Master Course Description for EE 446 (ABET sheet)

Title: Tiny Machine Learning for Ultra Low-Power Edge Computing (TinyML)

Credits: 4

Coordinator: Radha Poovendran, Professor, Electrical and Computer Engineering

Goals

This course studies the design and deployment of machine learning (ML) on ultra low-power edge devices (microcontrollers, embedded sensors). With billions of Internet of Things (IoT) devices worldwide, the ability to build compact yet accurate models under tight memory, compute, and energy budgets is essential for responsive, private, and reliable applications at the edge.

Students will build end-to-end TinyML pipelines in class – from sensing and data collection to model training, compression, and deployment. Applications span keyword spotting, visual wake words, anomaly detection, predictive maintenance, gesture recognition (magic wand), sign-language interpretation, and smart-lock audio recognition.

A recurring theme in the course is engineering under constraints: selecting algorithms, compression methods (quantization, pruning, knowledge distillation), and runtime designs that meet latency/footprint targets while preserving accuracy. We also highlight robustness and security of edge deployments ("Robust TinyML"), recognizing that adversaries can manipulate models and inputs in the wild.

Learning Objectives:

At the end of this course, students will be able to:

1. Deploy TinyML models on power- and performance-constrained devices to solve real-world problems.
2. Implement ML algorithms such as clustering, regression, classification, and ensembles; compare baselines with compressed neural models.
3. Use Python libraries (NumPy, Pandas, Scikit-learn) for data preparation, training, and evaluation.
4. Use TensorFlow for deep learning and TensorFlow Lite / TFLite Micro for TinyML deployment.
5. Use C/C++ to integrate embedded inference (e.g., Arduino Nano 33 BLE Sense) and simple I/O (BLE/serial/LED).
6. Measure accuracy, latency, memory footprint, and (when feasible) energy; explain trade-offs due to compression.
7. Apply PTQ, QAT, pruning, and knowledge distillation appropriately and articulate the design trade-offs.

Textbook

TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers, Pete Warden & Daniel Situnayake; O'Reilly Media, 2020.

Reference Texts

1. TinyML Cookbook: Combine artificial intelligence and ultra-low-power embedded devices to make the world smarter, Gian Marco Iodice; Packt Publishing, 2022.
2. TensorFlow / TensorFlow Lite documentation.
3. TinyML Foundation resources (tinyml.org).
4. SensiML documentation (as applicable to Week 9 activity).

Prerequisites

EE 242 and either AMATH 352, MATH 208, or MATH 136; and either IND E 315, MATH/STAT 394, STAT 390, or EE 391; or instructor permission. Recommended: EE 344.

Familiarity with Python programming; basic C/C++ helpful for MCU deployment. No prior machine learning coursework required (basics covered early in the course).

Topics

1. Introduction to TinyML; Python & toolchain overview; TinyML lifecycle and constraints [Week 1]
2. Compression foundations: pruning, PTQ vs QAT, and knowledge distillation; TFLite for TinyML [Week 2]
3. Keyword Spotting on streaming audio: data collection, training, metrics, on-device deployment [Week 3]
4. Visual Wake Words: datasets, MobileNets, transfer learning, deployment [Week 4]
5. Anomaly Detection: signal processing, unsupervised learning, thresholds, deployment [Week 5]
6. Wizard Magic Wand: BLE-based gesture tracking, CNN sketch, data collection/labeling, deployment [Week 6]
7. Predictive Maintenance: sensors (accel/gyro/baro/mag), data interfaces, TinyML framework, deployment [Week 7]
8. ASL Interpretation: motion features, neural modeling, TinyML pipeline, evaluation and deployment [Week 8]
9. Smart-Lock Audio Recognition: audio processing, TensorFlow/SensiML SDK, compile/flash, live inference UI [Week 9]
10. Lecture or additional time for the final project [Week 10]
11. Final Project Presentations (teams of 3–4; 9’ talk + 3’ Q&A). Final report due in Exam Week – Week 11.

Course Structure

Integrated labs occur during the second part of class; short in-class quizzes reinforce weekly material.

A team-oriented project (3–4 students) runs through the quarter with proposal, presentation, and final report.

Computer Resources

Python (NumPy, Pandas, TensorFlow/TFLite), TFLite Micro, Arduino IDE/CLI, BLE utilities, and (as applicable) SensiML SDK.

Students are expected to use personal laptops; ECE department computers may be used if available.

Hardware: Tiny Machine Learning Kit (Arduino Nano 33 BLE Sense).

Grading

60% In-class lab completion/quizzes

40% Project (Proposal 5% + Final Presentation 15% + Final Report 20%)

ABET Student Outcome Coverage

This course addresses the following outcomes

H = high relevance, M = medium relevance, L = low relevance to course.

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. (H) Students must identify constraints (SRAM/Flash limits, latency, energy) and select/design algorithms and compression methods to meet them. We emphasize sound engineering principles over ad-hoc heuristics by quantitatively comparing baselines vs compressed models (PTQ/QAT/pruning/distillation) and analyzing failure modes for embedded inference.

