Приложение на изкуствен интелект и изкуствени невронни мрежи в ГИС

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Application of artificial intelligence and artificial neural networks in GIS

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Abstract:

Artificial intelligence (AI) and artificial neural networks (ANN) are entering more and more fields, including geographic information systems (GIS), due to the growing need for automation in the analysis and processing of geospatial data. The current development aims to explore the integration of AI and ANN in GIS to improve analytical capabilities for working with geodata. This has important implications for improving natural resource management, urban planning, and environmental monitoring. AI is used to help data search, generate, and improve code for managing data in various desktop and web-based GIS. The study also applies ANNs to create maps by importing already trained neural networks. The results are helpful as they present opportunities for deeper analysis and inferring trends and patterns from available geodata. The application of AI and ANN in GIS represents a promising prospect for developing geospatial analytics, including in education. Future research could focus on optimizing these technologies for specific GIS applications.

Keywords: GIS, ANN, AI, OpenStreetMap, Leaflet, Interactive climate maps

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INTRODUCTION

Geographic Information Systems (GIS) are essential to spatial planning and decision-making in various fields. For example, in urban planning and development, GIS ensures support with data on topography, land use, and infrastructure; in natural resources management by helping to prevent environmental impacts; in ecology for climate change adaptation planning and disaster risk assessment; and in transportation for the planning and management of transport systems through traffic and transport infrastructure data.

Artificial Neural Networks (ANN) are computational algorithms inspired by the human brain's ability to process information and learn. They consist of units called neurons arranged in layers: an input layer that receives data, hidden layers that process the data, and an output layer that delivers predictions or classifications. Neurons in each layer are interconnected, and these connections have weights that are adjusted during training to minimize prediction error, a process known as backpropagation. ANNs are capable of learning by recognizing patterns and rules in the data, allowing them to perform tasks such as classification, prediction, and pattern recognition across various types of learning, including supervised, unsupervised, and reinforcement learning. Artificial intelligence (AI) covers ANNs and other technologies such as machine learning, computer vision, and language processing.

The combination of GIS with AI and ANN enables the analysis of geospatial data, improvement of data classification, recognition of patterns and complex relations, prediction of spatial phenomena, and automation of various processes. This has applications in education in urban and transport planning: 1) in simulations, students can use GIS and ANN to model urban plans and transport systems; 2) in data analysis, neural networks analyze the results of simulations and identify data patterns and relations.

Another group of applications is in environmental studies: 1) for biodiversity and climate change analysis: students collect and analyze data with GIS, and AI and ANN help to detect correlations and assess impacts; 2) for prediction and strategic planning: neural networks predict environmental changes, supporting the development of adaptation strategies and resource management.

ANALYTICAL EXPOSITION

Project objective and description

Our development objective is to integrate artificial neural networks (ANN) in a geographic information system (GIS) to explore their possibilities for use in the educational process. It is based on OpenStreetMap (OSM) [1], an editable project for free geospatial data and world maps that provides tools and APIs for application development, including web services.

This project uses a basic OSM map with added functionality and interactivity through Leaflet [2] and JavaScript [3]. OpenStreetMap does not integrate ANNs in its platform.

The specific goal of this project is to integrate pre-trained neural networks with OpenStreetMap using Leaflet and Javascript for GIS functionality. This will allow the visualization, modeling, and analysis of climate and solar data for Bulgaria.

The neural networks used were trained in 2022 [4] based on data from PVGIS [5] for the period 2005 – 2020 for the territory of Bulgaria. They are used to determine monthly values of 1) surface air temperature, 2) diffuse fraction (proportion between diffuse and total horizontal solar radiation), 3) horizontal solar radiation, and 4) albedo (reflectivity) of the terrain.

We also use generative artificial intelligence chatGPT [6] to optimize the JavaScript code and generate ideas and visualizations for the presentation.

Implementation

The neural networks are trained by analyzing sets of values that include input parameters and desired outputs. The primary learning objective is understanding the relationship between inputs and outputs by forming a multivariate function (model) with minimized errors through regression analysis. Training a neural network requires a powerful computer and more time (especially for more complex tasks). The parameters of the trained neural network are represented as matrices tuned during training. Using the trained network does not require a lot of computing power and much time.

