UM1866
User manual

Getting started with the osxMotionFx fusion and compass library for X-CUBE-MEMS1 expansion for STM32Cube

Introduction

This user manual describes the osxMotionFX fusion and compass calibration library. The osxMotionFX suite is filtering and predictive software. It uses advanced algorithms to integrate outputs from multiple MEMS sensors in a "smart" way, independent of environmental conditions, to reach optimum performance. osxMotionFX is an add-on software package for the X-CUBE-MEMS1 expansion for STM32Cube. This manual also provides an overview of the sample application using the library APIs and running on the STM32 Nucleo equipped with the X-NUCLEO-IKS01A1 expansion board. Finally, it presents an overview of the software installer used to install the software package on a Windows PC. The software is based on STM32Cube technology and expands STM32Cube-based packages. Information about STM32Cube is available on www.st.com at: http://www.st.com/stm32cube.

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1 osxMotionFX library add-on of X-CUBE-MEMS1 software, expansion for STM32Cube

1.1 Overview

The osxMotionFX library is a software package that expands the functionality provided by X-CUBE-MEMS1 software.

The key features of the package are:

- Complete middleware to build applications using temperature and humidity sensors (HTS221), a pressure sensor (LPS25HB) and motion sensors (LIS3MDL and LSM6DS0)
- Gyroscope bias and magnetometer offset calibration routine
- osxMotionFX (iNEMOEngine PRO) real-time motion sensor data fusion (under OPEN.MEMS license)
- Easy portability across different MCU families, thanks to STM32Cube
- Sample application to transmit real-time sensor and sensor fusion data to a PC
- Sample implementation available on board X-NUCLEO-IKS01A1 when connected to NUCLEO-F401RE or NUCLEO-L476RG

The osxMotionFX (iNEMOEngine PRO) suite is filtering and predictive software. It uses advanced algorithms to integrate outputs from multiple MEMS sensors in a "smart" way, independent of environmental conditions, to reach optimum performance.

The software comes with a sample application running on X-NUCLEO-IKS01A1, when connected to a NUCLEO-F401RE or a NUCLEO-L476RG.

1.2 Architecture

This software is an expansion for X-CUBE-MEMS1 software.

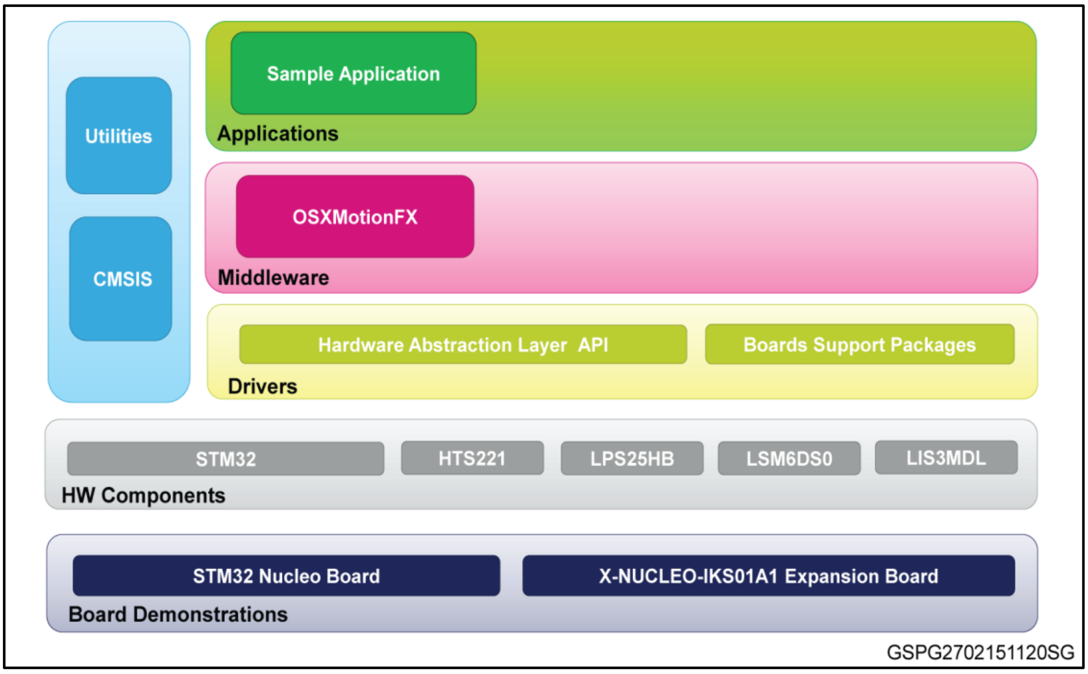
The package extends STM32Cube by providing a middleware component for the osxMotionFX library.

The software layers used by the application software to access and use the sensor expansion board are the following:

- STM32Cube HAL layer: The HAL driver layer provides a generic multi-instance simple set of APIs (application programming interfaces) to interact with the upper layers (application, libraries and stacks). It is composed of generic and extension APIs. It is directly built around a generic architecture and allows the layers that are built upon, such as the middleware layer, to implement their functionalities without dependencies on the specific hardware configuration for a given microcontroller unit (MCU). This structure improves library code reusability and guarantees easy portability to other devices.
- Board support package (BSP) layer: The software package needs to support the peripherals on the STM32 Nucleo board apart from the MCU. This software is included in the board support package (BSP). This is a limited set of APIs which provides a programming interface for certain board specific peripherals, e.g. the LED, user button, etc. This interface also helps in identifying the specific board version. If the sensor expansion board is used, it provides the programming interface for various inertial and environmental sensors. It provides support for initializing and reading sensor data.

The diagram below outlines the software architecture of the package:

Figure 1: osxMotionFX plus X-CUBE-MEMS1 software architecture

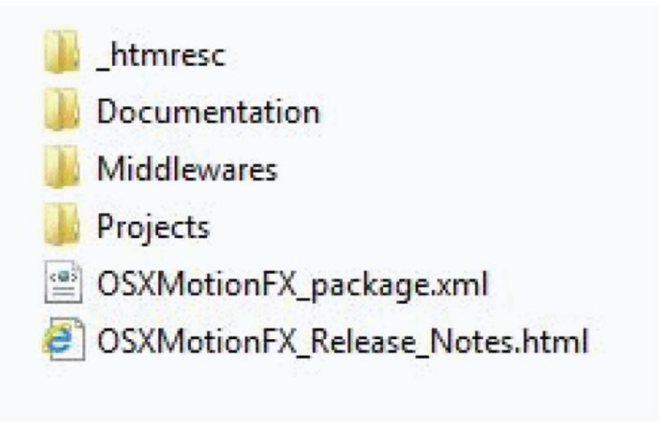


1.3 Folders structure

This section provides an overview of the package folders structure.

The image below outlines the architecture of the package

Figure 2: osxMotionFX package folder structure



The following folders are included in the software package:

- **Documentation**: this folder contains a compiled HTML file generated from the source code and documenting in detail the software components and APIs.
- **Middlewares**: this folder contains the osxMotionFX library binary code, documentation and license information.
- **Projects**: this folder contains a sample application used to access sensor and sensor fusion data, provided for the NUCLEO-F401RE and the NUCLEO-L476RG platforms

with three development environments (IAR Embedded Workbench for ARM, RealView Microcontroller Development Kit (MDK-ARM), System Workbench for STM32).

1.4 APIs

Detailed technical information about the APIs of osxMotionFX and compass calibration libraries can be found in a compiled HTML file, named OSXMotionFX_Package.chm, and located in the Documentation folder of the software package, where all the functions and parameters are fully described.

The osxMotionFX engine is provided as a node-locked library which allows derivative firmware images to run on a specific STM32 Nucleo device only. Licensing activation codes must to be requested from ST and included in the project (and will become part of the build process) prior to attempting its usage. The resulting firmware binary image will therefore be node-locked.

For complete information about the open.MEMS license agreement, please refer to the license file located in the Middlewares/ST/STM32_OSX_MotionFX_Library folder.

1.5 Sample application description

A sample application of osxMotionFX fusion and compass calibration using the sensor expansion board with the NUCLEO-F401RE board or the NUCLEO-L476RG board can be found into the Projects folder of the software package.

In this application, sensor and sensor fusion data are transmitted in real-time from the Nucleo board to PC via UART interface. Transmitted data can be viewed using Sensors_DataLog application, a PC-based application developed by STMicroelectronics included in the X-CUBE-MEMS1 package (refer to *section 1.6* for detailed usage of utility) that reads and visualizes the sensors data and the sensor fusion data. For more information about MotionFX engine refer to *paragraph 1.5.1*.

When the board is powered on, the compass is not calibrated. When the compass is not calibrated, LED2 (green LED) of the Nucleo board is off. In order to calibrate the compass, press the user button on the Nucleo board and perform the 8-movement calibration (see *paragraph 1.5.2* for details). You can calibrate the compass only when the sensor fusion is activated (press the "Start Sensor Fusion" button on the PC GUI). When the calibration is done, LED2 turns on and the compass points to the north.

By default, the calibration data is stored in RAM memory in order to be preserved when the board is reset. It is also possible to store calibration data in Flash memory. To do this, you need to compile the sample application "DataLogFusion" defining "OSXMOTIONFX_STORE_CALIB_FLASH" in the project.

By default, the application uses the fusion 9X (accelerometer + gyroscope + magnetometer). You can switch dynamically from fusion 9X to fusion 6X (accelerometer + gyroscope), pushing the apposite button on the “Sensors_DataLog” GUI. When using the fusion 6X, the compass calibration is no longer required.

1.5.1 6-axis and 9-axis sensor fusion osxMotionFX library

The osxMotionFX library implements sensor fusion algorithm for estimation of 3D orientation in space. It uses digital filter based on Kalman theory to fuse data from several sensors. Using this method it compensates for limitations of single sensors. For instance a gyroscope suffers from data drift that can affect the orientation estimation. This can be fixed by using the magnetometer that provides absolute orientation value. On the contrary magnetometer has not a very high bandwidth and suffers of magnetic disturbance; all these weaknesses can be compensated through the usage of gyroscope. 9-axis sensor fusion utilizes data from accelerometer, gyroscope and magnetometer (A+G+M) and provides absolute orientation in 3D space including heading i.e. magnetic North direction. 6-axis sensor fusion utilizes data from accelerometer and gyroscope (A+G), it does not use magnetometer. It has lower computational requirements, but it does not provide information about absolute orientation of the device. 6-axis sensor fusion is good for fast movements (e.g. for gaming) and when absolute orientation is not necessary. The osxMotionFX library contains both 6 and 9-axis sensor fusion. 6-axis and 9-axis sensor fusion algorithms are integrated in one library. They can even be running simultaneously.The osxMotionFX library has two very important internal functions which execute the sensor fusion computation: osx_MotionFX_propagate and osx_MotionFX_update. The osx_MotionFX_propagate is a prediction function and it is used to estimate the orientation in 3D space. This phase weights more gyroscope data. The osx_MotionFX_update is the function of correction. It is used to correct, if needed, the prediction solution. It weighs more accelerometer and magnetometer data. The osx_MotionFX_update function can be called either every time the osx_MotionFX_propagate is invoked or less in systems that have less computation power. The osx_MotionFX_update function takes approximately three times more computation time of the MCU compared to the osx_MotionFX_propagate function.

