Computer Vision

Thermal Imaging and Infrared

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Infrared Theory

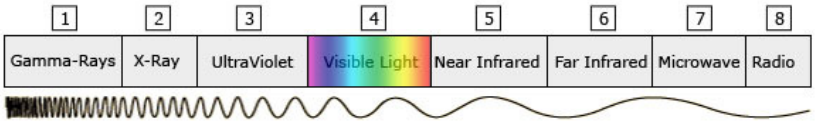
Electromagnetic spectrum

Color Temperature

Emissivity

BlackBody

Electromagnetic spectrum



1. 0.01nm – 0.1nm
2. 0.1nm – 1nm
3. 1nm – 100nm
4. 400nm – 700nm
5. 0.75 µm – 3 µm
6. 15 µm – 1000 µm
7. 1mm – 10cm
8. 1m – 10m

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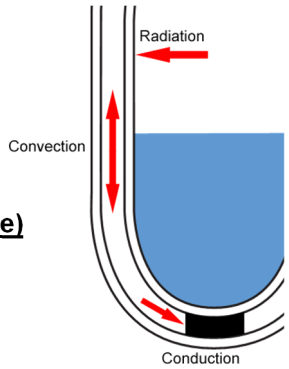
Energy flows

"Every object absorbs energy and will emit the same amount of energy when objects temperature is in balance"

- **Convection**
- **Conduction**

- **Radiation**
  - **<u>Absorption / Emission (Temperature)</u>**
  - **Reflection**
  - **Transmission (not discussed)**



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Color Temperature

Emission

1800K 4000K 5500K 8000K 12000K 16000K

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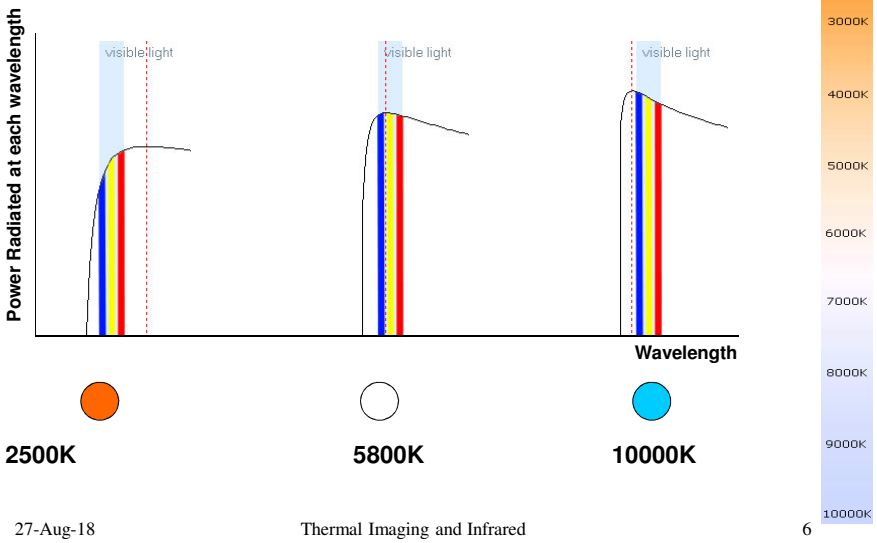
Color Temperature

Planck's law of black body radiation



2500K 5800K 10000K

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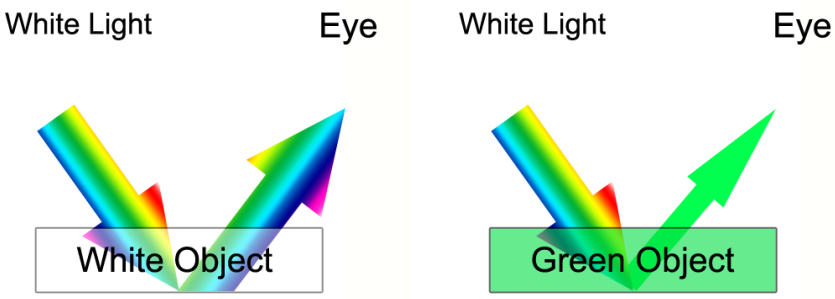
Colors & Reflecting

