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Investigation And Present Of The Thermal Imaging Camera

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Abstract
This research presented the thermal imaging camera and development it by using infrared sensors (elements). The camera thermography system depend on the emissivity value of the objects, and camera's algorithm will calculate a temperature that more closely matches the actual contact temperature of the object then will produce temperature variations image (thermal image).Since infrared radiation is emitted by all objects above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination.

Keywords: *Thermal image, thermography camera, Infrared.*

1. Introduction

Ever since the first commercial thermal imaging camera was sold in 1965 for high voltage power line inspections, by what would later become FLIR Systems, the use of thermal imaging cameras for industrial applications has been an important market segment for FLIR.
Since then thermal imaging technology had been evolved. A thermal imaging camera becomes compact systems that look just like a digital video camera or digital photo camera. They are easy to use and generate crisp real-time high-resolution images.
Thermal imaging technology was improved continually, and then become one of the most valuable diagnostic tools for industrial applications. By detecting anomalies (objects) that are usually invisible to the naked eye, thermal imaging allows evaluating the detraction of operating parts , so necessary corrective action can taken before costly system failures occur.
A thermal imaging camera is a reliable non-contact instrument which is able to scan and visualize the temperature distribution of entire surfaces of bodies, machinery and electrical equipment quickly and accurately. Thermography programs have contributed to substantial cost savings for our customers around the world.
A thermal imaging camera records the intensity of radiation in the infrared part of the electromagnetic spectrum and converts it to a visible image.

2. The infrared concept:

Our eyes were created to detect electromagnetic radiation in the visible light spectrum and all other forms of electromagnetic radiation, such as infrared, are invisible to human eye.
The existence of infrared was discovered in 1800 by astronomer Sir Frederick William Herschel. Curious to the thermal difference between light colors, he directed sunlight through a glass prism to create a spectrum and then measured the temperature of each color. He found that the temperatures of the colors increased from the violet to the red part of the spectrum.
After noticing this pattern Herschel decided to measure the temperature just beyond the red portion of the spectrum in a region where no sunlight was visible. To his surprise, he found that this region had the highest temperature of all.
Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-273.15 degrees Celsius or 0 Kelvin) emits radiation in the infrared region. Even objects that we think of as being very cold, such as ice cubes, it's already emitting infrared radiation.

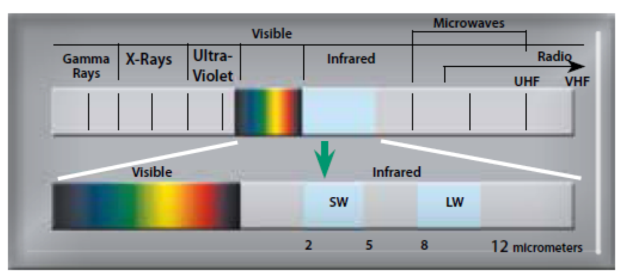

Fig. 1. The infrared radiation

The Infrared radiations part of the electromagnetic spectrum covers the range from roughly 400 THz to 300 GHz (0.75 to 1000 µm wavelength). It can be divided into three parts:
1- Far-infrared, from 30 THz to 300 GHz (10 to 1000 µm). The lower part of this range may also be called microwaves

2- Mid-infrared, from 120 to 30 THz (2.5 to 10 µm). Hot objects (Black body radiators) can radiate strongly in this range, and human skin at normal body temperature radiates strongly at the lower end of this region

3- Near-infrared, from 400 to 120 THz (0.75 to 2.5 µm). Physical processes that are relevant for this range are similar to those for visible light.

Hamlyn G. JonesA 2009 presented the outlines the potential applications of IR sensing in drought phenotyping, with particular emphasis on a description of the problems with extrapolation of the technique from the study of single leaves in controlled environments to the study of plant canopies is field plots, with examples taken from studies on grapevine (Vitis vinifera L.) and rice (Oryza sativa L.). Particular problems include the sensitivity of leaf temperature (and potentially the temperature of reference surfaces) to both temporal and spatial variation in absorbed radiation, with leaf temperature varying by as much as 15_C between full sun and deep shade. Examples of application of the approach to phenotyping in the field and the steps in data analysis are outlined, demonstrating that clear genotypic variation may be detected despite substantial variation in soil moisture status or incident radiation by the use of appropriate normalization techniques.

