LONG-TERM AUTONOMY

REPRESENTATIONS OF EXPERIENCE FOR NAVIGATION

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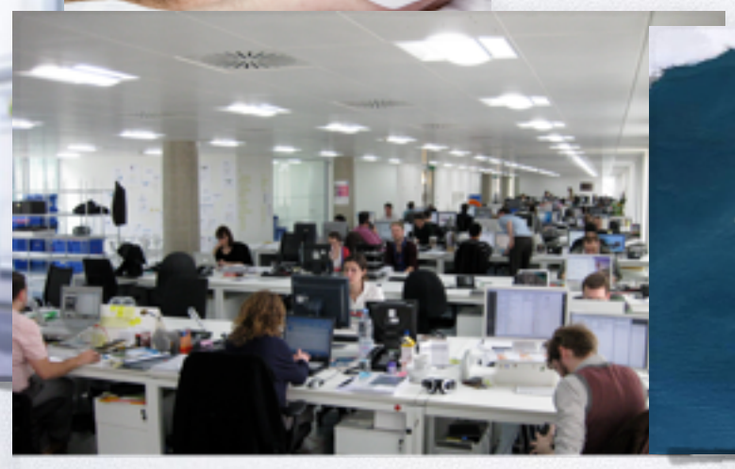
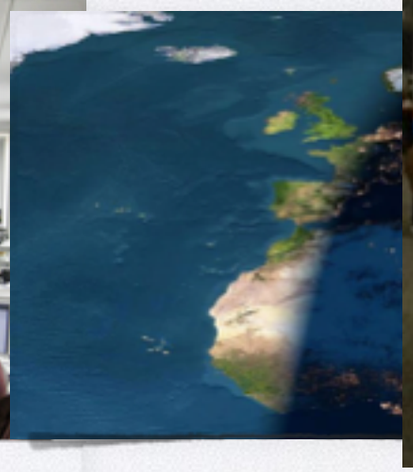
The world is not static!

But it's full of routines
