and navigation of various obstacles: slopes, potholes, flags (detection and right/left travel logic), switchbacks, center islands
-Vehicle simulation/virtual evaluation
-Overcoming environmental issues (grass, mud, rain, sun)
-Global Positioning System/waypoint navigation
-Safety design

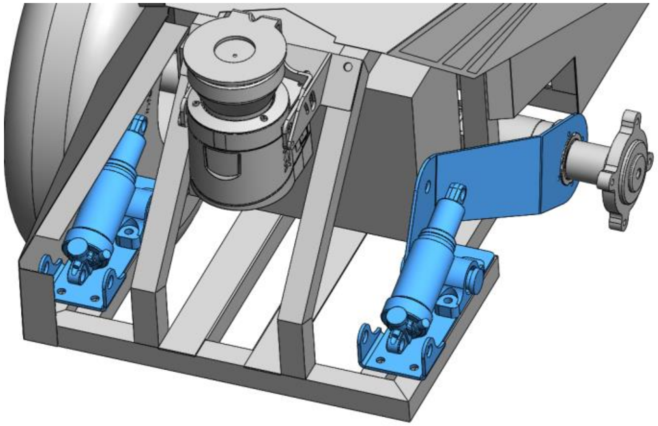
Technical Challenge #1 – Frame/Suspension/Mast Selection/Design

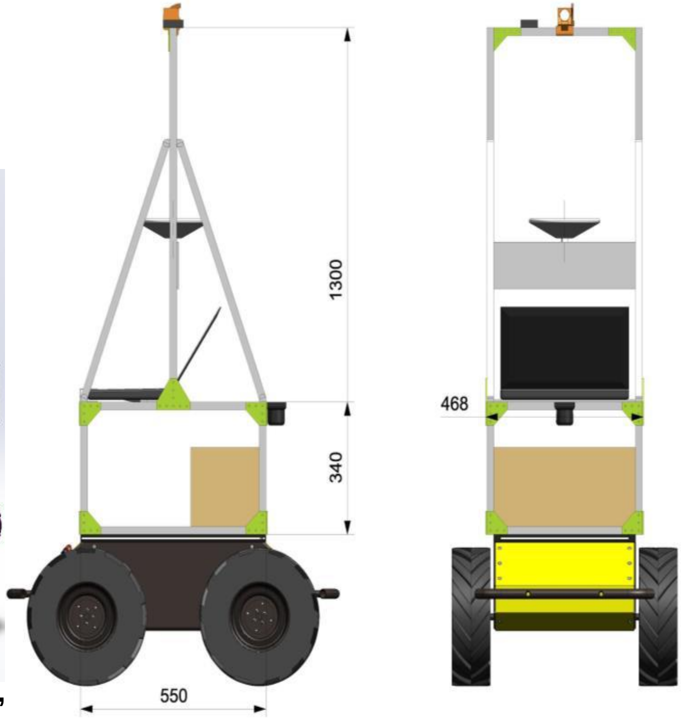
- -Center of gravity
- -Material selection (ex. 80/20 T-slotted aluminum framing)
- -Suspension systems
- -Prefabricated frames/suspension systems (electric wheelchairs)

