AUTOMATIC RECOGNITION AND LOCATION OF ROAD SIGNS FROM TERRESTERIAL COLOR IMAGERY

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Abstract

Mobile Mapping Systems (MMS) are an emerging technology in Geomatics. They have developed from a concept to a standard mapping tool. They differ from traditional mapping methods mainly by their fast data collection speed and low cost which makes them ideal for data collection in support of the intelligent transportation systems (ITS). The automatic recognition and location of road signs using a ground image algorithm, an important part of a MMS, has been developed but is still complex and not found in commercial systems.

In this paper an automatic road sign positioning and recognition algorithm is presented. For the data collection, the two calibrated sensors, RTK-GPS and digital CCD camera, integrated on a van are used. Road Sign Recognition consists of two parts: Sign detection and Sign Identification. Sign Detection is based on Semi-geometric correction. Sign Identification is based on Image Matching with a Sign Library. The Sign positioning requires of data extraction and Sign position computation. Data extraction is based on Data Synchronization. The Sign Position is based on a new simple algorithm based on surveying principles. However, the result is accurate to realize within a real application in the near future.

1 Introduction

Road Sign Recognition integrated with a Mobile Mapping Systems is a significant challenge. Currently two topics are researched and developed widely in Developed counties such as German, Japan, and others. Specially, Road Sign Recognition is complex and expensive in an experimental step, not in the market. Transforming from the complex sensor-separated system to a simple sensor-integrated system, it is a problem worthy of solution in this region.

Present Mobile Mapping Systems that have incorporated recognition systems are few in number (See Table 1).

Table 1 Mobile Mapping Systems available in the world

System	Developer/Research	Navigation Sensors	Mapping System
GeoVAN	Geospan Crop., USA	GPS/DR	10 VHS, voice recorder
GPS Van	The Ohio State University, USA	GPS/Gyro/Wheel counter	2 CCD, Voice recorder
GPS Vision*	Lambda Tech. Int. Inc, USA	GPS/INS	2 CCD Optical disc
Kiss*	Univ. of Bundeswger Munich and GeoDigital, Germany	GPS/IMU?Inclination Odometer/Barometer	IHVHS, 2BW CCD, Voice recorder
ON-SIGHT	TransMap Crop., USA	GPS/INS	4 color CCD
RGIAS	Rowe Surveying and Engg, Inc, USA	GPS	Video/Laser
TruckMAP	John E. Chance and Engg Inc., USA	GPS/Gryo//WA-GPS	Laser range finder, 1 video camera
VISAT*	The Univ. of Calgary and Geofit., Cadana	GPS/INS/ABS	8 BW CCD 1 color SVHS
WUMMS	Wuhan Technical Uni. Of surveying and Mapping, China	GPS	3 Color CCD, Laser Range, Finder

** MMS have road sign recognition systems
Source: Sompoch P., Special Study: Mobile Mapping, AIT, 1999

Mobile Mapping has been researched and developed since 1980 when the GPS was transferred from military to civilian users. There are three groups of methods. The first research specified the photogrammetry section such as photogrammetric aerotriangulation by GPS (van der Vegt 1988, Colonia 1989, Jacobsen 1993, Ackermann and Schade 1993, Merchant 1994). The second group emphasized mapping land vehicle by combining navigation sensors such as GPS, INS, CCD camera etc. for high-resolution mapping. (Hein 1989, Krabill 1989,chwarz 1993, Scherzinger 1995, Da and Dedes 1995, Schwarz 1996). The last one effects to research the automation rocessing such as the automatic matching of the ground bjects, and traction of the central line of a road (He and ovak 1992, Li 1994, Xin 995, Tao1996)

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Figure 1 the System Architecture

