SHORT-PAPER

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Published: 29 October 2024

Citation in BibTeX format

SIGSPATIAL '24: The 32nd ACM International Conference on Advances in Geographic Information Systems
October 29 - November 1, 2024
GA, Atlanta, USA

Conference Sponsors:
SIGSPATIAL

SIGSPATIAL '24: Proceedings of the 32nd ACM International Conference on Advances in Geographic Information Systems (October 2024)
https://doi.org/10.1145/3678717.3691275
ISBN: 9798400711077

ACCEPT: A Context-Sensitive, Configurable, and Extensible Prediction Tool using Grid-based Data Processing and Neural Networks in Geospatial Decision Support

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ABSTRACT

We introduce ACCEPT, a geospatial decision support system that merges robust, intuitive visualization with grid-based data processing and neural networks to enhance spatial data analysis and interpretation in context-sensitive scenarios. It offers versatile machine learning modules with multiple prediction models, tailored to specific requirements with user-defined configurable parameters and flexible predictive target selection. The system serves as an accessible introduction to geographic information systems (GIS) for the general public. The system maps Points of Interest (POIs) to grids, simplifying processes like weighting, intersection, and interpolation, enhancing data accessibility and manipulation. Our case studies show effective handling of spatial data, reflecting similar distribution patterns of POIs, spatial separation, local feature sensitivity, and proximity to infrastructure and kernel size affect evaluations. The extensible and user-friendly web interface includes geospatial data inquiries, overlay, import/export, statistic, and multiple map views, facilitating informed decisions in resource distribution and urban planning. It supports urban planners, analysts, and policymakers in achieving equitable resource distribution and enhancing residential justice, while also providing non-experts an introduction to advanced geospatial analyses, promoting wider engagement and understanding in spatial decision-making.

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SIGSPATIAL '24, October 29-November 1, 2024, Atlanta, GA, USA

ACM ISBN 979-8-4007-1107-7/24/10…$15.00
https://doi.org/10.1145/3678717.3691275

CCS CONCEPTS

• **Computing methodologies → Artificial intelligence**; • **Information systems → Geographic information systems**.

KEYWORDS

Grid-based Data Processing, Neural Networks, Context-Sensitivity, POI Mapping, Geospatial Decision Support, Spatial Data Mining

ACM Reference Format:

Teng-Yuan Tsou, Shih-Yu Lai, Hsuan-Ching Chen, Jung-Tsang Yeh, Pei-Xuan Li, Tzu-Chang Lee, and Hsun-Ping Hsieh. 2024. ACCEPT: A Context-Sensitive, Configurable, and Extensible Prediction Tool using Grid-based Data Processing and Neural Networks in Geospatial Decision Support. In *The 32nd ACM International Conference on Advances in Geographic Information Systems (SIGSPATIAL '24), October 29-November 1, 2024, Atlanta, GA, USA.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3678717.3691275

1 INTRODUCTION

We present ACCEPT, a cutting-edge geospatial decision support system that seamlessly integrates grid-based data processing and advanced neural networks with dynamic and intuitive visualization tools to revolutionize spatial data analysis. This platform is designed to enhance the interpretability of complex geospatial datasets in various context-sensitive scenarios, enabling precise and adaptable decision-making. ACCEPT boasts a suite of versatile machine learning models, including XGBoost, CNN + MLP, Vision Transformer, and more, each tailored to meet specific analytical needs with specific requirements with user-defined configurable parameters and

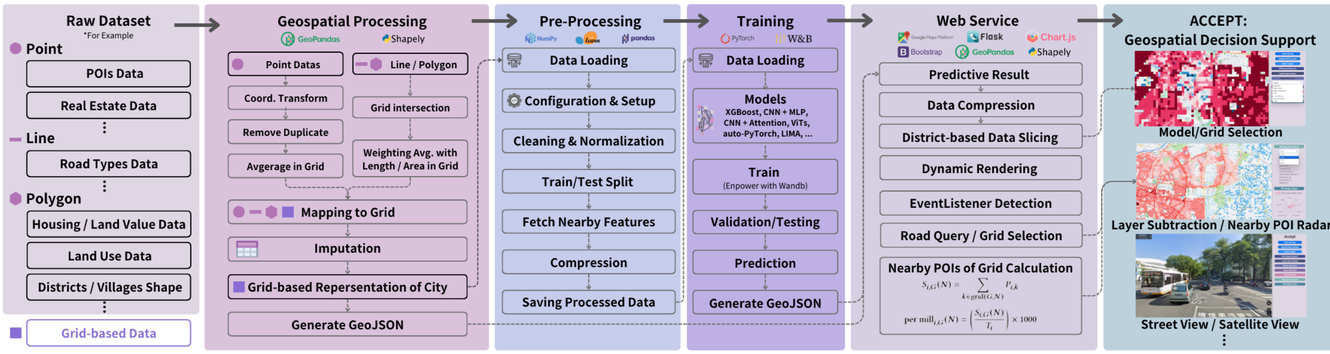

Figure 1: The automatic data pipeline and system framework of ACCEPT.

