Vice Chancellor's Distinguished Awards 2020: Innovation of the Year

The UJ-PEETS team of Samson Masebinu, Nickey Janse van Rensburg, Tafadzwa Makonese, Katharina Gihring and Pieter Erasmus wins the Vice Chancellor's Distinguished Award Innovation of the Year for 2020.

THE INNOVATIVE TOOL

Enabling Cities with Data – Application of Artificial Intelligence (AI) for Feature Extraction from Aerial Imagery was implemented for the City of Johannesburg to enable them, for the first time, to identify, locate, count and estimate the installed capacity of all solar photovoltaic and solar water heater systems installed across the City.

BACKGROUND

City managers have limited resources to investigate, monitor, collect, and respond to the almost daily changes of the city landscape. To investigate some of these changes, aerial imagery of the city is captured at regular intervals and places of interest are manually analysed. A data-driven decision was needed for their energy demand-side management to reduce the drudgery of analysing these changes manually. An AI model was developed and applied for the City of Johannesburg, extracting from the aerial imagery of the City of Johannesburg.

The City of Johannesburg and the Department of Housing installed about 76,000 Solar Water Heaters (SWH) for households between 2008 and 2016 within the City to reduce peak demand for electricity due to the stressed generation capacity of Eskom. Lack of records on the specific location of these SWHs has limited future rollouts and any performance assessment. City Power, the electricity utility company of the City of Johannesburg, reported that they have noticed a decline in electricity demand, but could not confidently attribute the reduction to their energy efficiency strategies, activities of residents of the city, or its operational losses. They had, however, noticed increased adoption of solar photovoltaic (SPV) installations across the City.

The National Energy Regulator of South Africa (NERSA) requires the City to provide a database of installed SPV. Unfortunately, the City did not have sufficient data to report to NERSA as households with SPV are reluctant to register their installation with City for several reasons, such as paying fees, monitoring and security risk. Furthermore, the City lacks the means to comb the length and breadth of its landscape to document and report all installed systems. Hence, the City needed an alternative low-cost tool of data acquisition on installed SWH and SPV within its jurisdiction.

NOVELTY

Responding to the City of Johannesburg´s need for a database with minimal cost and considering COVID-19 restriction, an AI approach was proposed since the objects of interest are installed in places exposed to sunlight and captured in any aerial imagery. Fortunately the City Geographic Information System (GIS) department captures the aerial imagery of the City every 5 years. The AI approach was based on convolutional neural network (CNN) model which was developed to analyse the high-resolution imageries of the City to identify, count, and geolocate all installed SWH and SPV systems within the City. The CNN architecture was based on the dynamic UNET structure with ResNet 34 model used with ImageNet weight initialization to train the CNN for segmenting by pixel, the image region belonging to SWH and SPV objects respectively (see Figure 1). Furthermore, the AI approach was used to further estimate the surface area of the installed SPV system to estimate the installed capacity.

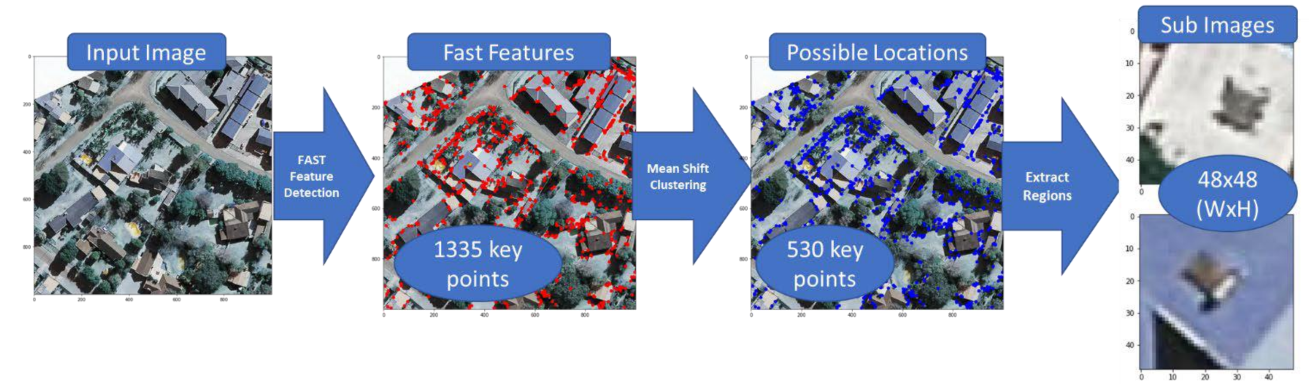

Figure 1 Visual representation of the CNN from high resolution imageries to identifying the SWP and SPV systems.

