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Design and Fabrication of Eu-Cycle

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ABSTRACT
EU-Cycle is a self balancing electric unicycle. A regular unicycle is powered by pedal and is balanced by a rider, whilst the EU-Cycle runs by an electric motor and balance by control system in the roll direction. The simple thing to do by rider is to lean forward for acceleration, to lean backward for braking. EU-Cycle is designed as to be a fast and portable means of transport among crowded area, home and office. Therefore, The EU-Cycle gives tough challenge to the unicycle. EU-Cycle has attracted print media including future stories in radio, television. Thus in addition to successful development of EU-Cycle in urban use, the project has to implement the EU-cycle as an educative device.

I. INTRODUCTION

Over the past twenty years, the unicycle has been the subject of a diverse range of papers. The main aim of EU-Cycle is to focus on emulating autonomous unicycles. There was limited evaluative literature available on these designs, therefore it's a critical design review was performed for the focus designs self-balancing unicycle (Focus Designs, 2009c), Trevor Black-well's Electric Unicycle (Blackwell, 2007b) and the Enicycle (Polutnik, 2010). It is noteworthy that literature discussing the dynamics of a 'ballbot' is used extensively through this review. A ballbot is a self-balancing robot which stabilises itself in two orthogonal planes on a ball. The dynamics of ballbot are relevant because the assumption can be made that motion in the two planes of the device are decoupled. Hence the dynamics for each of these planes are applicable to the planar motion of EU-Cycle.

The project aims at the design and fabrication of self-balancing unicycle, Known as EU-Cycle. EU-Cycle is similar to regular unicycle, but rather than being controlled by rider's feet by pedals; sensors, Micro controllers and motors are used in EU-Cycle to maintain stability in direction of travel. The rider can control the speed by leaning forward or backward. In this sense, EU-Cycle could also be described as a one-wheel segue.

A unicycle, especially considered in light of today's commuter transport requirements, is in fact apractical device. Compared with a bicycle, it is lighter, more portable and considerably cheap. Thus, a unicycle can easily be transported in car boots, trams, trains, and even in lifts to office cubicles. However, with a difficulty of pitch balancing removed, a self balancing is no more difficult to ride than a bicycle. The addition of electric power means that increased distances can be travelled with relative ease. Furthermore, a self balancing unicycle also improves on other self balancing scooters by offering better portability, lower cost and a heightened sense of freedom.

II. Mechanical Design

The Development process includes an investigation of existing designs which are ranked with a decision matrix. Following this a discussion of the mechanical design of components that were manufactured for the EU-Cycle. These include fork and spindle assembly, the main chassis, and the seat pole location. The design process focused on achieving five key goals: ease of manufacture, optimal centre of gravity (COG), durability, design flexibility and aesthetics.

To achieve these goals the design process was an iterative process involving modelling the EU-Cycle, COG analysis and static structural analysis of the critical components to determine component dimensions and COG of the EU-Cycle inclusive with rider.

2.1 FORK

The fork design addresses the major issue that is, asymmetrical motor rim combination. The wheel has an offset centre plane which is required to be aligned with the centre plane of the spindle. Failure to realign these planes would result in the tyre being in a plane that is not central to the rider. As such, the fork legs are offset as shown in figure 2.1. The forks also incorporate locations to attach rubber bump stops to the ends of the horizontal section to reduce damage to the EU-Cycle in case of collision.

