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INSTITUTE of TECHNOLOGY CARLOW

At the Heart of South Leinster

PIXEL, A VIRTUAL ASSISTANT WITH FACE RECOGNITION

Design Manual

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30th of April, 2021

Declaration on plagiarism

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Assignment Title	PIXEL, A VIRTUAL ASSISTANT WITH FACE RECOGNITION
Submission Date	30th of April, 2021

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This document was not presented in any previous research papers for the award of a bachelor's degree to the best of my knowledge.
The work is entirely mine, and I accept full responsibility for any errors that might be found in this report. At the same time, the reference to publish materials had been duly acknowledged.
I have provided a complete table of references for all works and sources used in the preparation of this document.
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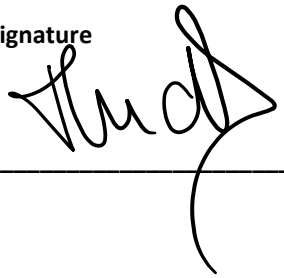

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ABSTRACT

This document presents the design of the interactive mirror "Pixel" Virtual Assistant. The device is designed to receive requests from users, process them, and deliver back a meaningful answer. The entire system is controlled by a Raspberry Pi Model 4B+, which is equipped with a speaker, a microphone, a camera, a temperature sensor, a GSM/GPS hat, cooling fans, and an LCD display cover by a two-way acrylic mirror.

The virtual assistant performs basic functionalities such as; time, weather, definitions, manipulate lists, and with the help of facial detection, facial recognition, speech recognition, and google text-to-speech, the device can interact with its users.

This document provides details about the hardware architecture, screen flows and diagrams, system flow, class diagrams and sequence diagrams that are necessary for the device implementation.

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INTRODUCTION

Pixel Virtual Assistant is a smart speaker encapsulated into a mirror dedicated for people with hearing deficiency and people with low computer skills. The smart speaker displays all the answers required by the user on the mirror surface, simultaneously with their narration.

The device is based on Raspberry Pi and compatible hardware modules, Python3, and other libraries.

This document aims to provide the system's hardware and software architecture, including screens flow, system flow, class diagrams, and sequence diagrams, as detailed as possible.

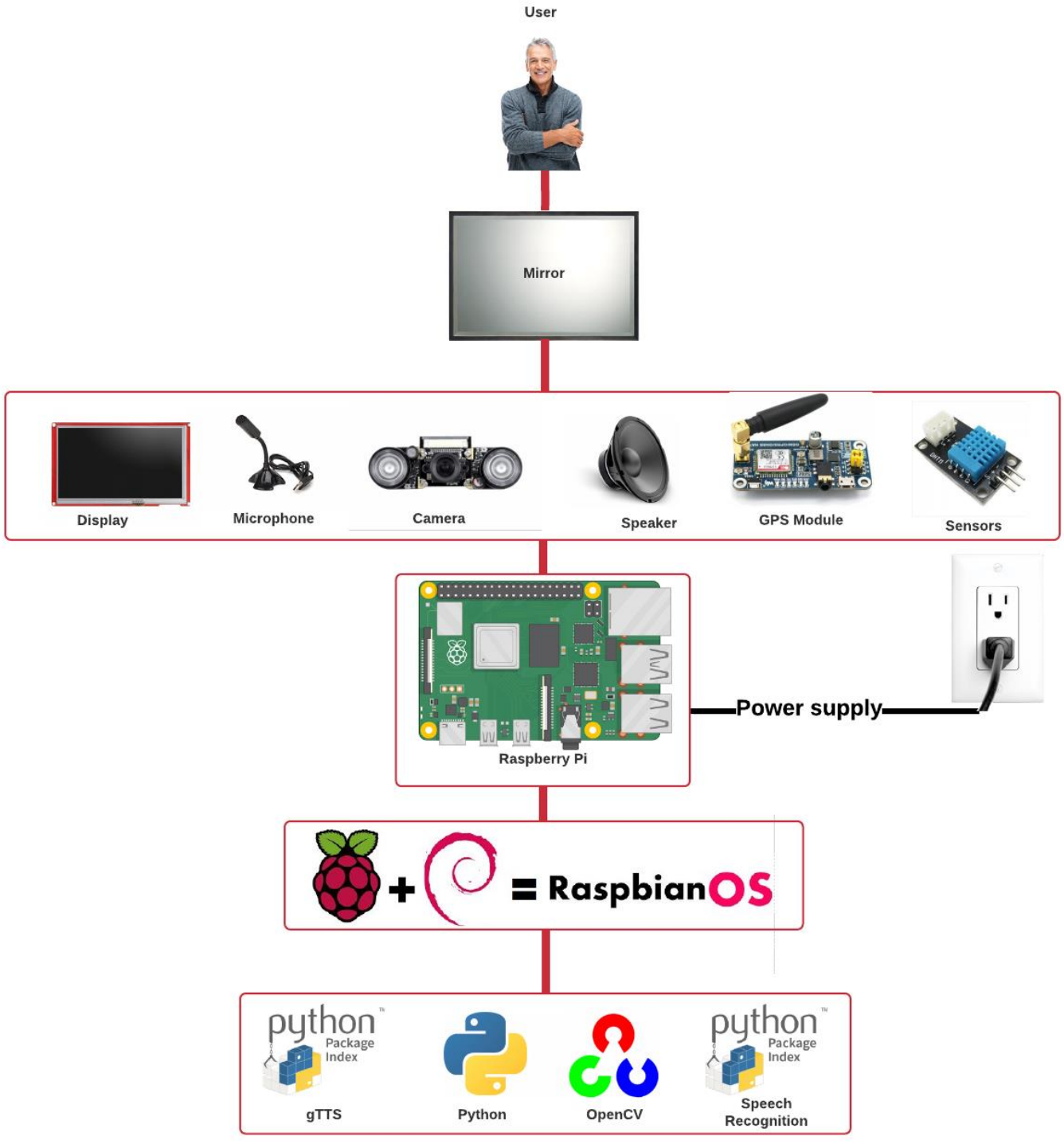


Figure 1 "System architecture."

The system is designed as seen in **Figure 2.**
The hardware components illustrated in **Figure 2** are detailed in the **Hardware Architecture** section that follows.
The code and functions implemented using the modules shown in **Figure 02** are described in the **System Design** section, where the primary use case diagram, multiple sequence diagrams, system flow diagram, and the class diagram are provided.

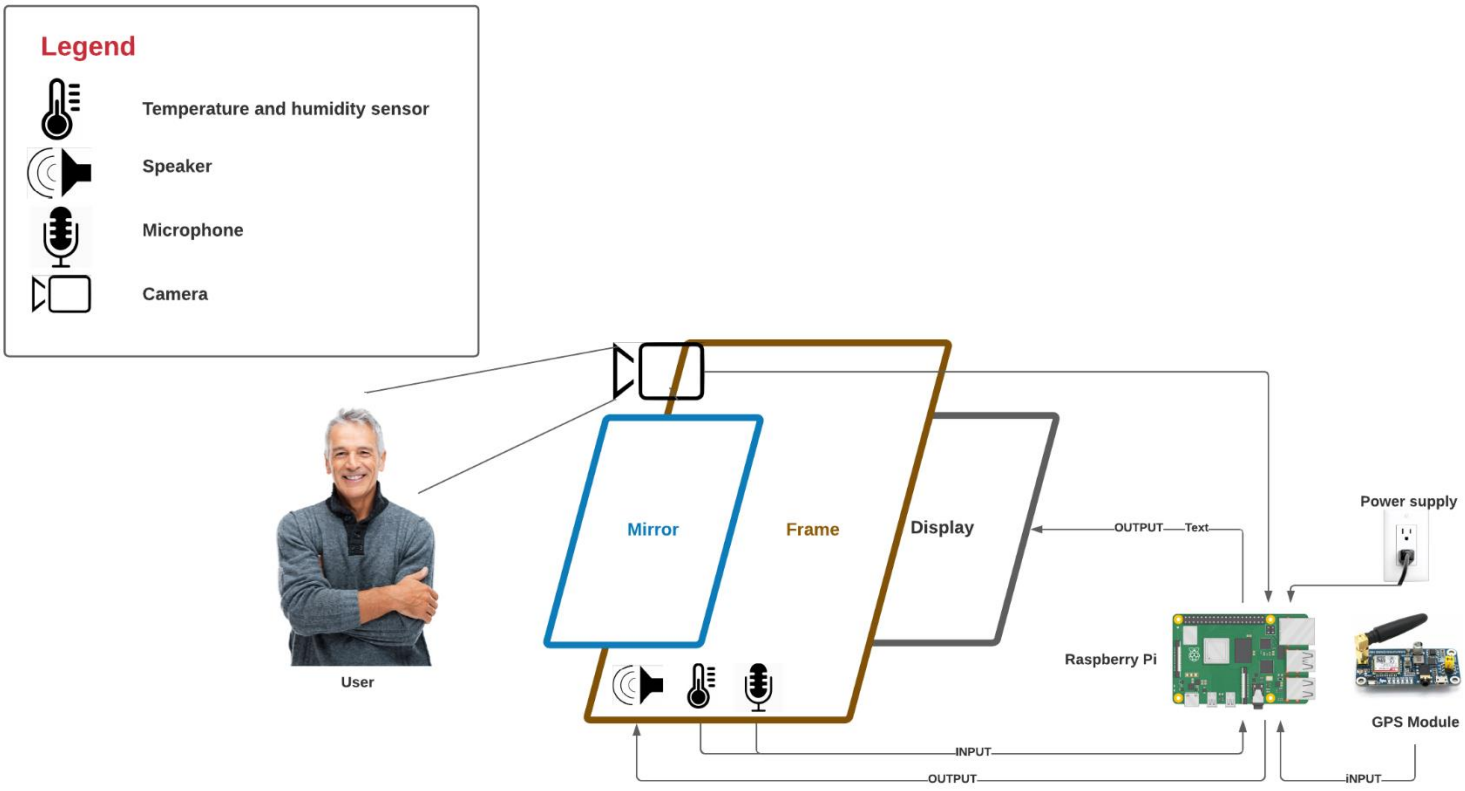


Figure 2 "Hardware architecture."

This diagram (**Figure 3**) is a schematic showing how the hardware components integrate into the frame. Later in this section, the frame crafting and hardware layout within the frame are detailed.

All the hardware described later in this section was detailed in detail in the “Research Document”.

RASPBERRY PI

The version of Raspberry Pi chose is model 4 B with the following accessories (Electronics, 2019)

- 4GB of RAM
- 1.5 GHz quad-core Arm Cortex
- VideoCore VI graphics
- True Gigabit Ethernet
- 2 USBs 3.0
- 2 USBs 2.0
- 2 Micro HDMI
- 1 USB C
- 4kp60 HEVC decode

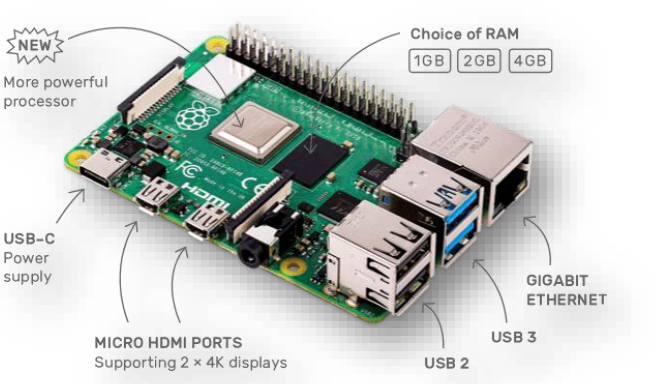


Figure 3 "Raspberry Pi 4"
Source: (Serasinghe, 2020)

Other models of Raspberry Pi can be used for this project, but OpenCV running time can impact the user's experience, as the library needs at least 1GB of RAM to run.

