Differentiable Spatial Planning using Transformers

ICML 2021

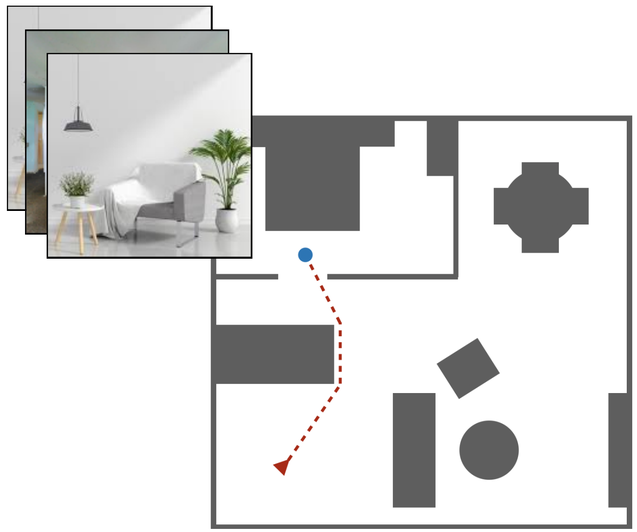
Devendra Singh Chaplot

Deepak Pathak

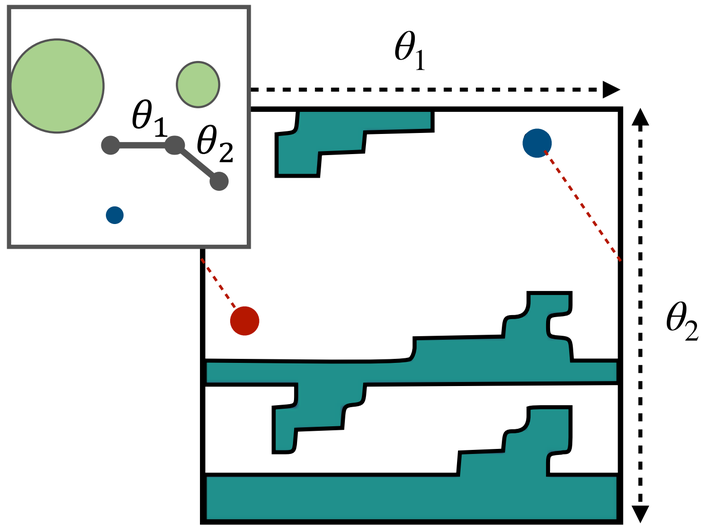
Jitendra Malik

Webpage: https://devendrachaplot.github.io/projects/spatial-planning-transformers

Spatial Planning



(a) Navigation



(b) Manipulation

- Input
  - ➡ spatial obstacle map
  - ➡ goal location
  - ➡ starting location
- Output
  - ➡ Shortest path to the goal.

Why learn to plan?

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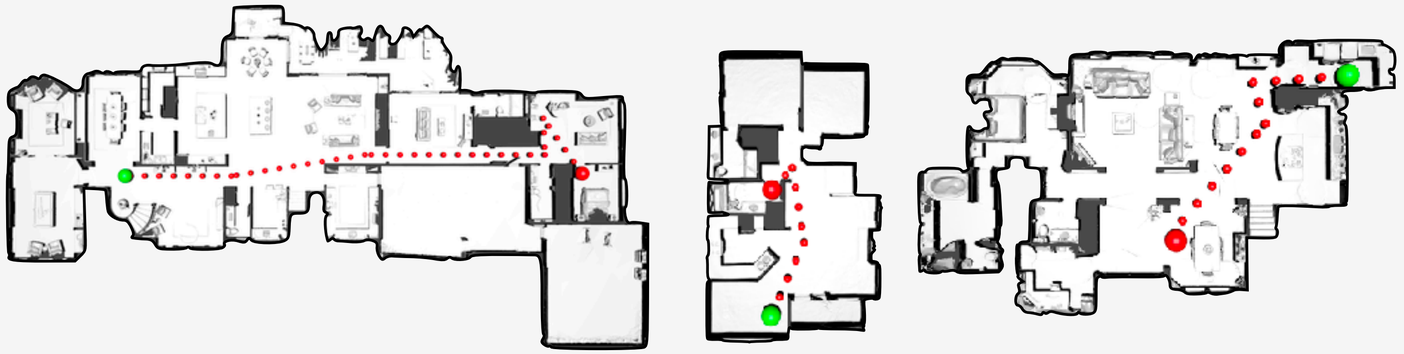
Exploit statistical regularity in data



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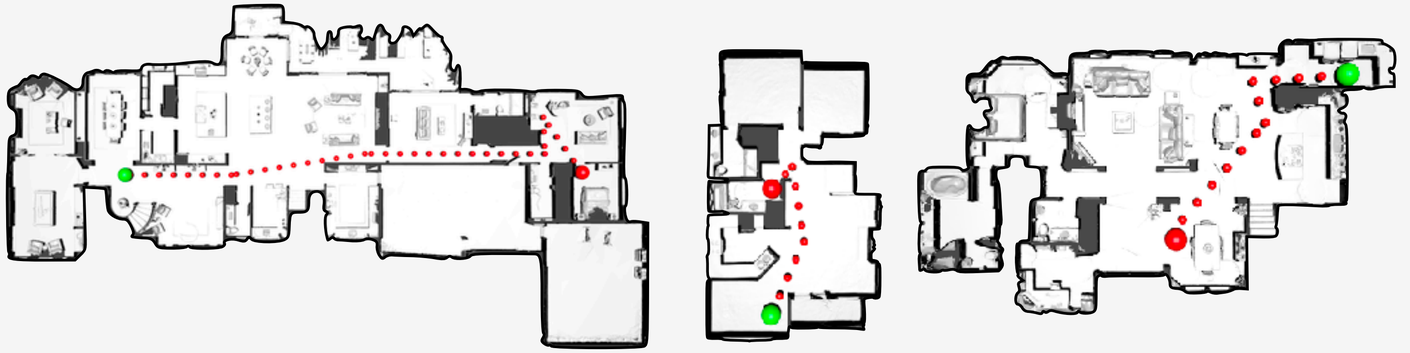
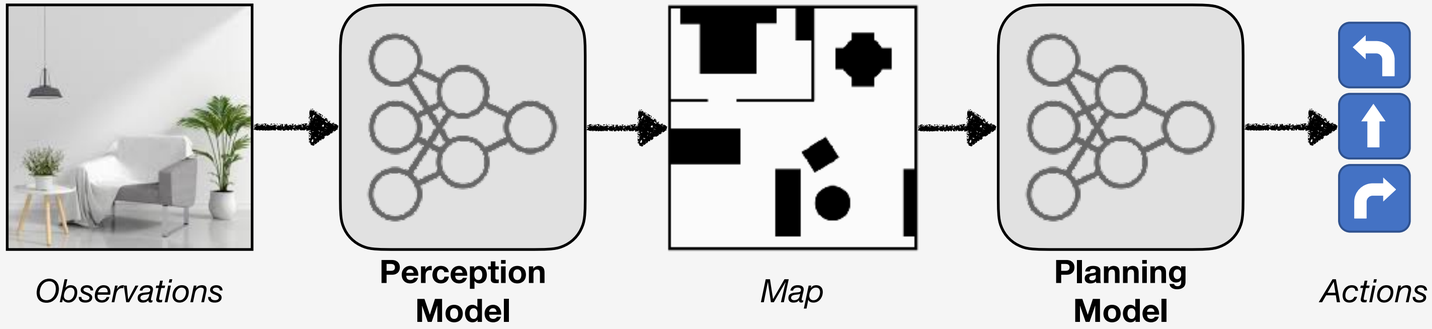
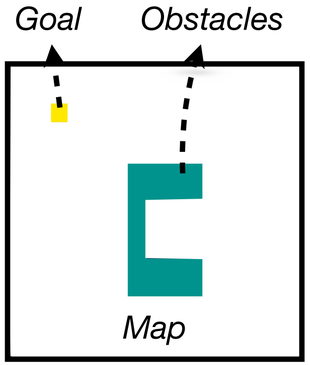


