# MODELLING AND ESTIMATION OF VEHICLE TRACKING USING AN IMPROVED PARTICLE FILTER

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**ABSTRACT**

**MODELLING AND ESTIMATION OF VEHICLE TRACKING USING AN IMPROVED PARTICLE FILTER**

This research focuses on reducing the particle size in the resampling stage of the particle filter approach by tracking a single vehicle with overlapping situation. Particle filter is competent to robustly tracking the vehicle under various situations. The vehicle can be tracked by estimating the position of the target vehicle with a set of distributed random particles with associated weight. Since the estimated position is computed based on the mean value of the hypotheses, the accuracy and efficiency of the particle filter are greatly affected by the particle size. Besides, the placement of the particles also plays an important role in producing accurate tracking results. In practice, the conventional particle filter is facing the particle degeneracy problem after a few iteration of the estimation process. Although the resampling stage in particle filter can overcome the particle degeneracy problem, the large number of particles required to resample is uncertain due to the encountered occlusion situation. Hence, a genetic algorithm based resampling technique will be embedded into the particle filter algorithm to reduce the amount of the resampling particles and subsequently reduce the particle size. Based on the nature of the genetic algorithm, a better estimation of position of the target vehicle can be obtained by recombining the information between the particles. With the improvement of the particle placement, the number of particles used in the resampling stage can be reduced and hence decrease the iteration of the resampling process. Results show that the particle filter with genetic algorithm resampling has successfully reduced 45.5 % of the particles in the resampling stage before the target vehicle is fully occluded by the obstacle vehicle. Subsequently, the developed algorithm has also reduced 50.2 % of the resampling particles when the target vehicle reappears but still partially occluded from the occlusion as compared to the fundamental resampling approach.

**_ABSTRAK_**

*Kajian Penyelidikan ini memberi tumpuan kepada pengurangan saiz zarah di peringkat persampelan semula penapis zarah dengan menjejaki kenderaan tunggal dalam keadaan bertindih. Penapis zarah adalah kompeten dalam pengesanan kenderaan yang mengalami pelbagai oklusi. Kenderaan boleh dikesan dengan menganggarkan kedudukan kenderaan sasaran dengan mengedarkan satu set zarah yang berat bersekutu secara rawak. Anggaran kedudukan dikira berdasarkan nilai min hipotesis, ketepatan dan kecekapan penapis zarah adalah sangat dipengaruhi oleh bilangan zarah. Selain itu, penempatan zarah juga memainkan peranan penting untuk menghasilkan keputusan pengesanan yang tepat. Walau bagaimanapun, penapis zarah konvensional sedang menghadapi masalah zarah degenerasi selepas beberapa lelaran proses anggaran. Walaupun peringkat persampelan semula dalam penapis zarah boleh mengatasi masalah zarah degenerasi, sebilangan besar zarah yang diperlukan untuk persampelan semula adalah tidak menentu disebabkan oleh keadaan oklusi yang dihadapi. Oleh itu, algoritma genetik berdasarkan teknik persampelan semula dibenamkan ke algoritma zarah penapis untuk mengurangkan jumlah zarah persampelan semula. Berdasarkan sifat algoritma genetik, anggaran kedudukan kenderaan sasaran yang lebih baik boleh diperolehi dengan menggabungkan maklumat di antara zarah-zarah. Dalam peningkatan penempatan zarah, bilangan zarah yang digunakan di peringkat persampelan semula boleh dikurangkan dan seterusnya mengurangkan lelaran proses persampelan semula. Keputusan menunjukkan bahawa penapis zarah dengan persampelan semula algoritma genetik telah berjaya mengurangkan 45.5% daripada zarah dalam peringkat persampelan semula sebelum kenderaan sasaran oklusi sepenuh diakibatkan oleh kenderaan halangan. Selain itu, algoritma genetik juga mengurangkan 50.2% zarah persampelan semula apabila kenderaan sasaran muncul semula tetapi masih separa terhalang dari oklusi jika berbanding dengan pendekatan persampelan semula asas.*

