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An Empirical Study of Pedestrian Detection Techniques with Different Image Resolutions

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Abstract: ***Pedestrians are essential objects in computer vision. In real world images, the art of detecting pedestrians is an essential task for many applications like video surveillance, autonomous driver systems etc., Pedestrian detection is a significant characteristic of the autonomous vehicle driving system because identifying the pedestrians minimizes the accidents between vehicles and pedestrians. In existing techniques, deformable part model was used for identifying the pedestrians in image. However, the detection accuracy of the pedestrians with the existing systems was very low with high time consumption. The objective of our research work is to reduce the pedestrian detection time and space complexity for storing the pedestrian objects. In order to identify the existing pedestrian detection issues, the empirical study is carried out in this paper.***

Keywords-Pedestrian, autonomous vehicle, deformable part model, space complexity, automatic driver-assistance systems, video surveillance.

I. INTRODUCTION

Pedestrian detection is an evolving theme in computer vision for real-time applications like driving assistance and video surveillance. Pedestrian detection attracted many researchers' attention in research community since past 10 years. The objective of pedestrian detection is to detect the apparent objects in with knowledge collected from the labeled pedestrian and non-pedestrian examples. An essential progress was made in the last decade because of its practical utilization in many computer vision applications such as video surveillance, robotics interaction.

The paper is structured as follows: Section II discusses the review on different pedestrian detection techniques; Section III portrays the study and analysis of the existing pedestrian detection techniques; Section IV illustrates the possible comparison between them with help of the table and graphs. In Section V, the discussion and limitations of the existing pedestrian detection techniques are studied, and Section VI concludes the paper. The key area of research is to study the existing pedestrian detection techniques issues in order to address in the future research works.

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II. LITERATURE SURVEY

A detection system with deformable part model (DPM) was introduced in [1] to partition the pedestrian data by using latent support vector machine (SVM)-based machine-learning technique. But, the time complexity and space complexity of pedestrian detection was not reduced using DPM. A new pedestrian detection method called Real Boost method was introduced in [2] to identify the pedestrians with existence of deformations. Boosted max feature (BMF) employs max operation to combine the selected pair of features for deformation. Boosted difference feature (BDF) employs difference operation between pair of features. However, pedestrian detection performance was not sufficient.

A new ensemble learning method was introduced in [3] for attaining maximal detection rate at false positive rates through optimizing partial AUC by structured learning. A new method extracted the low-level visual features depending on spatial pooling. However, the true positive rate for pedestrian detection was not improved using ensemble learning method. A probabilistic pedestrian detection framework was introduced in [4] where the deformable part-based model obtains the scores of part detectors. The visibilities of parts were modeled as hidden variables. When occluded parts were detected, the effects were removed from final detection score. However, object detection from the input image was not improved.

A simple motion-guided filter was used in [5] that increased the performance of off-shelf pedestrian detectors. The filter is self-determining of the detector and functioned on many surveillance videos. However, large amount of features was not taken for pedestrian detection as it lacks detection accuracy. A multi-resolution DPM pedestrian detection algorithm was introduced in [6] where resolution factor was added to collection of hidden variables in latent SVM model. During detection, standard DPM model was employed for high-resolution objects and rigid template was used in low resolution objects.

Multi-sparse descriptor (MSD) was introduced in [7] for pedestrian detection in images. The designed descriptor was introduced depending on multi-dictionary sparse coding with unsupervised dictionary learning and sparse coding. A family of dictionaries with representation capabilities was learnt from pedestrian data. But, the pedestrian detection time was not reduced. An aggregate channel feature was used in [8] for pedestrian detection.

The key objective was to reduce the false positives per image. The key objective was to improve the accuracy of the detector through removing false positives while preserving minimal missing rate. However, space and time complexity were not reduced using aggregate channel features.

