Enhancing Positioning of Photovoltaic Panels Using 3D Geographic Information

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1. Introduction

As the national mapping agency of Great Britain, Ordnance Survey (OS) is looking to launch a new generation of 3D products over the next few years and are keen to test and validate the value of 3D models, in particular with photovoltaic (PV) suitability assessments (Ordnance Survey 2012). Current desktop methods to assess a property for PV suitability are crude, unreliable and mostly two-dimensional. The argument presented in this paper concerns the capacity of 3D geographic information (GI) to enhance the desktop evaluation assessment of property suitability for photovoltaic panels. Qualitative interviews were used to gather data on potential users, forming a specification of their needs which consequently framed the development of a prototype solar panel positioning tool. The resulting tool presented an alternative, robust and 3D method of assessing a property for PV suitability, demonstrating the analytical potential of OS 3D data. This study offers an unconventional approach to PV analysis which could be incorporated into a wider renewable technology suitability assessment toolkit. This paper presents the results from the interviews and the prototype solar panel positioning tool.

2. Background

Recent trends in the use of 3D GI have been partly driven by web-based virtual globe applications such as Google Earth (Hudson-Smith *et al.* 2007). While still in its maturation, advances in 3D data have extended it from beyond simple visualisations and into an analytical information product. Applications include support for mineral discovery, noise mapping, public rescue operations, ecological studies and utility management (Zlatnova *et al.* 2002). Some benefits of 3D include increased realism but also immersive capabilities (Koller *et al.* 1995).

Within the PV industry, geographic information is used to within desktop evaluation of a property's suitability of installing a photovoltaic system although there has been limited adoption of 3DGI. Solar yield estimates can also be generated which allow the homeowners and investors to quantify financial benefits of installing a system. It also allows installers to optimize the positioning and select the most suitable type of panel i.e. thin-film modules on a north-facing roof in the UK. There have been many different methods of modelling PV potential (Yeboah-Amankwah & Agyeman 1990; Kaku & Potter 2009; Rae *et al*. 2009; Tsai 2010) but for an urban environment, topography is arguably the main constraint on solar irradiance. For roof-top systems, physical constraints include roof properties including area, pitch and orientation, and also overshadowing from nearby buildings. Within the PV industry, the three main assessment methodology and tools used by PV engineers are: 1) Standard Assessment Procedure (SAP); 2) PVGIS; and 3) PV*Sol.

3. Interviews with PV Engineers

Semi-structured interviews were used to gather data from potential users. Candidates were UK-based PV engineers from solar panel installation companies. An interview guide was used within each interview to provide structure and followed four main topics: General Questions, PV Suitability Assessment, Installation Process, PV in the UK and OS Data Product. An additional interview was carried out with two members of Newcastle City Council, UK, who were involved with the "i-SCOPE" project which aims to use 3D urban information models to create three smart city services including solar energy potential assessment. (i-SCOPE 2012). Figure 1 shows an extract of questions from the interview guide.

General Questions:

- Can you please tell me briefly about your company and market?
- How many employees work within this company?
- Does your company focus primarily on domestic or commercial properties?
- What proportion of the business are new-builds vs. retro fit?

PV Suitability Assessment and Installation Process:

- Can you step me through the process from a customer enquiry to the actual installation?
- What information do you require before a PV installation? Is there a desktop evaluation?
- How do you work out if a roof is suitability for a PV system?
- Are you aware of or actively engage with geographic information?
- Does your company monitor each system after the installation?

PV in the UK:

- How has the feed-in tariff cuts affected your company?
- Where do you see specific opportunities for the UK PV industry in the next 10 years?
- What do you think are the biggest barriers when it comes to implementing PV and other renewable energies?
- In your opinion, how has the PV market evolved in the past 5 years?

OS Data Product:

- Would a detailed inventory of solar roof potential for a whole city be useful for your company, for example, to target properties with good potential for PV installations?
- What other functionalities would you like to see included into a tool like this?
- Could this be used as a marketing tool?
- Would this tool be equally as useful in 2D?

Figure 1 – Extract from the Interview Guide

4. Key Findings

Below is a summary of key findings from the interviews:

- PV installers had limited awareness of and low interaction with geographic information. Knowledge of GI is limited to web mapping services such as Google Maps or Bing Maps and virtual globe applications such as Google Earth.

