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# An Introduction to Artificial Neural Networks

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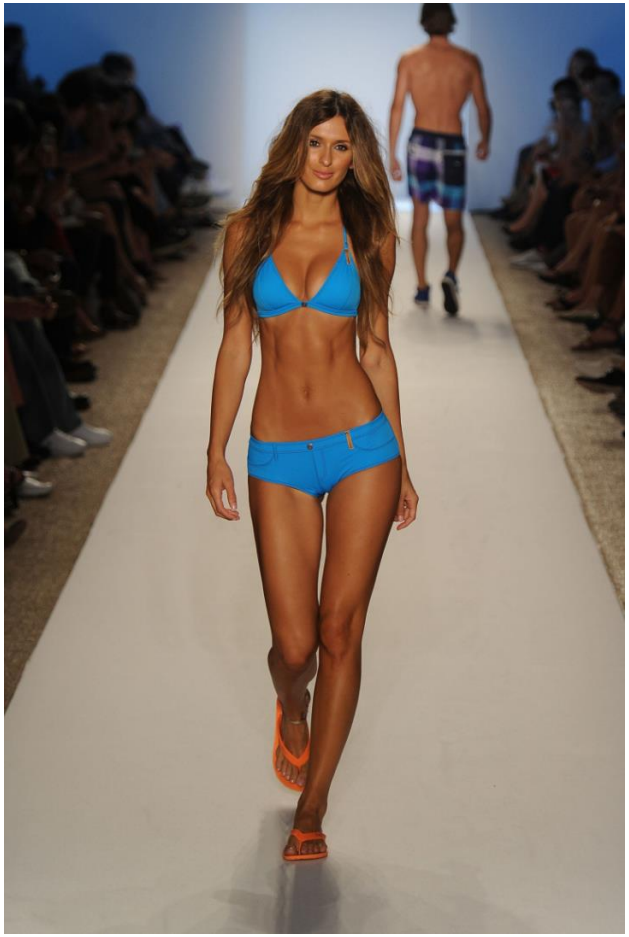
MSc Actuarial Science

Supervisors:
**Dr C Beyers**
**Dr P de Villiers**

# Two components to my research



# Intrigue into the human mind

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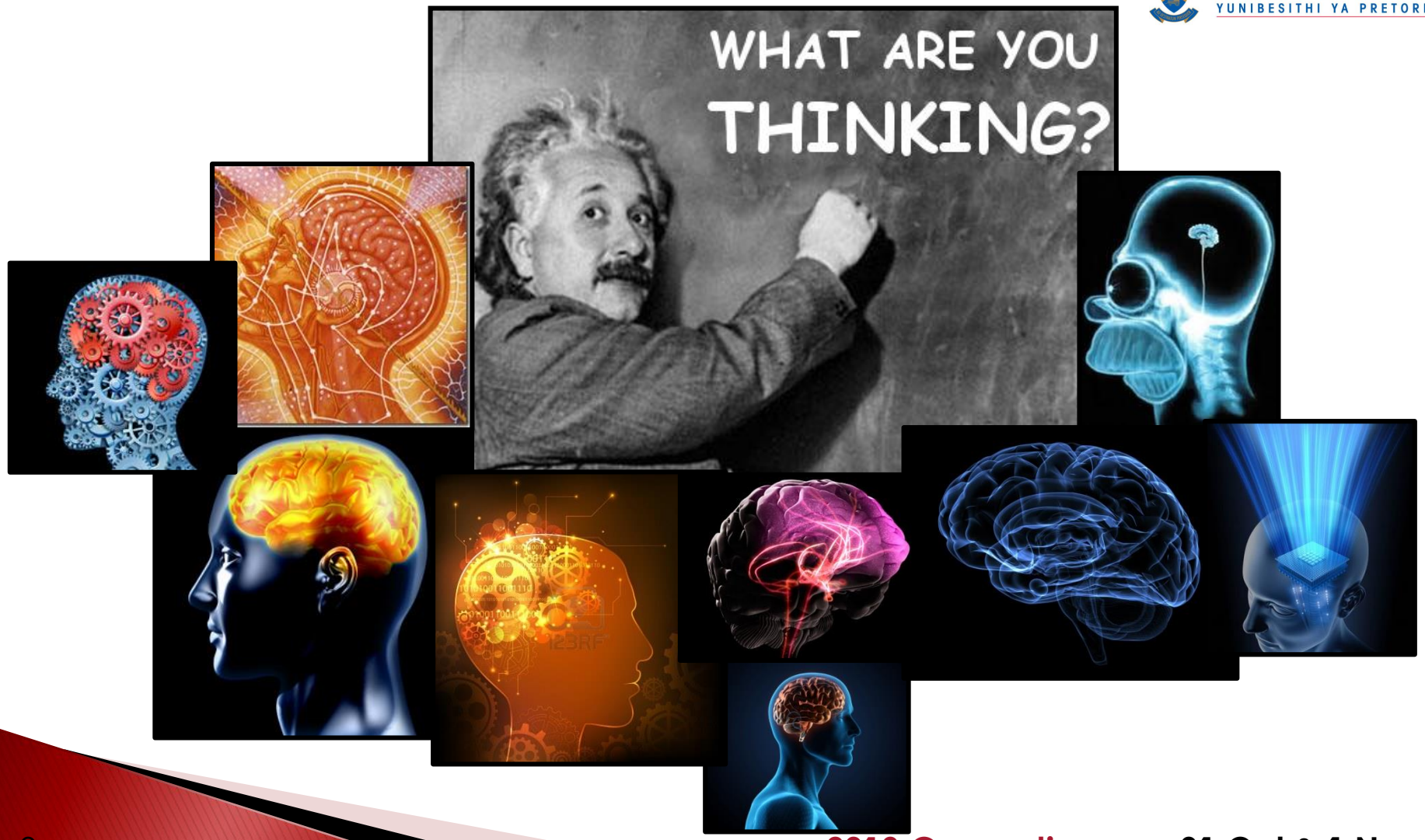
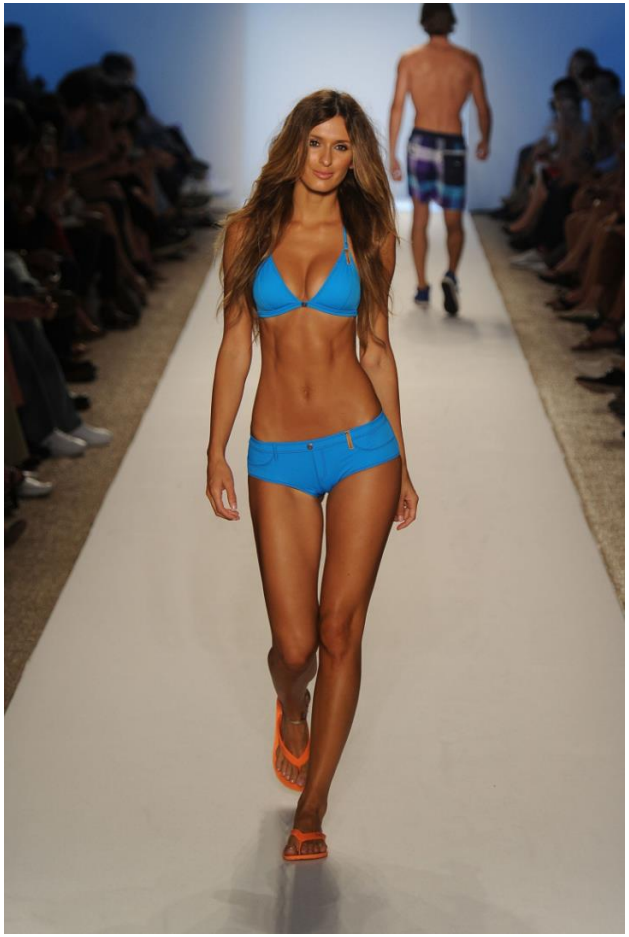
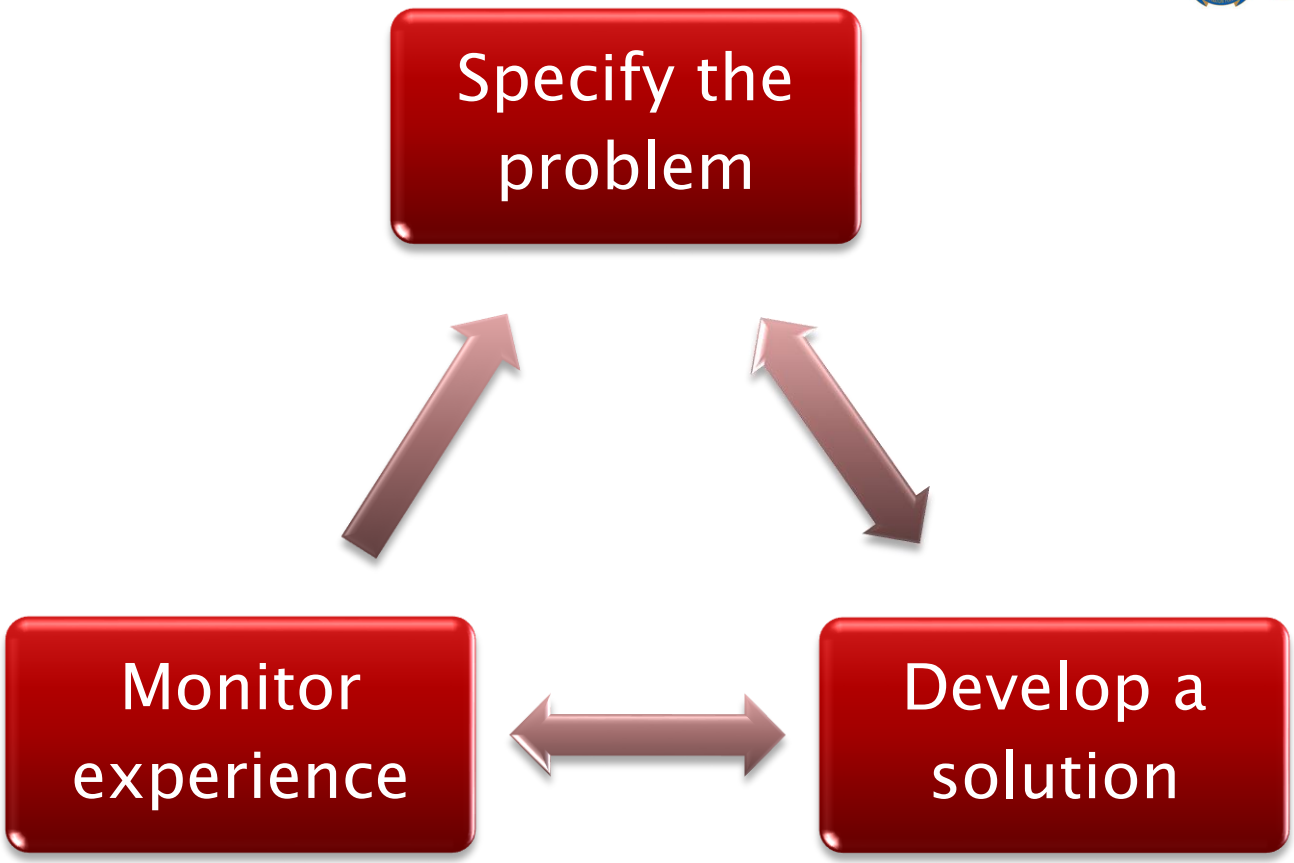


