UM2193

User manual

Getting started with MotionAR activity recognition library in X-CUBE-MEMS1 expansion for STM32Cube

Introduction

The MotionAR is a middleware library part of X-CUBE-MEMS1 software and runs on STM32. It provides real-time information on the type of activity performed by the user. It is able to distinguish the following activities: stationary, walking, fast walking, jogging, biking, driving.

This library is intended to work with ST MEMS only.

The algorithm is provided in static library format and is designed to be used on STM32 microcontrollers based on the ARM® Cortex®-M3, ARM® Cortex®-M33, ARM® Cortex®-M4 or ARM® Cortex®-M7 architecture.

It is built on top of STM32Cube software technology that eases portability across different STM32 microcontrollers.

The software comes with sample implementation running on an X-NUCLEO-IKS01A3 or X-NUCLEO-IKS4A1 expansion board on a NUCLEO-F401RE, NUCLEO-L152RE or NUCLEO-U575ZI-Q development board.

1 Acronyms and abbreviations

Table 1. List of acronyms

Acronym	Description
API	Application programming interface
BSP	Board support package
GUI	Graphical user interface
HAL	Hardware abstraction layer
IDE	Integrated development environment

2 MotionAR middleware library in X-CUBE-MEMS1 software expansion

2.1 MotionAR overview

The MotionAR library expands the functionality of the X-CUBE-MEMS1 software.

The library acquires data from the accelerometer and provides information on the type of activity performed by the user.

The library is designed for ST MEMS only. Functionality and performance when using other MEMS sensors are not analyzed and can be significantly different from what described in the document.

Sample implementation is available on X-NUCLEO-IKS01A3 or X-NUCLEO-IKS4A1 expansion boards, mounted on a NUCLEO-F401RE, NUCLEO-L152RE or NUCLEO-U575ZI-Q development board.

2.2 MotionAR library

Technical information fully describing the functions and parameters of the MotionAR APIs can be found in the MotionAR_Package.chm compiled HTML file located in the Documentation folder.

2.2.1 MotionAR library description

The MotionAR activity recognition library manages data acquired from accelerometer; it features:

- possibility to distinguish the following activities: stationary, walking, fast walking, jogging, biking, driving
- recognition based on accelerometer data only
- required accelerometer data sampling frequency: 16 Hz
- resources requirements:
  - Cortex-M3: 8.5 kB of code and 1.4 kB of data memory
  - Cortex-M33: 7.8 kB of code and 1.4 kB of data memory
  - Cortex-M4: 7.9 kB of code and 1.4 kB of data memory
  - Cortex-M7: 8.1 kB of code and 1.4 kB of data memory
- available for ARM Cortex-M3, Cortex-M33, Cortex-M4 and Cortex-M7 architectures

2.2.2 MotionAR APIs

The MotionAR APIs are:

- `uint8_t MotionAR_GetLibVersion(char *version)`
  - retrieves the version of the library
  - `*version` is a pointer to an array of 35 characters
  - returns the number of characters in the version string
- `void MotionAR_Initialize(void)`
  - performs MotionAR library initialization and setup of the internal mechanism
  - the CRC module in STM32 microcontroller (in RCC peripheral clock enable register) has to be enabled before using the library

Note: This function must be called before using the accelerometer calibration library.

- `void MotionAR_Reset(void)`
  - resets activity recognition algorithms

- `void MotionAR_Update(MAR_input_t *data_in, MAR_output_t *data_out, int64_t timestamp)`
  - executes activity recognition algorithm
  - `*data_in` parameter is a pointer to a structure with input data
  - the parameters for the structure type `MAR_input_t` are:
    - acc_x is accelerometer sensor value in X axis in g
    - acc_y is accelerometer sensor value in Y axis in g
    - acc_z is accelerometer sensor value in Z axis in g
  - `*data_out` parameter is a pointer to enum with the following items:
    - `MAR_NOACTIVITY = 0`
    - `MAR_STATIONARY = 1`
    - `MAR_WALKING = 2`
    - `MAR_FASTWALKING = 3`
    - `MAR_JOGGING = 4`
    - `MAR_BIKING = 5`
    - `MAR_DRIVING = 6`
  - `timestamp` is a relative time for actual sample in ms
- `void MotionAR_SetOrientation_Acc(const char *acc_orientation)`
  - sets the accelerometer data orientation
  - configuration is usually performed immediately after the `MotionAR_Initialize` function call
  - `*acc_orientation` parameter is a pointer to a string of three characters indicating the direction of each of the positive orientations of the reference frame used for accelerometer data output, in the sequence x, y, z. Valid values are: n (north) or s (south), w (west) or e (east), u (up) or d (down)
  - As shown in the figure below, the X-NUCLEO-IKS4A1 accelerometer sensor has an SEU (x-South, y-East, z-Up), so the string is: “seu”.