The typical operation flow of the osxMotionFX library can be summarized with the following steps:

1. Initialize sensors
2. Initialize the sensor fusion library and calibration library (osx_MotionFX_initialize and osx_MotionFX_compass_init)
3. Setup parameters of the library in a Knobs structure (osx_MotionFX_getKnobs and osx_MotionFX_setKnobs)
4. Start 6-axis or 9-axis engine (osx_MotionFX_enable_6X or osx_MotionFX_enable_9X)
5. At a selected output data rate of sensor fusion do regularly (e.g. using a timer of MCU or data ready signal from one of the sensors):
   – Read and convert data from sensors
   – Call osx_MotionFX_propagate
   – Call osx_MotionFX_update

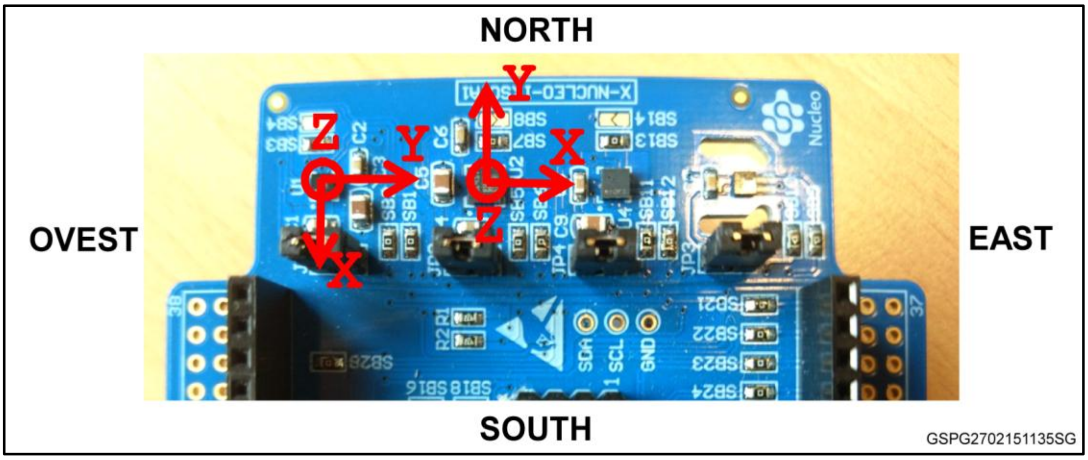
Both osx_MotionFX_propagate and osx_MotionFX_update functions take as an input sensor data and both of them also provide output data of Sensor Fusion library.

The osxMotionFX library is parameterized using a Knobs structure:

```
typedef struct
{
  float ATime;                           /*  merge rate to the accel                  */
  float MTime;                           /*  merge rate to the mag                    */
  float FrTime;                          /*  merge rate to the accel when external
accelerations occurs  */
  unsigned char LMode;                   /*  gyro bias learn mode,
                                                                1-static learning
                                                                2-dynamic learning
*/
  float gbias_mag_th_sc_6X;          /*  scaler for the gyro bias mag threshold nominal    */
  float gbias_acc_th_sc_6X;          /*  scaler for the gyro bias mag threshold nominal    */
  float gbias_gyro_th_sc_6X;         /*  scaler for the gyro bias mag threshold nominal    */
  float gbias_mag_th_sc_9X;          /*  scaler for the gyro bias mag threshold nominal    */
  float gbias_acc_th_sc_9X;          /*  scaler for the gyro bias mag threshold nominal    */
  float gbias_gyro_th_sc_9X;         /*  scaler for the gyro bias mag threshold nominal    */
  unsigned char modx;                            /*  setting to indicate the decimation,
                                                        set to 1 in
smartphone/tablet
                                                  set to >=1 in embedded solutions */
  char acc_orientation[QNUM_AXES];           /*  accelerometer data orientation          */
  char gyro_orientation[QNUM_AXES];          /*  gyroscope data orientation              */
  char mag_orientation[QNUM_AXES];           /*  magnetometer data orientation           */
  osxMFX_Engine_Output_Ref_Sys output_type;  /*  0: NED, 1: ENU                          */
  int start_automatic_gbias_calculation;
} osxMFX_knobs;
```

- *ATime*, *MTime* and *FrTime* represent the weighting stability of sensors in prediction (trust to the sensor); they can be a value from 0 to 1; it is recommended to keep default values
- *LMode* represents the gyroscope bias learning mode; the library automatically tracks and calibrates gyro zero-rate bias drift; the possible values of this parameter are:
  - LMode = 0 – learning off: This mode can be used in case gyro is already calibrated
  - LMode = 1 – static learning: Learning is performed only when the system is not moving
  - LMode = 2 – dynamic learning: Learning is performed also when the system is moving
- *gbias_xxx_th_sc* represent the thresholds that define when the gbias algorithm automatically starts. In fact if the data for each axis are below those thresholds, the algorithm for gbias calculation is executed. They should be found by testing (they are different for different part numbers). Values in example project are usually correct
- *modx* represents the decimation of osx_MotionFX_update call frequency. See resources optimization paragraph below for more details
- *acc_orientation*, *gyro_orientation*, *mag_orientation* represent the arrays of 3 characters describing orientation of sensor axis x, y and z. The possible values are: n (north), e (east), s (south), w (west), u (up), d (down). An example is shown in *Figure 3: "Example of x, y, z axis values"*:
- *output_type* represents the Sensor Fusion library output orientation: 0 means NED, 1 means ENU
- *start_automatic_gbias_calculation* represents a flag that restarts gyroscope bias calibration when set to 1

Figure 3: Example of x, y, z axis values



As shown in the *Figure 3: "Example of x, y, z axis values"* first sensor (magnetometer) is oriented SEU (x - South, y - East, z - Up) while the second (accelerometer + gyroscope) is ENU (x - East, y - Nor th, z - Up).

The osx_MotionFX_propagate and the osx_MotionFX_update functions expect input from sensors in osxMFX_input structure:

```
typedef struct
{
  float mag[NUM_AXES];              /*  calibrated mag [uT]/50    */
  float acc[NUM_AXES];              /*  acc [g]                   */
  float gyro[NUM_AXES];             /*  gyro [dps]                */
} osxMFX_input;
```

- *mag* represents magnetometer data after calibration in µT/50
- *acc* represents accelerometer data in g
- *gyro* represents gyroscope data in dps

The osx_MotionFX_propagate and the osx_MotionFX_update functions provide output of the sensor fusion in osxMFX_output structure:

```
typedef struct
{
  float rotation_9X[NUM_AXES];               /*  9 axes yaw, pitch and roll     */
  float quaternion_9X[QNUM_AXES];            /*  9 axes quaternion              */
  float gravity_9X[NUM_AXES];                /*  9 axes device frame gravity    */
  float linear_acceleration_9X[NUM_AXES];    /*  9 axes device frame lin accel  */
  float heading_9X;                          /*  9 axes heading                 */
… similarly for 6-axis SF

} osxMFX_output;
```

- *rotation* represents the orientation of the system in three angles format: yaw, pitch and roll
- *quaternion* represents orientation of the system in four numbers format; this format gives the same information as rotation; it has advantages for computation and therefore it is usually used by other algorithms (which can follow the sensor fusion)
- *gravity* represents the static acceleration (i.e. Earth's gravity) vector extracted from acceleration data
- *linear_acceleration* represents the dynamic acceleration (i.e. movement) vector extracted from acceleration data
- *heading* represents the direction to the magnetic North

Based on practical experience, it is recommended to use 100 Hz as output data rate for the sensor fusion library. For this reason it is important to set-up adequately the output data rate of the sensors. The gyroscope and the accelerometer should use an output data rate more than 100 Hz. The magnetometer can be set to a lower output data rate (i.e. an output data rate of 20/40 Hz is typically good for LIS3MDL sensor).

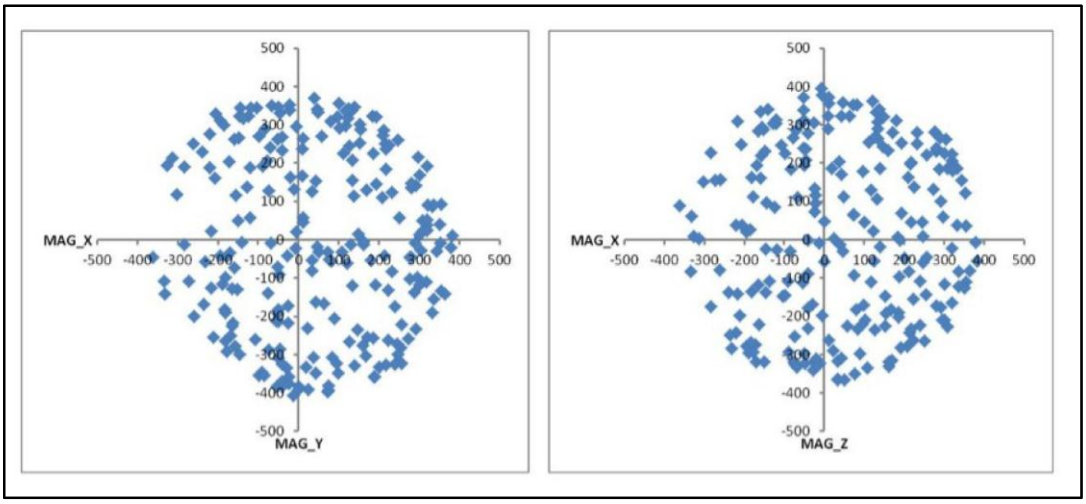
The osxMotionFX library is capable to compute both 6-axis and 9-axis sensor fusion. It can even do it in parallel. The library parameters structure osxMFX_knobs and the library output structure osxMFX_output have several fields which are dedicated to 6-axis and 9-axis respectively. It is only necessary to enable the desired 6-axis or 9-axis operation by calling osx_MotionFX_enable_6X or osx_MotionFX_enable_9X respectively. For 6-axis sensor fusion, magnetometer data are not required.

It is possible to scale the system requirements of the library in terms of MCU/MPU load. The osx_MotionFX_update function is a correction step in the Sensor Fusion algorithm. It requires approximately three times more computation power than osx_MotionFX_propagate function. If systems resources are limited (e.g. in embedded system) this function does not need to be called at the same frequency as the output data rate of the library. Using modx parameter in osxMFX_knobs structure, it is possible to decrease frequency of osx_MotionFX_update function calls. For example, it is possible to set modx equals to 2. Then the osx_MotionFX_propagate function will be called at the output data rate of the Sensor Fusion and the osx_MotionFX_update function will be called only after every second osx_MotionFX_propagate function call. For tablet or other system with MCU/MPU you can set modx to 1, for STM32F4 you can set modx to 1 and for STM32F1 you can set the modx to 2. The library can be used on Cortex-M0 (e.g. STM32L0) as well.

1.5.2 Sensors calibration in the osxMotionFX library

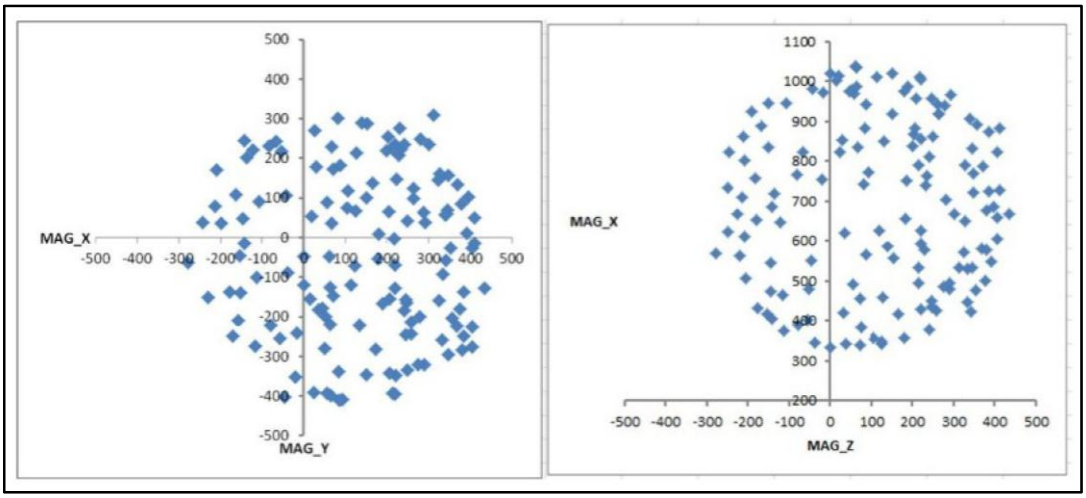
STMicroelectronics produces its sensors with high effort for a precise operation. However there are factors affecting operation of sensors that are often present only in final application. These factors need to be evaluated by users. The osxMotionFX library contains routines for calibration of magnetometer for hard iron effect and gyroscope calibration routines.Hard-iron distortion is normally generated by ferromagnetic material with permanent magnetic fields that are part of the object (e.g. a tablet) in use. These materials could be permanent magnets or magnetized iron or steel. They are time invariant and deform the local geomagnetic field with different offset on different directions. Generally, if the user performs many 3D rotations of the object in an ideal environment (no hard-iron/soft-iron distortion) and plots the collected magnetic sensor raw data, the result will be a perfect sphere with no offset.

