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MISSOURI S&T

Development of High Resolution Target Monitor

by

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16. Abstract

The proposed High-resolution Target Movement Monitor uses triangulation theory but in a unique way. Unlike the commercially available triangulation systems which use sensing diodes to perceive reflected laser signatures and are limited to very short distances, the proposed system uses lasers and image analyzing software to detect distance change between camera and the monitored surface. This proposed image analyzing technique removes the need to use the linear photodiodes that only measure laser spot light intensity and are limited in their receptiveness. Target measurements made through air (gaseous) and other transparent media may be analyzed. The main advantage of this system over the commercially available systems is its accuracy and low cost which makes this system attractive for monitoring mining and civil engineering structures. The accuracy and range of this system depend upon the resolution and the focal length of the camera that is used. The HRTMM system underwent some preliminary lab testing which showed very promising results. The investigators seek funds to evaluate this system at underground tunnels to asses the impact of elements such as dust, vibration and lighting on the performance of HRTMM.

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DEVELOPMENT OF HIGH RESOLUTION TARGET MONITOR

EXECUTIVE SUMMARY

The main goal of this project is to develop the existing high resolution target movement monitor (HRTMM) to work in different ambient conditions. The HRTMM was developed at the Missouri University of Science and Technology to detect and measure wall movements in underground mines to help reduce fatality and injury rates. Several methods can be used to detect sub millimeter movements in the underground mines. This monitor differs from the conventional methods in terms of cost induced for installment and maintenance of the system.

The system uses various concepts from image processing, optics and mining technology to detect the wall movement. Images of a laser dot are captured at a regular interval and the geometrical properties of the dot on the image are analyzed using image processing techniques. A software program is developed on the VC++ platform to calculate the geometrical features. The most important input needed for analyzing the images is the threshold value for the images. The effect of varying thresholds on the images generated from a series of experiments conducted in the laboratory is studied. The ultimate goal of these experiments is to deduce an algorithm for deciding the threshold value automatically without human intervention unlike the previous versions of HRTMM software. The implementation of the algorithm in the software module can be the next step in this project.

INTRODUCTION

To maintain a safe environment for personnel working in the mine, data is collected from various observational and instrumental devices and analyzed. This helps in providing prior information of instability in the rocks to the mine authorities. The observational techniques involve observation of the exposed rock mass. Some common technique being the Global Positioning Systems, Electronic distance metering etc. The other types of devices that detect and measure the wall movement are the instrumentation techniques. Common examples of such type are convergence meters, tape extensometers etc.

HIGH RESOLUTION TARGET MOVEMENT MONITOR BACKGROUND

Experimental Set-up:
The existing HRTMM monitor comprises of a laser, camera Nikon D200 and a metal target board. The camera and the target board are arranged in a line separated by some distance on the vibration table. The laser is placed in a way that it forms a third vertex of a right angle triangle with the laser and the camera forming the base of the triangle. The laser can be adjusted on the rotation disk in such a way that the laser dot (when the laser is switched on) falls on the target board and allows the camera to take the images of the dot.

Previous version of the software:
The images are stored in a folder and analyzed one by one by the software program. The program works on VC++ platform. It is interfaced to an image processing toolbox ImageMagick. ImageMagick is used to perform the image manipulation operations on the images to extract the geometrical feature of the images. The algorithm here basically aims at detecting the laser dot on the image and calculating the centroid of the dot.
The inputs to the program are: Image, threshold value, window size. The window size is a parameter that is used to generate a mask of length window size and breadth window size. It runs as a mask on the entire image to find the dot. A threshold value is needed for image thresholding. Any pixel whose value is above the threshold value is converted in to a white pixel and whose value is lower than the threshold is converted to a black pixel.

Thresholding maps the colored image to a binary image with the help of the manually entered threshold value. The output of the program is presented on the command prompt with the earlier version of the software. Desired output is the centroid position of all the dots and number of pixels encompassing the dot.

The dot once detected has to undergo certain operations to find the centroid. The centroid position of the dot varies with any physical movement of the target board or the change in the threshold value. The movement of the target board is controlled in the laboratory by the operator. So the other key factor in the system is the determination of a threshold value.

