Medicon Engineering Themes
Volume 7 Issue 1 July 2024
Article Type: Review Article
ISSN: 2834-7218

CiesMap Software. Location and Information Processing of Photovoltaic Systems in Cuba

Erisnel Lora Sugve*, Jose Emilio Camejo Cuan, Adrian Romeu Ramos, Ruben Ramos Heredia, Elisa Hernandez Silva, Raudel Dominguez Morales and Margenis Morell Pereira

Solar Energy Research Center, Santiago de Cuba, Cuba

***Corresponding Author:** Erisnel Lora Sugve, Solar Energy Research Center, Santiago de Cuba, Cuba.

Received: July 01, 2024; **Published:** July 12, 2024

Abstract

This article introduces CiesMap software, developed in Visual Studio 2022, designed to collect and manage information about photovoltaic systems (PV systems) in Cuba. It was applied in the diagnostic assessment of PV systems in the municipality of Guamá, Santiago de Cuba. CiesMap enables the recording of technical data such as location, generation capacity, and operational status of PV systems. Using an interactive satellite view through the GMap control, the software facilitates the identification of settlements and PV systems with color-coded markers. Moreover, CiesMap integrates with an Access database for storing and monitoring PV system information. This tool optimizes energy resource management, enhances strategic planning, and facilitates data-driven decision-making, thereby improving the operational efficiency of PV systems.

Keywords: CiesMap; Visual Studio; Database; C#; Photovoltaic Systems

Introduction

Given the highly prioritized nature that marked the stages of acquisition and assimilation of photovoltaic technology in Cuba in the late 1980s, it is evident that the most widespread variant in dispersed rural communities, distant from the national grid, is independent PV systems. These are largely characterized by non-standardized technology and inadequate selection of components based on environmental conditions. Only a meticulous technical support system can maintain these systems in satisfactory and stable operation.

Like other technologies striving to enhance efficiency, the focus has been predominantly on technical factors such as ensuring the selection of high-quality equipment and accessories capable of withstanding climatic rigor or those best suited to their intended use, among others.

The disregard or underestimation of the principle that all technology is conceived and designed to meet human needs, and therefore must always consider the social dimension, has resulted in many cases in “failures and reduced technology lifespan, funding and management issues, overuse and dissatisfaction, as well as lack of user acceptance, among others” [1].

Such instances have often led to technological discredit, accompanied by “loss of confidence in technical performance, both of which are challenging to reverse as customers verify these anomalies on-site and form a negative opinion that is difficult to change” [2].

Since 2009, Solidarity for Development and Peace (SODEPAZ), in coordination with the Cuban NGO CubaSolar, has implemented various projects aimed at introducing Renewable Energy Sources (RES) in Cuba, with a significant focus in the Guamá Municipality, Santiago de Cuba Province. These projects, financed by AECID and AACID, have been supported by the Municipal People’s Power and various local and provincial entities, the University of Oriente, the Solar Energy Research Center (CIES), and other provincial administration bodies. The active participation of the community has been crucial for the success of these initiatives.

The objective of these efforts has been to promote the adoption of a sustainable development model among the population of Guamá. To achieve this, various actions have been undertaken to increase awareness of environmental issues and develop demonstrative projects showcasing the use of RES in a more inclusive and social manner, integrating the use of natural resources with gender roles within the municipality and involving the local youth population.

Recently, a technical assessment of the photovoltaic installations in the Guamá Municipality was conducted to ascertain their operational status. For this purpose, the CiesMap software was developed, proving to be a fundamental tool for evaluating these PV systems. It has facilitated the processing and analysis of information by enabling specific data collection from PV systems installed in Guamá and visualizing their locations via satellite imagery. This capability has been pivotal for the efficient planning, monitoring, and management of energy resources. CiesMap has not only benefited the predominantly rural local community but also serves as a model applicable globally, contributing to energy sustainability and community development.

Development

Background in Photovoltaic System Management

Efficient management of PV systems is crucial to maximize their performance and ensure the sustainability of energy resources. In recent years, various software tools have been developed to facilitate the planning, monitoring, and maintenance of these systems. Below are some of the most prominent software solutions that have been developed and globally utilized.

