UM3368

User manual

Getting started with InfraredAL presence detection library in X-CUBE-MEMS1 expansion for STM32Cube

Introduction

InfraredAL is a middleware library component of the X-CUBE-MEMS1 software and runs on STM32. It provides real-time information about the presence of a person in the field of view of the sensor.

This library is intended to work with the STHS34PF80 sensor only.

The algorithm is provided in static library format and is designed to be used on STM32 microcontrollers based on the ARM® Cortex® -M0+, ARM® Cortex®-M3, ARM® Cortex®-M33, ARM® Cortex®-M4 or ARM® Cortex®-M7 architectures.

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-IKS01A3, X-NUCLEO-IKS02A1, and X-NUCLEO-IKS4A1 expansion boards on a NUCLEO-F401RE, NUCLEO-L073RZ, 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 InfraredAL middleware library in X-CUBE-MEMS1 software expansion for STM32Cube

2.1 InfraredAL overview

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

The library acquires data from the infrared sensor and provides real-time information about the presence of a person in the field of view of the sensor with its confidence.

This library is intended to work with the STHS34PF80 sensor only. Functionality and performance when using other sensors are not analyzed and can be significantly different from what described in the document.

A sample implementation is available on X-NUCLEO-IKS01A3, X-NUCLEO-IKS02A1, and X-NUCLEO-IKS4A1 expansion boards on a NUCLEO-F401RE, NUCLEO-L073RZ, NUCLEO-L152RE, or NUCLEO-U575ZI-Q development board.

2.2 InfraredAL library

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

2.2.1 InfraredAL library description

The InfraredAL sensor fusion library manages data acquired from the infrared sensor; it features:

- the presence detection and its level of confidence
- recommended sensor data sampling frequency of 1 Hz to 30 Hz
- resources requirements:flash ram
- Cortex-M0+: 3.23 kB of code and up to 0.52 kB of data memory
- Cortex-M33: 3.25 kB of code and up to 0.51 kB of data memory
- Cortex-M3: 3.17 kB of code and up to 0.51 kB of data memory
- Cortex-M4: 3.24 kB of code and up to 0.51 kB of data memory
- Cortex-M7: 3.25 kB of code and up to 0.51 kB of data memory
- available for ARM Cortex-M0+, Cortex-M3, Cortex-M33, Cortex-M4 and Cortex-M7 architecture

Note: *The size of dynamically allocated data memory is dependent on algorithm setup.*

2.2.2 InfraredAL library operation

The InfraredAL library implements human presence detection for workstation applications. The algorithms of the library are compatible with Microsoft Windows’s Wake-on-Approach and Lock-on-Leave features.

The library is designed for the STHS34PF80 TMOS IR sensor only. Its functionality and performance with other sensors have not been not analyzed and can differ significantly different from what is described here.

The library implements algorithms that provide an output flag which reports whether or not a user is present inside the field of view of the sensor (presence or absence states). The algorithms also provide an output value which reports the level of confidence on the output flag of presence detection. The confidence can range from 50% (complete uncertainty) to 100% (complete certainty) for both states.

At startup, the algorithms cannot know for certain whether the user was already in the sensor's field of view when they were started. In this phase, the presence state is obtained through a motion detection algorithm:

- the higher the movement, the more the confidence for absence will decrease or the confidence for presence will increase, or both
- the lower the movement, the more the confidence for presence will decrease or the confidence for absence will increase, or both

A true presence detection algorithm simultaneously checks whether a user enters or exits the field of view of the sensor. Once the presence has been ascertained (e.g., once the algorithm detects that a user has entered the field of view of the sensor), the presence state is obtained only through the true presence detection algorithm.

The true presence detection algorithm can be configured by changing the value of a threshold for presence detection during initialization. This threshold should be fine-tuned depending on the final application, and it should be configured to be lower than the change in the input signal baseline caused by a person entering the field of view at the distance from the sensor where the user is expected to stand at the workstation.

Note: The algorithms have been designed to work for workstation applications (e.g., PC and industrial workstations), where the distance from the sensor is limited (in the order of 0.5 to 1 m).

