# WTMH

## An **CWT-CNN** based **AI Server** for **Arrhythmia Screening** of Real-Time **Single-Lead ECG**

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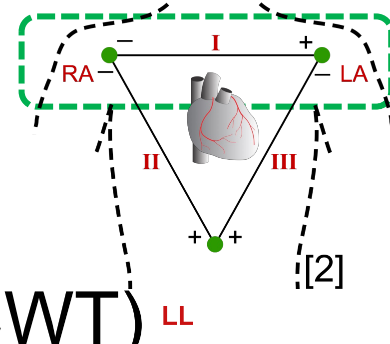
# Outline

- Introduction
- Architecture Diagram
  - Original Timely System
  - Revised Architecture
- Architecture & Result Comparison
- Issues Faced
- Energy Efficiency
- Conclusion
- Future work

# Introduction

- Objective:
  - Develop an AI server for real-time **single-lead ECG (單導程心電圖)** analysis for screening arrhythmia (心律不整).

[1]




[2]

- Problem trying to solve
  - When performing Continuous Wavelet Transform (CWT) in real-time and large-data detection insufficient processing speed leads to data accumulation.

Input ECG signal → (Continuously) → Signal processing + CWT → CNN → Result

The CWT is taking up too much time.

**Using 3 Hour ECG data to testify: (10501 heart beats)** **13.52 sec (segmentation) + 80.52 sec (CWT) + 8.63 sec (CNN)**



[1] https://www.englewoodhealth.org/service/heart-care/heart-conditions-we-treat/arrhythmia [2] https://cvphysiology.com/arrhythmias/a013a

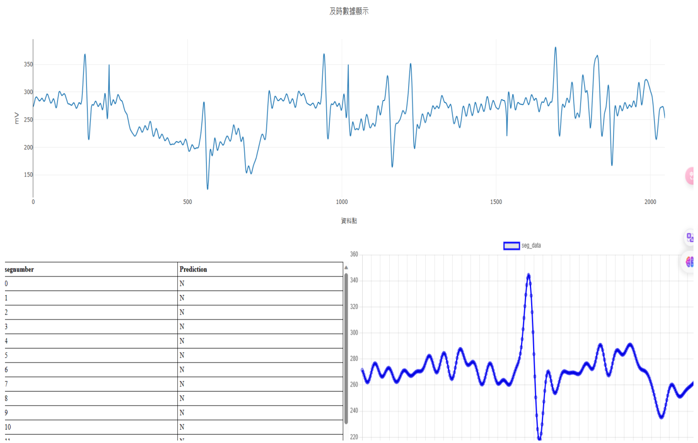
# Original Timely System Architecture Diagram

## Client

ECG signal → Signal Preprocessing

- ECG Signal
- AHA DB

- Windowing
- Normalization
- Low Pass Filter (fc = 20Hz)

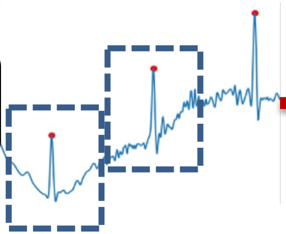


- Web UI

## Server

Feature generation: continuous wavelet transform (CWT)

Finding peaks & segmentation

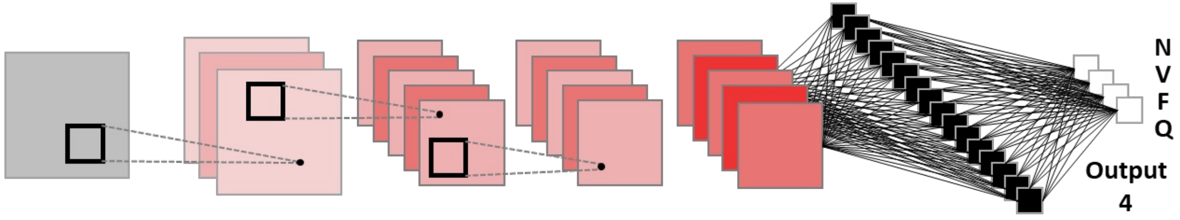


Feature generation

- Find R peaks
- Segment to 0.711 sec

- Continuous wavelet transform (CWT)