The OpenStreetMap base map and Leaflet library functionalities are implemented on the web pages using JavaScript. The parameters of the neural networks are loaded and activated with JavaScript functions, and the results of their work are visualized in different ways: numerically – through HTML forms on the web page – and graphically – on maps in OpenStreetMap.

Two interactive HTML pages are developed for the project. Each integrates four neural networks, with the output of one network serving as the input of another (Fig. 1).

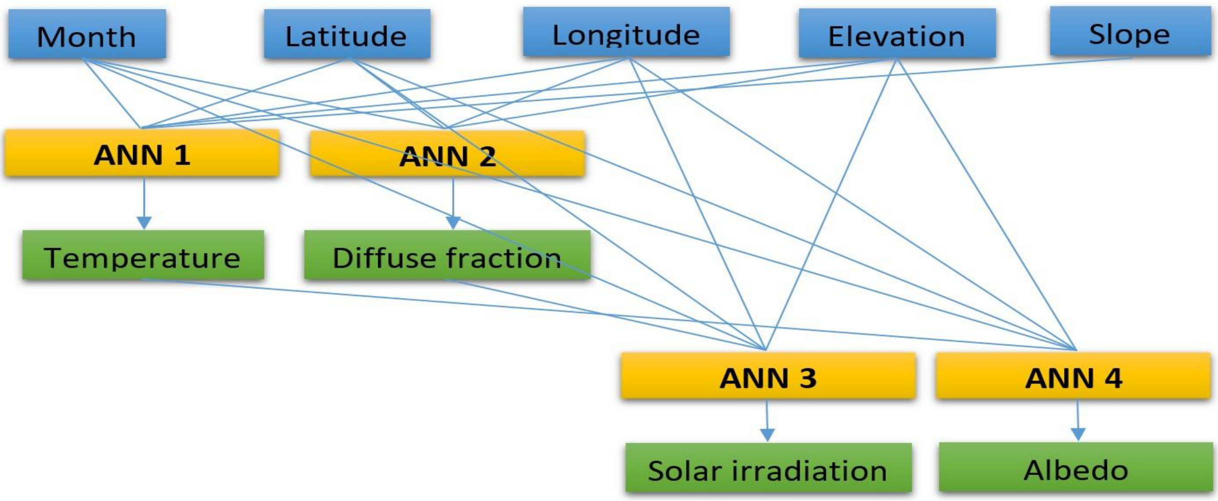

Fig. 1. Schema of the connections between inputs (in blue) and outputs (in green) in the project's integrated four artificial neural networks (in yellow).

The first HTML page (Fig. 2) implements an interactive web interface for climate data analysis using GIS and ANN. It displays the monthly values of each of the climatic parameters and annual summaries for a given geographical position.

