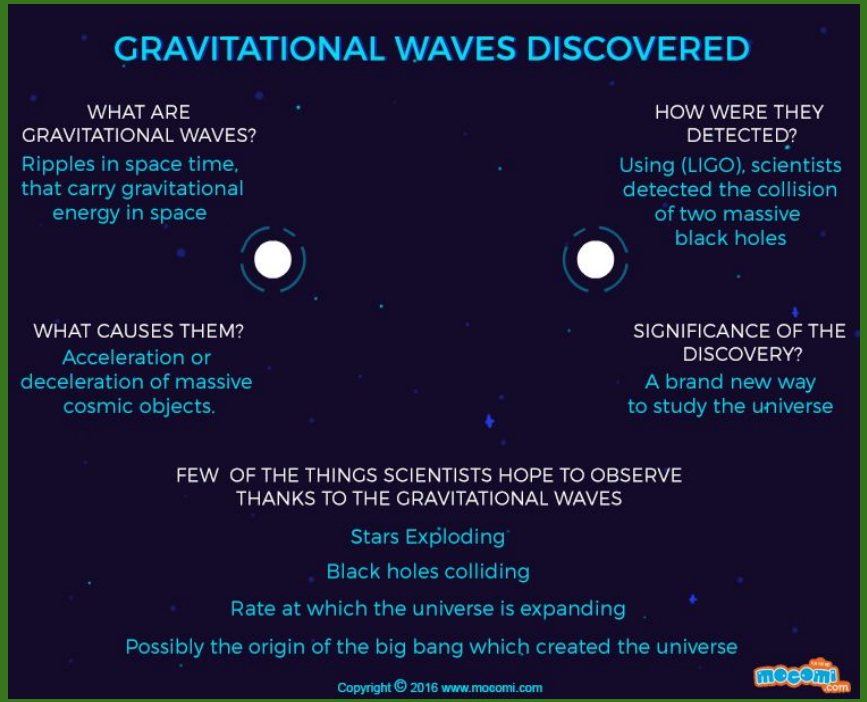
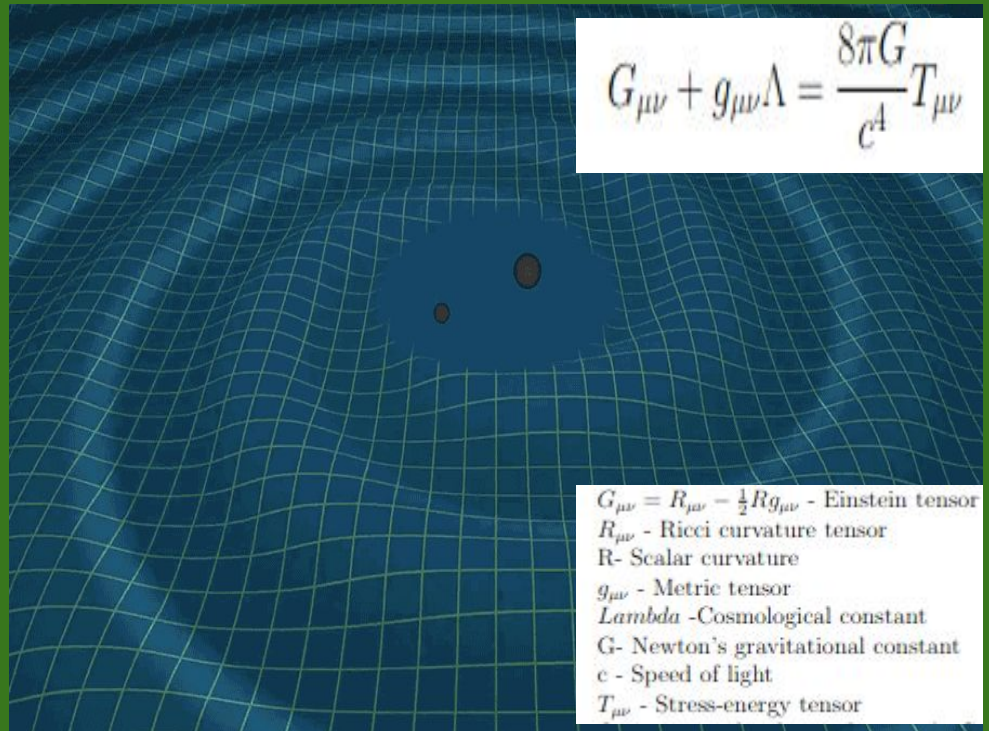
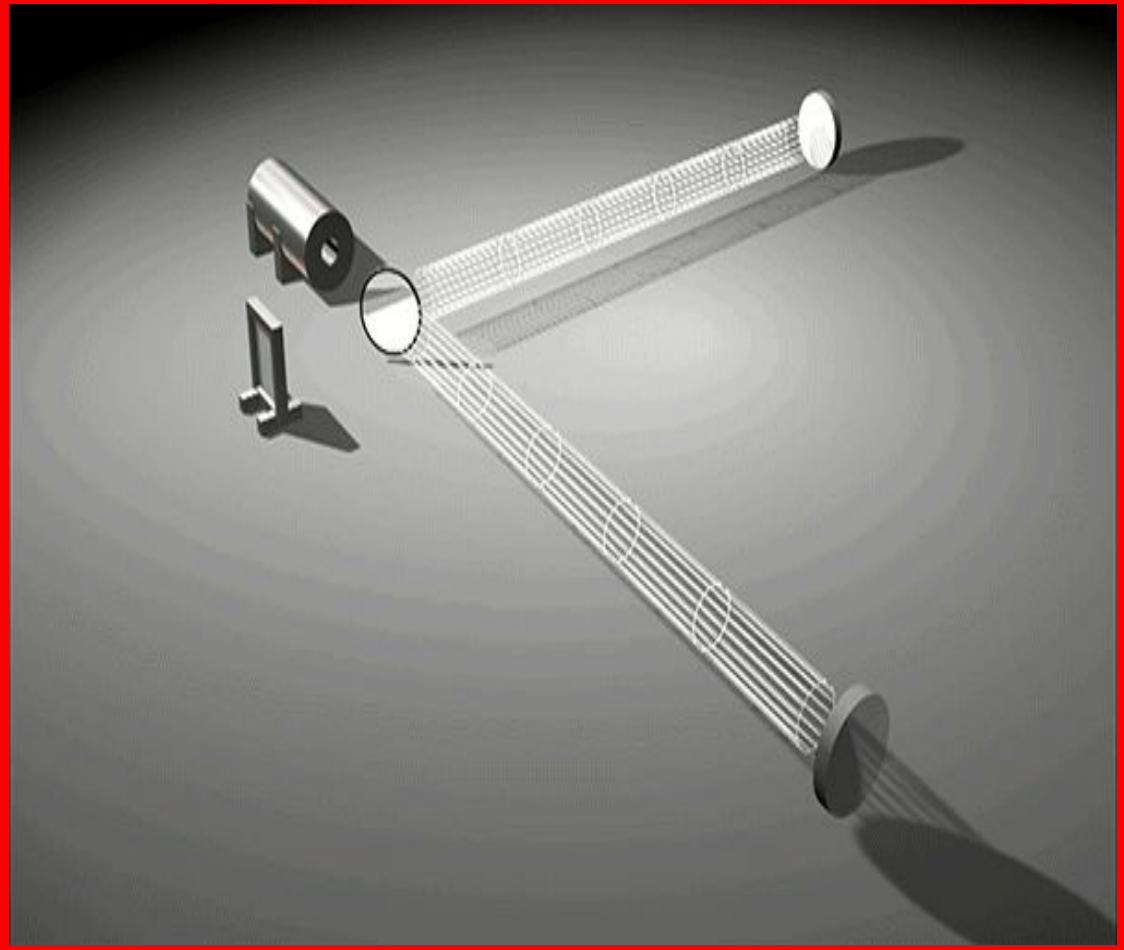
TESTING DIFFERENT MACHINE LEARNING ALGORITHMS FOR IDENTIFYING GRAVITATIONAL WAVES