flexible predictive target selection mechanisms. This extensible system is not only a robust tool for urban planners, analysts, and policymakers aiming to achieve equitable resource distribution and improved urban planning outcomes, but also serves as a gateway for the general public and non-experts to delve into the realm of geographic information systems (GIS). For example, consider a real estate analyst who needs to explore and predict the unit price of housing across different districts. Traditional GIS platforms might offer basic overlays of demographic data and sales history, but they struggle with integrating and interpreting complex, multilayered data dynamically. The analyst faces challenges in assessing price trends in real-time or adjusting for factors like new infrastructure developments or zoning changes. ACCEPT addresses these challenges by providing an advanced toolset that combines high-level data processing capabilities with real-time, adaptive visualization and analysis features. This enables not only seasoned GIS professionals but also newcomers to the field to make well-informed decisions quickly, enhancing both the accuracy and efficiency of urban and regional planning efforts.

2 DATA PIPELINE

The automatic data pipeline and system framework of ACCEPT (**Fig. 1**) consists of several stages. Firstly, raw datasets are categorized and processed according to their type, including **points** (i.e., POIs and real estate data), **lines** (i.e., road types data), and **polygons** (i.e., housing data, and land use data). We unify these three types of data into grid-shaped data through a series of operations, facilitating subsequent model training and visualization. Points data undergo coordinate transformations, duplication removal, and averaging within grids. Lines and polygons are treated with grid intersection techniques and weighted averaging based on their length or area. This phase also includes data imputation to avoid biases caused by missing data. Finally, generate a grid-based representation of cities and produce GeoJSON files.

The pre-processing stage follows standard machine learning practices, including data cleaning, normalization, and train-test splitting. Additionally, it involves fetching nearby features for each grid to enable the model to learn surrounding information. In the subsequent training phase, we utilize various models such as XGBoost[1], CNNs[5] combined with MLP [3] or attention mechanisms, Vision Transformer[2], and automated model frameworks like auto-PyTorch[6] and LIMA[4]. These methods are effective in various fields and can handle most training scenarios. We use Weights and Biases (W&B) to automate training and log data, aiding further model adjustments.

We have implemented a series of web service technologies to ensure a good user experience when using ACCEPT. These include data compression and dynamic rendering to reduce loading times, as well as road queries and grid selection for in-depth research of specific areas, and more. Lastly, ACCEPT is designed as a comprehensive geospatial decision support system, providing robust analysis, and prediction capabilities. It can visualize geospatial data on maps, provide an intuitive comparison, and offer predictive results based on specific needs, facilitating decision-making with extensive spatial information. For in-depth research, we also display nearby POI characteristics of selected grids based on:

$$S_{i,G}(N) = \sum_{k \in \text{grid}(G,N)} P_{i,k}$$

$$\text{per mill}_{i,G}(N) = \left(\frac{S_{i,G}(N)}{T_i}\right) \times 1000$$

$\text{grid}(G,N)$ represents all the positions within the $N \times N$ grid area centered on grid G; $P_{i,k}$ denotes the number of POI type i at grid position k, with $S_{i,G}(N)$ indicating the sum; N specifies the size of the grid area considered, typically an odd number for symmetry (e.g., 3×3 to 7×7); per $\text{mill}_{i,G}(N)$ is the per mill (‰) representation of POI type i within the $N \times N$ area centered on grid G, relative to the total number in the city; T_i is the total count of POI type i across the entire city area.

3 USER INTERACTION

The system flowchart of ACCEPT (**Fig. 2**) illustrates a comprehensive web GIS system that assists users in effectively processing and analyzing geospatial data. Users can utilize the various functions mentioned in Chapter 4 to view and analyze data through the web service frontend. Additionally, as mentioned in Chapter 2, the spatial data uploaded by users is first transformed into a grid-shaped format by the backend pre-processor. This formatted data is then used by the trainer along with a selected model to generate predictive results. These results are sent back to the web server, which updates the GeoJson data layers, rendering the updated predictive data on the frontend for the user to view. This seamless integration

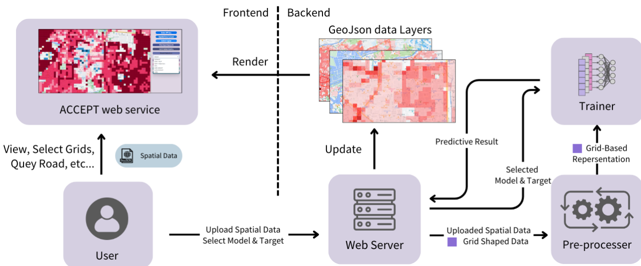

Figure 2: The system flowchart of ACCEPT. A web service system that integrates user interactions with backend processes to render and update geospatial data through predictive modeling and data preprocessing.

