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Object Tracking from Laser Scanned Dataset

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Abstract:

Laser scanners have a lot of advantages over conventional video cameras. Data processing in laser scanner system becomes faster and easier because there is no need to record real world videos. Besides, the problem of private life conservation is taken away. This paper proposes an approach to track objects from laser scanned dataset. Data points collected by each scan of laser scanners are considered as video frame. Support vector machine (SVM) along with Hungarian algorithm and Kalman filter are used to obtain trajectories of objects from the laser scanned dataset. Experimental results on the same laser scanned datasetshow that the method of SVM with Hungarian algorithm and Kalman filter performs better than that of its alternative having various thresholds with Hungarian algorithm and Kalman filter.

Keywords **—Laser Scanner, Kalman Filter, Object Tracking, Support Vector Machine.**

I. INTRODUCTION

The detection of both normal (e.g., [1-12]) and abnormal (e.g., [13-27]) video events is a cardinal chore of a surveillance camerasystem. An automated camera system can provide goodtrajectories of objects. But camera systems include severaldisadvantages as compared to the laser scanner systems. Manylaser scanners can be applied conjointly to widen the scanningarea. Laser scanners can easily observe big crowds via lowcost dataprocessing and high speed processor. The alternationof light illumination has no effect on the laser scanners. Theyare faster and easier about the transfer of moving objects intoreal coordinate systems. Besides, laser scanners take away theproblem of private life conservation. Consequently, a systemwith laser scanners is more convenient and efficient than thatof cameras. A lot of algorithms e.g., [28-57], have been proposed to get trajectoriesof pedestrians and/or vehicles from datasets obtained byvarious laser scanners. Due to miscellaneous algorithmic assumptions along with huge amount of data processing, the existing algorithms did not attend to theirfinal level of completeness and applicability. Henceforth, itis noteworthy for developing further new approaches capableof handling the workable quality of trajectories of bothpedestrians and vehicles for efficient traffic analysis.

This paper addresses how to track objects from laserscanned datasets collected by the use of two kinds of laserscanners namely LD-MRS and LMS-511. To get most qualifieddata, four laser scanners are employed. After combinedthe obtained data points from four laser scanners backgroundsubtraction is applied to obtain the moving objects in termsof points. As background points are removed the processingtime for foreground points will be reduced significantly. Fig. 1depicts its flowchart. Its key steps include: (i) Get blobs fromlaser scanned data points of every frame; (ii) Blob detectionand recognition by SVM; (iii)

Blob tracking with the helpof Hungarian method and Kalman filter. This paper would beconsidered as an incremental improvement of Galip et al. [46]and [51]. The usage of SVM along with Hungarian methodand Kalman filter for getting the trajectories of objects fromlaser scanned datasets is the key contribution of this paper.

The rest of the paper is orchestrated as follows: Section II notes the state-of-the-art methods relevant to the proposedapproach. Section III shows the detailed implementation stepsof the proposed framework; Section IV reports experimentalresults and discussion followed by few clues for further study;Section V concludes the paper.

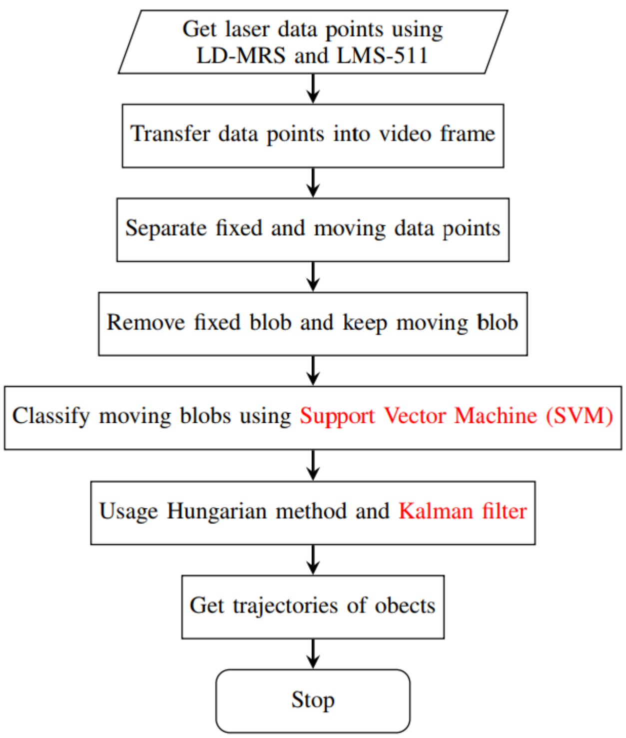

Fig. 1Flow diagram of our proposed framework.

