Validating Emissivity by Collecting Roof Material Data using Volunteered Geographic Information (VGI)

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Abstract

A relatively new research area known as volunteered geographic information (VGI) has emerged from the current geospatial revolution, advancements in latest web–based technologies, and embracement of the Web 2.0 era by the general population. A VGI tool has the ability to collect geographic data not available through an airborne or satellite sensor from a wide range of audiences. In this paper, we describe a simple and intuitive VGI tool implemented for the Heat Energy Assessment Technologies (HEAT) project that can be used to volunteer roof material data for single dwelling residences in Calgary. While this research is still in–progress, preliminary results demonstrate that users are actively engaged in volunteering roof material data. It is envisioned that these data can be used to validate emissivity values for the different roof materials observed in the current study area. Emissivity is critical for generating a variety of products available to the users on HEAT's GeoWeb application such as the amount of waste heat leaving homes, their estimated energy consumption, and associated HEAT Scores.

Background and Relevance

Humans have constantly exchanged information and made observations since the early ages, ranging from Neanderthal cave markings to landscape paintings in the Nazca Desert. In the 1900s, the Christmas Bird Count by the National Audubon Society[1] was established to understand bird population data for conservation purposes by involving local citizens within the project. It is now recognized as *the* pioneering example of what is known as *volunteered geographic information* (VGI). In its simplest form, VGI is defined as private citizens with little or no formal qualifications collectively collaborating and actively engaging in creating geographic content that can be consumed for multiple purposes (Goodchild, 2007). Silvertown (2009) noted that involving citizens within research is an excellent way to spread knowledge and educate the local population. In addition, volunteers offer high value to research, policy and practice as concluded by the UK Environmental Observation Framework based on a thorough review of more than 230 citizen science projects (Roy *et al.*, 2012). OpenStreetMap[2], eBird[3], Ushahidi[4], EDDMapS[5], and Project Noah[6] have set strong standards for researchers on how to successfully deploy VGI systems to solve community–based and scientific problems with a high volunteer retention rate.

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[1] National Audubon Society: Christmas Bird Count – http://birds.audubon.org/christmas-bird-count
[2] OpenStreetMap – http://openstreetmap.org
[3] eBird – http://ebird.org/content/ebird
[4] Ushahidi – http://ushahidi.com
[5] Early Detection and Distribution Mapping System – http://www.eddmaps.org
[6] Project Noah – http://www.projectnoah.org

Similarly, the Heat Energy Assessment Technologies (HEAT)[7] project is using VGI to validate emissivity values for different roof materials used on Calgary homes. HEAT is a free GeoWeb application designed to support urban energy efficiency by allowing residents to visualize the amount and location of waste heat leaving their homes, communities, and cities as easily as clicking on a home in Google Maps (Hay *et al.*, 2011). The HEAT project incorporates Geomatics solutions for community waste heat monitoring using Geographic Object–Based Image Analysis (GEOBIA) and Canadian built airborne Thermal Infrared (TIR) technology[8] to provide users with timely, in–depth, and *location–specific* waste heat information as well as opportunities to save their money and reduce their greenhouse gas (GHG) emissions. HEAT provides each home with a HEAT Score between 1 (low energy consumption) and 100 (high energy consumption) for comparative analysis, locations of hot spots showcasing the 12 hottest roof locations (shown 3 at a time), and estimated savings information – all of which are part of an interactive and multi–scale interface that provides waste heat maps for homes, communities, and city.

In the HEAT project, emissivity is required to convert 'relative temperature' defined by the TIR sensor into 'real temperature' values, which are essential for determining the amount of waste heat leaving homes, their estimated energy consumption, and associated HEAT Scores (Hay *et al.*, 2011). Emissivity is defined as a value between 0 (shiny mirror) and 1 (blackbody) that represents the relationship between a material and its ability to absorb and emit TIR energy. Thus, knowing roof material type is critical for determining its emissivity. Currently, the roof material data are not publicly available for single dwelling residences in Calgary. We hypothesize that (i) users will be actively engaged with this VGI tool, and that (ii) information volunteered by these users will provide additional support for validating emissivity values in the HEAT project.

