Feature tracking for visual servo based range regulation on a mobile robot

Michael Burke

CSIR Mobile Intelligent Autonomous Systems, PO Box 395, Pretoria 0001, South Africa.

Tel: +27 12 841 4849 Email: mburke@csir.co.za

Introduction

The ability of an agent to regulate the range and relative velocity between it and a target is a common requirement in autonomous robotic applications. Leader follower formation control for autonomous convoys requires that agents maintain a constant distance between one another, while unmanned aerial vehicles such as micro-copters frequently need to hover and regulate altitude.

Figure 1. A leader follower formation control application.

The typical approach towards accomplishing this task is to measure range using sensors such as laser range finders and sonar or through stereo vision techniques. A control signal acting on the agent's thrust or velocity is then used to minimise the error between the measured range and a desired set-point.

This poster presents a visual servo approach to straight line range and velocity regulation. The difference in velocity between a lead mobile robot and a follower is regulated in order to maintain a constant distance between the two agents. In order to relieve the burden of image processing, image based visual servo control of velocity and range, based on the regulation of relative scale changes between image features on the target, is used. Feature tracking is accomplished through a Kanade-Lucas tracker [2] operating on the features described by Shi and Tomasi in [3] and scale measurements are made using Procrustes analysis [4].

Methodology

The pioneer series of terrestrial wheeled mobile robots was used for experimental purposes, with a P3-AT skid steering robot as leader and a P3-DX differential drive robot as follower.

Assumptions:
- No communication between platforms is present.
- A single perspective camera is used.
- Platforms are able to measure and control their velocity accurately.

A KLT tracker is used to track features over time. The scale change between the tracked features and those on an original model is measured and used to control range using a Proportional-Integral controller. Relative velocity is also regulated by controlling range. The response of the follower to a step change in velocity was measured using platform velocities and a laser range finder measuring the distance between leader and follower.

Results

Results were compared to those generated through simulation in Simulink using the system model of Figure 2.

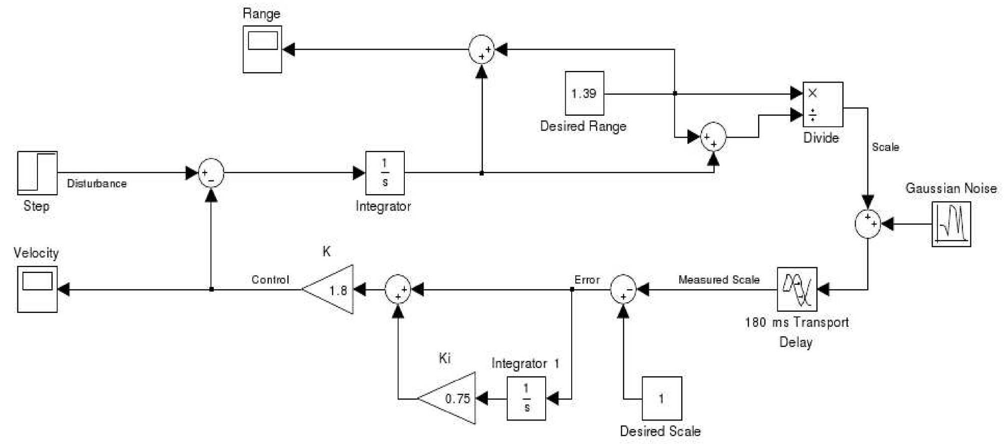
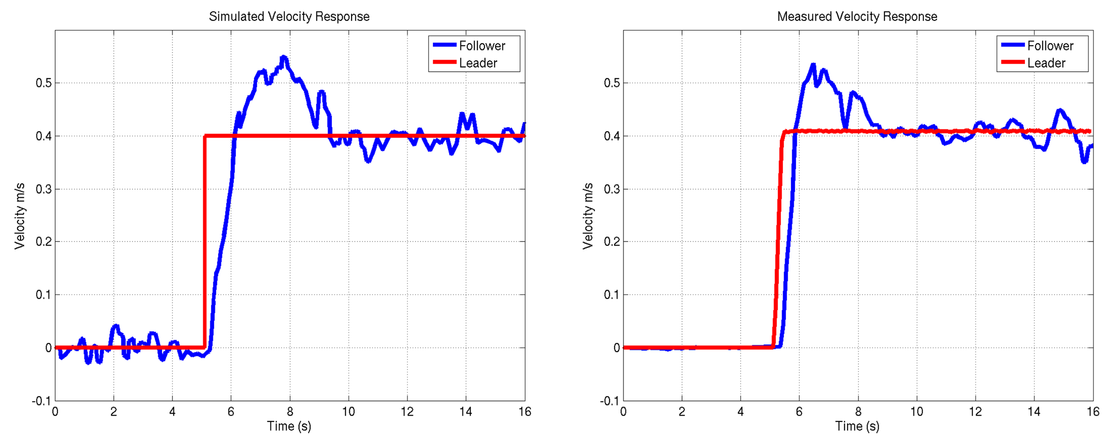


