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Stable Position Measurement of a Moving Airplane by Adaptive Camera Control

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ABSTRACT-*A method is developed to identify a taxiing airplane and measure its position correctly under various lighting and weather conditions by inputting a moving image from an adaptively-controlled camera into an image processor and analyzing the image in order to guide the plane to the appointed parking spot.*

Since the airplanes are moved in outdoors, there are many factors, such as varying sunlight levels, night lighting, and weather conditions like rain, that affect the input image and make it more difficult to accurately judge the airplane's position.

We propose an adaptive camera control system which controls the lens aperture and camera gain in order to get the best image to extract the characteristic points accurately under all condition. Cameras with an ordinary aperture lens systems have too small a dynamic range to produce suitable input images because saturated pixels in a bright area and dark areas affect the brightness of pixels adjacent to them. Our adaptive camera system converts radiance into gray levels in a variety of modes, so that the best mode can be selected according to the lightning characteristics.

To easily determine the characteristics to be used and validate their effectiveness, we constructed a 1:200 scale airport model and performed experiments with it in a darkroom, simulating the various environmental conditions encountered at actual airports. By identifying the edges of the tires and the guide line and approximating them as straight lines, we were able to measure the positions of the characteristic points to within 2 pixels under various conditions, corresponding to an accuracy of 20 centimeters in actual airports, which satisfies the desired specifications.

1. Introduction

The current method of docking an airplane necessitates a marshaller and other human observers. It would therefore be advantageous to have an automatic sensing and guidance system. This system should display the lateral displacement of the airplane from the truck line, its displacement from the stop line and its speed. In this paper, we examine a system which recognizes a taxiing airplane, and determines its position, which can then be displayed.

The sensing area from the entering position to the stop position is very long (20 meters to 100 meters from the terminal building) and the required accuracy is within 50 centimeters. A TV camera has the advantage of being able to cover the whole area with one sensor, so we adopted a technique which employs a TV camera.

Many TV camera measuring techniques are used in many fields. Most techniques are based on extraction of characteristic points from the image and calculation of the distances between them. Pattern matching techniques are also used. In the Factory-Automation field, controlling the camera position and lighting conditions makes for accurate distance measurement [1]-[4]. However, since airplanes are in outdoors, there are many factors, such as varying sunlight levels, night lighting, and weather conditions like rain, that affect the input image and make it more difficult to accurately judge the airplane's position.

We propose an adaptive camera control system which controls the lens aperture and camera gain in order to get the best image to extract the characteristic points accurately under all condition. Cameras with ordinary aperture lens systems have too small a dynamic range to produce suitable input images. The desired accuracy cannot be achieved because saturated pixels in bright area and dark areas affect the brightness of pixels adjacent to them (see Fig. 1). Our adaptive camera system converts radiance to digital 256 gray levels in a variety of modes, so that the best mode can be selected according to the lighting characteristics.

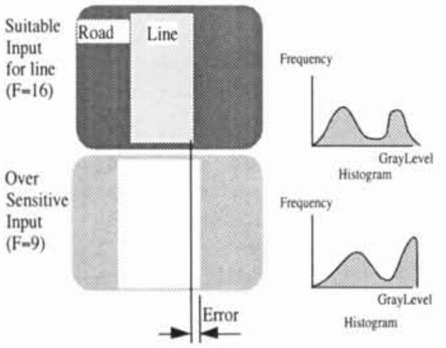

Fig. 1 Egde Characteristics

To control the conversion characteristics, the system uses the image to identify the objects which contain the characteristic points, and using these objects as a reference, controls the aperture adaptively. In the case of the airport, the position of the airplane can be measured using the guide line and stop line, which have fixed characteristic points with high radiance, and the tires and axle of plane which have moving characteristic points with low radiance.

2. Basic Idea of Adaptive Camera Control

Figure 2 shows the conversion characteristics from radiance to gray levels and resulting converted images. The radiance histogram of the scene is shown below. The three areas of importance in the scene are shown in Fig. 2 (A). The radiance is converted to digital gray levels using three different conversion characteristics. Using mode I, high radiance objects are mapped to a wide range of gray levels, allowing dark objects to be identified accurately to extract dark objects accurately. Using mode II, high radiance areas and low radiance areas are both saturated. Objects with high radiance are measured using mode III. By selecting a suitable mode for controlling the aperture and camera, we can accurately measure the positions of characteristic points both on high radiance objects and on low radiance objects.

