CS 581: High Performance Computing
Emory University
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Prof. Tianshi Xu

Homework # 4

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1 Environment

List the environment you used to run the code (Operating System, CPU, RAM, etc.).

Solution. The local environment where I was running the code was on a 2022 MacBook Pro with Apple M2 chip, 8 GB of RAM running macOS Sequoia 15.3.2. Additionally, my local Apple M2 has 10 built-in GPU cores.

2 Runtime Comparison

Report the measure outcomes of your two circuits.

Solution. To ensure that I have correctly coded the quantum teleportation ciorcuit, I have placed the circuit with my `cirq` circuit in Fig 1.

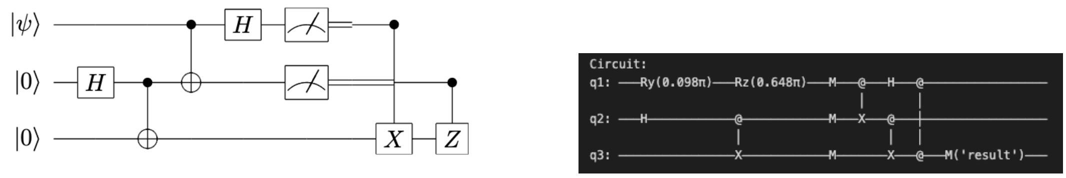

Figure 1: **Left:** The circuit diagram for quantum teleportation as seen in my textbook. **Right:** The ouputed circuit diagram from my `cirq` code.

Seeing the resemblance between the theoretical gate and the practical gate I created, I knew that my quantum teleportation circuit was correct, so upon running the code to produce the hisogram comparing the number of $|0\rangle, |1\rangle$ in both the randomly constructed quibt and the transported cubit, we see great agreement in Fig. 2. Overall, we see similar results, but it is apparent to the naked eye that there is not full agreement. This experiment was run 5 times to see how these results generalize. The random rotation angles in y and z are seen as well as the states and the Hamming distance between the qubit before and after teleportation in Tab. 3. Notice that Trial 1 is the same as the histogram in 2. However, the results get a lot closer in the other trials, where it appears that there is predominately more of one state compared to the other.

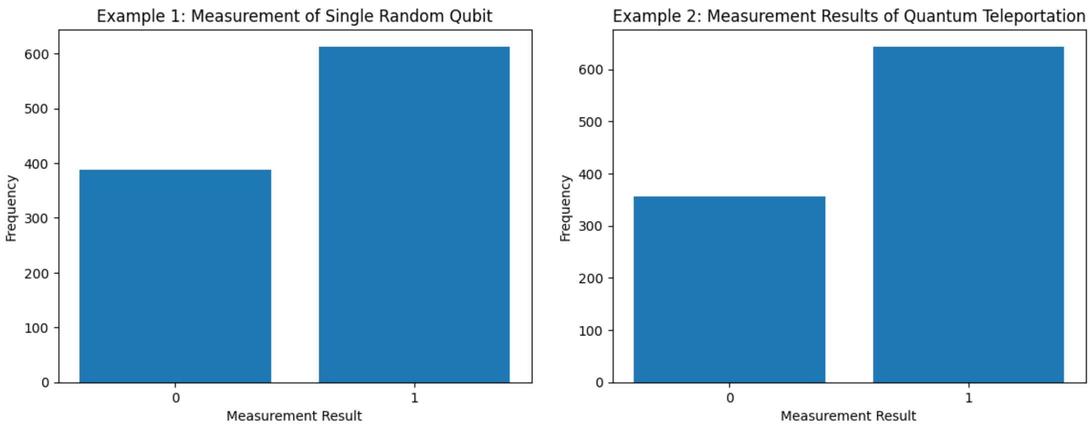

Figure 2: **Left:** A historgram displaying the results of measuring the random qubit 1000 times. **Right:** A histogram displaying the results of measuring the transported qubit 1000 times.

Trial	$\mathbf{R}_y$	$\mathbf{R}_z$	Alice's $\|\phi\rangle$	Bob's $\|\phi\rangle$	$\\|\cdot\\|_{\text{Hamm}}$
1	0.594π	0.011π	{ **0**: 387, **1**: 613}	{**0**: 356, **1**: 644 }	31
2	0.098π	0.648π	{**0**: 969, **1**: 31}	{**0**: 972, **1**: 28}	3
3	0.289π	0.69π	{**0**: 819, **1**: 181}	{**0**: 818, **1**: 182}	1
4	0.825π	-0.598π	{**0**: 84, **1**: 916}	{**0**: 90, **1**: 910}	6
5	0.589π	-0.584π	{**0**: 379, **1**: 621}	{**0**: 382, **1**: 618}	3

Figure 3: Running the code 5 times, we observe very similar results in the random qubit and the transported qubit for sundry random rotations, $\mathbf{R}_y$ and $\mathbf{R}_z$.

3 Homework Feedback

Please provide feedback on all four homework assignments if you want (won't be graded). Level of difficulty? Any suggestions?

Solution. Overall, very nice assignments. Very cool, well thought out, and related to class. **Homework 1:** I think HW1 was a very nice introduction different types of parallel coding like Pthreads and OpenMP. I think it would also be a fun extension to try to access the data in a column-major way to see how time comparisons can be if you don't use a smart memory access pattern. **Homework 2:** HW2 was tough, but in a very good way. It was really well designed so that we would have to all of them MPI commands. The task of the assignment was very clean. I learned a lot. I wish more assignments were of this caliber. **Homework 3:** I think HW3 was a great and easy introduction to CUDA programming. It was a little on the short side though, and I wish there was another extension, where we had to interact with CUDA code a little more thoroughly. **Homework 4:** Maybe this is juse because I have been doing quantum computing for 5 years now, but this was really simple for me. I also would have liked an assignment on other types of computing like analog computing. **Beyond Homework 4:** I think it would be really nice for someone who will have to use a lot of parallel code in his life (G-d willing) to have a last homework assignment on matrix algorithms both dense and sparse.

Acknowledgements

I would like to acknowledge that I am done with CS 581: HPC ;P