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# AN APPROACH FOR FEATURES MATCHING BETWEEN BILATERAL IMAGES OF STEREO VISION SYSTEM APPLIED FOR AUTOMATED HETEROGENEOUS PLATOON

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**ABSTRACT**

Recently, the stereo vision system (SVS) has been developed in measuring tasks. Using SVS in measuring tasks plays an important role in automated highway system (AHS) because the SVS can be used instead of high cost distance sensors. The AHS is being developed to be run in different environments (i.e. unstructured and dynamic environment) and to form different shapes of platoon (i.e. heterogeneous platoon). In this work, a proposed method has been developed to improve the performance of the SVS in terms of automated heterogeneous platoon. The first stage of improvement has been here introduced by proposing a method for matching the left and right image of SVS (i.e. bilateral image). The significant contribution of the proposed method is to localize the points of interest in matching considering the shape of context assigned to the localized object of interest. The idea behind this development is to localize alternative connected points whenever the back view of the preceding vehicle BVPV (i.e. reference object) is influenced by the environment, including but not limited to sunshine reflection. In order to eliminate the surrounding objects of the BVPV, the Histogram of Oriented Gradient (HoG) has been developed by a proposed enhanced procedure. The latter depends on passing a precise knowledge about the position of edges and enhancing the gradient of intensity values. As for feature extraction, the proposed method has been developed to use the smoothed image generated by DoG instead of using the original image. The similarity value between each enhanced blocks is calculated based on the Euclidean Distance. Similarity value of the successful matching is greater than 99% between each enhanced blocks. In comparison with other methods, including SIFT and HoG, the proposed method extracts many corresponding features at different distances (from 3 to 10 meters) for the whole BVPV.

**Keywords:** *Stereo Vision System, Automated Heterogeneous Platoon, Features Matching*

## 1. INTRODUCTION

Recently, the Stereo Vision System (SVS) has been developed not only to monitor the wide range of the surrounding but also to measure the distance about the object of interest [1]. Today, the automated highway system (AHS) is being extended to be robust to withstand the influences of dynamic and unstructured environments (e.g. desert). Moreover, the AHS is being developed to adapt the heterogeneous vehicles (i.e. different shapes of vehicles) [2].

The SVS plays an important role in AHS through detecting, tracking, locating, and recognizing the heterogeneous. Measuring distance about the object of interest enables AHS to reduce the cost because the SVS could be used instead of other measuring devices (i.e. RIDAR and LIDAR). However, the need for high accuracy prevents the SVS to be applied in automated heterogeneous platoon [1].

In SVS, the disparity image has to be accurate enough to generate the depth map associated with the object of interest. Alfraheed et al [3] [4] have introduced the back view of the proceeding vehicle (BVPV) as a reference object for the automated heterogeneous platoon. The problem arisen in their suggestion is that the number of the corresponding points between the left and right images of the SVS (i.e. bilateral images) is not high enough to generate an accurate depth map and disparity images. Starting from this challenge, the extracted features are used to increase the number of corresponding points by using them to match bilateral images. Thus, the corresponding points generated by SURF [5] have to be increased for calibrating SVS successfully.

Furthermore, these points have to be extracted in dynamic environments (e.g. hazy weather, dusty weather or etc ). Our significant contribution is to develop a robust and effective approach that is able to extract these points for Automated Highway Systems or Automated Vehicles in these environments.

The novelty introduced here is to improve the current work of the SVS in terms of the automated heterogeneous platoon. The SVS has to be more accurate once it is used to measure the distance of object of interest. In AHS, the reference object is located at different distances which vary from 3 meters to 10 meters. Therefore, the SVS can be installed in AHS instead of high cost distance measurement sensors. In this work, the first stage of improvement introduced aims to efficiently extract the corresponding points in context of feature matching instead of point matching. The extraction has to be also compatible with different distances of the object of interest.

The rest of the paper is organized as follows; after showing the introduction in section 1, the related work is given in section 2. The third section shows how the proposed method has been developed whilst the fourth section provides the results and discussions of the experiment. Finally, the conclusion is given in the last section.

## 2. RELATED WORK

In this section, the methods applied in this research paper were state of the art in feature extraction. Moreover, the literature review has been evaluated by highlighting the drawbacks of these researches in context of automated highway systems or automated heterogeneous platoon systems.

The feature extraction is one of the significant steps which enables the vision system to calculate the depth information and construct the object of interest in three-dimensional images (3D). The most of vision system are usually calibrated using chessboard (which is placed in front of the SVS) [6]. Some FPGA-based vision system deal with the embedded FPGA algorithms to reconfigure and calibrate the stereo images [7]. In automated heterogeneous platoon, the SVS is fixed on the front of the following vehicle in order to capture the BVPV. Once the platoon is electronically coupled, the SVS has to be calibrated based on the features of the BVPV. Practically, the platoon's system has to configure the SVS based on BVPV [1].