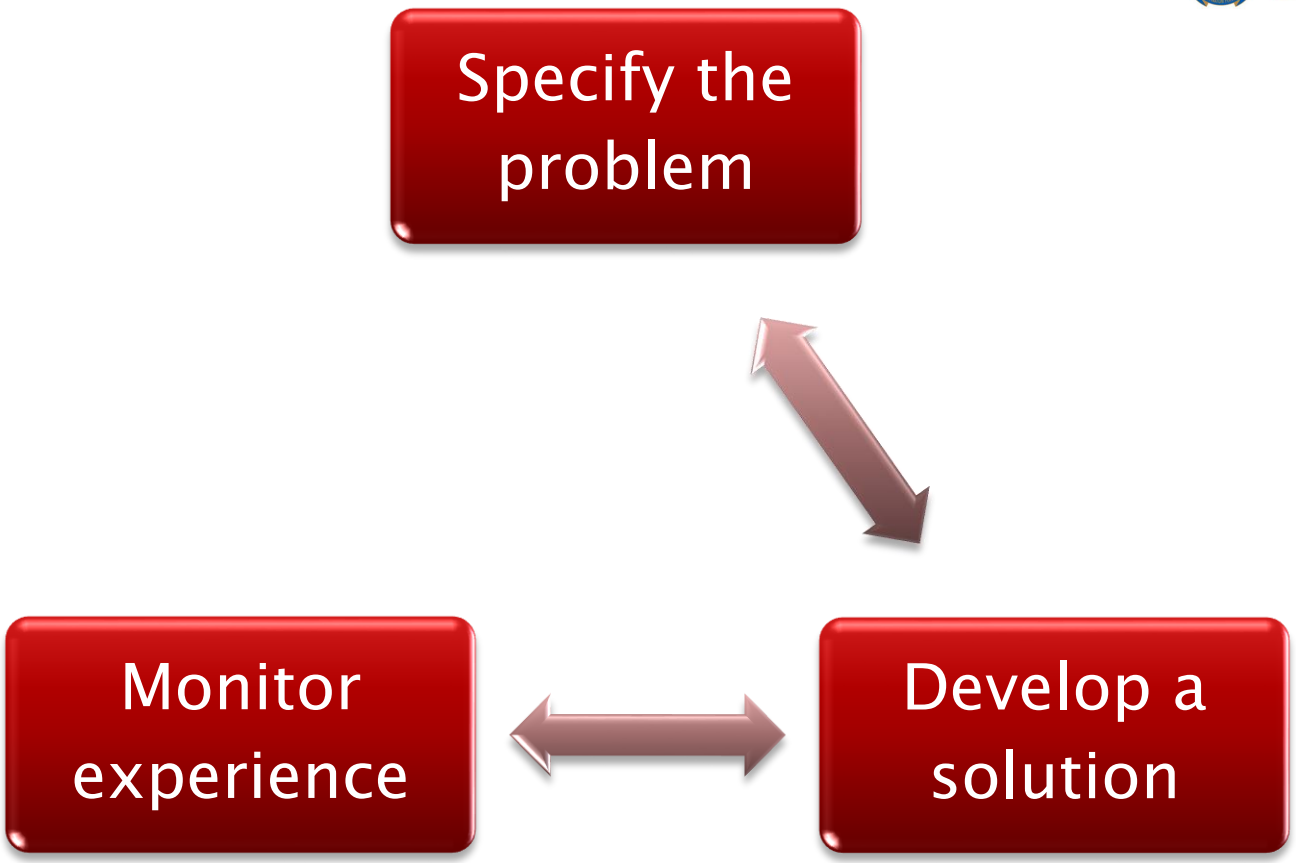
# Two components to my research



# Actuarial Control Cycle



# Actuarial Control Cycle



# Road Map

1. What are ANNs?
2. Where do they come from?
3. What do they look like?
4. How do they learn?
5. Problems they can solve?
6. Where have they been applied?
7. Summary

# 1. What are Artificial Neural Networks?

- Dynamic modelling technique
- Replicates the human brain's logic
  - Invented to further understanding of the human brain
- Has the ability to detect and project non-linear trends in data
- Can adapt and learn from changing environments

# 2. Where do Artificial Neural Networks come from?

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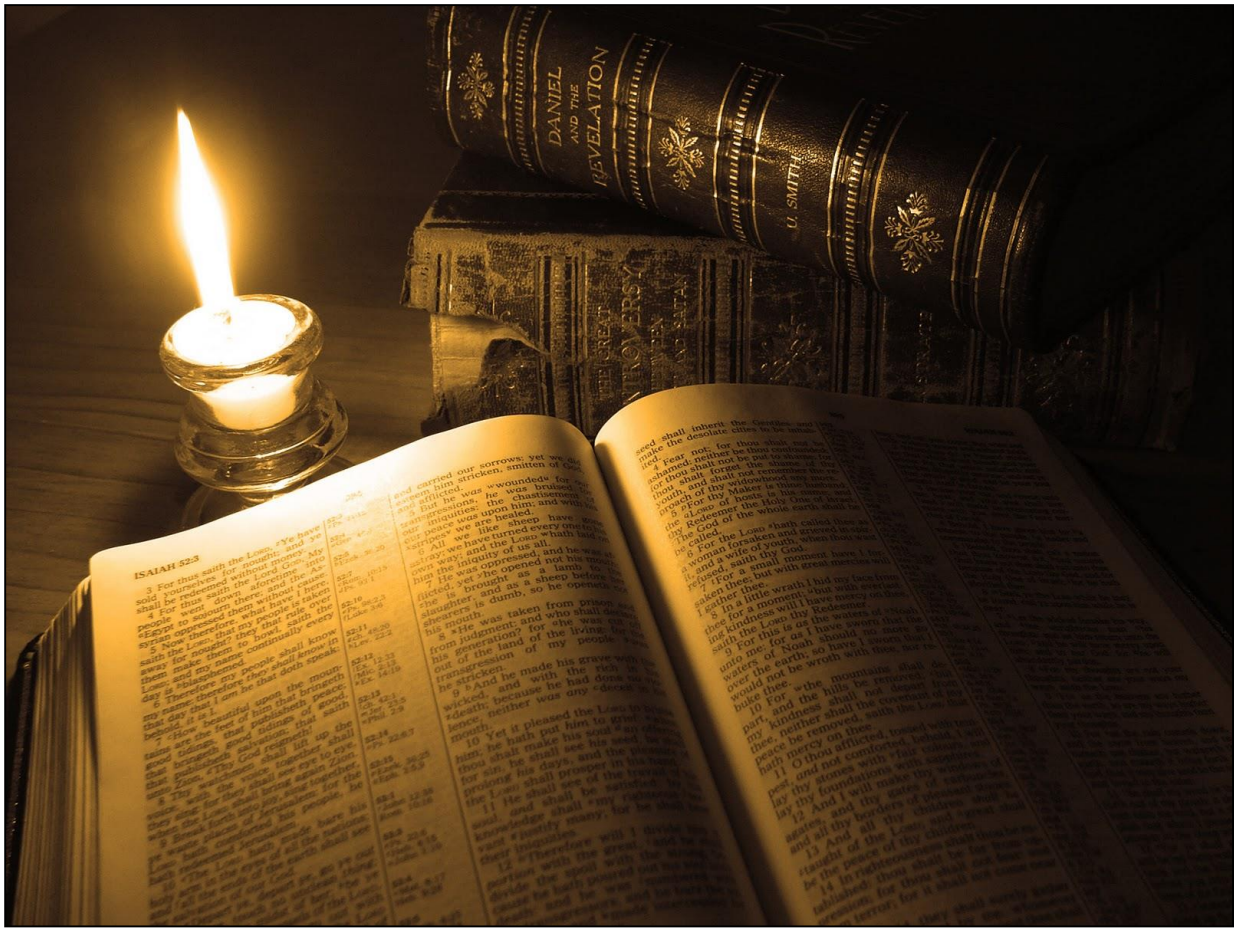

# The Human Brain

- 10 billion neurons
  - Neurons = processors
- 60 trillion interconnections
  - Massive complex system
- Characteristics
  - Massive parallel system
  - Fault tolerance
  - Adaptability

# A Biological Neuron

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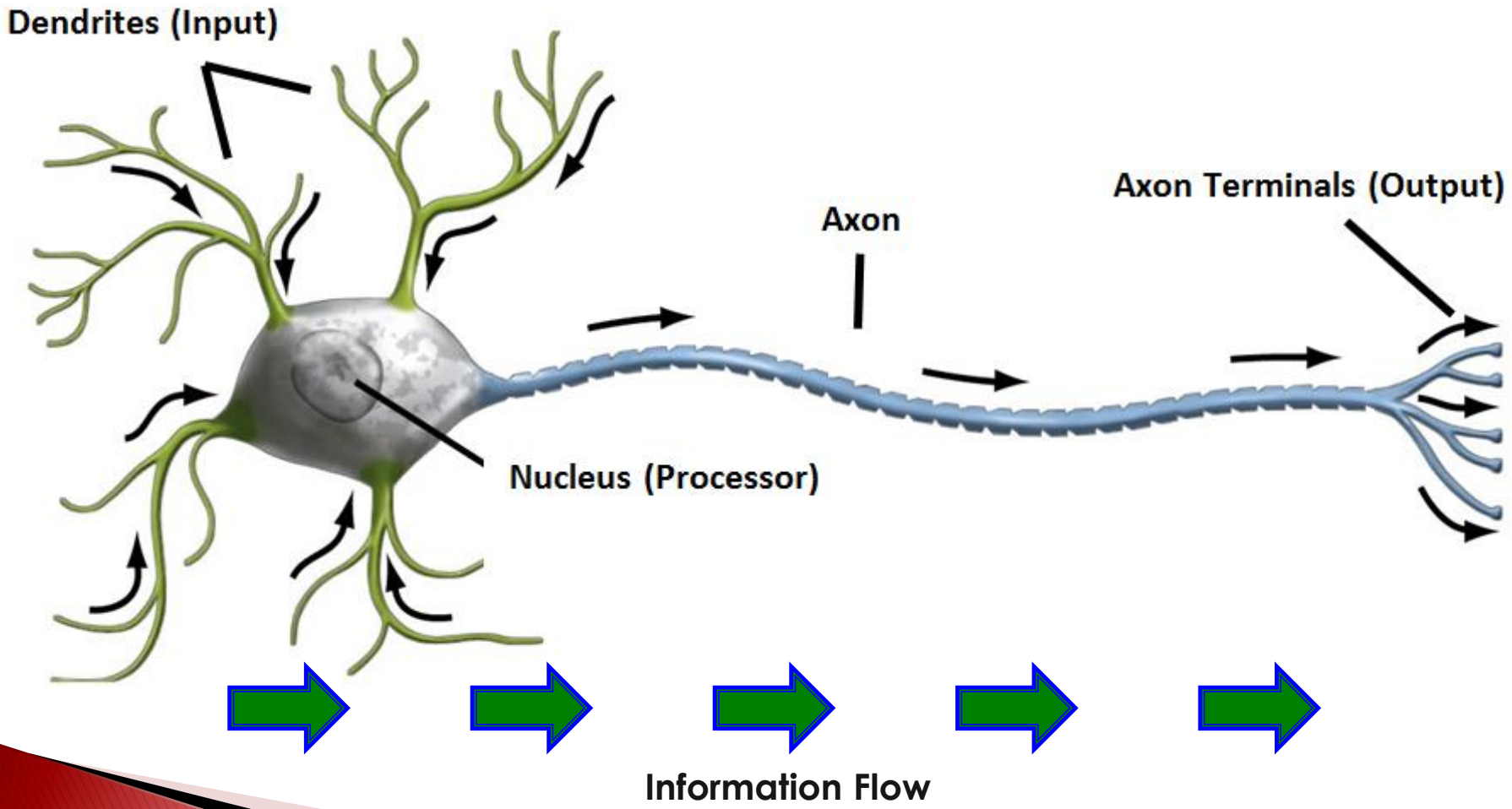
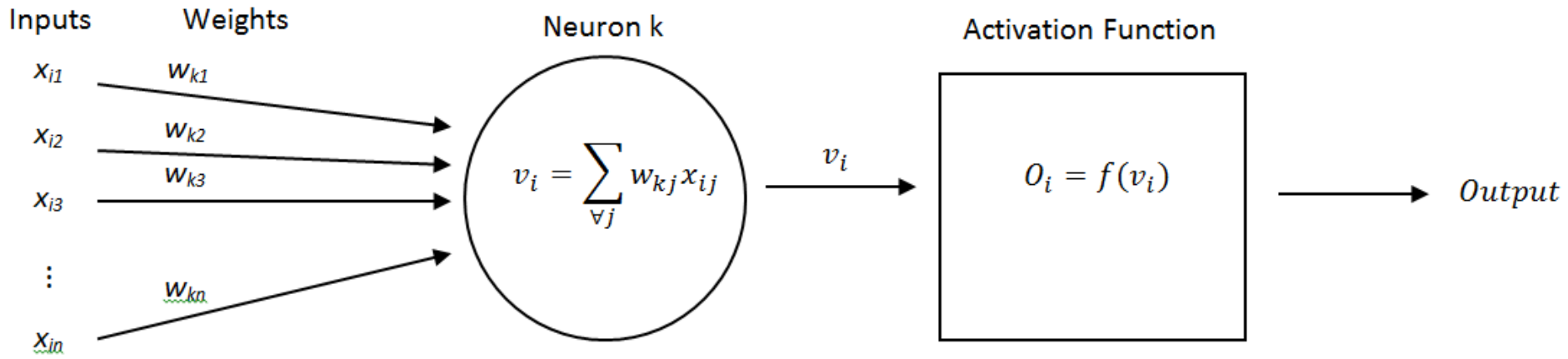
## Diagram of a Neuron

