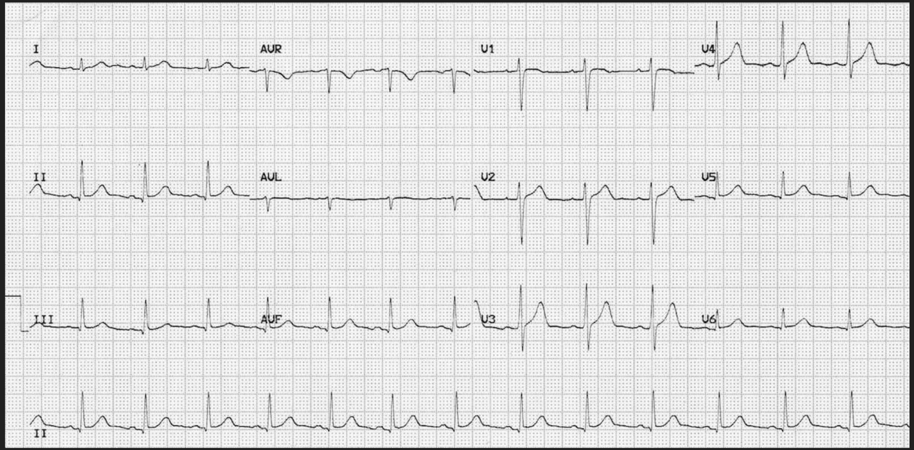
ECG Simulator Based on a Neural Network Trained With Real Patient Data

By
Raul Verduzco | Salvatore Gutierrez | Abisai Diaz

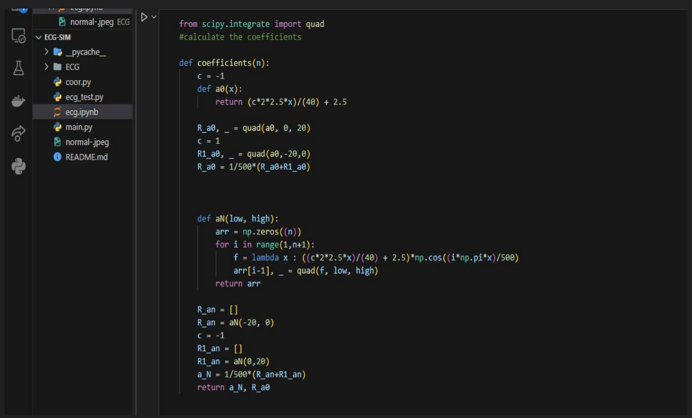
Data

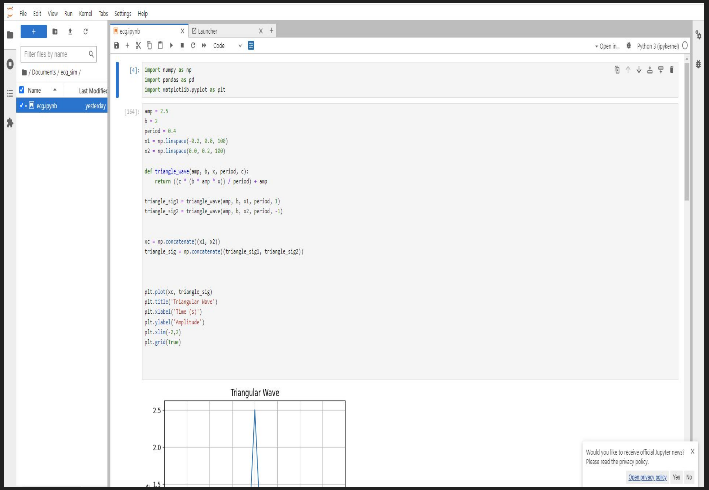
- Created Dataset
  - Ex: normal sinus rhythm, bradycardia, tachycardia, Vfib …
  - Images with all six leads
  - P waves, QRS wave, and T waves



Tools

- Python with Jupyter Notebook or Visual Studio Code
- Github
- Numpy library for math calculations
  - np.cos (cosine wave), np.quad (integrate), etc.





