# Accelerator Architectures for Machine Learning (AAML)

## Syllabus

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# Course overview

- Instructor: **Tsung Tai Yeh**
- TA team+:
  - Cheng-Han Tsai; Yu-Lun Ning
- Lecture: T34
- Location: ED-102
- Office Hour: 9 – 10 am Thursday
- My Office: EC 516
- Course web site:
  - https://reurl.cc/nvN566

Course website QR Code

# Discussion Forum

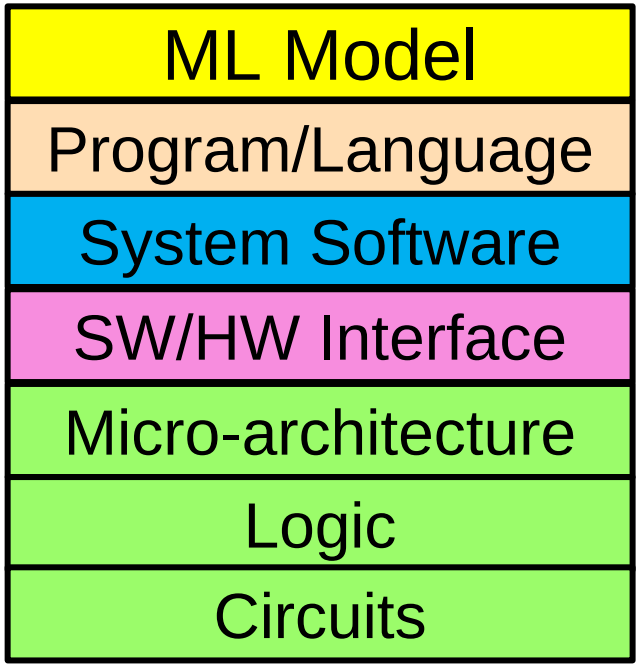
- Students should join our class discord discussion forum
- Discord forum
  - Course Announcement
  - Lab
  - Final Project

https://discord.gg/JFncfXUa

Discord Forum QR Code

# Course overview

- **Efficient Inference**
  - Basics of Deep Learning
  - Quantization + Model Pruning
- **AI Accelerator**
  - Digital/Analog AI Accelerators
- **Edge AI Acceleration**
  - TinyML Acceleration Architecture
- **Lecture + laboratory**
  - Class lecture + 5 labs + Final Project



# Intended Lecture Outcomes (ILOs)

- AAML Course Intended Lecture Outcomes
  - **Understanding** the construction of DNN models
  - **Describing** details of AI accelerators
  - **Implementing** dataflow AI accelerator on Google CFU Playground
  - **Designing** AI accelerator to improve the performance of DNN models

# What will you need to do in this course?

- Paper presentation (5%)
  - Groups of students present paper
  - Paper summary writing
- 5 Lab projects (55%) , Lab 1-2 (5%), Lab3-5 (15%)
  - Google CFU Playground
- 2 Quiz (20%)
- 1 Final Project (20%)
  - Optimize a Deep Neural Network Model on CFU Playground
  - Rule: 2 – 3 people/group

# Prerequisites

- **Courses:**
  - Basic Programming , Computer Organization, Advanced Computer Architecture
- **You should:**
  - Basic understanding of computer architecture and digital logic design
  - Comfortable with programming in C/C++, Verilog and Python

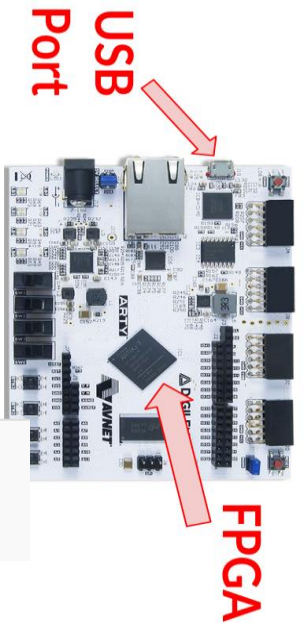
# Lecture

- **Class lecture**
  - This lecture also covers three topics about AI accelerators and DNN models
  - Lecture (2 hours)– summarize course materials of each topic
  - Lab preview or paper presentation (1 hour)
  - Lecture materials have shown on the class website