- Current desktop assessments were considered crude and are used only for preliminary investigation. There was a lack of trust on the reliability of the data used which may be improved should the data originate from a trusted organization such as Ordnance Survey. Two recognized issues were the "up-to-dateness" of satellite imagery and the difficulty to identifying the correct target property especially when delineating the start and end of roof lines in terraced housing. A full on-site evaluation was still viewed as compulsory.

- Aesthetics of PV panels were highly important to customers due to the possible effects on property value.

- PV installers may not be the ideal demographic of users for the OS 3D data, but there was suggestion that the customers and the public may in fact be potential users.

- Benefits of 3D for PV applications included establishing credibility, providing an element of professionalism and gaining the users' trust.

In response to the main question, it has been determined that there is capacity for 3D geographic information to enhance the desktop evaluation when assessing PV suitability but there is a lack of inclination and awareness to adopt it. It was found that PV installers did not interact frequently with geographic data within their assessment nor, a fortiori, with 3D geographic data. PV installers were content with their current methodology and did not perceive any additional benefits with 3D GI. In contrast to initial assumptions, the potential user base may in fact lay within the customers themselves rather than the installers. There was a need for a "quick, yet robust and professional" PV assessment service in the public domain for residents and homeowners as well as for local authorities in assessing housing stocks.

5. Forming a Specification

This solar panel positioning tool will utilize OS 3D data and should work as follows:

1. Read the 3D building data from a database;
2. Place solar panels on "suitable" roof faces of a property:
    a. with regards to tilt and orientation considerations;
    b. in an aesthetically pleasing manner, focusing on symmetry;

c. in compliance with any building regulations;

3. Write the panel positions back into the database after calculating the position of the panels
4. Output the visualization in a format that can be viewed by most web browsers.

The prototype tool should satisfy all of the above requirements to a certain degree. In accordance with the findings from Newcastle City Council, the tool will not include shadow analysis due to the vastly increased processing required compared to the relatively small impact. This tool offers an alternative approach; rather than assessing solar energy potential directly to determine the location of solar panels, the limited roof area available on a domestic roof in turn limited the number of possible configurations. The approach is therefore to maximise the number of panels on the roof, placing them geometrically. Tilt and orientation was still considered and therefore only suitable faces had panels installed.

The test data provided by Ordnance Survey for this study were 3D city models for a selection of buildings in Newcastle and Sheffield city centre. The data was in LoD2 (Kolbe *et al.* 2005), which had differentiated roof structures but the majority of the buildings do not have texturing. Individual buildings were extracted and used for testing.

6. Programming the Solution

From the above specification, a conceptual solution was developed which was then programmed using a combination of Oracle Database 11g and Java with the outputs visualised in Google Earth. Figure 2 outlines the solution.

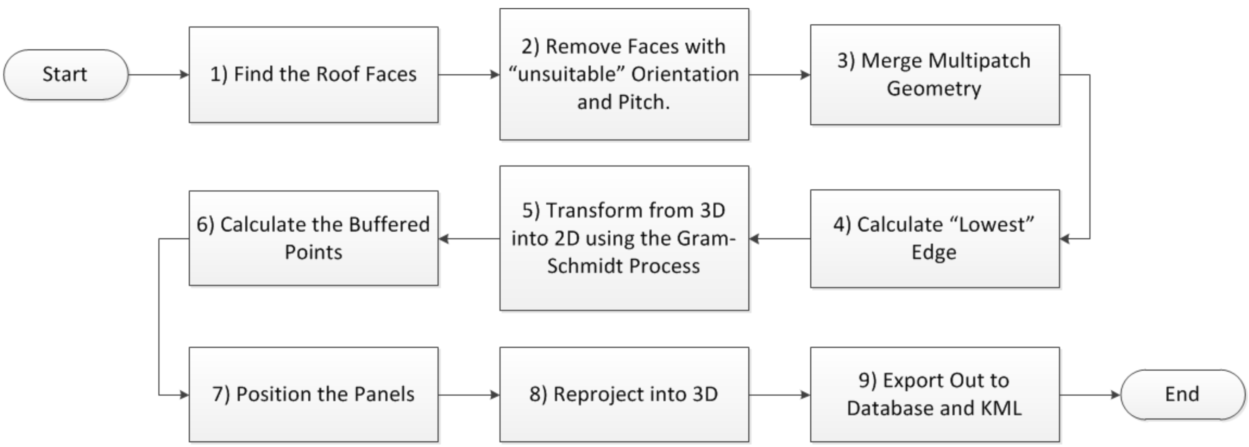

Figure 2 – Flowchart of the Proposed Solution

An example of the KML output is illustrated below in figures 3 as viewed in Google Earth. The panels are illustrated using flat trans-blue polygons with a white outline and have been raised off the surface by 35mm to give the impression of a 3D panel.

