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Rooftop analysis for solar flat plate collector assessment to achieving sustainability energy

Alberto-Jesús Perea-Moreno [a], Amós García-Cruz [b], Nuria Novas [b], Francisco Manzano-Agugliaro [b,*]

[a] Dpt. of Applied Physics, CEIA3, University of Cordoba, Campus de Rabanales, 14071 Cordoba, Spain
[b] Dpt. of Engineering and CIAIMBITAL (Research Center on Agricultural and Food Biotechnology), CEIA3, University of Almeria, Almeria 04120, Spain

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ABSTRACT

The insufficiency of current energy sources, elevated costs and global climate worriment are distinctive factors making of renewable energy an issue of boosting consideration. In this concern, solar energy is viewed as being indefinitely environmental friendly, carbon-free, beneficial nature with appreciated cost potentials and is witnessing fast progressing. Following the Horizon 2020 climate and energy package, the volume of gases emitted by greenhouses has to be cut down by 20% by all the European Union (EU) member countries in order to enhance energy performance by 20% and raise the renewable energy rate to 20% by 2020. Solar energy on building roofs plays a crucial aspect in renewable and sustainable energy consumption of high-density human habitats. A merest energy should be allocated to provide hot water service from solar sources, as other European norms for new buildings by the Spanish Technical Building Code, similarly to other European regulation on achievement objectives. The climate zone and the overall demand of hot water in the building regulate this minimal amount needed. This manuscript use a new methodology for automatic detection of geometric patterns from aerial or space images using a Hierarchical Temporal Memory (HTM) algorithm. In this way, an automatic method for the identification of building roofs in order to assess the opportunities available to install solar thermal systems in small urban areas has been developed. As case of study: a village with 7000 inhabitants was analyzed in the South of Spain. The maximum overall accuracy obtained among the different classifications made was 98.05%, avoiding problems related to the use of images with high spatial resolution, as in the salt-and-pepper noise effect. This approach contributes reducing the generated carbon and GHG emissions and open new perspectives for energy savings strategies to optimize the energy efficiency of buildings. In the case study, implementing the solar thermal systems would come out with a saving of 1.4 tons of CO_2 per inhabitant.

1. Introduction

In the last decades, the raise in energy interest made energy employment a crucial affair on large scale implementation (Baños et al., 2011). In the same concern, various environmental complications have arisen from the use of fossil fuels and other conventional energy sources (Perea-Moreno et al., 2016a,b; Manzano-Agugliaro et al., 2012). Alternative energy sources are the best focus solution to be explored due to the problems resulting from destructive substances released into the atmosphere resulting in climate change and global warming (Almeida et al., 2017). An explicit consequence of the EU strategy "20-20-20", the sustainability of urban areas promises to produce energy from renewable sources and to announce an extensive legislation on energy efficacy (Cadez and Czerny, 2016).

An assessment of the renewable energy potentials is required to define clear regional energy arrangements (e.g. national). In the recent years, a significant aspiration has been achieved towards this appreciation in various worldwide regions (Castellano et al., 2015).

A considerable amount of energy is consumed by the building sector and major profits can be granted to approach zero or nearly zero energy building by handling renewable energy technologies (Manzano-Agugliaro et al., 2015). Whether ensured through solar thermals systems or solar photovoltaic (PV), solar energy is

* Corresponding author.
E-mail address: fmanzano@ual.es (F. Manzano-Agugliaro).

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Acronyms

API	Application Programming Interface
belief$_i$	Probability of similarity
D	Dimension of the vector
DSM	Digital Surface Model
ED50	European Datum 1950
HTM	Hierarchical Temporal Memory
It	Increment
LiDAR	Light Detection and Ranging
maxDist	maxDistance
OBIA	Object-based Image Analysis
outputElementCount	Categories
PV	Solar Photovoltaic
requestGroupCount	Temporal groups
ScaleCount	Scale factor
scaleRF	Scale reference
SD	Standard Deviation
spatialOverlap	Spatial overlap
spatialRF	Spatial reference
UAV	Unmanned Aerial Vehicle

considered as an abundant, free and clean alternative energy source (Fernández-García et al., 2015).

