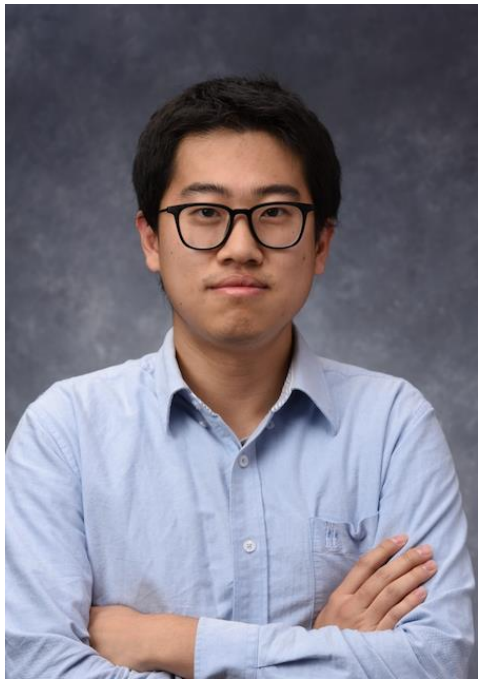
IEEE/ACM ICCAD 2022 INTERNATIONAL CONFERENCE ON COMPUTER-AIDED DESIGN 41st Edition

2022 ICCAD TinyML Design Contest

Zhenge Jia, Dawei Li, Lichuan Ping, Yiyu Shi

Contest Organizers



Zhenge Jia

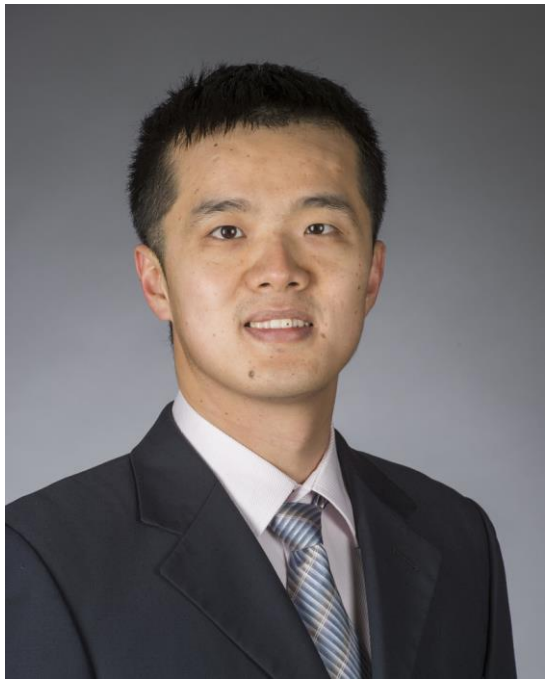
UNIVERSITY OF NOTRE DAME

Dawei Li

中南民族大學 SOUTH-CENTRAL UNIVERSITY FOR NATIONALITIES

Lichuan Ping

无双医疗 SINGULAR MEDICAL



Yiyu Shi

UNIVERSITY OF NOTRE DAME

Contest Problem

- **Heart Disease**: Heart disease is the leading cause of death in US, according to CDC 2020 Mortality Report.

- **Life-threatening Ventricular Arrhythmias**: Ventricular Tachycardia (VT) and Ventricular Fibrillation (VF) are the two most frequent recorded shockable rhythms causing **Sudden Cardiac Death (SCD)** [1].

- **Treatment**
  - **Primary Prevention**: Medical or interventional therapy undertaken to prevent SCD in patients who have not experienced symptomatic life-threatening sustained VT/VF.
  - **Secondary Prevention**: The Implantable Cardioverter-Defibrillator (ICD) is a small battery-powered device to deliver defibrillation for patients who are with a history of life-threatening ventricular arrhythmias.

[1] Cleveland Clinic, Ventricular Fibrillation and Ventricular Tachycardia, [Online], 2022.

Contest Problem

Motivation and Uniqueness

- **Innovation Needed**: Existing industry practice is simple rule based, and has not changed over the past a few decades. AI/ML can potentially revolutionized ICD design by extracting features not easily identifiable by or even unknown to human experts.