The algorithms have been designed to be resilient against the entrance into and the exit from the field of view of multiple people in addition to the main user.

If the presence detection state is consistently the same from the beginning, the algorithms can be configured so that true presence detection algorithm is performed from the start by forcing a certain presence state during initialization. The presence detection state can also be forced during execution (e.g., if the presence state is confidently known from some other source of information). As mentioned, the algorithms of the library have been designed to be compatible with Microsoft Windows's Wake-on-Approach and Lock-on-Leave features. This means that the ST Confidential entrance/approach of the user inside the field of view (passage from absence to presence) is detected within 1 second, while the exit/leave of the user from the field of view (passage from presence to absence) is detected within 5 seconds.

2.2.3 InfraredAL library parameters

In the following, the types that are defined in the header file of the library.

```
typedef void *IAL_Instance_t;
```

- pointer to the library instance loaded in data memory

```
typedef enum
{
  IAL_MCU_STM32 = 0,
  IAL_MCU_BLUE_NRG1,
  IAL_MCU_BLUE_NRG2,
  IAL_MCU_BLUE_NRG_LP,
} IAL_mcu_type_t;
```

- used MCU type

```
typedef enum
{
  IAL_INIT_OK = 0,        /* No error */
  IAL_INIT_ERR_ALLOC,     /* Instance NULL */
  IAL_INIT_ERR_ODR,       /* Wrong ODR value */
  IAL_INIT_ERR_RES,       /* Reserved error code */
} IAL_init_err_t;
```

- library status – error code returned by InfraredAL_Start API function

```
typedef enum
{
  IAL_RUN_OK = 0,         /* No error */
  IAL_RUN_ERR_ALLOC,      /* Instance NULL */
  IAL_RUN_ERR_UNINIT,     /* Instance uninitialised*/
  IAL_RUN_ERR_RES,        /* Reserved error code */
} IAL_run_err_t;
```

- library status – error code returned by InfraredAL_Update API function

```
typedef struct
{
  uint8_t  odr;
  uint8_t  tau;
} IAL_device_conf_t;
```

- the parameters of the device, that must be configured and/or retrieved in the application code and passed to the algorithm during initialization:
  - `odr` – ODR in Hz, possible values are from 1 Hz to 30 Hz
  - `tau` – transmittance of the optical system in the range of wavelengths between 5 µm and 20 µm, ranging from 0 [0%] to 1 [100%]

```
typedef struct
{
  uint16_t  ths;
  uint16_t  abs_lat;
  IAL_pres_state_t pres_init;
} IAL_algo_conf_t;
```

- the parameters of the algorithm that can be configured from the application code:
  - `ths` – threshold for presence detection [LSB]
  - `abs_lat` – latency for absence trigger [ms]
  - `pres_init` – initial presence state

```
typedef struct
{
  int16_t t_obj;
} IAL_input_t;
```

- the inputs of the algorithms that must be provided to the algorithms at each iteration:
  - `t_obj` – raw object temperature data [LSB]

```
typedef struct
{
  uint8_t pres_flag;     /* Presence detection flag [0: absence, 1: presence] */
  uint8_t pres_conf;     /* Presence detection confidence [%] */
} IAL_output_t;
```

- the outputs of the algorithms that are provided by the algorithms at each iteration:
  - `pres_flag` – presence detection flag [0: absence, 1: presence]
  - `pres_conf` – presence detection confidence [%]

2.2.4 InfraredAL APIs

In the following, the API functions that are defined in the header file of the library.

```
uint8_t InfraredAL_GetLibVersion(char *version)
```

- Retrieve the version of the library
  - `version` – pointer to an array of 35 characters
- Return the number of characters in the version string

```
void InfraredAL_Initialize(IAL_mcu_type_t mcu_type)
```

- Perform InfraredAL library initialization and setup of the internal mechanism

Note: This function must be called before using the presence detection library and the CRC module in STM32 microcontroller (in RCC peripheral clock enable register) has to be enabled.

```
IAL_Instance_t InfraredAL_CreateInstance(IAL_algo_conf_t *algo_conf)
```