Methods and Data

HEAT's VGI tool to collect roof material data is built using the Google Maps application programming interface (API) and within the existing graphical user interface (GUI) of HEAT's GeoWeb application. This tool enables users to volunteer roof material data such as asphalt, cedar, concrete, metal, etc. It tallies how many samples have been assessed and their individual locations by showing a green tick mark on each home (Figure 1). We note that limiting the number of allowable options to the user is one way to control data credibility and quality, which is a critical issue with VGI (Flanagin & Metzger, 2008). Additionally, integrating this tool with Google Satellite and Google Street View allows the design to be simple and intuitive. Currently, this tool is active online for approximately 38,000 single dwelling residences in Calgary, Alberta, and can be used at saveheat.co.

[7] Heat Energy Assessment Technologies (HEAT) – http://saveheat.co
[8] Thermal Airborne Broadband Imager (TABI)–1800 by ITRES – http://itres.com/products/imagers/tabi1800

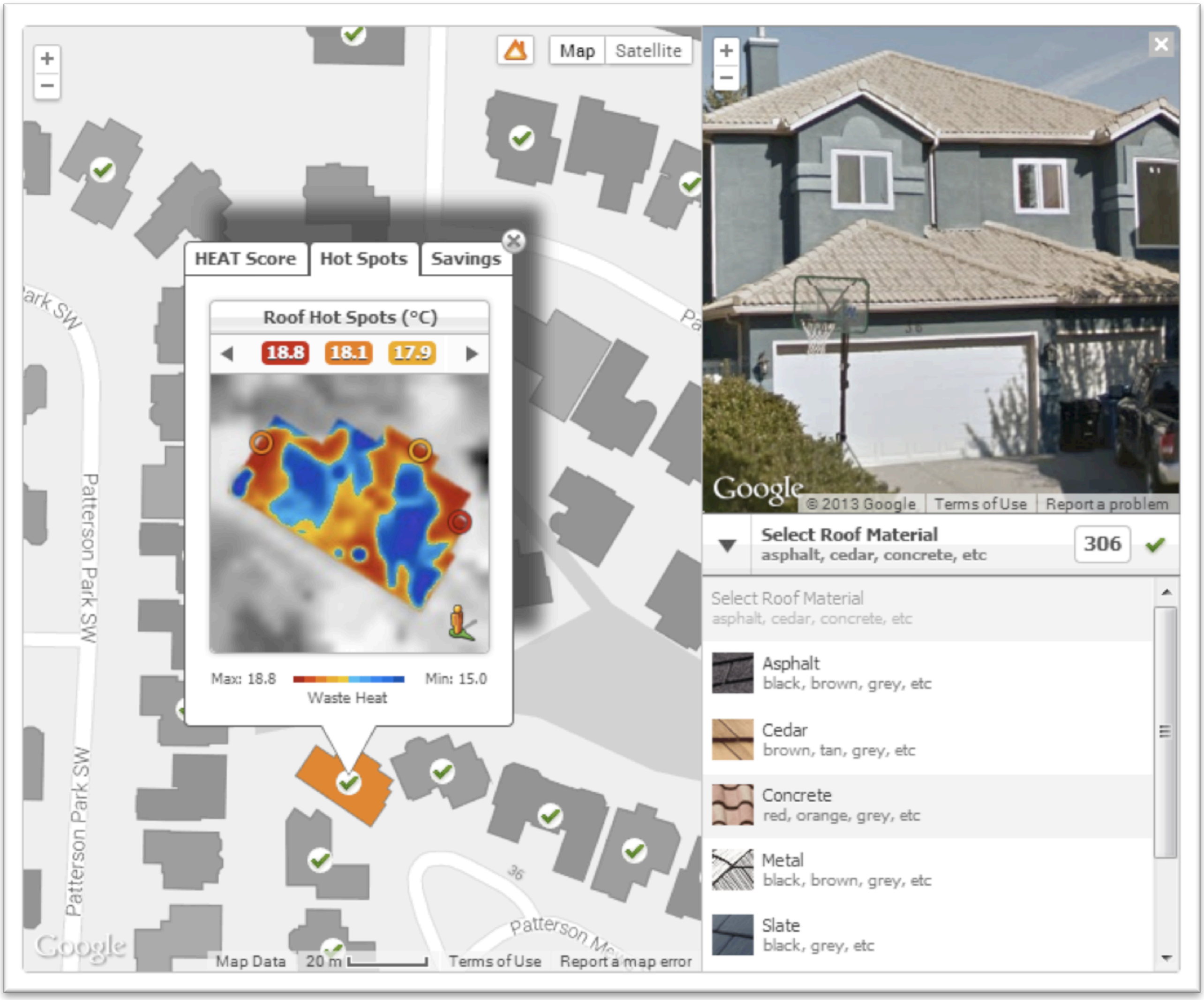

Figure 1 – The GUI of HEAT's VGI tool that can be used to volunteer roof material data