Figure 4: Magnetometer data in ideal environment or after calibration



The hard-iron distortion effect is to offset the sphere along the x, y and z axes; in the x-y plane, the hard-iron distortion is identified by an offset of the origin of the ideal circle from (0, 0), scatter plots for XY and XZ axis are ok to see if there is an offset.

Figure 5: Magnetometer data disturbed by hard-iron effect



Soft-iron distortion is generated by magnetically soft materials or current carrying PCB traces. While the hard-iron distortion is constant regardless of the orientation, the soft-iron distortion changes with the orientation of the object in the Earth's field (soft magnetic materials are changing their magnetization direction). Basically, the local geomagnetic field is deformed with different gain on different directions. The effect of the soft-iron distortion is to make the ideal full round sphere become a tilted ellipsoid; in the x-y plane, the soft-iron distortion is identified by a tilted ellipse with the origin in (0,0) for XY axis (XZ). If PCB is designed correctly, the soft iron effect is not present and therefore there is no need for soft iron effect compensation (valid for X-NUCLEO-IKS01A1).

Magnetometer has an offset by itself. Then there can be, and usually there are, hard iron and/or soft iron distortions. Hard iron effect is different from board to board – each board can be magnetized in a different way. Soft iron effect is always equal for all (same) boards – only one board can be characterized for soft iron and the result can be copied to the other boards. Magnetometer calibration library is included in osxMotionFX library. If PCB is well designed by taking into account the magnetometer placement (high current traces/other components clearance) soft iron will not be present. For this reason osxMotionFX library can compensate for hard iron effect only. When the calibration is enabled user needs to cover as much as possible 3D sphere by moving the board, otherwise there will be a drift in the output of the library.

Gyroscope has a zero-rate offset, which needs to be compensated. In the osxMotionFX library there is estimation of gyroscope offset done automatically all the time. Accelerometer calibration is not necessary for sensor fusion except for applications demanding very high orientation precision. Accelerometer calibration requires placing the system into a several positions perfectly aligned with direction of Earth gravity (see AN3182 for more information).

The osxMotionFX library includes the magnetometer calibration library, which compensates the hard-iron distortions. The magnetometer calibration can be done periodically at a slower frequency than sensor fusion output data rate (e.g. 25 Hz) and the flow can be summarized as:

1. Set input data from accelerometer and magnetometer to calibration library (osx_MotionFX_compass_saveAcc and osx_MotionFX_compass_saveMag functions)
2. Call calibration function (osx_MotionFX_compass_run function)
3. Check if calibration was successful (osx_MotionFX_compass_isCalibrated function):

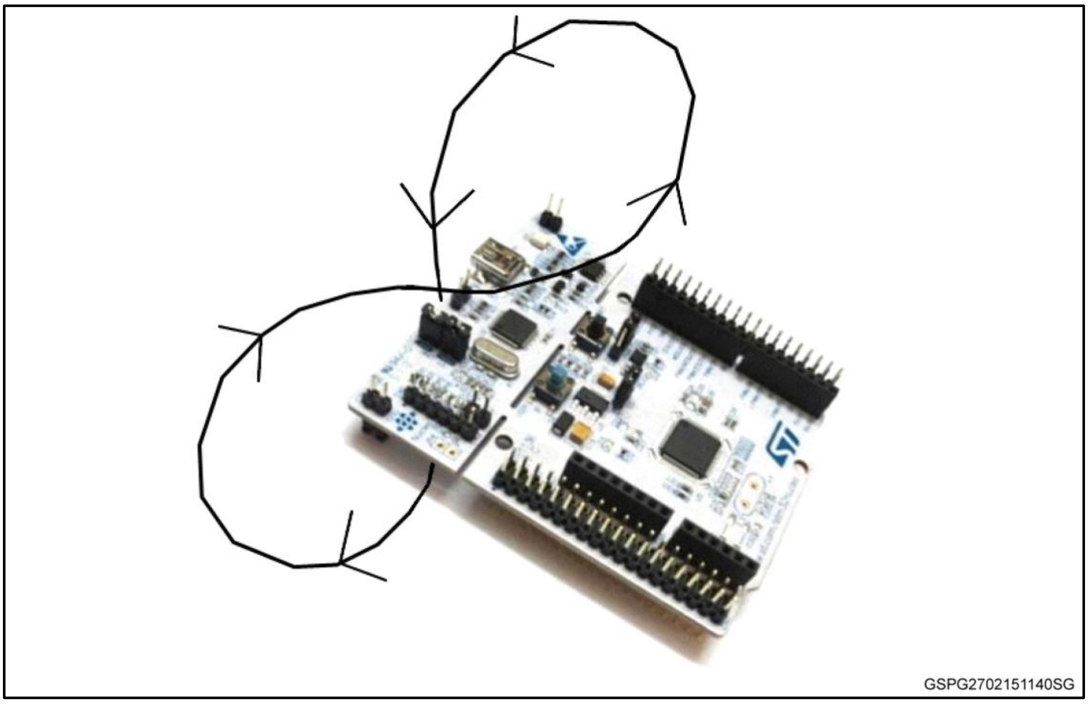
- If it returns 1 then the calibration was successful and the results (magnetometer offset) can be read by osx_MotionFX_getCalibrationData function
- Otherwise it needs to repeat all the operations from step 1.

4. Apply calibration results:
   - MAG_Calibrated.AXIS_X = MAG_Value.AXIS_X - magOffset.magOffX;
   - MAG_Calibrated.AXIS_Y = MAG_Value.AXIS_Y - magOffset.magOffY;
   - MAG_Calibrated.AXIS_Z = MAG_Value.AXIS_Z - magOffset.magOffZ;

After initiating the calibration routine, the Nucleo board should be slowly rotated performing a figure "6" movement in the 3D space. An example is shown in *Figure 6: "Example of rotation of the Nucleo board during calibration"*.

While performing this pattern, keep the Nucleo board clear of other magnetic objects such as cell phones, computers and other steel objects. To be sure that calibration was done properly it is recommended to check magnetometer data (after applying calibration results) using two 2D plots (see *Figure 4: "Magnetometer data in ideal environment or after calibration"* for an example of good calibration and *Figure 5: "Magnetometer data disturbed by hard-iron effect"* for an example of bad calibration). Magnetometer calibration can be restarted by calling osx_MotionFX_compass_forceReCalibration function.

Figure 6: Example of rotation of the Nucleo board during calibration



1.6 Sensor data logging utility

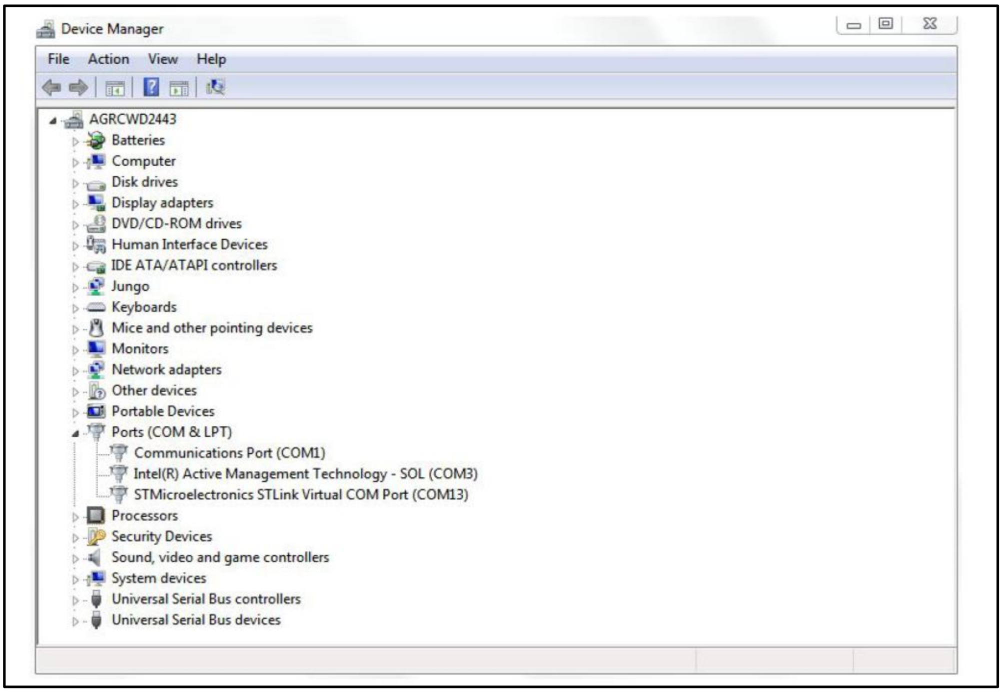
The X-CUBE-MEMS1 expansion for STM32Cube contains an utility for Windows PCs called "Sensors_DataLog". This utility is available in the ROOT_DIR\Utilities\PC_software folder.

This section describes the usage of the utility. Before using this utility, the user must ensure that the necessary drivers, as explained in the section relating to system setup, are installed and the expansion board along with NUCLEO-F401RE or NUCLEO-L476RG board is connected to the PC.

Please perform the following steps:

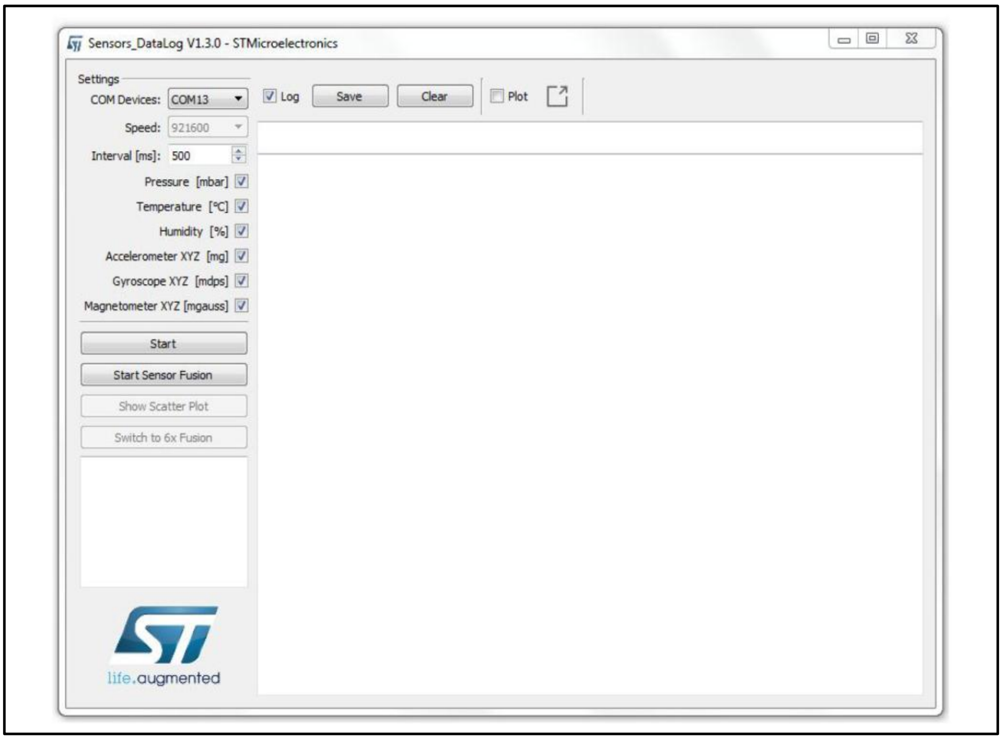
1. Check the Windows "Device Manager" to note the ST COM port; for example in *Figure 7: "Device manager view in Windows"* the port is COM13.

