Sobi: An Interactive Social Service Robot for Long-Term Autonomy in Open Environments

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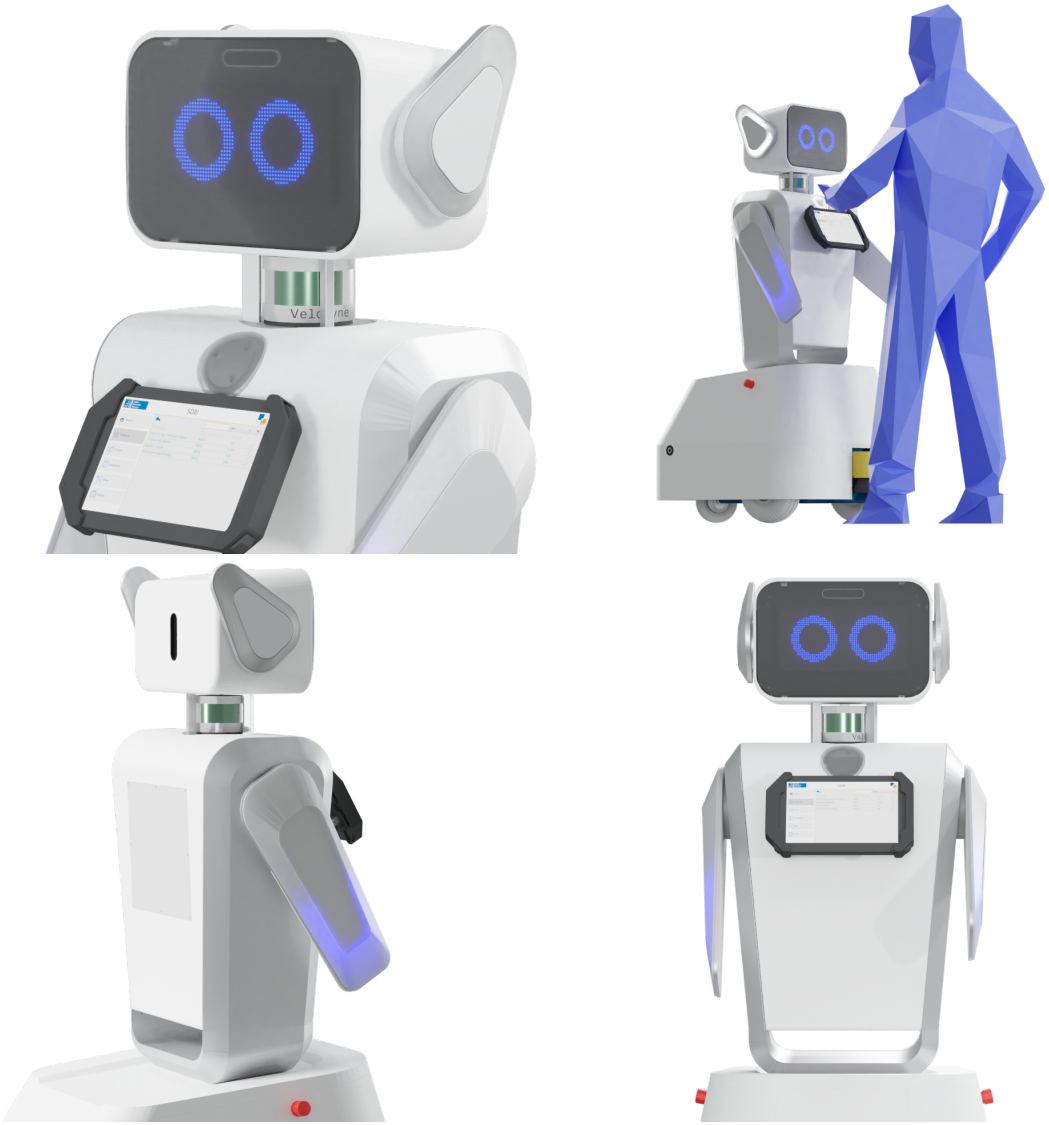
Requirements and design

