Getting started with MotionPW real-time pedometer for wrist library in X-CUBE-MEMS1 expansion for STM32Cube

Introduction

The MotionPW middleware library is part of the X-CUBE-MEMS1 software and runs on STM32 Nucleo. It provides real-time information about the number of steps and cadence which the user just performed with the wearable device (e.g. a smart watch).

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 or ARM® Cortex®-M4 architecture.

It is built on top of STM32Cube software technology to ease portability across different STM32 microcontrollers.

The software comes with sample implementation running on X-NUCLEO-IKS01A2 or X-NUCLEO-IKS01A3 expansion board on a NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-L152RE 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 MotionPW middleware library in X-CUBE-MEMS1 software expansion for STM32Cube

2.1 MotionPW overview

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

The library acquires data from the accelerometer and provides information about the number of steps and cadence the user just performed with the wearable device.

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.

A sample implementation is available for X-NUCLEO-IKS01A2 and X-NUCLEO-IKS01A3 expansion boards, mounted on aNUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-L152RE development board.

2.2 MotionPW library

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

2.2.1 MotionPW library description

The MotionPW pedometer library manages the data acquired from the accelerometer; it features:

- possibility of detecting the number of steps, cadence and confidence
- recognition based on accelerometer data only
- required accelerometer data sampling frequency of 50 Hz
- resources requirements:
  - Cortex-M3: 3.5 kB of code and 1.8 kB of data memory
  - Cortex-M4: 3.3 kB of code and 1.8 kB of data memory
- available for ARM® Cortex®-M3 and ARM® Cortex®-M4 architectures

2.2.2 MotionPW APIs

The MotionPW library APIs are:

- `uint8_t MotionPW_GetLibVersion(char *version)`
  - retrieves the library version
  - `*version` is a pointer to an array of 35 characters
  - returns the number of characters in the version string

- `void MotionPW_Initialize(void)`
  - performs MotionPW library initialization and setup of the internal mechanism including the dynamic memory allocation
  - 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 pedometer for wrist library.

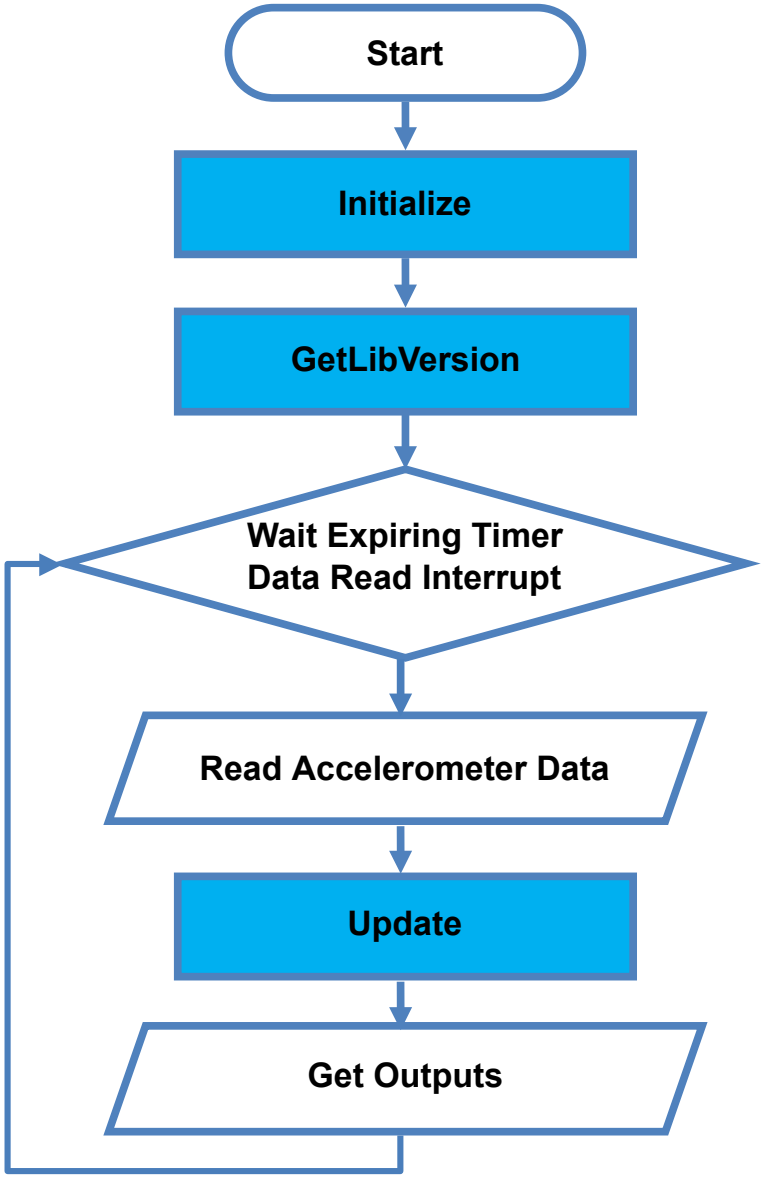
- `void MotionPW_Update(MPW_input_t *data_in, MPW_output_t *data_out)`
  - executes pedometer for wrist algorithm
  - `*data_in` parameter is a pointer to a structure with input data
  - the parameters for the structure type `MPW_input_t` are:
    - `AccX` is the accelerometer sensor value in X axis in g
    - `AccY` is the accelerometer sensor value in Y axis in g
    - `AccZ` is the accelerometer sensor value in Z axis in g
  - `currentActivity` is the enumerated input type `MPW_activity_t` with the following values:
    - MPW_UNKNOWN_ACTIVITY = 0x00

