STMicroelectronics SensorTile Internet of Things Curriculum

Introduction

The SensorTile is a new Internet of Things (IoT) system provided by STMicroelectronics integrating state-of-the-art processor, wireless interfaces, and sensor systems. The SensorTile can form the foundation for wearable consumer devices, wearable medical devices, residential IoT systems and vehicle IoT systems.

The SensorTile system provides an exceptionally powerful and well-supported platform for introduction to IoT technology. The SensorTile is remarkably compact as shown below.

An important advance is now the development of EmbeddedML that enables the SensorTile system to directly *learn* to recognize events that are detected by the SensorTile sensor systems and the EmbeddedML Neural Network. This provides a SensorTile microsystem with machine learning capability operating entirely independently of other computing resources for both Neural Network training and execution.

The Tutorials below introduce SensorTile development methods, the SensorTile device and sensors, along with complete applications including a series of machine learning systems.

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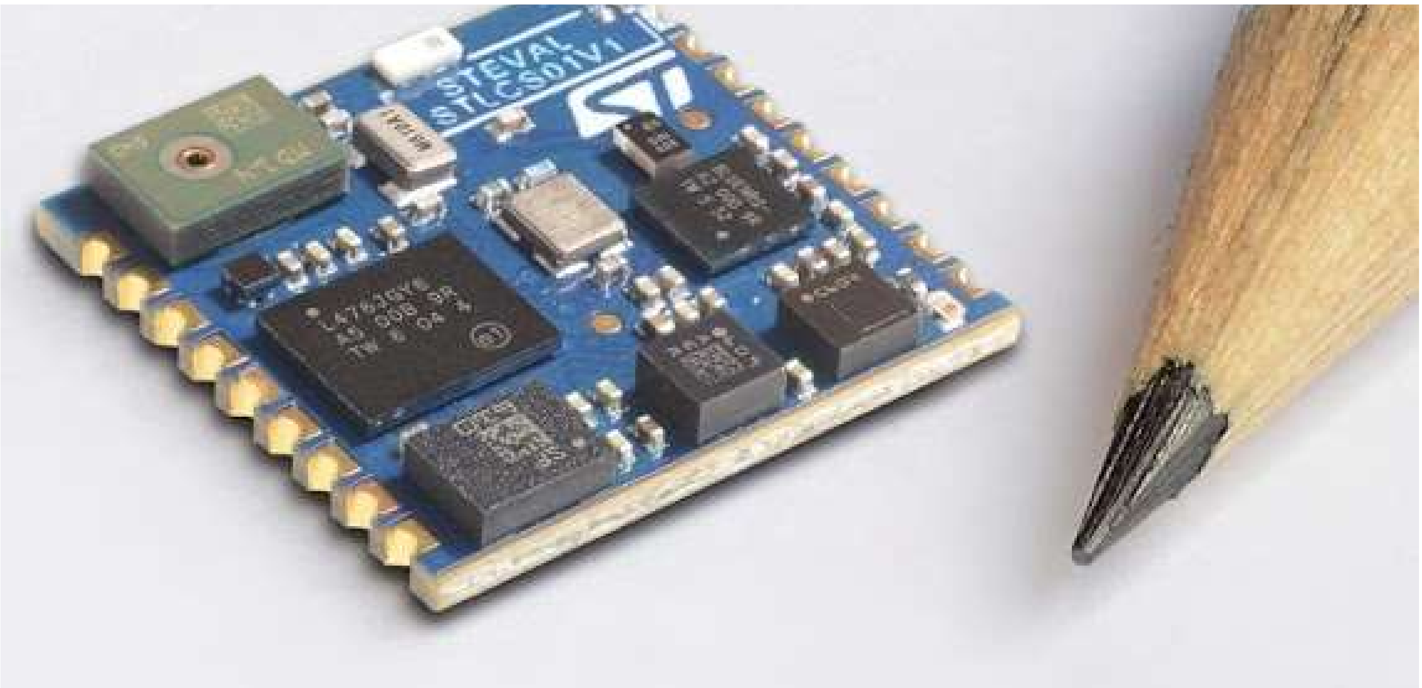

