Contribution ID: **145** Type: **Oral Presentation**

#7-145 Bayesian Optimization for real-time γ-localization measurements with robotic platforms

Wednesday, June 11, 2025 3:40 PM (20 minutes)

An adaptive measurement approach driven by Bayesian Optimization is described for applications where remote radiation measurements made with robots are constrained by stringent upper thresholds on the mass and power payload of the necessary instrumentation, as well by the time window within which measurements must be made, ultimately affecting their quality and maximum area coverage. The radiation detection hardware comprises a miniature cylindrical cerium bromide (CeBr3) detector, encased in an aluminium body with a photomultiplier tube (PMT) and a High Voltage (HV) module; and a RedPitaya Field Programmable Gate Array (FPGA, STEMlab 125-14) board configured as a Multi-channel Analyzer (MCA). The detector is coupled to a lightweight porous collimator, and mounted to a gimbal to enable energy-resolved angular scans in azimuth and incline. The apparatus is controlled via the Robot Operating System 2 (ROS2) middleware. Gaussian Process regression and a variety of kernel functions are employed to model the underlying radiation distribution of the measurement space, with the selection of subsequent measurement points driven by the model' s uncertainty estimates. The algorithm initializes by requesting measurements at the boundaries of the measurement space and a user-specified number of measurement locations within the boundaries (using stratified random sampling). Subsequent measurement locations are requested dynamically based on the Expected Improvement acquisition function with an exploration bonus term, while the measurement stopping conditions are based on the model's stability and the predicted uncertainties. This method allows reconstructing complex response curves while minimizing the number of required measurements. Its benchmark performance is compared against both non-time and time constrained, yet high spatial granularity laboratory datasets, under different geometric scenarios and radiation fields (serving as look-up tables of simulated measurements in the algorithm). Furthermore, its in-situ deployment performance at the TRIGA research reactor facility of the Jožef Stefan Institute is evaluated and utilised to fine-tune the method's capability in real-world environments (through the addition of bespoke and composite kernels). This approach constitutes a systematic and efficient strategy for radiation data acquisition that maximizes information gain in resource constrained robotic missions, and can be used both as a stand-alone characterisation activity and embedded to robotic navigation algorithms.

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Session Classification: #07 - Decommissioning, Dismantling and Remote Handling

Track Classification: 07 Decommissioning, Dismantling and Remote Handling