Exploring Low Cost Infrared Cameras to Reduce Energy Performance Gap in Buildings: *Using the Flir One Thermal Imaging Camera*

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www.built2spec-project.eu

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Thermal Imaging

- Produces a map of radiant heat from a surface
- Uses infrared radiation
- Usually presented as a temperature map
- A non-contact temperature measurement
- Wide range of applications
- Works on anything that is a different temperature from its environment
Thermal Imaging - History

- Since 1968
- Insulation effectiveness
- Mechanical services diagnostics
- Electrical connection checks

Barriers to entry:
- Price: €40,000
- Weight: 30 kg
- Complexity:
Thermal imaging - Recent

- Same applications
- Widely accessible
  - Price: €1000
  - Weight: 600g
  - Complexity:
Thermal imaging - Today

- More applications
- Everybody can have one
  - Price: €200
  - Weight: 32g
  - Complexity:
## Performance

Checked in BSRIA calibration laboratory

<table>
<thead>
<tr>
<th></th>
<th>Typical IR Camera</th>
<th>Smartphone Camera 1</th>
<th>Smartphone Camera 2</th>
<th>Smartphone Camera 3</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purchase Date</strong></td>
<td>2007</td>
<td>2015</td>
<td>2016</td>
<td>2017</td>
<td>year</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>10,000</td>
<td>135</td>
<td>165</td>
<td>200</td>
<td>UK Pounds</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>880</td>
<td>220</td>
<td>144</td>
<td>140</td>
<td>g</td>
</tr>
<tr>
<td><strong>Pixels</strong></td>
<td>320 x 240</td>
<td>80 x 60</td>
<td>160 x 120</td>
<td>160 x 120</td>
<td>No.</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>K</td>
</tr>
<tr>
<td><strong>Field of View</strong></td>
<td>25 x 19</td>
<td>50 x 39</td>
<td>46 x 35</td>
<td>55 x 43</td>
<td>Angular degrees</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td>-20 to 650</td>
<td>-10 - 120</td>
<td>-20 - 120</td>
<td>-20 - 400</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Wavelength</strong></td>
<td>8 to 14</td>
<td>8 to 14</td>
<td>8 to 14</td>
<td>8 - 14</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Minimum Focus</strong></td>
<td>400</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>mm</td>
</tr>
<tr>
<td><strong>Specified Accuracy</strong></td>
<td>± 2</td>
<td>± 2</td>
<td>± 2</td>
<td>± 2</td>
<td>K</td>
</tr>
<tr>
<td><strong>Measured Accuracy</strong></td>
<td>± 0.83</td>
<td>± 1.25</td>
<td>± 0.98</td>
<td>NA</td>
<td>K</td>
</tr>
</tbody>
</table>
Additional Features on the Smartphone Camera

- GPS location
- 3G, Wi-Fi & Bluetooth communication
- Image analysis app
- Fits in your pocket
- You can make phone calls on it!
It’s Easy, Isn’t it?

- It’s easy to get a thermal image
- How do you understand what’s going on?
  - Is there enough temperature difference?
  - Has it been constant for long enough?
  - What surface temperature should I expect?
  - What is the emissivity of the surface?
  - What is an acceptable variation?
Thermal Index

Difference between internal surface and external temperature

Difference between internal and external environmental temperatures

\[ \textit{Thermal Index}, TI = \frac{(T_{si} - T_o)}{(T_i - T_o)} \]
Insulation Effectiveness – Example using TI

- External temperature 9.0°C
- Accurate room temperature measurement = AR02* : avg 19.0°C
- AR01 : avg 15.9°C
- Thermal Index calculated for area AR01

\[
\text{Thermal Index, } TI = \frac{(15.9 - 9.0)}{(19.0 - 9.0)} = 0.69
\]
Co-relation between TI and U-value

<table>
<thead>
<tr>
<th>Thermal Index</th>
<th>0.69</th>
<th>0.75</th>
<th>0.9</th>
<th>0.97</th>
</tr>
</thead>
<tbody>
<tr>
<td>U Value</td>
<td>2.38</td>
<td>1.92</td>
<td>0.77</td>
<td>0.23</td>
</tr>
</tbody>
</table>

- $U = (1 - TI) / R_{si}$  \((R_{si} = \text{Inside surface resistance} = 0.13 \text{ m}^2\text{K}/\text{W for internal vertical surface})\)
- Uncertainty of measurement depends on $\Delta T$
- Depends on air movement
- Only applies at the point where measured
- Only applies at the time when measured
Some Answers

In ideal conditions with suitable:

- External and internal air temperatures
- External and internal radiant temperatures
- Known high surface emissivity
- Constant for long enough to reach equilibrium
- Low wind speed
- No precipitation
- You can calculate U value

But this never happens!
The Solution

Thermal Modelling

- Simple Finite Element Analysis of structure
- Based on temperature history
- Uses design thermal properties
- Tests for difference between measured and expected temperatures
Examples
Built2Spec

EU research project with 20 partners finishing in Dec 2018, aimed at ensuring build quality by making the process of building checks easier with research on:

- Energy Efficiency Quality Checks
- Indoor Air Quality Tools
- **Thermal Imaging Tools**
- Smart Building Components
- Building Information Modelling
- Airtightness Test Tools
- Acoustic Tools
- 3D and Imagery Tools
- Virtual Construction Management Platform
• Checking thermal performance of structure using a suitable infrared camera and networked processing
  – Measure site conditions for suitable period [BMS, sensor network etc.]
  – Position the camera and data collector in front of the area to be assessed
  – Collect location data [BLE, Tango or other] Match 3D location and model
  – Collect thermal image
  – Send data and thermal image to building model in the cloud
  – Compare thermal image with result of dynamic thermal model
    [model maps expected internal surface temperatures]
  – Move to new location and repeat
Conclusion

Smartphone infrared cameras help to ensure quality in insulation

Every project manager should have one

- BSRIA don’t sell them!
- But you can get them through websites:
  - www.flir.com/flirone
  - http://therm-app.com (Therm-App)
  - www.thermal.com (Seek Thermal)
  - www.i3-thermalexpert.com
  - www.catphones.com/ (Caterpillar brand)
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