Assignment 1

● Graded

Group

HARSH GUPTA
PARNIKA MITTAL
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...and 3 more

View or edit group

Total Points

55 / 60 pts

Question 1

Derivation - APUF arrival time

8 / 8 pts

✔ **+ 8 pts** A valid derivation showing that a linear model suffices to solve the problem.

− 2 pts Minor mistakes or insufficient details

+ 0 pts Completely wrong or else unanswered

Question 2

Dimensionality - APUF arrival time

2 / 2 pts

✔ **+ 2 pts** A dimensionality is derived for the map, possibly with minor mistakes

− 1 pt Minor mistakes e.g. large dimensionality > 100

+ 0 pts Completely wrong or else unanswered

Question 3

Derivation - COCO-PUF response

8 / 8 pts

✔ **+ 8 pts** A valid derivation showing that a linear model suffices to solve the problem.

− 2 pts Minor mistakes

+ 0 pts Completely wrong or else unanswered

Question 4

Dimensionality - COCO-PUF response

2 / 2 pts

✔ **+ 2 pts** A dimensionality is derived for the map, possibly with minor mistakes

− 1 pt Minor mistakes e.g. quadratic dimensionality > 100

+ 0 pts Completely wrong or else unanswered

Question 5

Code

30 / 35 pts

+ 0 pts No rubric -- see comments for mark breakup

+ 30 pts GROUP NO: 14

Grading scheme for code:
Dimensionality dd: dd < 100 (5 marks), 100 <= dd < 1000 (4 marks), dd >= 1000 (3 marks)
Train time tt (in sec): tt < 1 (10 marks), 1 <= tt < 2 (9 marks), 2 <= tt < 10 (8 marks), 10 >= tt (7 marks)
Map time mt (in sec): mt < 0.1 (10 marks), 0.1 <= mt < 0.5 (9 marks), 0.5 <= mt < 1.0 (8 marks), mt >= 1.0 (7 marks)
Error rate for Response0 e0: e0 < 0.05 (5 marks), 0.05 <= e0 < 0.1 (4 marks), e0 > 0.1 (3 marks)
Error rate for Response1 e1: e1 < 0.05 (5 marks), 0.05 <= e1 < 0.1 (4 marks), e1 > 0.1 (3 marks)

dd = 1024.0 : 3 marks
tt = 11.207 sec : 7 marks
mt = 0.037 sec : 10 marks
e0 = 0.03 : 5 marks
e1 = 0.007 : 5 marks
TOTAL: 30 marks

Question 6

Hyperparameters

Resolved 5 / 5 pts

✔ **+ 5 pts** Description of effect of at least two of the four hyperparameter experiments mentioned in the assignment package

− 2 pts Insufficient or missing details of hyperparameters e.g. missing grid values if grid search was used.

+ 0 pts Completely wrong or else unanswered.

Regrade Request **Submitted on: Jul 20**

In Part 6 of the problem, we have shown with graphs the best choice of hyper parameter over all four mentioned in the assignment package, and chose the best of them in our code. It was not explicitly mentioned to add descriptions, and we implicitly chose the best. The times were checked locally hence they are not scaled according to the evaluation script times. But the result still concurs with observations.

Updated

Reviewed on: Jul 21

Question assigned to the following page: [1]

Data Innovators - Report for Assignment 1 - CS771

1. Kshitij Bhardwaj - 230580

2. Harsh Gupta - 230445

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4. Parnika Mittal - 230736

5. Harshit Agarwal - 230458

1

There are two possibilities for the time upper signal of i^{th} Multiplexer takes:

