Laboratory course No. 2
Infrared Imaging

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1 Introduction

Almost everything that uses or transmits power gets hot eventually, that's when infrared imaging becomes useful. This lab provides the key knowledge concepts required for temperature measurement as well as introduces several parameters which define the efficiency of the measurement.

2 Study of the infrared camera through Altair software

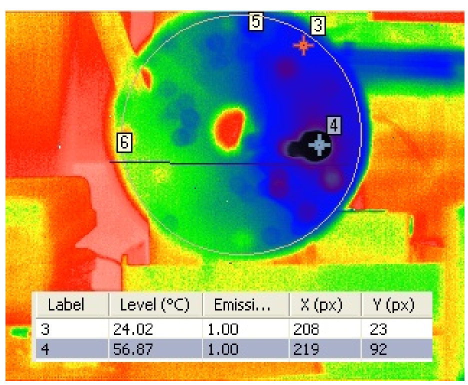


Figure 1: coordinates of the broken electronic device and the max temperature

On the electronic circuit we are trying to determine which transistor is broken;in order to do that, we have to remember that a broken electronic device heats up dramatically because of big current resistance. Knowing that, we just have to apply the voltage to our system and observe through the infrared camera which part of it heats up. The Fig 1 clearly shows the location of a broken

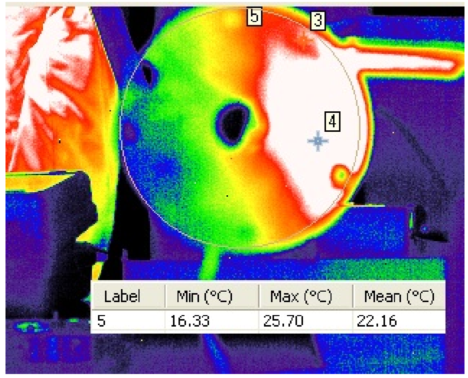


Figure 2: mean temperature of the circuit after heating

device - x:219,y:92. In the next Fig 2 you can observe the mean temperature of the circle.

The Fig 3 shows the profile temperature. According to the *heat propagation law* the temperature should decrease with the distance from the heat source-this describes the slope of the presented graph. The drop-down of the temperature is observed in the middle of the graph because the test line crosses the middle of the circle which indicates the temperature of the background(our lab room) and not the actual circle.

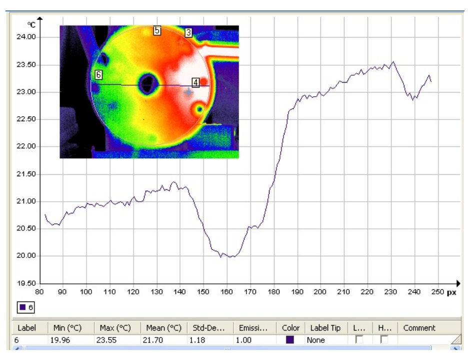


Figure 3: profile temperature of the circuit

3 Camera calibration

Each computer vision scientist should know that infrared camera measures so-called *Digital Level* and not the actual temperature of the object. Because of this a problem of camera calibration arises.
In order to calibrate the camera we came up with the following experiment: We use C.A. 1875 tutorial bench to heat a set of metal plates. While doing so we

want to simultaneously measure:
1. the actual temperature of the plate with digital thermometer.
2.measure the temperature of the plate with our camera.
Knowing the emission coefficient of the black plate we can calibrate the camera. The following graph illustrates the dependency between the real temperature of the body and it's digital level.

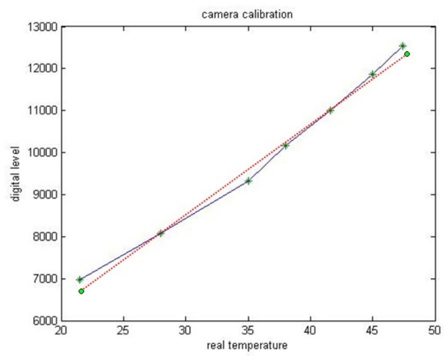
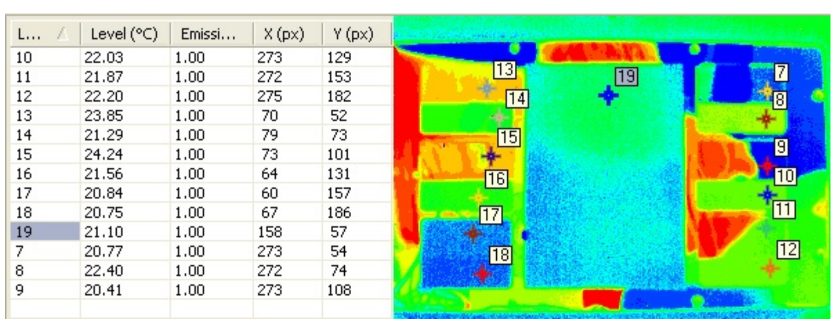


