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DESIGN AND EVALUATION OF TWO WHEELED BALANCING ROBOT USING LEGO MINDSTORMS NXT

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Abstract:

The uniqueness of the inverted pendulum system has drawn interest from many researches due to the unstable nature of the system. The idea of a mobile inverted pendulum robot has surfaced in recent years and has attracted interest from control system researchers worldwide. Two-wheeled balancing robot is one of interesting nonlinear plant. The goal is to control the robot so that it can move with only two wheels. This paper elaborates the design and evaluation of its chassis. The chassis is constructed with Lego Mind storm NXT and controlled by the NXT controller. The system uses gyroscopic sensor. From the experiments, it is shown that robot chassis design must address the mechanically stable issue. The chassis also considers the flexibility to mount such a load. Mounting load under the axis helps to stabilize the chassis. This makes the controller design easier. The load position opens the further research topic. Using Lego Mind storm is very helpful in design and evaluation of mechatronics set up.

1. INTRODUCTION:

The research on balancing robot has gained momentum over the last decade in number of robotics laboratories around the world. This is due to the inherent unstable dynamics of the system. Such robots are characterized by the ability to balance on its two wheels and spin on the spot. This additional maneuverability allows easy navigation on various terrains, turn sharp corners and traverse small steps or curbs. These capabilities have the potential to solve a number of challenges in industry and society. For example, a motorised wheelchair utilizing this technology would give the operator greater maneuverability and thus access to places most able-bodied people take for granted. Small carts built utilizing this technology allows humans to travel short distances in a small area or factories as opposed to using cars or buggies which is more polluting. This paper elaborates the design and evaluation of the Two-Wheeled Balancing Robot chassis. The chassis is constructed with Lego Mind storm NXT and controlled by the NXT controller. The system uses gyroscopic sensor from Parallax to evaluate the robot chassis.

BLOCK DIAGRAM OF TWO – WHEELED BALANCING ROBOT

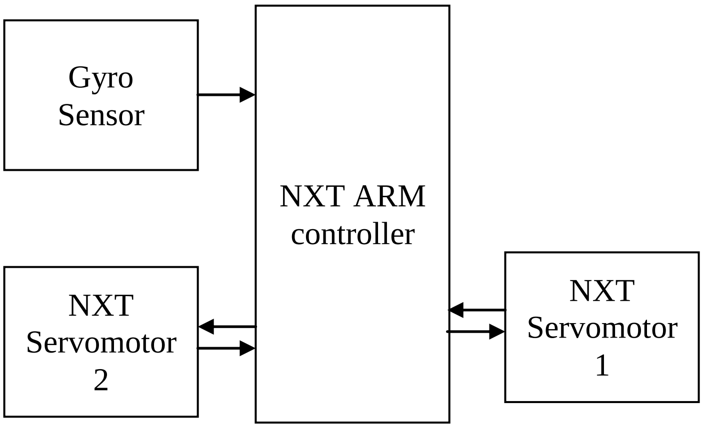

Figure (1): Block Diagram of Two – Wheeled Balancing Robot

2. LEGO MINDSTORMS NXT:

Lego Mind storms NXT is a programmable robotics kit released by Lego in late July 2006.It replaced the first-generation Lego Mind storms kit, which was called the Robotics Invention System. It comes with the NXT-G programming software, or optionally Lab VIEW for LEGO MINDSTORMS.A variety of unofficial languages exist, such as NXC, NBC, leJOS NXJ, and Robotic. A new version of the set, the new Lego mind storms NXT 2.0, was released on August 1, 2009, featuring a color sensor and other upgraded capabilities. The main component in the kit is a brick-shaped computer called the NXT Intelligent Brick. It can take input from up to four sensors and control up to three motors, via RJ12 cables, very much similar to but incompatible with RJ11 phone cords. The brick has a 100×60 pixel monochrome LCD display and four buttons that can be used to navigate a user interface using hierarchical menus. It also has a speaker and can play sound files at sampling rates up to 8 kHz. Power is supplied by 6 AA (1.5 V each) batteries in the consumer version of the kit and by a Li-Ion rechargeable battery and charger in the educational version. The Intelligent Brick remains unchanged with NXT 2.0.A black version of the brick was made to celebrate the 10th anniversary of the Mindstorms System with no change to the internals. Measure the additional dimension of rotation with the NXT Gyro Sensor. This sensor that lets you accurately detects rotation for your NXT Robot. The NXT Gyro Sensor returns the number of degrees per second of rotation as well as indicating the direction of rotation. Measure +/- 360° per second and build robots that can balance, swing or perform other functions where measurement of rotation is essential. The NXT Gyro Sensor contains a single axis gyroscopic sensor that detects rotation and returns a value representing the number of degrees per second of rotation. The Gyro Sensor can measure up to +/- 360° per second of rotation. The Gyro Sensor connects to an NXT sensor port using a standard NXT wire and utilizes the analog sensor interface. The rotation rate can be read up to approximately 300 times per second. The Gyro Sensor is housed in a standard Mind storms sensor housing to match the other Mind storms elements.