Instead of chessboard, Kim and Park [8] have presented a new stereo matching algorithm based on feature link matching. The latter utilizes the length and color information of these features in stereo images. Their method is so effective to decide correct correspondence and to increase the accuracy of stereo matching. Moreover, the point of features are determined by FAST (Feature from Accelerate Segment Test) extractor. Despite of the successfully achieved results, the FAST extractor is not tested against the external effects (i.e. sunshine).

Therefore, Lin et al [9] have proposed a stereo matching algorithm based on the dynamic programming to reduce the noise which may lead to incorrect results during stereo matching. In addition, they have an assumption that the disparity of the scene is always smooth. However, this assumption is not always guaranteed in the dynamic environment.

In contrast, Wang Xiaoli et al [10] have proposed a binocular stereo matching algorithm which uses SURF (Speed Up Robust Features) to construct SURF detector pyramid [11]. The latter enables the proposed algorithm to improve the matching speed of the binocular stereo vision. In addition, their algorithm searches for a specific feature point on a specific scale layer generated by multi-scale analysis. As a consequence, the search range is greatly reduced. Since there are five constraints (i.e. threshold and symmetric constraints) to run successfully the algorithm, the latter is not applicable in automate and real time application.

Furthermore, the Genetic Algorithm (GA) has been developed in [12] for solving the stereo matching problem. The proposed approach has used the scan-line algorithm for the stereo matching problem. As a result, the accuracy has been increased approximately 20% compared to results without using GA. The problem arisen by GA is generated from the various components of the GA framework (i.e. crossover operation). The GA usually requires a crossover mechanism which often degrades the performance of the algorithm either by ignoring relevant data or by increasing the algorithm's time complexity significantly.

Having a point of interest is a significant step in this work. Several of methods have been presented to detect points for stereo vision [13] [14] [15]. The SIFT (the Save Invariant Feature Transform) [16] is generally used to find the matching points in stereo vision. Here, the SIFT is used to localize the point of interest in the PVPV. Alhwarin et al [16] have presented a novel method

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to speed up SIFT feature matching. They have extended SIFT feature by a few pair wise independent angles, which are invariant to rotation, scale and illumination changes. Practically, when taking a picture from two different angles, the color of a certain pixel is changed due to lighting conditions. The dynamic environment of heterogeneous automated platoon generally causes the color changing problem. Thus, the aim of this work is not only to speed up the feature matching but also to increase the accuracy of matching.

Recently, Zhang et al [11] have proposed an efficient image matching algorithm based on SURF. This approach has enormous advantages of less computations and short time-consuming. Moreover, the Random Sample Consensus algorithm is used to eliminate the false match and wrong match points. In this work, their proposed approach is developed in terms of the automated heterogeneous platoon and in dynamic environment.

## 3. PROPOSED METHOD

Within this work, a proposed approach is introduced to improve the performance of stereo image matching in context of automated heterogeneous platoon. Generally, the image matching has been divided into two significant tracks, which are image matching based on image value and feature based image matching [17]. Since the application of this work relates to the real time applications, the second track of the image matching (based on the features) is chosen to develop the proposed approach.

The popular approach feature based image matching has been introduced in [18] as a SURF (Speed Up Robust Features) approach. Within the later, the points of interest are extracted based on the scale-and rotation invariant [11]. In other words, the FAST-Hessian detector is used to localize the points of interest. The Haar wavelet is used to generate a descriptor of the localized points and to extract features associated with them. The idea to extract the features in SURF is similar to SIFT (Scale Invariant Features Transform). In SIFT, the different scale image is applied using the Gaussian function to localize the point of interest [16]. Although both approaches are looking for the strongest points of interest, they do not take the shape context in their account. Some points are discarded because they are not available in the lower scale of the scale invariant.

Recently, Zhang et al [11] have proposed an efficient image matching algorithm based on SURF. That approach has enormous advantages of less computations and short time-consuming. Moreover, the Random Sample Consensus algorithm is used to eliminate the false matches and wrong match points. Although the successful results of their proposed approach due to eliminating the false matching, the approach has not been applied in dynamic environment and it does not take the shape of interest in its account.

Since having points of interest is a significant step in stereo image matching, the proposed approach is developed to extract points associated with edges of BVPV. The latter is considered here as a shape of interest in order to improve the efficiency of the proposed matching approach. Localizing the BVPV is necessary to keep the proposed approach running. Therefore, the BVPV has been detected and tracked in a video stream [4] [3].

