

# DESIGN OF VIRTUAL INSTRUMENTATION FOR AUTOMATED INSPECTION OF HIDDEN PROBLEMS IN BRIDGES

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## 1. Introduction

The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of the specimen nor the structure from which it is taken. However, one problem that has been prevalent within the concrete industry for years is that the true properties of an in-place specimen have never been tested without leaving a certain degree of damage on the structure.

Virtually all concrete structures exposed to nature experience deterioration over time. Inspection personnel have difficulty determining the quality of *in-situ* concrete that has experienced decay without direct material sampling. The disadvantage to material sampling is that an inspector must remove a portion of the structure, usually by means of coring, and make repairs to the sample area. Removing cores from a concrete structure is an intrusive process that can weaken the structure and usually leads to long-term durability concerns. Hence the thermography method can be applied.

Thermography is the determination of surface temperatures of objects and bodies with the help of infrared photography. A special-purpose camera captures what the human eye cannot see. The camera consists of an infrared permeable lens, a transmission line and a sensitive detector. The detector converts radiation into electric signals. After processing they are transformed into pixels so that the thermogram appears on the screen. Infrared thermography can be performed on most buildings with the following concerns: insulation, a leakage, moisture, electrical, heating and cooling problems. Moreover, there are other similar applications such as construction defects, to qualify or quantify if there are materials added as specified, and so on. All these applications can be carried out relatively easily without performing destructive testing.

The theory of infrared thermography is based on three well-known radiation

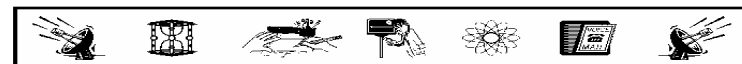
- The law about the relation between emission and absorption found by Kirchoff.
- Planck’s law of radiation
- Stefan–Boltzmann law.

Kirchoff ‘s law means that a body that absorbs much also emits much. When a “grey” body stands opposite a “black” body, absorption and emission are equal in the thermal balance. Thermography is based on the emission of objects. Therefore it uses the emission coefficient as the ratio of emissivity  $E$  of a real body to the emissivity  $s E$  of the black body under the same temperature.

$$\epsilon = E/Es \text{ (equation 1)}$$

**Table 1: Emission coefficients of construction materials**

Material	$\epsilon$
Concrete	0.94
Sand	0.93
Brick	0.93–0.94
Limestone	0.96
Render/plaster	0.90–0.96



Glass	0.93–0.96
Wood	0.96
Roofing felt	0.93
Gypsum	0.90
Paint	0.90–0.95
Clay	0.95
Brick earth	0.93

The main application of infrared thermography in the civil sector lies in construction thermography. Fortunately, most materials used in the building industry have emission coefficients between 0.90 and 0.96 (Table 1). Therefore good assessment of thermal properties of a building can be made with only one exposure with the same. Post-processing of the thermo grams for zinc or copper clad components can then still be done with the computer. A basic condition for using thermography on buildings is a difference of 20 K between the inside and the outside temperatures. In the literature 10 K are sometimes considered enough. It means that examinations of buildings are reasonable only during the winter when the surrounding temperature lies around the zero point. Inside exposures are of greater significance because atmospheric conditions such as wind, rain, snow or sun as well as conditions of the building itself like ventilated facades have an effect on the results of the exposure. While heat bridges can be seen from outside, there are cold bridges observable inside. Cold areas clearly stand out on walls, loft conversions, corners on the floor or window frames. But heated floors and heaters on walls can also be made visible. The position and length can be exactly determined. Furthermore, it is possible to find leaking or plugged heating systems, badly done insulation or hidden timbered framework, which has been plastered over. Pictures taken with thermographic cameras are admitted in court because they provide unambiguous proof of botched construction works. Construction frames benefit from them as well since they can photograph critical areas in order to design targeted constructional measures before reconstructing old buildings.

The specifications of the IR camera used in the project are given below.