- Create instance of InfraredAL library algorithm:
  - Allocate the memory for a library instance
  - Fill the structure pointed by `algo_conf` with the default values of the parameters for the configuration of the algorithms
  - Return a pointer to its memory location

Note: After calling this function, the algorithms can be initialized with the `InfraredAL_Start()` API function

- `algo_conf` – configuration of the algorithm
- Return pointer to new instance of the algorithm

```
void InfraredAL_DeleteInstance(IAL_Instance_t instance)
```

- Delete instance of InfraredAL library algorithm:
  - De-initialize the algorithm
  - Free the memory allocated for the instance

- `instance` – pointer to instance of the algorithm to be deleted

```
IAL_init_err_t InfraredAL_Start(IAL_Instance_t instance, IAL_device_conf_t
                                *device_conf, IAL_algo_conf_t *algo_conf)
```

- Start the InfraredAL engine:
  - Initialize (or re-initialize) the algorithm of the instance following the parameters set in the two structures pointed by `device_conf` and `algo_ conf`
  - Return an initialization error code (e.g.: if invalid device parameters were set)
- `instance` – pointer to instance of the algorithm to be started
- `device_conf` – configuration of the device
- `algo_conf` – configuration of the algorithm
- Return an initialization error code

```
void InfraredAL_Update(IAL_Instance_t instance, IAL_input_t *data_in, IAL_output_t *data_out)
;
```

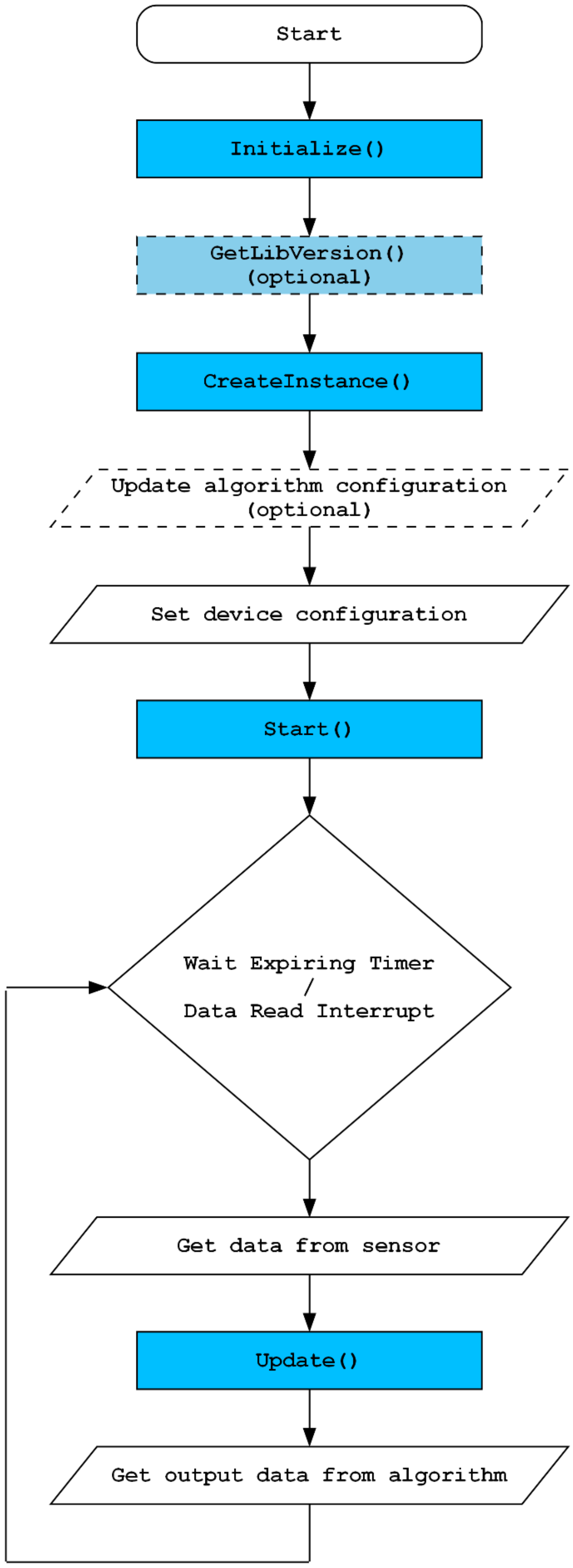
- Execute one step of the algorithm
- `instance` – pointer to instance of the algorithm
- `data_in` – input data
- `data_out` – output data

```
void InfraredAL_ForcePresState(IAL_Instance_t instance, IAL_pres_state_t pres_state);
```

