IEEE/RSJ International Conference on Intelligent Robots and Systems

ADAPTIVE LONG-TERM AUTONOMY

EMPOWERING END-USERS OF AUTONOMOUS SYSTEMS

Marc Hanheide

Lincoln Centre for Autonomous System

UNIVERSITY OF LINCOLN

marc@hanheide.net

@MarcHanheide

L-CAS

SHARED AUTONOMY

Shared Autonomy

- an overarching concept
- "shared control"
- anything between (remote-)controlled and fully autonomous

"[…] In practice, […] automation is not perfectly reliable and is usually not designed to reach the defined objectives alone, human supervision is still mandatory" (Mercier et al, 2008)

Symbiotic Autonomy

- should be for mutual benefit
- human and robot helping each other

The CoBots navigate through the environment unchaperoned and largely unmonitored. The robots exhibit *symbiotic autonomy*; they autonomously seek human assistance to perform tasks that involve manipulation, because the CoBots do not have arms.[11–13] A robot's

Joydeep Biswas & Manuela Veloso, CMU

ADAPTIVE AUTONOMY?

Shared Autonomy

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- "shared control"
- anything between (remote-)controlled and fully autonomous

Symbiotic Autonomy

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- human and robot helping each other

Adaptive Autonomy

- improve autonomous behaviour from past experience/human autonomy
- adjust levels of autonomy

action execution Autonomy (3)

goal selection Autonomy (1)

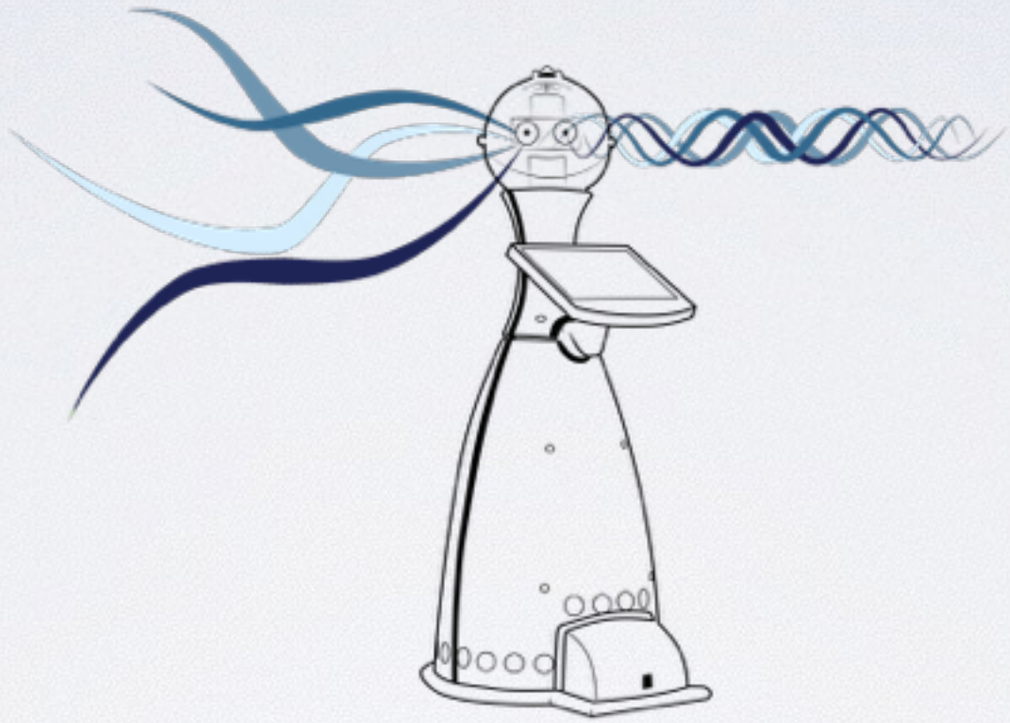
Shared Autonomy

- an overarching concept
- "shared control"
- anything between (remote-)controlled and fully autonomous

Robust, intelligent, autonomous behaviour

Symbiotic Autonomy

- should be for mutual benefit
- human and robot helping each other



Exploitation of structure for improved performance

Long run-times in everyday environments

Adaptive Autonomy

- improve autonomous behaviour from past experience/human autonomy
- adjust levels of autonomy

Novel opportunities to learn structure

Adaptive Autonomy

Increasing spatial, temporal, and semantic abstraction

Planning

User Requirements

Task Scheduling

Navigation Planning

Exploration Planning

Modelling

Robot Navigation Models

Human Movement Models

Human-Object Activity Models

Metric Spatio-Temporal (4D) Maps

Semantic Spatio-Temporal World Model

Meta-Room

Topological Map

Trajectories

Skeletons

Object instances

Object categories

2D/3D maps

Aggregation

Navigation Experience

People

3D features

Observations

Point Clouds, Images, Laser scans

Sensing

Do what users want in the way the want it

Robust, intelligent, autonomous behaviour

running for weeks

Exploitation of structure for improved performance

Long run-times in everyday environments

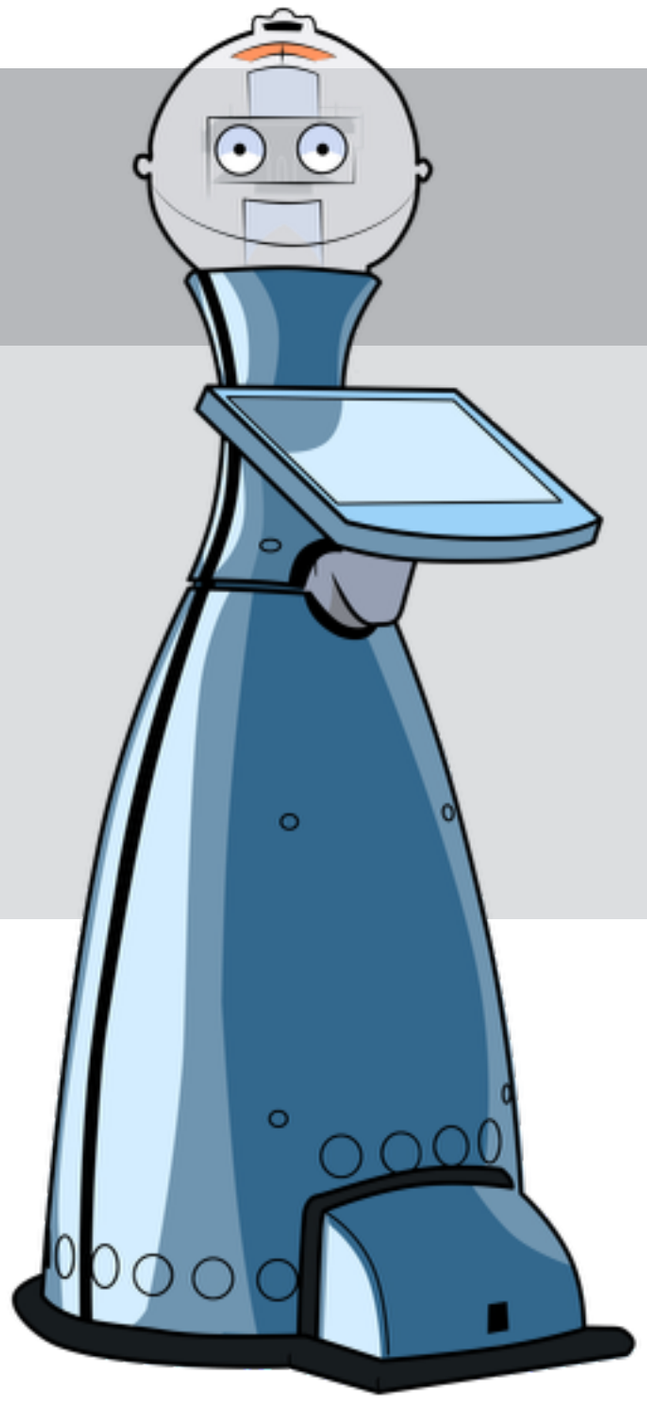
exploration!

Novel opportunities to learn structure

learn how the world changes and what users want

Year	MS	TSL	A%	Size	Tasks
3	MS8	60 days	30%	2000m^3	Security Task 2 (T4.2), Care Task 1 (T3.6), Care Task 2 (T6.2)

This milestone will see the addition of **attention and motivation mechanisms** for the robot **based on variations from predictable temporal and spatial structure** in the previously built representations, detecting such variations during patrols and autonomously examining them. In addition to this, **object and person tracking will be used to allow the system to track objects as they are manipulated by humans** and **learn the categories of objects that people regularly interact** with. Navigation will be influenced by the **predicted dynamics of the environment**, allowing the robot to **reduce travel times** by a significant amount of time and **guide humans appropriately** (Care Task 2). In Security Task 2. **arrangements of furniture will be detected through a comparison with existing spatial models**, and **basic activity models will be used to predict, and then verify, the movement of people in the robot's environment**.



Representation & Analysis

MongoDB

QSRLib

FreMEn

Sem. Maps

Executive Control

Routine

Task Executor

Scheduler

Optimal Nav

Localisation & Navigation

Monitored

Topological

Continuous

Perception

Trajectories

Meta-Rooms

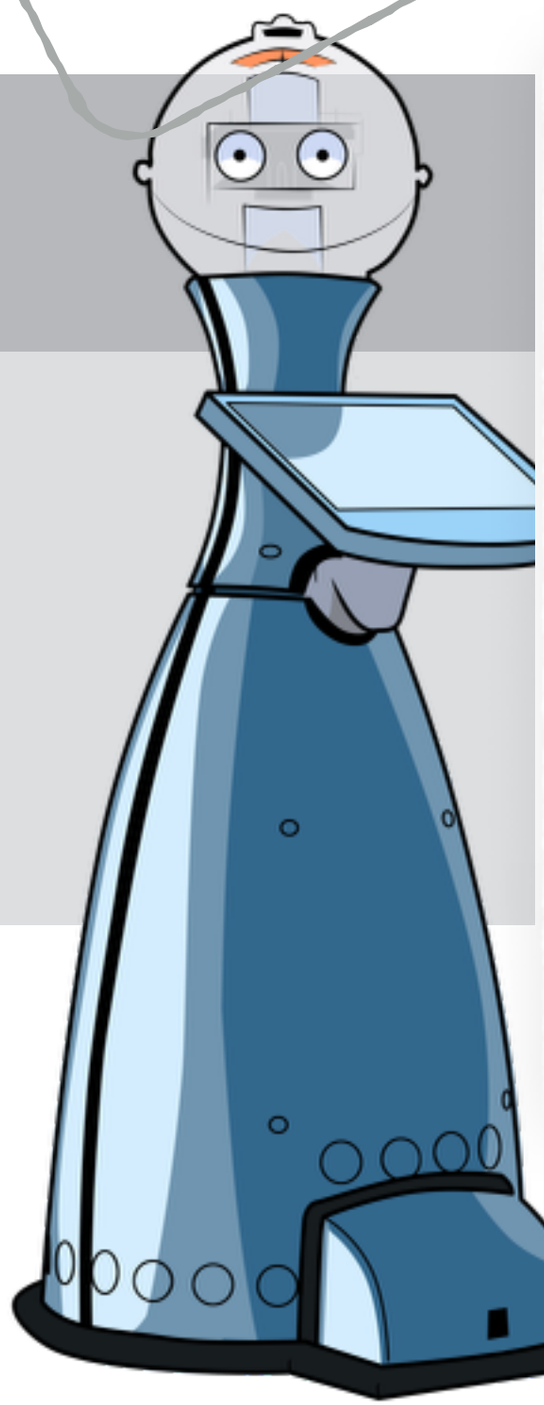
Person Detect

http://lncn.eu/strands

SEVENTH FRAMEWORK PROGRAMME

STRANDS

All Open Source & Binary Released



Representation & Analysis

MongoDB

QSRLib

FreMEn

Sem. Maps

Using the STRANDS repository

These steps are for a system administrator who wants to install STRANDS' release packages:

1. Enable the ROS repositories: Accomplish all the steps under `1. Installation` http://wiki.ros.org/indigo/Installation/Ubuntu#Installation.