(nearly periodic processes)





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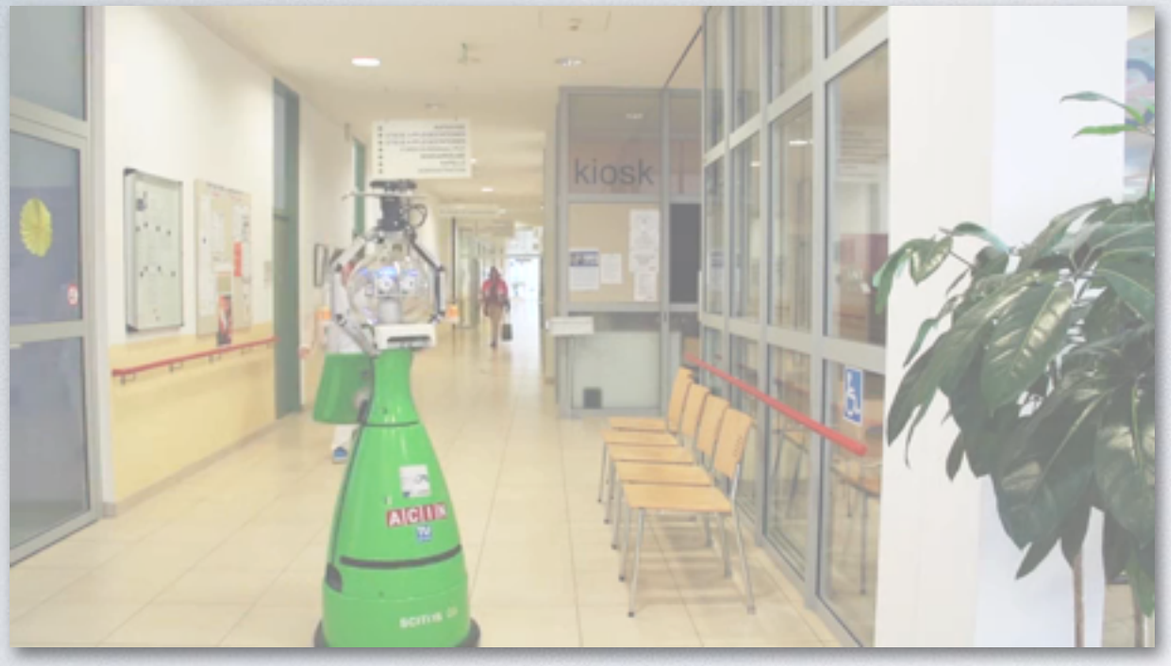
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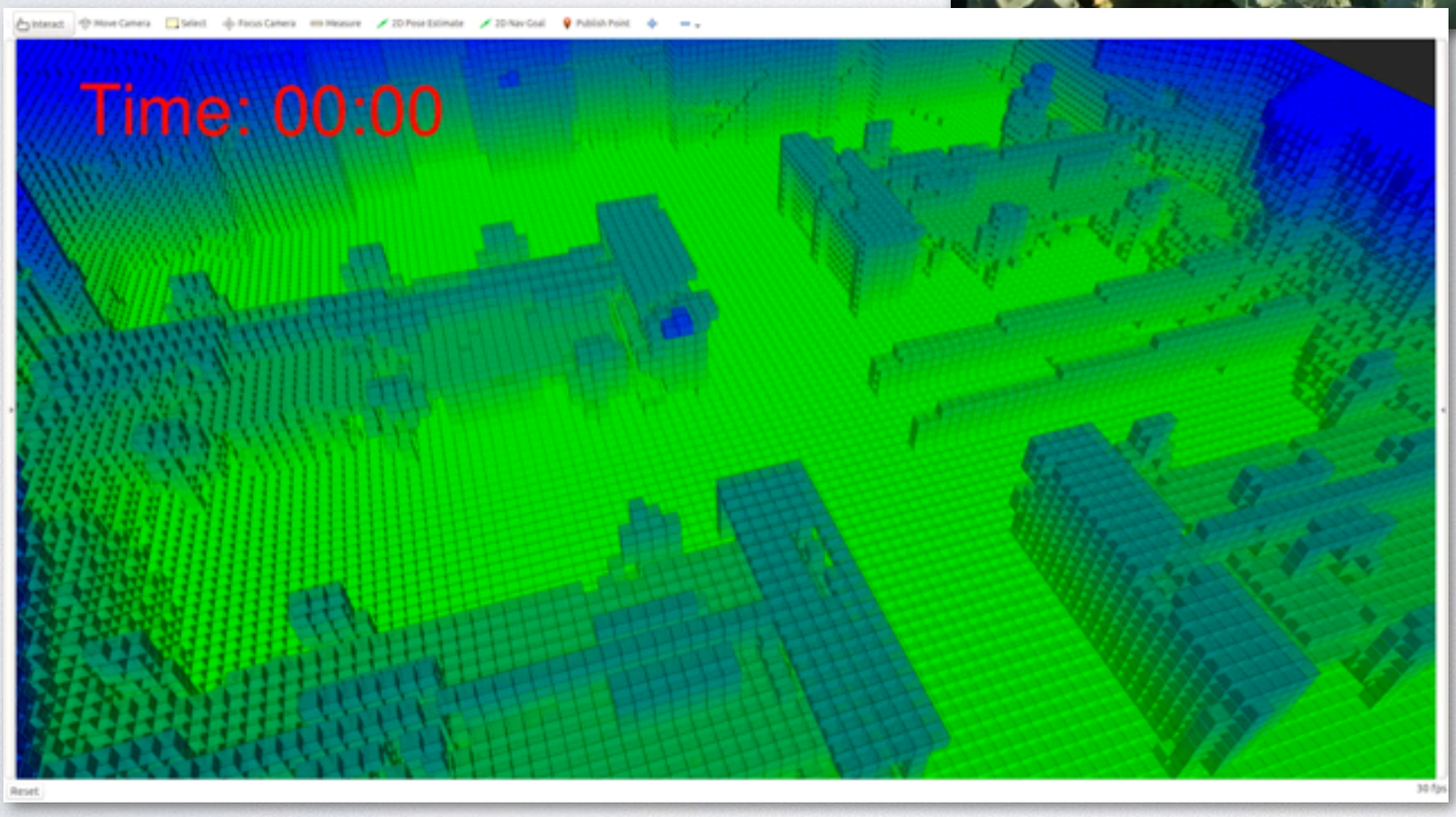
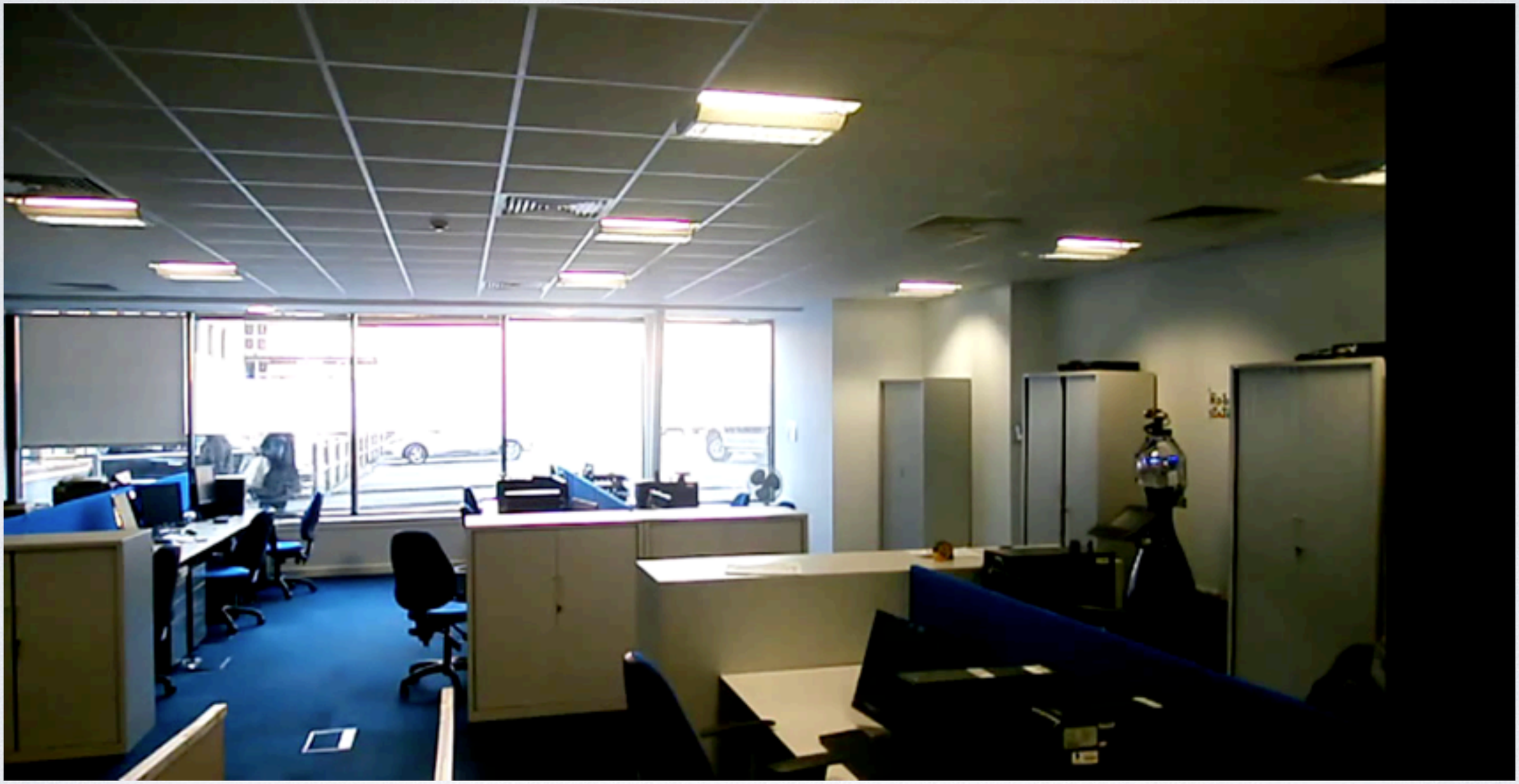