Previous Photovoltaic System Management Software

- *PVsyst*: is one of the most widely used software tools for designing and simulating photovoltaic systems [3]. Developed in Switzerland, PVsyst allows users to model and analyze the performance of PV systems under various conditions. However, its primary focus is on simulation and design rather than operational management and real-time monitoring.
- *SolarEdge*: offers a monitoring platform that enables real-time supervision of photovoltaic systems [4]. Its software provides detailed data on energy production, system performance, and maintenance alerts. Despite its advanced monitoring capabilities, it is more geared towards commercial and residential installations using specific SolarEdge hardware.
- *Sunny Portal*: developed by SMA, Sunny Portal is a monitoring tool that provides detailed information on the performance of photovoltaic systems [5]. It allows users to access historical and real-time data, generate reports, and receive event notifications. Similar to SolarEdge, it is designed to work with SMA hardware, which may limit its applicability to other systems.
- *Homer Energy*: is a simulation tool that assists in the design and optimization of hybrid energy systems, including photovoltaic systems [6]. It is useful for project planning and economic evaluation but does not focus extensively on continuous operational monitoring.
- *Open Solar*: is a free platform providing tools for solar project design, sales, and management [7]. It is primarily oriented towards installation companies rather than detailed monitoring and operational management of PV systems.
- *Aurora Solar*: is another software focusing on the design and simulation of photovoltaic solar systems [8]. It offers advanced 3D modeling tools and financial analysis but primarily emphasizes design rather than operational management.

These software solutions play a crucial role in enhancing the efficiency and effectiveness of photovoltaic system management, each catering to different aspects of system design, simulation, and operational oversight.

Limitations of Existing Software Solutions

Although these software solutions provide valuable capabilities for designing, simulating, and monitoring photovoltaic systems, they present specific limitations that CiesMap aims to address.

Firstly, many monitoring platforms, such as SolarEdge and Sunny Portal, are designed to work with specific hardware. This limitation can restrict their applicability in diverse installations, as integrating different types of hardware into a single monitoring platform may not always be feasible.

Secondly, most of the mentioned software solutions do not offer advanced integration of interactive satellite views. The lack of this functionality hinders visual and geographic identification of photovoltaic systems, which is crucial for efficient and accurate system management.

Finally, there is a limitation in regional data management. The ability to store and analyze detailed regional data is essential for strategic planning and informed decision-making. Many current software solutions do not provide adequate tools to handle and exploit this data effectively, reducing their utility in comprehensive management of photovoltaic systems at both local and regional levels.

Innovations Introduced by CiesMap

CiesMap distinguishes itself from other software solutions by offering a comprehensive platform that incorporates innovative features. One of the key innovations is the interactive satellite view with GMap, enabling precise geospatial visualization of photovoltaic systems in the Guamá municipality. This feature facilitates the identification and management of systems using color-coded markers, enhancing clarity and efficiency in monitoring. For instance, Solar Manager utilizes a cloud platform for acquiring and visualizing information from isolated photovoltaic systems, which aligns with some functionalities offered by CiesMap [9].

Additionally, various tools for managing photovoltaic projects have proven essential for efficient system supervision and maintenance [10].

CiesMap also integrates with Access databases [11], providing a flexible and accessible solution for storing and closely monitoring photovoltaic system information. This integration ensures that data is easily manageable and readily available for analysis and queries.

Finally, CiesMap optimizes energy resource management, facilitating strategic planning and data-driven decision-making. This contributes to sustainable development, enhancing both environmental sustainability and economic efficiency in the region by supporting the operational efficiency of photovoltaic systems.

Technologies Used for Software Development

Development Platform of CiesMap: CiesMap was developed using Visual Studio 2022 [12], a comprehensive development platform that allows the creation of robust and scalable applications. Visual Studio offers an advanced programming environment with efficient tools for software debugging and testing, ensuring the quality and reliability of the final product.

Programming Language: The C# programming language [13] was chosen for developing CiesMap due to its power and flexibility. C# facilitates integration with other essential technologies such as databases and geospatial controls, enabling the creation of a cohesive and efficient application.

Map Control: The GMap.NET control was implemented for interactive geospatial visualization. This control allows for the integration of satellite maps and the overlay of color-coded markers, facilitating precise identification of PV system locations. The capability to display detailed geospatial information significantly enhances the management and supervision of PV systems in the Guamá municipality.

Data Collection

Data from PV systems were collected through field surveys conducted with system operators, as well as from municipal records and data provided by local authorities in Guamá. The collected information includes details on system locations, specific characteristics, and operational status.

