Application of Web 3D GIS to Display Urban Model and Solar Energy Analysis using The Unmanned Aerial Vehicle (UAV) Data (Case Study: National Cheng Kung University Buildings)

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Abstract. Nowadays, the era encompasses everything smart, whether they are smartphones, smart people, or smart cities. The term 'Smart Cities' refers to an advanced urban town that has well-connected infrastructure and communication through data centers and automated networks, unless for the energy system. Solar energy is one kind of renewable energy. It is a clean, sustainable, and free energy source both for the public and governments. With the rapidly growing technology, the yield of solar energy increases, while its cost reduces. Thus, it gains importance and becomes widespread. Presently, the increasing importance of solar power makes a hot topic. We are currently facing a global warming issue where one of the leading causes is the use of fossil energies. Non-fossil energy, or better known as renewable energy, is an option to reduce the use of fossil energy as an effort to minimize the impacts of global warming. In this study, we collected the data from The Unmanned Aerial Vehicle (UAV) that is combined with GPS and IMU technology to get the 3D campus model in National Cheng Kung University (NCKU), Taiwan. The output of the data is true ortho-image, digital surface model (DSM), and building footprint. The building footprint was processed using the Autodesk Insight 360 and Autodesk Revit to get better 3d campus model. All three data were processed using ArcGIS Pro using Calculate Solar Radiation plugin. The result of this step is reaching the solar energy potential of NCKU. The final step is to show it into the Web 3D GIS to display the result. From the Web 3D GIS, everyone can access the information of NCKU solar energy potential using computer and also smartphones.

1. Introduction
Since 1990 the energy provided from renewable sources worldwide has risen at an average rate of nearly 2% a year, but in recent years this rate has increased to about 5% annually. As a result, the global contribution of renewables has increased from about 74 EJ in 2005 to about 89 EJ in 2009 and now represents 17% of global primary energy supply (528 EJ). Most of this renewable energy comes from the traditional use of biomass (about 39 EJ) and larger-scale hydropower (about 30 EJ), while other renewable technologies provided about 20 EJ [1].
Photovoltaic solar energy is the direct conversion of sunlight into electricity. The basic building block of a PV system is the solar module, which consists of the number of solar cells. Solar cells and modules come in many different forms that vary greatly in performance and degree of maturity. Applications range from consumer products (milliwatts) and small-scale systems for rural use (tens or hundreds of watts) to building integrated systems (kilowatts) and large-scale power plants (megawatts and soon up to gigawatts). The PV market – and hence, the PV industry – is developing rapidly as a result of market support programs in several countries. So far, self-sustained markets are modest in size, but this may well change during this decade. The theoretical potential of solar energy is huge, as expressed in the popular statement that the amount of sunlight hitting Earth in one hour equals the total annual primary energy use worldwide [1].

Fast digitalization of information technologies, improvements in the computer industry, especially in Internet interconnections, have developed a huge number of opportunities for the new role of existing systems and the establishment of new systems, clusters, or groups. Internet-of-Things (IoT) is now connecting different devices in a home and giving them the possibility to interact with each other, making more comfortable lives and their operation more efficient and usable [2]. Technological advances are now faster with the internet. Everyone can access various information in the world from a smartphone, tablet, or computer. One progress that combines the development of the internet, software, and hardware is the existence of Geospatial-based Information Systems, which is often called WebGIS. WebGIS is an advanced form of Geospatial Intelligence System (GIS) on the web platform. The smart city is integrating all these functions but also giving many additional features to make people living in a city much better.

Figure 1. Smart Cities Concept [Modified from Bhagya N S et al, 2018]

Many GIS-based approaches have been developed to analyze solar potential [3,4]. They are all DTM based methods, which means they are very suitable for large areas due to its low computational cost of raster-based calculations. They are very effective for 2.5D surfaces such as terrain and rooftops, but vertical facades require a 3D approach. In the cities which lie on a high latitude, placing panels on building facades are more important because in such places, the sun altitude is very low, and sun rays doesn’t hit rooftops but facades. Unfortunately, even using very high-resolution DTMs, 2.5D models are not enough to represent the shadow effect of neighboring buildings and other parameters of solar radiation on building facades and other vertical surfaces.

3D city models provide us with a better understanding of different city objects that interact with each other. Now, advancements in geosciences make it possible to create high quality and realistic 3D city models automatically. 3D city models are needed not only for visualization or navigation, but also for dealing with more complicated problems such as shadow analysis and solar potential analysis. With the
advancement of generating 3D city models, the need for 3D GIS tools such as solar radiation is increasing (Hofierka and Kanuk, 2010) [5]. The calculation of solar radiation that reaches 3D objects can be straightforward. Hence, the shadow effect of neighboring buildings is a much more complicated issue since some facades or roofs can be shadowed only partially.

