COL 788

Advanced Topics in Embedded Computing
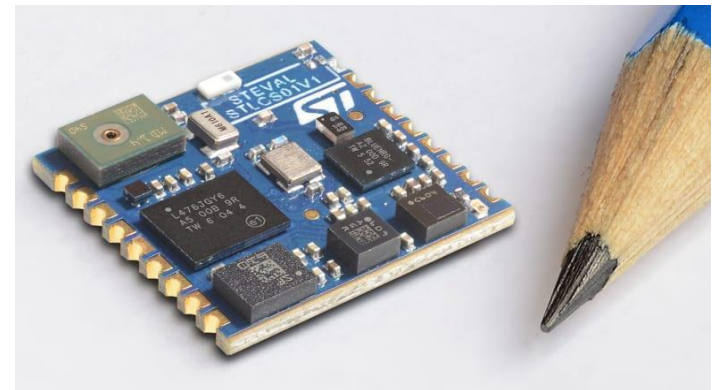
Classes: Mon, Tue, Wed 10-11 AM

3-0-0 is given in course webpage, but better to have a 2-0-1 course or a 1-1-1 course

Embedded Systems Definition

Embedded Systems Definition

- A system "embedded" in real world

Different Form Factors/ Capabilities

NVIDIA AGX Orin Hardware Specs

|	Jetson AGX Orin 32GB	Jetson AGX Orin 64GB
AI Performance	200 TOPS (INT8)	275 TOPS (INT8)
GPU	NVIDIA Ampere architecture with 1792 NVIDIA® CUDA® cores and 56 Tensor Cores	NVIDIA Ampere architecture with 2048 NVIDIA® CUDA® cores and 64 Tensor Cores
Max GPU Freq	930 MHz	1.3 GHz
CPU	8-core Arm® Cortex®-A78AE v8.2 64-bit CPU 2MB L2 + 4MB L3	12-core Arm® Cortex®-A78AE v8.2 64-bit CPU 3MB L2 + 6MB L3
CPU Max Freq	2.2 GHz	
DL Accelerator	2x NVDLA v2.0	
DLA Max Frequency	1.4 GHz	1.6 GHz
Vision Accelerator	PVA v2.0	
Memory	32GB 256-bit LPDDR5 204.8 GB/s	64GB 256-bit LPDDR5 204.8 GB/s
Storage	64GB eMMC 5.1	
CSI Camera	Up to 6 cameras (16 via virtual channels) 16 lanes MIPI CSI-2 D-PHY 2.1 (up to 40Gbps) | C-PHY 2.0 (up to 164Gbps)	
Video Encode	1x 4K60 | 3x 4K30 | 6x 1080p60 | 12x 1080p30 (H.265) H.264, AV1	2x 4K60 | 4x 4K30 | 8x 1080p60 | 16x 1080p30 (H.265) H.264, AV1
Video Decode	1x 8K30 | 2x 4K60 | 4x 4K30 | 9x 1080p60| 18x 1080p30 (H.265) H.264, VP9, AV1	1x 8K30 | 3x 4K60 | 7x 4K30 | 11x 1080p60| 22x 1080p30 (H.265) H.264, VP9, AV1
UPHY*	Up to 2 x8, 1 x4, 2 x1 (PCIe Gen4, Root Port & Endpoint) 3x USB 3.2	
Networking*	1x GbE 1x 10GbE	
Display	1x 8K60 multi-mode DP 1.4a (+MST)/eDP 1.4a/HDMI 2.1	
Other I/O	4x USB 2.0 4x UART, 3x SPI, 4x I2S, 8x I2C, 2x CAN, DMIC & DSPK, GPIOs	
Power	15W - 40W	15W - 60W
Mechanical	100mm x 87mm 699-pin Molex Mirror Mezz Connector Integrated Thermal Transfer Plate	

Raspberry PI Hardware Specs

Specification

Processor:	Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
Memory:	1GB, 2GB or 4GB LPDDR4 (depending on model)
Connectivity:	2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 5.0, BLE Gigabit Ethernet 2 × USB 3.0 ports 2 × USB 2.0 ports.
GPIO:	Standard 40-pin GPIO header (fully backwards-compatible with previous boards)
Video & sound:	2 × micro HDMI ports (up to 4Kp60 supported) 2-lane MIPI DSI display port 2-lane MIPI CSI camera port 4-pole stereo audio and composite video port
Multimedia:	H.265 (4Kp60 decode); H.264 (1080p60 decode, 1080p30 encode); OpenGL ES, 3.0 graphics
SD card support:	Micro SD card slot for loading operating system and data storage