Classification: SEmbedNet CNN model



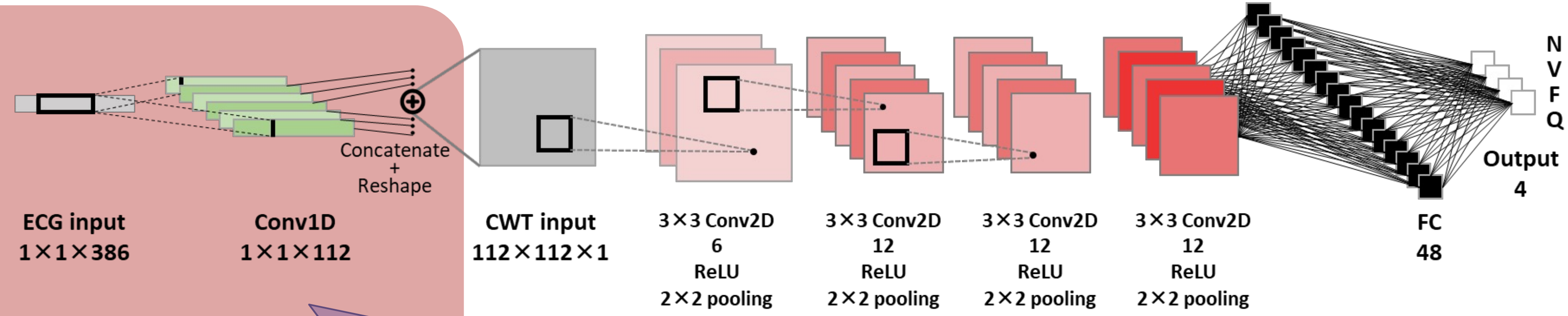

- Normal beat
- Ventricular beat
- Fusion beat
- Unknown beat

| Model | AlexNet | ResNet-50 | **Proposed CNN** |
|---|---|---|---|
| #Parameters | 62.4 M | 23.9 M | **0.04 M** |

