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Automobile location determination algorithm based on fundamental matrix and triangulation approaches

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Abstract
GPS has certain limitations, such as difficulty functioning indoors due to weak signal transmission and obstruction by building structures. It also faces challenges in urban areas with tall buildings blocking the view between the receiver and satellite. Additionally, certain applications require a higher level of accuracy than what is typically provided by GPS receivers. In this paper, computer vision technologies were utilized to develop an algorithm that calculates the location of an automobile using only two images as input. The fundamental matrix and triangulation methods were employed to determine the location of the target automobile. An NVIDIA Jetson TX2 Development Kit camera was used to capture two consecutive images of the automobile. The location of the targeted automobile was then determined through the use of the normalized 8-point algorithm and the triangulation approach. This algorithm is effective in both indoor and outdoor environments.

Keywords: Fundamental matrix, normalized 8-point algorithm, triangulation

1. Introduction

The common approach for determining location is GPS

The GPS system is capable of determining the location of any object uninterrupted, all over the world. It sends satellite signals to an indefinite number of users who can only receive these signals. This system is called a passive system since it is a one-way system. The system includes twenty-four working satellites that provide satellite signals freely anywhere on the planet. These twenty-four working satellites are organized into six orbital planes, each containing four satellites, as shown in Figure 1. This arrangement guarantees that four to ten satellites can be seen anywhere on the planet. To determine a location on the planet, we only require four satellites. As shown in Figure 2, the GPS system consists of the following components: the space segment, the control segment, and the user segment. The space segment contains the twenty-four -satellite constellation, with every satellite sending a signal that includes two carrier frequencies, two digital codes, and a navigation message. The carriers and codes are mainly utilized to compute the distance from the GPS satellites to the recipient’s device.

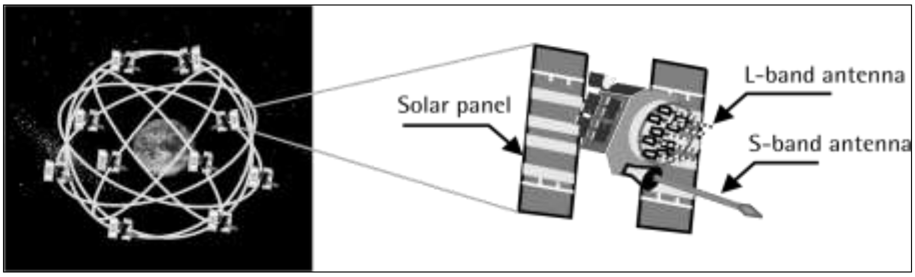

Fig 1: GPS constellation.

1.2 The Working Theory of GPS

The main principle of GPS is straightforward: it involves computing the distance between a recipient on the planet and three satellites whose locations are known. A Resection approach is then used to determine the recipient’s location. The GPS satellites send microwave radio signals that contain two carriers, two codes, and a navigation message.