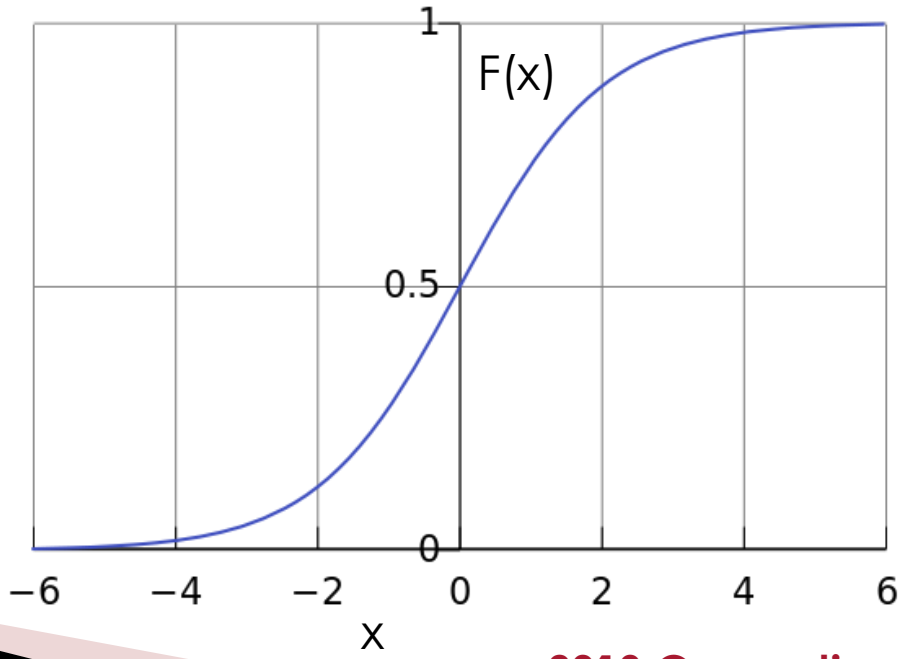


# An Artificial Neuron

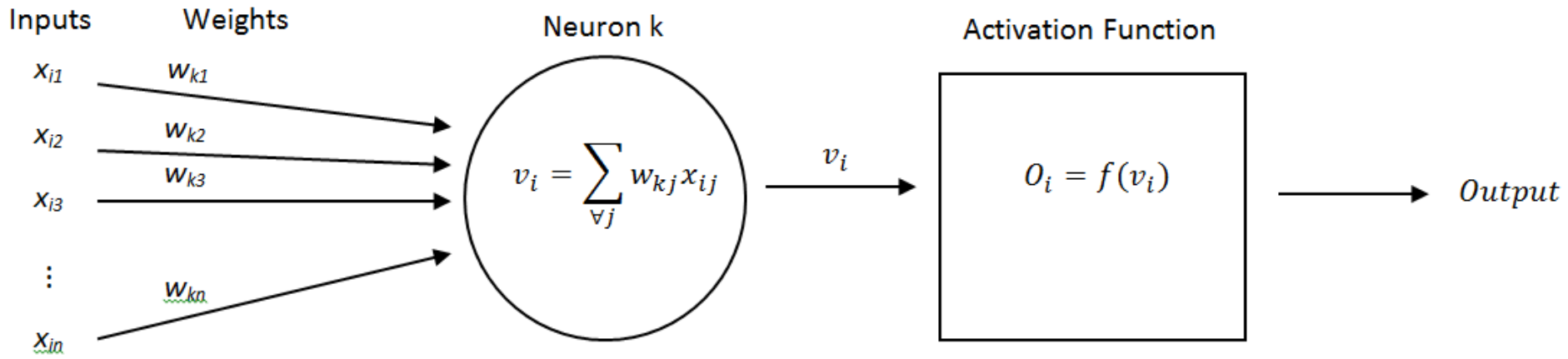


# An Activation Function

- Type of soft switch
- Sigmoid function $f(x) = \frac{1}{1 - e^{-x}}$
  - High values of x has values close to 1
  - Low values of x has values close to 0



# An Artificial Neuron



# 3. What do they look like?

- Several types of ANNs:
  - Recurrent
  - *Feed-Forward*
  - Bridged
  - Fully Connected Cascade
  - *Multi-Layered Perceptron*
- We will consider the ***Feed-Forward Multi-Layered Perceptron***
  - Simplest
  - Increase in complexity does not warrant increased accuracy in most practical cases

# Feed-Forward Multi-Layered Perceptron (FF MLP)

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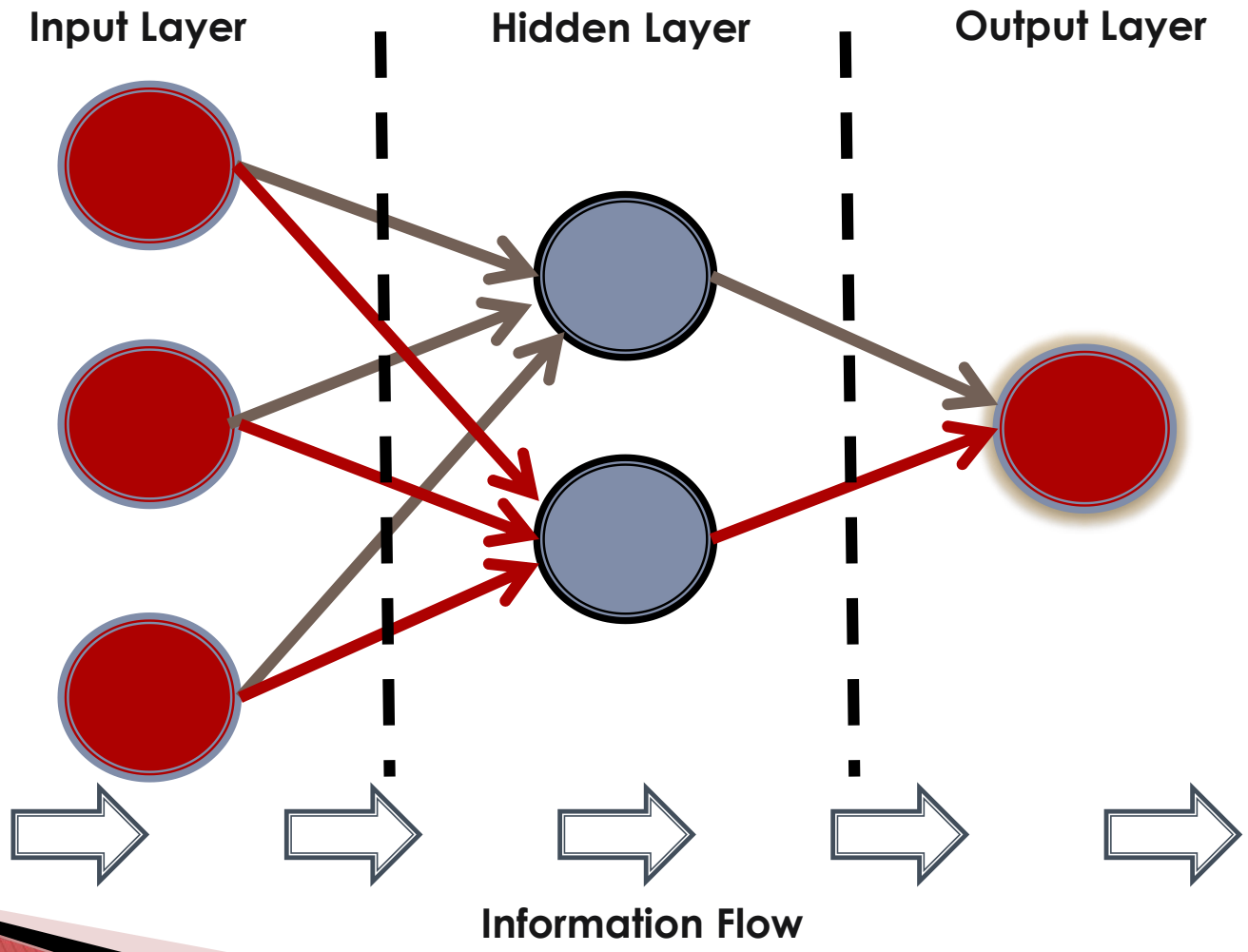

# Feed-Forward Multi-Layered Perceptron (FF MLP)

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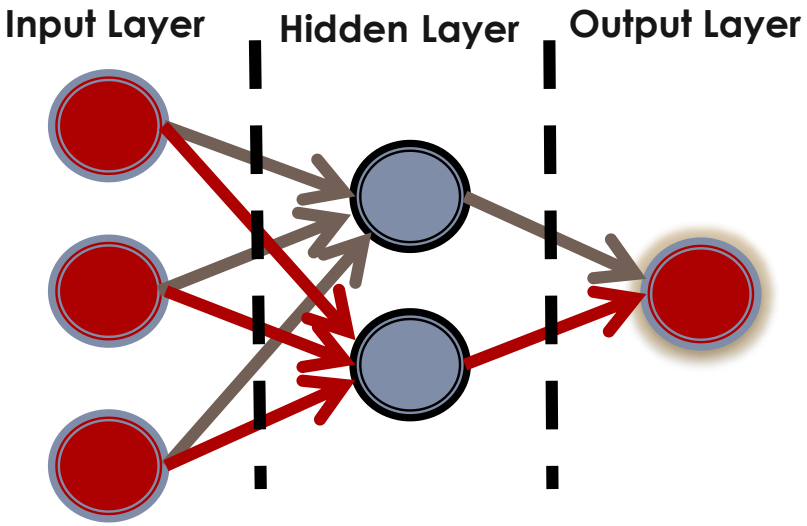
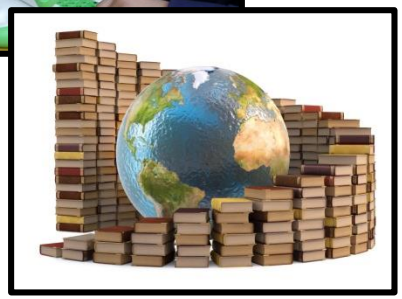
- Input layer
  - Data enters the system
  - Each neuron represents a variable
- Hidden layers
  - Can be several layers
  - Several neurons in each layer
  - A single layer is sufficient
- Output layer
  - Results of system
  - Can have several results



# 4. How do they learn?

# Human Learning



People learn in 5 different ways:

- Error-Correction
- Memory
- Competitive

**Supervised Learning**

- Hebbian
- Boltzmann

**Unsupervised Learning**

# Error-Correction Learning

# How?

We have gained knowledge from:

- Teachers
- Parents
- Guardians
- Past experience


**Made a decision that minimised error from past experience**

# Mathematically How?

- Choose an activation function

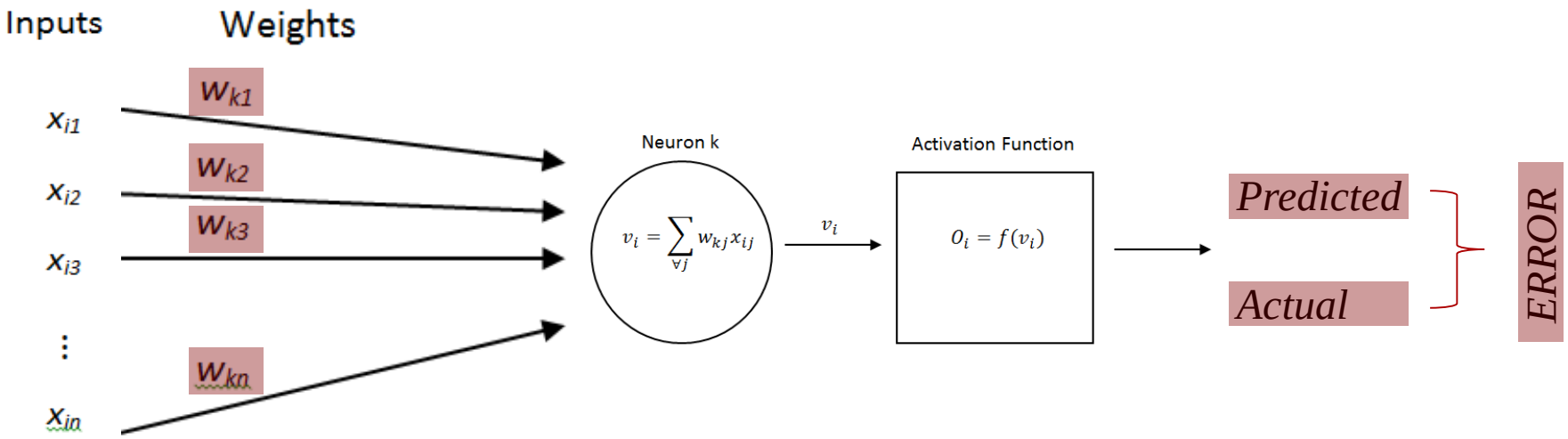
$$A()$$

- Choose an error function

$$E[(A() - actual)^2]$$

- Calculate total error using all past data
- Change the weights using a training algorithm
  - Based on gradient descent
- Specify a number of training cycles until error is small enough

