Remote Sight to Monitor Mound Site

Applying Machine Vision for Long-Term Stewardship

Automated monitoring systems, regardless of the type of sensor used, can and should be considered as an important component of the transition to long-term stewardship for DOE sites.

By David Reichhardt and Andrea T. Hart

The U. S. Department of Energy's Mound Site, which is located near Miamisburg, Ohio, is in the process of closure, turning over the majority of the land and remaining buildings to the Miamisburg Mound Community Improvement Corp. for their use. MSE Technology Applications Inc. (MSE) worked with the Mound Site operating contractor, CH2M Hill Mound Inc., to demonstrate a remote monitoring system for assessing environmentally sensitive areas within the Mound Site. The demonstration was in support of the Mound Site closure/turnover.

The DOE has imposed deed restrictions (designed to protect human health and the environment) on the property, including restrictions on the removal of soil, and has a continuing responsibility to enforce the deed restrictions in the future. The DOE Office of Environmental Management funded MSE to provide the design construction/installation and monitoring of the demonstration. The DOE–Ohio Office funded CH2M Hill Mound Inc. to provide the system hardware. MSE installed the system hardware at the site in September 2003 and evaluated the system's performance over the following year.

Remote monitoring of environmentally sensitive areas is an important component of many long-term stewardship plans for DOE facilities. However, remote monitoring does possess some problems. The monitoring objectives typically include a wide range of conditions such as monitoring soil erosion or subsidence or monitoring for activities that intrude into or disrupt the soil. Monitoring these