**Specifications**

**1. Environmental specification**

Operating temperature	
Range	-15°C to +50°C
Storage temperature	
Range	-40°C to +70°C

**2. Imaging Performance**

Field of view	25° x 25°
Minimum focus distance	0.3 m
Focus	Manual
Detector type	Focal Plane Array(FPA),uncooled
microbolometer	120 x120 pixels
Spectral range	7.5 to 13 µm

**3. Image storage**

Type	Built-in FLASH memory (50 images)
File formats	Standard JPEG

**4. Measurement**

Temperature range	-10°C to +350°C
Thermal sensitivity	< 0.2°C at 25°C
Measurement mode	Fixed spot in the middle of the image
Menu controls	Palettes (color or black and white), auto-adjust (automatic/manual)

Set-up controls Date/time, language, power down, display intensity Measurement corrections

Emissivity variable from 0.1 to 1.0  
Display 3.5" color LCD, 16K Colors

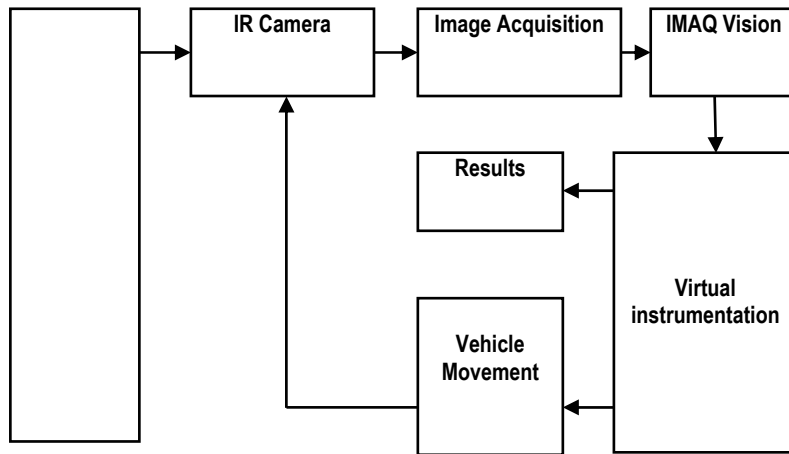
**5. Battery system**

Type	Li-Ion, rechargeable, field replaceable
Operating time	7 hours continuous Operation. Display shows battery status
Charging system	In camera, AC adapter
AC operation	AC adapter 90-260 V AC, 50/60 Hz

**2. Methodology**

IR Camera captures the thermograph image of the area under test. Infrared (IR) is widely used for nondestructive testing. This offers noncontact, wide area detection of subsurface defects, and can be used as an alternative or complement to conventional inspection technologies. Also it has very fast inspection rate.





**Figure1. Block Diagram**

The acquired image is then processed using IMAQ Vision Builder software. First the luminance plane from the image is extracted. Then two processes namely Pattern matching and Gray scale tracking is done as required. Initially pattern matching is done in order to find the superficial and internal cracks. Here many ROI of different types of cracks are collected and saved in database. Then this ROI is matched with acquired image, by which can locate the defects with the help of parameters such as center(X, Y), corners of the bounding box and it's score.

In Gray scale tracking the structural defects such as blisters, air ducts, chloride corrosion, and fake material can be found out on basis of its threshold values. The manual threshold operation allows us to indicate the defects in the extracted image. Also it can display the histogram of a portion of image by drawing an ROI around the defective region. Then particle analysis can be done to these selected ROI. This analysis gives all the parameters of the defect such as pixel, area, width, diagonal, shape etc. These values can be saved in spreadsheet for further analysis. The Lab View Block for the IMAQ script is created to make the results useful for automating the fault identification.

The automation process is done with the help VI Environment. Here the results obtained from Image processing like area and defect size in pixel are converted into real world measures like defect length in mm, and the location of defect in x, y co-ordinates are converted into distance from starting point of the bridge. The indication of defects is done with the change in movement vehicle which carries the IR camera. The first pause for few seconds in the vehicle indicates the start of the defect and the next pause for same delay indicates the end of the defect. These delays are produced by control pulses whose period is same as that of delay. The speed of the vehicle is also made to be different while it tracing the defective surface when compared to the normal surface. This is achieved by varying the number of cycles.

The hard ware unit consists of a vehicle having totally stepper motors. All the four stepper motors work in a synchronous a manner during the forward and backward motion. But during the right turn the stepper motors at the right side alone rotates and the remaining two stops until it turns about 180 degrees and vice versa. The remaining movements of the vehicle for indicating the location of the faults are as described above.

### 3. Results and discussion

As mentioned above the objectives are to over come the drawbacks of the traditional methods such as Visual inspection and Hammer sounding, for which using two methods called pattern matching and grayscale tracking.

