Skoltech

Skolkovo Institute of Science and Technology

Industrial Immersion Project

Development of hardware system and motion planning analysis for a Quadruped mobile robot

Master's Educational Program: Space and Engineering Systems

Student Egorov Anton

Company Advisor: Ivan Kalinov and Grigoriy Yashin

Skoltech Advisor: Dzmitry Tsetserekou

Moscow 2019

Introduction

Robots with four legs from decennium have gained considerable attention in various research and development sectors. The robots like Quadruped can fit through and locomote within tightly packed volumes that may be encountered in a collapsed building or a pile of rubble. They are used in search and rescue operations, space applications (Mars exploration), industries for lifting purpose containing solenoids and servo motors.

Nowadays robotic systems have the capability to behave autonomously and to improve the system performance by interacting with environments. Robots are able to rove, sense and respond in a given environment and are able to perform assignments and explore without human intervention.

This research work will involve the design and assembly of the robot with four legs which is a huge, heavy, inexpensive, four-legged robot. Since for the keeping stability of the robot on the surface only three legs are sufficient, quadruped possesses the great flexibility in walking. For instance, even if one of its legs would become incapacitated, the robot can still walk. The system separating the control signals, and the different microcontrollers. For the stable function of the robot, it is necessary to develop an embedded control system and creating motion and path planning algorithms.

Tasks

This work is targeted making four tasks:

1. Prepare reliable and stable hardware electronics for whole legs and flying systems.

   Develop:

   - A printed circuit board (PCB) for connecting Arduino Due microcontroller and peripherals: dynamixlels, encoders, and IMU sensors
   - Power supply system for the whole legged robot

2. Set up and calibrate the robot with new mechanics design and electronics using MATLAB tool and further make changes to the environment for programming Arduino

3. The final step includes real time simulation on a quadruped mobile robot.

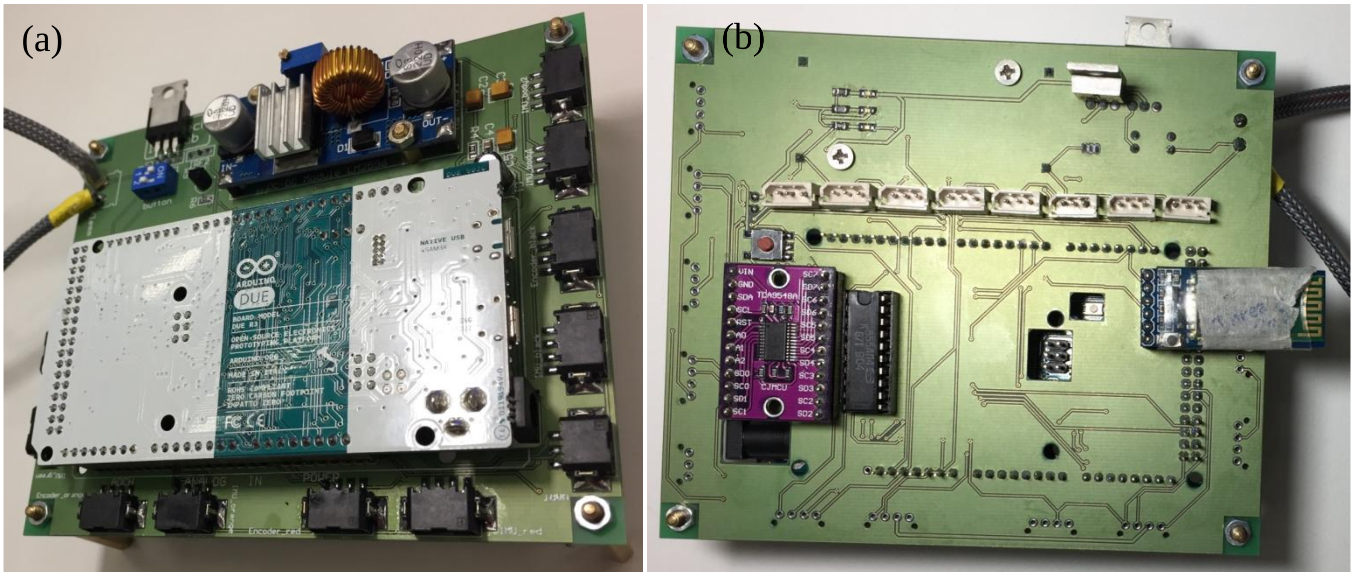
This report is devoted to the issue of the locomotion and legged robotics. The final part of the report contains results and conclusions.

