Object Tracking in Surveillance System using Particle Filter and ACF Detection

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***Abstract*— This paper presents a study on object tracking in surveillance systems using Particle Filter and Aggregate Channel Features (ACF) detection to address the challenges of accurately tracking multiple objects in dynamic environments. Object tracking is a crucial component in computer vision, with applications spanning from surveillance and security to autonomous navigation and robotics. In this work, we leverage Particle Filter, a robust Bayesian-based filtering algorithm known for its effectiveness in non-linear and non-Gaussian conditions, to track objects consistently over time. The ACF detection method is employed for its high precision in identifying objects across various frames, thereby enhancing initial detection accuracy. Performance testing is conducted across four datasets, using key metrics such as precision, Multiple Object Tracking Precision (MOTP), and Multiple Object Tracking Accuracy (MOTA) to evaluate effectiveness. The results show that while Particle Filter combined with ACF detection achieves consistently high precision (95-99%) and stable MOTP rates (69-79%), challenges arise in maintaining uninterrupted tracking accuracy, as evidenced by lower MOTA scores (3.1-7.2%) and a significant rate of false negatives, especially in complex scenarios with occlusions. These findings suggest that although Particle Filter and ACF detection are effective for initial detection and data handling, enhancements or hybrid methods may be required for applications demanding high accuracy in continuous multi-object tracking.**

Keywords—computer vision, multiple-object tracking, particle filter, clear mot, acf detection

I. INTRODUCTION

Computer vision has developed into a dynamic element of artificial intelligence focusing on enabling machines to comprehend and interpret visual inputs from their surroundings. Computer software and hardware are used to analyze and process visual information and data. It includes the process of acquiring, transmitting, processing, screening, storing and understanding visual information [1]. Object tracking is one of the important tasks in computer vision that tries to detect and track objects in image sequences. In object tracking, the target specifies in the first frame and must be detected and tracked in the next frames of the video [2].

Several studies have revealed how object tracking is an important field in computer vision. A study explains that real-time object tracking represents a pivotal and complex task within the field of computer vision [3]. Object tracking has been an active research area in the vision community in recent years. It has many potential applications in the fields of intelligent robots, monitoring and surveillance, human computer interfaces, smart rooms, vehicle tracking, biomedical image analysis, and video compression [4]. These fields are highly regarded for their transformative potential across various applications and industries.

Furthermore, other studies have defined Particle Filter. Awal *et al.* [5] explains that particle filter is a Monte Carlo and recursive Bayesian estimation-based filtering algorithm. Particle Filter performs superior compared to conventional methods such as the Kalman Filter when applied to non-linear or non-Gaussian conditions. Akca and Efe [6] also explain that in Particle Filter, continuous distributions are represented through an approximation, with posterior probabilities updated via random sampling particles. Unlike methods requiring functional approximation or linearization, the particle filter operates without these constraints. However, this advantage comes at the cost of increased computational demand.

In the context of Multi-Object Tracking, Multi-Object Tracking (MOT) is the task of detecting the presence of multiple objects in video and associating these detections over time according to object identities [7]. Yoon *et* al. [8] explains that MOT is important for many computer vision tasks with applications such as surveillance, traffic safety, automotive driver assistance systems, and robotics. Multi-Object Tracking also aims to estimate trajectories of multiple objects in the same category in videos [9].

Other papers have shown that Bayesian Filter is one of the most effective algorithms in the realm of object tracking. Ong *et al.* [10] performed a 3D Position Estimation using the Classical Bayesian Filter as a formulation and yields a high percentage of Multi-Object Tracking Accuracy (MOTA) and Multi-Object Tracking Precision (MOTP). One of the applications of Bayesian Filter is Particle Filter (PF). However, the implementation of Particle Filter for object tracking still has room for improvement. Sulistyaningrum *et al.* [11] shows that using Particle Filter for tracking, the accuracy of tracking and people counting has a rate of 89.33% and 77.33% respectively with no

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