Role of Active Vision in Optimizing Visual Feedback for Robot Control

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Summary. A purposeful change of camera parameters or “active vision” can be used to improve the process of extracting visual information. Thus if a robot visual servo loop incorporates active vision, it can lead to a better performance while increasing the scope of the control tasks. Although significant advances have been made in this direction, much of the potential improvement is still unrealized. This chapter discusses the advantages of using active vision for visual servoing. It reviews some of the past research in active vision relevant to visual servoing, with the aim of improving: (1) the measurement of image parameters, (2) the process of interpreting the image parameters in terms of the corresponding world parameters, and (3) the control of a robot in terms of the visual information extracted.

1. Introduction

The goal of visual feedback in robot manipulation is to help overcome uncertainties in modeling the robot and its environment, thereby increasing the scope of robot applications to include tasks that were not possible without sensor feedback, for example welding. An active control over the imaging process can potentially increase the role visual feedback plays in robot manipulation. Here we look at some of the issues involved in making the camera active, while confining ourselves to mainly visual servoing, that is, the positioning control of a robot from an initial to final position using visual feedback. This restricts the scope of our discussion to a lower level control, avoiding issues in active vision for reasoning at the higher, task level.

Any vision-guided task carried out with a stationary camera set faces inherent limitations, since there is no control of the imaging process. On the other hand, in order to best process the visual information the camera setting and position has to satisfy some fairly restrictive conditions. For example, the observed feature on an object may go out of the field of view, or out of focus, etc. Hence a camera set-up which can be dynamically changed during the course of a robot manipulation task should enhance the scope of both the image processing, image interpretation, and the control of a robot using the visual feedback. The main incentive for using a controllable imaging system would be an increase in the flexibility and reliability of the visual feedback and hence the degree of autonomy gained by the robot system involved in the servoing tasks.
Active vision refers to a purposeful change of camera parameters, for example, position, orientation, focus, zoom, to facilitate the processing of visual data. That is, active vision calls for a coupling between image acquisition and visual processing. The motivation for using active vision or more generally “active perception” can also be derived from biological vision systems that are known to be highly active and goal directed [8, 7, 9]. The basic idea is that active control of the geometric parameters of the sensory apparatus benefits a problem in various ways, for example, by transforming it from an ill-posed problem to a well-posed problem, or by constraining it in such a way that an efficient solution becomes feasible. Various forms of active control are employed—for example, tracking in [11], camera fixation in [1, 10], vergence control in [2], selective attention in [16], and control of focusing in [38]. Some of the research on active vision that could potentially benefit visual servoing are reviewed in this chapter.

Although various issues in visual servoing has been addressed in the literature (see [21] for a review), it has only been recently that active vision has been considered in the context of visual servoing. However, the idea of automatically changing the parameters of a sensor (including a camera) for task-level planning of robot manipulation has been widely investigated in “sensor planning” research [59].

A good introduction on the different mechanisms of visual feedback involved in visual servo control can be found in [49]. In particular, an important distinction made is that of the feedback representation mode, which can be either position-based or image-based. See Figure 1.1 for a schematic overview of the two types of visual servo control loops. The position-based approach basically involves the problem of “visual reconstruction” which is recognized to be difficult because of the inherent non-linearities in the transformation and the uncertainties in the imaging process. On the other hand, image-based approaches require more work in task specification in the feature (or image or camera) space [30, 37, 49, 53, 65, 33]. This distinction between position-based and image-based control will play an important role for introducing active vision in the servo loop.

The research in active vision for various 3D “recovery” problems in vision is particularly relevant to the position-based visual servoing, as will be shown later.

Basically the goal of the visual feedback is to extract from the raw input array of intensity values a small set parameters that help in the control. It is hoped that active vision will have an influence over how the visual feedback provided is more

- relevant (by using attentional mechanism),
- accurate (by changing resolution, focus, etc.), and
- reliable (to overcome modeling uncertainty, changes etc.),

for a given visual servoing task. Some of these advantages will be discussed here.