# **Discussion and Conclusion**

Testing and demonstration has shown that the communication network is robust, and that data can be transmitted throughout the network and to the simulation without corrupting the data in the process. It can be seen from the screenshots of the testbenches that each component has achieved the intended functionality, making the communication network reliable in providing data for the simulation. Furthermore, the project demonstration has shown that the communication network is capable of providing the data for the simulation in real-time. The tests have shown **(Do a quick test to show 16Hz update rate)** that the only liming factor is the update rate of the simulation which is approximately 16Hz and is due to the CP2102 and its internal buffer and timeout preventing the update rate from being higher which causes the simulation to not be as smooth as it would be if the update rate was higher. A possible solution to this problem would be to bypass the CP2102 by pairing the HC-05 device directly with the computer’s inbuilt Bluetooth module. Implementing this solution would additionally reduce the cost of the project as the UART to USB bridge and one of the HC-05 Bluetooth modules would no longer be necessary to transmit data to the computer.

The data conversion was successfully implemented with some of the errors such as drift or IMU offset being eliminated. There are problems with the way the data is being converted to angle in degrees due to the limitations of the trigonometric functions and the inherent problems of Euler angles such as gimbal lock that prevented the calculations from being reliable for any orientation and only provided reliable results within a defined range of motion as could be seen from the IMU test or the comparison of the arm position to position of the arm in the simulation where if the orientation angle of any of the IMU components exceeded 180 degrees or in some cases approached an angle of 90 degrees, like in the case of rotation about the y-axis, caused the orientation angle to diverge from the actual orientation. The use of Euler angles to estimate the orientation of the entire arm is therefore inadequate as a potential solution. The use of Quaternions, though much more complex and computationally expensive, avoids the problems such as gimbal lock or the limiting trigonometric functions and therefore is a potential solution for the system if the project was going to be developed further in the future.

Due to time constraints, the complementary filter for the z-axis was not implemented and therefore the system was unable to reliably measure the rotation angle in the z-axis as could be seen from the simulation tests and also the IMU testing. As a result, there was a loss of a degree of freedom. As mentioned in the theory section of the report, to maintain track of the rotation in the z-axis reliably, the magnetometer data is required to eliminate the drift in the z-axis. The extraction of this data is more complex as it requires the user to access a different chip on the MPU9250 in order to obtain the magnetometer data.

In the current state of the project, this robotic arm control system, though operational, with a robust communication network, is inadequate for as a control system for a robotic arm. This is mainly due to the fact that the methods used to convert the accelerometer and gyroscope data into orientation angle provide reliable data within limits beyond which the calculation methods become unreliable and therefore cannot be used as the user would not have full control of the robotic arm using this system which could pose potential danger to other people and equipment within the proximity of the robotic arm. The control system however, has the potential to be developed into a fully operational system if Quaternions are used as a means of calculating orientation angles of the arm instead of Euler angles.