GEOGRAPHICAL INFORMATION SYSTEM GIS
PER IL GOVERNO E LA GESTIONE DEL TERRITORIO

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GEOGRAPHICAL INFORMATION SYSTEM GIS
PER IL GOVERNO E LA GESTIONE DEL TERRITORIO

La collana raccoglierà gli atti di tutti gli interventi effettuati al convegno annuale GIS DAY organizzato presso il dipartimento di Architettura dell'Università degli Studi Federico II inerenti metodi e tecniche innovative che integrano piattaforme e applicazioni GIS con approcci, metodi e modelli di intelligenza computazionale in problematiche connesse all'analisi urbana e territoriale, quali: strategic urban planning per lo sviluppo sostenibile, rischi climatici e ambientali, monitoraggio del territorio, valorizzazione e rigenerazione del territorio.

GIS DAY 2023
IL GIS PER IL GOVERNO E LA GESTIONE DEL TERRITORIO

a cura di

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ISBN
979–12–218–1608–2

PRIMA EDIZIONE
ROMA 6 DICEMBRE 2024

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GIS Day 2023
ISBN 979-12-218-1608-2
DOI 10.53136/97912218160821
pp. 9-10 (dicembre 2024)

PREFAZIONE

Il 15 Novembre 2023, giornata mondiale dedicata alle tecnologie GIS, ha avuto luogo presso il dipartimento di Architettura Dell'università degli Studi di Napoli Federico II, l'evento ha visto la partecipazione di studiosi ed esperti del settore.

Il convegno GIS DAY 2023: *Strumenti e tecnologie GIS di supporto alle decisioni per l'analisi e la gestione complessa dei Sistemi Territoriali, Infrastrutturali ed Urbani,* si è svolto in tre sessioni specifiche connesse rispettivamente alle seguenti Tematiche:

– Strategic urban planning for sustainable development
– Environmental and climatic risk
– Landscape Enhancement and Regeneration

La quindicesima edizione si è svolta, come ogni anno, con il supporto di ESRI Italia che ci accompagna ogni anno, e la sponsorizzazione di ESRI America che ha offerto n. 10 licenze annuali della suite *ArcGis Pro for Personal Use*, comprensive di estensioni con le quali sono stati premiati i dieci lavori ritenuti più significativi ed originali.

I lavori scientifici esposti nei singoli interventi sono stati sottomessi dagli autori e pubblicati nella seguente monografia dedicata alla diffusione degli Atti di convegno.

Si ringraziano gli autori, che hanno offerto contributi scientificamente molto validi sulle metodologie e le tecniche GIS all'avanguardia oggi per affrontare problematiche di analisi territoriale e urbana, nonché tuti i partecipanti per i loro contributi nelle discussioni.

Un ringraziamento particolare va rivolto a Silvia d'Ambrosio, responsabile dell'ufficio ricerca del Dipartimento di Architettura e a tutto il suo staff, per il significativo lavoro svolto nella realizzazione complessiva dell'evento.

I curatori
Barbara Cardone, Ferdinando Di Martino, Vittorio Miraglia

SESSIONE I

STRATEGIC URBAN PLANNING FOR SUSTAINABLE DEVELOPMENT

GIS Day 2023
ISBN 979-12-218-1608-2
DOI 10.53136/97912218160822
pp. 13-32 (dicembre 2024)

INTEGRATION OF ALGORITHM AIDED DESIGN TOOLS IN GIS SYSTEMS FOR PHOTOVOLTAIC POWER PRODUCTION ESTIMATION AT NEIGHBORHOOD SCALE

HOSSEIN GHANDI(*), GIOVANNI NOCERINO(**)

Abstract: The growing integration of computation into planning and design processes is driving a new era characterized by design excellence, cost efficiency, and sustainable innovation. Nowadays, the enormous amount of software available on the market, deeply influences the way in which professionals with different expertise collaborate, underscoring the paramount importance of software interoperability. In this respect, in the field of urban design and planning, many of the limitations often associated with the most diffused GIS tools, which are often characterized by excessive rigidity as well as complexity of use, are increasingly addressed through the integration of Algorithm-Aided Design (AAD) tools, which offer great flexibility and leverage interoperability among different software platforms. This paper aims to investigate an effective approach to foster interoperability between GIS tools and 3D Algorithm Aided Design tools, exploring a data exchange workflow in which the use of algorithms enables the estimation of photovoltaic systems energy production at the neighborhood scale in an accessible and intuitive manner.
Keywords: Computational tools, GIS, Algorithm Aided Design, photovoltaic system, interoperability.