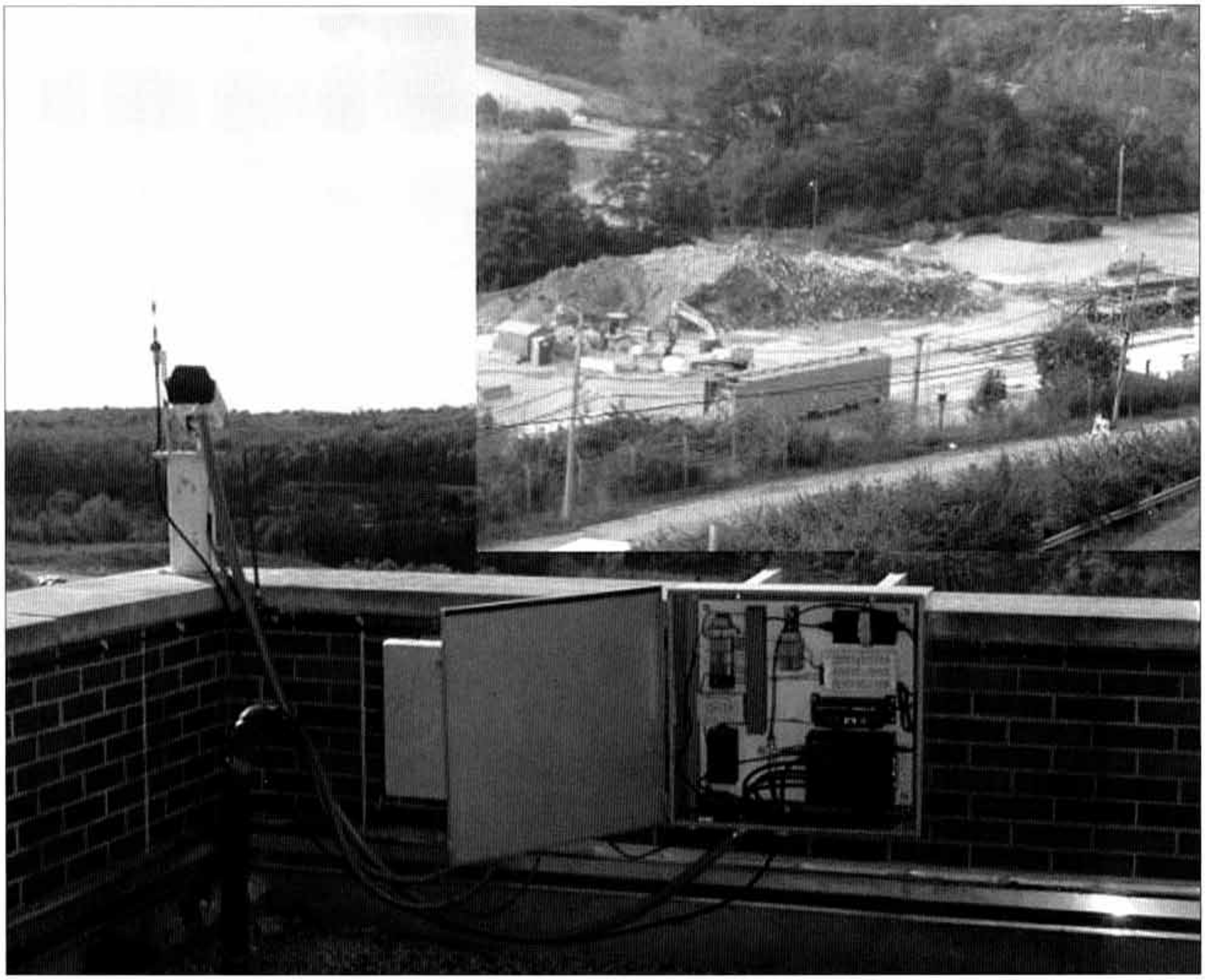

Fig. 1. The machine vision system monitoring the waste-soil-stockpile facility.

types of objectives, unfortunately, requires sensors that either do not exist or preclude large-scale deployment.

Remote site monitoring also requires the ability to feed information from the sensors into a data storage and analysis system. Ideally, the data storage and analysis system should be capable of automatically assessing the data, and, if the data assessment suggests the site is out of compliance, triggering a response. The purpose of the automated data acquisition and assessment is to reduce the labor requirements associated with the monitoring. For example, the response may be an automated phone call, fax, or e-mail informing a responsible party of the assessment so that the appropriate action may be taken.

Machine Vision for Remote Site Monitoring

Machine vision is the process of using a computer to extract information from digital images and then, based on the information, automatically take some form of action. MSE based the operation of the Mound remote site monitoring system on a machine vision platform. For this demonstration, the monitoring system consisted of digital cameras, radio modems, and an image-processing algorithm. Digital cameras provided the monitoring system with a sensor applicable to a broad range of monitoring objectives. The cameras recorded the visible features of the site, making it possible to detect visible change in the site from afar. In

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Fig. 2. Machine vision system monitoring the waste repository cap.

cases such as soil erosion or subsidence, visible change is an indicator that these processes are occurring. Radio modems provided a wireless network for transmitting the images from the cameras. This effectively tied several remote monitoring locations to a single computer that stored the images and ran the image-processing algorithm, which determined whether the images were changing and, if so, determined whether the site warranted further investigation.

Another feature of a monitoring system based on digital images is the ability to acquire data at some distance from the actual monitoring point. This is possible because it is not necessary to place sensors directly on or in the area or object monitored. This potentially reduces the exposure of workers during system installation and subsequent monitoring activities, compared with that during the direct installation of sensors into the monitoring points. It also may reduce the number of sensors required to monitor an area when compared with the number for traditional types of monitoring systems. For example, one or two strategically placed digital cameras could monitor a 100- × 100-meter section of landfill cover for subsidence features that are less than a meter across. To achieve this same level of coverage using accelerometers would require approximately 40 000 units (this estimate is based on accelerometers placed at half-meter intervals across the site).

Another important feature is the ability to assess data from different types of sensors (again, the digital camera can be thought of as a sensor) using the same algorithm. This is possible because, after converting the data from the different sensors to an image, the machine vision algorithm sees only the image and does not consider the data source. Thus, the machine vision system effectively provides a platform for integrating multiple data types. An example of this is the use of thermal images, radar images, and images from the visible spectrum of light for a single image analysis.

Machine Vision Deployment

For the demonstration at the Mound Site, MSE set up three monitoring stations, each with a different monitoring objective and hardware configuration. The monitoring objectives included monitoring a temporary waste-soil-stockpile facility associated with a soil removal-and-disposal activity, detecting landfill-cover subsidence, and detecting unauthorized soil removal or dumping at an area scheduled for future development.