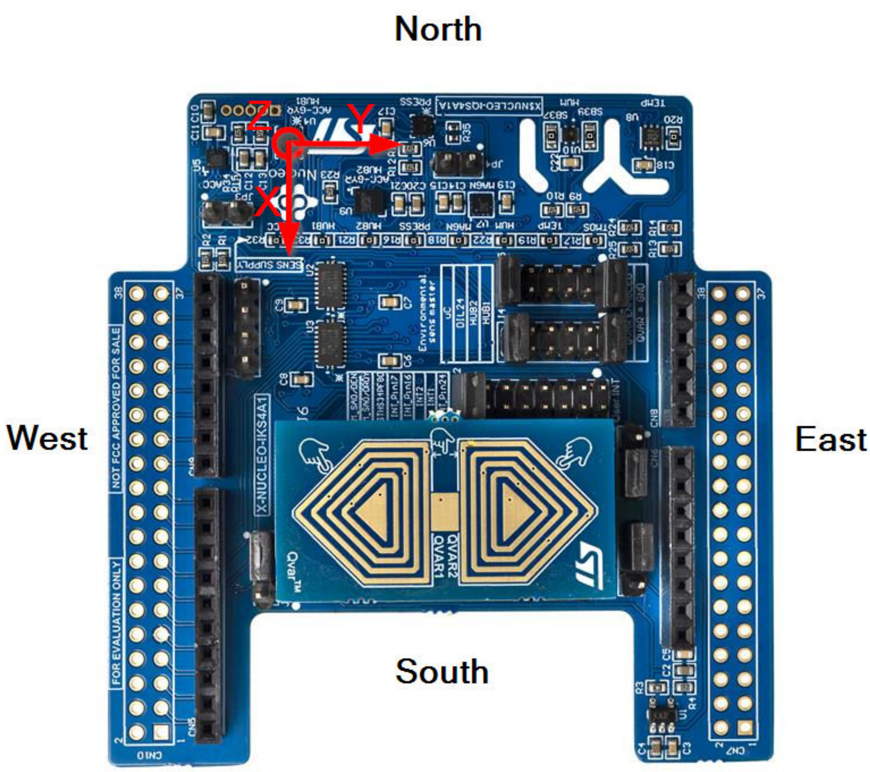
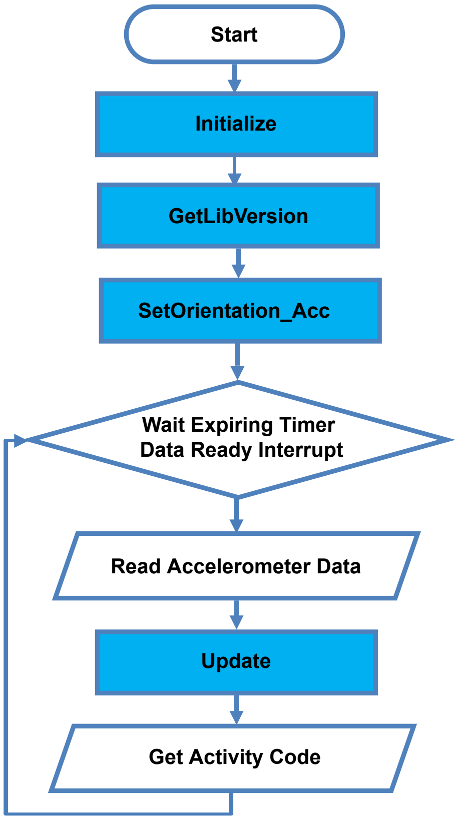


