Getting started with X-CUBE-LocalVUI

Introduction

The X-CUBE-LocalVUI STM32Cube Expansion Package enables local voice recognition on the STM32H747I-DISCO and STM32H573I-DK Discovery kits.

It provides the following features:

- Cloudless voice user interface (UI)
- Audio capture from board microphone
- Integration of automatic speech recognition (ASR) software
    - Sensory TrulyHandsfree™ (THF) software component
    - Sensory TrulyNatural™ (TNL) software component
- Capability to build and integrate a customized voice UI vocabulary model
    - Vocabulary model built with Sensory VoiceHub
- Support for wake word detection only, or wake word and command mode
- Detected command logged on Virtual COM port
- Possibility to connect the board as a USB device to record the microphone audio capture

It contains:

- Software components to acquire audio on microphone and interface with the third-party ASR
- Software components to trace detected commands and send captured audio through USB for debug
- Third-party ASR components
- For each Discovery kit, one application based on Sensory THF technology (binary and source code)
- One application based on Sensory TNL technology (binary and source code)

The applications show:

- How to perform an audio capture
- How to interface with voice recognition APIs
- How to integrate new vocabulary models generated with the Sensory VoiceHub

The X-CUBE-LocalVUI Expansion Package also provides a few tools to monitor and debug voice applications.

1   General information

The X-CUBE-LocalVUI Expansion Package runs on the STM32H7 microcontrollers based on the Arm® Cortex®-M7 processor and on the STM32H5 microcontrollers based on the Arm® Cortex®-M33 processor. The Table 1 defines the terms used in this document.

Table 1. Acronyms, abbreviations, and definitions

Term	Definition
API	Application programming interface
ASR	Automatic speech recognition
IDE	Integrated development environment
MCU	Microcontroller unit
PC	Personal computer
THF	Sensory TrulyHandsfree™
TNL	Sensory TrulyNatural™
UART	Universal asynchronous receiver transmitter
USB	Universal serial bus
Voice UI	Voice user interface

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2 Hardware description

2.1 Standard kit contents

STM32H747I-DISCO

The STM32H747I-DISCO Discovery kit is based on the STM32H747XI microcontroller. It provides the required connectivity ports. The introductory documents to both products are available from the product pages at *www.st.com*:

- STM32H747I-DISCO: *Discovery kit with STM32H747XI MCU* data brief (DB3608)
- STM32H747XI: *Dual 32-bit Arm® Cortex®-M7 up to 480MHz and -M4 MCUs, up to 2MB Flash, 1MB RAM, 46 com. and analog interfaces, SMPS, DSI* datasheet (DS12930)

STM32H573I-DK

The STM32H573I-DK Discovery kit is based on the STM32H573II microcontroller. It provides the required connectivity ports. The introductory documents to both products are available from the product pages at *www.st.com*:

- STM32H573I-DK: *Discovery kit with STM32H573II MCU* data brief (DB4957)
- STM32H573II: *Arm® Cortex®-M33 32-bit MCU+TrustZone® + FPU, 375 DMIPS 250 MHz, 2-Mbyte flash memory, 640 Kbytes RAM, Crypt* datasheet (DS14121)

2.2 User-provided items

- A Windows® development PC, with a free USB port
- At least one USB cable with a Micro-B connector (STM32H747I-DISCO) or a USB-C® connector (STM32H573I-DK)

The PC is used to:

- Power hardware
- Program firmware
- Display the STM32 firmware traces and results onto a serial terminal

The STSW-LINK009 ST-LINK USB driver must be installed on the PC. It is available from the STMicroelectronics website at *www.st.com*. STSW-LINK009 is required to program the firmware onto the STM32 microcontroller.

2.3 Additional hardware references

Table 2. STMicroelectronics documents

Product	Document type	Document title	Reference
STM32H747I-DISCO	User manual	Discovery kit with STM32H747XI MCU	UM2411
STM32H747XI	Reference manual	STM32H745/755 and STM32H747/757 advanced Arm®-based 32-bit MCUs	RM0399
	Programming manual	STM32F7 Series and STM32H7 Series Cortex®-M7 processor programming manual	PM0253
	Application note	STM32H745/755 and STM32H747/757 lines dual-core architecture	AN5557
STM32H573I-DK	User manual	Discovery kit with STM32H573II MCU	UM3143
STM32H573II	Reference manual	STM32H563/H573 and STM32H562 Arm®-based 32-bit MCUs	RM0481
	Programming manual	STM32 Cortex®-M33 MCUs programming manual	PM0264

Table 3. Arm Limited documents

Document title	Download from
ARMv7-M Architecture Reference Manual	developer.arm.com[1]
Arm Cortex-M7 Processor Technical Reference Manual	
Armv8-M Architecture Reference Manual	
Arm Cortex-M33 Processor Technical Reference Manual	

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3 Development environment setup

3.1 Programmer

The STM32CubeProgrammer (STM32CubeProg) can be used to program the application binaries to the target. It is available for download from its home page in the STMicroelectronics website at *www.st.com*.

