REMOTE SITE MONITORING FOR LONG TERM STEWARDSHIP: AN APPLICATION OF MACHINE VISION AT THE DOE MIAMISBURG CLOSURE PROJECT, MOUND SITE, OHIO

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ABSTRACT

MSE Technology Applications, Inc. (MSE) is demonstrating machine vision technology for automated remote site monitoring at the U.S. Department of Energy (DOE) Miamisburg Closure Project (MCP) Mound Site in Miamisburg, Ohio. The machine vision system will monitor soil intrusion and or disturbances, erosion, and subsidence. Additionally, the machine vision system will monitor part of a remediation activity. The demonstration has two parts: design and installation of the hardware, and development and optimization of the machine vision algorithms.

The machine vision hardware installed at Mound includes three digital cameras; a secure wireless data transfer network; and a computer for image processing, storage, and retrieval. Power for the machine vision system comes from both 120-volt ac electrical power and a 12-volt dc solar panel and battery system.

The machine vision image-processing algorithm subtracts one image from another image to identify regions where change has occurred. The image-processing algorithm can provide the image coordinates where the change occurred and magnitude of the area on the image that has changed. If the identified change meets some pre-defined criteria, the algorithm can initiate a response (i.e., automated email, phone call, etc.).

MSE has identified several issues associated with automated monitoring of remote areas using machine vision. These are based on the preliminary demonstration results, which show a significant amount of change occurring across the sites. The majority of the changes observed occur because of irrelevant factors or noise. Irrelevant noise in the images may include insects on camera lenses; variable lighting, due to clouds and or changing positions of the sun; and variable weather, such as snow, rain, and wind. To address these issues, MSE is exploring techniques such as averaging images over a time window and normalizing the light intensity of images. We expect these additional processing steps to improve the detection of relevant change(s) and reduce the number of false alarms generated by the machine vision system.

INTRODUCTION

MSE is working with the U. S. DOE Mound Site operating contractor, CH_2M Hill Mound, Inc., to demonstrate a remote monitoring system for assessing environmentally sensitive areas within the Mound Site, which is located near Miamisburg, Ohio. The Mound Site is in the process of closure and turning over the majority of the land and remaining buildings to the Miamisburg Mound Community Improvement Corporation (MMCIC) for their use. The demonstration is 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. DOE has a continuing responsibility to enforce the deed restrictions in the future. The DOE Office of Environmental Management (EM-50) funded MSE to provide the design construction/installation and monitoring of the demonstration. The US DOE-Ohio Office funded CH_2M Hill Mound, Inc., to provide the system hardware. MSE installed the system hardware at the site in September 2003 and is currently evaluating the system's performance. If the demonstration is successful, the monitoring system may become part of the Mound long-term stewardship program.

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, subsidence, or monitoring for activities that intrude into or disrupt the soil. However, monitoring these types of objectives 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, trigger a response. For example, the response may be an automated phone call, fax, or email informing a responsible party of the assessment so that the appropriate action may be taken. The purpose for the automated data acquisition and assessment is to reduce the labor requirements associated with the monitoring.

MACHINE VISION AS APPLIED TO REMOTE SITE MONITORING

MSE based the operation of the remote site monitoring system on a machine vision platform. 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. For this demonstration, the monitoring system consists of digital cameras, radio modems, and an image-processing algorithm. Digital cameras provide the monitoring system a sensor applicable to a broad range of monitoring objectives. The cameras record the visible features of the site, making it possible to detect visible change in the site. In cases such as soil erosion or subsidence, visible change is an indicator that these processes are occurring. The radio modems provide a wireless network for transmitting the images from the cameras. This effectively ties several remote monitoring locations to a single computer that stores the images and runs the image-processing algorithm. The image-processing algorithm determines if the images are changing, and if so, determines if the site warrants 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, as compared with the direct installation of sensors into the monitoring points. It also may reduce the number of sensors required to monitor an area when compared to traditional types of monitoring systems. For example, one or two strategically placed digital cameras could monitor a 100-meter by 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 only sees 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 using 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 from or dumping at an area scheduled for future development.

The machine vision system monitoring the waste-soil-stockpile facility consists 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. Figure 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 loading it onto rail cars for shipment to a disposal facility.

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

MSE secured the camera at this location in a weatherproof enclosure and mounted it on the knee wall along the edge of the roof using an existing, but unused, security-camera mounting post. This allowed the 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 a120-volt ac power-source (i.e., it is plugged into a standard electrical receptacle on the building). At this location, the embedded processor performs the image processing. If the embedded processor detects change, it transmits this information to the main computer, which is located in another building.

The machine vision system monitoring for subsidence or other activity associated with the waste-repository cap consists of a low-resolution camera and a radio modem that transmits the images to the main computer for processing. The power to operate this system is supplied 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 weather proof 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 is located approximately in the middle of the right edge of the inset (not shown).

Fig. 2 Machine vision system monitoring the waste repository cap

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 along side the camera, allows for acquiring images at night or during other low light conditions. The electricity powering this system is 120-volt ac power.

Figure 3 shows this system and the area monitored (lower left inset). MSE mounted the camera, infrared illuminator, and antenna approximately 25 feet above the ground. The inset in the upper right corner shows the antenna, camera, and infrared illuminator (from left to right). 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 of a well house visible to the right of the mounting pole. As with the other monitoring installations, the radio modem transmits the images to the central computer for processing via the radio modem.

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

The preliminary results from the demonstration indicate 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. MSE is investigating additional image processing techniques that will eliminate the irrelevant change from the images. Possible solutions include averaging the images over a time window before comparing the images and normalizing the light intensity of the images. We expect these additional processing steps to improve the identification of relevant changes at the site.

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