Figure 4: Camera calibration graph

4 Estimation of emission

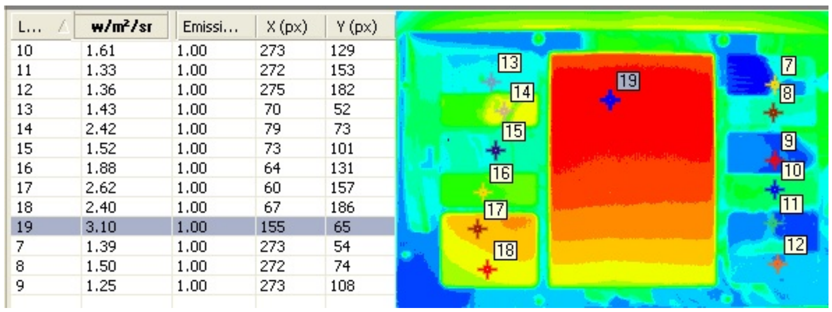
Before heating up C.A. 1875 tutorial bench we took a picture with infrared camera while the temperature of each metal is the same. Each metal in the picture appears to have different temperature. Moreover, each metal depending on the surface type (smooth or scratched) reflects different amount of heat radiation. We also know that the angle of reflection slightly influences the amount of radiation captured by camera. Knowing this we can conclude that infrared cameras can show proper result only when all the peculiarities presented are taken into consideration .



L...	Level (°C)	Emissi...	X (px)	Y (px)
10	22.03	1.00	273	129
11	21.87	1.00	272	153
12	22.20	1.00	275	182
13	23.85	1.00	70	52
14	21.29	1.00	79	73
15	24.24	1.00	73	101
16	21.56	1.00	64	131
17	20.84	1.00	60	157
18	20.75	1.00	67	186
19	21.10	1.00	158	57
7	20.77	1.00	273	54
8	22.40	1.00	272	74
9	20.41	1.00	273	108

Figure 5: different metal temperature appearance measured by IR camera

After that, we heat up the system until it reaches 55 degrees. The bench is programmed in such way that when it reaches 55 degrees it cools down to 50 and then the cycle repeats. We wait for the system to stabilize and then take another snapshot; the emission coefficient of each metal is then calculated using formula $\varepsilon_{metal} = \frac{L_{obj}}{L_{BB}}$,where L is luminance of captured object and black body correspondingly.



L...	w/m²/sr	Emissi...	X (px)	Y (px)
10	1.61	1.00	273	129
11	1.33	1.00	272	153
12	1.36	1.00	275	182
13	1.43	1.00	70	52
14	2.42	1.00	79	73
15	1.52	1.00	73	101
16	1.88	1.00	64	131
17	2.62	1.00	60	157
18	2.40	1.00	67	186
19	3.10	1.00	155	65
7	1.39	1.00	273	54
8	1.50	1.00	272	74
9	1.25	1.00	273	108

Figure 6

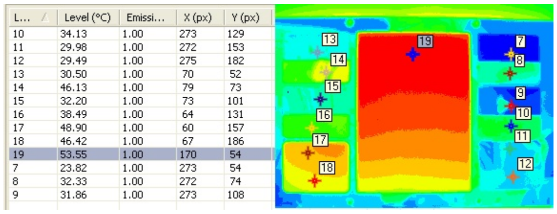
The table for emission coefficients is as follows(according to experiment):

metal	*luminance(w/m2/sr)*	*emissivity*
black body (point 19)	3.10	$\simeq 1$
Red copper (point 7)	1.39	0.40
Brass (point 9)	1.25	0.40
Aluminum (point 11)	1.33	0.42
Polish steel (point 13)	1.43	0.46
Stainless steel (point 15)	1.52	0.49
Laminate (point 17)	2.62	0.84

5 Transmission and reflection coefficients

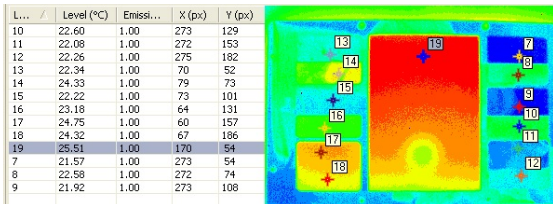
5.1 Transmission coefficient

In order to measure the transmission coefficient of the glass and black PVC we can first measure the *Digital level* or *temperature* of the object with infrared camera and then snap another frame with glass/PVC in front of it;the difference in measured digital levels will determine the transmission coefficient.