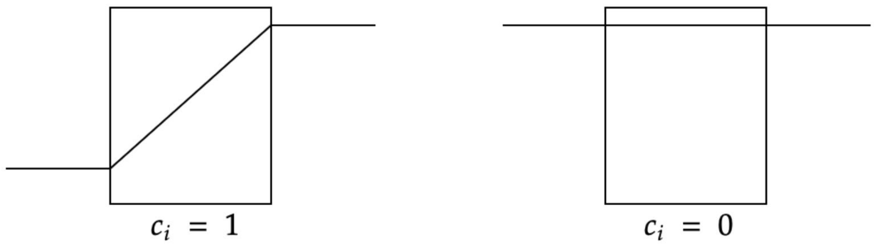
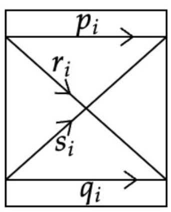


Figure 1: Defines the possible values of c for i'th Multiplexer and corresponding Multiplexer Configuration

For a Multiplexer, time delays $p_i,\ q_i, r_i,\ s_i$ are defined as:



Preprint. Under review.

$t_i^u = [(1-c_i)p_i + c_i r_i] + t_{i-1}^u$ (if the signal started upper at (*i-1*)th Multiplexer)

$t_i^u = [(1-c_i)q_i + c_i s_i] + t_{i-1}^l$ (if the signal started lower at (*i-1*)th Multiplexer)

where t_i^u refers to the signal that comes out as upper signal at last Multiplexer

Since we need the time of the signal that reaches as the upper signal we can think of it like finding out the time of the signal that starts out as upper but with the reverse challenge input given to us. So if the number of interchanges of signal from the last to the i^{th} Multiplexer is even then we need the time of the signal that enters the ith Multiplexer as the upper signal otherwise it cannot reach as upper signal and if it's odd then the lower signal at ith Multiplexer turns out to be the final upper signal

In order to know whether the final upper signal is UPPER or LOWER at the i^{th} Multiplexer, we can use the expression:

$$\prod_{i=i}^{31}(1-2c_i)$$

Hence the time that the final UPPER signal takes at i^{th} Multiplexer would be:

$$\begin{aligned} t_i^u &= [(1-c_i)p_i + c_i r_i][\frac{1+\prod_{i=i}^{31}(1-2c_i)}{2}] \\ &+ [(1-c_i)q_i + c_i s_i][\frac{1-\prod_{i=i}^{31}(1-2c_i)}{2}] \end{aligned} \tag{1}$$

which can be written as:

$$\begin{aligned} t_i^u = &\frac{(1-2c_i)}{2}\frac{(p_i+q_i-r_i-s_i)}{2} + \frac{(p_i+q_i+r_i+s_i)}{4} \\ &+ [\frac{\prod_{i=i+1}^{31}(1-2c_i)}{2}][\frac{(p_i-q_i-r_i+s_i)}{2}] \\ &+ [\prod_{i=i}^{31}(1-2c_i)][\frac{(p_i-q_i+r_i+-s_i)}{4}] \end{aligned} \tag{2}$$

Using the Following Substitutions:

$$\alpha_i = \frac{p_i-q_i+r_i-s_i}{4}$$
$$\beta_i = \frac{p_i-q_i-r_i+s_i}{4}$$
$$\gamma_i = \frac{p_i+q_i-r_i-s_i}{4}$$
$$b_i = \frac{p_i+q_i+r_i+s_i}{4}$$
$$d_i = (1-2c_i)$$

(i=0,1,2,...31)

$$w_i = \alpha_i + \beta_{i-1} \text{ (i=1,2,...31)}$$

$$w_0 = \alpha_0 \text{ (i=0)}$$

Questions assigned to the following page: 1, 2, and 3

$$x_i = d_{31}.d_{30}...d_{i+1}.d_i$$

Total Time (summation of time taken at each Multiplexer) would be:

$$T_{31}^u = \textstyle\sum_{i=0}^{31}(d_i\gamma_i + b_i + w_i x_i) + \frac{p_{31}-q_{31}-r_{31}-s_{31}}{4}$$

$$T_{31}^u = \sum_{i=0}^{31}(d_i\gamma_i + b_i + w_i x_i) + \beta_{31} \tag{3}$$

This can be written as $W^T\phi(c) + b$:

$$w_i = \alpha_i + \beta_{i-1} \text{ (i=1,2,...30)}$$

$$w_0 = \alpha_0$$

$$w_{31} = \alpha_{31} + \beta_{31} + \gamma_{31}$$

$$w_i = \gamma_{i-32} \text{ (for i=32, 33,... 62)}$$

$$\phi_i = x_i \text{ (for i=0, 1,... 31)}$$

$$\phi_i = d_{i-32} \text{ (for i=32, 33,... 62)}$$

$$b = \textstyle\sum_{i=0}^{31} b_i + \frac{p_{31}-q_{31}-r_{31}+s_{31}}{4}$$

$$\Rightarrow W^T\phi(c) + b$$

2

Dimensionality = 63
As 63 Linearly Independent terms are included in Linear Model **W**

3

$$\begin{aligned} T_i &= t_i^u + t_i^l \\ &= \sum_{i=0}^{i}[(p+q)(1-c_i) + (r+s)(c_i)] \\ &= \sum_{i=0}^{i}[(p+q-r-s)(\frac{1-2c_i}{2}) + \frac{p+q+r+s}{2}] \end{aligned} \tag{4}$$

Question assigned to the following page: 3

$$t_i^u = \sum_{i=0}^{i}[(1-2c_i)(\frac{p_i+q_i-r_i-s_i}{4}) + \frac{p_i+q_i+r_i+s_i}{4}$$
$$+ \prod_{i=i}^{31}(1-2c_i)(\frac{p_i-q_i+r_i-s_i}{4}) + \prod_{i=i+1}^{31}(1-2c_i)(\frac{p_i-q_i-r_i+s_i}{4})] \quad (5)$$

$$t_i^l = T_i - t_i^u = \sum_{i=0}^{i}[(1-2c_i)(\frac{p_i+q_i-r_i-s_i}{4}) + \frac{p_i+q_i+r_i+s_i}{4}$$
$$- \prod_{i=i}^{31}(1-2c_i)(\frac{p_i-q_i+r_i-s_i}{4})$$
$$- \prod_{i=i+1}^{31}(1-2c_i)(\frac{p_i-q_i-r_i+s_i}{4})] \quad (6)$$

For PUF0, delays remain the same, p_i, q_i, r_i, s_i
For PUF1, corresponding delays are denoted as $p_i^{'}, q_i^{'}, r_i^{'}, s_i^{'}$
(for the $i^{'}th$ Multiplexer)
Hence for Response0, if sign of $t_{31}^{l'} - t_{31}^{l}$ is positive, Response0 will be 1

Therefore, it can be written as:

$$\frac{1+sign(t_{31}^{l'}-t_{31}^{l})}{2}$$

Here

$$t_{31}^{l'} - t_{31}^{l} = \sum_{i=0}^{31}[d_i(\gamma_i^{'}-\gamma_i) + b_i^{'} - b_i - (w_i^{'}x_i - w_i x_i)] - \beta_{31}^{'} + \beta_{31} \quad (7)$$

This can be written as $W^T\phi(c) + b$:
(ϕ has the same meaning as before)

$$w_i = \alpha_i + \beta_{i-1} - \alpha_i^{'} - \beta_{i-1}^{'} \text{ (i=1,2,...30)}$$

$$w_0 = \alpha_0 - \alpha_0^{'}$$

$$w_{31} = \alpha_{31} + \beta_{31} + \gamma_{31} - \alpha_{31}^{'} - \beta_{31}^{'} - \gamma_{31}^{'}$$

$$w_i = \gamma_{i-32} - \gamma_{i-32}^{'} \text{ (for i=32, 33,... 62)}$$

Questions assigned to the following page: 3, 4, and 6

$$\phi_i = x_i \text{ (for i=0, 1,... 31)}$$

$$\phi_i = d_{i-32} \text{ (for i=32, 33,... 62)}$$

$$b = \sum_{i=0}^{31}(b_i - b_i^{'}) + \beta_{31} - \beta_{31}^{'}$$

$$\Rightarrow W^T\phi(c) + b$$

(All Other Notations are same as in Q1)

