Real-Time Detection of Atrial Fibrillation on the Edge

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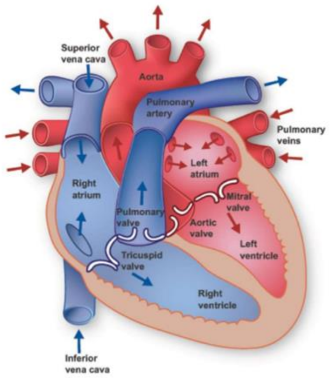
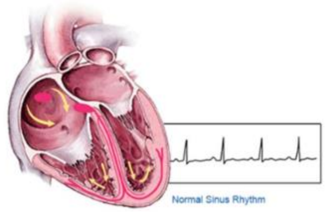
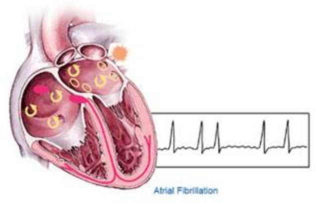
Introduction – The Problem

- Atrial fibrillation is the most common sustained cardiac rhythm disorder in adults [1].
- Atrial fibrillation is an abnormal heart rhythm consisting of fast and irregular beats in the upper chambers (atria) of the heart which occur due to abnormal electrical pulses [2].
- This can lead to blood pooling in the atria, thus increasing the risk of blood clots and strokes [2].
- This is often detected by a healthcare worker reading a patient's echocardiogram (ECG). This can be tedious and time-consuming.







Images sourced from references [2] and [3]

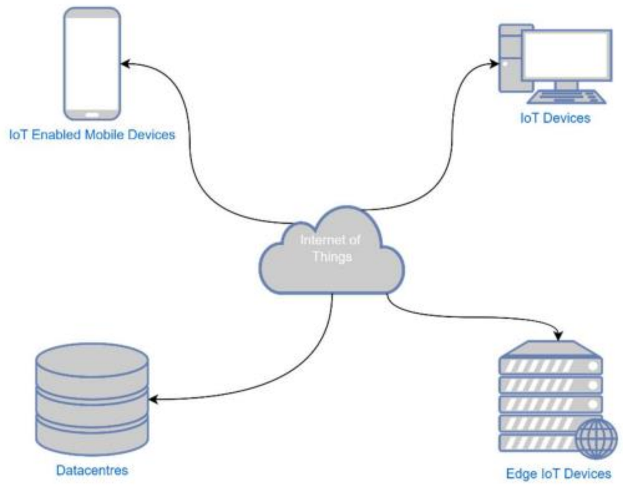
Introduction – A Potential Solution with Machine Learning

- Machine learning (ML) has proven successful in identifying atrial fibrillation in previous studies, below are some examples found during my literature review:

Paper's Author	ML Method Used	Outcomes
Faust et al [4]	Bidirectional LSTM	Blindfold Accuracy of 99.77%
Artis et al [5]	Artificial Neural Network	Accuracy of 92.34%
Yaghouby et al [6]	Genetic Algorithm	Accuracy of 99.11%
Zhou et al [7]	Threshold Evaluated with ROC	Accuracy of 96.05%

Introduction – A Potential Solution Incorporating The Internet of Things

- Next, we need to ask the question “How will all this data be moved around?”
  - Wi-Fi data transfer
  - Implementing IoT technology by using the MQTT protocol
- Wi-Fi
  - Will be useful in transmitting data from the patient's smart device to the ML server
  - Easy to simulate in a proof of concept
- MQTT
  - Great for transmitting data to a dashboard via an MQTT broker
  - Easy to implement in Python



Introduction – Objectives

Determine the most appropriate ML model from the following options:

- Long Short-Term Memory (LSTM)
- Bidirectional LSTM
- Gated Recurrence Unit (GRU)
- Bidirectional GRU

Build a working prototype ML program with the best of the four models.

Develop a program to use MQTT communications and the Adafruit IO dash display to show the following:

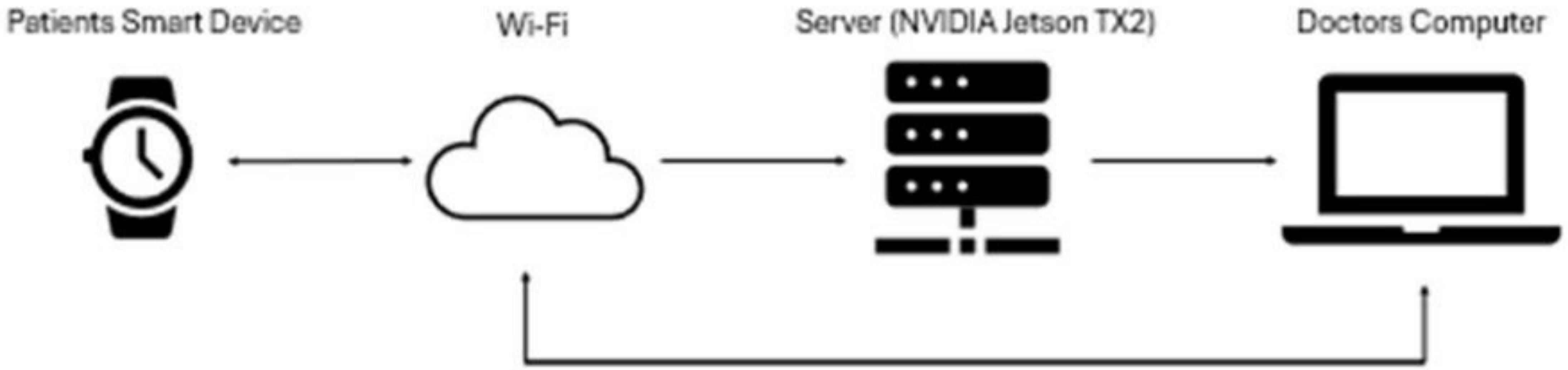
- ECG
- ML models result
- Accuracy of the ML models result

Integrate the working ML program and MQTT program to function together within one Python script.

Investigate and review methods of federated learning to mitigate security risks.

Approach and Methodology

- The mean accuracy, standard deviation and mean inference times will be measured across ten runs of each ML model.
- These results were obtained using blindfold evaluation.
- Inference times were obtained on the NVIDIA Jetson TX2 acting as a server for the implementation of IoT Edge technology.
- These characteristics can then be compared to make an informed decision on which ML model would be most suitable in this application.
- Work was then begun on developing the programs for determining the presence of atrial fibrillation and communicating data to the dashboard via MQTT.
- The practical work was then completed by integrating these programs together for a full working proof of concept.
- Finally, research was conducted into two potential federated learning methods to mitigate security risks:
  - Centralised federated learning
  - De-centralised federated learning