Figure 1. Sensor orientation example

2.2.3 API flow chart

Figure 2. MotionAR API logic sequence



2.2.4 Demo code

The following demonstration code reads data from accelerometer sensor and gets the activity code.

```
[…]
#define VERSION_STR_LENG 35
[…]

/*** Initialization ***/
char lib_version[VERSION_STR_LENG];
char acc_orientation[] = "seu";

/* Activity recognition API initialization function */
MotionAR_Initialize();

/* Optional: Get version */
MotionAR_GetLibVersion(lib_version);

/* Set accelerometer orientation */

MotionAR_SetOrientation_Acc(acc_orientation);

[…]

/*** Using activity recognition algorithm ***/
Timer_OR_DataRate_Interrupt_Handler()
{
```

```
MAR_input_t data_in;
MAR_output_t activity;

/* Get acceleration X/Y/Z in g */
MEMS_Read_AccValue(&data_in.acc_x, &data_in.acc_y, &data_in.acc_z);

/* Get current time in ms */
TIMER_Get_TimeValue(&timestamp_ms);

/* Activity recognition algorithm update */
MotionAR_Update(data_in, data_out, timestamp_ms);
}
```

2.2.5 Algorithm performance

The activity recognition algorithm only uses data from the accelerometer and runs at a low frequency (16 Hz) to reduce power consumption.

Table 2. Algorithm performance

Activity	Detection probability (typical)(1)	Best performance	Susceptible	Carry positions
Stationary	92.27%		Holding in hand and heavy texting	All: trouser pocket, shirt pocket, back pocket, near the head, etc.
Walking	99.44%	Step rate ≥ 1.4 step/s	Step rate ≤ 1.2 step/s	all
Fast walking	95.94%	Step rate ≥ 2.0 step/s		All
Jogging	98.49%	Step rate ≥ 2.2 step/s	Duration < 1 minute; speed < 8 Km/h	Trouser pocket, arm swing, in-hand
Biking	91.93%	Outdoor speed ≥11 Km/h	Passenger seat, glove compartment	Backpack, shirt pocket, trouser pocket
Driving	78.65%	Speed ≥ 48 Km/h	Passenger seat, glove compartment	Cup holder, dash board, shirt pocket, trouser pocket

1. *Typical specifications are not guaranteed*

Table 3. Cortex-M4 and Cortex-M3: Elapsed time (µs) algorithm

Cortex-M4 STM32F401RE at 84 MHz			Cortex-M3 STM32L152RE at 32 MHz		
Min	Avg	Max	Min	Avg	Max
2	6	153	8	130	4883

Table 4. Cortex-M33 and Cortex-M7: elapsed time (µs) algorithm

Cortex-M33 STM32U575ZI-Q at 160 MHz			Cortex-M7 STM32F767ZI at 96 MHz		
Min	Avg	Max	Min	Avg	Max
< 1	2	74	5	9	145

3 Sample application

The MotionAR middleware can be easily manipulated to build user applications; a sample application is provided in the Application folder.

It is designed to run on a NUCLEO-F401RE, NUCLEO-L152RE or NUCLEO-U575ZI-Q development board connected to an X-NUCLEO-IKS01A3 or X-NUCLEO-IKS4A1 expansion board.

The application recognizes performed activities in real-time. Data can be displayed through a GUI. The algorithm recognizes stationary, walking, fast walking, jogging, bike riding and driving activities.

USB cable connection is required to monitor real-time data. The board is powered by the PC via USB connection. This allows the user to display the activity detected, accelerometer data, time stamp and eventually other sensor data, in real-time, using the MEMS-Studio GUI application.