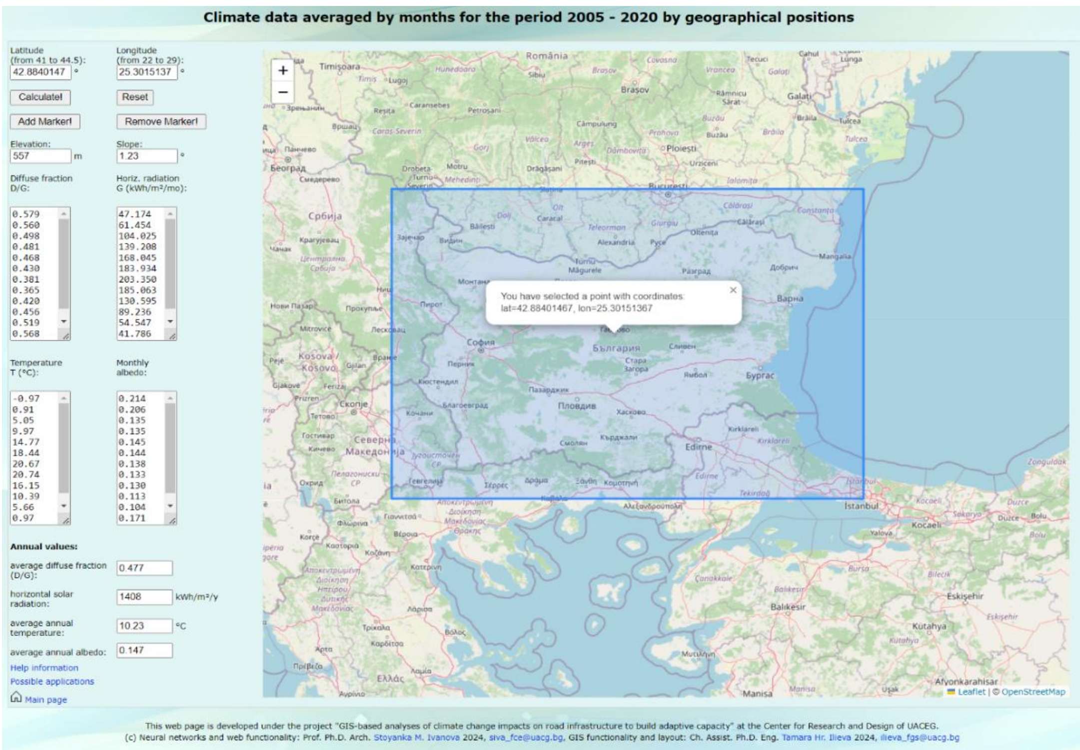

Fig. 2. Screen from the first HTML page displays monthly and annual data of various climate parameters by specified geographical position.

The second HTML page (Fig. 3) provides a web interface to visualize maps with climate data in Bulgaria through ANN. It uses canvas elements to dynamically generate maps with adjustable color scales and transparency, a user interface with options for month selection, transparency, resolution, and climate analysis for temperature, diffuse fraction, solar radiation, and albedo.

