Aalto University
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Engineering

FCAI Finnish Center for Artificial Intelligence

How do spatial motion patterns change over time, and how can we model them effectively?

Mapping Spatial Motion Patterns in Non-Stationary Environments

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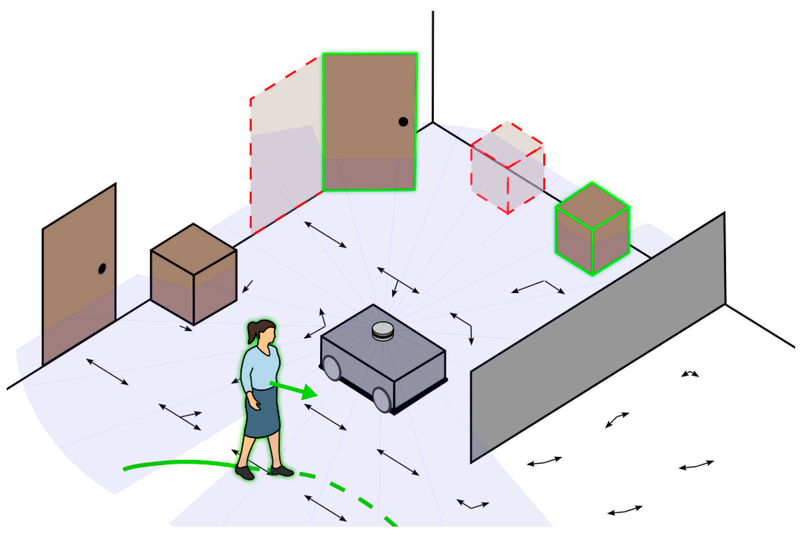
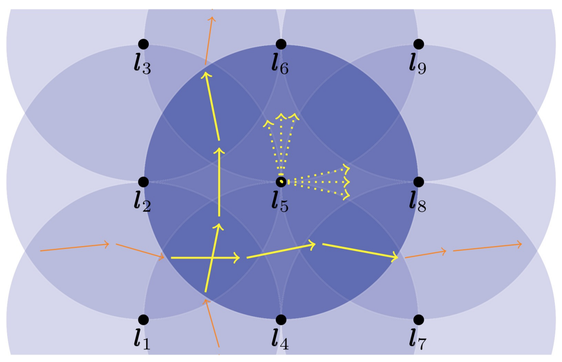
What is Maps of Dynamics and how does it work?

What?
Spatial or spatio-temporal representations of patterns of dynamics.
How?
Retaining information about the patterns of changes or motion relying on past observations [1].

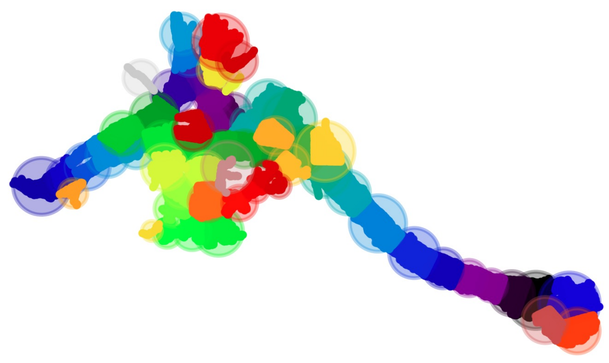


Existing approaches to directional maps rely on fixed occupancy cells and cannot modeling sudden changes in motion patterns.