The idea behind this development is first to use BVPV as a reference point in bilateral images of SVS. This would be especially beneficial since the BVPV enables the SVS to restrict its functions to a particular part of frame instead of processing the whole frame. Therefore, the running time of the image matching is reduced [1]. Secondly, the proposed approach is required to increase the number of points used in the stereo image matching. Increasing the number of points enables the approach to be robust and effective against the influences of the dynamic environment of the automated heterogeneous platoon (e.g. shadow, dust, sunshine reflection, hazy weather …, etc.). Once some points of interest are eliminated in the stereo image matching due to either false matching or color changing problem, other new points are undertaken to image matching instead of those eliminated points. Since the extracted points are associated with the edges of BVPV, they are clearer than the eliminated points and close to them.

The proposed approach is required to match the BVPV located on the left and right images of SVS. The approach is supplemented by the detection and tracking agents [4] [3] to extract key points required to match the stereo images in video stream. Therefore, the proposed approach has to be also applicable under real time constraints. Additionally, the dynamic environment represents a challenge for localizing key points because it often changes the appearance of BVPV. Therefore, the agent has to be adaptable in dynamic environment.

The significant contribution of this work is to localize the points of interest in the image matching considering the shape of context assigned to the localized object of interest. This would be especially beneficial since it enables the SVS to

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recognize its reference object (i.e. the Back View of Preceding Vehicle BVPV) for calibration process. Meaning that, the number of the points of interests is increased whenever the BVPV is moved away from the stereo cameras (i.e. the distance between BVPV and SVS is approximately 10 – 12 meters).

Furthermore, the shape of context enables the proposed approach to localize the points of interest in the normal scale of the Gaussian function (i.e. $\sigma$ =1) instead of looking for the point of interest at the lower scale (i.e. $\sigma$ = 6). Although the localized points at lower scale are stronger than those at the normal scale, the shape of context offers the connected points of interest which enables the proposed approach to localize alternative points whenever the reference object is exposed to environmental influences (e.g. sunshine reflection, shadow … etc). In the Following, the main steps of the proposed approach are presented.

### 3.1. Back View Localization

Here, the detection and tracking process are not discussed. Both processes have been already published in [3] [4] respectively. Agents assigned with each of them are used to localize the BVPV. Using the coordinates of BVPV, both of the left and right images of SVS are replaced by the corresponding located back view. Instead of processing the whole frame of SVS, the proposed approach focuses its function on the located area. The latter is transformed as an input to the next step.

### 3.2. Edge Detection based on the Difference-of-Gaussian

The main goal of this step is to extract edges of the localized BVPV. The criterion used to detect the edges depends on a Difference-of-Gaussian Function D(x, y, $\sigma$) which is computed from the difference of the two nearby scale separated by a constant multiplicative factor k [19]:

$$D(x, y, \sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) \qquad (1)$$

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \qquad (2)$$

Where:

D(x, y, $\sigma$) is a variable-scale Gaussian.

I(x,y) is an input image. It represents here the BVPV.

* is the convolution operation in x and y.

Once the Difference-of-Gaussian Function is convolved over the image of I(x,y), the smoothed image is generated as shown in Figure 1 - A. It is then converted to black-while image based on a threshold value computed from histogram process [20]. Figure 1 - B shows edges of the BVPV which are marked with the black color and the background is colored by white. Although, the other surrounding objects are included in the black-white image, the objects associated with BVPV often represent the most significant connected objects.

The proposed approach automatically converts the BVPV into a black-white image. Moreover, the approach automatically reduces the noise in the images due to the generated smooth image. As a consequence, the approach reduces the effect of the dynamic environment (i.e. sunshine reflection and color changing problem). Furthermore, the approach enables the SVS to extract the edges assigned with the BVPV whenever the latter is moved away from the stereo system.

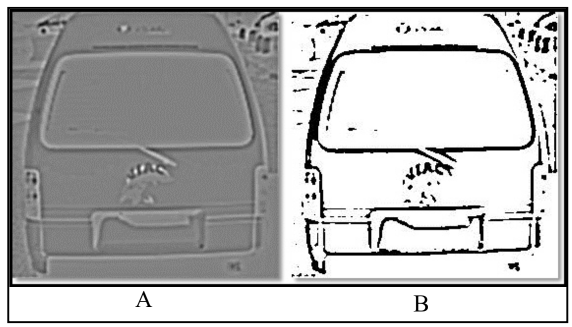


*Figure 1: (A) Smoothed image of BVPV generated by using Difference of Gaussian (B) Black-White image of the generated smoothed image*