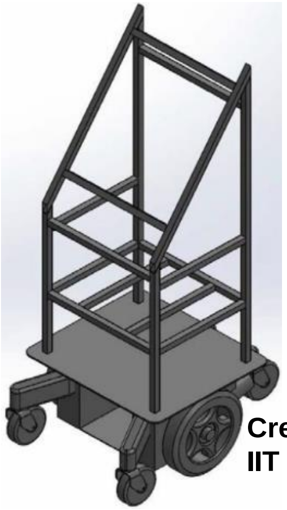
Manufactured Steering Column

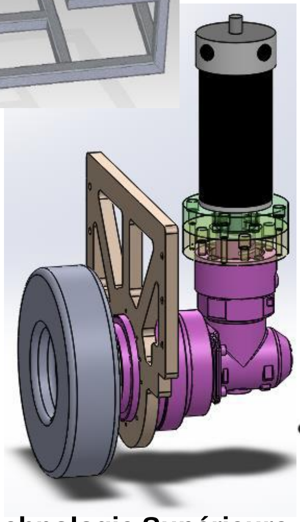


Moment diagram of the steering column





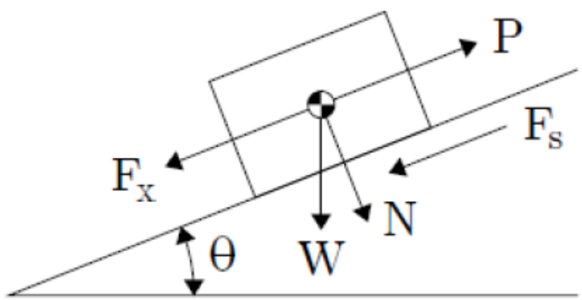




Credit for photos: Oakland University, École de Technologie Supérieure, IIT Kharagpur, LTU, University of Cincinnati IGVC Design Reports

Technical Challenge #2 –Power/Battery/PCB Analysis/Selection/Fabrication

- -Motor selection: torque analysis/free-body diagrams
  - -Vehicle weight, coefficient of friction, # of motors, wheel diameter, etc.
- -Power draw determination, voltage considerations
- -Vehicle power selection: primarily batteries (Lithium Ion, Lithium Polymer, Lead Acid)
- -Printed circuit board design



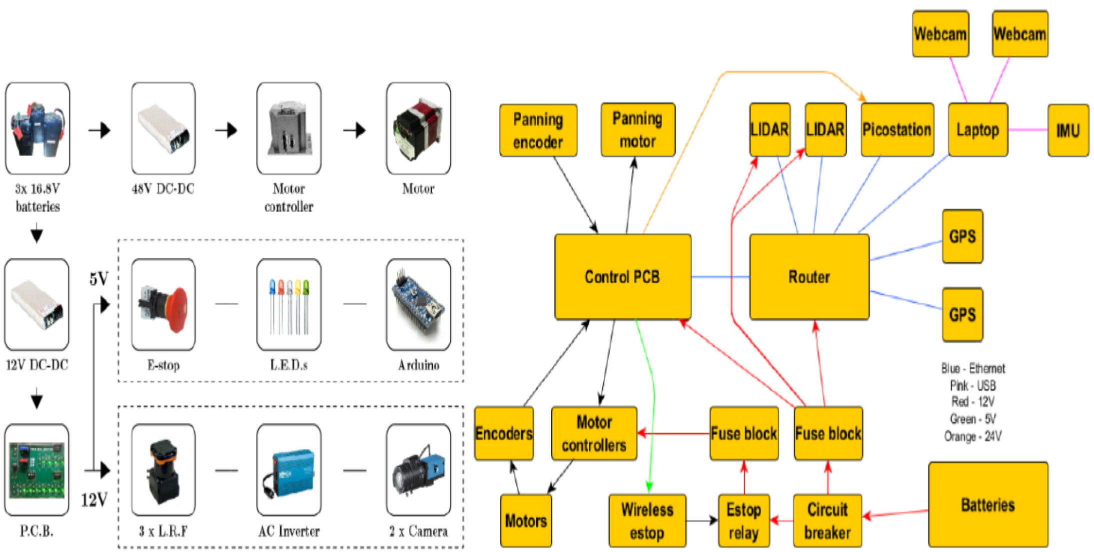
2015 CSUN Vehicle Free-body Diagram

2015 CSUN Vehicle Power Draw Data[1].

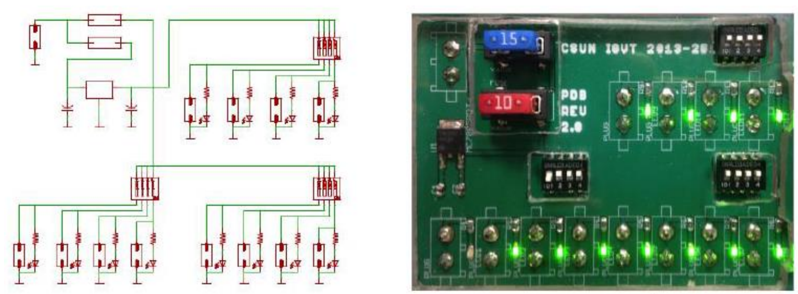
Type of Load	Normal Load	Extreme Load
Total base load	177	177
Transient motor load	154	910
Total load	331	1087
Total at 88% DC/DC efficiency	376	1235