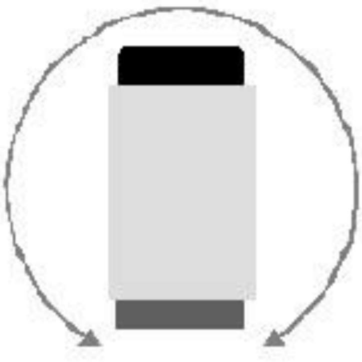

Figure (2): Gyro Sensor Rotation

The axis of measurement is in the vertical plane with the gyro sensor positioned with the black end cap facing upwards is shown. To quick test your new sensor, plug it into port 1 of your NXT brick and select View – Ambient light – Port 1. As you rotate the sensor as shown, you'll notice that the readings will change from the nominal 40 center value. The faster you rotate the sensor, the larger the deviation from 40. This is a test only and not a demonstration of how the sensor should be used.

3. NXT BRICK OPERATIONS SCHEMATIC:

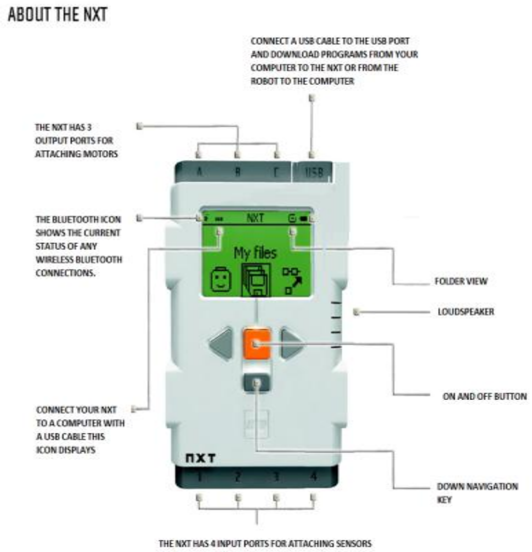

Figure (3): NXT Brick Operations Schematic

4. NXT–G (GRAPHICAL PROGRAMMING ENVIRONMENT):

The NXT-G programming language that is the core of the LEGO MINDSTORMS Education NXT Software makes building complex programs quick and easy. Complex programs can be built by combining simpler blocks.

Each program you build and then download to the NXT Intelligent Brick becomes a file directly accessible from the NXT brick menu. However, complex programs can quickly fill the limited flash memory available on the brick. This guide describes techniques you can use to write efficient programs for creating complex behaviors with a minimum use of flash memory.

Start by maximizing the free space on your brick before you download your own programs. When an NXT brick is in factory default condition (brand new or recently updated firmware provided by LEGO Education), the brick's flash memory includes a set of default files used for built-in features such as "Try Me" program and on-brick programming.

These default files are called system files and they don't normally appear in LEGO MINDSTORMS Education NXT Software v2.0. To see these files:

1. Open the NXT Window
2. Click on the Memory tab
3. Check the box next to "Show System Files"

It is always safe to delete any of these files with the Delete button; however, you will temporarily lose the built-in features they provide. After manually deleting system files, use the Delete All button to further maximize usable space for your programs. Clicking this button will delete any non-system files on your brick and will optimize the flash memory usage of the system files remaining on the brick. For more information about the system files and managing memory on the NXT in general, refer to the Help topic Files and Memory on the NXT included with LEGO MINDSTORMS Education NXT Software v2.0.

5. CONCLUSION:

Chassis design with LEGO bricks is very useful. When we cannot be sure about mechanics aspect of our design, LEGO makes it easier in building the mock up. Sure that mock up from LEGO cannot be used directly to real application, but it cut the design time. It is important to address the flexibility in chassis design. The load position, as in model, can be changed to see the overall performance of the system. This opens the further research, i.e. relationship between PID controller parameters and load position. It is necessary to design a chassis that is mechanically stable. This helps in designing appropriate controller. If the chassis does not fulfill this requirement, the controller must compensate it and this is too costly. This paper also includes the preliminary research about mounting load to the chassis to influence the stability. Indeed, the load can help the chassis to have greater stability. Thus, the Two-Wheeled Balancing Robot is designed and its performance has also been evaluated from the detailed study of the NXT-G and NXC software. NXT-G software gives better performance considering the execution time, time taken to code the program etc than the NXC language.

ONE – WHEEL BALANCING ROBOT:

Self Balancing One Wheel Robot or a mono-wheel robot's program can be written in both Robotic and NXT-G environments. Employs two motors, HiTechnic gyro and Ultrasonic sensor. The HiTechnic Gyro sensor is located near the inverted pendulum's pivot point in order to minimize potential lever arm acceleration induced errors while measuring the tilt angle (angular velocity).

The Ultrasonic sensor measures distances to the closest obstacle in its field of view. The design incorporates a loop feedback mechanism using a PID (proportional-integral-derivative) controller. This tracks the tilt angular rate (gyro), calculates the robot's tilt angle using a discrete integral (Adams- Bash forth 2nd Order integration), tracks the robot's position changes (drive motor encoders), calculates its linear velocity (simple derivative of position), and zeroes out the loop feedback errors.

This model also includes learning (training session) to find the gyro sensor's angular rate bias. Design incorporates an adaptive tilt angle bias. Uses low pass filters in determining biases and control signals to the motors. The design optimizes the timing of the loop feedback in order to get the fastest response times in the NXT-G environment.

ONE – WHEELED SELF BALANCING ROBOT:

Figure (4): One – Wheeled Self Balancing Robot

The left and right wheels are synchronized to make smooth center-pivot-turns and to run in straight lines. The design incorporates Obstacle (Collision) Avoidance and turning of the robot when approaching too close to an obstacle. Applies a workaround to correct a potential NXT design flaw in the sensor port analog to digital reference voltage conversion and mitigates startup errors in the gyro sensor readings when using other analog I/O devices.

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