Morse Code Datasets for Machine Learning

Sourya Dey, Keith Chugg, Peter Beerel

9th International Conference on Computing, Communication and Networking Technologies

July 2018

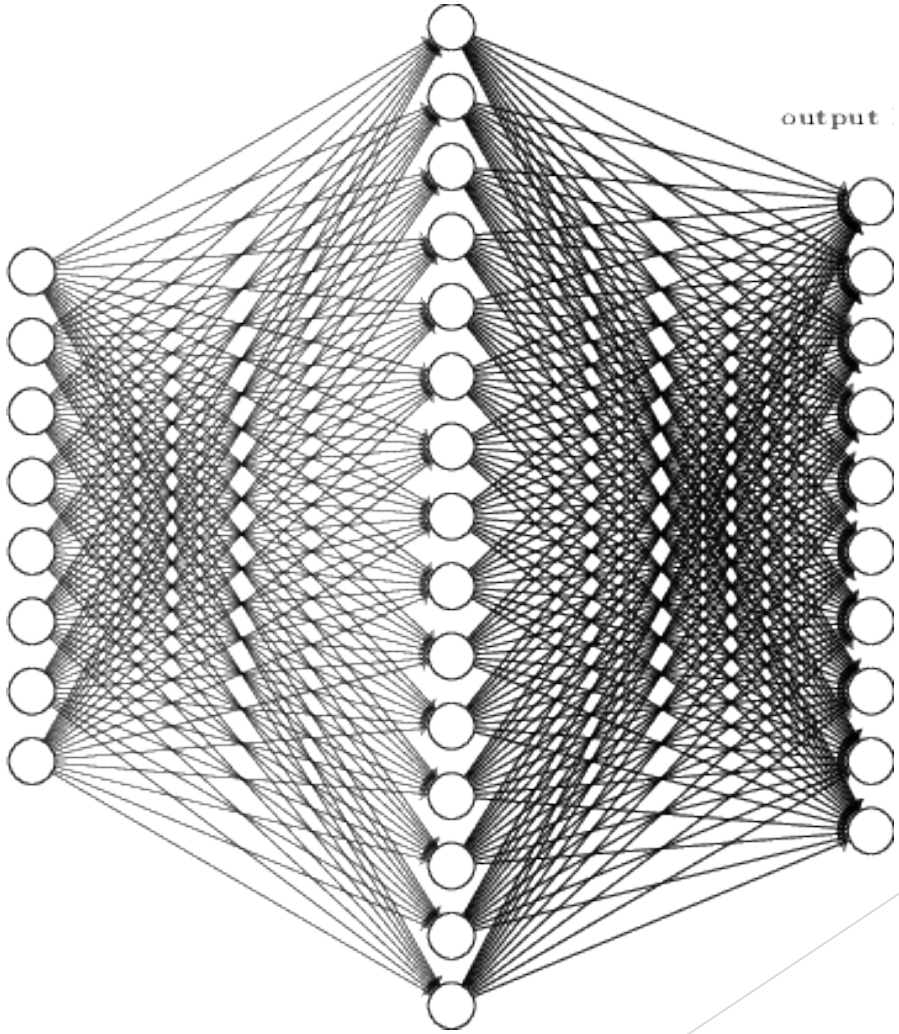
USC University of Southern California

Machine Learning and Neural Networks

An algorithm to learn from data and classify it

Machine Learning and Neural Networks

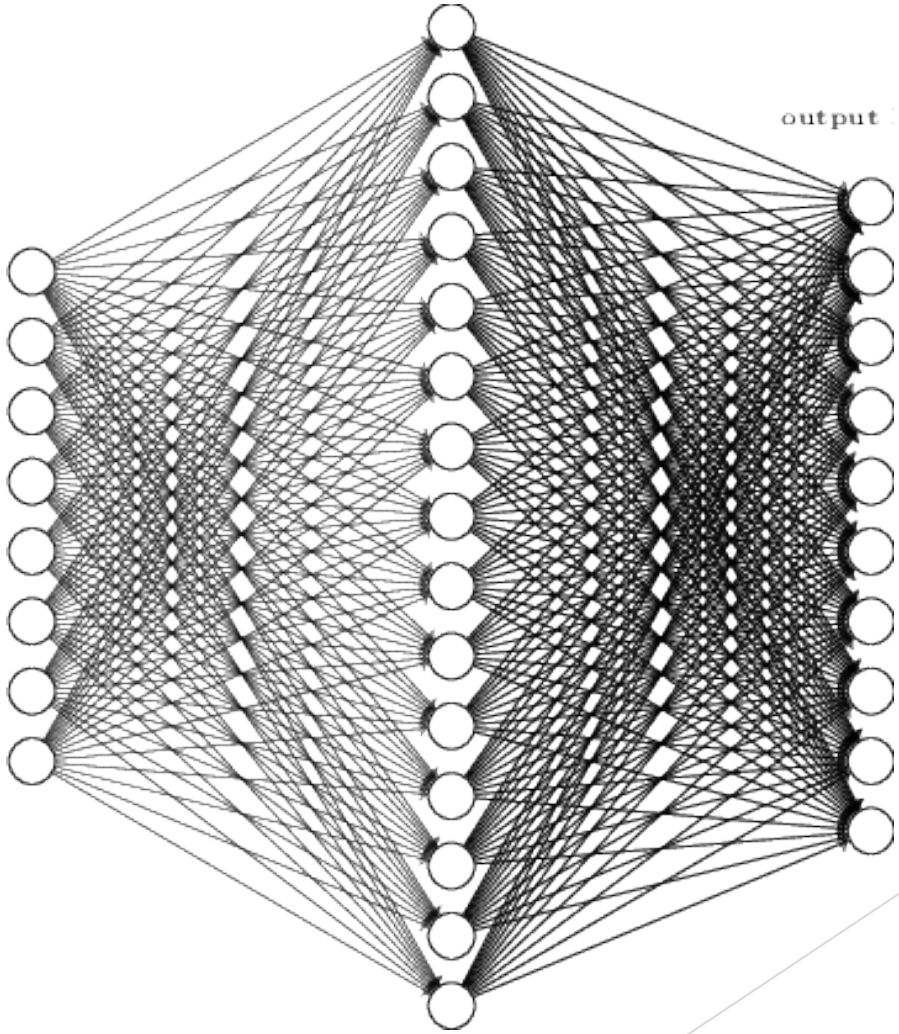
An algorithm to learn from data and classify it



Machine Learning and Neural Networks

An algorithm to learn from data and classify it

Need a lot of data for good performance



Issues with Natural Data

- Most data is naturally collected and labeled by humans
- Labeling is time-consuming (e.g. Imagenet[1])
- Data can have missing features (e.g. Lung cancer dataset[2])

1: http://www.image-net.org/
2: http://archive.ics.uci.edu/ml/datasets/Lung+Cancer

Synthetic data as a Solution

- **Synthetic data** generated and labeled using algorithms
- Can be mass-produced cheaply without missing features

- Algorithm can be tuned to:
  - *Adjust difficulty*
  - Get any distribution

Overview of our Work

- Algorithm to generate Morse code classification datasets of varying difficulty
- Metrics to evaluate difficulty of a dataset

Overview of our Work

- Algorithm to generate Morse code classification datasets of varying difficulty
- Metrics to evaluate difficulty of a dataset

Morse code is a system of communication to encode characters as dots and dashes

\+ • — • — •

Overview of our Work

- Algorithm to generate Morse code classification datasets of varying difficulty
- Metrics to evaluate difficulty of a dataset

Morse code is a system of communication to encode characters as dots and dashes

\+ • — • — •

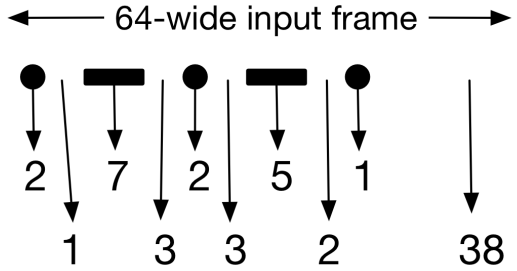
64 character classes

The Algorithm

Step 1:

Frame length: 64

Dot: 1-3
Dash: 4-9
Intermediate space: 1-3
Leading spaces: None
Trailing spaces: Remaining at end



Codeword Length = 26. Remaining spaces = 38

The Algorithm

Step 1:

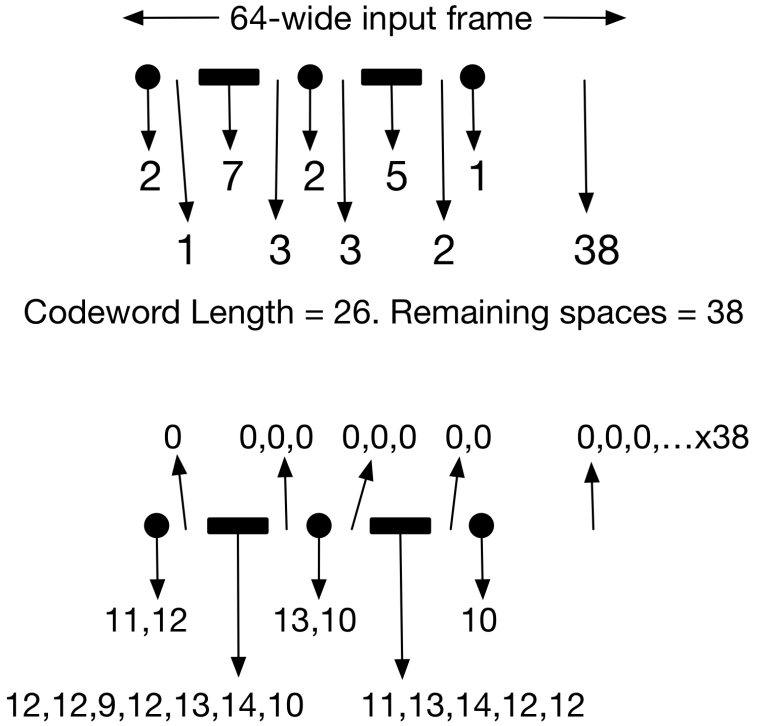
Frame length: 64

Dot: 1-3
Dash: 4-9
Intermediate space: 1-3
Leading spaces: None
Trailing spaces: Remaining at end

Step 2:

Expected value range = [0,16]

Dot, dash = *Normal*(12,4/3)
Space = 0



The Algorithm

Step 1:

Frame length: 64

Dot: 1-3
Dash: 4-9
Intermediate space: 1-3
Leading spaces: None
Trailing spaces: Remaining at end

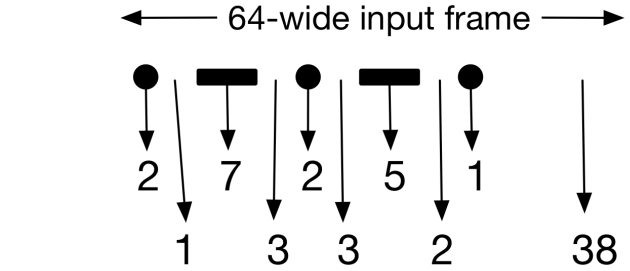
Step 2:

Expected value range = [0,16]

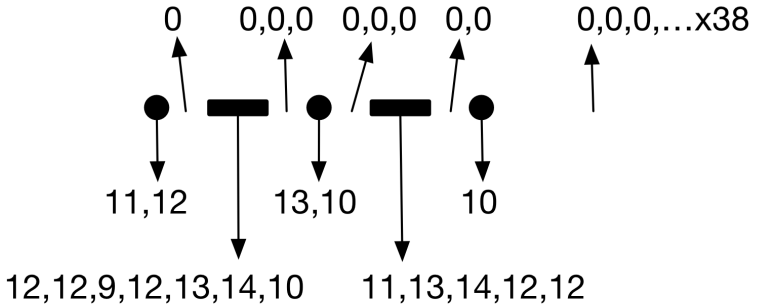
Dot, dash = *Normal*(12,4/3)
Space = 0

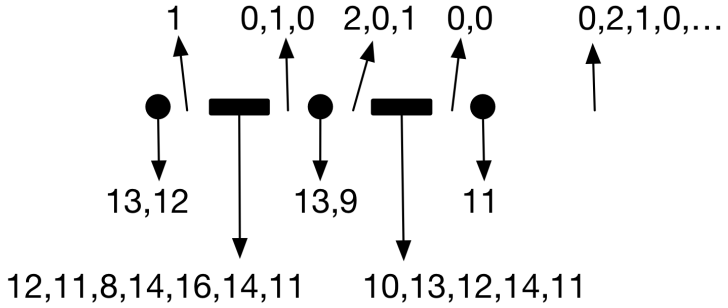
Step 3:

Additive Noise = *Normal*(0,σ)
(For this case, σ=1)