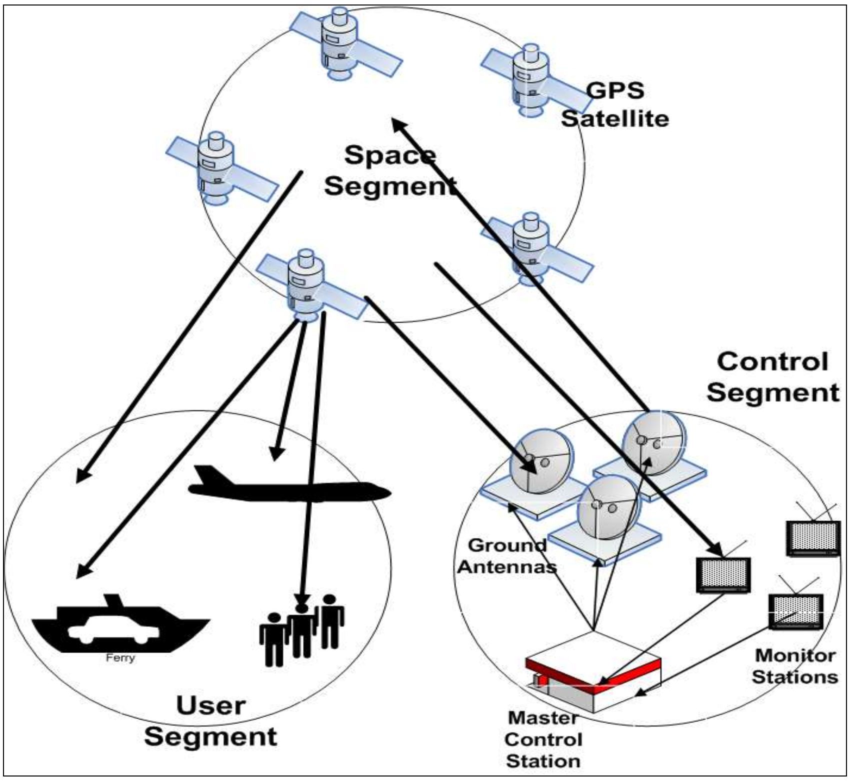

Fig 2: GPS segments.

These signals are received by the recipient, who can analyze them to compute their distance from the satellites during the navigation message. To compute the location of the recipient, four spheres are intersected, each with a radius equal to the distance from the recipient to a specific satellite. This method is illustrated in Figure 3 [1].

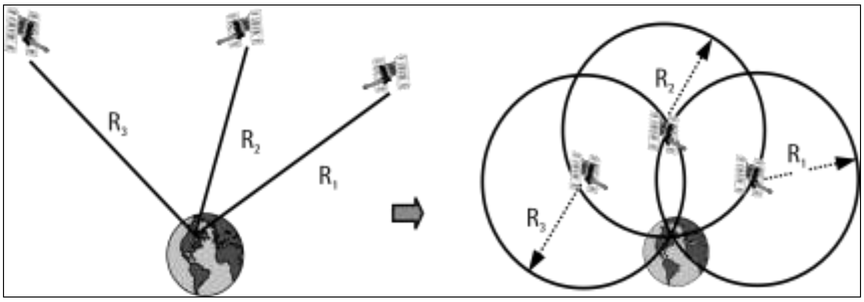

Fig 3: Basic idea of GPS positioning.

GPS has certain limitations, such as difficulty functioning indoors due to weak signal transmission and obstruction by building structures. It also faces challenges in urban areas with tall buildings blocking the view between the receiver and satellite. Additionally, certain applications require a higher level of accuracy than what is typically provided by GPS receivers. In this paper, computer vision technologies were utilized to develop an algorithm that calculates the location of an automobile using only two images as input. The fundamental matrix and triangulation methods were employed to determine the location of the target automobile. The location of the targeted automobile was then determined through the use of the normalized 8-point algorithm and the triangulation approach. This algorithm is effective in both indoor and outdoor environments.

2-Method

This paper utilizes the following concepts.

2.1 Epipolar Geometry: Epipolar geometry relies on three factors: the internal calibration of the camera, the relative rotation between two views, and their translation. It is worth noting that epipolar geometry does not require view construction. When a point is present in the left view, it is projected onto an epipolar line in the right view. The relationship between the two views is visually explained in Figure 4 [2].

Fig 4: Epipolar geometry.

2.2 Fundamental Matrix

$$x_r^T F x_l = 0 \quad (1)$$

Point X is captured by both the left and right cameras, with xl and xr representing the images captured by each camera, respectively. The relationship between the two images is defined by the fundamental matrix, which connects the coordinates of the point in the left image with its corresponding point in the right image. However, to compute the three-dimensional coordinates of the point, we need the essential matrix, which also provides the rotation and translation between the two images. Furthermore, the normalized eight-point Algorithm is used to calculate the fundamental matrix [3].

2.3 Computing Fundamental Matrix in Practice

Figure 5 illustrates the steps involved in the fundamental matrix approach for computing the relationship between two views of a car. The process begins by capturing two views of the vehicle and applying filters, such as noise removal or grayscale conversion. Next, the feature detection process is carried out to identify significant points using methods like the ORB detector. The feature matching step follows, where points in the two views are matched using techniques like the BF matcher. The matched points are then normalized, and the fundamental matrix is computed. Figure 6 shows real views of 100 identified points [4].