3. Measuring the Position of a Taxiing Airplane

3.1 Object-Region Extraction

To control the conversion characteristics, the system recognizes from the image the objects which have characteristic points. The most stable objects that indicates the position of the airplane are its tires, especially the front tires. Thus we use the front tires as target objects and control the camera system in order to extract them from the input image. The most stable objects for the identifying appointed position of the parking spot are the guide lines and stop line.

The guide lines in the spot area are lighter than the road. The gray level in the line regions is thus higher than in the other objects. These regions are detected by dividing the input image into suitably sized blocks and analyzing the gray level histogram of each block.

In the image of a parking spot, the airplane's tires have characteristic gray level distribution. That is, the tire region contain many dark pixels. Thus, the tire blocks can be also extracted by analyzing the gray level histograms. Figure 3 shows an example of object-region extraction.

3.2 Camera Control

Our system has multi-mode conversion characteristics from radiance to gray levels.
The positions of dark objects, such as tires, are mea-

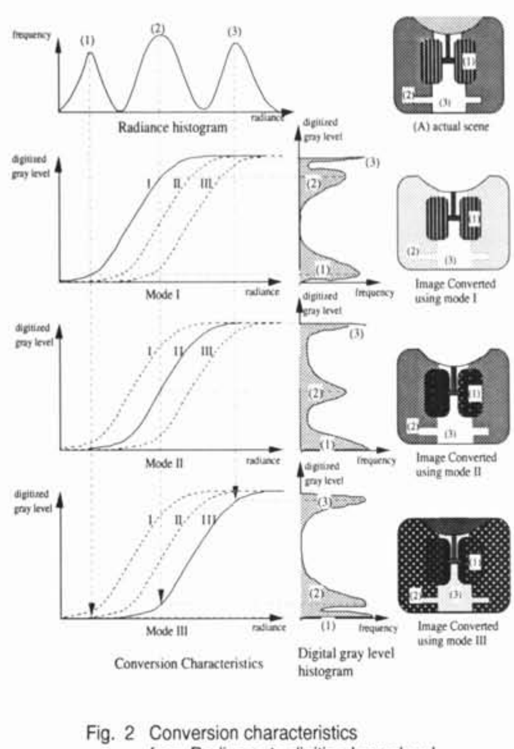

Fig. 2 Conversion characteristics from Radiance to digitized gray level and resulting images using these

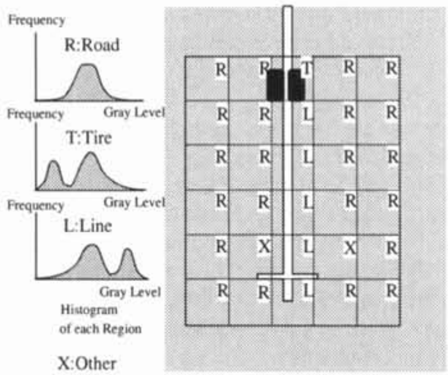

Fig. 3 Object Region Detection

sured in mode I, while light objects, such as lines, are located in mode III.

The lens aperture and camera gain are programed separately for each mode. The basic position is mode II, using a normal auto aperture lens system which controls the aperture by using analog camera signals. Then we control aperture to select other mode for measurement of each object. In this case, the aperture is twice as wide in mode I and half as wide as in mode III. If the target objects' regions are still saturated, the camera gain control is controlled.

3.3 Extraction of Tire Edges

The characteristic points of the tires are defined as the corners of the rectangle surrounding them. The procedure used to obtain these characteristic points is shown below.