Reflection



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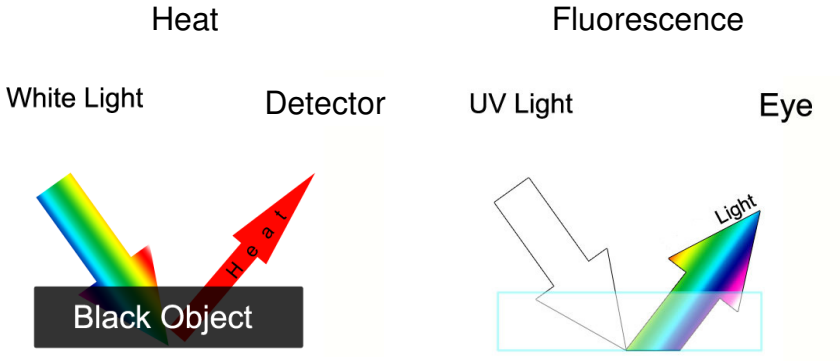
Colors & Reflecting

Absorption & Emission



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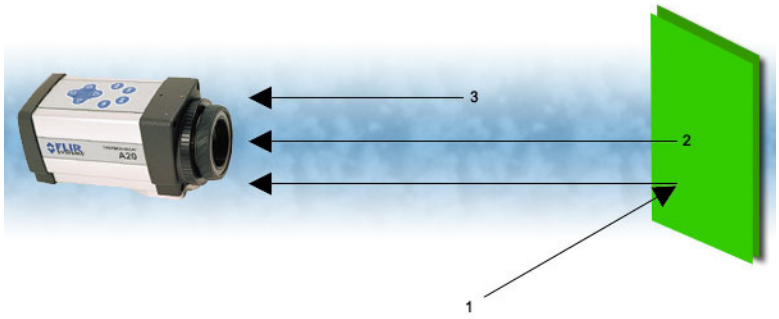
Infrared signals setup



1 Reflection
2 Object Temperature
3 Atmosphere

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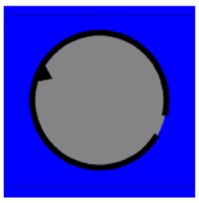
BlackBody

A theoretical *blackbody* absorbs all radiation of all wavelengths, it does not reflect any radiation.



Emissivity = 1

An eye is a practical example of a blackbody
(It is not a perfect *blackbody,* but a *graybody*)

Higher emissivity is better

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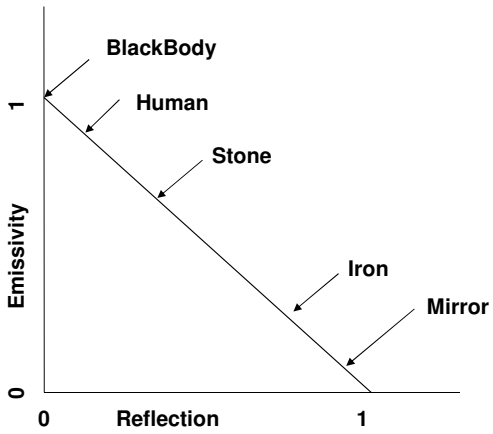
Emissivity

Emissivity = 1 – Reflection

- **Polished Steel: 0,07**
- **Sand: 0,60**
- **Paper: 0,7 to 0,9**
- **Human Skin: 0,95**

Lightweight emergency thermal blankets are based on reflective metallic coatings.
They lose little heat by radiation.



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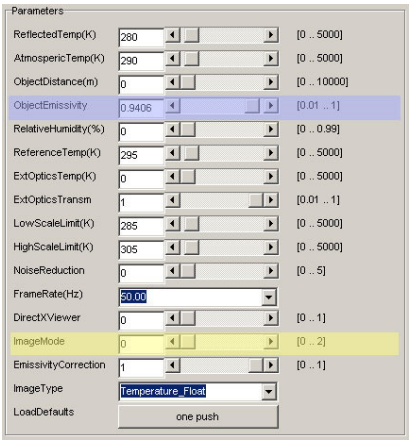
IR Camera Parameters

Object Emissivity:

A value between the 0 and 1 for calculating the temperature



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Retrieve Images

5 different type of images.