The machine vision system monitoring the waste-soil-stockpile facility consisted of a high-resolution camera, an embedded processing unit, and a radio modem. MSE installed this system on the roof of a building near the site. This location provided an ideal vantage point for monitoring and provided access to power for the system. Fig-

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edge of the roof using an existing, but unused, security-camera mounting post. This allowed camera installation without drilling additional holes into the building. Next to the camera is the antenna used to communicate with the main computer. To the right of the camera are the embedded processor and radio modem housed in an all-weather enclosure. The electrical power for this system is from a 120-volt, alternating current power source (i.e., it is plugged into a standard electrical receptacle on the building). At this location, the embedded processor performed the image processing. When the embedded processor detected change, it transmitted this information to the main computer, located in another building.

The machine vision system monitoring for subsidence or other activity associated with the waste-repository cap consisted of a low-resolution camera and a radio modem that transmitted the images to the main computer for processing. The power to operate this system was supplied

ure 1 is a photograph of the waste-soil-stockpile facility monitoring system. The inset in the upper right corner shows the waste-soil-stockpile facility. Soil from a remedial excavation is stored here before it is loaded onto railcars for shipment to a disposal facility.

MSE secured the camera at this location in a weatherproof enclosure and mounted it on the knee wall along the

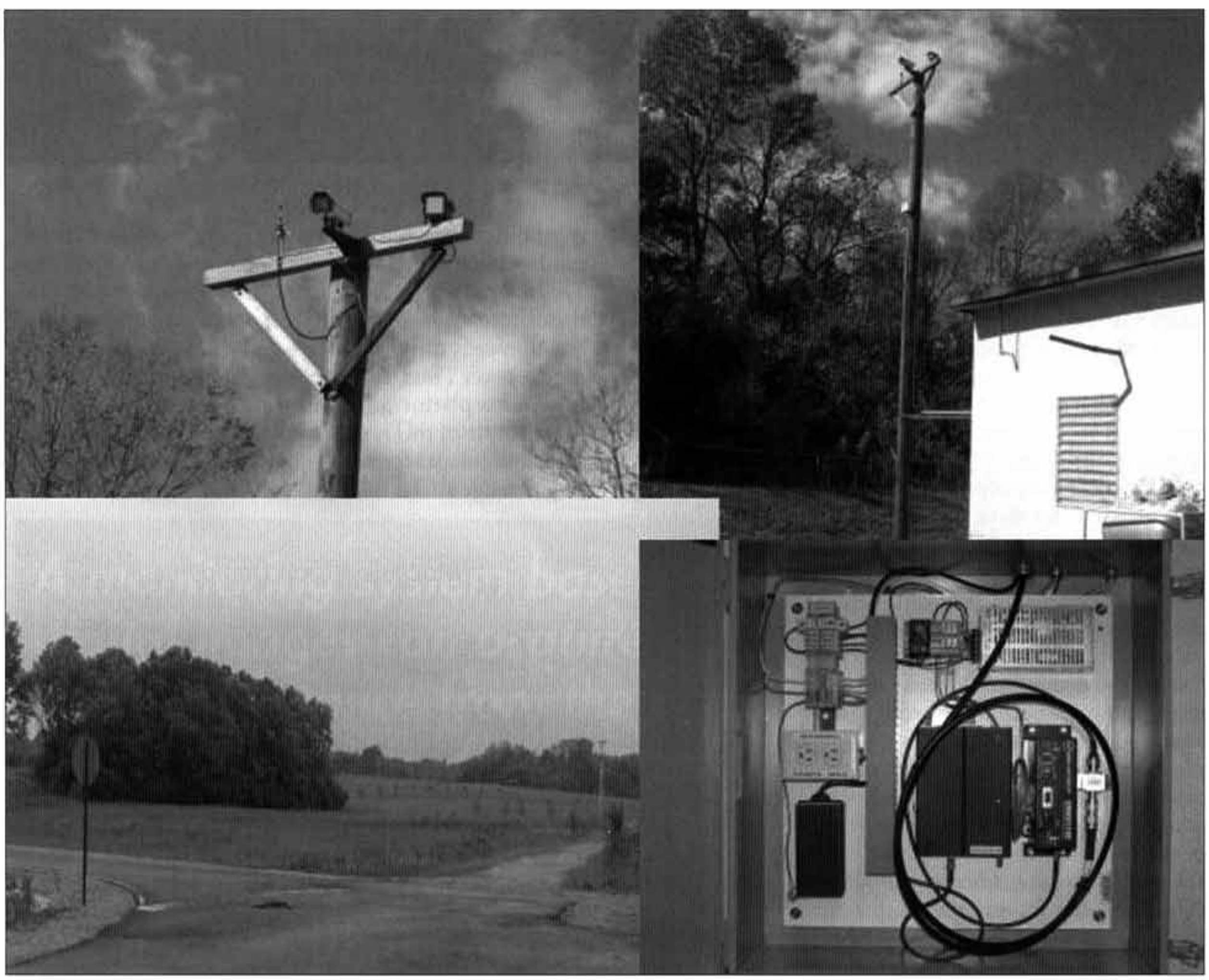

Fig. 3. The machine vision system with infrared illuminator monitoring for soil removal.

by a series of solar panels and batteries.

Figure 2 shows the camera and antenna mounted on top of a pole approximately 25 feet high; the solar panels used to charge the batteries are also mounted on the pole. At the base of the pole are the batteries and the weatherproof housing for the radio modem. The lower left inset shows the housing with the radio modem. The upper left inset is the landfill cover. The camera (not shown) is located approximately in the middle of the right edge of the inset.

The system monitoring for soil removal from the area scheduled for future development is similar to the system monitoring the landfill cover. However, an infrared illuminator, located alongside the camera, allows for acquiring images at night or during other low light conditions. The electricity powering this system is 120-V ac power.

Figure 3 shows this system and the area monitored (lower left inset). MSE mounted the camera, infrared illuminator, and antenna approximately 25 ft above the ground. The inset in the upper right corner shows, from left to right, the antenna, camera, and infrared illuminator. This location provided a vantage point for the camera that maximized the area monitored. The radio modem (located in the lower left inset) is located inside a well house visible to the right of the mounting pole. As with the other monitoring installations, the radio modem transmitted the images to the central computer for processing.

