A New System for Detecting Obstacles in Front of a Train

Masato UKAI
Senior Researcher, Signalling Systems, Signalling & Telecommunication Technology Division

To ensure the safety of train operations, it is absolutely essential that we prevent trains from hitting an obstacle and possibly derailing. At present, however, detection of an obstacle in front of the train depends largely on the sight of the driver. We therefore developed an onboard system that detects obstacles in front of the train for the driver.

Two conventional methods employed to detect obstacles are: the active method using millimeter wave radar or laser radar, and the passive method using image recognition (machine vision). The former is now being put into practical use for motor vehicles. However, this method has several problems that remain to be solved, such as insufficient spatial resolution and short detection distance. The method is still not suitable for railway operations, where the required detection distance is as long as several hundred meters. We therefore decided to apply a passive detection method using a single-lens camera. We chose a low-brightness CCD camera that can be used day and night, to permit use of the system even in the dark.

Processing images from an onboard camera faces the following problems.

Figure 1. Extraction of rails through application of the Hough transformation

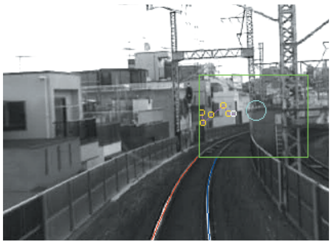

Figure 2. Detection of rail vanishing point

Figure 3. Pan head for automatically tracking rail vanishing point

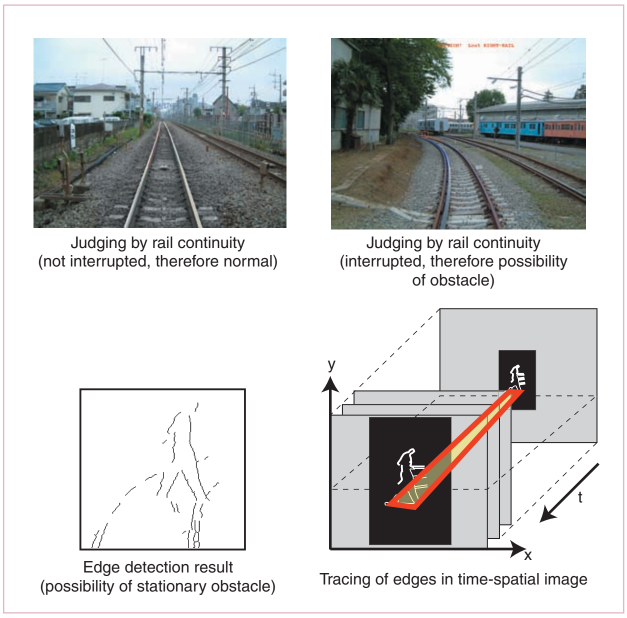

Figure 4. Results of detection of stationary obstacle

First of all, since a telephoto lens is used to monitor long-distance perspectives, images are susceptible to blurring, especially when vehicle vibrations are large. When blurring occurs, a moving vector (optical flow) consisting of horizontal and vertical components appears on the entire monitor screen. Therefore, when an optical flow in a certain direction is observed on the entire screen, it should be judged ascribable to a blur. Another problem is that when the train is moving, the background also appears to be moving, although it is of course stationary. We devised image processing techniques that compensate for these factors.

In order to detect an obstacle accurately, it is necessary to have a clear sense of the railway track space. The system we developed detects the rails on which the train is running, and narrows down the search region from the positional relationship between the rail and obstacle. Since the rails can be thought of as two parallel lines extending straight ahead from the place of observation, we extracted the rails by applying one linear detection technique, the Hough transformation (Fig. 1). To enable the system to capture the target within its field of vision even in a curved rail section, the distant rail vanishing point was obtained (Fig. 2) and the camera's field of vision was controlled so that the vanishing point appeared at or near the center of the monitor screen (Fig. 3).

When the obstacle is a moving object, it is effective to analyze the optical flow in its images on the monitor screen. Since the obstacle is a rigid body and its optical flow inside its region is almost uniform, the extent of danger posed by the obstacle can be judged by the optical flow's size, direction of movement, and position.

When the obstacle is stationary, it is extremely difficult to distinguish it from a stationary point in the background. We therefore worked out the following method:

When an interruption in rail continuity was detected, we assumed the possibility of a stationary obstacle resting on or beside the rail(s). Paying attention to the fact that an obstacle shows a brightness distribution representing a change from the background, and the fact that it contains a comparatively higher number of horizontal and vertical edges, we isolated the region in which the obstacle existed by analyzing the average and dispersion of brightness and the brightness profiles projected horizontally and vertically. The edges and other characteristic points of the obstacle were extracted from the isolated region and analyzed on time-spatial photographic images laid out on a time-serial basis. Since the loci of groups of characteristic points of an identical obstacle are linearly plotted in the direction of the time axis, we could detect a stationary obstacle by emphatically correlating the point groups that converged linearly (Fig. 4).