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Development of Semi-Autonomous Feature Tracking Algorithm

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Abstract
In this paper, development of a feature tracking algorithm was introduced for the surveillance by Unmanned Ground Vehicle. As far as the feature tracking, there are two approaches such as sensor used method and feature used method, respectively. The objective of the paper is represented, if the suspected unit is detected by the camera, Unmanned Ground Vehicle is set to stop and wait for the template information. Once the template is set and stored, the tracking algorithm performed to follow the moving objects. And the vision camera is panned and tilted so that the camera continuously follows the object. For the feature tracking algorithm, Mean Shift and Cam Shift are introduced. The Mean Shift is an algorithm that finds modes in a set of data sample, manifesting an underlying probability density function based on various feature space in the region. As far as the Cam Shift algorithm, it is an extended Mean Shift algorithm that is from the stopped images to moving images. It is based on the HSV color based algorithm that means that the probability distribution is not fixed but changeable so that the performance in real time is better than other conventional algorithm

Keywords: *Feature Tracking, Mean Shift Algorithm, Cam Shift Algorithm, Color Based Algorithm, Feature Detection*

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I. INTRODUCTION

In the future warfare, military unmanned vehicles and military robots will execute the battle and the battle support mission. It is predicted that the multi-ability of the unmanned system will be larger within the hazardous places. Military unmanned systems are actively used in noncombatant sectors, such as collecting information, dangerous work, guard work and has proved its efficiency that makes possible to predict that unmanned system will be use wider. Especially, UGV (Unmanned ground vehicle) is regarded as a main stream of the future warfare, which can be representative of 'Future Combat System'.

For fulfilling the reconnaissance, his unit requires many function requirements such as mobility control, obstacle avoidance, and dynamic stabilization. Although this these matters are dealt with significantly, it is emphasized that the detection of the object that we are interested in during the operation should be dealt with. For this reason, there are many sensors attached to the vehicle. Among the sensors for the outdoor environment detection, the most popular and practical usage is camera used detection. Compared to the other sensor based detections, it is effective due to the fact that camera makes visualization of the outdoor environment in which the user knows it immediately. In addition to that, this method can specify the detection function, such as IR signal detection during the night environment or chasing the moving objects.

In this reason, the camera based detection and tracking system is necessary technology for improving the SUGV usage diversification and its performance. Feature is the interesting part of an image in color based feature tracking algorism, and it is the starting point for many computer vision algorithms. There are two main issues about feature detection. Repeatability addresses that the feature should be detected the same point independently in two or more different images of the same scene. Distinctiveness represents that the corresponding features between different images are reliably matched each other. There are many different kinds of features, and each has unique characteristics. Among many features, features can be categorized as edges, corners, and blobs. Edges are sets of points in the image which have a strong gradient magnitude about one dimension. Corners are point-like features in an image which have strong gradient magnitude about two dimensions. Blobs are the regions of interest or combination of interest points

There are many kinds of feature detector algorithm developed by eminent researchers, and they can be classified as Table 1.

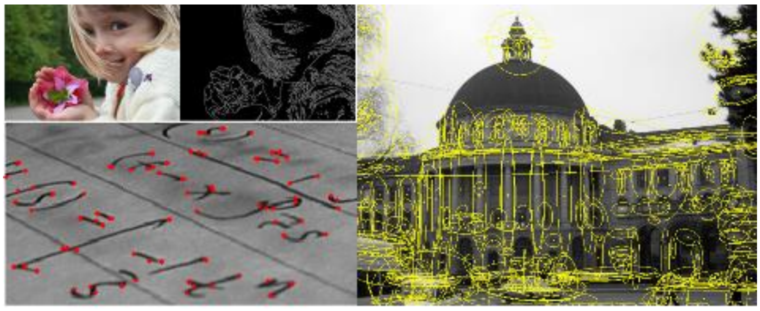

Figure1: Edge, corner & blog features in an image

Table 1: Classification of the feature detector

Feature detector	Edge	Corner	Blob
Canny	x		
Sobel	x		
Harris & Stephens / Plessey	x	x	
SUSAN	x	x	
Shi & Tomasi		x	
Level curve curvature		x	
FAST		x	
Laplacian of Gaussian		x	x
Difference of Gaussians		x	x
Determinant of Hessian		x	x
MSER			x
PCBR			x
Grey-level blobs			x

Most of the tracking algorithms are based on assumptions as follow; Brightness consistency, Spatial coherence, Temporal persistence.