3.2 Toolchains and IDEs

The X-CUBE-LocalVUI Expansion Package provides support for two toolchains:

- STMicroelectronics STM32CubeIDE: It consists in an Eclipse®-based user interface and the preintegrated GNU Arm compiler collection.
  STM32CubeIDE is available for download from its home page in the STMicroelectronics website at *www.st.com*.

- IAR Systems® IAR Embedded Workbench® for Arm® (EWARM).
  EWARM is available for download from the IAR Systems® website at www.iar.com.

Note: *Eclipse is a registered trademark of the Eclipse foundation.*

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Important: *When unzipping, the extraction path must not be too long, or the toolchain might report errors while building.*

In Windows®, it is advised to substitute a drive letter to the installation directory, and to open the project files from this new virtual drive. For instance:

```
> subst P: C:\Users\mary\Downloads\X-CUBE-LocalVUI_v1.0.0
```

3.3 Other software required to develop and debug applications

- Serial terminal software emulator to read the console log from the STM32 board via the USB COM serial port (such as Tera Term).
  Configure the serial port as follows:
  - 921 600 bauds
  - 8-bit data
  - No parity
  - 1 stop bit
  - No flow control
- Audio capture software, if there is a need to record the board audio input (such as Audacity®).

4 Hardware setup

STM32H747I-DISCO

- Connect the USB cable from the ST-LINK USB CN2 board connector to the development computer. The ST-LINK is an in-circuit debugger and programmer soldered on the STM32H747I-DISCO board. It is used for power supply, programming the embedded application in the flash memory, and interacting with the application through the serial Virtual COM port.
- Additionally, it is possible to connect another USB cable from the USB_OTG_HS CN1 board connector. This connection can be used to record the board audio capture on the PC.

STM32H573I-DK

- Connect the USB cable from the ST-LINK USB CN10 board connector to the development computer. The ST-LINK is an in-circuit debugger and programmer soldered on the STM32H573I-DK board. It is used for power supply, programming the embedded application in the flash memory, and interacting with the application through the serial Virtual COM port.
- Additionally, it is possible to connect another USB cable from the user USB CN17 board connector. This connection can be used to record the board audio capture on the PC.

5 Use of precompiled applications

5.1 Sensory THF application

Depending on the target, the THF precompiled binary is available as `X-CUBE-LocalVUI\Bin\STM32H747I-DISCO_xCubeLocalVuiThf.hex` or `X-CUBE-LocalVUI\Bin\STM32H573I-DK_xCubeLocalVuiThf.hex`.

To use the THF precompiled application, follow these steps:

1. Open STM32CubeProgrammer (STM32CubeProg)
   a. Find the device serial number ending with *"STM32H747I-DISCO"* or *"STM32H573I-DK"* available for connection
   b. Connect
   c. Navigate to the tab [**Erase and Programming**]>[**Download**]
   d. Choose the file to program: `X-CUBE-LocalVUI\Bin\STM32H747I-DISCO_xCubeLocalVuiThf.hex` or `X-CUBE-LocalVUI\Bin\STM32H573I-DK_xCubeLocalVuiThf.hex`
   e. Click on [**Start Program**]
2. Open Tera Term
   a. Navigate to [**File**]>[**New Connection**]>[**Serial**]
   b. Find the COM port *"COMx: STMicroelectronics STlink virtual COMPort (COMx)"*
   c. Click on [**Open**]
3. Reset the board
4. Observe that the traces on the UART are like in the example below:

```
Tslice Version = 6.8.0
Calling SensoryProcessInit
STM32 & THF ready
Wake words =
- sensory
List of available commands =
- turn_on_the_air_conditioning
- turn_the_air_conditioning_off
- turn_on_the_light
- turn_the_light_off
- room_temperature
- outside_temperature
- outside_humidity
- get_the_lights
- make_it_colder
- make_it_hotter
- turn_off_the_air_conditioning
- turn_the_air_conditioning_on
- turn_off_the_light
- turn_the_light_on
--------------------------------- Listening to wake word ...
```

5. Exercise the application and check in the traces whether the recognition was successful:

```
--------------------------------- Listening to wake word
... ===> sensory 3
--------------------------------- Listening to commands ..
===> turn_on_the_air_conditioning
```

5.2 Sensory TNL application

The TNL precompiled binary is available as `X-CUBE-LocalVUI\Bin\STM32H747I-DISCO_xCubeLocalVuiTnl.hex` for the STM32H747I-DISCO Discovery kit.