III. PEDESTRIAN DETECTION

Pedestrian detection based on the histogram of oriented gradients (HOG) is an essential technique. The designed technique computes the occurrences of gradient orientation in localized parts of image. The designed technique identifies the pedestrian when the whole body of pedestrians appears in system. Pedestrian detection is an essential issue in many applications like robotics, video surveillance and computerized driver assistance. Pedestrian detection techniques are enhanced one, but the detection results of current systems are not adequate to be used in practice. The key issue is to identify the pedestrians, despite large inconsistency of shape and appearance caused by variations in pose, clothing, occlusion and lighting. The detection rate reduces when vehicle or surrounding facilities cover person body parts. For addressing these issues, many pedestrian detection techniques are employed for detecting part of an object.

Effective Pedestrian Detection using Deformable Part Model based on Human Mode

Pedestrian detection in pattern recognition employs the combination of many feature descriptors and classifiers. Detection technique is divided into two steps, namely feature extraction step and classification step. In the first step, image features used in object detection comprises [13]Haar-like features, HOG, speed-up robust feature (SURF) and local binary pattern (LBP). The histogram of oriented gradients employed consistently in pedestrian detection is robust at differentiating objects with the unique contour. In the second step, pedestrian detection techniques are classified using the classification algorithm.

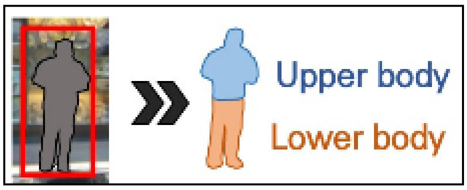

Fig.1 Training Data Partitioning based on Deformable Part Model (DPM)

As shown in fig. 1, deformable part model (DPM) partitions pedestrian training data into two elements, namely upper and the lower body using latent support vector machine (SVM) -based machine-learning technique. The designed algorithm used training data depending on DPM. Pedestrian training data size is 48x96 for upper body and 40x40 for lower body. The training algorithm changes the size for minimizing the unnecessary background. Deformable parts are formed by the object model by a low-resolution 'root' template and collection of spatially flexible high-resolution part templates individually. Deformable part models emerged as a tool for addressing the essential demands. Latent discriminative learning included an iterative procedure that varies the parameter estimation step between known and unknown variables. The designed technique separates the object instances into disjoint groups with the simple theme and learning of the separate model.

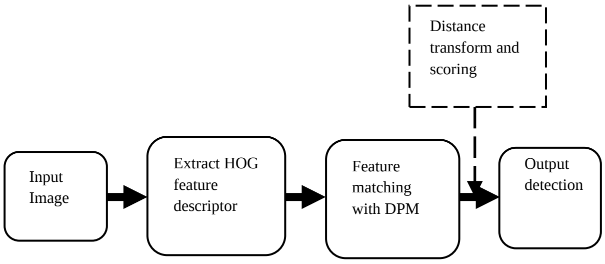

Fig. 2 Overall Pedestrian Detection Process

From fig.2, the overall pedestrian detection process is explained. Initially, the input image is given. Then, the HOG feature descriptor is used to extract the feature from the input image. After that, feature matching is carried out using DPM. Finally, with help of distance transform and scoring function, output detection is carried out. The designed technique minimizes the false positive as there are many images that look like pedestrian's arms, legs and torso resulting in false positive.

A. Robust Pedestrian Detection under Deformation using Simple Boosted Features

A novel pedestrian detection method employs two low-level boosted features, namely Boosted max feature (BMF) and Boosted difference feature (BDF) to identify the pedestrians with of deformations. BMF employs max operation for gathering pair of features invariant to deformation. BMF employed a multiple of deformation managing the region to cover scale dependent deformations like many head size. BDF employs the difference process between pair of features for increasing the localization accuracy of pedestrian detection. A spatial pyramid pool method employed the multiple sized blocks for improving the richness of boosted features in region and employ method to guide the tree-structured classifier for pedestrian detection method. A region-of-interest method was introduced to remove the false positives efficiently.

The features are constructed with the low-level features like ACF, HOG, and Haar. Aggregated channel feature (ACF) is selected as feature because it provides best detection results in pedestrian detection. When ACF is used, size of blocks to aggregate each channel is selected as it changes the amount of information. [14-15]The feature from size of blocks includes the information regarding area. With small and large area information, the spatial pyramid pool (SPP) method employs multiple sizes of blocks into two boosted features. BMF makes low-level feature invariant to the large deformation caused by variations in scale and location. BMF takes maxima randomly selected features because one of them is considered as a feature. BDF employs absolute difference operation between pair of features in SPP. It addresses the problem and increased the localization accuracy.