Tasks

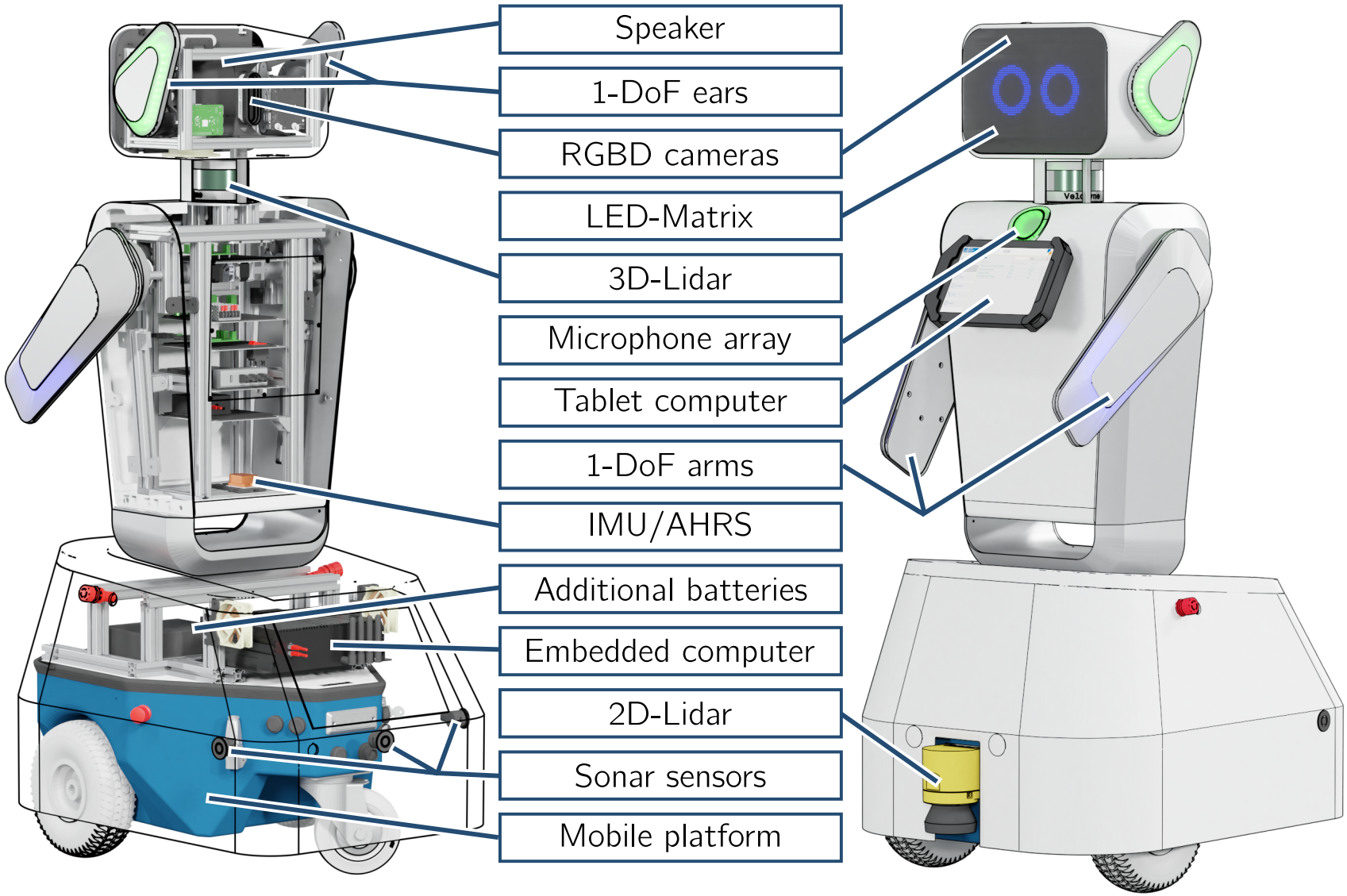
- Provide information inside/outside of buildings
- Guiding

Key Requirements

- Autonomous indoors, partially autonomous outdoors
- Operation for several hours
- Robust localization and navigation
- Approachable design
- Intuitive user interface