2015 UNSW Power Draws of Vehicle Components[2].

Component	Power	Current and Voltage	Source
2 × SICK LMS111	18 W	2 × 0.75 A at 12 V	Platform
XSens MTi-G IMU	0.4 W	80 mA at 5 V	Laptop
Wireless Router	12 W	1 A at 12 V	Platform
2 × Logitech C920	4.5 W	2 × 450 mA at 5 V	Laptop
Trimble GPS Receiver	3.8 W	-	Internal
Control Electronics	1.5 W	125 mA at 12 V	Laptop
Safety Light	6 W	500 mA at 12 V	Platform
Laptop	35 W	-	Internal
Picostation WiFi Bridge	8 W	0.33 A at 24 V	Platform
4 × Motors	720 W	4 × 15 A at 12 V	Platform



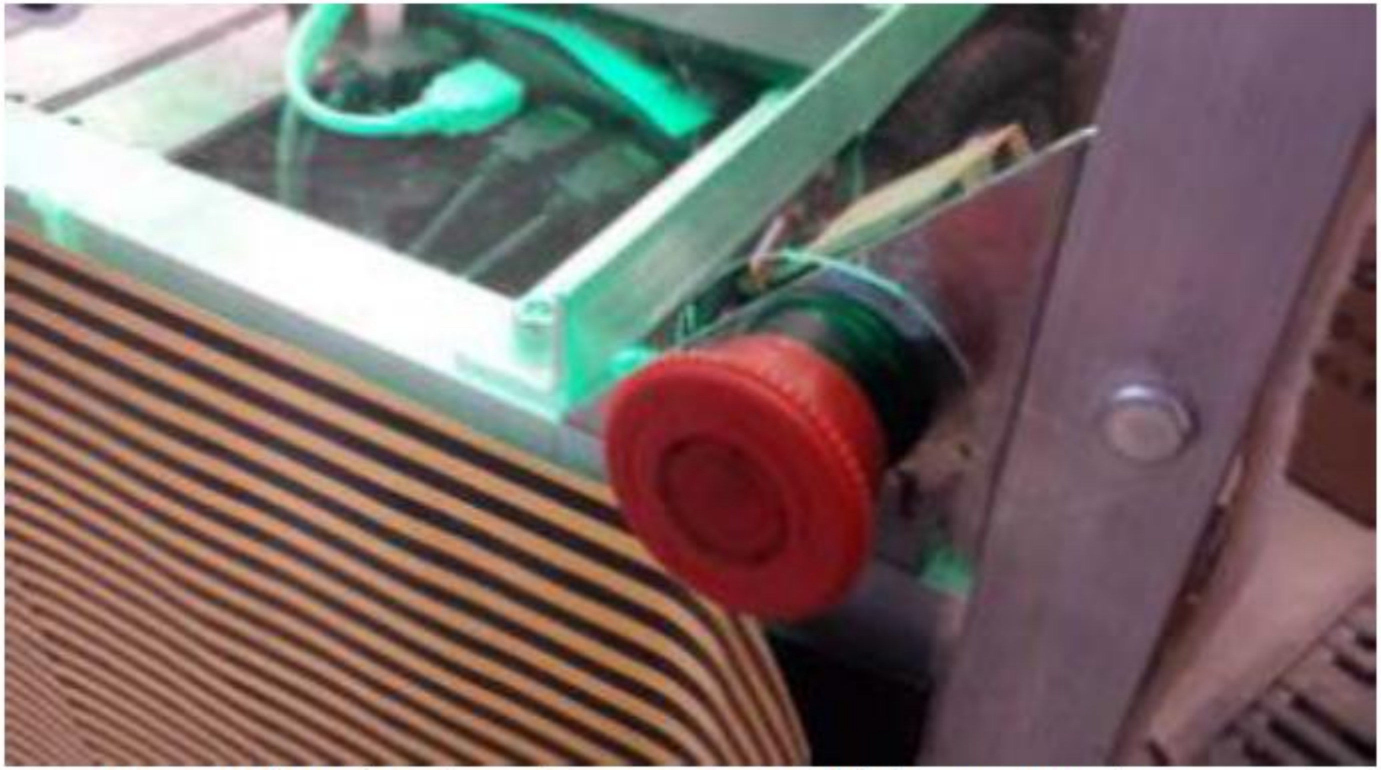
2015 CSUN/UNSW vehicle components, respectively.