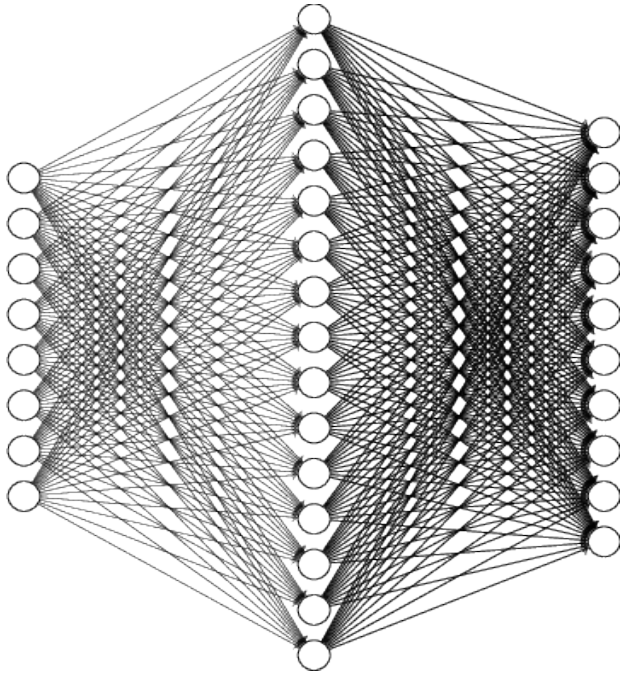
Codeword Length = 26. Remaining spaces = 38