First assumption indicates that the image measurements (e.g., brightness) in a small region remain the same although their location may change. Second assumption addresses that neighboring point in the scene typically belong to the same surface and hence typically have similar motions. The last term means that the image motion of a surface patch changes gradually over time. There are two representative object tracking algorithms, Lucas-Kanade explained below.

In computer vision, the Lucas–Kanade method is a widely used differential method for optical flow estimation developed by Bruce D. Lucas and Takeo Kanade [1]. It assumes that the flow is essentially constant in a local neighborhood of the pixel under consideration, and solves the basic optical flow equations for all the pixels in that neighborhood, by the least square criterion.

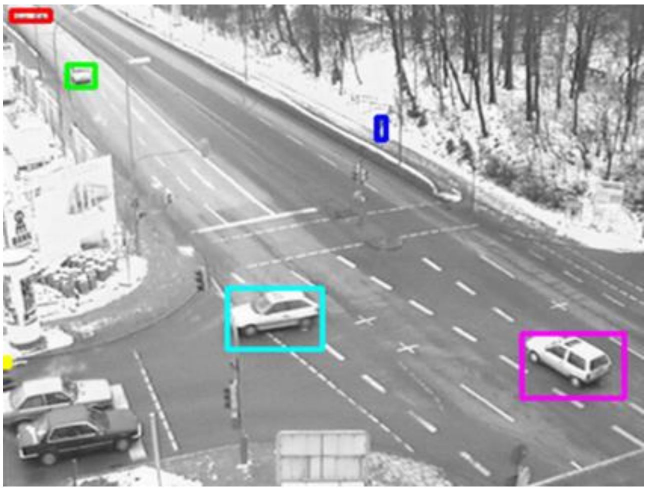

Figure 2: Vehicle & pedestrian tracking at the crossroad

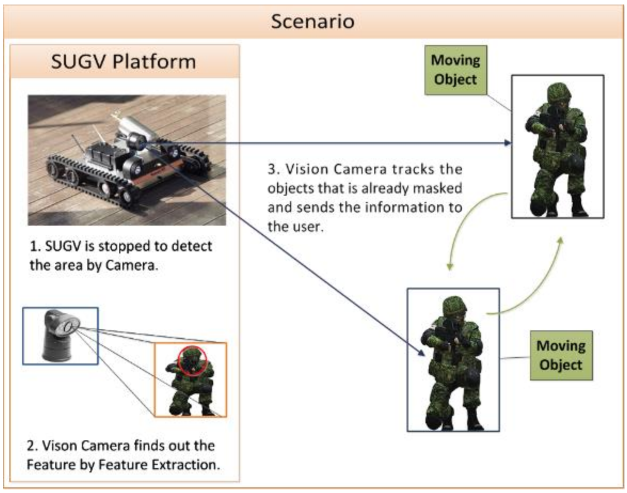

Figure 3: Final scenario of this project

The objective of the paper is represented shown in Fig. 3. First of all, if the suspected unit is detected by the camera, SUGV or UGV is set to stop and wait for the template information. Secondly, once the template is set and stored, the tracking algorithm is performed to follow the moving objects. Finally, the vision camera is panned and tilted so that the camera continuously follows the object.

II. BASIC KNOWLEDGE OF FEATURE TRACKING ALGORITHM

2.1 Mean Shift Algorithm

The Mean Shift Algorithm is a robust finding local extrema method in the density distribution of data set. It is successfully applied in a continuous distribution and in essence, it is a "hill climbing" method applied by density histogram of the data. Fig. 4 shows that Circle type window in the 2D data distribution is moved by Mean Shift algorithm. In the process of trying to find a peak, statistically, Stable operation is guaranteed because the data points on the outside are not affected.