Time: 00:00

A ROBOT PATROLLING (ONE WEEK)



WHY AND HOW TO MODEL ROUTINES?

- Why:
  - better localisation
  - better planning
  - detect deviations
  - predict the future
- How:
  - (binary) states

$$s_j(t)=\{0,1\}$$

$$s(t)=[s_1(t),s_2(t),\ldots,s_J(t)]^T$$

  - derive spectral model using FT

$$S(\omega)=FT(s(t))$$

  - keep the most prominent S

WHY AND HOW TO MODEL ROUTINES?

now extended to real-valued states and non-uniform sampling

- Why:
  - better localisation
  - better planning
  - detect deviations
  - predict the future

- How:
  - (~~binary~~) states

$$s_j(t) = \{0, 1\}$$

$$s(t) = [s_1(t), s_2(t), \ldots, s_J(t)]^T$$

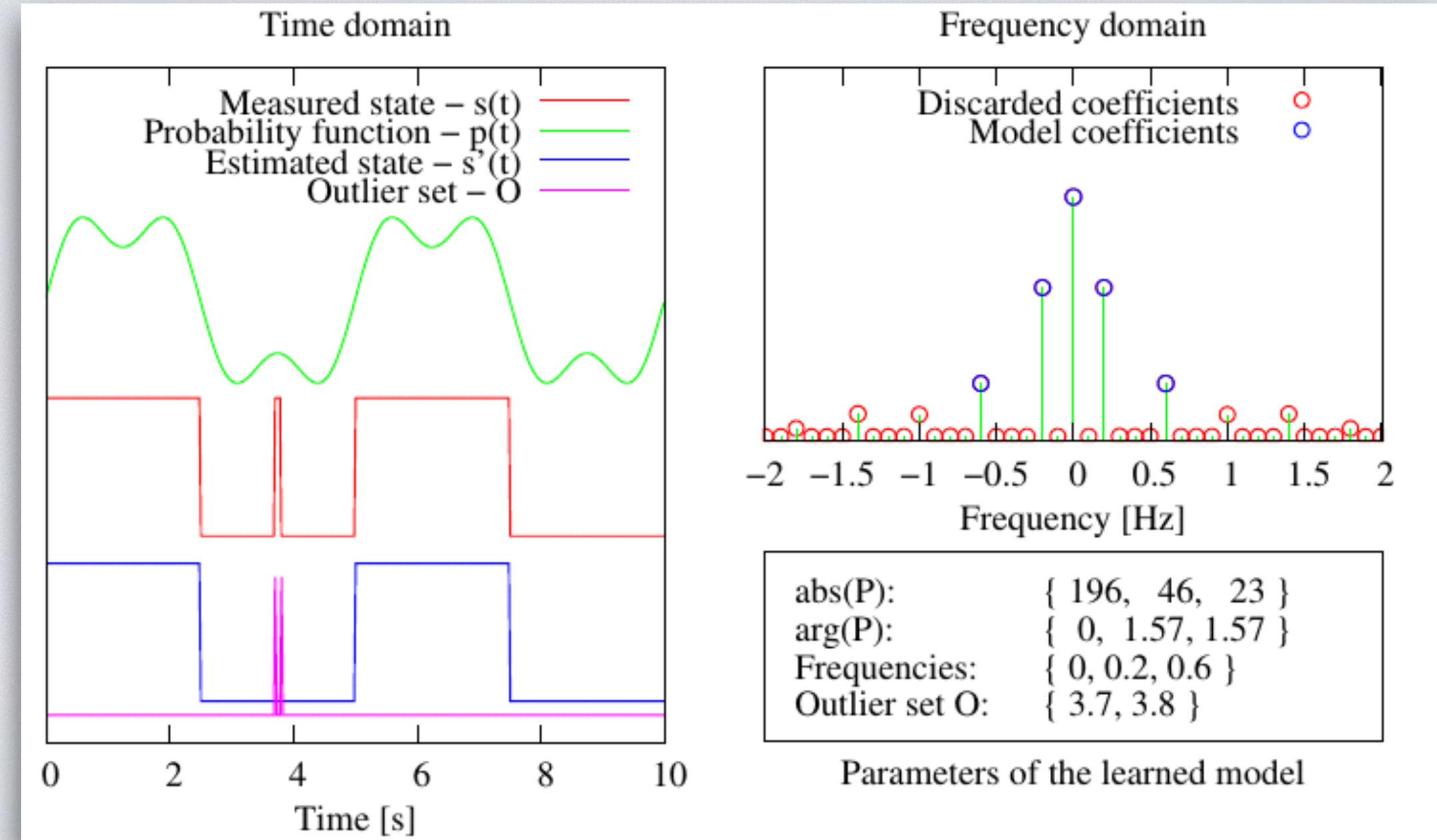
  - derive spectral model using FT

$$S(\omega) = FT(s(t))$$

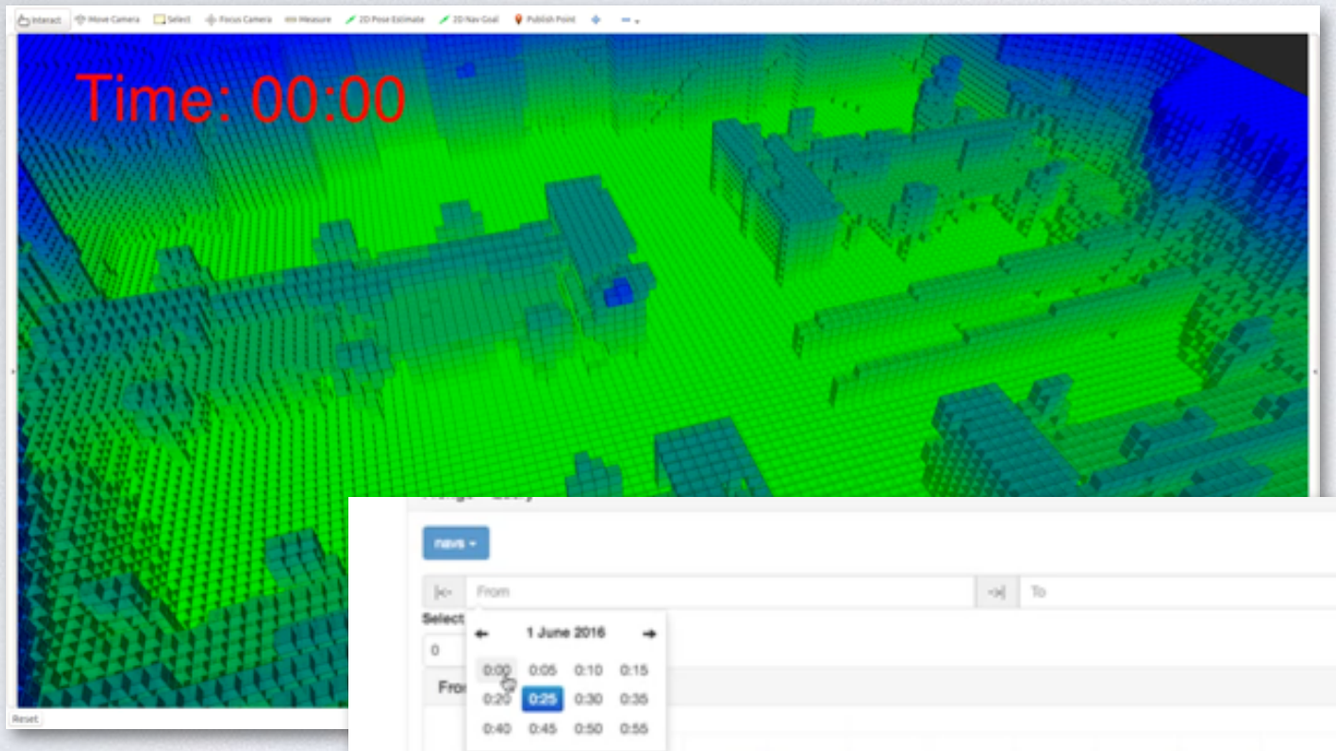
  - keep the most prominent S

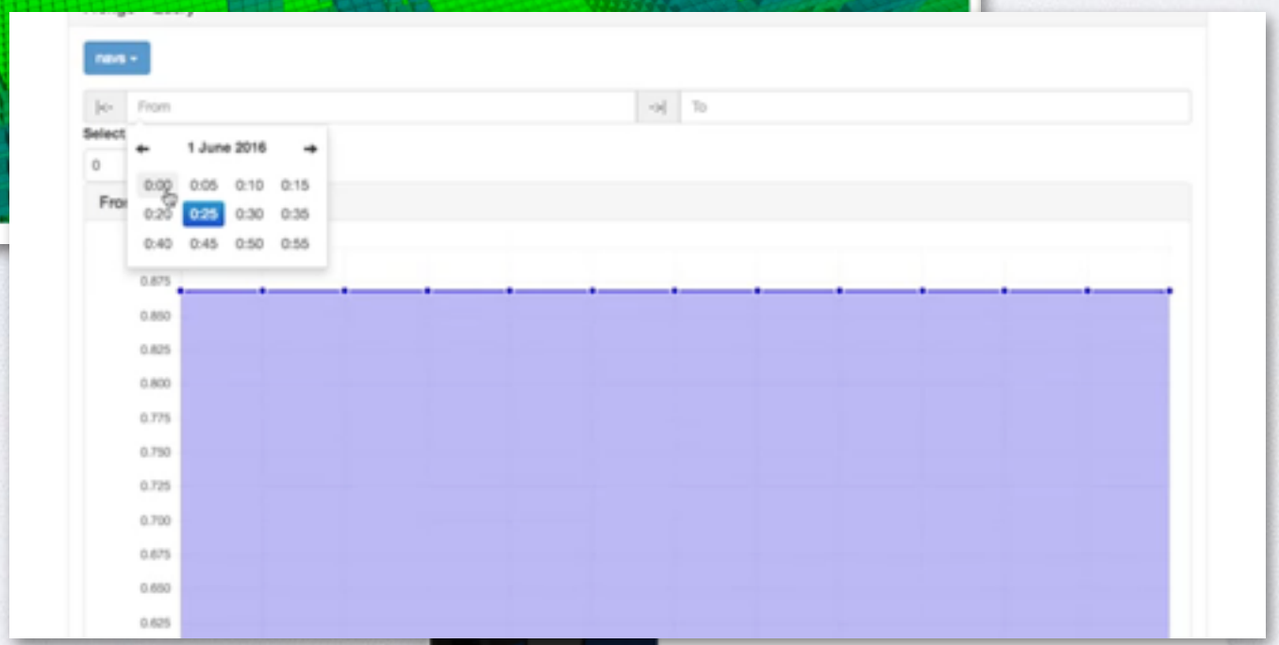
Indeed, our current model also takes recency into account

FREQUENCY MAP ENHANCEMENT

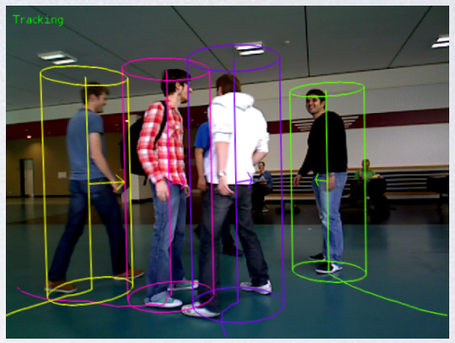


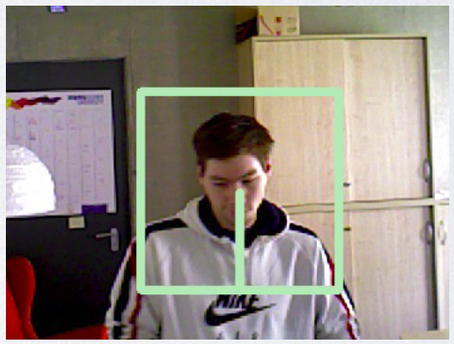
STATES?