# Revised Architecture Diagram

**Feature Generation & Classification : combined as a CNN model**

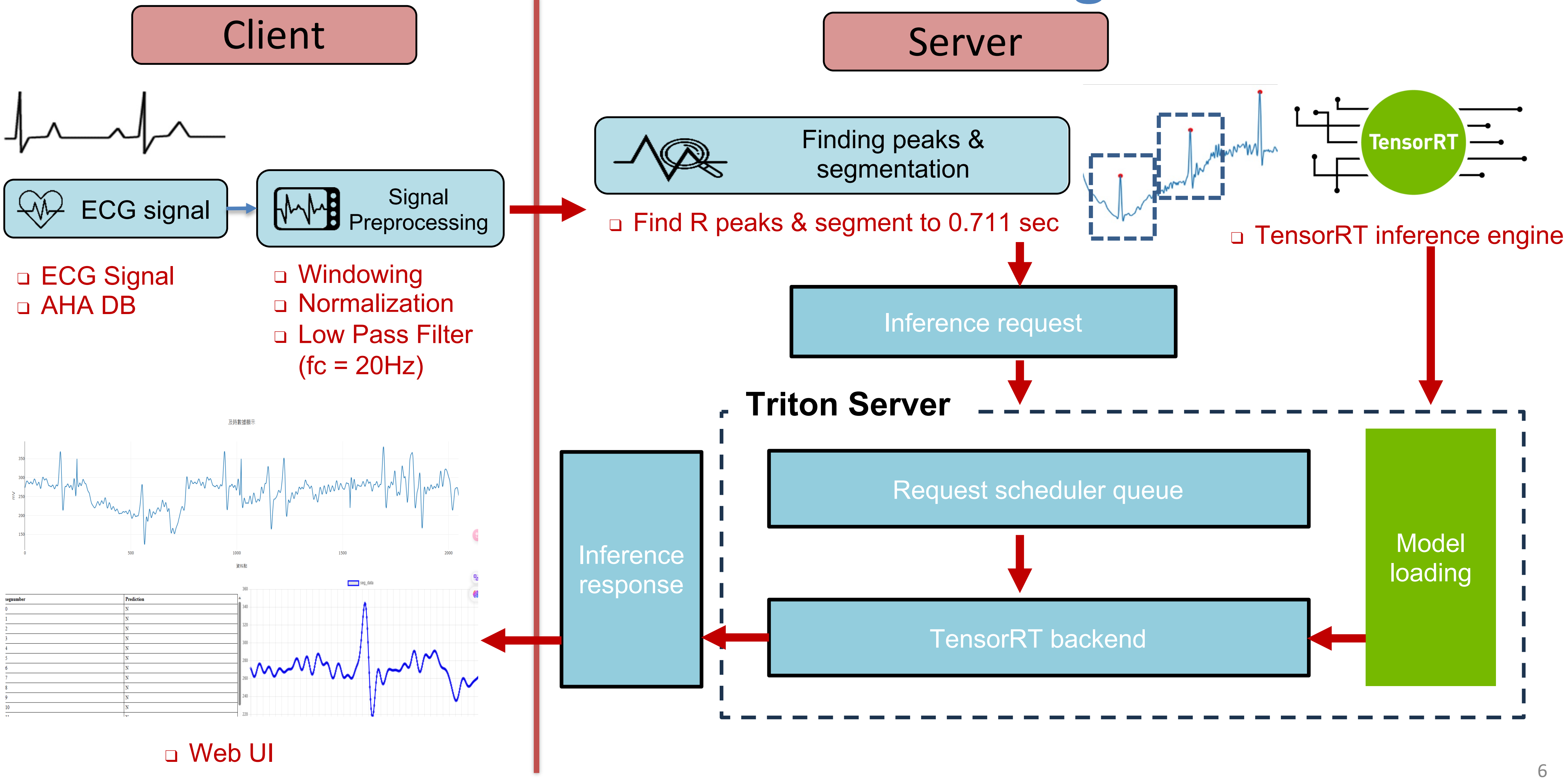
Pytorch Wavelet
acceleration



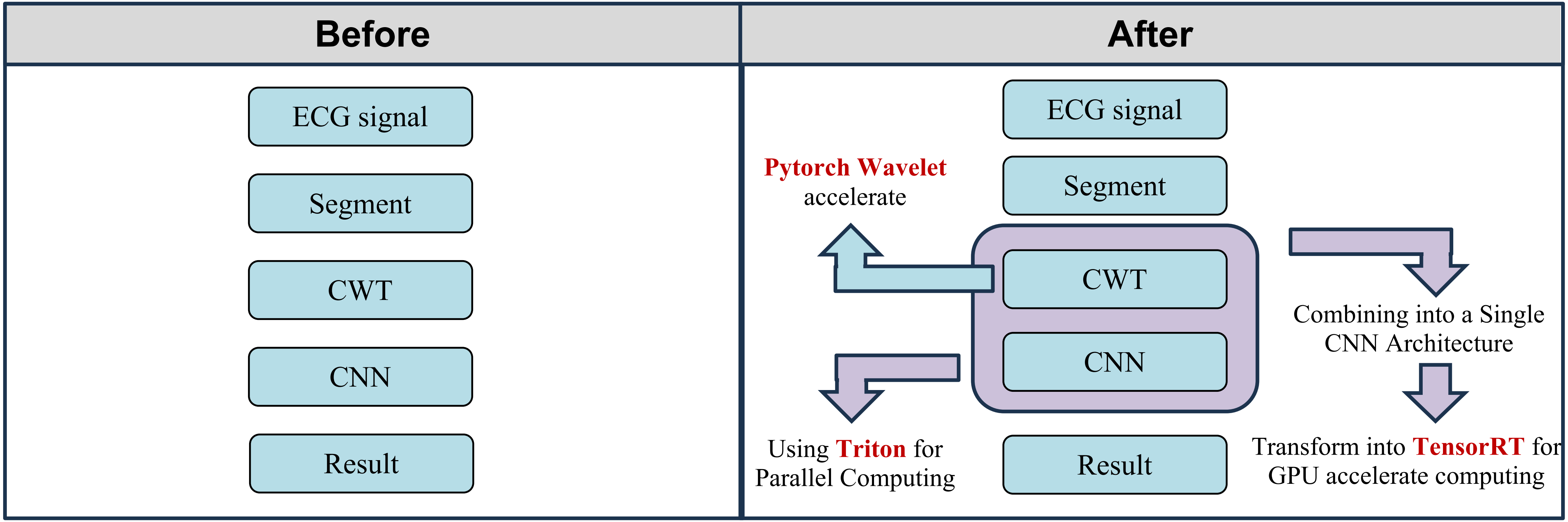

- Continuous wavelet transform (CWT)