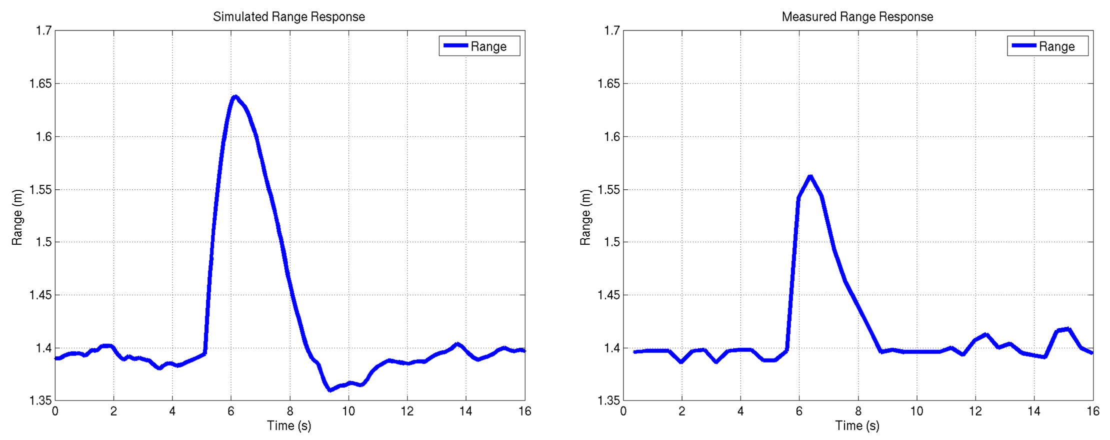
Figure 2. Theoretical model used for simulation.

Results of the simulated and experimentally measured system responses to a leader step change in velocity of 0.4 m/s are presented. Controller parameters were tuned empirically so that the step response met with limitations in the feature tracker.



a.) b.)

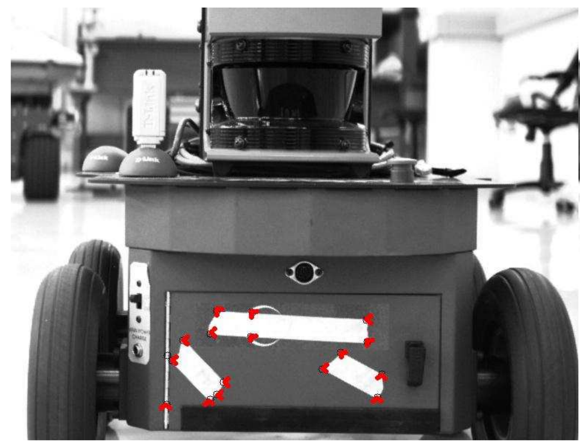
Figure 3.
a.) Simulated Velocity Response b.) Measured Velocity Response



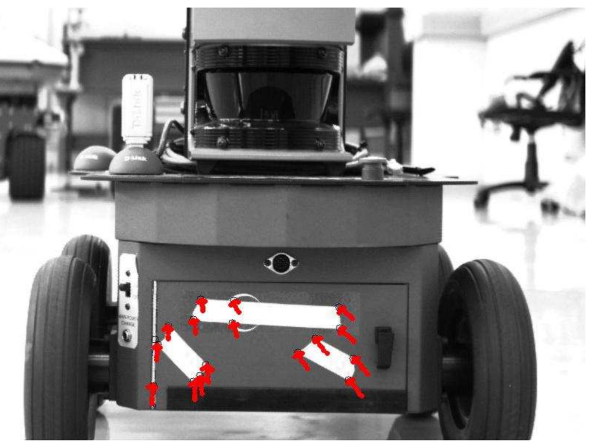
a.) b.)

