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Use of a Hand-held Thermal Imager to Detect Cavities and Rotten Tissue in Trees

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Abstract

The presence of cavities and/or rotten tissue in trees poses a serious problem for their survival and for the safety of passers-by, because the damage can progress and cause the tree or parts of it to suddenly crack down.

The various diagnostic systems currently used generally entail a long period to be carried out and are difficult to use or can be dangerous for man. They are often invasive, in that they envisage the carrying out of holes onto the plant. The holes made on the tree can become the access and spread routes for pathogens.

The use of a hand-held infrared (IR) camera allows to spot the presence and size of possible cavities/damage also in the aerial parts of big trees from the ground and in real time.

The proposed method allows a non invasive investigation and is totally harmless for man too. It is a rapid, user-friendly and safe system of investigation.

It is the only system among the known investigation apparatuses that also provides the images of the situation present in the plant and allows to easily and reliably follow the evolution of the phenomenon.
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1. Introduction

The assessment of the health conditions of the trees located in open-sky areas is fundamental for public administrators and the technicians tasked with the management of urban trees, since more and more often damage, even serious one, can injure people and destroy things, in that trees can suddenly crack down also in the absence of external causes. The problem is worsened by the fact that the only external signs revealing the existence of cavities, or rotten tissue are often small holes, partially withered foliage, and decortication that only an arborist can relate to internal damage. Since the only weapon at disposal is prevention, the early detection of damage is essential.

1.1 Classical Methods of Analysis

The systems used to detect the presence of damage in tissue can be classified in four categories, and precisely:

1. Percussion of the trunk with a hammer and interpretation of the sound produced;
2. Samples of tissue collected with a Pressler auger, visual assessment of the tissue and possible measurement of their resistance to cracks;
3. Insertion of measuring probes in the tissue;
4. Use of radioisotopes, radiographic systems, or radar systems.

The above-mentioned systems request a physical contact with the area to be investigated and necessitate the use of supports to reach the tree's aerial parts. Some methods provide for information that is not easy to interpret or that depends on variable factors (excess of resin, or moisture in tissue).

Almost all these methods envisage that holes having from 2mm to 12mm in diameter be carried out. They can further aggravate the already existing problems, or become access routes for pathogens or parasites. The systems that use isotopes and radiation can be dangerous for humans or are so bulky that they can only be used in favourable conditions.

A limit which is common to all the currently-used apparatuses is the fact that they give information only on the point being investigated, or on the trunk section at the height at which the investigation is executed. The information on the conditions of the entire plant can be collected either by deduction, on the basis of the operator's experience, or with tests repeated at various levels thus prolonging the time necessary to carry out the investigation.

The more invasive the diagnostic system used, the more precise the result.

It is anyway a good practice to use these methods after a careful visual tree assessment carried out according the Visual Tree Assessment (VTA) principles. This investigation technique has been introduced a few years ago (Mattheck and Breloer, 1994) , it has proved its validity and is used as a reference in legal cases in Germany.

1.2 Thermography

The system proposed (Catena 1990, Catena 1992, Catena and Catena 2000, Catena et al. 1990) consists in the use of a hand-held IR camera that can detect the presence of discontinuities due to cavities or rotten tissue within the plant. Such discontinuities can be spotted thanks to the variation in the thermal conductivity of the tissue affected by the phenomenon as opposed to the surrounding tissue that is still undamaged. This entails the fact that the two areas present a different surface temperature, highlighted by the apparatus that thus provides for an actual thermal map of the areas under investigation. In the case of trees, the area where the variation is present has a generally lower surface temperature. The system is non invasive and thus totally harmless for the tree.

2. Materials and Methods

The apparatus used for this investigation is an AVIO TVS 610 portable camera that is sensitive in the 8 – 14 µm wavelength interval. To carry out the investigation, any IR camera can be used, whatever the wavelength interval in which it works, as long as it has high geometric resolution and thermal sensitivity, and can visualise and record the images of the scene filmed. The apparatus has a geometric resolution of 1.4 mrad and a thermal sensitivity of 0.1 °C at room temperature. The sensor is made up of a 320x240 microbolometers matrix which needs not to be cooled down. It can also measure the surface temperature of the objects investigated. The sensing device, commands and 5'' screen which displays the real-time thermal image are contained in a single apparatus, which is slightly bigger than a common camera. The camera which is equipped with a battery allowing up to 4 hours continuous functioning weighs about 3 kg.