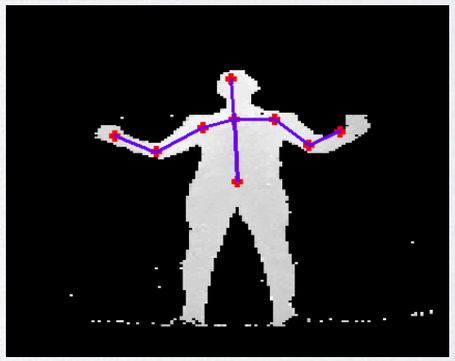




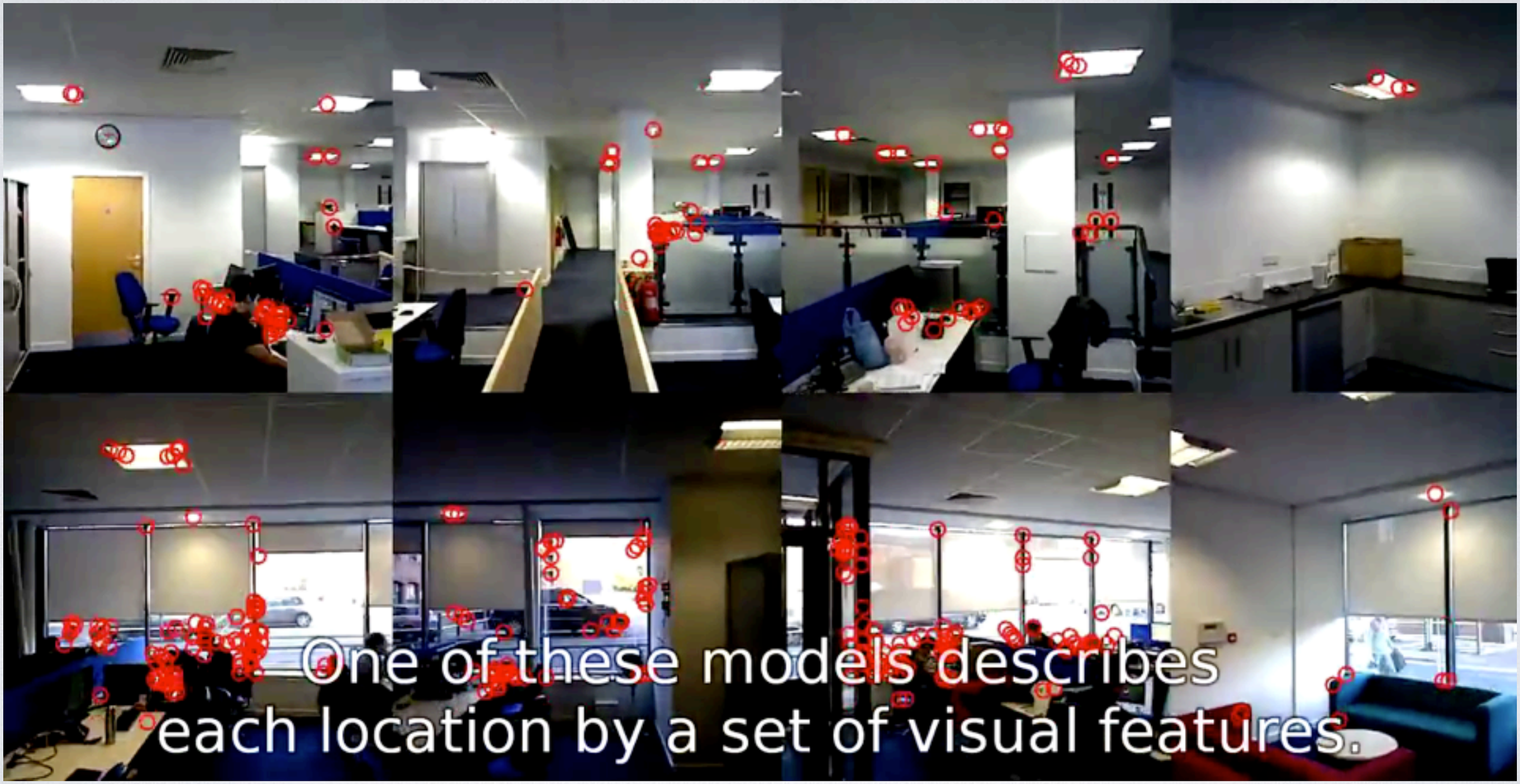
$$scene(Monitor, Keyboard, Laptop, Cup, Bottle) \Leftrightarrow$$
$$in\text{-}front\text{-}of(Keyboard, Monitor) \wedge$$
$$left\text{-}of(Laptop, Keyboard) \wedge$$
$$right\text{-}of(Cup, Keyboard) \wedge$$
$$behind\text{-}of(Bottle, Cup) \wedge$$
$$close\text{-}to(Bottle, Cup).$$







VISUAL TOPOLOGICAL LOCALISATION



["Long-Term Topological Localisation for Service Robots in Dynamic Environments using Spectral Maps" that will be presented at IEEE/RSJ International Conference on Intelligent Robots and Systems 2014]

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A FEW RESULTS

TABLE I

OVERALL LOCALIZATION ERROR (%)

1 week prediction

3 months prediction

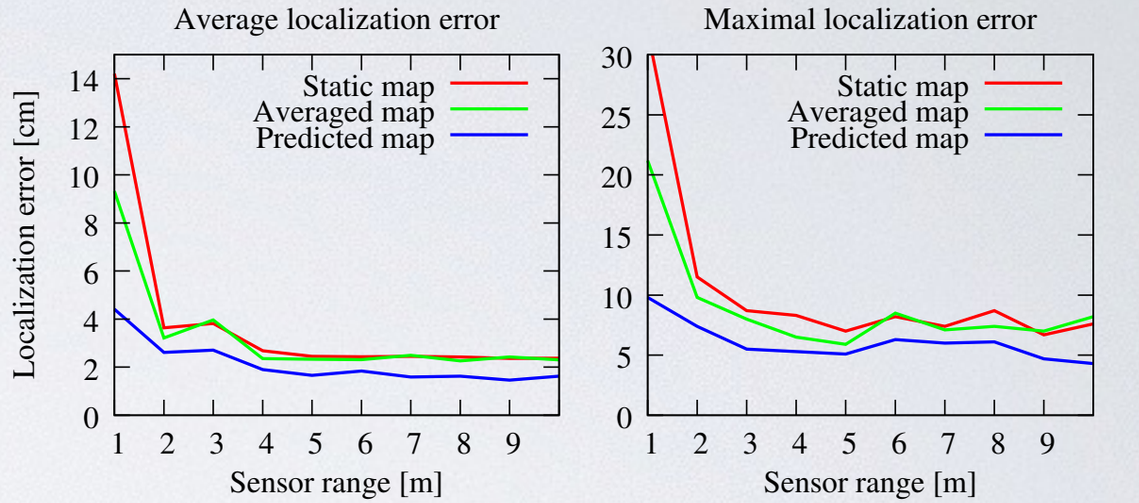
Model type	Model order	Image features		Occupancy grids	
		Nov	Feb	Nov	Feb
static	-	35%	45%	21%	17%
spectral	1	25%	26%	14%	13%
spectral	2	22%	27%	14%	8%
spectral	3	18%	24%	14%	17%
spectral	4	17%	29%	7%	17%