1. Introduction

Nowadays, urbanization has exerted a considerable influence on the quality of our life due to increasing the need for energy, leading to increasing land surface temperature caused by human-made high-albedo

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surfaces [1-2]. Hence, HVAC systems are much in demand, causing an increase of 1.1% in energy-related CO_2 emissions with electricity and heat generation in 2023 as the biggest contributors (IEA,2023) [3]. Consequently, the renewable energy technologies and clean energy transition are underscored to shrink energy consumption [4].To achieve it, a multi-faced approach is required to create a shared platform for individual disciplines to provide a comprehensive approach to a given complex problem via multidisciplinary and transdisciplinary collaboration [5-7]. As a result, this enables disciplines to promote creativity, efficiency, communication, sustainability, and technology integration [8].

Renewable energy technologies are the core of that transition [9] while among renewable technologies, solar photovoltaic (PV) installations grew exponentially, with a 26-fold increase in 13 years from 2010 to 2022 [10]. Furthermore, considerable advancements in the technology to improve PV panels' performance have been achieved in recent years. In this context, in the field of architecture, computer-aided tools also allow to employ of computational power for modeling and simulating relevant environmental aspects of a project, exchanging data in various work environments, and providing a feedback loop during the early stage of design to reach optimization [11]. However, most of these tools still present several challenges, such as the complexity of workflows and modeling, leading to a steep learning curve and time-inefficient simulations. Undoubtedly, each tool has its strengths and weaknesses, and it should be chosen carefully according to the project's demands and requirements. In the case of PV panel production evaluation, some relevant factors to take into account are calculation accuracy, cost-effectiveness, user-friendliness, user interaction, and time efficiency. Additionally, tool interoperability is also a pivotal criterion that should not be taken for granted.

In terms of solar panel systems, the efficiency can be evaluated by software at multiple scales: standalone buildings, neighborhoods, cities, regions, or even for a country as they rely on different numerical algorithms and coding that elucidate the distinguishments of the applied algorithm and coding via various complexity, required inputs, and generated outputs [12]. At the urban scale, Geographic Information System (GIS) tools, emerge as cutting-edge tools in spatial, temporal, and location-specific analyses of solar resources. A GIS-based model can be applied to different regions' scales, and the shading effects of the terrain can be modeled using a shading algorithm [13]. Moreover, it also provides information on population distribution, buildings' locations and characteristics, local energy resources, or the localization of sensors [14]. One of the fundamental advantages of GIS consists of providing a straightforward visualization of spatial information by clear legends that can be sufficiently comprehended by decision-makers, administrators, and non-experts. Furthermore, it can be used to predict, assess risk, and identify hazardous locations of natural resources. Regarding PV panels, the Solar Analyst Tool (SAT) developed by ERSI facilitates the analysis of solar radiation study on ArcGIS by offering two distinct methods named "Area Solar Radiation" and "points Solar Radiation". The former involves the analysis of a specific area and the latter concentrates on a point determined by x and y coordinate [15].

Although GIS offers numerous advantages, it is essential to be aware of its limitations and complexities as well. Apart from the equipment costs, there is the cost of training due to a steep learning curve. In addition, frequent updating of datasets or data models may lead to errors in results if not considered attentively. Geographic errors will also affect the results since GIS handles large-scale data, considering the quality of the collected data directly influences the accuracy of the results [16]. Concerning analyzing solar potential, it usually requires extensive calculations, especially for large-scale estimates and it is also difficult to implement accurate roof features like roof availability due to dependency on available information [17]. Thus, integration in the process can be an alternative solution to promote interoperability and user-friendliness in such a complex process, considering the current advancements in technology that bring software compatibility (Figure 1).

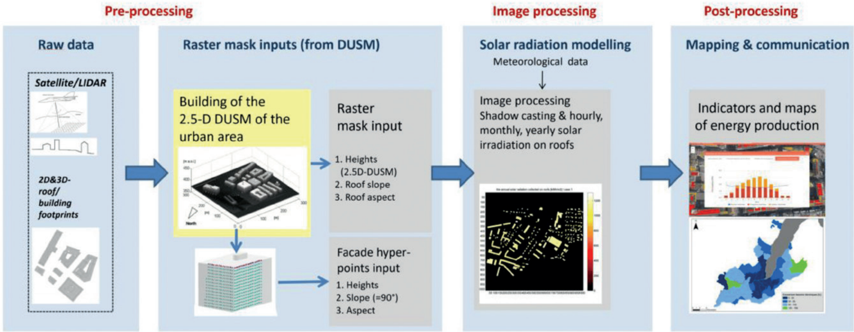

Figure 1. The process of solar modeling and mapping from raw data acquisition to solar mapping. Adapted from [18].