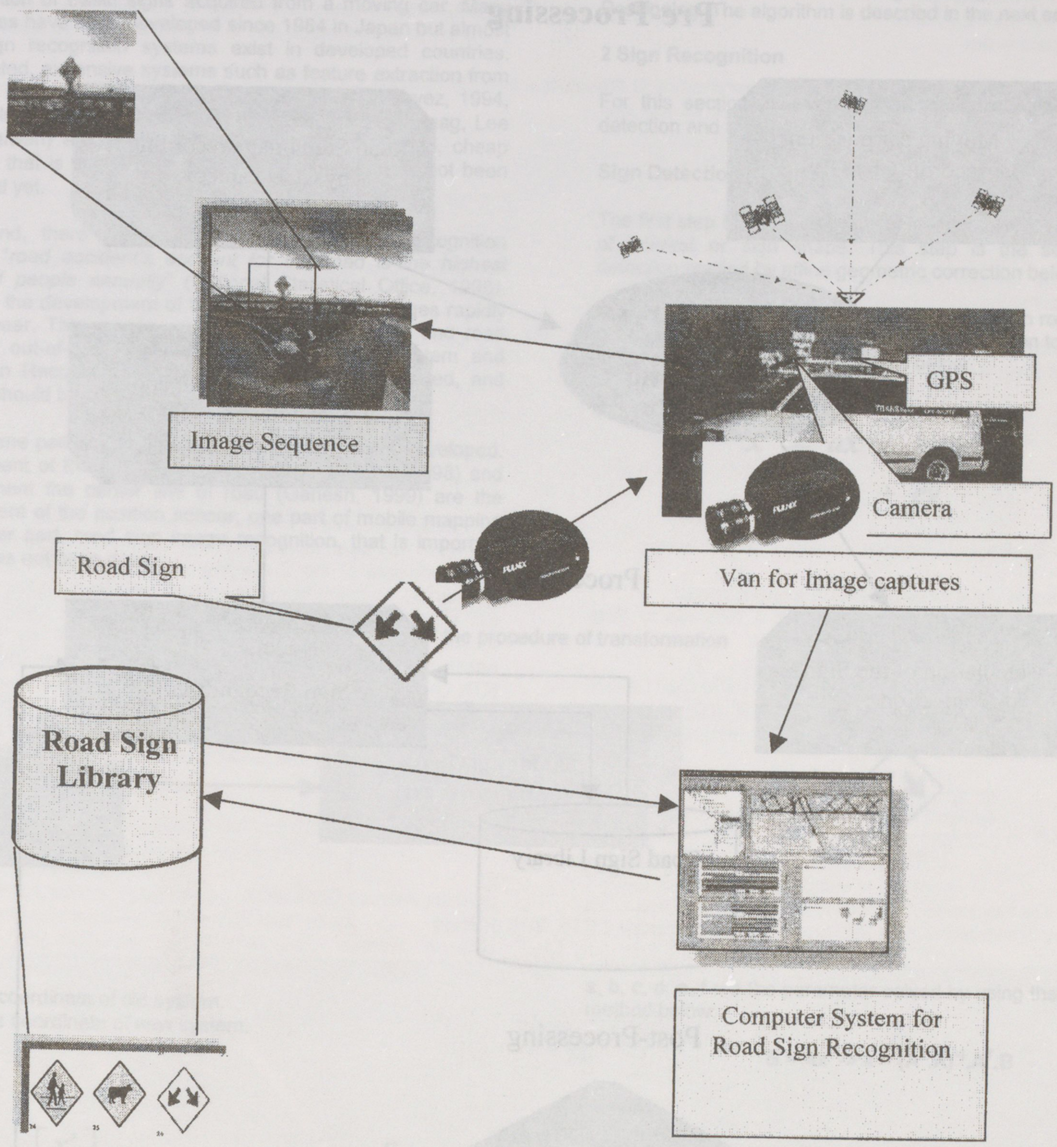
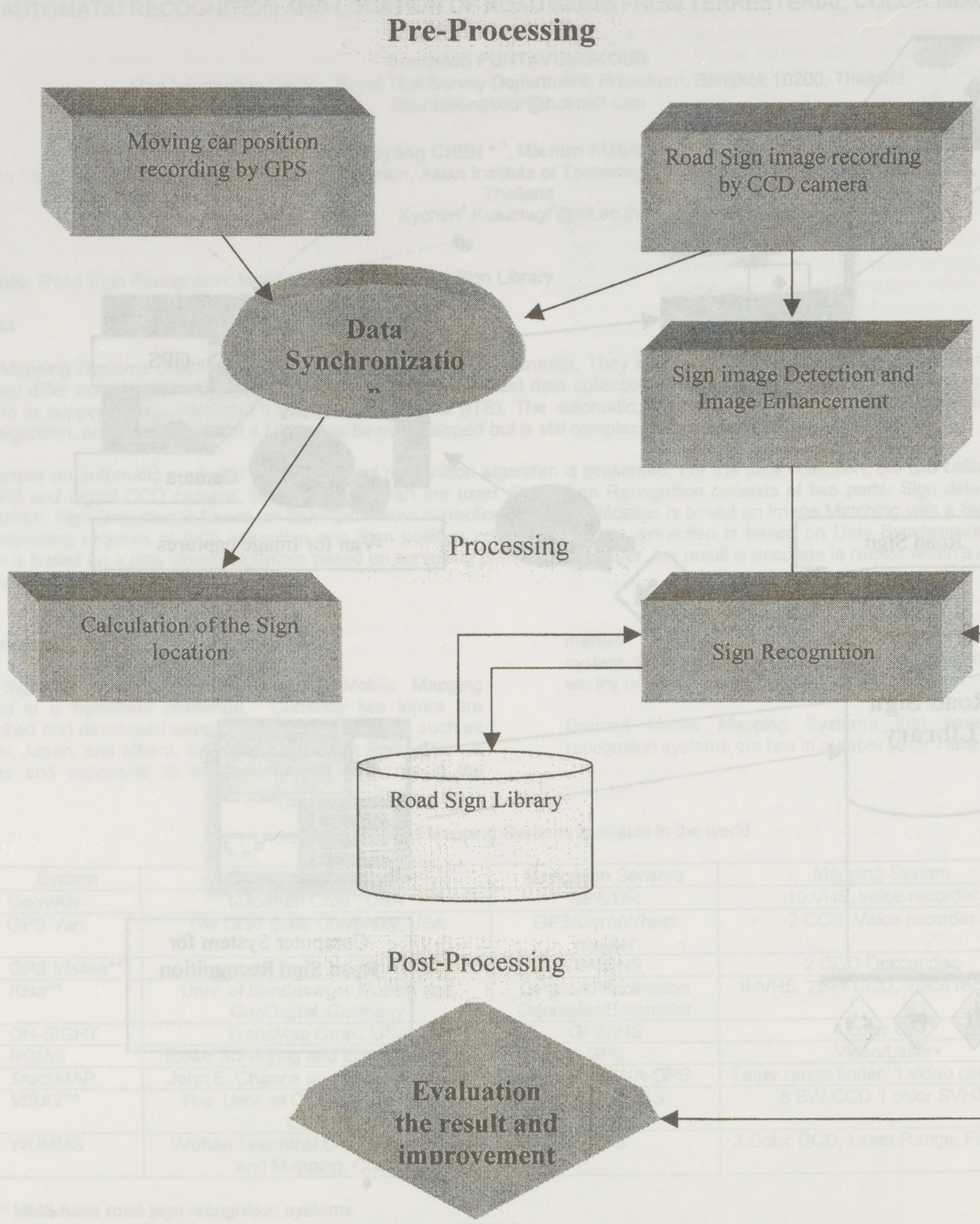