Tackle unknown maps



Map images from the Gibson dataset (Xia et al. CVPR 2018)



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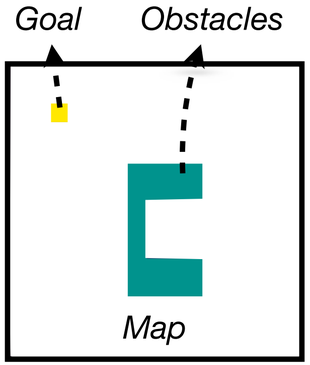

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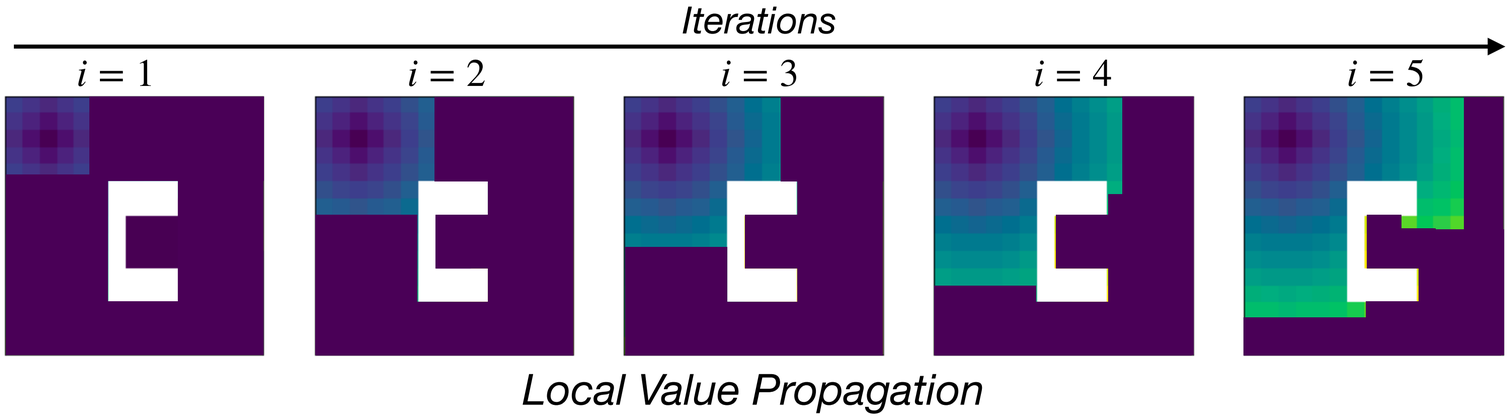
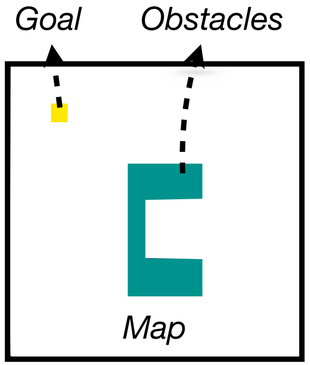


Local Value Propagation

- Prior Methods: Inductive bias on local value propagation using CNNs
  - VIN [1]: CNNs with tied weights
  - GPPN [2]: Convolutional LSTMs



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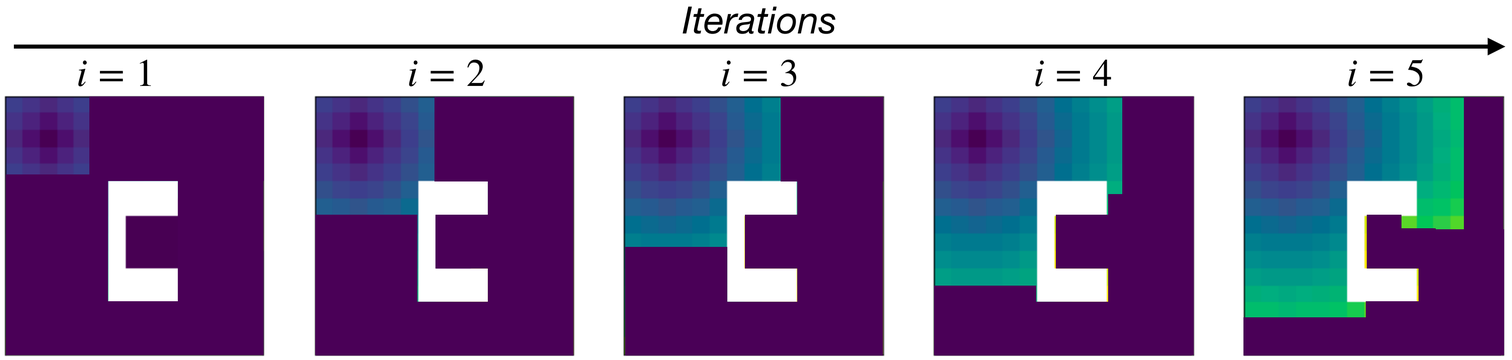

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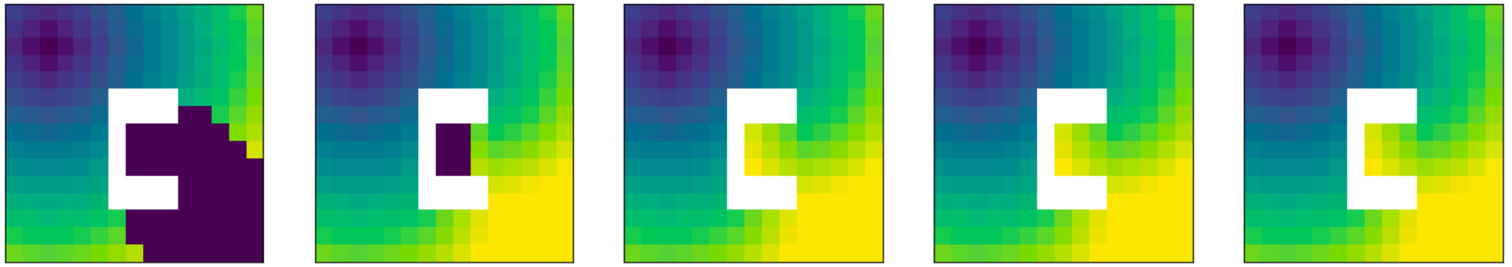