#### a. Pattern Matching

Pattern matching involves comparing the predefined patterns (cracks) with the acquired image, which gives the results (details about the defects) such as number of defects closely related to the predefined pattern, and their degree of closeness (score), center (X,Y co-ordinates), and corners of the bounding rectangle.

The score is the integer assigned to the match that present in our acquired image.

Score -1000 shows perfect match

Score – 0 shows no match

Following are the image and predefined pattern (crack) taken for pattern matching.



Figure 2. Acquired IR Image

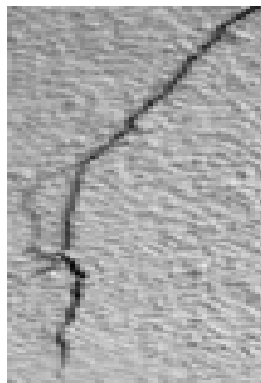


Figure 3. Predefined Pattern

The resulting image in pattern matching is given below. The details about the defects (Numerical data) obtain in pattern matching are as follows

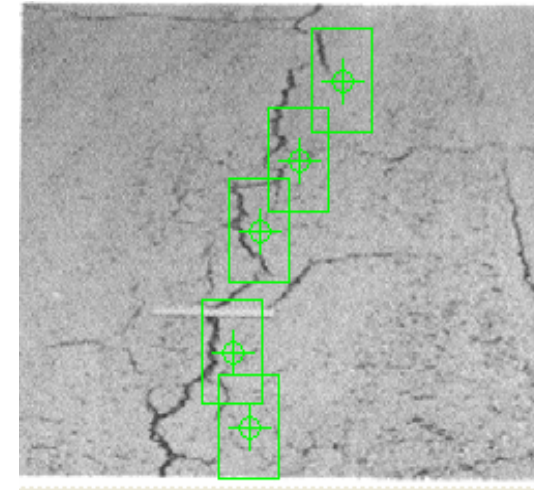


Figure 4. Matched Defects

Results...	1	2	3	4	5
Center X	107.000	90.000	141.000	159.000	98.000
Center Y	111.000	130.000	140.000	231.000	214.000
Score	1000	667	608	562	553
Angle	0.000	0.000	0.000	0.000	0.000

Figure 5. Pattern Matching Results

**b. Gray Scale Tracking**

Gray scale tracking is purely based on the temperature profile of the construction materials used. It is used to locate structural defects such as blisters, air ducts, chloride corrosion, and fake material residues inside the bridge on basis

of its threshold values. Before getting into Gray Scale Tracking it should have a detailed study about the materials used. And should know the temperature profile of each and every objects used in our case. The color extracted IR image results in black and white (single color or grayscale) image. Hence, the gray value corresponds to the object of particular temperature. Thus the materials having particular temperature profile can be easily tracked using this gray scale tracking.

Infrared image taken for the processing The resulting image during the gray scale tracking is of gray scale tracking is as follows.

