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DETECTION ON HEAD OF MOTORCYCLIST WITHOUT HELMET: A REVIEW

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Abstract. *Traffic accidents are the main cause of death in the world. Most of the victims are the motorcyclists without a helmet. Many researchers have developed a system that can detect motorcyclists who do not wear a helmet. This system consists of a motorcycle detection subsystem and detection subsystem on a head without helmet. There are papers that already discuss about review of detection on vehicle and motorcycle. However, review about detection on head without helmet has not been done yet. By that, this paper proposed a review about detection on head without helmet. This paper presents a review of the general steps on detection system of motorcyclist without helmet. In addition, many methods at each step (region of interest, feature extraction, and classification) have been presented and compared. At the end of the article, several conditions that cause errors and ways to increase accuracy are also explained.*

Keywords: Rider's head detection, ROI, Feature extraction, Classification

1. **Introduction.** Recognition to image object is a basic step on computer vision research that can be applied in many studies, such as sports [1], maritime protection [2], human activity analysis [3], and road transportation system [4]. One of the interesting things that are being developed in road transportation system is the detection on motorcyclists without helmet to decrease death by traffic accident.

Traffic accidents are one of the top 10 main causes of death [5]. Two-wheeler riders hold the highest death number which is 74% [6]. The main cause is head injury due to not wearing helmet. Motorcyclists who wear helmet correctly could decrease the risk of death by 40% and serious injury by 70% [6].

In order to reduce the motorcyclists who do not wear a helmet, some researchers already developed a system that can automatically detect the motorcyclists who do not wear a helmet by using computer vision. Generally, this system is divided into two parts, which are motorcycle detection subsystem and detection subsystem on head without helmet. Some researchers also did a review on vehicle detection and motorcycle detection. Sun et al. did a review on computer vision-based road vehicle detection that focused on attached camera on the vehicles [7]. Antony and Suchetha reviewed a road detection that has been divided into 2 processes: training and detection process. The detection process itself is divided into 4 steps: retrieving video data, preprocessing, feature extraction, and classification [8]. Besides that, Yang and Pun-Cheng reviewed a vehicle detection that

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focused on environment variation and separated them into 2 kinds which are appearance and movement based method [9]. Mukhtar et al. reviewed detection system and vehicle tracking to avoid crash. The contribution of this paper is the motorcycle detection technique, the price comparison and the range parameter sensor that is used [10]. Anaya et al. did a review on motorcycle detection for ADAS (Advanced Driving Assistance System) with two different approaches, which are computer vision and Vehicle to Vehicle system (V2V) [11]. From the review that has been done, review about head without helmet detection has not been done yet. Therefore, this paper will review the detection on head without helmet.

The rest of this paper is organized as follows. Section 2 presents the general steps on detection of motorcyclist without helmet. Section 3 presents the result and discussion. Lastly, Section 4 concludes the paper, suggesting future research directions.

2. **General Steps.** In general, the research on motorcyclist without helmet detection on the road is divided into 2 subsystems: motorcycle detection subsystem and detection subsystem on head without helmet, as seen in Figure 1. The motorcycle detection subsystem is divided into three processes, which are segmentation, feature extraction, and classification. The segmentation process is used to separate moving object from its background. On this step, most of the researchers use Gaussian Mixture Model (GMM) due to its ability to adapt with environmental changes [12]. To remove the noise from segmentation, morphology operation is commonly used before feature extraction process is done. Feature extraction process is used to extract moving objects from segmentation result. The last process is a classification that was used to classify motorcycle object and other objects such as cars, bicycles, and pedestrians. This motorcycle object is processed in the next subsystem that is detection of head without helmet.