(1) Rough extraction of tires
(2) Detection of object edges in these regions
(3) Approximation of the edges as straight lines
(4) Extraction of the characteristic points at the intersections of these straight lines

The rough tire regions are extracted as mentioned in the previous section. We then analyze the gray level of pixels on the lines in each region, in the case of a vertical edge we analyze the pixels on the horizontal lines (Fig. 4). The edge point is where the gray level changes from that of the tire to that of the road. In our high quality input image (using a typical CCD sensor with 410,000 pixels), the gray level changes over 2 or 3 pixels because of smoothing in the camera circuit. So we define the mid-point of this transition as the edge. The position of the object in the image is calculated by approximating the edges as straight lines and obtaining the points where these edges intersect.

Figure 5 shows how actual distance is calculated.

4. Experimental Result

To easily determine the characteristics to be used and validate their effectiveness, we constructed a 1:200 scale airport model and performed experiments with it in a darkroom, simulating the various environmental conditions encountered at a real airport. By identifying the edges of the tires and the line and approximating them as straight lines, we were able to measure the positions of the characteristic points to within 2 pixels under various conditions, corresponding to an accuracy of 20 centimeters in actual airports, which satisfies the de-

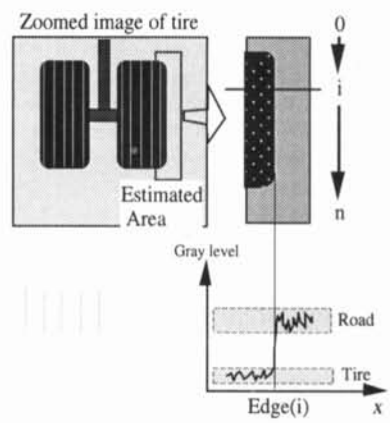

Fig. 4 Tire Edge Detection

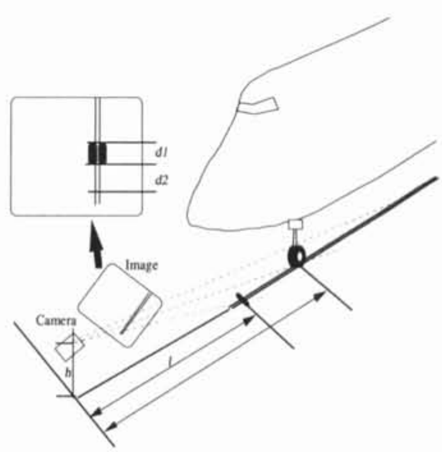

Fig. 5 Distance Calcuration

sired specifications.

To evaluate of the model simulation's reliability, we collected images of an actual airport while controlling the lens aperture. The gray level histograms around the tires and the line were almost the same. By extracting the edges of the tires and the line and approximating them as straight lines, we could also obtain the positions of the characteristic points to within 2 pixels.

5. Conclusion

We have proposed a stable position measurement technique that operates various outdoor conditions using adaptive camera control. According to our experimental results, the proposed camera control method is very effective. By identifying the edges of the tires and the guide lines and approximating them as straight lines, we can measure the positions of the characteristic points to within 2 pixels under various conditions, corresponding to an accuracy of 20 centimeters in actual airports.

We are now ready to install a real-time distance measuring system in an actual airports and test it under actual conditions.

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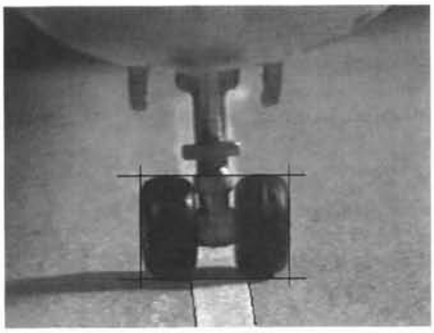

Fig. 6 A simulation result using darkroom

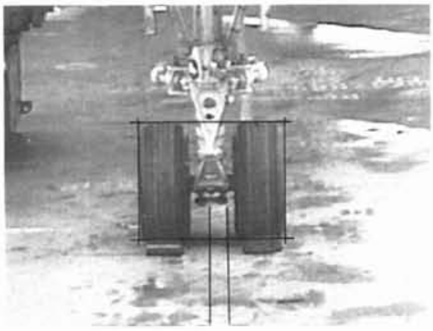

Fig. 7 An identifying result from an actual image