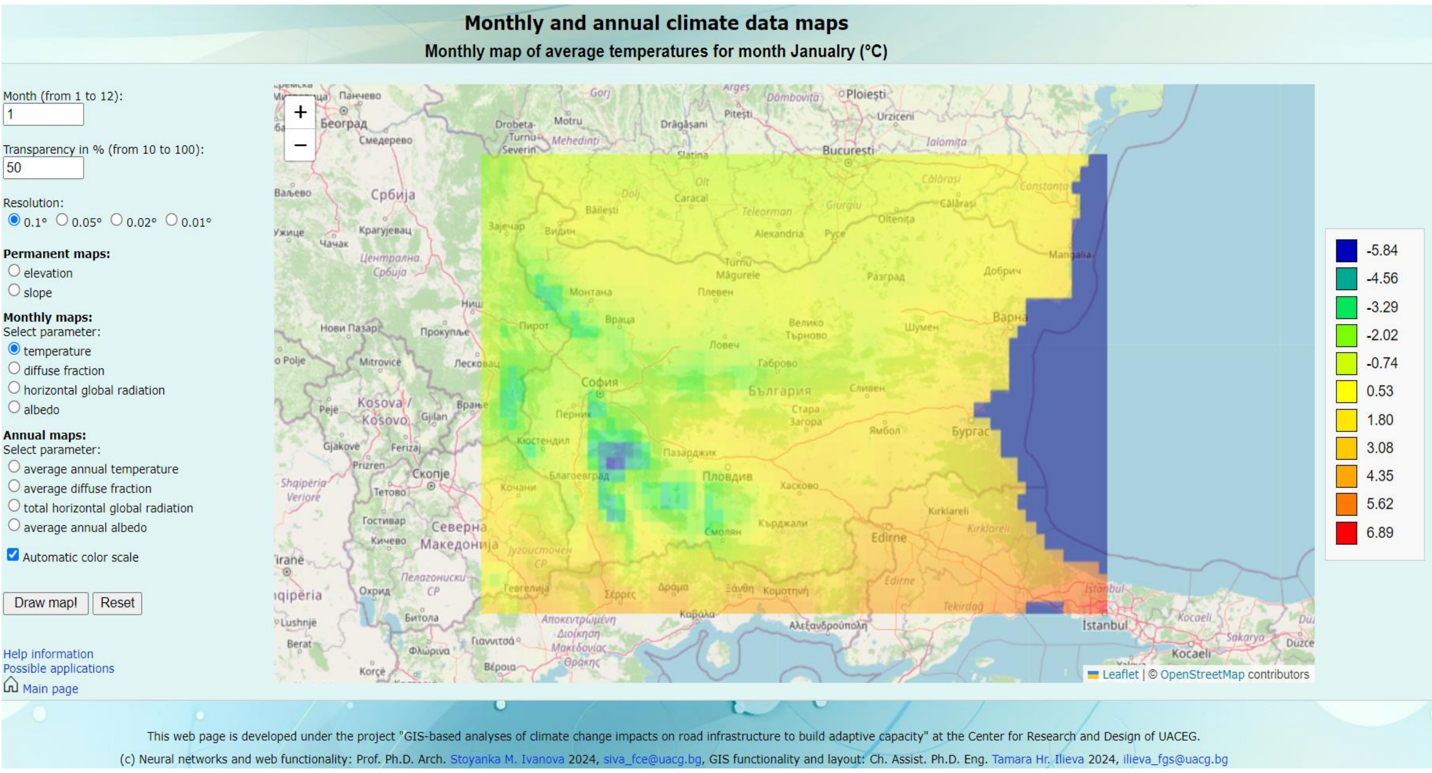

Fig. 3. Screen from the second HTML page displays monthly and annual maps of different climate parameters with different resolutions and transparency.

Both of the HTML pages provide a web interface for the visualization of climate data maps for the territory of Bulgaria via ANN as follows:

- data calculations and visualization: JavaScript code calculates and visualizes climate parameters such as temperature, diffuse fraction, horizontal solar radiation, and albedo;
- analysis functionality: complex calculations activate, process, and visualize the results of neural networks;
- documentation and help through links to pages with help information and ideas for applications of the development.

Results

The development results show that JavaScript-enhanced web pages can effectively combine modern GIS and ANN technologies, providing functionality and interactivity. The pages efficiently process and visualize complex geospatial and climate data through interactive maps. ANN visualization and geospatial analysis deliver accurate, on-demand information critical to research and applications. Through interactivity, the interfaces allow users to select parameters and specify locations for obtaining climate information. Data visualization makes it easier to understand the data presented, which is essential in training and practical work.

Discussion

Neural network training was performed with input data with a geographic resolution of 0.1°, resulting in poor prediction accuracy in areas with sharply changing topography. Input data is limited to the period 2005 – 2020, i.e., do not reflect future climate conditions.

Opportunities for future development include 1) developing more advanced ANNs to predict climate change based on climate scenarios and 2) refining machine learning algorithms to achieve higher accuracy and detail.

CONCLUSION

The implemented project successfully integrates GIS and artificial neural networks (ANN) into interactive web pages for climate data analysis and visualization. The pages provide dynamic generation of various climate maps (52 basic maps with different resolution variants). AI has been mainly used to help coding with JavaScript language for previously unknown capabilities.

Prospects for future research involve providing climate data for future periods according to different climate scenarios for the work of architects, urban planners, and engineers.

The development has the potential to be applied in the educational process at UACEG and other higher education institutions – in urban planning for optimization of urban development and planning of green areas; in architectural design to obtain up-to-date climate data for the design of energy-efficient buildings; for disaster risk management: to analyze risks and develop strategies; for energy planning: prediction of solar energy potential and planning of PV systems; in education and research: to support research on sustainability and resource management.

ACKNOWLEDGMENTS

The development was financed under the "GIS-based analyses of climate change impacts on road infrastructure to build adaptive capacity" project at the Research, Consultancy and Design Centre of UACEG.

REFERENCES

1. OpenStreetMap, https://www.openstreetmap.org/about
2. Leaflet Javascript, https://leafletjs.com/reference.html
3. Javascript, https://www.w3schools.com/js/
4. Ivanova, St. Artificial Neural Networks for Energy Efficiency, UACEG – Sofia, 2022
5. PVGIS, https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html
6. chatGPT, https://chat.openai.com