Probabilistic Bisection & Surrogate Functions for Solar Panel Orientation

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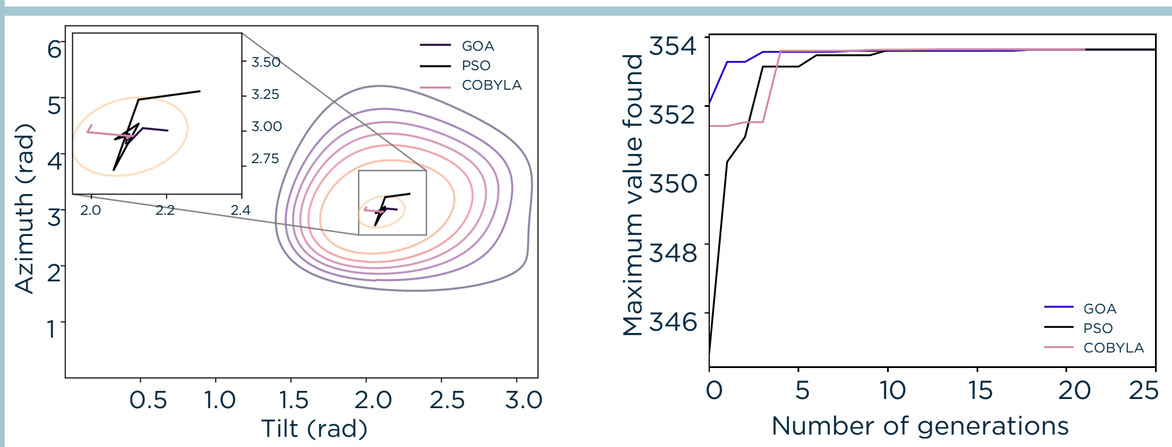
1. Introduction

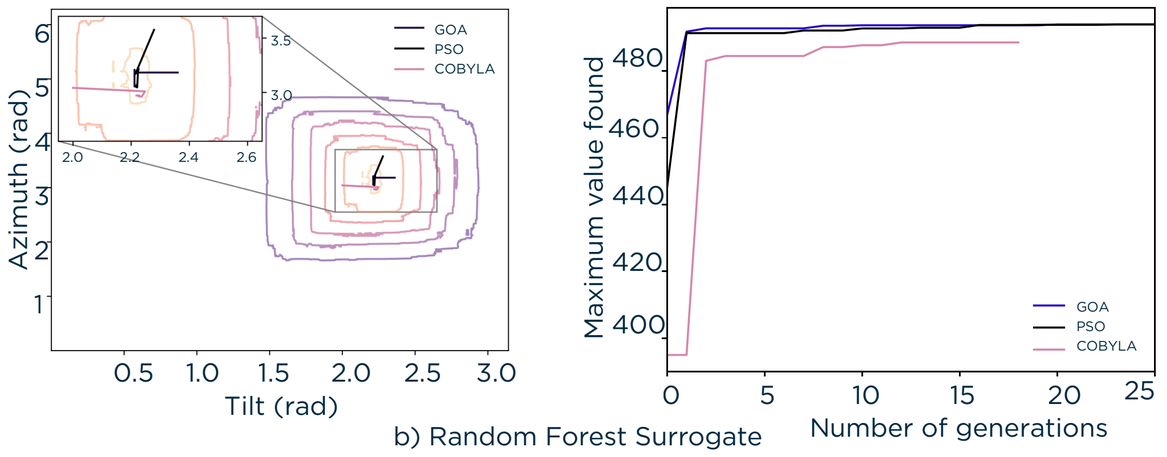
- Solar power is an increasingly important contributor to global energy needs. Can be expensive to model and limited work optimising panel orientation for annual output.
- Solar power predicted is often noisy due to external factors such as weather & solar eclipses.
- Surrogate functions lower fidelity and computational cost.
- Optimisation methods for panel orientation were compared.
- Probabilistic Bisection Algorithm (PBA) is the bisection method, but returns an accurate sign with probability p>0.5.

