EDGAR – A Self-Balancing Scooter

- University of Adelaide develops EDGAR
- Rapid control prototyping of self-balancing scooter
- Real-time control project for final year students

Mechatronic Engineering students at the University of Adelaide often undertake real-time control projects as part of their final year thesis. One of these projects, EDGAR (Electro-Drive Grav-Aware Ride), covers the design and testing of a two-wheeled, self-balancing vehicle capable of carrying a human. A dSPACE DS1104 R&D Controller Board was used to rapid-prototype the controller prior to embedding the controller on a low-cost microcontroller target.

As part of their final year, Mechatronic Engineering students at the University of Adelaide are required to undertake 300-500 hours on a design project involving systems engineering and integration. Many of these projects involve real-time control, and the dSPACE DS1104 R&D Controller Board is the preferred development tool. The aim of the EDGAR project was to design and build a self-balancing scooter that functioned in a similar manner to the Segway Human Transporter (HT), using a control law to stabilize the scooter by feeding back angular position signals from a gyroscopic unit into signals for the drive system. The design is loosely based around the Segway HT, which is the first commercially available self-balancing vehicle. The design is based on the successes and failures of other attempts at replicating a Segway HT.

▲ *Final-year student Simon McMahon is taking EDGAR for a test drive through the University of Adelaide campus.*

Hardware Operation

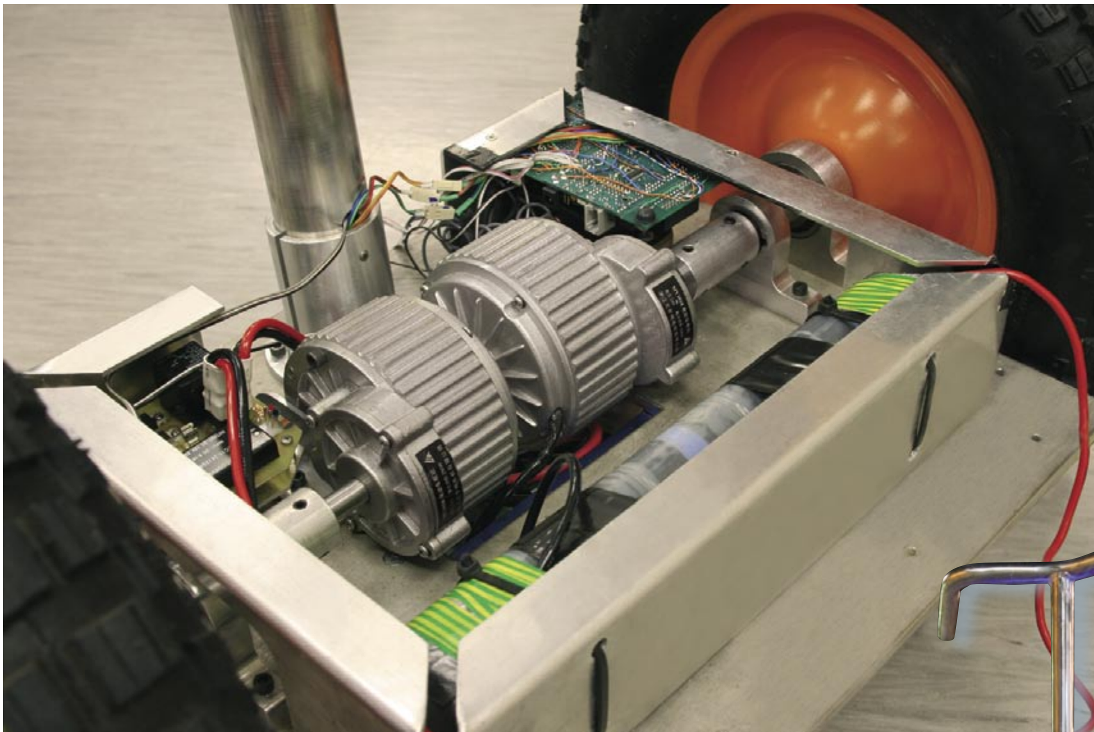
EDGAR was designed to be robust and easy to use whilst not compromising on strength and weight. The design included special attention to aesthetics of the vehicle and the ergonomics of the rider-vehicle interface. The process EDGAR goes through to self-balance is similar to how a human balances. The human brain recognizes the force due to gravity on the vestibular system, from which it is able to detect the orientation. It then sends impulses to the muscles in the limbs to maintain balance. Similarly EDGAR's controller receives information from an inertial sensor and then sends appropriate commands to the drive system to provide balance in pitch.

The Control System

An inertial measurement unit is used to measure the angle and angular rate of the pitch, roll and yaw of the device. These signals are then communicated to the DS1104 board via a serial RS232 link.

The drive system consists of two coaxial geared motors driven by a dual channel motor controller often used in hobby robotic applications. Two capacitive sensors located in the footplate detect the presence of a rider. We use this information to activate or deactivate the stabilizing controller. LEDs in the handle bars indicate a number of different operational states.

Steering (yaw) control is open-loop differential control of the torques to the left and right motors. The desired steering angle can be chosen using a potentiometer-instrumented grip in the handlebars.



◀ *EDGAR's insides. From front to back: Battery pack, two coupled motors and gearboxes, power distribution board, microcontroller and inertial measurement unit.*

Control Development

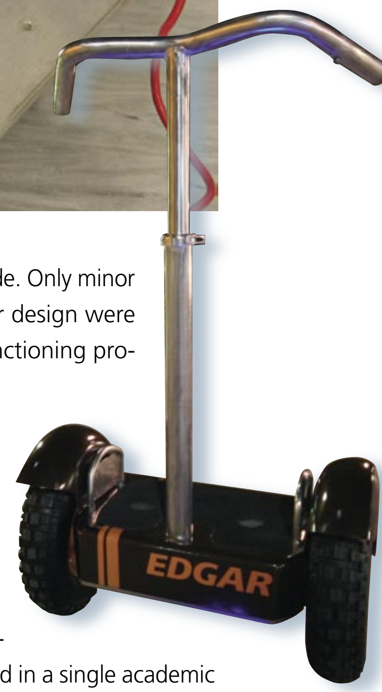
Prior to developing the real-time controller, we studied the dynamics of EDGAR on a Simulink® model. This allowed the development of the control laws in the safety of a virtual environment. A virtual reality model was added to visualize the behavior of EDGAR, thus verifying appropriate performance.

Initial control development of the physical EDGAR was undertaken using Simulink with a DS1104 board and the experiment environment ControlDesk. All signals from the DS1104 to the electronics on EDGAR were delivered via a multi-core cable. The DS1104 provided the ADC, DAC, PWM, serial and digital ports necessary for the safe and functional operation of EDGAR. We tested numerous stabilizing controllers including significant logic control to ensure safety.

Once the details on the controller were finalized, it was cross-compiled for a Freescale MC9S12 microcontroller using a Simulink embedded target developed at the University of Adelaide. Only minor changes to the initial controller design were necessary to achieve a fully functioning prototype.

> *"The dSPACE platform allowed the students to build extremely advanced control laws very rapidly, focusing on the control issues, rather than being distracted with lower-level concerns such as microcontroller programming or electronics."*
> ***Dr. Ben Cazzolato***

Outlook



The design and development of EDGAR provided the students with an interesting and enjoyable platform to learn real-time control. A fully functional device was built and tested in a single academic year. Having validated the design approach, a revised design is being developed this year by five new students, incorporating larger motors and more powerful motor controllers.

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