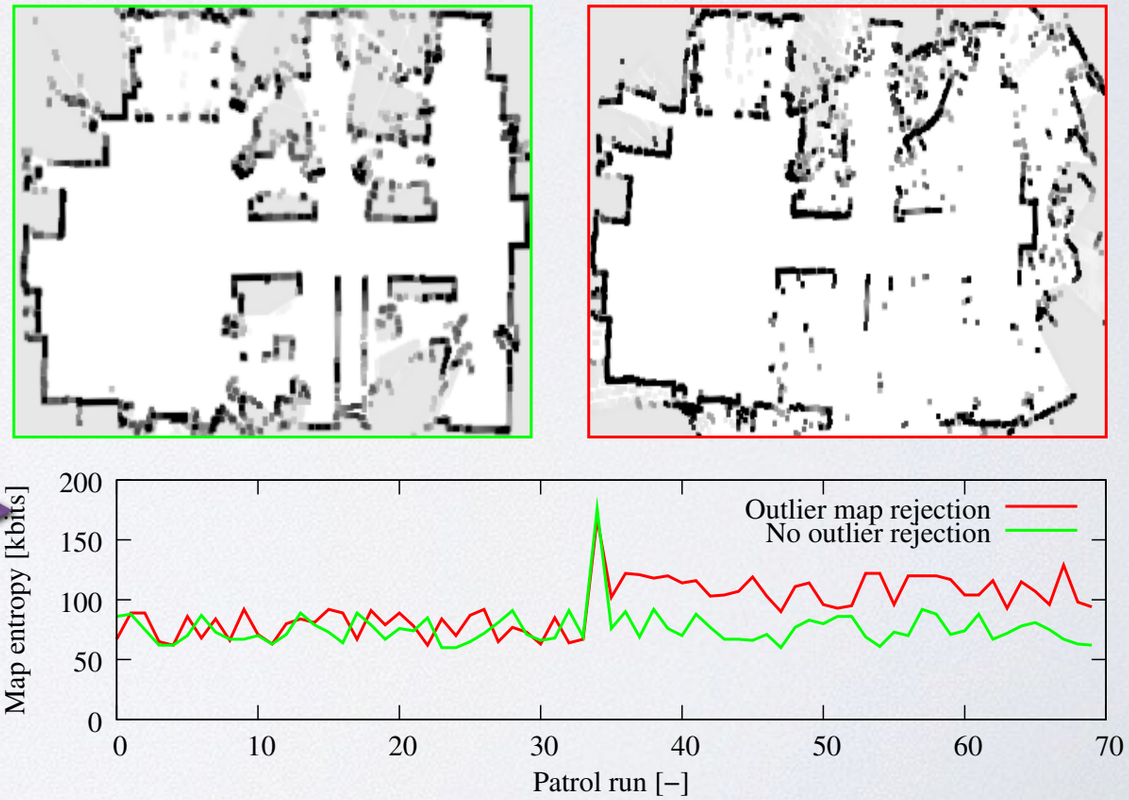
[Krajnic et al "Long-Term Topological Localisation for Service Robots in Dynamic Environments using Spectral Maps", IEEE/RSJ International Conference on Intelligent Robots and Systems 2014]

PREDICT 2D GRID MAPS

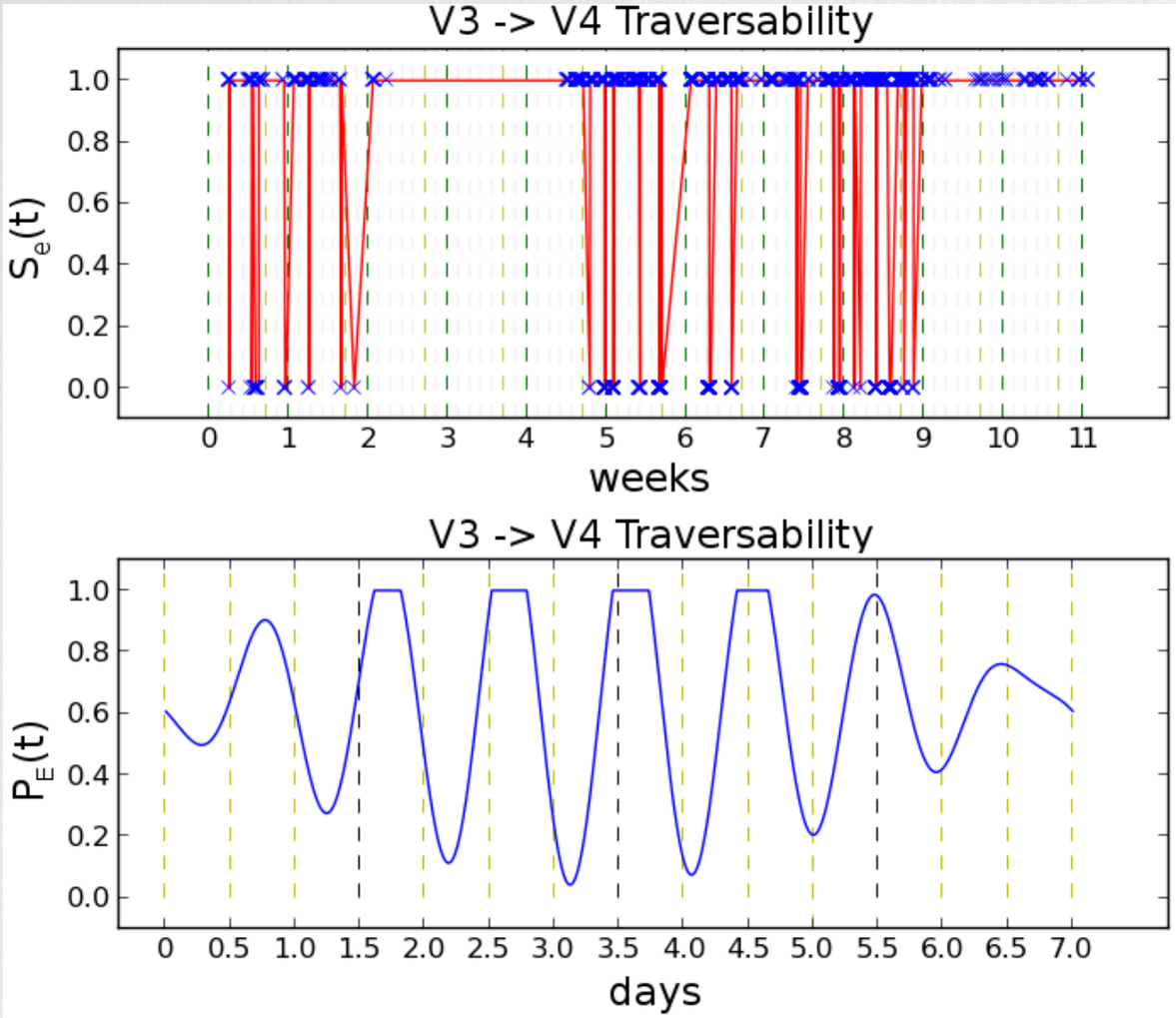
- better accuracy and robustness in localisation

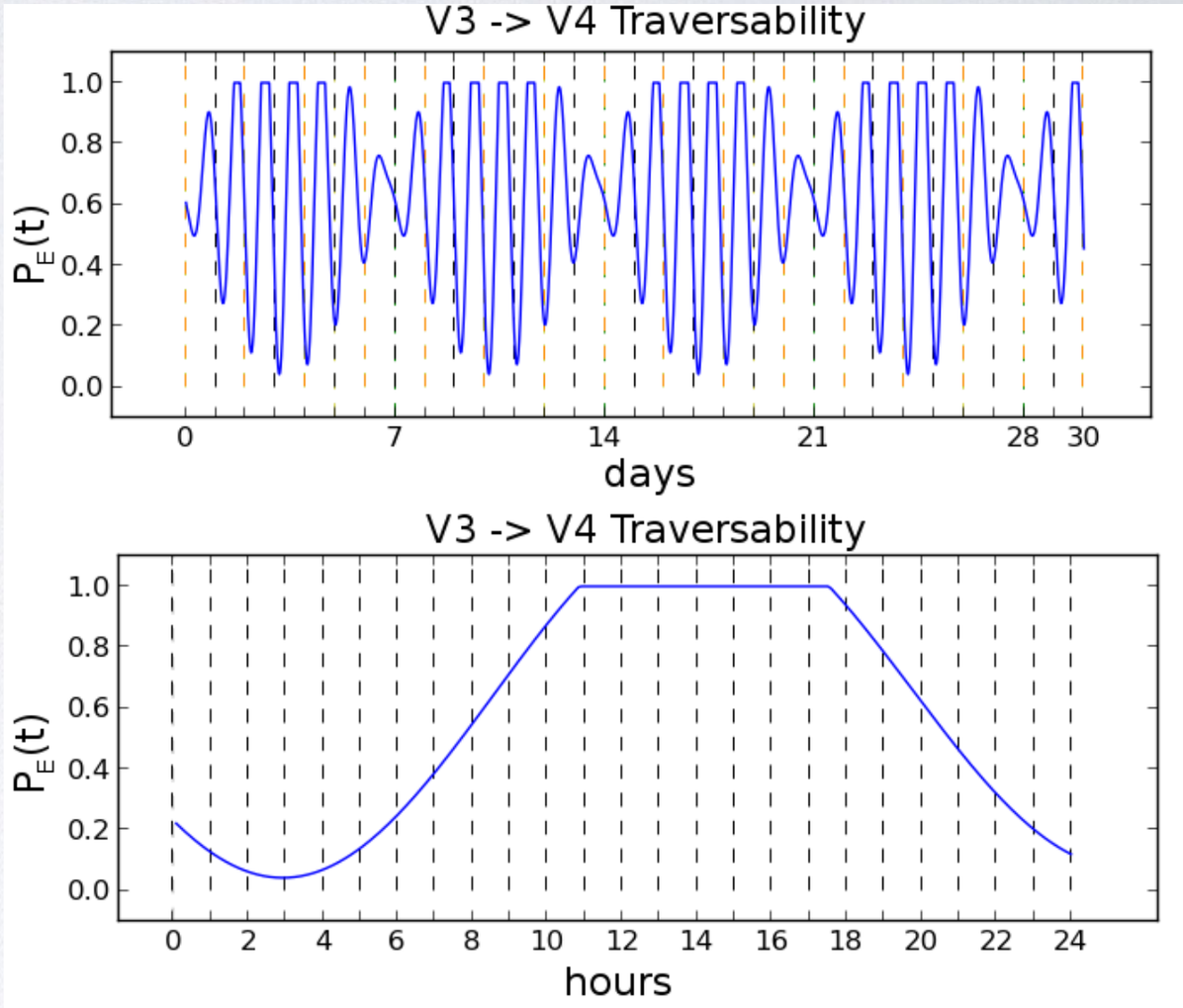
IROS 2016:
Persistent Localization and Life-Long Mapping in Changing Environments Using the Frequency Map Enhancement





