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## Abstract

Spatial Decision Support Systems (SDSS) are pivotal for resolving complex geospatial challenges but face critical limitations in harmonizing conflicting stakeholder objectives, capturing complex spatiotemporal heterogeneity, and enabling efficient large-scale data processing. This research presents an integrated, CI-Driven framework that systematically addresses these gaps through three interconnected perspectives. The **Human Perspective** confronts *participatory planning* challenges by developing a web-based MCDA platform to balance energy and ecological priorities in offshore wind site selection. To address the **Environment Perspective**, we introduce a novel agent-based model that simulates the emergence of large-scale epidemic patterns from *heterogeneous individual behaviors*. Foundational to these efforts, the **Machine Perspective** resolves underlying *performance bottlenecks* by creating NetCDFaster, a machine-learning-powered tool that dramatically accelerates *data access for high-performance computing (HPC)*. Together, these validated components form a cohesive framework that advances SDSS from specialized tools toward a scalable, holistic system for scientific discovery.

**Keywords:** GIS, Spatial Decision Support System (SDSS), Cyberinfrastructure (CI), Offshore Wind Site Selection, Epidemic Transmission Modeling

## Introduction

Addressing critical geospatial challenges, from renewable energy planning to public health management, is faced with obstacles including: (1) **harmonizing conflicting stakeholder objectives in participatory decision-making**, (2) **modeling complex, heterogeneous spatio-temporal systems**, and (3) **optimizing computational & I/O bottlenecks in large-scale data processing** [1-4]. Our research confronts these issues by designing and implementing a unified GeoCI system powered by GeoAI to deliver both scalable decision support and highly optimized data querying approach.

To achieve this, our work delivers three core contributions:

- Implement an SDSS to collect conflicting decision criteria among multiple stakeholders to achieve public participatory collaboration in offshore wind energy site selection application [5].
- Develop and validate a spatiotemporal epidemic transmission model by capturing the heterogeneity of individual cognitive behaviors thereby improving prediction accuracy to optimize public health strategy [6].
- Construct and deploy a GeoCI framework to enhance spatial decision support systems by improving data retrieval efficiency and the scalability of interactive visualization through machine learning-enabled optimization [7].

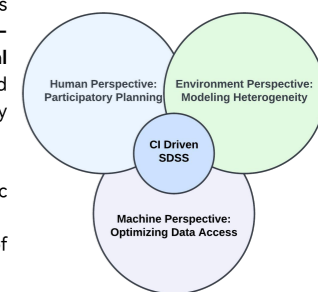


Fig-1. The illustration of the core research areas in designing spatial decision support systems

## Human Perspective

### Objective: Participatory Planning in Site Selection

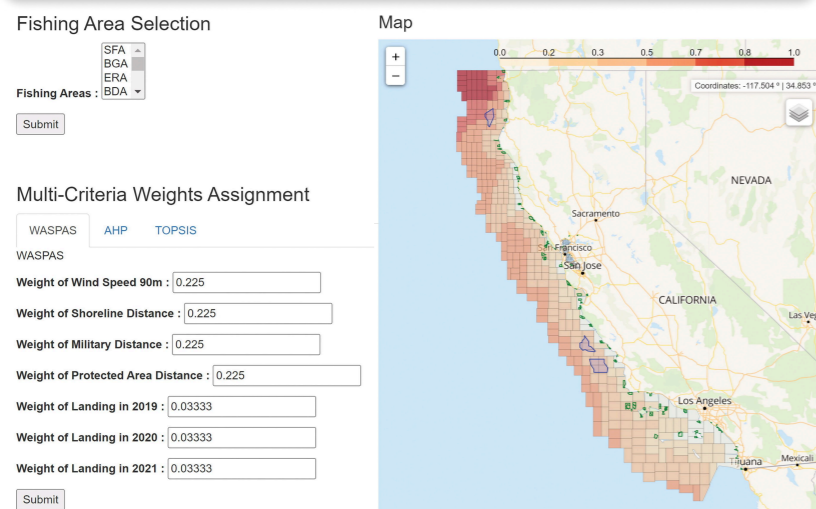


Fig 2-1. Offshore Wind farm site selection human-ocean interaction tool user interface

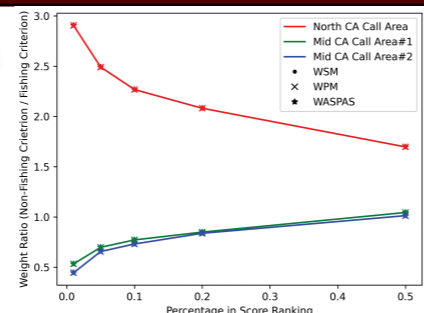


Fig 2-2. Weight ratio (non-fishery criterion/fishery criterion) with respect to percentage in ranking.

