INSPECTION OF PAVEMENT SURFACES BY THERMOGRAPHY

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ABSTRACT:

Road pavements are maintained through the use of Pavement Management Systems. These systems work by gathering road data on existing pavements. The system gathers data such as the mechanical properties of the pavement, geometric alignment of the pavement, traffic flow data, axle loads and others. To minimise the deterioration of the mechanical properties of pavements, the physical state is assessed at a predetermined interval in order to identify developing defects that will require remedying. Systems currently used to collect the physical defect data are categorised into Network Level Surveys and Project Level Surveys. The Network Level survey comprises the use of methods adopting the use of manual visual Road Condition Survey, Roughness measurement and Road Condition Survey vehicles. Whereas the use of Road Condition Survey Vehicles results in detailed and accurate data, it is a capital-intensive method to which more economical alternatives are being sought. Advances in Remote Sensing methods introduces the possibility of undertaking manual visual road condition surveys through the use of devices such as thermography cameras in the execution of such surveys. This paper aims to look at the use of thermography cameras in collecting the visual defect data. An infrared camera as well as an HD camera was installed on the roof of a vehicle, and an infrared video of the road surface was acquired while driving. The kind of information that could be obtained from the infrared data under conditions, such as motion, was then confirmed using the InfREC analyser software. Still infrared images captured in identification of defects contain sufficient level of detail, such that defects could be identified and temperature variations within the section assessed. While in motion however identification was better captured, visually, using an HD camera.

1. INTRODUCTION

Road agencies all over the world have developed a Road Maintenance Management system in the administration of their road network. This system involves some form of monitoring of the deterioration of the physical road infrastructure including pavements.

In the early stages of this system a Network Level survey comprising of a manual Visual Road Condition Survey and Roughness measurements was adopted. This is the system currently in use in developing countries. The current practice is that trained raters traverse sections of the road network and identify and manually rate distresses that are observed in the process. Distresses observed include crack and rutting defects. In developed countries, capital intensive state of the art devices known as Road Survey Vehicles are employed in assessing the condition of the road pavement network.
In recent times efforts are underway to identify more economical and less labour-intensive approaches to undertake this exercise by taking advantage of remote sensing and GIS applications in road asset management. Some of these technologies include the use of Non-Destructive Devices and Tests in pavement assessment, the adoption of drones in the execution of road condition surveys and the use of AI in processing road images captured by camera.

This paper aims to look at the use of thermography through the adoption of infrared cameras in the execution of road condition surveys. By adopting this method, the laborious collection of road defect data by manual means would be minimized and a relatively cost-effective alternative of collecting and analysing reliable data can be obtained. The safety of raters in the execution of the survey will also be improved.

1.1 Remote Sensing

1.1.1 Background

Remote sensing is a means by which we assess the state of an object without being in direct contact with the object in question. "Remote sensing is defined as the science and technology by which the characteristics of objects of interest can be identified, measured or analysed without direct contact." (Japan Association on Remote Sensing, 1996). (Lillesand, et al., 2023) also defined it as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation."

It is a powerful technology that involves the acquisition of information about an object and has emerged as a crucial tool in various fields, and in particular infrastructure asset management. It offers a non-destructive means of assessing the state of infrastructure while improving the speed and accuracy at which data is gathered. The ability to gather data at a distance enables analyst and decision makers to gather insights and make informed decisions about systems under their management.

Due to the widespread application of remote sensing it has found use in disciplines such as:

- Geographic Information Systems
- Plant Sciences
- Earth Sciences
- Land use and land cover

1.1.2 Methodologies in remote sensing

Various methodologies are employed in remote sensing, depending on the desired outcome and the specific environment parameter being studied. They include:

- Passive remote sensing
- Active remote sensing
- Spectral Imaging
- Multispectral imaging
- Light Detection and Ranging (LiDAR)

Passive remote sensing measures the natural energy reflected or emitted by the target or object under study, such as the radial energy of the sun reflected by a body. Active remote sensing on the other hand measures emitted energy that is reflected by the target. In this study, passive remote sensing was adopted in taking thermographic imagery readings.

