Meta-heuristics for improved RF emitter localization

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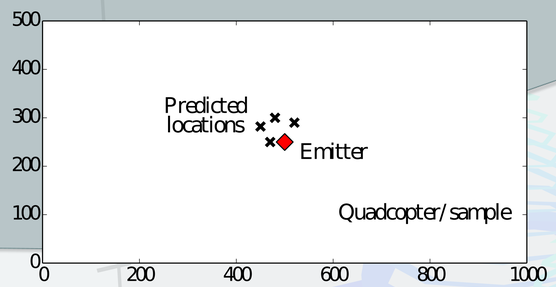
Making PDOA viable for small UAV platforms through meta-heuristics

Background

RF emitter localization

One method of locating an RF emitter is Power Difference of Arrival (PDOA). PDOA relies on measuring the differences in received signal strength at multiple points in space. Given a guess for the emitter location, it is possible to calculate an error measurement using the free space path loss model.

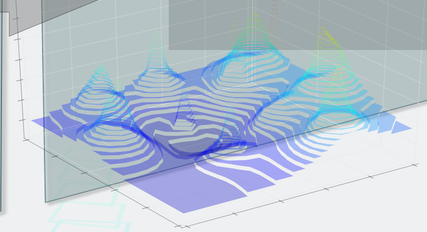
An estimate of the emitter location be can found by solving the non-linear error function for the emitter position. Non-linearity makes this a time consuming optimization. In this paper, meta-heuristics are applied to solve this optimization problem faster, and more precisely, than conventional methods



Non-linear optimization problem

$$P_{kl} = P_k - P_l$$

$$Q(x, y) = \sum_{k<l} [P_{kl} - 5\alpha \log(\frac{(x-x_l)^2 + (y-y_l)^2}{(x-x_k)^2 + (y-y_k)^2})]^2$$



Challenges

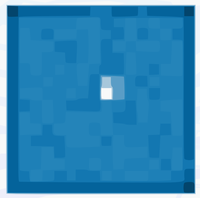
Multi-modality/deceptiveness makes this problem challenging. Instances of the optimization problem often has multiple local optima. These are caused by noisy sensor measurements and the local optima may often be far away from the true emitter location

Strict time constraints are enforced as the goal of this paper is to enable the use of PDOA on resource restricted platforms. The search space is smooth, which may allow for use of local information.

Lack of optimality guarantees combined with strict time constraints make this a challenging problem for meta-heuristic search.

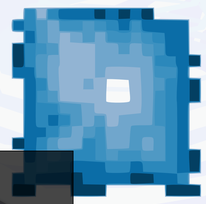
Methods

Preselect NM



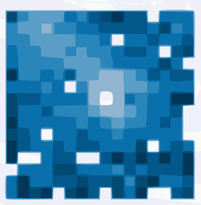
The figures are histograms of how each algorithm explores a single problem instance, accumulated over several runs

PSO

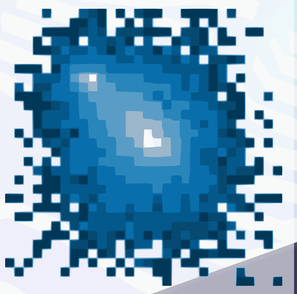


NM

Diff. Evo.



CMA-ES



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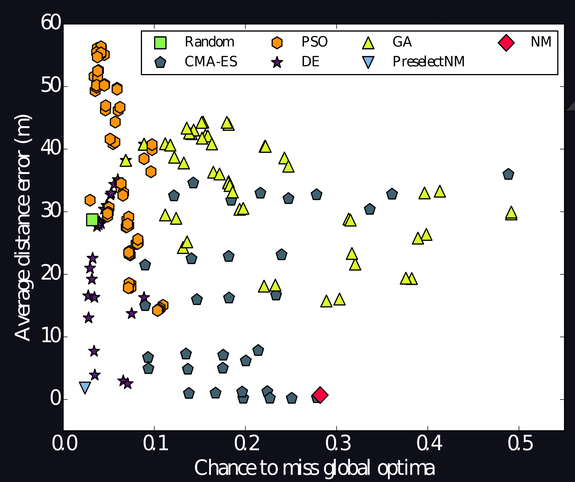
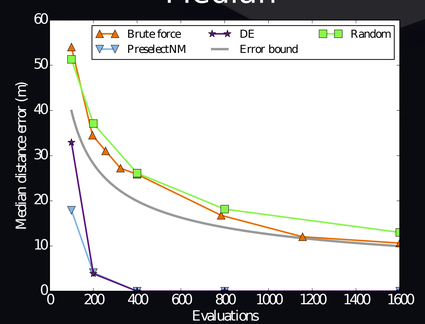
Results and conclusion

Multi-objective performance

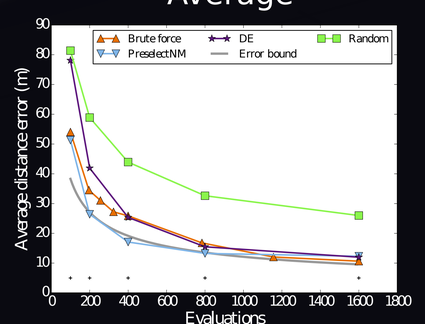


Unreliability affects average performance

Median



Average



Conclusion

A no-cost speedup up 2x can be achieved using Preselect NM

Using median metric (instead of average), 400 evaluations with a meta heuristic is comparable to 40 000 evaluations (100x) using "brute force"

For quick convergence and hill climbing, an adaptive mutation/permutation step is essential.

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