EXPERIMENTS CONDUCTED AND RESPECTIVE RESULTS

The laboratory scale experiments to study and understand the effect of threshold on the HRTMM system are conducted in the optics lab at Missouri University of Science and Technology.

1. Stationary target

Experimental Set-up: The first set of experiments did not include any target movement. The Nikon D200 camera was connected to the laptop which controlled the camera. The images of the target were captured once every 5 seconds. The images were saved in JPEG format.

The idea behind this experiment was to observe the effect of threshold on the images of a stationary target. Each image was passed through the program with a window size of 7 and varying thresholds from 50 to 150. Any threshold below 50 would unnecessarily detect noise as valid information. Internally in the software, the image would be read by the editor and gray scaled using the threshold. The mask generated by the software depends on the window size. In this case, a mask of 7X7 is generated and it runs on the entire image. The pixels with binary value 1 are marked. The adjacent regions are found out. The dot with maximum number of pixels is the one with maximum area. The geometric properties of dot of our interest are noted down from the command prompt.

This process is continued for all the images. The instructions have to given for each image independently. Also the threshold values were also varied from 50 to 150.

Results: Plots of centroid versus threshold were obtained to check the pattern that the curve follows. For all the images, the curve followed a similar pattern with just a couple of points falling out of the curve. This was expected as the images were captured with no target movement. But the interesting observation was that for a particular image, a cluster of centroid positions were formed for a certain range of threshold values. This was true for all the images. This lead to the thought that a range of threshold can be decided based on the plots that could give us the minimum standard deviation between the centroid positions (that are forming a cluster) for a particular range of thresholds.

Problems encountered: Initially the change of VB versions caused problem with the functioning of the code. The most difficult part in the previous experiment conducted was the data collection from the software. To analyze the images, the code had to be run several times with manual intervention for inputting the window size, the varying threshold values and the image names. The speed of the code was not as expected. The need for the output to be copied from command prompt to another format was also time consuming. Thus the need arose to modify the code to produce an output in a formatted way in an excel sheet and to automatically work in a batch mode. The cause of the problem was the usage of ImageMagick libraries which decreased the speed of operation.

Software modification: The need to automate the code to perform on a group of images for a range of thresholds was overcome by using file and string operations. The code was automated to take the inputs from a text file that contains all the images numbers to be analyzed. The range of thresholds is also given by the user at the beginning of the program and the code runs on all the images for all the values of thresholds and also produces the details of all the images. The performance speed of the code could not be improved as the basic ImageMagick libraries in use by the code can not be modified.

2. Moving target

Experiment Set-up: The experimental set-up remained the same as that of the previous experiment except that the position of the target board. The target is moved away from the camera in sub millimeter increments and several images are obtained at each position and analyzed as a function of centroid position, target movement and varying threshold values.

The target was moved in sub-millimeter increments and 10 images were taken at each of the 10 positions. The analysis is being done on the images. The reason for considering 10 images at each position is to average the centroid positions of all the images at that position for all the threshold values and observe the cumulative effect. This average method might smooth the curve formed. This experiment is in the data processing stage.

Results: It is expected to give a direction towards automatic thresholding for different ambient light conditions. This work is expected to be done by the end of this semester.

Software modification with OpenCV: OpenCv is an open computer vision toolbox developed by Intel. It can be used to perform various image processing operations. OpenCv is expected to improve the speed of the code that is being used by the HRTMM system. Therefore, the concentration has shifted towards replacing ImageMagick with OpenCv which might improve the speed of the code by at least 10 times. This modification will help in analyzing huge amounts of images for the experiment with the moving targets. Also there would be no need to specify the window size. The algorithm used here would scan the entire image pixel by pixel and detect the blob with maximum area. It is expected that the results produced by OpenCv would be similar to the ImageMagick results.

CONCLUSIONS AND FUTURE WORK

With the implementation of HRTMM code with OpenCv by the end of this semester, the project if funded in the future can be extended. OpenCv has a capability to connect to a webcam and capture images. The parameters of the images being captured can be set according to the user and this would lead to the automation of this entire HRTMM system. With proper interfacing and GUI implementation, this whole system can be automated to capture images with a given set of camera and optical parameters, analyze data in regular intervals and give formatted output that ca detect wall movements.