### 3.3. Key points Localization

Starting from the black-white image of the BVPV, the significant objects of the BVPV are extracted because there is a need for eliminating the so small connected objects and the surrounding objects of the BVPV. The morphological operations [21] [22] are here used to determine precisely the edges of BVPV and find out the connected pixels associated with them. Figure 2 - A shows a sample of the extracted connected objects. Additionally, the number of the connected pixels is also given by using the morphological operations. Therefore, the proposed approach has offered to apply a threshold value either to extract all of the connected objects or to extract particular connected objects (e.g. the maximum connected object) as shown in the Figure 2 - B. Each point of the extracted objects is localized as a point of interest in the stereo image matching. Although the number of these points is extremely high in comparison with the SIFT [16] and SURF [5] [23], it enables the proposed

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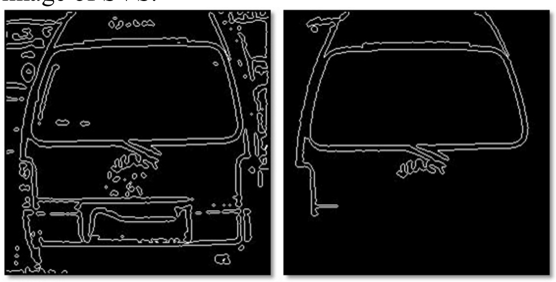
approach to offer new points instead of those disappeared due to the environmental effects. Furthermore, the proposed approach reduces the false matching of the selected points (e.g. from the left image of SVS) by offering points which are close to the corresponding location in the right image of SVS.



A B

*Figure 2: (A) sample of the extracted connected objects (B) the connected objected assigned with the maximum number of points*

Within this step, features which describe the localized key points are constructed based on the Histogram of Oriented Gradient (HOG) [24]. The reason behind using HOG-based features is its ability to efficiently characterize the local object appearance and shape by the distribution of the local intensity gradients or edge direction [24]. Moreover, effects of illumination and shadowing are reduced by normalizing the contrast of the local response over spatial regions called blocks [24]. The latter is normally extracted by 36 × 36 pixels.

In this work, the mechanism of HOG is improved in a proposed enhancement procedure. The procedure consists of two ways. First, a precise knowledge is passed to HOG about the edge positions according to the shape of context and the localized points of interest extracted in the previous steps of the proposed approach. In the second way, the gradient of the intensity values is enhanced based on the smoothed image generated here using Difference-of-Gaussian Function D(x, y, σ). As a consequence of both ways, the appearance of region around the point of interest is enhanced compared with the original region of the input image. Beside the effect reductions of illuminations and shadowing, the gradient generated in HOG is smoothed compared with the gradient generated without using enhancement procedure. Therefore, the features extracted precisely describe the point of interest and distinguish it from other similar points.

Figure 3 shows samples of the blocks in different locations of the BVPV. These blocks are extracted before the method of HOG extracts the features required in the image matching. The blocks located in the top side of the Figure 3 represent those extracted from the original image. The original blocks are numbered from A1 to A5. In contrast, the corresponding blocks extracted from the smoothed image generated by Difference-of-Gaussian (DoG) are numbered from B1 to B5.

The approach proposed here distinguishes itself from the HOG by passing a precise knowledge into the features extraction process about the edge position via the shape of context. Several of blocks are automatically localized based on the precise knowledge of the shape of context. In Figure 3, those blocks are selected to show how the proposed approach is able to focus its functions on shape of context instead of using only the corner points.

Due to the need to reduce the effects of illumination, the distraction of the gradient and distribution of the local intensity, the proposed approach has used the smoothed image generated by DoG in the previous steps instead of using the original image in calculating the oriented gradient of the HOG (i.e. dy / dx ).

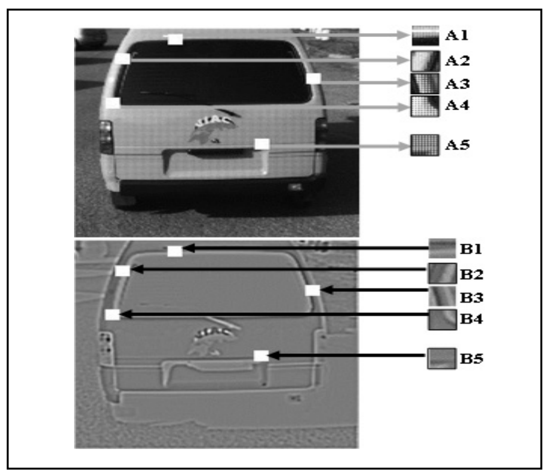



*Figure 3: Samples of blocks extracted from the original image of the BVPV (A1 to A5) and the corresponding blocks (B1 to B5) in the smoothed image generated by Difference-of-Gaussian*

As shown in Figure 3 , the corresponding blocks (i.e. B1, B2, …. B5) are therefore extracted from the smoothed image. Moreover, Table 1 TABLE (see: Annexure 1) shows a comparison between the blocks of original image (i.e. the column C1) and the corresponding blocks of the smoothed image (i.e. C3) based on the a wireframe mesh in C2 and C4 respectively. The comparison shows that the mesh of the corresponding blocks (B1, B2, …,B3) seamlessly appears more than that of the original image (A1, A2, … A5 respectively). This means that the distraction of the intensity in the original blocks is reduced in the corresponding ones.