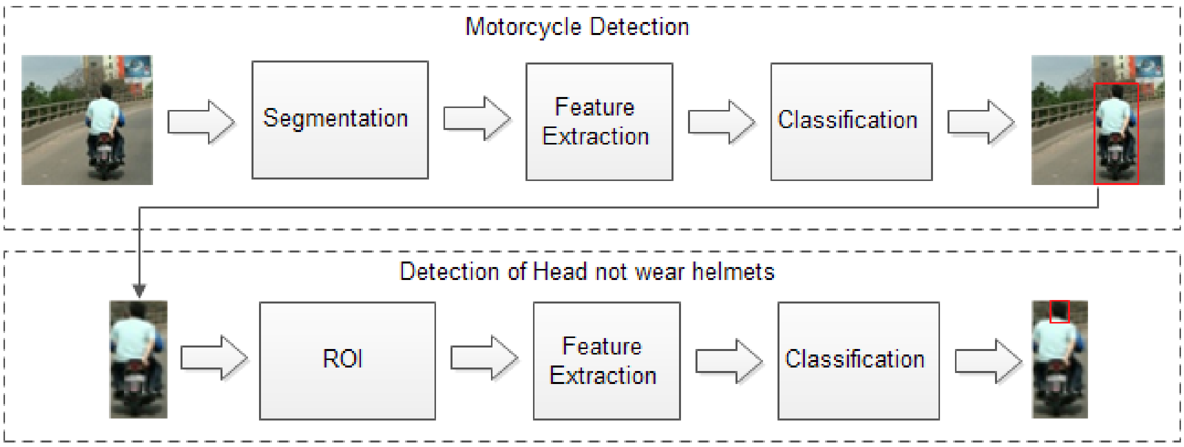

FIGURE 1. General steps on motorcyclist without helmet detection

Head without helmet detection subsystem is divided into 3 steps: Region of Interest (ROI), feature extraction, and classification. The overall research about motorcyclist without helmet can be seen in Table 1. The every step will be explained in the next sub-chapters.

2.1. **Region of Interest (ROI).** Determination of the ROI on motorcyclist's head aims to see which head belongs to the driver or the passenger. Head region is the differentiator whether the motorcyclist wears a helmet or not. The motorcyclist's head is above the motorcycle image; hence the researcher takes the upper parts of this image. The differences between one researcher and the other are the size of the taken image, which are 20%, 25%, and 33.3% from image height.

Table 1. Summary of motorcyclist without helmet research

Ref.	**ROI (%)**	**Feature Extraction**	**Classification**	**Accuracy (%)**
[13]	–	HOG	SVM	85.00
[14]	20	CHT, LBP, and HOG	NB, RF, and SVM	93.80
[15]	25	arc circularity, intensity, and color	KNN	89.00
[16]	–	CHT	–	77.00
[17]	20	HOG	MLP	91.37
[18]	25	arc circularity, intensity, color, and CS-LBP	KNN	89.00
[19]	25	HOG	SVM	93.80
[20]	25	HOG	SVM	93.80
[21]	25	CNN: AlexNet	CNN: AlexNet	98.63/87.11
[22]	–	CNN: YOLOv2	CNN: YOLOv2	94.70
[23]	–	CNN: VGG16, VGG19, Inception-V3, and mobil-nets	CNN: VGG16, VGG19, Inception-V3, and mobil-nets	85.19
[24]	33.3	CNN: VGG16	CNN: VGG16	99.04
[25]	33.3	CNN: iter_45, Inception-V3 and full ImageNet	CNN: iter_45, Inception-V3 and full ImageNet	85.29
[26]	33.3	CNN: AlexNet	CNN: AlexNet	98.00
[27]	–	R-CNN	R-CNN	95.00
[28]	20	HOG	MLP	91.30
[29]	25	arc circularity, intensity, color, and HOG	LR, RF, MLP, and SVM, DT, and KNN	96.00

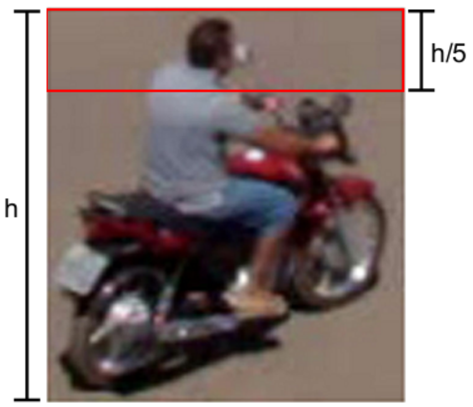

Figure 2. Example on determining ROI [28]

Silva et al. used 20% of the upper part from motorcycle image as ROI, just like Figure 2. The result from ROI is not yet specific; thus Silva et al. continued the sub window process with 4 steps: grayscale image, thresholding with Otsu algorithm, detecting edges with Sobel algorithm, and Circular Hough Transform (CHT) to look for circle shape on image [14,17,28].

