Spatial Intelligence through combined sensing, using computer vision and on board electromagnetics modelling for future self securing networks

UK IC Postdoctoral Research Fellow
Timothy Pelham, PhD, MIET, MIEEE
Department of Electrical Engineering, University of Bristol

Overview

As the cost of antenna arrays continues to decrease, there is an emerging opportunity for a combination of computer vision, efficient electromagnetics modelling, and modular antenna array design to provide enhancements to the situational awareness of platform operators. A combination of simulated and measured signals are used to demonstrate the initial capability of the Spatial Intelligence Node for combined sensing and onboard electromagnetics (LyceanEM).

Method

The Spatial Intelligence Node is populated by an Nvidia Orin AGX, providing 275 TOPS at 60W, 3 Oak-D W cameras, and 2 USRP B210 software defined radios, providing 4x4 MIMO. This allows for spatial mapping within the Anechoic Chamber based upon the radio emissions of the LoRa module (LoPy 4 module on a Pytrack 2.0 X carrier board) at 867MHz. Rotation of the LoRa antenna allows for spatial and RF fingerprinting of multiple LoRa modules, and combined characterization of the consistent scene within the anechoic chamber [2].

The chamber was mapped using a time of flight camera on a consumer S21 5G + smartphone, allowing the spatial intelligence node to use a prepopulated map due to the poor lighting conditions.

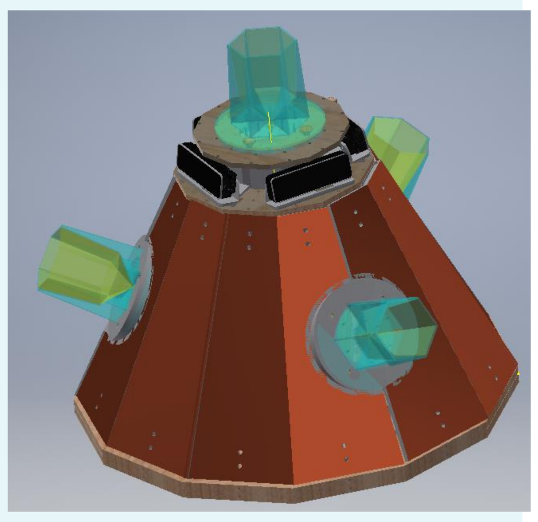


Figure 1: Spatial Intelligence Node

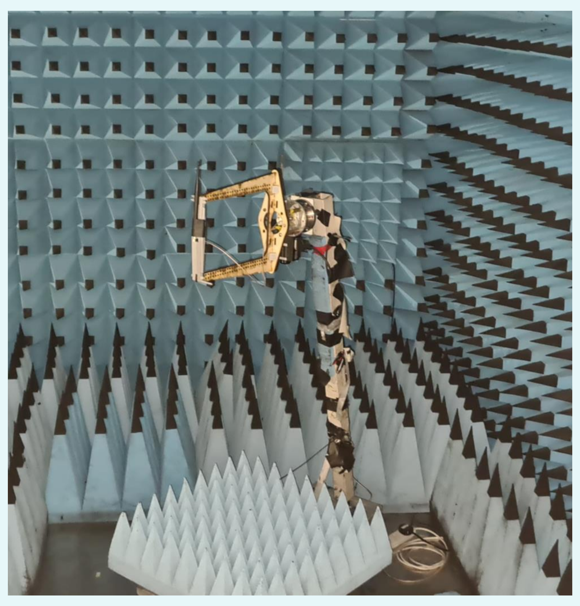


Figure 2: LoRa Antenna on Rotator at 45 degrees

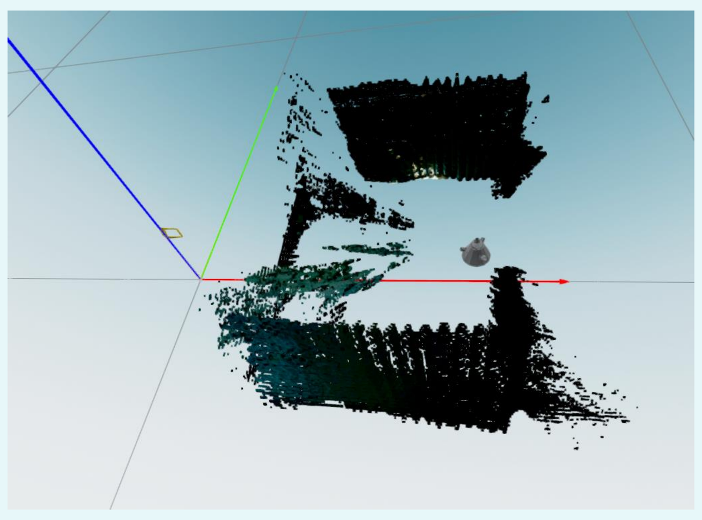


Figure 3: Onboard Camera Map

Results

Paired Sum and Difference estimation was used to produce the angles of arrival for each beacon position, and coherent wavefront steering was used to produce a spatial map of normalized power from each detected point within the chamber.