HEAT's VGI tool was developed by adopting the three–tier architecture. The (i) *presentation tier*, also known as the *client–side*, incorporates latest web based technologies such as HyperText Markup Language (HTML5), JavaScript (JS) and its libraries like jQuery, and Cascading Style Sheets (CSS3). As noted previously, the Google Maps API is also used to embed a mapping component into this application along with (a) Google's newly updated and very high–spatial resolution satellite imagery of Calgary, and (b) Google Street View – both of which can be used to investigate the roof material under observation. Additionally, the implementation of Google Street View for the purpose of identifying a roof material makes this tool and the user experience unique. To the best of the authors' knowledge, Google Street View has not been used in this manner for any other research purposes. Common Gateway Interface (CGI) scripts written in the Python programming language represent the (ii) *logic tier* (i.e., *server side*), while the (iii) *data tier* is represented by a database server using the PostgreSQL geospatial database management system, and PostGIS as its spatial extension.

In most VGI applications, a user has to draw points, lines, or polygons for entities seen on a map. However, with HEAT's VGI tool, point geometry is created *for* the user when they volunteer roof material data in order to make it easy to use, as volunteers emphasize *simplicity* the most in a VGI application (Newman *et al.*, 2010). This point geometry is then stored in the database along with the user's IP address (for geolocation), date and time, and the home's unique identification number – all of which are attached to a home's location on map.

Results and Discussion

It should be noted that this is an on–going research. As such, preliminary results are being presented in this paper. From June–November 2013, the total volunteered roof material data were 2,426 with a mean of 11 contributions per day. Volunteers have classified roof material as follows: asphalt (1,369), cedar (397), concrete (367), metal (115), slate (66), rubber (58), and other (54). Of the total volunteered data, 1,244 volunteers have classified 1,815 unique homes. This represents 5% of the study area. The difference in the total volunteered roof material data (2,426) versus the total unique homes classified (1,815) is due to the fact that some volunteers have contributed roof material for *multiple* homes in their community and/or city. However, the average roof contribution *per* home is approximately 1.33. This tells us that these volunteers were probably either (i) homeowners contributing their home's roof material, or (ii) users testing the tool on a randomly selected home. While the majority of these volunteers were from Calgary, HEAT's VGI tool witnessed participation from around the globe with users volunteering roof material data from New York, Torino, Madrid, Yekaterinburg, Roosendaal, and more. The maximum number of contributions by a single volunteer was 155.

In addition to *limiting* the number of provided options (as previously noted) to the user, these results can be seen as another method to control data quality in research projects that adopt VGI. For example, the higher the number of specific roof material (e.g. asphalt) submissions defined for a home, the more likely it is to be that type. As a result, a correlation can be defined between contributions and data quality. In other words, *the higher the number of data contributions, the better the data quality*. This relates back to the Linus' Law (Haklay *et al.*, 2010) within the open–source community, which states: "Given enough eyeballs, all bugs are shallow".

Currently, data from this research are being cross verified with the multiple listing services (MLS) data. Although not available at the beginning of this research, it was recently provided by the Calgary Real–Estate Board (CREB) for single dwelling residences in Calgary to ensure the credibility and quality of the volunteered data. Additionally, these data will also be compared with a roof material classification generated from an R, G, B, Near–Infrared (NIR) ortho–mosaic of Calgary that was acquired in 2012 at a 25cm spatial resolution. Once this is complete, emissivity will then be validated for each home in Calgary to reflect changes in the amount of the waste heat, their estimated energy consumption, and associated HEAT Scores.

Conclusion and Future Work

By integrating a VGI tool within the HEAT project, there is an opportunity to further enhance scientific, local, and personal knowledge as well as foster lasting and meaningful engagement on urban energy efficiency. HEAT's VGI tool has witnessed participation from volunteers every day since it was introduced. Results from this research are currently being used to validate emissivity values that can improve the accuracy of residential energy efficiency. Work described in this paper is part of an on–going research project supported by the Alberta Real–Estate Foundation that will allow users to volunteer energy related geospatial, consumption (kWh/GJ), and building data through a more sophisticated web–enabled VGI system.

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