# Learning Mechanism



# Applying Learning

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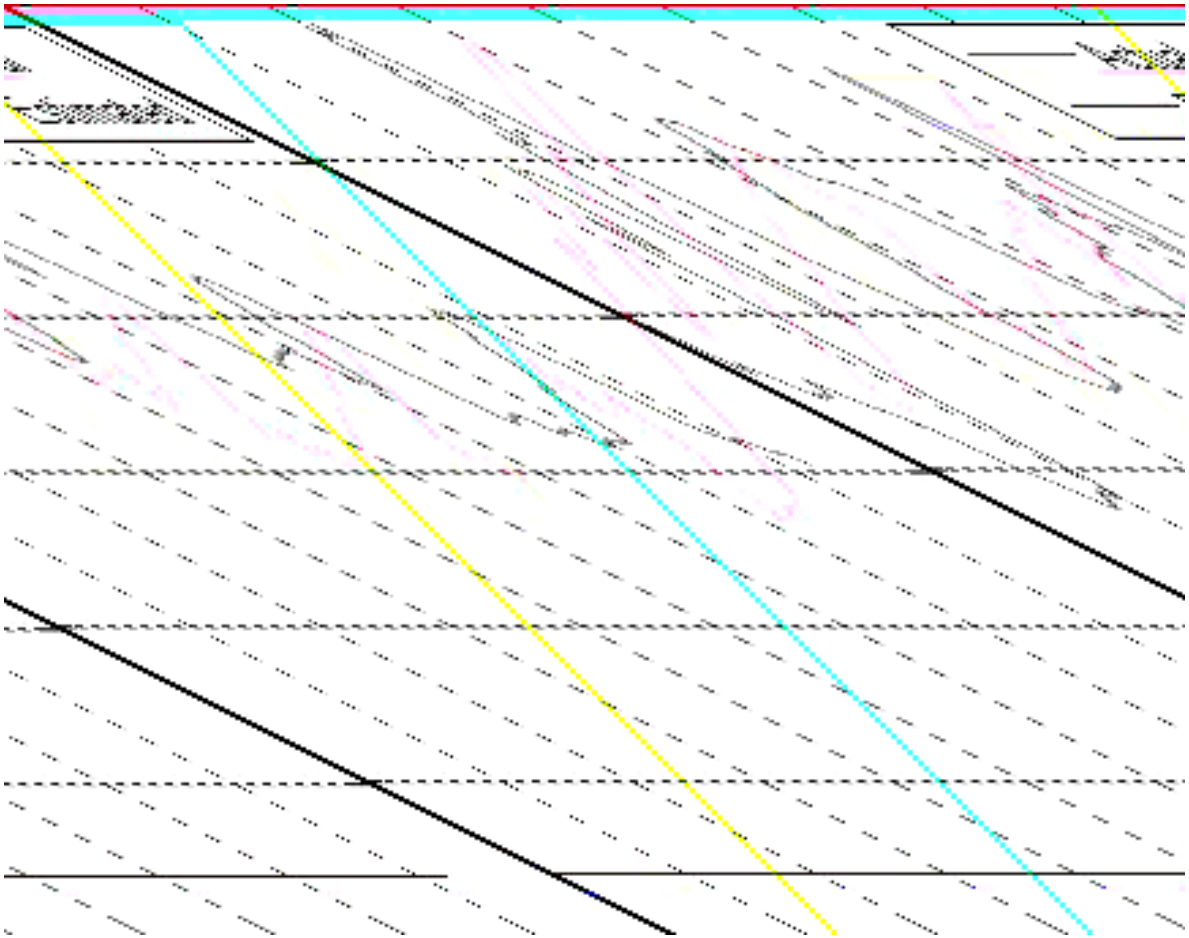
- Average return on Money Market 1975 - 2010
- Sources of data:
  - Firer, C and Staunton, M., 2002. 102 Years of South African financial market history. Investment Analysts Journal, 56, 57-65
  - Firer, C. and McLeod, H., 1999. Equities, Bonds, Cash and Inflation: Historical performance in South Africa, 1925 - 1998. Investment Analysts Journal, 50, 7-28.

## Actual vs Expected





Return on the Money Market

Months since 1 Jan 1975

# 5. Problems ANNs can solve

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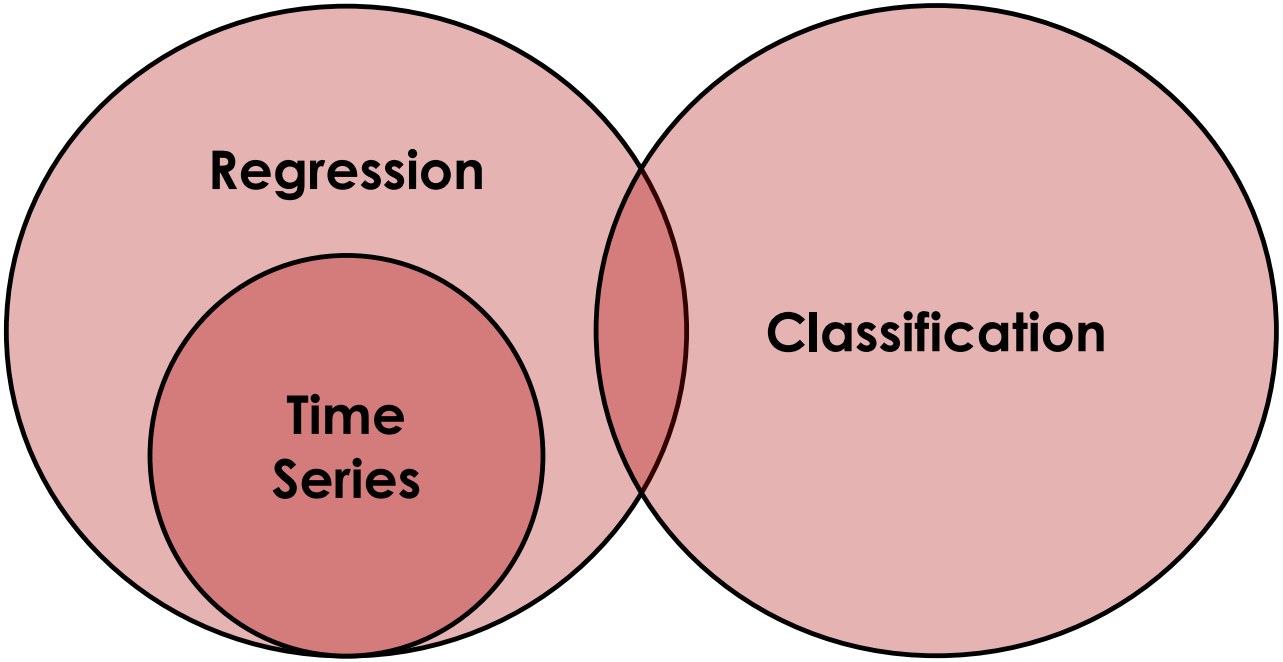
Three types of problems:



# 5. Problems ANNs can solve

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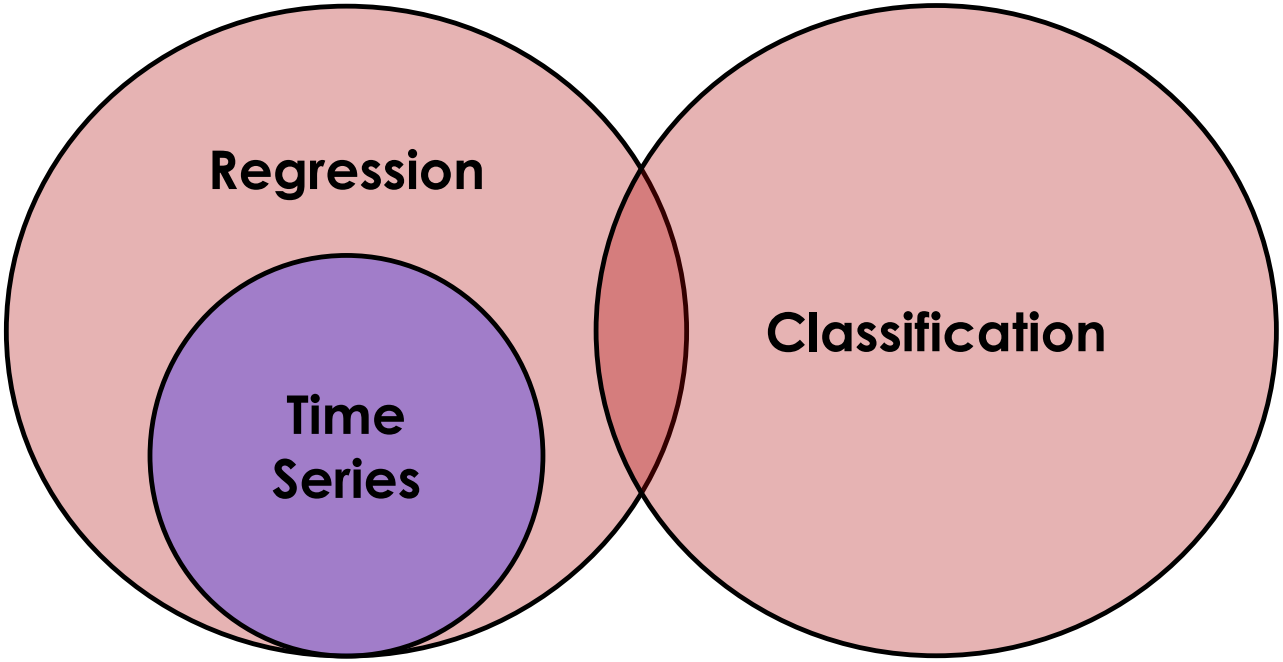

# Time Series Problem: One Month Inflation Prediction

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- Predict one month ahead inflation
- Sources of data:
  - Firer, C and Staunton, M., 2002. 102 Years of South African financial market history. Investment Analysts Journal, 56, 57-65
  - Firer, C. and McLeod, H., 1999. Equities, Bonds, Cash and Inflation: Historical performance in South Africa, 1925 - 1998. Investment Analysts Journal, 50, 7-28.

| | Number of Observations |
|---|---|
| Training Set Size | 332 |
| Testing Set Size | 100 |