**TABLE OF CONTENTS**

**LIST OF TABLES**

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| **2D** | Two Dimensional |
| **3D** | Three Dimensional |
| **ASIR** | Auxiliary Sampling Important Resampling |
| **BLAST** | Bell Laboratories Layered Space-Time |
| **DCDS** | Different Color and Shape |
| **DCSS** | Different Color with Similar Shape |
| **GA** | Genetic Algorithm |
| **GAPF-RS** | Genetic Algorithm Based Particle Filter Resampling |
| **GRNN** | General Regression Neural Network |
| **HSV** | Hue, Saturation and Value |
| **IDAS** | Intelligent Driver Assistant System |
| **KLD** | Kullback-Leibler Distance |
| **LIDAR** | Light Detection and Ranging |
| **LADAR** | Laser Detection and Ranging |
| **RADAR** | Radio Detection and Ranging |
| **RBPF** | Rao-Blackwellised Particle Filter |
| **RGB** | Red, Green and Blue |
| **RMSE** | Root Mean Square Error |
| **SCDS** | Similar Color with Different Shape |
| **SIMD** | Single-Instruction Multiple-Data |
| **SIR** | Sampling Important Resampling |
| **SIS** | Sampling Important Sampling |
| **XYZ** | Tristimulus Values |
| **YCrCb** | Luminance, Red-difference and Blue-difference |

## LIST OF SYMBOLS

| | |
|---|---|
| $a_i$ | Shape Feature of the Reference Model Vehicle |
| $A$ | Set of Points for Vehicle A |
| $b_{dist}$ | Bhattacharyya Distance |
| $b_i$ | Shape Feature of the Target Vehicle |
| $B$ | Set of Points for Vehicle B |
| $C$ | Children Solution |
| $D_{KL}$ | Kullback-Leibler Divergence |
| $e$ | Exponential |
| $E$ | Mean State |
| $H_{dist}$ | Hausdorff Distance |
| $i$ | Particle Index Number |
| $K^{th}$ | Rank |
| $L_i$ | Sum of Likelihood Ratio |
| $log$ | Logarithm |
| $max$ | Maximum Value |
| $N_{eff}$ | Effective Sample Size |
| $\widehat{N_{eff}}$ | Estimation of Effective Sample Size |
| $N_c$ | Number of Samples |
| $N_p$ | Number of Particles |
| $N_{thres}$ | Threshold of Effective Sample Size |
| $P$ | Parent Solution |
| $p_u$ | Color Histogram of the Target Vehicle |
| $p(X_t\|Z_t)$ | Posterior Probability Density Function |

| | |
|---|---|
| $p(Z_t \mid X_t)$ | Observation Probability Density Function |
| $q_u$ | Color Histogram of the Reference Vehicle |
| $rand$ | Random Value |
| $S_t^i$ | Estimated Mean State |
| $t$ | Frame Index |
| $W_t^i$ | Normalized Weight |
| $w_t^i$ | Weights that Associate to the Particles |
| $x$ | Real X-position of Target Vehicle |
| $x_e$ | Estimated X-position of Target Vehicle |
| $X_t$ | State Vector |
| $y$ | Real Y-position of Target Vehicle |
| $y_e$ | Estimated Y-position of Target Vehicle |
| $Z_t$ | State Space Estimations |
| $\rho$ | Bhattacharyya Coefficient |
| $\Sigma$ | Summation |
| $\alpha$ | Weight Factor |
| $\beta$ | Factor Balancing |
| $\sigma$ | Adjustable Standard Deviation |
| $\varphi$ | Likelihood Ratio |
| $\hat{\varphi}$ | Normalized Likelihood Ratio |
| $\varphi_c$ | Color Likelihood |
| $\varphi_s$ | Shape Likelihood |

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview of Vehicle Detection and Tracking

Recently, the number of the on-road vehicles has been increased significantly. Meanwhile, the on-road incidents created by the drivers are also elevated. Hence, vehicle tracking has drawn the attention among the researchers due to its numerous fields of applications such as traffic surveillance and security monitoring system, intelligent driver assistant system (IDAS), road traffic control assistant system and navigation system (Gustafsson *et al.* 2002). Vehicle tracking normally consists of the combination of hardware and software. Hardware is referred to the device that attached to the vehicle or installed on the road to get the input information. Meanwhile software is used to process the input data extracted from the hardware.

There are two types of sensors which are active sensors and passive sensors being implemented in the vehicle tracking (Rabie *et al.*, 2002). The active sensors measure the distance through the travel time of a signal emitted by the sensors and reflected from the nearby vehicle. However, the disadvantages of active sensors are low spatial resolution and slow scanning speed. Furthermore, when a large amount of vehicles are moving simultaneously in the same direction, the active sensors often provide incorrect signal (Sun *et al.*, 2006). Nevertheless, passive sensors such as cameras have the advantage of low cost due to the development of the video surveillance infrastructure growing vastly in recent years. Video sensors can also provide a wide range of information that used to describe the vehicle. For instance, the features of vehicle such as color, shape, edge and motion can be obtained by extracting the data from the video sensor via image processing techniques.