MIRROR

The mirror used is a two-way acrylic mirror, which allows light to pass from one side only.

The acrylic mirror chosen for the project is an acrylic sheet placed into the frame and under which the LCD display is hidden.

Figure 4 "Acrylic mirror"
Source: (Amazon, 2020)

The bright colors of the display that rest on the mirror's inner side can pass through the mirror surface, giving the user the illusion that the text appears on the mirror's surface.

At the same time, the users of the device can see their reflection in the mirror.

The acrylic sheet can be replaced with a two-way mirror sticker on a standard glass or plastic, but the mirror aspect won't look as natural.

DISPLAY

A 10.1-inch display compatible with Raspberry Pi 4 is used for the project. This display hides under the two-way acrylic mirror.

Other displays can be used as long as there are compatible with the Raspberry Pi.

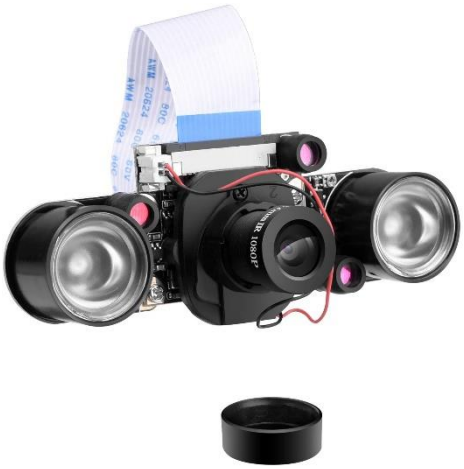
When choosing the display, measurements need to be taken to ensure that the screen fits under the two-way acrylic mirror. Another important reason for choosing this type of display is represented by the possibility of attaching the Raspberry Pi on its back; therefore, it is secure, offers the opportunity of saving space when creating the project, and delivers a tidy finite product.

The Raspberry Pi is attached to the back of the screen, and it can be powered by the display; therefore, it eliminates the need to use multiple power cables.

Figure 5 "Display"
Source: (Amazon, 2020)

CAMERA

The camera used to implement the virtual assistant is a 5 MP camera with infrared. The camera was chosen as it has excellent night vision, allowing the users to use the device in poor lighting conditions. The camera can be changed with any camera compatible with the Raspberry Pi, but its impact on the virtual assistant may vary depending on the camera's abilities and its quality (Amazon, 2021).



Longruner Raspberry Pi Camera Module automatically switches from day to night vision for a better and clear image during the day and night. It also provides adjustable focus. This Camera Module is a custom-design easy plug-and-play for Raspberry Pi. It plugs into one of the two small sockets on the board's upper surface to connect to the Raspberry Pi. This ribbon cable links and powers the camera module to the Raspberry Pi (Amazon, 2021).

Figure 6 "Camera"
Source: (Amazon, 2021)

MICROPHONE

Gyvazla USB microphone was chosen for this project. This microphone cancels the noise and isolates the main sound source. (Amazon, 2021)

Figure 7 "USB Microphone"
Source: (Amazon, 2021)

Using a USB connector, the plug-and-play design provides a smooth connection with the Raspberry Pi without installing any software. Gyvazla USB microphone offers a comprehensive frequency response for acute and transparent sound. (Amazon, 2021)

This project does not require any particular microphone. There are multiple choices that the developer can choose from. Still, several aspects need to be considered when choosing a microphone, such as noise cancellation, cable's length, microphone size, drivers required, and the port supported by the Raspberry Pi.

The Raspberry Pi used for this project does not have a JACK port (a converter is needed if the microphone has a JACK input). The microphone needs a cable long enough to allow the microphone to be installed into the front of the frame. If the microphone is positioned inside the frame, capturing the user's voice might be impossible or hard to intercept.

SPEAKER

The speakers used for this project, IBest WM8960 HI-FI Hat Audio Module compatible with the Raspberry Pi 4, were chosen for multiple reasons, such as low power consumption, dual-channel speaker interface, directly drives speakers, and size (which is an essential quality as the speakers need to be integrated into the wooden frame) (Amazon, 2021).

Figure 8 "Audio module speakers"
Source: (Amazon, 2021)

The audio module is equipped with a card Hat that can be connected with the Raspberry Pi through the GPIO pins; however, the display board is fitted with an I2S port, allowing the speakers to be connected directly to the screen board without using the hat.

Other speakers may be used for this project, but voltage, size, and clarity must be considered.

TEMPERATURE/HUMIDITY SENSOR

The temperature and humidity sensor represents an additional functionality for this project, informing its users about the temperature and humidity detected in the room where the device is installed.

Figure 9 "Temperature and Humidity Sensor"
Source: (Amazon, 2021)

The sensor has a temperature range from -40 to 80 degrees Celsius with an accuracy of +- 0,5 degrees. The humidity ranges from 0 to 100, providing an accuracy of +- 2%. (Amazon, 2021)

HALJIA DHT22 AM2302 is equipped with a hole for fastening screw; therefore is easy to install and attached to the frame used for this project.

There are a variety of related sensors available with the same functionalities required for this project. When selecting a sensor, factors such as ease of installation, size, and accuracy must be considered.

GSM/GPRS/GNSS HAT

The GPS module chosen for this project is Waveshare Raspberry Pi GSM/GPRS/GNSS Bluetooth Hat with low power consumption.

The module supports text messages and phone calls which are essential key features for this project. GPS, COMPAS, Glonass, LBS base station positioning, and omni-positioning are all supported and available with the GPS module. The module also offers the possibility of Bluetooth connection, functionality not used in this project. (Amazon, 2021)

Figure 10 "GSM/GPRS/GNSS Module"
Source: (Amazon, 2021)

The GSM/GPRS/GNSS Module is equipped with a SIM slot, a GPS antenna, and a GSM antenna allowing the developer to create functionalities like “Call location”, “Send SOS”, “Get weather “. When the board is turned off, a CR1220 battery is needed to measure the passage of time. This battery will keep the real-time clock (RTC) running for up to 3 years.

The GPS Hat can be connected with the Raspberry Pi via the USB or the UART interface. For this project, the USB interface was the best match, as if the hat was placed over the Raspberry Pi, it would cover the GPIO pins, and some pins are reserved for the cooling fans.

Multiple GSM/GPRS/GNSS can be chosen for this project, but the code implemented for this hat might need to be altered to benefit from all the functionalities that the hat provides.

A SIM card needs to be inserted into the hat as several skills for this project directly benefit from the GSM and GPRS functionalities.

Note:
To perform a call using this hat, a set of headphones with a microphone is needed, with a Jack plug.

COOLING FAN

The Raspberry Pi, encased in the frame, having connected to the board all the other components have begun to transmit high-temperature signals, warning the developer that the temperature has exceeded the safe limits.

Figure 11 "Cooling fan"
Source: (Amazon, 2021)

Therefore Makerfire Raspberry Pi Fan has been chosen to enable and maintain a safe level of the board temperature. The cooling fan reduced the Raspberry Pi temperature readings from over 80C degrees to around 50C degrees. A second fan was connected to the Raspberry Pi and positioned where the camera is set. This area represented a risk giving the fact that the camera is situated close to the wooden frame.

These fans provide a quiet and safe environment, cooling the Raspberry Pi and extending its working life. The Makerfire Raspberry Pi Fan offers a unique terminal interface (“One-to-Two” interface) where the developer can choose which voltage to use 3.3V or 5V.

The variety of cooling fans compatible with Raspberry Pi is enormous. These particular fans were chosen as they are powerful, small, and quiet.

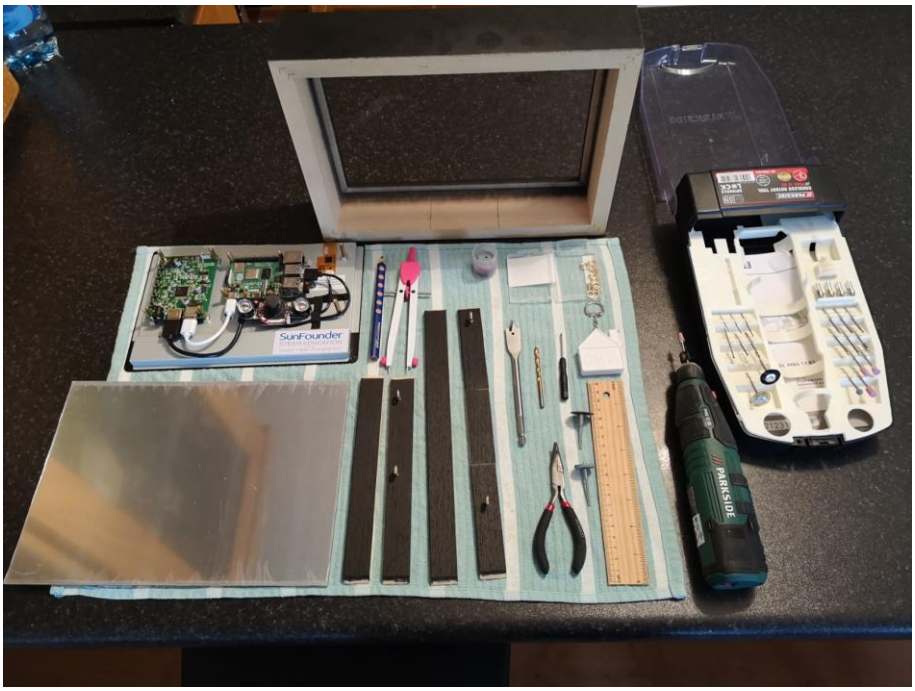
FRAME

The frame encapsulates and hides all the hardware used to implement “Pixel” Virtual Assistant. A critical factor in choosing the size of the frame is represented by the two-way acrylic mirror ordered from Amazon with the dimension of an A4 (29.7cm/21cm); Therefore, the frame used for this project comes with the following dimensions:

- Length = 34 cm
- Height = 25.5 cm
- Width = 7 cm

A local carpenter manually crafted the frame, considering the difficulty of crafting wood for someone who is not a professional wood crafter. On the idea of creating stability and security for the two-way acrylic mirror and display, four wood laths were provided as an addition to the frame.