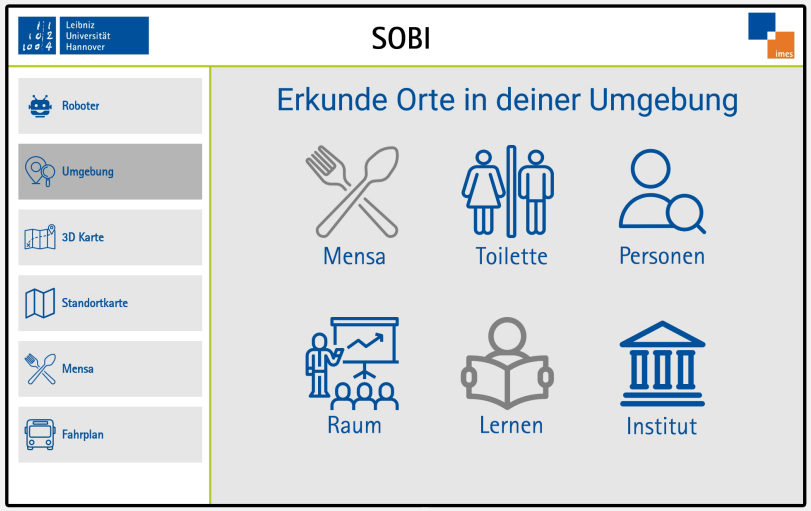


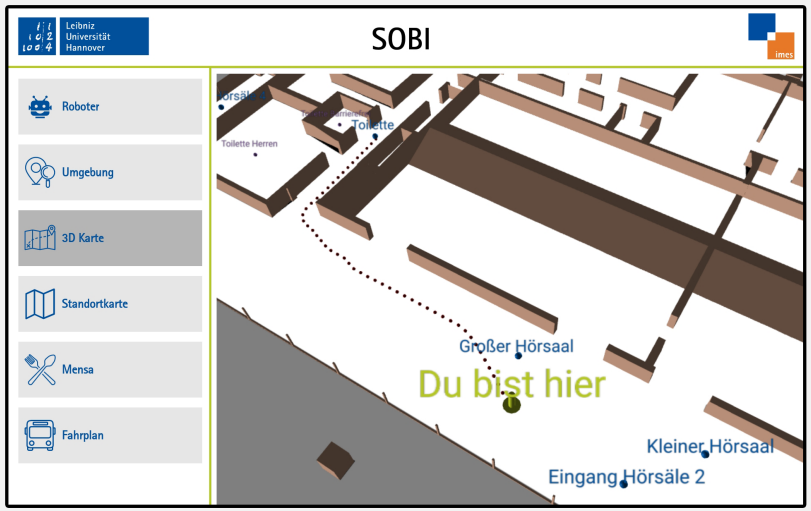
Hardware components



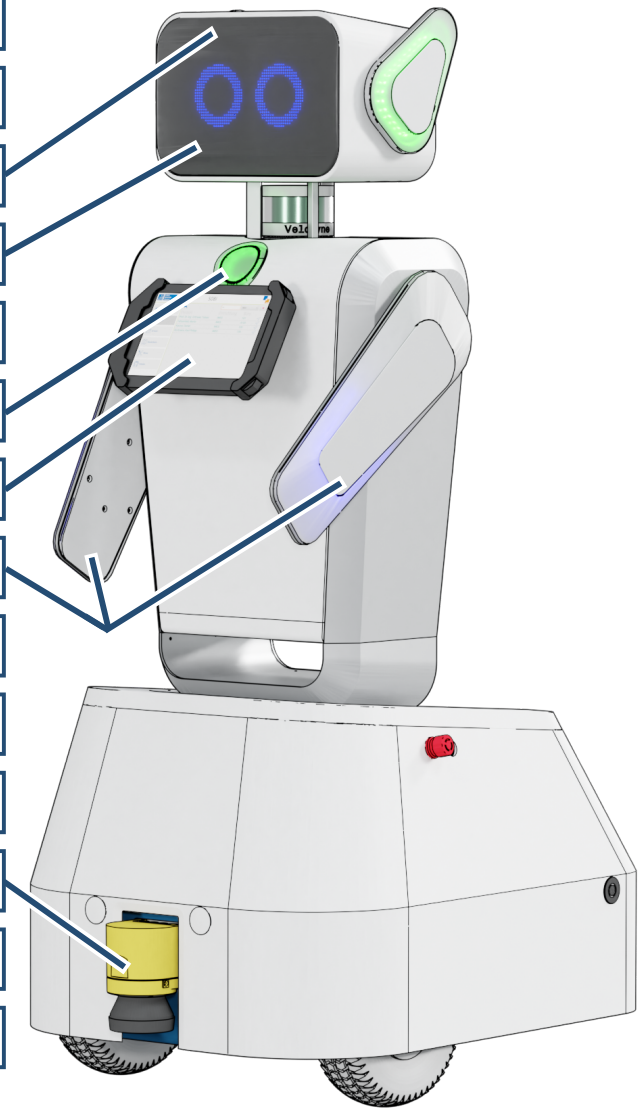
Hardware components

Tablet GUI





- Speaker
- 1-DoF ears
- RGBD cameras
- LED-Matrix
- 3D-Lidar
- Microphone array
- Tablet computer
- 1-DoF arms
- IMU/AHRS
- Additional batteries
- Embedded computer
- 2D-Lidar
- Sonar sensors
- Mobile platform