# Lab

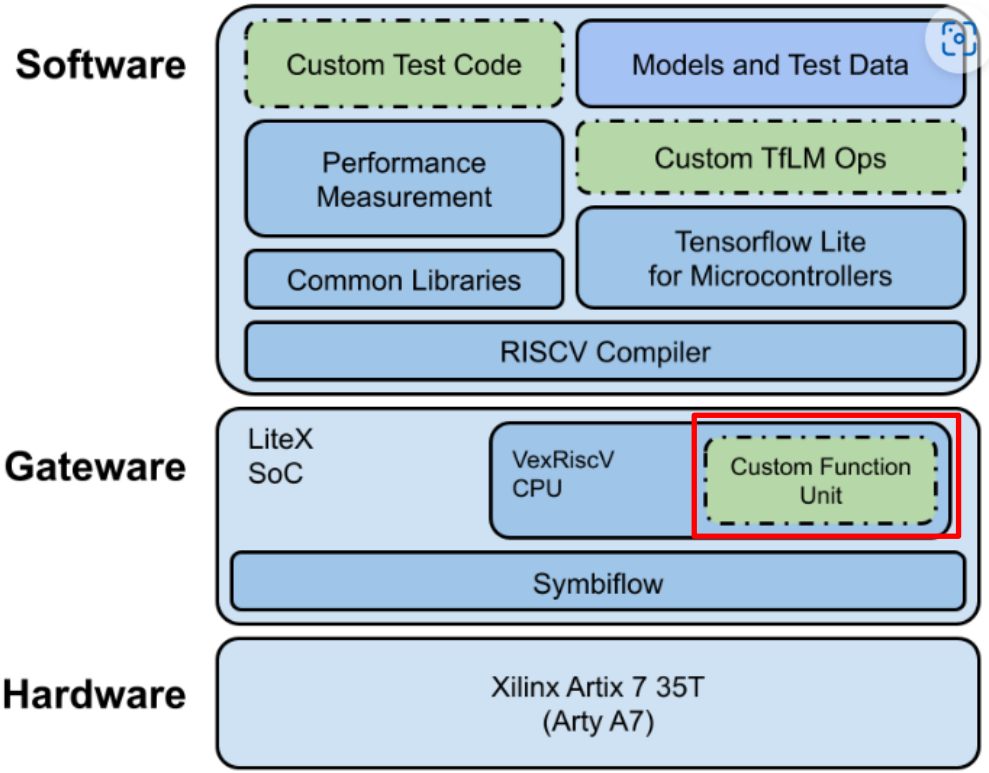
- **Platform**
  - **Google CFU Playground on Nexys A7-100T FPGA Board**
- Overview of AAML Labs
  - Build CFU + Run a model
  - CFU + (SIMD + Quantization)
  - Systolic Array Implementation (Verilog)
  - CFU + element-wise engine
  - Systolic Array + element-wise engine

https://nycu-caslab.github.io/AAML2024



# CFU Playground

- **Google CFU Playground**
  - TensorFlow Lite for Microcontrollers (TFLM)
  - RISC-V CPU + Custom Function Unit
  - Simulation on FPGA




*CFU Playground Overview*

# Lab

- One lab every two weeks
  - Lab 1-2 takes 5% each, 3-5 takes 15% each
  - Late submission:
    - 20% off for two weeks, 100% off for four weeks
- **Lab Demo**
  - Biweekly demonstration
  - Time: 12:00 – 1:00 pm on Thursday
  - Location: ED 102
  - TA will ask students questions about each lab assignment, 10% off if you do not answer TA's question correctly

# Final Project

- The final project take **20%** score
- Problem:
  - How to optimize a Deep Neural Network Model on CFU Playground
  - Designing an AI accelerator to improve the performance of a DNN model by using CFU playground