Transform Pytorch deep learning model into
TensorRT inference engine

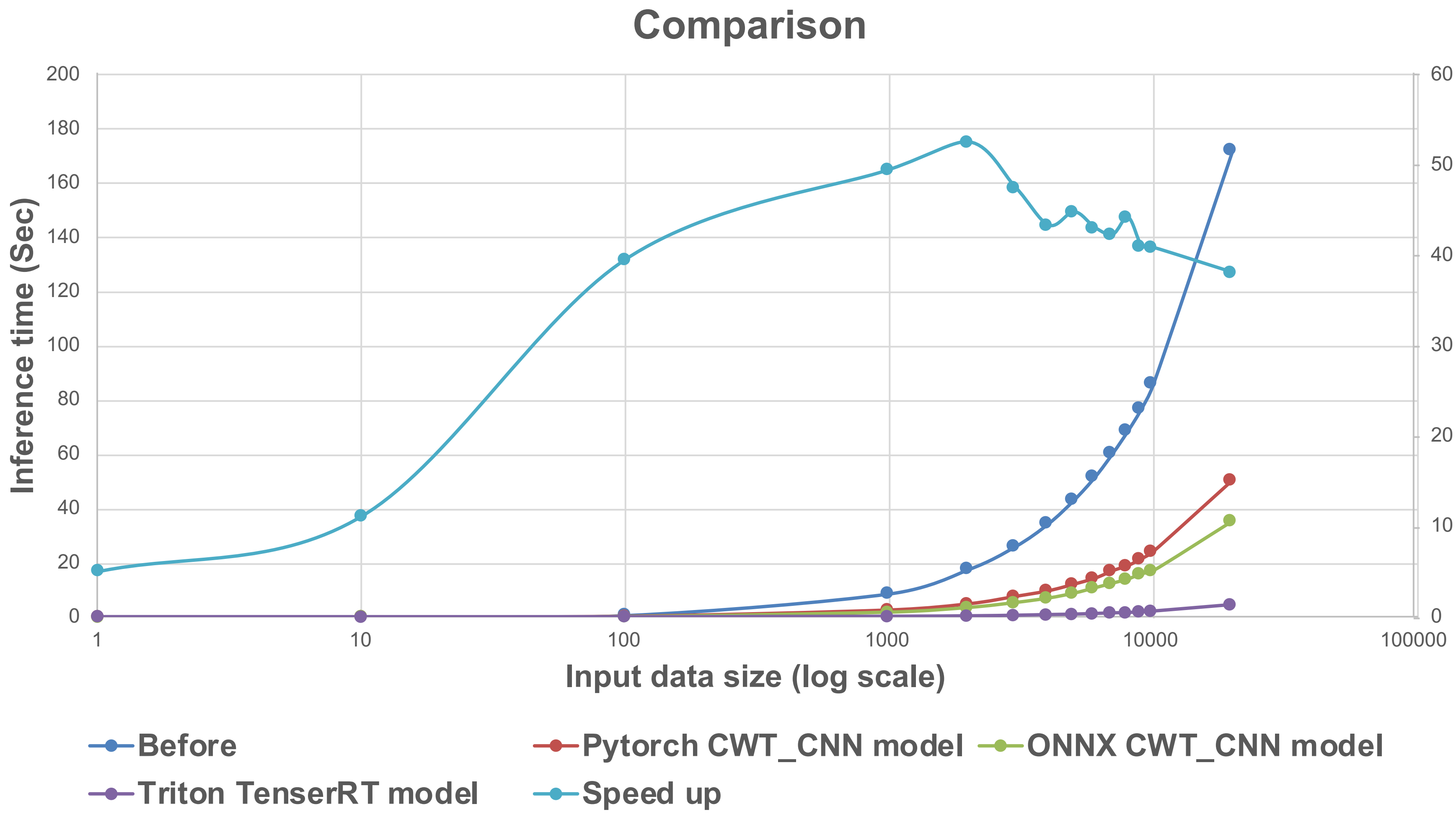
# Revised Architecture Diagram



# Architecture Comparison Table



# Result Comparison Graph



# Issues Faced

- The PyTorch-Wavelet package found online do not meet our requirement
  - Selecting a frequency range from 4 to 40
  - Solution: modifying the source code to include frequency range selection
- Unable to compress PyTorch-Wavelet and CNN concatenation into TensorRT
  - Reason: because the parameter of the filter in CWT is not fixed (is constructed when the model is initialized)
  - Solution: extracting the filter parameters into the CWT+CNN model
- We are using float64 as TensorRT input, but the model is built with float32 input, so it cannot get all the input data.

# Energy Efficiency

| INPUTS | |
|---|---|
| # CPU Cores | 8 |
| # GPUs (A100) | 1 |
| Application Speedup | **2.8x** |
| Node Replacement | 1.4x |

**GPU NODE POWER SACINGS**

| | AMD Dual Rome 7742 | 8x A100 80GB SXM4 | Power Saving |
|---|---|---|---|
| Compute Power (W) | 1540 | 6500 | -4960 |
| Networking Power (W) | 65 | 93 | -25 |
| **Total Power (W)** | **1605** | **6593** | **-4988** |

| | |
|---|---|
| Node Replacement | 0.2x |

**ANNUAL ENERGY SAVINGS PER GPU NODE**

| | AMD Dual Rome 7742 | 8x A100 80GB SXM4 | Power Saving |
|---|---|---|---|
| Compute Power (W) | 13490 | 56940 | 43450 |
| Networking Power (W) | 570 | 814 | 244 |
| **Total Power (W)** | **14060** | **57754** | **43694** |

| | |
|---|---|
| $/kWh | 0.34 |
| Annual Cost Savings | 14855.85 |
| 3-year Cost Savings | 44567.54 |

| | |
|---|---|
| **Metric Tons of $CO_2$** | 31 |
| **Gasoline Cars Driven for 1 year** | 7 |
| **Seedlings Trees grown for 10 years** | 512 |