Figure 7: Device manager view in Windows



2. Launch Sensors_DataLog.exe and check if the COM device number for the current expansion board is correct.

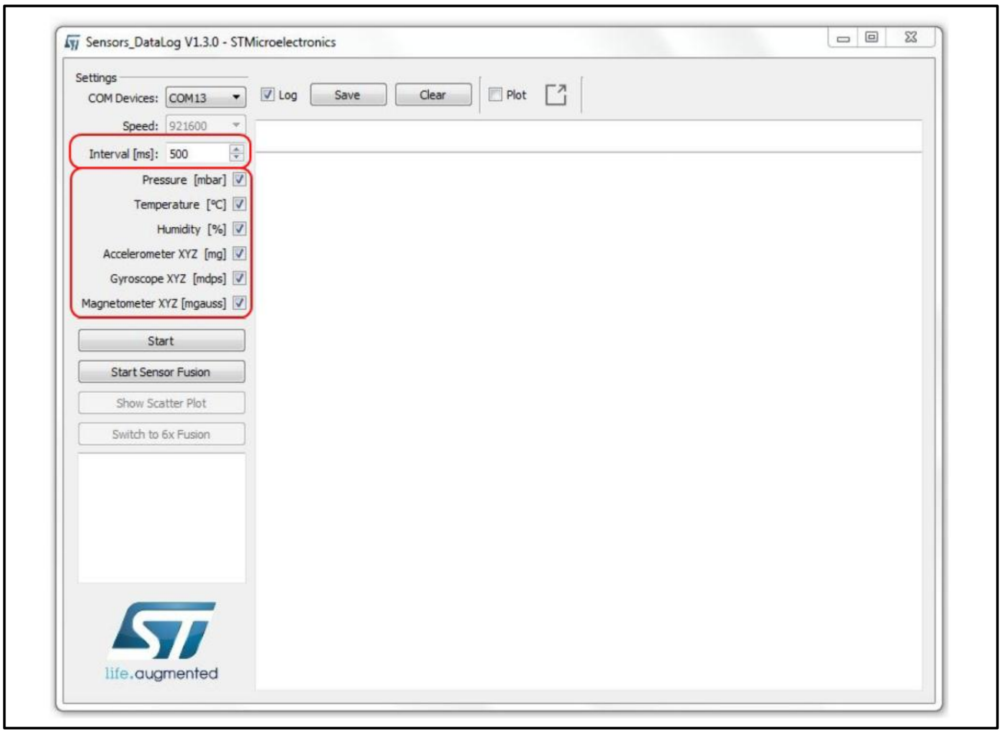
Figure 8: Sensors_DataLog Utility snapshot 1



3 Select between various sensors (pressure, temperature, humidity, accelerometer, gyroscope, magnetometer) available on the expansion board (see *Figure 9: "Sensors_DataLog Utility snapshot 2"*).

4 Set appropriate delay/interval in milliseconds between consecutive data points; the default is 500 ms (see *Figure 9: "Sensors_DataLog Utility snapshot 2"*)

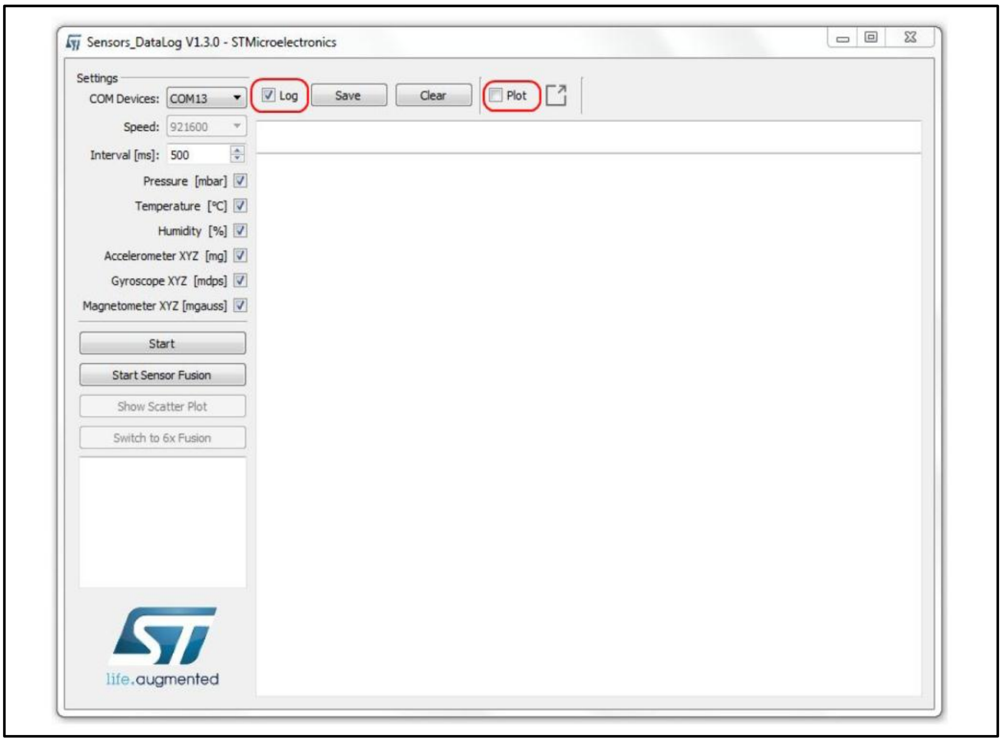
Figure 9: Sensors_DataLog Utility snapshot 2



5 Save the log in a file within the folder called "SensorsDataLog" using the "Save" button, or clear it with the "Clear" button (see *Figure 10: "Sensors_DataLog Utility snapshot 3"*).

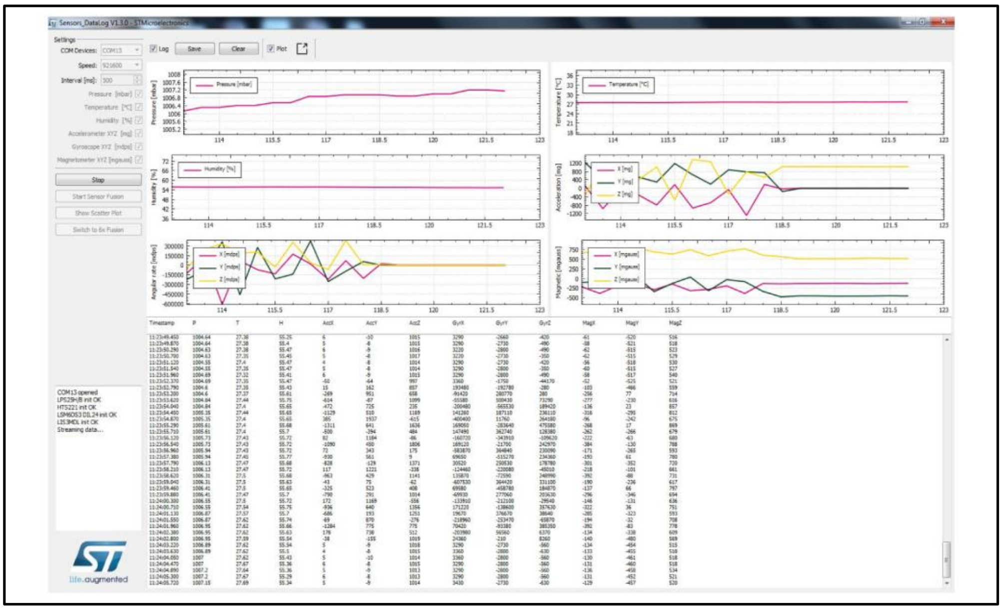
6 Check the "Plot" CheckBox to visualize the data log for the selected sensors (see *Figure 10: "Sensors_DataLog Utility snapshot 3"*).

Figure 10: Sensors_DataLog Utility snapshot 3



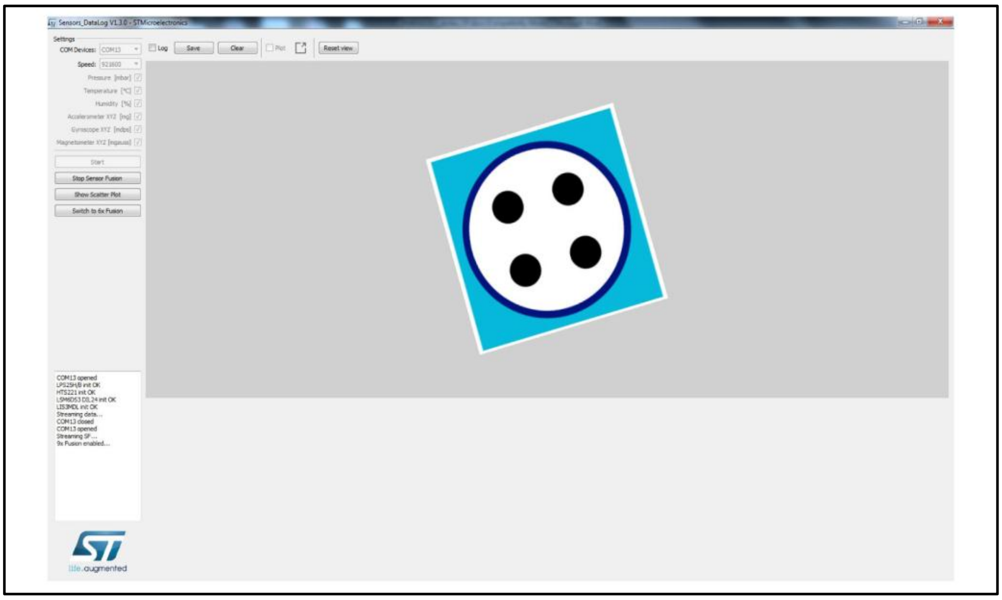
7 Press Start, and data is displayed as shown in *Figure 11: "Sensors_DataLog Utility snapshot 4"*

Figure 11: Sensors_DataLog Utility snapshot 4



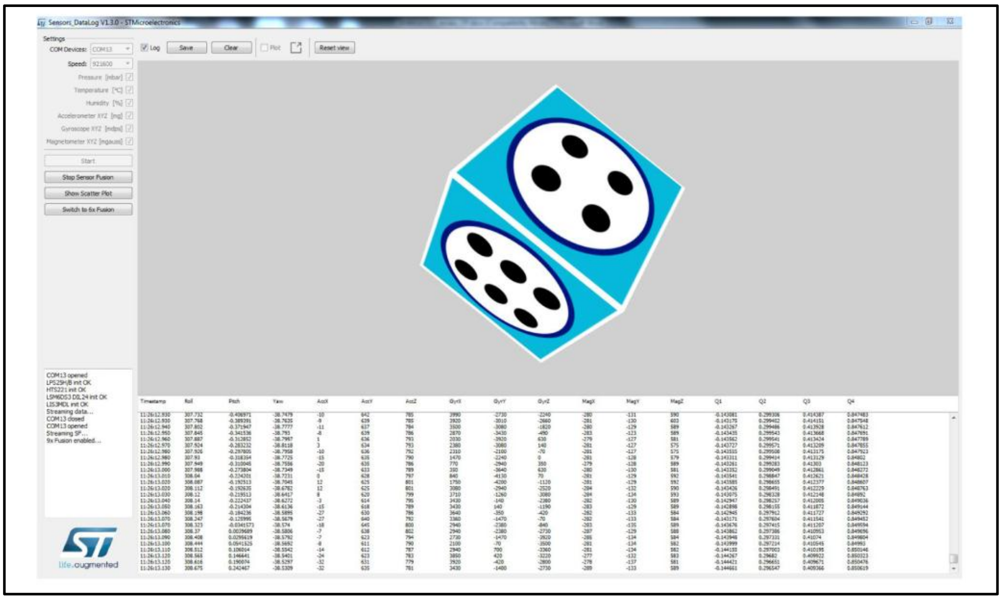
8 Press "Start Sensor Fusion" and a 3D cube is displayed as shown in *Figure 12: "Sensors_DataLog Utility snapshot 5"*. The cube animation is generated using sensor fusion quaternions