Figure 2 the conceptual framework



Road Sign Recognition is a field of applied computer vision research concerned with the automatic detection and classification of traffic signs acquired from a moving car. Many researches have been developed since 1984 in Japan but almost Road sign recognition systems exist in developed countries. Complicated, expensive systems such as feature extraction from occluded images based in colors (Kentarnavaz, Estevez, 1994, USA), color based signs finder for highways (Frank, Haag, Lee Gang, Taiwan) etc have been developed but a simple, cheap algorithm that is suitable for developing countries has not been developed yet.

In Thailand, there is no research on road sign recognition although "*road accident's account for the road is the highest deaths of people annually*" (National Statistical Office, 1998). Moreover the development of highways systems changes rapidly in each year. This reason makes the road database and road map fast out-of-date. Thus the Mobile Mapping System and Road Sign Recognition System that are not complicated, and low-cost should be considered.

In AIT, some parts of the mobile mapping have been developed. Improvement of the accuracy for RTK-GPS (Dinesh, 1998) and Measurement the center line of road (Ganesh, 1999) are the development of the position sensor, one part of mobile mapping but another part, road sign image recognition, that is important equally, has not been done.

Therefore, the purpose of this study is to develop the new simple algorithm of the Thai Road Sign Recognition and Road Sing Positioning. The algorithm is descried in the next section.

2 Sign Recognition

For this section, the study was separated to two steps: Sign detection and Sign identification.