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B. Pedestrian Detection with Spatially Pooled Features and Structured Ensemble Learning

The main aim of Pedestrian detection is to detect the visible pedestrians in image using knowledge gained through labelled pedestrian and non-pedestrian exemplars. A new ensemble learning method attained the maximal detection rate at range of false positive rates through partial AUC through structured learning. For increasing the high object detection results, new designed approach extracts the low-level visual features with the spatial pooling for improving the translational invariance and strength of detection process.

IV. COMPARISON OF DIFFERENT PEDESTRIAN DETECTION TECHNIQUES & RESULTS

In order to compare thedifferentpedestrian detection techniques, number of images is taken to perform the experiment. For comparison, three pedestrian techniques such as deformable part model (DPM), RealBoost method and ensemble learning method are taken. For conducting the experiment, input images are taken from Penn-Fudan Database. Penn-Fudan Database is an image database for pedestrian detection. The images are captured from the scenes around campus and surrounding environment. The required objects in images are taken as pedestrians. Each image has at least one pedestrian. Various parameters are used for pedestrian detection are true positive rate, pedestrian detection time and space complexity.

A. True Positive Rate (TPR)

True positive rate measures the proportion of pedestrian that are correctly detected. TPR is defined as the ratio of number of pedestrians that are correctly identified from images to the total number of images. It is measured in terms of percentage (%). True positive rate is mathematically formulated as,

$$TPR = \frac{number\ of\ pedestrians\ \ that\ are\ correctly\ detected\ from\ images}{total\ number\ of\ images} * 100 \quad (1)$$

When the true positive rate is higher, the method is said to more efficient.

Number of Images (Number)	True Positive Rate (%)		
	DPM	RealBoost Method	Ensemble Learning Method
10	78	71	64
20	80	72	66
30	83	74	69
40	85	76	71
50	87	78	73
60	88	80	74
70	90	82	76
80	91	83	78
90	93	85	81
100	95	87	82

Table I Tabulation For True Positive Rate

Table I describes the comparison of true positive rate using different pedestrian detection techniques for number of images ranging from 10 to 100. The true positive rate comparison takes place on existing deformable part model (DPM), RealBoost method and ensemble learning method. From the table, it is clear that the true positive rate of DPM is higher than RealBoost method and ensemble learning method. The performance analysis of true positive rate is shown in fig 3.

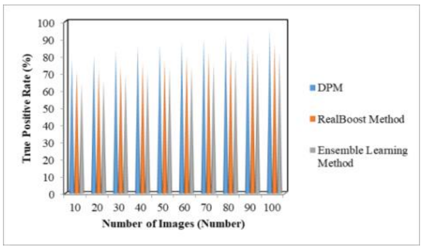

Fig. 3 Measure of True Positive Rate

Fig. 3 describes the true positive rate comparison of existing techniques. True positive rate of deformable part model (DPM) is comparatively higher than that of RealBoost method and ensemble learning method. By using the latent support vector machine (SVM)-based machine-learning technique, the pedestrian objects are correctly identified from the input image. The latent SVM-based machine-learning technique separates the object instances into disjoint groups with separate model. Research in deformable part model has 10% higher true positive rate than RealBoost method and 19% higher true positive rate than ensemble learning method.

B. Pedestrian Detection Time (PDT)

Pedestrian detection time is defined as the amount of time taken for detecting the pedestrian. It is the product of number of images and time consumed for detecting pedestrian from one image. It is measured in terms of percentage (%). The mathematical formula for pedestrian detection time is given by,

$$PDT = n * time\ (pedestrian\ \ detection\ from\ one\ image) \quad (2)$$

From (2), 'n' denotes the number of images. When the pedestrian detection time is lesser the method is said to be more efficient.