Figure 12: Sensors_DataLog Utility snapshot 5



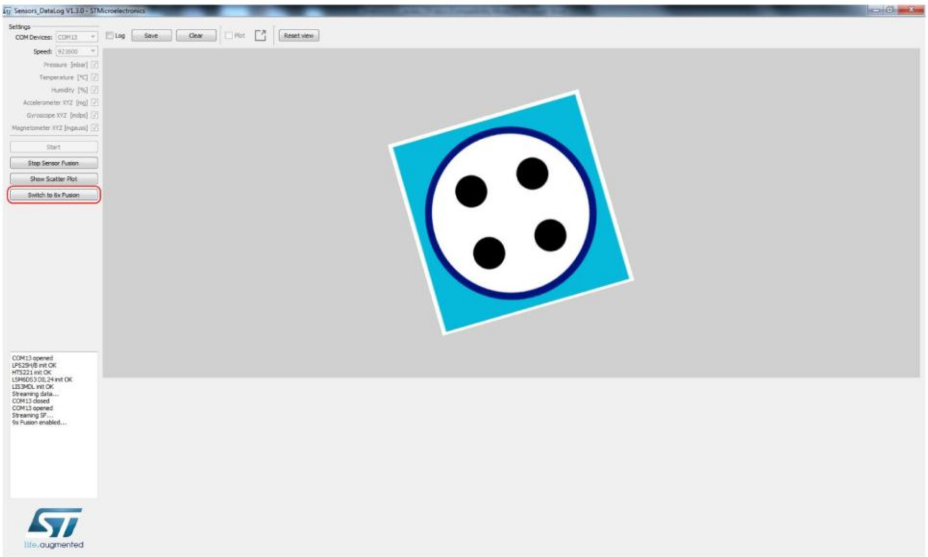
9 Check the "Log" CheckBox in order to see the MEMS sensors data and the sensor fusion data (quaternions and Euler angles) as shown in *Figure 13: "Sensors_DataLog Utility snapshot 6"*

Figure 13: Sensors_DataLog Utility snapshot 6



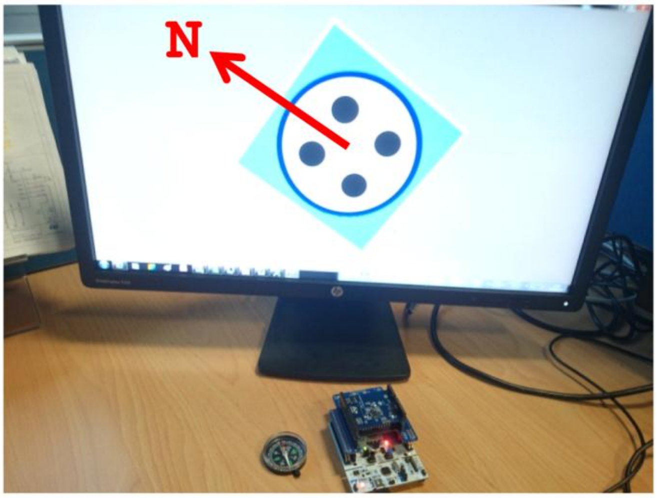
10 Press “Switch to 6x Fusion” to pass dynamically from 9x fusion to 6x fusion as shown in *Figure 14: "Sensors_DataLog Utility snapshot 7"*. In order to come back to 9x fusion you can press “Switch to 9x Fusion”.

Figure 14: Sensors_DataLog Utility snapshot 7



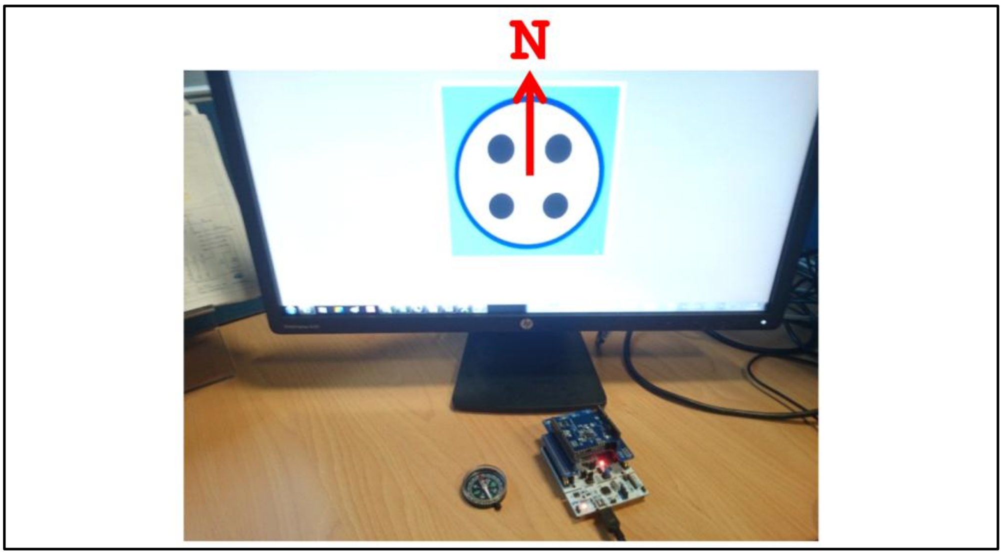
When the board is powered on, the compass is not calibrated so the cube could not point to magnetic north. It is shown in *Figure 15: "View of the board and Windows utility after power on"*.

Figure 15: View of the board and Windows utility after power on



When the compass is not calibrated, LED2 (green LED) of the Nucleo board is off. In order to calibrate the compass, you must press the user button on the Nucleo board and then perform the 8 movement calibration (see *paragraph 1.5.2* for more details). You can calibrate the compass only when the sensor fusion is activated (press the "Start Sensor Fusion" button on the PC GUI). When the calibration is completed, wait a few seconds until the cube shown in the GUI points to north (see *Figure 16: "View of the board and Windows utility after calibration"*). When the calibration is done, LED2 turns on.

Figure 16: View of the board and Windows utility after calibration



It is possible to check the quality of the magnetometer calibration, displaying the scatter plot of the magnetometer. Press “Show Scatter Plot” as shown in *Figure 17: "Sensors_DataLog Utility snapshot 8"* and you will see the magnetometer scatter plot as shown in *Figure 18: "Sensors_DataLog Utility magnetometer scatter plot"*.

Figure 17: Sensors_DataLog Utility snapshot 8

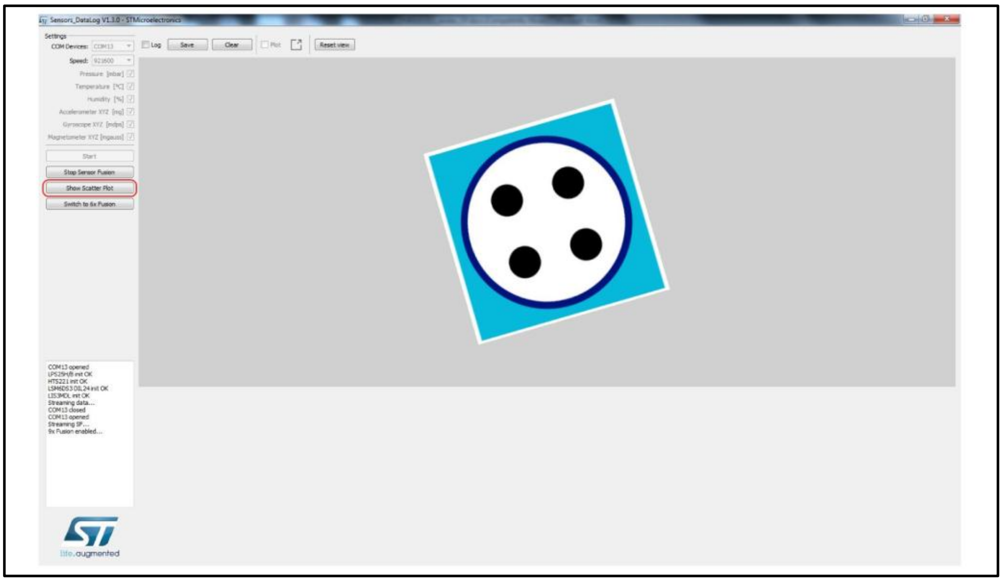
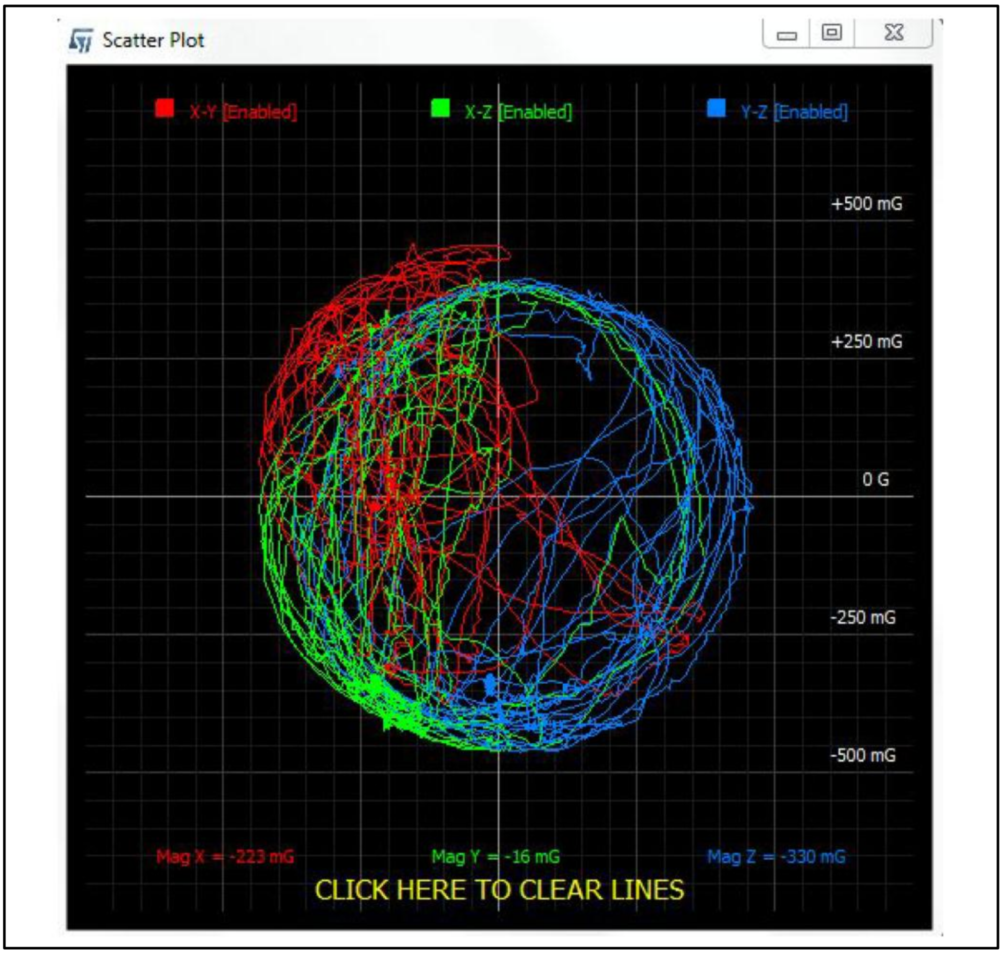


Figure 18: Sensors_DataLog Utility magnetometer scatter plot



By default, the calibration data is stored in RAM memory in order to be preserved when you reset the board. It is also possible to store calibration data in Flash memory. To do this, you must compile the sample application "DataLogFusion" defining "OSXMOTIONFX_STORE_CALIB_FLASH" in the project.

2 System setup guide

2.1 Hardware Description

This section describes the hardware components needed for developing a sensor-based application.

The sub-sections that follow describe the individual components.