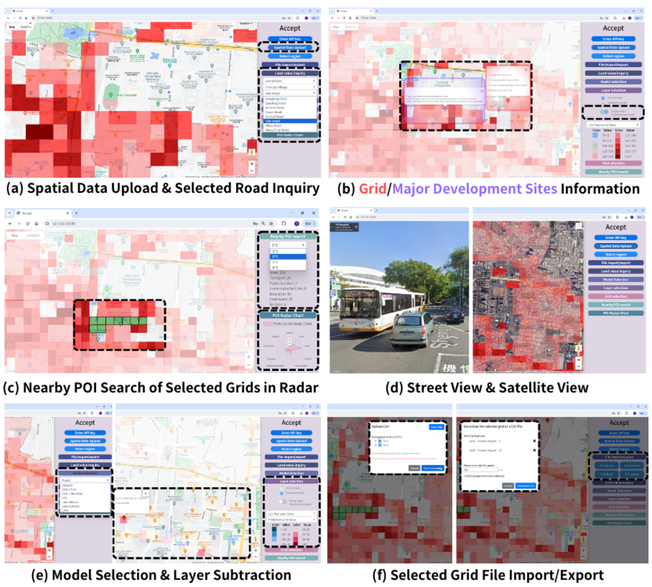

Figure 3: The interfaces of ACCEPT. (a) spatial data upload and selected road inquiry; (b) grid/major development sites information; (c) nearby POI search of selected grids in radar; (d) street view and satellite layers;(e) model selection and layer subtraction; (f) selected grid file import/export.

between the frontend and backend ensures that the system provides real-time data processing, and enhances user engagement through dynamic updates and interactive visualizations.

4 SYSTEM OVERVIEW

ACCEPT streamlines the process of mapping POIs onto grids, facilitating the application of data processing techniques such as weighting, intersection, and interpolation. This approach significantly enhances data accessibility and manipulability, making it easier to handle and interpret (see **Fig. 3**). After users upload geospatial data, through the data pipeline, they can view the mapped geospatial information on the grid within the system. The system uses color intensity to differentiate between different values, allowing users to switch between different layers. If two layers are selected, the system will subtract the values of the selected layers and display the differences on the map using different colors to represent the numerical distribution. This helps users clearly and intuitively observe the distribution of values across different regions.

Furthermore, users can choose different models and prediction targets. Based on the given parameters, the selected model can generate predictive results. For example, if a user uploads historical housing prices and POI distributions of a city, a machine learning model can be trained to predict future housing price trends based on the POI data. Additionally, users can select one or more grids to observe nearby POIs for in-depth analysis of various shapes of areas. ACCEPT also uses Google Maps as the base map, allowing users to understand the surrounding environment of a specific area through street view or satellite imagery.

5 CASE STUDY

Our case studies highlight effective spatial data handling, demonstrating similar POI distribution patterns, spatial separation, local feature sensitivity, and the impact of proximity to infrastructure and kernel size on evaluations. For instance, we used housing unit prices for spatial data analysis and prediction. Users can input a road name, and ACCEPT will automatically select corresponding grids, providing local information like historical and predicted unit prices and nearby POIs. Users can also manually select grids for specific areas, offering a quick view of development status.

The analysis of grid-based data highlights the significant impact of POIs (**Fig. 4**). The search range for nearby POIs in grids G demonstrates that the sensitivity of radar map values changes with the size N of the grid area; this sensitivity enables the model to accurately capture the characteristic distribution patterns of POIs. For instance, even with a closer distance of 0.87 km, POI pattern might be different, but might be similar in a far distance of 36.62 km. Furthermore, major development sites significantly influence the unit price of housing, as evidenced by a marked upward trend in predictive versus historical values. This correlation underscores the importance of incorporating POI data into predictive models for urban planning and real estate analysis.

The distribution of housing unit prices is context-sensitive, as intuitively shown in **Fig. 5**, where the CNN+MLP model effectively models various scenarios. The results in **Fig. 6**, generated by the CNN+attention model, reveals that this model can even capture the impacts caused by human factors: spatial separation is caused by the division of administrative regions, and the model predictions show local feature sensitivity, such as the distinct spatial contour of the Science Park compared to its surroundings. Additionally, proximity to infrastructures like train stations and the model's kernel size also affect the evaluation results. These case studies demonstrate that our system can provide precise predictions and even assist users uncover hidden correlations in the data.