- **Absolute Image Pixels (IntImage)**
  - **Absolute values from the sensor**
- **Object Signal Pixels (FloatImage)**
  - **Corrected values for influence by atmosphere and for Reflected Temperature.**
- **Temperature (FloatImage)**
  - **Temperatures in Kelvin**
- **Relative Temperature (IntImage)**
  - **Temperature relative to the high and lower scale limit**
- **Relative Temperature Image Lut (IntImage)**
  - **Image based on a Lut**

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Emissivity Calculation

3 ways of determining the emissivity of an object

- **Look the material up in an emissivity table**
- **Change the emissivity value until the temperature indicated by the camera is the same as the temperature of the object**
- **Use the reversed temperature measurement formula (Supported by the FLIR A20 Camera)**

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Emissivity Calculation

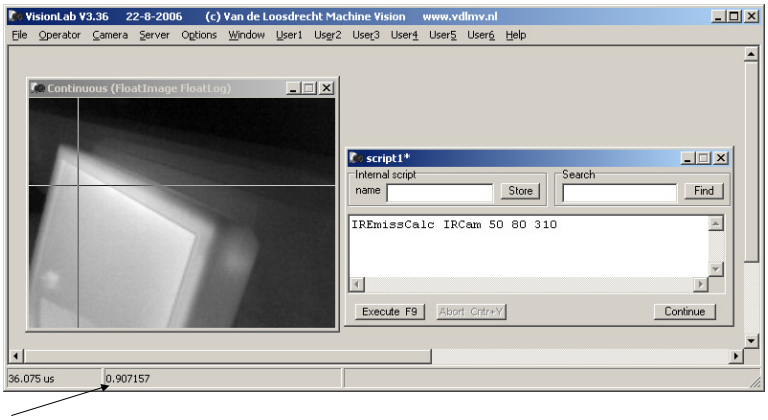
IREmissCalc <CameraName> <Xpos> <YPos> <Temperature>

The function IREmissCalc uses the reversed formula to determine the emissivity of an object.

Demonstration Code:

- **ImageMode set at 0**
- **ImageType Temperature Float**
- **IREmissCalc IRCam 50 80 310**

Emissivity Calculation



Emissivity

EmissivityMap

An emissivity map is used to give every pixel a different emissivity value.

- **Not using a single emissivity**
- **Used when monitoring different materials in a single image**
- **Emissivitymap is a DoubleImage with the same size as the infrared snapshot.**

EmissivityMap

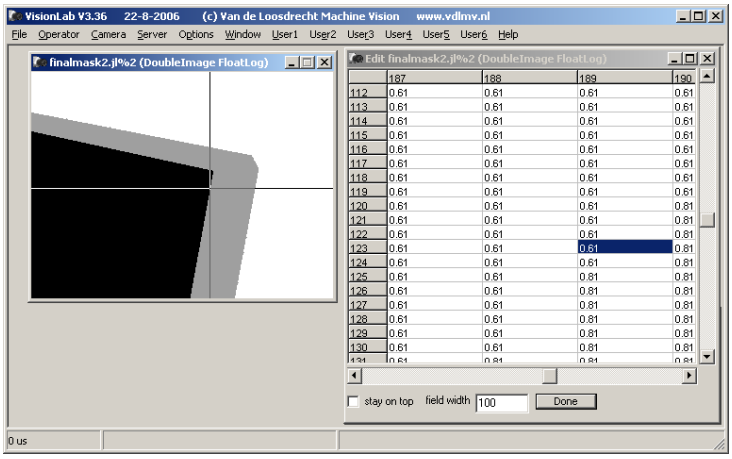
IRSetEmissMap <CameraName> <EmissMap>

The function sends an emissivitymap to the camera.

Demonstration Code

- **Create a new DoubleImage with the same size as the IR Image**
- **Enter pixel values between 0.01 and 1**
- **IRSetEmissMap IRCam EmissMask**