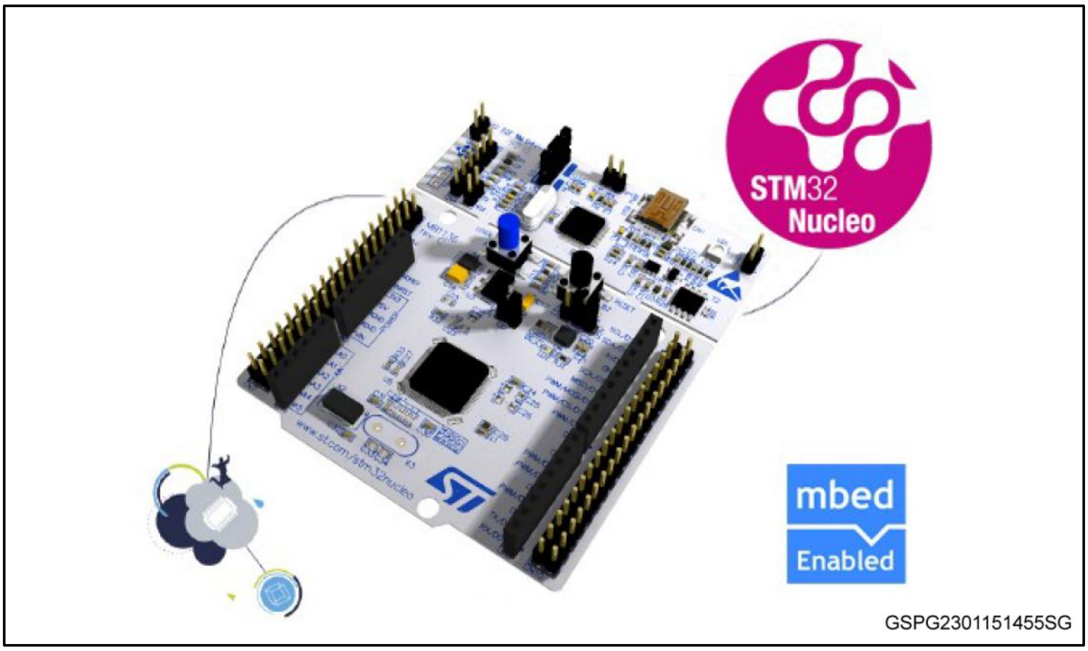
2.1.1 STM32 Nucleo platform

The STM32 Nucleo boards provide an affordable and flexible way for users to try out new ideas and build prototypes with any STM32 microcontroller lines. The Arduino™ connectivity support and ST morpho headers make it easy to expand the functionality of the STM32 Nucleo open development platform with a wide choice of specialized expansion boards. The STM32 Nucleo board does not require any separate probes as it integrates the ST-LINK/V2-1 debugger/programmer. The STM32 Nucleo board comes with the STM32 comprehensive software HAL library together with various packaged software examples.

Information about the STM32 Nucleo boards is available on st.com at:

http://www.st.com/stm32nucleo

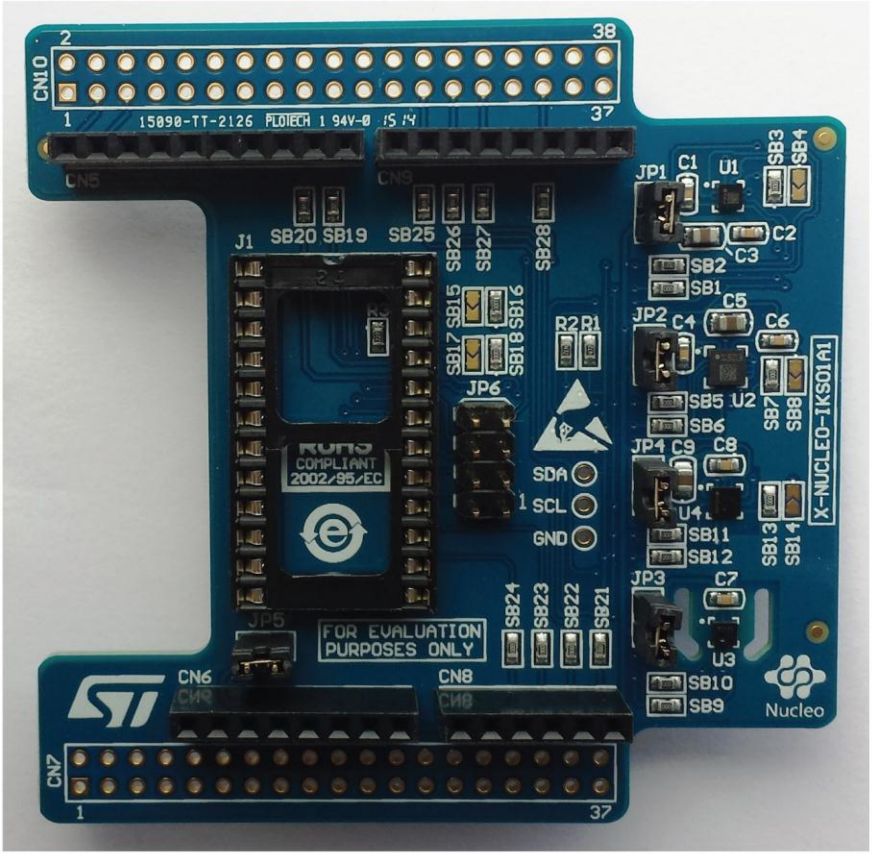
Figure 19: STM32 Nucleo board



2.1.2 X-NUCLEO-IKS01A1 expansion board

The X-NUCLEO-IKS01A1 is a sensor expansion board for use with the STM32 Nucleo system. It is also compatible with Arduino UNO R3 connector layout, and is designed around the STMicroelectronics humidity (HTS221), pressure (LPS25HB) and motion sensors (LIS3MDL and LSM6DS0). The X-NUCLEO-IKS01A1 interfaces with the STM32 MCU via I^{2}C pin, and the user can change the default I^{2}C address and the device IRQ by changing one resistor on the evaluation board.

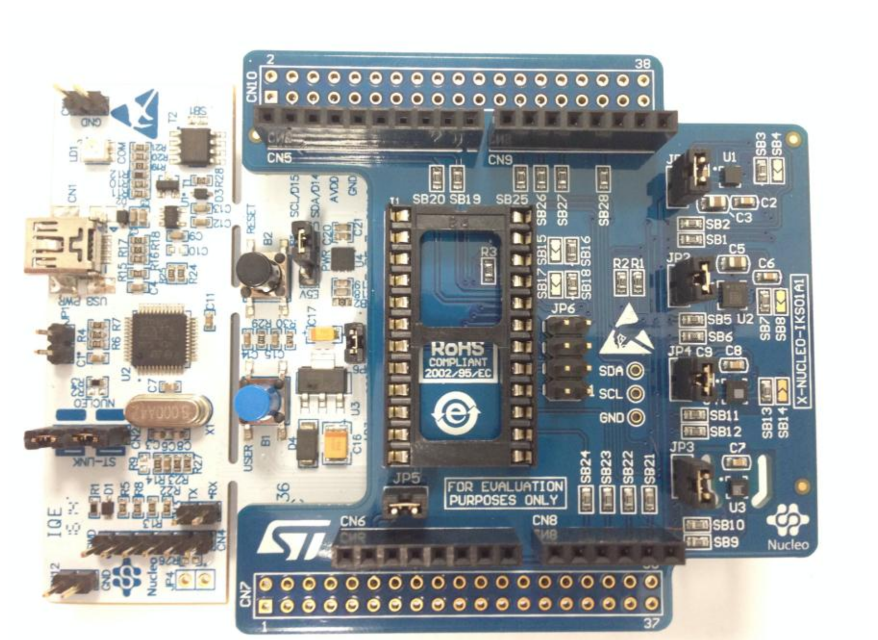
Figure 20: X-NUCLEO-IKS01A1 sensor expansion board



Information about the X-NUCLEO-IKS01A1 expansion board is available on st.com at:

http://www.st.com/x-nucleo

Figure 21: Sensor expansion board connected to STM32 Nucleo board



2.2 Software description

The following software components are needed in order to set up a suitable development environment for creating applications using the osxMotionFX library for the STM32 Nucleo, equipped with the sensor expansion board:

- X-CUBE-MEMS1: an expansion for STM32Cube dedicated to sensor application development. The X-CUBE-MEMS1 firmware and related documentation is available on st.com.
- osxMotionFX: an add-on software package for X-CUBE-MEMS1 that provides fusion and compass calibration APIs. The osxMotionFX firmware and related documentation is available on st.com.
- Development tool-chain and compiler: The STM32Cube expansion software supports the following three environments:
  - IAR Embedded Workbench for ARM® (EWARM) toolchain + ST-LINK
  - RealView Microcontroller Development Kit (MDK-ARM) toolchain + ST-LINK
  - System Workbench for STM32

2.3 Hardware and software setup

This section describes the hardware and software setup procedures and required system setup.

2.3.1 Hardware setup

The following hardware components are required:

1. One STM32 Nucleo development platform (suggested order code: NUCLEO-F401RE or NUCLEO-L476RG)
2. One sensor expansion board (order code: X-NUCLEO-IKS01A1)
3. One USB type A to Mini-B USB cable to connect the STM32 Nucleo to the PC

2.3.2 Software Setup

This section lists the minimum requirements for the developer to set up the SDK, run the sample testing scenario based on the GUI utility and customize applications.

2.3.3 Development tool-chains and compilers

Please select one of the integrated development environments supported by the STM32Cube expansion software, and read the system requirements and setup information provided by the selected IDE provider.

2.3.4 PC utility

The Sensors_DataLog utility for PC has following minimum requirements:

- PC with Intel or AMD processor running one of the following Microsoft operating systems:
  - Windows XP SP3
  - Windows Vista
  - Windows 7
- At least 128 MBs of RAM
- 2 X USB ports
- 40 MB of hard disk space

2.3.5 System setup guide

This section describes how to set up different hardware components before writing and executing an application on the STM32 Nucleo board with the sensor expansion board.

2.3.6 STM32 Nucleo and Sensor expansion boards setup

The STM32 Nucleo board integrates the ST-LINK/V2-1 debugger/programmer. The developer can download the relevant version of the ST-LINK/V2-1 USB driver by accessing the STSW-LINK008 or STSW-LINK009 on www.st.com (according to which Microsoft Windows OS is used).

The sensor expansion board X-NUCLEO-IKS01A1 can be easily connected to the STM32 Nucleo motherboard through the Arduino UNO R3 extension connector, see *Figure 21: "Sensor expansion board connected to STM32 Nucleo board"*. The sensor expansion board is capable of interfacing with the external STM32 microcontroller on the STM32 Nucleo via an inter-integrated circuit (I^2C) transport layer.

2.3.7 Sensors_DataLog GUI setup

The Sensors_DataLog GUI included in the X-CUBE-MEMS1 software package is a graphical user interface that can be used to interact and obtain sensor and sensor fusion data. Please see *section 1.6* for a description of the how this PC utility works.

This utility retrieves sensor data from the connected STM32 Nucleo board and displays it in a tabular form, and graphically as well.

In order to use the Sensors_DataLog GUI, make sure you have correctly set up your hardware and software.

The utility can be launched by simply double-clicking on the Sensors_DataLog.exe file, located in the "Utilities\PC_software\Sensors_DataLog" folder.

2.3.8 osxMotionFX installer setup

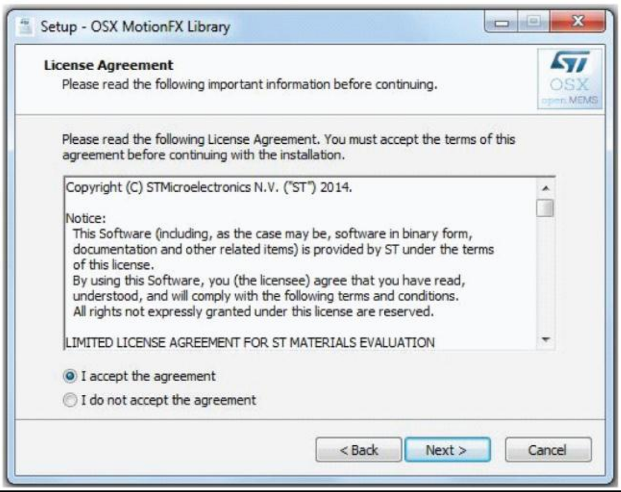
The osxMotionFX software package is provided with a Windows installer (osxMotionFX_Setup_vXXX.exe), that guides the user in the correct installation of the software package. The installer also includes the osx License Wizard tool which allows the user to automatically obtain a valid node-locked license for their Nucleo board. The installer of this wizard is described in the *paragraph 2.3.9*.