2. Enable the STRANDS repositories:

   i. Add the STRANDS public key to verify packages:

   ```
   curl -s http://lcas.lincoln.ac.uk/repos/public.key | sudo apt-key add -
   ```

   ii. Add the STRANDS repository:

   ```
   sudo apt-add-repository http://lcas.lincoln.ac.uk/repos/release
   ```

3. update your index:

   ```
   sudo apt-get update
   ```

4. install any packages you want using `sudo apt-get install <pkg-name>`

Person Detect

http://lncn.eu/strands

SEVENTH FRAMEWORK PROGRAMME

STRANDS

Betty at
Transport Systems Catapult,
Milton Keynes, UK

Henry at
Haus der Barmherzigkeit,
Vienna, Austria

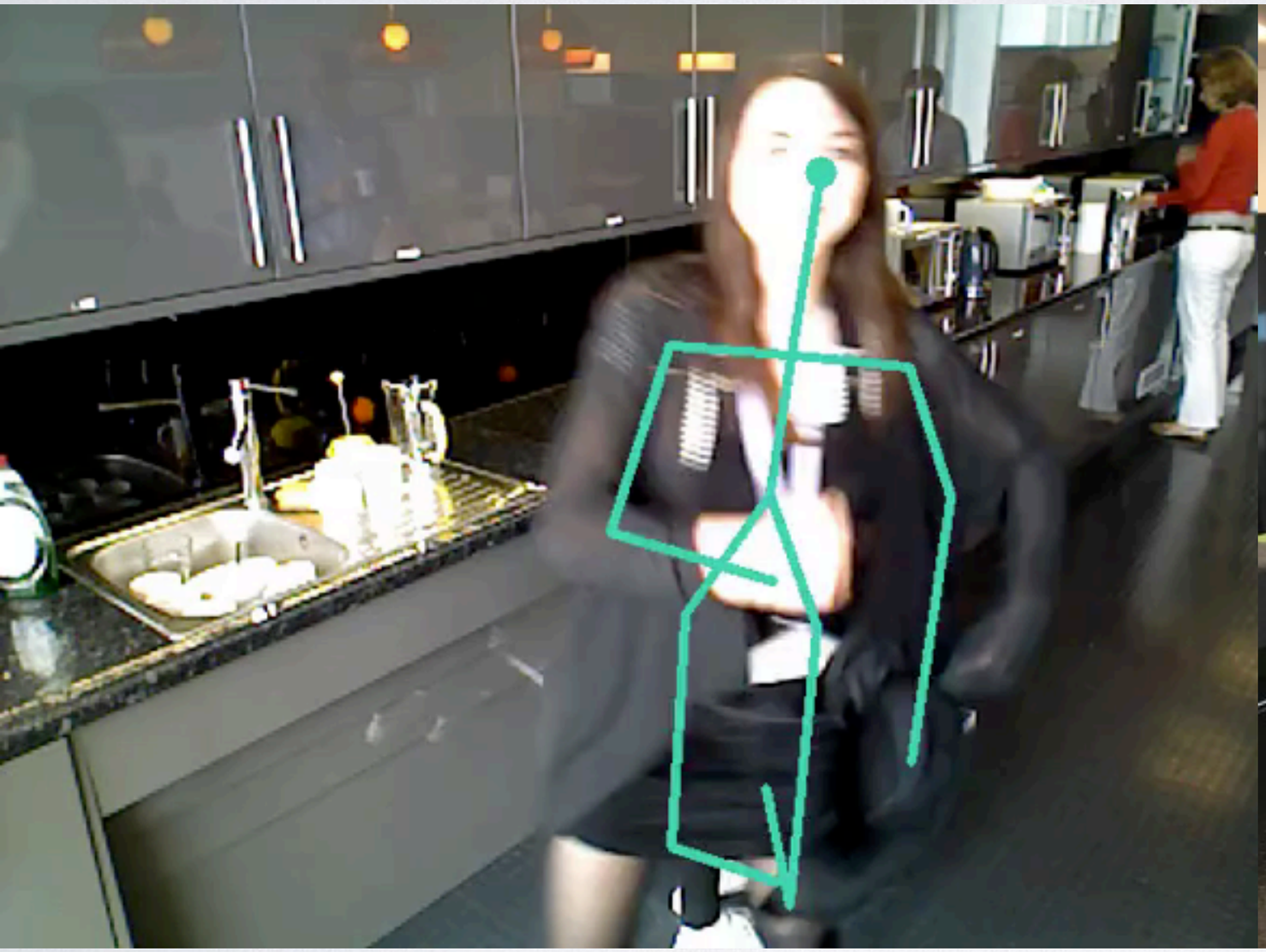
Symbiotic Autonomy

- should be for mutual benefit
- human and robot helping each other

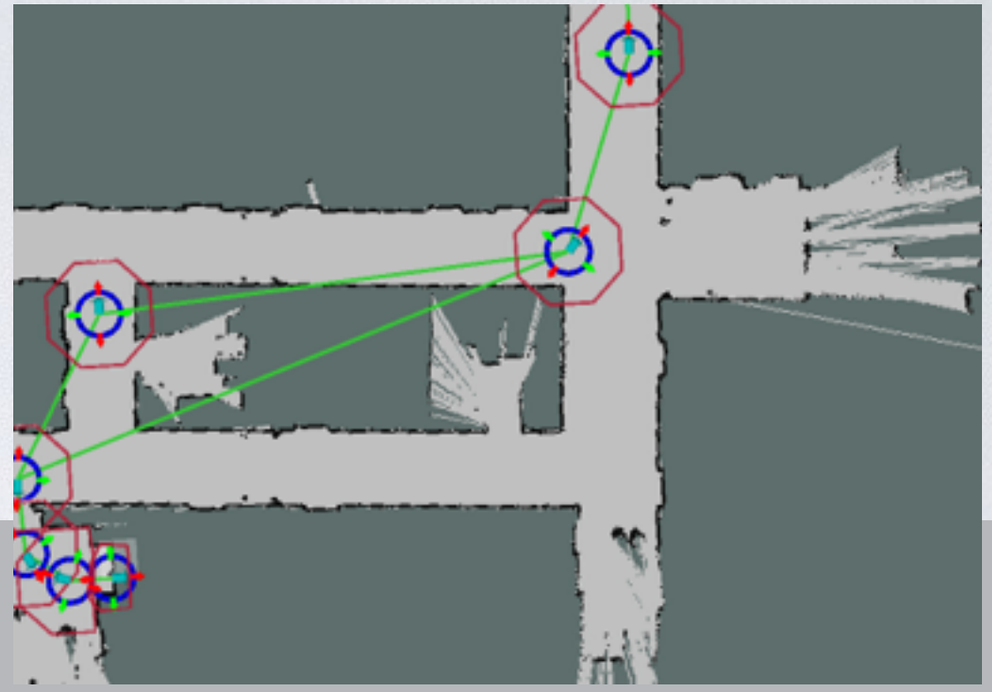
LONG-TERM AUTONOMY IN SECURITY

"[…] In practice, […] automation is not perfectly reliable and is usually not designed to reach the defined objectives alone, human supervision is still mandatory" (Mercier et al, 2008)