Nowadays, a variety of vehicle tracking techniques have been developed to improve the traffic control and management for the purpose of building up a robust and reliable traffic surveillance system. The traffic surveillance system is responsible to gather, process, analyze and disseminate traffic data (Wu *et al.*, 2006). Thus, a large set of traffic data such as stationary vehicles, acceleration of vehicles, snaking vehicles, direction of vehicles, vehicles stopped at road shoulder will be required to determine the location of those vehicles which are potentially become the causes of traffic congestion and accidents.

Vehicle tracking techniques also play an important role to develop a reliable traffic flow modelling system. Therefore, a wide range of basic traffic parameters will be required such as traffic flow density, queue length, vehicle occupancy and acceleration of vehicles to assists the traffic flow modelling system (Wang *et al.*, 2008). Based on the traffic parameters obtained, the traffic flow can be modelled and simulated based on the vehicle tracking techniques (Yokoe *et al.*, 2011). As a result, the traffic control system can control the traffic light and optimize the traffic flow in order to avoid the occurrence of traffic jam or traffic congestion in urban area.

Furthermore, vehicle tracking techniques can also be implemented in the IDAS to assist vehicle drivers through a safety warning message (Kannan *et al.*, 2010). IDAS contains the functions such as collision avoidance, lane change assistance, parking assistance and driver drowsiness detection. Hence, the safety parameters such as driving situations, vehicle dynamic, vehicle surrounding and environment need to be obtained through visual tracking techniques. Based on the safety parameters determined, IDAS can be used to track and analyze the vehicles or obstacles approaches. Hence, the development of vehicle tracking techniques still requires continuous improvement in order to implement in various type of applications via various optical sensors.

## 1.2 Vehicle Tracking via Particle Filter

Traffic congestion comprises a complex dynamics problem and incorporates many traffic parameters interacting with each other (Papageorgiou *et al.*, 2009). Hence, microscopic traffic models can be used to describe the individual vehicles and provide a detailed representation of the traffic process. Moreover, microscopic models are usually implemented in small area. Tracking vehicle in microscopic using optical sensors is always a challenging task due to the high probability of vehicle appearance changes and illumination changes. Besides that, occlusion or overlapping incidents also raise up the difficulty of vehicle tracking process.

Normally, the optical sensors are mounted on the pole near to the roadside to capture the traffic scene. Hence, occlusion will become a common scene due to the low angle view of the camera. Occlusion is a difficult problem in vehicle tracking. This is due to the information that describe the vehicle might be lost or influenced by the obstacles. Hence, in order to robustly tracking the vehicle or differentiating the target vehicle with the obstacles, a fusion of multiple features will be required to provide more information about the vehicle (Sheng *et al.*, 2012). In this research, color feature and shape feature will be used to characterize the vehicle for tracking purpose.

The purpose of vehicle tracking is to estimate the position of the interested vehicle correctly in the video sequences. However, vehicle tracking could lead to non-linear and non-Gaussian situations due to the dynamic changes of the traffic flow. Particle filter is a technique to implement a recursive Bayesian filter with Monte Carlo simulations. Nevertheless, particle filter has been proven as an approach which can overcome nonlinear and non-Gaussian situations and multimodalities which caused by the clutter background and occlusions incidents (Lin *et al.*, 2009).



Particle filter is an approach that utilizes the sequential estimation of relevant probability distributions by using important sampling techniques and the estimation of distribution will be in discrete random measure. The key idea is to represent the posterior distribution based on a finite set of random weighted particles. The common problem faced by particle filter is particle degeneracy due to the variance of the importance weights increases in time thereby making the algorithm impossible to evade the weight degradation. However, particle degeneracy problem can be mitigated by setting a huge number of particles so that a better proposal distribution can be obtained or using resampling approach (Yu *et* *al.*, 2010a). Studies have shown that the determination of appropriate number of particles used in tracking purpose is always difficult (Fox, 2003). In this research, a proper initial amount of particles implemented in the particle filter algorithm will be determined based on the tracking conditions.