STM Sensortile Hardware Specs
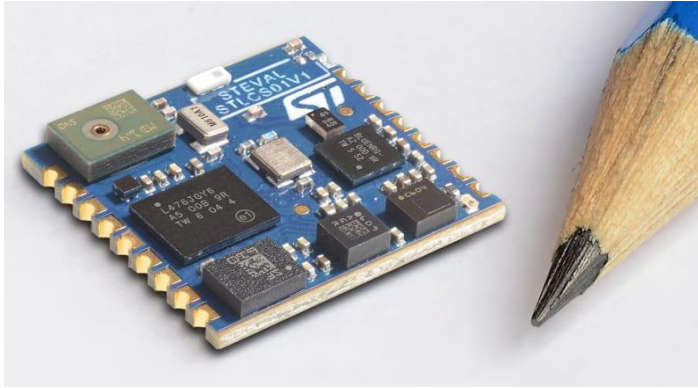
STLCS01V1 SensorTile component board features

- Very compact module for motion, audio, environmental sensing and Bluetooth® low energy connectivity with a complete set of firmware examples
- Mobile connectivity via the STBLESensor app, available for iOS™ and Android™
- Main components:
  - STM32L476JG – 32-bit ultra-low-power MCU with Cortex®M4F
  - LSM6DSM – iNEMO inertial module: 3D accelerometer and 3D gyroscope
  - LSM303AGR – Ultra-compact high-performance eCompass module: ultra-low power 3D accelerometer and 3D magnetometer
  - LPS22HB – MEMS nano pressure sensor: 260-1260 hPa absolute digital output barometer
  - MP34DT05-A – 64 dB SNR digital MEMS microphone
  - BlueNRG-MS – Bluetooth low energy network processor
  - BALF-NRG-02D3 – 50 Ω balun with integrated harmonics filter
  - LD39115J18R – 150 mA low quiescent current low noise LDO 1.8 V
- 2 V - 5.5 V power supply range
- External interfaces: UART, SPI, SAI (serial audio interface), I²C, DFSDM, USB OTG, ADC, GPIOs

The STM32L476xx devices are the ultra-low-power microcontrollers based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 MHz. The Cortex-M4 core features a Floating point unit (FPU) single precision which supports all Arm® single-precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The STM32L476xx devices embed high-speed memories (Flash memory up to 1 Mbyte, up to 128 Kbyte of SRAM), a flexible external memory controller (FSMC) for static memories (for devices with packages of 100 pins and more), a Quad SPI flash memories interface (available on all packages) and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

Commonalities between different form factors

- Mostly ARM Architecture, not X86
- Many peripherals to help in "embedding" in real environments

Use based on application requirement

NVIDIA AGX Orin Use

Embedded CNN based vehicle classification and counting in non-laned road traffic

Mayank Singh Chauhan
IIT Delhi
cs5160394@cse.iitd.ac.in

Arshdeep Singh
IIT Delhi
arshdeep.cs516@cse.iitd.ac.in

Mansi Khemka
Delhi Technological University
mansikhemka_bt2k15@dtu.ac.in

Arneish Prateek
IIT Delhi
ch1140786@chemical.iitd.ac.in

Rijurekha Sen
IIT Delhi
riju@cse.iitd.ac.in

EcoLight: Intersection Control in Developing Regions Under Extreme Budget and Network Constraints

Sachin Kumar Chauhan, Kashish Bansal and Rijurekha Sen
Department of Computer Science and Engineering
Indian Institute of Technology Delhi
{csz188012,cs5150285,riju}@cse.iitd.ac.in

Raspberry PI Use

Delhi Pollution Dataset

HOME | ABOUT | PUBLICATION | ETHICAL DOCUMENTATION | SENSOR CALIBRATION | NOVELTY | DATASET

Air pollution is one of the biggest concerns faced by developing countries like India and the world at large. The capital of India, Delhi and the National Capital Region (NCR), sees life threatening air pollution levels. We present a new Particulate Matter (PM) dataset for Delhi-NCR, which contains PM data recorded over three months from November 2020 to January 2021 over an area spanning 559 square Kms. The data has been collected using vehicle-mounted IoT sensors, designed and built in IITD incubated startup Aerogram. The deployment is in collaboration with the Delhi Integrated Multi-Modal Transit System (DIMTS) buses with permission from the Delhi Ministry of Transport. The 13 bus dataset has

Computer Science Subjects Relevant

- Computer Architecture
- Operating Systems
  - More generally "systems software"
- Application Software
  - Embedded Machine Learning
- System Security
- Other performance Metrics
  - Power (battery)
  - Heating

Computer Science Subjects Relevant

- Computer Architecture
- Operating Systems
  - More generally "systems software"
- Application Software
  - Embedded Machine Learning
- System Security
- Other Metrics
  - Power (battery)
  - Heating
  - Cost
  - Weight

Trade-offs

All data collection projects require cooperation of various stakeholders and parties. Ours is no exception. To collect PM data using mobile sensors at scale, we needed to work with the Delhi government to attach our low cost sensors to DIMTS buses. For this, we required a number of permissions and ethical clearances. We have attached all the relevant documents on this page.