IMPLEMENTATION CASE

Aerial imagery obtained from the City of Johannesburg GIS department was compressed as image wavelets with projections for each compressed wavelet (ECW and PRJ files). SWH and SPV objects were tagged to form a dataset. The split for the dataset used for this application was 80% training data and 20% validation data. This way each epoch of training gives the CNN enough variability so that a lower number of epochs can be used to train the model and reduce overfitting. Data augmentation such as flipping, warping, and rotating was also included in the training step to further combat overfitting.

Through the implementation of the AI methodology, it was established that in 2015 and 2019 there were 129,195 and 133,986 SWH installed respectively and 3,338 and 6,830 SPV installed respectively (see Figure 2). The AI SWH identification accuracy was 90.10% and 84.53% for 2015 and 2019, respectively. Whereas it was 88.18% and 72.86% for SPV during the same period. Beyond the AI accuracy, Google Earth verification was further carried out as a virtual verification step using a statistically significant sample size.

The results established that 88.7% of the SWH and 73.70% of the SPV were correctly identified, by the AI approach based on the 2015 data. The Google Earth verification for the statistically representative dataset for 2019 is currently ongoing.

Figure 2 Identified SPV and SWH from aerial imagery.

Table 1 AI Identification accuracy for the SWH and SPV

	SWH		SPV	
	2015	2019	2015	2019
AI Counts	145,654	158,507	4,528	9,373
AI Accuracy	90.10%	84.53%	88.18%	72.86%
Google Earth Verification	88.70%	*	73.70%	*
Min. Certainty	88.70%	84.53%	73.70%	72.86%
Counts with Min. Certainty	129,195	133,986*	3,338	6,830*

**Google Earth verification for 2019 data set is ongoing*

The SPV installed capacity was estimated to generate 63 MW as of 2019. Available data for commercial systems that the City could account for indicated only 40 MW as of 2019. Hence, the AI approach showed that cumulative household installations and recent commercial systems that have not been recorded on the City database amount to about 23 MW.

Beyond the installed capacity, the orientation of the SWH and SPV were also captured. The orientation of a solar energy-dependent system affects its energy conversion efficiency. Through the implemented approach, it was established that 78.2% of the SWH and 99.6% of the SPV were orientated Northwards as shown in Figure 3. The AI approach was used to generate the required database storing all identified object, their coordinates and surface area in a structured form in Microsoft Excel as illustrated in Figure 4.