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15th April 2018. Vol.96. No 7


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Although the distraction is reduced, the edge position appears unclearly. As shown in the column C5, the black-white block is therefore generated based on the Gaussian function G(x, y, σ) which generates the smoothed image in equation 2. The black and white regions are colored by the mean intensities value of the corresponding region in the original image as shown in the column C6 of the Table 1. Consequently, the wireframe mesh of the colored block (i.e. in column C7) clearly shows the edge position in comparison with the wireframe mesh of the original image in the column C1. Moreover, Figure 5 shows several of enhanced blocks located in the original image.

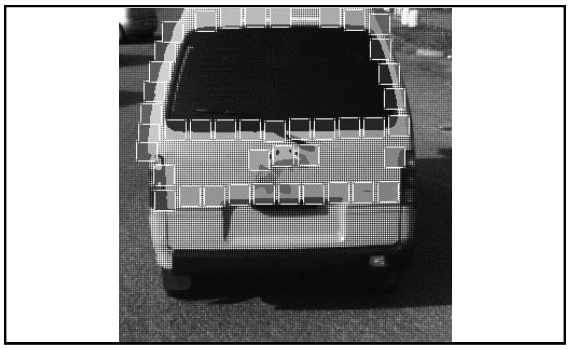

*Figure 5: Samples of the enhanced blocks located on the original images*

### 3.5. Feature Matching

Having the matching between HOG features of the left stereo image and those of the right stereo image is the main purpose of the feature matching step. As an input of this step, many of the enhanced blocks are given from the left stereo images (**$A_M$**) and the enhanced block of the right stereo image (**$B_N$**). For instance, **N** is the number of the enhanced blocks of the left stereo image while **M** represents the number of the enhanced blocks of the right stereo image.

The Euclidean Distance (ED) is applied in most of the image analysis and pattern recognition [25] [26]. Here, the ED is used to find the similarity value between each enhanced block of the left stereo image (**$A_M$**) and other enhanced blocks of the right stereo image (**$B_N$**). The ED is calculated based on the following equation:

$$\text{Similarity value} = ED\,(x,y) = \sqrt{\sum_i (x_i - y_i)^2} \quad (3)$$

Where:

i : A count variable represents the number of HOG features. Normally, they are 36 features.

x : Features extracted from the enhanced block located in the left stereo image.

y : Features extracted from the enhanced block located in the right stereo image.

The number of the similarity values (i.e. ED) generated for each block in the left stereo image (**$A_M$**) is N values because each block of A is compared with all blocks of B. Actually, the ED is calculated between features of an enhanced block of A and features of enhanced blocks of B as shown in Figure 4. Each ED is approaching zero whenever the both blocks are more similar.

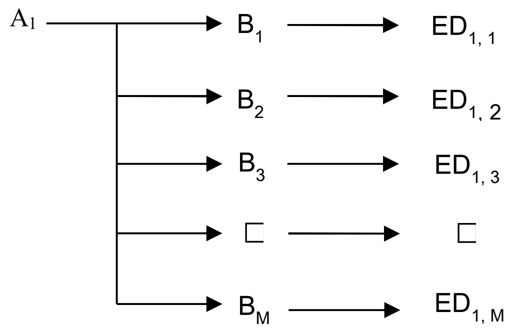


*Figure 4: The comparison mechanism between the features of an enhanced block of A and features of enhanced blocks of B*

The first criterion used here to distinguish the positive match from the negative match is that the similarly value has to be more than or equal to 99%, which means that the ED has to be between 0 and 0.009 (both 0 and 0.009 are included). After applying the first criterion, several of similar blocks are clustered as similar blocks. Therefore, a second criterion is required to separate the positive match from the negative match. The second criterion is that the number of similar blocks in the right stereo image (**$B_N$**) has to be one or two blocks. Actually, there are only one or two blocks are similar at maximum. In case there are more than two, the proposed method has not clearly determined the positive match. Although the successful results have been achieved using both criteria, the results of similarity matching still have false matching. Sometimes, the proposed method has therefore applied a shifting procedure to align the similar blocks.

Figure 6-A shows seven blocks at different positions over the back view (i.e. $A_M$). The contrast similar blocks of these blocks (i.e. $B_N$) have been shown in Figure 6-B. The similarity value associated with the similar block ($B_N$) has been shown in Figure 6. Depending on the above criteria, some of these blocks are accepted in matching process and other blocks are ignored.