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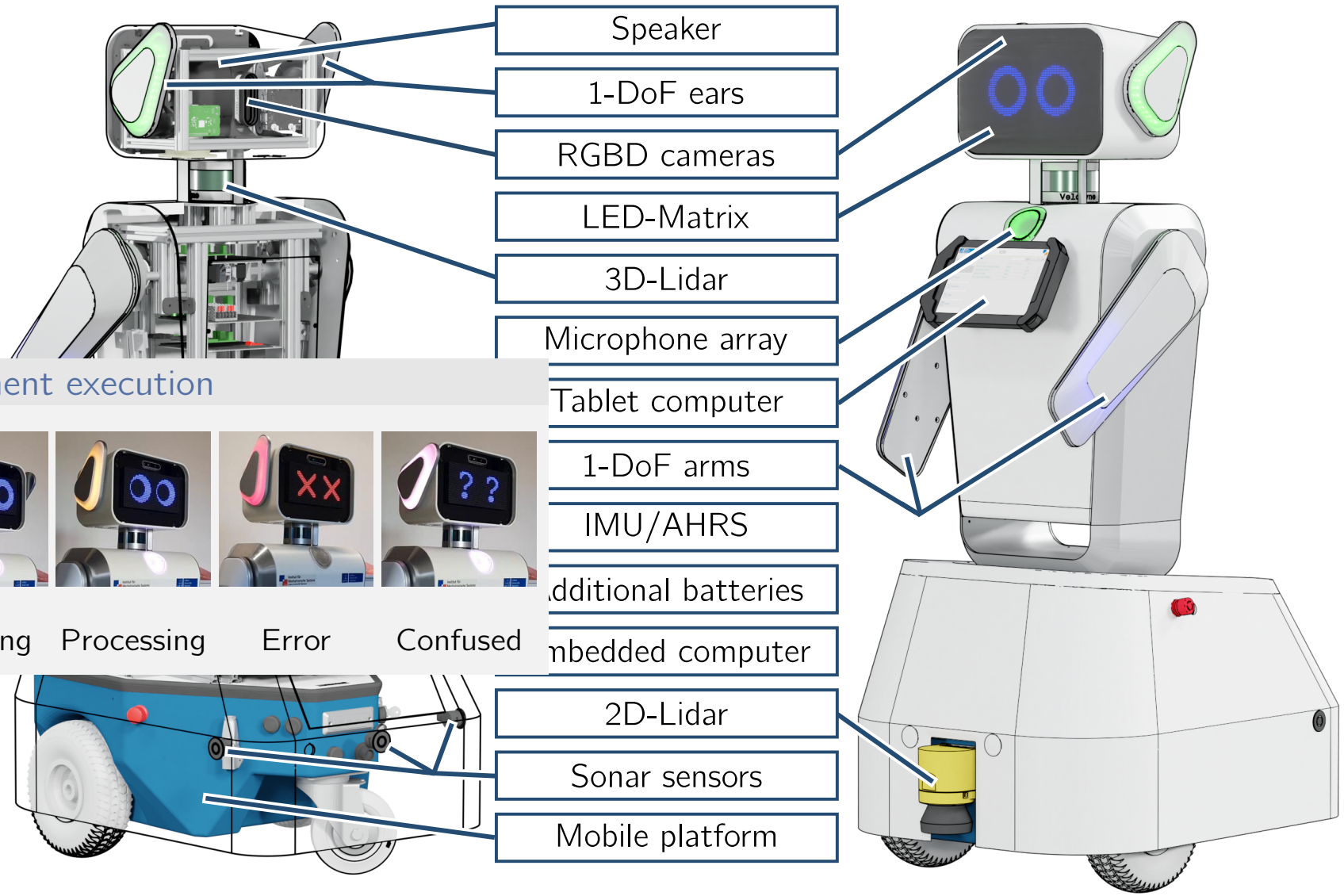
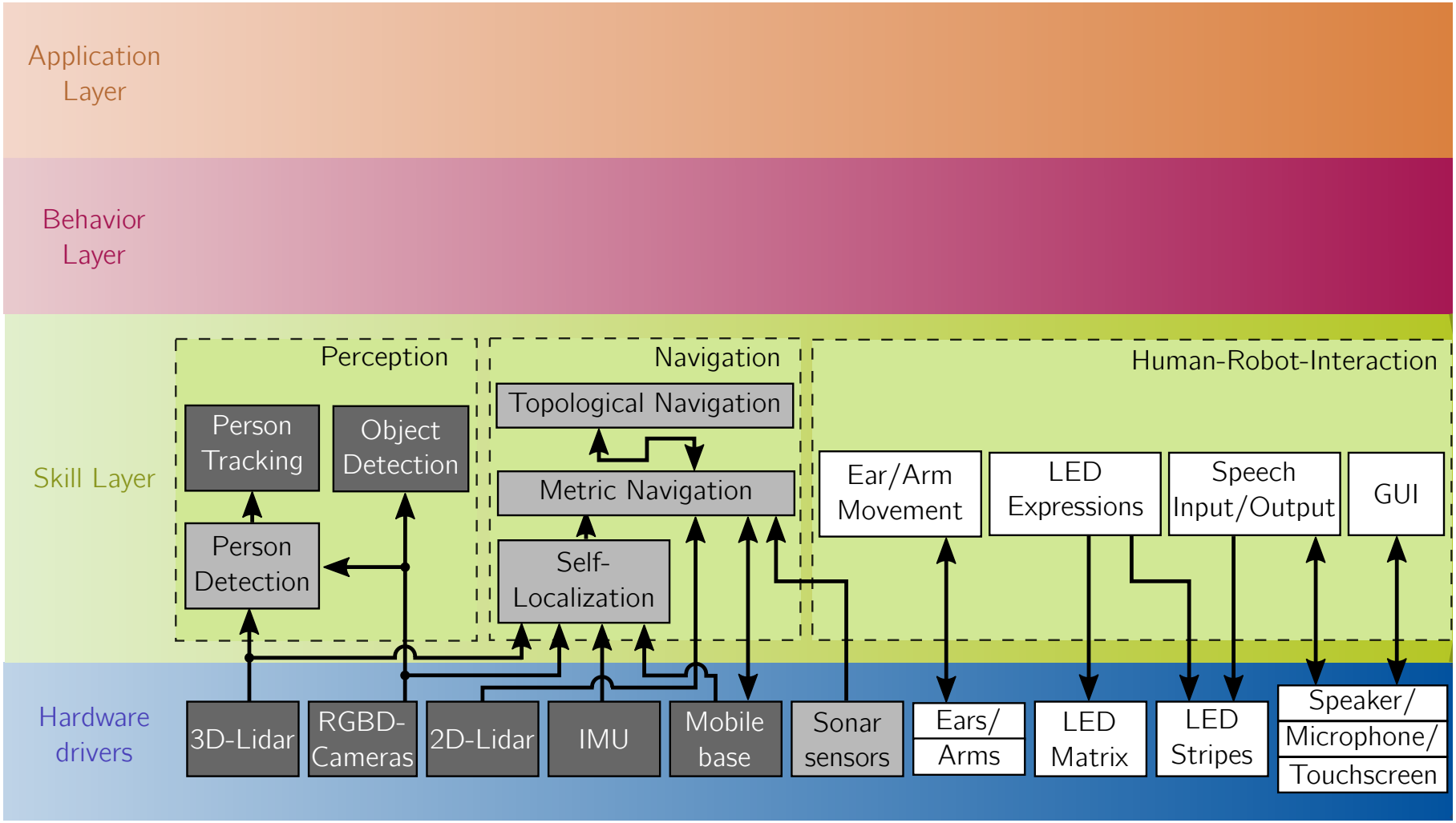