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The SensorTile system includes these components:

1. The SensorTile Processor System is an STM32L4 microprocessor based on the ARM Cortex M4 system. This provides introduction to the ARM processor architecture that is deployed on nearly every smartphone on earth.
2. The SensorTile Sensors includes:
    1. The LSM6DSM combining state of the art MEMS microaccelerometer and microgyroscope.
    2. The LSM303AGR combining microaccelerometer and magnetometer for compass heading
    3. The LPS22HB barometric pressure sensor for determination of altitude and atmospheric pressure.
    4. The MP34DT04 microphone
3. The SensorTile also includes a Bluetooth Low Energy (Bluetooth Smart) wireless interface the BlueNRG-MS system.
4. The SensorTile also includes non-volatile flash storage that stores the executable code that enables IoT system operation.
5. The SensorTile also includes a cradle accessory with additional features including:
    1. SD Card Flash Storage System
    2. STC3115 Battery Monitor providing detailed energy monitoring for the SensorTile
    3. HTS221 Humidity and Temperature environmental sensors

This Web site includes Tutorial and Reference Designs intended to introduce the development environment for the SensorTile system and provide experience in novel application development.

Development environments are essential to development of software for IoT systems and other products. These provide support to developers for both creation of systems, testing, debugging, and installation of software systems on platforms. This development environment is referred to as an Integrated Development Environment (IDE). This includes all of the software tools required to create a software distribution for the SensorTile, compile this software system into the processor instruction set using a Build capability, execute this system using a Debug capability, and also create an "image" file that can be installed in the SensorTile non-volatile storage.

Tutorials

1) Tutorial 1: Introduction to STMicroelectronics Development Environment and DataLog Project Example.

There are two versions of this tutorial. One for Apple Mac Platforms, and one for Microsoft Windows Pl[illegible]orms.

Apple Mac) Tutorial 1: Introduction to STMicroelectronics Development Environment and DataLog

Windows) Tutorial 1: Introduction to STMicroelectronics Development Environment and DataLog Project Example for the Microsoft Windows Platform

This Tutorial provides an introduction to the SensorTile platform and its development tools.

The Tutorial steps include:

a) Installing an Integrated Development Environment (IDE) on a personal computer.

b) Obtaining reference design example project software. This will specifically include a sensor Data Logging system.

c) Usage of the IDE to Import, Build, Run, Debug and Flash the SensorTile board to run the example Data Logging project.

2) Tutorial 2: Sensor System Signal Acquisition, Event Detection and Configuration

This Tutorial provides experience in the development of applications that acquire IoT system sensor signals, detect events in the sensor system data stream, and also configure sensor systems.

The Tutorial steps provide:

a) An introduction to control of sensor signal acquisition and sensor system configuration. These topics are fundamental to IoT system development.

b) An introduction to sensor signal detection and notifications.

c) An experience in software system development for the SensorTile IoT system demonstrating important capabilities of the System WorkBench Integrated Development Environment in accelerating system development.

3) Tutorial 3: Accelerometer Sensor Systems and Orientation and Event Detection

This Tutorial provides additional experience in sensor system data processing including recognition of gesture motion. Experience from this Tutorial provides guidance for the development of capable IoT systems that recognize and may even guide specific motion.

The Tutorial steps provide:

a) An introduction to accelerometer sensor systems and methods for detection of sensor orientation by exploiting gravitational acceleration signals.

b) Measurement of orientation by the polar coordinate system.

c) An introduction to gesture recognition through the use of sensor information and state machine systems for characterizing specific behavior.

4) Tutorial 4: Introduction to Audio Sampling and Signal Processing

This Tutorial provides experience in sensing and generation of audio signals using the state-of-the-art

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The Tutorial steps provide

a) An introduction to audio sensor signal acquisition systems.

b) An introduction to audio signal generation with the opportunity to hear and see audio signal waveforms.

c) An introduction to DSP systems with several demonstrations that provide immediate and direct experience valuable for next steps in system development.