Infrared thermography is a technique based on the fact that bodies at temperatures above 0K emit radiation in the infrared wavelength of the electromagnetic spectrum. (Lu, et al., 2017) studied the effect of delamination in a bridge concrete deck on the infrared thermography technique. In this method active thermography was used. It was found that the depth at which delamination occurs within the pavement had an impact on the accuracy of detecting the size of the defect present. (Solla, et al., 2014) also studied an approach to identifying cracking in asphalt pavement using infrared thermographic methods in which the results showed the possibility of conducting road inspections using thermal imagery.

This research aims to study the application of remote sensing in gathering condition data of pavement surfaces by adopting infrared thermography camera, visual camera, and drone technology.

1.2 Pavement Defects

- Alligator Cracks
  Alligator cracks refer to a series of interconnected cracks that form on a road surface.

Figure 1 Alligator Cracks

- Longitudinal Cracks

Longitudinal cracks are cracks that form on road surfaces and are oriented in direction of traffic flow.

Figure 2 Longitudinal Cracks

- Transverse Cracks

This type of defect are cracks that occur in a direction perpendicular to that of traffic flow on a carriageway.

Figure 3 Transverse Cracks

2. METHODOLOGY

The aim of the study was to identify the potential of thermal cameras in identifying crack defects such as those shown in Figure 1 to Figure 3 on pavement surfaces using an infrared thermography camera. To obtain thermal imagery an NEC R300SR-S InfRec camera with instantaneous field of view of 1.21mrad was used. Table 2 shows the measuring field of view. The thermal camera is able to capture composite imagery comprising a thermal image and a visual image in photo mode, as shown in Figure 4. It is not able to capture similar imagery while recording a video, as such a HC-X1500 Panasonic 4k camera was also used in recording video footage for observation. Recording of the video imagery was run concurrently. During recording of the video footage, driving speed was limited to 50km/hr, also frame rate for the thermal camera was set to five frames per second. The ability to be able to extract imagery from video is critical, as it facilitates the capturing road defect data without the need to stop at each defect location. Observation was also made with a Mavic 2 enterprise drone. Details of the recording device are shown in Table 1.

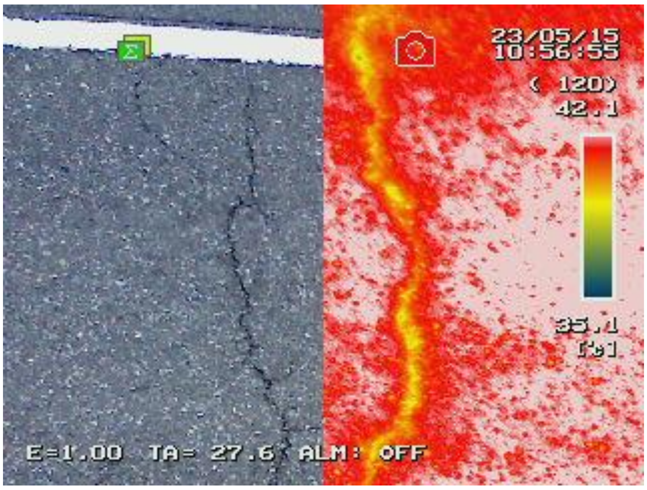

Figure 4 Composite image of crack defect

Table 1 Equipment

Equipment	NEC InfRec R300SR-S	Panasonic 4k Camera	DJI Mavi 2 Enterprise Drone	
Model	R300SR-S	HC-X1500	Mavic 2 Enterprise (Thermal Camera)	Visual Camera
Analyser	InfRec NS9500 Standard			
Detector Type	Uncooled focal plane array (Microbolometer)		Uncooled Vox Microbolometer	
Number of pixels	320(H) x 240(V)		640 x 512	-
Video Resolution				3840 x 2160 @ 30fps 1920 x 1080 @ 30fps
Video Format				MP4
Temperature range	-40 – 120			
Spectral range	8 - 14μm		8 - 14μm	

Table 2 Measuring field of view of R300SR-S

Measuring distance (m)	Minimum detectable size (H x V mm)	Horizontal range (m)	Vertical range (m)
0.1	0.12 x 0.12	0.038	0.029
1.0	1.21 x 1.21	0.38	0.29
10	12 x 12	3.8	2.9
100	121 x 121	38	29