4 MEMS-Studio application

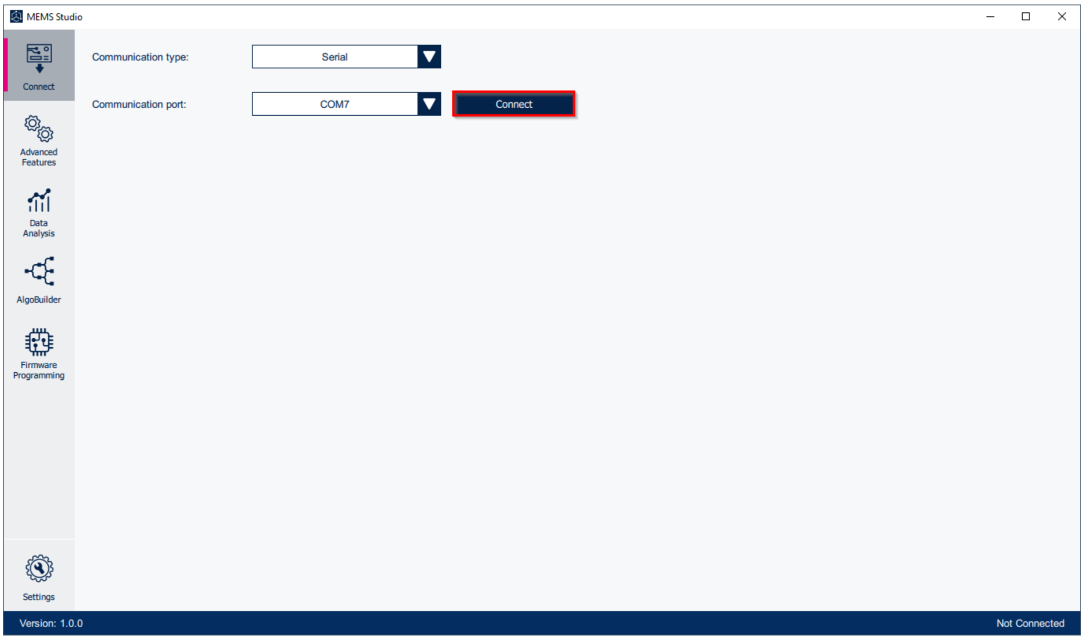
The sample application uses the MEMS-Studio GUI application, which can be downloaded from www.st.com.

Step 1. Ensure that the necessary drivers are installed and the STM32 Nucleo board with appropriate expansion board is connected to the PC.

Step 2. Launch the MEMS-Studio application to open the main application window.

If an STM32 Nucleo board with supported firmware is connected to the PC, it is automatically detected the appropriate COM port. Press **Connect** button to open this port.

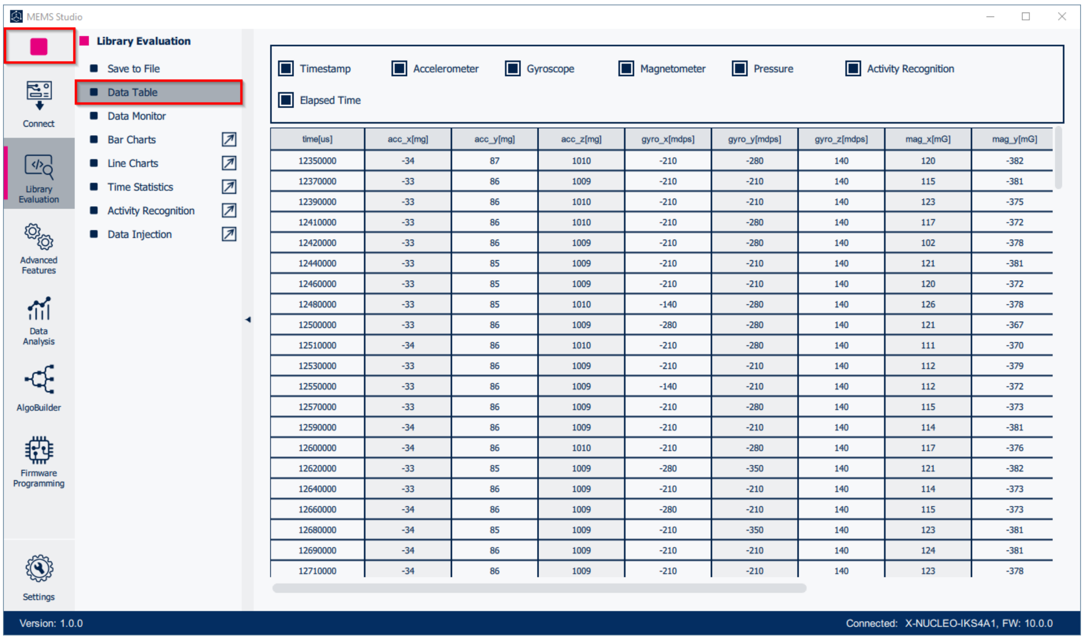
Figure 3. MEMS-Studio - Connect



Step 3. When connected to STM32 Nucleo board with supported firmware *Library Evaluation* tab is opened.

To start and stop data streaming toggle the appropriate start / stop button on the outer vertical tool bar.
The data coming from the connected sensor can be viewed selecting the *Data Table* tab on the inner vertical tool bar.