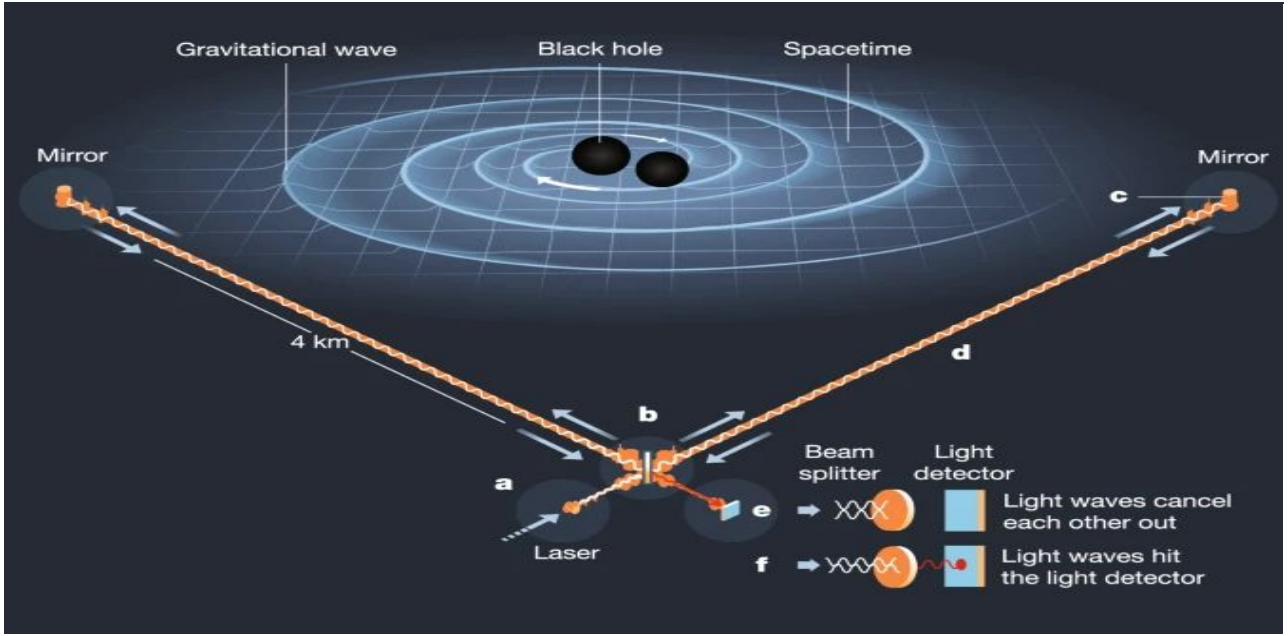
UNDERSTANDING GW AND ITS IMPORTANCE

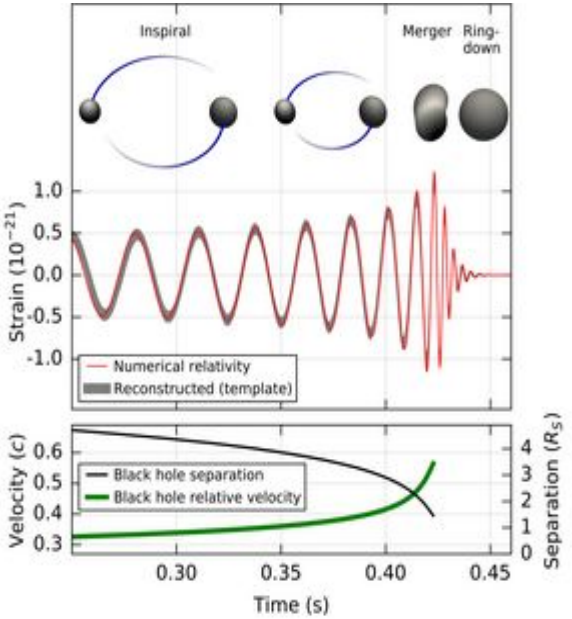


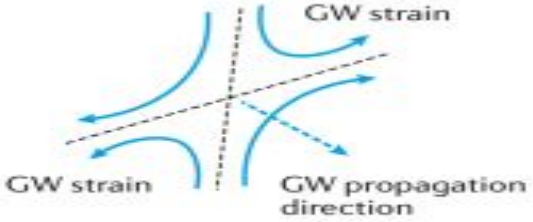


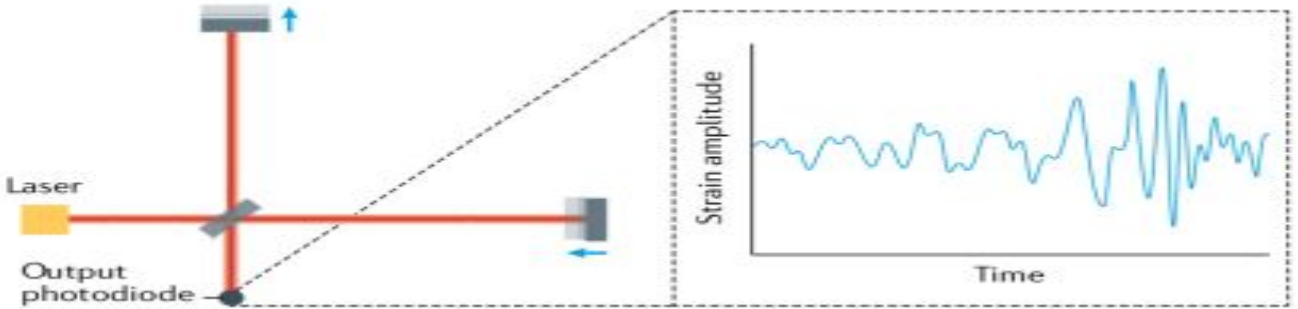
GW DETECTION PRINCIPLE




Gravitational wave
Black hole
Spacetime
Mirror
Mirror
4 km
a
b
c
d
e
f
Laser
Beam splitter
Light detector
Light waves cancel each other out
Light waves hit the light detector


Inspiral
Merger
Ring-down
Strain (10^{-21})
Numerical relativity
Reconstructed (template)
Velocity (c)
Separation (R_S)
Black hole separation
Black hole relative velocity
Time (s)


GW strain
GW strain
GW propagation direction


Laser
Output photodiode
Strain amplitude
Time

Problem Statement

Huge amount of data -(observational runs&time,instruments no.&sensitivity)

Methods-(human inspection,hard coded algorithm,matched filtering)

Hypothesis

- **ML can study GW,**classify GW,eliminate noise, separate GW

Justification of Study

Detections-(theory,observation)
Big data

Objectives

- **Main-(develop&test different models&algorithms)**
- **Specific-(algorithm for automatic detection,study&classify signals,eliminate noise,reduce human limitations)**

CLASSIFICATION OF GRAVITATIONAL WAVES WITH DIFFERENT MACHINE LEARNING ALGORITHMS

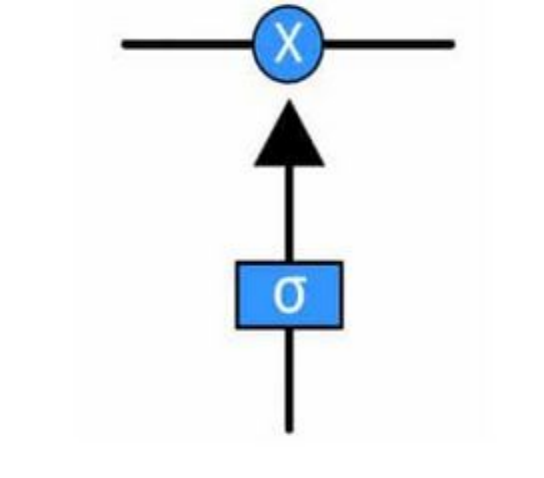
Dataset

- Source-(EGO,Kaggle)
- Data Generation-(factors masses,spin,distance)
- Data Prepation(visualization,tokenization)
- Data Augemention(modification,coping,synthetic data)

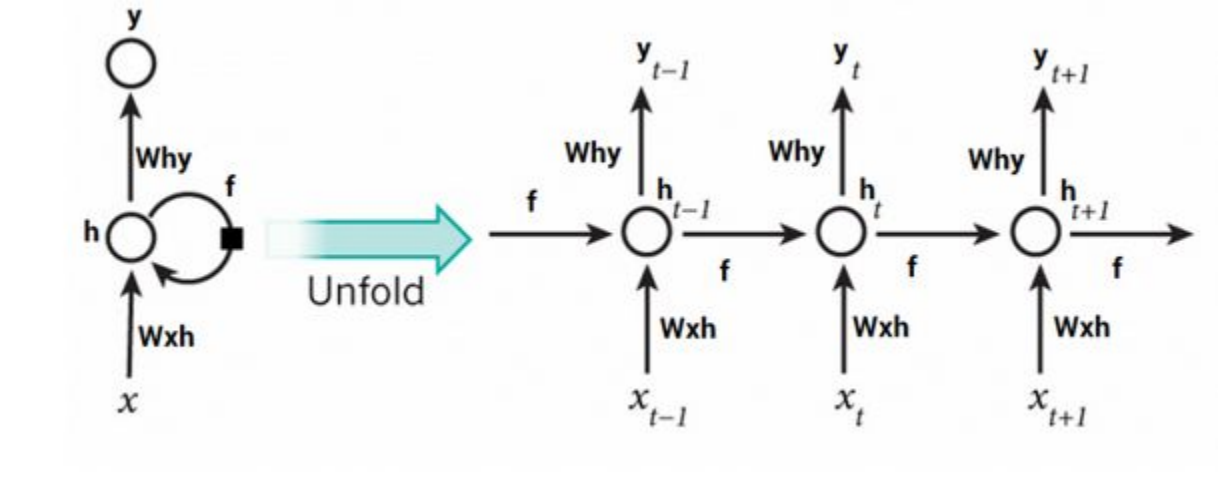
Methodology

- Setting Parameters and Other Factors
- Algorithms Used (Conv1D,NN,RNN&LSTM)
- Model Building,Training and Testing Process