ICAT EMC certification

ICAT EMC certification of our instrument verifying that it doesn't interfere with the bus's electro-mechanical properties [PDF]

Delhi Integrated Multi-Modal Transit System (DIMTS) letter of support

DIMTS letter of support [PDF]

Delhi Pollution Control Commitee (DPCC) letter of Support

Delhi Pollution Control Commitee (DPCC) letter of Support [PDF]

Delhi Ministry of Transport (MOT) Permission

Delhi Ministry of Transport (MOT) permission letter [PDF]

Letter of funding for "SCIENCE & ENGINEERING RESEARCH BOARD (SERB),INDIA"

Letter of funding for project "Scalable Spatio- Temporal Measurement and Analysis of Air Pollution Data for Delhi-NCRusing Vehicle-Mounted Sensors" from SCIENCE & ENGINEERING RESEARCH BOARD (SERB), Department of Science & Technology, Government of India [PDF]

Computer Science Subjects Relevant

- Computer Architecture
- Operating Systems
  - More generally "systems software"
- Application Software
  - Embedded Machine Learning
- System Security
- Other performance Metrics
  - Power (battery)
  - Heating

Riju teaches some core concepts	Students read and present papers	Hands-on project

Course Evaluation Plan

- Mid-term exam (20%) on the concepts Riju teaches
- Paper presentation by each student (10%)
  - Level of understanding
  - Clarity of presentation
- End-term/major exam (30%) on all research papers
  - Thinking and application of knowledge to different scenarios

Course Evaluation Plan

- Mid-term exam (20%) on the concepts Riju teaches
- Paper presentation by each student (10%)
  - Level of understanding
  - Clarity of presentation
- End-term/major exam (30%) on all research papers
  - Thinking and application of knowledge to different scenarios
- Project using Sensortile in groups of 3 students (40%)
  - Inertial sensor data
  - Microphone data
  - Data acquisition, processing with ML algorithms
  - Measurement of metrics – accuracy, latency, power, heating
  - Optimizations to reach better trade-offs

Course Evaluation Plan

- Mid-term exam (20%) on the concepts Riju teaches
- Paper presentation by each student (10%)
  - Level of understanding
  - Clarity of presentation
- End-term/major exam (30%) on all research papers
  - Thinking and application of knowledge to different scenarios
- Project using Sensortile in groups of 3 students (40%)
  - Inertial sensor data
  - Microphone data
  - Data acquisition, processing with ML algorithms
  - Measurement of metrics – accuracy, latency, power, heating
  - Optimizations to reach better trade-offs

Audit – do only project and score 20/40

Pass both theory and project (20/40) parts

Students with best projects can work directly with STM researchers as intern/project staff

Why do the course?
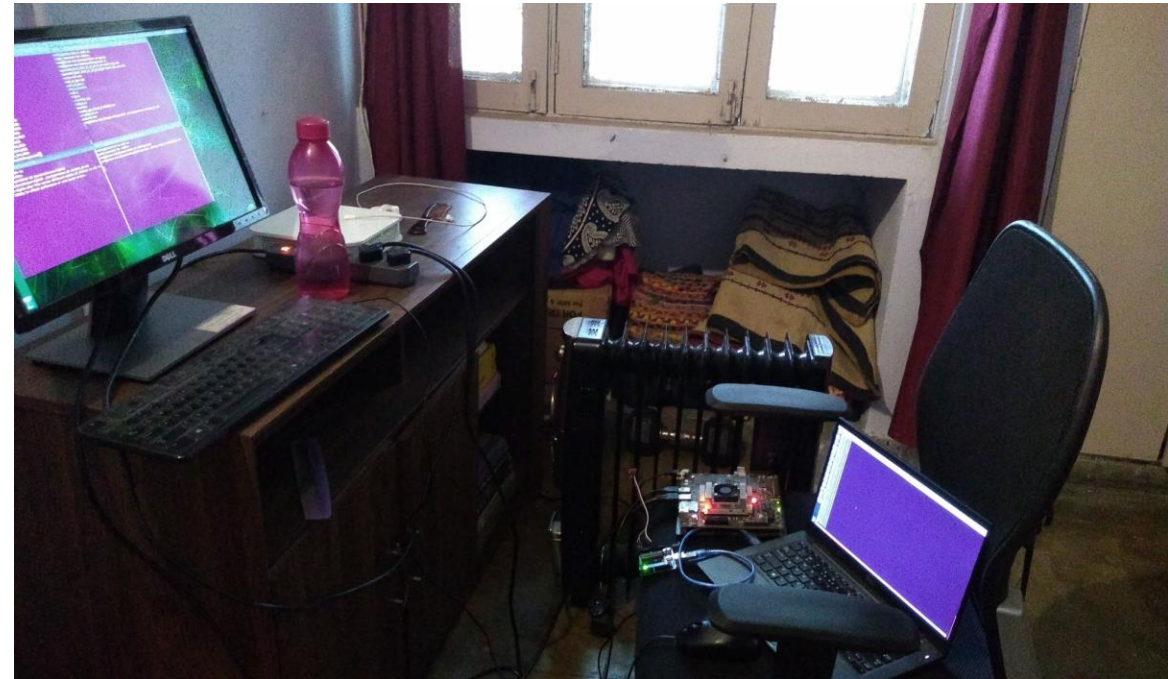
Can become a life-long hobby to play with these tiny things.

Why not do the course?

Nothing will automatically work.