Integrated Eye-in-Hand/Eye-to-Hand Visual Servoing

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Introduction

Visual Servoing is a method to control the motion of a robot with the feedback extracted from a vision sensor. The information to control the end effector of a robotic system is collected by one or more cameras observing the operation range. The biggest advantage of this technique is the increased flexibility for robots of all kinds in a changing environment.

In visual servoing there are two common setups for the positioning of the camera. The first one is called eye-to-hand and means that the camera is placed at a fixed point in the workspace. The other possibility is to attach the camera to the end-effector of the robot, this one is called eye-in-hand. The eye-to-hand setup has the advantage to have a panoramic sight of the workspace, whereas with eye-in-hand you have a very limited sight. But speaking about the accuracy the eye-in-hand approach is far ahead, because the camera is closer to the target and has the possibility to explore the workspace. Due to the fixed position of the eye-to-hand camera the pose in respect to the world coordinate system has to be established once, the eye-in-hand camera on the other hand has a fixed position in respect to the gripper.

Visual Servoing can be classified in two main categories, which are image-based visual servoing (IBVS) and position-based visual servoing (PBVS). The IBVS technique is based on the error between the current and the desired visual features. An example for these features are the image coordinates of

some points on the object of interest. In order to reach the desired feature set the error to the current feature set has to be minimized. Therefore this method uses 2D image data in contrast to the PBVS technique which is a model based approach. It estimates the pose of the target with respect to the camera, using a 3D model of the object. The goal is to move the camera from the current estimated pose to the desired pose.

Task description

The advantages of both camera positioning approaches can be used in a hybrid setup, with the combination of a mobile eye-in-hand camera and a global eye-to-hand camera system. This idea will be evaluated and a method to combine the information from two different camera angles will be implemented.
There are several researches dealing with the possibility of cooperation among multiple cameras. In [1] the used system consists of a fixed eye-to-hand camera and an eye-in-hand camera which is attached to the end-effector. The control of both cameras is totally independent in this case, in particular the global camera controls the translating degrees of freedom with a landmark a the end of the translating joins. The local camera on the end-effector controls the rotation and the orientation of the grasper to center the target in the image. The approach in [2] is similar, as the eye-to-hand camera controls the pose of the robot manipulator with respect to the workspace and the eye-in-hand camera is in charge to estimate the pose of the target object itself. A different and more complex implementation is described in [3], where the amount of eye-to-hand and eye-in-hand cameras are variable. The data of all cameras are completely combined to achieve a real integration without different tasks for different cameras.

The task is to investigate the approaches for a combination of an eye-in-hand and an eye-to-hand camera. The object tracking and the servoing will be done by existing standard methods, in order to focus on the information integration of two camera angles.
The configuration will be implemented and evaluated in a simulated environment. To point out the difference between the combination of two cameras and the use of a single camera system several experiments in the simulation

are required. The improvements can be shown by measuring the distance between the end-effector and the object of interest over time.
Another possibility to show the advantage of the combined camera approach is to come up with a simulated situation in which the single eye-in-hand or single eye-to-hand setup would fail.

Time schedule

1. **week:** Study the basics for visual servoing and investigate the existing techniques

2. **week** : Study and understand the two simulation environments Matlab's Machine Vision Toolbox and ViSP, in order to decide on one

3. **week** : Investigate and study the provided hardware and the previous visual servoing systems

4. **week** : Setting up the simulation environment for the implementation

6. **week** : Implementation of the combined visual servoing

10. **week** : Integrate the existing methods for object tracking and servoing

11. **week** : Test the implementation

13. **week** : Visualize and compare the results between combined and single camera visual servoing

14. **week** : Write the report

16. **week** : Completion

References

[1] G. Flandin, F. Chaumette, E. Marchand, "'Eye-in-hand/eye-to-hand cooperation for visual servoing"', in *Proceedings of the 2000 IEEE International Conference on Robotics and Automation*, April 2000, vol. 3, pp. 2741-2746.

[2] M. Elena, M. Cristiano, F. Damiano, M. Bonfe, "'Variable structure pid controller for cooperative eye-in-hand/eye-to-hand visual servoing"', in *Proceedings of the 2003 IEEE International Conference on Control Applications*, June 2003, vol. 2, pp. 989-994.

[3] V. Lippiello, B. Siciliano, L. Villani, "'Eye-in-Hand/Eye-to-Hand Multi-Camera Visual Servoing"', in *Proceedings of the 2005 IEEE International Conference on Decision and Control*, December 2005, pp. 5354-5359.