3. Theoretical analysis

Thermal imaging is, therefore, particularly well-suited for screening plants for differences in stomatal conductance, especially under laboratory conditions (e.g. Raskin and Ladyman 1988; Merlot et al. 2002) where the environmental conditions can be closely controlled. These and other uses of thermal imaging in plant science have been reviewed by Jones (2004). Because leaf temperature is dependent on environmental factors such as air temperature, humidity, wind speed and incident radiation, as well as stomatal aperture, many attempts have been made to normalize the data to account for environmental variation. The first normalization for environmental variation was in terms of air temperature (Ta), achieved by accumulating differences between leaf temperature (Tleaf) and Ta as a measure of plant stress (Jackson et al. 1977). Further normalization was achieved by Idso et al. (1981) who developed the 'crop water stress index' (CWSI), which relates the observed temperature to the temperature of non-stressed and non-transpiring crops under the same environmental conditions; by noting the ambient humidity at the same time, effects of humidity variation could also be corrected. Rather than using actual empirical crop temperatures as references for calculation of CWSI, Jones and others have developed the approach of using physical wet and dry reference surfaces for application to field screening (Jones 1999a, 1999b, 2002; Cohen et al. 2005).

A particularly helpful feature of the use of wet and dry reference temperatures is that they can readily be used for the derivation of indices that do not require detailed environmental information. A useful index for screening purposes, and in other cases where absolute estimates of stomatal conductance may not be required, is the index of stomatal conductance (*Ig*) introduced by Jones (1999a), where the index is proportional to stomatal conductance (for a constant boundary layer conductance) and is calculated as.

$$Ig = (Tdry \_ Tleaf) / (Tleaf \_ Twet) \quad (1)$$

Where *Twet* is the temperature of a wet surface and *Tdry* is the temperature of a non-transpiring surface. This can be converted to a stomatal conductance (g_l) using

$$g1=Ig/ (raW + (s/_\gamma)\, r\mathrm{HR}) \quad (2)$$

Where *raW* is the boundary layer resistance to water vapour (sm–1), and *r*HR is the parallel resistance to heat and radiation transfer by the leaf (see Jones 1992).

Theoretical analysis has shown that this approach may be extended beyond the calculation of a stress index to the estimation of an actual stomatal conductance (Leinonen et al. 2006), and that as good results may be obtained using only dry reference surfaces, or even, where full environmental measurements are available, calculation of the theoretical wet and dry reference temperatures. From an analysis of the full leaf energy balance, Leinonen et al. (2006) and Guilioni et al. (2008) showed that stomatal resistance (rs; the reciprocal of the conductance) may be estimated, without the use of reference surfaces, from

$$rs = \_\ \rho cp r\mathrm{HR}(s(Tleaf \_ Tair) + D) /_\gamma\ ((Tleaf \_ Tair)\ \rho cp \_\ r\mathrm{HR}Rni))\ \_\ raW \quad (3)$$

where *R*ni the net isothermal radiation (the net radiation that would be absorbed by a leaf if it were at air temperature, Wm–2), r the density of air (kgm–3), cp the specific heat capacity of air (J kg–1K–1), s the slope of the curve relating saturating water vapor pressure to temperature (Pa _C–1), g the psychometric constant (PaK–1) and D the air vapor pressure deficit (Pa). Where any of these key variables are unavailable, reference surfaces may substitute, with suitable rearrangement of the equations (Leinonen et al. 2006).

Thermal imaging using infrared (IR) is now an established technology for the study of stomatal responses and for phenotyping plants for differences in stomatal behaviour.

In all the studies discussed here, thermal images were obtained using a Thermacam P25 (FLIR Systems, Danderyd, Sweden), long-wave thermal imager with a sensitivity of 0.08_C and accuracy of _2_C. Parallel visible images were obtained with either the onboard digital imager or a normal digital camera.

For phenotyping purposes, images can be obtained over a range of distances from the canopy of interest. In some studies the camera may be held within a couple of meters of the canopy, but for most phenotyping applications, and for many agronomic applications, it is necessary to view a larger area of canopy so that substantial numbers of genotypes can be compared simultaneously. As shown later, this minimizes problems caused by any rapid changes in solar irradiance. Several options are available to expand the area of view; these include mounting the camera on mobile platforms such as a 'cherry picker' (Möller et al. 2007) or other mobile platforms. The camera can also be elevated on a hand-held pole to ~5m above the ground, which, when combined with an oblique view, allows viewing of a useful area of crop.