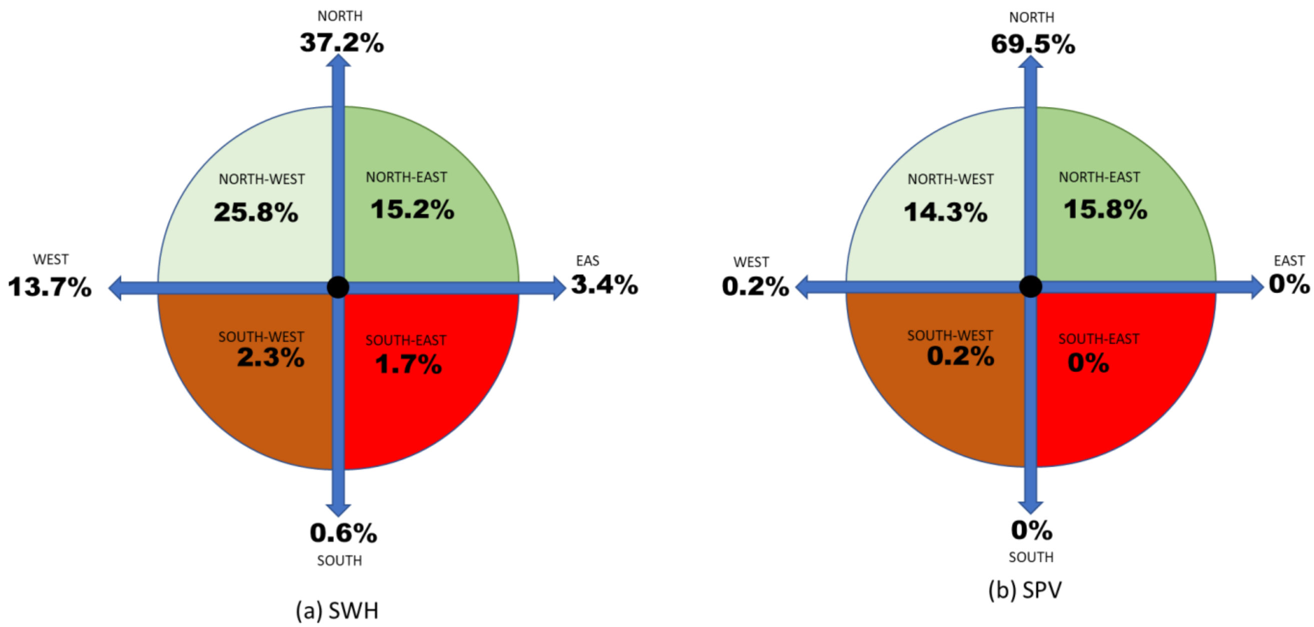

Figure 3 Orientation of SWH and SPV in the City of Johannesburg

	img_name	row	col	lat	long	obj_type	pixel_weig	area
0	AB111_09_12_1	874.6795775	979.5158451	-26.16999793	27.68768862	PV	1704	38.34
1	AB111_16_07_1	607.8902027	355.375	-26.17903446	27.67914966	PV	592	13.32
2	AB111_17_08_1	959.6793478	351.9438406	-26.18087788	27.68062403	PV	552	12.42
3	AB113_13_15_1	874.987013	700.6266234	-26.22959148	27.69110451	PV	308	6.93
4	AC112_16_04_1	424.726817	82.83709273	-26.20608573	27.70394611	PV	399	8.9775
5	AC113_10_02_1	840.4279919	938.6855984	-26.22558259	27.70201283	PV	493	11.0925
6	AD111_06_16_1	118.1559322	260.6542373	-26.16549041	27.75266574	PV	295	6.6375
7	AD111_07_16_1	530.6531792	18.78757225	-26.1673992	27.75228259	PV	692	15.57
8	AD111_08_15_1	429.8875413	438.6372657	-26.16860884	27.7513994	PV	907	20.4075
9	AE110_18_19_1	601.6656535	103.0364742	-26.15560886	27.78703455	PV	658	14.805
10	AE112_13_04_1	151.0367647	280.7463235	-26.20218549	27.76430987	PV	272	6.12
11	AE115_02_16_1	188.9095967	89.38664812	-26.26871359	27.78133643	PV	719	16.1775
12	AF108_08_04_1	489.6332882	489.8822733	-26.08784434	27.7958098	PV	739	16.6275
13	AF108_08_04_2	550.2089552	495.5447761	-26.08792641	27.79581745	PV	268	6.03
14	AF108_10_11_1	445.0102916	51.30703259	-26.09057295	27.80561866	PV	583	13.1175
15	AF108_10_13_1	833.3634945	462.9921997	-26.09112853	27.8092286	PV	1282	28.845
16	AF108_11_06_1	739.065534	475.7912621	-26.09226766	27.7987418	PV	412	9.27
17	AF108_11_10_1	794.8169492	631.4974576	-26.09239487	27.80497077	PV	1180	26.55
18	AF108_12_10_1	754.1164327	50.0388109	-26.09368618	27.80408591	PV	1211	27.2475
19	AF108_12_10_2	795.1020115	11.33333333	-26.09374118	27.80402733	PV	696	15.66
20	AF108_12_13_1	610.6324786	600.3190883	-26.09353598	27.80941011	PV	351	7.8975
21	AF108_13_03_1	609.261586	92.93511843	-26.09475687	27.79364467	PV	971	21.8475

Figure 4 Database with the required information on coordinates, surface areas, aerial photo for each identified SPV and SWH.

VALUE PROPOSITION

The novel approach implemented in this project is of interest due to its potential rapid deployment to other municipalities across South Africa and other countries. For the future, it is planned to develop a website-based model where the municipalities can upload their aerial imagery and with the click of a button, they will be able to intelligently identify all SWH and SPV systems installed within their jurisdiction. This information can be used to understand their Greenhouse emission footprint, the installed energy reduction measure and alternative energy potential, particularly SPV.

The summarized value propositions anticipated from this novel approach of applying AI for feature extraction for municipalities are:

- To make a well-informed decision based on their aerial imagery;
- Reduced labour cost: the risk associated with sending field workers to force people to register their SPV system can be minimized;
- Reduction in municipal revenue due to action of resident relating to electricity can be better understood; and
- Through the established database, maintenance of the SWH and SPV systems can be done.

The derivative propositions of the approach are:

- Vacant roof spaces with potential for installation of SPV can be identified and potential installation capacity can be calculated. This offers municipality an alternative energy source to minimize GHG emissions, the effect of load shedding and the knock-on effect on the local economy;
- Illegal waste disposal sites can be seen from the aerial imagery of the City therefore the hotspot for illegal waste dumpsites can be rapidly identified. Presently, it costs Pickitup R60 million annually to clean up illegal dumpsites in the City of Johannesburg.
- The redesign of the commercial district and urban planning considering all flows of people, transport, goods, space can be optimally used.

About University of Johannesburg´s Process, Energy and Environmental Technology Station

The University of Johannesburg's Process Energy & Environmental Technology Station (UJ-PEETS) was established in 2010 under the support of the University of Johannesburg and the Technology Innovation Agency (TIA), an agency of the Department of Science and Innovation (DSI). It is mandated is to support SMEs through technology innovation, knowledge transfer and capacity development within the green economy. It is a leading technology station contributing towards improving the competitiveness of industry and SMEs through the application of specialized knowledge, technology and facilitating the interaction between industry (especially SMEs) and academia.