(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. (M) The team project requires designing and implementing an embedded ML solution that meets functional/resource specs. Students consider privacy (on-device processing), safety (false positives/negatives), and deployment context.

(3) An ability to communicate effectively with a range of audiences. (M) Students submit a proposal, deliver a live demo/presentation, and write a final report in an engineering format with figures, metrics, and clear justifications.

(4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. (H) The course discusses risks of ubiquitous sensing and adversarial manipulation in edge settings. Students document assumptions, limitations, and mitigations (e.g., robust preprocessing, anomaly detection, safe defaults).

(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. (H) Teams of 3–4 plan milestones, distribute tasks (data, modeling, firmware), integrate, and iterate based on profiling and user feedback.

(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies. (H) Students learn evolving toolchains (TFLite Micro operator support, Arduino updates, SDK changes) via documentation and experimentation; they adapt workflows when encountering operator gaps or memory issues.

Religious Accommodations Policy

Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/).

Accommodations & Access

If you have already established accommodations with Disability Resources for Students (DRS), please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course. If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), you are welcome to contact DRS at 206-543-8924 or uwdrs@uw.edu or disability.uw.edu. DRS offers resources and coordinates reasonable accommodations for students with disabilities and/or temporary health conditions. Reasonable accommodations are established through an interactive process between the student, instructor, and DRS. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law.

Academic Integrity

Engineering is a profession demanding a high level of personal honesty, integrity, and responsibility. Therefore, it is essential that engineering students, in fulfillment of their academic requirements and in preparation to enter the engineering profession, adhere to the College of Engineering Statement of Principles. Any student in this course suspected of academic misconduct (e.g., cheating, plagiarism, or falsification) will be reported to the College of Engineering Dean's Office and the University's Office of Community Standards and Student Conduct to initiate the student conduct process. For any assignment, quiz, or exam that is suspected of academic misconduct, you will be given an "X" grade until after the instructor has received notification by the Dean's office that the conduct process is complete. If a student is found responsible for academic misconduct, the student will receive a grade of zero on the assignment, quiz, or exam. If a student is found not responsible, the student will receive a grade based on the standard grading criteria for that assignment, quiz, project, or exam.

Title IX

The UW, through numerous policies, prohibits sex- and gender-based violence, harassment, and discrimination and expects students, faculty, and staff to act professionally and respectfully in all work, learning, and research environments.

For support, resources, and reporting options related to sex- and gender-based violence, harassment, or discrimination, refer to the UW Title IX's website, specifically the *Know Your Rights & Resources* guide. Should you wish to make the Office of the Office of the Title IX Coordinator aware of a Title IX concern, visit the Make a Title IX Report webpage.
Please know that if you choose to disclose information to me about sex- or gender-based violence, harassment, or discrimination, I will connect you (or the person who experienced the conduct) with resources and individuals who can best provide support and options. You can also access additional resources directly:

- You can request anonymous support, from SafeCampus
- You can request confidential support, from a confidential advocate.
- If you know you want to submit a formal complaint, contact the Civil Rights Investigation Office.

Please note that some senior leaders and other specified employees have been identified as *Officials Required to Report*. If an Official Required to Report learns of possible sex- or gender-based violence, harassment, or discrimination they are required to contact the Office of the Title IX Coordinator and report all the details they have in order to ensure that the person who experienced harm is offered support and reporting options.

Relevant Websites

- Title IX: uw.edu/titleix/
- Survivor resources: uw.edu/titleix/survivor-resources/
- Confidential advocates: uw.edu/sexualassault/support/advocacy/
- SafeCampus: uw.edu/safecampus/
- Officials Required to Report: uw.edu/titleix/employee-reporting-expectations/
- Policies: uw.edu/titleix/policies/

Mental health & wellbeing resources

The following wellbeing & mental health resources are available to you on campus:

- Let's Talk connects you with support from a counselor without an appointment via drop-in hours.
- The Counseling Center provides you with personal counseling, assessment, referral, and crisis intervention services (206-543-1240).
- UW LiveWell provides you with support and case consultation if you are experiencing personal hardship, including academic hardship as the result of extenuating life circumstances (206-543-6085).
- Husky Health & Well-Being provides you with a central online resource for access to health and wellness services across the campus.
- Academic Advising can help if you are experiencing challenges navigating academic commitments.
- SafeCampus is here for you to privately discuss mental, emotional, or physical safety and well-being concerns for yourself or others (206-685-SAFE [7233]). SafeCampus's team

of caring professionals will provide individualized support, while discussing short- and long-term solutions and connecting you with additional resources when requested.

- Forefront Suicide Prevention provides information and services to reduce suicide by empowering individuals and communities to take sustainable action, championing systemic change, and restoring hope.
- Crisis Clinic: If you or someone you know experiences a crisis outside of business hours, please call the Crisis Clinic at 206-461-3222 or toll-free at 1-866-427-4747.
- Food and Housing: If you are experiencing food or housing insecurity, you can start with UW Emergency Aid (https://www.washington.edu/emergencyaid/) or the UW Food Pantry (https://www.washington.edu/anyhungryhusky/).
- Study Centers: https://www.engr.washington.edu/current/academics/studycenters

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