The Neural Network

64 input neurons = Frame length of each Morse codeword

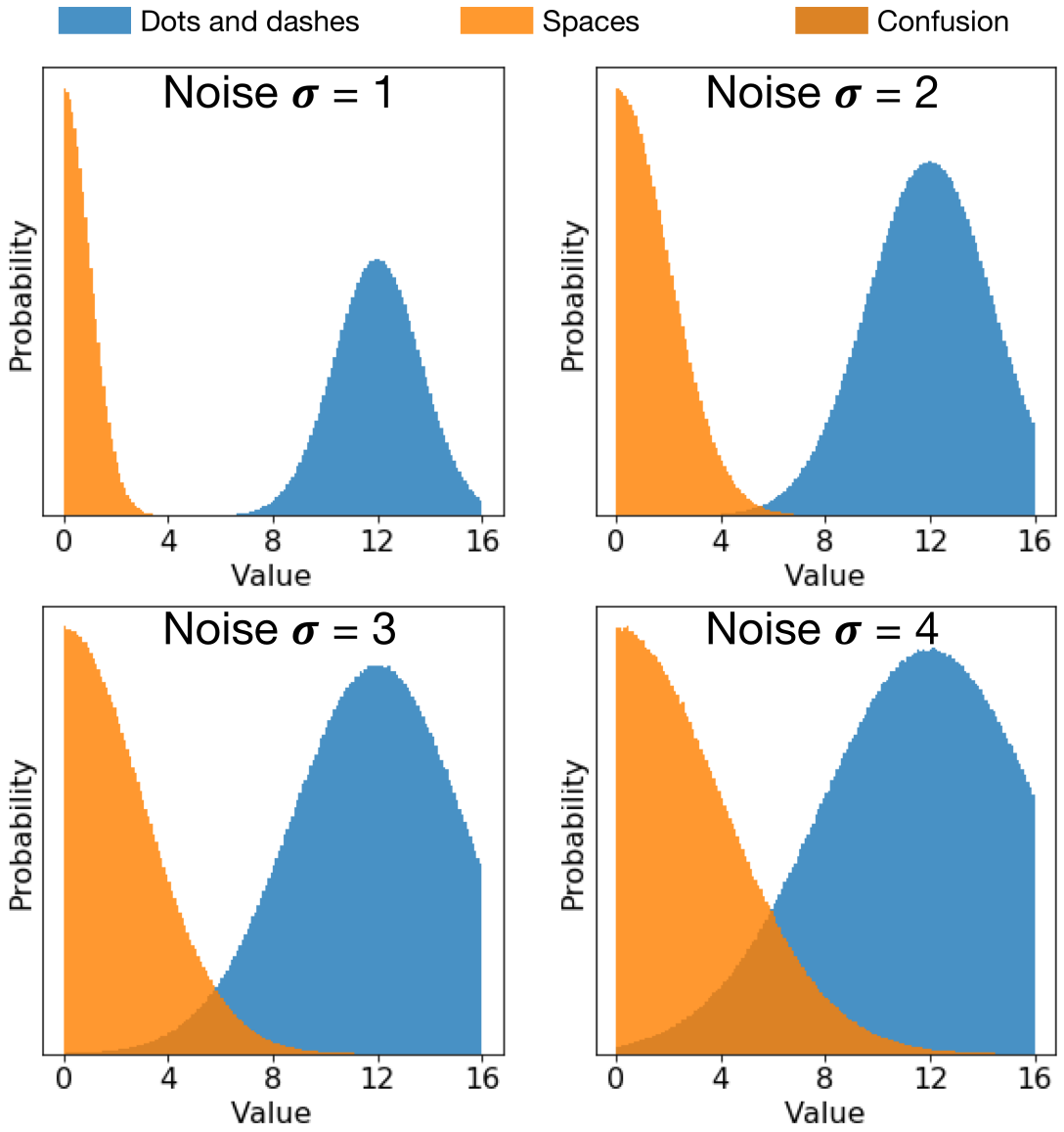


64 output neurons = Number of character classes

1024 hidden neurons

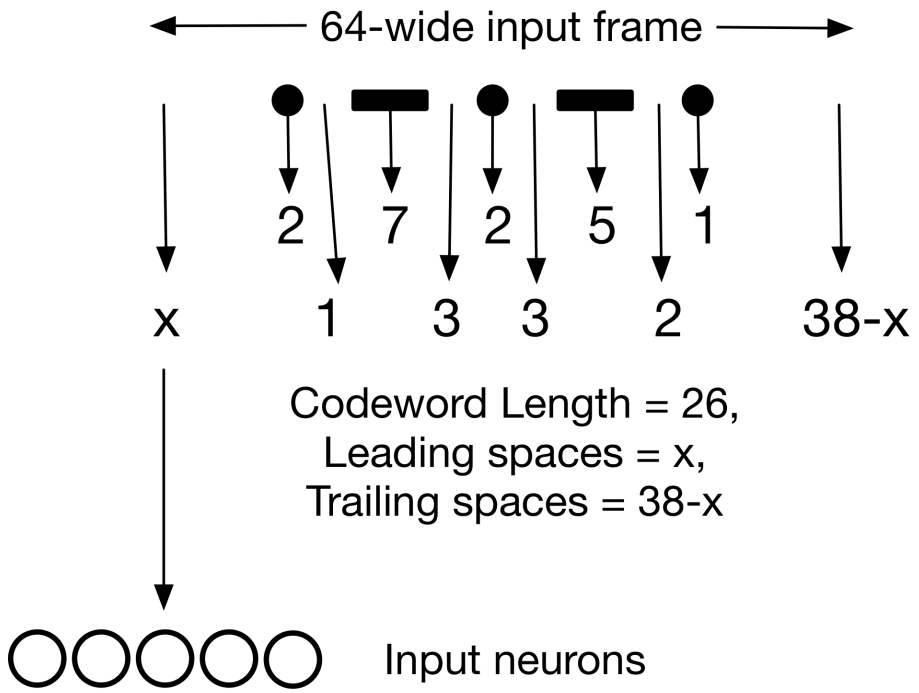
Variations and Difficulty Scaling - 1

Increasing σ of noise leads to confusion between dots, dashes and spaces