**POWER ASSUMPTIONS**

| **Node Configurations** | **Baseline Node** AMD Dual Rome7742 | **Alternative** 8x A100 80GB SXM4 |
|---|---|---|
| CPU SKU | 7742 | 7742 |
| # CPU | 2 | 2 |
| # CPU Core | 128 | 128 |
| **CPU Power (W)** | **450** | **450** |
| GPU SKU | 0 | A100 80BG SXM4 |
| # GPU | 0 | 8 |
| **GPU Power (W)** | **0** | **3200** |
| Network Type | IB EDR | IB EDR |
| #Network Ports | 1 | 2 |
| **Network Card Power (W)** | **30** | **60** |
| **RBoM Power** | **300** | **450** |
| **Total Compute Node Power (W)** | **1100** | **6500** |
| **Core Network Power / Node** | **46** | **93** |
| **Total Power / Node** | **1146** | **6593** |

# Energy Efficiency

| | GPU NODE POWER SAVINGS | | | ANNUAL ENERGY SAVINGS PER GPU NODE | | |
|---|---|---|---|---|---|---|
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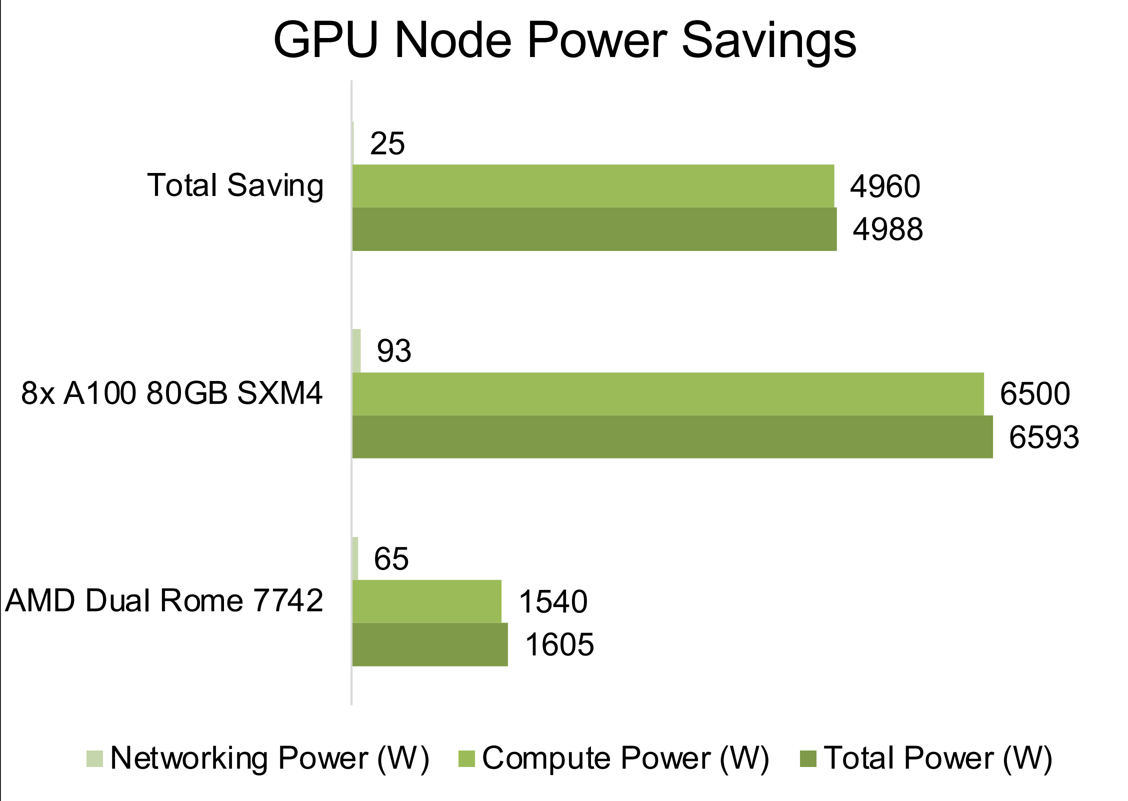
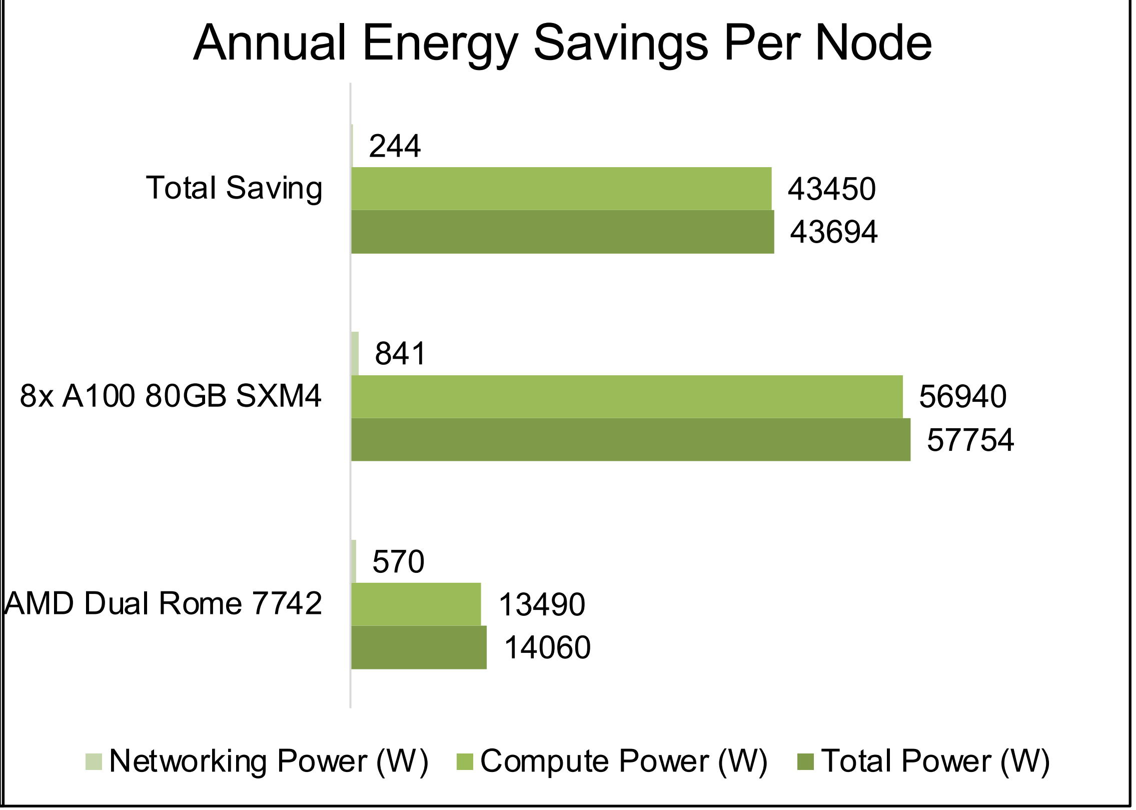
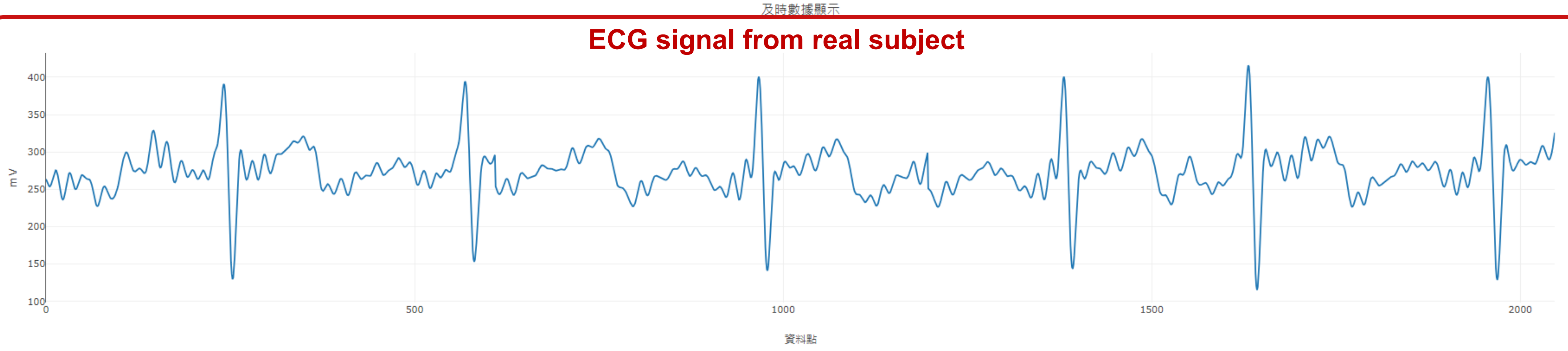