The platform used was a private vehicle as shown in Figure 5. The thermal camera was set up in such a way that it was at an angle to the carriageway and its measuring distance of the point of interest, at a distance of 3m. This setup enabled the review of defect data to be done in a way that allows for viewing of a greater section of the pavement. Viewing the pavement in this way allowed for identification of defects in relation to the carriageway (Figure 6), otherwise the image viewed cannot be comprehended. Also, the set up prevents solar radiation from reflecting of the car directly into the thermal camera.

Video imagery was taken of a selected route with defects present and assess the imagery captured to identify cracks. The video recorded was later processed with the InfRec Analyser NS9500 to break the video into its component frames for selection of the crack defects. While in video mode however, the thermal camera cannot simultaneously record visual imagery of the route as can be done when taking still photos. As such a HC-X1500 Panasonic 4k camera was also mounted alongside the thermal camera to capture the visual imagery. In order to have information on the defects identified and to be able to produce a damage map, the cameras were used alongside a GPS recording device.

Figure 5 Thermal and HD camera set up

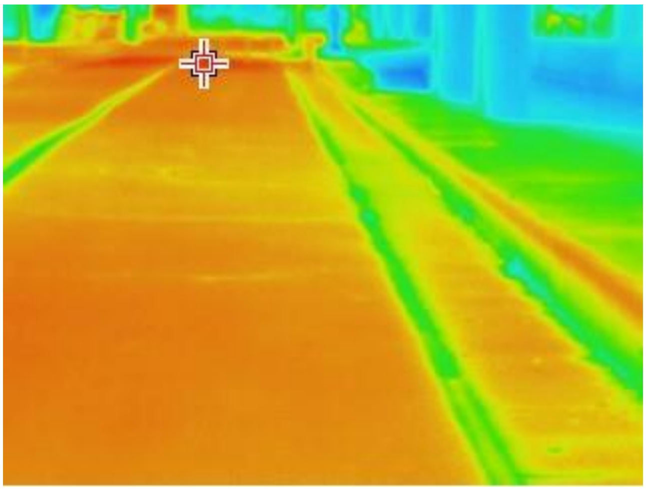

Figure 6 Thermal Imagery

3. RESULTS AND DISCUSSIONS

Still photos were taken on a candidate road in the Kanazawa Institute of Technology that had defects present. Analysis of the still photos in InfRec Analyser NS9500 showed that there was a variation in temperature between the sound pavement and the point at which cracks were identified. This is shown by the line graph in Figure 7. A histogram produced from analysis of the image also shows that the lower temperatures were recorded within the crack. The results showing the temperature variations at the point of the defect are in agreement with the work done by (Solla, et al., 2014).