Variations and Difficulty Scaling - 2

Distribute remaining spaces randomly between leading and trailing



Variations and Difficulty Scaling - 3, 4

Dash length is 3-9, can be confused with dots and spaces

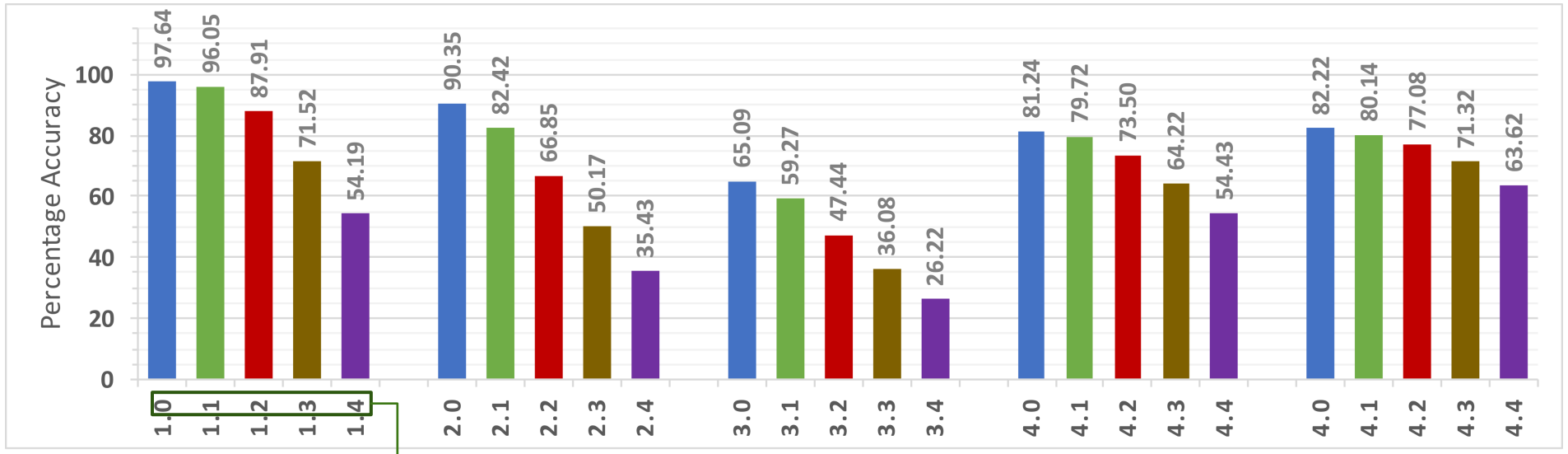
Variations and Difficulty Scaling - 3, 4