Task 1. Reliable and stable hardware electronics for whole legs and flying systems

1. *A printed circuit board (PCB) for connecting Arduino Due microcontroller and peripherals: dynamixlels, encoders, and IMU sensors.*

To validate the different configurations of the legged robot I have performed hardware implementation on dedicated hardware, such as Arduino Due (Microcontroller) for high and low level implementation, respectively.

The Arduino board used in this work is the board (Figure 1(a)), which is based on Atmel SAM3X8E (32-Bit ARM microcontroller). It has an onboard speaker, three buttons and LEDs, a reset button, logic and servo power inputs, an I/O bus with 54 digital pins and power and ground, and a 5 vdc 1.5 amp regulator.



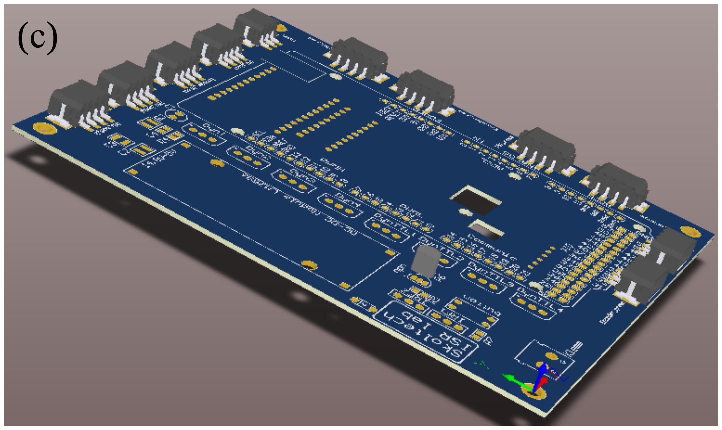


Figure 1. Hardware used in this project: (a) Arduino Due and high power part system, (b) Multiplexer, buffer and Bluetooth module, (c) breakout board

Besides, in Figure 1(b), I show the bottom layer of the PCB board (Figure 1(c)). For instance, buffer (Figure 4(c)) is used to handle eight dynamixlels in the robot and multiplexer is used to connect six IMU sensors, accordingly.

To connect and control dynamixlels through the Arduino DUE, we also use a breakout board, which allows us an easy connection to high-density connectors on the Arduino by routing all signals to one 40-pin and several other 10-pin 2-mm headers (see Figure 4(d)). This PCB was developed in Altium Designer program for connecting other peripherals: encoders, and IMU sensors.

2. *Power supply for legs and flying systems of the robot*

In Figure 2, I present the most interesting implementation of power supply for drone with four legs and powerful flying systems. As you can see from Figure 2(b), I'm making our cables, but to protect them, I use thermal sheath on the top of the welds, and then braided sheath and thermal sheath again to protect the whole cable. The first thermal sheath ensures that we don't get to touch the wires, where the second one wraps the braided sheath and ensure it stays there.