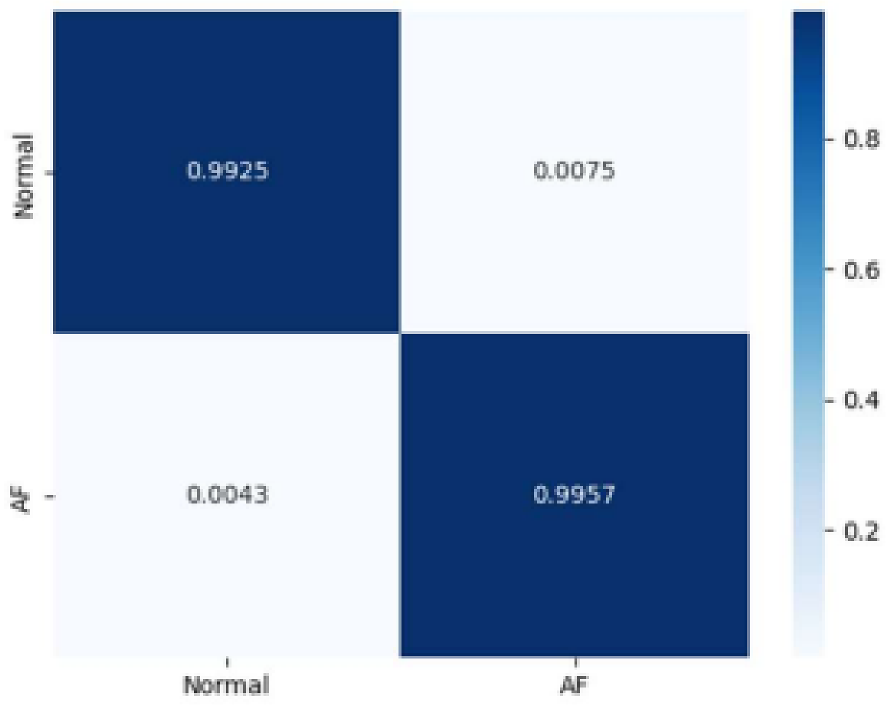


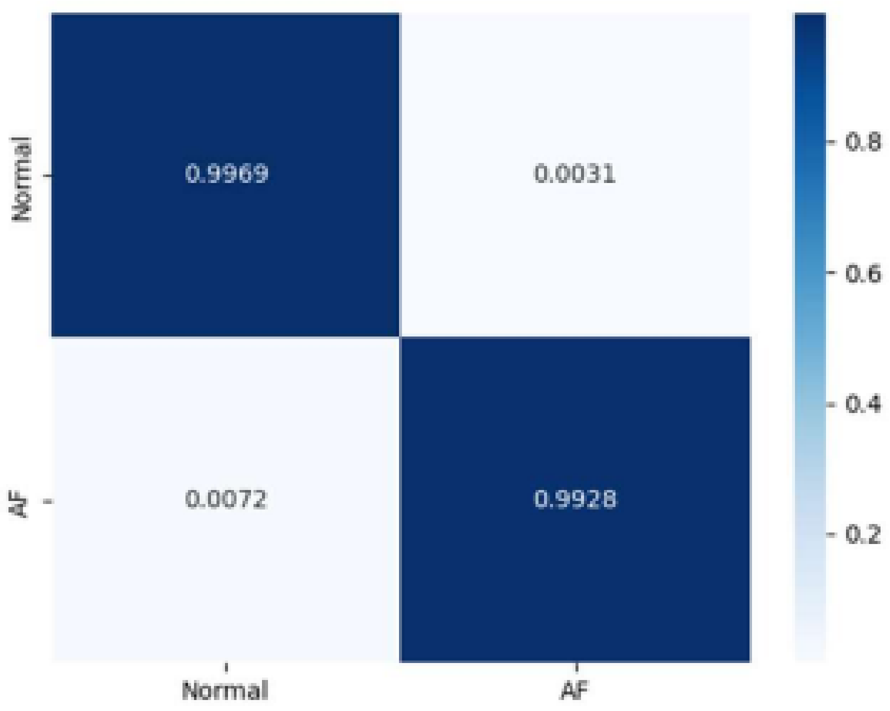
System Overview

Outcomes of Machine Learning Model Testing

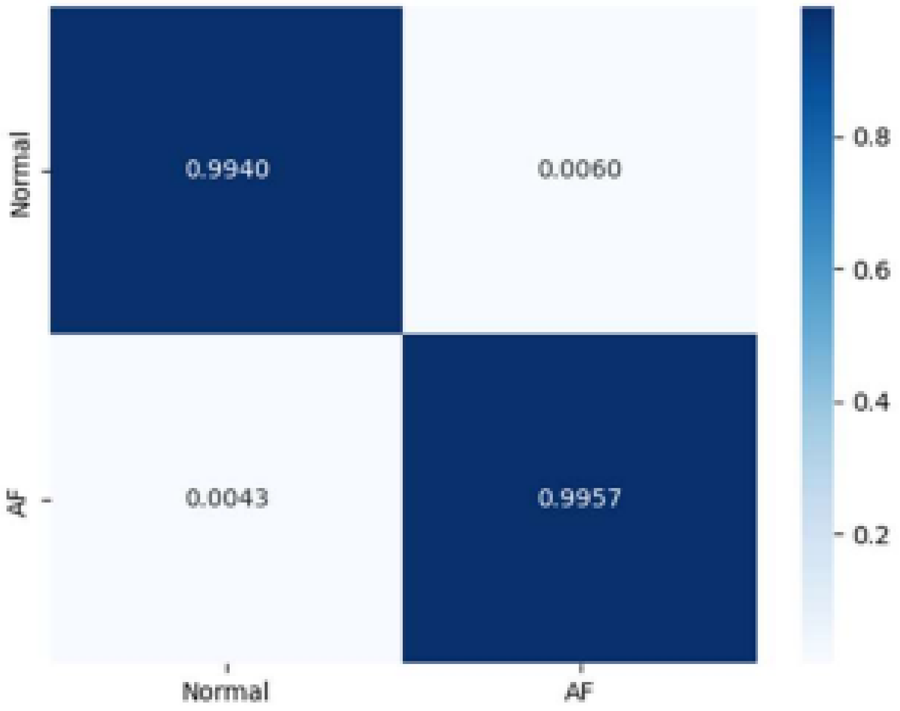
- My own testing had promising results for each of the ML models, below is a table summarising my findings, with the next slide showing the confusion matrices.