# Problems

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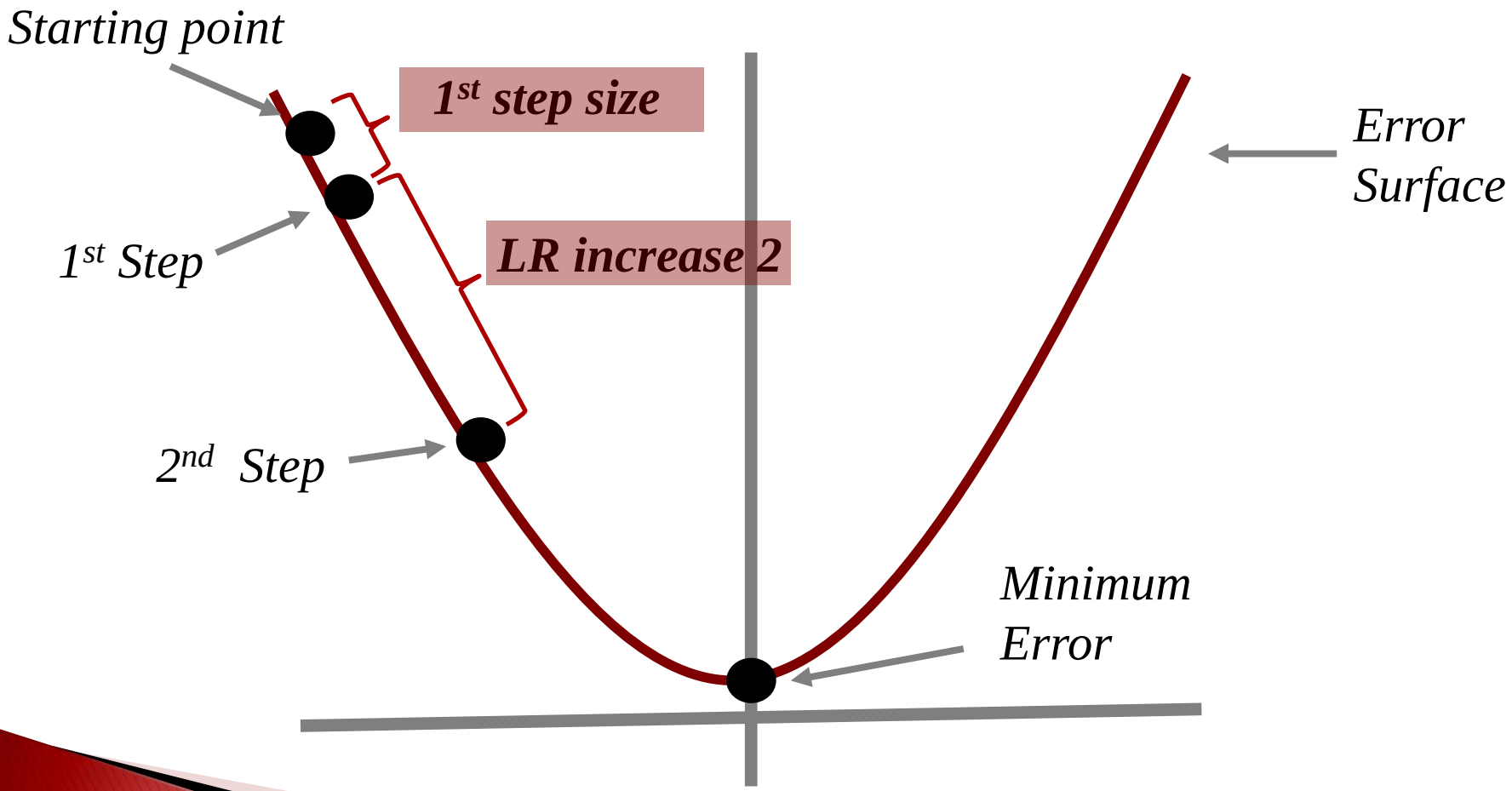
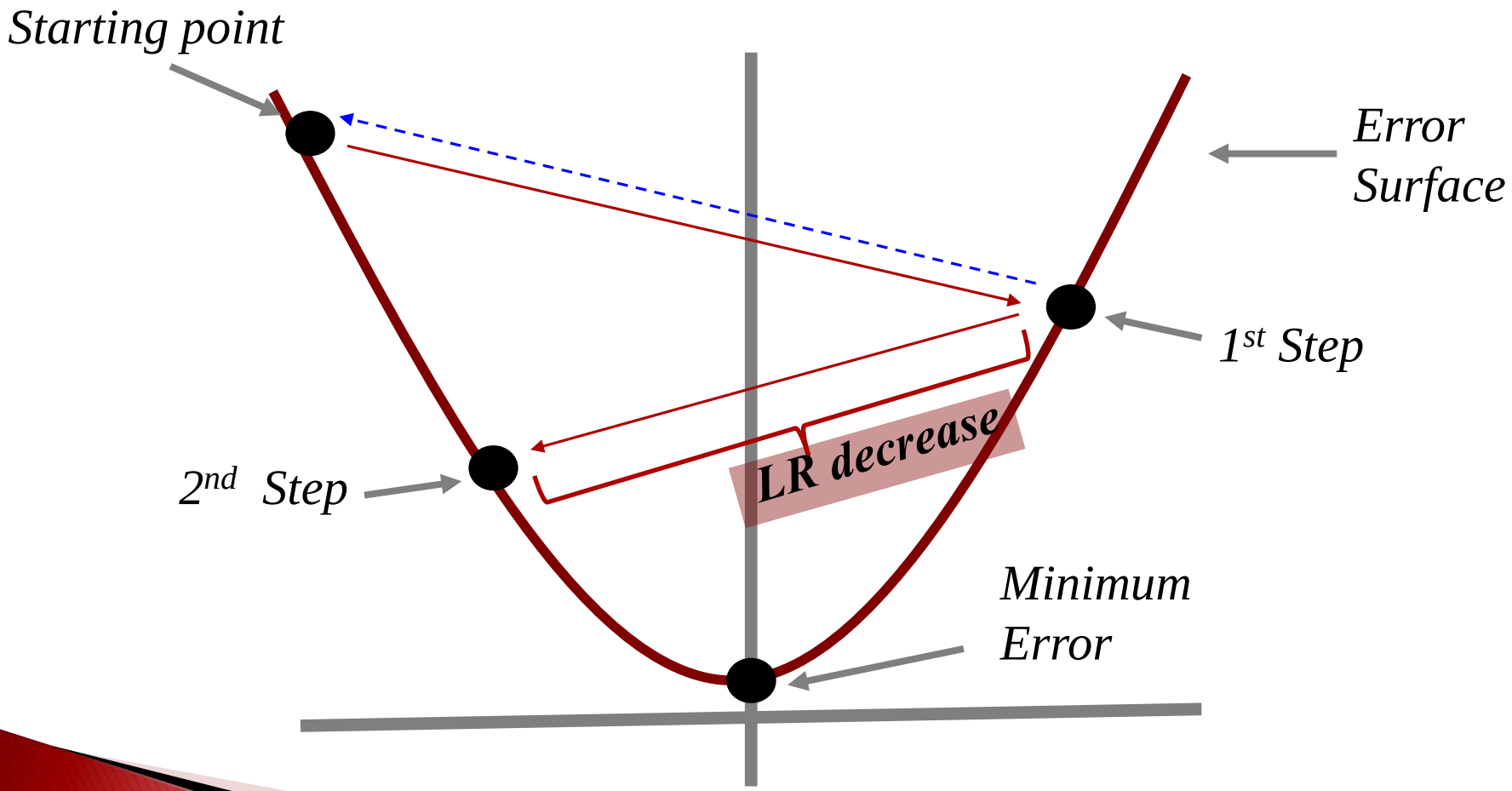
- Input Neurons
  - Partial Auto-correlations suggests 24 previous months
- Hidden Neurons
- Resilient Propagation Algorithm
  - Learning Rate increase and decrease parameters

# Learning Rate Increase



# Learning Rate Decrease



# Problems

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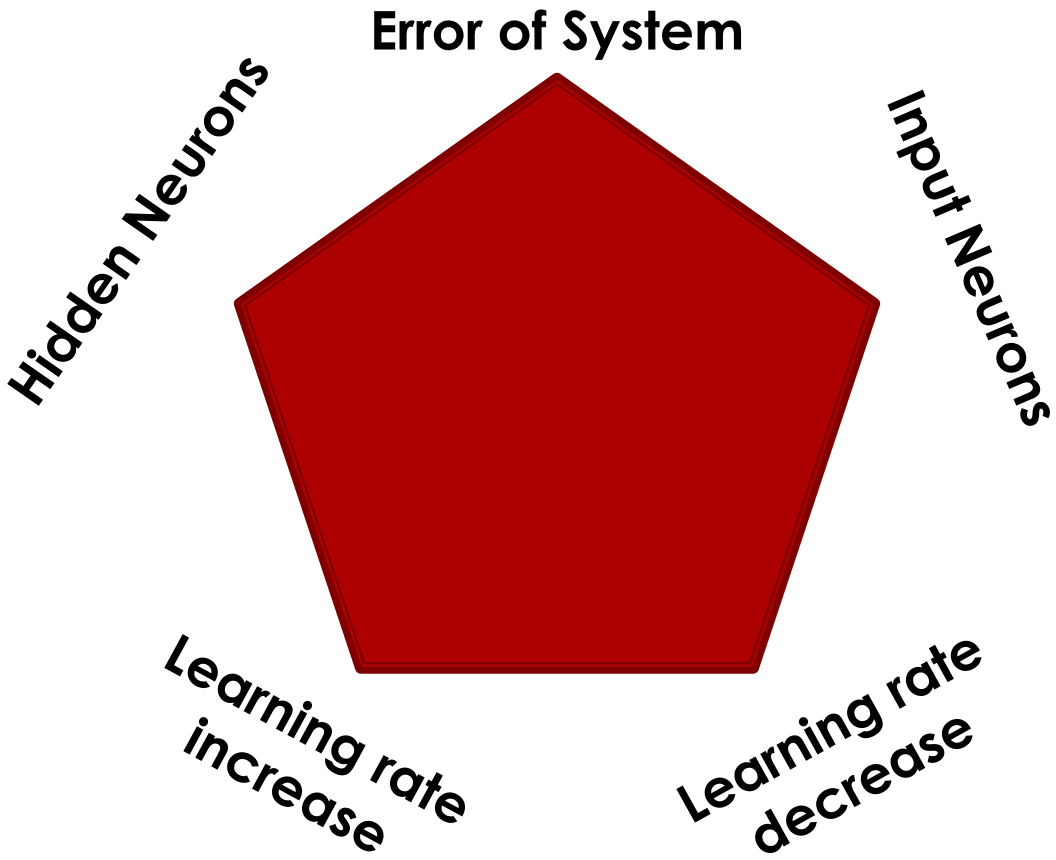
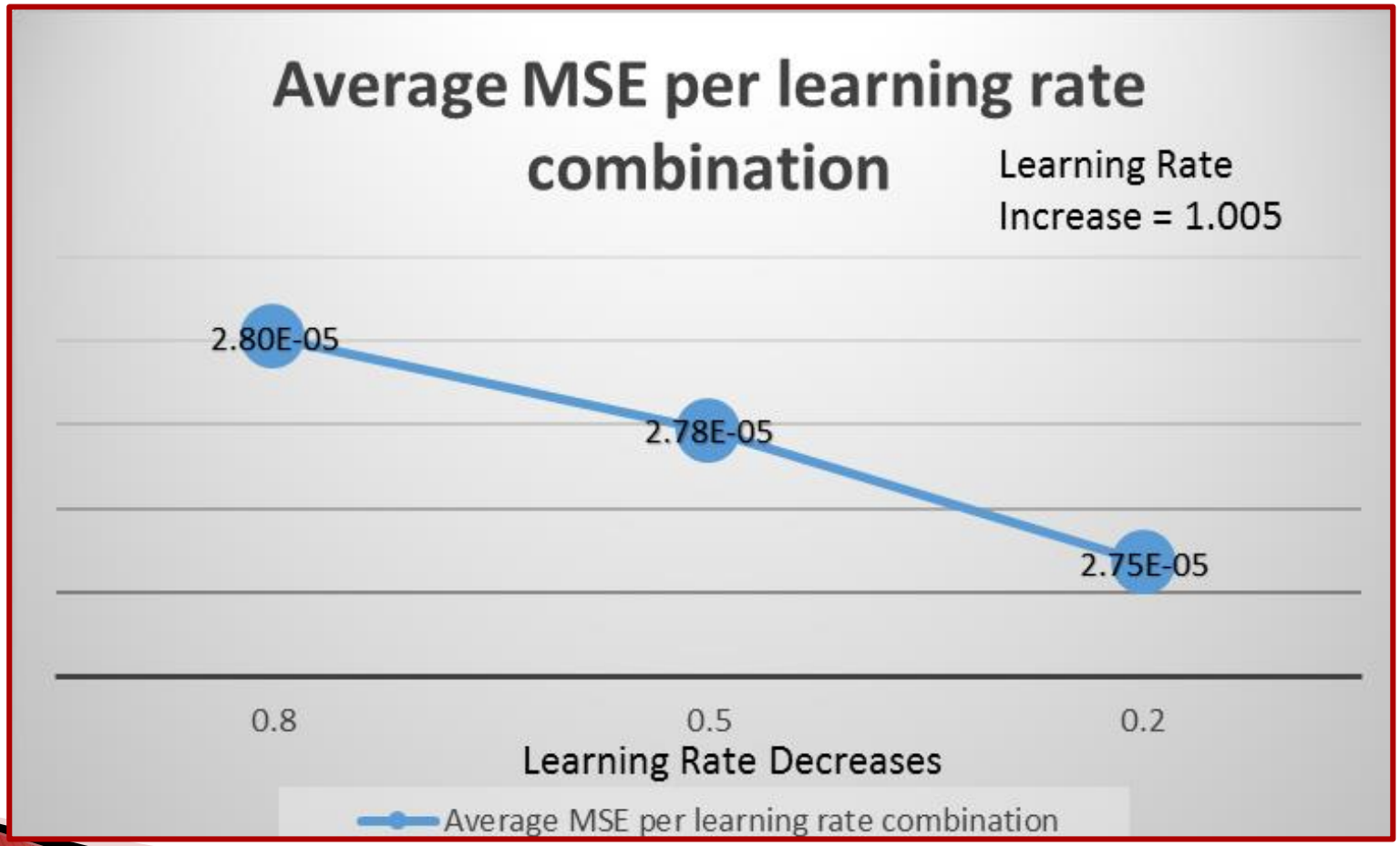
# Solution


Error of System
Input Neurons
Learning rate decrease
Learning rate increase
Hidden Neurons

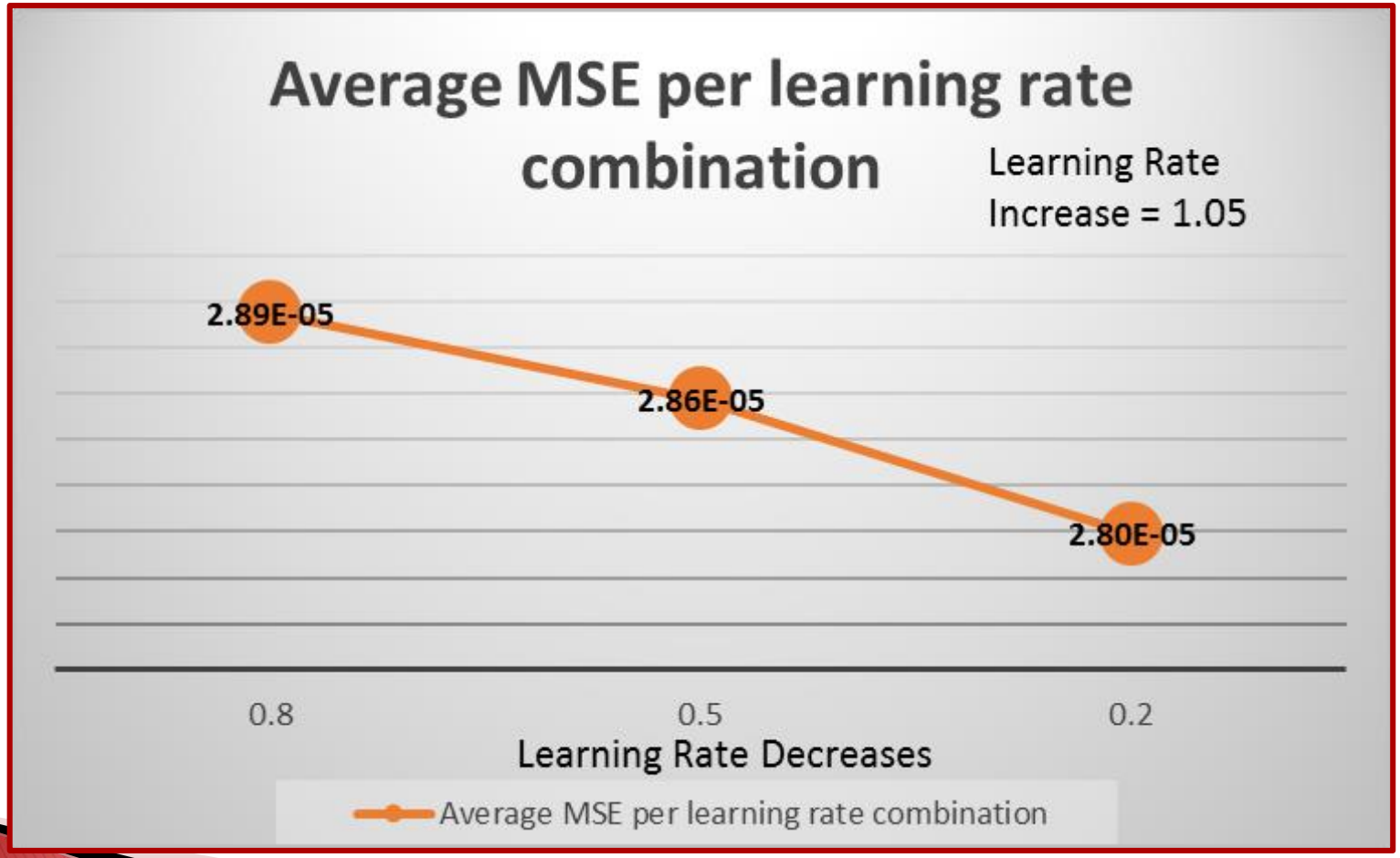
# Experiment: Predicting Inflation
# Learning rate changes

