Figure 1. Long Island Railroad switch heaters in Queens, N.Y., during a winter storm.

Metropolitan Transportation Authority Facebook/Patrick Cashin

Dual-Band Monitoring Keeps Trains Running in Winter

Keeping critical parts of the railroad infrastructure free of snow, sleet, hail and ice – and even detecting unauthorized persons walking the rails – is essential for a safe and uninterrupted transportation service. Dual-band monitoring of critical rail elements with a PTZ (pan, tilt and zoom) camera platform in the visible and thermal infrared ranges can remotely inspect installed switch heaters at a range of up to 2000 ft.

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Railways must run around the clock, seven days a week – interruptions for subsystem or component failures cannot occur. A single disabled part in the wrong place and at the wrong time can paralyze entire rail branches and cause delays that can last for hours. In the winter, the moving parts of a rail network can fail because of snow and ice accumulation, which typically occurs between stock rails and switch point blades.

To keep trains running in all weather conditions, railroad companies use snow and ice removal equipment: air blowers designed to keep switches clear of snow and ice, self-propelled plows tailored for quick clearing of the heaviest of snow accumulation, and plow attachments that can be added to existing equipment. A static solution is the use of heater elements close to the switch points so that the rail temperature in those areas can be kept above freezing. These heaters can be powered by gas, electricity or geothermal energy.

Switch point heating raises the temperature of rails to melt ice or snow before it can accumulate between the point blade and the stock rail. Any ice keeping the switch mechanism from working properly is removed, as well. Three parts must be heated: stock rail, switch blade and switch mechanism. In simple cases, the heating elements are easily mounted on the shoulder of the inner side of the stock rail. The radiated heat combined with the conducted heat in the rails keeps the area between stock rail and switch blade free from ice and snow.

Switch-mechanism heaters can also keep locks and linkage parts free of snow and ice. They consist of a steel heat-conducting plate with a heating element similar to the rail-heating element. They are placed in the switch-mechanism duct.

Figure 1 shows some switch heaters used by the Long Island Railroad in Queens, N.Y., during a winter storm. These gas-powered heaters can keep the rail transport area open even during an electrical power failure.

Supervision of switch point heating

To ensure reliable operation throughout the winter, it is important to get instant error messages about failed or missing heating elements in critical switches. One solution is the use of two temperature sensors on each switch. The hot-rail sensor is normally mounted on the shoulder of the heated rail, whereas the cold-rail sensor is often mounted under the rail, apart from the heated zone. This will prevent sunshine from interfering with a correct cold-rail temperature reading.

Another way to ensure proper operation is to observe the switches from above instead of below. From a bird's-eye view, the heated switches look like hot spots on the ground. They are easily detected by infrared cameras in the long-wave infrared (LWIR) wavelength range between 8 and 14 µm.

LWIR cameras for this application are based on uncooled microbolometer arrays that, unlike photon detectors, act as energy detectors. Microbolometers consist of thermally isolated microbridges, with a temperature-sensitive material added on top. The temperature-sensitive material can be V_2O_5, a-Si or poly-SiGe. The microbridges are micromachined directly on the surface of the circuits. This establishes a compromise between a good electrical contact, which is needed to read out the detector element, and a poor thermal contact, which prevents thermal leakage of the absorbed radiation.

Figure 2 shows a stationary monitoring solution called GeoCamPro. It was developed by the Dutch company Secure in Air for ProRail, which serves as an installation and maintenance company for the Nederlandse Spoorwegen railway company.

In this setup, a precise PTZ camera platform is mounted on the roof of a building about 150 ft high. The platform's rotation tolerance is tight, not exceeding 0.01°. The building is located in the vicinity of the railway yard nearby a station, where most of the switches and heaters are located. The scene therefore can be easily monitored from this elevated position (Figure 3).

The platform is equipped with two cameras to enable a dual-band view of the scene: a high-resolution thermal camera Xenics Gobi-640-GigE (Figure 4a) with a 100-mm lens covering the LWIR range, plus a daylight camera with a zoom lens of 500-mm focal length. This camera features a 640 × 480-pixel image resolu-

Figure 2. Dual-band image fusion on the PTZ platform GeoCamPro, which monitors switch heaters at a maximum range of 2000 ft.

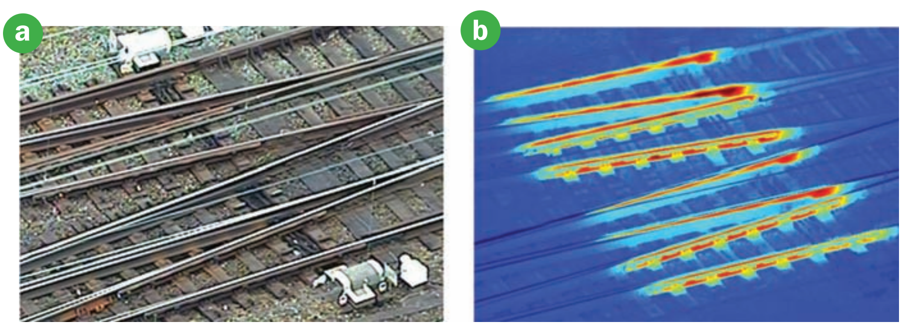

Figure 3. (a) A group of switches. **(b)** An LWIR image of the same switches shows that their temperature is elevated.

tion based on a microbolometer array with a 17-µm pitch, which requires no cooling. This advanced thermal sensor safely detects tiny temperature differences down to 50 mK and delivers them as thermal images at up to 50 fps. Powerful image processing onboard the camera provides images with good contrast. It also can self-adjust automatically. This way, the camera will adapt contrast and brightness automatically according to the scene, and the dynamic range is optimized for various environmental conditions.