For crop phenotyping, however, the usual requirement is the comparison of genotypes, with absolute values of stomatal conductance or stress index being of less interest. In such cases, inclusion of a substantial number of genotypes in each image (or the use of repeated reference varieties) allows effective internal normalisation of the data to correct for changes in incident light or local variation in soil.

Hamlyn G. Jones, Rachid Serraj 2002, produce an applications-oriented review covering infrared techniques and devices. At the beginning infrared systems fundamentals are presented with emphasize on thermal emission, scene radiation and contrast, cooling technics, and optics. Special attention is put on night vision and thermal imaging concepts. Next section shortly concentrates on selected infrared systems and is arranged in order to increase complexity; from smart weapon seekers, image intensifier systems, thermal imaging systems, to space-based systems. Finally, other important infrared techniques and devices are shortly described between them the most important are: non-contact thermometers, radiometers, LIDAR, and gas sensors.

4. Seriousness of thermal imaging (utilization)

In simplest terms, a thermal imager operates like the human eye, but is much more powerful. Infrared energy from the environment travels through a lens and is registered on a detector. The thermal imager measures very small relative temperature differences and converts otherwise invisible heat patterns into clear, visible images that are seen through either a viewfinder or monitor. Thermal imagers cannot see through walls, glass or other solid objects, but they can detect heat that has transferred to the surface of an object.

Thermal Imaging systems collect light at wavelengths longer than visible light but shorter than 1 mm. The IR spectrum is divided in the following ranges:

- ✓ Near Infrared (NIR), 0.75 µm to 1.4 µm
- ✓ Short Wave Infrared (SWIR), 1.4 µm to 3 µm
- ✓ Mid Wave Infrared (MWIR), 3 µm to 5 µm
- ✓ Long Wave Infrared (LWIR), 8 µm to 12 µm
- ✓ Very Long Wave Infrared (VLWIR), 12 µm to 25 µm
- ✓ Far Wave Infrared (FWIR), 25 µm to 1 mm

The thermal image forming process:

-A special lens focuses the infrared light emitted by all of the objects in view.
-The focused light is scanned by the infrared-detector elements creating electric impulses.
-The impulses are sent to a signal-processing unit that translates the information from the elements into data for the display.
-The signal-processing unit sends the information to the display, where it appears as various colors depending on the intensity of the infrared emission.

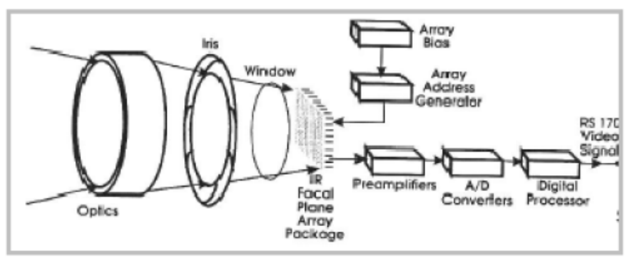

Fig. 2. The assembly of thermal image system

There are two distinctive detector technologies:
1- Direct detection (photon counting)
2- Thermal detection

Direct detection translates the photons directly into electrons. The charge accumulated, the current flow, or the changes in conductivity are proportional to the radiance of objects in the scenery viewed. This category contains many detectors: Lead Selenide (PbSe), Mercury Cadmium Telluride (HgCdTe), Indium Antimonies (InSb), Platinum Silicide (PtSi), etc. Except for thermal imagers, working in the SWIR range, all infrared cameras based on the direct detection technology are detectors cooled to cryogenic temperatures, close to -200°C.

Thermal detection uses secondary effects, such as the relation between conductivity, capacitance, expansion and detector temperature. The following detectors are included in this category: bolometers, thermocouples, thermopiles, pyroelectric detectors etc. They do not require cryogenic temperatures.