Waranusast et al. determined ROI with upper part of motorcycle blob and then background subtraction process is done in order to get binary image. To remove small noises, closing morphology operation is needed [15]. Ashvini et al. also used 25% of upper part from motorcycle blob as ROI [18]. Dahiya et al. also used 25% upper part from motorcycle blob, then use background subtraction with background in the same position so the binary image is achieved. This method is more efficient than using CHT that takes more time [19,20]. This method is also used by Vishnu et al. [21]. Talaulikar et al. also used 25% upper part from motorcycle blob and then it is converted into binary image. To reduce noise, median filtering, flood fill, erodes, and dilation processes are done [29].

Some researchers use bigger portion which is 33.33% part from motorcycle blob as ROI [24-26]. ROI was used as an input from Convolution Neural Network (CNN) to gain feature and classification process.

2.2. **Feature extraction technique.** After the head area is found, the next steps are the extraction feature and classification. Generally the extraction feature process on helmet detection is divided into 3 kinds which are shape-based feature extraction, combination (shape, texture, and color) and CNN. Shape-based feature extraction is widely used on helmet detection such as using CHT and Histograms of Oriented Gradients (HOG). Marayatr and Kumhon used CHT descriptor to automatically detect motorcyclist without helmet; however, there are only 13 test data. The detection mistake happens on motorcycle that carries 2 people or more [16]. Chiverton used HOG descriptor on motorcyclist with or without helmet tracking system and classification using static camera. HOG descriptor is generated from Sobel operator to count edges [13]. Silva et al. proposed on mixing CHT and HOG. HOG is used with 9 blocks, with each block consisting of 9 cells. Data that is used is taken from a static environment, such as the changes on shadow position and there are parked cars along the road. The test is done by comparing HOG descriptor with the other descriptors: Wavelet Transform (WT), Local Binary Pattern (LBP), WT+LBP, WT+HOG, LBP+HOG, and WT+HOG+LBP. The classifier is also compared with several classifiers: Support Vector Machines (SVM), Radial Basis Function Network (RBFN), Multi Layer Perceptron (MLP), Naïve Bayes (NB), Random Forest (RF), and K-Nearest Neighbor (KNN). The test result of every descriptor and classifier combination shows description of combination of HOG and MLP produces the best accuracy, as shown in Table 1 [17,28].

Dahiya et al. compared HOG, Scale-Invariant Feature Transform (SIFT), and LBP descriptor to detect motorcyclist without helmet using SVM classifier. From the test using 5-fold cross validation, it shows the best accuracy using HOG descriptor and SVM classifier with linear kernel. This test is done in relatively rare road; thus the test on more complex road is not available yet [19].

To increase the accuracy result, some researchers combined various feature extraction namely shape, texture, and color. Waranusast et al. proposed it in the same case by using 9 features on the rider's head: arc circularity on the quadrant 1, arc circularity on the quadrant 2, arc circularity on the quadrant 3, arc circularity on the quadrant 4, average intensity on the quadrant 1, average intensity on the quadrant 2, average intensity on the quadrant 3, average intensity on the quadrant 4, and average hue on the quadrant 3 [15]. The rider's head is divided into four quadrants by determining the head centroid, and then it is divided into vertical and horizontal. The result of the divided quadrants can be seen in Figure 3. Quadrant 1 (Q1) and quadrant 4 (Q4) are located on the back of the rider's head, while quadrant 2 (Q2) and quadrant 3 (Q3) are located on the face of the rider's head. The accuracy results of close recording, distant recording, and medium distance recording are shown as 84%, 68%, and 74%, relatively. The biggest mistake happens in distant recording.