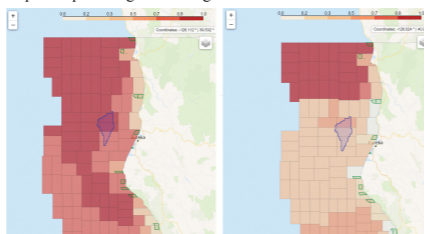


Fig 2-3. Suitability score visualization of Eureka Call Area of emphasizing non-fishery criteria (left) versus with consideration of fishery criteria (right).

## Environment Perspective

### Objective: Modeling Heterogeneous Features

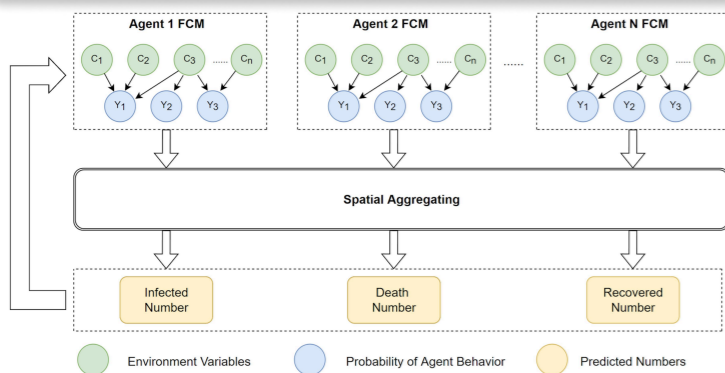


Fig 3-1. High-level system design of the hybrid FCM-ABM pandemic spreading pattern prediction model.

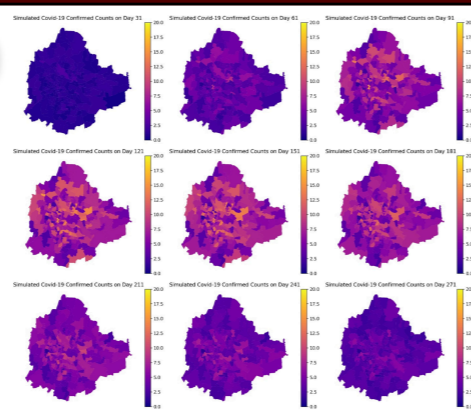


Fig 3-2. Geographic plots showing daily confirmed COVID-19 cases in ward level across the Bengaluru Urban District, in 300 days, at 30-day intervals. Colors range from purple (low) to orange (high), and the color bar quantifies case distribution, allowing easy comparison over time.

## Machine Perspective

### Objective: Optimizing Data Access

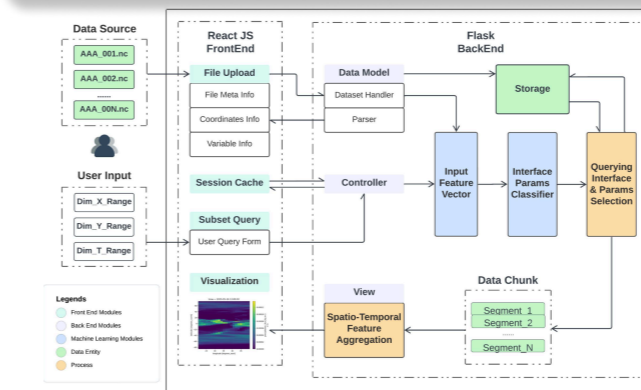


Fig 4-1. System-level design overview of the NetCDFaster architecture

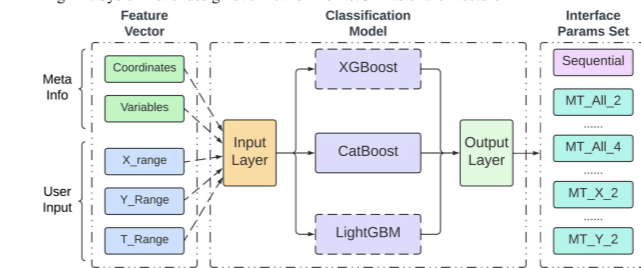


Fig 4-2. Illustration of the dynamic interface parameter classifier in NetCDFaster.