TOPOLOGICAL EDGE TRAVERSABILITY MODELLING USING FREMEN





J. Pulido Fentanes, B. Lacerda, T. Krajník, N. Hawes, and M. Hanheide. Now or later? predicting and maximising success of navigation actions from long-term experience. In ICRA, 2015.

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FRONGO LIVE: NAV STATS

FRONGO OFFLINE

Frongo - Query

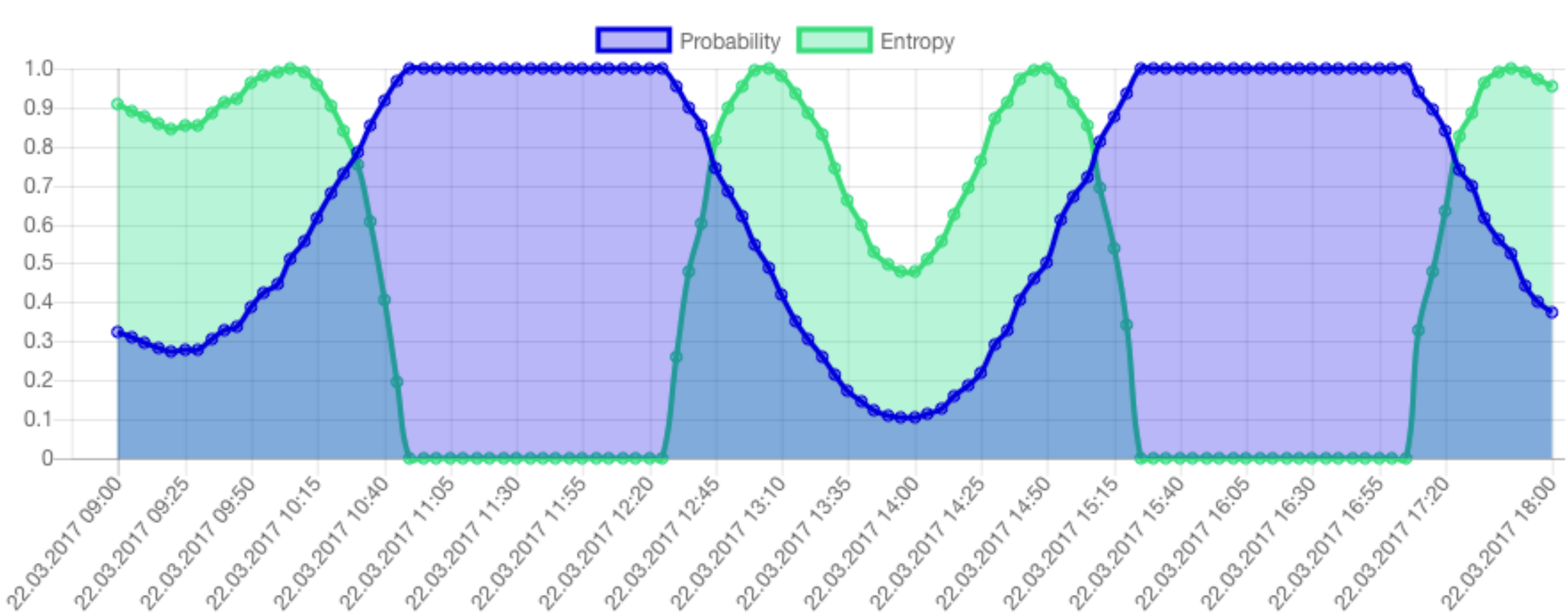
navs_erf

|<- 22.03.2017 09:00 ->| 22.03.2017 18:00

Select Order

2

Frongo Predictions



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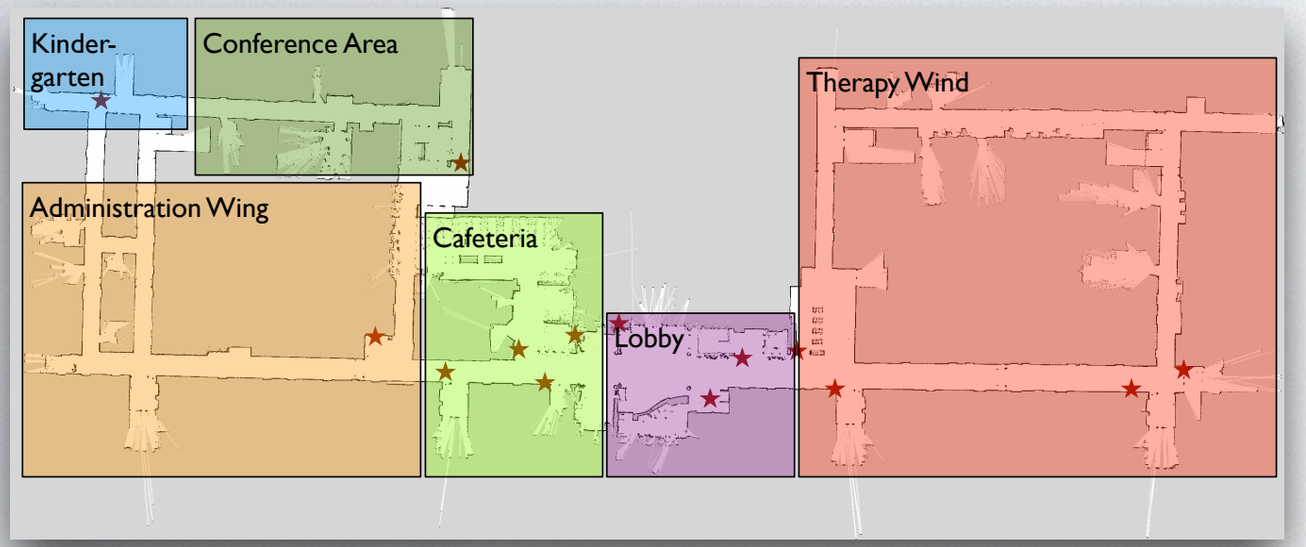
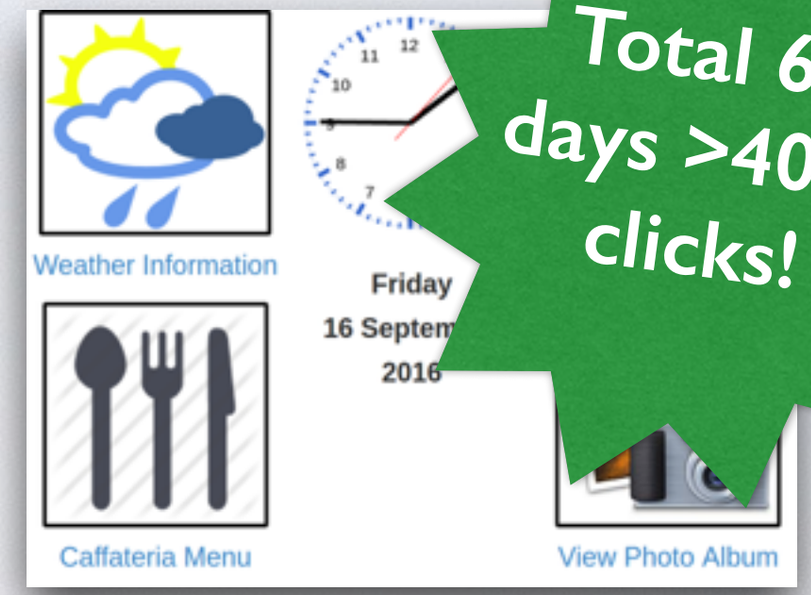
ADAPTIVE INFO-TERMINAL