Other Tools

- Math
  - Basic Understanding of calculus concepts like integrating
  - Other

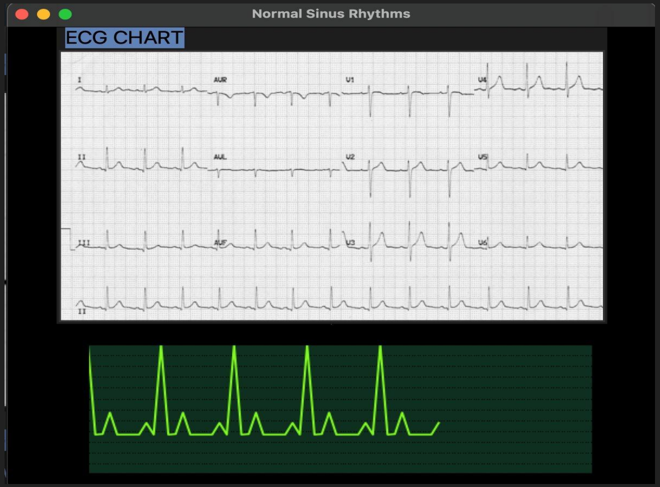
$$f(x) = \left\{ \begin{array}{ll} \left(\frac{-bax}{l} + a\right) & \text{if } (0 < x < \frac{l}{b}) \\ \left(\frac{bax}{l} + a\right) & \text{if } (-\frac{l}{b} < x < 0) \end{array} \right\}$$

$$\begin{aligned} A_0 &= \frac{1}{P}\int_P s(x)\,dx \\ A_n &= \frac{2}{P}\int_P s(x)\cos\left(2\pi\tfrac{n}{P}x\right)dx \qquad \text{for } n \ge 1 \\ B_n &= \frac{2}{P}\int_P s(x)\sin\left(2\pi\tfrac{n}{P}x\right)dx, \qquad \text{for } n \ge 1 \end{aligned}$$

$$s_N(x) = A_0 + \sum_{n=1}^{N}\left(A_n\cos\left(2\pi\tfrac{n}{P}x\right) + B_n\sin\left(2\pi\tfrac{n}{P}x\right)\right)$$

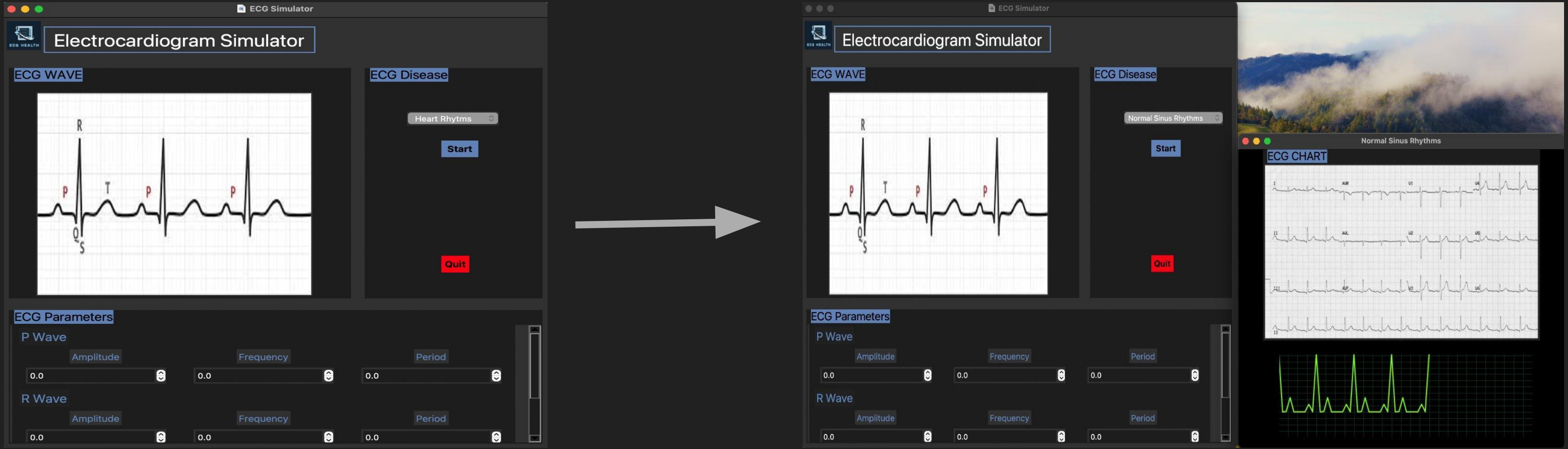
ECG rhythms

- Last week- Normal ECG
- Added: sinus arrhythmia, sinus bradycardia, sinus tachycardia, Vfib, Afib, and Unstable Angina



GUI

- Updated the GUI
  - Allow user to select ecg rhythms
  - Displays ECG chart and the simulation of the live ecg wave
  - Working on allowing the user to alter the wave based on parameter (amplitude, frequency, and period)