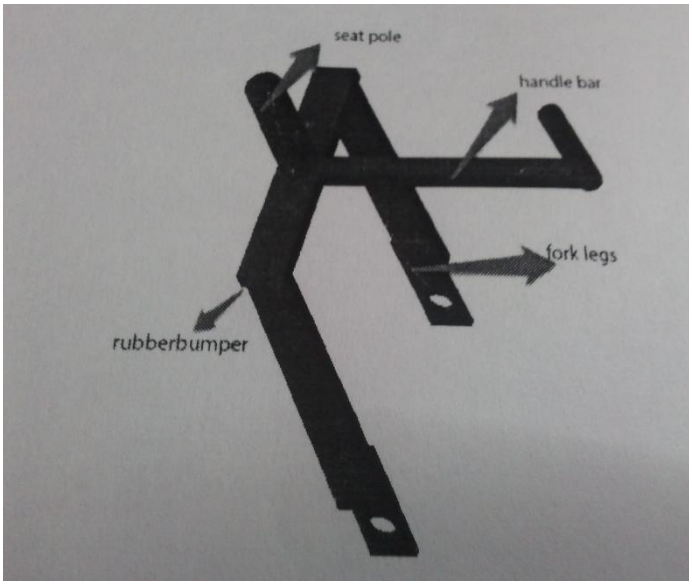

Figure 2.1: Fork Pro-e model

2.2 MASS DISTRIBUTION FOR BALANCING EU-CYCLE

The weightbias of the EU-Cycle is a major requirement of the design to make the EU-Cycle to balance in an upright position. To determine the desired COG, both the EU-Cycle and the rider's combine COG were required to be located vertically over the hub motor's axle line to ensure that the balance angle of the EU-Cycle was vertical.
Pro-engineer creo was used in calculating the centre of gravity of the EU-Cycle. The connection between the seat and seat post is adjustable in the angular and longitudinal directions.

2.3 CHASSIS DESIGN

The final designas shown in figure 2.3, incorporates mild steel spacers, rubber bumpers and bash plates as this is the area of the EU-Cycle that is affected in the majority of collisions. These type of extra features are necessary to increase the durability of the design and provide the spacing required for electrical components. While this is the only prototype design, these measures are necessary to increase the lifetime of device.

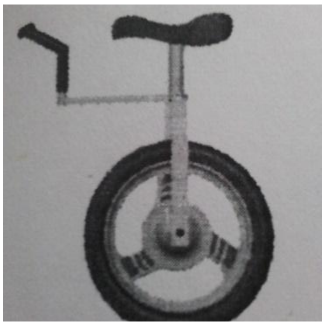
Figure 2.3: Final EU-Cycle Chassis

III. ELECTRICAL DESIGN

3.1 SENSOR UNIT

Motion interface is the important function being used in the EU-Cycle navigation. With the ability to precisely and accurately track user motions, motion tracking technology can convert user position into data understand by the microcontroller. The MPU 6050 is the integrated 6-axis motion tracking device that combines a 3-axis gyroscope, 3-axis accelerometer and a digital motion processor (DMP) all in a small 4×4×0.9mm package. With its dedicated 12C sensor bus, it directly accepts inputs from an external 3-axis compass to provide a 6-axis motion fusion output. The MPU-6050 features three 16-bit analog-to-digital converters (ADCs) for digitising the gyroscope outputs and three 16-bit ADCs for digitising the accelerator outputs. For precision, the parts feature a user programmable Gyroscope full scale range of ±250 to ±2000 degree/sec (DPS) and a user programmable accelerometer full scale range of ±2g to ±16g.

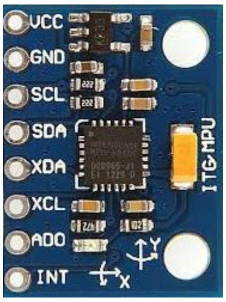

Figure 3.1: MPU 6050

With all the necessary on-chip processing and sensor components required to support EU-Cycle, The MPU-6050 uniquely enables low power motion interface with reduced processing requirements for the system processor. Additional features includes small package size, lower power consumption, high accuracy, repeatability, high shock tolerance and application specific performance programmability all at a low consumer price point.

3.2 CONTROL UNIT

The control unit is brain of EU-Cycle. Arduino Uno along with ATMEGA328, as shown in figure 3.2 constitute to control unit. In order to stabilise the rider in the centre of plain the control unit analyse the data from sensor unit and give signal to the motor driver. The main reason behind choosing this microcontroller is its feasibility to program when in operation and inbuilt debugger.

Figure 3.2: Arduino uno

3.3 MOTOR DRIVER

In this project a H-bridge made of two TIP147 and two TIP142 as shown in figure 3.3 was used. Based on the signal given by the sensor unit the control unit trigger the transistor Q1 and Q2 for forward direction, Q3 and Q4 for reverse direction of the motor. The proposed driver is capable of driving a motor that runs at 24V and 40Amps.

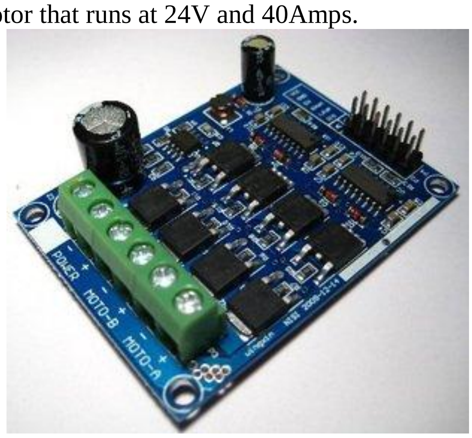

Figure 3.3: H-bridge driver circuit

3.4 MOTOR

The designed EU-Cycle was capable of driving a load of 120kgs and runs on battery bank. So, to meet the requirements a 300W, 24V brushed DC motor was chosen. The reason for choosing brushed motor is its high efficiency and easy control.