Thermal images can be recorded with a portable videocassette-recorder or stored on a PCMCIA Compact Flash card (a 10Mb card can contain up to 50 images) which allows to transfer the images onto a computer, where they can be processed and transformed in bitmap images by using the appropriate software. The system used can provide black-and-white and colour thermal images of the area investigated: by using the normal programmes for image processing, the thermal image of the entire tree can be reproduced, if necessary. A reference scale, shown in picture 4, is present only on the original images (*.iri) and allows to immediately assess the actual differences in temperature.

In black-and-white images, the existence and extension of possible damage are revealed by the presence and size of an area presenting a generally darker shade of grey than that in the surrounding part. In colour images, the damage is instead revealed by an area presenting a colour different from the one of the surrounding part.

The investigation is carried out from the ground, by pointing the camera lens to the selected tree and analysing the images of the various areas filmed. Where a thermal discontinuity is present that is not due to damage on the trunk surface, internal damage is present. It is therefore possible to analyse also the plant’s aerial parts from the ground. The appropriate filming distance is up to 20-25 m: greater distances wouldn’t permit the detection of small-sized damage. Thanks to the manoeuvrability of the camera, only 1-2 people are needed, and the investigation results quick and effortless. The investigation is totally harmless for the plant, since it is non invasive.

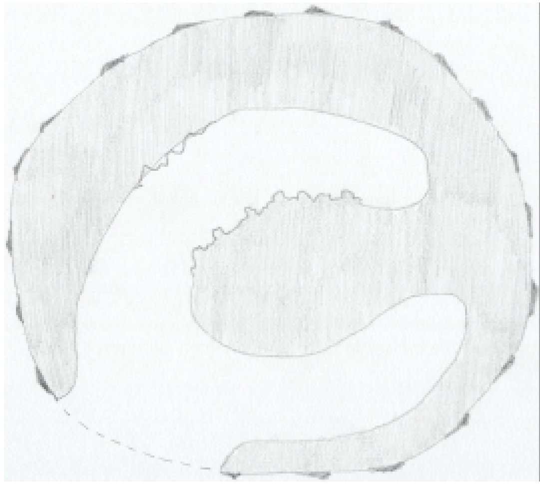
In order to avoid wrong results, the operator has to be careful not to film sun-drenched parts. In fact, if the sun heats the tree surface, it may cancel the difference in temperature between the healthy and the damaged areas. For the same reasons, the apparatus cannot be used with temperatures below zero: even though investigations with temperatures ranging between +2 and +35 °C have successfully been carried out. Also the presence of moisture on the tree trunk alters results, in that water itself is given in black in black-and-white images, and in colour thermograms, water has a colour different from the one in dry areas.

Since the apparatus measures the temperature of the tree surface, the area concerned doesn’t have to be covered by moss, creepers and/or epiphytes or any other thing, in that they may alter results. Moreover, all the differences in the shades of grey or colours are not due to the presence of cavities: before proceeding with the measure, the presence of possible surface damage such as erosions, decortications, callus of cicatrization on the trunk have to be searched for, because they interfere with the image assessment. An expert in urban trees or user of this system having a minimum experience can be able to detect the presence of such surface interference or alterations at first glance and to evaluate their impact on the thermal image.

3. The Thermal Investigation

Picture 1 shows the trunk of a palm tree (*Phoenix canariensis*) which presents a cavity at about 1,5 m from the ground. This cavity occupies almost the entire tree section, and is full of detritus, therefore its actual size cannot be distinguished. It has the form of a horizontally positioned U, as shown in picture 2.

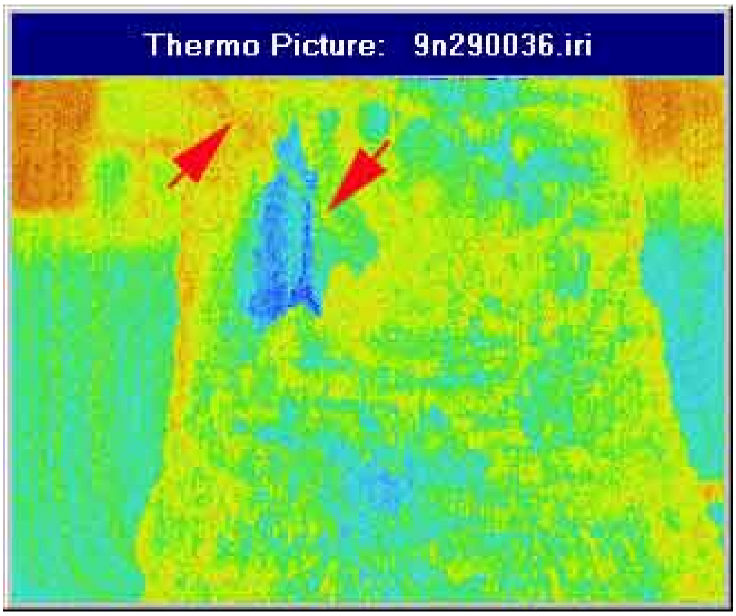
Picture 1 – in this picture it is possible to see the presence of a big cavity, full of detritus, which opens in the trunk of a palm tree (*Phoenix canariensis*) at about 1.5 m from the ground