Before running the installer, you need to download the latest release of the X-CUBE-MEMS1 software package and unzip this package in your workspace. For example, if you have the X-CUBE-MEMS1 package in "C:\workspace\STM32CubeExpansion_MEMS1_VX.X.X", at this point you can run the installer and see the welcome window as shown in *Figure 22: "osxMotionFX installer snapshot 1"*.

Figure 22: osxMotionFX installer snapshot 1

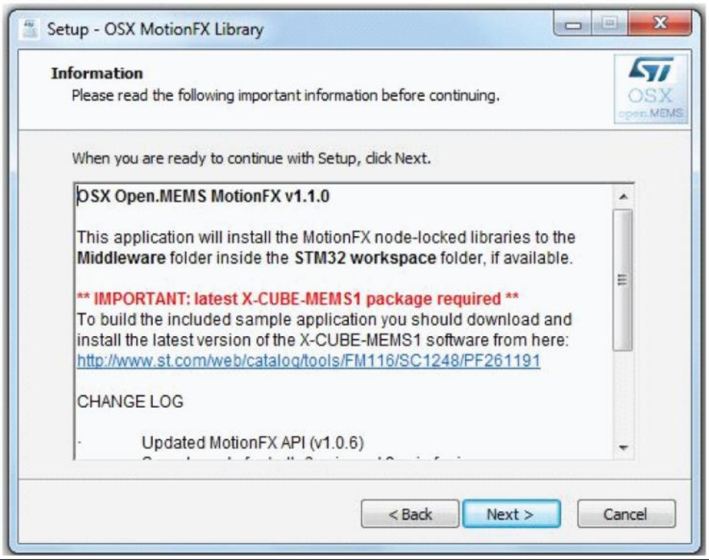
You must then accept the license agreement as shown in *Figure 23: "osxMotionFX installer snapshot 2"*.

Figure 23: osxMotionFX installer snapshot 2



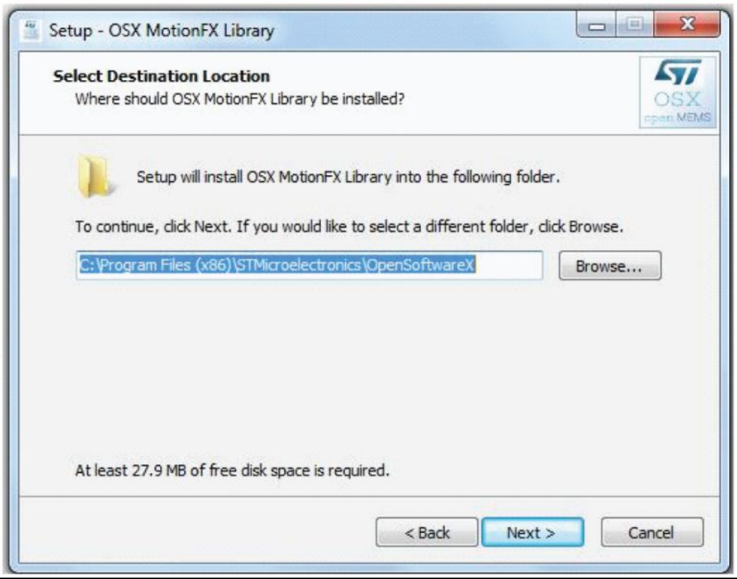
The installer provides some information, such as the requirements of the latest release of the X-CUBE-MEMS1 software package (see *Figure 24: "osxMotionFX installer snapshot 3"*).

Figure 24: osxMotionFX installer snapshot 3



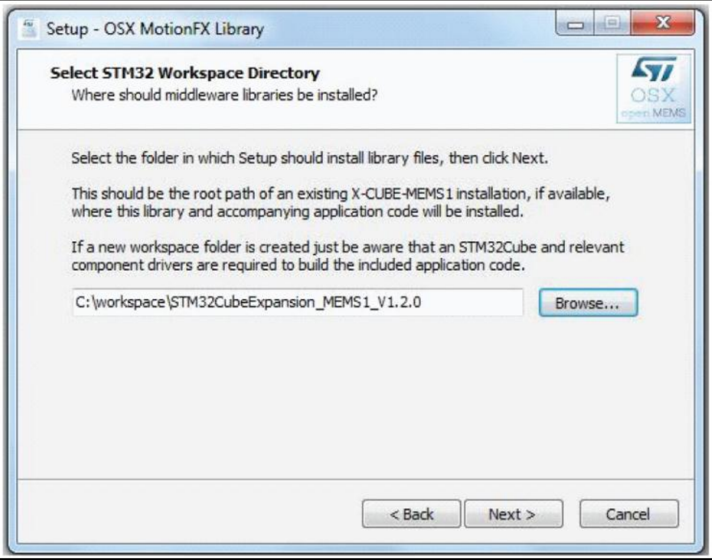
In the next step, the installer asks for the destination location of the osxMotionFX library, as shown in *Figure 25: "osxMotionFX installer snapshot 4"*

Figure 25: osxMotionFX installer snapshot 4



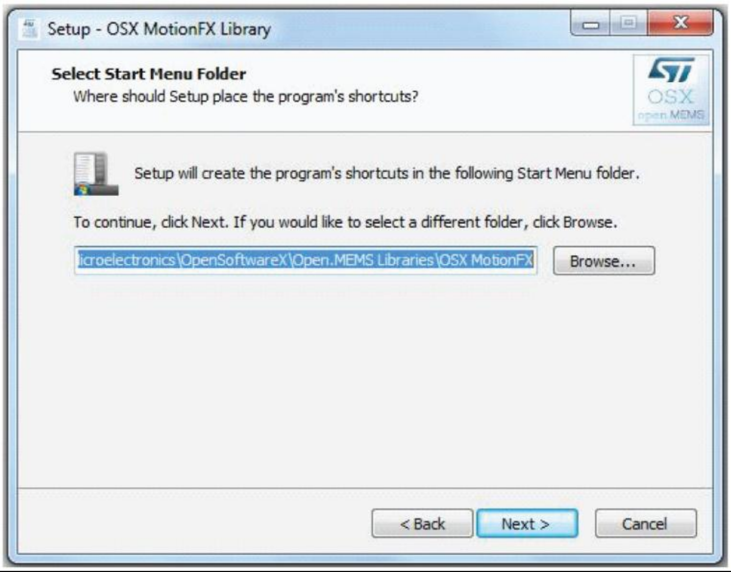
After this, you must provide the path to the X-CUBE-MEMS1 package (see *Figure 26: "osxMotionFX installer snapshot 5"*). Remember to insert the correct path to the X-CUBE-MEMS1 package, otherwise the sample application will not compile. This is the path where you can locate the folders "Documentation", "Projects", "Drivers", "Utilities", etc. contained in the X-CUBE-MEMS1 software package. In our example it is "C:\workspace\STM32CubeExpansion_MEMS1_V1.2.0".

Figure 26: osxMotionFX installer snapshot 5



In the next step, you must provide the path to the Start menu folder where the shortcuts are installed (see *Figure 27: "osxMotionFX installer snapshot 6"*).

Figure 27: osxMotionFX installer snapshot 6



After this point the osxMotionFX installer can finish the software installation.

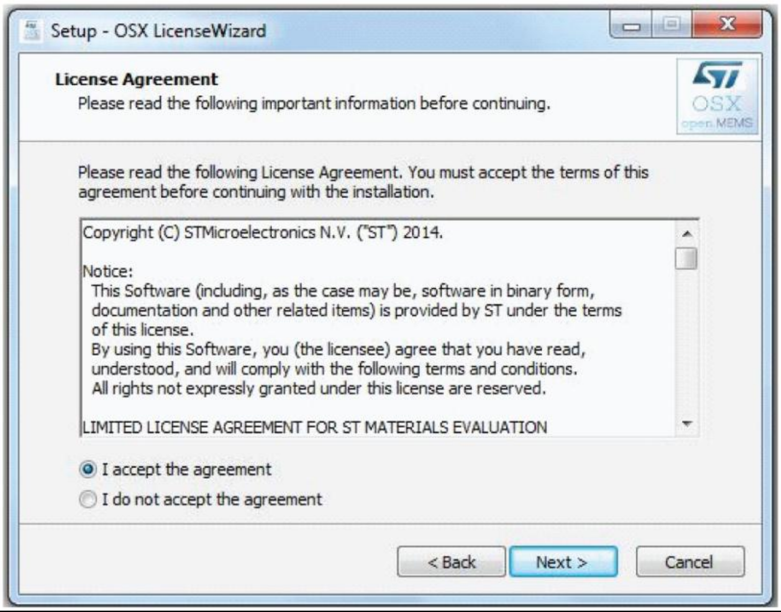
2.3.9 osx License wizard

This tool allows the user to automatically obtain a valid node-locked license for their Nucleo board. You can see in *Figure 28: "osx License Wizard snapshot 1"* the welcome window.

Figure 28: osx License Wizard snapshot 1

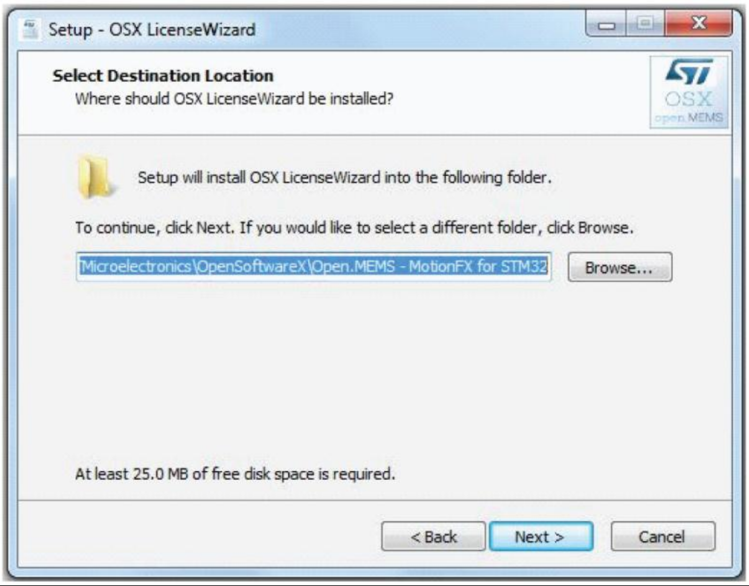
You need to accept the license agreement as shown in *Figure 29: "osx License Wizard snapshot 2"*.

Figure 29: osx License Wizard snapshot 2



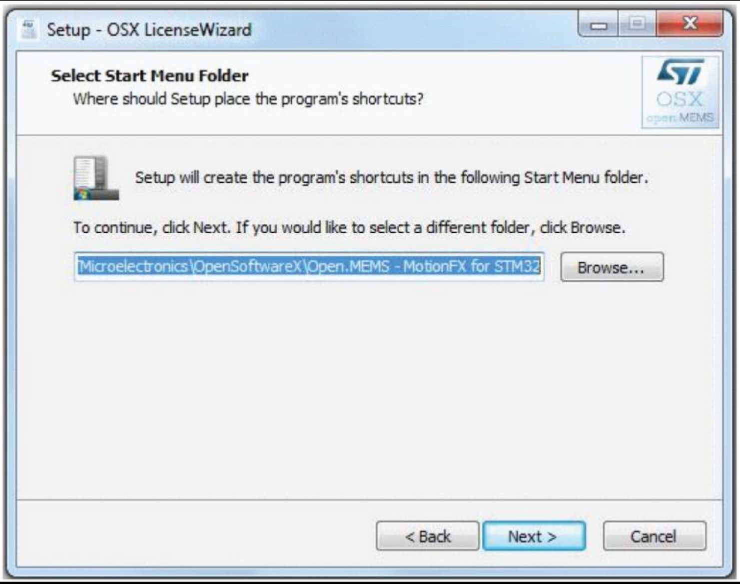
In the next step, the installer asks for the destination location of the osx License Wizard, as shown in *Figure 30: "osx License Wizard snapshot 3"*.