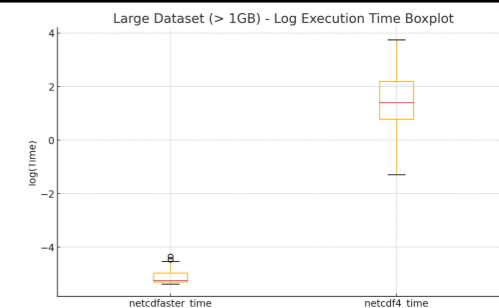


Fig 4-3. Comparison of time cost (log scale) between NetCDFaster and NetCDF4 Python APIs on large datasets ( $\geq 1$  GB).

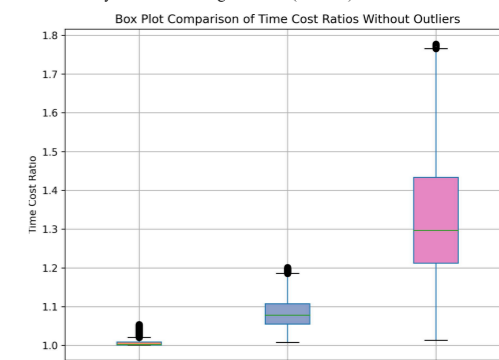


Fig 4-4. Box plot comparison of time cost ratios: Total time cost to minimum time cost ( $t^{total}/t^{min}$ ), average time cost to minimum time cost ( $t^{avg}/t^{min}$ ), and maximum time cost to minimum time cost ( $t^{max}/t^{min}$ ) using the NetCDFaster optimal classifier.

## Acknowledgement & References

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- [1] J. D. Barkan, P. J. Densham, and G. Rushton. Space matters: Designing better electoral systems for emerging democracies. *American Journal of Political Science*, 50:926-939, 10 2006. doi: 10.1111/j.1540-5907.2006.00224.x.
- [2] H. Goosen, R. Janssen, and J. E. Vermaat. Decision support for participatory wetland decision-making. *Ecological Engineering*, 30:187-199, 06 2007. doi: 10.1016/j.ecoeng.2006.11.004.
- [3] P. Jankowski, S. Robischon, D. Tuthill, T. Nyerges, and K. Ramsey. Design considerations and evaluation of a collaborative, spatio-temporal decision support system. *Transactions in GIS*, 10: 335-354, 05 2006. doi: 10.1111/j.1467-9671.2006.01001.x.
- [4] C. Yang, R. Raskin, M. Goodchild, and M. Gahegan. Geospatial cyberinfrastructure: Past, present and future. *Computers, Environment and Urban Systems*, 34:264-277, 07 2010. doi: 10.1016/j.compenurbysys.2010.04.001.
- [5] Song, Z., Chapman, P., Tao, J., Chang, P., Gao, H., Liu, H., Brannstrom, C., & Zhang, Z. (2024). Mapping the Unheard: Analyzing Tradeoffs Between Fisheries and Offshore Wind Farms Using Multicriteria Decision Analysis. *Annals of the American Association of Geographers*, 114(3), 536-554. <https://doi.org/10.1080/24694452.2023.2285371>
- [6] Song, Z., Zhang, Z., Lyu, F., Bishop, M., Liu, J., & Chi, Z. (2024). From Individual Motivation to Geospatial Epidemiology: A Novel Approach Using Fuzzy Cognitive Maps and Agent-Based Modeling for Large-Scale Disease Spread. *Sustainability*, 16(12), 5036-5036. <https://doi.org/10.3390/su16125036>
- [7] Song, Z., Zhang, Z., Sussman, A., Xie, Y., Brenner, J., & Liu, J. (2025). NetCDFaster: Optimizing NetCDF data querying and geo-visualization using high-performance machine learning. *SoftwareX*, 31, 102269. <https://doi.org/10.1016/j.softx.2025.102269>