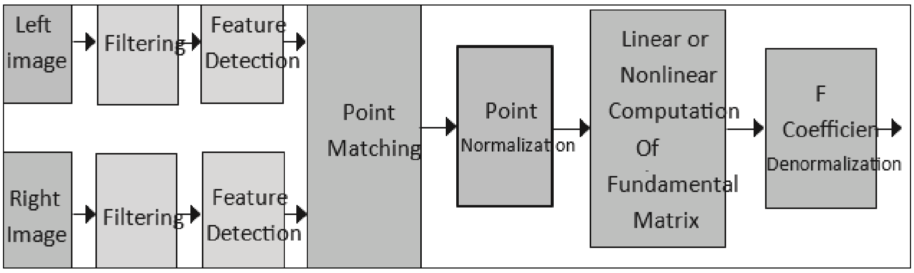

Fig 5: Computation of the F approach.

Fig 6: Real views of 100 identifying points.

2.4 Triangulation

Point X is captured by both the left and right cameras, with x and x' representing the image points captured by each camera, respectively. The relationship between the two images is defined by the fundamental matrix, which connects the coordinates of the left image point with the corresponding point in the right image. The camera matrices P and P' should be known [5].

$$x = PX \ (2) \ x` = P' X \quad (3)$$

The two rays corresponding to the identifying points x and x' will meet in space if and only if the points satisfy the epipolar constraint xrT F xl = 0. Figure 7 depicts the triangulation method.

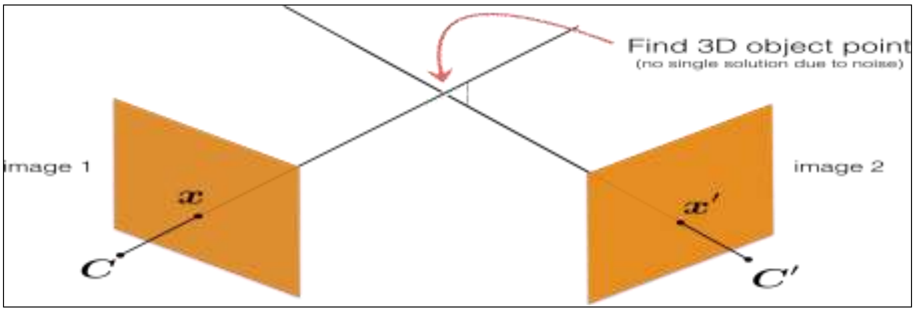

Fig 7: Triangulation method.

2.6 The Built System

The built system relied on an Nvidia Tx2 board and applied the Suliman algorithm as follows: First, the scene of an automobile was captured by the left camera and then by the right camera of the NVIDIA Jetson TX2 Developer Kit, resulting in two successive views of the automobile. The internal calibration of the camera needed to be known. These two captured views were then received by the Suliman algorithm, which used image processing technologies to analyze them. In the first stage, feature detection was performed using ORB detector, while in the second stage, feature matching was implemented using BF matcher. As a result, eight points were selected. In the third stage, the coordinates of these selected points were extracted. Then a normalization stage was performed, where the centroid of these eight selected points in the left view was determined, and the range was computed. Then the entire eight selected points were normalized between zero and one. This process was also performed for the right view. The fundamental matrix was then calculated. Finally, the three-dimensional coordinates of the selected points were calculated using the triangulation approach, and the angles which these points made with the x-axis, y-axis, and z-axis were also calculated.

Suliman algorithm ()
{Camera takes two images of an automobile perform camera calibration matrix perform feature detection using ORB detector perform feature matching using BF matcher coordinates extraction perform normalization compute the fundamental matrix compute the essential matrix perform triangulation approach calculating the angles}
Suliman algorithm for the Automobile location Determination.

3. Results

The objective was to create a computer program that could identify the location of a vehicle using computer vision technologies. This was achieved through a series of stages. Firstly, the left and right cameras of the NVIDIA Jetson TX2 Developer Kit captured two successive views of the automobile, and the internal calibration of the camera was determined. The captured views were then processed by the Suliman algorithm using image processing technologies. In the first stage, feature detection was performed using ORB detector, and in the second stage, feature matching was implemented using BF matcher. As a result, eight points were selected, as shown in Figure 8. In the third stage, the coordinates of these selected points were extracted, as depicted in Figure 9. A normalization stage was then performed, where the centroid of the eight selected points in the left view was determined, and the range was computed. The entire eight selected points were normalized between zero and one, which was also performed for the right view, as demonstrated in Figure 10. The fundamental matrix was then calculated, as seen in Figure 11. Then, the camera calibration matrix was determined using the chess board approach, as shown in Fig. 12. The essential matrix was then computed since the fundamental matrix equals the essential matrix multiplied by the camera matrix, as shown in Fig. 13. Finally, the triangulation approach was used to calculate the three-dimensional coordinates of the selected points, and the angles made by these points with the x-axis, y-axis, and z-axis were also calculated, as illustrated in Figures 14 and 15, respectively.
Therefore, by using just two consecutive images and applying image processing techniques we were capable of computing the location of the vehicle.