Measurement discretization



Baseline: Fixed Cells x

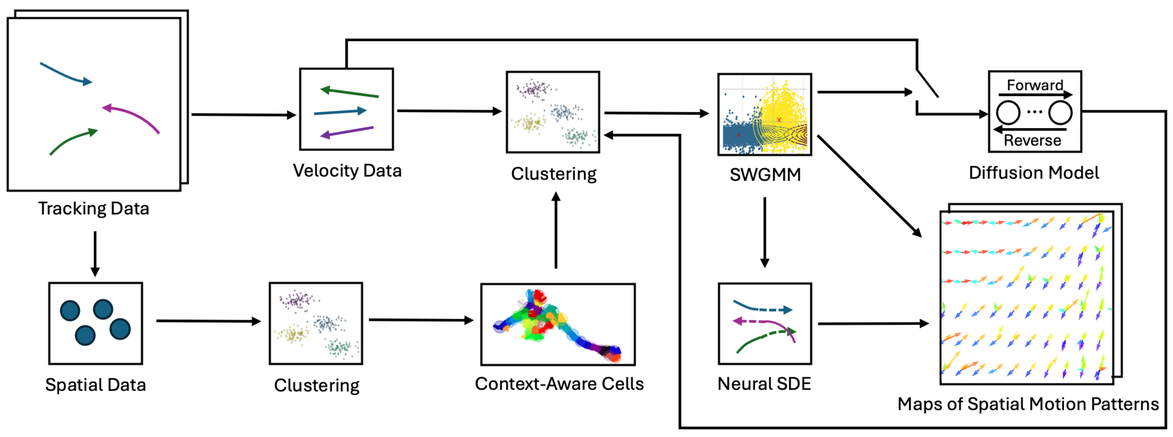


Ours: Context-Aware Cells

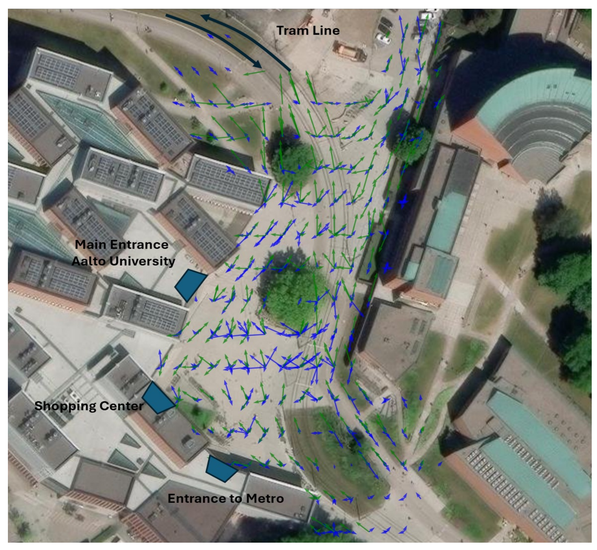
The left figure is the baseline CLiFF-Map's measurement discretization procedure [2]. The fixed occupancy cells is determined manually.

In our work, each color with the circle represents a different cell. The cells are determined based on the density of historical observations and their spatial distribution.

Overview



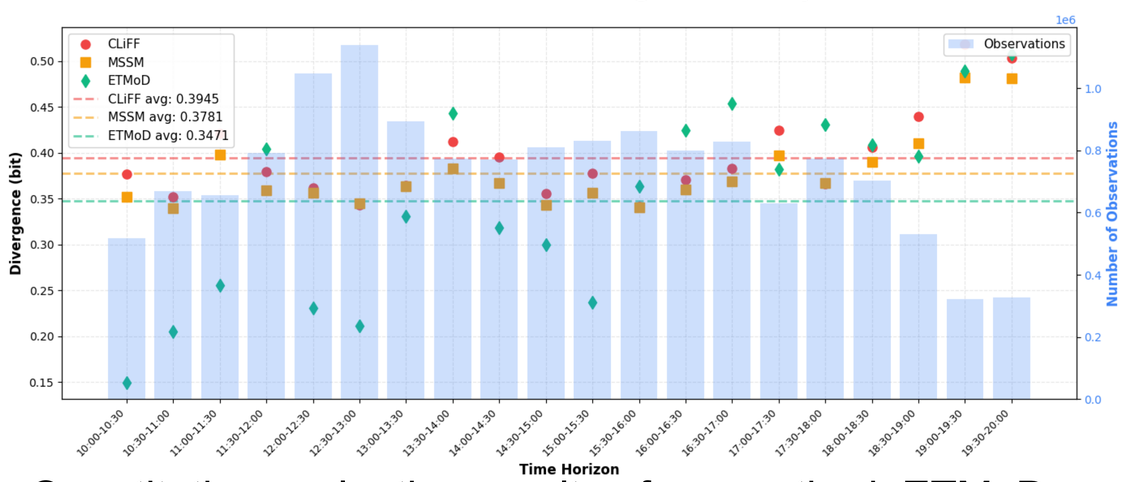
Experiments and results



Mapping results at Aalto University
blue - pedestrian, green - cyclist

Our contributions

- We employ a grid-shifting clustering algorithm based on location and velocity, enabling faster and more interpretable generalization of representations.
- Our model captures complex multi-modal distributions while automatically selecting regions of interest.
- By leveraging Neural SDEs, the model effectively captures the continuous evolution of motion patterns in map representations.
- The integration of diffusion models use an event-triggered mechanism enable the model adapt to new events.



Quantitative evaluation results of our method, ETMoD, compared with CLiFF-Map [2] and MSSM [3].

References

1. T. P. Kucner, et al. Survey of maps of dynamics for mobile robots. The International Journal of Robotics Research, 2023.
2. T. P. Kucner, et al. Enabling flow awareness for mobile robots in partially observable environments. IEEE Robotics and Automation Letters, 2017.
3. J. Shi and T. P. Kucner. Learning temporal maps of dynamics for mobile robots. Robotics and Autonomous Systems, 2025.