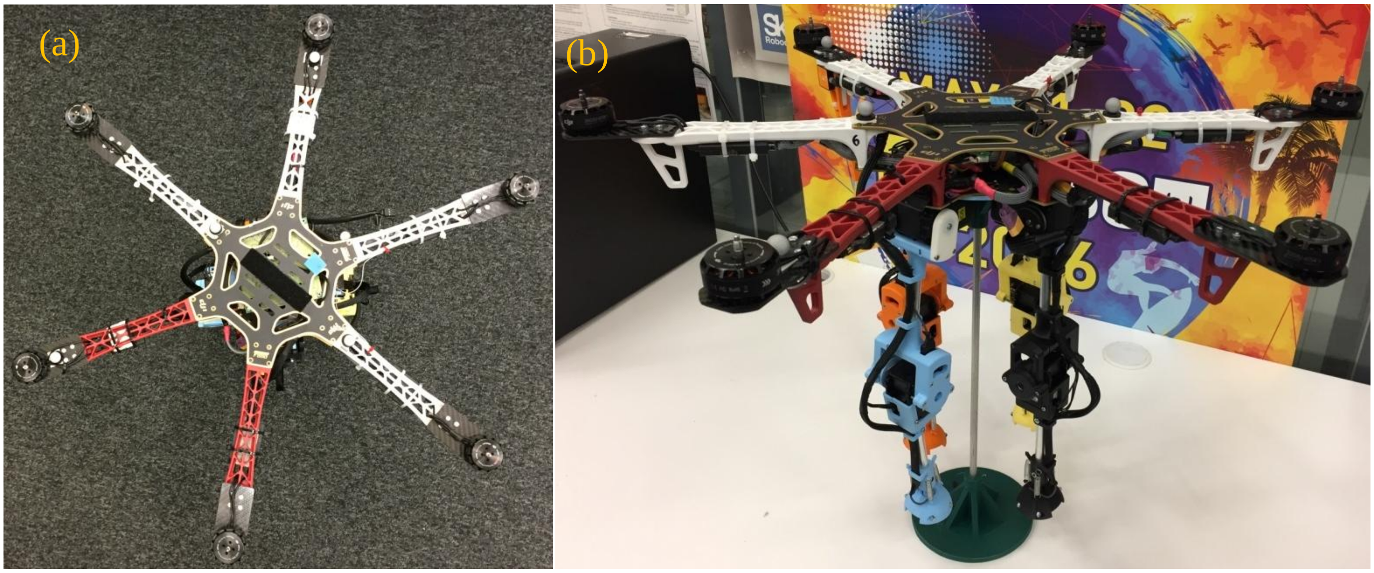


Figure 2. Quadruped mobile robot with: (a) Flying system, (b) four-legged drone whole body

Task 2. Set up and calibrate the robot with new mechanics design and electronics using MATLAB tool and further make changes to the environment for programming Arduino

Finally, in Figure 3, I show real time simulations during the walking useing MATLAB tool. This part includes configure and calibrating the robot with new mechanics design and electronics and further made changes to the environment for programming Arduino.