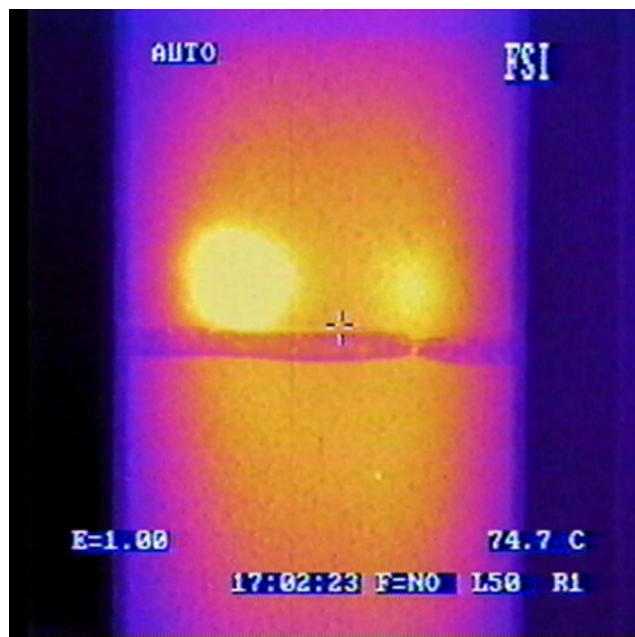


Figure 6. Acquired IR Image

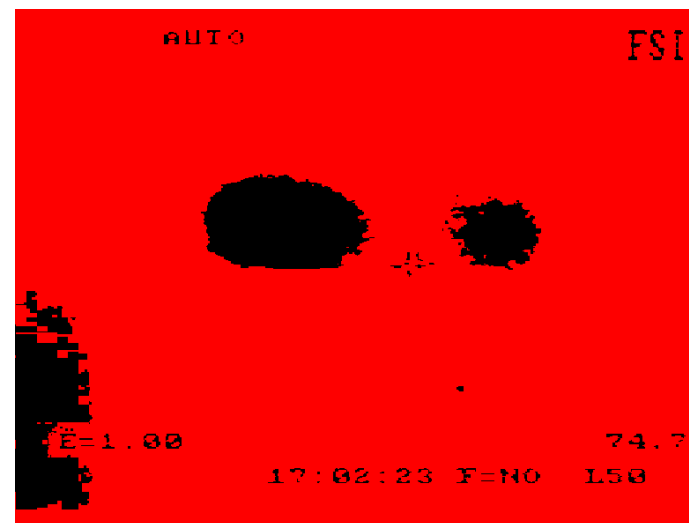


Figure 7. Gray scale tracking - Image Result

Locating the defects I gray scale tracking involves particle analysis. It gives the details about the faults such as pixel, area, width, diagonal, shape etc.

The following is the tabulation that gives the location of the defect in the given surface as well as subsurface. This table contains the parameters of the defects such as,

1. No. of pixels it occupies
2. Area (in pixels)
3. Center of mass X
4. Center of mass Y
5. Width
6. Height
7. Longest segment length
8. Perimeter
9. Diagonal Unit etc.,



Object #	Pixels	Area (unit)	Number of Holes	Holes area	Total area	Image area	Ratio Area	Ratio Area
1	5.04E+05	5.04E+05	104	25334	5.29E+05	5.94E+05	84.92	95.21
2	5	5	0	0	5	5.94E+05	0	100
3	4	4	0	0	4	5.94E+05	0	100
4	16	16	0	0	16	5.94E+05	0	100
5	2	2	0	0	2	5.94E+05	0	100
6	3	3	0	0	3	5.94E+05	0	100
7	5	5	0	0	5	5.94E+05	0	100
8	9	9	0	0	9	5.94E+05	0	100
9	1	1	0	0	1	5.94E+05	0	100
10	1	1	0	0	1	5.94E+05	0	100
11	3	3	0	0	3	5.94E+05	0	100
12	18	18	0	0	18	5.94E+05	0	100
13	34	34	0	0	34	5.94E+05	0.01	100
14	105	105	0	0	105	5.94E+05	0.02	100
15	27	27	0	0	27	5.94E+05	0	100
16	239	239	0	0	239	5.94E+05	0.04	100
17	10	10	0	0	10	5.94E+05	0	100
18	8	8	0	0	8	5.94E+05	0	100
19	16	16	0	0	16	5.94E+05	0	100
20	1	1	0	0	1	5.94E+05	0	100
21	248	248	0	0	248	5.94E+05	0.04	100
22	5	5	0	0	5	5.94E+05	0	100
23	30	30	0	0	30	5.94E+05	0.01	100
24	40	40	0	0	40	5.94E+05	0.01	100
25	248	248	0	0	248	5.94E+05	0.04	100
26	24	24	0	0	24	5.94E+05	0	100

Figure 7. Gray scale tracking – Pixel Results

#### 4. Conclusion

Infrared thermography provides an invaluable service to forensic engineering and constructional defect investigations in that it allows the engineers a non-destructive method to substantiate their visual findings to find what is happening behind or inside the bridges. Flaw detection and evaluation of blisters by means of infrared thermography is possible. The advantages of infrared thermography over the destructive testing techniques are that sizeable sections, such as blisters, can be scanned fast and efficiently, without the need to be destroyed during testing. This results in major savings in factors such as time, people, work and machinery

It has implemented a fully automated system, which ensures accuracy to find the faults in the bridge surfaces. By

implementing this project in the construction areas, fault identification can be done in an efficient manner. It is clear that IR thermography can provide the maintenance engineers with both the qualitative and quantitative information relating to the structural defect.

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