Figure 30: osx License Wizard snapshot 3



In the next step you must provide the path to the Start menu folder where the shortcuts are installed (see *Figure 31: "osx License Wizard snapshot 4"*).

Figure 31: osx License Wizard snapshot 4



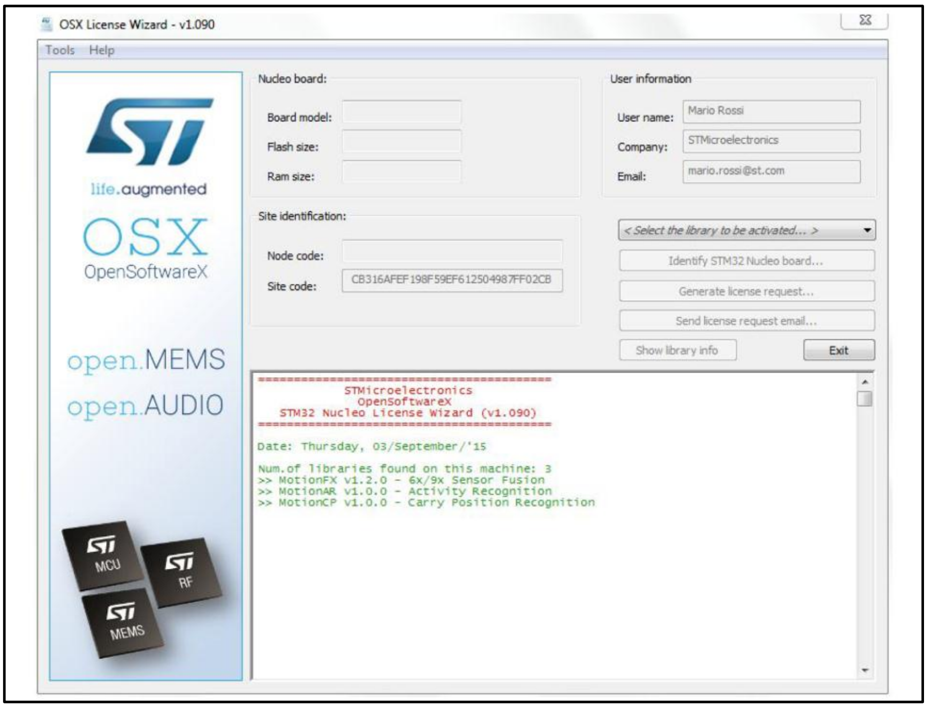
After this step, the osx License Wizard can finish the software installation.

The osx License Wizard needs to access some information on the Nucleo board in order to create the request for the node-locked license. For this reason the osx License Wizard asks for the installation of some additional packages ("Microsoft VS 2013 redistributable" and "STM32 ST-LINK Utility"), if you have not already installed them (see *Figure 32: "osx License Wizard snapshot 5"*.

Figure 32: osx License Wizard snapshot 5

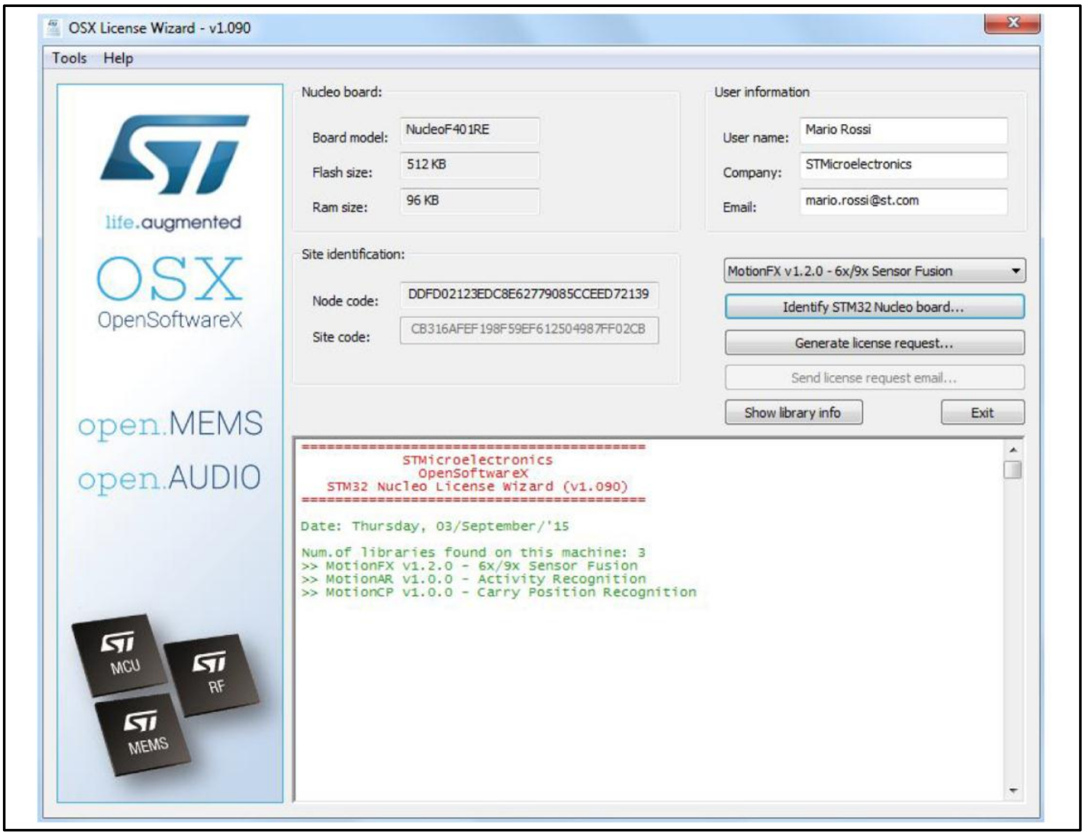
Before starting the osx License Wizard, you must connect via USB cable the Nucleo board that you want to link to the node-locked license. Then, you can run the osx License Wizard. First, you need to select the library you want to activate as shown in *Figure 33: "osx License Wizard snapshot 6"*.

Figure 33: osx License Wizard snapshot 6



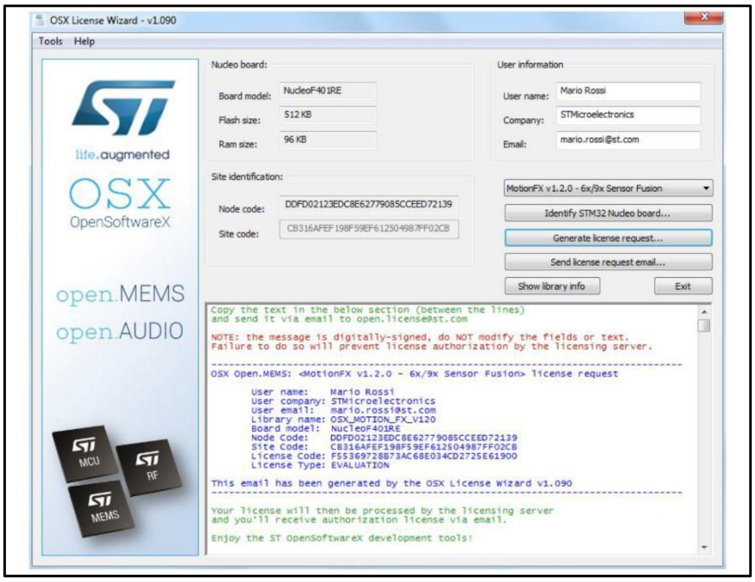
The next step is to identify the Nucleo board plugged into your PC. To do this, you can press the "Identify STM32 Nucleo board" button (see *Figure 34: "osx License Wizard snapshot 7"*).

Figure 34: osx License Wizard snapshot 7



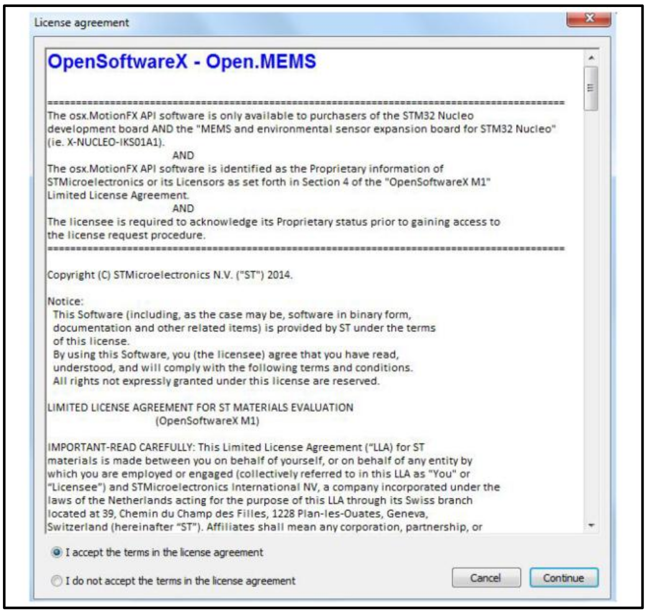
At this point you should see information about your Nucleo board. Then, you should edit the "User name", "Company" and "Email" forms and press the "Generate license request" (see *Figure 35: "osx License Wizard snapshot 8"*).

Figure 35: osx License Wizard snapshot 8



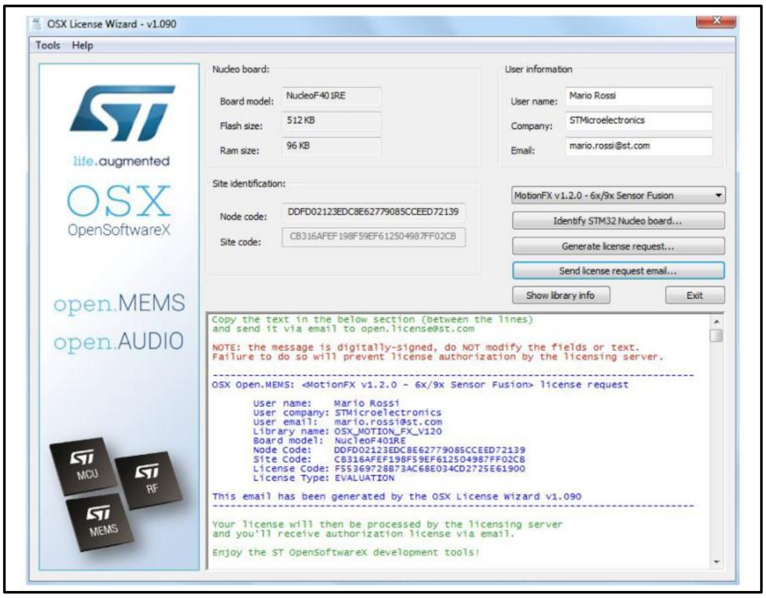
Then, you should accept the license agreement (see *Figure 36: "osx License Wizard snapshot 9"*).

Figure 36: osx License Wizard snapshot 9



Finally, you press the "Send license request email" button as shown in "*Figure 37: "osx License Wizard snapshot 10"*".

Figure 37: osx License Wizard snapshot 10



Once the license activation codes are received, edit the content of the osx_license.h file

Note: also delete or comment the "#error...." line, found in the Middlewares\ST\STM32_OSX_MotionFX_Library folder of your workspace.

3 Acronyms and abbreviations

Table 1: Acronyms and abbreviations

Acronym	Description
NED	x-North, y-East, z-Down
ENU	x-East, y-North, z-Up
SEU	x-South, y-East, z-Up

4 References

- UM1859: Getting started with the X-CUBE-MEMS1 motion MEMS and environmental sensor software expansion for STM32Cube.

5 Revision history

Table 2: Document revision history

Date	Revision	Changes
15-Apr-2015	1	Initial release.
12-Jun-2015	2	Updated: Title on the cover page and osxMotionFX plus X-CUBE-MEMS1 software architecture figure.
06-Oct-2015	3	Updated: Section 1.5.1 6-axis and 9-axis sensor fusion osxMotionFX library.