Dash length is 3-9, can be confused with dots and spaces

Dilate inputs by 4x

Property	Before Dilation	After Dilation
Frame length (= Number of inputs)	64	256
Space	1-3	4-12
Dot	1-3	4-12
Dash	3-9	12-36

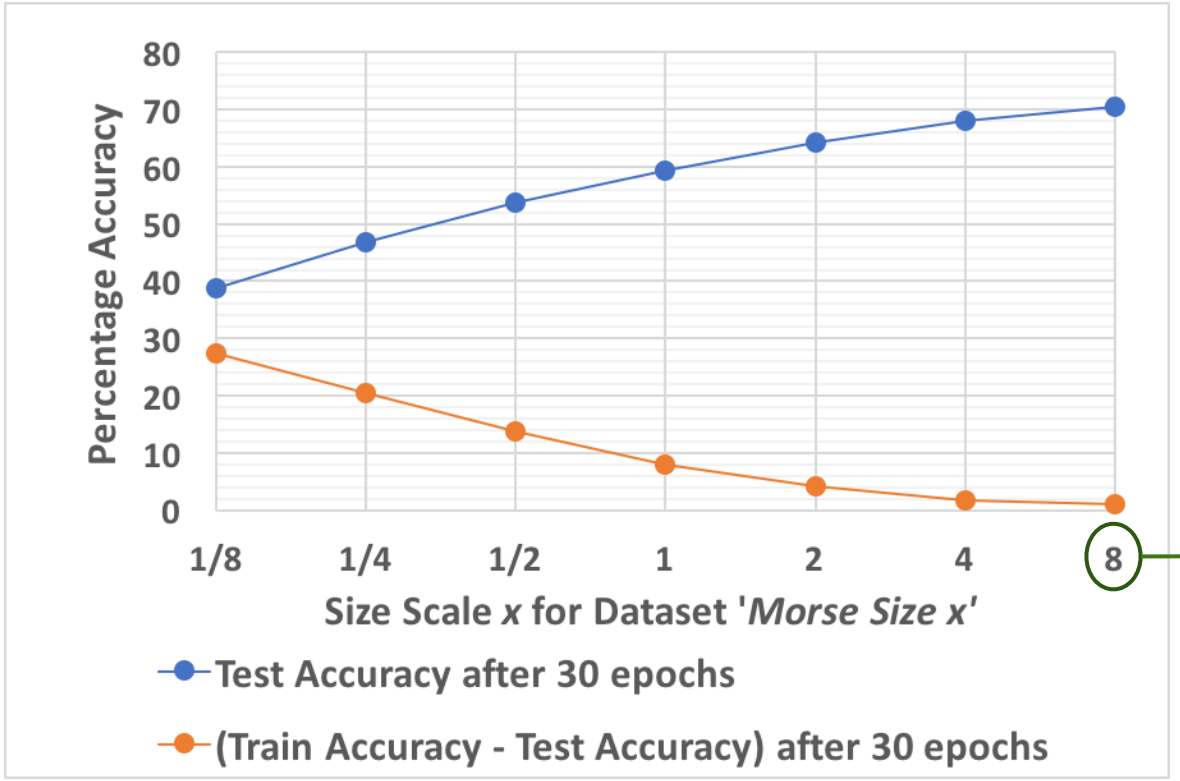
Classification Accuracy on Test Data



Standard deviation σ of added Gaussian noise

Increasing Dataset Size

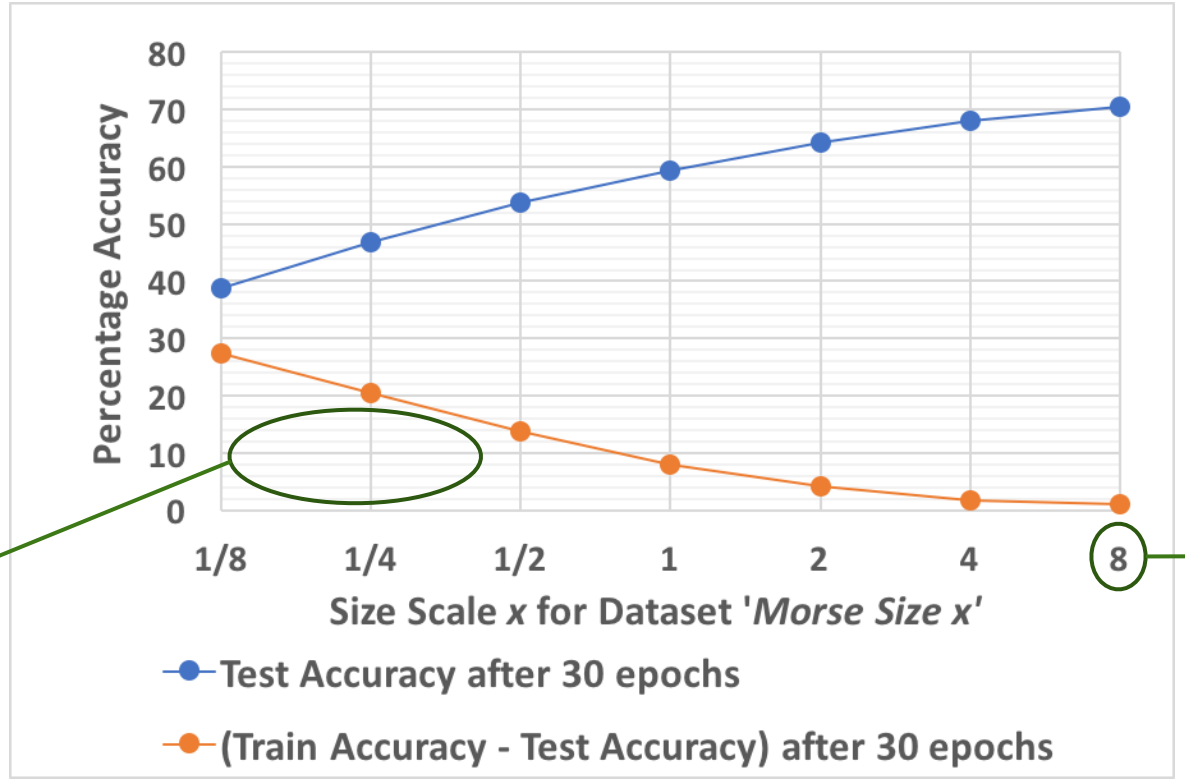
Unlimited amounts of data can be easily generated using computer algorithms



~3M training samples

Increasing Dataset Size

Unlimited amounts of data can be easily generated using computer algorithms



Overfitting region

~3M training samples

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

$$\sum_{m=1}^{M} P(m) \left[\max_{\substack{j \in \{1,2,\cdots,M\} \\ j \neq m}} P_{PW}\left(j|m\right) \right] \leq P(E)$$

$$\leq \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} P_{PW}\left(j|m\right)$$

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

$$L = \sum_{m=1}^{M} P(m) Q\left(\sqrt{\frac{d_{min}(m)^2}{4{\sigma_m}^2}}\right) \leftarrow \sum_{m=1}^{M} P(m) \left[\max_{\substack{j \in \{1,2,\cdots,M\} \\ j \neq m}} P_{PW}(j|m)\right] \leq P(E)$$