Furthermore, the implementation of genetic algorithm (GA) in the particle filter can help to produce a better estimation results with dynamic problems and solve the particle degeneracy problems. Thus, GA will be implemented in the resampling stage in order to reduce the resampling particle size to obtain the desired tracking results with less number of iterations or generations.

## 1.3 Scope of Work

This research is focusing on developing a particle filter algorithm with multiple features to track a single vehicle. The particle filter based vehicle tracking algorithm will be tested by tracking a moving vehicle under various occlusions. The various occlusions mentioned here are referred to the target vehicle which is free from occlusion, partially occluded before fully occlusion, fully occluded, partially occluded after fully occlusion and without occluded after fully occlusion by a moving obstacle vehicle. At last, the particle filter will be further improved to form a better estimation process in order to increase the tracking accuracy. Based on the better estimation process, the improved particle filter can reduce the unnecessary particles in the resampling stage.

## 1.4 Research Aim and Objectives

The aim of this thesis is to develop a particle filter based vehicle tracking algorithm that can reduce the number of particle in the resampling stage of the particle filter for vehicle tracking purpose. The vehicle is tracked under overlapping situations and clutter background. GA is adopted into the particle filter resampling algorithm in order to produce a better estimation results and reduce the particles required in the resampling stage. The developed particle filter associated with GA is implemented to track vehicle using data captured with optical sensors to investigate the improvement of the tracking efficiency. The research aim can be achieved through the following objectives:

### 1.4.1 To Develop Particle Filter Based Vehicle Tracking Algorithm

The particle filter based vehicle tracking algorithm with sampling important resampling process is developed. The key idea of particle filter is to represent the posterior distribution based on a finite set of random weighted particles. Furthermore, fusion of color feature and shape feature of the vehicle will be used to determine the likelihood and assign the weight to each particle. The color likelihood is computed based on Bhattacharyya distance value and shape likelihood is determined based on Hausdorff distance. The performance of the developed particle filter algorithm is investigated by tracking the overlapping vehicle with fixed initial particles and resampling the particles using sampling important resampling.

### 1.4.2 To Reduce Particle Size Required in Resampling Stage

Sampling important resampling is applied to particle filter algorithm for observing the particle size required to resampling and number of resampling iterations. GA is further implemented to the particle filter resampling stage in order to obtain a better estimation results and hence reduce the particles size required for resampling. At the same time, the iteration of resampling can also be reduced. The performance of the tracking algorithm is examined in terms of accuracy and efficiency.



### 1.4.3 To Evaluate and Assess the Developed Improved Particle Filter Based Vehicle Tracking Algorithm

The developed GA based particle filter tracking algorithm is implemented to track vehicle in image sequences based on the captured video data. The performance of standard resampling and GA based resampling are compared. Evaluation and assessment of the developed GA based particle filter tracking algorithm are carried out to track vehicle under various overlapping incidents.

## 1.5 Thesis Outline

This thesis is organized as the following:

Chapter One describes overview on vehicle detection and tracking. Scope of work, research aim and efforts are presented in this chapter while the organization of this thesis is included in thesis outline.

Chapter Two presents the reviews of particle filter in vehicle tracking. This chapter begins with the reviews of vehicle tracking techniques. The existing vehicle tracking techniques such as region based, model based, active contour based and feature based are discussed. Next, reviews on particle filter tracking algorithm with different resampling is carried out. Subsequently, the improved particle filter tracking algorithm with artificial intelligent are reviewed and discussed.

Chapter Three illustrates the development of particle filter vehicle tracking algorithm. This chapter started with illustration of the framework of particle filter. The extraction of color and shape features and the observation likelihood determination are discussed.

Chapter Four presents the implementation of particle filter vehicle tracking with multiple features. Subsequently, the procedures with different features to track a vehicle are discussed. The performance of the vehicle tracking with different features is evaluated and investigated.

Chapter Five discusses the conventional resampling scheme in particle filter for vehicle tracking purpose. This chapter begins with discussion on the problems faced by particle filter. The performance of the vehicle tracking with different standard resampling steps is examined and analyzed.

Chapter Six presents the vehicle tracking with improved particle filter. This chapter introduces the development of GA resampling. Subsequently, the performances of GA based particle filter is discussed and evaluated. In addition, the adaptive particle size is demonstrated and discussed. Lastly, the performances of GA based particle filter with adaptive particle size is discussed and evaluated.

Finally, the conclusions, the achievements and future works are listed in Chapter Seven.