**Robotic Self Balancing Unicycle - Student Design Competition 2013**

**Project Description**

The goal of this project is to design and construct a robotic self-balancing unicycle for National Instruments. Using NI hardware and software, such as the Compact Rio Real-Time Controller and LabVIEW software, this project is an effort to demonstrate NI’s real-time solutions and their Robotics Tool Kit as a viable solution for advanced robotic systems and controls. In addition to the physical device, NI has also asked the team to utilize the Robotics Simulator within LabVIEW to model and program the unicycle, and ensure that the development environment is behaving appropriately. This robotic prototype is being designed to serve primarily as a demonstration robot where National Instruments showcases the prototype.

· **Start Date**

o 08/30/2012

· **Target Date**

o 05/20/2013

· Team Presentation

# **Contact Information**

University:

[Rose-Hulman Institute of Technology](http://www.rose-hulman.edu/)

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Submission Language:

English

# **Project Information**

Title: [Robotic Self Balancing Unicycle](https://decibel.ni.com/content/projects/robotic-self-balancing-unicycle)

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**Products and Parts**

o NI Software

§  [NI LabVIEW Base](http://www.ni.com/labview/) (FSM Logic)

§  [NI LabVIEW Robotics Module](http://sine.ni.com/nips/cds/view/p/lang/en/nid/209856) (Sensor and Robot Simulation)

§  [NI LabVIEW Control Design and Simulation Module](http://sine.ni.com/nips/cds/view/p/lang/en/nid/209850) (System Response and Plant Simulation)

§  [NI LabVIEW Real-Time Module](http://sine.ni.com/nips/cds/view/p/lang/en/nid/209855) (cRIO Deployment)

§  [NI LabVIEW FPGA Module](http://sine.ni.com/nips/cds/view/p/lang/en/nid/11834) (For NI9870 Interfacing)

o NI Hardware

§  [NI cRIO-9024 RT](http://sine.ni.com/nips/cds/view/p/lang/en/nid/207371) (Real time controller)

§  [NI 9870](http://sine.ni.com/nips/cds/view/p/lang/en/nid/204259) (RS232 Serial Interface Module)

o Electronics

§  [RoboteQ](http://roboteq.com/) - [MBL1650](http://www.roboteq.com/brushless-dc-motor-controllers/hbl2350-dual-75a-brushless-dc-motor-controller-with-encoder-hall-inputs) (DC Brushless Motor Controller)

§  [Microstrain](http://www.microstrain.com/) - [3DM-GX3® -45](http://www.microstrain.com/inertial/3dm-gx3-45) (Orientation Feedback)

o Hardware

§  [Aoduo Motor Factory](http://www.aoduomotor.com/) - [16” Alloy E-bike Hub Motor](http://www.alibaba.com/product-gs/236035747/waterproof_16inch_alloy_e_bike_hub.html) (Drivetrain and Gyroscopic Motors)

§  [Aluminum Extrusion](http://www.8020.net/) (Frame Material)

o Other (Build of Materials)

**The Challenge**

As a part of Rose-Hulman Senior Robotics Design, our team sponsor and client, National Instruments, asked us to design, simulate and prototype a robotic demonstration as a showcase NI’s software and hardware development tools targeted for robotic. Consensus came across the team and the robotics department as a proposed self-balancing unicycle project had appealed to everyone. The dynamically unstable system would prove a challenge to build and control, but not outside the team’s current knowledge of modeling and simulation. The system would resemble that of an inverted pendulum.

**Academic Relations Department**

<Which problem were you solving? Insert the description of your project.>

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**The Solution**

<Briefly describe how the project works.>

Using an Inertial Measurement Unit (IMU) from MicroStrain as a feedback sensor for the control system, the real-time controller deployed on NI cRIO calculates the direction and magnitude of the control effort to the necessary to maintain a balanced state. The 3-phase RoboteQ motor controllers act upon the control effort to provide the required power to the hub motors, and also serve as a method for encoding the wheel’s position back to the real-time controller. At the moment, the robot is constrained to forward- backwards motion and side-to-side freedom. The controller aims to continuously compute the optimal controller gains for the motors giving the systems instantaneous state that accounts for orientation and velocity.