- Force a presence state value
- `instance` – pointer to instance of the algorithm
- `pres_state` – presence state value to be forced

2.2.5 API flow chart

Figure 1. InfraredAL API logic sequence



2.2.6 Demo code

```
#define IAL_STR_LENG  35
[...]
/*** Initialization ***/
char lib_version[IAL_STR_LENG];
IAL_mcu_type_t mcu = IAL_MCU_STM32;
IAL_Instance_t IAL_Instance;
IAL_algo_conf_t algo_conf;
IAL_device_conf_t device_conf;
IAL_init_err_t status;
IAL_run_err_t run_err;
IAL_pres_state_t pres_state;
/* Library API initialization function */
InfraredAL_Initialize(mcu);
/* Optional: Get version */
InfraredAL_GetLibVersion(lib_version);
/* Create library algorithm instance */
IAL_Instance = InfraredAL_CreateInstance(&algo_conf);
/* Setup device configuration */
device_conf.odr = 30;
[...]
/* Start the algorithm engine */
status = InfraredAL_Start(instance, &device_conf, &algo_conf);
/* Optional: Force a presence state value */
pres_state = IAL_PRES_STATE_PRESENCE;
InfraredAL_ForcePresState(instance, pres_state);
/*** Using Presence Detection algorithm ***/
Timer_OR_DataRate_Interrupt_Handler()
{
  IAL_input_t data_in;
  IAL_output_t data_out;
  /* Get data from sensor */
  ReadSensor(&data_in.t_amb);
  /* Execute one step of the algorithms */
  Run_err = InfraredAL_Update(instance, &data_in, &data_out)
  /* Get output data from algorithm */
  uint8_t pres_flag = data_out.pres_flag;
  uint8_t pres_conf = data_out.pres_conf;
}
```

2.2.7 Algorithm performance

Table 2. **Elapsed time (µs) algorithm**

MCU	Min	Average	Max
Cortex-M4 STM32F401RE at 84 MHz	1	1.88	3
Cortex-M3 STM32L152RE at 32 MHz	<1	<1	1
Cortex-M33 STM32U575ZI-Q at 160 MHz	<1	<1	1
Cortex-M0+ STM32L073RZ at 32 MHz	<1	<1	1