## Decreases with Increase of 0.5%



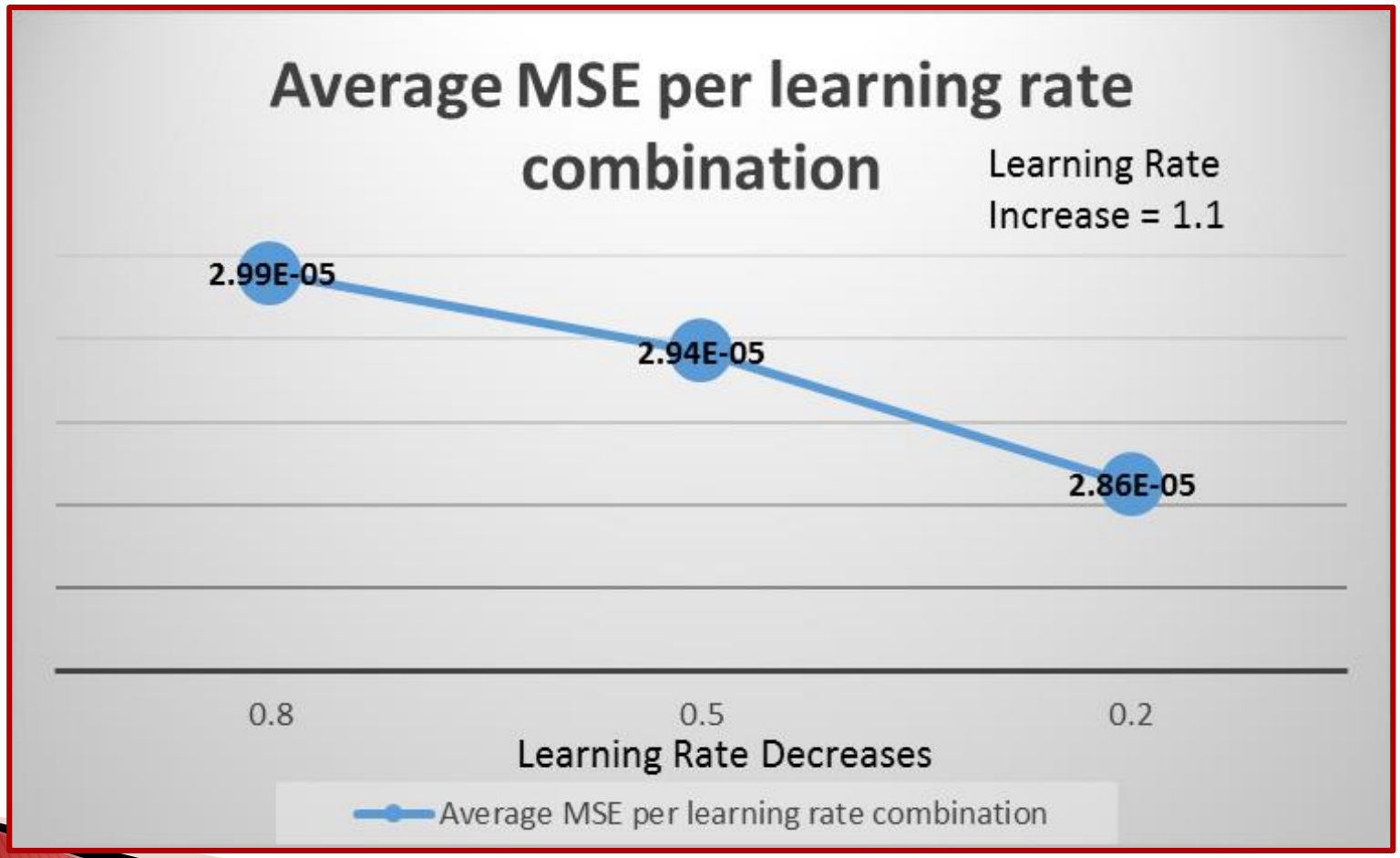
# Experiment: Predicting Inflation
# Learning rate changes

## Decreases with Increase of 5%



# Experiment: Predicting Inflation
# Learning rate changes

## Decreases with Increase of 10%



# Experiment: Predicting Inflation
## Learning rate changes
## Increases with Decrease of 20%

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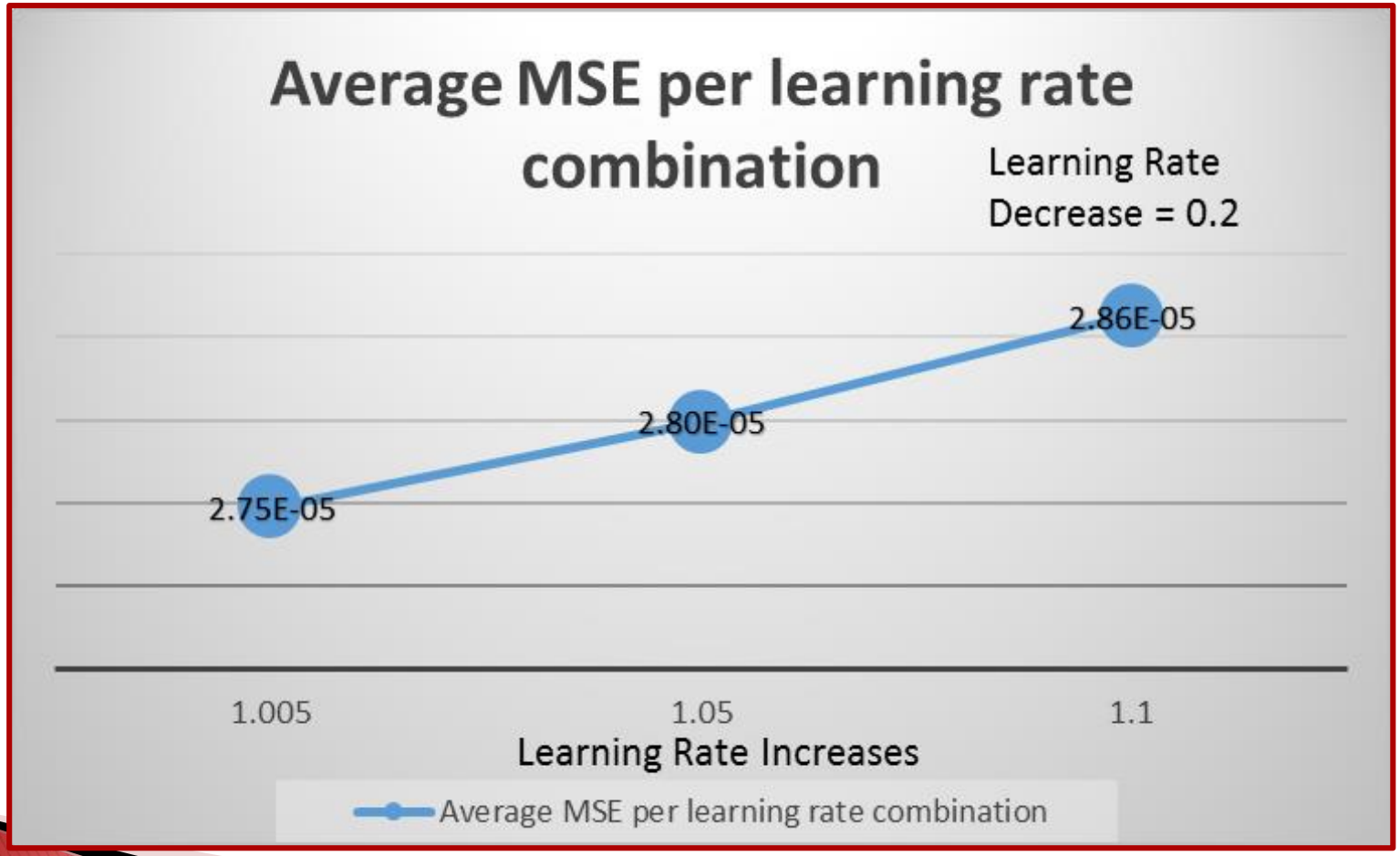

# Parameters

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| Learning Rate increase | Learning Rate Decrease |
|---|---|
| 0.5% | 20% |

# Experiment: Predicting Inflation

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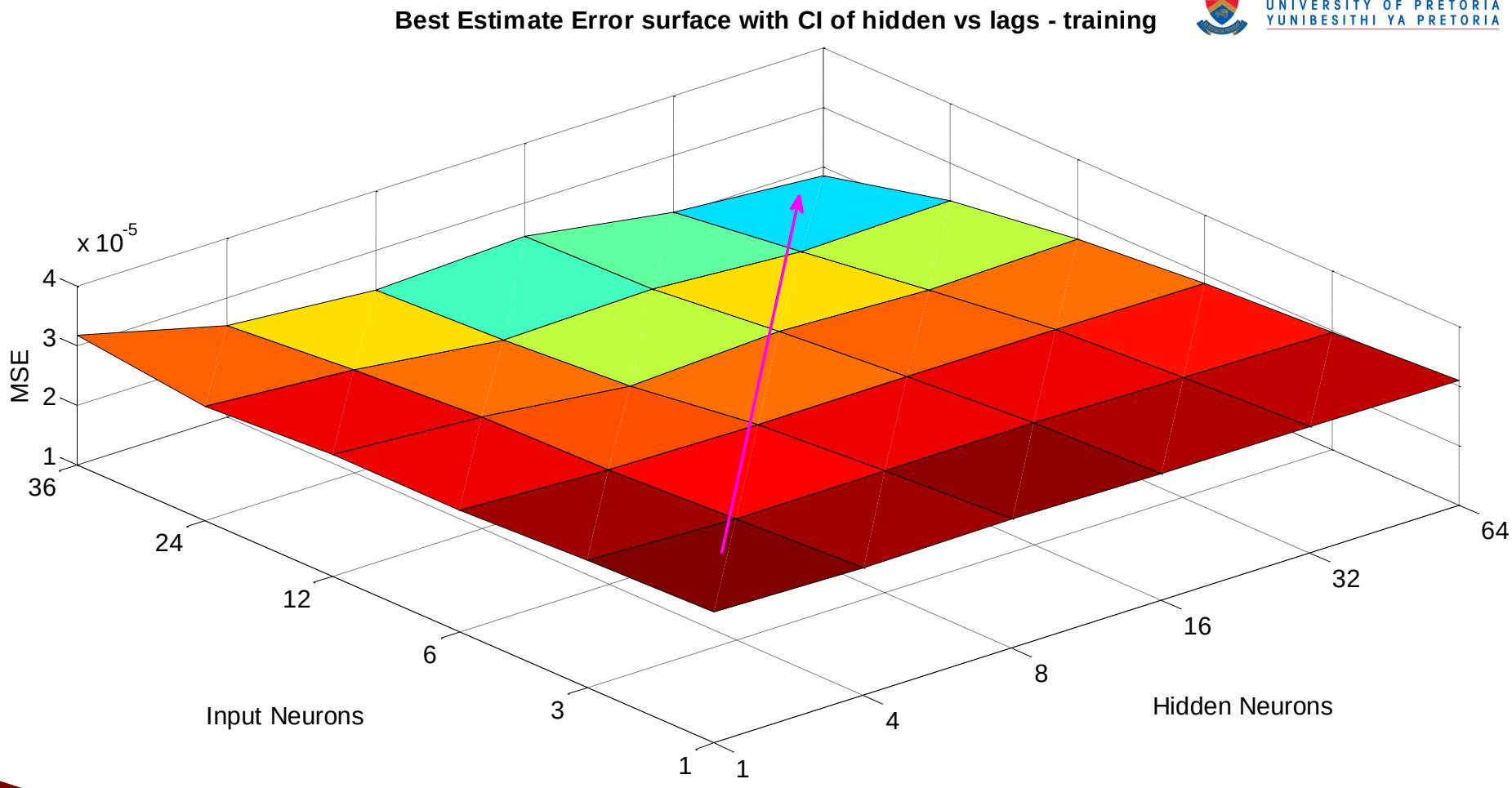