PEOPLE LOVE ROBOTS



SURFACE/WORKER CHECKING



Localisation
& Navigation

Optimal Nav

Monitored

Topological

Continuous

PEOPLE ARE HELPFUL TO ROBOTS

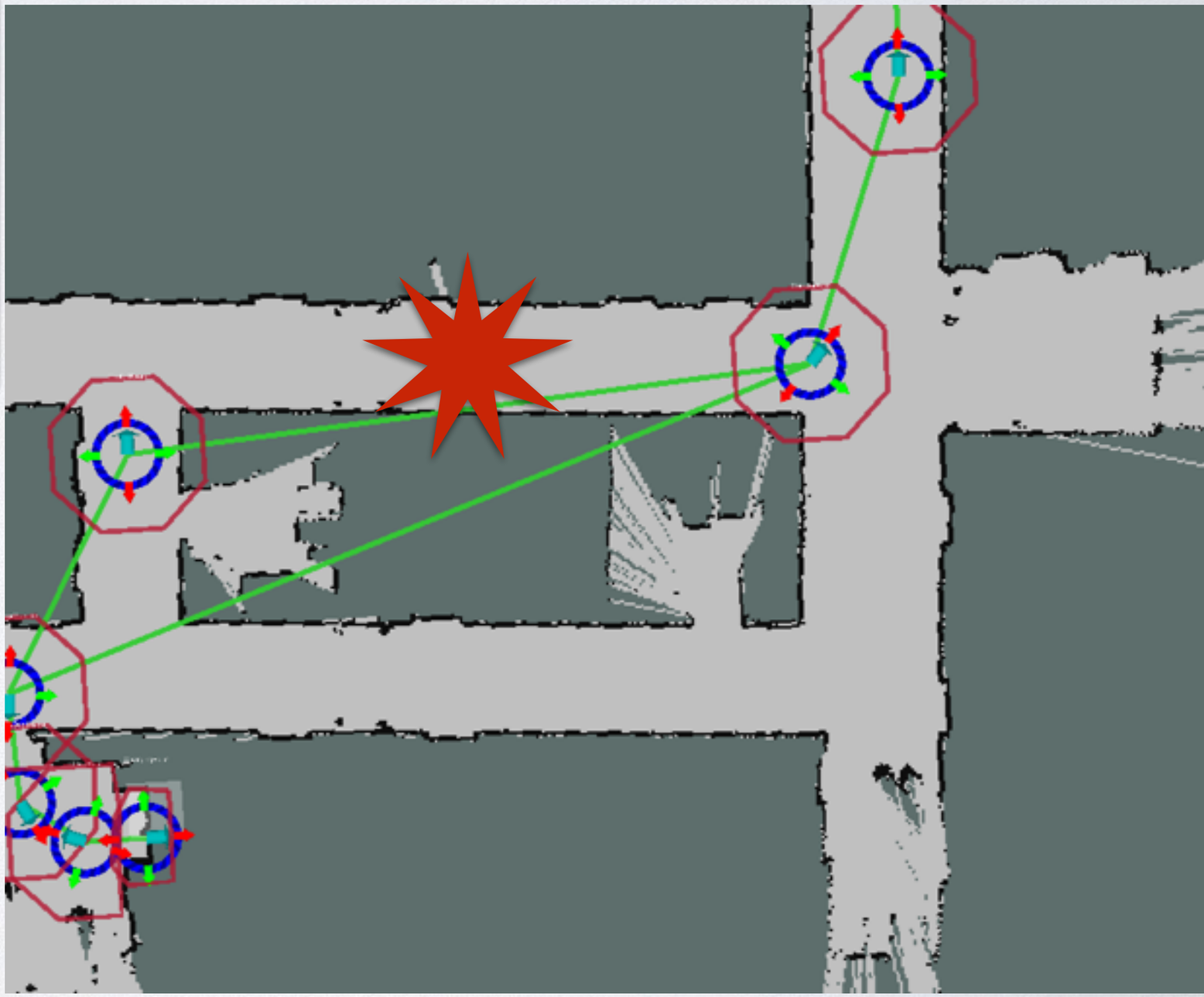
Symbiotic Autonomy

- should be for mutual benefit
- human and robot helping each other

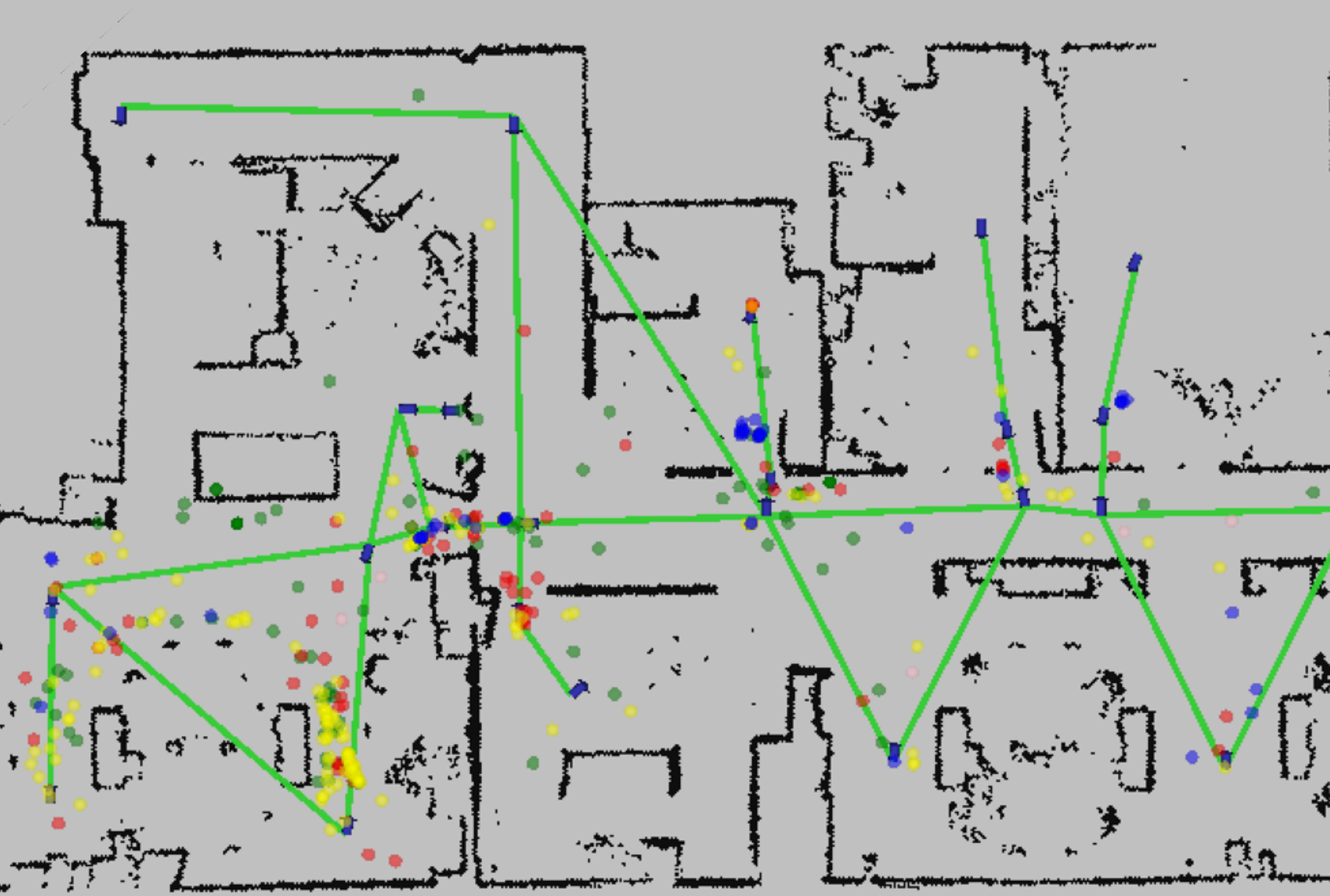
Monitored

Topological

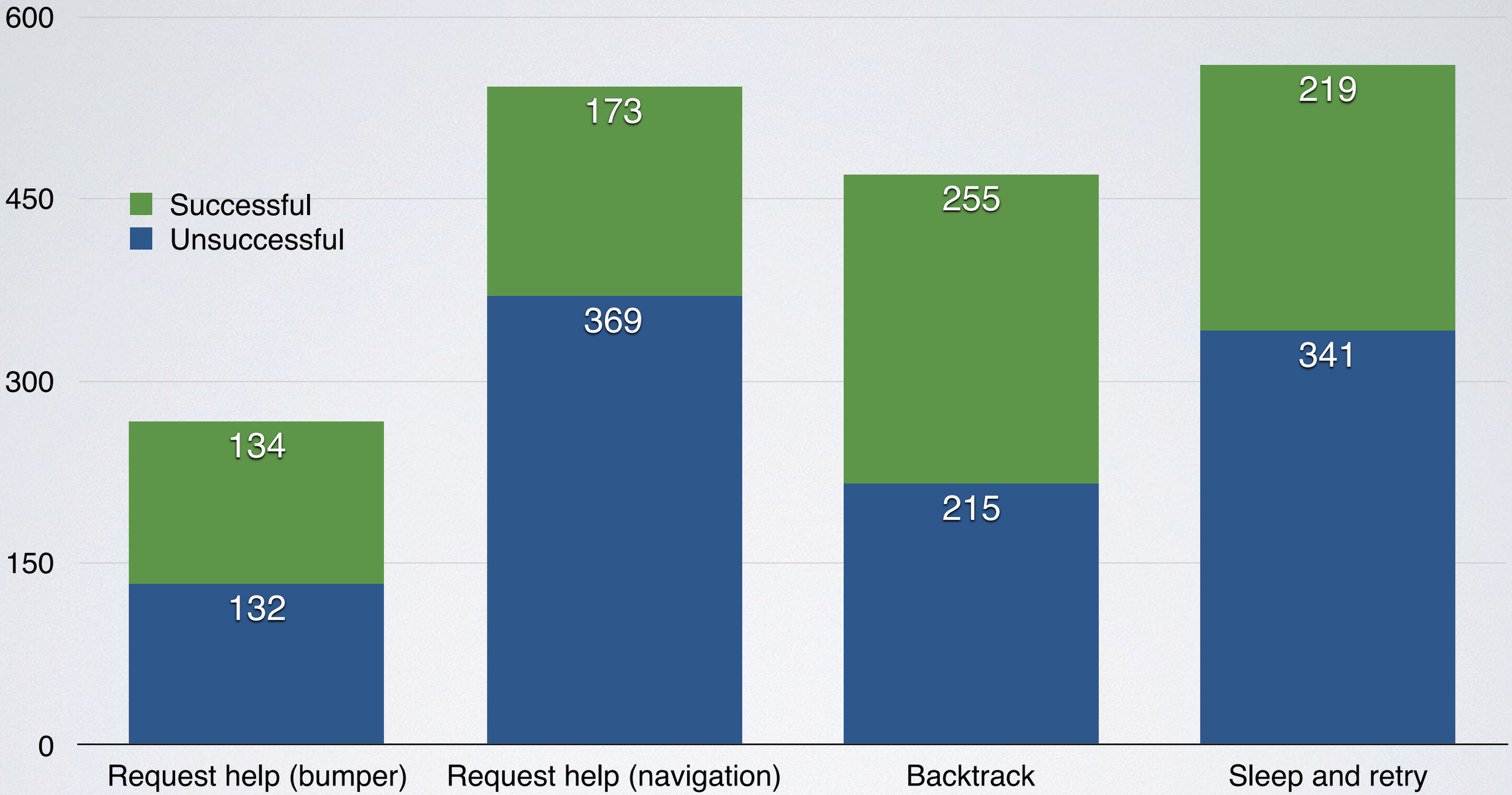
Continuous



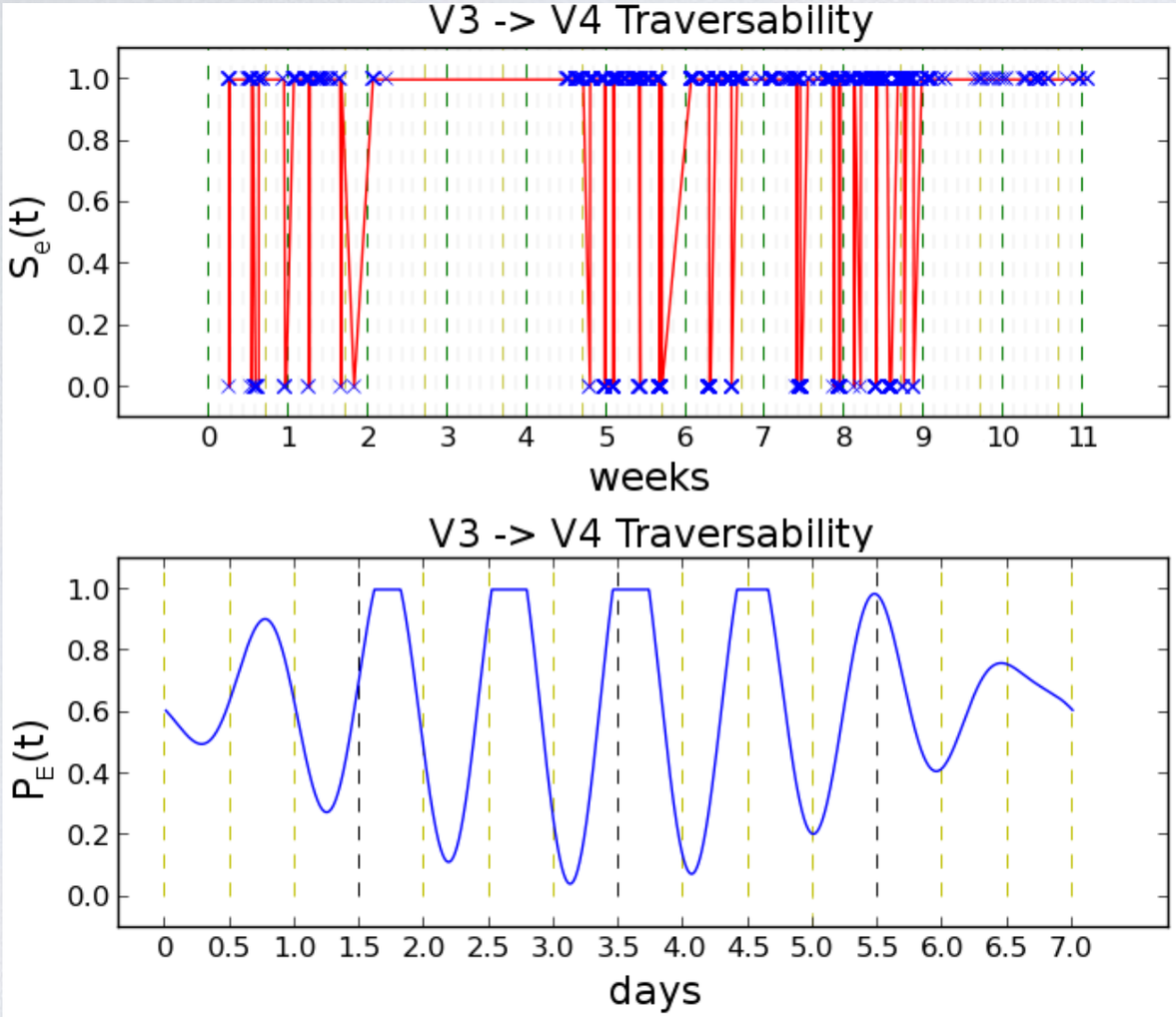
request help (bumper)
request help (nav)
backtrack
retry