II. STATE-OF-THE-ART METHODS

Many algorithms have been proposed in the literature using various laser scans to detect and/or track objects. In this section, we are going to discuss the most relevant works towards our current problem of interest.

Mendes et al. [28] detected and tracked multi target with laserscanner in outdoor semi-structured environment. Xavier et al. [29] proposed an approach to detect fast line, arc/circle and leg from laser scan data in a player driver. Cui et al. [30] suggested a robust tracking of multiple people in crowds using laser range scanners. Shao et al. [31] detected and tracked multiple pedestrians by using laser range scanners. Arras et al. [32] pointed an approach for efficient people tracking in laser range data using a multi-hypothesis leg-tracker with adaptive occlusion probabilities. Gate et al. [33] hinted a fast algorithm for pedestrian and a group of pedestrians' detection using a laser scanner. Vu et al. [34] detected and tracked laser scanner based moving objects using data-driven Markov chain Monte Carlo. Gidel et al. [35] detected and tracked pedestrians in an urban environment using a multilayer laser scanner. Mozos et al. [36] detected multi-part people using 2D range data. Song et al. [37] proposed a laser-based system for fully online detection of abnormal activity via an unsupervised method. Shao et al. [38] suggested an algorithm for 3D crowd surveillance and analysis using laser range scanners. Song et al. [39] addressed a laser based approach for intelligent surveillance and abnormality detection in extremely crowded scenarios. Zhao et al. [40] pointed an algorithm for omnidirectional detection and tracking of on-road vehicles using multiple horizontal laser scanners. Wada et al. [41] proposed an approach for accurate positioning of mobile phones in a crowd using laser range scanners. Fotiadis et al. [42] detected human from a mobile robot using fusion of laser and vision information. Kaneko et al. [43] detected various sitting-and-moving behaviors and face-to-face communication using laser scanners. Kim et al. [44] used a robust object segmentation using a multi-layer laser scanner. Akamatsu et al. [45] developed a person counting system using a 3D laser scanner. Galip et al. [46] introduced a novel approach to obtain trajectories of targets from laser scanned datasets. Shalal et al. [47] proposed an orchard mapping and mobile robot localisation using on-board camera and laser scanner data. Leigh et al. [48] hinted an algorithm for person tracking and following with 2D laser scanners. Tsugita et al. [49] detected pedestrian and tracked a mobile robot with multiple 2D laser range scanners. Kim et al. [50] proposed a sensor fusion algorithm for detecting vehicles using laser scanner and stereo vision. Galip et al. [51] recognized objects from laser scanned data points using support vector machine. Weinrich et al. [52] hinted an approach for generic distance-invariant features to detect people with walking aid in 2D laser range data. Ishi et al. [53] designed a system for detecting moving objects in capturing video images using laser range scanners. Liu et al. [54] detected pedestrian on the slope using multi-layer laser scanner. Zou et al. [55] pointed an approach for static map reconstruction and dynamic object tracking for a camera and laser scanner system. Gizlenmistir et al. [56] suggested an algorithm for production of airborne laser scanner skilled advanced unmanned air vehicle and the potential of preliminary data. Halmheu et al. [57] optimized a system for successive laser scanner detection and control of mobile robots.

Instead of these developments, the desired level of effectiveness did not observe due to widely algorithmic assumptions and huge amount of data processing. So the room for improvement of algorithms is still empty to get trajectories of objects from laser scanned datasets.

III. IMPLEMENTATION STEPS

A. *Collection of data points*

Laser scanners scan the area in 2D (just one layer scanabove 5 cm from the ground) by sending beams with 0.25degree, then each beam hits objects e.g., cars, pedestrian legs,and walls (samples are shown in Fig. 2). Laser scanners returndistances with angles that the beams hit, to get those dataWireshark is used. The connection between LMS-511 laserscanner and computer is provided by Ethernet cable. Thedata stream is captured by SOPAS Engineering Tool, whichis a program developed by SICK AG. Afterwards those distances are converted into X-Y coordinatesas demonstrated in Fig. 3.