2015 CSUN Virtual/Actual Main PCB[1].

Technical Challenge #3 –E-Stop/Safety Considerations/Design/Implementation

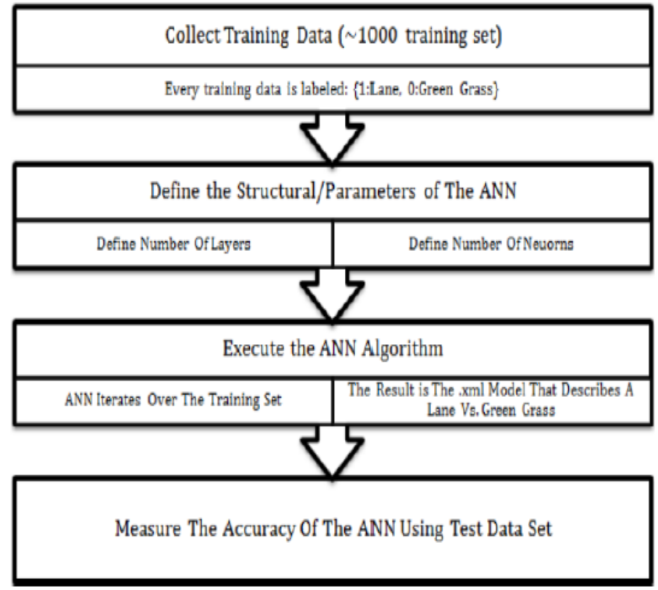
-Vehicle mounted e-stop
-Wireless e-stop (cut power to motor controllers, etc.)
-Adding additional failsafes: turn off motors if fail to receive commands from the computer or wireless joystick after set number of milliseconds (200ms – Oakland University team)



2015 Oakland University Team's Vehicle Mounted E-Stop

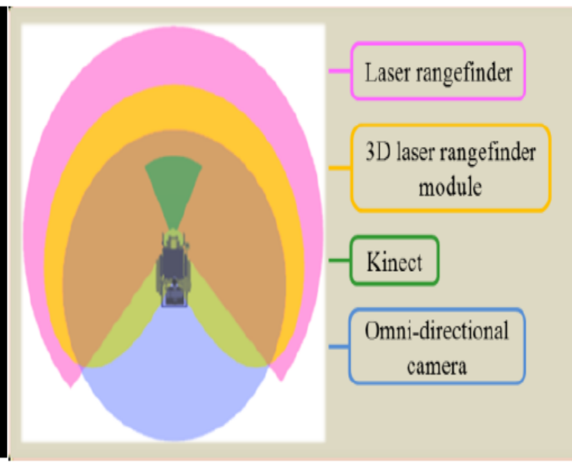
Tech Challenge #4 - Machine Vision - Sensor Selection/Processing/Implementation

- -Mono/stereo cameras, LADAR, etc.
- -Redundancy
- -3-D sweeping
- -Processing/integration of sensor feeds
- -World map generation - simultaneous localization and mapping (SLAM)
- -Noise filtering
- -Scene segmentation/recognition
- -Varying obstacle detection - lines, barrels, flags, potholes, ramps, etc.
- -Processing techniques - self-learning approaches (Artificial Neural Network (ANN), etc.)



2015 Oakland University Team's ANN White Line Detection Process

Sensor	Role
Laser rangefinder	Detection of distant obstacles up to 30 m for SLAM navigation.
3D laser rangefinder module	Near detection of three-dimensional shape obstacles up to 10 m.
Kinect	The combination of an RGB camera with a depth-image sensor allows detecting and identifying color flags (red or blue) within a distance of 2 m.
Omni-directional camera	Mainly used for the detection of stable lanes and obstacles within a radius of 3 m.