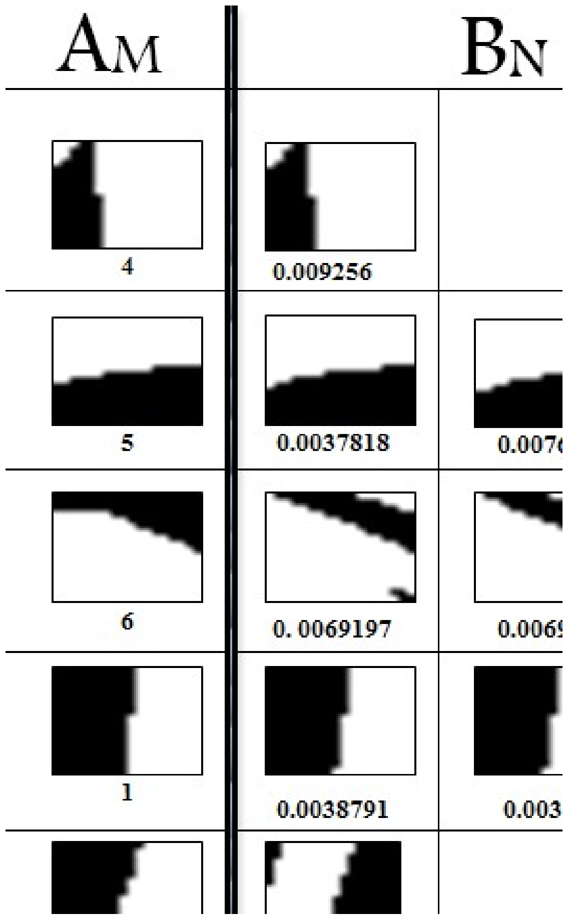


*Figure 6: Samples of the enhanced blocks with the assigned similarity values*

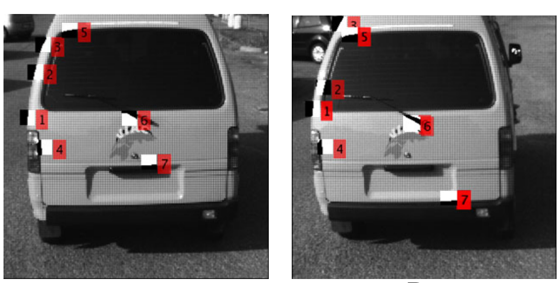


*Figure 7: Seven samples of the extracted features blocks at different positions over the BVPV. (A) The selected blocks (i.e. $A_M$ ) from the left image of SVS. (B) The similar blocks (i.e. $B_N$ ) extracted from the right image of the SVS*

## 4. RESULTS OF EXPERIMENT AND DISCUSSION

The proposed method has been run on the data of the experiment. The latter includes two stream videos for a back view of vehicle. The first stream is captured by the left camera of the stereo vision system. In contrast, the second stream is captured by the right camera of stereo vision system. Since the scope of the proposed method is the dynamic environment, the distance between the Stereo Vision System (SVS) and the back view of the vehicle varies from 2 meters and 30 meters in the captured stream video. The experiment is performed using a non-optimized implementation and run on a PC with 2 GHz Intel Due Core CPU. The experiment data is taken from a video stream captured by the Artificial Vision and Intelligent System Laboratory (VisLab) of Parma University in Italy [27].

The proposed method has shown the number of the matching points between the right and left images of the SVS has been increased. Furthermore, the matching points have been extracted in different positions at back view. Figure 8 shows the matching points at an approximately 3 meter distance. Since the number of matching points is high and the need arises for perfectly results showing the matching points, which are distributed in four samples as shown in Figure 8. Moreover, the merged image at Figure 8 shows both of the right and left images that include the matching points.

In few cases, the matching step cannot precisely determine the matching points because the rate value of similarity is very high and the number of the similar blocks is more than two. Therefore, the shifting procedure has been applied to accurately position the two similar blocks. Figure 9 shows some matching blocks after shifting them to the appropriate position. As a consequence, the number of the matching points has increased and the whole shape of the back view is precisely determined.

The dynamic environment (i.e. sunshine reflection) plays a role not to partially allow the the back view to be visible. Moreover, whenever the back view is moved away from the SVS, it also partially disappeared. Figure 10 shows the back view at an approximately 10 meter distance. The proposed method has successfully determined the matching blocks between the right and left images despite of the dynamic environments.