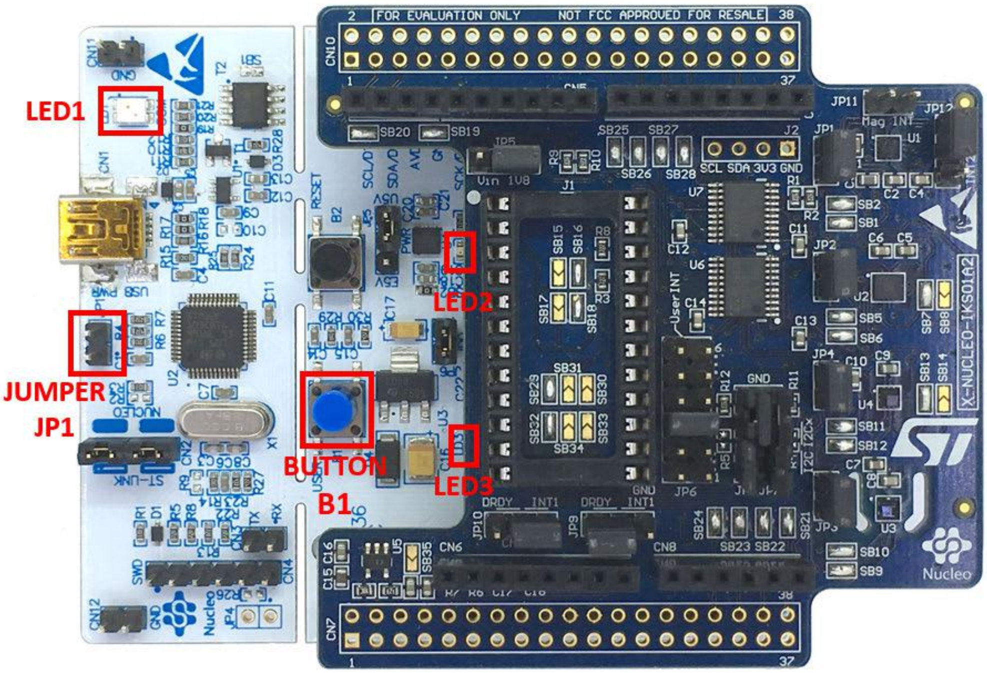
2.3 Sample application

The InfrearedAL middleware can be easily manipulated to build user applications. A sample application is provided in the Application folder.

It is designed to run on X-NUCLEO-IKS01A3, X-NUCLEO-IKS02A1, and X-NUCLEO-IKS4A1 expansion board on a NUCLEO-F401RE, NUCLEO-L073RZ, NUCLEO-L152RE, or NUCLEO-U575ZI-Q development board.

The application provides real-time information about the presence of a person in the field of view of the sensor and its confidence.

Figure 2. **STM32 Nucleo LEDs, button, and jumpers**



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.

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

2.3.1 MEMS Studio application

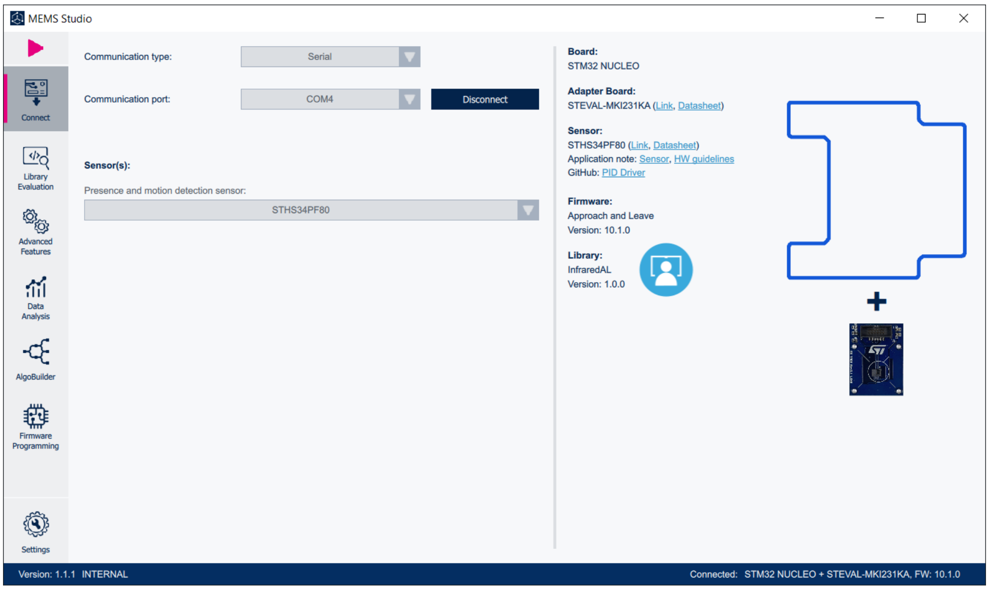
The sample application uses the MEMS Studio application, which can be downloaded from www.st.com.

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 and the appropriate COM port is opened.

Step 3. Press the [**Connect**] button to start communicating.



