CMLE Interview Challenge Problem

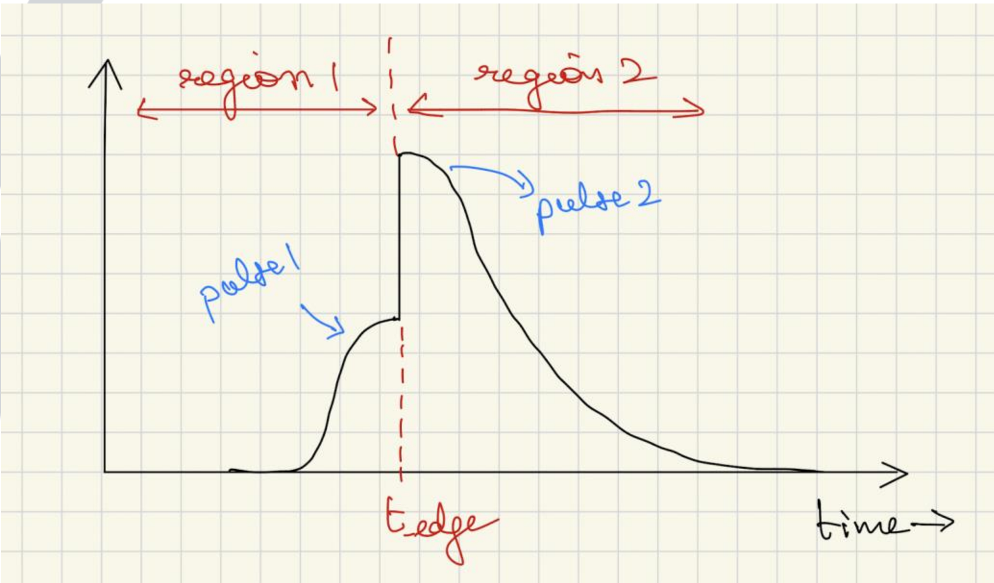
Context

We have a precision sensor/detector that produces time-series signals. In each experimental run, we record measurements from this sensor corresponding to varying scan parameter values. This signal/measurement has a unique structure as described later in this document. We analyse each signal to obtain a ratio. When plotted against the corresponding scan parameters, we obtain a sinusoidal pattern. We are interested in the phase shift of this sinewave.

You are provided with datasets from multiple experiments for two experimental conditions (A and B) and given some tasks.

Signal Structure

The scan parameters are phase in successive increments of 36 degrees, covering a total range of 0° to 1764°. For a given scan parameter value, an ideal detector trace looks something like below:



Each detector trace contains two measurement regions. The transition time between regions (**t_edge**) is provided separately for each condition, as the two conditions have different signal timing:

Region	*Time Window*	*Signal Shape*
Region 1	Before t_edge	A single Gaussian-like pulse (partially captured)
Region 2	After t_edge	Sum of three Gaussian-like pulses (partially captured)

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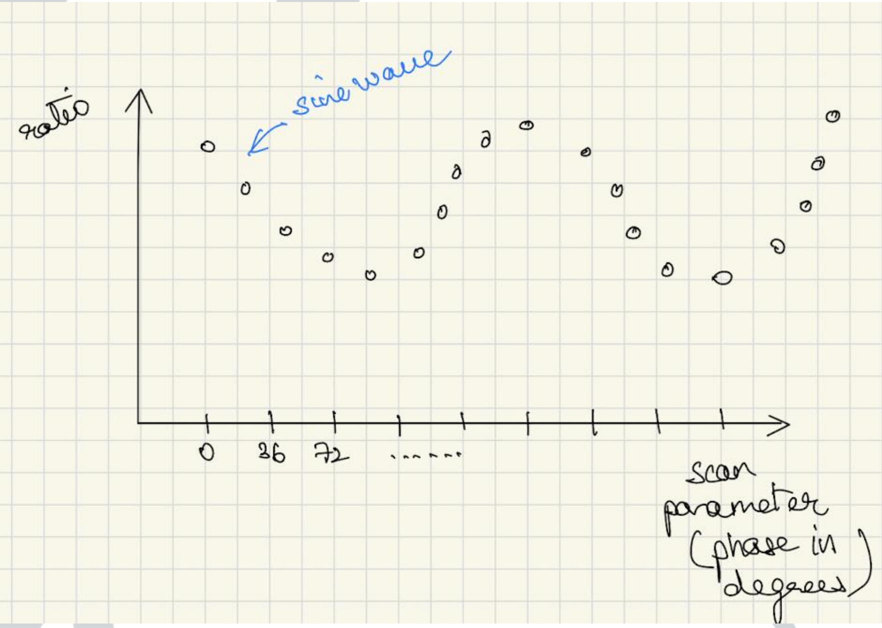
Use `t_edge_a` for condition A signals and `t_edge_b` for condition B signals.

The quantity of interest is the **ratio of peak amplitudes** of these two gaussian pulses in the two measurement regions:

$$ratio \ = \frac{Peak\ Ampltiude\ (Pulse\ 1)}{Peak\ Amplitude\ (Pulse\ 2)}$$

When this ratio is plotted against the corresponding scan parameter (phase), it forms (ideally) the sinusoidal fringe pattern as below:



We are interested in the phase shift of this sinewave.

Data

You are provided with **30 data files** (`*data/scan000.npz*` *through* `*data/scan029.npz*`). Each file represents one experimental run (~5.5 minutes of data) and contains measurements under two experimental conditions (A and B).

Each `.npz` file contains:

Array	*Shape*	*Description*
`time`	(488,)	Time axis in seconds
`signals_a`	(50, 488)	50 detector traces for condition A
`signals_b`	(50, 488)	50 detector traces for condition B
`scan_param_a`	(50,)	Scan parameter values for condition A (degrees)
`scan_param_b`	(50,)	Scan parameter values for condition B (degrees)

`t_edge_a`	scalar	Transition time for condition A (seconds from `time[0]`)
`t_edge_b`	scalar	Transition time for condition B (seconds from `time[0]`)

The scan parameter sweeps from 0° to 1764° in each condition.

Your Tasks

Primary Task

For each experimental run (ie datafile) and condition (ie A and B), estimate the phase shift most accurately with the least uncertainty you can achieve. Report your estimates in milliradians with uncertainty.

Secondary Tasks

- If you needed to achieve similar uncertainty with **significantly fewer data points**, what would you do? Demonstrate.

Evaluation

We are evaluating a diverse range of skills as described in the job posting. Use this opportunity to showcase any relevant capabilities you possess.

There is no single "correct" approach. We're interested in:

- How you think about problems
- What you try and why
- Your ability to interrogate and process noisy data
- How you communicate your work
- The breadth and depth of your technical skills
- Your code writing and software engineering skills

Keep the job description in mind as you approach this challenge.

Important Notes:

- Note that the time windows do not capture the complete Gaussian pulses—only portions of them. The peak pulse amplitudes of a pulse may or may not be contained within each recorded region.
- If we were to record each Gaussian pulse independently, we would find that they don't both peak at the same time.
- The data contains all kinds of **noise throughout**. Robust analysis should identify and account for this.
- Condition A measurements are independent from Condition B, but they have similar experimental setups.
- All 30 experiments were conducted successively, under the same experimental conditions, and with the same instrument.

Next Steps

Submit your work in whatever format best demonstrates your approach and be prepared to walk us through your work during the interview.

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