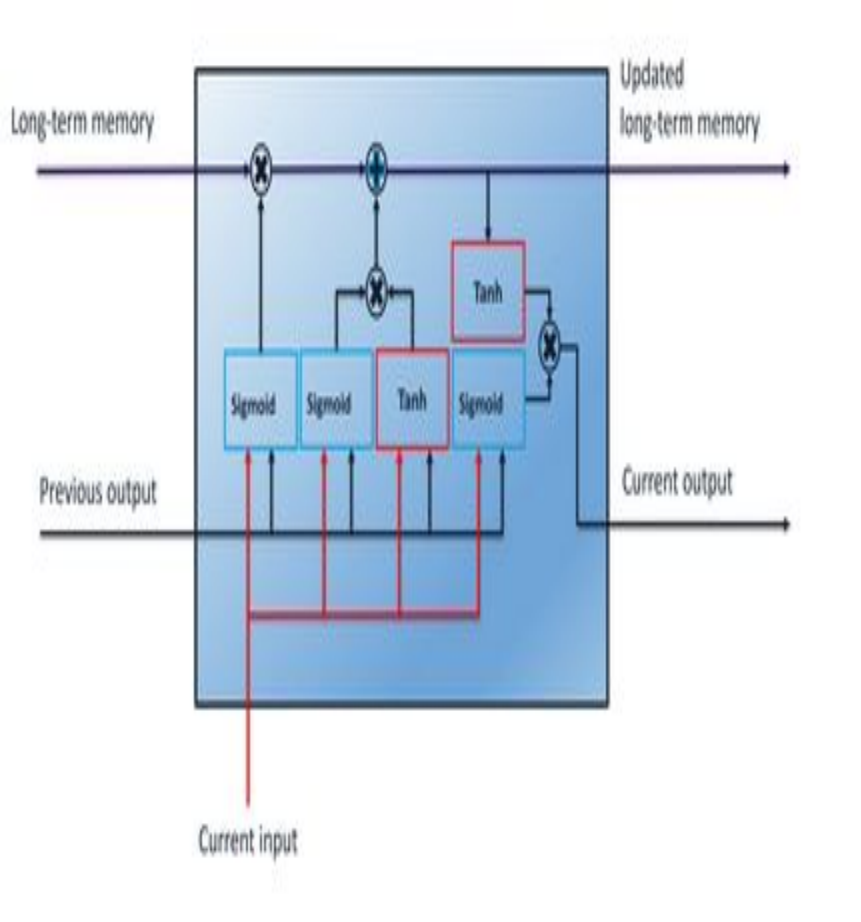
UNDERSTANDING MACHINE LEARNING

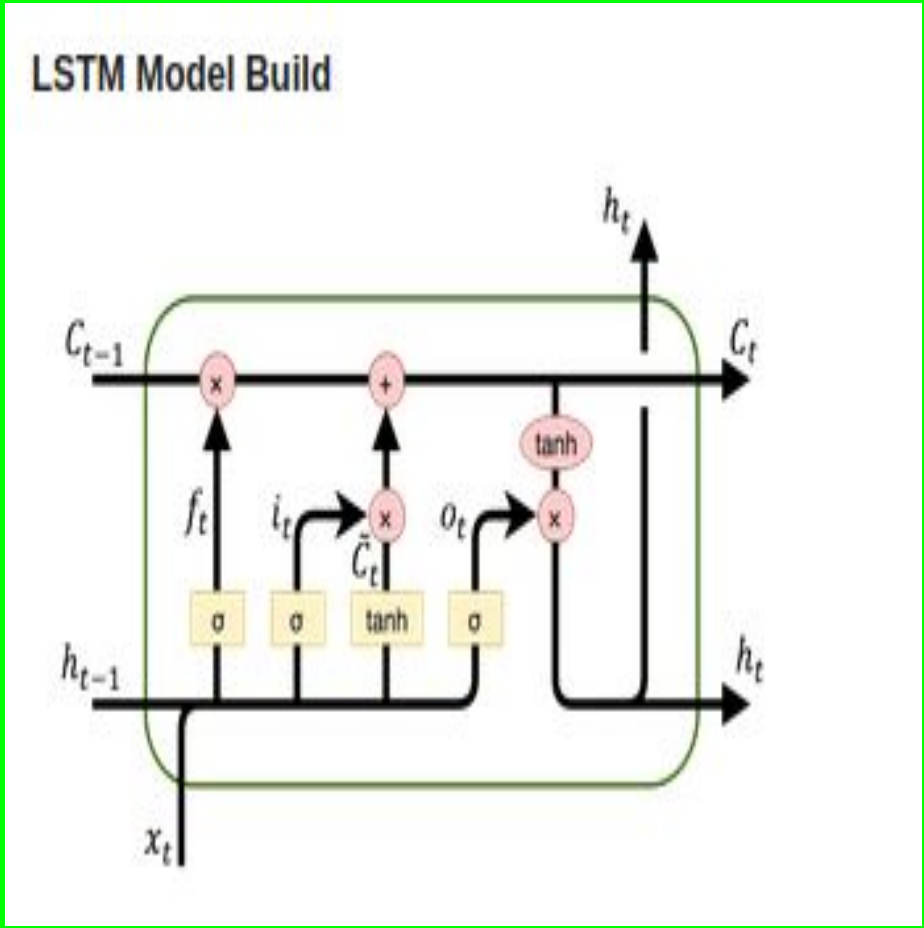


Simple NN Unit Structure



RNN Unit Structure and Flow of Information

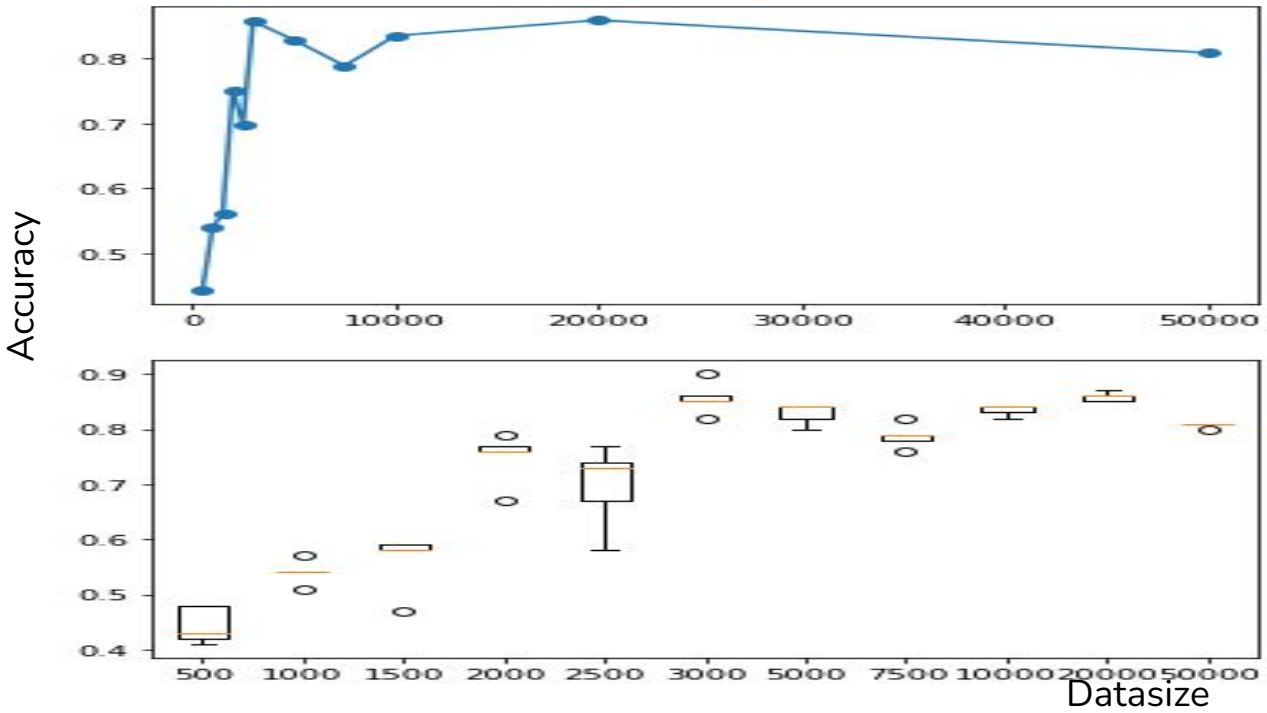




LSTM Unit and Its Operation-(Gates,Activation Function,Memories)

Impact Of Datasize On Training ML Model

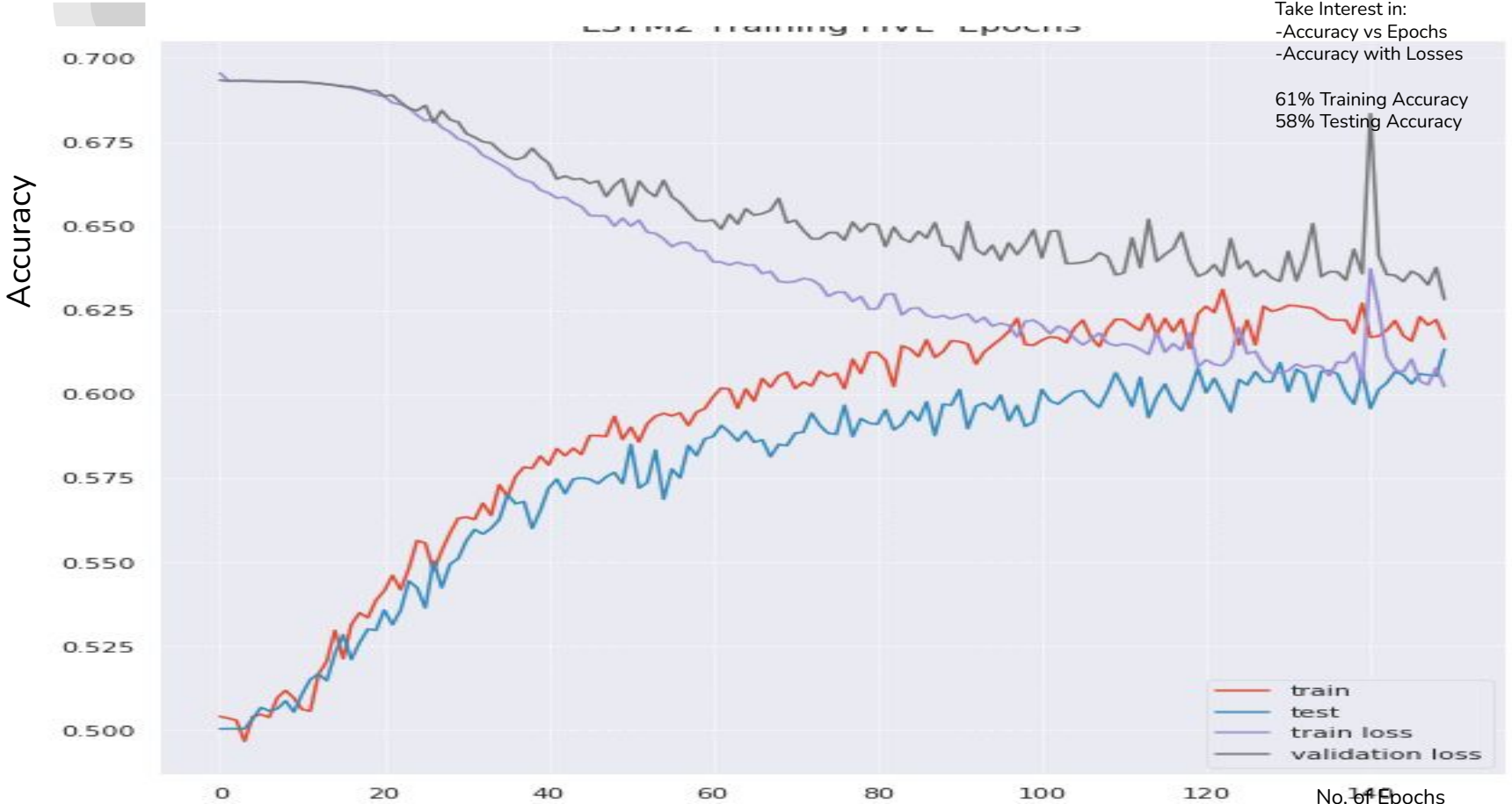
```
Train Size=500, Test Accuracy 44.400
Train Size=1000, Test Accuracy 54.000
Train Size=1500, Test Accuracy 56.200
Train Size=2000, Test Accuracy 75.000
Train Size=2500, Test Accuracy 69.800
Train Size=3000, Test Accuracy 85.600
Train Size=5000, Test Accuracy 82.800
Train Size=7500, Test Accuracy 78.800
Train Size=10000, Test Accuracy 83.400
Train Size=20000, Test Accuracy 85.800
Train Size=50000, Test Accuracy 80.800
```