Figure 12 "Wooden frame"
Source: Theodora Tataru, 2021



For the input and output devices such as camera, microphone speaker, and temperature sensors it was required multiple wood crafting tools such as drill machine, different types of saw blades, measuring tape, and other tools, as seen in **Figure 14.**

Figure 13 "Wood crafting tools"
Source: Theodora Tataru, 2021

Figure 15 "Crafting process 1"
Source: Theodora Tataru, 2021

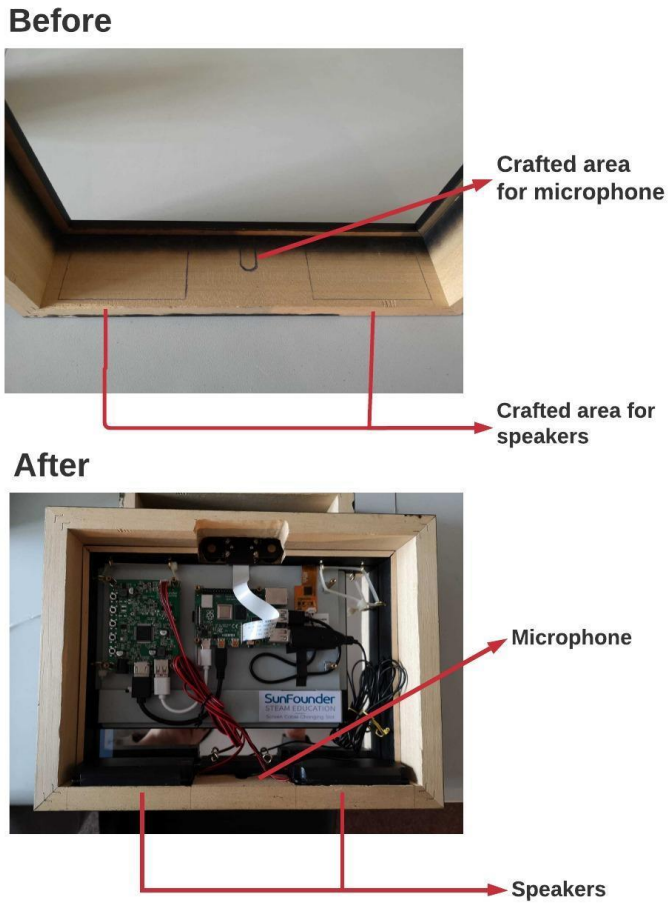


Figure 14 "Crafting process 2"
Source: Theodora Tataru, 2021

Figure 15 and **Figure 16** showcase how the process of crafting wood was performed to enable the frame to host the necessary input and output devices. Both figures present the frame state “Before” and “After” the wood was crafted.

The process of incorporating the camera and its infrared lens into the frame is shown in **Figure 16.** The “Before” section in this figure reveals the frame in the early stage of crafting. However, in the “After” section of **Figure 16,** it can be observed how the camera and the infrared lens have been attached to the frame.

In the “Before” segment of **Figure 15**, it can be seen the initial stage of the frame, with the necessary dimensions for wholes marked on the wood. These markings match the places where specific input or output hardware components will rest inside the frame. In the “After” segment, within the same figure, the wooden frame's final stage can be seen, with all the hardware components resting inside.

COMPLETE FRAME

The complete frame of “Pixel, Virtual Assistant” as shown in **Figure 15** and **Figure 16,** includes all hardware components required to achieve full functionality.

Figure 16 "Front view of the frame"
Source: Theodora Tataru, 2021

The front of the frame represented in **Figure 17** displays the use of Raspberry Pi key modules, such as:

- the camera, positioned on the upper side of the frame
- the microphone, found on the lower side, has the same colour as the frame camouflaging it in the design
- the speakers, installed on the lower side underneath the frame

As seen in **Figure 17**, the two-way acrylic mirror is encapsulated in the middle of the frame. The mirror is displaying on its surface all information transmitted by the screen, which is positioned directly behind the acrylic mirror.

Below, **Figure 18** displays the layout of the Raspberry Pi modules inside the frame. Some components are equipped with long cables; therefore, the extra lent of cable that is not needed must be tied to allow airflow and not interfere with the rest of the components.

The Raspberry Pi rests on the display's back, and the screen rests under the two-way mirror, facing the acrylic.

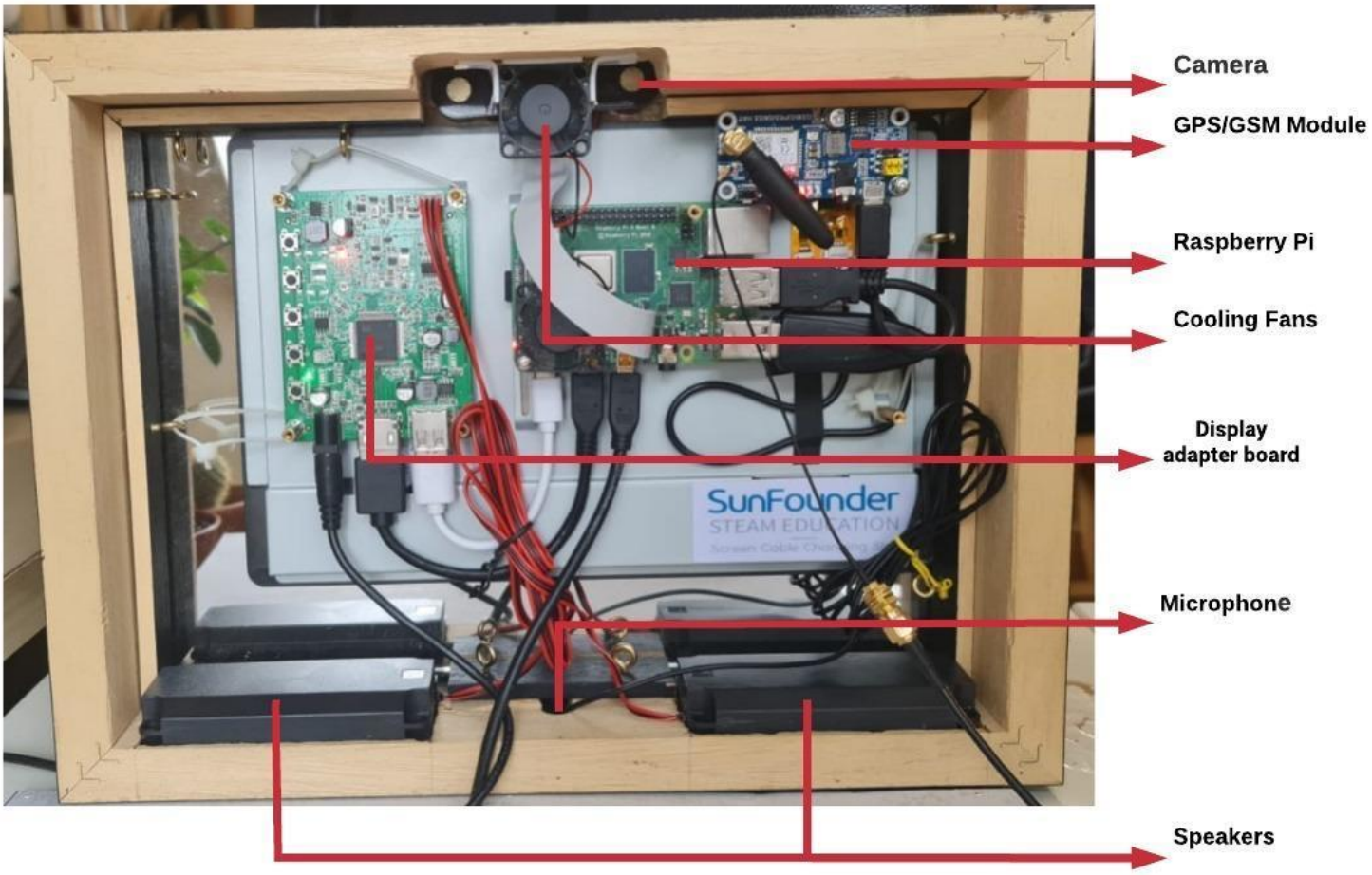


Figure 17 "Back view of the frame"
Source: Theodora Tataru, 2021

The sensor, speaker, camera, and microphone are placed under the wooden frame, with the necessary templates cut out from the frame to allow the hardware to acquire a clear input and provide a good output.

Figure 18 presents a schema that describes where each hardware piece rests.

USER INTERFACE

The user interface is designed very simple, with a black background and white text.

Because black does not reflect light, it was selected as the background color of the interface; therefore, the screen cannot be seen through the two-way mirror. In contrast, most text displayed is white, as this color reflects the most light from all the color spectrum. The result of all these choices is that the text passes through the two-way mirror, giving the illusion that the text appears on the mirror surface.

The interface reflects a minimalistic style. The project's objective is to deliver the requested information to the user via the two-way mirror without agglomerating the mirror surface.

The display is on standby until a user steps in front of the mirror, and the camera detects a face. As the user interacts with the device, all the information and the virtual assistant's responses are displayed on the mirror surface. When the user decides to step away from the mirror, the device will enter standby mode after a certain period of time.

REQUEST SCREEN

The interface that is displayed to the user most often can be observed in **Figure19**. When the user initiates an interaction (stands in front of the mirror), the screen lights up and displays in real-time what the virtual assistant narrates.

The field **“Clock”** is updated in real-time without being requested by the user.

The field marked as **“Virtual Assistant response”** is updated every time the virtual assistant delivers a response to the user’s request.

“Virtual Assistant Status” reflects the virtual assistant's state: listening, processing, starting, answering, and calling.

And lastly, but not least important, the **“Notification Panel”** displays notifications related to the user or the environment, such as reminders that can be useful to the user but not critically essential.

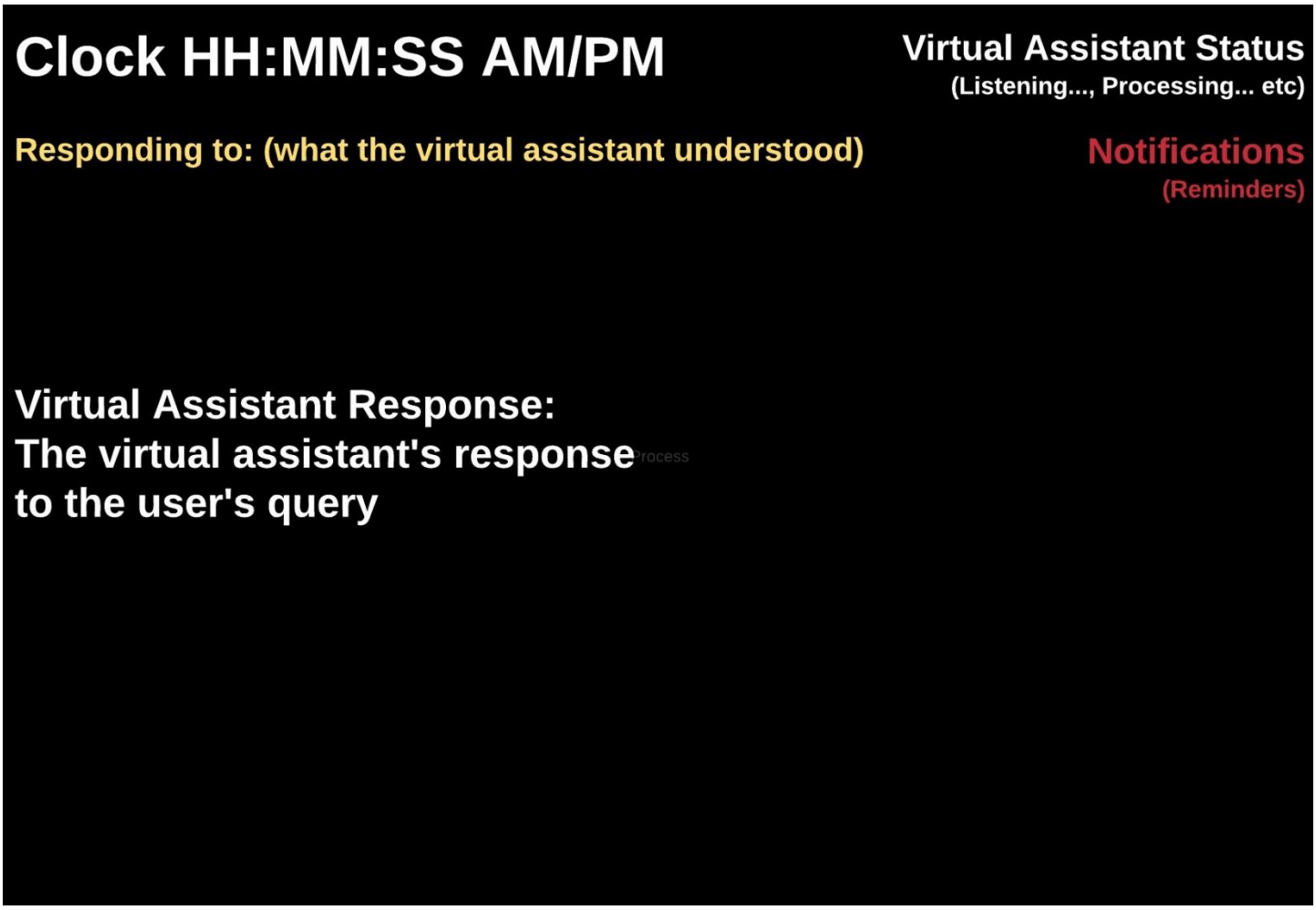


Figure 18 "Main screen"
Source: Theodora Tataru, 2021

STANDBY SCREEN

As seen in **Figure20**, only the black background with the current time is present on the screen when the device is on standby. Once the camera detects a face, the device awakes the virtual assistant, and the **"Main screen"** is displayed.