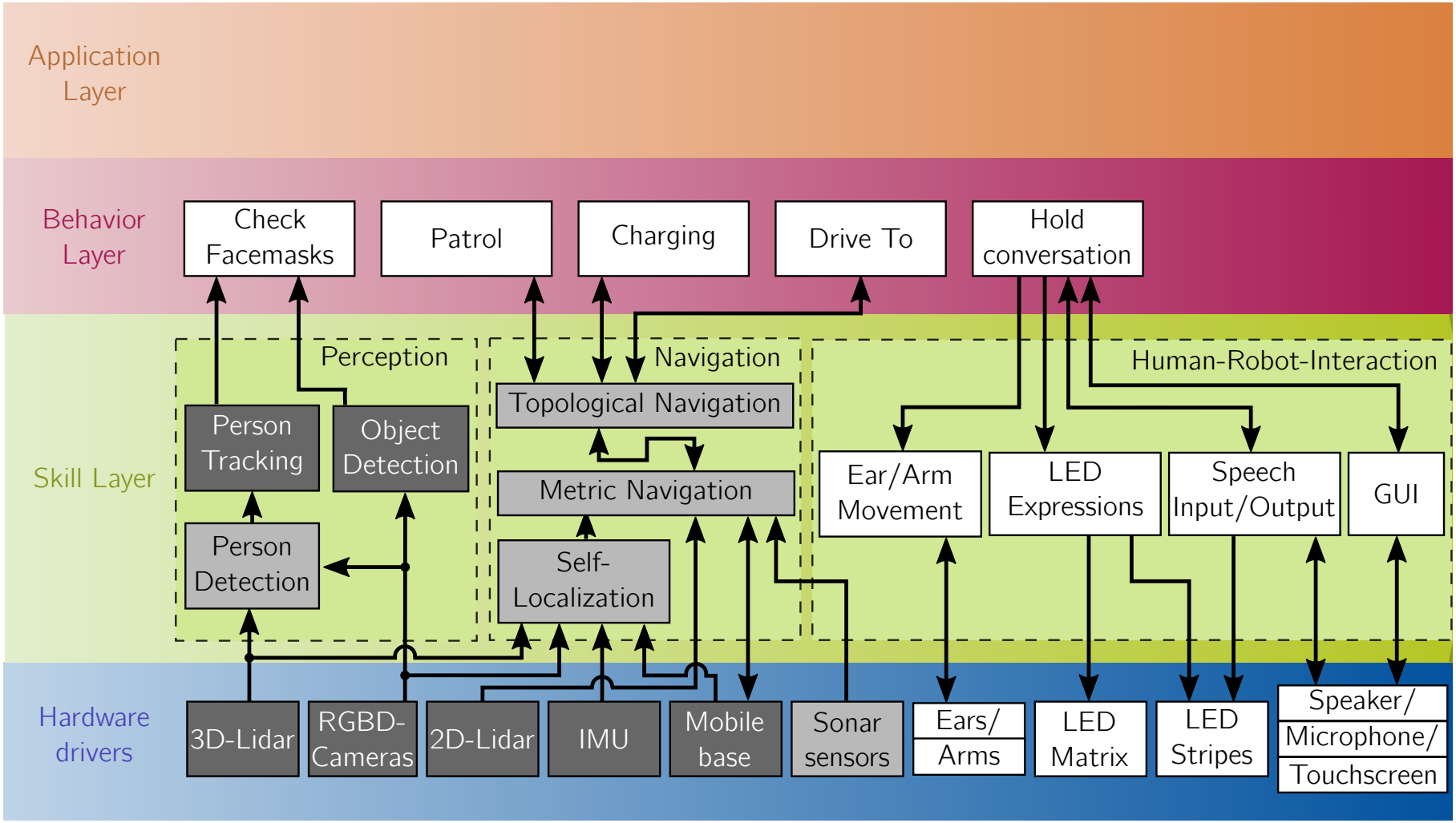
Sentiment execution

Software structure



Legend : Third party ROS program | Modified/extended third party ROS