Once data was obtained, it was entered into the Access database using forms specifically designed to ensure consistency and accuracy of information.

Testing and Validation

Tests were conducted to verify the software's functionalities. These tests included proper map display, accuracy of color-coded markers, data integrity in the database, and interoperability between different system modules.

The information recorded in CiesMap was validated by comparing it with original field-collected data and official records. Cross-checks were performed to ensure the accuracy and reliability of stored data, thereby guaranteeing the quality and precision of information managed by the software. This was put into practice in the diagnosis conducted on PV systems in the Guamá municipality.

Utility and Software Applications

CiesMap offers multiple benefits and applications that optimize the management of photovoltaic systems (PV systems) in the Guamá municipality, enhancing both operational efficiency and strategic planning.

Firstly, CiesMap enables more efficient management of available energy resources, maximizing PV system performance while minimizing associated costs. By providing detailed and up-to-date information on each system, the software facilitates identification of areas needing optimization, ensuring more effective resource utilization.

Moreover, the software provides valuable information for strategic planning of future PV system installations. By considering the energy needs and demands of the municipality, CiesMap helps in more precise and effective planning, ensuring new installations are located optimally and meet community energy requirements.

Reports and analyses generated by CiesMap enable energy management officials to make informed, data-driven decisions. This capacity for informed decision-making significantly enhances operational and strategic management of PV systems, reducing risks and increasing efficiency.

CiesMap also promotes sustainable development by facilitating monitoring and recording of maintenance activities performed on each photovoltaic system. This contributes to prolonging the lifespan of PV systems and ensuring their operational efficiency over time, promoting sustainable practices in energy resource management.

Finally, the software offers global compatibility features, allowing its use for managing both PV systems and solar water heater systems worldwide. This global monitoring capability expands the application possibilities of CiesMap, making it a versatile and adaptable tool for various needs and contexts.

Results and Discussion

Next, we present the main window of the software, which allows observing from a satellite view the location of each PV system, applied in the diagnosis conducted in the municipality of Guamá. In this view, green markers indicate settlements, and red markers pinpoint the location of PV systems (Figure 1).

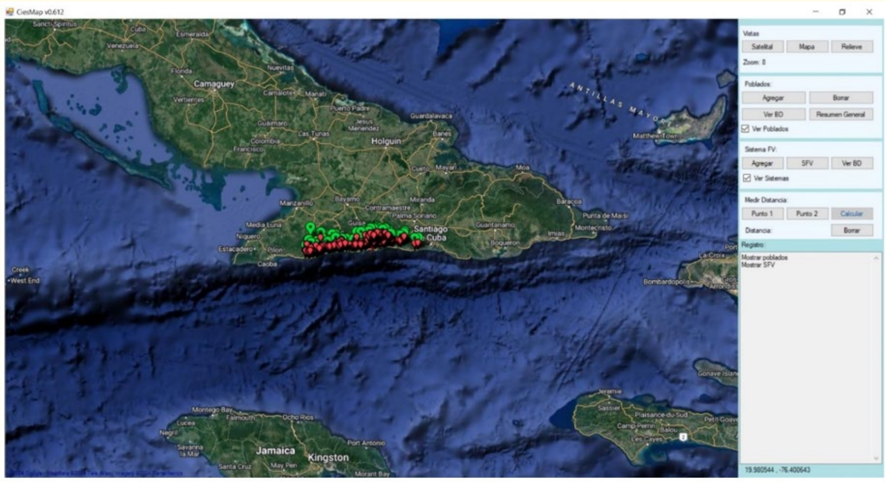

Figure 1: Main Window of CiesMap Software.

A more focused view on the Guamá territory allows for a more detailed recognition of the distribution of the systems (Figure 2).