Sign Detection

The first step in the recognition of the sign is to identify the region of Interest or sign shape. This step is the semi-automated detection applied by affine geometric correction below:

The affine transformation is applied to solve both rotated and scaling distortion of image due to the 3Dimension to 2Dimension projection of a camera by formulae below

$$x' = ax + by$$
$$y' = dx + ey \qquad (1)$$

Figure 3 the procedure of transformation

Where
x, y is the coordinate of old system.
x`, y` is the coordinate of new system.

a, b, c, d, e, f are the parameter solved by using the least square method below:

$$B = Ax \;\rightarrow\; x = (A^T.A)^{-1}.A^T.B \qquad (2)$$

$$B = \begin{bmatrix} x'_1 \\ y'_1 \\ x'_2 \\ y'_2 \\ x'_3 \\ y'_3 \\ x'_4 \\ y'_4 \end{bmatrix} \quad A = \begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_1 & y_1 & 1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_2 & y_2 & 1 \\ x_3 & y_3 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_3 & y_3 & 1 \\ x_4 & y_4 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_4 & y_4 & 1 \end{bmatrix} \quad x = \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \end{bmatrix}$$

Where
A = a metric of the old coordinate
B = a metric of the old coordinate
x metric of the parameter

This step was the Sign extraction form the environment and the geometric correction of the distorted image as size as the sign image in Sign Library.

Sign Identification

The key part of this study is the identification of Road Sign type. The research was simplified with the gray-scale image processing. The image matching with Normalized Euclidean Distance was considered in this step below:

Euclidean Distance, simple Image Matching was applied for Road Sign Recognition by formulae below:

$$E(i,j) = \sum_i \sum_j [g(i,j) - t(i,j)] \quad (3)$$

Where

E (i,j) is the Euclidean Distance between target image and Template.
g(i,j) is a gray scale value of each pixel in a target image.
t(i,j) is a gray scale value of each pixel in a template in Sing Library.

The most similarity of a target image and template in Sign Library provides the minimum the Euclidean Distance (E (i,j)) compared with the Euclidean Distance(E (i,j)) of every template in Sign Library .

$$NED = \frac{\sum_i \sum_j [g(i,j) - t(i,j)]}{(imagesize)^2} \quad (4)$$

Because of a large number of the Euclidean Distance (E (i,j)), the Euclidean Distance is normalized by dividing with some constant. Here the power of image size is applied by formula below:

$$NED = \frac{E(i,j)}{(imagesize)^2} \quad (5)$$

Where

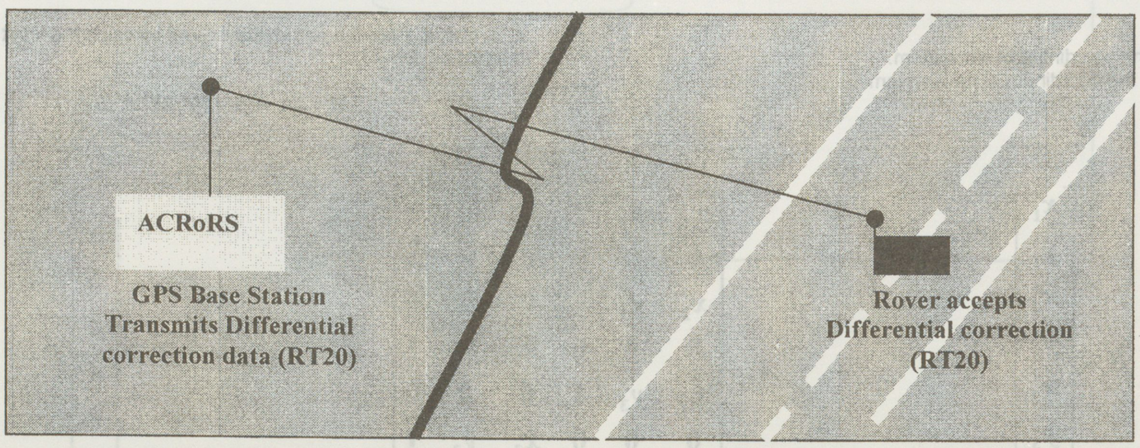
NED is the Normalized Euclidean Distance.
The image size = (a range of gray scale)*(the wide of image)*(the length of image)*(number of color channel)

Compared with all sign image in Sign Library, The minimum value of the Normalized Euclidean Distance with each sign image in Sign Library identifies the type of the sign from a target image.

