Executive Summary

Visual odometry, the estimation of the position and orientation of a mobile robot based on the images from the onboard camera, is a challenging task for a legged robot in a bounding mode. Many researches have been conducted to improve the accuracy of visual odometry of wheeled robots via integration of inertial information. However, visual odometry of legged robots remains largely uninvestigated. The high pitch angle during the bounding motion causes a large vertical displacement, which can be erroneously detected as displacement in arbitrary directions. The added pitch to the motion during bounding makes visual odometry more susceptible to different factors such as camera resolution and pitch frequency. This research explores the hypothesis that the error in visual odometry estimation of a bounding legged robot is primarily caused by the pitch motion being confused as vertical displacement in the z-axis (vertical axis).

A MATLAB simulation has been created to generate image frames from the camera view of a bounding legged robot. The simulation randomly generates cubical clumps of points to form objects in the 3D world where one pixel corresponds to one inch in real life unit. It then uses epipolar geometry to perform visual odometry on the generated image frames. A simulation has been used instead of real image data because working with real image data can be challenging due to presence of random noise. The simulation assumes perfect lighting conditions and creates 100% accurate feature matches between two consecutive image frames. By essentially zeroing out all other noises, the simulation allows the observation of the effect of pitch exclusively.

For simplicity, a legged robot was simulated to move forward in a straight line. The first experiment was conducted to explore the effect of resolution on the accuracy of visual odometry by increasing the resolution from 500 by 500 to 5000 by 5000. The second experiment was conducted with zero pitch in order to verify that the simulation works. In the following experiments, the pitch angle was increased gradually starting from 2 degrees and its effect on visual odometry was observed. The last experiment was conducted to explore the effect of pitch frequency on visual odometry.

In the first experiment, it was observed that higher resolution reduced error in visual odometry. Thus, for the rest of the experiments, the simulation used infinite resolution in order to reduce random noise. In the second experiment, zero pitch showed negligible magnitude of error in the order of 10^{-12}, which verified that the simulation works. In the following experiments, with increasing pitch angle, it was observed that the presence of pitch angle indeed was confused as vertical displacement as seen by the oscillation in z value. In the last experiment, it was observed that there existed a max pitch frequency for every pitch angle over which the visual odometry lost track. It was observed that the max frequency value decreases logarithmically with increasing pitch angle.

In conclusion, the results show that increasing pitch angle tends to create the illusion that there is vertical displacement. They also showed that high pitch frequency might be a significant cause of visual odometry error for a bounding legged robot. While the research was not comprehensive, the results of this research would provide a good starting point for other researches that attempts to improve the accuracy of visual odometry for legged robots.