Gaze Tracking for Human Robot Interaction

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1 Introduction

Humans use a number of communication cues in their daily interaction with other humans: primarily speech but also gestures, pointing and gaze [1]. The main purpose of gaze is to provide visual information to the subject, but at the same time a person's gaze implicitly provides information to an outside observer about what the subjects are focusing their attention on. There is a number of ways how eye gaze is implicitly used during communication: gaze aversion, mutual gaze, gaze pointing, join attention, etc.

Humans are very good at reading other people's gaze, but robots are less so. This ability would be especially important for humanoid robots to be able to mimic human abilities. However, most human robot interaction experiments today use head pose as a proxy for real eye gaze often times because it's easier to extract than eye gaze [2] [3] [4] [5]. But "head gaze" does not provide all the information that eye gaze does [6], thus enabling robots to perform eye tracking could significantly improve its abilities and also its acceptance by humans. A proof of concept gaze tracker was realized by Matsumoto and Zelinsky [7] and implemented on the HRP2 humanoid [8]. More recently Sciutti et al. [9] implemented a mutual gaze detection system on the iCub which facilitated a teacher/student scenario. Still, so far no extensive use of eye gaze tracking has been done in human-robot interaction.

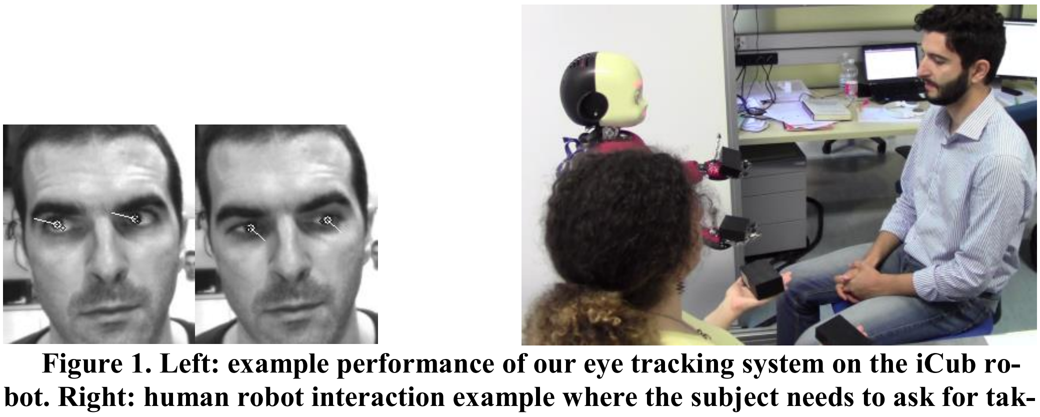

Figure 1. Left: example performance of our eye tracking system on the iCub robot. Right: human robot interaction example where the subject needs to ask for taking toy building blocks from the robot.

Published at SAGA Workshop 2015, proceedings archived under DOI: 10.2390/biecoll-saga2015_0.
Individual article archived under DOI: 10.2390/biecoll-saga2015_5

2 Our Contribution

We implemented a monocular feature-based passive gaze tracking algorithm on the iCub platform with the goal of facilitating human robot interaction. The first step in eye tracking is detecting faces and finding face features. For this purpose we used King's implementation [10] of Khazemi and Sullivan's approach for finding features like the corners of the eyes and mouth [11]. We also used Baltrusaitis implementation of the constrained local models approach for tracking head pose [12]. Once these measures were found we proceeded to apply an eye model to the detected center of the pupil similarly as in [13]. The model finally provided the estimate of the gaze angle of the subject, see Figure 1. We then performed a validation experiments in which we found the gaze estimates to be quite acceptable for our setup: the absolute error in the horizontal plane was 5 degrees on average. The accuracy of our system was limited by the cameras used in the iCub setup. We employed PointGrey Dragonfly2 cameras in 1024x768 resolution with fixed-focus 4mm lenses, which produce images of the iris with 20 pixels in diameter when the subject is at 60cm. Knowing that the average diameter of the iris [14] is similar in size to the average eye radius (12mm) [15], then one pixel difference in the middle of the iris corresponds to about 3 degrees difference in gaze. Thus our accuracy is greatly influenced by the hardware used. It is foreseeable that the progressive development of cheaper and small cameras will allow future robotic platforms to have higher resolution sensors, with a consequent improvement of the accuracy of our system. In the meanwhile, the current hardware already enables a gaze estimation from the iCub robot that it can exploit to manage human-robot collaboration tasks.

We also conducted a proof of concept human robot interaction experiment in which subjects were seated opposite of the robot and experimenter, who held toy building blocks in their hands, see Figure 1. The subject's role was to ask for the blocks in specific order, but we did not provide information on how to communicate with the robot. Participants used a combination of speech, pointing and gaze to achieve the task, but the robot really only reacted to gaze. More precisely, the robot handed over pieces of toy building blocks when it detected a succession of mutual gaze and gazing at the requested object. The subjects were not aware of the robot's gaze reading ability, but could still complete the task of building a pillar out of these blocks just by using natural eye behavior (paper submitted to Humanoids 2015). Hence, the robot succeeded in exploiting naturally occurring human gaze behavior to control its helping actions in a collaborative manner.

Future benefits of a built-in gaze tracker in a humanoid robot can be manifold: it could improve turn taking, joint attention and in general the processing of all the communicative gaze cues typical of human interaction. Furthermore, the robot could potentially be used for diagnosing early behavioral problems associated with gaze processing as Autism Spectrum Disorders, by monitoring subjects' gaze in real time.

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Individual article archived under DOI: 10.2390/biecoll-saga2015_5

ACKNOWLEDGMENTS: The research presented here has been supported by the European CODEFROR project (PIRSES-2013-612555).

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Published at SAGA Workshop 2015, proceedings archived under DOI: 10.2390/biecoll-saga2015_0.
Individual article archived under DOI: 10.2390/biecoll-saga2015_5