# Experiment: Predicting Inflation

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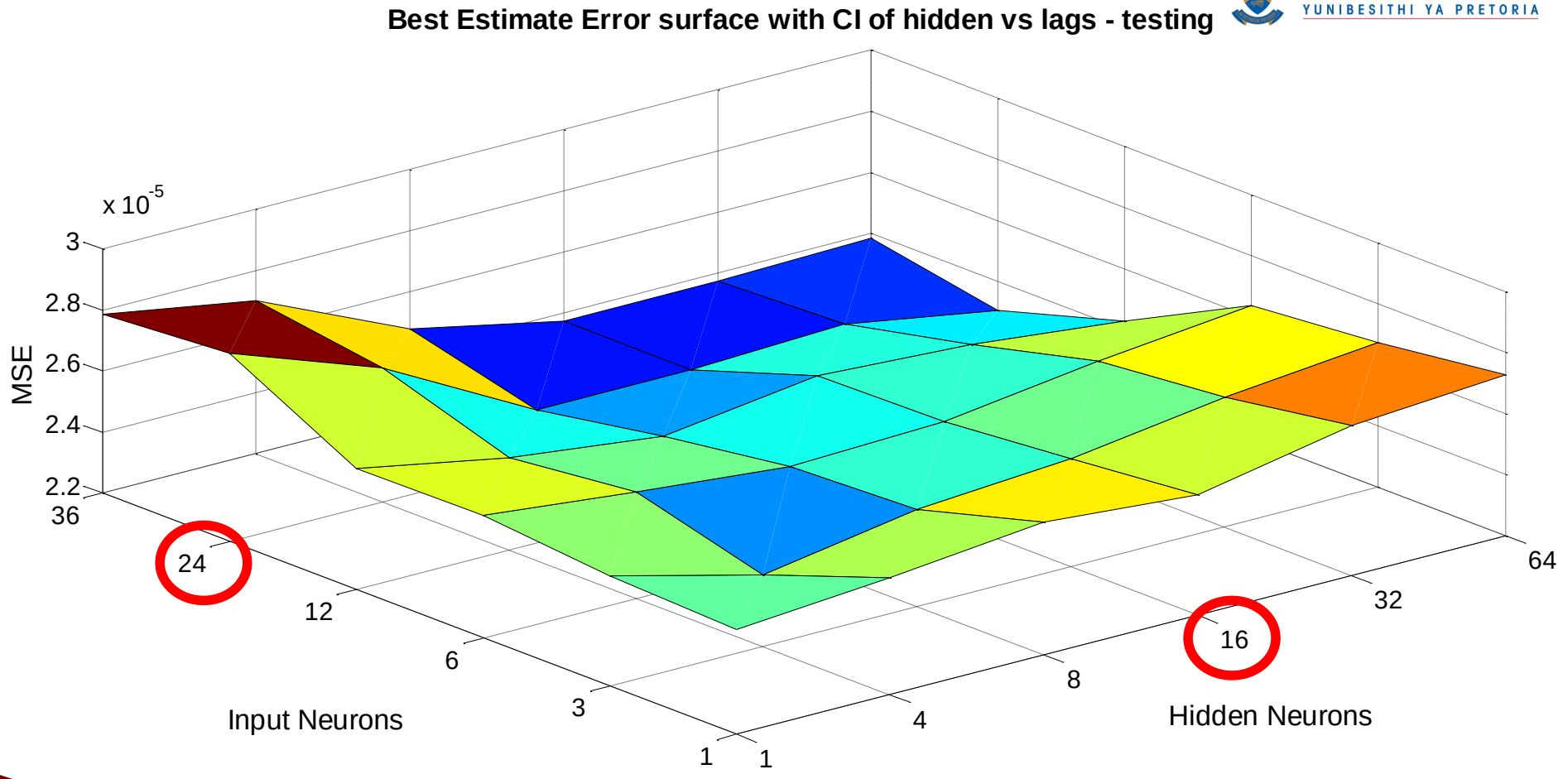

# Experiment: Predicting Inflation
## Optimal ANN

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| Structure | ANN – Training Set MSE | ANN – Training Set RMSE | ANN – Testing Set MSE | ANN – Testing Set RMSE |
|---|---|---|---|---|
| 24-16-1 | 0.000022 | 0.0047 | 0.0000229 | 0.0048 |

# Experiment: Predicting Inflation Output

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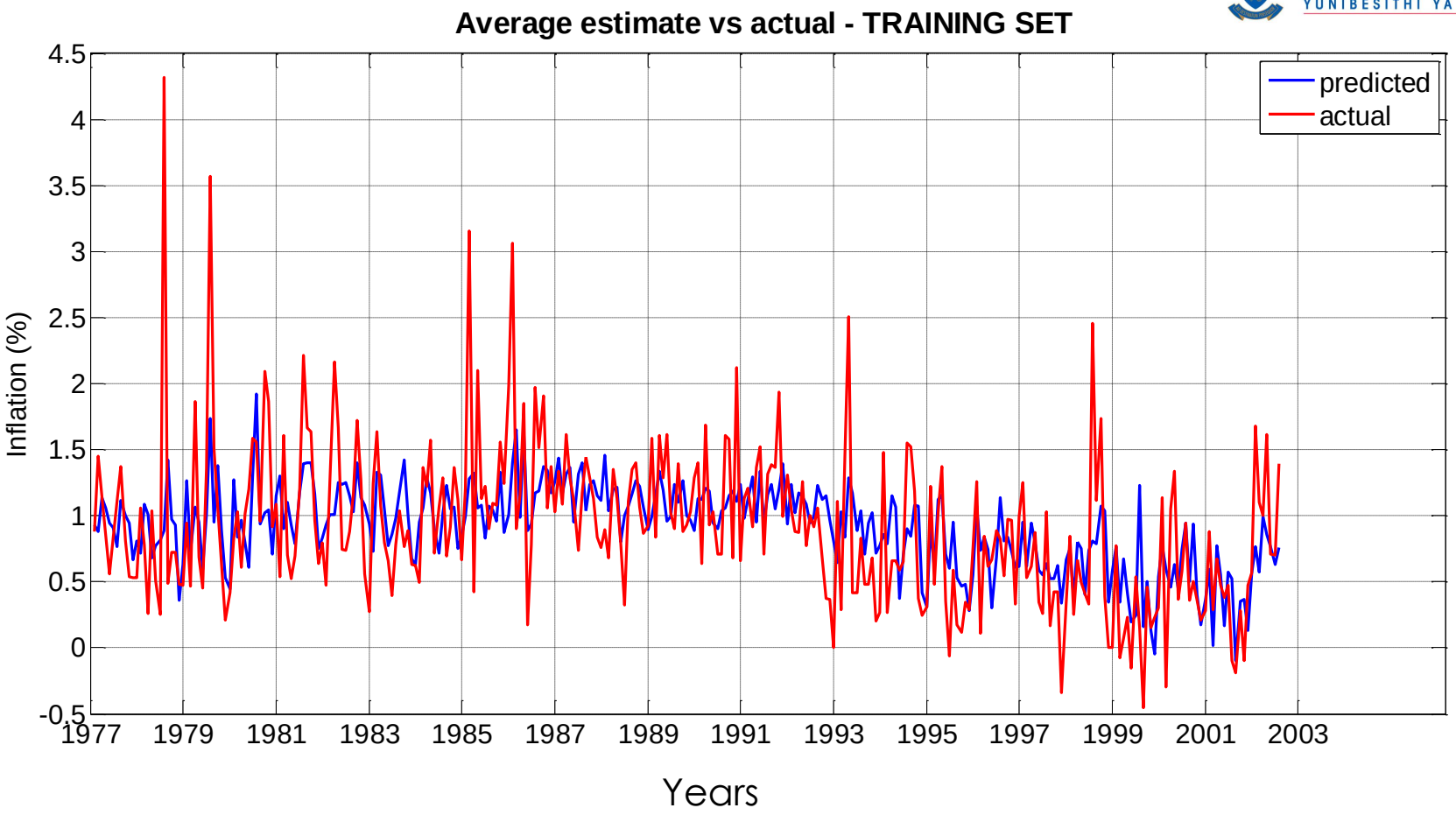

# Experiment: Predicting Inflation Output

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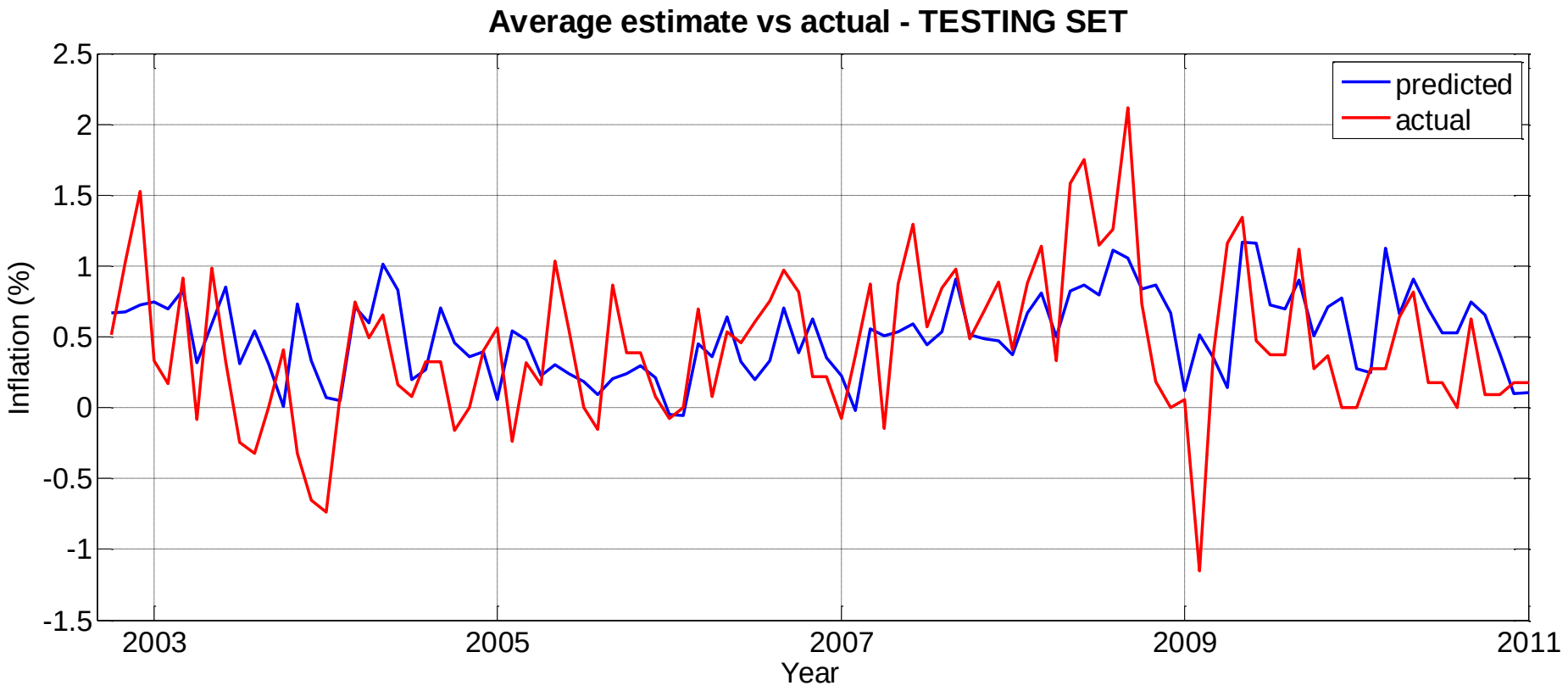

# Time Series Problem: Results 1

| | ANN – Training Set | ANN– Testing Data (100 data points) | Exponential Smoothing | AR(13) |
|---|---|---|---|---|
| Root Mean Squared Error | 0.0045 | 0.0048 | 0.00535 | 0.00504 |

Problems:

- Not consistent comparison
- Exponential and AR(13) have the advantage

Expectations:

- ANNs will perform best when considering more than 1 time step predictions

# 5. Problems ANNs can solve

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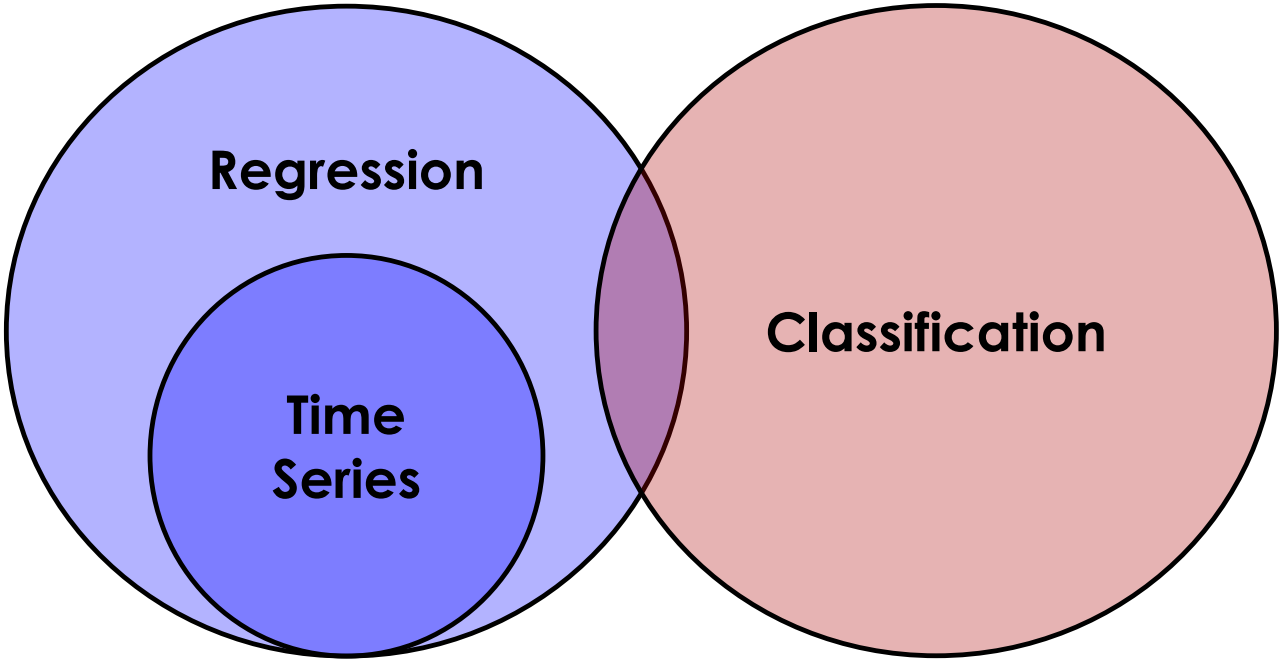
Three types of problems:



# Regression Problem: Function Tracker

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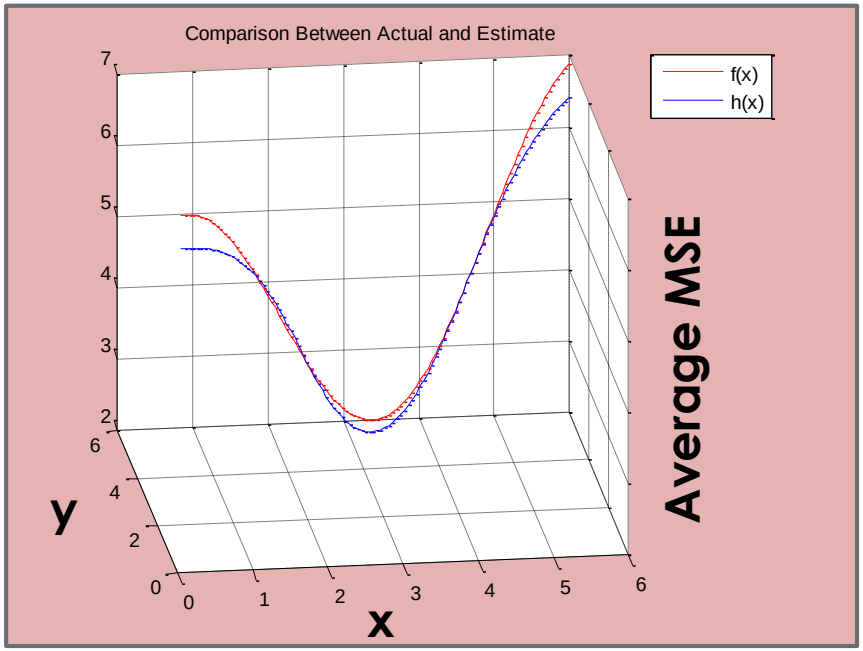
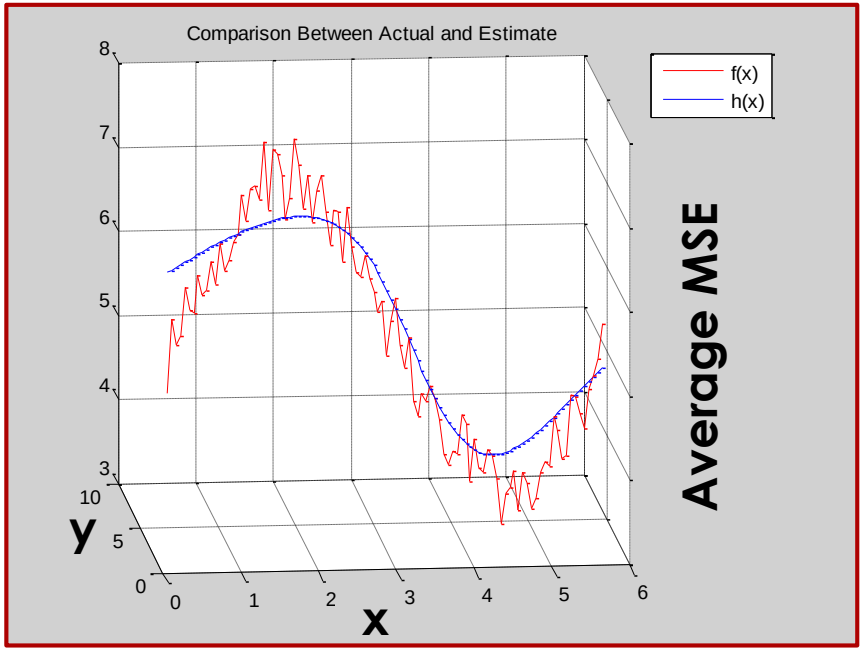
## Cosine function




## Sin function with noise



# 5. Problems ANNs can solve

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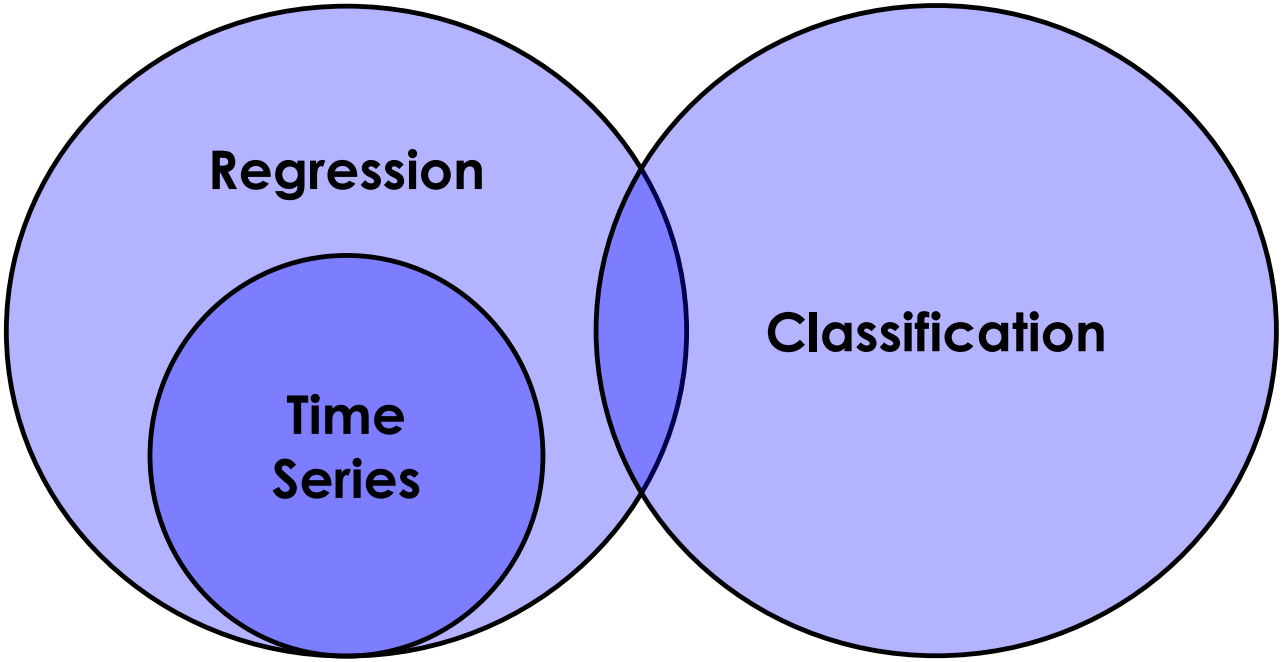

# Classification Problem: Handwriting Classification

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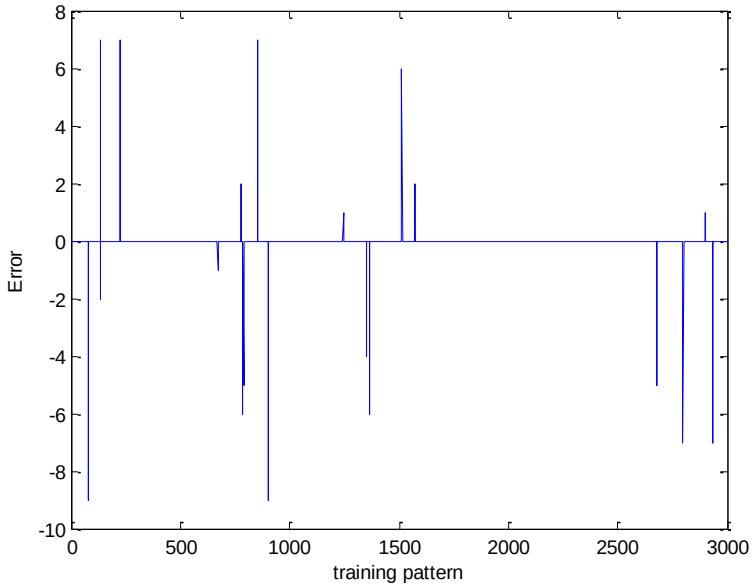
- Classify written symbols in 1 of 10 categories
- Training data – 3000 images
- Testing data – 200 images

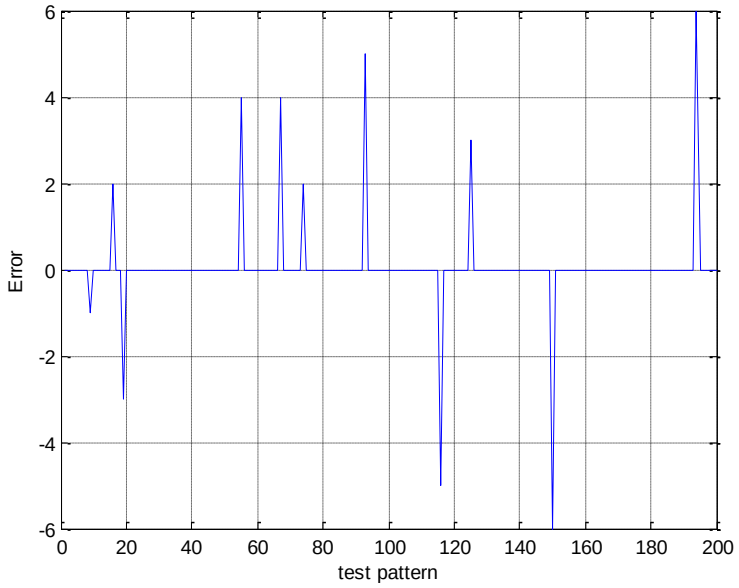
# Classification Problem: Results

| | Training Data | Testing Data |
|---|---|---|
| Classification Accuracy | 99% | 95% |

## Training Set




## Testing Set



# Industry Applications

- Fraud detection
  - Credit Card Fraud
  - Online Banking Fraud
  - Insurance Claims Fraud
- Assessing Mortgage Risk
- Trading Strategies
  - Buy/Sell?
  - Increase or decrease?

# 6. Areas of Application

- Detecting credit card fraud
- Mortgage risk assessment
- Predicting bankruptcy

**Classification Applications**

- Forecasting forward interest rates
- Predicting future general insurance claims
- Predicting stock exchange movements
- Forecasting commodity prices
- Forecasting foreign exchange rates

**Regression and Time Series Applications**

# 7. So why ANNs? – Summary

- Dynamic Modelling Technique
  - Detects non-linear relationships
  - Adapts to changing environments
- Types of problems:
  - Regression
  - Time Series
  - Classification

# Future work

- Money Market
- Bond Market
- Equity Market
- Combination of markets
- Fraud detection

# Thank you

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- Dr P. de Villiers

  (Department Electronic, Electric and Computer Engineering)

- Dr C. Beyers

  (Department of Insurance and Actuarial Science)

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# Questions?


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- Matthew.Smith@up.ac.za