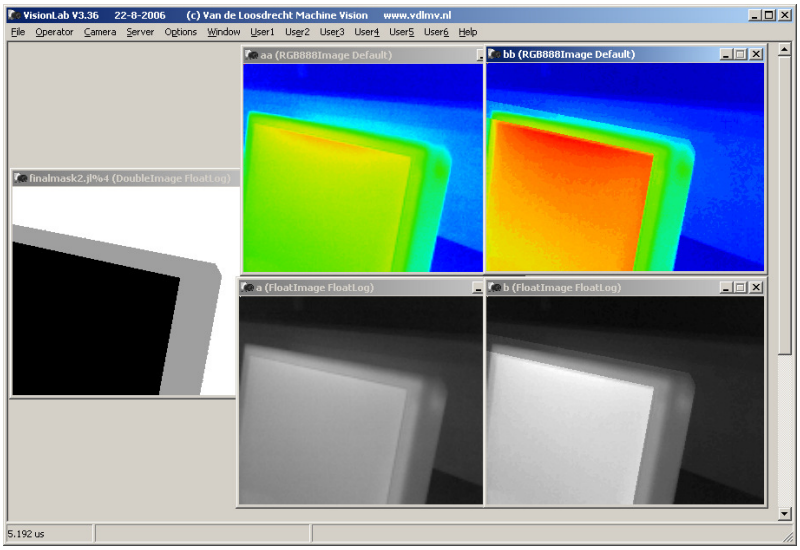
EmissivityMap



EmissivityMap

- **Create an EmissivityMap first**
- **IRSetEmissMap**
- **Camera setparam IRCam EmissivityCorrection 0**
  Standard global Emissivity value will be used
- **Make a snapshot**
- **Camera setparam IRCam EmissivityCorrection 1**
  IR Camera is using the Emissivitymap just created
- **Make a snapshot**

EmissivityMap



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TemperatureMap

A TemperatureMap is used to calculate emissivity values in an image.

The TemperatureMap

- **An image of an arbitrary size**
- **Every pixel contains the known temperature of the pixel in the infrared image**
- **The same as IREmissCalc only then for multiple pixels**
- **Returns an image with the emissivity values**

Calculating will take some time, the whole image would take approximately 25 minutes.

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TemperatureMap

IRTemperatureMap <CameraName> <TemperatureMap> <ReturnEmissivityMap> <Left> <Top> <Width> <Height>

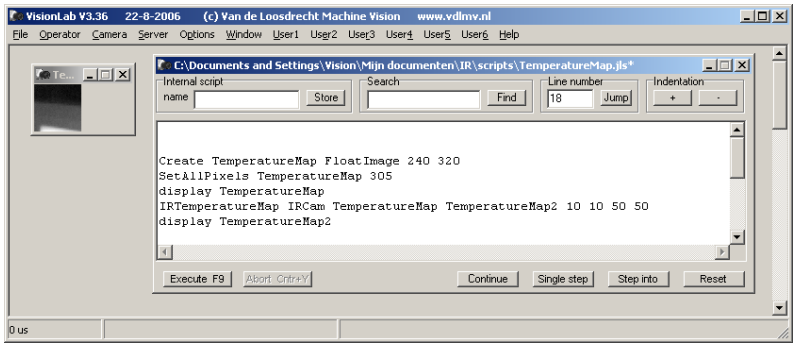
The function uses the camera to calculate multiple emissivity values for known temperature pixels. The return value is an image.

Demonstration Code

- **Create a new FloatImage of 50 x 50 pixels**
- **Enter known pixel temperatures**
- **IRTemperatureMap IRCam TemperatureMap EmissivityMap 10 10 50 50**
- **Display EmissivityMap**

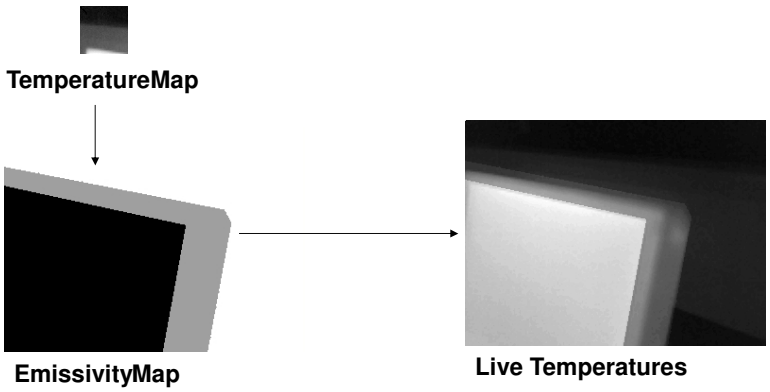
TemperatureMap

TemperatureMap image



EmissivityMap & TemperatureMap

Combination of these 2 functions



Experiments

Measuring the temperature of shiny objects
(Objects with a high emissivity)