The device enters into standby mode after the user leaves or steps away from the mirror.

Figure 19 "Standby Screen"
Source: Theodora Tataru, 2021

SCREENS FLOW

The screen flow activity between the “**Main Screen**” and “**Standby Screen**” is presented in **Figure 21**.

The device shows the "Standby Screen" when the user moves away from the mirror and the "Main Screen" when the user moves in front of the mirror.

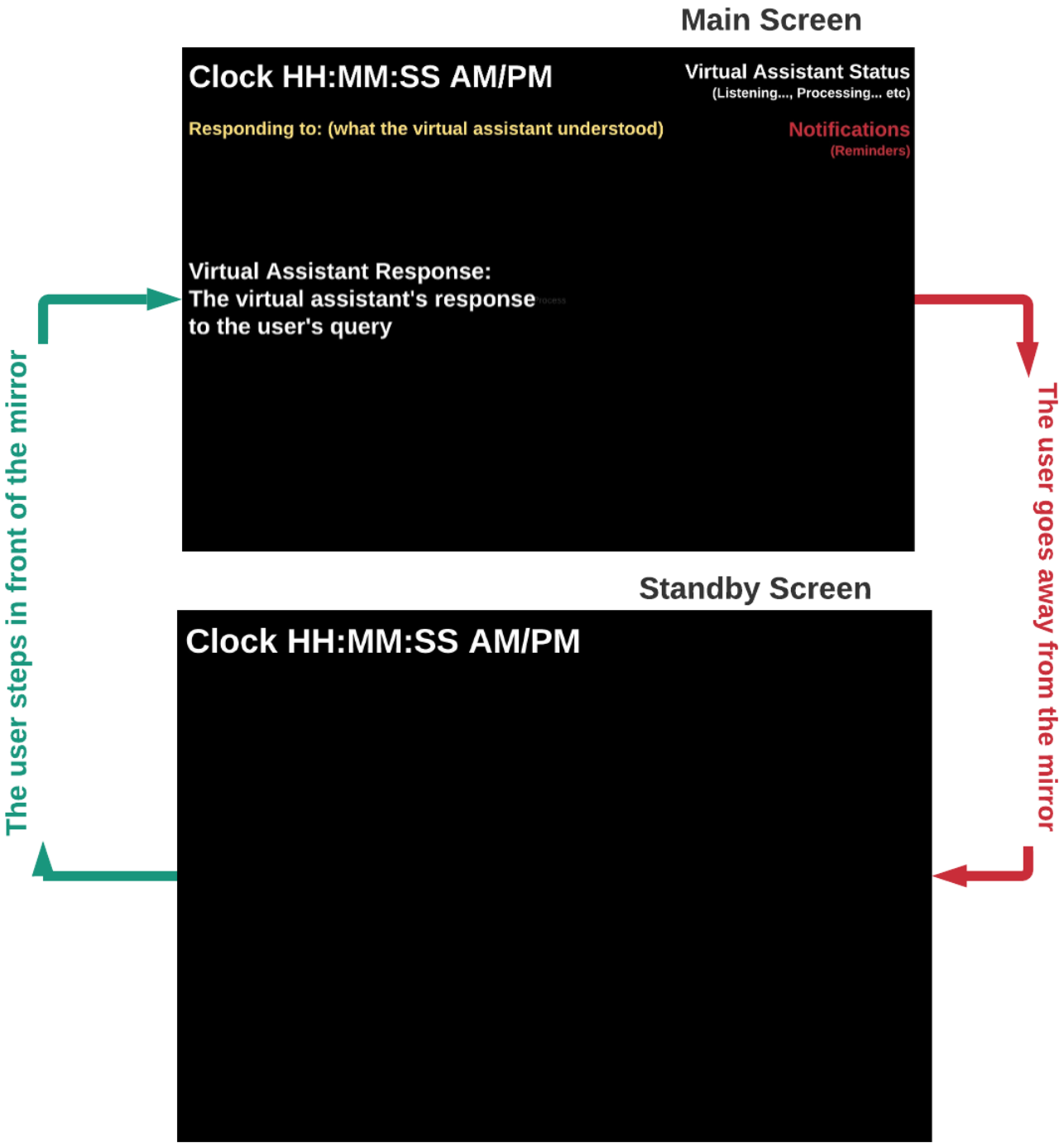


Figure 20 "Flow screen"
Source: Theodora Tataru, 2021

SYSTEM DESIGN

In this chapter, the system design and system flow chart are detailed. The main functionalities diagram is also provided, but the "Functionality Document" needs to be accessed for the explicit description of the use cases.

