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Image processing of leaks detection in sequence of infrared images

Abstract

This work presents the method of leaks detection in recorded sequence of infrared images. Infrared field measurements were taken on small experimental embankment during flood process simulation. The leak processes took place thru initially dry facility. Getting wet areas were visible in infrared images as lower temperatures part of embankment on its air side. Image processing methods allowed to localize the leak in thermal images, despite the impact of external factors on the measurement and differences in objects emissivity in the observed scene.

Keywords: image processing, infrared image, experimental embankment, leaks detection.

1. Introduction

Infrared thermography is a fast and remote method used for temperature measure based on infrared radiation registered on the detector array [1]. Infrared cameras have different types of detector arrays, one of them is microbolometer focal plane array. Infrared cameras based on this type of uncooled detectors are cheaper than cooled photon detectors. The disadvantage of cooled detector is its thermal drift [2]. Infrared measurements are exposed to high impact of external conditions, difficulties and ambiguities in the interpretation [3]. There are many applications of infrared imaging, almost in every area of life. It is increasingly used for environment's observations with drones and aircraft.

This paper describes an experiment performed as part of a project called Information Computer System for Monitoring River Embankments [4]. The aim of this project is to study processes occurring in the soil embankments during the floods with development of system monitoring the state of embankments.

2. Experiment description

The infrared images were registered as a part of field measurements on small experimental embankment during flooding process [4, 5, 6, 7]. This embankment (Fig. 1) was located in open terrain, under a tent, which saved it from rain. Small experimental embankment was 4 m long and 3 m wide. The embankment was built from sandy material with a high filtration coefficient. The embankment was situated on a layer of impermeable clay. Water side slope inclined in the ratio of 1:1.5 and the air side slope was in the ratio 1:1. Due to the slopes ratio surface of the slopes have been secured against landslides with steel grating. On the water side slope tank was created. It was filled with water for all upcoming experiments. Tank was restricted by steel plate with a height of 1 m.

Flood experiment started at 10:20 and lasted until 18:00.

Infrared measurements showed that the tent is transmitting infrared radiation from the Sun. The thermal images were captured by FLIR T620 infrared camera with microbolometer focal plane array, which spatial resolution is 640×480 pixels. Used lens and small distance from the observed object (3 meters) did not allow to have the view on the whole embankment's water side surface.

Images were recorded in every 30 seconds. The images were registered sequentially: left side of embankment, center, right side, center, left side and so on. Camera was located on a tripod. Physical parameters of the embankment such as emissivity and reflected temperature, which are necessary to measure the temperature using an infrared camera were not measured or estimated. Emissivity 0.8 for sand and a reflected temperature equal to the atmospheric temperature of 30°C were assumed. Due to these assumptions temperature was interpreted as a measure of quality based on the relative temperatures. Applying NUC procedure every 1 minute allowed to minimize thermal drift.

Fig. 1. Small experimental embankment

Figure 2 presents infrared images of central part of embankment registered during flooding. Top image without the leak is first image taken to analysis. Middle image, where leak is visible, is image number 52. Bottom image, on which leak increases, is image number 108 from sequence.

3. Sequence of infrared images processing method

Presented analysis uses infrared images of central part of the embankment. First step of processing was to reject blurred images and those in which a man is in the field of view. Next steps were performed using MATLAB software [8]. Apparent temperature range of the images is from 18 to 42.5°C. It was converted to range from 0 to 1 to easier image processing Matlab functions use.

The sequence of images presents not exactly the same scene, so the first step of processing was to shift the region of interest using automatic procedure. Figure 3 presents mean image of sequence before and after shifting and cropping procedure. The mean image before cropping is blurred, what indicates that the images in the sequence do not represent the same scene of view. The mean image after shifting procedure presents sharp-edged objects, so all images in the sequence present the same field of view. It allows analysis of the course of given point of image in time.

Region of interest (ROI) was limited to area without visible parts of the cable installation. Steel tubes with very low emissivity were cut from ROI. Three areas in the ROI image were separated for analysis.

Figure 4 presents ROI with the scheme of areas analyzed in time. Those areas are: dry during whole flooding experiment area in top part of the ROI; center area, which is dry in the beginning and getting wet during experiment; and bottom area – wet sand during whole flooding experiment.