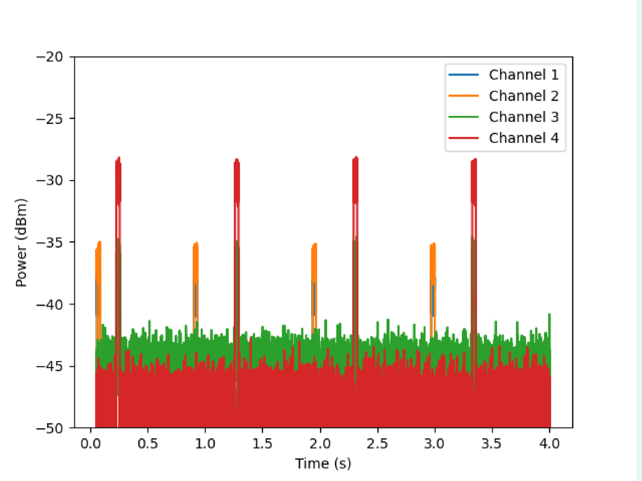


Figure 4: Received LoRa pulses

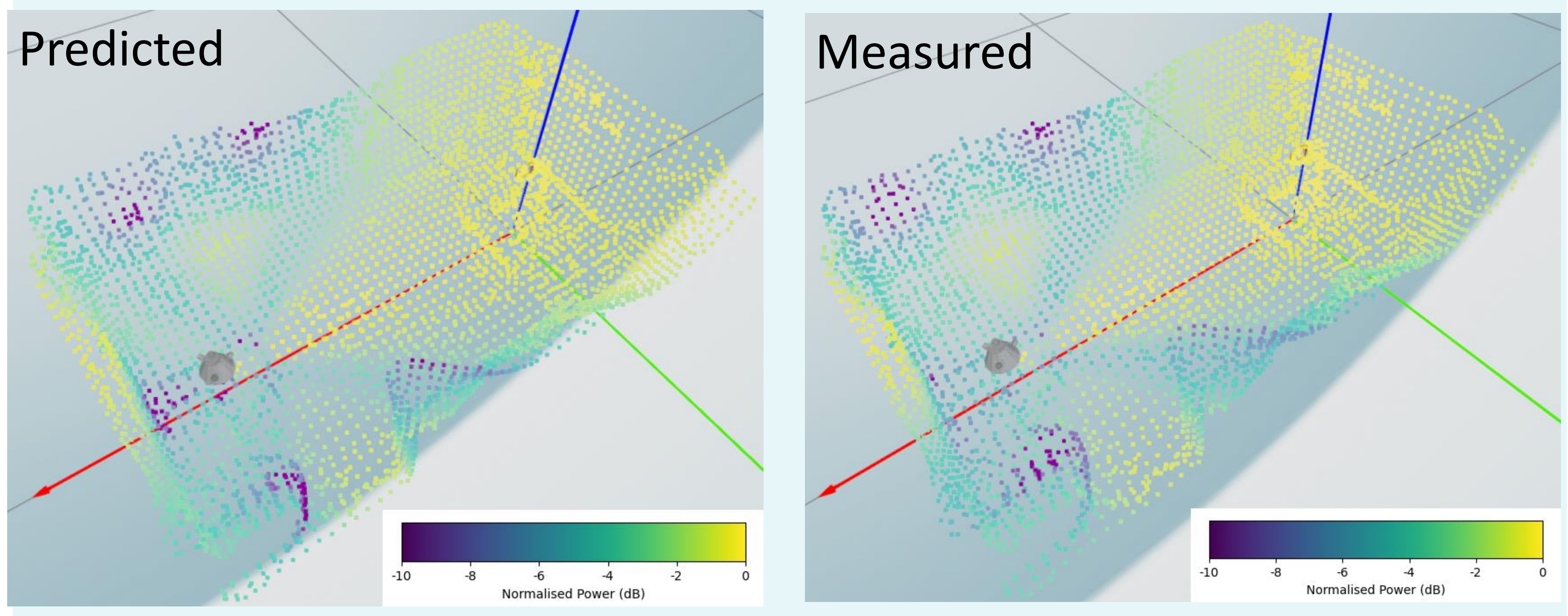
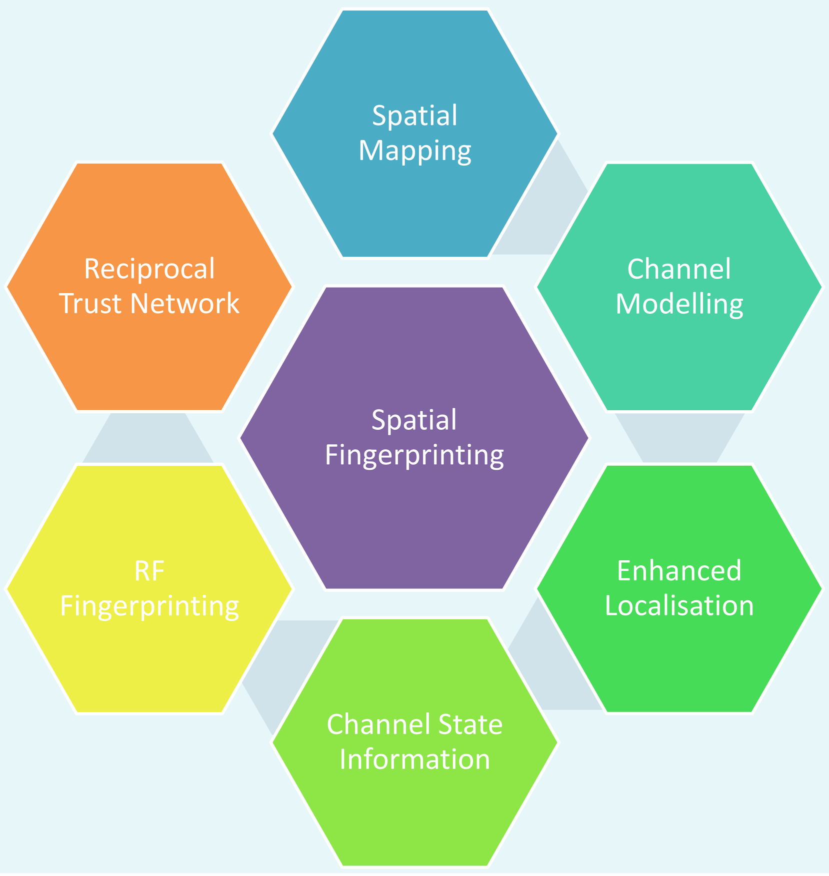