Number of Images (Number)	Pedestrian Detection Time (ms)		
	DPM	RealBoost Method	Ensemble Learning Method
10	31	24	36
20	33	27	39
30	36	31	43
40	40	35	47
50	42	39	49
60	44	41	52
70	47	43	55
80	50	46	59
90	53	48	63
100	56	51	66

Table II Tabulation For Pedestrian Detection Time

Table 2 explains the comparison of pedestrian detection time using different pedestrian detection techniques for number of images ranging from 10 to 100. The pedestrian detection time comparison takes place on existing deformable part model (DPM), RealBoost method and ensemble learning method.

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From the table, it is clear that the pedestrian detection time of RealBoost method is lesser than DPM and ensemble learning method. The performance analysis of pedestrian detection time is shown in Fig. 4.

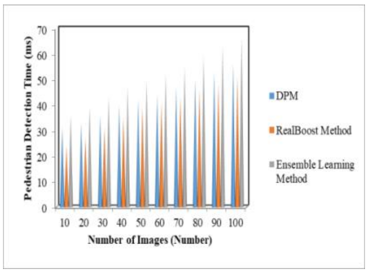

Fig. 4 Measure of Pedestrian Detection Time

Fig. 4 explains the pedestrian detection time comparison of three techniques, namely DPM, RealBoost method and ensemble learning method. Pedestrian detection time of RealBoost method is comparatively lesser than that of deformable part model (DPM) and ensemble learning method. By means of two low-level boosted features called BMF and BDF, pedestrians are identified using existence of deformations with minimal pedestrian detection time consumption. Boosted max feature (BMF) uses max operation to collect selected pair of features for making invariant to deformation. Boosted difference feature (BDF) employs the difference operation between selected pair of features for improving the localization accuracy of pedestrian detection. Research in RealBoost method consumes 12% lesser pedestrian detection time than deformable part model and 25% lesser pedestrian detection time than ensemble learning method.

C. Space Complexity (SC)

Space complexity is defined as amount of memory space consumed for storing the decomposed parts of images. SC is product of number of images and memory space consumed for storing one image. It is measured in terms of megabytes (MB). Space complexity is mathematically formulated as,

$$SC = n * memory\ space\ consumed\ (storing\ decomposed\ parts\ of\ an\ one\ image) \quad (3)$$

From (3), 'n'denotes number of images. When the space complexity is lesser, the method is said to be more efficient.

Number of Images (Number)	Space Complexity (MB)		
	DPM	RealBoost Method	Ensemble Learning Method
10	37	33	21
20	41	36	24
30	43	38	27
40	45	41	30
50	48	43	32
60	51	47	35
70	54	50	38
80	56	52	41
90	60	55	43
100	63	58	46

Table III Tabulation For Space Complexity

Table III illustrates the comparison of space complexity using different pedestrian detection techniques for number of images ranging from 10 to 100. The space complexity comparison takes place on existing deformable part model (DPM), RealBoost method and ensemble learning method. From the table, it is clear that the space complexity of ensemble learning method is lesser than DPM and RealBoost method. The performance analysis of space complexity is shown in Fig. 5.

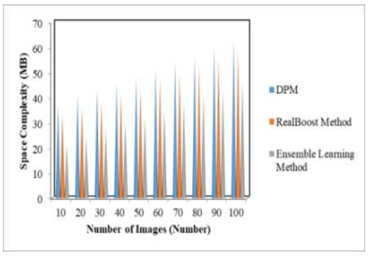

Fig. 5 Measure of Space Complexity

Fig. 5 illustrates the space complexity comparison of three techniques, namely DPM, RealBoost method and ensemble learning method. Space complexity of ensemble learning method is comparatively lesser than deformable part model (DPM) and RealBoost method. The ensemble learning method attained the maximal detection rate at user-defined range of false positive rates through optimizing the partial AUC. A conventional boosting-based visual detector is transformed into pAUCEnsT-based visual detector with variations to the existing code. This in turn helps to minimize the space complexity. Research in ensemble learning method consumes 33% lesser space complexity than deformable part model and 26% lesser space complexity than ensemble learning method.