    - MPW_WALKING = 0x01
    - MPW_FASTWALKING = 0x02
    - MPW_JOGGING = 0x03
  - `*data_out` parameter is a pointer to a structure with output data
  - the parameters for the structure type `MPW_output_t` are:
    - `Nsteps` is number of steps performed by user
    - `Cadence` is the cadence of user steps
    - `Confidence` is the confidence of calculated output parameter

- `void MotionPW_ResetPedometerLibrary(void)`
  - resets the library internal variables and mechanism into default values (including current step count)
- `void MotionPW_ResetStepCount(void)`
  - resets the current step count

2.2.3 API flow chart

Figure 1. MotionPW API logic sequence



2.2.4 Demo code

The following demonstration code example reads data from the accelerometer sensor, obtains the current activity from MotionAW library and gets the number of steps, cadence and confidence.

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

/*** Initialization ***/
char lib_version[VERSION_STR_LENG];

/* Pedometer API initialization function */
MotionPW_manager_init(ACCELERO_handle);

/* Activity recognition API initialization function */
MotionAW_manager_init(ACCELERO_handle);
```

```
/* OPTIONAL */
/* Get library version */
  MotionPW_manager_get_version(lib_version, &lib_version_len);

[…]

/*** Using Pedometer for wrist algorithm ***/
Timer_OR_DataRate_Interrupt_Handler()
{
  MPW_input_t MPW_data_in;
  MPW_output_t MPW_data_out;
  MAW_input_t MAW_data_in;
  MAW_output_t MAW_data_out;

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

  /* Get current activity */
  MotionAW_Update(&MAW_data_in, &MAW_data_out);

  /* Run pedometer for wrist algorithm */
  MotionPW_manager_run(&MPW_data_in, &MPW_data_out);