B. *Recognition of moving and fixed blobs*

The collected data points in Fig. 3 consist of both stationary and moving objects. The recognition of moving and stationary blobs can be performed by histogram and threshold [46]. Fig. 4 depicts the recognition of moving and stationary blobs as marked by red and blue, respectively.

Fig. 2 The way of LMS-511 laser scanner collects laser data points.

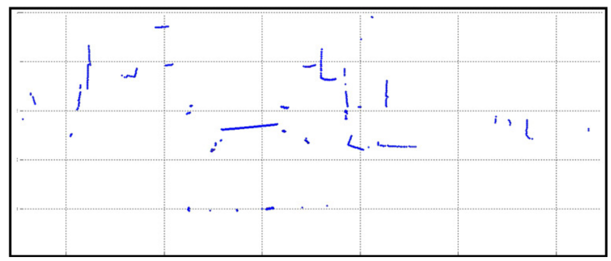

Fig. 3 Obtained laser data points of various objects using LMS-511.

C. *Estimation of moving blobs*

As blue and red blobs are recognized, it is easy to remove blue blobs. The red blobs in Fig. 5 are representing the movingobjects, which should be tracked over frames. There are mainlytwo type of objects namely pedestrian and vehicle. But itis important to classify them properly. Unlike the usage of variousthresholds ([46]) for blobs, we have used SVM to classifythem.

D. *Type of blob recognition using SVM*

The SVM is an approach to construct learning machine that minimizes the generalization error. It is based on very plain and intuitive ideas. It finds an optimal separating hyperplane between data points of various classes in a possibly high dimensional space. The elements of the input data that define boundaries are called support vectors. The Fig. 6 depicts sample training and testing images for SVM.The output of the SVM indicates whether a blob would be a pedestrian or a vehicle.

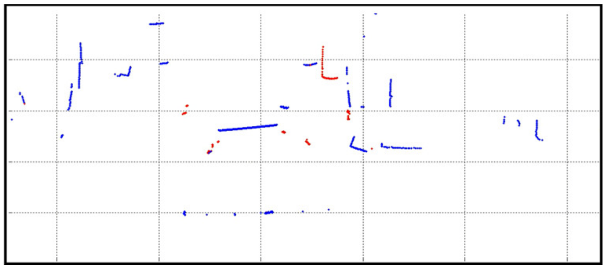

Fig. 4 Recognition of moving (red) and fixed (blue) data points of various objects.

Fig. 5 Moving blobs upon removing blue blobs.

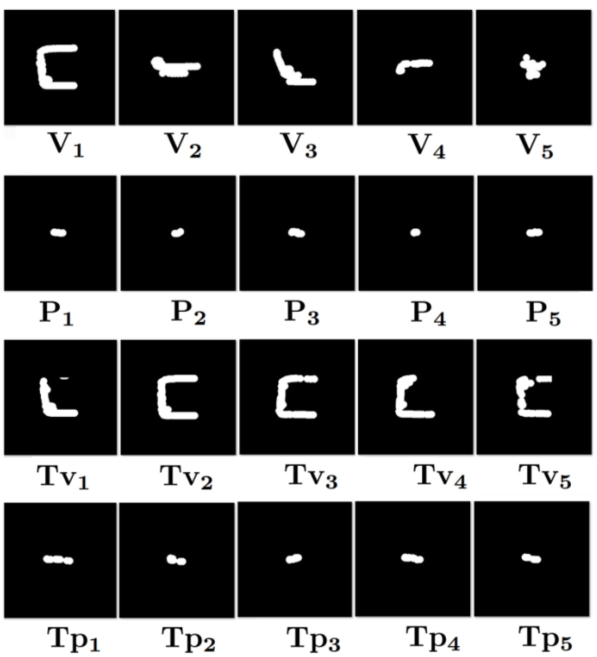

Fig. 6 Images from V_1 to V_5show sample training inputs for the vehicles. Images from P_1 to P_5 display sample training inputs for pedestrians. Images from Tv_1 to Tv_5 depict sample test inputs for vehicles. Images from Tp_1 to Tp_5 represent sample test inputs for pedestrians.