5) Tutorial 5: SensorTile Firmware Programming

This Tutorial provides valuable experience in the creation of firmware applications using the state-of-the-art SensorTile system and tools.

The Tutorial steps provide:

a) An introduction to integration of source code and header files into new SensorTile projects.

b) Experience in configuring the firmware build system.

c) Complete development experience valuable for next Tutorials that integrate multiple system resources and associated capabilities.

6) Tutorial 6: Introduction to Bluetooth Low Energy Wireless Interfaces

This Tutorial provides an introduction to the important principles of Bluetooth Wireless Interfaces. This includes also valuable experience in data transport between the SensorTile system and an embedded Linux platform - the BeagleBone.

a) This Tutorial will prepare students for many next steps in wireless IoT system development that will be appearing in the following Tutorials and Reference Designs.

b) This will include development of new firmware providing access to multiple sensors on the SensorTile platform.

7) Tutorial 7: Introduction to Bluetooth Low Energy Communication and the GATT Profile

This Tutorial introduced Bluetooth Wireless Communication principles and methods. This includes hands-on experience with communication of SensorTile sensor data to the BeagleBone platform.

a) This Tutorial provides experience in the communication protocol central to global IoT applications: The most important GATT profile and associated communication protocols. The BlueZ Bluetooth system interface, hosted on Linux platforms, is also included.

b) This Tutorial also included a demonstration of bidirectional communication with control of events on the SensorTile by an application on the BeagleBone.

8) Tutorial 8: Introduction to Motion Data Acquisition via Bluetooth Low Energy Communication

multiaxis motion sensor data.

a) This includes the installation of the FP-SNS-ALLMEMS1 firmware application provided by STMicroelectronics.

b) Through use of gatttool, this Tutorial provides the BeagleBone system with a high performance, wireless SensorTile motion sensor.

c) This addresses an important need for compact and wearable motion sensing systems for IoT systems.

9) Tutorial 9: Introduction to Inertial Sensing

This Tutorial provides an introduction to Inertial Sensing through a demonstration of displacement sensing.

1. This includes an extension of the Datalog application with increased sampling rate and addition of anti-aliasing and drift-reduction filters.
2. This also includes the SensorTile Animation System that permits visualization of SensorTile motion sensor data in real time.
3. This Tutorial provides users with the background required to develop new motion classification systems based on displacement of the SensorTile.

10) Tutorial 10: Introduction to EmbeddedML Machine Learning

This Tutorial provides an introduction to a new breakthrough in Machine Learning technology. This introduces the EmbeddedML system (developed by Charles Zaloom of UCLA). This new system is a complete Neural Network system with automated training and execution hosted on the SensorTile microprocessor and integrated with SensorTile sensor inputs.

1. This is based on the familiar Datalog application and includes the complete EmbeddedML capability.
2. This illustrates Neural Network implementation and execution with a model system based on a logic gate structure.
3. This Tutorial prepares users to develop the next set of novel systems that integrate SensorTile sensor inputs for recognition of real-world events.

11) Tutorial 11: IoT Machine Learning for Recognition of Motion Events

This Tutorial provides the first introduction to a fully integrated system that acquires sensor data, learns to recognize events, and then executes on new sensor data to predict the occurrence of motion events.

1. Critical experience is provided in the development of methods for designing and computing the characteristic “features” that can be applied to train a Neural Network Machine Learning System to recognize events.
2. This system will takes advantage of the insights and experience from Tutorial 3 for sensing.
3. This also applies the concept of state machines from Tutorial 3 for development of sensor data acquisition, learning, and execution.

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This Tutorial extends the concepts of Tutorial 11 to develop systems that recognize not only motions, but motion patterns consisting of two orientation changes of the SensorTile.

1. This system provides experience and insight into systems that can grow to expand and enable learning and event recognition with data sources provided by multiple sensors with signals resolved in time and frequency characteristics.