$$\leq \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} P_{PW}(j|m)$$

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

$$L = \sum_{m=1}^{M} P(m) Q\left(\sqrt{\frac{d_{min}(m)^2}{4{\sigma_m}^2}}\right) \leftarrow \sum_{m=1}^{M} P(m) \left[\max_{\substack{j \in \{1,2,\cdots,M\} \\ j \neq m}} P_{PW}(j|m)\right] \leq P(E)$$

$$\leq \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} P_{PW}(j|m)$$

$$\downarrow$$

$$U = \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} Q\left(\sqrt{\frac{d(m,j)^2}{4{\sigma_m}^2}}\right)$$

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

$$L = \sum_{m=1}^{M} P(m) Q\left(\sqrt{\frac{d_{min}(m)^2}{4{\sigma_m}^2}}\right)$$

$$D = \frac{\sum_{m=1}^{M} \frac{\sigma_m}{d_{min}(m)}}{M}$$

$$\sum_{m=1}^{M} P(m) \left[\max_{\substack{j \in \{1,2,\cdots,M\} \\ j \neq m}} P_{PW}(j|m)\right] \leq P(E)$$

$$\leq \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} P_{PW}(j|m)$$

$$U = \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} Q\left(\sqrt{\frac{d(m,j)^2}{4{\sigma_m}^2}}\right)$$