3 methods

- **Masking Tape**
  - **Masking tape has a higher emissivity.**
- **Sanding**
  - **Reducing the amount of reflection of shiny objects.**
- **Drilling a hole with a depth of 7 times its diameter**
  - **Simulating a blackbody**

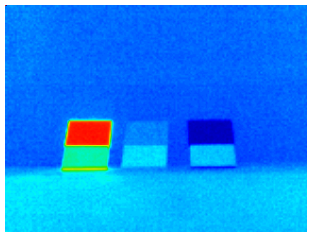
Experiment Masking Tape

Experiment Masking Tape

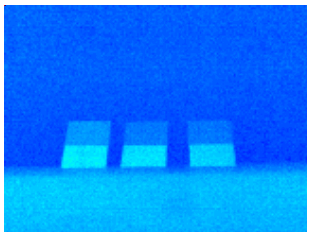
Order of temperature from left to right.

- **Hot**
- **Room temperature**
- **Cold.**

Masking tape is on the top half.



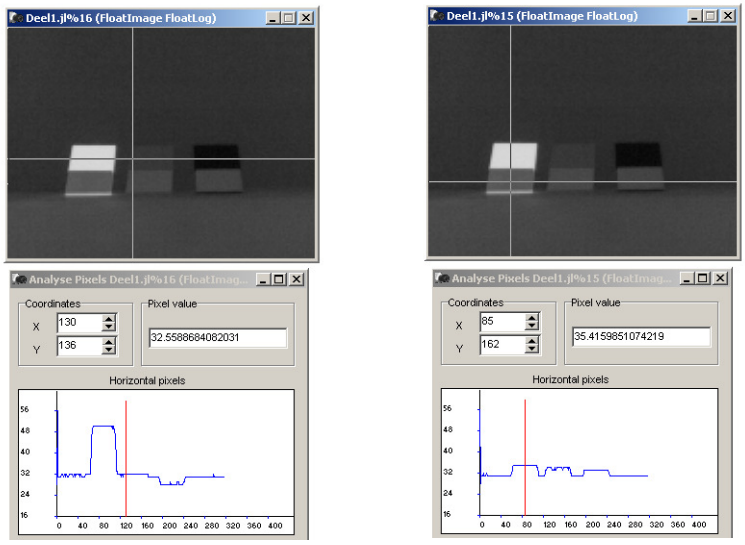
Immediately



after a few minutes

- **Normal background**

Experiment Masking Tape



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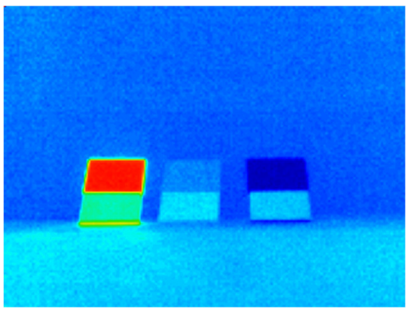
Experiment Masking Tape



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Experiment Masking Tape Hot Background

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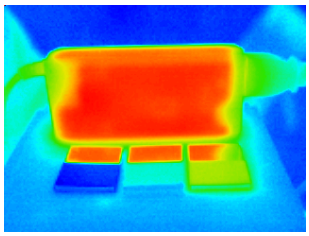
Experiment Masking Tape Hot Background

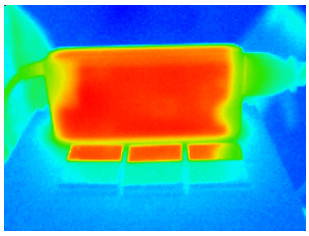
Order of temperature from left to right.

- **Cold**
- **Room temperature**
- **Hot.**

Masking tape is on the bottom half.