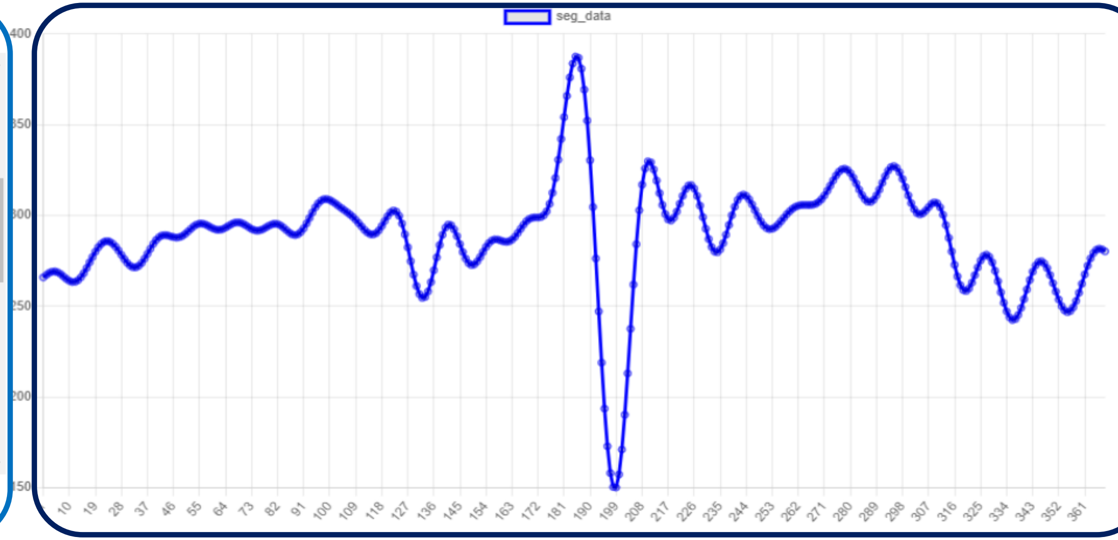
# Demo Video

**ECG signal from real subject**



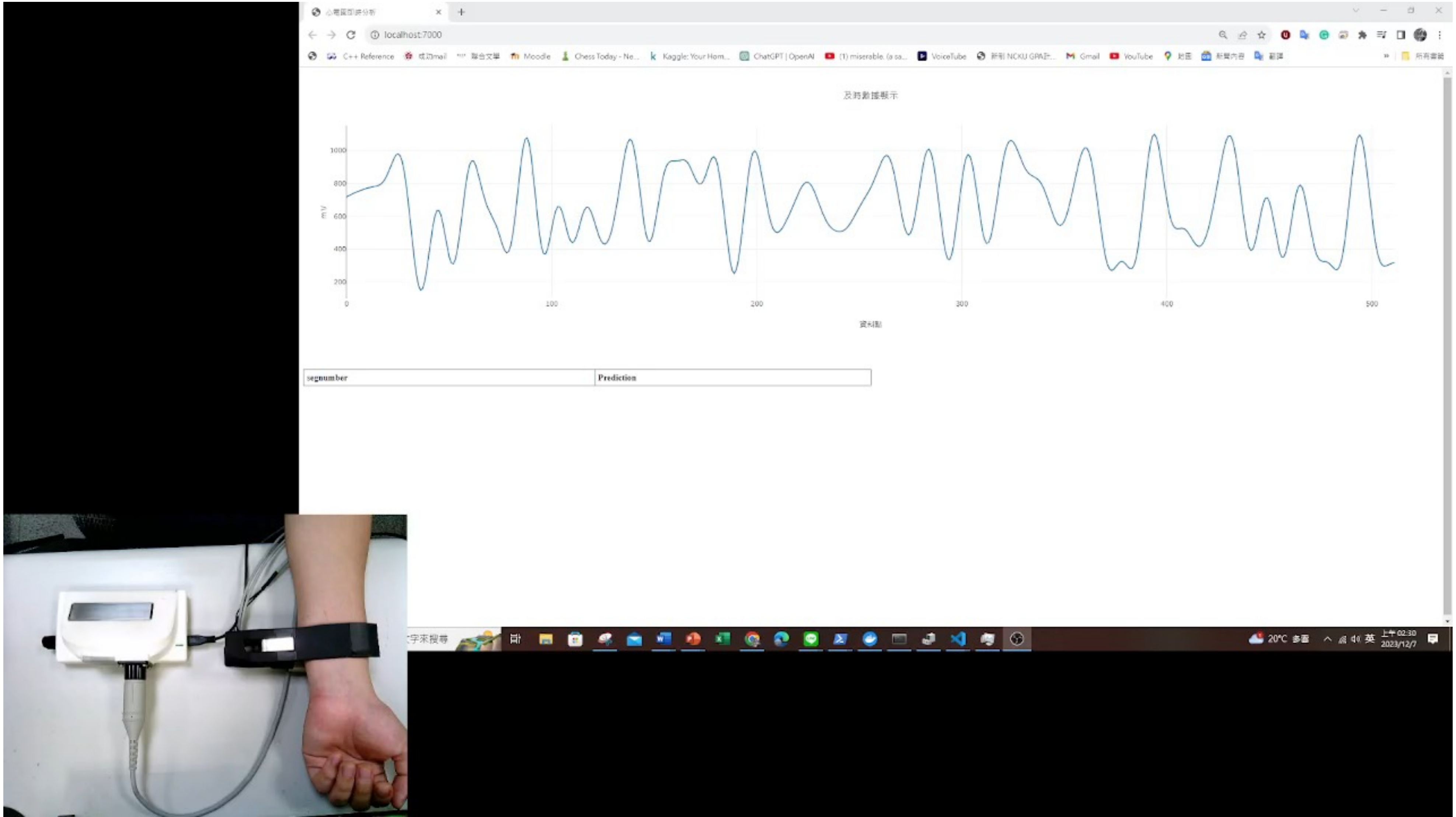

| | |
|---|---|
| 13 | N |
| 14 | Q |
| 15 | Q |
| 16 | Q |
| 17 | Q |
| 18 | Q |
| 19 | N |
| 20 | N |
| 21 | N |
| 22 | N |
| 23 | N |
| 24 | N |
| 25 | N |

**Table of detection results**




**ECG waveform of selected segment**

# Demo Video



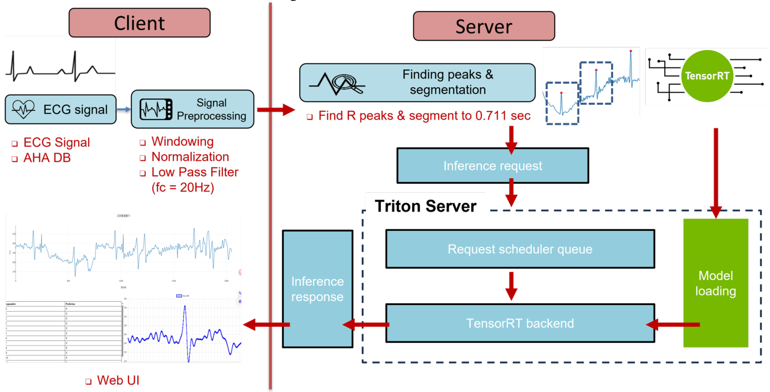
# Conclusion

- Conduct CWT transform in Pytorch model format
- Concat CWT and CNN Pytorch model
- Transform the concated model into tensorRT inference engine
- Inference the result through Triton server
- Speed up 40X for Large-ECG-data (3hours up) inference
- Speed up 5x for timely ECG inference

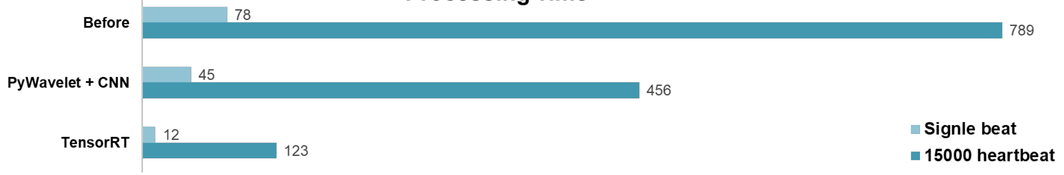
## Application Background

- The use of ECG for disease detection is becoming increasingly common.
- If servers are used to provide this service, the following benefits can be realized:
  1. Data storage(SQL)
  2. Retrain model(latest models)
  3. Case Reports
  4. Automatic annotation

**System architecture**




**Processing Time**




## Hackathon Objectives and Approach

### Objectives

- Accelerate CWT
- More stable system

### Approach

- Pytorch-Wavelet
- TensorRT
- Triton inference server

## Technical Accomplishments and Impact

- Instant ECG analysis and database creation
- Monitor patient status remotely
  (Ex: home care & Ambulance ECG connects hospital)
- Patient database
- Convenient long-time ECG data (holter ECG, overnight ECG) annotation

# Future Work

- Add more comprehensive CSS and JavaScript
  - Appearance and login interface, etc.
- Enhance cybersecurity-related management
- Enhance the manageability of the server
  - Automate Routine Tasks:
    - Use automation tools to handle repetitive tasks like updates, backups, and monitoring. Scripts and automation platforms can save time and reduce errors.
  - Establish Security Protocols:
    - Implement strict security measures, including firewalls, intrusion detection systems, and regular security audits.
- Extend to 12-leads ECG data