Dataset Evaluating Metrics

Difficult datasets have increased probability of classification errors

$$L = \sum_{m=1}^{M} P(m) Q\left(\sqrt{\frac{d_{min}(m)^2}{4{\sigma_m}^2}}\right)$$

$$\sum_{m=1}^{M} P(m) \left[\max_{\substack{j \in \{1,2,\cdots,M\} \\ j \neq m}} P_{PW}(j|m)\right] \leq P(E)$$

$$\leq \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} P_{PW}(j|m)$$

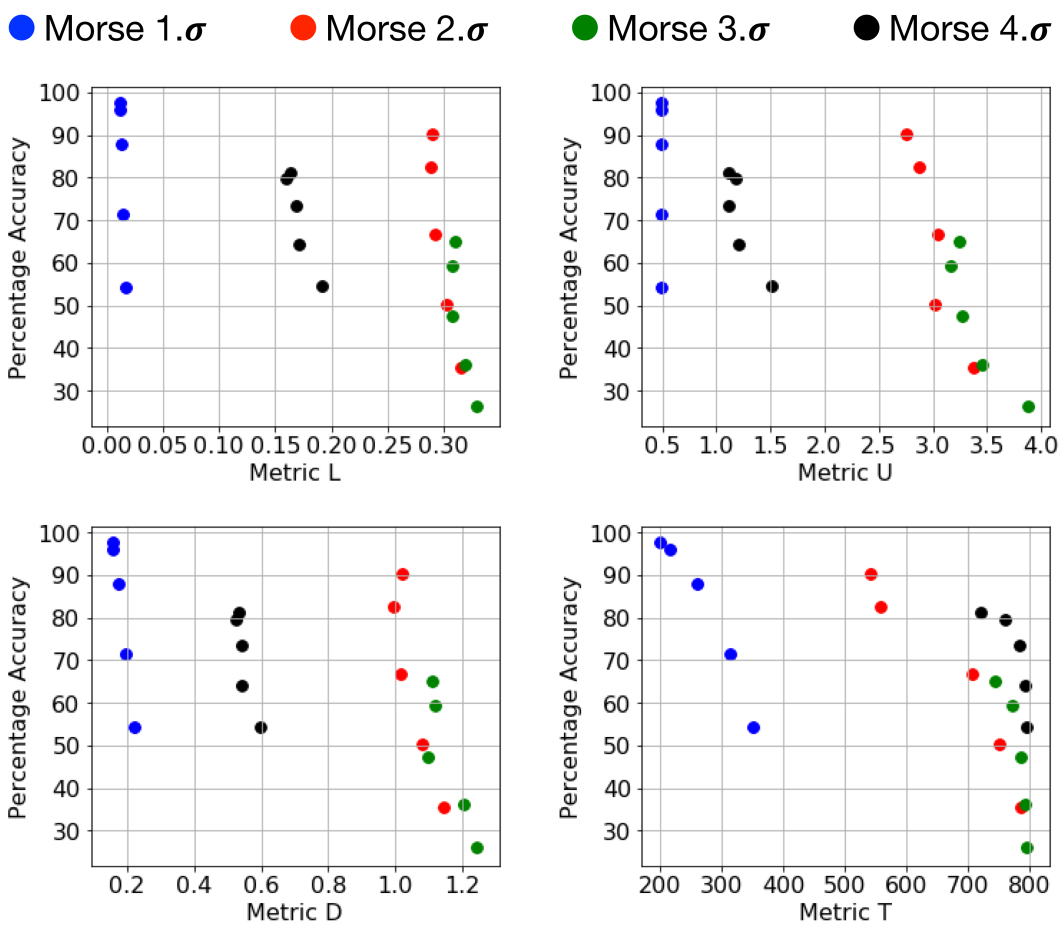
$$D = \frac{\sum_{m=1}^{M} \frac{\sigma_m}{d_{min}(m)}}{M}$$

$$U = \sum_{m=1}^{M} P(m) \sum_{\substack{j=1 \\ j \neq m}}^{M} Q\left(\sqrt{\frac{d(m,j)^2}{4{\sigma_m}^2}}\right)$$

$$T = \sum_{m=1}^{M} \sum_{\substack{j=1 \\ j \neq m}}^{M} \mathbb{I}\left(d_1(m,j) < 0.05\right)$$

Performance of the Metrics

Harder datasets have lower accuracy and higher metric values



Metric	-ρ
L	0.59
U	**0.64**
D	0.63
T	**0.64**

Conclusion

- Algorithm to generate machine learning datasets of tunable difficulty
- Synthetic data to solve challenges associated with natural data
- Metrics to evaluate dataset difficulty prior to training

Thank you!

Questions?

Contact: souryade@usc.edu