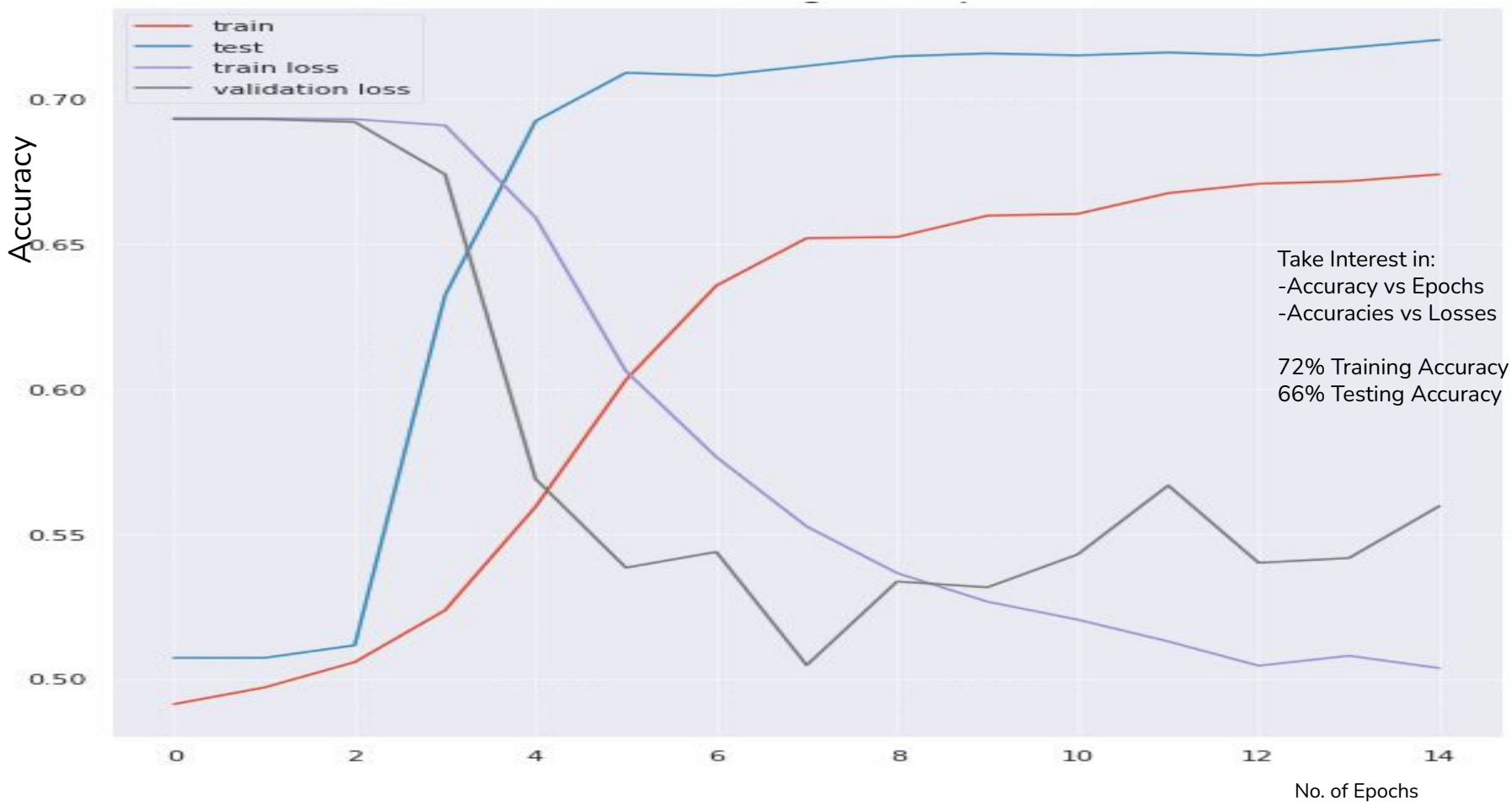
Take Interest in:
-accuracy vs datasize
-uncertainity vs datasize