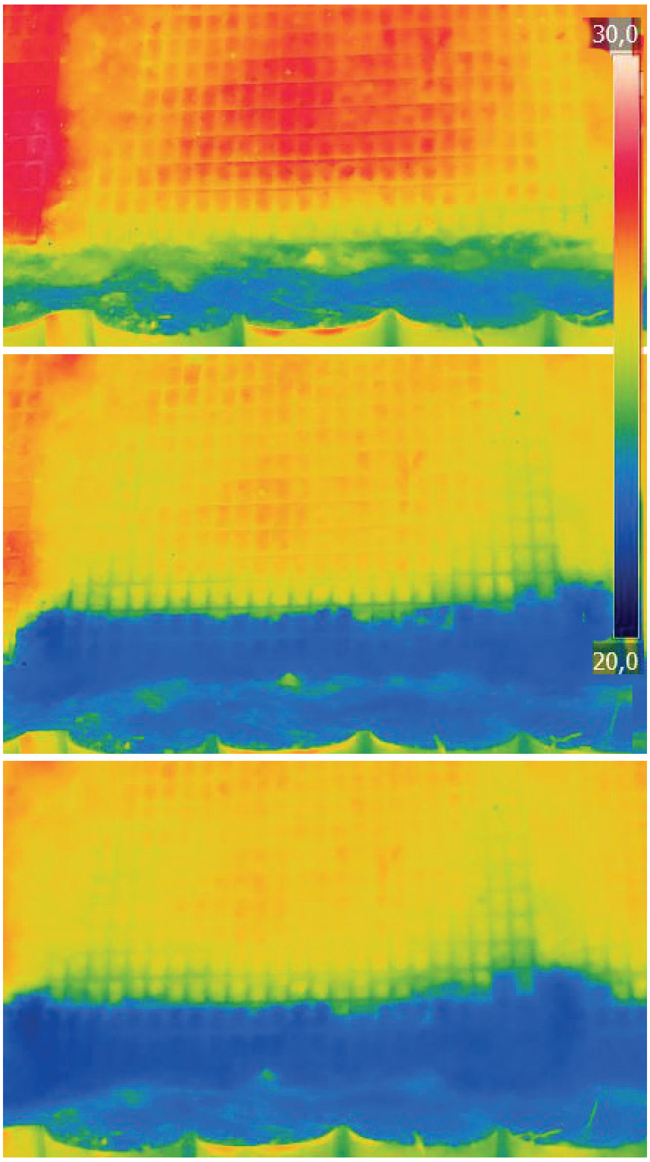

Fig. 2. Infrared images of central part of embankment registered at frame number 1 (top image without the leak), at frame number 52 (middle image, leak is visible), and frame number 108 (bottom image, leak increases)

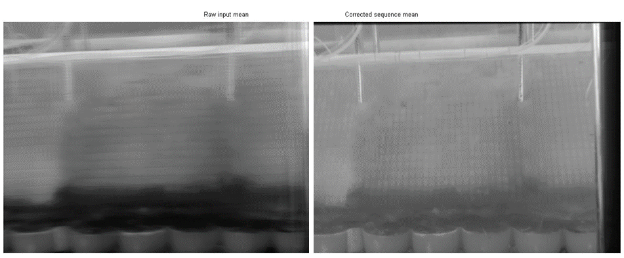

Fig. 3. Mean image of sequence before (left image) and after (right image) cropping procedure

Time analysis of those areas helped in the further development of the sequence image processing methods. In the sequence of images we can see very strong influence of solar radiation, higher temperatures in the moments when the Sun is not covered by clouds.

This influence of Sun is visible on every curve in Fig. 5. This caused flickering during playing the sequence. The next step was to bring images to the same level. This procedure was performed using the curve obtained on the top-dry part of the area, which was not exposed to the influence of other factors (all time dry), Fig. 5.