Long distance Value Propagation

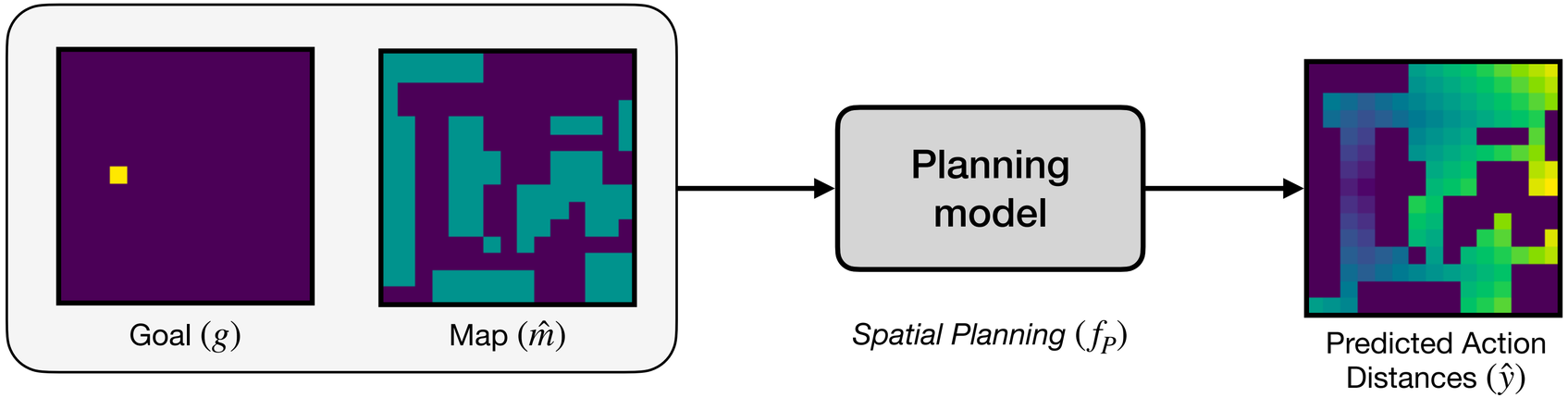
- Prior Methods: Inductive bias on local value propagation using CNNs
  - VIN [1]: CNNs with tied weights
  - GPPN [2]: Convolutional LSTMs
- Long distance value propagation
  - Value can be propagated between two distant points with no obstacle between them
  - Transformers are well suited, can attend to arbitrary cells

[1] Value Iteration Networks (VIN) [Tamar et al. NeurIPS 2016]
[2] Gated Path-Planning Networks (GPPN) [Lee et al. ICML 2018]

Planning with known maps

Planning with known maps

Navigation



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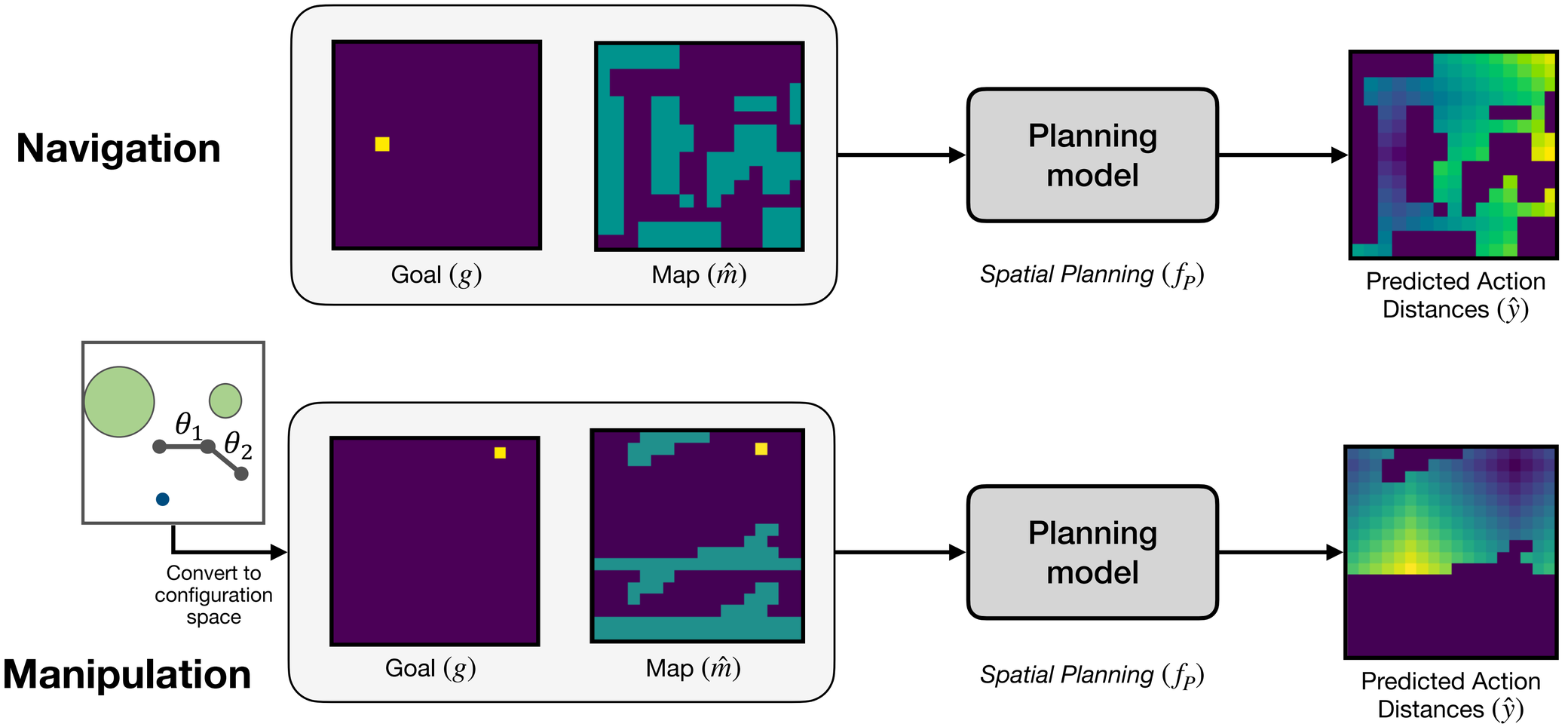

Spatial Planning Transformer (SPT)

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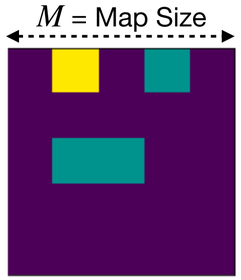
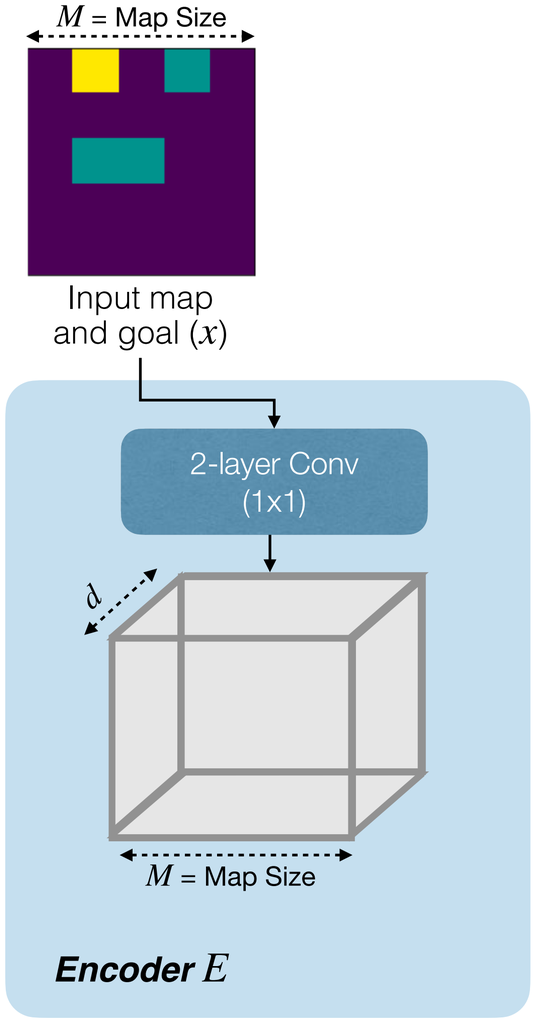


Input map
and goal (x)

Spatial Planning Transformer (SPT)