2. Methodology

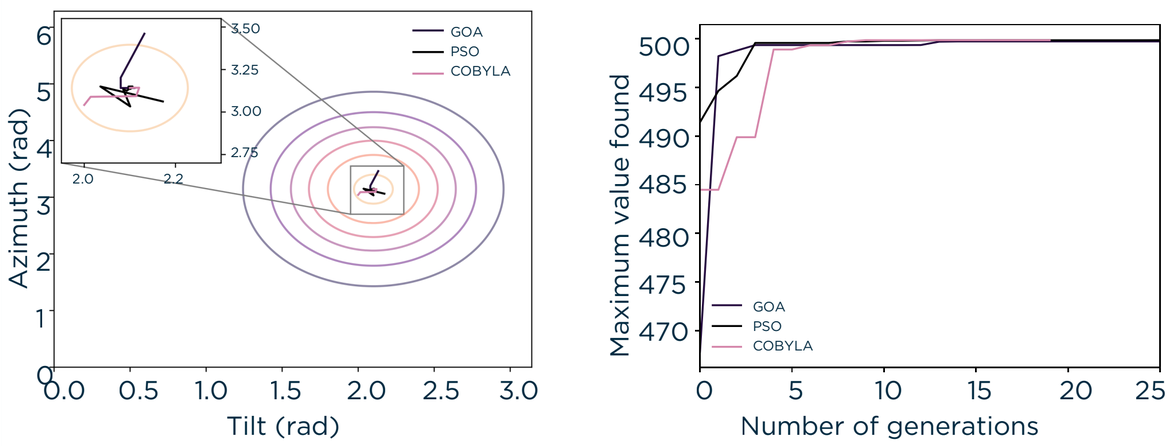
- Annual energy output was derived from Yang *et al., (*2024). The latitude, longitude and weather data were taken from Oslo, Norway. The cell used was the Adani Solar ASP-7-305.
- 3 surrogates were developed: a neural network (NN), a random forest (RF) surrogate and a Gaussian surrogate. Particle swarm (PSO), genetic optimisation algorithms (GOA) and COBYLA (Powell, 1994) were compared.
- PBA was used to determine minimum tilt angle to surpass 24.7375MWh (Fig 2) for 100 evenly spaced p in [0.65,0.95] for fixed azimuth. Iteration number to convergence was recorded.



a) Neural Network Surrogate



b) Random Forest Surrogate



c) Gaussian Surrogate

Figure 1: Surrogate Contours & Optimisation Comparison

3. Results and discussion

- The RF surrogate had highest fidelity (R =0.989) followed by the Gaussian surrogate (R =0.967). NN had the lowest fidelity. The Gaussian surrogate was the most efficient to compute. Fidelity fell significantly (R >-100) when computing larger values (>1e5), so training data had to be scaled.
- GOA performed better than PSO and COBYLA (Fig. 1). COBYLA sometimes did not converge at the correct solution (Fig. 1b). GOA is very expensive to compute, so PSO may be better to use industrially.
- There was a clear relationship between number of iterations to convergence and p. The function fitted in Fig. 2 took the form:

$$y = \frac{2118.562}{-13.287(p - 0.5)}$$

- Other relationships could be possible. The research on Probabilistic Bisection is very limited, so exploring how this relationship works in greater depth would be a good avenue for further research.

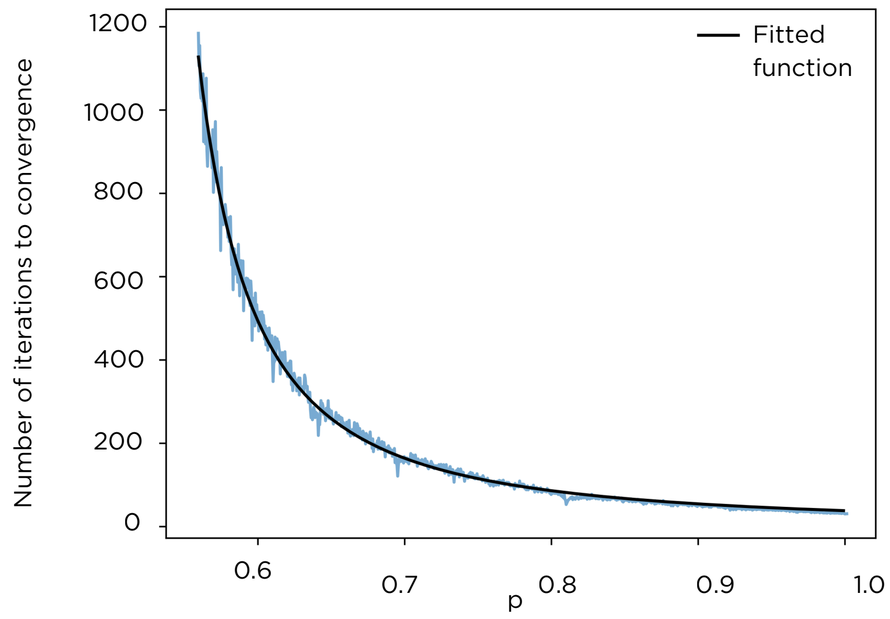


Figure 2: Iterations to convergence against p

4. Conclusion

- RF performed the best of the 3 surrogates. NN may be useful for more complex systems. GOA generally optimised in fewer iterations, but PSO may be better in industrial use cases. There is a clear relationship between iterations to convergence and p for PBA.
- Further work on accurate PV modelling needs to be done.
- PBA requires research for practical use cases, as well as determining the precise relationship between p and number of iterations to convergence. Systematic comparison of optimisation methods is an exploratory area.

References

- Powell, M.J., 1994. A direct search optimization method that models the objective and constraint functions by linear interpolation. In Advances in optimization and numerical analysis (pp. 51-67). Dordrecht: Springer Netherlands.
- Solar, Adani (2026). ASP-7-305. URL: https://energypal.com/best-solar-panels-for-home/adani-solar/asp-7-305
- Yang, D. and Kleissl, J., 2024. Solar irradiance and photovoltaic power forecasting. CRC Press..