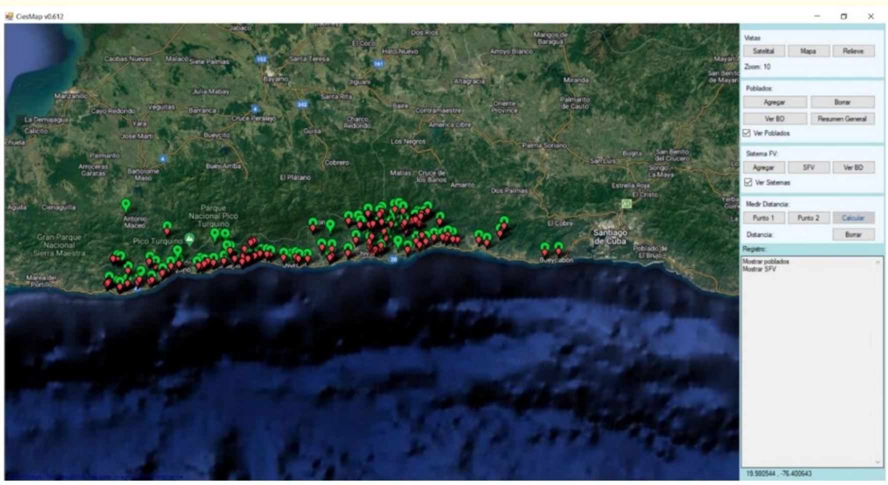

Figure 2: Main Window of Guamá Municipality.

The software, through the GMap control (Google Maps viewer), allows interaction with the satellite view, providing the option to zoom in or out to detail locations or installed systems more precisely. An example of this can be seen in Figure 3, where the Ocujal Hospital is observed along with the different PV systems connected to it.

Figure 3: Aerial View of Ocujal Hospital.

The application is linked to an Access database for storing information from each installation. Stored data includes details of People's Councils and Villages, along with their coordinates. Similarly, specific data from photovoltaic systems are recorded, such as location coordinates, responsible parties, model of each system component, start date, current operational status, among other details (Figure 4).

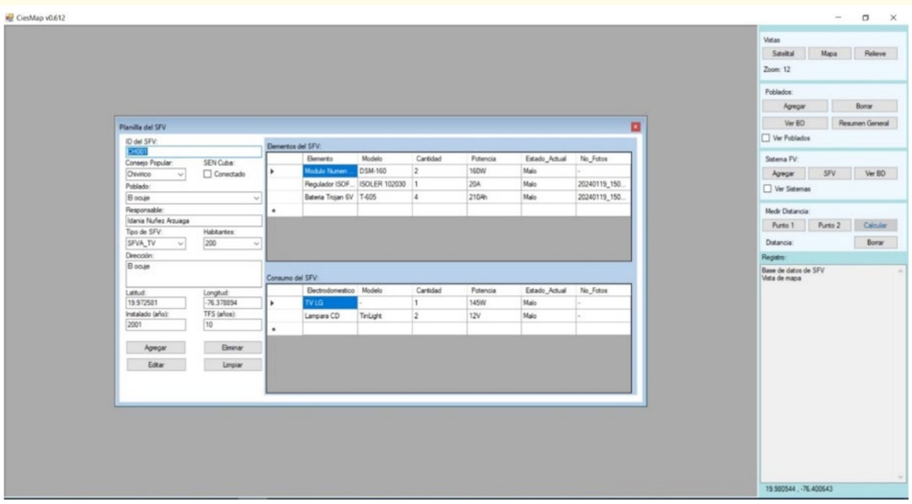

Figure 4: Display of PV Systems Visualized in a Spreadsheet.

The database can be monitored and managed through the CiesMap software. Figure 5 shows various systems already stored, which can be selected to view specific details of each photovoltaic system or to visualize its location using the integrated map in the software.

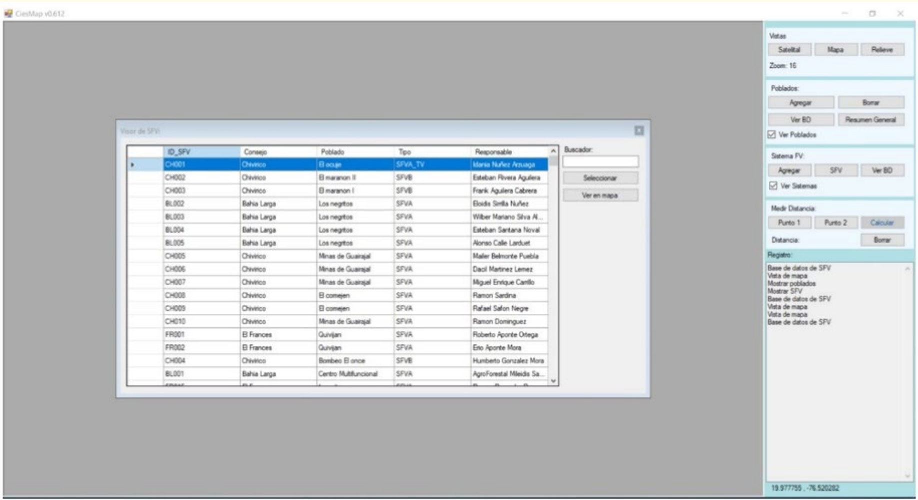

Figure 5: PV Systems Stored in Database.

