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Building defect detection: External versus internal thermography

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ABSTRACT

Many buildings suffer from defects in the building envelope, such as missing insulation, thermal bridging, cracks and moisture problems. Thermography is one technology that can help to identify such defects. However, there are different approaches towards assessing the building envelope. Pass-by thermography is an emerging method, which is used to capture single thermal images of external building elevations. Compared with traditional walk-through thermography, it is much quicker and cheaper to perform. Yet it is currently unclear how successful this methodology is at detecting building defects. This paper qualitatively compares pass-by thermography and walk-through thermography. A set of 122 residential dwellings in South West England was inspected using the both methodologies. Results show that substantially more defects were detected using walk-through thermography, with internal inspections yielding the greatest number of detected defects. Significant constraints with walk-past thermography were identified, such as unknown occupancy behaviour, transient climatic conditions, fixed viewing angles and spatial resolution limitations, which were all found to have a greater impact on image results than during walk-through thermography.

Although trends in conductivity defects were found from target comparison analysis between similar dwellings, viewing single external elevations under walk-past thermography was found to miss many different defect types, which would have normally been discovered during traditional walk-through thermography.

1. Introduction

Thermography is used to quickly detect thermally significant defects and heat loss from the built fabric and thus is uniquely placed to help tackle increased energy use, fuel poverty and thermal comfort issues. Traditional methods of inspection using this technology comprise of thermographers walking around a building recording images. Under this methodology, a number of significant limitations to building thermography (such as transient climatic conditions, emissivity variations and camera operation) exist, which require expert knowledge to accurately interpret the thermal patterns and apparent temperature readings captured in the thermal image. With smaller cameras, the emergence of the digital movement, increased portability, lowering costs, and the introduction of uncooled microbolometers in the 1990s [1], thermal cameras have become much more commercially focused in recent years [2].

Recently, new passive (using natural heat sources and boundary conditions such as solar radiation, air movement and atmospheric temperature [3]) building thermography methodologies have been developed and used as an alternative to traditional walk-through thermography [4]. By carefully selecting the most appropriate methodology, some of the known limitations can be mitigated. One example is the application of time-lapse thermography, which allows to observe climatic and material transient changes over prolonged periods of time [5]. This in turn enables the observation of defect patterns over-time, allowing for enhanced interpretation.

Another new methodology is pass-by thermography, where single external elevations of buildings are imaged over short time periods. At present this approach is not well known and only recently beginning to be applied in practice.

It is important that new methodologies are compared with those that are commonly used so that a deeper understanding of application and limitations can be made. This view is predicated on comments by some thermography researchers, who warn about the risk of defect misinterpretations from images collected using pass-by thermography. For instance, Schwoegler [6] suggests how

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drive-by thermography (a form of pass-by thermography) will face limitations to image interpretation due to emissivity variances, changing view angles, thermal mass variations and unknown occupancy habits.

This paper explores the suggested strengths and limitations to pass-by thermography in comparison with traditional walk-through thermography on residential dwellings in Devon and Cornwall, England.

2. Current building thermography approaches

2.1. Traditional walk-through thermography

The most commonly used passive building thermography methodology is walk-through thermography, also known as the 'traditional' method [4]. This methodology is outlined by the American Society for Testing and Materials (ASTM) [7], the Residential Energy Services Network (RESNET) [8] and British Standard BS EN 13187:1999 [9] and involves the thermographer walking around the building examining all external building components from both the internal and external sides. Utilising the benefit of real time feedback [10], the thermal camera is used to systematically scan all building surfaces looking for any potential thermal anomalies [11]. Upon viewing a thermal anomaly, the thermographer then records a thermal image for analysis and possible inclusion within a report [7].

There are however certain climatic requirements that need to be met for thermographic analysis. Pearson [12], UKTA [13] and the British Standard for qualitative thermography [9] are a selection of sources that list the key climatic requirements for conducting thermographic surveys. These include:

- Wind speeds lower than 5 m/s;
- At least 10 °C temperature difference between internal and external spaces;
- Surfaces free from direct solar exposure both during the survey and in the hours preceding the survey;
- Undertaken during cloudy conditions to avoid reflecting a clear sky.

