Tunnel Scanning System Using Image Processing To Detect Lining Deformations

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We have developed an efficient tunnel scanner with line sensor cameras capable of taking high-precision panoramic annular images of the surface of a tunnel lining, at a low cost (see Fig. 1). The system does not require a special vehicle, but instead can be mounted on a railcar used for construction or maintenance purposes. Photographic equipment is basic, consisting of cameras, lights, control devices and the like. The 5,000 pixel line sensor cameras are mounted on the railcar and aimed at the tunnel walls. The railcar travels at a speed of 10 to 30 km/h, and can take images of the surfaces of a single-track tunnel with just one run. A double-track tunnel requires two runs, one on each track to obtain images of the entire section. Continual image taking is possible for dozens of kilometers per run. Basically, only the image taking and recording is done on the railcar, with off-line processing of image data being performed above ground. Our new system performs far better than a conventional photographic system, in terms of filming speed, recording time and memory. The resolution is the same as the number of camera pixels for cross-sectional directions, but depends on the running speed and scan rate for longitudinal directions. Under ordinary circumstances, the pixel pitch setting is around 0.8 mm horizontal/vertical.

In general, it is technically difficult to make focal adjustments for line sensor cameras under static conditions. Taking advantage of the fact that when the focal condition appears as a picture signal waveform configuration, we devised a method of analysis that evaluates the sharpness of waveforms using threshold values derived from a histogram (see Fig. 2). By quantifying the degree of focal accuracy, we made it possible to perform the proper focal adjustments.

Another problem we faced was blurred images caused by railcar vibrations. If a line sensor camera is subjected to vertical vibrations, the resulting image is conspicuously misaligned by one line per image. To correct these one-line unit misalignments we chose as a standard baseline the track's electric cables (which must be installed in a straight line), measured the amount of misalignment from the wave pattern edge, then made corrections by shifting all lines in the image by exactly the amount of measured misalignment. The system does not use a special sensor, and can obtain an excellent image with misalignments corrected.

Splicing of multiple photographic images is conventionally done by hand, but the image mosaicing method we adopted for panoramic images permits the effective production of excellent resolution panoramic annular images.

We also developed an image processing algorithm for the automatic detection of cracks, which are one typical deformation in tunnel linings. Generally, cracks are darker than their surroundings and take the form of indented, blackish wavy lines. We focused on the fact that there are luminance gradient variations along line edges, and selected cracks offering more detailed luminous variations than the cameras' resolution would recognize. We then adopted a Hysteresis threshold processing method that would select only edges joined to edges detected by the high threshold values. This has made it possible to measure the width of cracks, etc., with a high degree of accuracy (see Fig. 4).

Our tunnel scanner is now being used by a number of railway operators. We plan to raise its efficiency and precision, to enable it to detect cracks with even greater precision in the future.

Fig.1. Tunnel-scanner system for tunnel wall image recording.

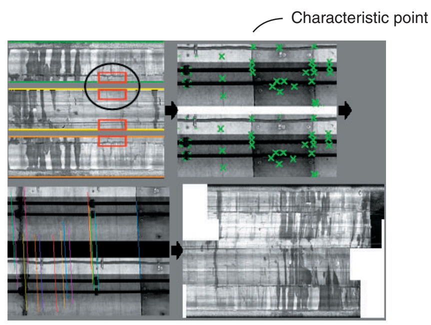

Fig.3. Joining procedure based on the characteristic points.

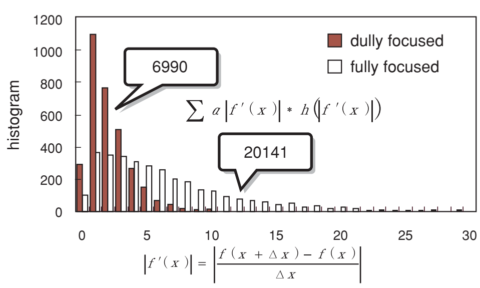

Fig.2. The first derivation histogram of line camera data.

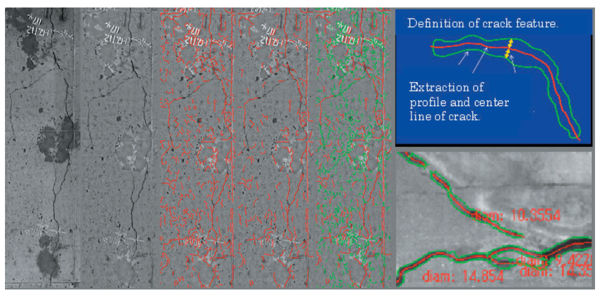

Fig. 4. An example of maximum crack width measurement.