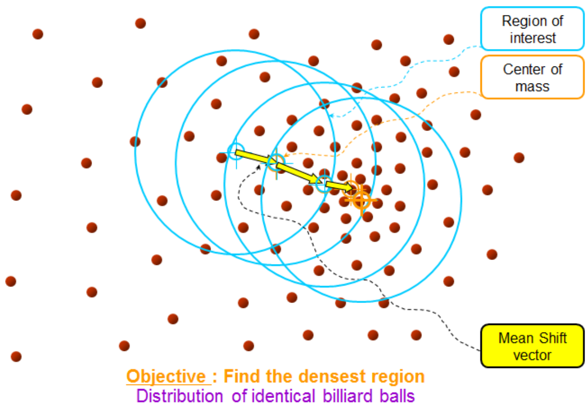

Figure 4: Mean Shift Algorithm path

2.2 Cam Shift Algorithm

The object is being tracked by the camera on UGV being panned and tilted when it is out of bound of image. For the sake of even better quality of our tracking system, it is necessary to adopt Cam Shift algorithm which overcomes the limitations from the conventional Mean Shift Algorithm. Cam Shift is firstly introduced by Gary R. Bradski[2]. It is modified form of Mean Shift tracking algorithm. The main difference between the two algorithms is the point that the search window in Cam Shift adjusts itself in size. And this method uses color information, but rather than relying on a single color, it tracks a combination of colors. Since it tracks by color, it can follow a face through orientation changes that the Haar-face detector cannot handle. If we have well-segmented distributions (such as face), then Cam Shift will automatically adjust itself for the size of face as the person moves closer or further from camera. Cam Shift is a simple, computationally efficient face and colored object tracker which was originally developed for hands-free gaming. It is designed to be very fast and lightweight algorithm. Therefore, the computer can do other tasks while tracking. On the other hand, since it was developed as a gaming interface, Cam Shift also has a limited ability to detect changes in head position, such as tilting the head to one side. While acknowledging the limitation imposed by its simplicity, we can still see that Cam Shift tracks virtually as well as more expensive tethered trackers or much more sophisticated, computationally expensive vision systems, and it tracks well in noisy environments.

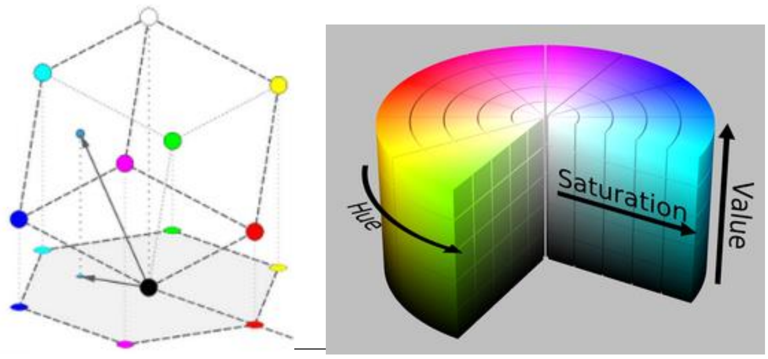

Figure 5: Hue and chroma in HSV chromaticity plane and HSV cylinder

III. PROPOSED METHOD OF FEATURE TRACKING ALGORITHM

3.1 Reason of using Cam Shift Algorithm

In the previous section, feature tracking technology is sorted out sensor based and vision based approach. As far as the objective of the project is concerned, it is considered that the tracking algorithm should not be dependent on the sensor quality and performance. In this reason, one of the most popular algorithms, Cam Shift algorithm is applied to the system.

Cam Shift algorithm is introduced by G.R. Bradski in Intel Technology Journal in 1998. This algorithm is based on the Mean-shift algorithm explained, but its performance is better because the HSV color statistic space is used. It means the object is detected with minimum information in searching area as long as other features are not much overwrapped. It also uses Hue channel based approach so that the calculation burden is less than other algorithm based on RGB color space.

Cam Shift algorithm is proceeded by following statements:

- Firstly, Set the region to track, then calculate the Hue 1D histogram in the region.
- Get the Hue data from the input image, and calculate the probability Distribution based on the Hue histogram.
- Based on the probability distribution, calculate the center area and its area with this rule

$$m(x) = \frac{\sum_{x_i \in N(x)} K(x_i - x) x_i}{\sum_{x_i \in N(x)} K(x_i - x)}$$

Where, N(x) is the neighborhood of x, a set of points for which. $Kx \neq 0$

- With calculated center point and its area information, re-calculate the new data of the center point and area in the next frame.
- Repeat until the value is converged.