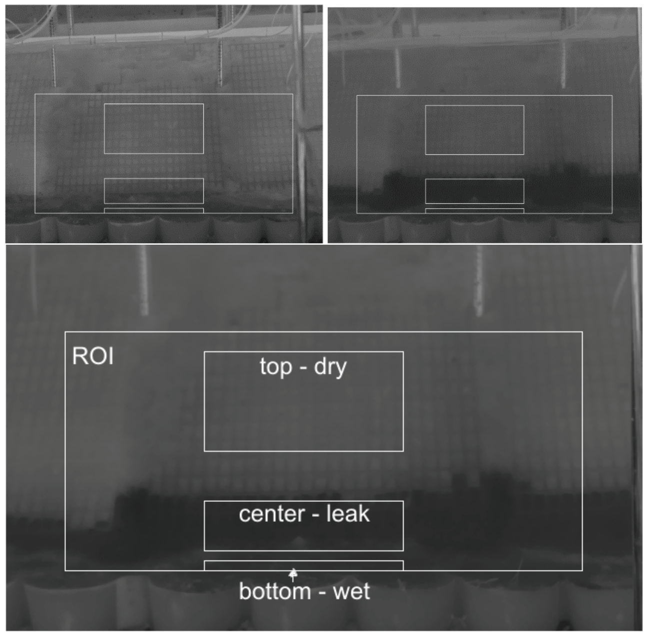

Fig. 4. Areas for analysis in the scene

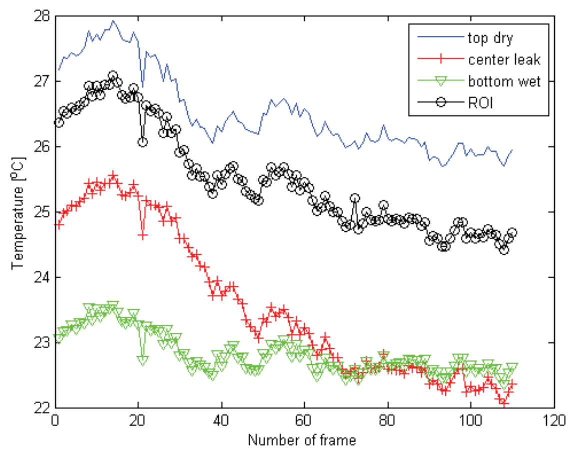

Fig. 5. The particular average temperatures variations of each region

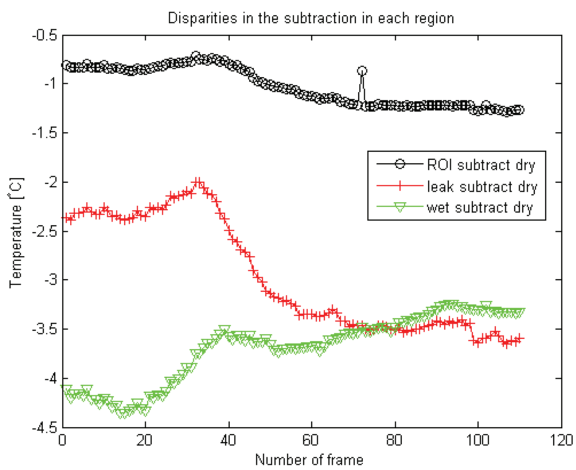

Fig. 6. Disparities in the subtraction in each area

Figure 6 presents the curves which are the result of subtraction of curves presented in Figure 5. The curves in this figure are the temperature observed in particular regions with removed influence of direct Sun radiation. Dry area subtracted from center (leak area) is red curve with crosses. Dry area subtracted from bottom (wet area) is represented by green curve with triangles. Black curve with circles represents result of subtraction of ROI and top-dry section. Black curve has almost constant course in time, and its temperature level is lower by about 0.5°C than in dry area. Green curve values gradually increases over time. Only when surface in this region reaches the leakage of lower temperature, the temperature on curve temporarily decreases (37th frame). Red curve is at beginning similar to the course of the green and black curve, but at a different temperature level. Leakage is noticeable here at 35 frame, when the temperature curve sharply decreases by about 2 degrees.

Figure 7 presents the result of gradient filtration (*g*=[1 0 -1];] of course of each pixel in ROI, in time domain. Variations in temperature during the measurement are mostly similar one to each other. The biggest derogation from the course can be seen for the area of the leak, which occurs for 35 frame. Higher gradients for all curves are visible in moments when covering Sun by clouds begins and ends.

