Biped Robot Prototype - Embedded system integration with PID controller

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Introduction

In modern industry robots capable of mimicking human behaviour are of great importance not just for industrial purposes but also for medical work. Each year standards and accomplishments in sector of robotics and embedded systems are improving faster than before. Therefore understanding of such systems is crucial for upcoming engineers.

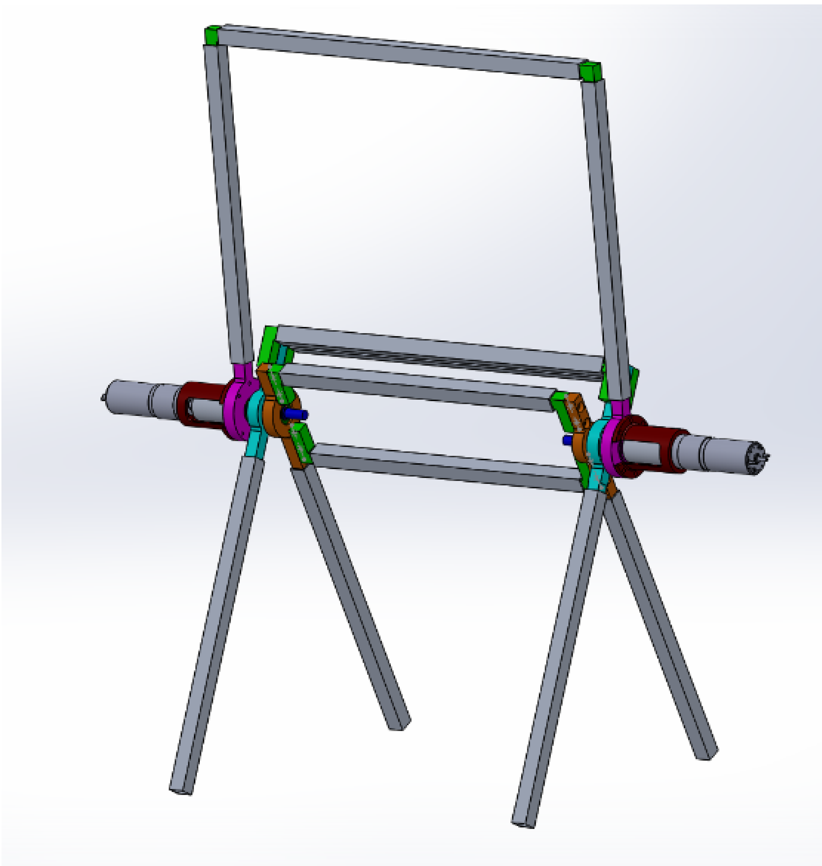

Figure 1: Prototype Biped robot Frame

Multiple master and bachelor thesis have been written on subject of biped gait robots at Norwegian University of Science and Technology (NTNU). This project aims to provide a development and test platform with the biped prototype at the department of engineering cybernetics at NTNU.

Circuit Design

One of the main tasks the group had, when first trying to understand the wiring, and how everything was connected, was understanding the documentation. Much of the robots wiring system was built with unreliable solutions and with many protoboards in its design. To replace these protoboards the group decided to develop new PCB boards with connectors for each component. Since the previous work performed on robot had encountered issues with wiring and noise in the system, new wiring to each component would need to be developed. The new wiring scheme would be made in way that reduced the risk of connecting components the wrong way. This would hinder future work from accidentally damaging the Beaglebone or sensors connected. The focus of this new system of boards and wiring was to make it simple, easy to plug and play, and flexible enough for future changes to the robot.

New Wiring System

In order to create a more robust wiring system with ethernet cables, three custom connector PCBs was created. A main connector board, IMU connector board and an encoder connector board implements headers which makes it possible to use ethernet cables to connect the system components. The main connector board functions as a cape that connects to Beaglbones P8 and P9 headers. The focus of the design was to make it easy to connect and disconnect all the different components the robot uses. To achieve this the board uses Ethernet ports to connect to the IMUs and Encoders, and ordinary screw Terminals for the motor and Servo connections.To power the the Motor the board also splits 48 volts to two separate screw connectors for each motor controller. The IMU connector board help facilitate the LSM9DS1 breakout board and to connect the LSM9DS1 IMU chip through R-45 connectors and Ethernet cables to the main board. The encoder connector board interfaces the 10-pin connector from the encoder with the RJ45 header which transfers data through an Ethernet cable to the Beaglebone.