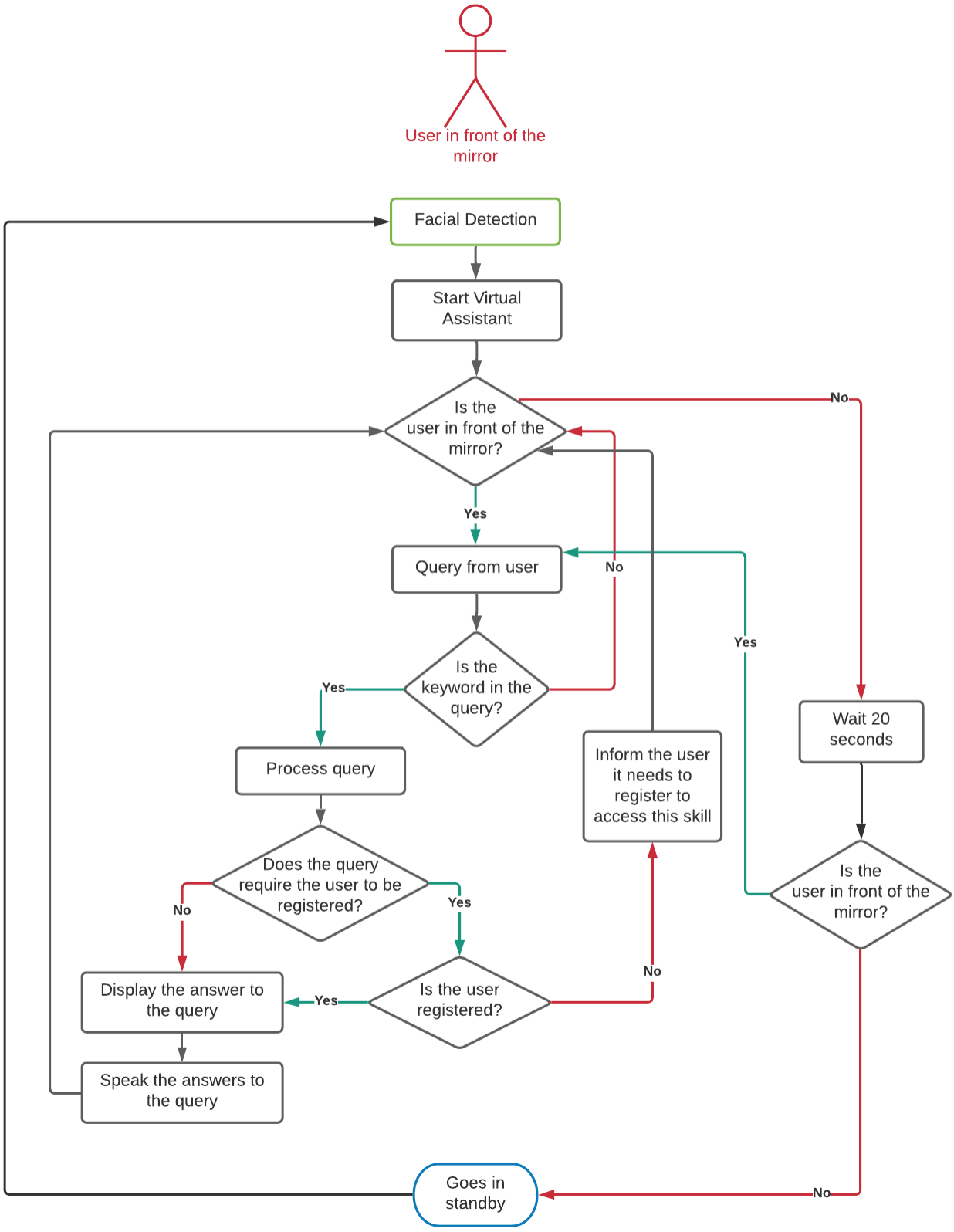


Figure 21 "System flow chart"
Source: Theodora Tataru, 2021

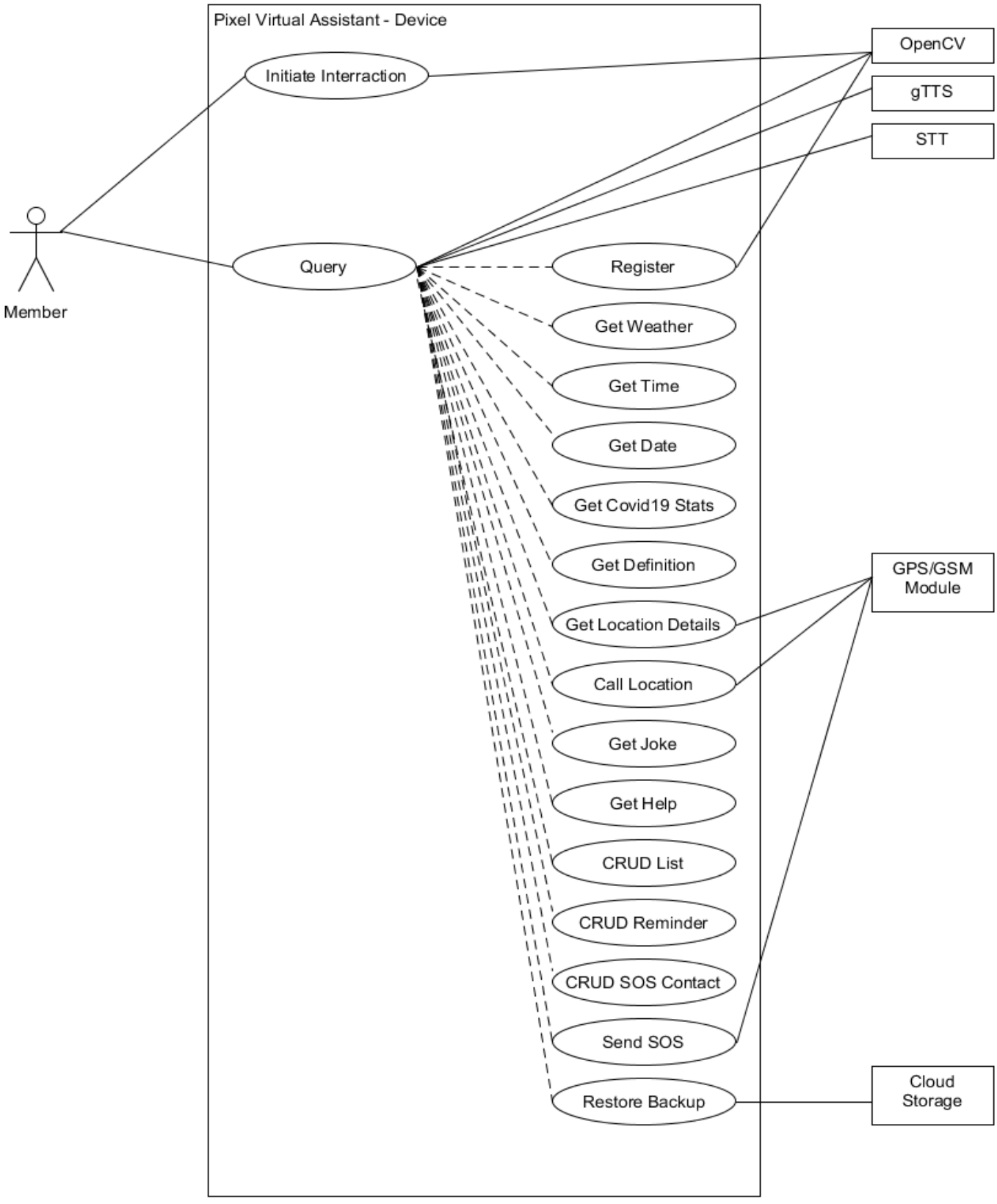


Figure 22 "Main use case"
Source: Theodora Tataru, 2021

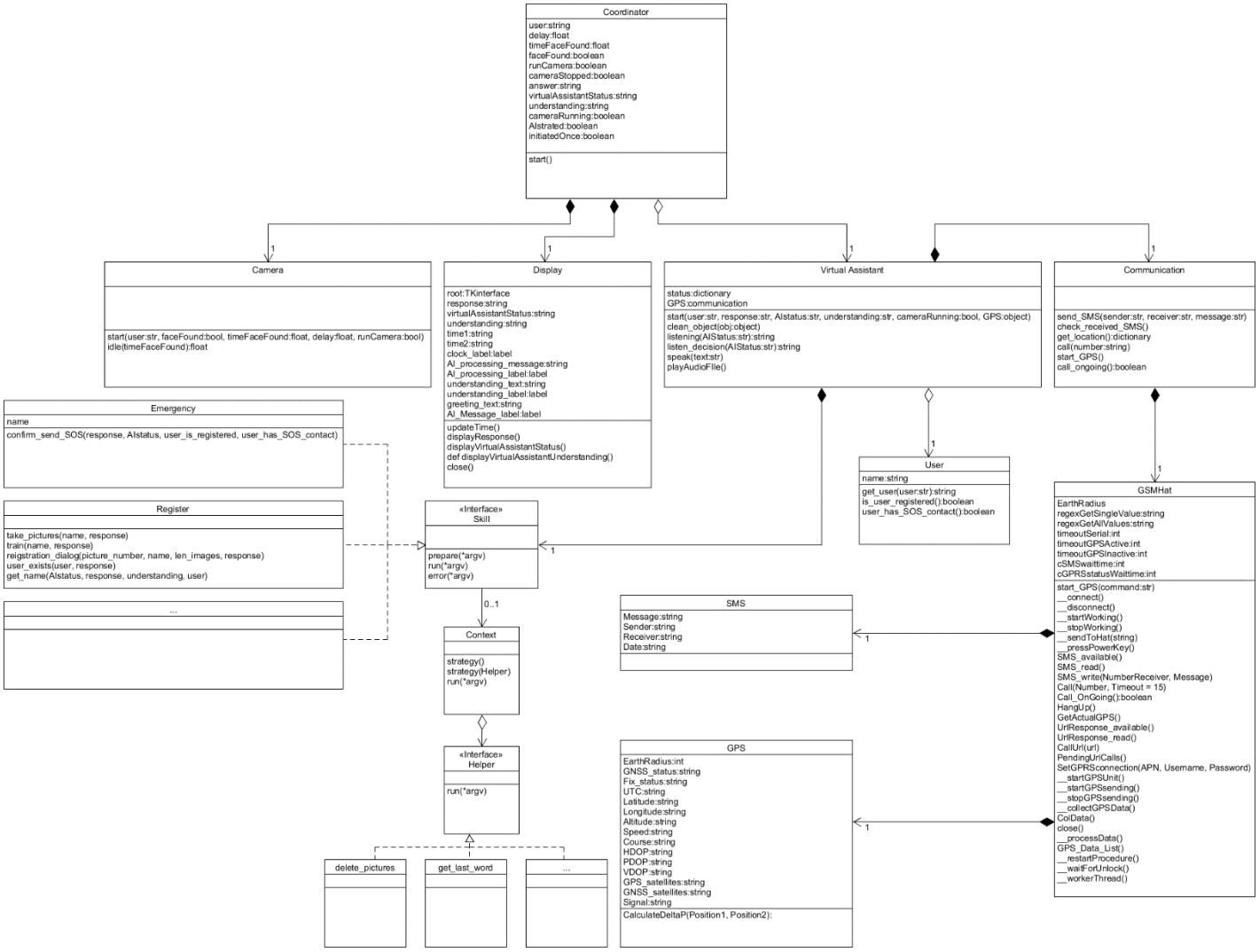


Figure 23 "Class Diagram"