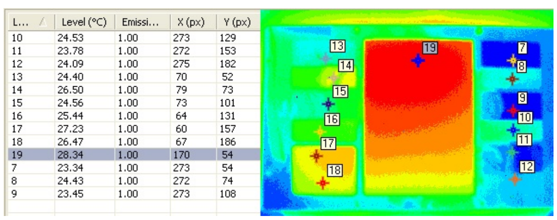
L...	Level (°C)	Emissi...	X (px)	Y (px)
10	34.13	1.00	273	129
11	29.98	1.00	272	153
12	29.49	1.00	275	182
13	30.50	1.00	70	52
14	46.13	1.00	79	73
15	32.20	1.00	73	101
16	38.49	1.00	64	131
17	48.90	1.00	60	157
18	46.42	1.00	67	186
19	53.55	1.00	170	54
7	23.82	1.00	273	54
8	32.33	1.00	272	74
9	31.86	1.00	273	108

Figure 7: Normal image



L...	Level (°C)	Emissi...	X (px)	Y (px)
10	22.60	1.00	273	129
11	22.08	1.00	272	153
12	22.26	1.00	275	182
13	22.34	1.00	70	52
14	24.33	1.00	79	73
15	22.22	1.00	73	101
16	23.18	1.00	64	131
17	24.75	1.00	60	157
18	24.32	1.00	67	186
19	25.51	1.00	170	54
7	21.57	1.00	273	54
8	22.58	1.00	272	74
9	21.92	1.00	273	108

Figure 8: Glass



L...	Level (°C)	Emissi...	X (px)	Y (px)
10	24.53	1.00	273	129
11	23.78	1.00	272	153
12	24.09	1.00	275	182
13	24.40	1.00	70	52
14	26.50	1.00	79	73
15	24.56	1.00	73	101
16	25.44	1.00	64	131
17	27.23	1.00	60	157
18	26.47	1.00	67	186
19	28.34	1.00	170	54
7	23.34	1.00	273	54
8	24.43	1.00	272	74
9	23.45	1.00	273	108

Figure 9: Black PVC

According to Fig 8 and Fig 9 the transmission coefficient of glass and black PVC are:

$$\tau_{glass} = \frac{25.51}{53.5} = 0.48$$

$$\tau_{blackPVC} = \frac{28.34}{53.5} = 0.53$$

5.2 Reflection coefficient

As for the reflection coefficient of copper we can calculate the difference between the digital level of an object and it's reflection from the copper plate. Copper plate will not reflect the same amount of radiation as the object itself due to absorption. In order to make our calculations precise we chose Saeed's nose as an object to be observed.

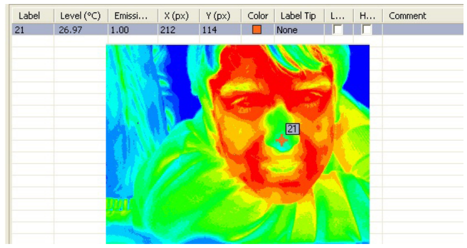


Figure 10: measured object

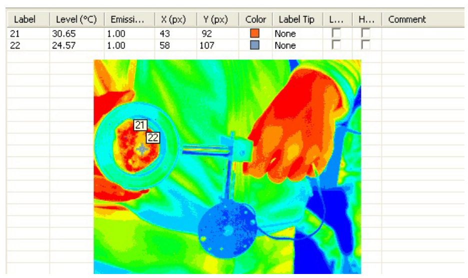


Figure 11: object observed through copper reflection

the reflection coefficient $R = \dfrac{24.57}{26.97} = 0.91$

6 Active thermography - Second experiment

A plate with flat-bottom-holes is used in this experiment. When we look at the plate from the opposite side we cannot observe holes. In order to detect them we can heat the plate up and see which parts heat-up faster;the different heating rate will indicate that red(according to provided scale) region is thinner than the rest of the plate(the thinner parts get hot faster than thick ones).

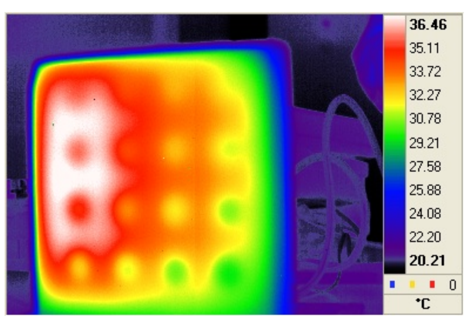


Figure 12: object shape defect detection

7 Conclusion

Active thermography has a wide range of possible applicatioins. First, it is convenient to measure the exact temperature of an object when we can not reach it with thermometer by any reason.

Second, thermography can be used to detect defects of the heated body since the density of the break point is different from the rest of the body. Thermography is also used to detect dust/dirt in turbines in nuclear stations since blades during rotation rub against the wall/dust and produce heat. Active thermography is also used in cases where the temperature has to be measured almost constantly for example in F1 races it is used to detect if the tire has to be changed after another circle of the race. Active thermography is also used to observe the heat leakage from the house through the windows and small cracks. The last,but not the least is the application in medical purposes. For instance a horse with a broken leg does not step on it, therefore it's horse-shoe appears to be colder than the rest 3 during running. Drawing a conclusion infrared imaging is an awesome addition to the knowledge set of computer vision scientist!