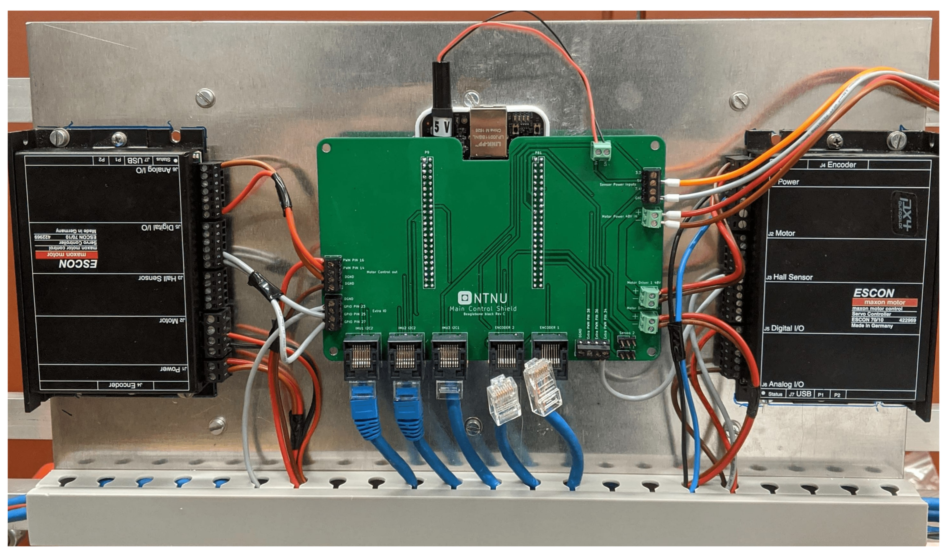

Figure 2: Main connector board

Embedded system

The goal of the embedded system was to read all the sensors, and to control the motor and servos from the Beaglebone. This was to remove the costly dSpace ControlDesk from the project, and make it open source and easy to modify. Thorough documentation of the embedded development and code in GitHub repository was also an important goal of this project. It was decided to develop new code for all the sensors; servos and motors. Arduino used in the system were also removed since they represented an unnecessary complexity to the communication system between the Beaglebone and IMU. Since the code from the last group was written in Arduino C and in C++, and most of the members knew how to code in C, the new code was written in standard C++.

Beaglebone Black

The Beaglebone is the central processing unit of the embedded system of the biped robot. The Beaglebone Black is an open-source hardware System on Chip (SoC) development board made for intermediate level developers.

System Components

The inertial measurement unit used in the embedded system of the bipedal robot is the LSM9DS1 iNEMO system-in-package module developed by STMicroelectronics, this module has the ability to sense a total of 9 degrees of freedom, I2C was used for as the protocol for communication with the unit. The encoder used in this project is a Scancon 2RMHF industrial encoder that outputs two square wave pulse signals. Four Turnigy TGY-SC340V 7.4 Volt servos were used in the project to control the actuators at the end of the robot legs. The motor used in the embedded system of the robot are the Maxon 14887 DC motor which has the capability to output 150W, the motor is connected to a gearbox which gears the motor 1-to-6. The motor is controlled with the help of an ESCON 70/10 servocontroller.

ROS - Robot Operating System

The code developed for the system was with ROS implementation in mind because there are clear advantages for using ROS as the cross process communication framework, first it is easy to expand upon and very modular. Including additional sensor nodes or other servos and motors is easy to add, and is done quickly

PD - controller

Determining a strategy on how system will be controlled and which controller to use, were based upon fact that robot is underactuated and underpowered. A system identification was performed, this involved modeling of the system with MATLAB and Simulink. Then it was determined to utilize a Proportional-Derivative controller for the control of the biped robot, the reasoning behind this decision was that the actuators found on the robot do not have the power needed to execute error correcting executions of the integral portion of an PID controller. In order to implement a PD-controller in the embedded system of the robot a discretization of the system, the method chosen to perform this was with trapezoidal approximation. This research was then used to create a C++ controller code which can be implemented on the embedded system of the biped robot.

Summary and conclusions

The primary goal of this project was to develop a robust foundation for further development on this project. This meant having wiring that is simple enough for new students to understand, but also modular enough to not impede future changes. The group ended up with a new wiring system and fully functional C++ code for each sensor, servo, and motor. This code was short, easy to understand, and simple enough to perform further development. Documentation of the code in a GitHub repository will also aid the future development on the robot. The secondary goal of this project was to preform research into implementation of a PD – controller on the bipedal robot with the aim of the robot performing one or two steps. The research presents a suggestion for how the PD controller and how it could be implemented in ROS. In conclusion the current biped robot prototype has a functional embedded system with new modular wiring and the theoretical groundwork for the implementation of a PD controller for the robot is completed. The current system fulfills the main goals set for this project, but the group acknowledges that the limited testing of the physical system hinders the group to conclude that the control system of the robot is fully completed and ready for further development without modification uncovered by future testing.