Results and Discussion

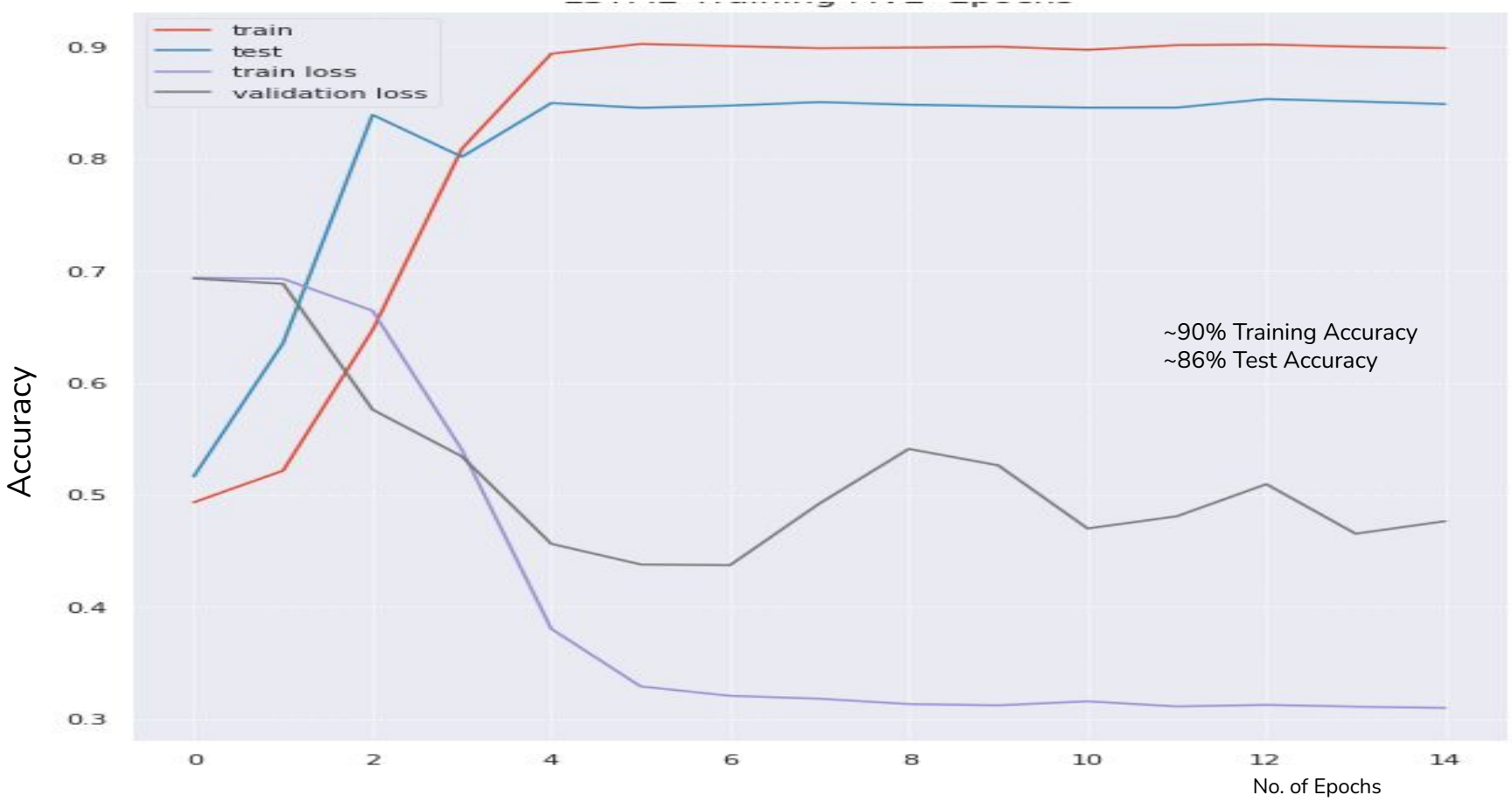
Results For RNN Training 150 Epochs



Result for LSTM Training With 15 Epochs



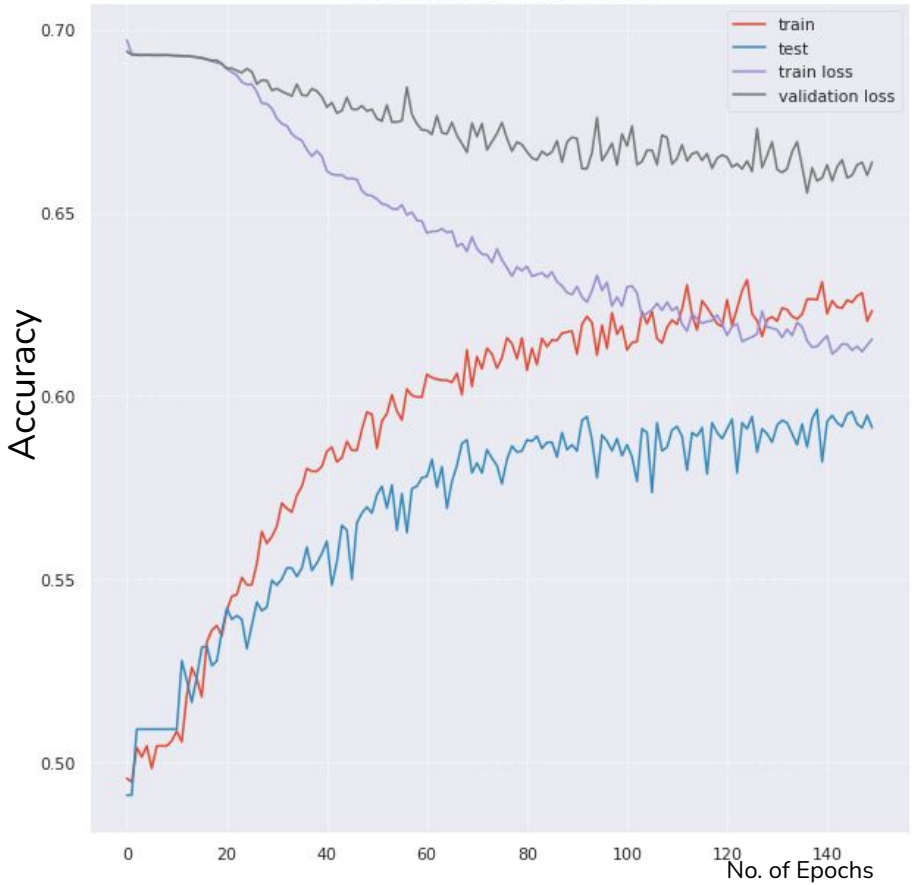
Results For Improved LSTM Training



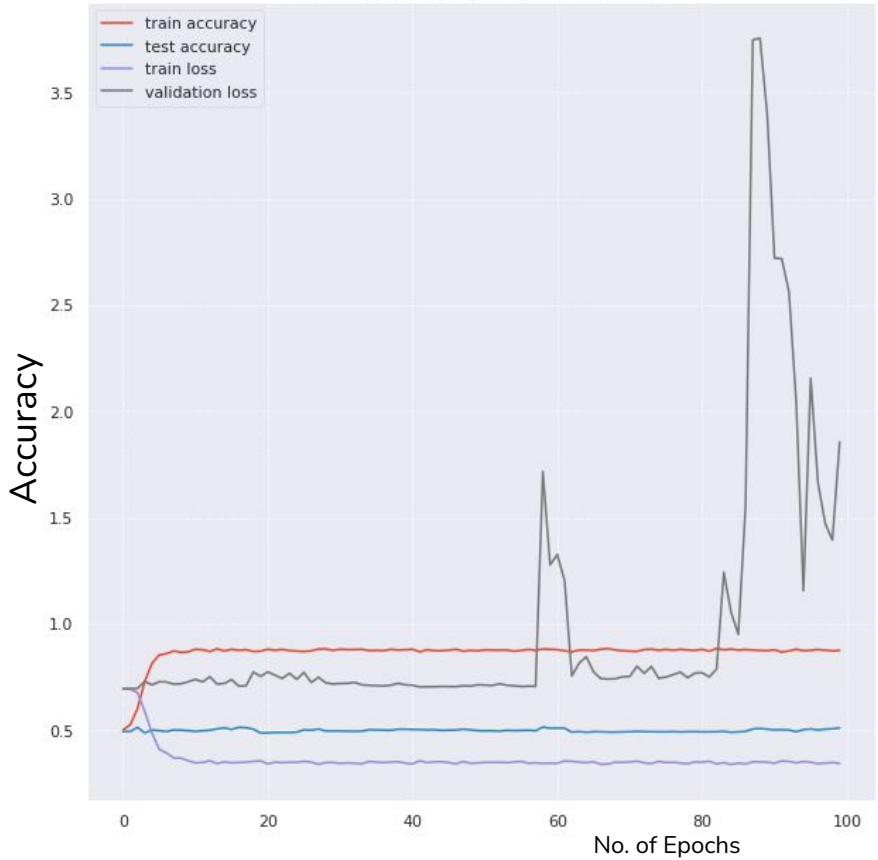

THANK YOU
ASSA
ANY QUESTION?
Presented by:
OKOTH VINCENT

Results and Discussion

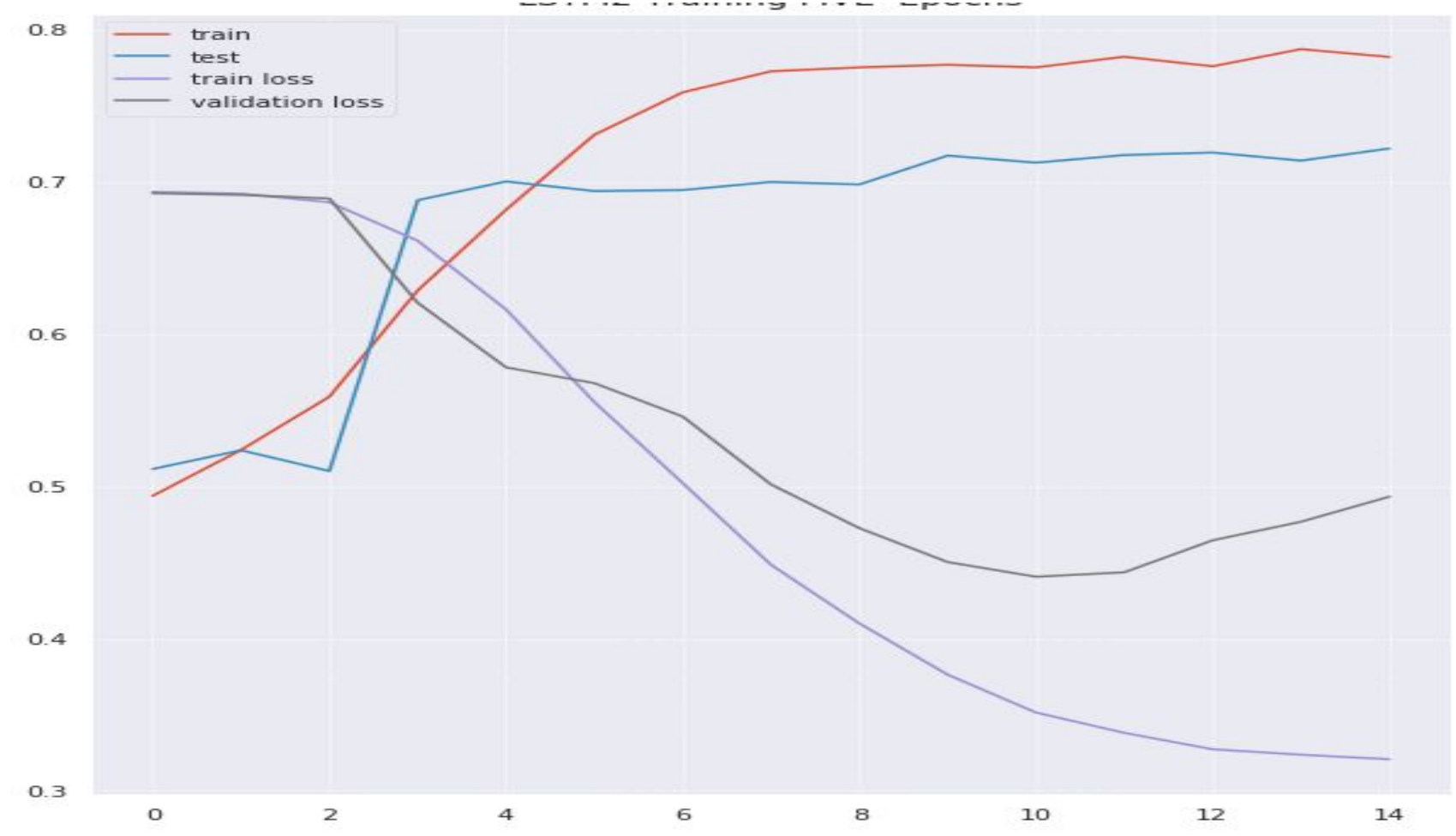
RNN Training One Hundred and Fifty Epochs