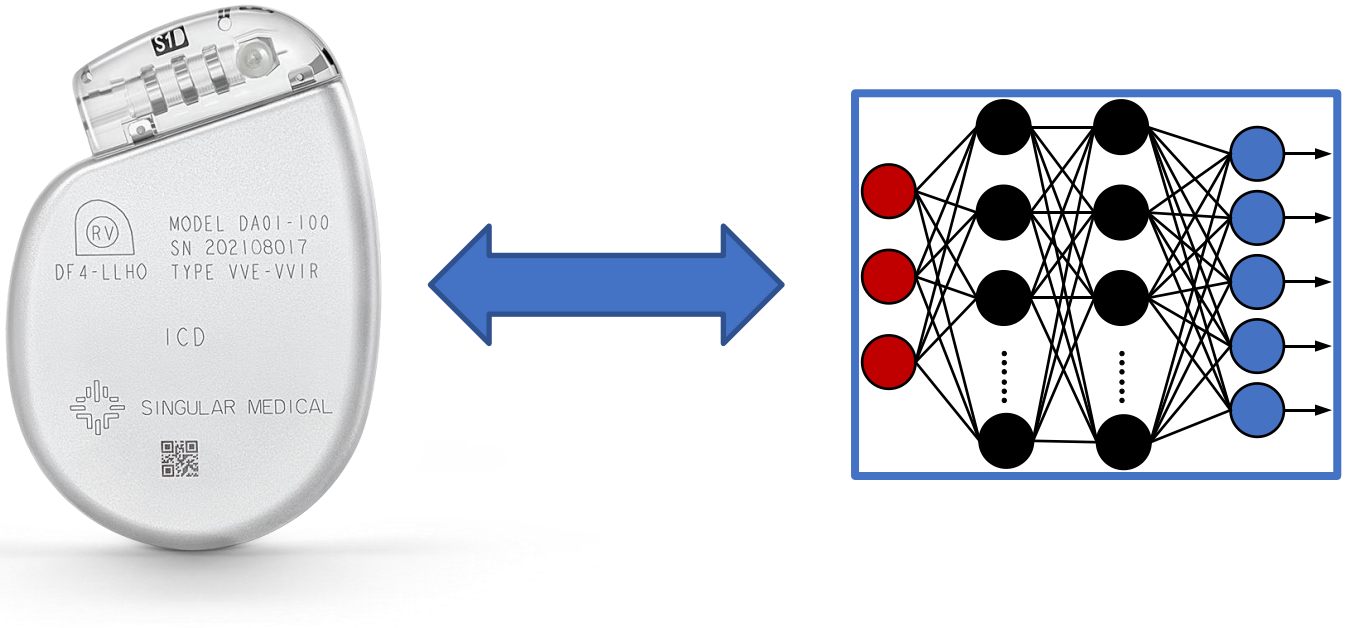
- **Resource Constraints**: A critical challenge here is the extremely low power budget, memory footprint, low latency and high accuracy on extremely resource-constraint embedded platforms (flash memory <128K, power <1 uW, latency < 5ms, accuracy > 90%).

- **AI/ML Contest**: While many machine learning competitions exist, they mostly focus on computer vision only and does not utilize hardware platforms to such an extreme limit (tinyML).

Contest Objective

Life-threatening ventricular arrhythmias detection on the resource-constraint ICD with

- **high accuracy**
- **low latency**
- **low memory occupation**.



Dataset

- **Training and Testing Dataset**: A large dataset for intracardiac electrograms (IEGMs) from implantable devices is provided by Singular Medical.
  - 80% of subjects' data for training (30,213 2s IEGM segments in total)
  - 20% of subjects' data for testing (8,373 2s IEGM segments in total)

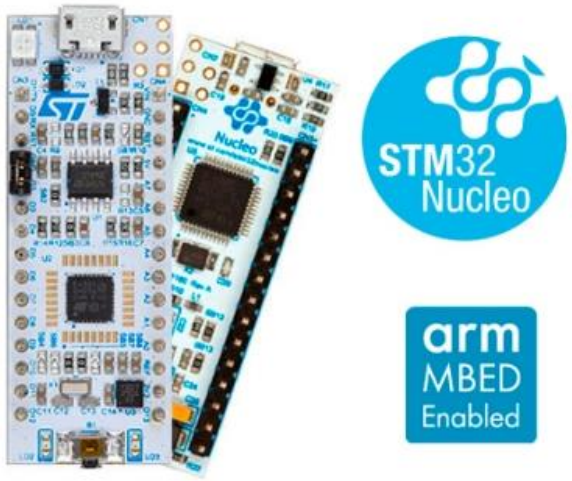
- **Categories**: Several different arrhythmias including
  - ventricular tachycardia
  - ventricular fibrillation
  - atrial fibrillation
  - supraventricular tachycardia
  - etc.

- **Goal**: Teams are required to discriminate life-threatening ventricular arrhythmias (VT & VF) over each 2s IEGM segment.

Hardware Platform

Microcontroller Platform (STM32L432 Nucleo-32)

- Support X-Cube-AI framework
- ARM Cortex-M4 core at 80 MHz
- 256 Kbytes of flash memory
- 64 Kbytes of SRAM
- Embedded ST-LINK/V2-1 debugger/programmer
- Low cost ($10)



- Teams are free to implement their design using any other framework/tool on Nucleo-32

Evaluation Metrics

Evaluation Score

$$\text{Score} = 100 \cdot F_\beta + 20 \cdot L_n + 20 \cdot M_n$$

Accuracy (0.0-1.0)

$$F_\beta = (1+\beta^2) \times \frac{\text{Precision} \cdot \text{Recall}}{(\beta^2 \cdot \text{Precision}) + \text{Recall}}, \beta = 2$$

- The detection accuracy on life-threatening VAs is the most important metric in ICDs
- Gives a higher weight to recall

Latency (0.0-1.0)

$$L_n = \left(1 - \frac{L - Min_L}{Max_L - Min_L}\right)$$

- L is the average latency of inference executed on MCU over segments from testing dataset measured
- L_n is the normalized by $Min_L = 1ms$ and $Max_L = 200ms$