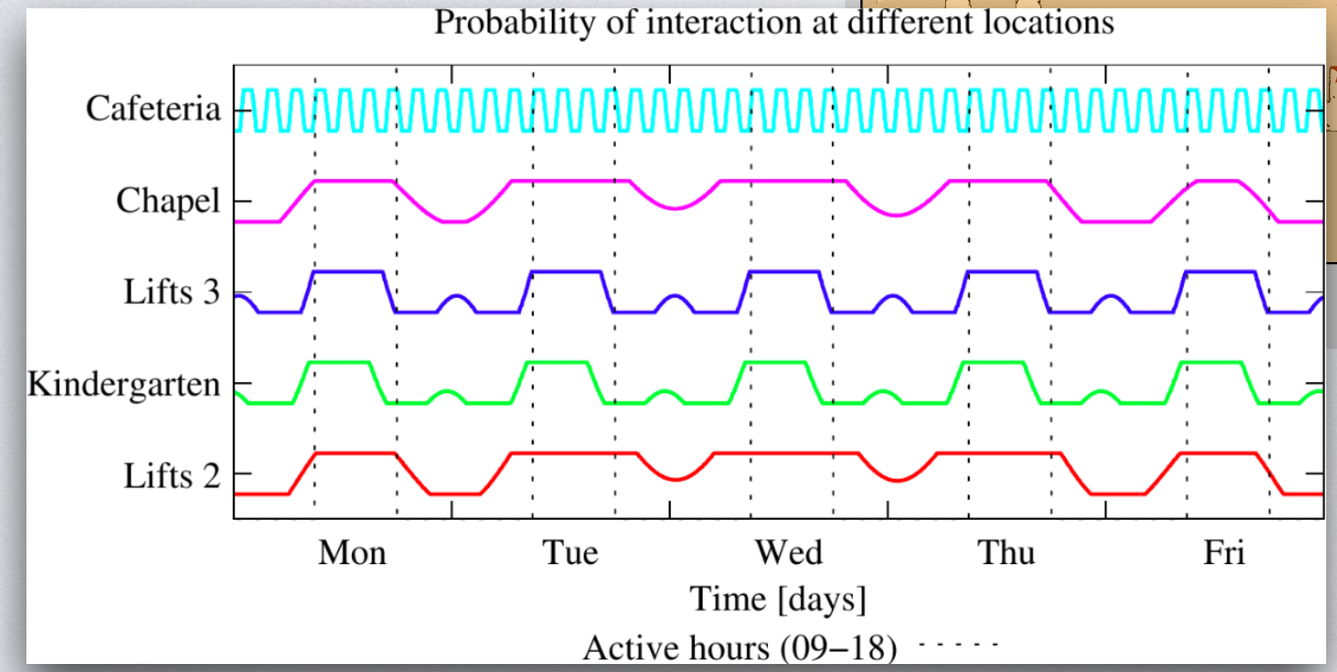


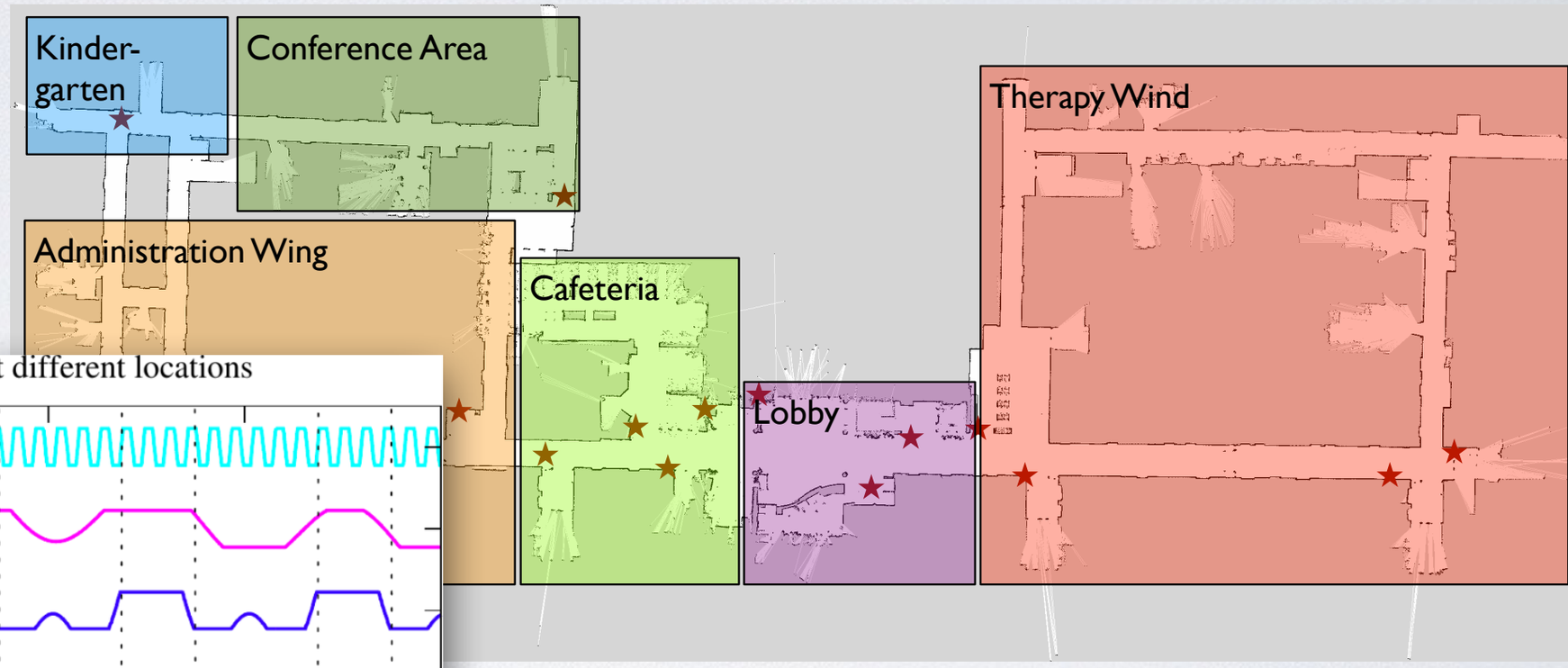
Total 63 days >4000 clicks!

- data recorded:
  - **where** is the robot **when**?
  - **did** people use the robot where it was? (success!)