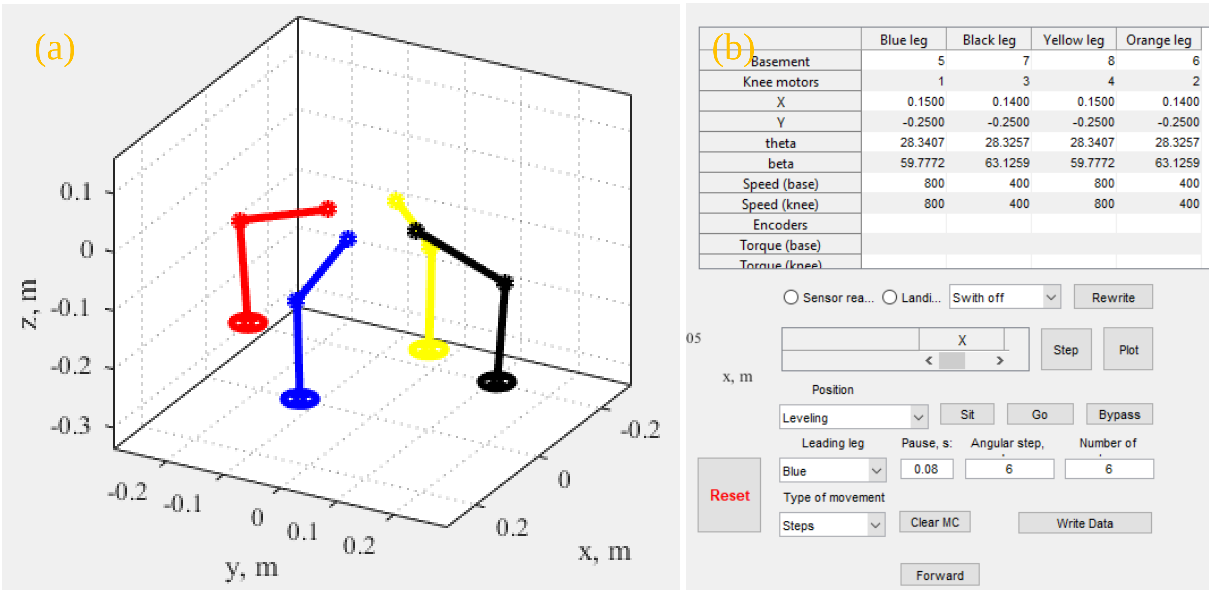


Figure 3. (a) MATLAB interface in real time, (b) robot parameters in real time

Task 3. Testing the entire system

To validate the different configurations of the legged robot, we have used real drone with arm and with four legs, such as those shown in Figure 4.

In the scope of the robot locomotion analysis, we conduct a series of experiments to define the optimal trajectory of the motion cycle and to set up dynamixlels' parameters. Then we test the robot motion among the predetermined trajectory.

For the robot locomotion coordinates selection, I carried out four stages of testing. Firstly, it is necessary to define the stable positioning of the robot on three legs. To achieve this, I tested different combinations of the distance between side legs and distances between point *A* and supporting leg during the robot tilting on this leg from the initial position.

On the second step, I analyzed the forward movement of the leading leg. In this case, incorrect positioning leads to instability and probable swaying from side to side. The small distance between the leg and point *A* (d_i) can lead to rolling over. A larger value of this parameter reduces the step size, and accordingly the movement speed. Increasing d_i reduces the distance between the robot body and ground, and respectively working range of β and θ is decreased as well, that directly influences on the step size.

Figure 4.Real time simulation on a quadruped robot: (a) Initial position, (b) CoM displacement, (c) Lift the leading leg,(d) Lower the leg, (e) CoM transfer, (f) Lift the supporting leg, (g) Leveling and view from the side of supporting leg after one step

The most challenging stage of the locomotion cycle is the moving of the robot CoM from the supporting leg to the leading leg. The robot moves to a new position immediately during this step, thus, the previous steps are the preparation to the motion. At this stage, the robot should lift the side legs up and quickly move the CoM to a new position, so as not to incline to the side until the end of the movement. Thus, at this moment, the motors of the supporting and leading legs undergo maximum load. If the trajectory is incorrectly selected, the robot tries to lift up and remain in place, which is possible with an excessively large distance d_i. Also, the robot can tip over if the distance between the ground and the side legs is too small. This is due to the fact that the robot will have time to slightly tilt to the side and one of the legs will remain in the same place, while the leading leg will pull the robot behind it.

General conclusion

In this report, the investigation of control and hardware systems for a drone with four legs was conducted. The overall work was divided into several steps. First, I carried out a locomotion robotics search. I have fully prepared drone with arm and with four legs and reliable, stable hardware. I also designed perfectly configured robot motion algorithm.

These results will not allow me to stay on issues of problems with electronics. Based on this I will be able to work with no problems on locomotion algorithm for climbing down from uneven terrain and algorithm of obstacle avoidance based on the embedded optical torque sensors at knee joint of the legs.