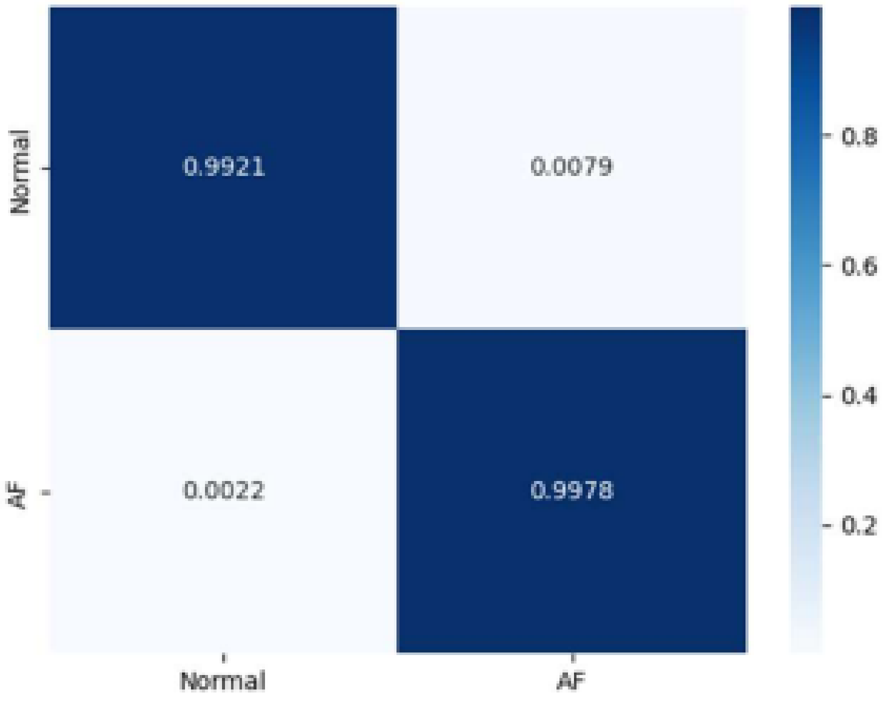
ML Model	Inference Time (Seconds)	Mean Blind-Fold Accuracy (%)	Standard Deviation
GRU	244.46	99.433	0.084
Bidirectional GRU	444.81	99.449	0.201
LSTM	339.00	99.503	0.142
Bidirectional LSTM	599.31	99.555	0.0802





Outcomes of Machine Learning Model Testing

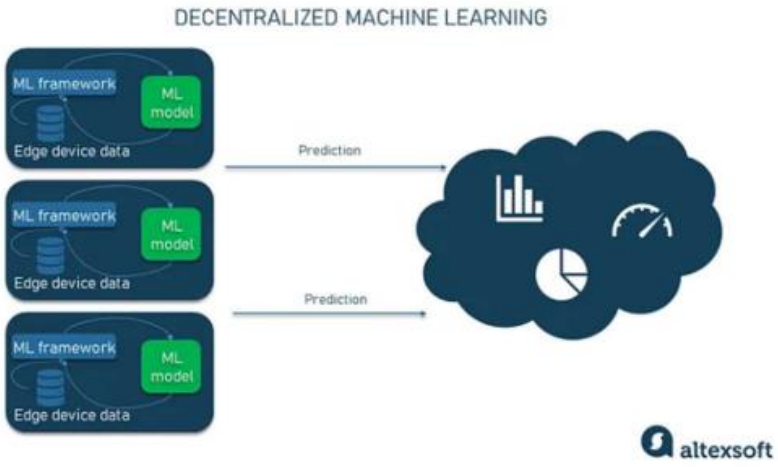




Outcomes of Machine Learning Model Testing

Outcomes of the Full Proof of Concept Testing

- Successfully identified incoming data and opened the file
  - Patient ID extracted from file name
- Data successfully extracted from file and interpreted by the ML model
- All data and ML models decision displayed well on MQTT dashboard



Methods to Mitigate Security Risks

- First potential method – Centralised federated learning [8]:
  - Data is not collected on a central server
  - ML models are trained locally on a user's device
  - Decisions are then sent to central server
  - Can potentially impact the speed of the system due to a high number of devices [9].
- Second potential method – Decentralised federated learning (gossip learning) [10]:
  - Like centralised federated learning in the sense that data is kept on the user's device
  - Based on an "opportunistic exchange of models among nodes"
  - Communicates data between devices on its way to the server
  - Could potentially improve on the speed issue encountered with centralised federated learning.

Images sourced from references [11] and [12]

Recommendations for Future Work

Implementation of decentralised federated learning

Improved data security

Implement a personalised MQTT broker

Commercial ones (like Adafruit IO) have data limits

Adafruit IO worked well for the proof of concept but would not be suitable in real world applications

Critical Evaluation

Starting this project, I was very inexperienced with ML in Python

- This impacted the projects planned timeline
- Should have spent more time practicing in the run up to starting this project

The project would have gone a lot smoother had I taken the time to make my own MQTT broker

- The ECG in that nice screenshot took nearly an hour…
- I was also nearly banned from Adafruit a couple of times for trying to send too much data

Conclusions

- Overall, all worked well as a proof of concept
- All deliverables were achieved
- Shows promising results and potential for real-world applications
- A more powerful ML server may be needed to reduce inference times

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Acknowledgements

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Any Questions?

Thank you for listening!