Immediately



after a few minutes

- **Hot background**

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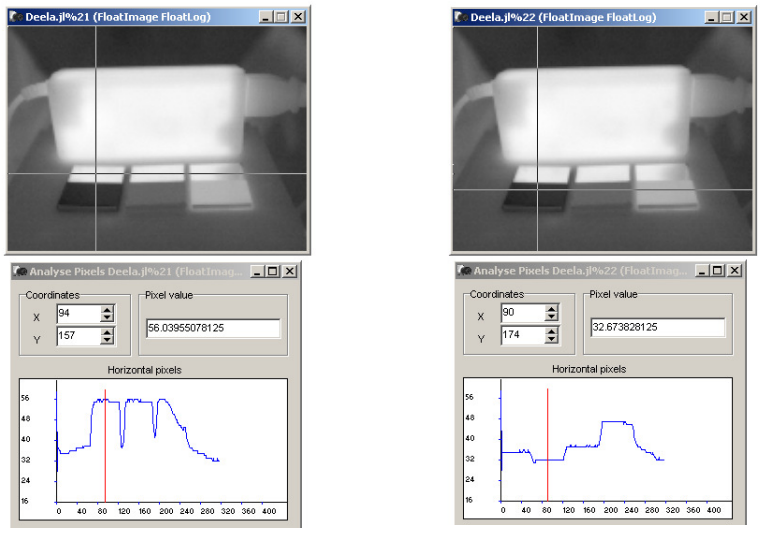
Experiment Masking Tape Hot Background



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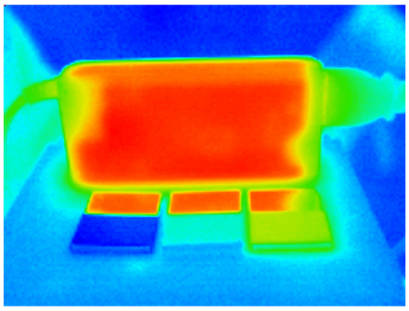
Experiment Masking Tape Hot Background



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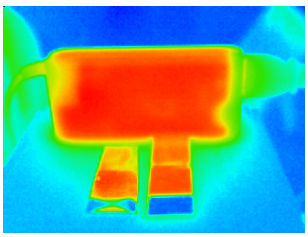
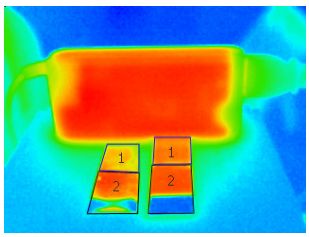
Experiment Sanded

Experiment Sanded

Materials from left to right

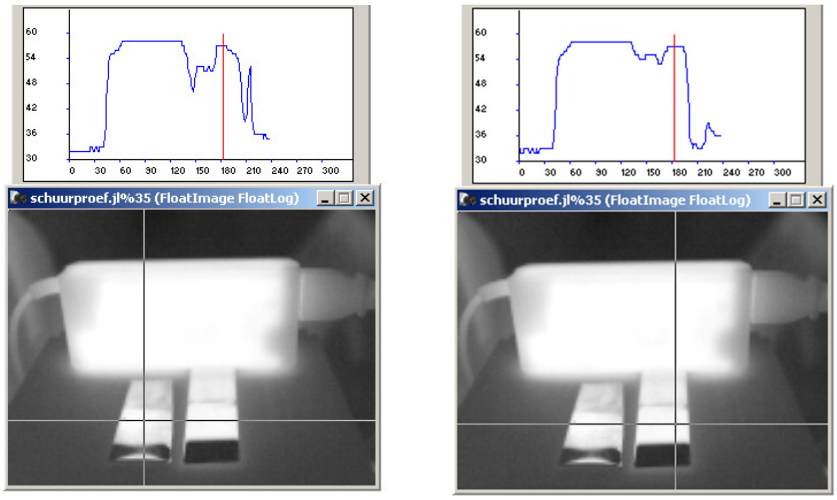
- **Red Copper**
- **Brass**





1. **Sanded.**
2. **Not Sanded.**

Experiment Sanded



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Fields of usage

Kwantitative measurement (Measuring absolute temperatures)

- **Not used a lot, due to the complex nature of temperature measurement**

Kwalitative measurement (Measuring relative temperatures)

- **Electrical Engineering**
- **Mechanical engineering**
- **Building inspections**
- **Many other fields**

