
A TEMPLATE FOR ARXIV STYLE *

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ABSTRACT

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1 Introduction

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2 Contribution

3 Notation and Definitions

Definitions and assumptions

- We will use j when referring to a stabilizer, i when referring to a generator, k when referring to a bit
- We take e_Z to be the error vector
- We take σ_Z
- Let \mathcal{C}_Z be a code which can correct Z errors and \mathcal{C}_X be a code which can correct X errors.

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- Let $H_X \in F_2^{M \times N}$ be the parity check matrix for \mathcal{C}_X as well as the generator for \mathcal{C}_Z .
- Let $H_Z \in F_2^{M \times N}$ be the parity check matrix for \mathcal{C}_Z as well as the generator for \mathcal{C}_X .
- Let M be the number of stabilizers. Let us also only consider the case where M is the number of generators. This results from when H_Z and H_X have the same number of rows.
- Let N be the number of bits.
- Assume H_X is the adjacency matrix of a (δ, γ) -left-expander bipartite graph where A is the set of bits and B is the set of stabilizers. Assume the graph is Δ_B, Δ_S regular.

For the rest of the paper, we will only consider Z errors. The algorithm and analysis remain the same if considering X errors, but H_Z must be used as the generator matrix and H_X must be used as the parity check matrix.

Notation

4 Background

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4.1 Small Set Flip

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$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j | y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^N \sum_{j=1}^N \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \quad (1)$$

4.1.1 Headings: third level

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5 Algorithm: K-Top Probabilistic Flip Method (K-Top PFM)

5.1 A Moral Reason/ Intuition

The algorithm is essentially the same as Small Set Bit Flip [TODO: CITE] with a minor difference, only a constant number of generators are checked. The idea here is that given a syndrome σ and a parity check matrix, H_X , the i th row of $H_X^T \sigma$ equals the number of error-ed checks that a qubit touches. Then, the k th row of $H_Z H_X^T \sigma$ is roughly correlated to the number of error-ed checks that the qubits in the k th generator touch. This rough correlation comes from the fact that we are working with expander codes. So then, if you get the generators touching the most error-ed stabilizers, it

Algorithm 1: sort-top-K(T)**Data:** A vector $T \in \mathbb{Z}_2^N$ **Result:** A set S of the top K indices in T

- 1 $S \leftarrow$ indices of a descending radix sort of T 's rows;
- 2 **return** A set of the top K indices in S ;

Algorithm 2: probabilistic-set-flip(E)**Data:** A syndrome $\sigma_0 \in \mathbb{F}_2^M$ **Result:** Deduced error \hat{E} if the algorithm converges and \perp otherwise

- 1 $\hat{E} \leftarrow 0^N$;
- 2 $\sigma \leftarrow \sigma_0$;
- 3 **while** $\exists F \in \mathcal{F} : |\sigma_Z| - |\sigma_Z \oplus H_Z \mathbf{k}| > 0$ **do**
- 4 $T \leftarrow H_Z H_X^T \sigma$;
- 5 $\text{generators} \leftarrow \text{sort-top-K}(T)$;
- 6 $\text{to-check} \leftarrow \bigcup_{i \in \text{generators}} \mathcal{P}(\mathcal{C}_{Z_i})$;
- 7 $\mathbf{k} \leftarrow \arg \max_{\mathbf{k} \in \text{to-check}} \frac{|\sigma_Z| - |\sigma_Z \oplus H_Z \mathbf{k}|}{|\mathbf{k}|}$;
- 8 $\hat{E} \leftarrow \hat{E} \oplus \mathbf{k}$;
- 9 $\sigma \leftarrow \sigma \oplus \sigma_X(\mathbf{k})$;
- 10 **end**
- 11 **return** \hat{E} if $|\sigma| = 0$, \perp otherwise.

would stand to reason that flipping some subset of qubits from a “highly error-ed generator” would result in decreasing the syndrome.