program | Custom self-developed program

Software structure



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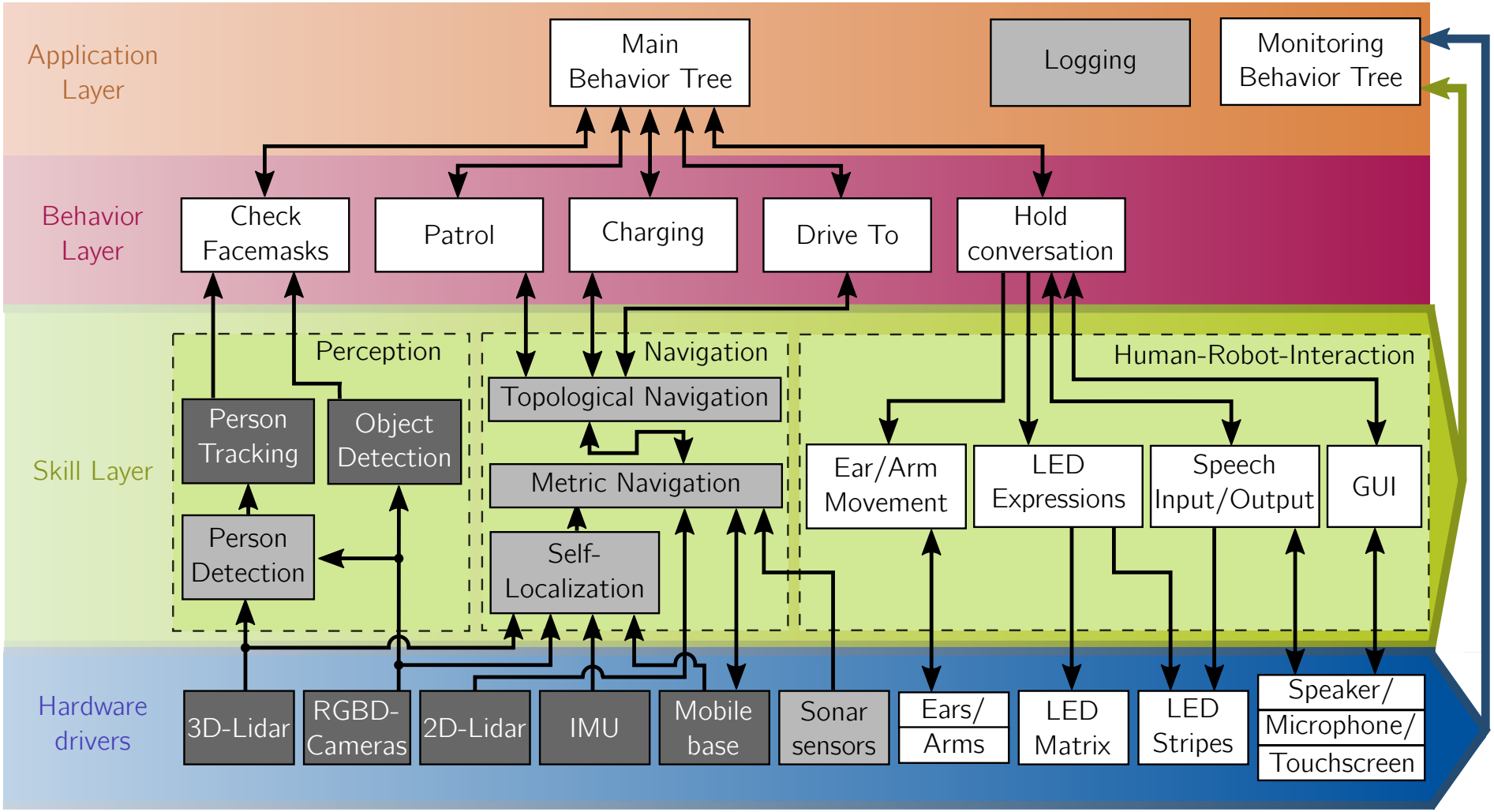