Source: Theodora Tataru, 2021

ABSTRACT SKILL CLASS DIAGRAM

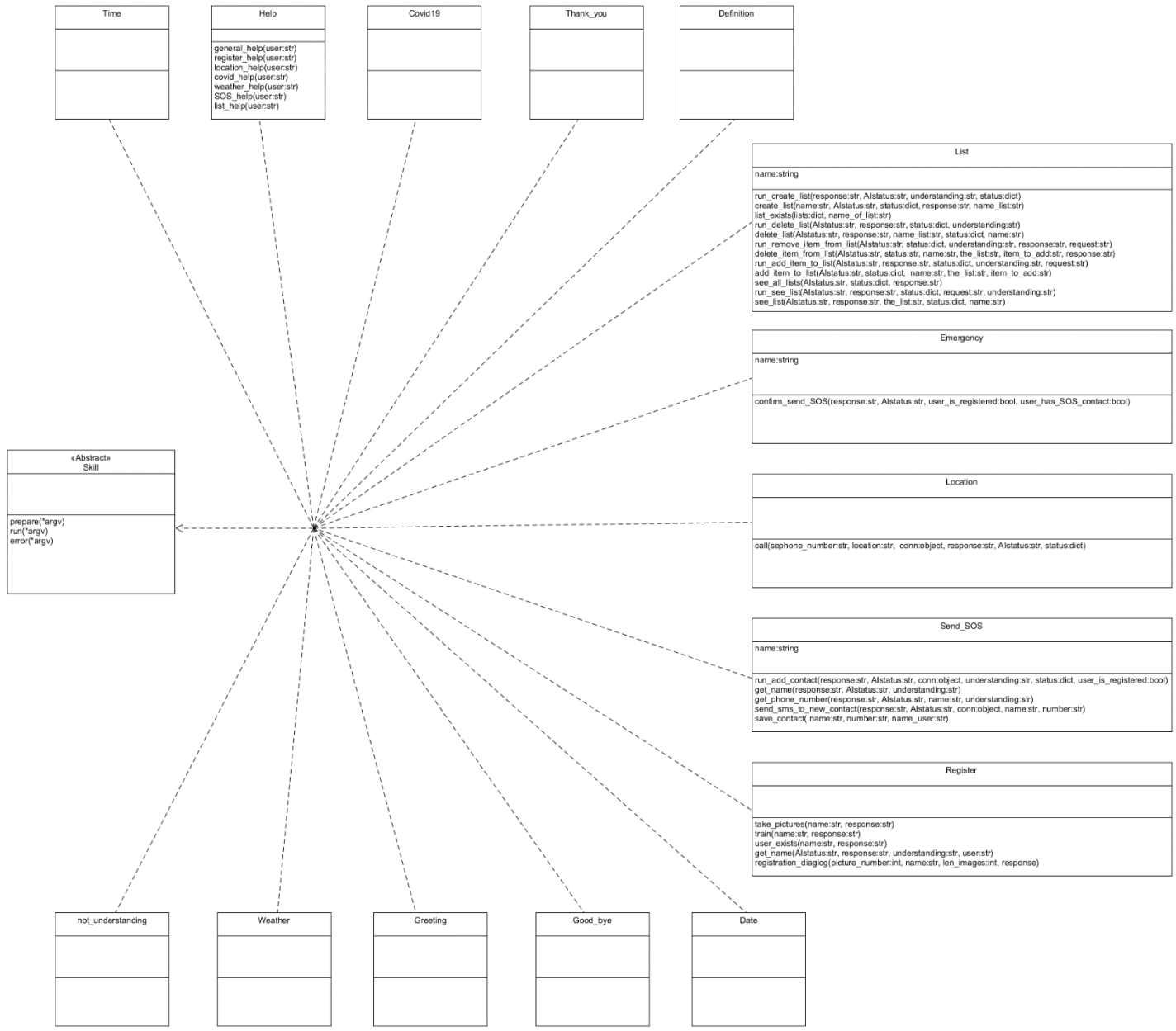


Figure 24 "Abstract skill class diagram"
Source: Theodora Tataru, 2021

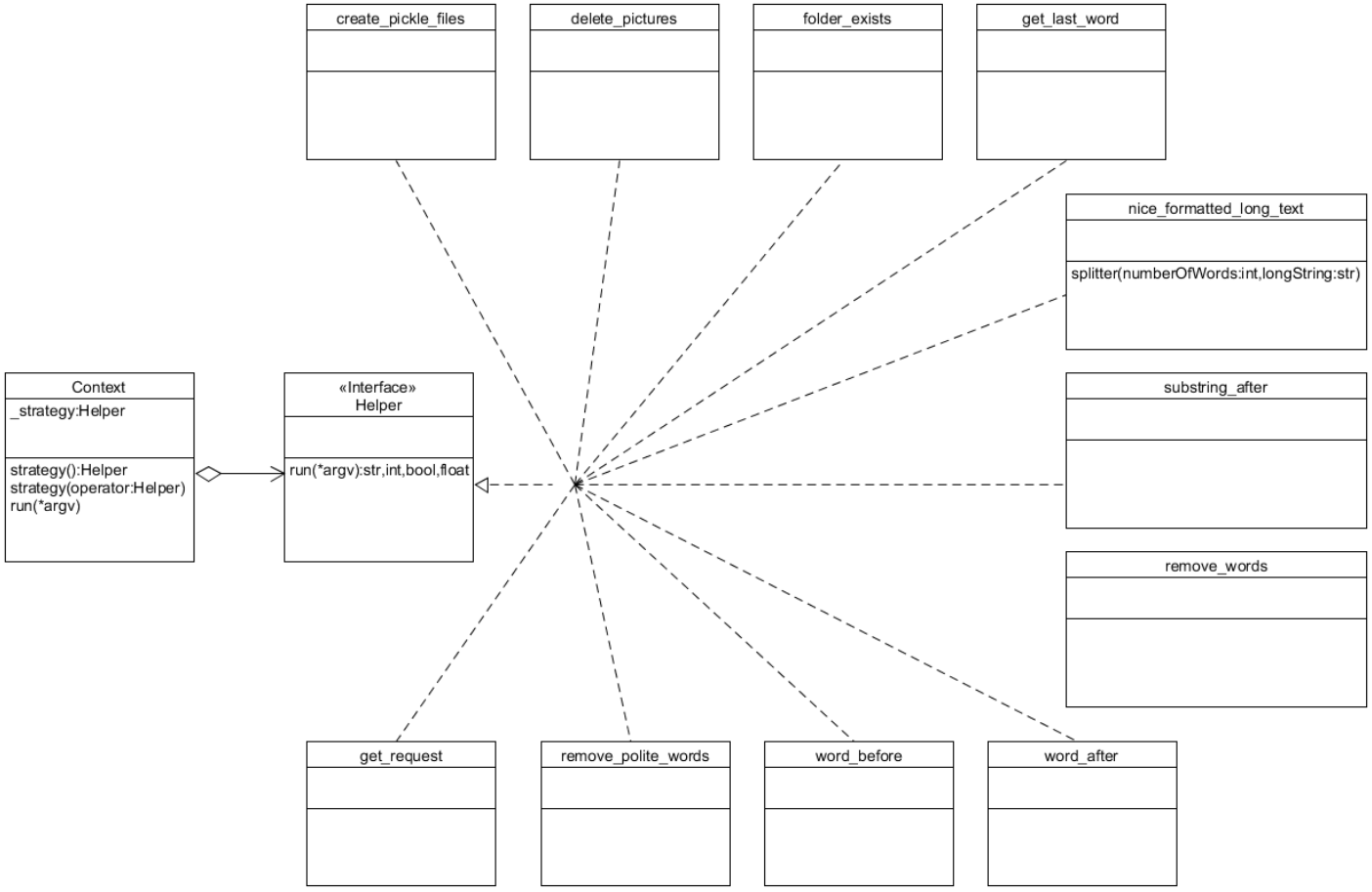


Figure 25 "Strategy pattern – helper"
Source: Theodora Tataru, 2021

SEQUENCE DIAGRAMS

This section of the document presents the diagrams corresponding with the detailed use cases from the "Functional Specification Document", (starting at 23). The detailed use cases for this diagram can be found from page 24 onwards in the "Functional Specification Document".

! Before proceeding to diagrams, an important **note** must be read:

NOTE:

The following process are running in **parallel**, being controlled by the main process "**Coordinator** ":

- Camera process
- Virtual_assistant
- Display

These processes, are sharing in between the following variables:

```
• user:str
• delay:float
• timeFaceFound:float
• faceFound:boolean
• runCamera:boolean
• cameraStopped:boolean
• answer:str
• understanding:str
• virtualAssistantStatus:str
• cameraRunning:boolean
```

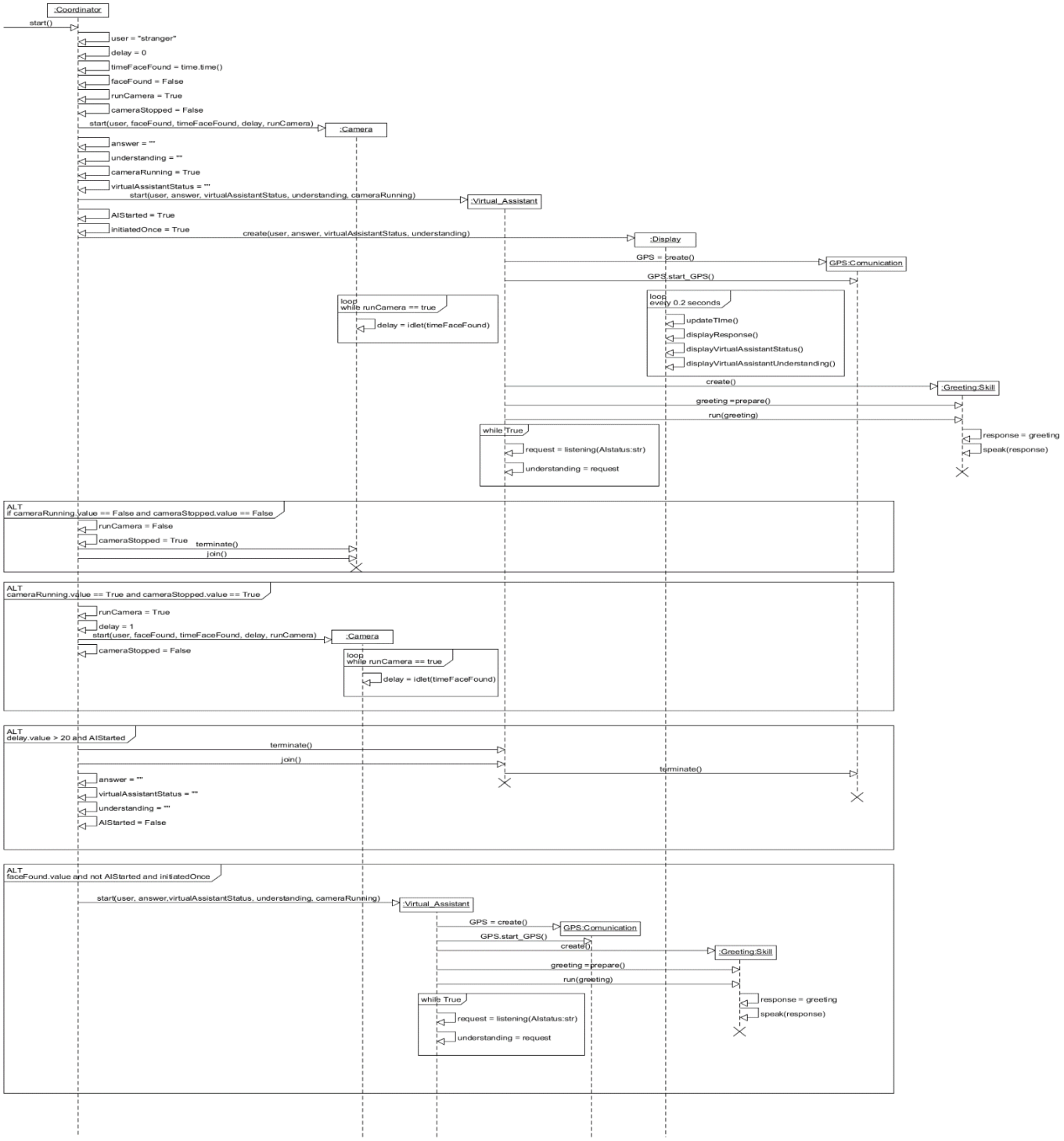


Figure 26 "Initiate interaction - sequence diagram"

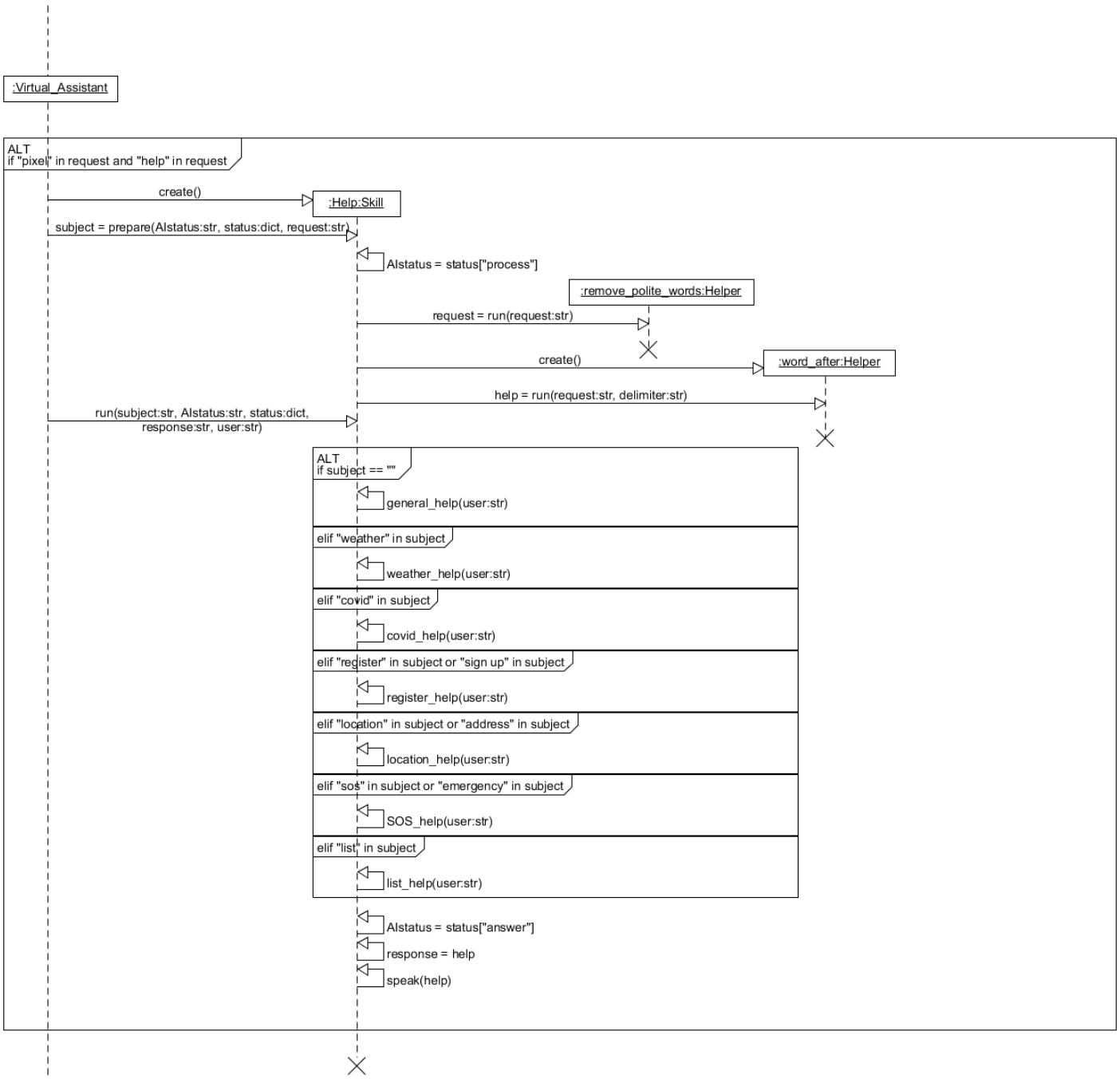


Figure 27 "Request help – sequence diagram"