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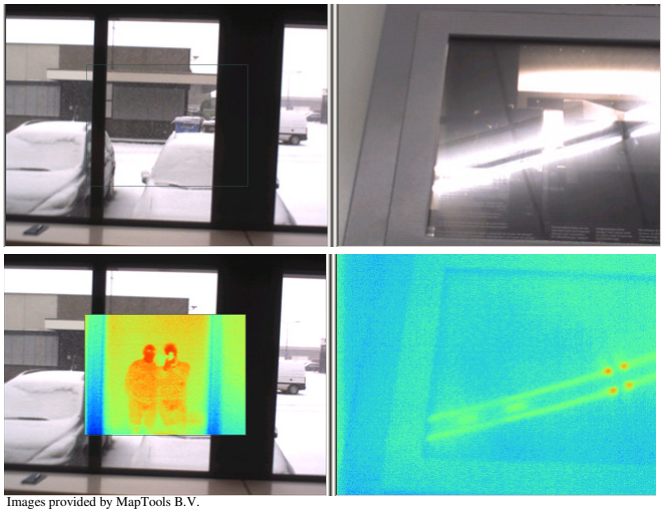
Examples
(Infrared reflection)



Images provided by MapTools B.V.

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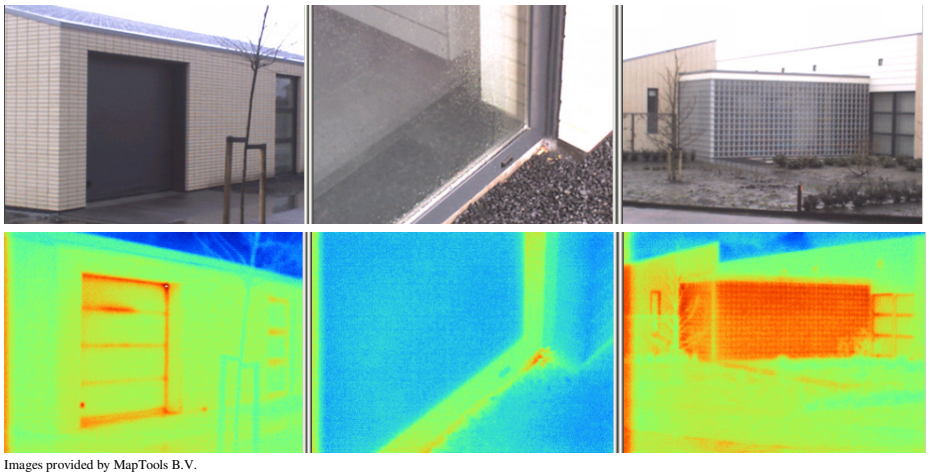
Examples
(Building Inspection)



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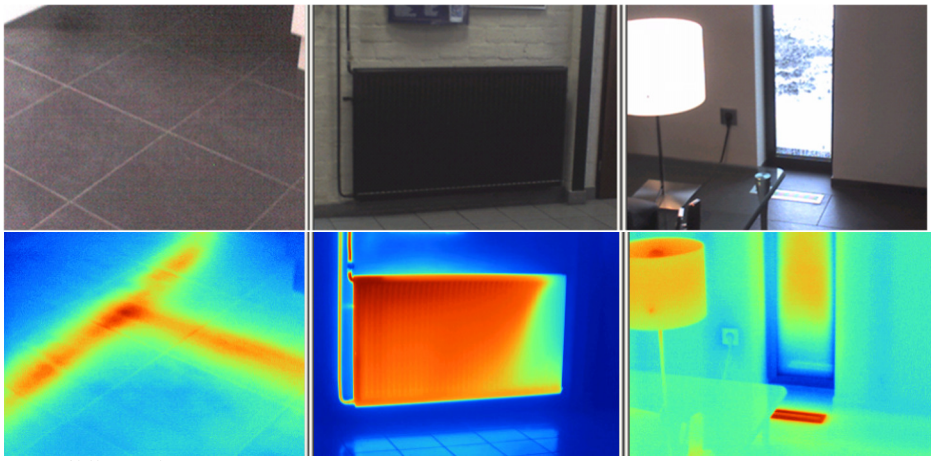
Examples
(Building Inspection)