Ashvini et al. combined 4 different features namely arc circularity, average intensity, average hue and CS-LBP [18]. The features are used as an input from KNN classifier to classify it into two classes: head with helmet or without helmet. The proposed method focused on data taking problem from several points of view which are front, back, and the side. However, the rider's head image is sliced manually.

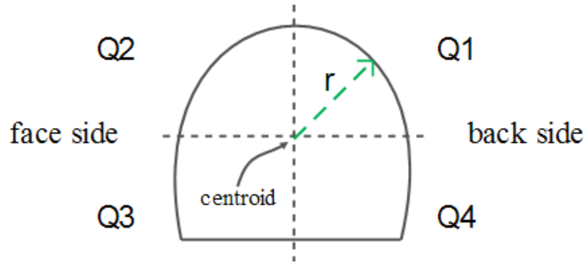

Figure 3. Distribution of head quadrant

Talautikar et al. combined 4 features namely arc circularity, average intensity, average hue and HOG [29]. HOG descriptor is composed from 16×16 block with 50% overlap and each block consists of 2×2 cells. Then, the composed features are chosen with Principal Component Analysis (PCA).

Silva et al. proposed geometric, shape, and texture features based detection on motorcyclist without helmet [14]. The used features are the combination of CHT, LBP, and HOG. CHT is used to find geometric shapes on the image. The result from LBP and HOG feature extraction is being inputted on classification process. This research compares 3 classifiers which are Naïve Bayes, RF and SVM. From the test result, LBP and HOG descriptors generated the best accuracy by using RF classifier. The downside of this method is the inability to detect low resolution image that is recorded at night or noon.

2.3. **Classification.** Waranusast et al. classified head with or without helmet using KNN based on generated features from the 4 quadrants [15]. Those features are arc circularities on 4 quadrants, average intensities on 4 quadrants, and average hue on third quadrant. While Ashvini et al. also used KNN classifier to classify head with or without helmet [18]. Besides the arc circularity feature, average intensity, and average hue, add texture feature using CS-LBP descriptor.

Chiverton used SVM classifier with linear kernel for classifying motorcyclist using helmet or not [13]. Dahiya et al. also compared SVM with 3 kernel which are linear, MLP, and Radial Basis Function (RBF) [19]. As an input from classifier, compare 3 descriptors which are HOG, SIFT, and LBP. From all combination tests, it shows the best accuracy by 93.8%, with using linear kernel and HOG descriptor, while for other combination produced the same accuracy by 82.89%. The average time on each frame is 11.58 ms, so it could be applied in real-time condition.

Silva et al. compared 3 classifiers that described probabilistic, geometric, and tree. On probabilistic family use Naïve Bayes. On geometric family use SVM and tree-based family use RF algorithm. The amount of used tree on RF algorithm is 80 trees, while SVM classifier uses linear kernel. From tests using 10-fold cross validation, RF generated the best accuracy [14]. Then Silva et al. tried to use MLP classifier and HOG descriptor. The nine block HOG descriptor is used where every block consists of 9 cells. MLP architecture is used by using one hidden layer with 50 neurons. The proposed method is compared with other classifiers and descriptors. The comparator classifiers are SVM, RBFN, NB, RF, and KNN. The comparator descriptors are WT, HOG, LBP, WT+LBP, WT+HOG, HOG+LBP and WT+HOG+LBP. From every classifier and descriptor combination test, it is concluded that MLP and HOG descriptor combination generates the best accuracy by 91.37% [17,28].

2.4. **CNN based technique.** CNN is also widely used with several models. Generally, the architecture of CNN is divided into 2 parts: feature extraction and fully connected layer. Feature extraction layer is used to encode an image to be a representative feature from its image. Then that feature is put into a fully connected layer to be classified.