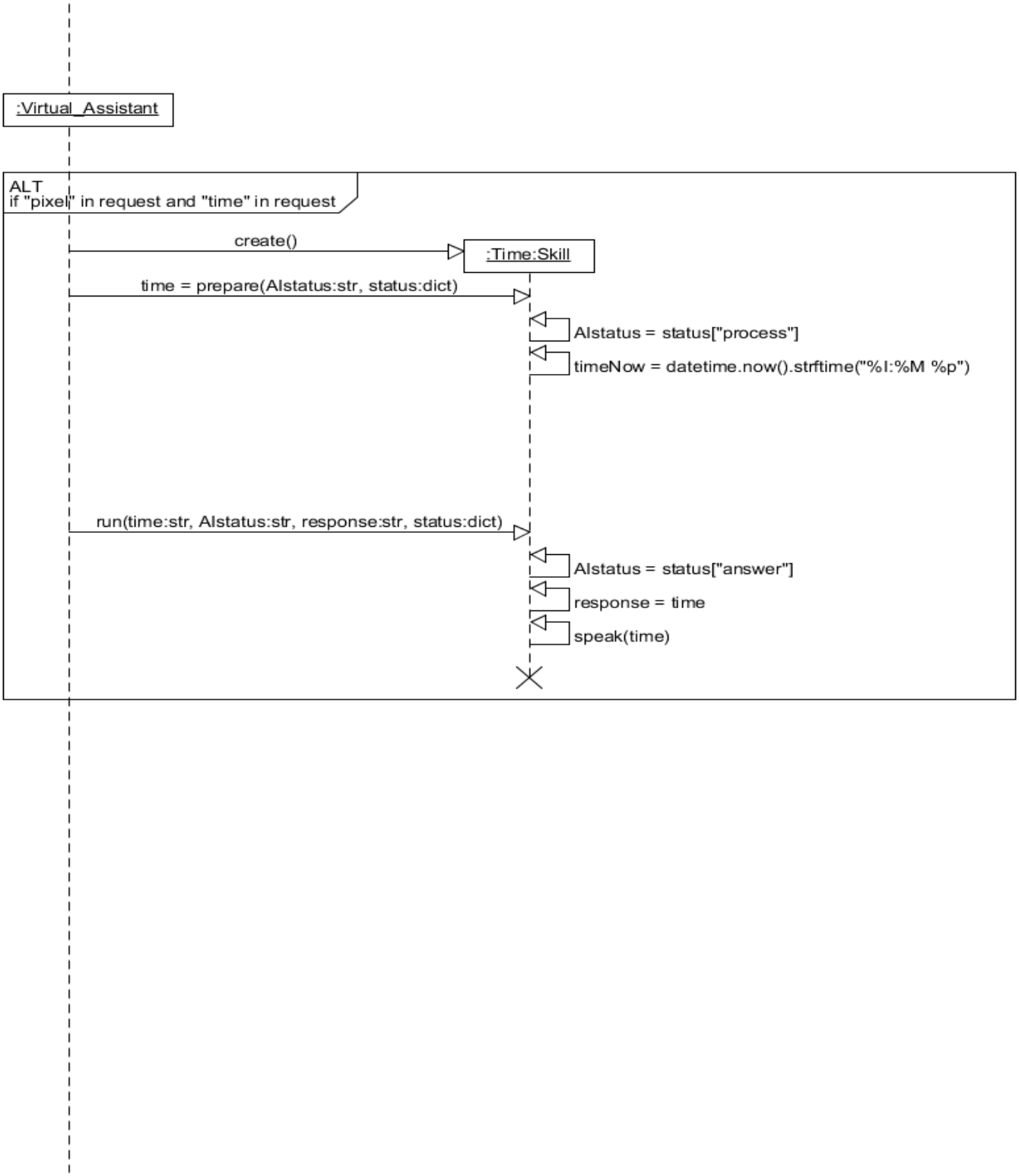


Figure 28 "Request time - sequence diagram"

Figure 29 "Request date - sequence diagram"

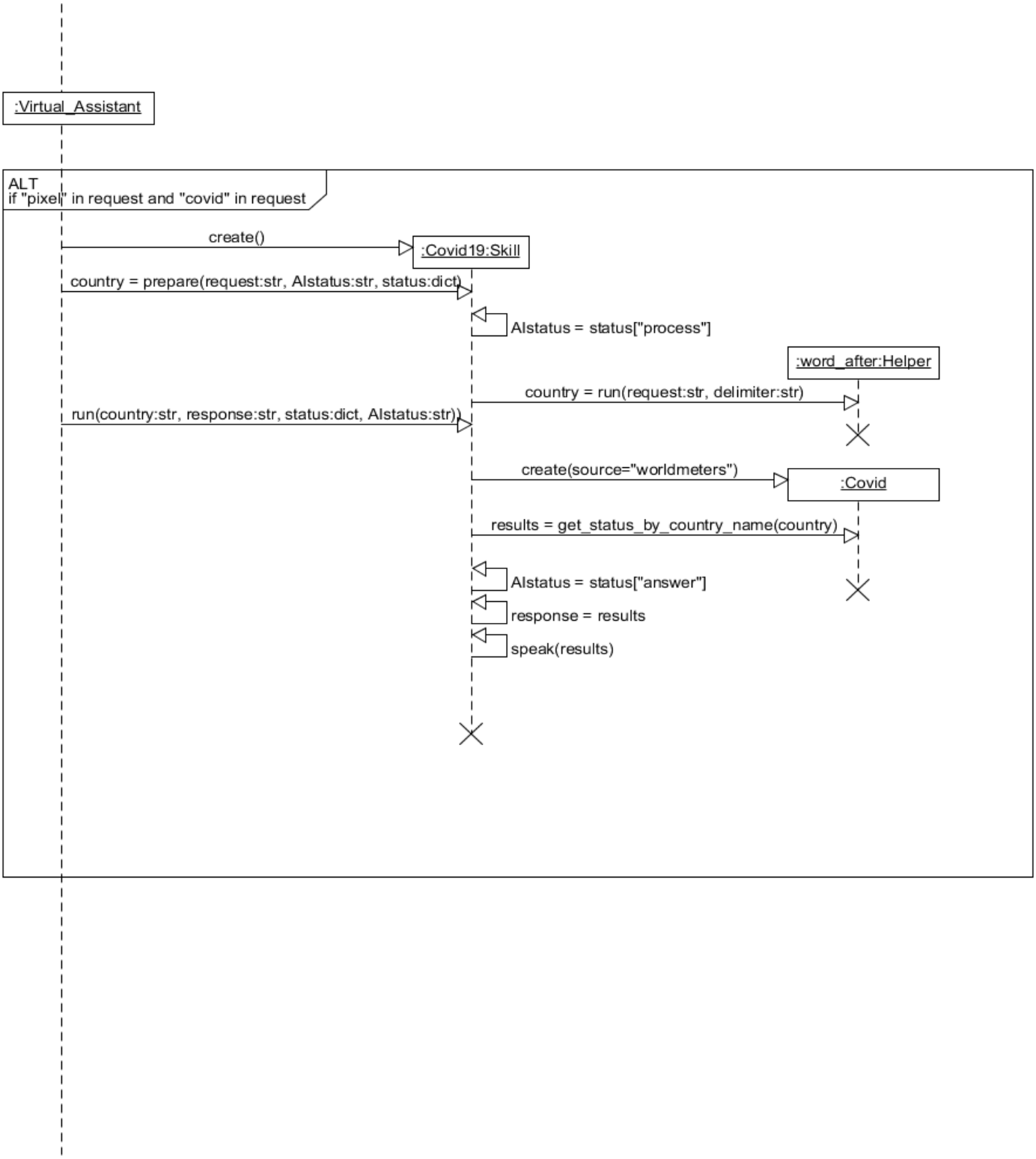


Figure 30 "Request Covid19 stats - sequence diagram"

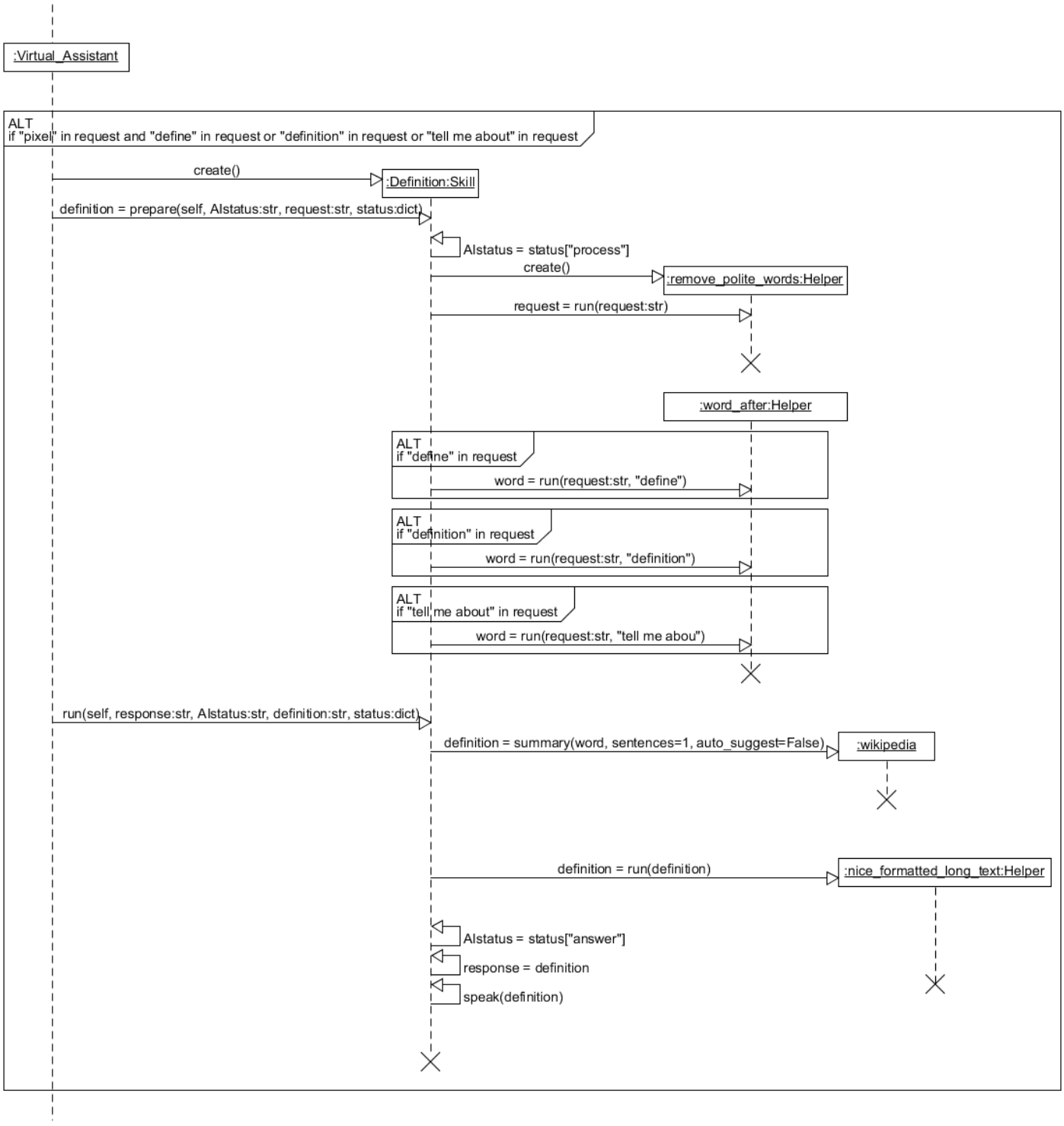


Figure 31 "Request definition - sequence diagram"