l t $a_l(t)$

SPATIO-TEMPORAL MODELLING





l t → Frequency Map Enhancement „FreMEn“ → $a_l(t)$

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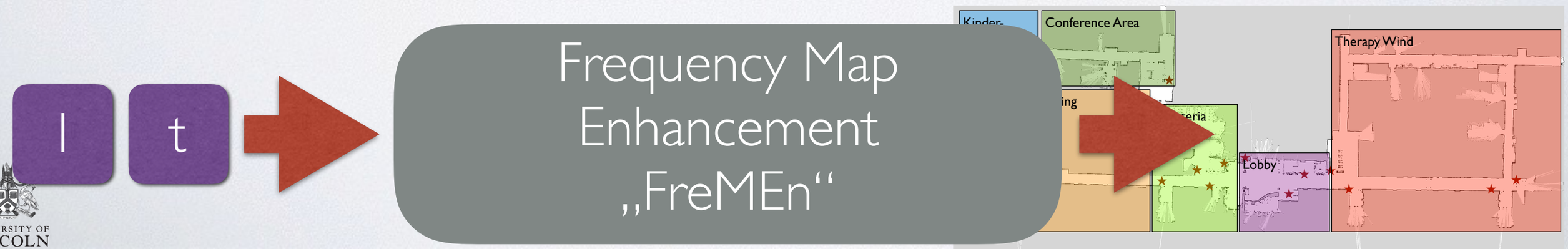
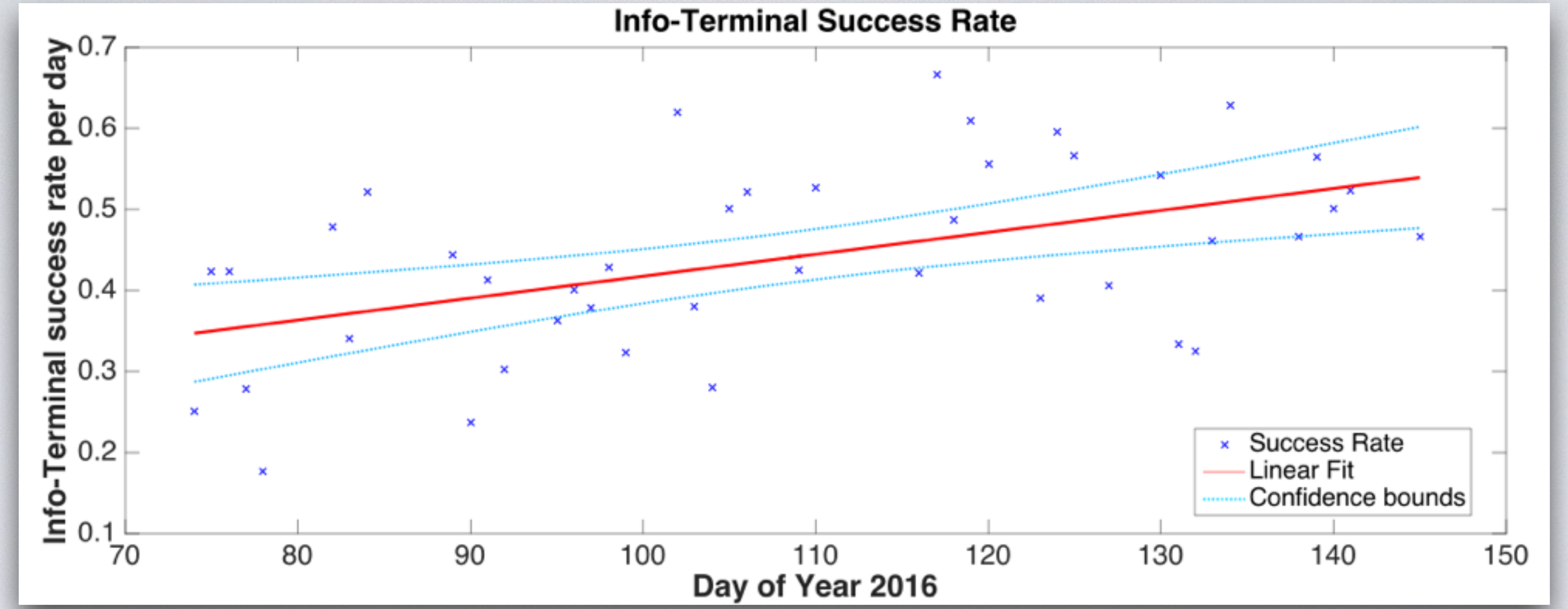
CHOOSING THE NEXT LOCATION

- predicted utility of a location *l*: $u_l(t) = \epsilon\, h(p_l(t)) + (1-\epsilon)\, p_l(t)$
- use utility to sample next location to go, greedily, new place every 10 minutes

- Here we set ***ε=0.5*** (exploration-exploitation ratio)
- start with $p_l(t) = 0.5$ at the beginning
- more on exploitation-exploration and planning horizons in
  Kulich, M., Krajnik, T., Preucil, L., and Duckett, T. To explore or to exploit? Learning humans' behaviour to maximize interactions with them. In Proceedings of the Workshop on Modelling and Simulation for Autonomous Systems (MESAS)



MORE AND MORE INTERACTIONS



- Linear regression on average success rates per day.
- rejection of H0 (constant number of interactions) with $p=0.000674$.

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FRONGO LIVE: INTERACTIONS

FRONGO OFFLINE

Frongo - Query

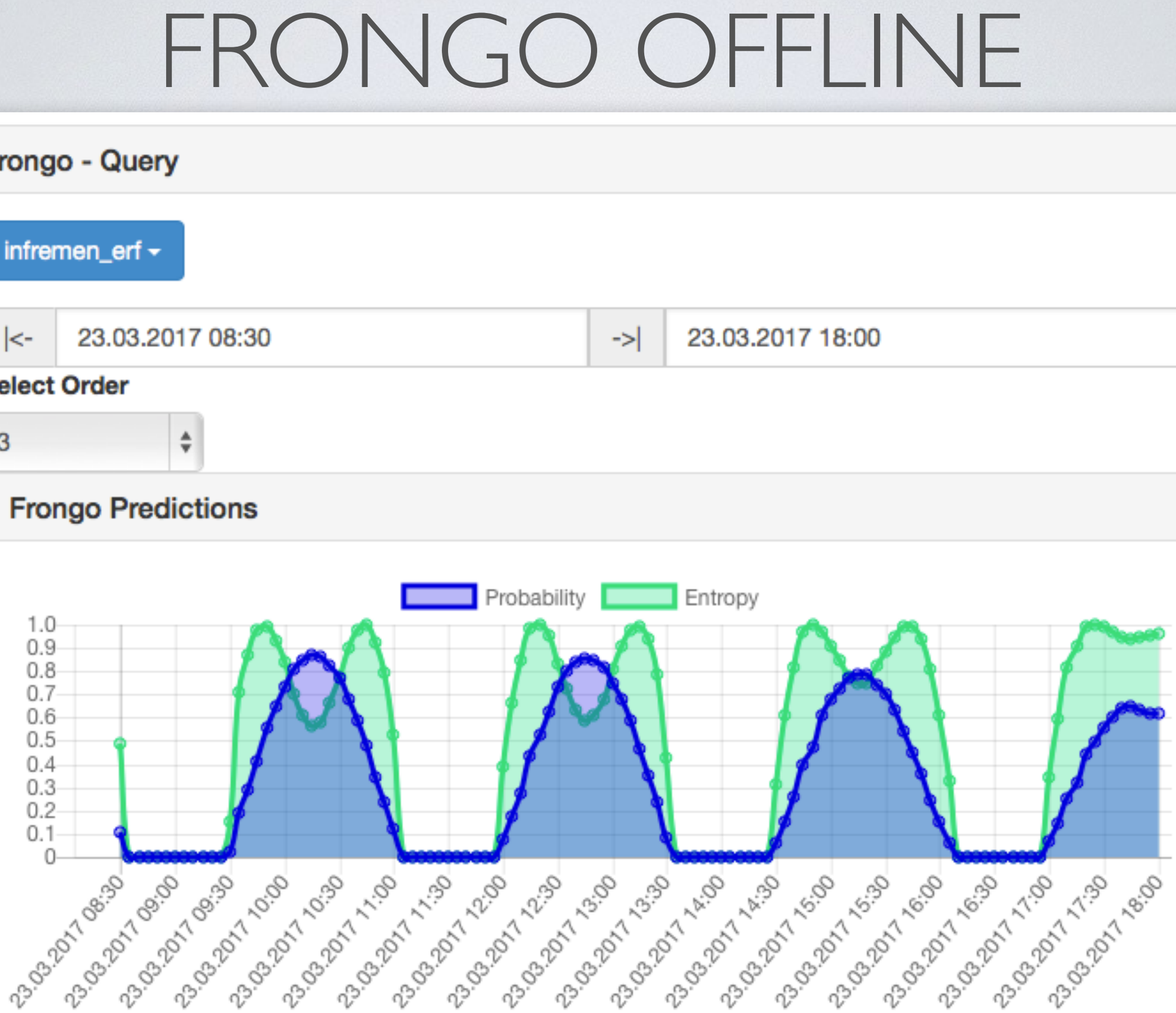
infremen_erf

|<- 23.03.2017 08:30 ->| 23.03.2017 18:00

Select Order

3

Frongo Predictions



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Embrace the Change: Prospects and Challenges of Long-term Autonomy and Interaction

Robots do fail: (interactive) Recovery behaviours are needed

Learning **routines** can help building more effective and efficient systems, spectral models are very powerful to improve long-term navigation.

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http://fremen.uk

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