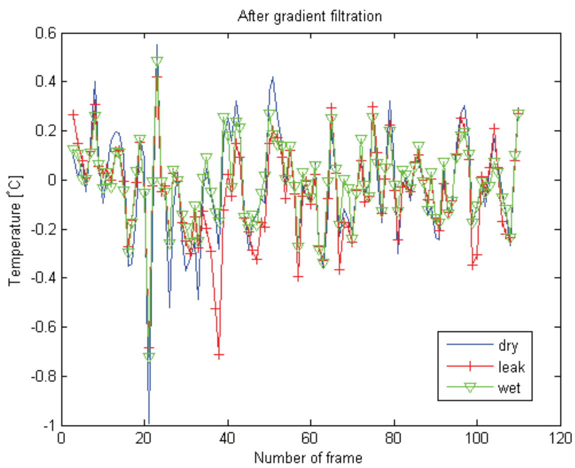

Fig. 7. The temperatures after gradient performed in each region

Analysis of the temperature changes over time in separate areas led to develop the sequence processing procedures to detect places where a leak occurred.

Next few steps of sequence of infrared images processing are standard image processing procedure, which consists of different operations performed with images: multiplication, subtraction, threshold, morphological operations [9]. These procedures made it possible to isolate whole leakage on ROI part of image. As a result the binary image with leak was made. Depending on parameters used in processing (for example the size and shape of the structural element used in morphological closing procedure) we can obtain slightly modified results. Example of final results is presented in Figure 8, treshold level 0.1, closing procedure using disk shape structural element with size 3 was used. Example result of leakage detection for image number 52 (top image in Fig. 8) and 108 (bottom image in Fig. 8). The binary result image with leak area is combined with first infrared image from sequence.

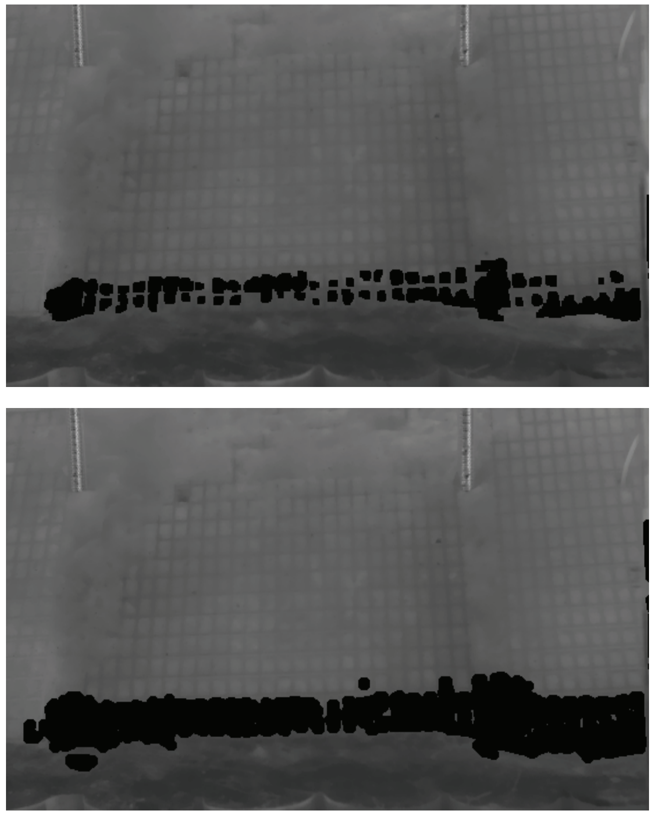

Fig. 8. Example result of leakage detection for image number 52 (top) and 108 (bottom)

4. Conclusions

Infrared thermography allowed to register leak of water in experimental embankment. The lower temperature of the water seeping away through the embankment caused changes in temperature on getting wet surface. Image processing methods allowed to localize the leak on the thermal images, despite the impact of external factors on the measurement and differences in objects emissivity in the observed scene.

As future work more measurements on natural embankments will be performed. The influence of grass, vegetation, heterogeneity in embankment's surface for thermal imaging and leaks detection is planned to check. The results of presented method will help subdue any potential difficulties in interpreting this type of measurement. This can be helpful for application in river embankments infrared monitoring for leaks detection.

This work was supported by the National Centre of Research and Development (NCBiR), Poland, project PBS1/B9/18/2013 (no. 180535) [4].

This work was partly supported by the AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, as part of statutory project no. 11.11.140.613.

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Received: 17.11.2016 *Paper reviewed* *Accepted: 03.03.2017*

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