# Analysis of Noisy Gradient-Descent Bit Flipping (NGDBF

Using MATLAB/Octave and the PRISM Model Checking Tool

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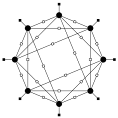

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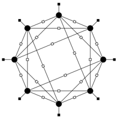

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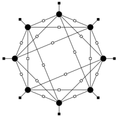

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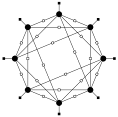
- Absorbing sets are a special case of a trapping sets that are stable in a bit flipping decoder [1]



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  - Given a threshold $\theta$ flip bit $i$ if $E_i < \theta$

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# Sample Generation

- Samples are pulled from Gaussian distribution with a mean of 1 and a standard deviation of $\sigma = \sqrt{\frac{1}{R*10^{SNR/10}}}$, where $R$ is the code rate

```
loop_check = get_error_sample_size(sym_size);
valid_samples = zeros(1,loop_check); % initialize valid samples
valid_idx = 1;
error_samples = zeros(1,loop_check); % initialize error samples
error_idx = 1;
while valid_idx <= loop_check || error_idx <= loop_check
   temp = normrnd(1,sigma); % generate samples
   if temp > 0 % sort valid samples
      valid_samples(valid_idx) = temp;
      valid_idx = valid_idx +1;
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- There is probably a better way to do this, and finding that is on the to-do list

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# Energy Calculation

- To create the model, all possible energy values must be calculated

```
%initialize Energy and check node matrices
E = zeros(2^sym_size,sym_size);
chk_nodes = ones(1, check_size);
chk_sum = zeros(1,sym_size);
% Calculate all possible energy values for each state
for row = 1:2^sym_size
   % Calculate all check nodes
   for adj_row = 1:check_size
         for adj_col = 1:sym_size
            if adj_mat(adj_row,adj_col) == 1
               chk_nodes(adj_row) = chk_nodes(adj_row)*x(row,adj
               chk_sum(adj_col) = chk_sum(adj_col)+chk_nodes(adj
            end
         end
   end
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- The syndrome, called chk_nodes here, is also calculated

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## Transition Probabilities

- Using the energy calculations, the transistion matrix is generated

```
p = ones(2^sym_size,2^sym_size);
% Flip probabilities calculated according to Eq 3.13 in T. Tithi
% dissertation (pg. 26)
for row = 1:2^sym_size
   px = zeros(1,sym_size);
   for p_idx = 1:sym_size
         px(p_idx) = normcdf(theta,E(row,p_idx),sigma);
   end
   rowbin = dec2bin(row-1,sym_size);
   for col = 1:2^sym_size
         colbin = dec2bin(col-1,sym_size);
         for p_idx = 1:sym_size
            if rowbin(p_idx) == colbin(p_idx)
               p(row,col) = p(row,col)*(1-px(p_idx));
            else
               p(row,col) = p(row,col)*px(p_idx);
            end
         end
```

# Write Files and Process Outputs

- The model is written using the helper functions write_model.m and write_explicit_model.m

```
% Process Output for transient and steady state
if (tag(3) == 't' && tag(4) == 'r') || (tag(3) == 's' && tag(4)
      str_idx = regexp(output,regexptranslate('wildcard','0:\(*\
      output = substr(output,str_idx);
      split_output = strsplit(output,"\n");
      for out_idx = 1:2^sym_size
         str_to_parse = char(split_output(out_idx));
         if (str_to_parse(1) >= "0") && (str_to_parse(1) <= "9")
            temp = textscan(str_to_parse,"%d:(%d)=%f");
```

# Write Files and Process Outputs

- The model is written using the helper functions write_model.m and write_explicit_model.m
- A system call to PRISM runs either a transient analysis, steady-state analysis, or a user-defined property analysis

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% Process Output for transient and steady state
if (tag(3) == 't' && tag(4) == 'r') || (tag(3) == 's' && tag(4)
    str_idx = regexp(output,regexptranslate('wildcard','0:\(*\
    output = substr(output,str_idx);
    split_output = strsplit(output,"\n");
    for out_idx = 1:2^sym_size
        str_to_parse = char(split_output(out_idx));
        if (str_to_parse(1) >= "0") && (str_to_parse(1) <= "9")
            temp = textscan(str_to_parse,"%d:(%d)=%f");
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# Write Files and Process Outputs

- The model is written using the helper functions write_model.m and write_explicit_model.m
- A system call to PRISM runs either a transient analysis, steady-state analysis, or a user-defined property analysis
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- A system call to PRISM runs either a transient analysis, steady-state analysis, or a user-defined property analysis
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  - It works with some properties, but this needs to be expanded

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# What's Next

- Issues and Possible Solutions

# What's Next

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  - Runtime

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  - Runtime
    - Large trapping sets take a long time to run

# What's Next

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- Issues and Possible Solutions
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    - Large trapping sets take a long time to run
    - Maybe rewrite in C?
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    - Also takes a long time for large trapping sets

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  - Runtime
    - Large trapping sets take a long time to run
    - Maybe rewrite in C?
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  - Use PRISM output to generate FER graphs

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        - May need to run more simulations for each initial state and take average?

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  - Runtime
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    - Need to determine if PRISM is slow or just file I/O
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    - Maybe use some kind IS?
- To do
  - Use PRISM output to generate FER graphs
    - May need to run more simulations for each initial state and take average?
  - Validate tool against Tasnuva's dissertation results

# Sources


- [1] T. Tithi, “Error-Floors of the 802.3an LDPC Code for Noise Assisted Decoding”, *All Graduate Theses and Dissertations*, pp. 7465, 2019.

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- [3] T. Wadayama, K. Nakamura, M. Yagita, Y. Funahashi, S. Usami, and I. Takumi, “Gradient descent bit flipping algorithms for decoding LDPC codes”, *Communications, IEEE Transactions on*, vol. 58, no. 6, pp. 1610-1614, 2010.

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- [4] C. Winstead and E. Boutillon, “Hardware Demonstration of Noisy Gradient Descent Bit Flipping (NGDBF) for IEEE 802.3 Standard Code”.
- [5] “Trapping Set Ontology”, https://uweb.engr.arizona.edu/~vasiclab/Projects/CodingTheory/TrappingS (accessed Aug 4, 2023).