AprilTrack: A Particle-Filter based AprilTag Tracker

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Abstract— **The AprilTrack algorithm proposed in this paper seeks to bridge two existing fields of research in computer vision literature: fiducial detection and monocular object tracking. With a rise in the popularity of fiducials, or artificial markers, as a source of ground-truth position data for mobile robots, there has been a considerable interest in designing both robust and blur-resistant fiducials. This paper attempts to improve on existing fiducials such as the AprilTag marker by augmenting fiducial detection algorithms with a particle-filter based monocular object tracker which reliably tracks a fiducial's position and orientation in six degrees of freedom, allowing for tag-based localization in situations where still frame based methods would be unable to do so. This novel particle-filter based algorithm is evaluated on several datasets involving both ego-motion and tag-based-motion and is compared to standalone tag detection algorithms and ground-truth tag position data.**

I. Introduction

Visual tracking of fiducial markers (or fiducials) plays an important role in many robotics and computer vision related fields, including augmented and virtual reality, visual odometry, and object tracking. Due to these scenarios taking place in tructured indoors environments where illumination is often limited, long exposure times to compensate for the reduced lighting produce blurred images, especially when taken from a mobile platform such as quadrotor.

The majority of previous literature in fiducial detection and monocular object tracking has been focused single-frame fiducial detection. A common assumption in these algorithms is that the image being processed is blur free, expectation which breaks down in empirical situations. For instance, the widely-used AprilTag [cite] marker and its successor, the AprilTag 2 [cite], rely on strong gradients between the tag's background and the surrounding white border to detect the tag. As shown in figure 1, oftentimes such algorithms fail to detect tags that have been blurred, either missing them entirely or discarding them as false positives as the identifying characteristics are completely blurred (for AprilTags this consists of a 6x6 binary grid in the center of the tag).

There has been considerable interest in designing blur resilient fiducials. For instance, Meghshyam et al. [cite] use ringed markers to ensure that a region of the tag will always be perpendicular to the blur direction. However, this approach, while resistent to linear blur, does not take into account more complex blurs (e.g resulting from the tag itself pivoting around an axis). In addition, the increased resilience to blur comes at the cost of localization accuracy as only the center point of the tag can be reliably determined, whereas with other tags, such as the AprilTag, full pose estimation can be done based on just a single tag.

Unlike previous attempts to engineer more resilient tags, we propose to exploit the temporal coherence between successive frames in a video sequence. As many high-blur scenarios, such as a quadroter-mounted moving camera or tracking an AprilTag-labeled moving object, involve a continuous stream of images taken at equidistant time intervals, we propose using prior knowledge on a fiducial's location to augment the detection algorithm. As such, this paper presents a novel particle-filter-based tracking algorithm (AprilTrack) capable of tracking AprilTags in 6 DOF.

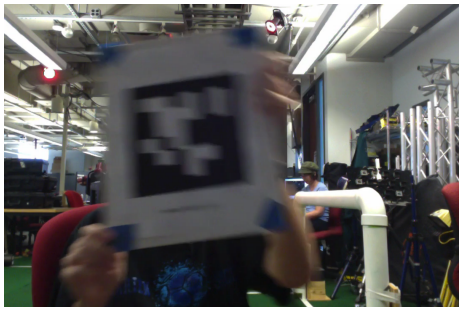

Fig. 1. A blurred tag. Such tags are difficult for still frame based algorithms to detect as the payload (the ID encoded in the center of the tag) will often be discarded as invalid.