Figure 4. MEMS-Studio - Library Evaluation - Data Table

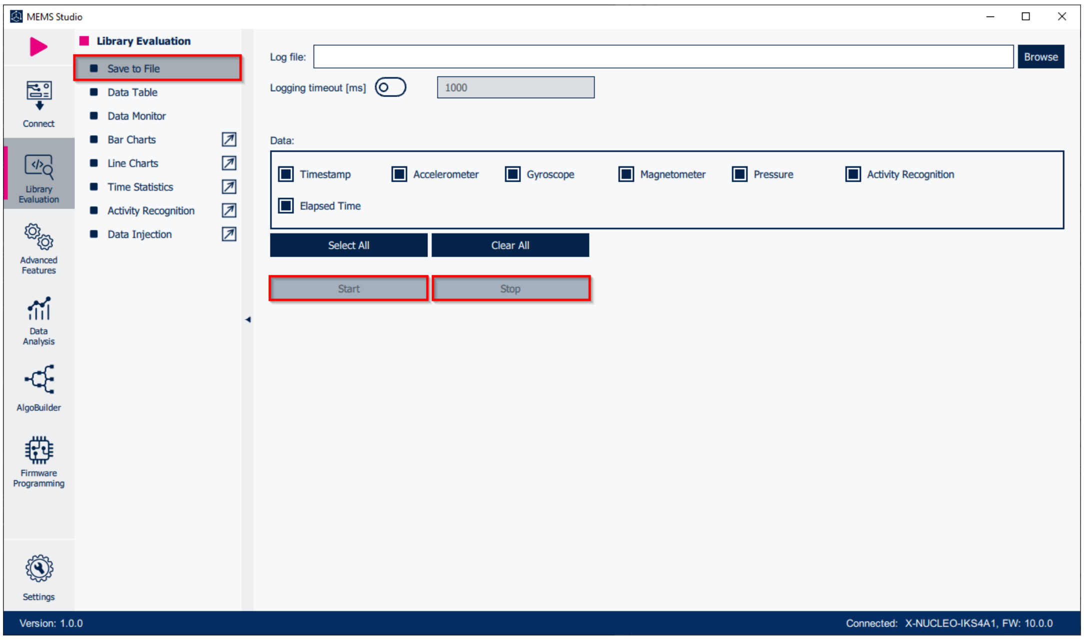


Step 4. Select the *Activity Recognition* tab on the inner vertical tool bar to open the dedicated application status view.

Figure 5. MEMS-Studio - Library Evaluation - Activity Recognition

Step 5. Select the *Save to File* tab on the inner vertical tool bar to open the data logging configuration window. Select which sensor and activity data to save to log file. You can start or stop saving by clicking on the corresponding Start / Stop button.

Figure 6. MEMS-Studio - Library Evaluation - Save to File



5 References

All of the following resources are freely available on www.st.com.

1. UM1859: Getting started with the X-CUBE-MEMS1 motion MEMS and environmental sensor software expansion for STM32Cube
2. UM1724: STM32 Nucleo-64 boards (MB1136)
3. UM3233: Getting started with MEMS-Studio

Revision history

Table 5. Document revision history

Date	Version	Changes
10-Apr-2017	1	Initial release.
26-Jan-2018	2	Updated Section 3 Sample application. Added references to NUCLEO-L152RE development board and Table 3. Elapsed time (µs) algorithm.
19-Mar-2018	3	Updated Introduction, Section 2.1 MotionAR overview and Section 2.2.5 Algorithm performance.
14-Feb-2019	4	Updated Figure 1. Sensor orientation example, Table 3. Elapsed time (µs) algorithm and Figure 3. STM32 Nucleo: LEDs, button, jumper. Added X-NUCLEO-IKS01A3 expansion board compatibility information.
20-Mar-2019	5	Updated *Section 2.2.2 MotionAR APIs, Figure 3. MEMS-Studio - Connect, Figure 4. MEMS-Studio - Library Evaluation - Data Table, Figure 5. MEMS-Studio - Library Evaluation - Activity Recognition* and *Figure 6. MEMS-Studio - Library Evaluation - Save to File.*
04-Apr-2024	6	Update Section Introduction, Section 2.1: MotionAR overview, Section 2.2.1: MotionAR library description, MotionAR APIs, Section 2.2.4: Demo code, Section 2.2.5: Algorithm performance, Section 3: Sample application and Section 4: MEMS-Studio application.

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