The purple part explains the center of the Mean-Shift and the yellow part for the calculated Cam Shift region. It is true that the area of the Cam Shift is larger with respect to time [2].

3.2 Feature Tracking Algorithm in Visual C++

In other to put the feature tracking algorithm in Visual C++ environment, which is the language for the UGV platform, Cam Shift open source library, OpenCV is used. First of all the input image is to be initialized. Then, the histogram is also set to be initialized. Secondly, the image is projected to HSV space. With HSV data set, Hue channel is brought and extracted point and area information. Then, the histogram in the interest region is calculated and tracked with Cam Shift algorithm

3.3 Feature Tracking Algorithm in Visual C++

As shown in Fig. 6, a feature tracking program based on the Cam Shift algorithm is applied to the Visual C++ environment. In dialog frame, there are camera video, target image, and tracking video in 2x2 matrix form. On the upright side, there are buttons related to on/off, tracking region set, and capture, respectively.

As far as the preset Cam Shift parameter, the slider bar form is applied to the form because of the instant optimality check. Last but not least, there result and log data is shown on the down right side and lower column of the dialog.

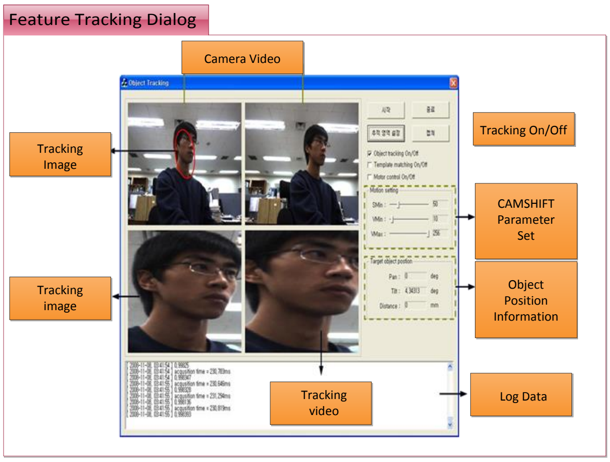

Fig. 6. Feature tracking dialog in visual C++ environment

As shown in Fig. 7, a feature tracking algorithm is implemented in indoor environment. The tracking target is set to be the face of the human. From the result, it is obvious that the target already set is followed and its performance is checked with the good result. However, number (5) in Figure 10 is noticed that the tracking is failed on account of the object vanished by wall. However, once the target value is on the camera, the tracking is restarted and performed as shown in the number (6).

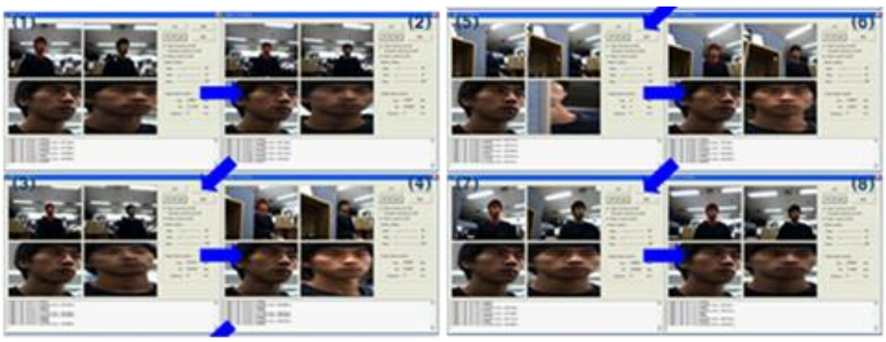

Fig. 7. Feature tracking result

IV. RESULT AND DISCUSSION

The WCA-363N rugged IR PTZ Camera is used. A frame image size of 640□480 data is used. We get 7 frames each second. 12VDC model is designed for vehicle application. Ground for both power and video is just one and therefore the power is not isolated and may damage by surge input if it is installed in genera circumstance not in Vehicle. These cameras offer optimal sensitivity in both day and night shooting applications. At a set level of darkness, the IR-cut filter is automatically disabled (ICR ON) and the near-infrared sensitivity is increased. At a set level of brightness, the filter is automatically enabled (ICR OFF). The IR-cut filter automatically engages depending on the ambient light, allowing the camera 24/7 operation in a variety of lighting conditions.