2012 Hosei Team's Sensor Roles and Fields of View

Technical Challenge #5 – Vehicle Simulation/Real-Life Testing

-Simulation advantages

-Vehicle can be worked on simultaneously

-Virtual vehicle can be evaluated many times faster than real-time

-Simulation disadvantage

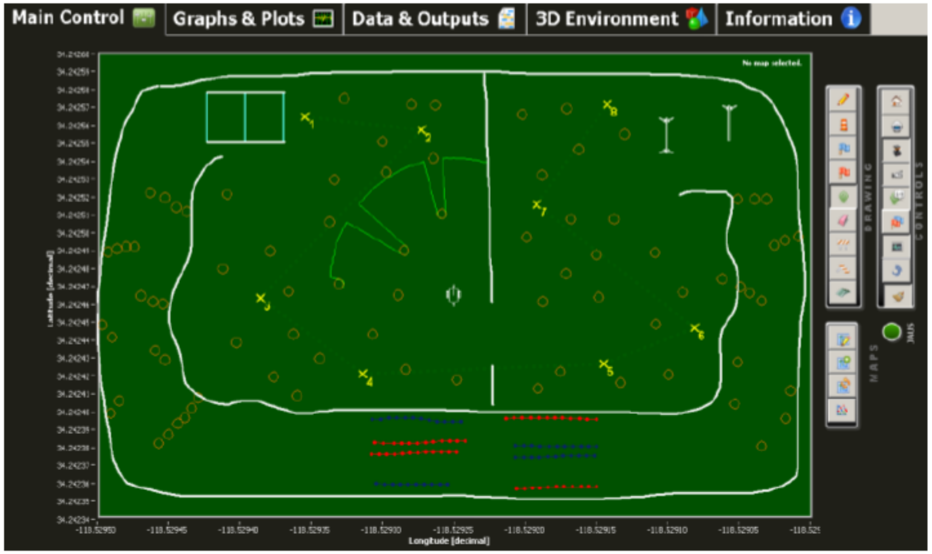
-Only as good as input data/simplifying assumptions

-Requires efficient data analysis - extract useful performance data

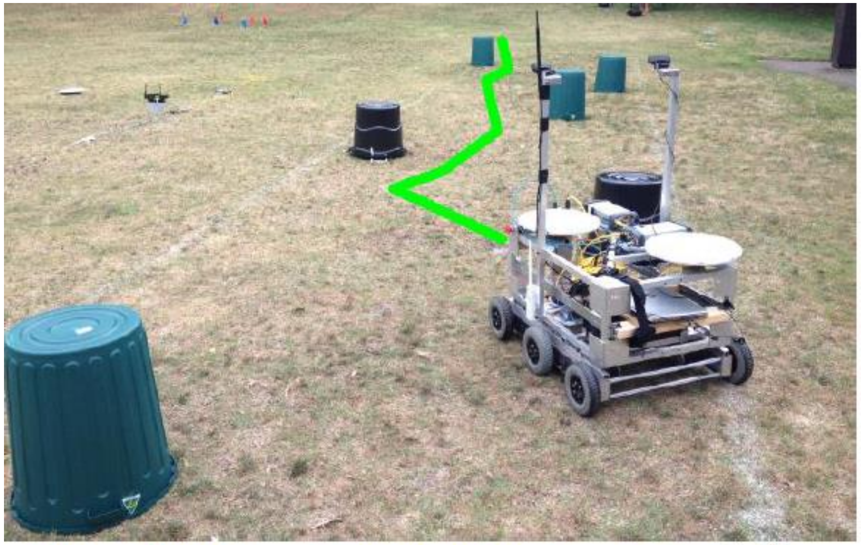
-Can simulate entire vehicle at once, or focus on individual sensors

-Introduce noise

-Growing virtual toolset for simulation, analysis and optimization of real-life system performance: neural networks, evolutionary systems, deep learning (likely huge potential in near future)



2015 CSUN Team's Simulation of the IGVC Auto-Nav Challenge Course



2015 UNSW Team's Mock IGVC Auto-Nav Challenge Course

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Intelligent Ground IGVC Vehicle Competition