}
```

2.2.5 Algorithm performance

The pedometer for wrist algorithm uses data from the accelerometer only and runs at a low frequency (50 Hz) to reduce power consumption.

Table 2. Elapsed time (µs) algorithm

Cortex-M4 STM32F401RE at 84 MHz									Cortex-M3 STM32L152RE at 32 MHz								
SW4STM32 2.6.0 (GCC 7.2.1)			IAR EWARM 7.80.4			Keil µVision 5.24			SW4STM32 2.6.0 (GCC 7.2.1)			IAR EWARM 7.80.4			Keil µVision 5.24		
Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
2	134	1920	40	50	615	40	101	1291	11	762	5979	298	369	2928	325	588	4951

2.3 Sample application

The MotionPW 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-L476RG or NUCLEO-L152RE development board connected to an X-NUCLEO-IKS01A2 or X-NUCLEO-IKS01A3 expansion board.

The application recognizes the steps, cadence and confidence in real-time. The data can be displayed through a GUI or stored in the board for offline analysis.

Stand-alone mode

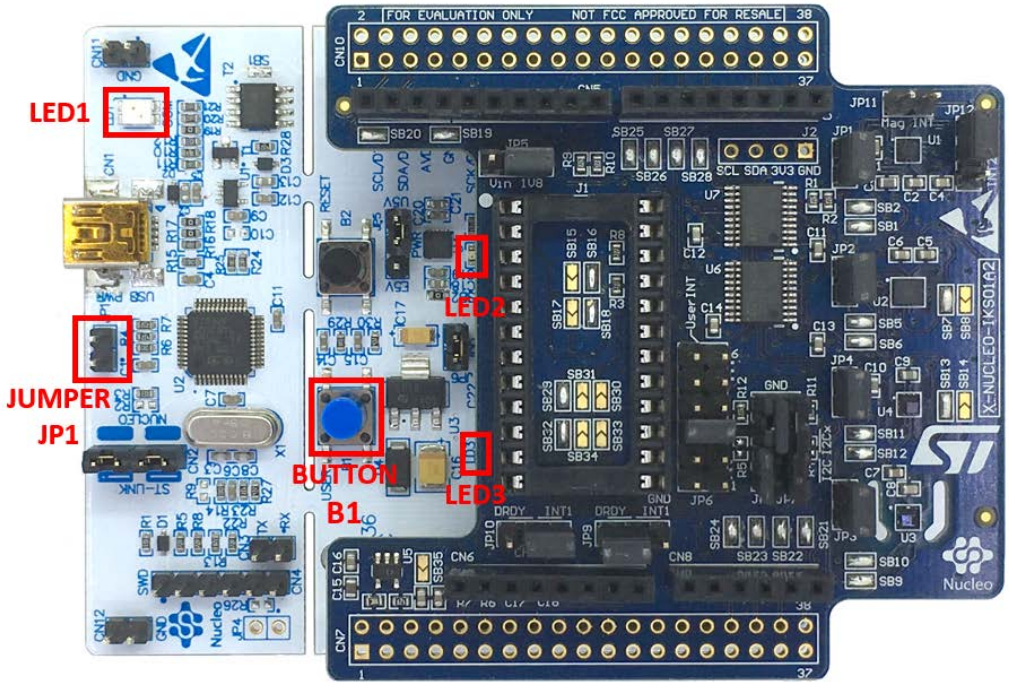
In stand-alone mode, the sample application allows the user to detect performed steps, cadence and confidence and store them in the MCU flash memory.

The STM32 Nucleo board may be supplied by a portable battery pack (to make the user experience more comfortable, portable and free of any PC connections).

Table 3. Power supply scheme

Power source	JP1 settings	Working mode
USB PC cable	JP1 open	PC GUI driven mode
Battery pack	JP1 closed	Stand-alone mode

Figure 2. **STM32 Nucleo: LEDs, button, jumper**



The above figure shows the user button B1 and the three LEDs of the NUCLEO-F401RE board. Once the board is powered, LED LD3 (PWR) turns ON and the tricolor LED LD1 (COM) begins blinking slowly due to the missing USB enumeration (refer to UM1724 on www.st.com for further details).

Note: After powering the board, LED LD2 blinks once indicating the application is ready.