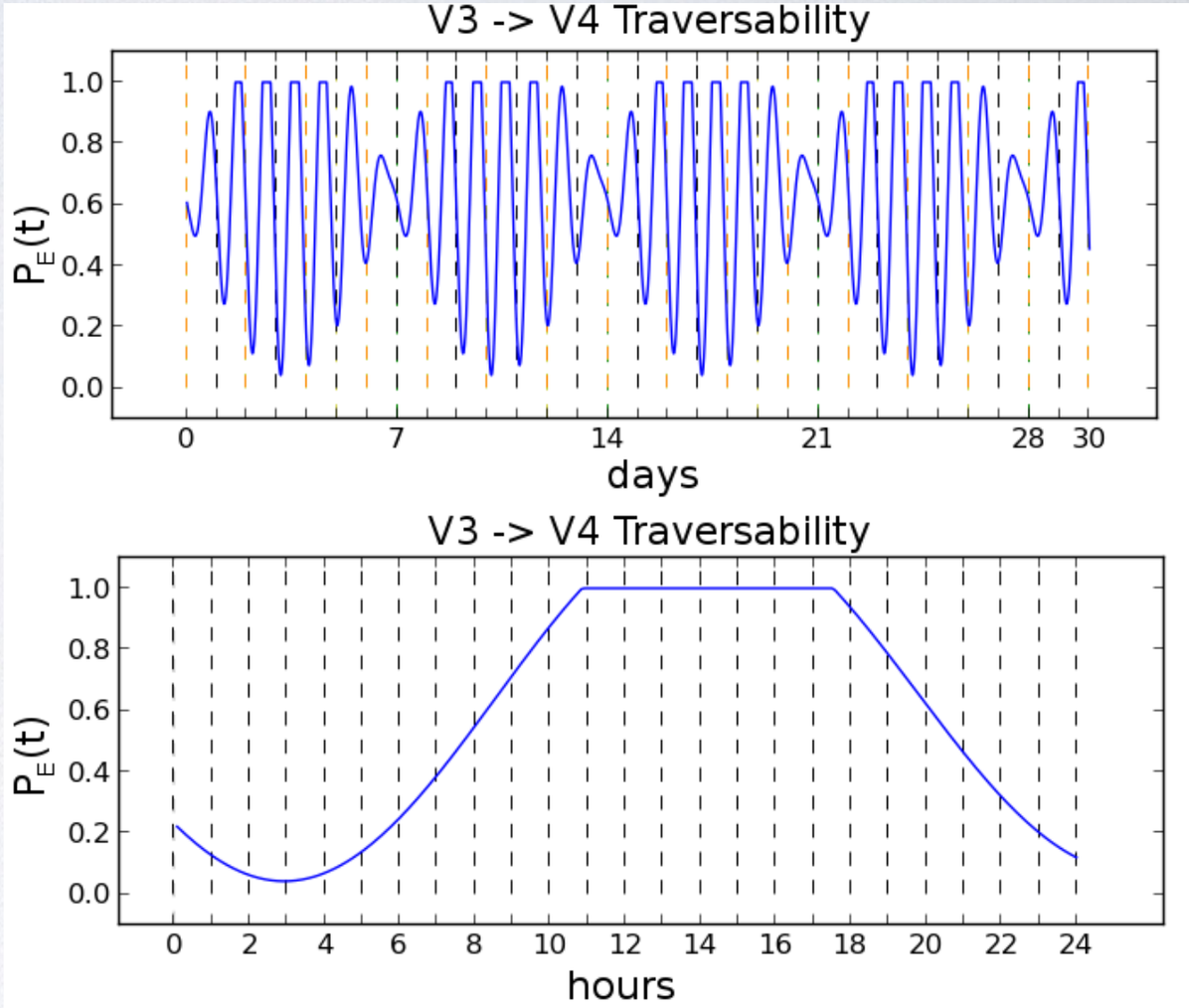


Security 2015 Monitored Navigation Recoveries



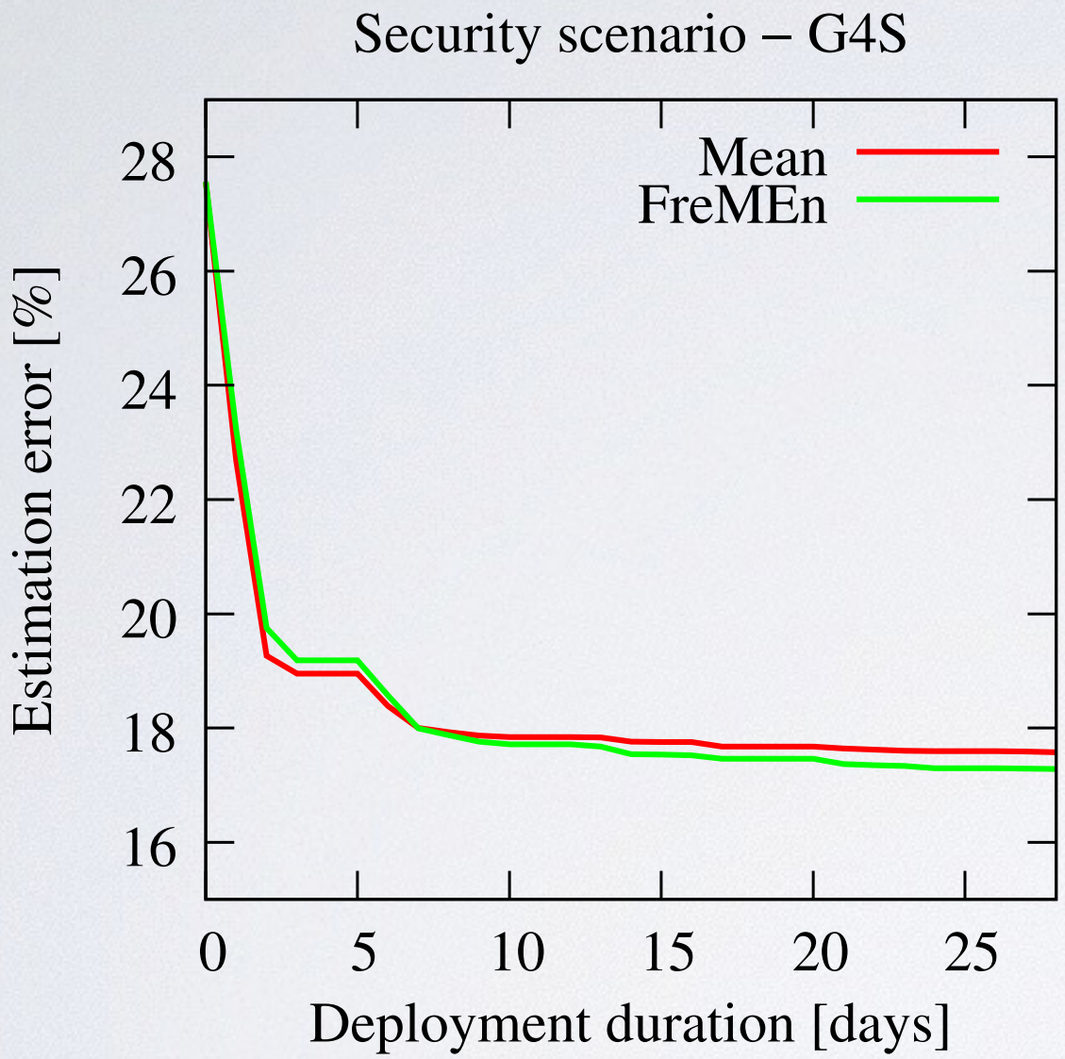
Topological Edge Traversability Modelling using **FreMEn**

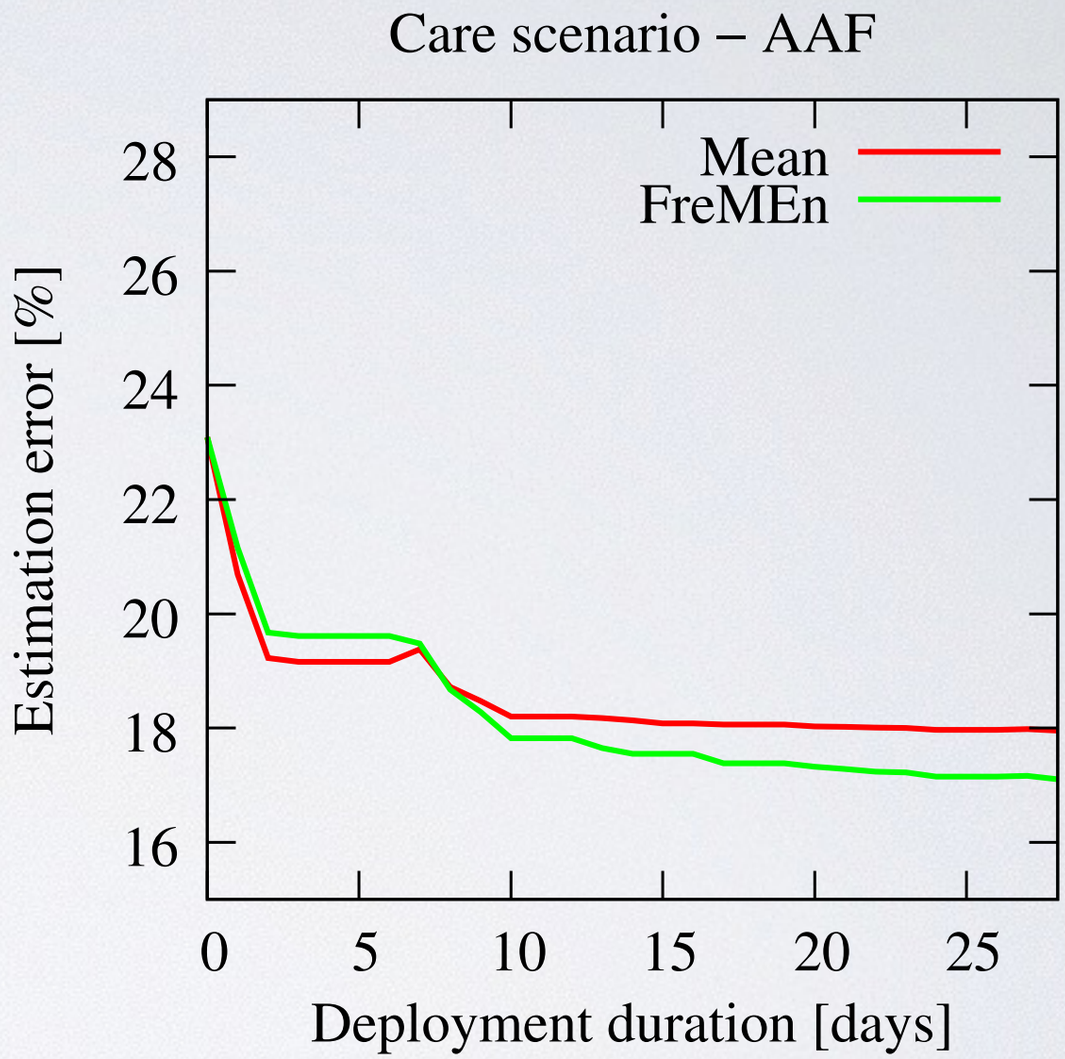




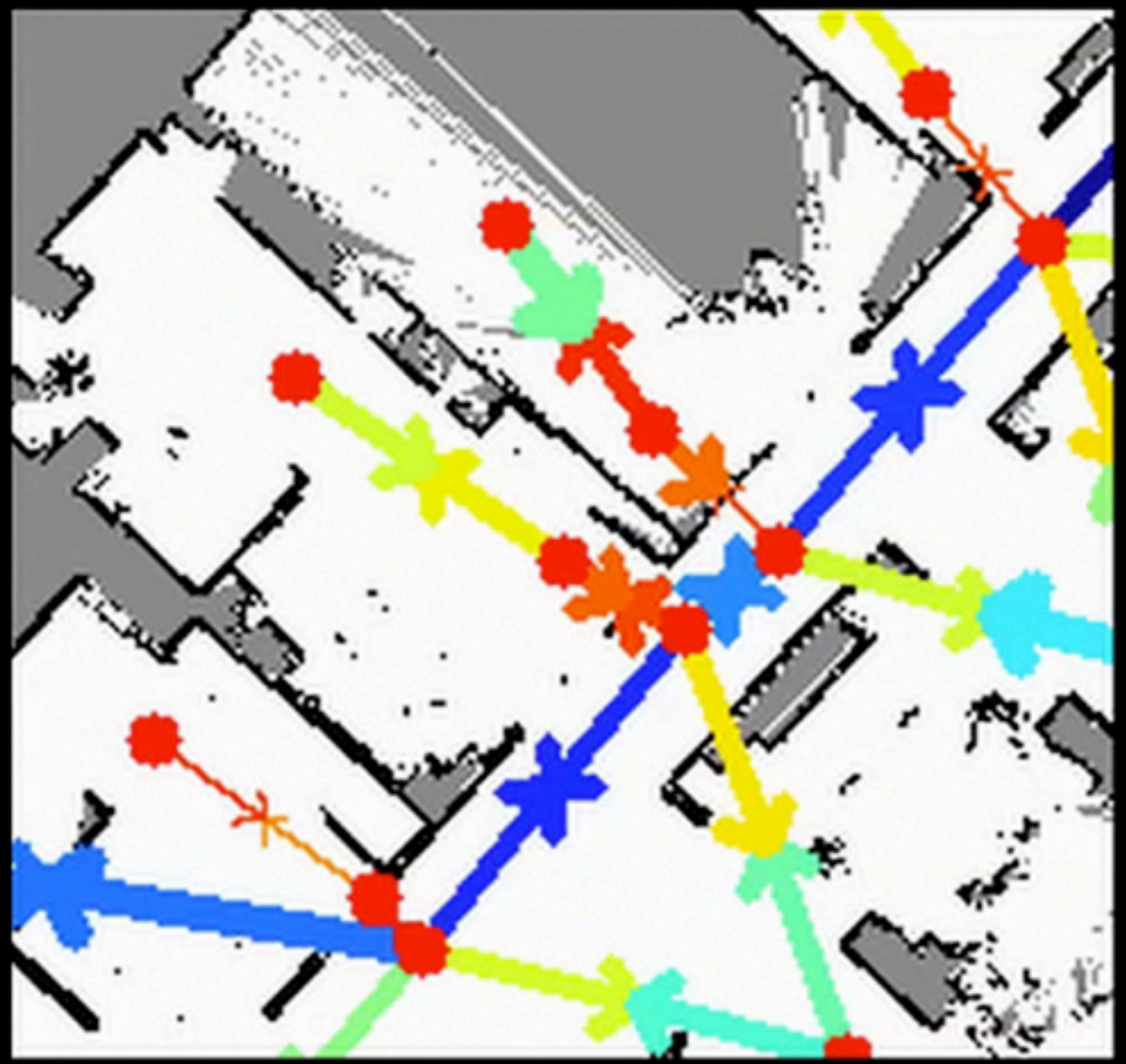
J. Pulido Fentanes, B. Lacerda, T. Krajník, N. Hawes, and M. Hanheide. Now or later? predicting and maximising success of navigation actions from long-term experience. In ICRA, 2015.

Topological Edge Duration Prediction



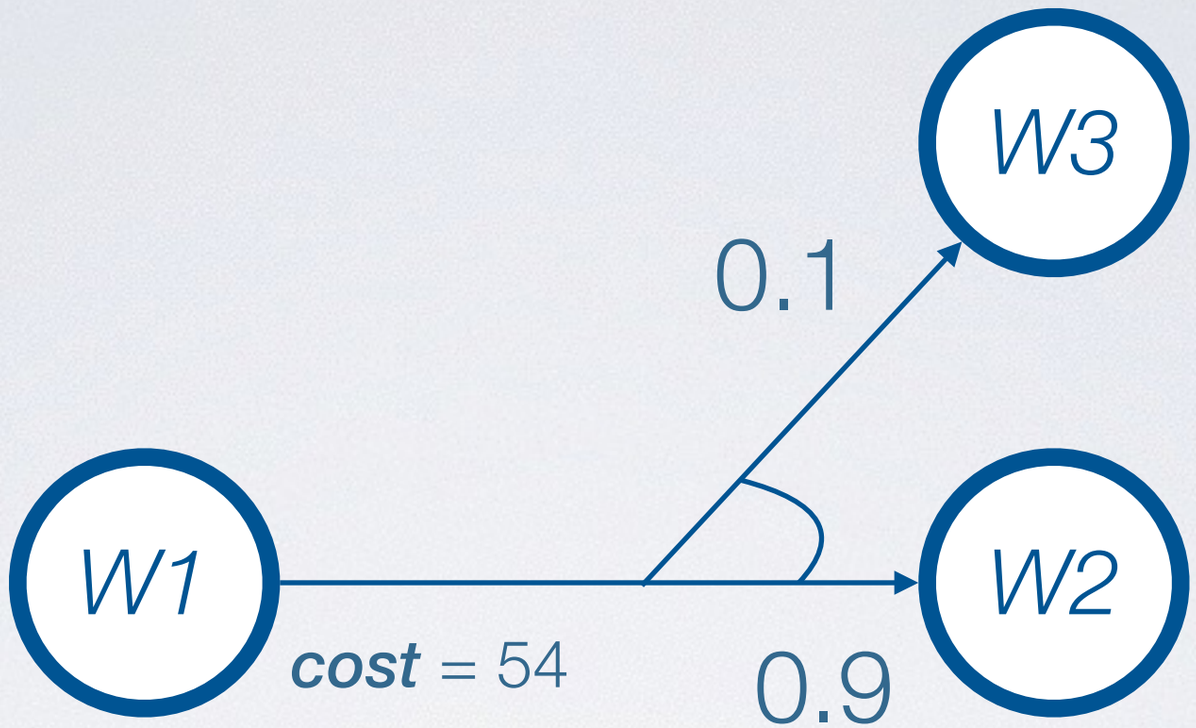


Sun 07 Jun 2015 01:00:00 (BST)



Predicted Speed (m/s)

0 0.5



action goto *W2* from *W1*

B. Lacerda, D. Parker, and N. Hawes. Optimal and Dynamic Planning for Markov Decision Processes with Co-Safe LTL Specifications. In: IROS 2014.