The steps to program the precompiled application and start the UART traces are the same as in Section 5.1 Sensory THF application.

The traces simply list the wake word, not the commands (refer to the TNL readme file for the set of available commands):

```
Rejection is set to 0.300000
Available vocabulary:
1: "sensory"
STM32 & TNL ready
------------------------- Listening to wake word or commands ...
```

The following traces are displayed when the recognition is successful:

```
Sensory trigger found 9
"small cappuccino"
Printing Intent informations:
nlu : { orderBeverage { size small } { beverage cappuccino } }
orderBeverage : { size small } { beverage cappuccino }
size : small
beverage : cappuccino
```

6 Applications build from sources

For each target, all the applications can be built from their sources with either the STM32CubeIDE or the EWARM toolchains:

1. Double-click on the project in the selected toolchain
2. Compile, program the target, and debug as usual.

STM32H747I-DISCO

Table 4. Sensory THF application projects (STM32H747I-DISCO)

Toolchain	Project path
STM32CubeIDE	`X-CUBE-LocalVUI\Projects\STM32H747I-Discovery\Applications\sensory_thf\STM32CubeIDE\xCubeLocalVuiThf\.project`
EWARM	`X-CUBE-LocalVUI\Projects\STM32H747I-Discovery\Applications\sensory_thf\EWARM\Project.eww`

Table 5. Sensory TNL application projects (STM32H747I-DISCO)

Toolchain	Project path
STM32CubeIDE	`X-CUBE-LocalVUI\Projects\STM32H747I-Discovery\Applications\sensory_tnl\STM32CubeIDE\xCubeLocalVuiTnl\.project`
EWARM	`X-CUBE-LocalVUI\Projects\STM32H747I-Discovery\Applications\sensory_tnl\EWARM\Project.eww`

STM32H573I-DK

Table 6. Sensory THF application projects (STM32H573I-DK)

Toolchain	Project path
STM32CubeIDE	`X-CUBE-LocalVUI\Projects\STM32H573I-DK\Applications\sensory_thf\STM32CubeIDE\.project`
EWARM	`X-CUBE-LocalVUI\Projects\STM32H573I-DK\Applications\sensory_thf\EWARM\Project.eww`

7 Change of grammar and vocabularies

Both the Sensory THF and TNL applications can be upgraded with customized grammar and vocabularies. It can be achieved in a few steps:

1. Define a custom vocabulary model from the Sensory VoiceHub portal at voicehub.sensory.com
2. Build from VoiceHub
3. Download the model
4. Uncompress the files and copy them to the proper folder

The way to integrate new vocabularies is described in detail in the readme file of each application.

The Sensory THF application example supports both use cases:

• wake word only
• wake word plus commands

8 Record of board audio input on PC

This feature is provided as a debug tool. It helps to check the correct capture of the board microphone that is sent to the ASR.

Once a USB cable connects the USB_OTG_HS CN1 board connector (for STM32H747I-DISCO) or the user USB CN17 board connector (for STM32H573I-DK) with the PC, the Audacity® software displays a device called the *"Microphone (STM32 Headset)"*.

Select this device as an input to record the audio as captured by the microphone of the board.

Revision history

Table 7. Document revision history

Date	Revision	Changes
27-Apr-2022	1	Initial release.
17-Jun-2022	2	Added the integration of Picovoice™ products: • Added *Picovoice application* • Updated *Introduction*, *Applications build from sources*, and *Change of grammar and vocabularies*
24-Nov-2022	3	Removed Picovoice™ support: • Removed *Picovoice application* • Updated *Introduction*, *Applications build from sources*, and *Change of grammar and vocabularies*
12-Dec-2023	4	Added the support for the STM32H573I-DK Discovery kit: • Updated Introduction, General information, Sensory THF application, and Record of board audio input on PC • Added dedicated sections in Hardware description, Hardware setup, and Applications build from sources

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