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15th April 2018. Vol.96. No 7

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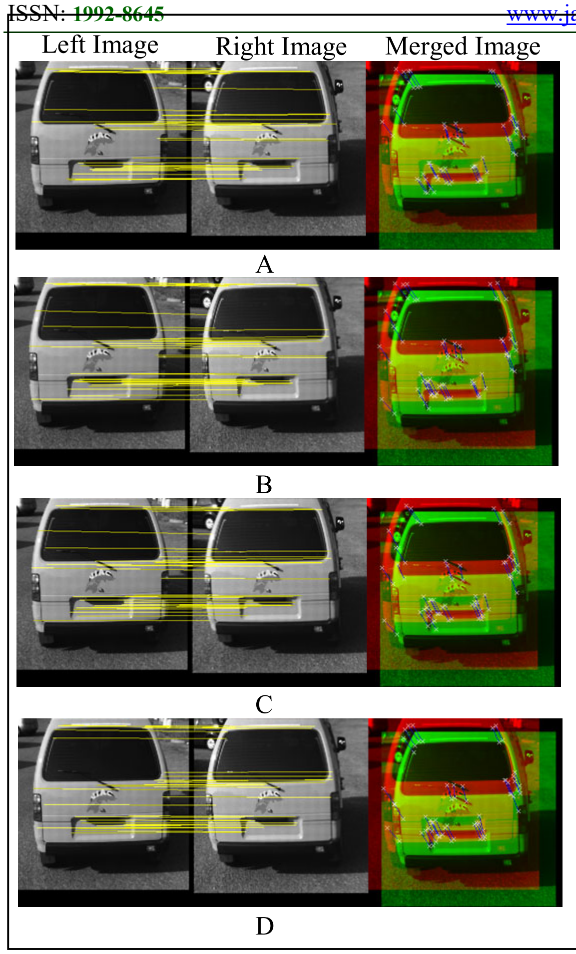


*Figure 8: The matching results between left and right image of the SVS at approximately 3 meter distance*

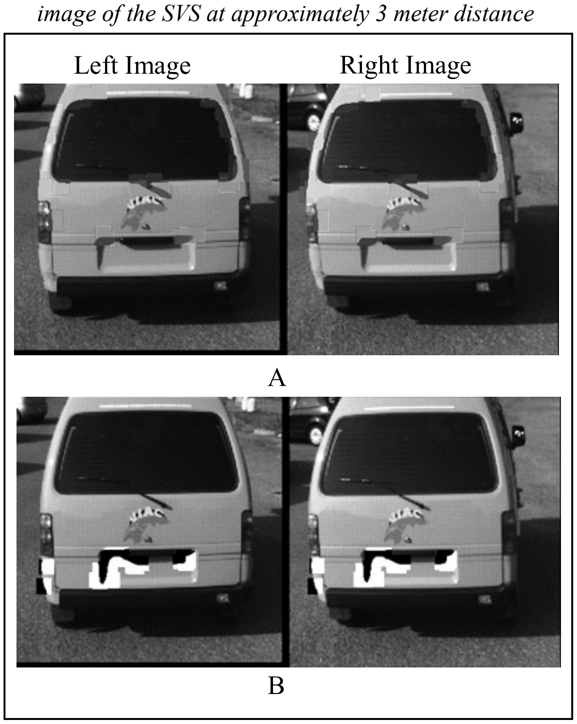


*Figure 9: The matching blocks between left and right image of the SVS at approximately 3 meter distance. A and B are different samples*

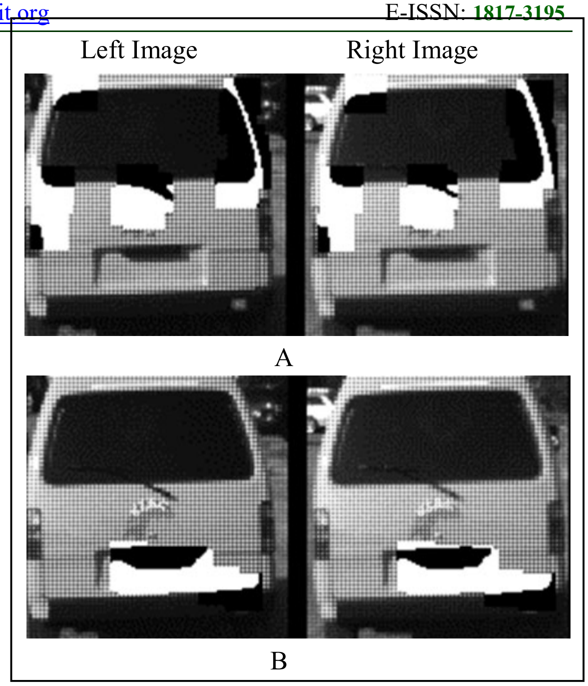


*Figure 10: The matching blocks between left and right image of the SVS at approximately 10 meter distance. A and B are different samples.*

In comparison to other methods, the proposed method distinguishes itself through adapting the dynamic environments and a far distance of back view. Two methods, namely HoG [24] and SIFT [16], are compared to the proposed method. Table 2 shows the comparison between the proposed method, on the one hand, and the HoG approach and SIFT approach, on the other hand.