The Unmanned Aerial Vehicle (UAV) technology has gained great attention in recent years. It is viewed as a low-cost alternative for large local scale aerial mapping and other applications requiring the modeling of a relatively small area only. In urban areas with high-rise buildings, large terrain height differences, and dense tropical vegetation, it is a challenging task to build 3D models, especially when the UAV is restricted to a relatively low flying height of 150 meters above ground. Currently, UAV has become a primary resource to acquire remotely-sensed GIS data [6].

Based on the above explanation, in this paper, we want to create the 3D City Model (DSM Building footprints) using UAV Data, solar potential analysis based on DSM and fit onto the building models, and show the 3D City Model and Solar Potential Analysis in WebGIS Platform. The study area is in National Cheng Kung University, Taiwan.

2. Material and method

2.1. Materials

All data are collected by using the UAV. The UAV type is HAWK. It has eight axes body configuration, 1050mm wheelbase. The flight control system is PixHawk2.1, using the MP operation interface. The materials that are used in this research are true ortho-image, digital surface model (DSM), and building footprint.

![Figure 2. Materials](image)

Based The software that are used in this study are Revit, Google Sketchup, and ArcGIS Pro. The first two software are used to make the 3D buildings, while the ArcGIS Pro is for calculating the solar radiation potential [8]. The calculated solar radiation can be used to calculate solar radiation maps for every month and the whole year, based on a Digital Terrain Model (DEM) and 3D features such as buildings and trees or a Digital Surface Model (DSM). The output is a solar radiation raster for every selected month showing kWh/m2/day at the resolution entered. This study is focusing on the DSM and 3d buildings for the whole year.

The atmospheric parameters used in this analysis are calibrated to historical solar radiation averages provided by the NASA Surface meteorology and Solar Energy global data sets. These averages are
provided at a one-degree resolution for the globe. While this resolution is adequate for most analyses, there may be some inaccuracy in areas with high variability in weather patterns over short distances.

2.2. Methodology
From those materials, we can make the simple 3D campus model in ArcGIS software. Then we can make it better by using the Revit software. The final step is processing the 3D campus model in the ArcGIS Pro software. The name of the plug-in is "calculate solar radiation." After we get the result, we can publish it into the WebGIS using ArcGIS Online. The methodology that we used can be seen in the following diagram.

3. Result and Discussion
The main result is the solar radiation on DSM and 3d buildings. For the DSM, the solar radiation color indicates the energy potential. The red to white color represents high to low, respectively. For the buildings, the meaning of the color is the same as the DSM. But in the buildings, there is another information. The highest energy potential, shown in red color, has 5 kWh/m2 per day. The lowest energy potential, shown in white color, has 0 kWh/m2 per day. The result is shown in Figure 4.
In the WebGIS, there are three layers: DSM (Scene0605_WTL1), NCKU buildings (ncku97_building), and the solar energy potential fit to the buildings (ncku97_building_may_radiation_roofPanel). We also can see the solar pattern based on the time that we had set before, the base map that we used, and also the measurement to calculate the length and the area. The WebGIS address is URL: https://arcg.is/1ruvii.

The estimation of the solar potential on a suitable roof and façade area has to take into account factors such as the spacing between buildings to avoid overshadowing, their orientation, and the type of roof [10][11][12][13]. This study provides the potential energy in both places. The rooftop shows the higher solar energy potential than the façade. The reason is because there is no light barrier on the rooftops. The light barrier on the façade dispels the sunlight.

The concept of a Solar Smart City is like an atom structure. In essence, the neighborhoods energetically behave as particles with positive, negative, or no electrical charge, and their energy balance is managed and improved utilizing the smart solar grid that keeps the energetic performances of the whole city stable [9]. The construction of a GIS platform based on the proposed parametric elements allows the automatic approach to geometric and spatial characteristics of buildings, their energy performances, and smart grid integration across all the sub-spatial units [9]. With this result, we hope there will be a solution for energy consumption in NCKU campus.
4. Conclusion
Based on the result, NCKU buildings have high potential solar energy. Not only the buildings, but the high potential solar energy is also detected on the surface around buildings. We believe that spatial information is the foundation of smart cities. These data are not only useful for government departments or GIS analysts. Using powerful cloud servers and GIS analysis tools, we can make solar radiation distribution and provide citizens with the ability to build solar panels and become a reference to its construction location.

In the past, the analysis of solar power potential can only be known by professional experts. Now, through 3D GIS technology, ordinary people can also participate in it. In the future, any spatial information can be stored in the cloud big data database, providing analysis, cloud browsing, and downloading, which will be a major innovation in smart cities.

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