Tutorial

Title
Machine Learning for Low Power IoT Sensors

Abstract
The Internet of Things (IoT) paradigm enables various smart objects to be connected, this allows us to interact with our environment in an intelligent way. It is believed that low power and ultra-low power sensors would outnumber any other IoT devices by 2030. To achieve the full potential of IoT applications, AI techniques are required to analyze the sensor data on the edge for real-time analytics, reduced latency, and less privacy concern. Low power consumption edge AI also creates significant opportunities for green AI and sustainable IoT research, which aligns with the conference's theme of "Improving the quality of life". In this tutorial, we will first provide a comprehensive overview of low power sensors and compare various IoT communication protocols. We will walk through the detailed end-to-end data integration steps from sensors to the loud data platform using real life award-winning smart cities examples. Since low power sensors are constrained by power and processing resources, integration with computationally intensive Machine Learning (ML) for intelligent processing and decision making becomes a unique challenge. This tutorial will review various methods for applying ML and deep learning to low power sensor solutions. Different hardware and software options will be discussed including bio-inspired chipsets, traditional centralized learning, federated ML, pruning and TinyML for edge computing. We will demonstrate the latest design of our acoustic sensor with edge ML capability for real time sound classification. Development trend and future research opportunities for edge AI and IoT will also be presented.

Duration
Two-hours

Motivation -
The integration of machine learning with low power IoT sensor especially edge AI has gained explosive growth of interest. Low power consumption not only posts interesting challenges to AI and IoT researchers, but also creates significant opportunities for green AI and sustainable IoT (**"Improving the Quality of Life")**. The audience will also find it very beneficial to learn how machine learning and IoT technologies are applied in the award-winning smart city use cases at The City of Calgary.

Expected audience
Academic researchers, educators, students, industry practitioners and engineers. The target audience requires basic understanding of any of these fields: machine learning, sensor, sensor network, communications or signal processing.

Outline of contents

Internet of Things (IoT) accounts for more than 8 billion connected devices, this number will continue to grow and reach 41 billion by 2027. With the rapid development of Low Power Wide Area Network (LPWAN) sensor technology over the last few years, it is believed that low power and ultra-low power sensors would outnumber any other IoT devices by 2030. This tutorial aims to provide awareness for low power sensor technology with the emphasis of integration with edge-based Machine learning (ML) for real-life applications. We will provide a state-of-the art review of LPWAN technology and demonstrate step-by-step sensor integration procedure with cloud applications. Different hardware and software methods for applying Machine Learning to IoT sensors will be reviewed and discussed in this tutorial.

LPWAN technology offers cost effective long range, ultra-low power bi-directional communications for battery-operated IoT sensors. This tutorial provides comprehensive overview of LPWAN technical characteristics and detailed comparison of various communication protocols. This tutorial will elaborate the end-to-end IoT data integration using real life smart cities IoT examples, which cover detailed steps from sensor to radio gateway, network server, data ingress with Microsoft Azure using MQTT (Message Queue Telemetry Transport) and Restful API, data storage and processing in the enterprise Azure platform. The tutorial will demonstrate award-winning low power sensor solutions including underground water level monitoring, waste bin and needle bin sensors, smart parking, and copper theft detection.

Enabling sensors with intelligence using ML would be of great interest to provide smart decisions and automation. Low power consumption edge AI also creates significant opportunities for green AI and sustainable IoT research, which aligns with the conference's theme of **"Improving the quality of life".** Since battery-powered sensors are by deign highly constrained by power, memory and processing resources, integration with computationally intensive ML becomes a unique challenge. This tutorial reviews and discusses various methods for applying ML to IoT sensor solutions, including bio-inspired hardware, neuromorphic neural network for edge processing, quantization, model pruning, federated ML framework, and TinyML for edge computing. We will explore the major implications and explain the detailed approaches of these solutions. To provide the audience with effective learning experience, we will demonstrate the detailed design of our latest acoustic sensor with edge ML for real time sound classification. Performance analysis and comparison with centralized ML models will be discussed.

Challenges and future opportunities for the edge AI/ML research will also be highlighted to conclude this tutorial.

Key references

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List of speakers

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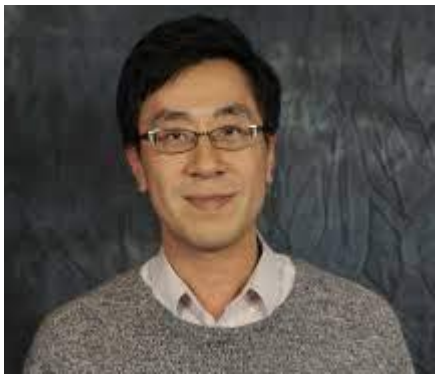

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