*Table 2: A comparison between the proposed method and the other approaches*

| Methods /Parameters | Adapting at 3 meter distance | Adapting at 10 meter distance | Spreading out the points of interest |
|---|---|---|---|
| The Proposed Method | Yes | Yes | At the Whole BVPV |
| HoG | No | No | Partially |
| Sift | No | No | Partially |

Figure 11 shows the back view at an approximately 3 meter distance. The HoG Method extracts two matching points. Although the distance of the back view is short, the HoG method cannot find the enough matching points. In contrast, the proposed method finds some matching points at the same distance as shown in Figure 11.

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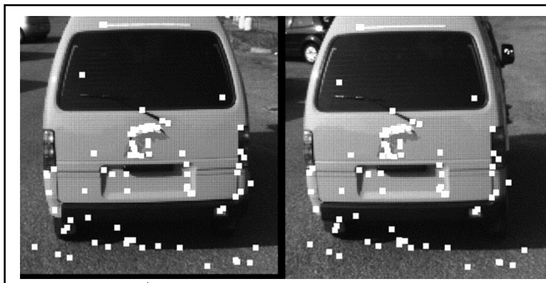
*Figure 11: The Matching results based on HoG method at approximately 3 meter distance*

The second compared method is the Sift method. Figure 12 shows so many points of interest at both of the left and right images of stereo vision system. Unfortunately, these points are not spread out over the whole back view. For instance, most points of interest are located at the shadow of the back view which disappeared while the vehicle is moving. The Sift method is also tested over a back view at an approximately 10 meter distance as shown in Figure 13. Because the appearance of the back view is partially disappeared, the Sift method cannot locate the points of interest and it does not find the matching points



A B

*Figure 12: The Matching results based on the SIFT method at approximately 3 meter distance. (A) Left Image (B) Right Image*

A B

*Figure 13: The Matching results based on the SIFT method at approximately 10 meter distance. . (A) Left Image (B) Right Image*

In summary, the proposed method is able to match both the left and right images related to SVS. This matching enables the latter to be calibrated not only while the back view of the front vehicle is moving but also whenever the back view partially disappeared at curves or moving away from SVS. Moreover, the proposed method is able to overcome the disappeared appearance due to the dynamic environment. As a consequence, the system of the automated heterogeneous platoon is enabled to calibrate SVS based on the back view. In addition, the platoon system is enabled to calibrate the SVS whatever the shape of the back view is.

## 5. CONCLUSION

Within this work, the mismatching of the corresponding points of the Stereo Vision System (SVS) has been addressed in terms of the automated highway heterogeneous platoon. The proposed method has been developed for improving the matching results of the SVS. Firstly, the proposed method depends on localizing the object of interest. In this work, the Back View of the Preceding Vehicle (BVPV) is taken as a reference object for SVS. The BVPV is then processed to extract its edges based on the Difference-of-Gaussian (DoG). The extracted edges of BVPV are enhanced to ensure that their points are connected. In order to eliminate the surrounding objects of the BVPV, the Histogram of Oriented Gradient (HoG) has been developed by a proposed enhanced procedure. The latter depends on passing a precise knowledge about the edges position and enhancing the gradient of intensity values. Furthermore, the step of the feature extraction has been developed to use the smoothed image generated by DoG instead of using the original image. As a consequence, the effects of the illumination, the distraction of the gradient and distraction of the local intensity are reduced. Once the features are extracted, the matching step is applied. The similarity value of each enhanced block is calculated based on the Euclidean Distance. The latter has been used because it is efficiently applied not only in image analysis but also in pattern recognition. For each enhanced block, if the similarity value is greater than 99%, the block is a perfect match. If the similarity value is greater than 99% and there are more than two corresponding enhanced blocks, a shifting procedure has been applied to align those blocks. The proposed method distinguishes itself from other methods through its ability to increase the corresponding points between bilateral images of SVS. In addition, it can be adaptable with the dynamic environment and heterogeneous platoon.

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The limitation of this study is to run the proposed method in the dynamic environment. However, the proposed method is not tested in other environments (e.g. hazy weather).

## 6. FUTURE WORK

In future, the proposed method will be developed over other conditions of the dynamic environment, including but not limited to hazy weather. In addition to this future development, the calibration process of the SVS will be implemented according to the proposed method.

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**Annexure 1:**

*Table 1: Comparison between the original blocks, corresponding blocks of the smoothed image and the enhanced blocks based on the proposed enhanced procedure*