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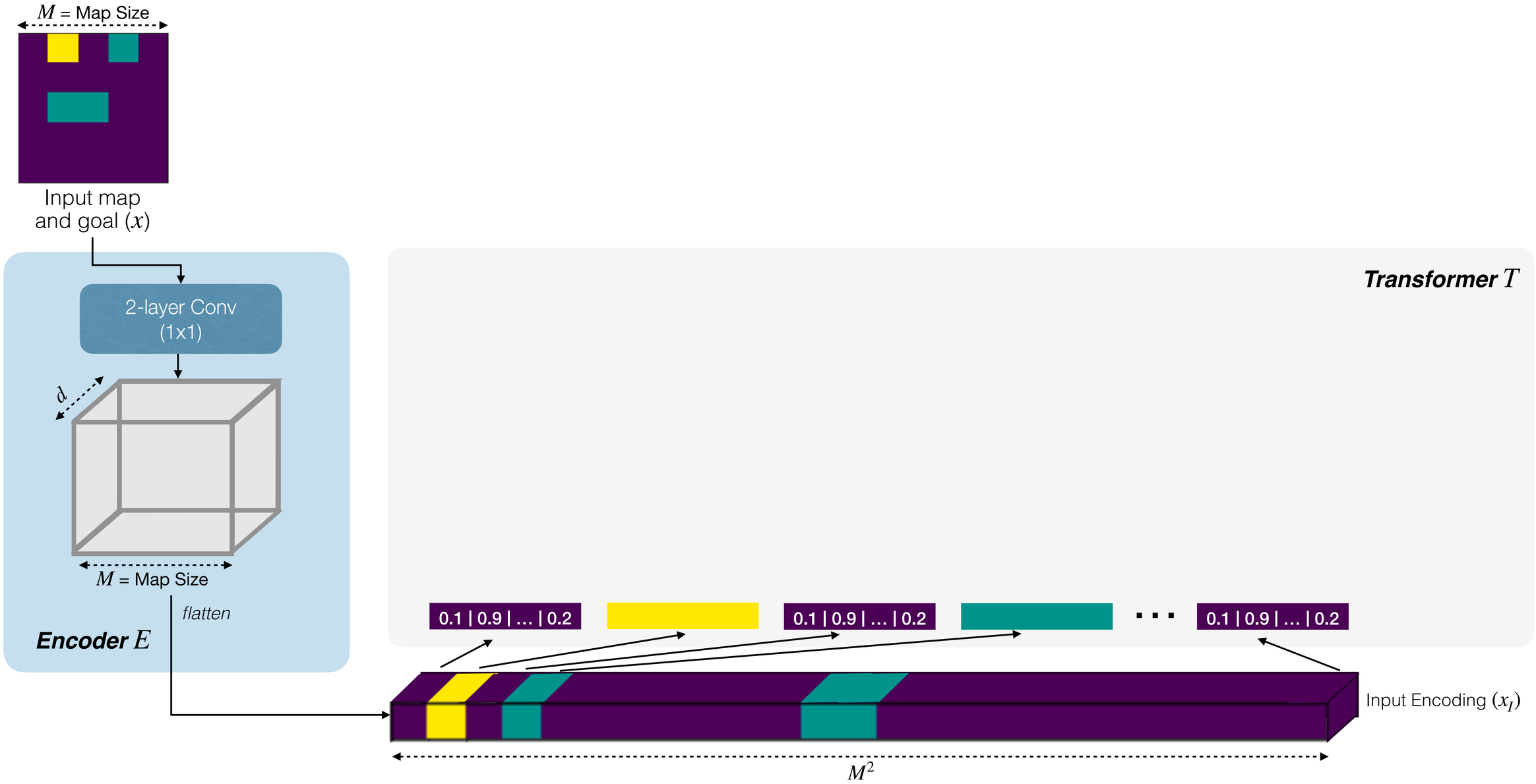

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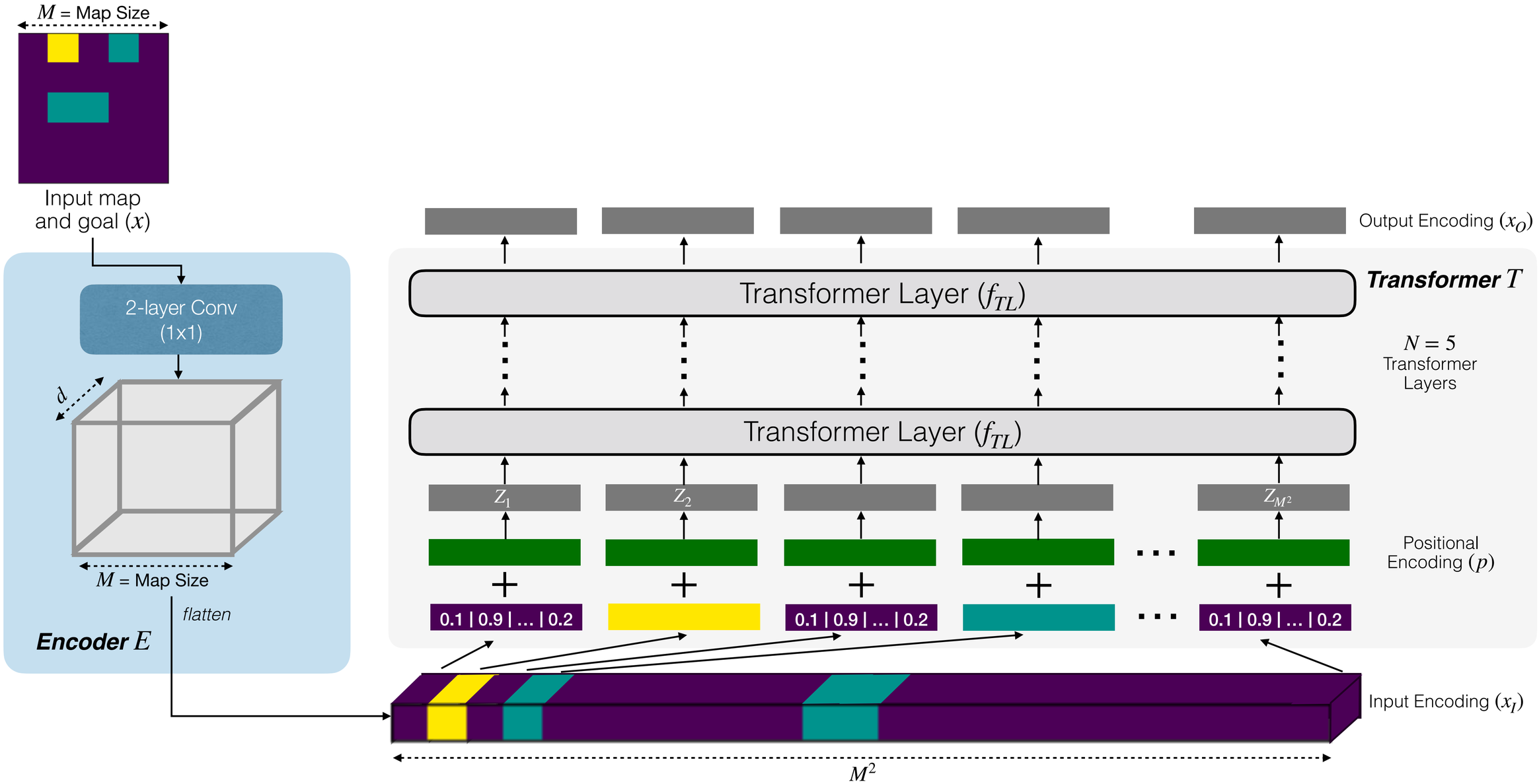