V. DISCUSSION AND LIMITATIONS ON DIFFERENT PEDESTRIAN DETECTION TECHNIQUES

Deformable part models are essential tool for addressing the demands. Latent discriminative learning employed iterative process that changes the parameter estimation step between the known and unknown variables. The designed technique partitions the object into disjoint groups with learning of separate model. But, the parallel implementation was not carried out as there were many computational blocks that are independent from each other. In addition, time complexity and space complexity of pedestrian detection was not reduced.

A Real Boost method was used to guide the tree-structured classifier for pedestrian detection method. Two low level features are used to detect the pedestrians from the input images. A region-of-interest method was introduced to remove the false positives efficiently while detecting the pedestrians. However, pedestrian detection performance was not sufficient as the false positives were not correctly identified. In addition, features failed to analyze sequential data with temporal information and failed to track by detection method for increasing the detection results.

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A new ensemble learning method mines the low-level visual features with the spatial pooling for pedestrian detection. Spatial pooling applied in sparse coding for generic image classification issues. A new structured ensemble learning approach enhances partial area under ROC curve (pAUC) between two false positive rates. However, pedestrian detection accuracy was not improved.

A. Related Works

A high-level human-specific descriptor was employed in [9] for detecting the pedestrians in multiple videos. Through attaining the feature matrix from sliding window, multiple mapping vectors were employed to project the original feature matrix into mask spaces. However, the designed descriptor failed to increase the accuracy for pedestrian detection. An effective Histogram of Oriented Gradient pipeline coupled with neuro-inspired spatio-temporal filter in [10]. However, the memory space required for pedestrian detection was not reduced.

A new density enhancement method was introduced in [11] for increasing the quality of sparse point cloud. The radial basis function (RBF)-based interpolation was carried out depending on local coordinate system. However, the pedestrian detection time was not reduced using density enhancement method. Multi-Task model was introduced in [12] for finding out their similarities and differences. The model comprised the resolution aware transformations for mapping pedestrians in resolutions to space where shared detector differentiate the pedestrians from background. But, the true positive rate of pedestrian detection was not improved using Multi-Task model.Spatial pooling is used in sparse coding for generic image classification issues. Spatial pooling used features like covariance features and LBP descriptors for improving the accuracy of pedestrian detection. A new structured ensemble learning approach enhanced the partial area under ROC curve (pAUC) between false positive rates.

The ensemble learning called pAUC Ensemble learning with Tight bound (pAUCEnsT). The designed approach shares the similarities with existing boosting methods and optimizes the multivariate performance measure by structured learning. A conventional boosting-based visual detector is changed into pAUCEnsT-based visual detector with existing code. The designed approach is well-organized as it develops efficient weak classifier training and efficient cutting plane solver for enhancing the partial AUC score in structured SVM. The designed approach is principled ensemble method that optimizes the partial AUC in false positive range [α,β].Ultra wideband (UWB) communication systems, which enable the delivery of data from a rate of 110 Mb/s at a distance of 10m to a rate of 480Mb/s at a distance of 2m, are ideally suited to application in short range wireless communications because they can share a frequency band with existing narrowband systems and offer a higher data rate than 802.11 or Bluetooth [6].One of the communication methods for IEEE 802.15.3a standard is Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM), which offers 528 MHz bandwidth [7][8]. To minimize power consumption and provide multiple Simultaneous Operating Pico net (SOP) satisfying the FCC regulatory, a MB-OFDM UWB system has been proposed.Interleaver generally used to reduce the error by aligning the incoming bits in UWB.

B. Future Direction

The future direction of pedestrian detection is to detect the correct objects from the input image with lesser time consumption for reducing the space complexity using different quantization and deformable part model.

VI. CONCLUSION

A comparison of different existing pedestrian detection techniques is studied. From the survival study, it is observed that the existing pedestrian detection techniques consumes large amount of time and memory space. The survival review describes that the existing DPM was not suitable for parallel implementation as there were many computational blocks that are independent from each other.

In addition, features were not analyzed the sequential data with temporal information and failed to track by detection method. The wide range of experiments on existing methods evaluates the performance of the many pedestrian detection techniques with its limitations. Finally from the result, the research work can be carried out using quantization techniques along with deformable part model for improving the true positive rate and minimizing time as well as space complexity.

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