DOORS

Optimal Nav

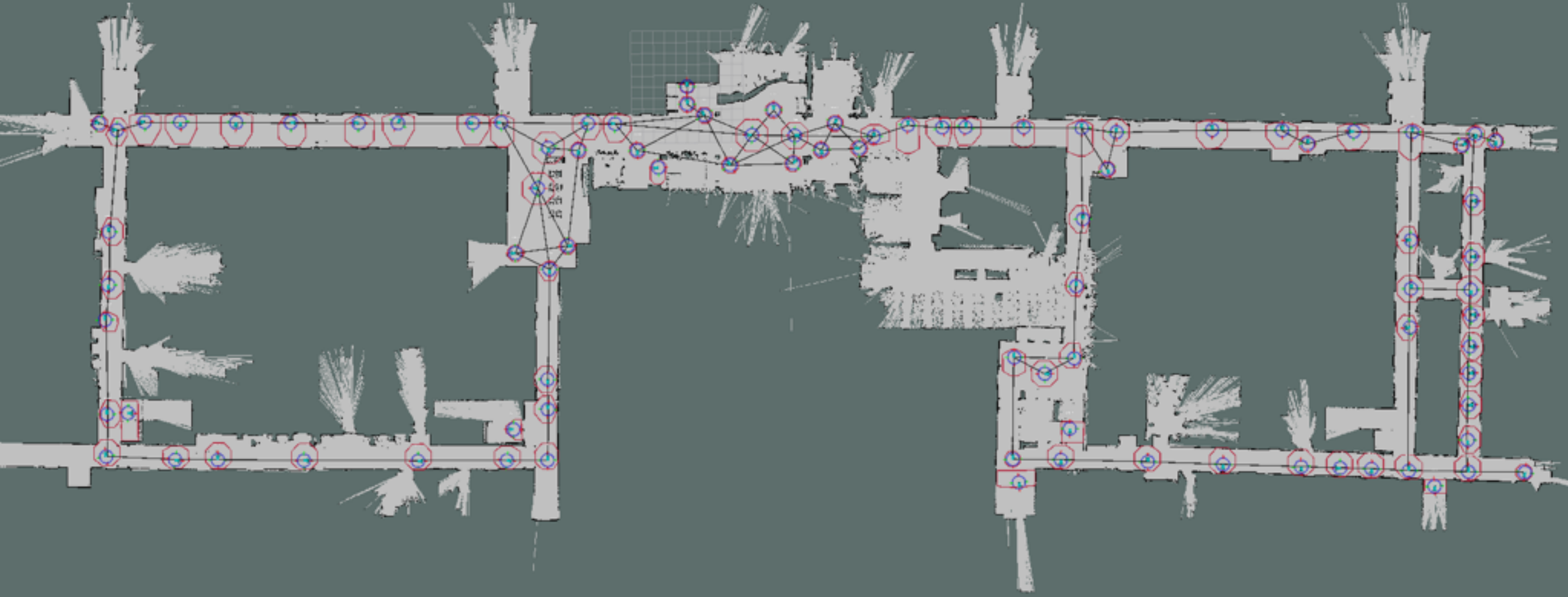
Topological

x2

LONG-TERM AUTONOMY IN CARE HOME

Adaptive Autonomy

Haus der Barmherzigkeit, Vienna, Austria



HENRY AT THE CARE HOME

Info-Terminal

Improve when and where to offer

Bellbot

Walking Group

occupational therapy

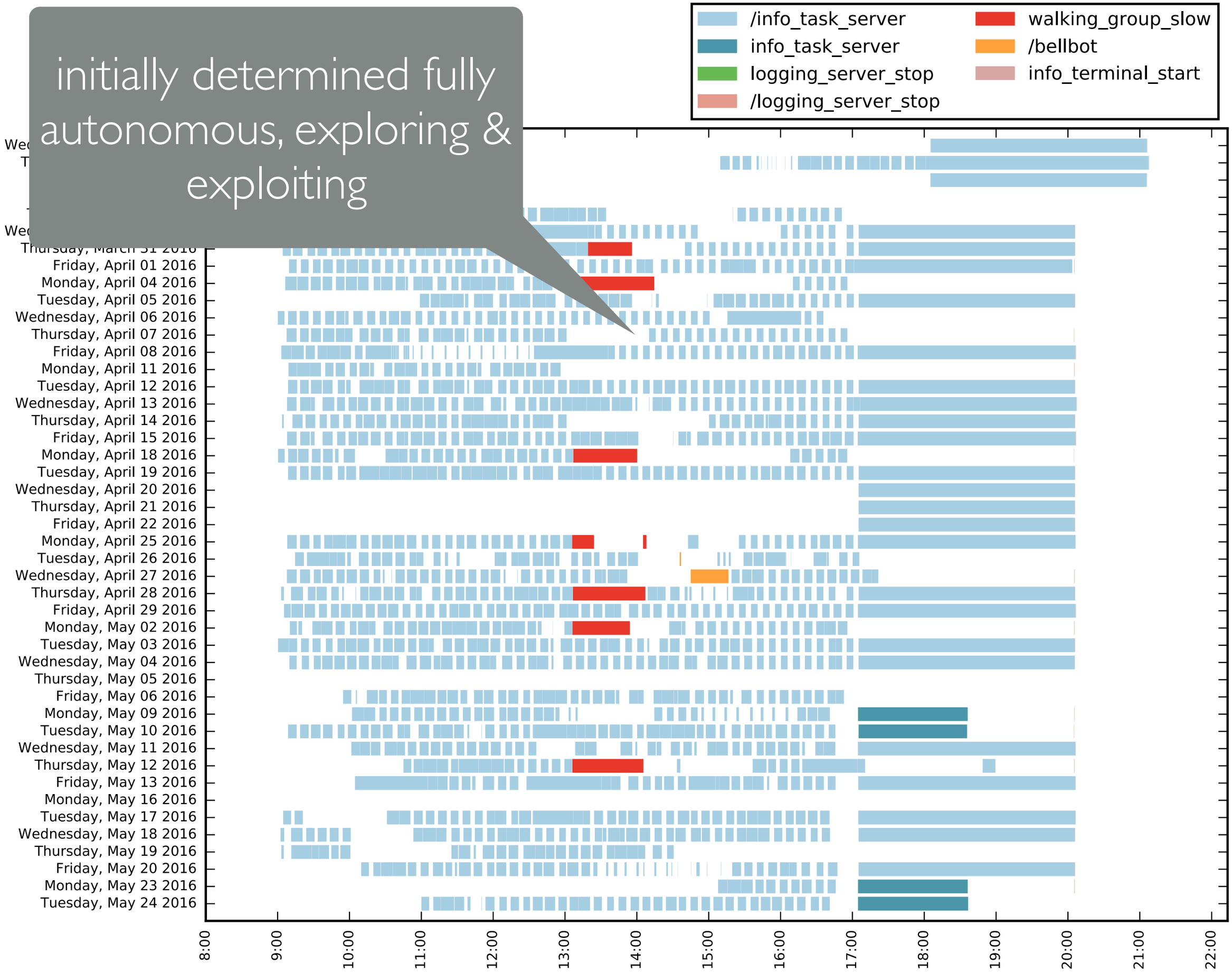
Navigation is a challenge

learn from experience

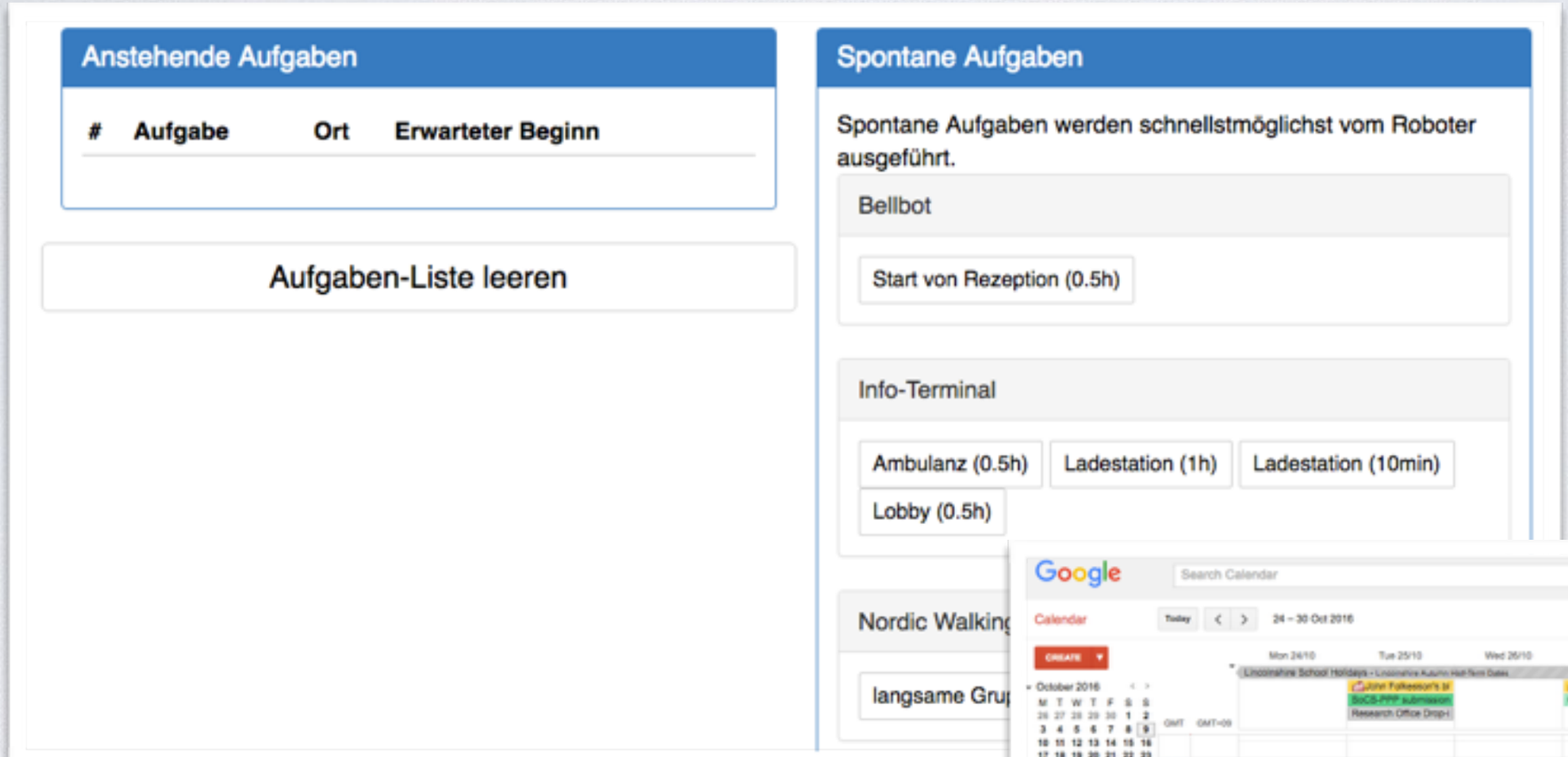
	Care Y3	Care Y2
Deployment	21/3/16 to 27/5/16	18/5/15 to 17/6/15
Working Hours	Weekdays days 7.00 to 19.00	Most days 8.00 to 21.00
Distance	~50km	23.41km
Tasks	1890	865
Available Work Time	529 hours, 13 minutes	252 hours, 54 minutes
Autonomous Ti	, 13 minutes	135 hours, 20 minutes
A%	.53%	53.51%
	Lifetime (TSL)	
Max	25 days, 11:29 hours (includes 8 days off)	15 days, 5:33 hrs (includes 5 days off)
2nd best	15 days, 9:30 hours (includes 4 days off)	
Cumulative	55 days, 9:57 hours (includes 16 days off)	29 days, 5:53 hrs (includes 10 days off)

