Automatic Method for Detecting and Categorizing Railcar Wheel and Bearing Defects

Hanieh Deilamsalehy, Timothy C. Havens, Pasi Lautala, Michigan Technological University

Worldwide, railways are among the safest transportation services. Nevertheless, every year some serious accidents are reported. A noticeable portion of these accidents is as a result of defective wheels, bearings, or brakes. Train wheels are subjected to different types of damage due to their interaction with the brakes and the track, and they are required to be periodically inspected. If the wheel damage remains undetected, it can worsen and result in overheating and severe damage to the wheel and track. The most usual cause of wheel damage is severe braking, which applies directly to the wheel and results in local heating of the wheel. This can stop the wheel from rotating while the train is still moving, producing a defect called a "flat spot." This project will focus on automatically detecting flat-spotted wheels from thermal imagery using computer vision methods. In addition to that, we introduce a novel algorithm to detect hot bearings.

Defective Wheel Detection Methods

Train wheels are subjected to wear and different types of defects because of their interaction with the brakes and track. A defective wheel can cause damage to both track and the vehicle. There are two main options to identify a damaged wheel at an early stage. The first option is manned inspection, which is costly and time consuming. Furthermore, the defect may have not happened by the time of inspection. Remote automatic detection is the second option. This option is faster and cheaper once all the equipment is installed and therefore can be done more often. For the remainder of this research brief, we will introduce our proposed algorithm for hot-spotted wheel and hot bearing detection, which increases the maintenance efficiency. Our algorithm is developed based on thermal images taken of train wheels. Some samples of thermal images taken with a track-side imaging system are shown in Figure 1.

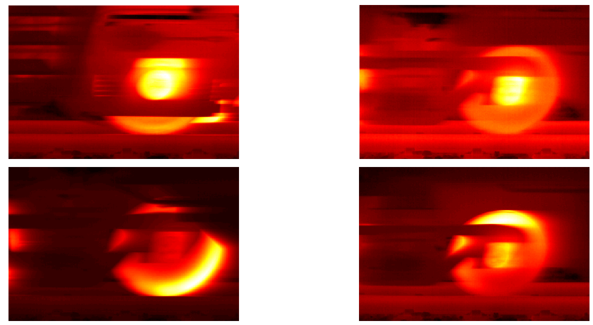

Figure 1. Thermal images taken by track-side thermal imaging system.

Automatic Wheel Hot-spot and Hot Bearing Detection

If there is a skidded wheel, the metal wheel heats up locally at the area of damage. To automatically detect the skidded wheel, several steps of image processing and computational intelligence algorithms are used. Figure 2 shows the block diagram of the algorithm proposed in this research work.

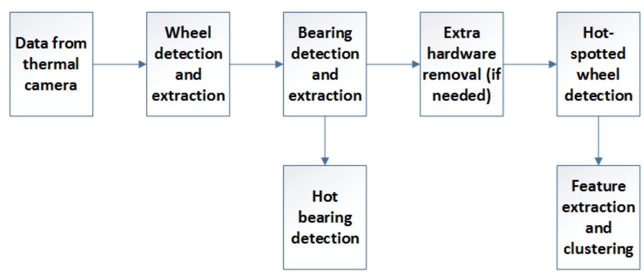

Figure 2. Automatic wheel defect detection block diagram.

To detect hot spots[i]:

1. Identify and segment the wheel region using Hough transform.
2. Detect and segment the bearing region out, employing the Hough transform.
3. Use Bit Planes algorithm for hot-spot detection.
4. Categorize the damage level of the detected hot-spotted wheels using a fuzzy inference system.

5. Categorize the defective wheels into one of the five different damage levels using fuzzy inference system. Level 1 is the least significant damage level and Level 5 is the most severe damage.

Figure 3 illustrates the wheel and bearing segmentation steps, and Figure 4 shows the hot spot detected from a wheel thermal image by the algorithm.