With the ever-increasing resolution that is available in off-the-shelf digital cameras, getting enough resolution is typically not difficult. Data storage and data transmission associated with higher resolution images, however, do present problems that must be considered in the design.

Identifying Relevant Changes

The preliminary results from the demonstration indicate that there is a significant amount of change occurring at each of the sites that does not pertain to the monitoring objectives. This includes change due to variable lighting from the sun's movement and cloud cover. Variable weather patterns such as rain, wind, and snow also cause changes not related to the monitoring objectives. To address these issues, MSE investigated additional image-processing techniques to eliminate the irrelevant changes from the images. These included averaging the images over a time window before comparing the images and normalizing the light intensity of the images. These additional processing steps did improve the identification of relevant changes at the site.

Designing the System—Lessons Learned

Several important lessons were learned from this demonstration with regard to developing automated monitoring systems using machine vision. The outdoor settings proved extremely difficult to monitor for subtle changes. Large changes such as vehicles entering an area or a major subsidence event could be detected, but smaller scale changes could not be detected with any degree of reliability. However, there are controlled settings where such a monitoring system could be used. These might include an enclosed drum storage facility where a thermal imager could be used to monitor for increased drum temperatures or monitoring for conditions inside a tank or enclosed vault, again, where the lighting could be controlled. Low light conditions are not a significant issue for machine vision applications because of the availability of cameras that can function with very little light and of systems such as thermal imagers.

Another issue that should be considered when designing a machine vision monitoring system is the use of a camera with an appropriate level of resolution. With the ever-increasing resolution that is available in off-the-shelf digital cameras, getting enough resolution is typically not difficult. Data storage and data transmission associated with higher resolution images, however, do present problems and must be considered in the design.

The demonstration was very successful in showing that remote monitoring and data transmission systems can be set up with off-the-shelf components. The solar-powered system worked well in an environment that lacked electrical power, and the radio modems allowed for data transfer to a central computer for archiving and processing.

The lessons learned from this demonstration suggest that automated monitoring systems, regardless of the type of sensor used, can and should be considered as an important component of the transition to long-term stewardship for DOE sites. ■

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