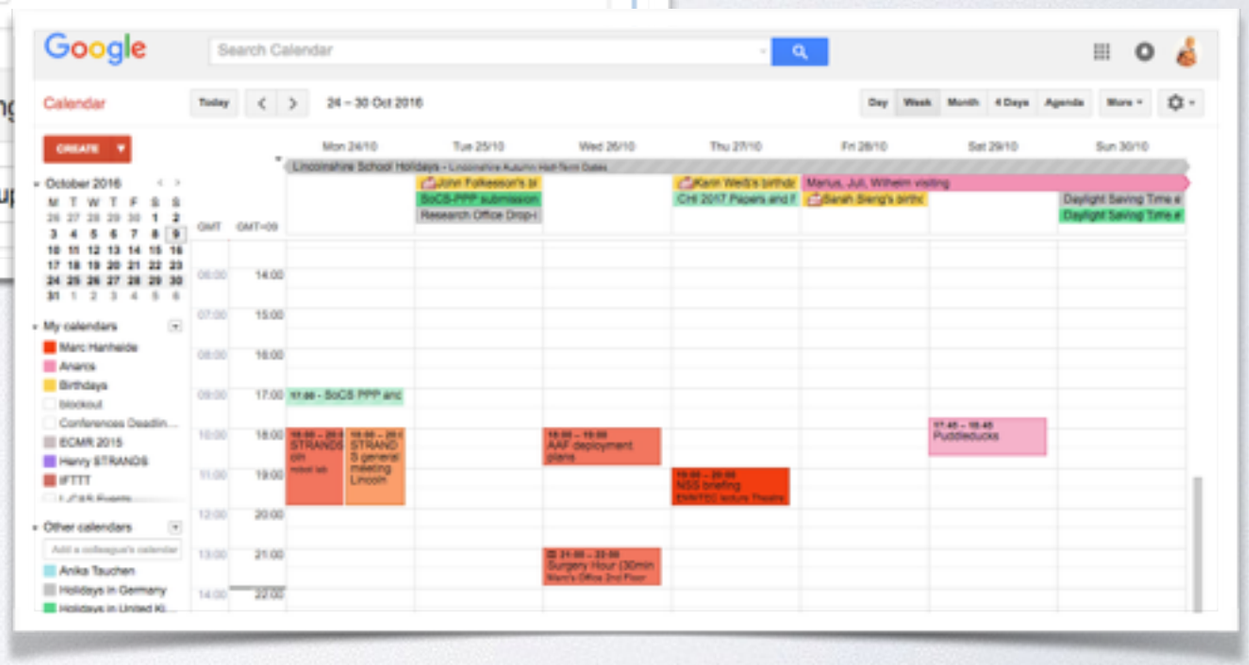
no developers/ engineers on-site

initially determined fully autonomous, exploring & exploiting



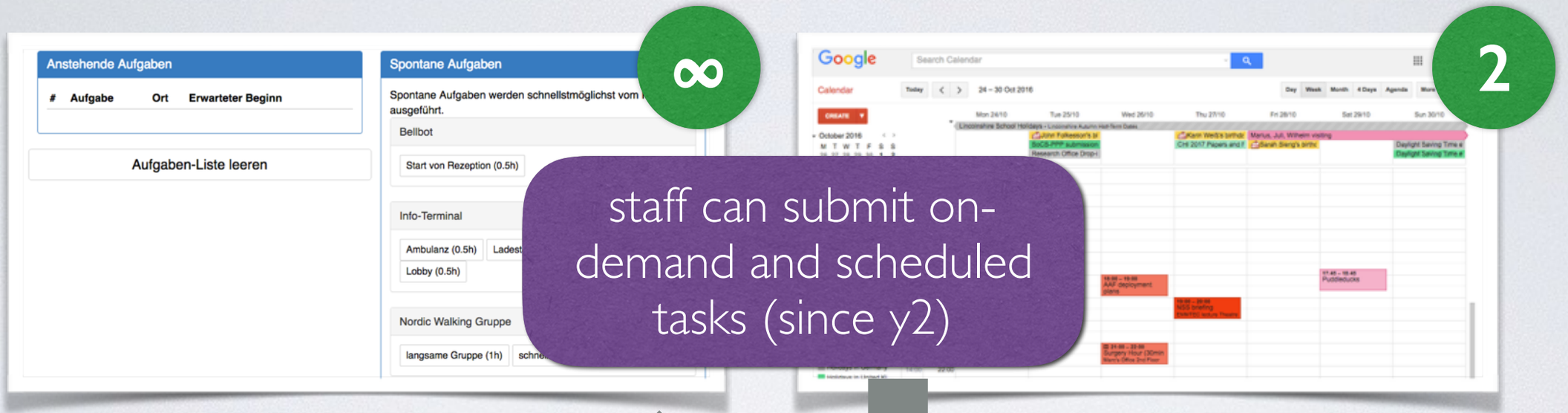
EMPOWERING END-USERS





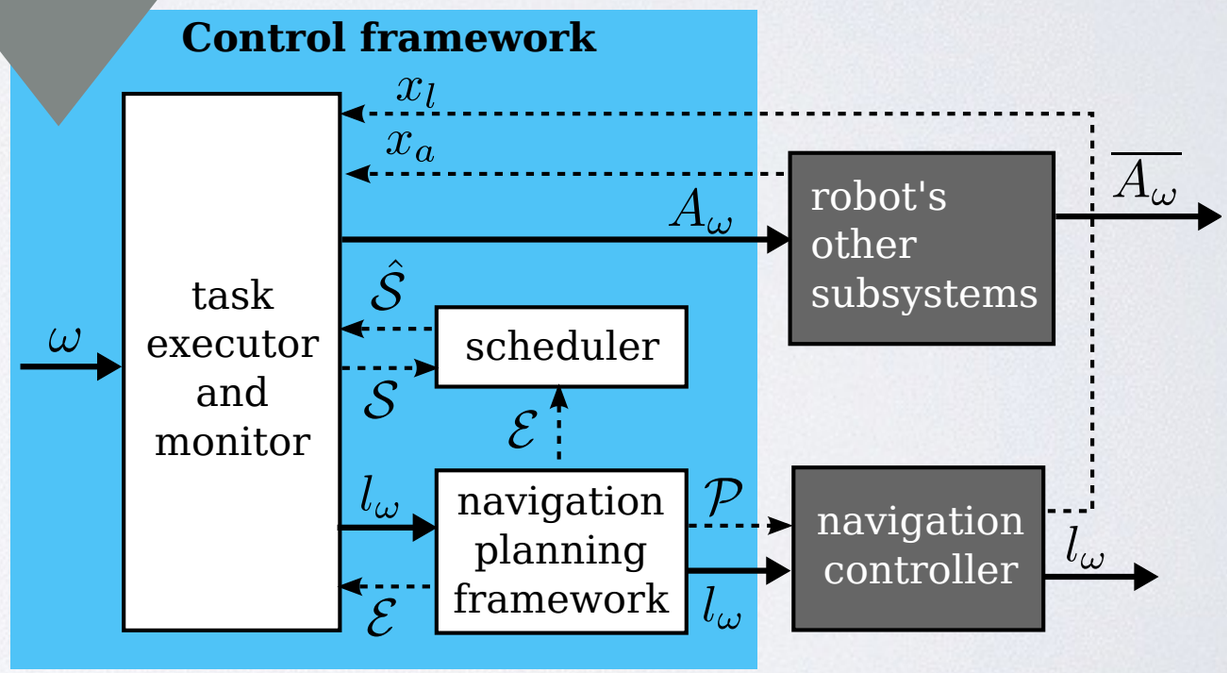
staff can submit on-demand and scheduled tasks (since y2)

SCHEDULING TASKS



1

Autonomous Task Generator



Mudrová, L., Lacerda, B. & Hawes, N., 2015. An Integrated Control Framework for Long-Term Autonomy in Mobile Service Robots. In ECMR.

WALKING GROUP

Goal: visual and acoustical stimulation, entertainment during waiting & resting, source of motivation and group coherences

Contents: picture, video and music gallery

y2: fully autonomous

WALKING GROUP

Goal: visual and acoustical stimulation, entertainment during waiting & resting, source of motivation and group coherences

Contents: picture, video and music gallery

Therapists

- Positive attitude „cool“, „exciting“

Issues

- Navigation
- […]
- Lacking flexibility

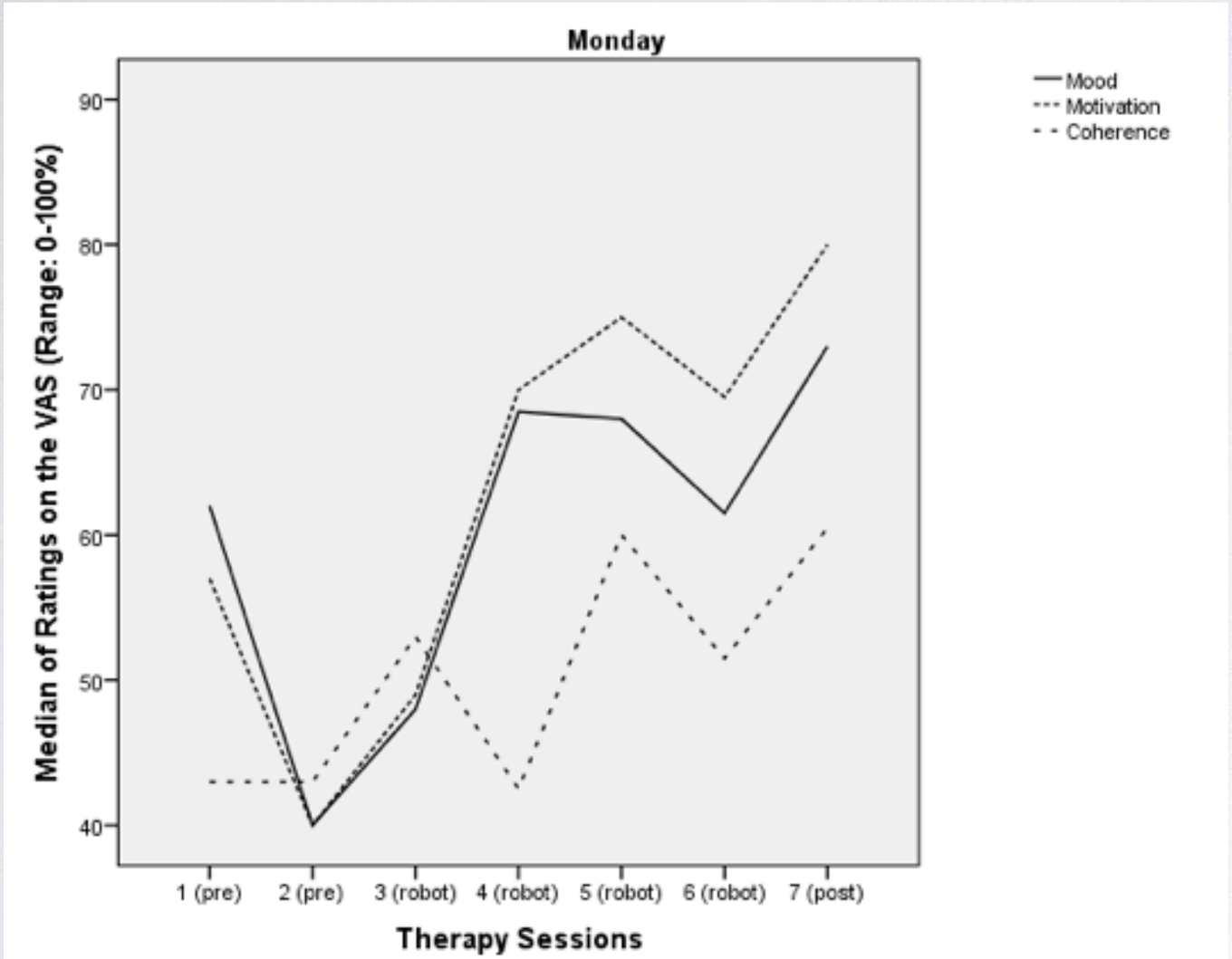
Problems with Participants

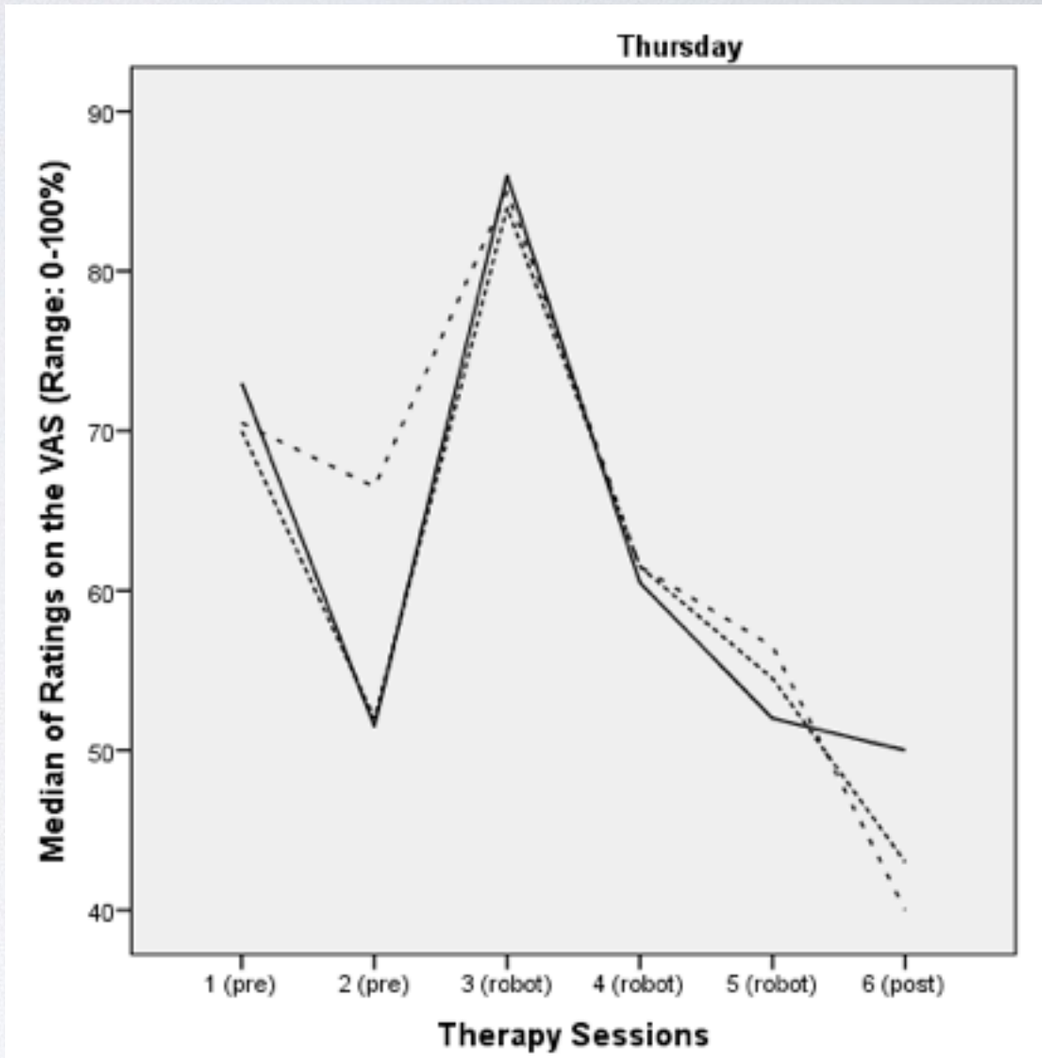
- Health issues
- Participants going astray