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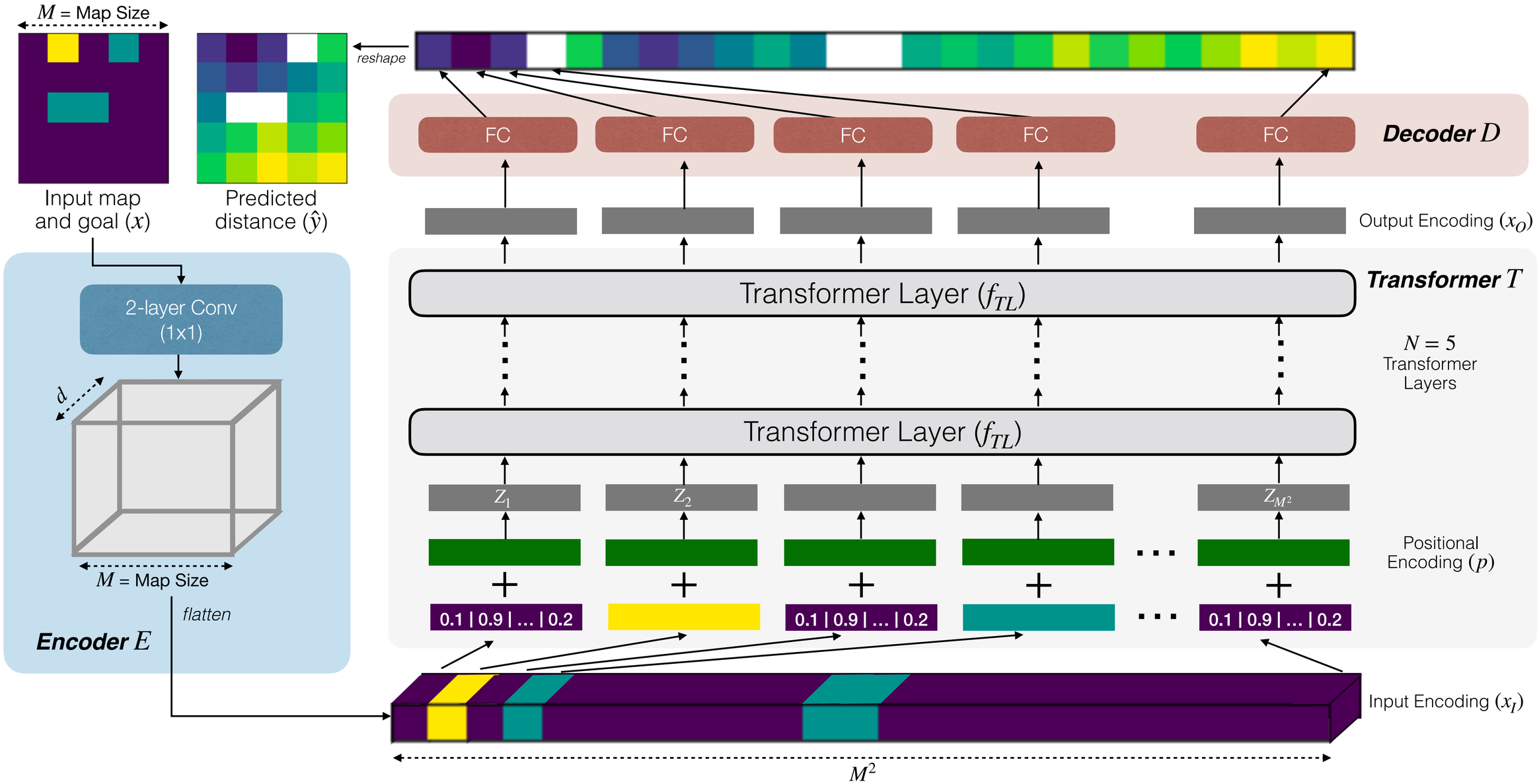

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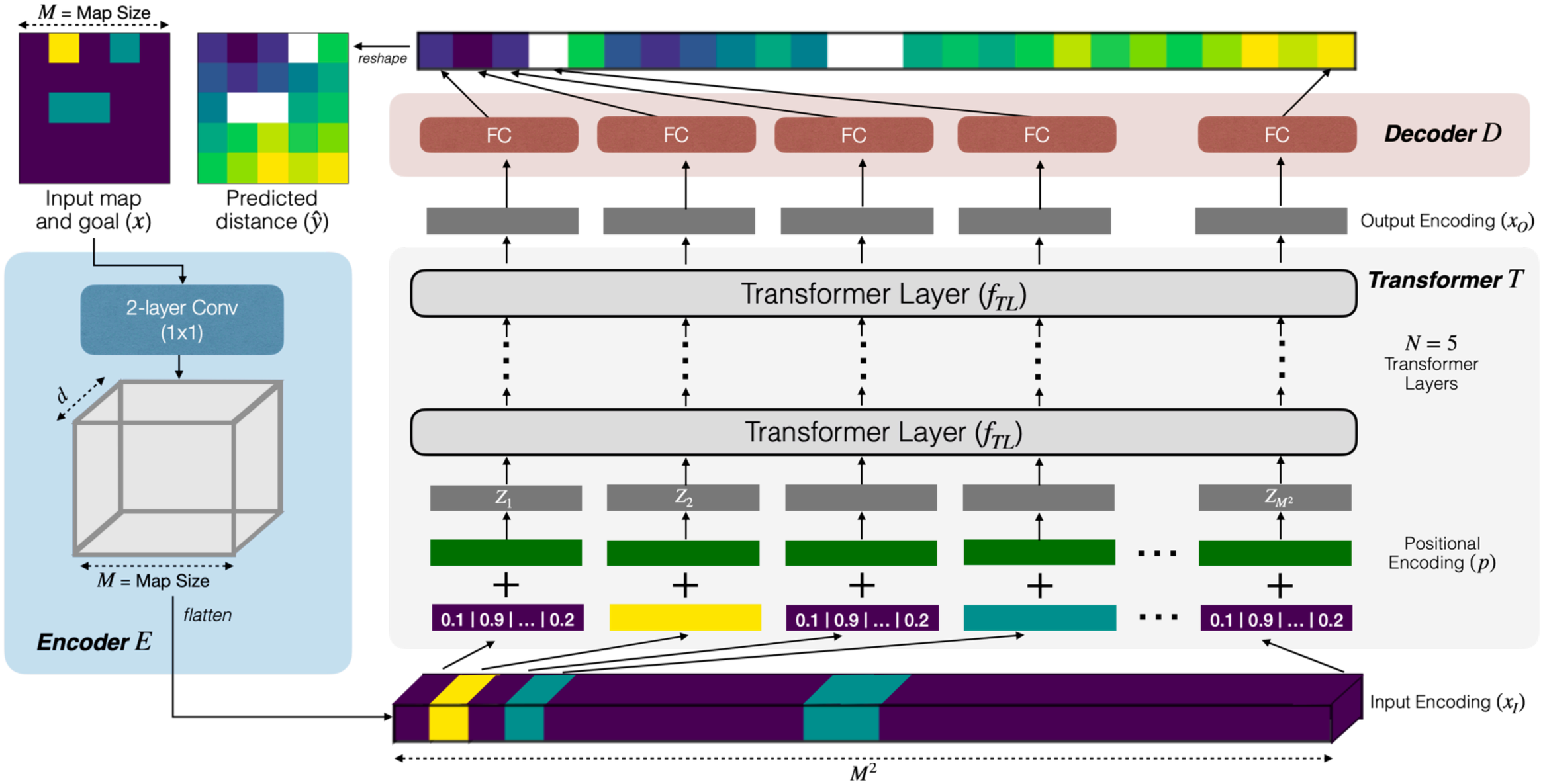
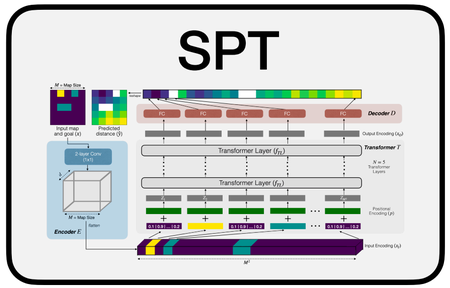