The Camera delivers clear, high-quality pictures even in backlight, by increasing exposure in dark areas while decreasing it in bright areas a corrected image with clear details results. It is built in 45 pcs LED (Infra-red or white), so it provides visible distance up to 80m in dark (manual focusing). This stable and reliable design makes ideal for car application such as traffic monitoring, car surveillance, because it has IP66 grade, Aluminum die-casting body and Image Stabilizer function. The newly developed focus motor adopts the special ceramic ball as pedestal of shaft (current one is steel ball). This will greatly enhance the durability of focus motor. By increasing the speed of rotation of zoom motor and redesigning the motor screw, the zoom speed will be faster. (4.0sec --> 2.5sec). These cameras feature this function. Each incorporates SMART Lens Control technology, which monitors the focus position of the lens while zooming, and automatically compensates for any mechanical misalignment that may occur over long periods of continuous usage. With this beneficial feature, periodic lens initialization is no longer required during continuous 24-hour operation.

4.1 Fetching Frame Images

The PTZ camera is connected by RS-485 communication. The camera signals are connected by T-BNC connector to IP network server and USB-Image grabber.

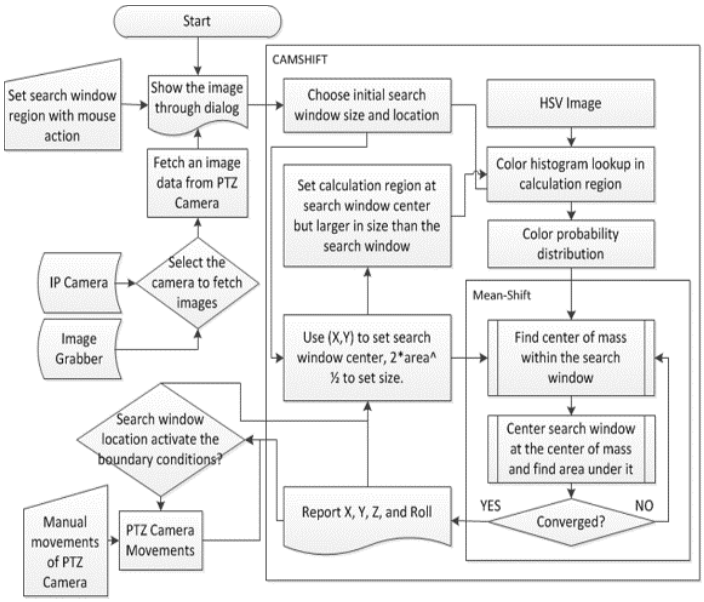

Figure 8: Flowchart of PTZ camera tracking using Cam Shift

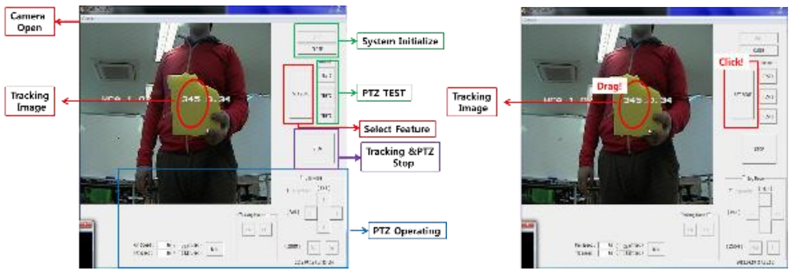

Figure 9: Feature Tracking Dialog and window selection

As the program starts, the main dialog with some buttons appears without showing image from PTZ camera. We need to choose the source of frame images to be processed. Each image comes through the IP network, which makes this system more portable and widely applicable. Frame images are directly transported through the wire without using any mobile network.

Figure 10: Image from Image grabber and IP camera

As the ‘Set zone’ mode is activated, the system watches the mouse action as a user input. The first click is processed to be one corner of the region of interest to extract the sample hue values to make a reference histogram and the second click is the corner of the other side of it.

When a rectangle has determined which has its diagonal connecting the two clicking points, the region information is sent to be used to set the initial search window size and location.