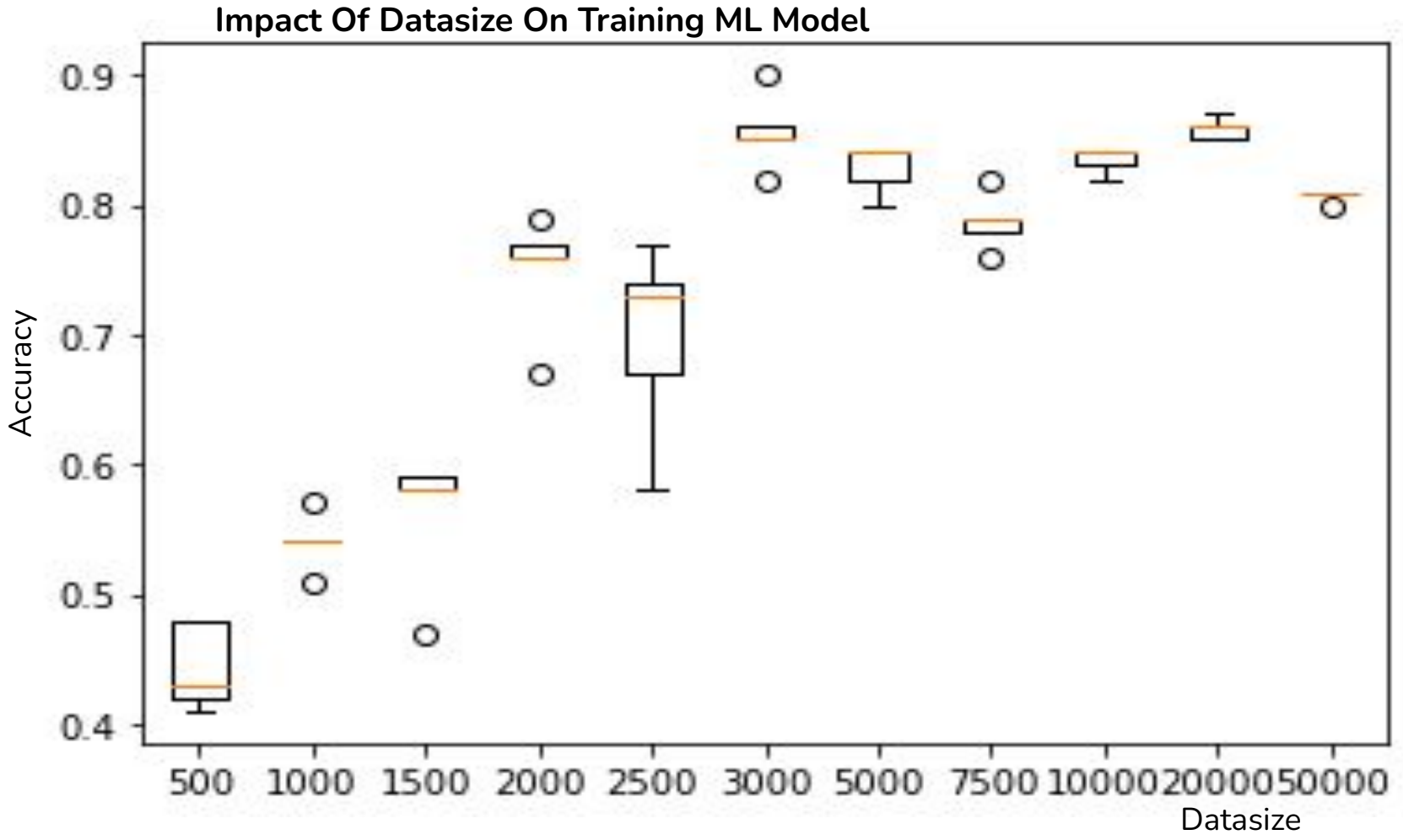


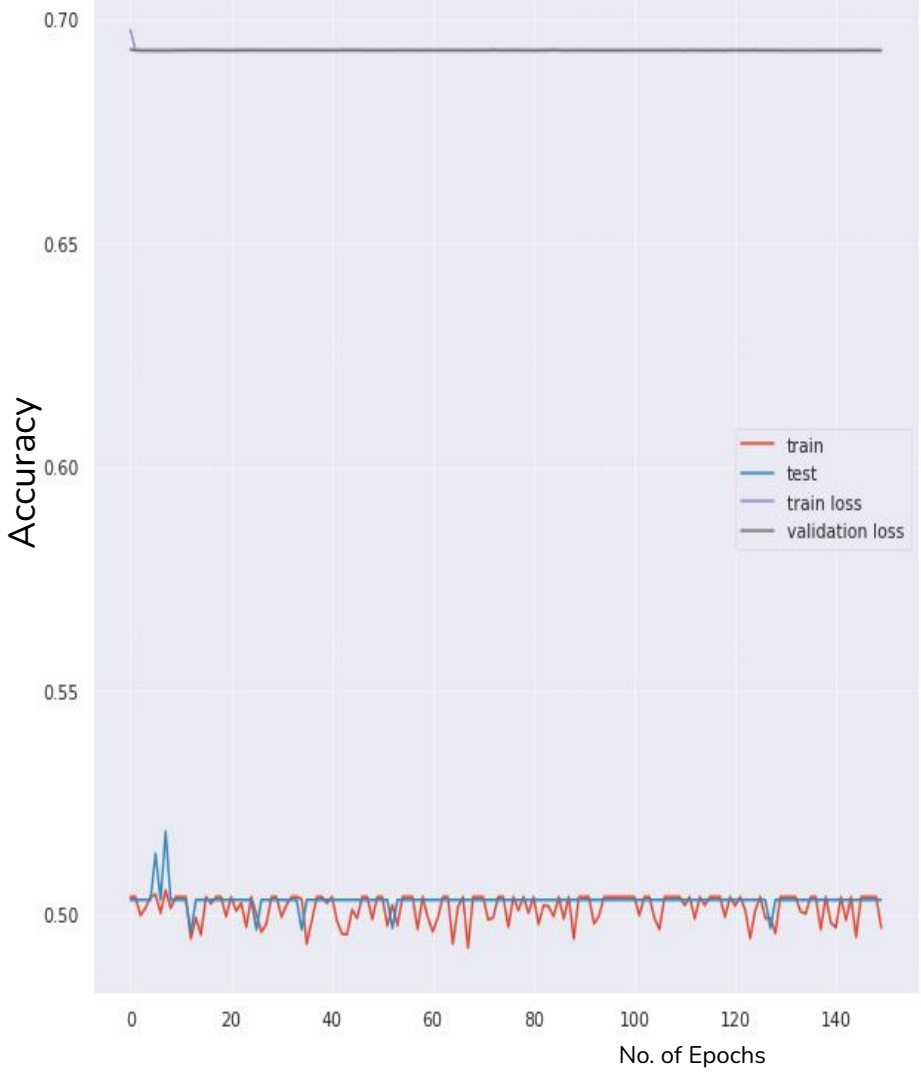
LSTM Training One Hundred Epochs

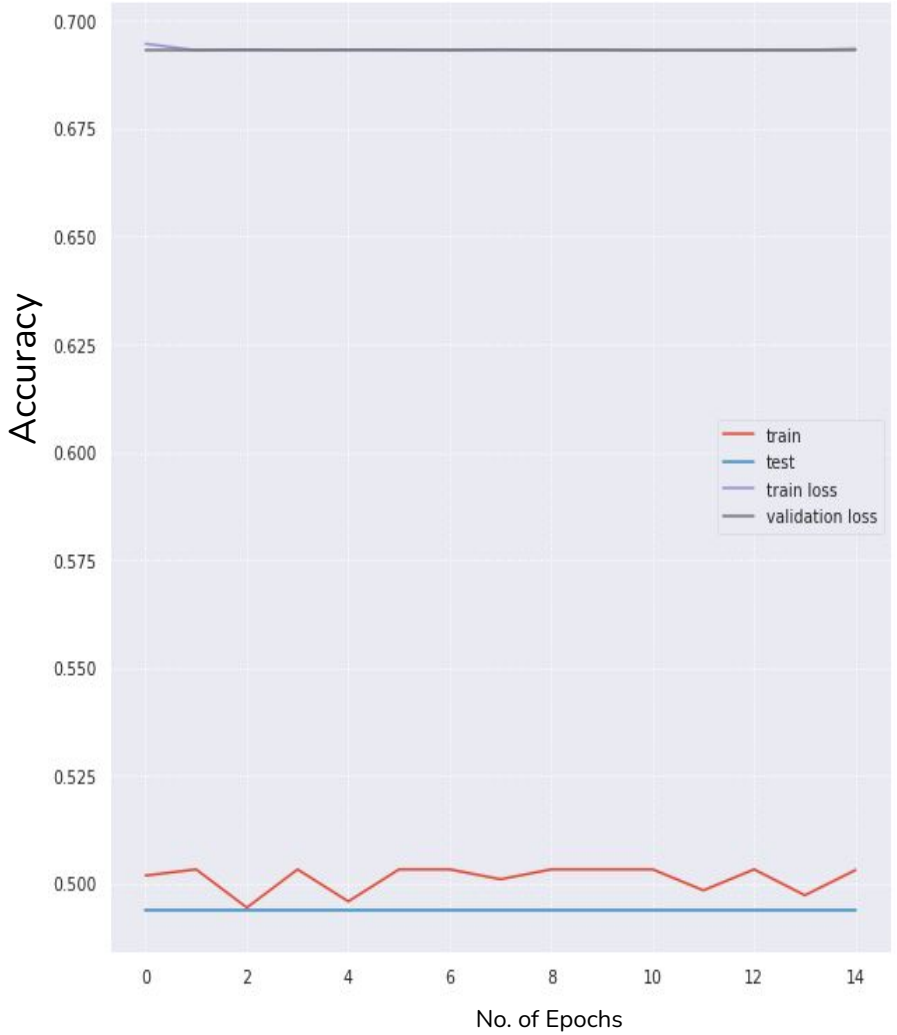


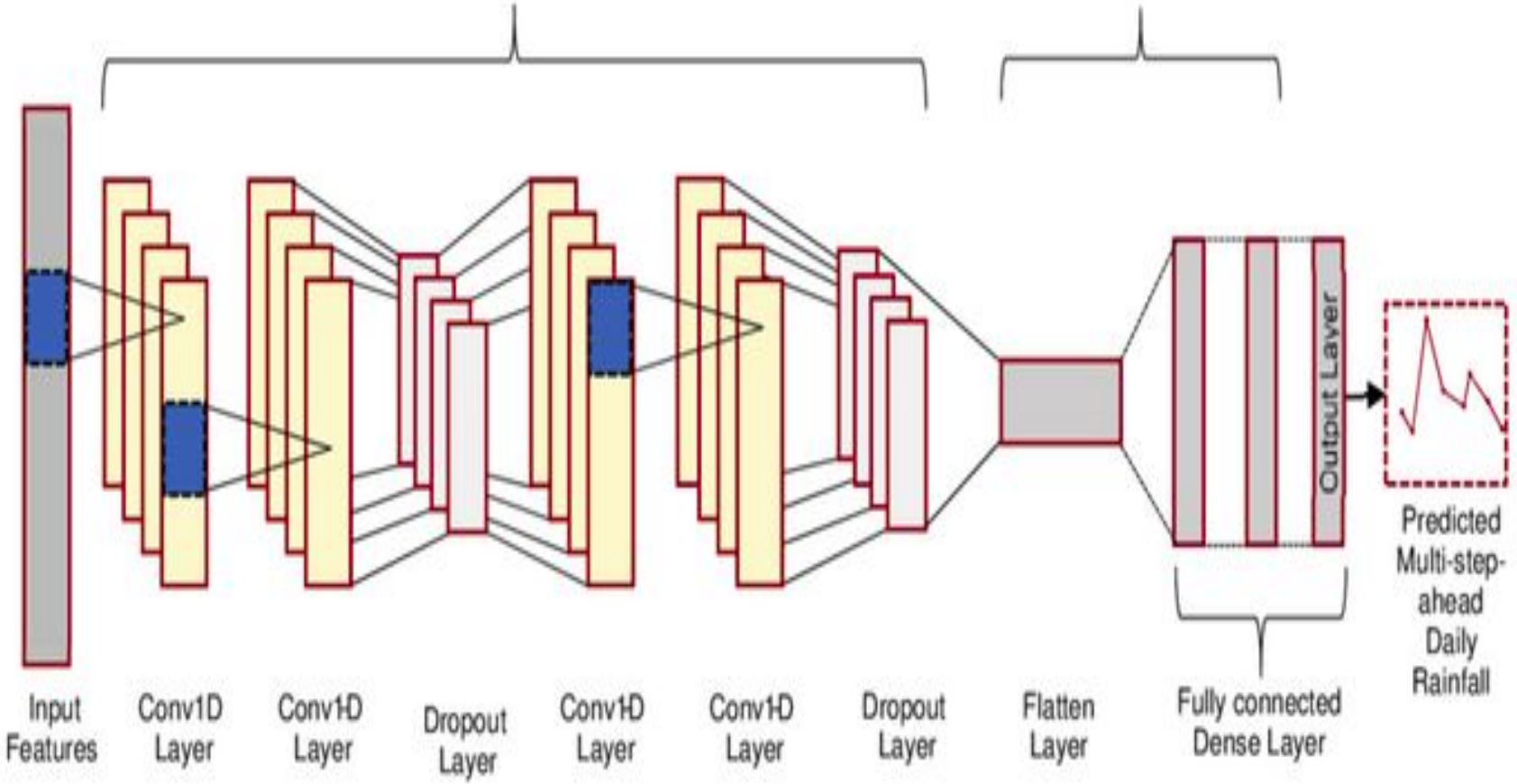
Results For RNN-LSTM Model




Impact Of Datasize On Training ML Model
Accuracy
0.9
0.8
0.7
0.6
0.5
0.4
500
1000
1500
2000
2500
3000
5000
7500
10000
20000
50000
Datasize


Accuracy
0.70
0.65
0.60
0.55
0.50
0
20
40
60
80
100
120
140
No. of Epochs
train
test
train loss
validation loss


Accuracy
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0.525
0.500
0
2
4
6
8
10
12
14
No. of Epochs
train
test
train loss
validation loss


Output Layer
Predicted Multi-step-ahead Daily Rainfall
Input Features
Conv1D Layer
Conv1D Layer
Dropout Layer
Conv1D Layer
Conv1D Layer
Dropout Layer
Flatten Layer
Fully connected Dense Layer

GRAVITATIONAL WAVES
Timeline to discovery

1916
Albert Einstein first proposes the existence of gravitational waves as part of his general theory of relativity. Many researchers doubt that they exist at all, believing them to be a mathematical quirk.

1957
Physicists Felix Pirani, Hermann Bondi, and Richard Feynman predict that gravitational waves might be detected by a 'sticky bead argument'. The idea being that if a gravitational wave passed through a stick with a bead on it, it would cause the bead to move back and forth and heat up both the bead and stick with the friction generated.

1962
Russian scientists ME Gertsenshtein and VI Pustovoit published a paper proposing 'interferometers' as a way to detect gravitational waves.

1967
Rainer Weiss (one of LIGO's co-founders) proposes a method that would use laser beams to measure the stretching and squashing of space caused by a passing gravitational wave. They were working independently of ME Gertsenshtein and VI Pustovoit, who proposed something similar in 1962.

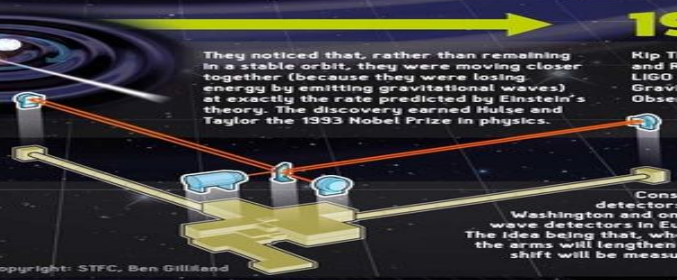
1969
Joseph Weber claims to have detected gravitational waves using a device called a resonant bar detector, but no one can replicate his results.

1974
Rainer Weiss meets physicist Kip Thorne and convinces Thorne that a laser-based instrument would give them the best chance of finding gravitational waves. They start working on the project that would become LIGO.

1978
Russell Hulse and Joseph Taylor provide the first experimental evidence for the existence of gravitational waves by observing two neutron stars orbiting each other (a binary system).