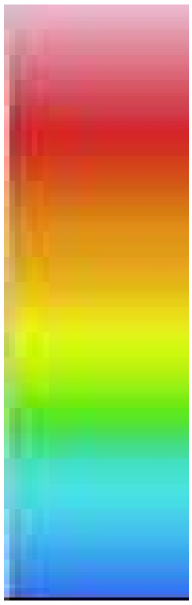


Picture 2 – representation of the cavity at the height of the opening

The thermography in picture 3 reveals the extension of the cavity, displayed in green, blue, and light-blue. The presence of various colours is connected to the different thickness of the healthy tissue still present. The correspondence between the actual dimension of the cavity and the dimension detected by the thermography has been verified by inserting a metallic probe into the detritus. The thermal image of the probe is shown by arrows in picture 3.

Picture 4 shows the scale of colours from which it is possible to observe the differences in temperature that are present in thermal images. The scale goes from the coldest temperature, at the bottom, to the warmest one, at the top.





Picture 3 – the thermography shows that the cavity affects a big part of the trunk section and goes downwards. What is shown by the thermography has been verified by inserting the probe indicated by the arrows in the opening.

Picture 4 – Chromatic scale of reference for colour thermographies from which it is immediately possible to detect the differences in temperatures existing in the image.

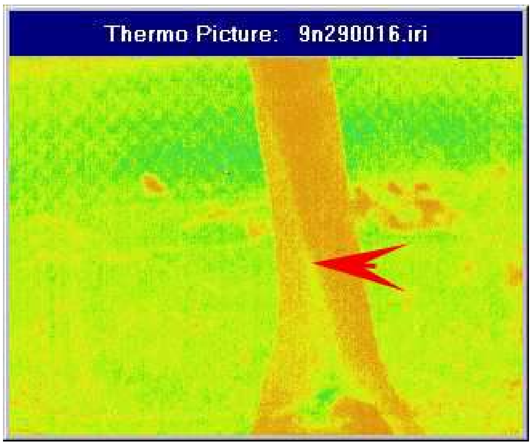
Picture 5 shows the thermography of a bay-tree (*Laurus nobilis*) which unlike the palm tree in picture 1, didn't present any external signs of damage. The image has been obtained by uniting 4 thermographies with the use of a normal image processing software. The assessment of the colours present indicates that the entire trunk is damaged, from its base to its branches, which are all healthy, instead. The plant was deemed dangerous, and it was suggested to cut it down. The precision of the investigation has been confirmed in the following days, when the tree cracked down, because of a downpour, before any measure could have been taken. The photograph in picture 6 shows the various logs that have been obtained from the tree: it is to be noticed that the thinnest ones taken from the branches are undamaged.

The photograph in picture 7 shows a stump of bay tree on which two trunks grew. One of them has been cut down in the past. Only a rotten stump is left of it which is seen in the foreground in the photograph. Such stump has partially been incorporated by the trunk left. The relative thermography (picture 8) shows the presence of rotten tissue at the trunk base which goes up the trunk, and particularly affects the depression which can be seen along the trunk. If the thermography is observed well, it is possible to notice that the damage narrows as it goes up the trunk. The damage at the trunk base has been verified by inserting a probe into the rotten tissue of the stump. Whereas to assess the damage along the trunk a core has been taken with a Pressler auger at 50 cm from the ground, in the point shown by the arrow, where the damage was very little. The photograph of the core, clearly shown in picture 9 shows how the damage in that position affects only the first centimetre beneath the bark.

Picture 5 (left) – Collage of thermographies of a bay-tree which doesn't show any visible sign of damage. From the colour assessment, it can be inferred that the entire trunk is damaged, up to its branches, which are undamaged, instead. The plant has been deemed dangerous and it was suggested to cut it down, but it cracked down during a downpour, a few days after the thermal assessment.

