Project 12: Benchmarking crosspoint calibration

The goal of this project is to benchmark the cross point calibration, which can directly estimate the optimal control parameter at arbitrary precision. Unlike the ping-pong calibration where the use of an empirical formula is used to update the control parameter.

Firstly, benchmarking modules were implemented to enable efficient experiments and analysis. This made it easy to configure experiments, visualize data, compare results, and save them.

The data was generated with *ibmq_ehningen* and 60 experiments were taken into account. The number of shots was 256 and each calibration was executed two times. Every calibration takes qubit 0 for the experiment. The rough calibration was used for both calibration methods.

Since the last checkpoint, the fit of the ping-pong fine amplitude calibration was updated to get a better comparison with cross point calibration. The fitting algorithm was ported from qiskit experiments. It became clear that the fit of the second round has a great variance, because of bad fitting parameters. Therefore more initial guesses for the `numpy.curve_fit()` are added and after fitting it is inspected with a Chi^2 test. The test is an indicator of how good the fit corresponds to the measured data. The fit with the best Chi^2 result is chosen to calculate the π-amplitude. The variance can be lowered by a factor of 1.5.

The variances of ping-pong calibration is larger than the one of cross point calibration. This indicates fit model imperfections of the ping-pong calibration. The fit function is

$$f(x) =- cos((\Delta\phi + \pi) \cdot x - \frac{\pi}{2}) + b \quad (1)$$

where $\Delta\varphi$ is the difference to the initial angle φ and x is the x-data. The cross point calibration seems to be likely better, because of its simple fit model. Which can be described with

$$f_1(x) - f_2(x) = 0. \quad (2)$$

The difference of the two function values f_1 and f_2 is zero at the crosspoint and the amplitude can be directly estimated.
The imperfection of ping-pong calibration is assumed to arise from the trigonometric fit model, where it is assumed that the amplitude *amp* = 1. Usually this is not true due to readout relaxation error or small *Z* error (frequency offset) contribution. However the amplitude and Δθ cannot simultaneously fitted because in the small Δθ limit the model can be approximated to ~ *amp* * Δθ.

This argument is also supported from the aspect of uncertainty of fitting parameters. Analysis of the experimental results shows numerically that the uncertainty of the fitting parameters is smaller for the crosspoint calibration than for the pingpong calibration. This suggests that the crosspoint calibration is more stable than the pingpong calibration in terms of fitting. By the time of the final showcase, it is planned to verify whether this pattern holds for other systems and settings.