They noticed that, rather than remaining in a stable orbit, they were moving closer together (because they were losing energy by emitting gravitational waves) at exactly the rate predicted by Einstein's theory. The discovery earned Hulse and Taylor the 1993 Nobel Prize in physics.

1984
Kip Thorne, Ronald Drever, and Rainer Weiss found the LIGO (Laser Interferometer Gravitational-wave Observatory) Project.



1990s
Construction begins on LIGO – two L-shaped detectors with four-kilometre-long arms (one in Washington and one in Louisiana), along with gravitational wave detectors in Europe (the VIRGO and GEO600 detectors). The idea being that, when a gravitational wave passes through, the arms will lengthen and shorten by a fraction – the precise shift will be measured by lasers travelling along the arms.

2001
LIGO begins operations. At the end of its run in 2010, as expected, LIGO had found no evidence of gravitational waves. LIGO had proved the technology worked – it just needed to be more sensitive.

2007
The VIRGO laser interferometer based in Italy, designed to detect gravitational waves begins operation.

NEXT PAGE

GRAVITATIONAL WAVES
Timeline to discovery

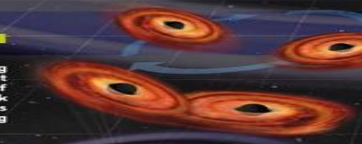
2010
LIGO begins upgrades to become Advanced LIGO. This new facility will be ten times more sensitive than the old one, and includes technology from the UK-German GEO600 detector and from Australia.

2011
VIRGO upgrade commences that will eventually improve the sensitivity by a factor of ten.

2015
In September, Advanced LIGO begins its first engineering and test run. Although only operating at less than half its final sensitivity, it detects its first gravitational wave event on September 14.

2015
LISA Pathfinder is launched – a test bed mission for the first space-based gravitational wave detector. LISA Pathfinder will test technology for the planned LISA (Laser Interferometer Space Antenna) mission.

2015
In the 'Boxing Day' binary at least one of the black holes was spinning

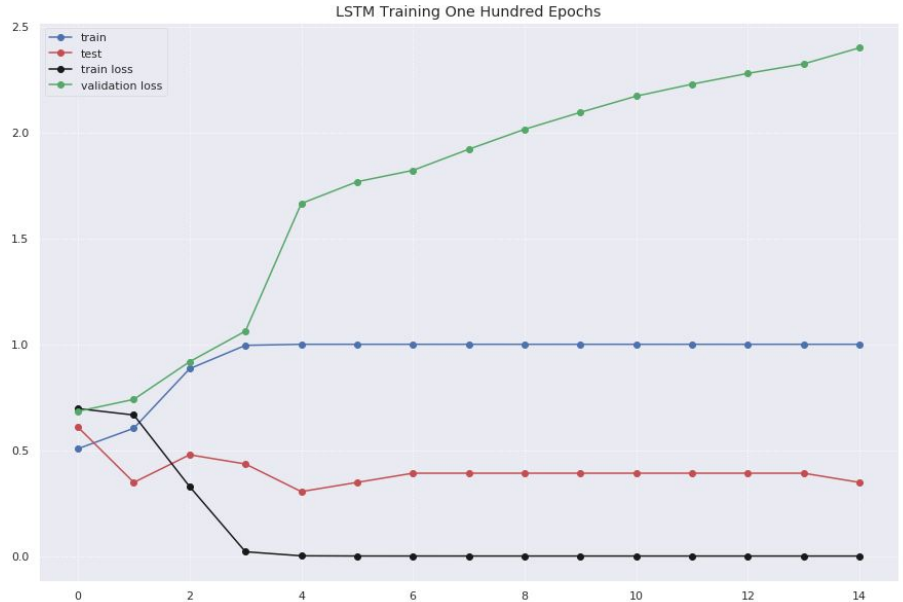


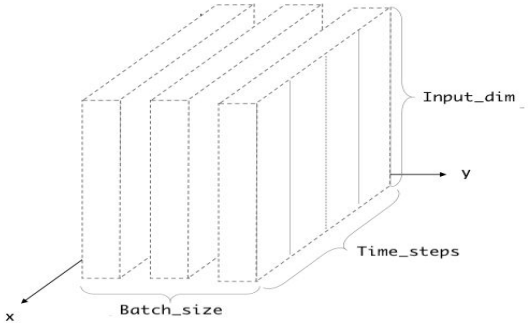
2016
In February, the LIGO Scientific Collaboration announce that they had indeed detected gravitational waves on September 14, 2015. The waves had been created by two black holes, spiralling in toward each other and merging into a single black hole.