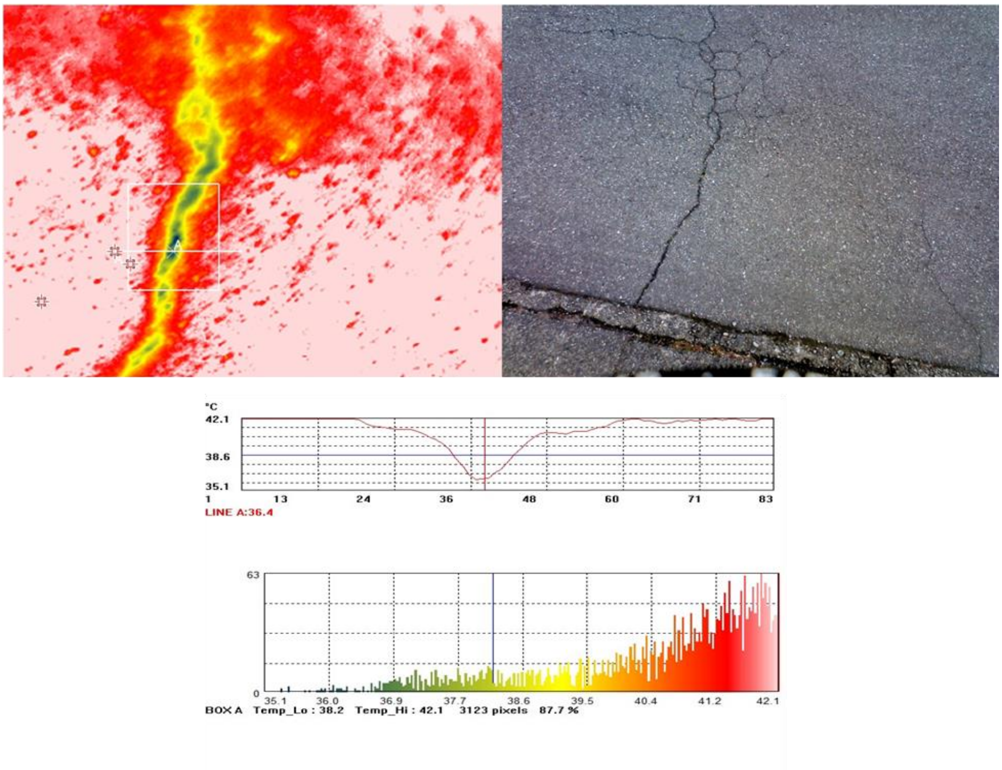

Figure 7 Temperature Distribution in Defect Zones

The field survey was undertaken on a road leading from Takahashimachi to Arimatsu on a cloudy day with ambient temperature of 32°C. In stationary state sufficient information was captured from the extracted imagery (Figure 8). While in motion however the quality of the image was insufficient to gather enough information on the state of the pavement surface (Figure 9).