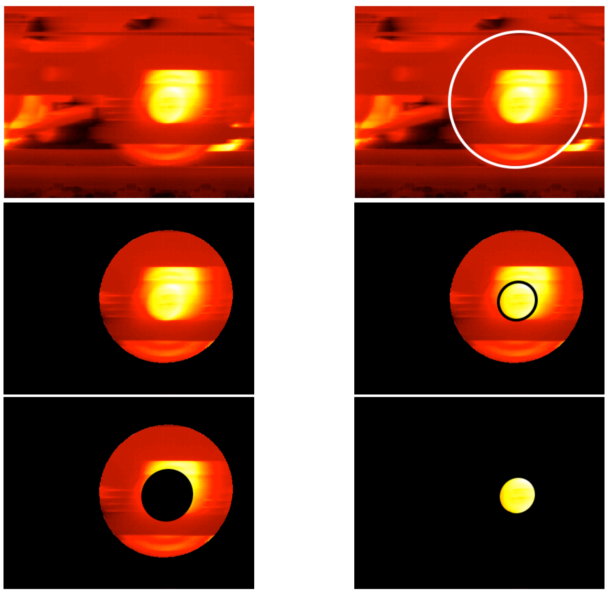

Figure 3. Image segmentation of wheel and bearing regions.

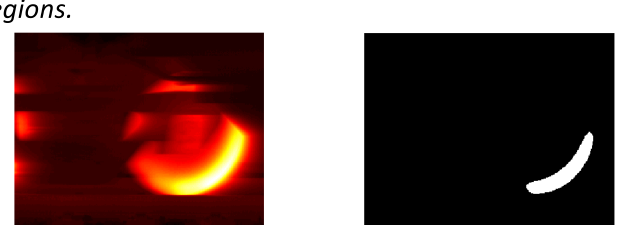

Figure 4. Hot spot detection.

If a wheel is detected with a hot spot, the severity of the damage is estimated and, based on the damage level, the proper solution is taken.

In order to detect the hot bearing, our algorithm proposes the following steps:

1. Identify the wheel outline from the original thermal image and segment the wheel region using the Hough transform.
2. Identify and segment the bearing region from the segmented wheel part using the Hough transform.

(These first two steps of algorithm are in common with the hot-spotted wheel detection algorithm.)

3. Calculate the mean intensity and temperature of the bearing.
4. Indicate the hot bearings based on a pre-determined temperature threshold.

Results and Conclusion

We applied our proposed algorithm to four different data sets from a Union Pacific (UP) railroad. The four data sets contain 352, 353, 94, and 419 thermal images, respectively. Our algorithm detected 19, 28, 91, and 41 defected wheels in each data set accordingly. We also applied our hot bearing detection algorithm to the first data set consisting of 352 images. The intensity distribution of this data set is shown in Figure 5. By knowing the threshold, we can conclude that every bearing with a temperature higher than the indicator temperature is a hot bearing.

The conversion of intensity to temperature was unknown in these data; however, the histogram shows the distribution of bearing temperature accordingly.

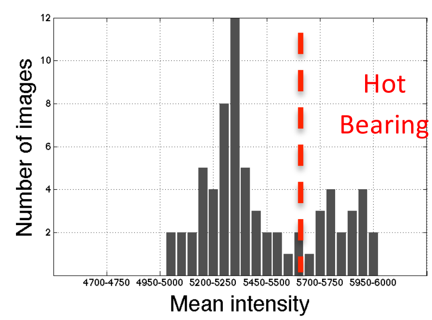

Figure 5. Bearing intensity distribution.

Acknowledgements

This work was funded by a National University Rail (NURail) Center, a US DOT-OST Tier 1, and University Transportation Center. We would like to thank Tom Bartlett and William GeMeiner at Union Pacific for providing us with data and guidance in this project.

---

[i] The detailed method can be found in our paper "Automatic method for detecting and categorizing train car wheel and bearing defects," Joint Rail Conference (JRC) March 2015