Mistry et al. categorized CNN to detect motorcyclist without helmet. The used model is YOLOv2 [22]. Vishnu et al. also used CNN, but using AlexNet model on empty and dense traffic. The test on 5-fold cross validation generated accuracy by 98.63% on empty traffic, and 87.11% on dense traffic. CNN is compared to HOG and SVM and CNN generated a better accuracy [21]. Raj et al. also used AlexNet model to find motorcyclist who does not wear a helmet [26]. The test is done by using some total training data and some optimization algorithm on training process. The optimization algorithm used is SGD, AdaGrad, AdaDelta, Adam, and RMSProp. From the test, it can be seen that SGD generated the best accuracy. The mistake happens when the passenger uses hat.

Kulkarni et al. used CNN with VGG16 model to classify the motorcyclist's head [24], while Forero used CNN with several models: iter_45, Inception-V3 network and full ImageNet Network [25]. Boonsirisumpun et al. compared several CNN models and Single Shot MultiBox Detector (SSD) to detect helmet. The models are VGG16, VGG19, Inception-V3, and MobileNets. On the test with 10-fold cross validation, MobileNets gives better accuracy than other models. Accuracy on detection combination model MobileNet and SSD gives better accuracy from Inception V3 and SSD model [23].

Mayya and Nayak proposed the technique that can reduce the computation time to summarize traffic surveillance video to detect violation using Faster Regions with Convolutional Neural Network (R-CNN). This method could detect motorcycle passenger; however, there are mistakes on detecting cyclist [27].

3. **Result and Discussion.** ROI determination process, feature extraction and classification on head without helmet will affect accuracy result and computation time. ROI determination is to determine the head area; however, there are still problems on motorcycle that carries 2 people or more, where the head could be blocked with other head or passenger's body part. Other problem is children passengers that sit in front of the driver. To overcome these problems, zoom the ROI portion and then slide the windows with particular size to do scanning with ROI image. However, that process will add computation time.

In extraction feature process, some researchers already try to use several features or descriptors to detect motorcyclist's head with or without a helmet. HOG descriptor is widely used by researchers. The use of HOG descriptor gives an accurate result better than SIFT, WT, LBP, WT+LBP, WT+HOG, LBP+HOG, and WT+HOG+LBP [17,19,28].

In classification process, some researchers also use some classifiers. The use of SVM classifier with linear kernel gives better accuracy than using MLP kernel and RBF kernel [19]. While Silva et al. compared SVM classifier with NB and RF. From these tests, RF classifier gives the best accuracy [14]. Silva et al. also compared some classifiers which are MLP, SVM, RBFN, NB, RF, and KNN. From the test, it can be concluded that MLP gives the best accuracy [17,28].

Some researchers also have given some CNN models to do feature extraction process along with classification process. Those models are YOLOv2, AlexNet, VGG16, VGG19, iter_45, Inception-V3, full ImageNet and MobileNets. The test that compares VGG16, VGG19, Inception-V3, and MobileNets resulted in MobileNets has the best accuracy.

From all the research that has been done, there are still mistakes on some condition such as low resolution image due to recorded from afar [14,15], 2 people or more on the motorcycle image [27], unable to detect passenger [26], bicycle rider considered as motorcyclist [27], and mistakes on dense traffic [21]. Increasing accuracy and computation time could be increased with some steps: combining some descriptor, adding feature selection, and modified CNN model. The topics of future research need to be resolved such as motorcycle passenger detection and occluded motorcycle detection.

4. **Conclusions and Future Research.** Detection on motorcyclist without helmet could be done by using computer vision method approach. Some researchers have developed this detection system by dividing it into two subsystems: detection subsystem on motorcycle and detection subsystem on head without helmet. In this paper, there is a review that focuses on detection subsystem on head without helmet. This subsystem consists of 3 processes namely ROI determination, feature extraction, and classification. Generally, the ROI determination portion is divided into 3: 20%, 25%, and 33.33% of upper part. On feature extraction process, HOG descriptor generated better accuracy than other descriptors. On the classification process, MLP classifier gives better result than the others. Some CNN models also have been used as feature extractor along with classification that gives pretty good accuracy. The increasing accuracy and computing time could be increased with some ways: combining some descriptors, adding selection feature process and modifying CNN model.

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