Figure 5.
a.) Simulated Range Response b.) Measured Range Response

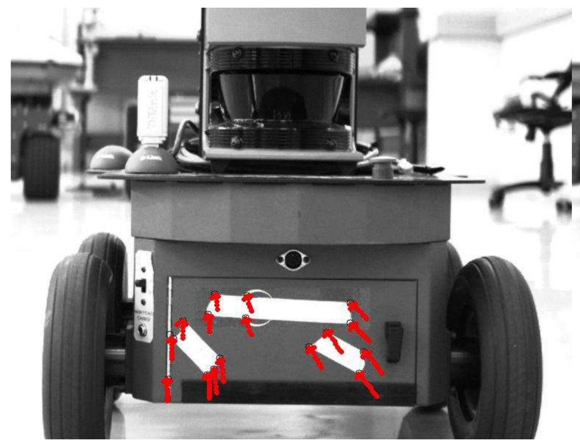
System limitations:
- Lost features over extended time periods caused the system to fail.
- Affine motion introduces problems in Procrustes scale measurement.
- Salient features are required on the lead robot.



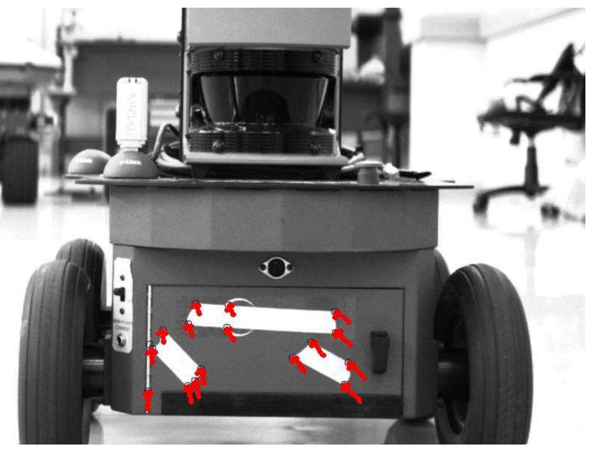
a.) Initial tracked feature positions.



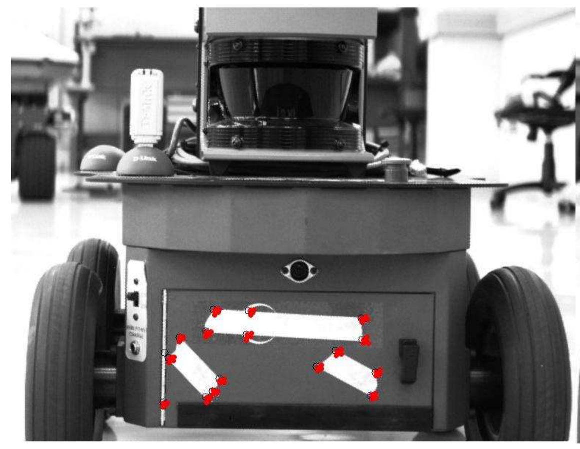
b.) Features start to move away as leader moves forward.



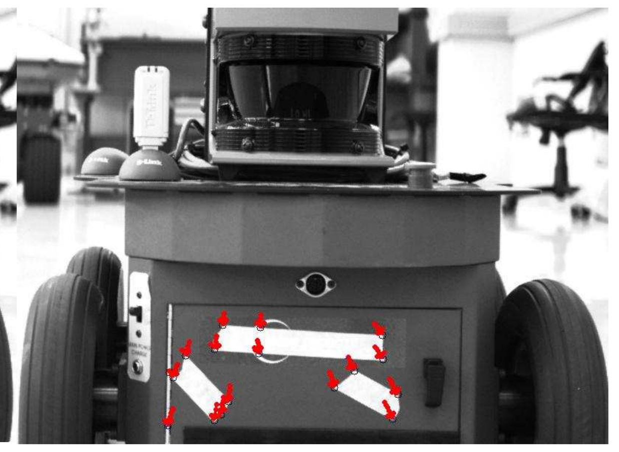
c.) Features reach maximum distance from starting positions as leader reaches maximum distance from follower.