2016
On June 15, the Boxing Day event is announced. This new observation indicates that there is a rich population of binary black holes in the Universe, whose properties are gradually starting to emerge. Gravitational-wave astronomy is no longer a field of single detections, but of regular observations. This discovery transforms the LIGO detector into a true astronomical observatory.

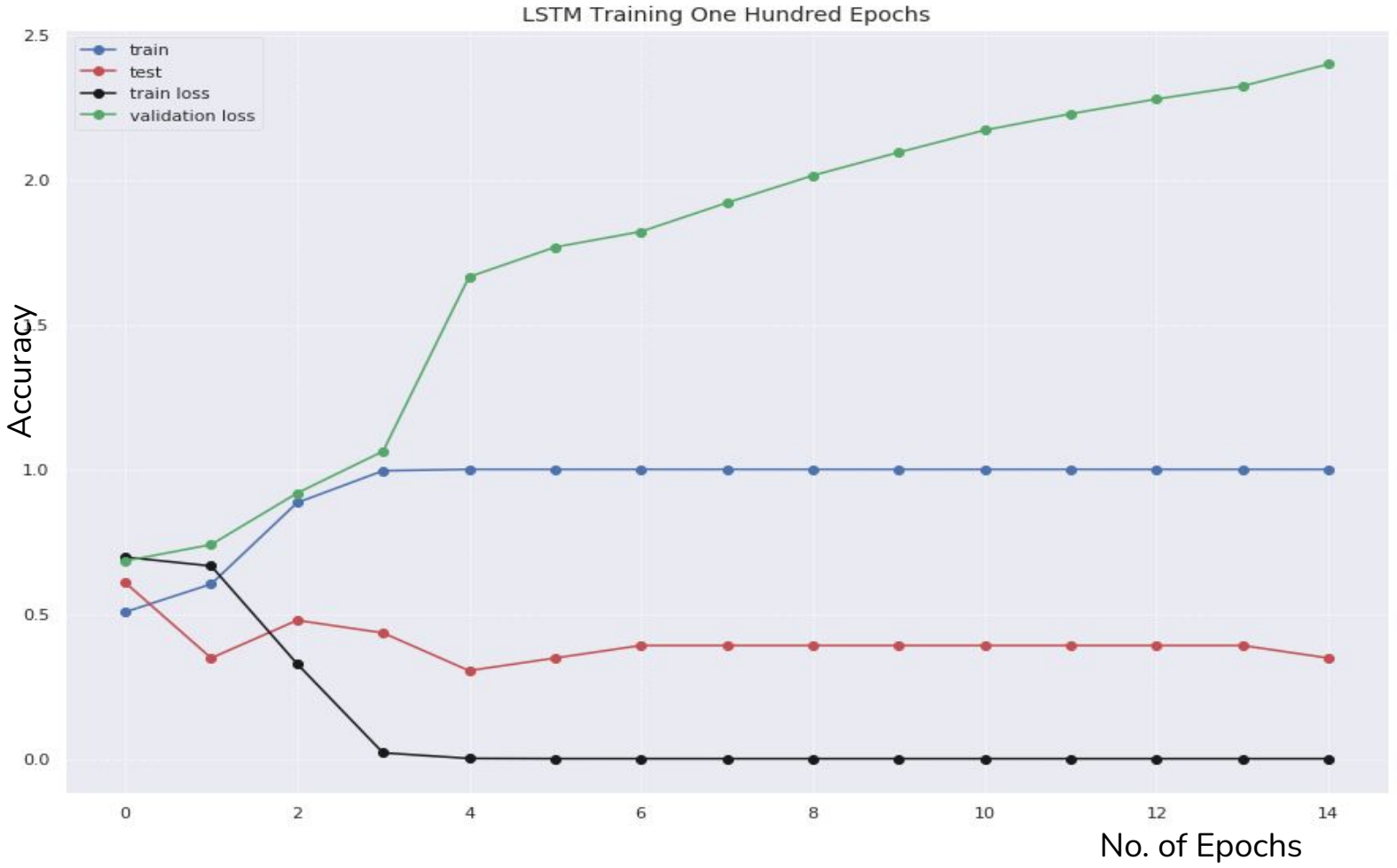
The FUTURE
Following Advanced LIGO going on-line in 2017, a third LIGO detector is due for completion in India in 2024. In the 2030s more sensitive ground-based detectors are foreseen, and LISA will be launched. LISA will extend our capabilities to 'listen' to new kinds of dark phenomena in the Universe.

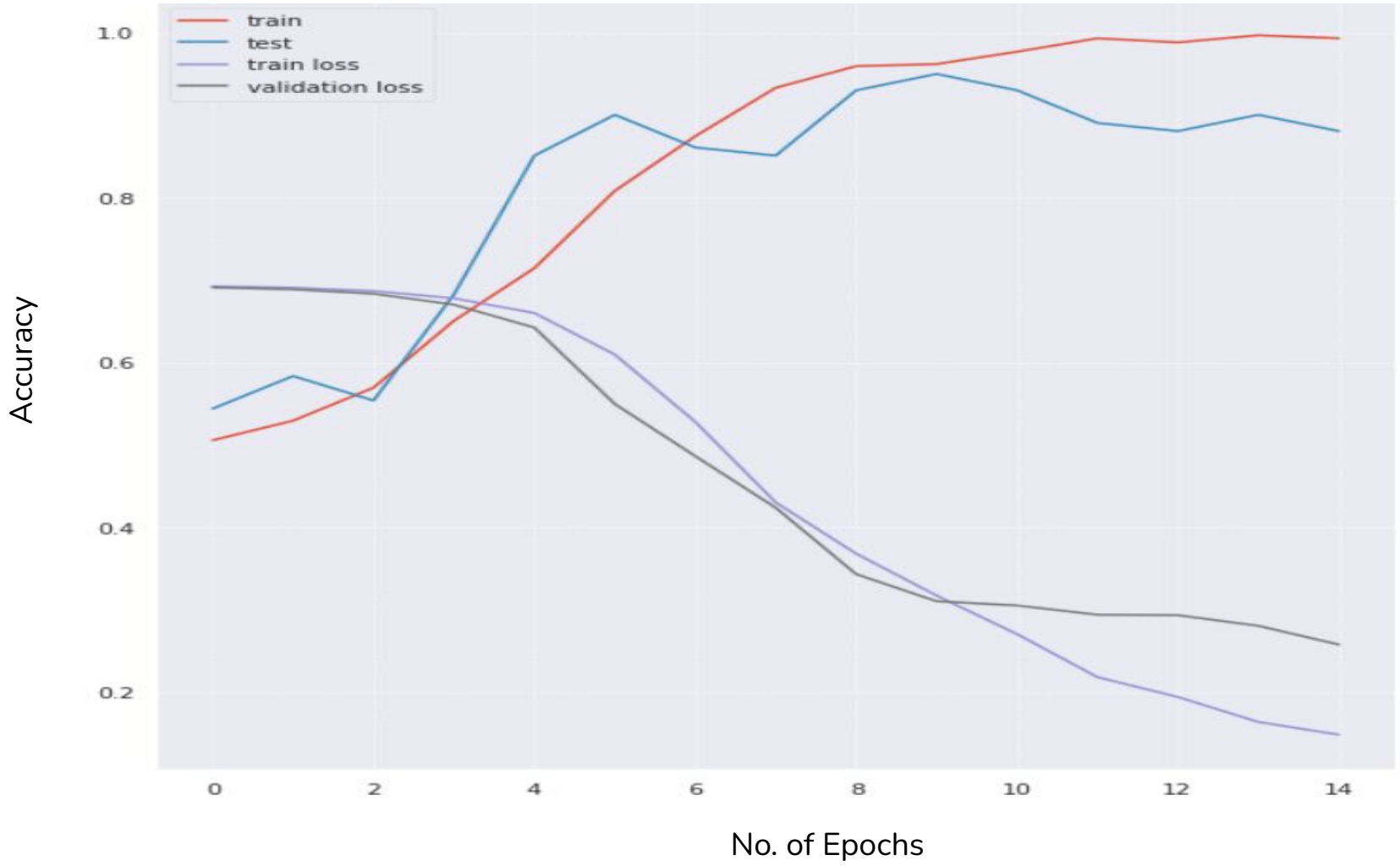
History-(Newton's and Eintein's GR Theories)
Introduction-(Defination)
Theory of GW
EFE-(equation,linearized)
Detection-(Principle,Instruments)
Importance-(unique info,complementary,fundermental laws)
Properties-(unimpended propagation,EM)
Comparison with Cosmic EM-(source,propagation)
Sources-(comsmological,Binary Sytems)





Input shape for LSTM network


LSTM Training One Hundred Epochs
train
test
train loss
validation loss
Accuracy
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
No. of Epochs


train
test
train loss
validation loss
1.0
0.8
0.6
0.4
0.2
Accuracy
0
2
4
6
8
10
12
14
No. of Epochs