Training SPT with synthetic data



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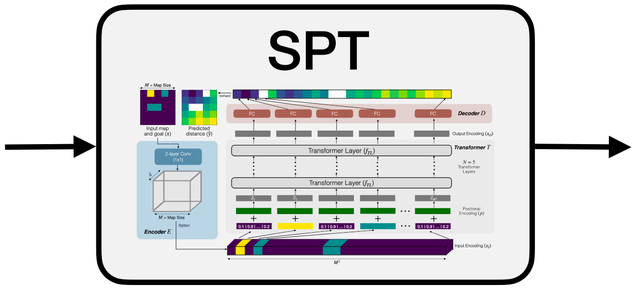
Input map and goal (x)



Predicted distance ($\hat{y}$)

MSE Loss

Ground truth (y^*)

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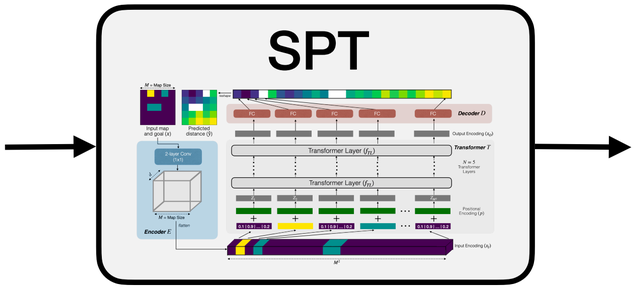

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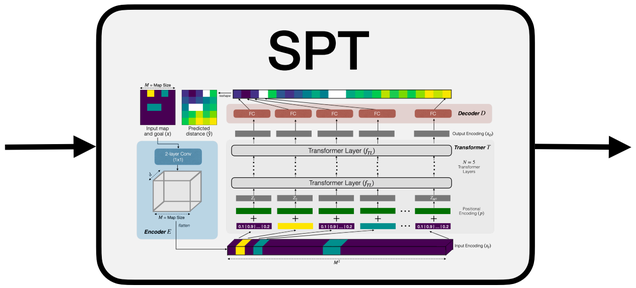

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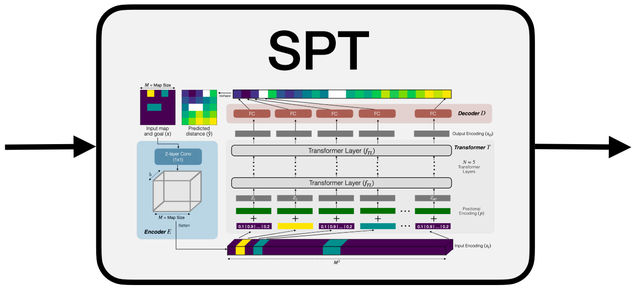

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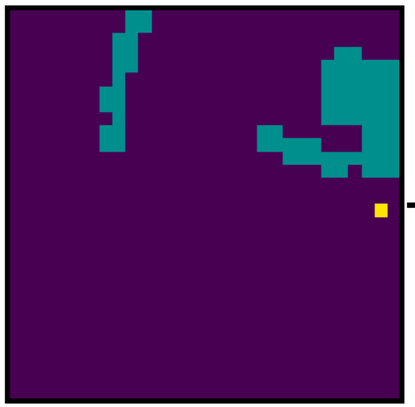

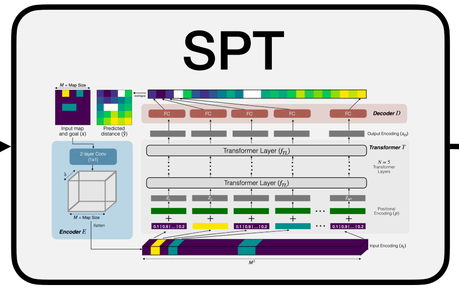

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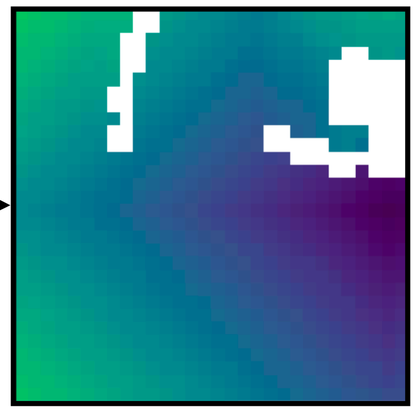

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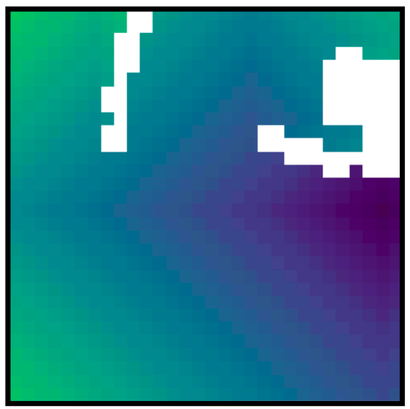

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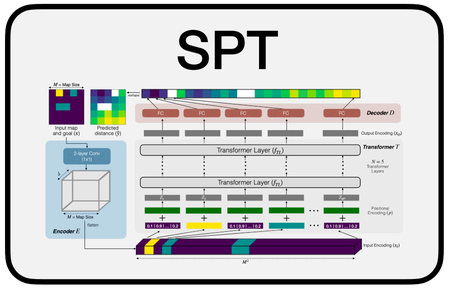

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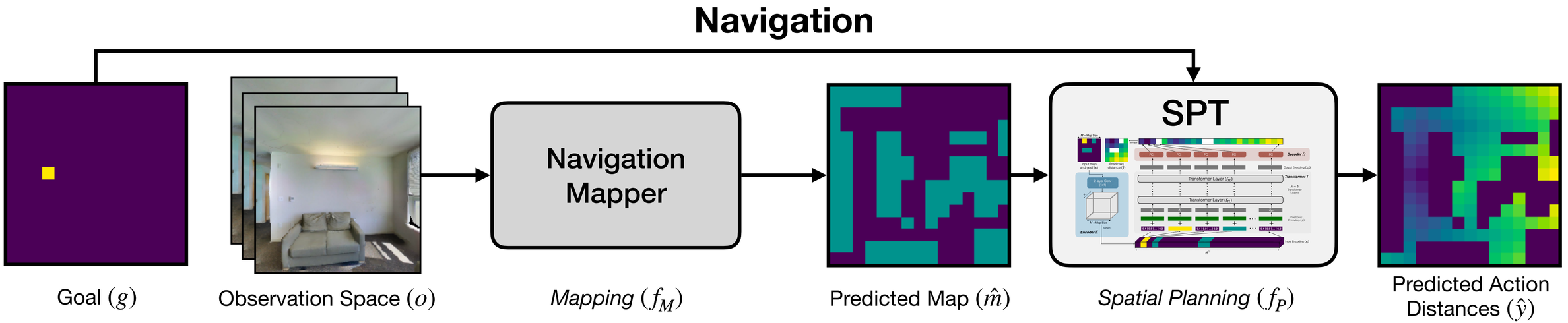