3 Sign Positioning

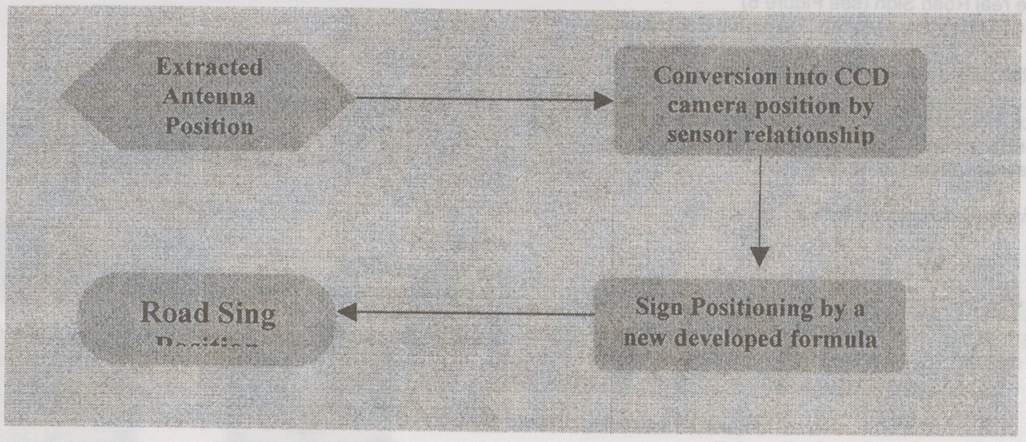
To obtain the high accurate Road Sign position, the new algorithm has been developed. The Data synchronization and the basic principle of the Surveying are applied with RTK-GPS as well as the constant from the sensor calibration. While the digital CCD camera records the digital image of the Road Sign, the moving rover station position are recorded by RTK-GPS positioning techniques simultaneously. With the advantage of RTK-GPS, the high accurate rover position is provided between 8-20 cm Standard Deviation every second. Moreover the important factor is unavoidable that the rover station antenna is on the road central line while the rover station is moving (see Figure 5).

Fiqure 4 RTK-GPS method



After the rover position and time are recorded by RTK-GPS positioning techniques, some rover position is extract by using the time as same as the image recorded time. The extracted rover position is calculated for the Road sign recognition in the next step.

Figure 5 Scheme of Road sign position by a new algorithm



After the position of rover is extracted, it is converted into the digital CCD camera position on the vehicle. This position is applied to calculate the Road Sign position below:

$$P_{CCD} = P_{Antenna} + C \qquad (6)$$

Where

P_{CCD} is the Digital CCD camera position on the moving vehicle.
$P_{Antenna}$ is the GPS antenna position on the moving vehicle, extracted from Step No.3.
C is the GPS antenna position and digital CCD camera position relationship on the vehicle from sensor calibration.
C is the GPS antenna and Digital CCD camera position relationship on a vehicle from the instrument calibration.

This formula is divided in 2 axis: x and y axis for a planar coordinate (Northing, Easting) based on WGS-84 datum by following:

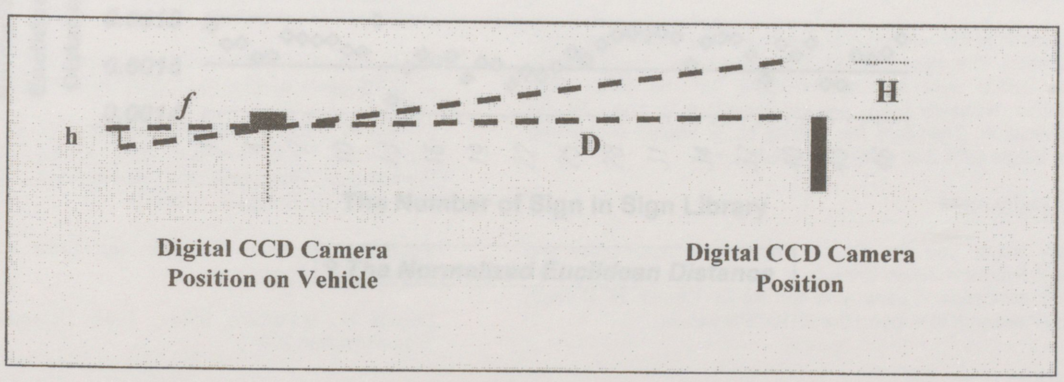
$$X_{CCD} = X_{Antenna} + \Delta X$$
$$Y_{CCD} = Y_{Antenna} + \Delta Y \qquad (7)$$

Where

X_{CCD} is the Digital CCD coordinate in Easting.
Y_{CCD} is the Digital CCD coordinate in Northing.
$X_{Antenna}$ is the GPS coordinate in Easting.
$Y_{Antenna}$ is the GPS coordinate in Northing.
ΔX is the GPS antenna and Digital CCD camera in x-axis.
ΔY is the GPS antenna and Digital CCD camera in y-axis.