Because of these requirements, in cool maritime climates similar to the UK this means that thermographic inspections are often undertaken during the cooler months (October to March) of the year and during the coolest part of the day (during the hours of darkness). This latter issue is further restricted by the need to gain access to dwellings, limiting inspections to sociable hours in the evening/night time.

Traditional thermography affords the opportunity for detailed thermographic analysis of buildings where potential defects can be viewed from many different angles and distances. Also the results from this methodology can be used in combination with other techniques, such as air-tightness testing, to enhance air-leakage detection [14] and computer simulation, which can enhance defect understanding through comparison with thermal models [15,16]. However this walk-through thermography can be time-consuming, especially in buildings with many rooms [17]. Smale [18] indicates that a single dwelling walk-through survey might take between 60 and 150 min to complete, with more lengthy periods expected for non-domestic buildings. With increased time comes increased cost and this is reflected in the price charged for a single traditional thermographic survey. For example, one UK based company charges between £275 (1–3 bedroom dwelling) and £475 (5 bedroom dwelling) per survey [19].

2.2. Street pass-by thermography

Given the timescales and costs involved in traditional thermographic surveys, there has recently been a drive to reduce both of these factors. One methodology in particular, pass-by thermography has been developed to speed-up the inspection process in order to survey many more building in one survey period.

One form of pass-by thermography currently being explored uses vehicle-mounted thermal cameras to survey residential streets [20–22]. The cameras used capture high-resolution thermal images of each dwelling's front elevation as it passes by. This methodology appears similar to that used by Google Street-view [23] for street photography and is referred to as a *drive-by* approach [20].

It is clear that driving past buildings with a thermal camera will permit a larger number of properties to be surveyed during the same survey period of traditional walk-through thermography. In addition, pass-by thermography does not require access to dwellings, so occupants do not need to be home. This means that such thermographic inspections can be undertaken outside of sociable hours when residents are home and awake. This can therefore minimise discrepancies in results between dwellings due to surveying many buildings under similar climatic conditions. Yet, the temporal resolution (sensor refresh rate) and speed at which many modern day thermal cameras are able to record images is not currently sufficient without improved equipment that is currently prohibitively costly for many commercial enterprise. Recent research and development work by MIT and spin-off company, Essess [20–22] has centred on developing a system, which seeks to improve the temporal resolution while maintaining spatial resolution by using multiple thermal cameras, slow driving speeds and image enhancement algorithms, such as their Kinetic Super Resolution process. Whilst findings by Miller & Singh [22] demonstrated how drive-by thermography could be between 4 and 4.5 times cheaper than the cost of a traditional methodology, some estimates for single elevation pass-by thermography in the UK are as low as £5 per building [24]. This therefore makes the cost savings for pass-by thermography approximately 55–95 times the cost for walk-through thermography.

In the UK, a pass-by approach to thermographic building inspections has been commercially developed and applied on housing association properties. One such example applied single elevation thermal imaging on 30,000 dwellings in Scotland in 2012. The specific details of this methodology have not been published, so only implied assumptions can be made from literature by Clyde Valley Housing Association [25], who were one of the clients having dwellings surveyed. Nevertheless, from internal reports and press releases on this project, it appears that data from these studies has been collected using a *walk-past* methodology, where a thermographer walks from dwelling to dwelling, thermal imaging the front elevation of each one.

As part of the research undertaken by MIT on drive-by thermography, Phan [20] undertook preliminary walk-past studies of dwellings located in Massachusetts during January 2010. For this research, walk-past surveys were conducted over 7 nights from 6 p.m. to 2 a.m. Key observations from this work included:

- Each dwelling took approximately 10–15 min to survey.
- Between 20 and 30 homes could be surveyed per night. (this was viewed by Phan as being too slow to scale up to inspect entire towns or cities).
- Working in cold weather conditions was physically demanding.
- Unexpected heat loss from draughts, poor insulation, windows, doors and roofs was discovered.