And For Response 1: sign of $t_{31}^{u} - t_{31}^{u'}$ decides the response
Here

$$t_{31}^{u} - t_{31}^{u'} = \sum_{i=0}^{31}[d_i(\gamma_i - \gamma_i^{'}) + b_i - b_i^{'} + (w_i x_i - w_i^{'} x_i)] + \beta_{31} - \beta_{31}^{'} \quad (8)$$

This can be written as:

$$\Rightarrow W^T\phi(c) + b$$

(All Notations are same as above)

4

Dimensionality for Response 0 = **63**
Dimensionality for Response 1 = **63**

6

Here we will discuss the model performance of LinearSVC and LogisticRegression considering the metrics:
(1) my_fit Time : Time taken by the my_fit() function in seconds
(2) 1 - Accuracy (Response 0) : Accuracy Losses for the Response 0 Arbiter PUF
(3) 1 - Accuracy (Response 1) : Accuracy Losses for the Response 1 Arbiter PUF

For all the above mentioned metrics, the lower the output values, the better the model performance

Question assigned to the following page: 6

(a) changing the loss hyperparameter in LinearSVC (hinge vs squared hinge)

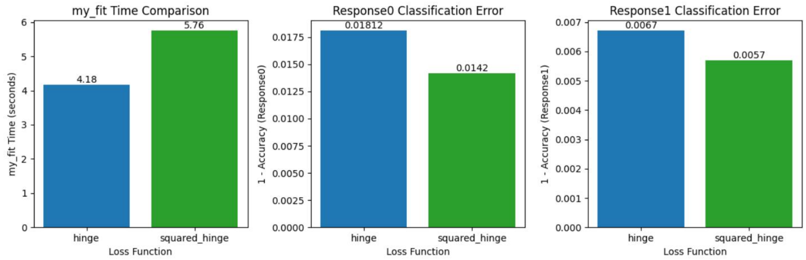


Figure 2:

(b) setting C in LinearSVC and LogisticRegression to high/low/medium values

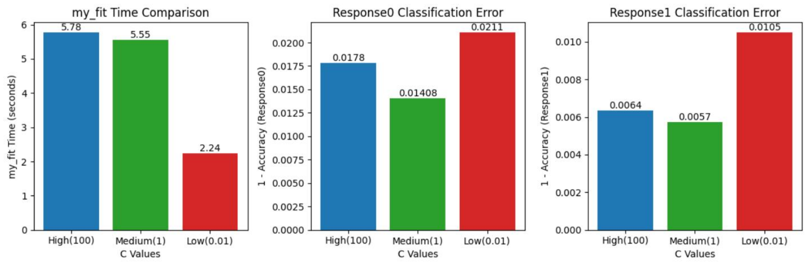


Figure 3: LinearSVC model statistics with varying hyperparameter C (inverse regularization)

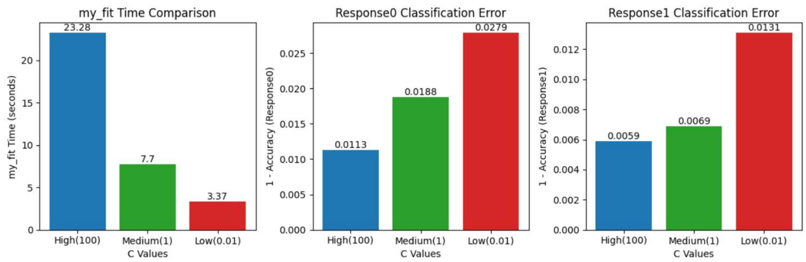


Figure 4: Logistic Regression model statistics with varying hyperparameter C (inverse regularization)