6 CONCLUSION

In conclusion, ACCEPT is a sophisticated geospatial decision support system that enhances spatial data analysis by combining grid-based data processing, advanced machine learning models, and dynamic visualization tools. Through case studies, ACCEPT has demonstrated its capability to support various context-sensitive

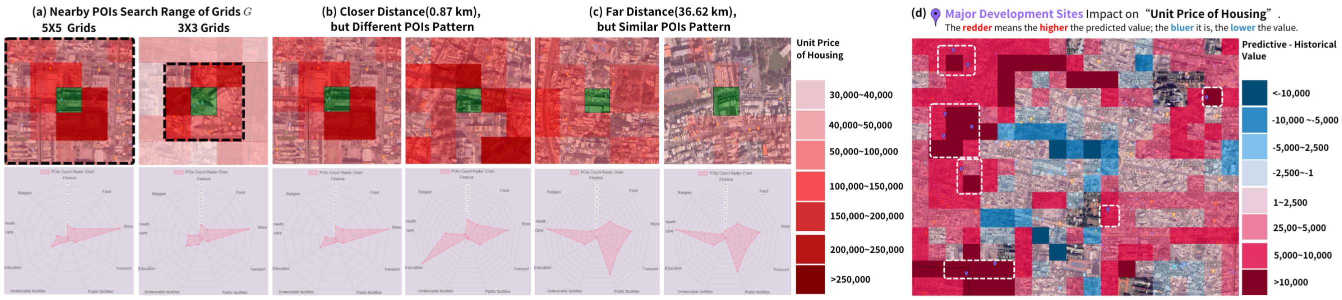

Figure 4: The impact of POIs in grid-based data. (a) nearby POIs search ranges of grids G; (b) closer distance (0.87 km) in different POIs pattern; (c) far distance (36.62 km) in similar POIs pattern; (d) major development sites impact on unit price of housing.

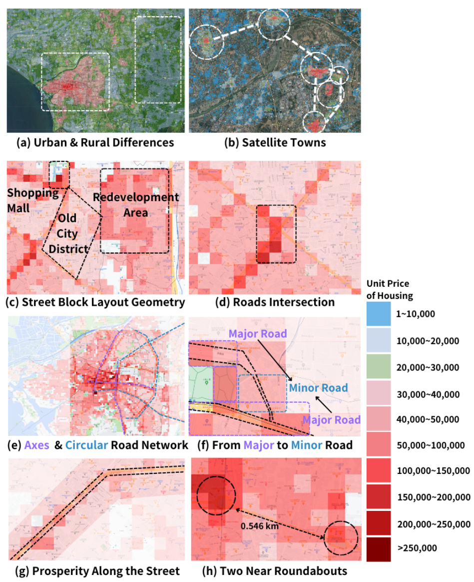

Figure 5: The distribution of unit price of housing generated by CNN+MLP model. (a) urban-rural differences; (b) satellite towns; (c) street block layout geometry; (d) roads intersection; (e) axes and circular road network; (f) from major to minor road; (g) prosperity along the street; (h) two near roundabouts.

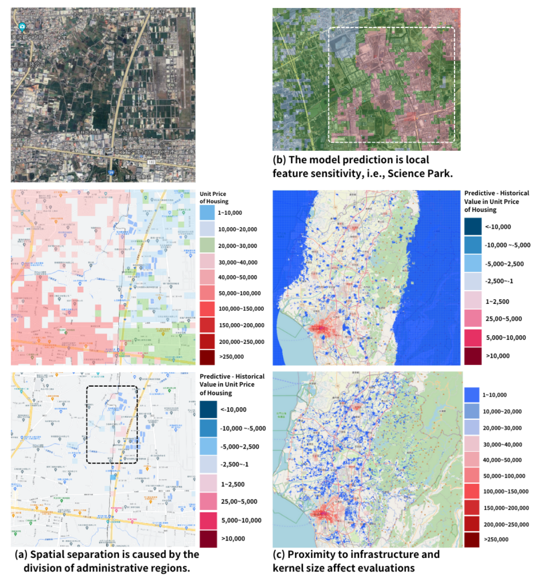

Figure 6: Results analysis of CNN+attention model. (a) spatial separation; (b) local feature sensitivity; (c) proximity to infrastructure and kernel size affect evaluations.

scenarios. The equipped machine learning models effectively capture the implicit meanings within spatial information and generate reasonable inference results. ACCEPT not only assists experts in promoting precise and efficient urban and regional planning but also empowers non-experts to quickly generate predictive results, serving as an entry point into the field of GIS.

ACKNOWLEDGMENTS

This work was partially supported by National Science and Technology Council (NSTC) under Grants 111-2636-E-006 -026 -, 112-2221-E-006 -100 - and 112-2221-E-006 -150 -MY3.

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