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Monitoring Behavior Tree

Name	Detection	Reaction
Node monitor	Node not pingable	Restart node
Navigation monitor	No global path found and *MoveBase* recoveries failed	1. Wait and retry 2. Move backwards 3. Ask Supervisor
Localization monitor	No loop closure detected	1. Slow rotate 2. Restart localization 3. Slow rotate 4. Ask Supervisor

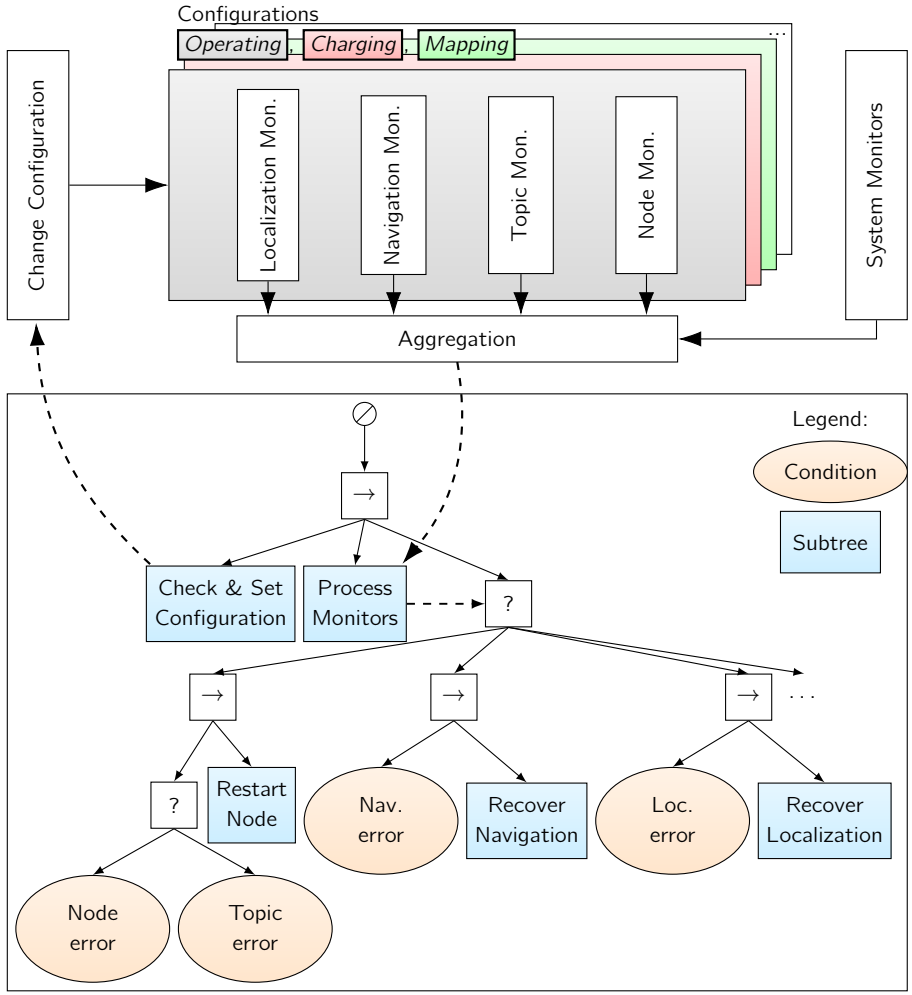

Figure: Structure of the monitoring framework

Experimental results

Task

- Patrol a floor during office hours (9 am–5 pm)
- Charge if necessary and at night

Criteria

- Mean time operating per day
- Mean time moving per day t_m
- Autonomy percentage $A\% = t_m/8\,\mathrm{h}$
- Total System Lifetime (TSL)
- Quantity/Success of recovery behaviors