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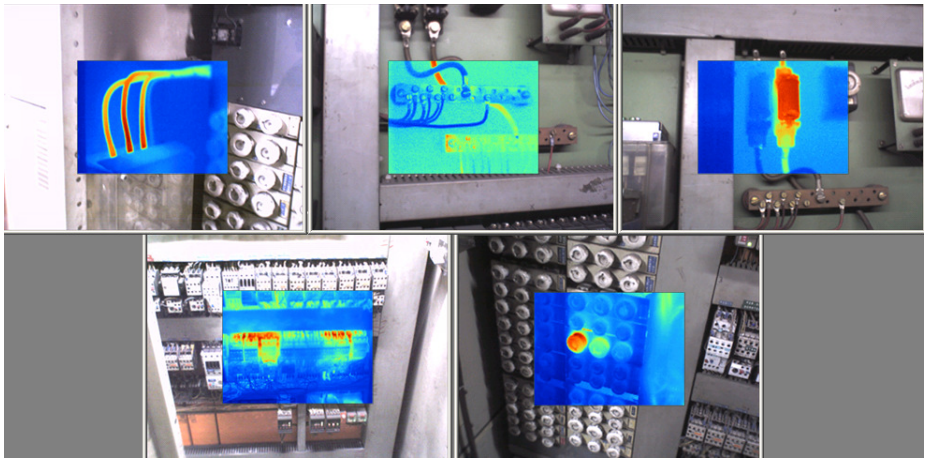
Examples
(Electrical Engineering)



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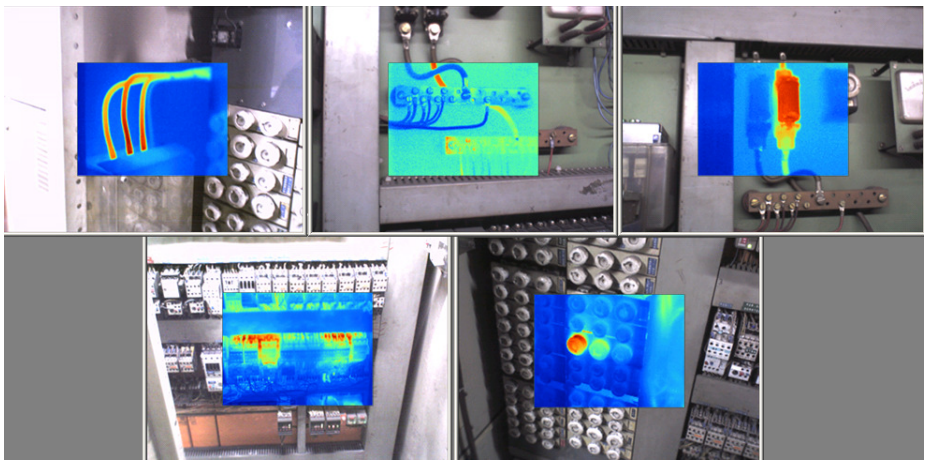
Examples
(Electrical Engineering)



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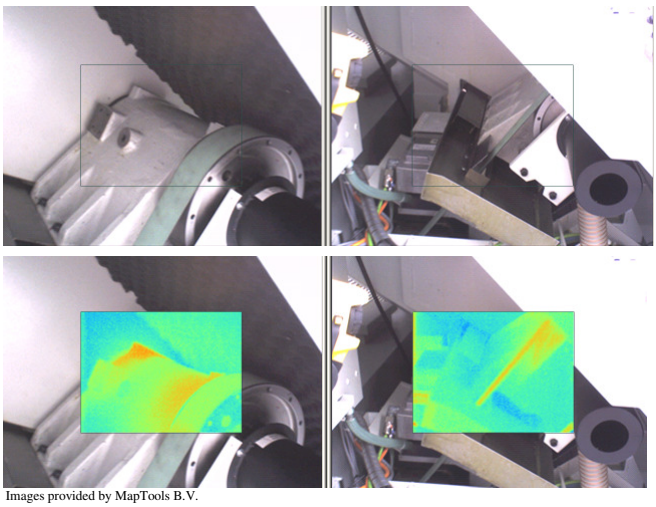
Examples
(Mechanical Engineering)



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Advantages and Disadvantages

Advantages

- **Quick measurement of object temperature**
- **Non invasive measurement**
- **Ability to use Computer Vision techniques for automating temperature measurement**

Disadvantages

- **Kwantitative measurement depends on al lot of parameters**
  - **Emissivity**
  - **Atmosphere Temperature**
  - **Object material**
- **Expensive equipment**