13) [Tutorial 13: IoT Machine Learning of Rotation Angle Motion Patterns by Gyroscope Sensing]

This Tutorial introduces SensorTile self-learning systems based on motion sensing. This introduces the SensorTile microgyroscope sensor.

1. The SensorTile microgyroscope sensor measures rotation rate. Thus, this system introduces a method to compute angular orientation by the time integral of rotation rate.

Reference Designs

The SensorTile Reference Designs provide complete, end-to-end experience in development of a system. This experience prepares developers for innovation and implementation of new systems.

1) [Reference Design 1: STMicroelectronics SensorTile Reference Design: Motion-Controlled Audio Signal Processing System]

This Reference Design includes a SensorTile system that integrates development experience from the previous Tutorials. These Tutorials should all be completed prior to starting on this Reference Design. This system combines capability for motion detection with audio signal processing. It produces a Sensor Tile system that detects the users motion and orientation of the SensorTile to control audio signal processing.

Frequently Asked Question List

A Frequently Asked Questions List for the SensorTile System is constantly being expanded. As questions arrive from the SensorTile Forum, these will be added here.

1. [STMicroelectronics SensorTile Frequently Asked Questions List]

Student Project Reference Designs

Many UCLA students have collaborated in the development of Internet of Things (IoT) SensorTile systems in course projects. The senior capstone design course has included teams who have developed novel systems for motion classification with SensorTile data sources and machine learning methods.

This has included systems with single and dual SensorTile devices along with signal processing, signal feature extraction, neural network design, neural network training, and finally in-field performance analysis.

Reference Designs have been developed by these student teams that include design and development

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development,

If you have questions regarding the Reference Designs, please contact kaiser@ee.ucla.edu.

1) STMicroelectronics SensorTile Reference Design: Basketball Freethrow Classifier by Machine Learning

This Reference Design developed by Alexander Graening and James Xu describes the comprehensive development of a system capable of detecting characteristics of the Basketball Freethrow motion. This relies on the complete set of signal acquisition from SensorTIle systems, signal processing, and machine learning. The SensorTile systems are used in pairs with attachment at upper and lower arm.

2) STMicroelectronics SensorTile Reference Design: Basketball Hookshot Classifier by Machine Learning

This Reference Design developed by Ziyue Yang and Zhitong Qian describes the comprehensive development of a system capable of detecting the characteristic motion of arm and hand associated with optimal and suboptimal Basketball Hookshot motion. The complete description of SensorTIle systems, signal processing, and machine learning development is included The SensorTile systems are used in pairs with attachment at upper and lower arm.

3) STMicroelectronics SensorTile Reference Design: Tennis Motion Classifier by Machine Learning

This Reference Design developed by Bonnie Lam and Gheorge Schreiber describes the another comprehensive development of a system capable of detecting Tennis motion swing types and swing quality. This also relies on the complete set of signal acquisition from SensorTIle systems, signal processing, and machine learning. Here the SensorTile is attached to the tennis racket.

4) STMicroelectronics SensorTile Reference Design: Resistance Training Motion Classifier by Machine Learning

This Reference Design developed by Guang Liew and Zhijie Yao describes another development based on dual SensorTile motion sensors each providing data sources for feature extraction. This system classifies proper and improper resistance training motions by SensorTile data sources and machine learning classifier systems.

5) STMicroelectronics SensorTile Reference Design: Climb On: A Climbing Motion Classifier by Machine Learning

This Reference Design developed by Loic Maxwell and Craig Young describes the development of a unique system that classifies the complex motions occurring in climbing. This classifies proper and improper motion applying dual SensorTile systems and a series of signal processing, feature extraction, and machine learning solutions.

6) STMicroelectronics SensorTile Reference Design: Shoulder Rehabilitation Motion Classifier by Machine Learning

This Reference Design developed by Michael Qi and July Zamora also applies dual SensorTile data sources machine learning system design and performance analysis.