Department of Electrical and Computer Engineering
North South University

Senior Design Research

RESCUED: Robust Quantum Error Correction With Surface Code In Noisy Channels Using Ensemble Decoder

Saikat Barua (1731052042)

Monika Rahman (1821654042)

Apurba Jalal Uchash (1620457042)

Faculty Advisor:

Dr. Mahdy Rahman Chowdhury

Associate Professor

ECE Department

Spring, 2023

LETTER OF TRANSMITTAL

July, 2023

To

Dr. Rajesh Palit
Chairman,
Department of Electrical and Computer Engineering
North South University, Dhaka

Subject: **Submission of Capstone Research Report on "RESCUED: Robust Quantum Error Correction With Surface Code In Noisy Channels Using Ensemble Decoder "**

Dear Sir,

With due respect, we would like to submit our **Capstone Research Report** on **"RESCUED: Robust Quantum Error Correction With Surface Code In Noisy Channels Using Ensemble Decoder "** as a part of our BSc program. The report deals with enhancing Quantum Computing Performance through Advanced Decoding Techniques. This Research was very much valuable to us as it helped us gain experience from practical field and apply in real life. We tried to the maximum competence to meet all the dimensions required from this report.

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We will be highly obliged if you kindly receive this report and provide your valuable judgment. It would be our immense pleasure if you find this report useful and informative to have an apparent perspective on the issue.

Sincerely Yours,

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Saikat Barua
ECE Department
North South University, Bangladesh

.....
Monika Rahman
ECE Department
North South University, Bangladesh

.....
Apurba Jalal Uchash
ECE Department
North South University, Bangladesh

APPROVAL

Saikat Barua (1731052042), Monika Rahman (1821654042), and Apurba Jalal Uchash (1620457042) from Electrical and Computer Engineering Department of North South University, have worked on the Senior Design Research titled " RESCUED: Robust Quantum Error Correction With Surface Code In Noisy Channels Using Ensemble Decoder " under the supervision of Dr. Mahdy Rahman Chowdhury partial fulfillment of the requirement for the degree of Bachelors of Science in Engineering and has been accepted as satisfactory.

Supervisor's Signature

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Dr. Mahdy Rahman Chowdhury

Associate Professor

Department of Electrical and Computer Engineering

North South University

Dhaka, Bangladesh.

Chairman's Signature

.....

Dr. Rajesh Palit

Professor

Department of Electrical and Computer Engineering

North South University

Dhaka, Bangladesh.

DECLARATION

This is to declare that this Research is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. All Research related information will remain confidential and shall not be disclosed without the formal consent of the Research supervisor. Relevant previous works presented in this report have been properly acknowledged and cited. The plagiarism policy, as stated by the supervisor, has been maintained.

Students' names & Signatures

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1. Saikat Barua

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2. Monika Rahman

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3. Apurba Jalal Uchash

ACKNOWLEDGEMENTS

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ABSTRACT

RESCUED: Robust Quantum Error Correction With Surface Code In Noisy Channels Using Ensemble Decoder

Quantum error correction is essential for protecting quantum information from errors due to decoherence and other forms of noise. However, decoding quantum error-correcting codes optimally is a computationally hard problem. In our study, we present an ensemble decoder that combines the strengths of different decoders to achieve lower logical error rates and the ability to decode multiple errors. We have used statistical techniques to assign a given error syndrome to the decoder that is most likely to decode it correctly. Different Variants of the Noise model were applied to accurately simulates the effects of noise on transmitted quantum states. The performance of the ensemble decoder was compared to that of conventional decoders, such as minimum-weight perfect matching (MWPM) and union-find (UF) decoders, in both the Symmetric and Asymmetric Noise Models. In the Symmetric Noise Model, the probabilities of bit-flip and phase-flip errors are assumed to be equal, while in the Asymmetric Noise Model, these probabilities can differ. The comparison also included erasure errors, where the original information state of a qubit is erased or lost. The objective of the comparison was to assess the proficiency of the ensemble decoder in rectifying these types of errors relative to traditional decoding techniques. Our findings suggest that the ensemble decoder outperforms the conventional decoders in this noise model, especially for higher code distances. Further, Threshold Simulations were conducted to investigate the influence of lattice size and noise asymmetry on the logical error rate and threshold values of the ensemble decoder. It is evident that increasing the lattice size reduces the logical error rate and that the threshold and pseudo-threshold values increase with step-wise changes in noise asymmetry. The findings of the study highlight the significant potential of the ensemble decoder in the fields of quantum error correction and communication.