Memory (0.0-1.0)

$$M_n = \left(1 - \frac{M - Min_M}{Max_M - Min_M}\right)$$

- M is the flash occupation of MCU for the storage of the deep neural network model and the program
- M_n is normalized by $Min_M = 5KiB$ and $Max_M = 256KiB$

Evaluation

Evaluation Score

$$\text{Score} = 100 \cdot F_\beta + 20 \cdot L_n + 20 \cdot M_n$$

Accuracy (0.0-1.0)

$$F_\beta = (1+\beta^2) \times \frac{\text{Precision} \cdot \text{Recall}}{(\beta^2 \cdot \text{Precision}) + \text{Recall}}, \beta = 2$$

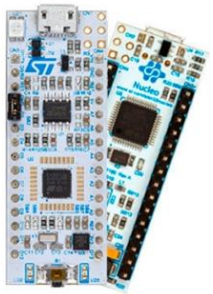
Latency (0.0-1.0)

$$L_n = \left(1 - \frac{L - Min_L}{Max_L - Min_L}\right)$$

Memory (0.0-1.0)

$$M_n = \left(1 - \frac{M - Min_M}{Max_M - Min_M}\right)$$

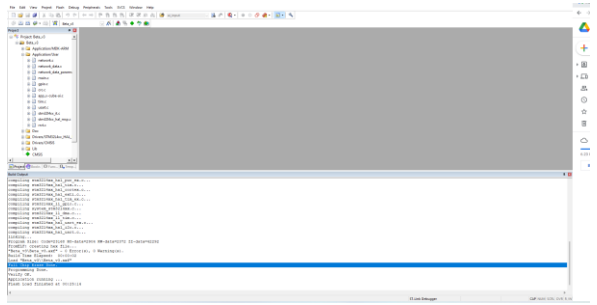
Evaluate on the MCU over testing segments (evaluation framework provided)



IEGM segment

Inference result

Read from Keil once the project built



Results & Awards

- **Results of Top 40 Team**

- **1st Place Award** US $4500 / team
- **2nd Place Award** US $1500 / team
- **3rd Place Award** US $500 / team

- **4th-8th Place Award** Honorable Mention Certificates

Top 8 Teams

Rank	Team Name	Final Score	F_beta	Latency	Flash
1	Gatech EIC Lab Team	135.43187	0.972	1.747	26.390
2	SEUer	132.98377	0.946	1.712	24.480
3	MIT-HAN-Lab	132.91372	0.934	0.538	11.180
4	HuskyCS Deepical	132.84182	0.978	26.197	35.460
5	UBPercept	132.21299	0.930	0.221	16.400
6	MAD-AI	131.90820	0.953	17.745	26.810
7	SDUAES	131.59601	0.955	21.879	27.780
8	VIPS4Lab @ UNIVR	130.35990	0.945	4.843	51.980

Awards

Honorable Mention

Team VIPS4Lab @ UNIVR

Team Member: Luigi Capogrosso, Federico Cunico, Andrea Avogaro, Federico Girella, Andrea Toaiari, Geri Skenderi, Franco Fummi and Marco Cristani

University of Verona

Awards

Honorable Mention

Team SDUAES

Team Member: Tianren Zhou, Shuangyi Wang, Dehao Yu, Zhining Cao, Zhaoyan Shen, Zhiping Jia

Shandong University

Awards

Honorable Mention

Team MAD-AI

Team Member: Matteo Risso, Alessio Burrello and Daniele Jahier Pagliari

Politecnico di Torino

Honorable Mention

Team UBPercept

Team Member: Pranay Meshram, Changjae Lee, Tianchen Yu, Karthik Dantu and Jinjun Xiong

University at Buffalo

Awards

Honorable Mention

Team HuskyCS Deepical

Team Member: Shanglin Zhou, Jun Bai, Sahidul Islam, Ya-Sine Agrignan, Xi Xie, Sheida Nabavi, Mimi Xie, Caiwen Ding

University of Connecticut & The University of Texas at San Antonio

Awards

3rd Place

Team MIT-HAN-Lab

Team Member: Hanrui Wang, John Heo, Wei-Chen Wang, Jessica Zheng, Wei-Ming Chen, Ji Lin, Han Cai, Song Han

Massachusetts Institute of Technology

Awards

2nd Place

Team SEUer

Team Member: Jingwei Zhang, Chaoyao Shen, Xinye Cao, Yu Zhang, Yuning Ji, Jingxuan He, Zhipeng Zhong, Zihan Zhou, Guofang Xu, Guoqing Li, Meng Zhang

Southeast University

Awards

1st Place

Team Gatech EIC Lab Team

Team Member: Chaojian Li*, Shang Wu*, Junchi Teng*, Sixu Li, and Yingyan (Celine) Lin

Georgia Institute of Technology & Rice University

Thank You

A great **thank you** to our sponsors and data provider!

Wrap-up

- The first ICCAD TinyML contest on healthcare application
- Over 150 registered teams from 50+ organizations
- Questions: tinymlcontest@gmail.com
- Thank you to all participated teams!