When the user button B1 is pressed, the system starts acquiring data from the accelerometer sensor and detects the steps, cadence and confidence; during this acquisition mode, a fast LED LD2 blinking indicates that the algorithm is running. During this phase, the detected steps and cadence are stored in the MCU internal flash memory. Data are automatically saved every 5 minutes to avoid excessive data loss in case of an unforeseen power fault.

Pressing button B1 a second time stops the algorithm and data storage and LED LD2 switches off.

Pressing the button again starts the algorithm and data storage once again.

The flash sector dedicated to data storage is 128 KB, allowing memorization of more than 16,000 data sets.

To retrieve those data, the board has to be connected to a PC, running Unicleo-GUI. When stored data is retrieved via the GUI, the MCU flash sector dedicated to this purpose is cleared.

If LED LD2 is ON after powering the board, it represents a warning message indicating the flash memory is full.

Note: Optionally, the MCU memory can be erased by holding the user push buttondown for at least 5 seconds. LED LD2 switches OFF and then blinks 3 times to indicate that the data stored in the MCU has been erased. This option is available only after power ON or reset of the board while LED LD2 is ON indicating the flash memory is full.

When the application runs in stand-alone mode and the flash memory is full, the application switches to PC GUI drive mode and LED LD2 switches OFF.

The flash memory must be erased by downloading data via the Unicleo-GUI or the user push button (see the above note).

PC GUI drive mode

In this mode, a USB cable connection is required to monitor real-time data. The board is powered by the PC via USB connection. This working mode allows the user to display detected steps, cadence and confidence, accelerometer data, time stamp and eventually other sensor data, in real-time, using the Unicleo-GUI.

In this working mode, data are not stored in the MCU flash memory.

2.4 Unicleo-GUI application

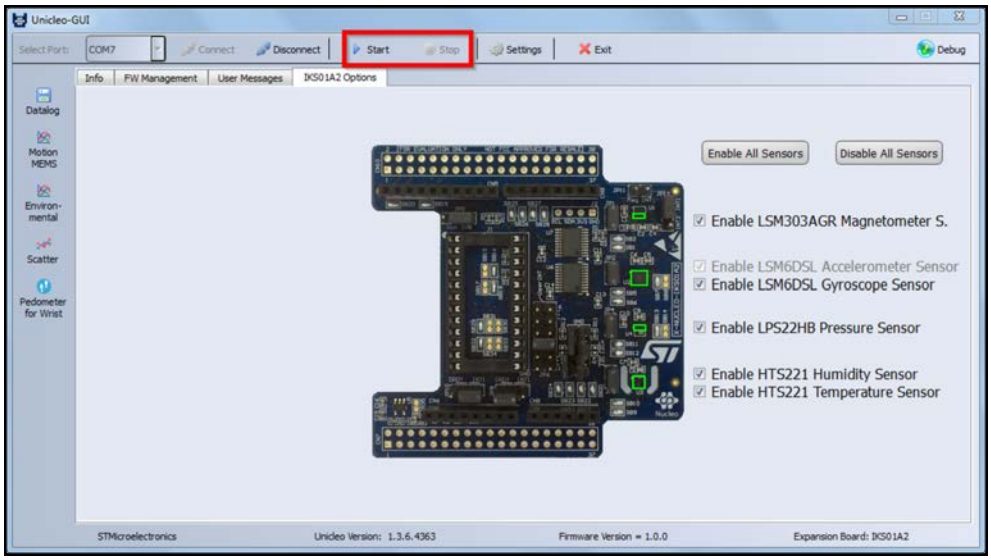
The sample application uses the Windows Unicleo-GUI utility, which can be downloaded from www.st.com.