Figure 3.4: 24V,300W brushed DC Motor

IV. DYNAMICS OF THE 2 DEGREE OF FREEDOM (DOF) SYSTEM

The dynamics of EU-Cycle are developed from the inverted pendulum model used extensively in driver and Thorpe [2004] and further developed in Fong and uppill [2009]; Huang [2010]; Lauwers et al. [2006] to include the translation motion of the pendulum. However, these derivations are inconsistent with regards to co-ordinate frames and non-conservative forces. Therefore an extensive verification process was undertaken to derive the dynamics of the EU-Cycle. The process was based on dynamics derived in Nakajima et al. [1997]; Nagarajanet al. [2009] and through coordinate transforms, verified with the papers discussed above. The following assumptions have been made in the derivation of the dynamics, with reference to the coordinate system and directions.

- Motion is restricted to the xy-plane.
- A rigid cylinder is used to model the chassis and a vertically orientated thin solid disc is used to model the wheel.
- Coulomb friction arising from the bearings and tyre ground contact is neglected and hence only viscous friction is considered.
- The motor is controlled via an intelligent controller in current mode such that the input into the plant is a torque command.
- There is no slip between the tyre and the ground. The model is defined in terms of coordinates ϕ and θ, where ϕ rotation of the frame about the z-axis and θ rotation of the wheel relative to the frame angle.

V. PD CONTROLLER

The control strategy employed here uses a standard proportion-derivative (PD) controller. The implementation of this controller can be seen in figure 5. The reason for why a PID controller was not used is that a human naturally adds to reduce the steady state error and the addition of integral control can degrade the performance of the controller the controlled response [Clark et al., 2005]. A low pass filter was used on the derivative control term to make the controller proper and to filter out nice from the sensors in the physical system.

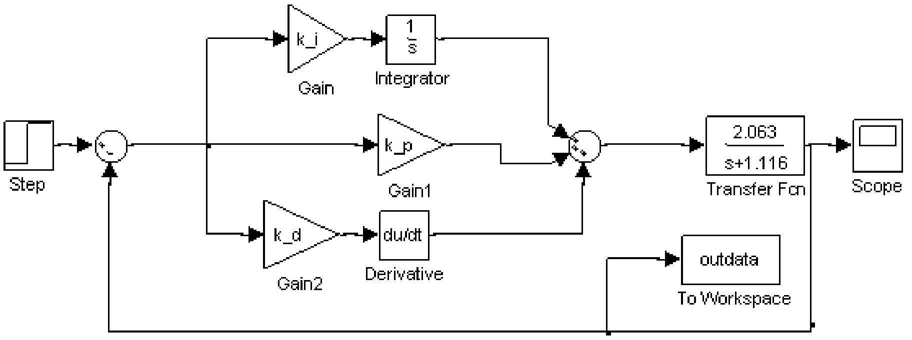

Figure 5: Block diagram of PD Controller

VI. CONCLUSION AND FUTURE WORKS

In this paper dynamics of the unicycle were derived and presented. Future work includes the development of a model based non-linear controller and a back stepping controller. These control strategies will be compared and benchmarked, with the optimal strategy being implemented into the EU-Cycle design. A higher capacity motor controller shall also be integrated into the system to alleviate the high tendency to saturate. Another planned development is the addition of active stabilization in the roll direction. This will use either a reaction wheel or a control moment gyroscope and this actuator will allow the EU-Cycle to be a completely self balancing electric unicycle.

References

[1.] T. Blackwell. TheElectric Unicycle, 2007.
[2.] R. Arbon, E. Arcondoulis, M. Gilmour, and R. Matthews.
[3.] M.A. Clark, J.B. Field, S.G. McMahon, and P.S. Philps.
[4.] The WASP: Wired Aerofoil stabilised platform. Honour Thesis, The University of Adelaide, 2006.
[5.] J. Fong and S. Uppill. Design and build a ballbot. Honours thesis, The University of Adelaide, 2009.
[6.] K. Hofer. Observer-based drive-control for self-balanced vehicles. In proceedings of IEEE/IECON 32nd. Annual conference on industrial electronics, pages 3951-3956, 2006.
[7.] R. Nakajima, T. Tsubouchi, S. Yuta, and E. Koyanagi.
[8.] J. Driver and D. Thrope. Design, Build and control of a single/double rotational inverted pendulum. Honours thesis, The University of Adelaide, 2004.