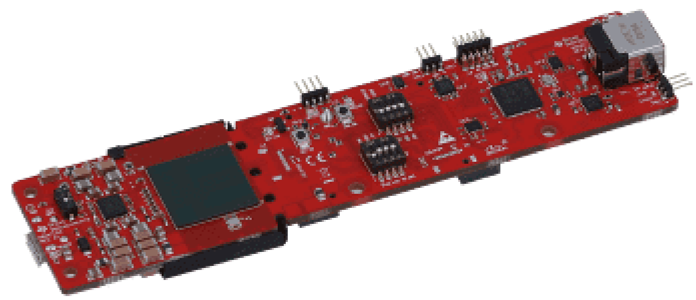
mmWave Radar-based Deep Collision Prediction

Abstract: Classical state-of-the-art approaches to autonomous navigation in cluttered environments involve the steps of a) estimating the robot's pose and the map of its surroundings, b) building a map representation applicable for collision-checking (e.g., occupancy mapping, cost maps), and c) identifying admissible collision-free paths in this representation. However, a set of new research contributions has demonstrated that motion planning can take place more efficiently by exploiting the strengths of deep learning. Current works, demonstrated with both aerial and ground systems, have demonstrated that we can safely predict the likelihood of a path colliding directly on a sequence of recent depth or camera observations. However, a limitation of such methods is that they require low-noise range or visual data which are often impossible in extreme degraded environments such as dust- or smoke-filled settings or areas with weak geometries and low-texture. Yet, an alternative is possible if we are to exploit the recent progress in mmWave radar imaging. Motivated by the above, in this project and thesis we seek to understand the complexities of mmWave radar imaging and develop a deep learning-based collision predictor that correlates a window of radar data, extracts appropriate features and can predict if a future trajectory is colliding with the environment without assuming access to a consistent 3D map or any other depth/visual cue. When successful, this technology can break new ground and allow autonomous flying or ground robots to reliable access some of the most extreme environments on Earth.



Tasks:

- Hardware interface and understanding of data of mmWave radars
- Literature overview of deep collision prediction methods (on range and visual data)
- Neural network design for radar-based deep collision prediction
- Training, inference, redesign and network fine-tuning
- Experimental evaluation onboard a flying robot of the Autonomous Robots Lab

Literature (indicative):

[1] Guan, J., Madani, S., Jog, S., Gupta, S. and Hassanieh, H., 2020. Through fog high-resolution imaging using millimeter wave radar. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 11464-11473).

[2] Lu, C.X., Rosa, S., Zhao, P., Wang, B., Chen, C., Stankovic, J.A., Trigoni, N. and Markham, A., 2020, June. See through smoke: robust indoor mapping with low-cost mmwave radar. In Proceedings of the 18th International Conference on Mobile Systems, Applications, and Services (pp. 14-27).

[3] Sugimoto, S., Tateda, H., Takahashi, H. and Okutomi, M., 2004, August. Obstacle detection using millimeter-wave radar and its visualization on image sequence. In Proceedings of the 17th International Conference on Pattern Recognition, 2004. ICPR 2004. (Vol. 3, pp. 342-345). IEEE.
[4] Nguyen, H., Fyhn, S.H., De Petris, P. and Alexis, K., 2022. Motion Primitives-based Navigation Planning using Deep Collision Prediction. arXiv preprint arXiv:2201.03254.

Relevant Funded Project:

- **Title:** SENTIENT: Science of resiliENt auTonomy In pErceptually-degraded eNvironmenTs
- **Partners:** NTNU, Scout Drone Inspection, DNV, Altera, Equinor
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