Sustainability is based on three pillars: economic, social and environmental, with an occasionally fragile and difficult balance among the pillars (Almeida et al., 2017). Due to the enormous number of entities to take into consideration (e.g, millions of buildings in a country), estimating the energy engendered by solar thermal systems in building is seen as the most complicated among the applicable technologies (AlFaris et al., 2016). Although complex, such information is treasured for the enlargement of efficient building energy codes. Similarly, to other European norms established on achievement objectives, the Code of Technical Building in Spain (MVIV, 2009) stands for assuring a minimum amount of energy for hot water service from solar sources which bets on the climate zone and the overall water demand in the building. For the case of Spain, 70% is the recorded percentage from the overall hot water demand except for the ultimate challenged zones. For optimization purposes of the vacant area, the remaining roof area can be invested for PV systems, for example, in order to upgrade once this requirement is satisfied. Upon this, it is relatively essential to estimate the possible roof-top areas in urban areas.

Practically, estimation of the solar energy potential in urban setting can be applied differently from simple estimations to airborne LiDAR technologies (Szabó et al., 2016).

Automatic scanning of the buildings is possible with the latter methods, with building a 3D model of the city as well.

For example, a solar 3D urban model of the Campus of the University of Lisbon was developed to evaluate the solar resource of buildings and integrate the potential of roofs with that of facades. To assess this potential, a digital surface model (DSM) of the urban region was built from LiDAR data (Redweik et al., 2013).

Unless a convincing extent of manual work is done, the cited technologies do include some major error which becomes a disadvantage. Moreover, many decision makers do not accept to implement these technologies with practically elevated cost of software and equipments (Torres-Sánchez et al., 2015).

Based on building typology, a substitute approach to determine roof-top areas of urban areas in described in this paper.

For this purpose, information of important use can be analysed and extracted from the images through the employment of powerful and automatic software. In order the Object-based Image Analysis (OBIA) techniques are applied not only for a high level of adaptability but automation as well. These techniques overcome some constraints of pixel-based methodology by combining neighbouring pixels with a homogeneous spectral value after a partition process to use the conceived objects as the primary elements for analysis (Martínez-Rubio et al., 2016). Subsequently, OBIA merge spectral, topographic and contextual information for those items to perform more complex classifications. These techniques have been successfully applied to images obtained by UAVs in urban areas (Kohli et al., 2016).

In recent years, the technology involved in remote sensing and object recognition has considerably advanced (Andreopoulos and Tsotsos, 2013; Li et al., 2015a), with diverse applications ranging from recognition and vehicle classification (Battiato et al., 2015) to the facial recognition of individuals (Siddiqi et al., 2015). Studies on detection and object recognition can be classified into two categories: keypoint-based object detection (Hare et al., 2012) and hierarchical and cascaded classifications (Li et al., 2013). Parallel to this development, a new technology applicable to the classification of digital pictures emerged: the Hierarchical Temporal Memory (HTM) learning algorithm. This classification technology is based on both neural networks and Bayesian networks but involves a particular algorithm based on a revolutionary model of human intelligence – the memory-prediction theory developed by Jeff Hawkins (Hawkins and Blakeslee, 2004). This assumption relies on the workings of the human cerebral cortex, which has architecture in the form of “layers” in which information flows bidirectionally from the senses to the brain. From this operating hierarchy, a hypothesis of how the human mind works is created. The key point of this algorithm is found in the duality of the information received. All information we perceive has a spatial component and a temporal one; information is received by the human brain not as an isolated pattern but as a succession of patterns. The cerebral cortex stores the patterns that we perceive and how they are ordered in time. In light of that concept, the memory-prediction theory states that the cerebral cortex stores the new patterns and their evolution over time so that once these sequences stabilize the brain can make predictions (or inferences) enabling it, without observing a full sequence, to know what pattern it is observing because it knows the sequence in which the patterns occur over time (Hawkins and Blakeslee, 2004).

Thus, this new technology developed by Jeff Hawkins not only presents a new model of how human intelligence functions but also models a neural network system capable of emulating this theory. This classification technology is not specific to image analysis but is versatile for any type of information (from medical information to economic data), with a dual role: learning and pattern recognition in data flows and classifying unknown data according to the training received. Currently, we can find this technology integrated into the free software application NuPIC developed by NUMENTA®, which is used to classify data streams (Hawkins et al., 2011). These data can be of many types, ranging from sign language (Rozado et al., 2012) to eye retinal images for biomedical purposes (Boone et al., 2010). There are open areas of research using HTM as a classifier for land planning, which is where our work focuses. In a previous study, Perea et al. (2009) conducted an analysis of high-resolution images for classification and land planning in agricultural environments; starting from images from a UltracamD® photo sensor of a region of southern Spain, classification results were obtained that recognized the ground cover up to 90.4%.

Thus, given the positive results previously obtained in the classification of images, the aim of this paper is to propose a new methodology for automatic detection of geometric patterns (solar flat collector) in rooftops from aerial or space images in order to