Any object that has temperature above absolute zero (-273.15 degree Celsius) emits radiations in the infrared region (such as ice cubes).
Emissivity is a term representing a material's ability to emit thermal infrared radiation; warmer objects will emit more thermal infrared radiation.
Infrared detectors (thermometers) use to detect radiation in the infrared range (roughly 9–14 µm).
Specialized thermal imaging cameras use Focal Plant Arrays (FPAs) that capable of detecting radiation in the mid (3 to 5 µm))
Use large numbers of IR detector at the same time to measure (scan) emissivity (IR thermal radiation) on entire area will produce thermal IR variations image.

5. Advantages of thermograph Camera:

- Shows a visual picture for temperature variation over a large area to find deteriorating, i.e., higher temperature components prior to their failure.
- Used to detect objects in dark areas
- Find defects in shafts, pipes, and other metal or plastic parts
- Safety applications
- Research and developments

And the limitation of thermography Camera is:

- Most cameras have ±2% accuracy in measurement of temperature
- Only able to directly detect surface temperatures
- Quality cameras often have a high price range

Infrared (IR) thermometers are reliable for single-spot temperature readings and scanning large areas or components
Appendix A represents some of types of thermal camera applications.

It's concluded that:

- Camera thermography system depend on the emissivity value of the objects, and camera's algorithm will calculate a temperature that more closely matches to the actual contact temperature of the object, then temperature variations will produce image (thermal image).
- Thermograms is the overall process to produce thermal image (Thermography)
- Since infrared radiation is emitted by all objects above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination.
- Black Body is a theoretical object which will radiate infrared radiation at its contact temperature. If a thermocouple on a black body radiator reads 50 °C, the radiation the black body will give up will also be 50 °C. Therefore a true black body will have an emissivity of 1.

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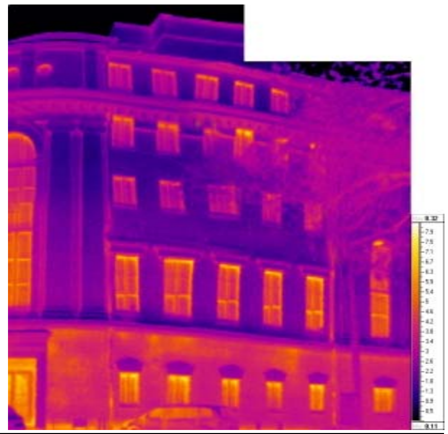
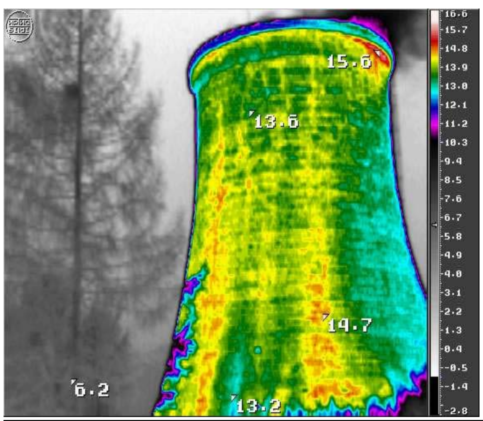
Appendix A

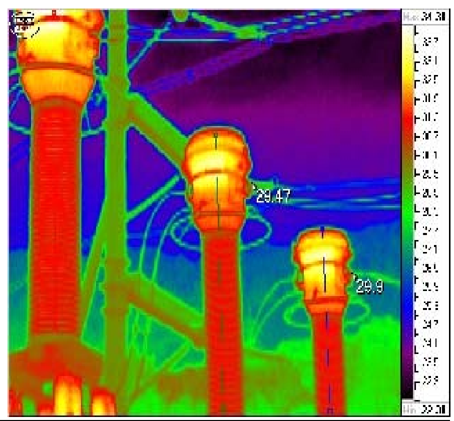
Thermal camera applications

- Building: temperature distribution to detect insulation leakage spots.

