**Research Internship: Zoe @ Matterhorn Studio**

**Project**: Machine Learning for Optimising Laser Beams with Deformable Mirrors, specifically with Bayesian Optimisation

**Time**: In a first instance, part-time, 2nd May to 31st of May (22 working days), or full-time (or anywhere in between). Full-time would probably require you to pause all your tutoring, so I’d strongly recommend part-time for the trial! A possible extension to be determined 29th of May!

**Salary**: Standard UK PhD Full-time Stipend: £17668/year; £1473/month; £19668/year if in London, £1,639/month (<https://www.ukri.org/what-we-offer/developing-people-and-skills/find-studentships-and-doctoral-training/changes-to-the-minimum-stipend-from-1-october-2022/>)

**Specific steps:**

* Characterise beam quality with e.g. Gaussian Mixture Models, specifically variational GMM
  + <https://scikit-learn.org/stable/modules/mixture.html#variational-bayesian-gaussian-mixture>
* Optimise beam quality with Bayesian Optimisation by reducing number of peaks identified by vGMM
  + <https://www.youtube.com/watch?v=c4KKvyWW_Xk>
  + <https://machinelearningmastery.com/what-is-bayesian-optimization/>
  + <https://arxiv.org/abs/1807.02811>
* Most likely, things won’t be that easy, so let’s be flexible

**Outcomes:**

* Jakob: evaluate Zoe’s fit, evaluate potential of suggested method, evaluate possible extension of internship
* Zoe: evaluate fit with Jakob, evaluate fit with this kind of ML work, learn more Machine Learning methods: Gaussian Process, Bayesian Optimisation, Gaussian Mixture Models

**Definition of “success”:**

We should more carefully define some specific test cases to aim for.

E.g. ability to identify an arbitrary number of local maxima (say between 1 and >5) in a focal spot image as a quality metric. Focal spot images can be “noisy” so we also need to test against “pathological” over counting of noise as an apparent maxima.

Comparison of new quality metrics against software tools Zoe has already developed during her Masters project, are these new tools faster, more accurate ?

Test of one or more new method (focal spot quality metric and / or optimisation algorithm) on a physical test system with a 9-actuator DM and an aberrated focal spot.

**Resources:**

What specific resources are required to allow the project to progress, what fraction should be based on pre-recorded data sets (e.g. focal spot images) versus access either in person or remote to real world hardware ?

Is Zoe still able to access Imperial College via VPN ? If so we should set up a lab based test system she can access to run some of the work remotely. If not, we will have to come up with an alternative solution to remote access to lab hardware.

Question for Zoe, what “old” data sets do you still have access to. Lets document number of images, image size, some kind of description of the mix of “good” and “bad” images.

Lets define some new test data sets to generate. What specifically do we want, examples with multiple maxima for example ?

Mirror systems, I suggest we begin with a 9 actuator DM system as we have several of these “live” at the moment and Zoe will be familiar with running them. This also provides a well defined starting point for benchmarking new algorithms against tools Zoe developed during her masters project.

15 actuator system. This needs a bit more work before it is usable, unfortunately RAS is the limiting factor here as we are moving into exam marking seasons so I have lots of demands on my time right now.

**Documenting the work:**

How will the work be documented ? Zoe should run a lab book documenting what she attempts to do, we also need to be able to archive data sets, e.g. focal spot images, code.

Set up one-notes and provide access to other team members.

Set up Github for code samples and version control.

**Project Supervision Meetings:**

We need to define how the project will be managed and how progress will be monitored, suggestions fed into the work and outputs discussed. Suggest weekly Teams meeting, say Mondays 11-12 ?