The next important parameter for Sign position in this method is the distance between the Digital CCD camera position and Sign position in the real world by following:

Figure 6 the calculation of the Distance from the CCD Camera to the Road Sign



$$\frac{h}{H} = \frac{f}{D} \tag{8}$$

Where
h = the height from Image of Road Sign
H = the height of the real Road Sign (see Figure 6)
f = Focus length of CCD Camera from the Instrument Calibration part
D = Distance from the CCD Camera to the Road Sign

Finally, the distance from the camera position to the road sign and the camera position is determined. The Road Sign position is calculated by the new developed formula below:

From figure 7, the formula is obtained below:

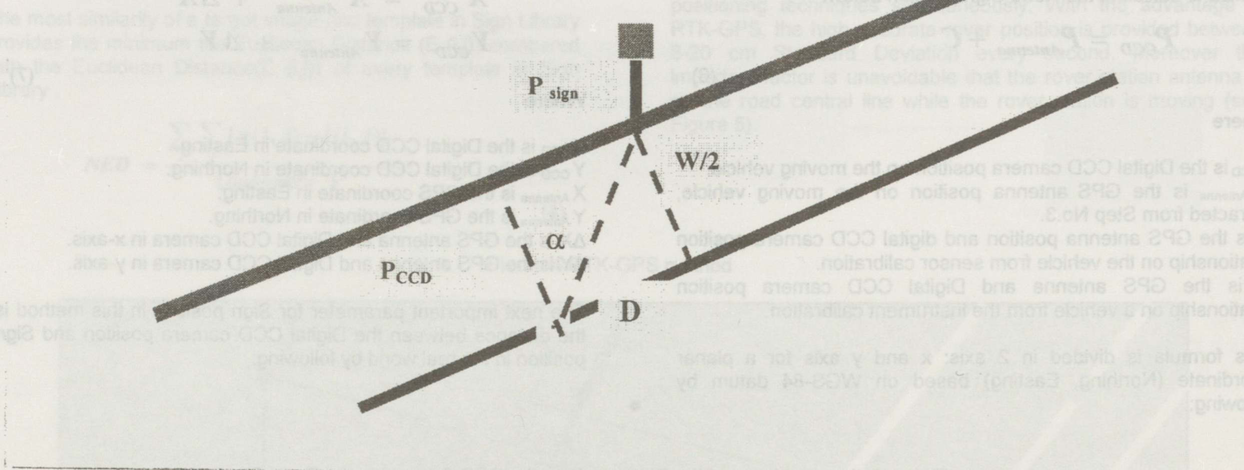
$$\alpha = Sin^{-1} \frac{w/2}{d} \tag{9}$$

Where
w is the road width.
d is the distance between the road sign and the digital CCD camera position.
Therefore the position of road sign is calculated by following

$$X_{sign} = X_{CCD} + dCos\alpha$$
$$Y_{sin\,g} = Y_{CCD} + dSin\alpha \tag{10}$$

Where
w is the road width.
d is the distance between the road sign and the digital CCD camera position.
Therefore the position of road sign is calculated by following

Figure 7 Positioning of Road Sign

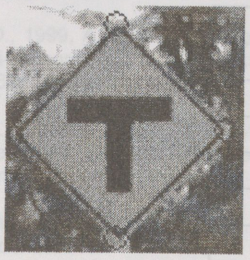


4 Result

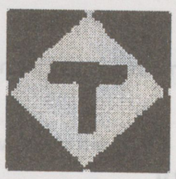
The algorithm has been valiadted in this study below:

Some example of Sign Recogntion Result form the study

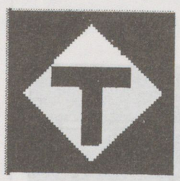
Figure 8 Sign No.4 Result



-Four Points were selected to calculate the affine parameter and the distorted road sign image was extracted.