Too low locus of control?

y2: fully autonomous

WALKING GROUP





Medians of subjective ratings of therapists and observers across slow and fast patient groups for:

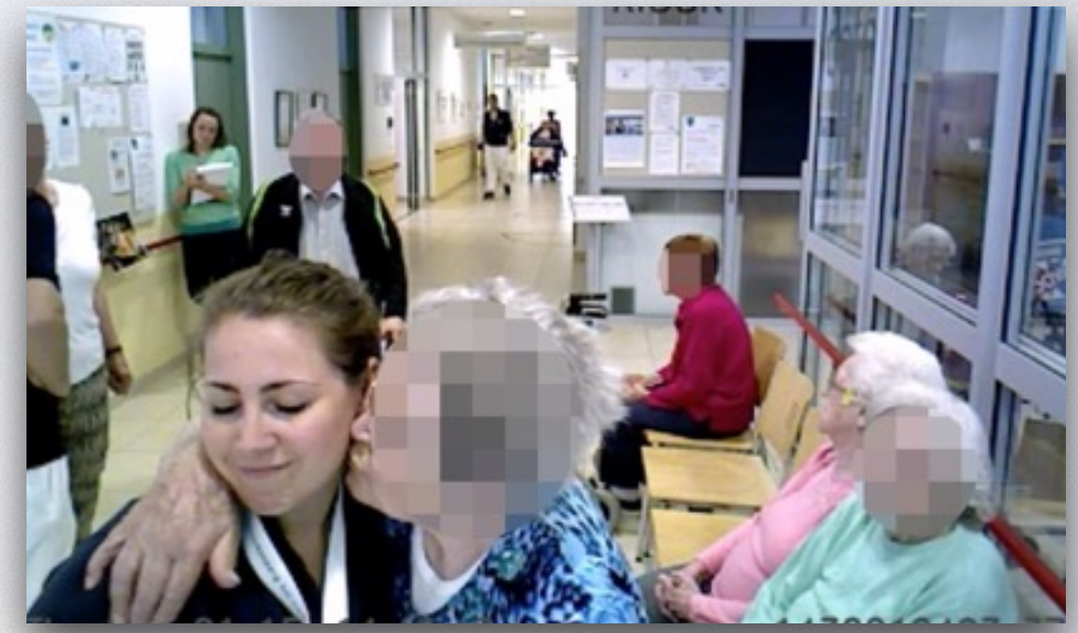
overall atmosphere/mood (0=aggrieved, 100=cheerful),
motivation (0=demotivated, 100=very motivated),
group coherence (0=loose, 100=strong)

y2: fully autonomous

WALKING GROUP

y2: fully autonomous

y3: more control requested, quote "too autonomous"

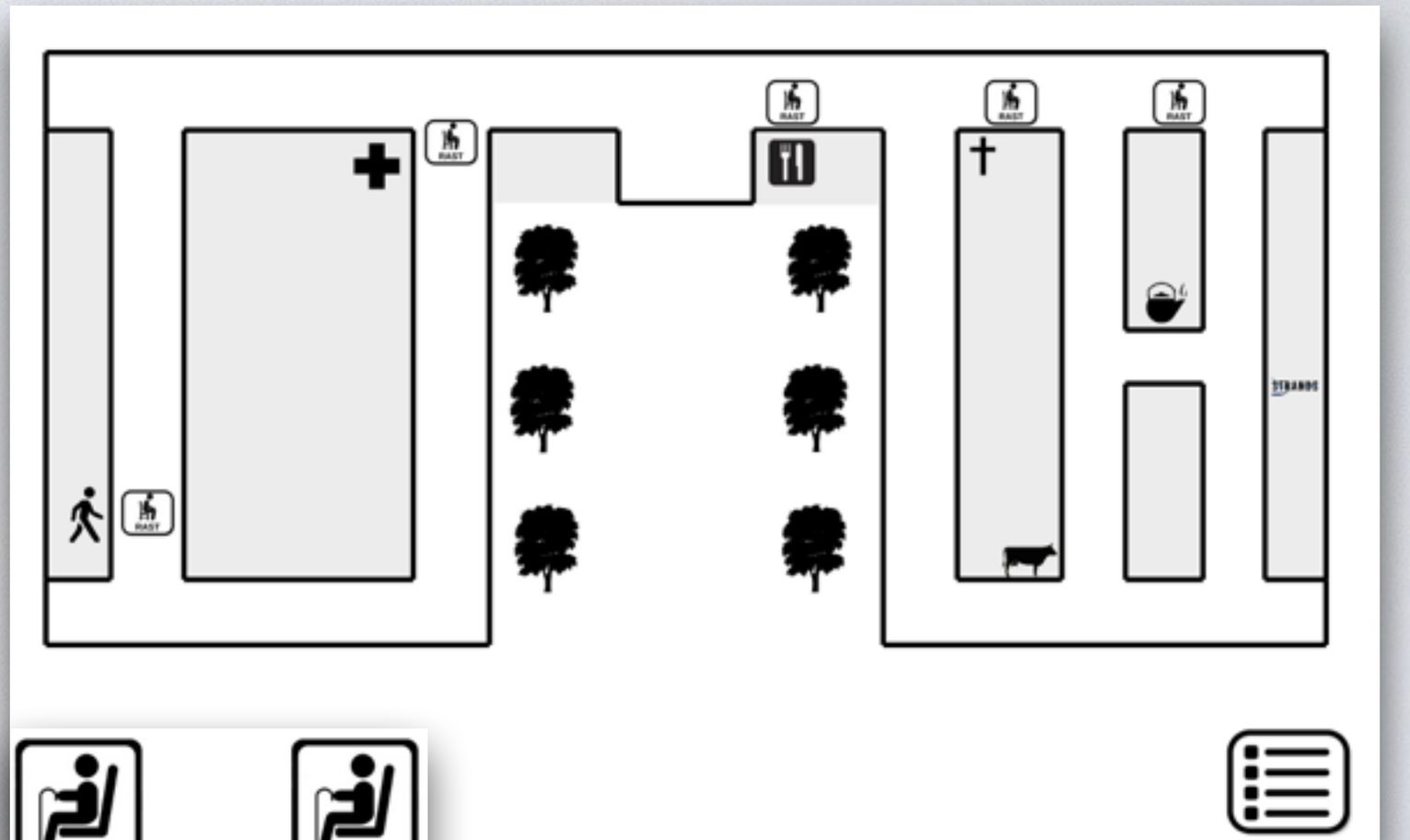


- facilitate human creativity
- spontaneous change of plans
- more responsive to patients

WALKING GROUP

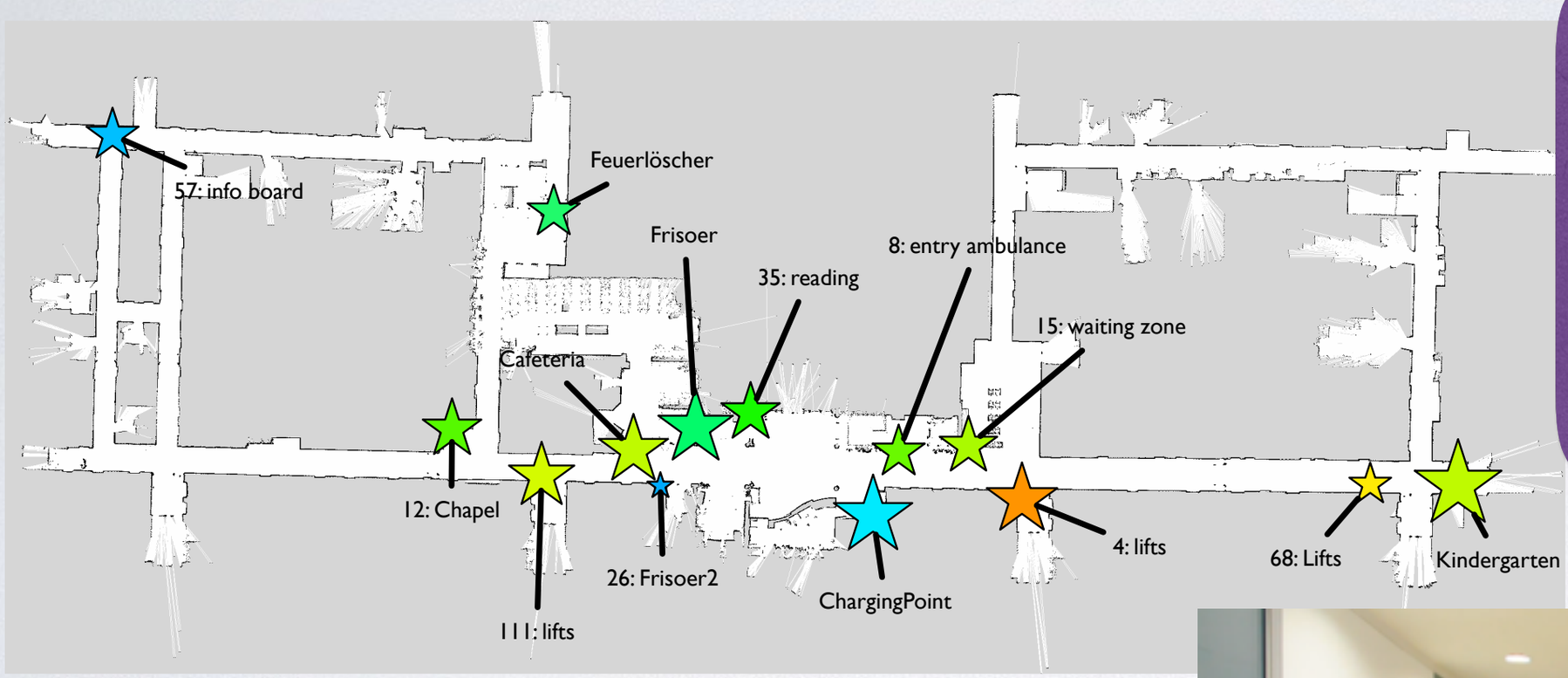
y2: fully autonomous

y3: more control requested, quote “too autonomous”



Result: higher acceptance by therapists (now expressing they want to use it again)

LEARNING THE WHEN AND WHERE OF INFO-TERMINAL



human's intentions vary, but we might be able to exploit regularities in the changes?