6 PFM Analysis

Definitions

Let us start by defining a slew of random variables

- Let $S_j = 1$ if and only if $\sigma_{Z_j} = 1$ and 0 otherwise.
- Let $L_j = 1$ iff $S_j = 0 \wedge \exists k \in \Gamma(\text{stabilizer } j)$ such that $e_{Z_k} = 1$ and 0 otherwise. In other words, think of L_j as indicating whether stabilizer L_j is “lying” about not neighboring an error-ed bit.
- Let \aleph_i be the number of unique stabilizers in the neighborhood of a generator. More formally,

$$\aleph_i = \bigcup_{k \in H_{X_i}} \Gamma(k).$$

- Let G_i be the number of stabilizers in the neighborhood of a generator such that the stabilizer is flagged. More formally,

$$G_i = \sum_{j \in \aleph_i} S_j$$

- Let G'_i be T_i in the algorithm. Note that G'_i equals TODO: reference here

$$G'_i = \sum_{k \in H_{X_i}} \sum_{j \in \Gamma(k)} S_j$$

- Define E_i to be the number of “lying” stabilizers in \aleph , or,

$$E_i = \sum_{j \in \aleph_i} L_j$$

- E'_i be equal to the sum of the number of neighboring “lying” stabilizers of each bit in generator i . Specifically,

$$E'_i = \sum_{k \in H_{X_i}} \sum_{j \in \Gamma(k)} L_j$$

- Define $\mathcal{O}_i^G = G'_i - G_i$. \mathcal{O}_i^G can be thought of as the number of “over-counted” flagged stabilizers which contribute to G'_i .
- Define $\mathcal{O}_i^E = E'_i - E_i$. \mathcal{O}_i^E can be thought of as the number of “over-counted” lying stabilizers which contribute to E'_i .

Observations and Lemmas

Lemma 6.1. *For a generator, given E_i and G_i , we can find some correction vector $\mathbf{k} \in \mathbb{F}_2^N$ such that $|\sigma_Z| - |\sigma_Z \oplus H_Z \mathbf{k}| \geq G_i - E_i$ and $|\mathbf{k}| \leq \frac{1-\delta}{\Delta_B} (G_i + E_i)$ for $G_i > E_i$.*

Proof. TODO: part 1 is that there are 3 types of stabilizers in neighbourhood. Those from G' , those from E , and those in neither. If those in neither, there is no neighbourhood in their error, so you can leave those bits alone. Then, by flipping bits connected to G' you decrease syndrome by G' , but you add in at most E'

part 2: each flipping bit effects at least $(1-\delta) \Delta_B$ stabilizers □

Lemma 6.2. *Assuming that the error rate is independent and the distribution of $\Gamma(j)$ is i.i.d for all stabilizers j , S_1, S_2, \dots, S_M are independent and*

$$\Pr[S_j = 1] = .$$

Proof. □

Lemma 6.3. *Assuming that the error rate is independent and the distribution of $\Gamma(j)$ is i.i.d for all stabilizers j , L_1, L_2, \dots, L_M are independent and*

$$\Pr[L_j = 1] = .$$

Proof. □

Distributions on the random variables

Probability of single generator error

Probability of error

Error Probability Graphs

7 PFM Numerical Simulations

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8 PFM Future Outlook

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9 Conclusion

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10 Acknowledgments

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11 Examples of citations, figures, tables, references

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The documentation for natbib may be found at

<http://mirrors.ctan.org/macros/latex/contrib/natbib/natnotes.pdf>

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11.1 Figures

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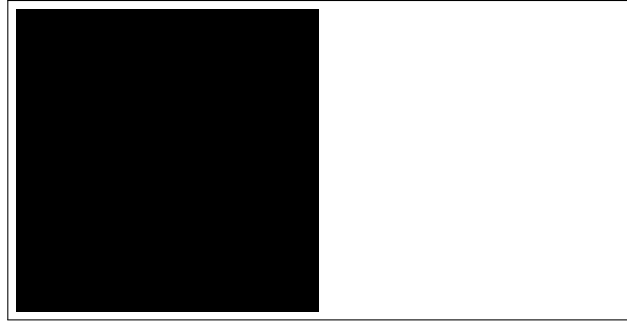


Figure 1: Sample figure caption.

Table 1: Sample table title

Part		
Name	Description	Size (μm)
Dendrite	Input terminal	~ 100
Axon	Output terminal	~ 10
Soma	Cell body	up to 10^6

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11.2 Tables

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11.3 Lists

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12 Conclusion

Your conclusion here

Acknowledgments

This was supported in part by.....

²Sample of the first footnote.

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