The camera is optimized for demanding user requirements. Its design accommodates reduced volume, weight and power consumption, opening a new range of applications for LWIR sensors. Optimization of the implemented hardware and smart use of the field-programmable gate array have significantly lowered power consumption, so that the camera now can be powered via Gigabit Ethernet connection. This lowers installation cost, particularly for multiple cameras in a network; it also increases reliability and allows easy integration of the camera in security environments.

The system's PTZ platform with visible-realm and LWIR cameras scans up to 50 objects per minute at a maximum range of 2000 ft. The onboard thermography calibration of the thermal camera covers the standard range from −4 to 248 °F, which is sufficient for this applica-

Figure 4. An experimental setup for the IR monitoring of switch heating by drones: **(a)** high-resolution LWIR camera Gobi-640; **(b)** two cameras and communication equipment as payload of a drone; **(c)** drone takeoff; and **(d)** inspection flight.

tion. Optionally available are thermography calibrations from 122 to 752 °F, 572 to 2192 °F, and up to 3632 °F for advanced industrial applications.

Just as the railroad switches are affected by snow, sleet or ice, so is the surveillance equipment. Precautions were taken to withstand severe weather conditions: When the temperature of the surveillance system falls to about 41 °F or below, an internal heater is initiated to heat the complete casing of the cameras. This is necessary only for de-icing the equipment; the LWIR camera itself is specified for a wide temperature range from −40 to 167 °F. To reduce the chance of snow or rain collecting on the camera windows, they are roofed by rain hoods. No raindrops on the windows were reported.

In this application, corrosion is also an important issue. The complete camera housing is filled with nitrogen gas at 1.5× atmospheric pressure and features moisture absorption. Even under extremely cold conditions, the presence of moisture is virtually impossible, but even if this were the case, it would immediately be absorbed.

Dual-band surveillance operation

The first step in setting up a dual-band surveillance is to establish a baseline picture as a reference for each important point or spot in the field: the switches, joints and other objects to be monitored. They are registered as symbols in a digital geographical map, which can be displayed by a smart geographical viewer. During operation, both cameras will continuously take pictures in the infrared and visible range of every spot of a railway yard near a station, where most switches and heaters can be found.

Each picture is stored and compared to the one previously taken and to the baseline. This creates a film of every spot in the field with daylight and LWIR exposure. It can be viewed in quick motion to recognize differences and trends, and to

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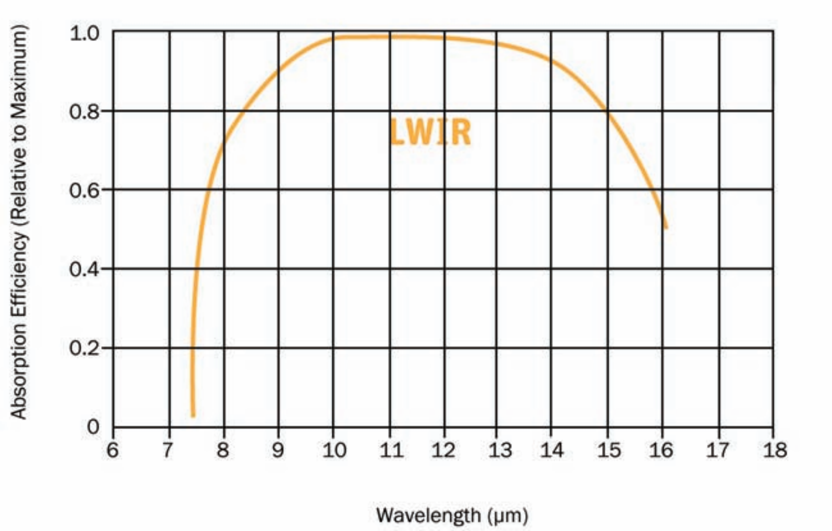

Figure 5. An illustration of the setup's absorption efficiency by wavelength.

reveal the cause of a detected problem.

When the LWIR camera detects a switch-gear problem, an alarm sounds (if the user so desires) and the problem spot is highlighted on the map. Now the operator can point and zoom the daylight camera to that point to investigate what is going wrong: Is there a mechanical problem, or has ice formed between the switch points?

The system works to a large extent autonomously, with a low false-alarm rate, optimized by self-learning algorithms. The situation where a heater doesn't work at all, for example, represents a major problem. If it is working but not properly (a scenario could be that only one of several switch heaters is not operational) and there is no freezing temperature, this is simply a matter of concern. The user can decide, judging by the amount of data delivered, how to analyze the problem and resolve it later.

Additional functions

Switch heaters are not the only source of elevated temperatures in railway networks to be monitored by a LWIR camera. Such advanced systems can also help discover unauthorized persons walking between the rails (causing possible disturbances and delays for travelers), as well as assist in the supervision of hotboxes on passing trains (at least from one side).

The LWIR system can also be an important addition to regular procedures used on construction sites to deliver information about the progress of construction measures, possible damages, security breaches, waste, the status of fences and the proper closing of gates.

Outlook

A few years ago, Secure in Air tested its deployment aboard a drone to monitor railroad switch heaters from the air. The LWIR camera (Figure 4a), a daylight camera and communication equipment were mounted as a payload (Figure 4b) on a self-built drone (Figure 4c) based on a Trex 600 with autopilot from MicroPilot. Mission time (Figure 4d) amounted to just a few minutes, but the system demonstrated the feasibility of dual-band monitoring of railroad switch heaters.

Meet the authors

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