E. Tracking each type of object

Upon recognition of the type of blobs, it is important totrack them over frame in time. Like Galip et al. [46], we haveused Hungarian method and Kalman filter to track individualblob over time.

IV. EXPERIMENTAL RESULTS

A. *Dataset and Parameters*

To conduct our experiment, we have used the same datasetof Galip et al. [46]. The dataset consists of a total of 550ground truth images. Those images were obtained by the usageof both LMS-511 and LD-MRS. A total of 258 pedestrians and 292 vehicles were levelled. Randomly 25 pedestrians and 25vehicles were selected for training and the rests for testingpurposes.

B. *Trajectories of objects*

The Fig. 7 demonstrates a sample object tracking results. Red and white circles represent the centroid of respectiveobject. Both pedestrian and the vehicle were tracked properly.

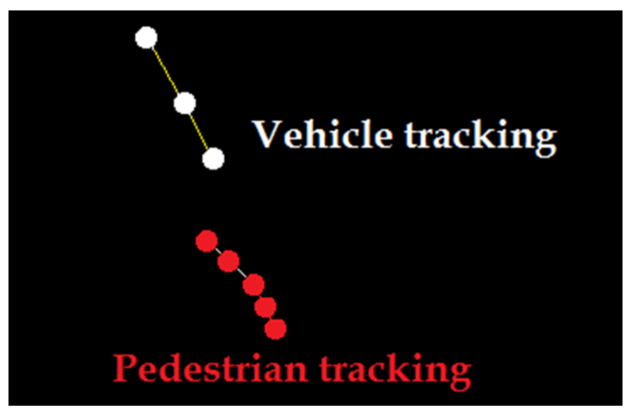

Fig. 7 Sample objects tracking results.

C. *Comparative study of errors*

We have performed several statistical measures, e.g., RMSE ⇒ Root Mean Squared Error, CV(RMSE) ⇒ Coefficient of variation of the root mean squared error, MAE ⇒ Mean Absolute Error, and MAPE ⇒ Mean Absolute Percentage Error.

Table I compares miscellaneous statistical measures between our SVM approach and the threshold approach of Galip et al. [46]. The error rate of our method is lesser than that of Galip et al. [46].

D. *Finding*

For tracking object from the same laser scanner dataset, the SVM with Hungarian method and Kalman filter performed better than the threshold method with Hungarian method and Kalman filter.

E. *Future works*

The current approach would be modified by considering SVM and Hungarian method with particle filter and then the results would be compared. In addition, more tests with new datasets and the effect of cache memories (e.g., [58-62]) in parallel processing environment (e.g., [63]) are left as future works. Nowadays, the mathematical methodology namely DOE (design of experiments) is used extensively for planning-conducting experiments, analyzing, and interpreting data [64-66]. The possibility of usage DOE would be investigated in the long run. The analysis of area under receiver operating characteristic (AUC) curve would be performed. AUC values will always satisfy the inequality of $0 \leq AUC \leq 1$. Larger AUC values indicate better classifier performance [67]. A complete statistical analysis [68] would be performed to compare the performance of the proposed approach with miscellaneous state-of-the-art algorithms. Kalman filter has low computational requirements. But if the system does not suit nicely into a linear model or if the sensor uncertainty (e.g., faulty sensors [69]) does not fit with Gaussian model, then its performance decreases drastically. Future study would also take into account this problem.

TABLE I
VARIOUS STATISTICAL MEASURES

Objects	Two Methods and their Error Estimations	
	Galip et al. [45]	Ours
	RMSE CV(RMSE) MAE MAPE	RMSECV(RMSE)MAE MAPE
Pedestrians	2.3937 0.2568 2.0700 21.72%	2.3937 0.2568 2.0700 21.72%
Vehicles	1.0100 0.5316 0.7000 47.17%	0.75657 0.3915 0.5300 37.19%

V. CONCLUSION

We evinced an efficient approach to track moving objects from laser scanned datasets. Laser scanned data points from each scan were considered as a video frame. Blobs were extracted and then SVM with Hungarian method and Kalman filter were applied to get complete trajectories of movers. The results of SVM and Hungarian method with Kalman filter performed better than those of threshold based approach with Hungarian method and Kalman filter by using same laser scanned dataset. Future study would decrease the error rates a bit more. Instead of Kalman filter, other filters along with Monte Carlo techniques [70] would be investigated.

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