Personal statement

Prior to beginning the project I done a fair amount of background reading to gain some familiarity with how computations are performed in lattice field theory. Upon starting, Brian, Roger and myself discussed the direction in which the project should head. After this, the first 3-4 weeks were spent implementing, tuning, and testing the validity of random walk Monte Carlo for a 1 dimensional harmonic oscillator. We checked to see that the results for certain observables agreed with their analytical predictions and results of similar simulations in the literature. Following on from this, I began to work on producing code to carry out the Hamiltonian Monte Carlo (HMC) algorithm to simulate the 1D quantum mechanical harmonic oscillator once again. Owing to a bug in my implementation of HMC, it took me until week 6 to have this correctly running. Once again, we spent a good amount of time checking that my implementation gave the expected results for various observables and the ground state wavefunction of the harmonic oscillator. Once we were confident that my code was running as intended, I next looked into reproducing some known properties of the HMC algorithm (namely behaviour surrounding the acceptance rate and relationships between parameters of method).

Whilst carrying this out, I began to work at extending my code for the harmonic oscillator to the anharmonic oscillator. As this is not an analytically soluble system, I relied on comparison with previous results in the literature. To verify that my code was written correctly, I tried to reproduce the ground state wavefunction of the anharmonic oscillator. I had some difficulty in finding suitable parameters to carry out this test but eventually ended up finding that my results were in good agreement to a parameter set used in a previous work.

At this stage of the project it was approximately 8 weeks into semester 1. I was concurrently doing additional testing of HMC for the two quantum mechanical systems aforementioned and starting to look into methods of analysing autocorrelations and errors in my data. I spent a significant time figuring out why I was having trouble using a pre-packaged python code to measure autocorrelations in my simulation data via a technique called the Gamma method. I eventually managed to resolve this issue but we decided that it would be best to change course and not focus so much at autocorrelation analysis. Instead, for the last few weeks I started looking at simulations of free field theory in 1 and 2 dimensions. Just before finishing up for Christmas, we decided to start looking into Fourier acceleration of free field theory simulations.

Over the course of the Christmas break and into the beginning of semester 2, I finished up working on 2d scalar field simulations with HMC and some small things that were left to do with the QM systems. I also began to work on understanding the premise of Fourier acceleration and implementing it analytically and numerically for 1 dimensional free field theory. I encountered significant difficulty in implementing a correct approach to one element of Fourier acceleration: proper sampling of Fourier transformed fields. This was one of the main roadblocks I encountered in this project and took a while to overcome with help from my supervisors. The first 4-5 weeks of semester 2 consisted of writing up the theory for the various elements that go into Fourier accelerating HMC and actually coding it up in python. The coding of the accelerated algorithm proved to be tricky owing to the conventions used in Python for fast Fourier transforms (FFTs). Afterwards, I carried out similar tests to those mentioned previously to ascertain with reasonable confidence that the simulations were running correctly. I then went on to develop the corresponding code for interacting field theory and began to develop tests of Fourier acceleration. These were applied to both the free case and the interacting case.

The remainder of the semester was spent on analysis of these tests of Fourier acceleration, further reading of the literature relevant to potential applications of the method, and completing the write up of the report.