Figure 5: LyceanEM and Measured Spatial Maps of the Chamber

Beacon Position	Estimated Azimuth	Error	Estimated Elevation	Error
-90°	-176°	-0.2°	-14°	20.8°
-45°	-177°	-0.19°	21°	-13.8°
0°	170°	10°	25°	-17.7°
45°	177°	2.2°	-24°	31.2°
90°	106°	70°	-26°	32.8°

Conclusions and Further Work

The initial measurements show strong agreement between the predicted LyceanEM spatial map of the chamber and the measured (97.1% correlation), together with the low angle of arrival errors compared to the beamwidth of the antennas (91°).
The primary interest for continuing research is that of Spatial Fingerprinting for Self-Securing Wireless networks. This approach proposes the addition of RF Fingerprinting methods to categorize and identify nodes. This combination with Enhanced Localization enabled by sensor fusion and onboard electromagnetics modelling will support the formation of reciprocal trust relationships between nodes.
This approach also allows for the primary scatter of a surface to be calculated and cancelled, with applications in medical imaging, ground penetrating radar, and more general environment characterization.



[1] Pelham, T. G., Freire, A. L., Hilton, G., & Beach, M. (2021). Polarimetric Scattering with Discrete Raytracing for OTA Analysis. In *15th European Conference on Antennas and Propagation, EuCAP 2021* [9410981] (15th European Conference on Antennas and Propagation, EuCAP 2021).
[2] Nair, M., Cappello, T., Dang, S., & Beach, M. A. (2022). RF Fingerprinting of LoRa Transmitters Using Machine Learning with Self-Organizing Maps for Cyber Intrusion Detection. 2022 IEEE/MTT-S International Microwave Symposium

Royal Academy of Engineering
University of BRISTOL