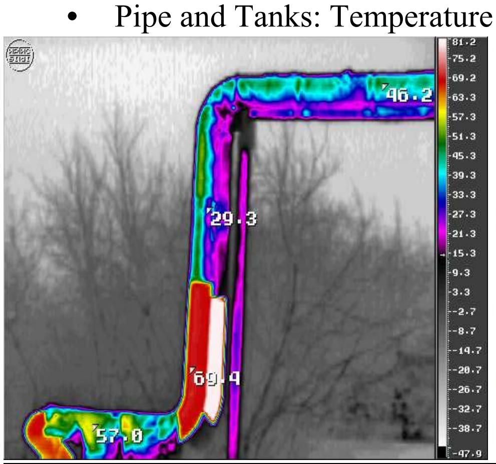


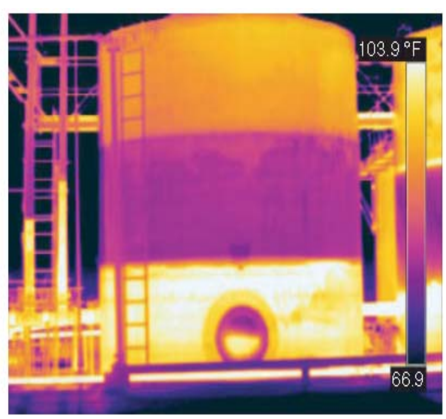
- Thermal power plant: temperature distribution to detect weekend points at chimneys and equipments.





- Pipe and Tanks: Temperature distribution to detect corroded areas.





Reference

1- Hamlyn G. Jones, Rachid Serraj, Brian R. Loveys, Lizhong Xiong, Ashley Wheaton and Adam. Price, (Thermal infrared imaging of crop canopies for the remote diagnosis and quantification of plant responses to water stress in the field), CSIRO PUBLISHING, Functional Plant Biology, 2009, 36, 978–989

2- Raskin I, Ladyman JAR (1988) Isolation and characterisation of a barley mutant with abscisic-acid-insensitive stomata. Planta 173, 73–78. doi: 10.1007/BF00394490

3- Merlot S, Mustilli AC, Genty B, North H, Lefebvre V, Sotta B, Vavasseur A, Giraudat J (2002) Use of infrared thermal imaging to isolate Arabidopsi mutants defective in stomatal regulation. The Plant Journal **30**(5), 601–609. doi: 10.1046/j.1365-313X.2002.01322.x

4- JonesHG(2004) Application of thermal imaging and infrared sensing in plant physiology and ecophysiology. Advances in Botanical Research 41,107–163. doi: 10.1016/S0065-2296(04)41003-9

5- Jackson RD, Reginato RJ, Idso SB (1977) Wheat canopy temperature: a practical tool for evaluating water requirements. Water Resources Research 13, 651–656. doi: 10.1029/WR013i003p00651

6- Idso SB, Jackson RD, Pinter PJ, Reginato RJ, Hatfield JL (1981) Normalizing the stress-degree-day parameter for environmental variability. Agricultural Meteorology 24, 45–55. doi: 10.1016/0002-1571(81) 90032-7

7- Jones HG (1999a) Use of infrared thermometry for estimation of stomatal conductance in irrigation scheduling. Agricultural and Forest Meteorology 95, 139–149. doi: 10.1016/S0168-1923(99)00030-1

8- Jones HG (1999b) Use of thermography for quantitative studies of spatial and temporal variation of stomatal conductance over leaf surfaces. Plant, Cell & Environment 22(9), 1043–1055. doi: 10.1046/j.1365-3040.1999. 00468.x

9- Jones HG, Stoll M, Santos T, de Sousa C, Chaves MM, Grant OM (2002) Use of infrared thermography for monitoring stomatal closure in the field: application to grapevine. Journal of Experimental Botany 53(378), 2249–2260. doi: 10.1093/jxb/erf083

10- Jones HG (1992) 'Plants and microclimate.' 2nd edn. (Cambridge University Press: Cambridge)

11- Leinonen I, Grant OM, Tagliavia CPP, Chaves MM, Jones HG (2006) Estimating stomatal conductance with thermal imagery. Plant, Cell & Environment 29, 1508–1518. doi: 10.1111/j.1365-3040.2006. 01528.x

12- Guilioni L, Jones HG, Leinonen I, Lhomme JP (2008) On the relationships between stomatal resistance and leaf temperatures in thermography. Agricultural and Forest Meteorology 148(11), 1908–1912. doi: 10.1016/ j.agrformet.2008.07.009

13- A. Rogalsk and K. Chrzanowski, Infrared devices and techniques, OPTO-ELECTRONICS REVIEW 10(2), 111–136 (2002)

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