POSTER

ECG Simulator Based on a Neural Network Trained With Real Patient Data

CALIFORNIA STATE UNIVERSITY BAKERSFIELD
School of Natural Sciences, Mathematics and Engineering

KernMedical

Chengwei Lei[1], Salvatore Gutierrez[2], Raul Verduzco Guillen[3], Abisai Diaz[4]

[1]Kern Medical Simulation Center
[2]Department of Computer and Electrical Engineering and Computer Science, CSU-Bakersfield

Research Background

Heart disease is a prominent issue in Kern County. Kern County has the fourth-highest number of deaths caused by heart disease. Nurses in Kern Medical Center train to learn and recognize patterns that may indicate common heart diseases. However, they still use pre-printed ECG results in their training. This may have the negative result of having them memorize the individual result instead of learning to recognize the pattern.

This research is sectored into two parts with the goal of providing the nurses with a better method of learning different ECG patterns. The first is to create an ECG simulator that generates the patterns nurses need to learn. The second is to use machine learning and previous patient data to add variance similar to the variance in real patients. This will allow the nurses to train using more realistic data.

Methodology

ECG waves are periodic signals composed of a P wave, QRS complex, and T wave. Fourier analysis is a mathematical tool used to decompose these complex signals into simpler sinusoidal components. Fourier analysis allows us to generate accurate representations of the original waveforms through sinusoidal summation.

Fourier Series

$$s_N(x) = A_0 + \sum_{n=1}^{N} \left(A_n \cos\left(2\pi \frac{n}{P} x\right) + B_n \sin\left(2\pi \frac{n}{P} x\right) \right)$$

Q,R,S Wave

$$f(x) = \begin{cases} \left(\frac{-bax}{l} + a\right) & \text{if } (0 < x < \frac{l}{b}) \\ \left(\frac{bax}{l} + a\right) & \text{if } (-\frac{l}{b} < x < 0) \end{cases}$$

P,U WAVE

f(t) = a(t-c)^4 +A

ECG Waves

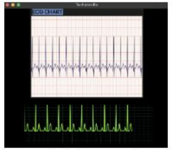
Typical Normal Lead II ECG compared to our simulated ECG

The QRS waves are 4ms spaced out making the heart rate normal

ECG for Sinus Bradycardia against the simulated Bradycardia

Bradycardia is a common rhythm that shows the R waves wider apart

Sinus Tachycardia



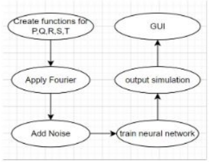
Tachycardia is known to have a faster heartbeat which is shown in both the chart and simulation

Preliminary Results

GUI:

In-progress Machine Learning

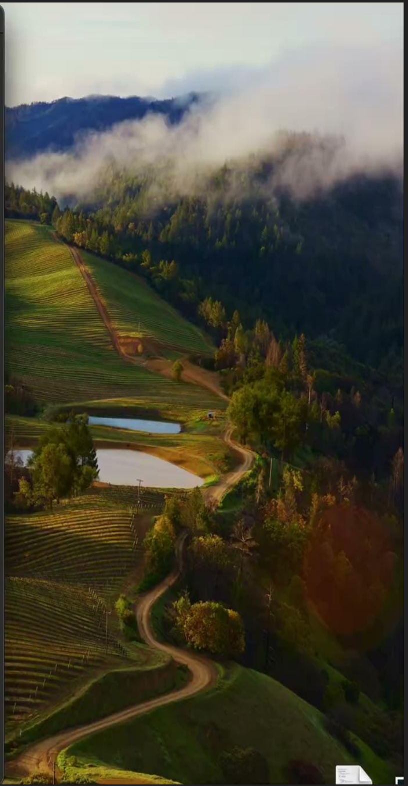
Our next step involves adding noise to the ECG signals to enhance realism. Three main types of noise are typically encountered: random noise, baseline wander, and powerline interference. By incorporating these types of noise into our simulator, we aim to create more authentic ECG waveforms.



Conclusion and Future work

Heart disease can be a matter of life and death, so it is be adequately prepared before they begin working with real patients. Providing Kern Medical nurses with more realistic data can help them get accustomed to the fuzzier details before they work with real patients. The updated ECG simulator would help doctors and nurses by providing them with more realistic ECG for their training exercises.

Simulation of ECG




ECG Simulator
Electrocardiogram Simulator
ECG WAVE
R
P
T
P
P
Q
S
ECG Disease
Heart Rhytms
Start
Quit
ECG Parameters
P Wave
Amplitude
Frequency
Period
0.0
0.0
0.0
R Wave
Amplitude
Frequency
Period
0.0
0.0
0.0