The CiesMap software offers the advantage of allowing an initial visualization of the location and caching data for later use, in case of no internet access. Additionally, it provides the option to download three different types of maps: satellite map, mixed satellite map with Google markers, and terrain elevation map. This helps to understand mobility challenges for physically accessing each location where PV systems are located.

Another benefit of the software is the ability to interact with the data entered in the database, providing a powerful tool for management and analysis of information. For settlements or villages where the systems are located, the software allows reviewing the place name and coordinates through a form in the application. This functionality facilitates identification and tracking of each locality, ensuring a precise and updated record (Figure 6).

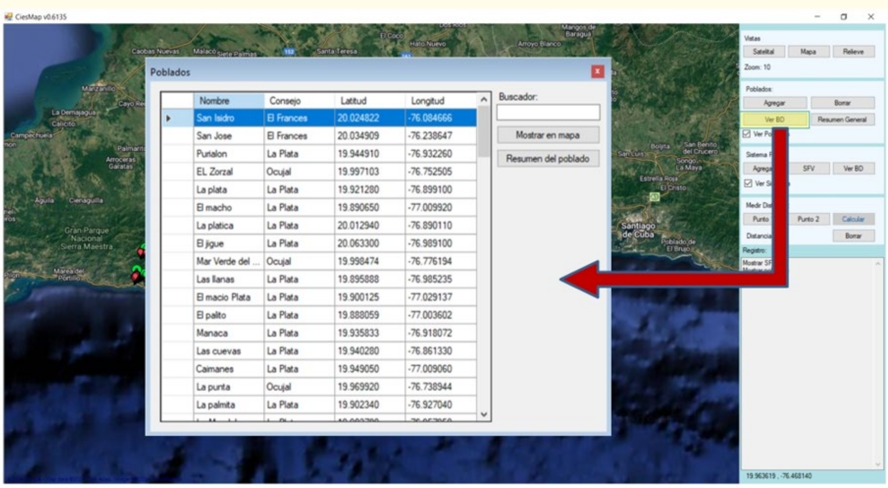

Figure 6: Access to the Settlements Form.

For PV systems, the software allows for a detailed exploration of the elements comprising each specific system. It also provides the capability to conduct statistical analyses, both individually and by settlement or People's Councils. This enables a comprehensive and comparative evaluation of the different installed systems.

The software also facilitates analysis of the various components that make up PV systems. It allows for obtaining quantitative data to assess the operational status of installed elements during the projects carried out. This analytical capability helps identify which projects were more effective and which did not meet the goal of energizing communities (see Figure 7). Thus, CiesMap not only provides a management platform but also serves as a decision support tool for informed decision-making and continuous improvement of solar energy projects.

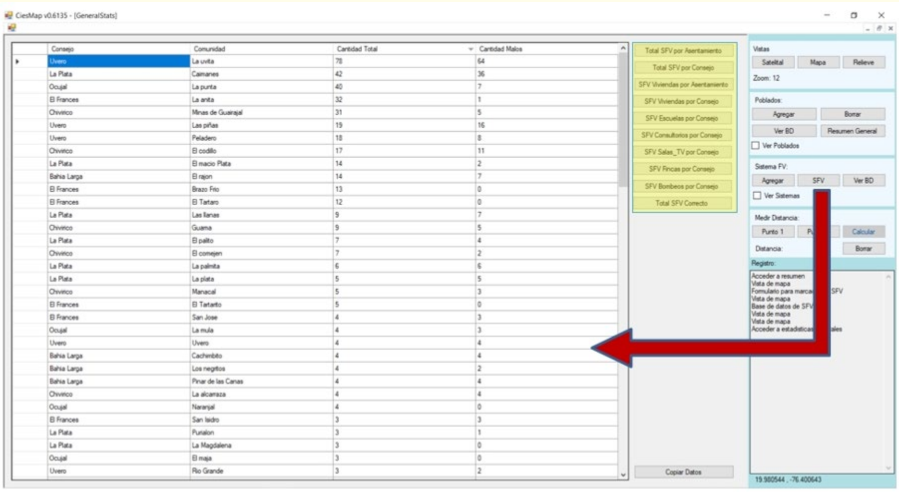

Figure 7: Example of Data Processing from CiesMap.