MEMS Studio

Communication type: Serial

Communication port: COM4

Disconnect

Sensor(s):

Presence and motion detection sensor: STHS34PF80

Board:
STM32 NUCLEO

Adapter Board:
STEVAL-MKI231KA (Link, Datasheet)

Sensor:
STHS34PF80 (Link, Datasheet)
Application note: Sensor, HW guidelines
GitHub: PID Driver

Firmware:
Approach and Leave
Version: 10.1.0

Library:
InfraredAL
Version: 1.0.0

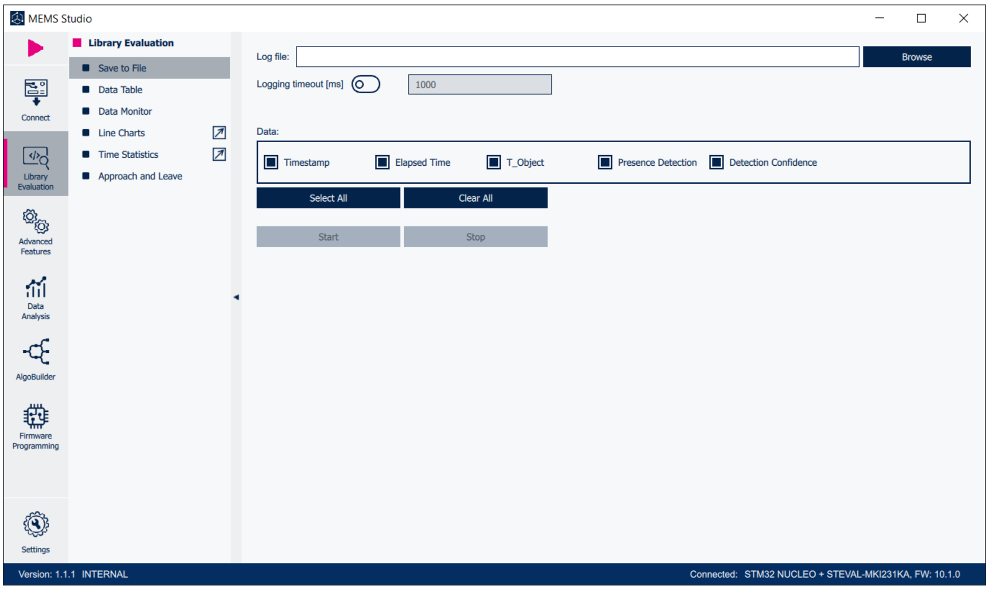
Version: 1.1.1 INTERNAL

Connected: STM32 NUCLEO + STEVAL-MKI231KA, FW: 10.1.0

Figure 3. MEMS Studio Connect window

Step 4. 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 [**Data table**] and [**Data monitor**] tabs.



MEMS Studio

Library Evaluation
- Save to File
- Data Table
- Data Monitor
- Line Charts
- Time Statistics
- Approach and Leave

Log file:

Browse

Logging timeout [ms] ○ 1000

Data:

☑ Timestamp ☑ Elapsed Time ☑ T_Object ☑ Presence Detection ☑ Detection Confidence