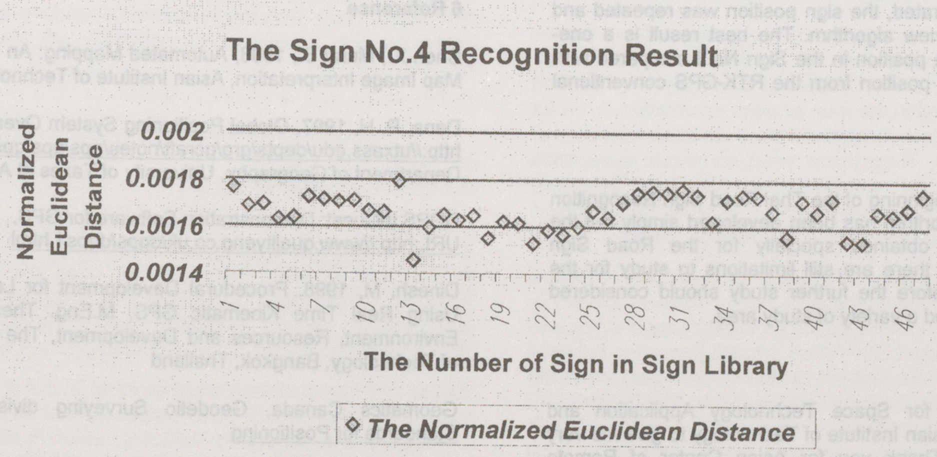


-After a distorted sign image was selected and corrected for geometry, two images were displayed. The left image is a geometric corrected image of the same size as the sign in Sign Library. The right image is an interpolated image.



-After a geometric corrected image was calculated for Normalized Euclidean Distance with every Sign image in Sign Library, the program sorted the minimum Normalized Euclidean Distance (NED) from all images of Sign Library and finally that image was display as the temple matching result. (See Figure 8)

Figure 9 the Sign No.4 Recognition Result



The recognition result was provided very accurately because the gray-level image processing is simple and fast to calculate the template matching. Moreover the sign images do not have the pattern variation. However, still, this step is not a real-time processing depending on the hardware.

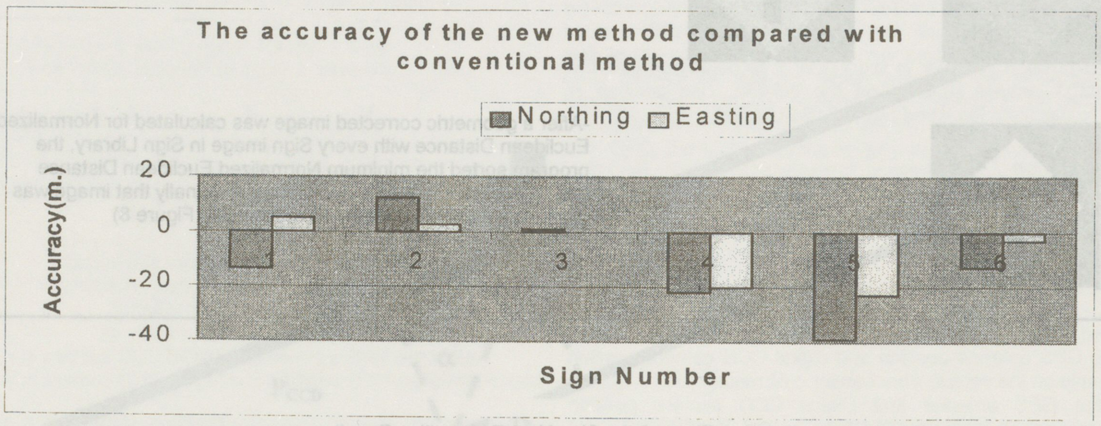
Example of Sign Positioning by a new algorithm

The result was calculated (see table 2) and compared the accuracy with the conventional method (see the figure 9).

Table 2 each sign position by the indirect measurement

	Northing(Meter)	Easting(Meter)
Sign No.1	1554294.8	647194.1
Sign No.2	1554266.4	647046.8
Sign No.3	1554272.9	646760.6
Sign No.4	1554289.3	646318.5
Sign No.5	1554231.7	646156
Sign No.6	1554136.7	646136.8

Figure 11 the accuracy of the new method compared with conventional method



After sensor was calibrated, the sign position was repeated and recalculated with the new algorithm. The best result is a one-meter difference of the position in the Sign No.3 compared with the high-accurate sign position from the RTK-GPS conventional method.

5 Conclusion

This research is the beginning of the Thai Road Sign Recognition and Location. The algorithm has been developed simply but the accurate result was obtained specially for the Road Sign Recognition. However there are still limitations to study for the real application. Therefore the further study should considered with the Single GPS and a variety of study area.

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