Question assigned to the following page: 6

(c) changing tol in LinearSVC and LogisticRegression to high/low/medium values

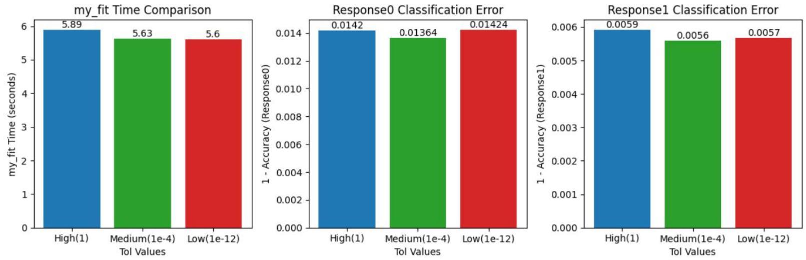


Figure 5: LinearSVC model statistics with varying Tolerance

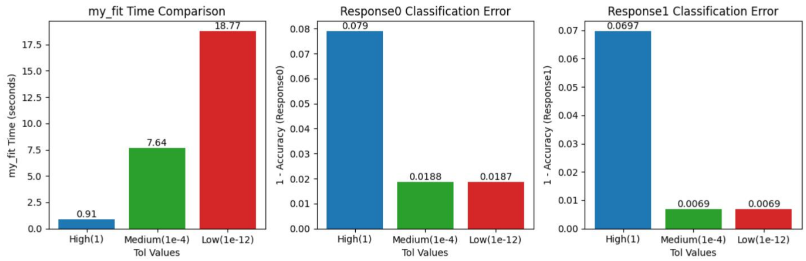


Figure 6: Logistic Regression model statistics with varying Tolerance

(d) changing the penalty (regularization) hyperparameter in LinearSVC and LogisticRegression (l2 vs l1)

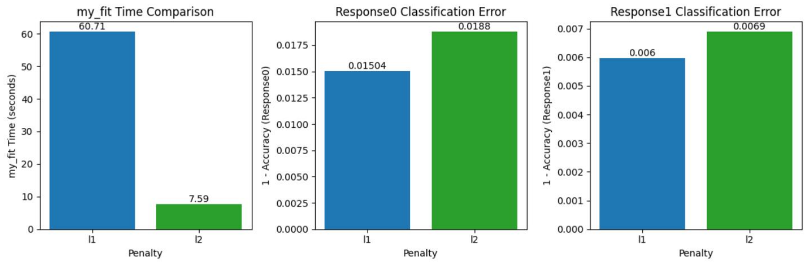


Figure 7: LinearSVC model statistics with varying norms used in penalization

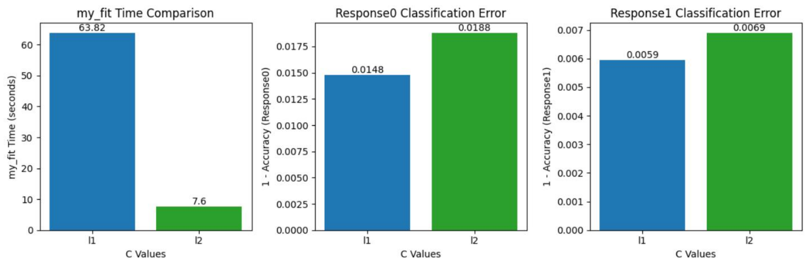


Figure 8: LinearSVC model statistics with varying norms used in penalization

No questions assigned to the following page.

7 References

1. Khatri-Rao Product - Wikipedia
2. matplotlib Documentation
3. scikit-learn Documentation
4. Modelling Delay-based Physically Unclonable Functions through Particle Swarm Optimization - *Nimish Mishra, Indian Institute of Technology Kharagpur, Kuheli Pratihar, Indian Institute of Technology Kharagpur, Anirban Chakraborty, Indian Institute of Technology Kharagpur, Debdeep Mukhopadhyay, Indian Institute of Technology Kharagpur*