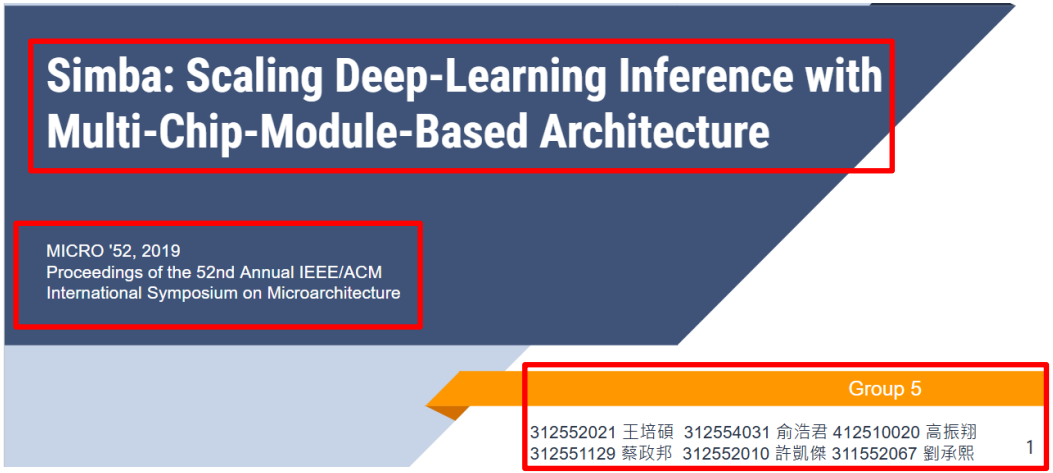
# Paper Presentation

- **Paper Presentation**
  - 7 papers, 5 - 7 students are responsible for the presentation of one paper (30 – 40 mins)
  - Upload paper slide to discord “paper-collection” channel before the presentation
  - Peer review feedback form – students need to fulfill **5** times attendance, 1% score off when you less than 5 times attendance
  - Each paper presentation takes **5 %** of the total score

# Paper Presentation Slide

- The paper presentation slide should include:
  - Paper Title
  - The origin of the paper and year
  - Name of presenters
  - Research problems
  - Contributions and outcome
  - Methodology
  - Evaluation

# Paper Presentation Slide Template




## Outline

- Introduction (Research problem)
- Research Background (Related work)
- Contribution
- Design
  - Designing SNAFU to Flexibility
  - Designing SNAFU to Minimize Energy
  - SNAFU-ARCH : a Complete ULP System W / Cgra
- Evaluation
- Conclusion

# Schedule

## Course Outline

| Week | Date | Lecture Topics | Paper Report | Lab Deadline | Misc. |
|---|---|---|---|---|---|
| 1 | 9/5 | Basics of AI Accelerator[pdf] | Syllabus[Syllabus] | | Build AI Silicon |
| 2 | 9/12 | Large Language Model | | | CFU Playground |
| 3 | 9/19 | Quantization | RaPiD, ISCA, 2021[pdf] | | |
| 4 | 9/26 | Pruning and Sparsity | | Lab 1 | |
| 5 | 10/3 | Systolic Accelerator | TPU v4, ISCA, 2023 [pdf] | | |
| 6 | 10/10 | Holiday | | | |
| 7 | 10/17 | Digital AI Accelerator | | Lab 2 | |
| 8 | 10/24 | GPGPU Architecture | vegeta, HPCA 2023 [pdf] | | |
| 9 | 10/31 | GPU Tensor Core | | Lab 3 | |
| 10 | 11/7 | Sparse DNN Accelerator | Trapezoid, ISCA 2024 [pdf] | | Quiz-1 |
| 11 | 11/14 | Chiplet Accelerator | | Lab-4 | |
| 12 | 11/21 | Analog ML Accelerator | Gemini, HPCA 2024 [pdf] | | |
| 13 | 11/28 | TinyML Acceleration Architecture | Sushi, MICRO 2023 [pdf] | | |
| 14 | 12/5 | Invited talk | | Lab-5 | |
| 15 | 12/12 | Exam | Flumen, ISCA 2023 [pdf] | | Quiz-2 |
| 16 | 12/19 | Final Project | | | |
| 17 | 12/26 | Final Project | | | |

# Textbook

- Vivienne Sze, Yu-Hsin Chen, Tien-Ju Yang, Joel Emer, **Efficient Processing of Deep Neural Network**, Morgan and Claypool Publisher, 2020
- You can download the e-book from NYCU library through EBSCOhost E-book database within NYCU campus