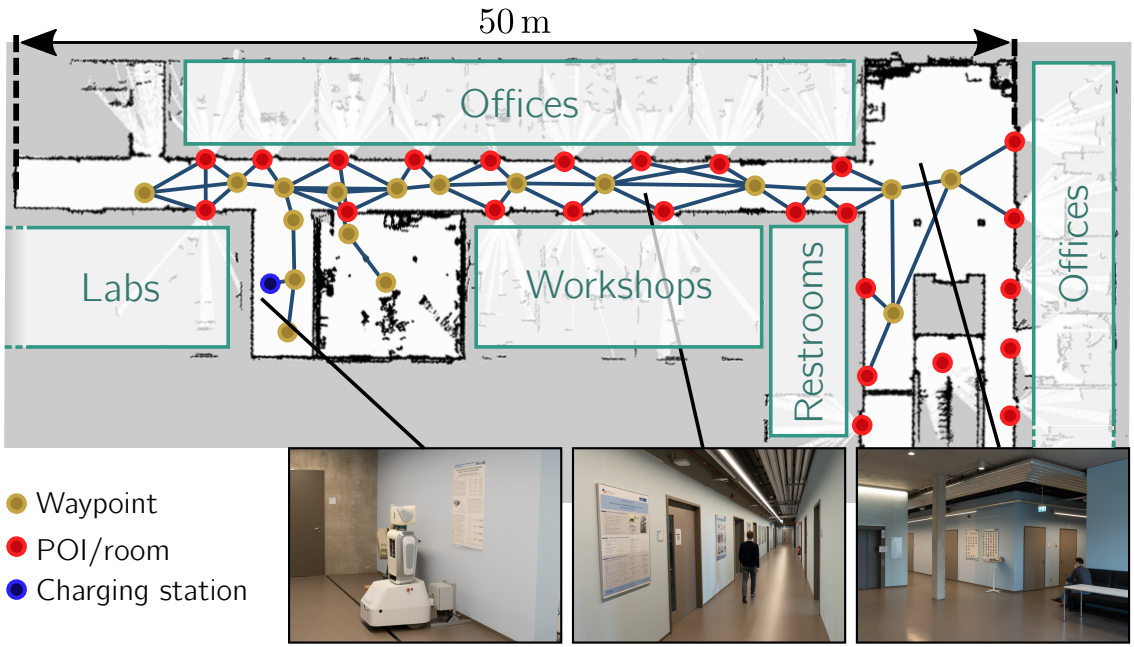

Figure: Environment used for validation

Experimental results

Table: Executed recovery behaviors sorted by category.

Type	Reaction	#	success
ROS	Restart node	32	62.5 %
Navigation	Wait and retry	194	70.6 %
	Move backwards	41	48.8 %
	Ask supervisor for teleoperation	5	100 %
Localization	Slow rotate	76	84.2 %
	Restart localization & rotate again	12	66.6 %
	Ask supervisor for re-localization	4	100 %

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Table: Metrics of the deployment. Weekend days are excluded.

Metric	Value
Timespan	12 days
Mean time operating per day	5.9 h
Mean time moving per day t_m	5.5 h
A%	69 %
Traveled distance	66.6 km
Max TSL	90.6 h
Docking attempts	28 (27 successful)

Lessons learned

Hardware

- Use as many **established components** with ROS support, full integration and standard interfaces (e.g. Ethernet/USB) as possible
- **Distribute computational load**/minimize network load (e.g. one computer for image processing)

Software

- Fully support the findings from [1][2][3]: **Toleration of program restarts** and transition to a clean state
- Sensors: Cover a large field of view $\leftrightarrow$ Overlap for registration
- Place the charging station in **feature rich environment** $\rightarrow$ Quickly regain localization estimate

[1] Wim Meeussen et al. (2011). "Long Term Autonomy in Office Environments". In: *ICRA, Workshop on Long-term Autonomy*

[2] Nick Hawes et al. (2017). "The STRANDS Project: Long-Term Autonomy in Everyday Environments". In: *IEEE RAM*

[3] Shengye Wang et al. (2018). "TritonBot: First Lessons Learned from Deployment of a Long-Term Autonomy Tour Guide Robot". In: *RO-MAN*

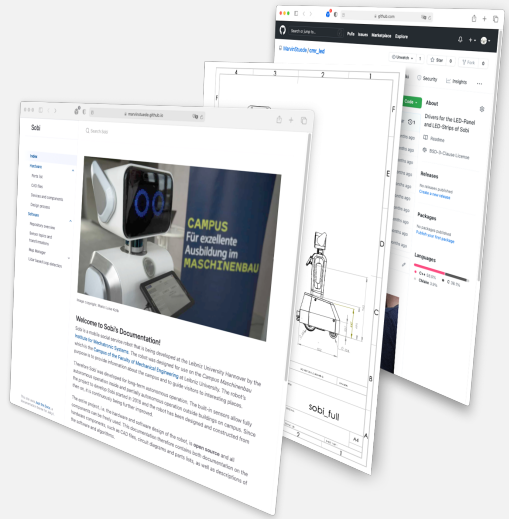
Conclusion

Sobi

- Robot for LTA tasks in open spaces
- Outlook
  - Further outdoor deployments
  - Record time- and location-dependent usage patterns for service improvement

Open Source Project

- Publication as open source hardware & software project: `marvinstuede.github.io/Sobi/`
  - Software repositories and HowTo's
  - CAD Files, Circuit diagrams, Drawings
  - Component and price list



Thank you!

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