The integration among tools can minimize manual inputs to delimit or avoid mistakes and simplify the process by leveraging the capabilities of existing tools. A possible holistic solution is to implement an Algorithm-Aided Design (AAD) approach to overcome the restrictions of traditional CAD software.

The use of algorithms to incorporate and manage large amounts of information in design workflows is becoming increasingly common among researchers and practitioners due to the diffusion of Visual Programming Languages (VPL) [19]. That facilitates computer programming by replacing text syntax with graphical elements, in design workflow and offers a user-friendly and streamlined environmental analysis on any scale. One of the most diffused VPLs, Grasshopper (GH) for Rhinoceros (McNeel), provides an easy-to-use platform that allows individuals without advanced coding skills to write algorithms and program custom tools or workflows. Its flexibility and ease of use make it a popular choice [19]. Moreover, in terms of environmental analysis, Rhino has direct compatibility and interoperability with various validated energy simulation engines like Energy Plus [20] due to the implementation of several specific plug-ins. One of the most complete and widely used is Ladybug Tools [21], which offers several advantages in calculating solar radiation and performing shading analysis (figure 2). The implementation of Ladybug tools enables architects and designers to efficiently manage

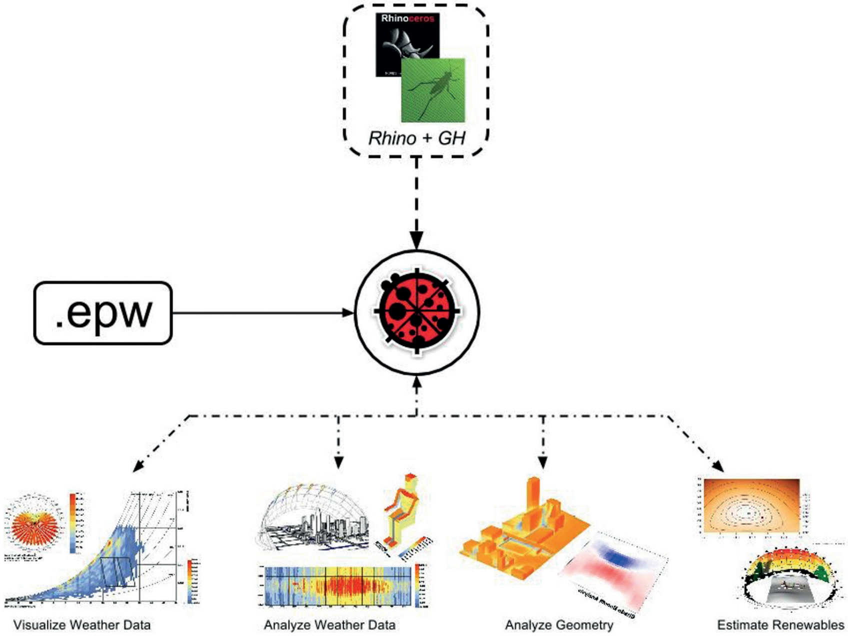

Figure 2. Ladybug is among the most comprehensive 3D Computer-Aided Design (CAD) interfaces (Source: ladybug. tools).

climate data and incorporate energy performance into the design workflow from the initial conceptual stages. Additionally, interoperability with GIS tools, made possible by other specific Grasshopper plug-ins, allows for effective information exchange between the two working environments.

The principal objective of the research is to propose a method and a computational tool l that, by exploiting the flexibility of GH and its interoperability with different software environments, allows the calculation of the photovoltaic potential at the urban scale and the integration of the calculated information in a GIS – based working environment.

The most tangible benefit of the workflow developed is the possibility to control the data in 3D using the Rhino interface, which is not possible in a lot of widespread GIS software (such as QGIS). The possibility to manage 3D shapes allows for an accurate consideration of the shadow loss based on morphological patterns. Moreover, the algorithm uses plug-ins to refine the proposed workflow, introducing pre-defined steps that minimize the risk of confusion and complexity due to an algorithm-oriented process.