Conclusions

The development of CiesMap software, designed for managing photovoltaic systems using Visual Studio 2022 and an Access database, positions itself as a powerful tool for data collection, analysis, and efficient management. This system plays a fundamental role in optimizing available energy resources, enabling the management of renewable energy at national and international scales.

Furthermore, thanks to CiesMap, it has been possible to accurately identify the location of each photovoltaic system (PV) at the coordinates level on the satellite map of Guamá municipality. This capability for visualization and spatial analysis allows direct interaction with the database, facilitating detailed statistical assessments of the processed information. This not only enhances the strategic planning of future installations but also contributes to the continuous evaluation and optimization of existing projects, ensuring an efficient and sustainable use of renewable energy resources in the region.

Conflict of Interest Statement

The authors declare no conflicts of interest related to the presented research.

Author Contributions

Conceptualization: Erisnel Lora Sugve, José Emilio Camejo Cuán, Elisa Hernández Silva.

Data Curation: Erisnel Lora Sugve, Adrián Romeu Ramos, Rubén Ramos Heredia.

Formal Analysis: Erisnel Lora Sugve, José Emilio Camejo Cuán, Adrián Romeu Ramos.

Investigation: Erisnel Lora Sugve, José Emilio Camejo Cuán, Elisa Hernández Silva, Adrián Romeu Ramos, Rubén Ramos Heredia, Raudel Domínguez Morales, Margenis Morell Pereira.

Methodology: Erisnel Lora Sugve, José Emilio Camejo Cuán, Adrián Romeu Ramos.

Supervision: José Emilio Camejo Cuán, Elisa Hernández Silva, Rubén Ramos Heredia.

Original Draft Preparation: Erisnel Lora Sugve, José Emilio Camejo Cuán, Adrián Romeu Ramos.

Review and Editing: Erisnel Lora Sugve, José Emilio Camejo Cuán, Elisa Hernández Silva, Adrián Romeu Ramos, Rubén Ramos Heredia.

Acknowledgments

Solidarity for Development and Peace, SODEPAZ.

References

1. Villalobos C, Schweiser P and Ramírez E. “Empowerment and strategies for intensifying the participation of user communities in the rural electrification process” (2002).
2. Morante F and Zilles R. The importance of user participation in the implementation of rural electrification projects with photovoltaic technology (2002).
3. Mermoud A. PVsyst: Software for the study and simulation of photovoltaic systems. International Energy Agency (IEA) PVPS Task 13 (2012).
4. Fuchs G, Mauch W and Stryi-Hipp G. “SolarEdge: Innovative power optimizers and inverters for photovoltaic systems”. International Journal of Renewable Energy Technology 8.2 (2017): 134-147.
5. Gagliarducci M, Petrone G and Spagnuolo G. “Monitoring and maintenance of photovoltaic installations: Sunny Portal by SMA”. Journal of Solar Energy Engineering 138.3 (2016): 031013.
6. Lambert TW, Gilman P and Lilienthal PD. “Micropower system modeling with HOMER”. In Integration of alternative sources of energy. John Wiley & Sons, Inc (2006): 379-418.
7. OpenSolar. OpenSolar: Free solar design and sales software (2020).
8. Sharma A and Inamdar AB. “Aurora Solar: Advanced solar design software with 3D modeling and financial analysis capabilities”. Renewable Energy Research and Applications 2.1 (2019): 45-54.
9. Redalyc. Solar Manager: Cloud Platform for the Acquisition and Processing of Information on Isolated Photovoltaic Systems (2023).
10. Seslab. Tools for Photovoltaic Project Management (2023). (SESLab).
11. “Microsoft Access provides robust capabilities for integrating with various software solutions, ensuring seamless data management and interoperability”. (Microsoft, 2023)
12. “Visual Studio 2022: The Best IDE for .NET and C++ Developers”. Microsoft Docs 2023.
13. Albahari J and Albahari B. C# 11.0 in a Nutshell: The Definitive Reference. O’Reilly Media (2023).

Volume 7 Issue 1 July 2024