4.2 CAMSHIFT

The frame images through the PTZ camera have the RGB color system. However, this system has a serious disadvantage that it is sensitive to environmental illumination, that is, the RGB value varies corresponding to the amount of lighting on the same color object. For this reason, the frame images need to be converted to HSV color system.

Figure 11: Image histogram

Since the hue value of the HSV color system is relatively insensitive to the change of illumination, it is suitable to be a reference value for being tracked. Hue color histogram is generated with the dominant hue values of selected region. This is maintained by each tracking object as a member structure. Each tracking object also has its own back-project image of the region of interest which represents the 2-dimensional color probability distribution of the hue values of the member histogram. The center of mass point within the search window is determined by the Mean-shift algorithm and the search window shifts to have its’ center is corresponded to the center of mass point. As the algorithm converges, the last center point is sent to be the size and the location of the search window.

4.3 Pan Tilt Zoom Camera Movements

Test whether the search window violates the horizontal and vertical boundary constraints using the coordination of the center point location of the search window and its’ size (height and width). If one of the 4 boundary constraints is activated, the system sends the signal to move the camera viewing direction toward the side of the active boundary. By doing so, the PTZ camera keep the tracking object inside of the camera view.

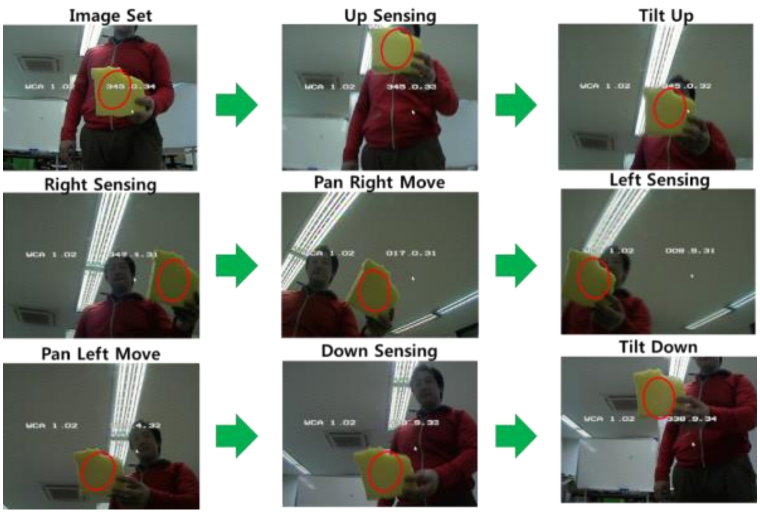

Figure 12: Cam Shift algorithm using PTZ boundary sensing

In case of the tracking failure, jog controller is ready at hand that the four-way camera movement is manually controlled. As shown in Fig. 13 and Fig. 14, a feature tracking algorithm is implemented in indoor environment. The tracking target is set to be the human body. From the result, it is obvious that the target already set is followed and its performance is checked with the good result. However, number (4), (5), (6) in Fig. 14 are noticed that the tracking is failed old tracking image. These situations are occurred by disappeared image because of camera was moving. The algorithm was focused on last selected feature only.

Figure 13: Result of features tracking using IP network server

Figure 14: Result of features tracking using Image grabber

V. CONCLUSION

In this project, development of a feature tracking algorithm was introduced for the surveillance by Unmanned Ground Vehicle. As far as the feature tracking, there are two approaches such as sensor used method and feature used method, respectively. Considering that the price and size of the sensor attachment, the feature based method was chosen to the tracking algorithm.

For the feature tracking algorithm, Mean Shift and Cam Shift are introduced. Firstly, the Mean Shift is an algorithm that finds modes in a set of data sample, manifesting an underlying probability density function based on various feature space (color, scale, etc.) in the region. As far as the Cam Shift algorithm, it is an extended Mean Shift algorithm that is from the stopped images to moving images. It is based on the HSV color based algorithm, which means that the probability distribution is not fixed but changeable so that the performance in real time is better than another conventional algorithm. For the performance check and feasibility test, the Cam Shift was applied to the visual C++ environment. Based on the dialog-based program was generally performed corresponding to the various target image with respect to the color histogram data. For the practical usage, the algorithm was considered both image grabber and IP sever network environments so that the system was applied to indirect and direct circumstances

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