2. Methodology

2.1. *Workflow description*

To accomplish the research objective, regarding data provision, the proposed workflow takes advantage of already existing plug-ins to meliorate the process by simplified and fundamental inputs. Therefore, it begins in the GIS environment by generating a shapefile of the targeted area. This file is used to generate the 3D mass context in Rhino using the Grasshopper plug-in called Local Zone thereby geometrical information such as roof area will be provided and Environmental data will be extracted by Energy Plus Weather Format (EPW[1]) using Ladybug. To illustrate, the workflow comprises an initial stage involving the provision of fundamental parameters as inputs, which serve as the basis for conducting the simulation. Subsequently, an algorithm written in Grasshopper uses these parameters in executing the simulation using Ladybug component and generating information. Finally, the output stage is dedicated to either export the generated data, aligning with the user inputs, into a CSV file or Visualize on GH interface. To point out, Python script is fitted into the algorithm of the workflow to ensure the efficiency of data management and avoid the spaghetti appearance of the GH canvas, leading to proposing a clean and coherent process (Figure 3).

(1) The US Department of Energy's building simulation software named Energy Plus, includes global weather data provided in Energy Plus weather format. It is derived from twenty sources including Typical Meteorological Year (TMY) data. Energy Plus Weather (EPW) files are freely available on the Energy Plus website (U.S. Department of Energy (DOE)) and architects commonly use them to access a specific location of interest. Our simulator is based on the information given by EPW via Ladybug plugin in order to study shadow and sun radiation.

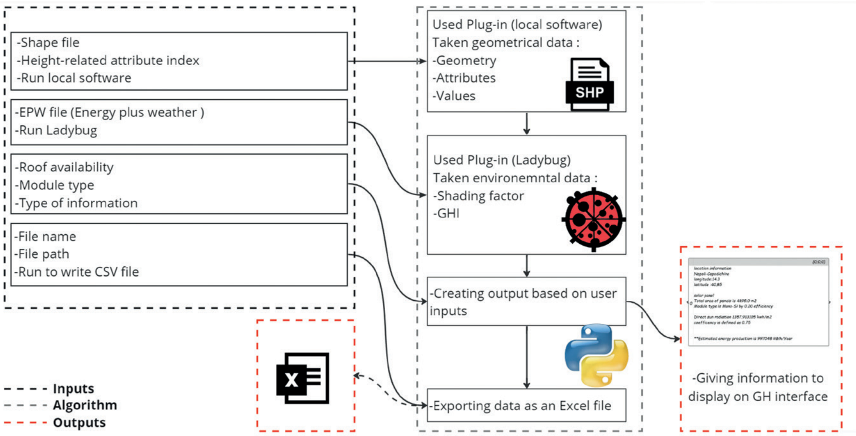

Figure 3. The interaction of inputs and outputs with the algorithm.

2.2. *Equation and parameters*

The workflow is developed on the formula mentioned below to estimate the output of a photovoltaic system. This formula is the most relevant and used equation due to its simplicity while including crucial factors such as module efficiency and area as well as it is found the most used equation in online sources and relevant articles [22-26].

$$E = A * r * H * PR$$

where;

E is the energy output (kWh)

A is the total solar panel area (m^2)

r is the module efficiency (%)

H is Global Horizontal Irradiance (GHI) (shadings not included) (kWh/m^2)

PR is the performance ratio or losses (considered around 75% to 85% [22,26] as default value but in this article is set as 88% (shadings not included) by referring to National Renewable Energy Laboratory (NRI)[2] default value list) (Table 1)

(2) NREL's PVWatts® is a web application developed by the National Renewable Energy Laboratory (NREL) that estimates the electricity production of a grid-connected roof- or

Table 1. The default value used for PR factor.

Category	Default Value from NRI (%)	Default Value on Grasshopper (%)
Soiling	2	2
Shading	3	X variable
Snow	0	0
Mismatch	2	2
Wiring	2	2
Connections	0.5	0.5
Light-Induced Degradation	1.5	1.5
Nameplate Rating	1	1
Age	0	0
Availability	3	3
Total value	15	12 + X variable

The shading loss by NRI is considered around 3% as the default value in general conditions as shown in Table 1, but for the proposed workflow is set as a variable in the algorithm and adjusted based on the morphology of the imported area. This is because buildings can cast shadows on each other, affecting the efficiency of the PV panels. The shadow impact is calculated by subtracting the Global Horizontal Irradiance (GHI) of the area without buildings (via EPW) from the actual GHI while considering the presence of buildings.

Moreover, most solar panels installed for residential buildings today are between 250 to 365 watts, considering panels above and below that range are also available [27] and the most effective solar modules are poly-crystalline and mono-crystalline due to their exponential advancements. As a result, the average value has been determined for the algorithm as 300-watt PV panels with an efficiency of 18% for Polycrystalline (Poly-si) and 20 % for Monocrystalline (Mono-si).

ground-mounted photovoltaic system based on a few simple inputs (https://pvwatts.nrel.gov/pvwatts.php).