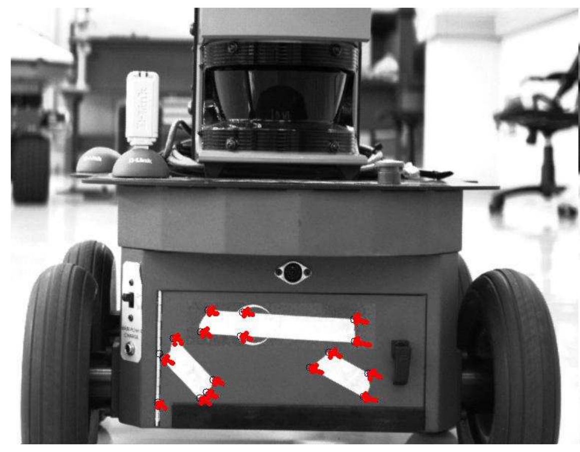
d.) Control kicks in and follower starts reducing gap between robots, with decreased optical flow resulting.



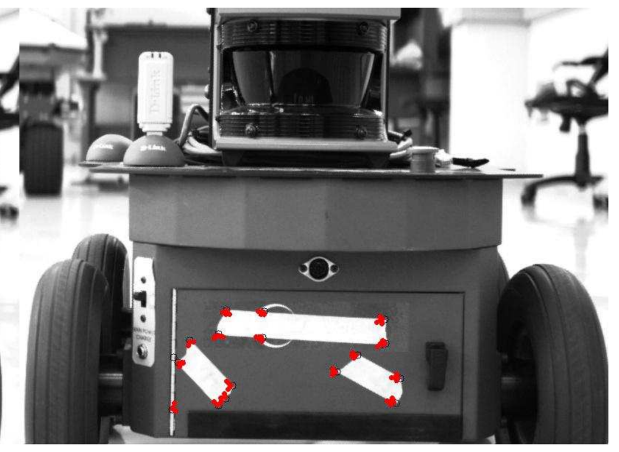
e.) Features almost restored to original positions.



f.) Follower overshoots and optical flow direction changes.



g.) Follower nears velocity of leader and optical flow reduces.



h.) Follower reaches velocity of leader, features returned to approximate starting positions.

Figure 6. Optical flow of features during the system response to a step change in range.

Conclusions

- The image plane control paradigm is effective as it greatly relieves the burden of image processing.
- Range can be maintained through relative scale measurements.
- Visual servo control is limited by feature tracking inefficiencies.
- The Kanade-Lucas feature tracker proved effective over short travel distances, but was not sufficiently robust over extended periods of time.

Ongoing Work

An improved system has been implemented since the date of submission. This system uses a more advanced feature detector, based on randomised trees which is more robust to occlusions and affine motion than KLT. An alternative method of calculating scale, using homography, has been implemented and the range regulation system now operates effectively over a range of motion and is not affected by the time over which the system operates.

References

[1] P. Corke, P. Sikka, and J. M. Roberts, "Height estimation for an autonomous helicopter," in ISER '00: Experimental Robotics VII. London, UK: Springer-Verlag, 2001, pp. 101–110.

[2] B. D. Lucas and T. Kanade, "An iterative image registration technique with an application to stereo vision," in Proceedings of the 7th International Joint Conference on Artificial Intelligence (IJCAI '81), April 1981, pp. 674–679.

[3] J. Shi and C. Tomasi, "Good features to track," in Computer Vision and Pattern Recognition, 1994. Proceedings CVPR '94., 1994 IEEE Computer Society Conference on, Jun 1994, pp. 593–600.

[4] D. G. Lowe, "Distinctive image features from scale invariant keypoints," International Journal of Computer Vision, vol. 2, no. 60, pp. 91–110, 2004.

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