Fig 8: feature matching process

```
pts1=[[180 422]
      [212 428]
      [213 420]
      [182 428]
      [206 420]
pts2=[[180 422]
      [212 428]
      [213 420]
      [182 428]
      [206 420]
```

Fig 9: Extraction of the coordinates

```
[1.22347177 1.29237819 1.20050297 1.29237819 1.200502
 1.29237819 1.28089379 1.28089379 1.20050297 1.211987
 -1.16528413 1.26940939 -2.24481804 1.21198737 -1.142315
 -1.14231532 1.26940939 1.23495618 -0.79778322 -1.176768
 -0.45325112 -0.45325112 -0.77481441 -0.57957956 -303953]
 [1.        1.         1.         1.         1.]
```

Fig 10: Normalization process

```
F= [[-9.66004289e-21 1.97323402e-05 1.71161539e-03]
[-1.97323402e-05  5.74848234e-21  4.31833796e-03]
[-1.71161539e-03 -4.31833796e-03 1.11022302e-15]]
```

Fig 11: Fundamental matrix

```
([[243,0,157],
  [0,243,122],
  [0,0,1]])
```

Fig 12: Camera matrix

```
E= [[-5.70415873e-16 1.16517496e+00 1.00090750e+00]
  [-1.16517496e+00 3.39442134e-16 2.96547614e-01]
  [-1.00090750e+00 -2.96547614e-01 1.11022302e-16]]
```

Fig 13: Essential matrix

```
P best [[-2.34194499e+00 -3.05471086e+01 -2.47431580e+01]
[-8.45707084e+00 -4.70520669e+01 -3.73648766e+01]
[3.99068169e+01 2.12361275e+02 1.73167080e+02]
[-1.66951407e+00 -2.04348523e+01 -1.62276768e+01]
[-8.54710185e+01 -5.19803337e+02 -4.23866480e+02]
[5.95155066e-01 4.20489992e-02 7.85992831e-01]
[-1.22053569e+00 -1.86741960e+01 -1.48295086e+01]
[-9.90921060e+00 -5.49510769e+01 -4.37806941e+01]
```

Fig 14: The coordinates of the selected points

Anglex = 81.748389

Angley = 39.939786

Anglez = 51.312694

Fig 15: Angles of the selected identifying point

4. Discussion
The paper introduces a novel algorithm for determining the location of a vehicle using computer vision techniques, including the fundamental matrix and triangulation. This algorithm can be used both indoors and outdoors and relies on only two consecutive images. The image processing and computer vision mechanisms utilized in this paper, such as image enhancement, fundamental matrix, and triangulation, computed the vehicle location accurately and quickly without needing satellite signals. However, the algorithm highly relies on feature detection, and the existence of outlier features may result in imperfect locations. Furthermore, the system needs obvious views of the vehicle and may not perform excellently in harsh weather conditions such as fog or rain, although image enhancement filters can be applied to enhance performance.

5. Conclusion
This study utilized computer vision technologies to locate automobiles. By capturing only two images of a vehicle, its location can be determined. This technique could be useful in cases where a vehicle has been stolen and the location needs to be reported to the police. Additionally, the location determination approach could also be applied to trucks and lorries.

6. Abbreviations
Not applicable

7. Declarations
- The author is committed to the Committee on Publication Ethics (COPE) guidelines.
- -The author agreed to publish the article.
- The author has no relevant financial or non-financial interests to disclose.
- No funding was received for conducting this study.
- -[Hamed M. Suliman] conducted all the experiments and wrote the whole article.

8. Acknowledgements
Not applicable

9. Data Availability Statement
No datasets generated during the study.

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