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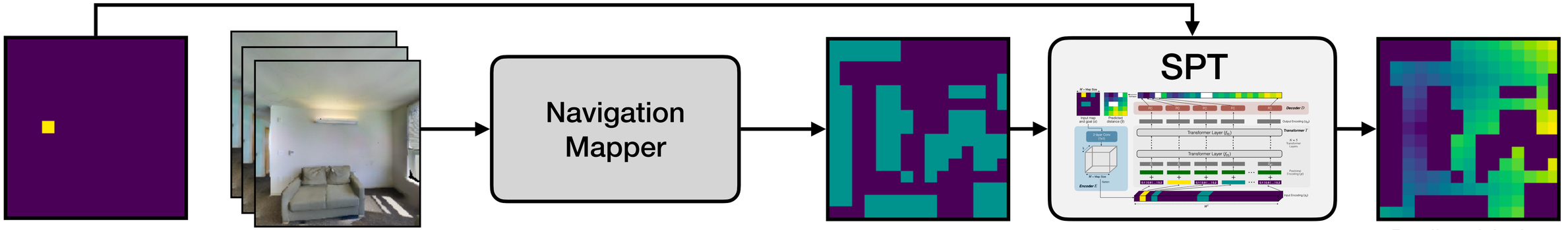
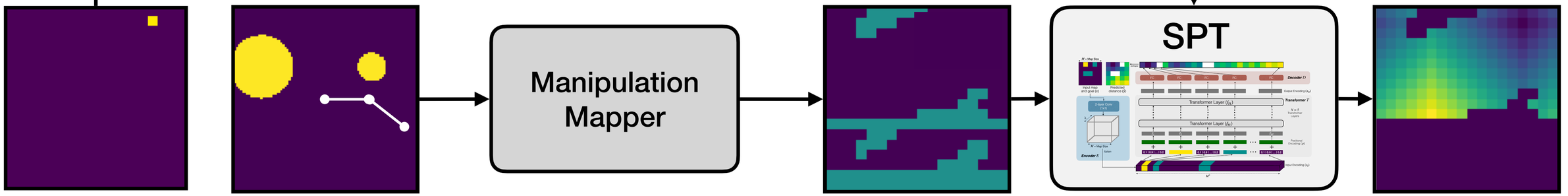


Goal (g) | Observation Space (o) | *Mapping* (f_M) | Predicted Map $(\hat{m})$ | *Spatial Planning* (f_P) | Predicted Action Distances $(\hat{y})$

Manipulation



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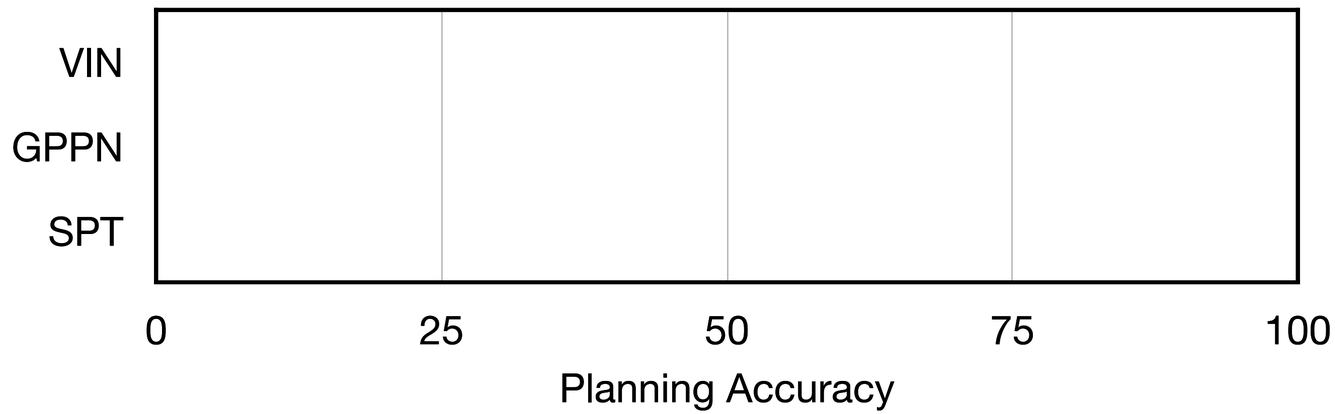
- Datasets
  - In-distribution (0-5 obstacles)
  - Out-of-distribution
    - More obstacles (15-20 obstacles)
    - Real-world maps (Gibson dataset) [Xia et al. CVPR 2018])