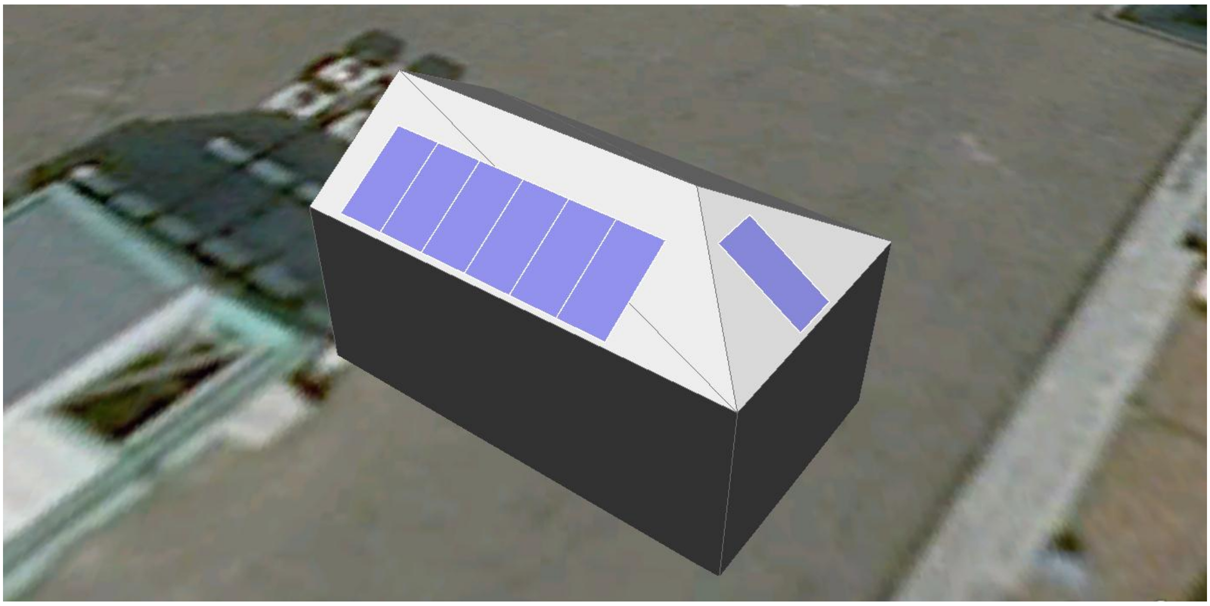

Figure 3 – KML Visual Output

As an initial prototype, the tool worked well. The process of positioning the panels geometrically was fast and robust and preliminary testing shows that a full assessment took between 2.72 to 2.77 seconds per building. As a one-off, non-stored assessment solution, this was an acceptable processing time. The strength of the tool lay within the 3D to 2D transformation matrix where a short and robust piece of code transformed the problem into two-dimensions. The missing dimension in theory reduced the number of calculations required although the exact performance benefits are yet to be quantified.

Figure 4 – Mock-up of output with the inclusion of texturing and increased photorealism

7. Discussion and Future Work

Throughout this study, a number of opportunities for future work arose. Additional interviews and focus groups with the public to gather feedback on the prototype tool would be useful. The inclusion of texturing to provide better photorealism (Figure 4) and the incorporation of an analytical output providing details on financial benefits and carbon emission reductions would vastly expand the scope of the tool.

This study has demonstrated the potential and value of Ordnance Survey 3D data in augmenting desktop evaluation of PV suitability. The additional dimension brings advantages of realistic visualisations, establishing credibility amongst its users and imparts an air of professionalism. The resulting prototype tool was capable of yielding quality solar panel positioning assessments for domestic building with underlying methodologies that are robust, sound and transferable to a wider context. Looking forward, the tool may be used to help inform the public on possible energy efficiency improvements that can be made to their properties, contributing to national efforts in reducing carbon emissions. In all, three-dimensional geographic information undoubtedly offers a wealth of functionalities and enhancements for photovoltaic suitability assessment; it is a matter of will which determines whether this potential is realised.

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Biographies

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