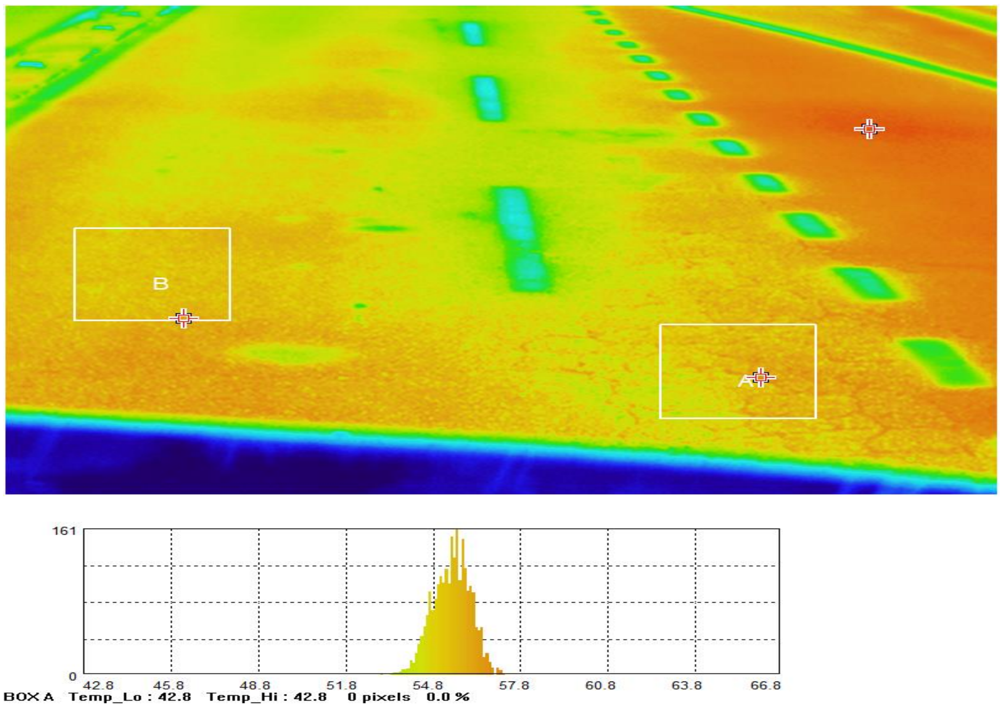

Figure 8 Alligator Cracks in extracted while stationary Thermal Photo

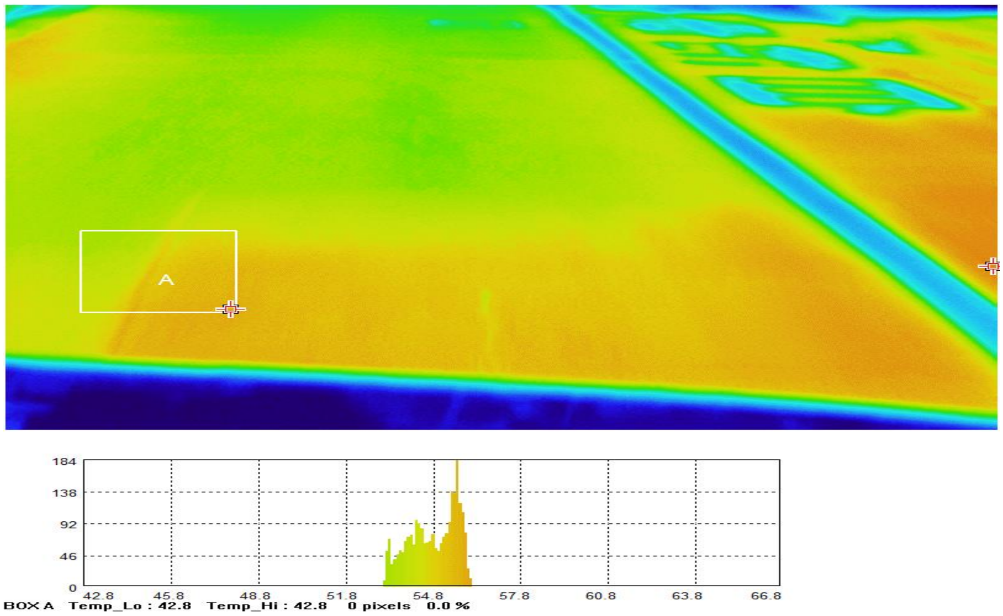

Figure 9 Patch section in extracted while in motion Thermal Photo

The normal video taken was also processed and divided into frames. These frames were then examined and sections of the route where crack defects were present were identified.

Figure 10 Extracted image from normal video

CONCLUSION

This paper investigated the use of thermography cameras in collecting the visual defect data on road pavement surfaces under conditions such as motion. Thermal imagery as well as normal video imagery was collected.

Still infrared images captured in identification of crack defects on a road contain sufficient level of detail, such that defects could be identified and temperature variations within the section assessed. Due to the time it takes infrared thermography to compose the quality of an image, however, the amount of detail captured through video imagery while in motion in this method was limited. It was also possible to identify the defects visually in the normal video under similar conditions of motion. The next steps of this study include researching the capacity of a thermal camera mounted on a drone to identify similar defects and also translation of this data onto a GPS map using coordinate data gathered.

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REFERENCES

Campbell, J. B., 1996. *Introduction to Remote Sensing.* New York: The Guilford Press.
Japan Association on Remote Sensing, 1996. *Remote Sensing Note.* Tokyo: Japan Association on Remote Sensing.
Lillesand, T. M., Kiefer, R. W. & Chipman, J. W., 2023. *Google Scholar.* [Online]
Available at:
https://books.google.co.jp/books?hl=en&lr=&id=AFHDCAAAQBAJ&oi=fnd&pg=PA30&dq=remote+sensing+and+image+interpretation&ots=0Dunl-gE9s&sig=Da1CMeL7dKAK6BtLVgspfgI3Awc&redir_esc=y#v=onepage&q=remote%20sensing%20and%20image%20interpretation&f=false
Lu, Y., Golrokh, A. J. & Islam, M. A., 2017. Concrete Pavement Service Condition Assessment Using Infrared Thermography. *Hindawi, Advances in Materials Science and Engineering.*
Solla, M., Laguela, S., Gonzalez-Jorge, H. & Arias, P., 2014. Approach to identify cracking in asphalt pavement using GPR and infrared thermographic methods: Preliminary findings. *NDT&E International.*
Tokunaga, M., 2020. Extraction of Debilitated Trees along the road by Blocked NDVI. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* XLIII-B3-2020(2020 XXIV ISPRS Congress).