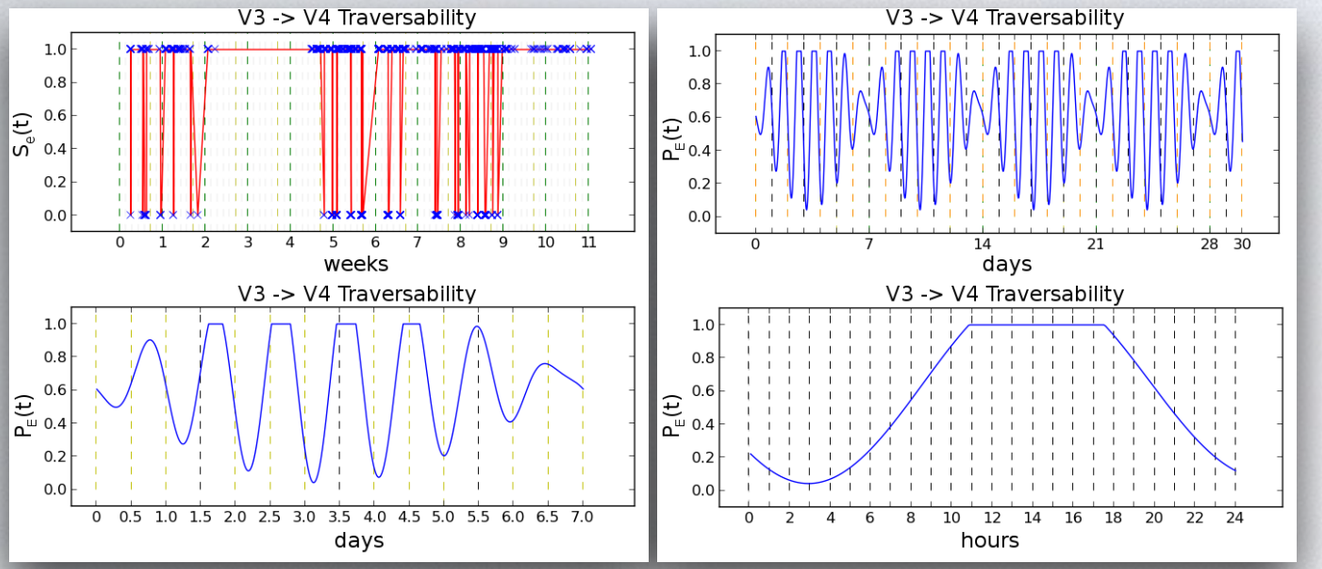
Successful Info-terminals %

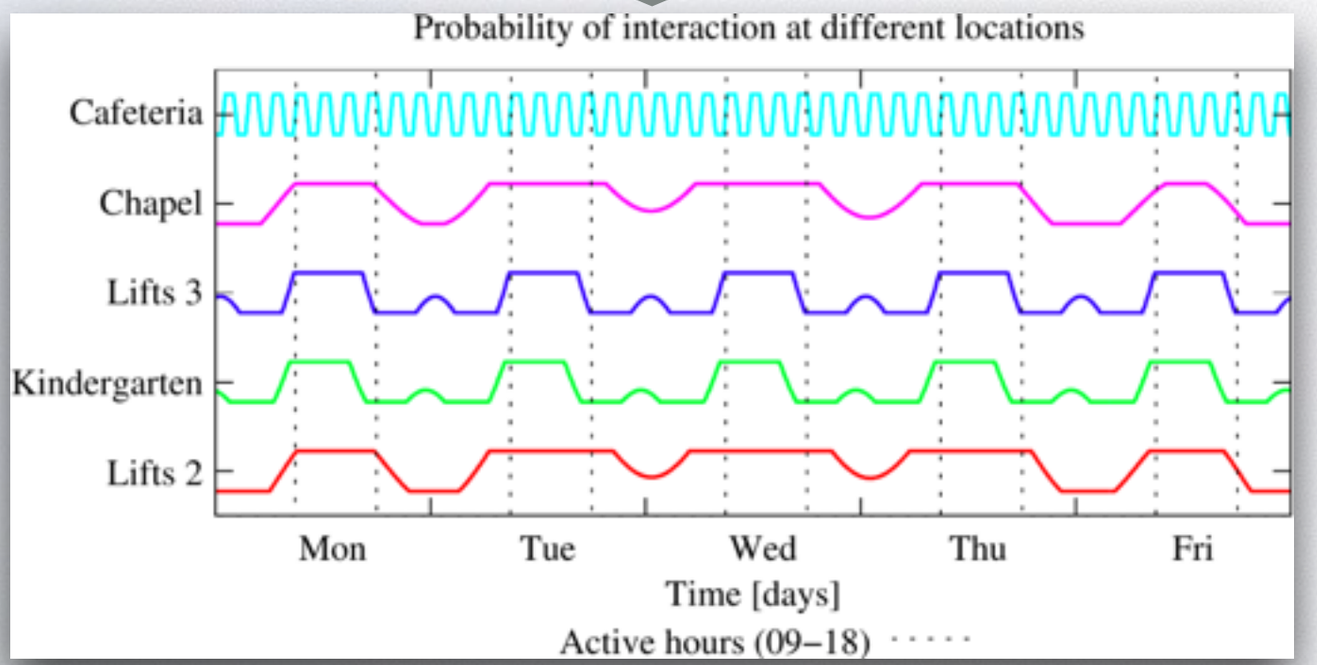
30% 70%

Clicks per interaction % ☆ ☆ ☆

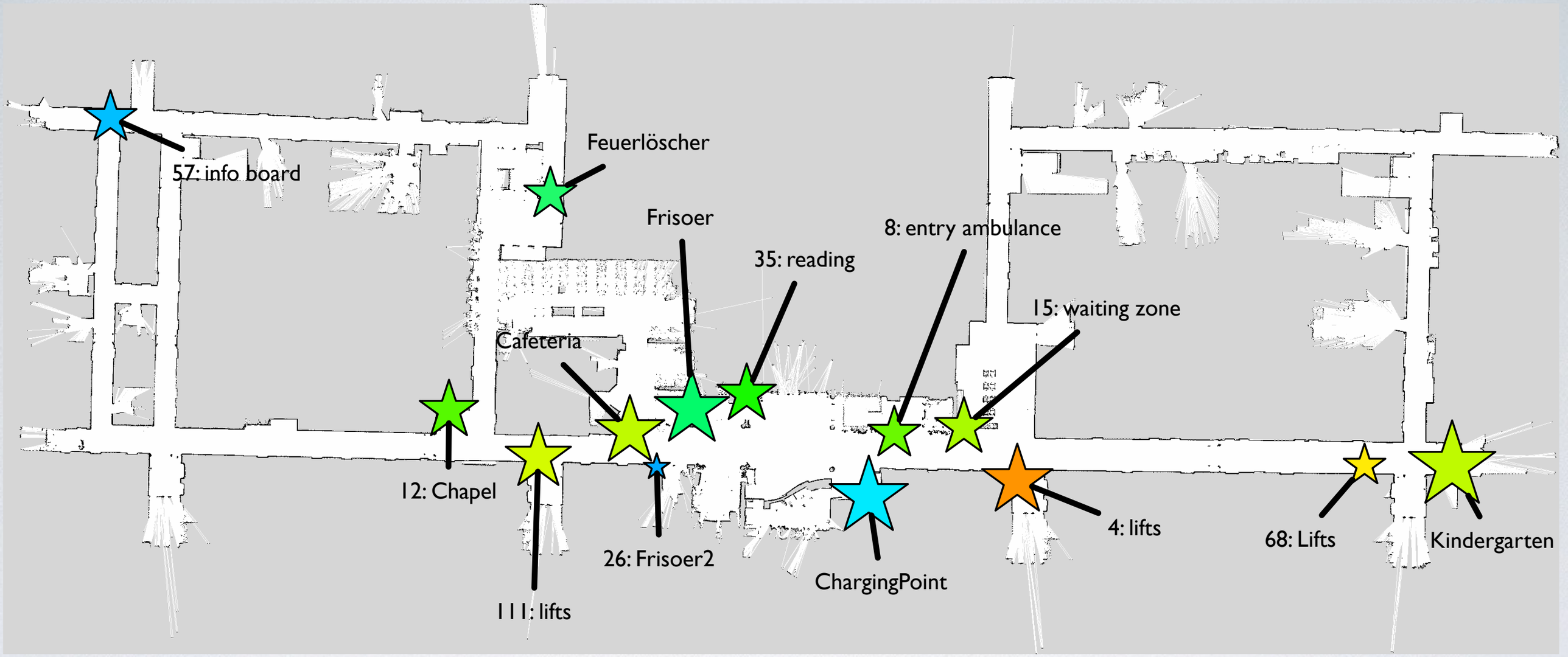
2.07 6.67

ANTICIPATING USERS' TASKS





- Model probability of interaction "success" as periodic probability distribution
- Exploit prediction to improve where the service is offered when
- Explore actively to learn
- greedy 50/50 exploration/ exploitation



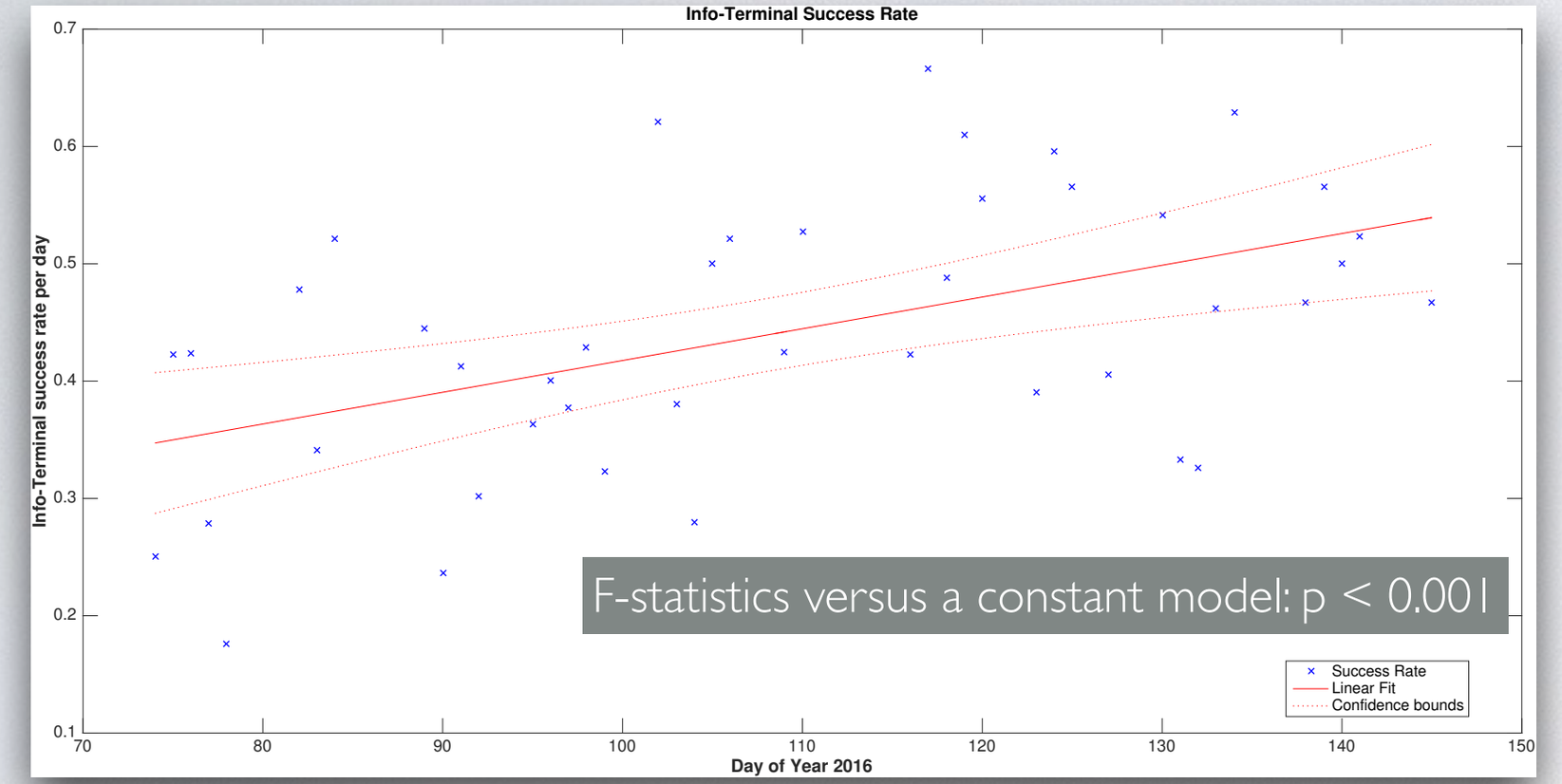
Successful Info-terminals %

30% 70%

Clicks per interaction %

2.07 6.67

ADAPTIVE AUTONOMY



user's needs / intentions might be well captured by periodic models

from experience learn to do what your users want

	Kindergarten	Ambulance	Feuerloescher	Waiting Zone	Lifts 1	Cafeteria	Reading Zone	Chapel	Lifts 2	Lifts 3	Infoboard	Frisoer 1	Frisoer 2	SUM
Menu	25	61	23	34	43	48	34	36	69	49	23	37	7	489
Weather	29	37	28	34	35	44	36	28	45	33	10	20	7	386
News	21	33	24	34	31	29	14	22	36	29	13	41	3	330
Photo	165	127	96	128	79	110	111	110	170	62	71	69	10	1308
SUM	240	258	171	230	188	231	195	196	320	173	117	167	27	2513

CONCLUSION

Robots benefit from "exploiting" complaint users, the "mutuality" in symbiotic autonomy may be hard to maintain.

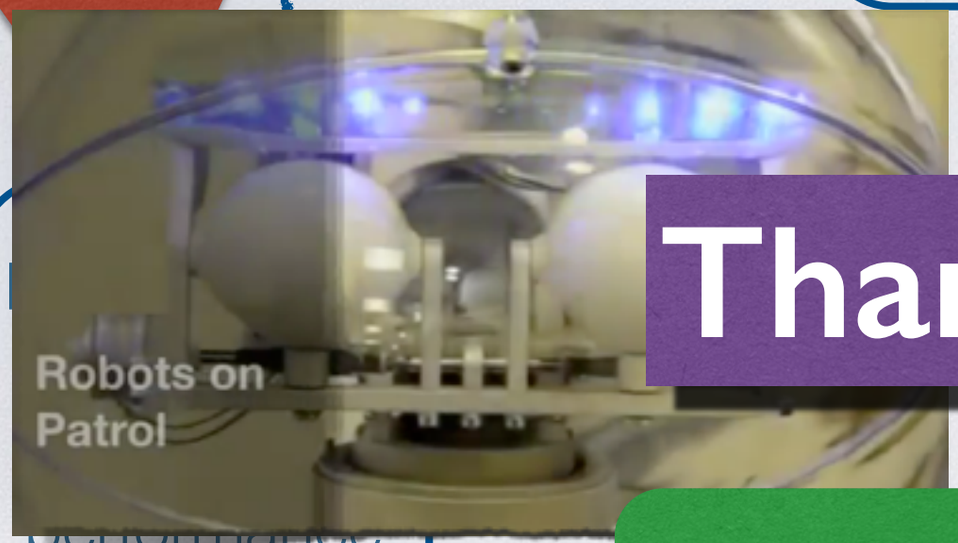
Full autonomy is a two-edged sword, user want and need to feel in control for acceptance.

Adaptive Autonomy allows users to effect/change the autonomous behaviour, which subsequently adapts to their changes

adaptive autonomy

Robust, intelligent, autonomous behaviour

running for weeks



Thank you!

Carpe Diem

Carpe Noctem

learn human behaviour

learn how the world changes

https://lcas.lincoln.ac.uk/wp/

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STRANDS

LINCOLN ROBOTICS

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