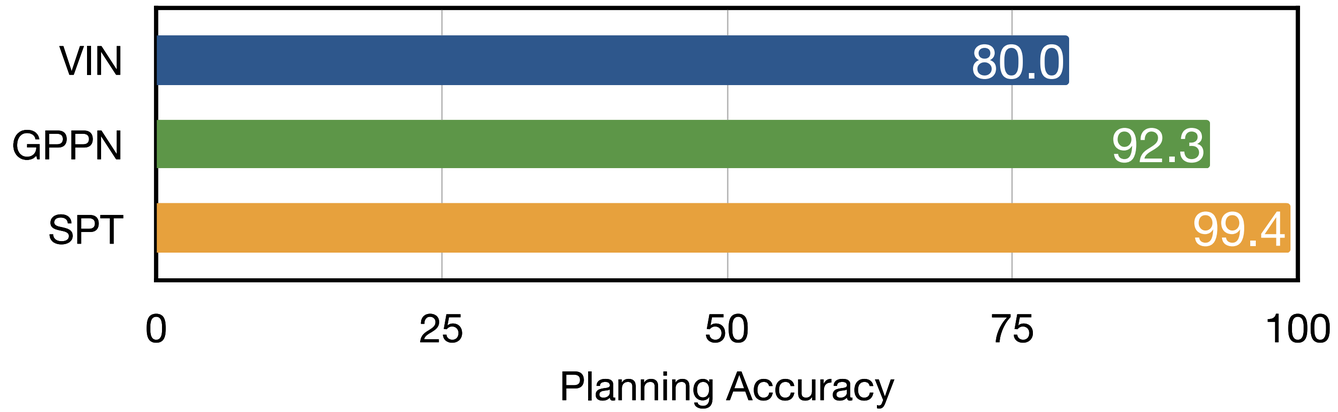
Results

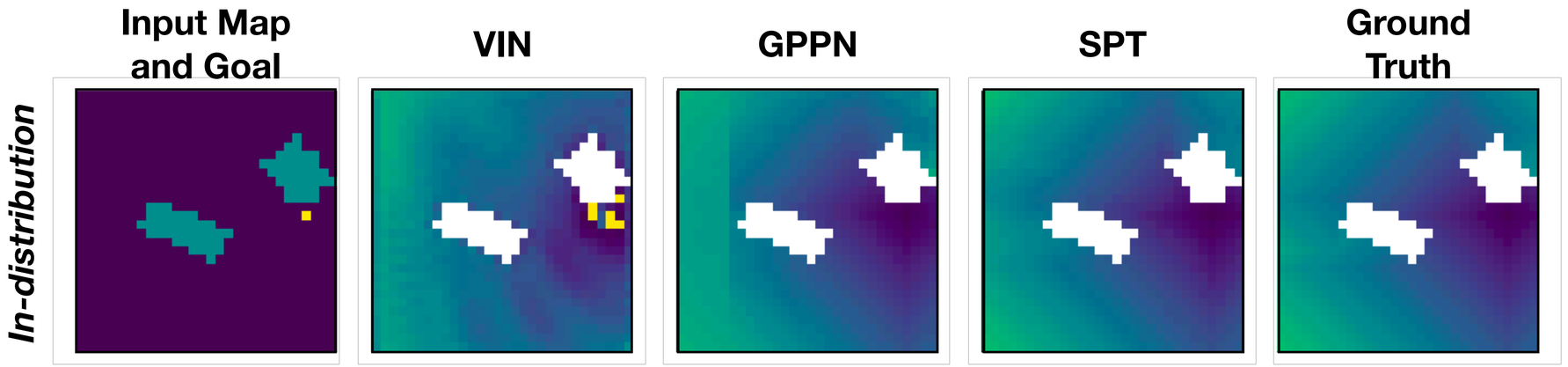


Input Map and Goal | **VIN** | **GPPN** | **SPT** | **Ground Truth**

Results

In-distribution





Results

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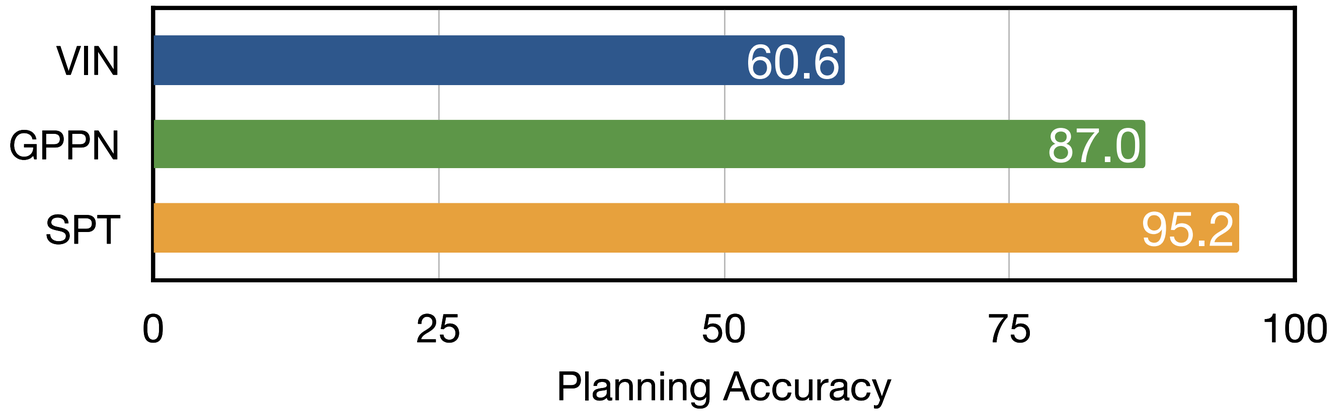
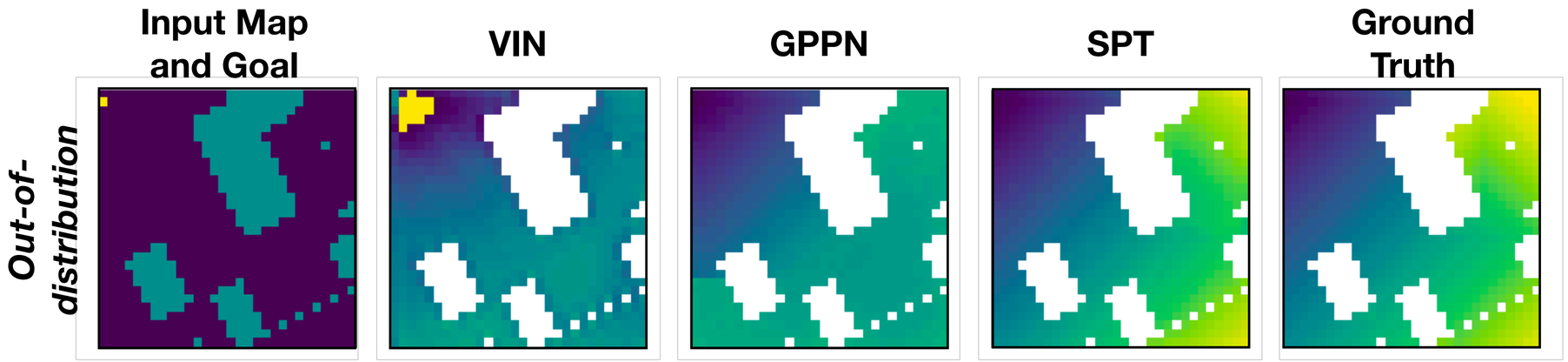
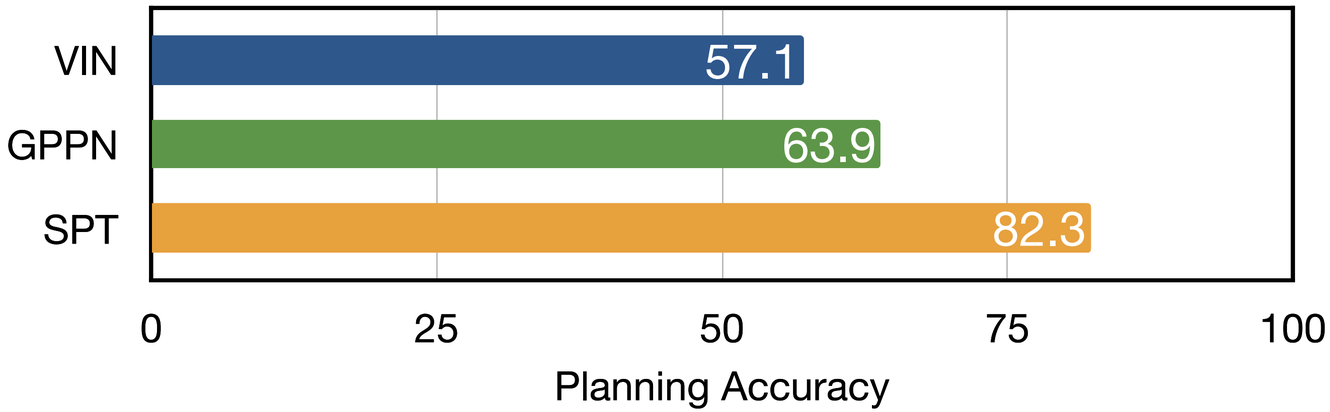
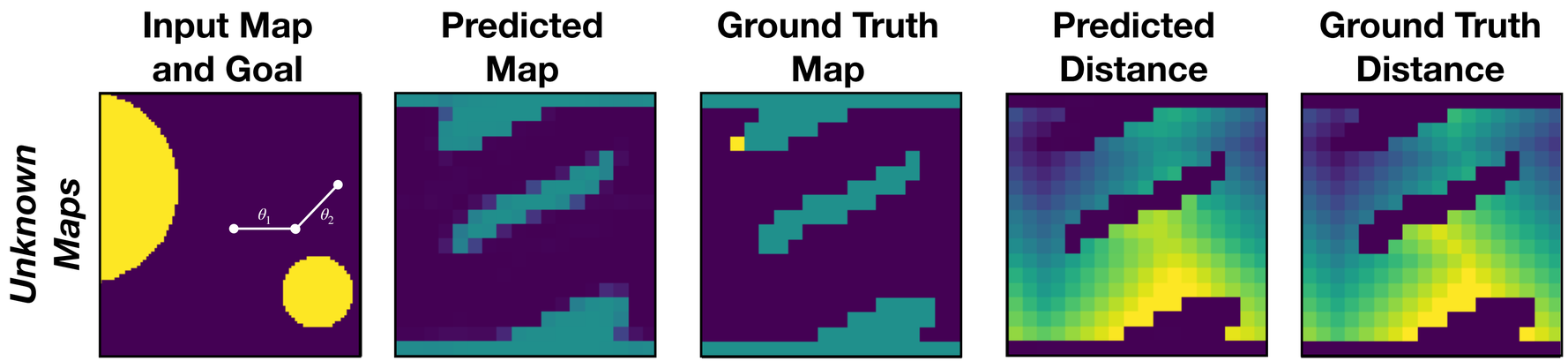




Results

Unknown maps





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Thank you

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