Robotic Implementation of Biological Bayesian Models for Visuo-inertial Image Stabilization and Gaze Control

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***Abstract*— Robotic implementations of gaze control and image stabilization have been previously proposed, that rely on fusing inertial and visual sensing modalities. Human and biological system also combine the two sensing modalities for the same goal. In this work we build upon these previous results and, with the contribution of psychophysical studies, attempt a more bio-inspired approach to the robotic implementation. Since Bayesian models have been successfully used to explain psychophysical experimental findings, we propose a robotic implementation using Bayesian inference.**

I. INTRODUCTION

Neural interactions of human vision and vestibular system occur at a very early processing stage [1]. Artificial systems should also exploit this sensor fusion [2], since MEMs inertial sensors can be easily incorporated alongside the camera's imaging sensor, providing an artificial vestibular system, providing valuable data about camera ego-motion and how world features are expected to be oriented [3].

There is strong evidence for a probabilistic computational framework in the human brain for perception [4], and a significant amount of current research on artificial perception is shifting towards a *bioinspired approach*, implying a Bayesian framework for artificial perception models.

II. IMAGE STABILIZATION AND GAZE CONTROL

Our robotic implementation of gaze control and image stabilization will basically perform visuo-inertial servoing, exploring the complementarity of the two sensing modalities, but the sensory inputs will be processed using Bayesian inference.

The image optical flow provides motion data from the visual sensor. We use an algorithm primarily based on Zelek's [5] adaptation of the block matching (correlation) algorithm presented in [6]. A smooth motion field is assumed and also a Gaussian prior probability density in which slower speeds are more likely. The output of the algorithm is a Gaussian distribution over the space of image velocities, at each position in the image. The mean of the distribution is a gain-controlled modification of the basic optical flow solution. The covariance matrix captures directional uncertainties, allowing proper combination with inertial data.

To process the inertial data, we follow the Bayesian model proposed by Laurens and Droulez [7]. To overcome the non-linearity of the motion equations and the high dimension space of possible distributions, particle filtering is used. The fact that some motions are more probable than others in human head motion is also replicated in the robotic version, limiting periods of sustained acceleration and also long duration rotations at constant velocity.

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III. RESULTS AND CONCLUSIONS

Preliminary results show that the image stabilization yields satisfactory results, when subject to motions similar to what humans experience in normal conditions, but the current setup has clear limitations in dynamic response.

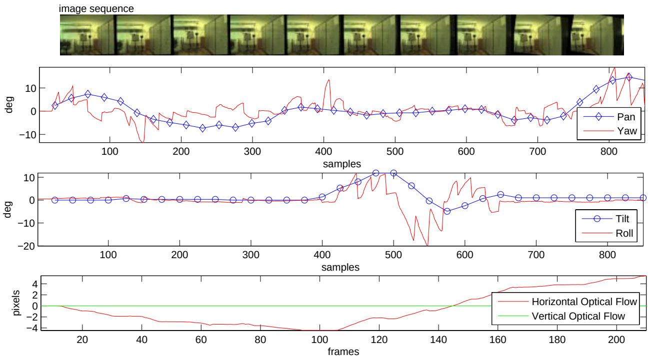

Fig. 1. Observed yaw and roll, pan and tilt motor control, and remaining observed optical flow.

Current work is being done to optimize the optical flow code to have a full working real-time solution. The optical flow contribution will enable gaze following of moving targets, and eventually as input for image cropping to have a stabilized output stream of images to overcome the dynamic limitations of the motors. The construction of a a custom system with a better dynamic performance has been initiated.

Project web page with further details about this work: `http://paloma.isr.uc.pt/bacs/`

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