Select All

Clear All

Start

Stop

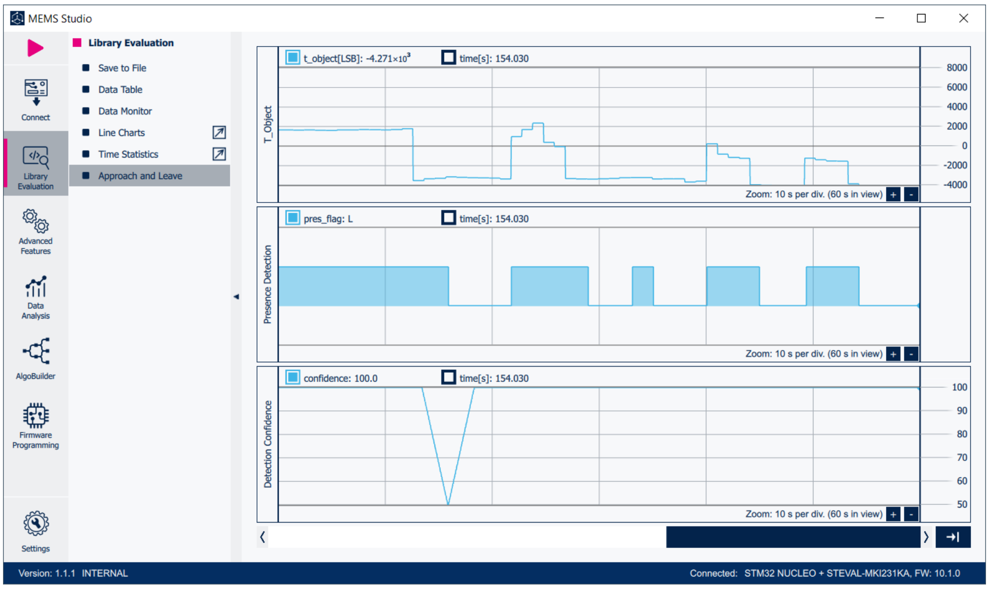
Version: 1.1.1 INTERNAL

Connected: STM32 NUCLEO + STEVAL-MKI231KA, FW: 10.1.0

Figure 4. Library Evaluation window

Step 5. Click on the [**Approach and Leave**] icon in the vertical toolbar to open the dedicated application window to see the temperature of the object in LSB, presence detection flag (H = presence, L = absence), and the detection confidence in %.

Figure 5. **Approach and Leave window**



t_object[LSB]: -4.271×10³ time[s]: 154.030

pres_flag: L time[s]: 154.030

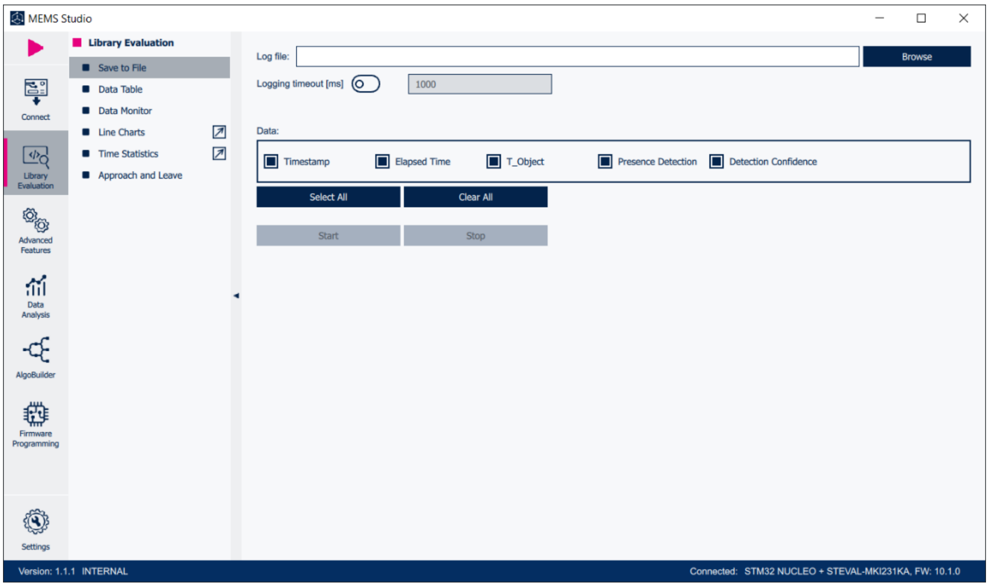
confidence: 100.0 time[s]: 154.030

Version: 1.1.1 INTERNAL

Connected: STM32 NUCLEO + STEVAL-MKI231KA, FW: 10.1.0

Step 6. Click on the [**Save to file**] icon in the vertical toolbar to open the datalog configuration window: you can select the data to be saved in the files. You can start or stop saving by clicking on the corresponding button.

Figure 6. **Datalog window**



Log file:

Logging timeout [ms] 1000

Data:

☐ Timestamp ☐ Elapsed Time ☐ T_Object ☐ Presence Detection ☐ Detection Confidence

Version: 1.1.1 INTERNAL

Connected: STM32 NUCLEO + STEVAL-MKI231KA, FW: 10.1.0

3 References

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

[1] Getting started with the X-CUBE-MEMS1 motion MEMS and environmental sensor software expansion for STM32Cube (UM1859)

[2] STM32 Nucleo-64 board (UM1724)

[3] Getting started with Unicleo-GUI for motion MEMS and environmental sensor software expansion for STM32Cube (UM2128)

Revision history

Table 3. Document revision history

Date	Version	Changes
05-Aug-2024	1	Initial release.

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