<Explain the benefits using LabVIEW and NI tools.>

The advantages using LabVIEW Robotics toolkits and the LabVIEW Simulation tools along the NI cRIO controller, provided the team with powerful engineering tools that facilitated the creation of the entire unicycle development cycle from design, to modeling, to prototyping and deployment. The control design via LabVIEW Robotics toolkit consisted on creating a non-linear model where the user can input the basic specifications of the unicycle (i.e. mass of bottom wheel, radius of wheel, length to center of robot, etc). LabVIEW’s simulated display of the modeled plant allowed us to quickly tune the control parameters and/or controller type by observing the stability, steady-state output response, and controller effort gains without actually testing it on the physical robot.

<Insert image(s) of project with captions.>

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|  |
| Figure 1. **Proposed unicycle design sketch-up model.** This is the proposed design of the unicycle with the 2 hub motor wheels being used to provide motion and stability. Also depicted in the motor is one of the two 12 volt batteries, the cRIO 2024, and part of the RoboteQ motor controller. |

|  |
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|  |
| Figure 2. **Constructed model of the unicycle using LabVIEW simulation toolkit.** |

|  |
| --- |
| [PICTURE OF FULLY ASSEMBLED ROBOT] |
| Figure 3. **Fully assembled self-balancing unicycle system.** In this picture(s) you can see the main components of the robot such as the RoboteQ motor controllers, the cRIO 9024, the two 12 volt batteries, the emergency-stop switch, the 2 hub-motor wheels, and a solid-state relay switch. |

|  |
| --- |
|  |
| Figure 4. **Electrical circuit wiring for main components.** Here you can see the wiring for some of the major electrical components and some of the major circuit protection devices such as the 70A main breaker. |

<Insert video here.>

Code:

[GitHub](https://github.com/ruffsl/ROBO)

* Time Line
  + Overall
    - Modeling
    - Construction
    - Tuning
    - Documentation
  + Phase 1

§ Scope of Work

· Prior developing ideas, but before starting the project, the team set out to define scope of work and achievable goals that determine completion, ensuring that both the team and our client remained on the same page and shared expectations. It was decided that the team would design, model, and build a demonstration robot that would serve as a physical example of could be achieved using robotic tools from National Instruments. The robot would also include relevant instructions for operation and maintenance as well as project documentation for future distribution.

§ Training Plan

· In order to establish a credible reference for success in project completion, the team also decided generating a testing plan. This would be a good way to maintain priorities and schedules along with the scope of work.

§ System and Model Design

· Because a self-balancing robotic unicycle will prove difficult to model and control, efforts to simulate and describe the system where commenced early during the project. This was to allow ideas and discoveries made during the modeling stage to positively impact the one prototype we had the chance to construct.

§ Part listings and specking

§ Computer Simulation

§ System Characterization

§ Control Testing

§ Part Ordering and Inventory

§ Design Review

o Phase 2

§ Control Testing

§ Part Ordering and Inventory

§ Control Testing

§ Part Ordering and Inventory

§ Control deployment

§ System Testing

§ Design Review

o Phase 3

§ Fine Tuning Overlap

§ Release Project Cleanup

§ Collect Resources

§ Tutorial and Instructions

§ Demonstration

§ Final Report

§ Community Publication

Completion:

(beta, alpha, or fully functional)>

Future Work

Future work would involve tuning the motor controllers and system controller for better transitional response of the unstable system to a steady-state system. In addition, by adding a slip-ring mechanism to the top half of the robot, the top wheel would then be able to turn in place and act as a balancing flywheel in all directions as was originally designed for the unicycle robot. Once full controller capabilities and locomotion are fully implemented as originally designed, the next step would be to add some object tracking and path exploration behaviors to the robot using a LIDAR and the GPS capabilities of the IMU. To achieve this goal, a couple of LIDAR (Light Imaging Distance and Ranging) sensors would be placed on the sides of the robot to detect and measure the distance to objects. In addition to LIDARS, enabling the GPS features of the IMU can allow to robot to determine its location in a world. Finally, with the use of the Kalman filter capabilities of the IMU, the sensor error and uncertainty range will be minimized to help increase localization accuracy and path planning performance.

Attach Poster (30 in. x 38 in.) and LabVIEW Code

<Include captions for all graphics material. Type your photo or graphic caption underneath each graphic using this 10 pt Times New Roman font. Embed all graphics. Remember—you must provide individual electronic files for each graphic you include in your paper. Place photos in text after first reference—you must include a reference to all graphics in the text. Include screen captures if you use National Instruments software products. Screen captures must have a minimum resolution of 72 dpi at 100 percent. All other graphics must have a minimum resolution of 300 dpi.>