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 Unicleo-GUI application to open the main application window.

If an STM32 Nucleo board with supported firmware is connected to the PC, it is automatically detected and the appropriate COM port is opened.

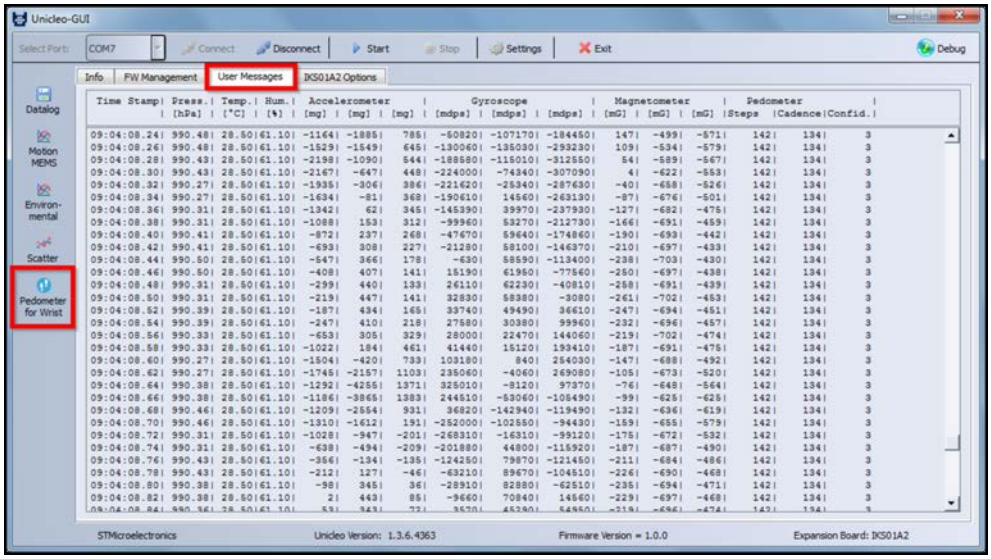
Figure 3. Unicleo-GUI main window



Step 3. Start and stop data streaming by using the appropriate buttons on the vertical tool bar.

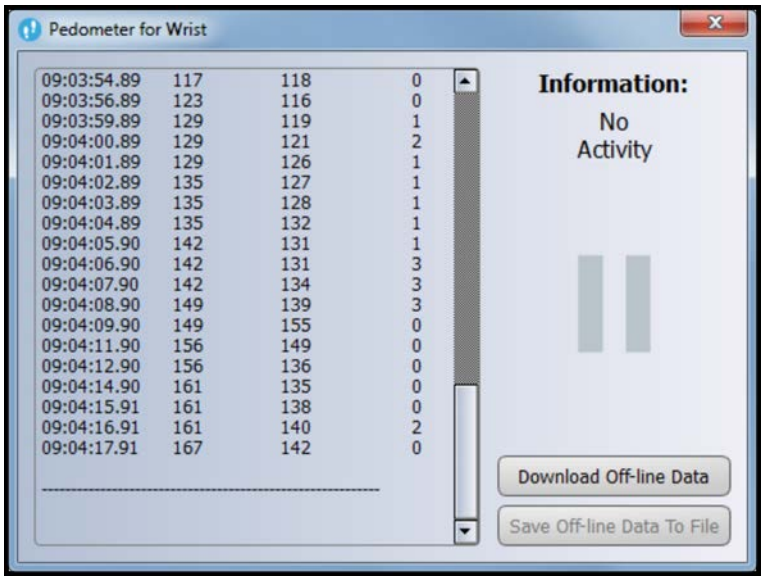
The data coming from the connected sensor can be viewed in the User Messages tab.

Figure 4. User Messages tab



Step 4. Click on the Pedometer for wrist icon in the vertical tool bar to open the dedicated application window.

Figure 5. **Pedometer for wrist window**



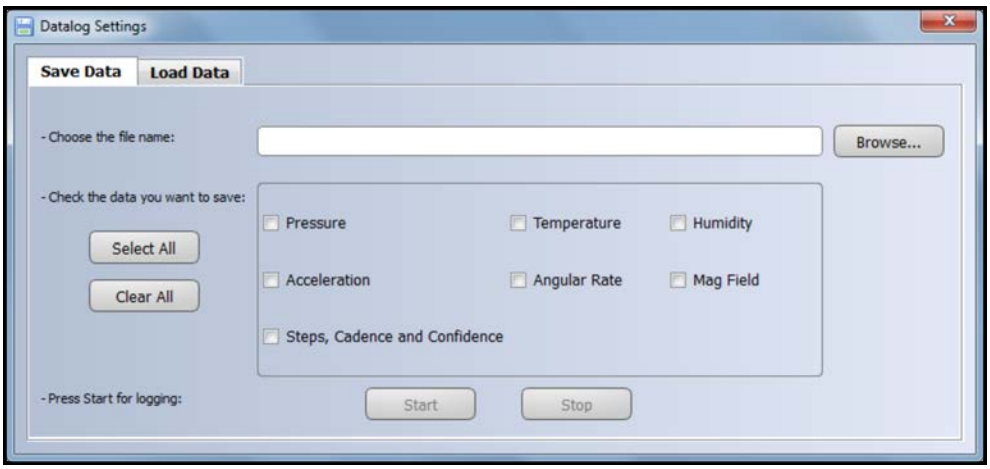
If the board has been working in stand-alone mode and the user wants to retrieve stored data, press **Download Off-line Data** button to upload the stored activities data to the application. This operation automatically deletes acquired data from microcontroller.

Press the **Save Off-line Data to File** button to save the uploaded data in a .tsv file.

Step 5. Click on the Datalog icon in the vertical tool bar to open the datalog configuration window:

you can select which sensor and activity data to save in files. You can start or stop saving by clicking on the corresponding button.

Figure 6. **Datalog settings window**



3 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 board
3. UM2128: Getting started with Unicleo-GUI for motion MEMS and environmental sensor software expansion for STM32Cube

Revision history

Table 4. **Document revision history**

Date	Version	Changes
24-Jan-2018	1	Initial release.
21-Mar-2018	2	Updated Introduction and Section 2.1 MotionPW overview.
20-Feb-2019	3	Updated Table 2. Elapsed time (µs) algorithm and Figure 2. STM32 Nucleo: LEDs, button, jumper. Added X-NUCLEO-IKS01A3 expansion board compatibility information.

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