Picture 6 – the various logs obtained from the sectioning of the felled tree: it has to be noticed that the thinnest logs, taken from the branches, are undamaged.

Picture 7 (right) - A stump of bay tree on which two trunks grew. One of them has been cut down in the past. Only a rotten stump is left of it, which is seen in the foreground in the photograph.

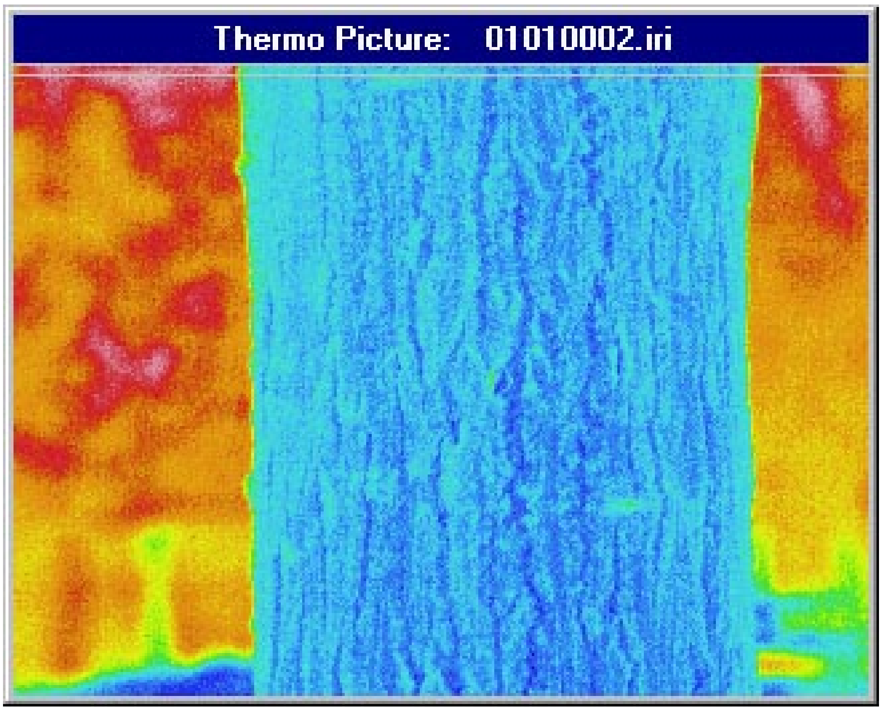


Picture 8 – the relative thermography shows the presence of damage that goes from the base upwards, thus affecting the depression along the trunk. The damage narrows as it goes up the trunk.

Picture 9 – Photograph of the core taken in the point which is indicated by an arrow in picture 8. In this point the damage affects only the first centimetre of tissue beneath the bark.

Picture 10 shows what the thermography of a healthy tree is like: it is to be noticed that the chromatic distribution and therefore temperature is homogeneous. This tree is a cedar (*Cedrus atlantica*): the streaks in dark are the thermal image of the deep furrows which characterise its bark, unlike the bay-tree's.

This also shows that the operator has to be careful in order to have an optimnal use of thermography. To avoid mistakes, when he/she is assessing a tree belonging to a species that he/she has never assessed before, it is necessary to see how its bark appears on thermograms.



Picture 10 – This is the thermography of a healthy tree (*Cedrus atlantica*): the colour distribution and thus temperature are homogeneous, which indicate the absence of damage. The streaks in dark blue are the thermal image of the furrows that feature the bark of this species.

4. Conclusions

The thermography allows to spot the presence of damage also in its early phase, within the plant, thus allowing an early diagnosis without running the risk of damaging the plant. If this technique is utilised, the use of invasive diagnostic systems can be limited to the plant and parts of it in which the thermography has actually detected a damage that has to be quantified.

The simplicity of use and possibility to assess large portions of the plant, also aerial parts from the ground make the investigation quick and fit to be carried out at the same time as the visual assessment (VTA).

Moreover the total non invasiveness of the apparatus doesn't aggravate or spread the already present damage, and doesn't cause or favour the penetration of pathogens in healthy tissue.

The possibility of storing images and thus confronting them with those of the same tree portion taken at later times allows to follow the possible evolution of the pathology.

The system constitutes an important advance in the definition of the health and stability conditions of trees, in order to properly manage and maintain urban trees.

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