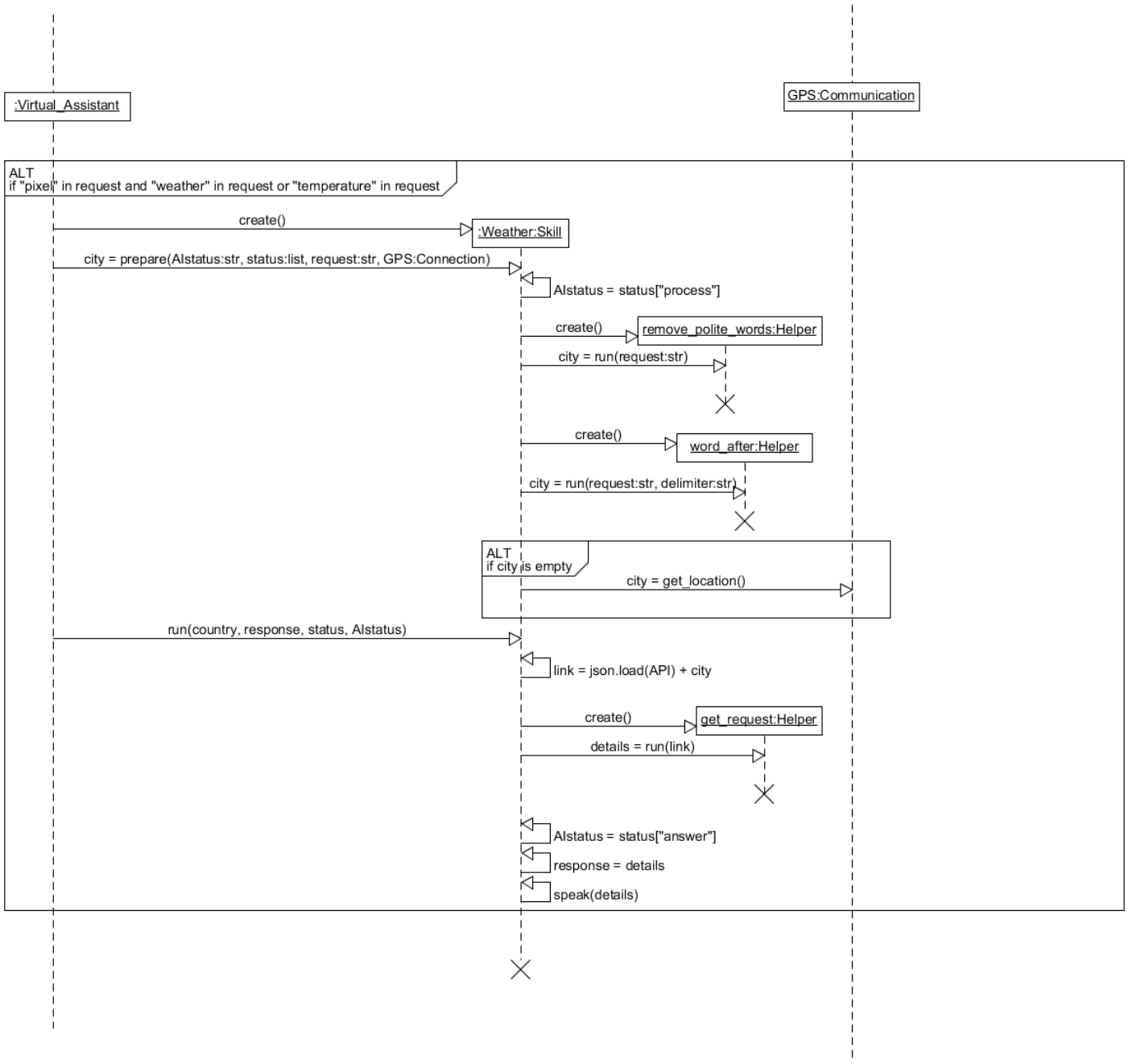


Figure 32 "Request weather - sequence diagram"

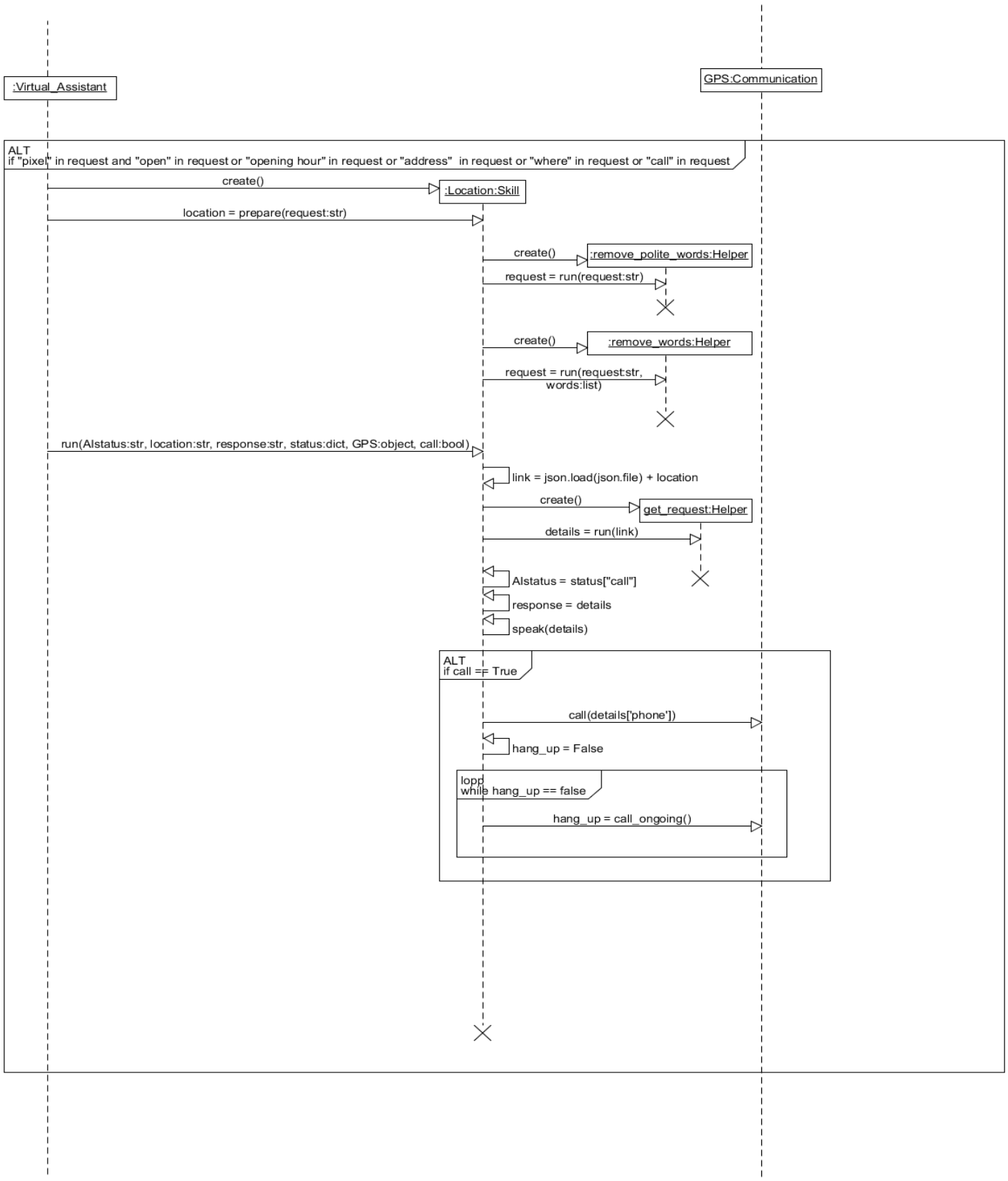


Figure 33 "Location request - sequence diagram"

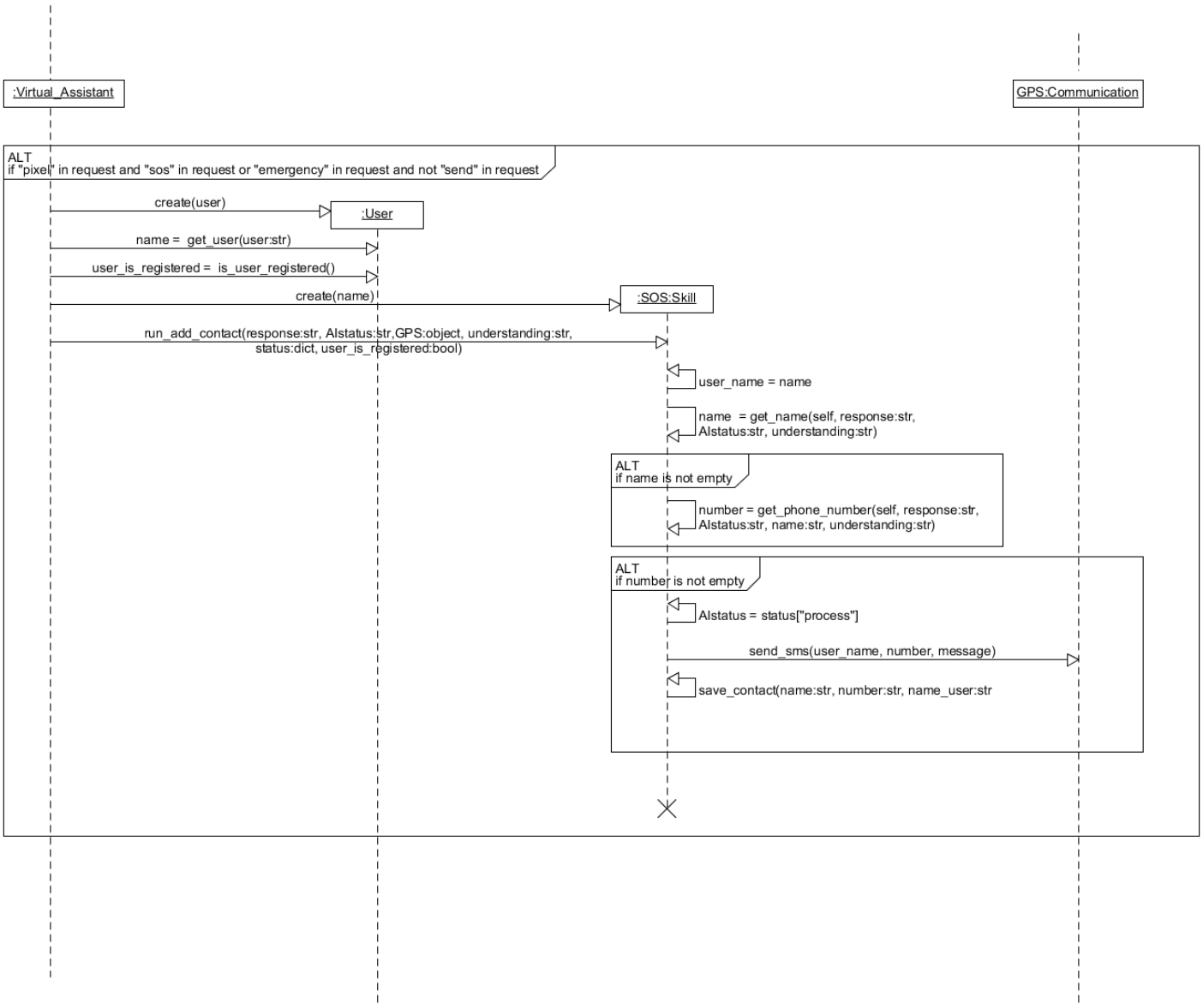


Figure 34 "Create SOS contact - sequence diagram"

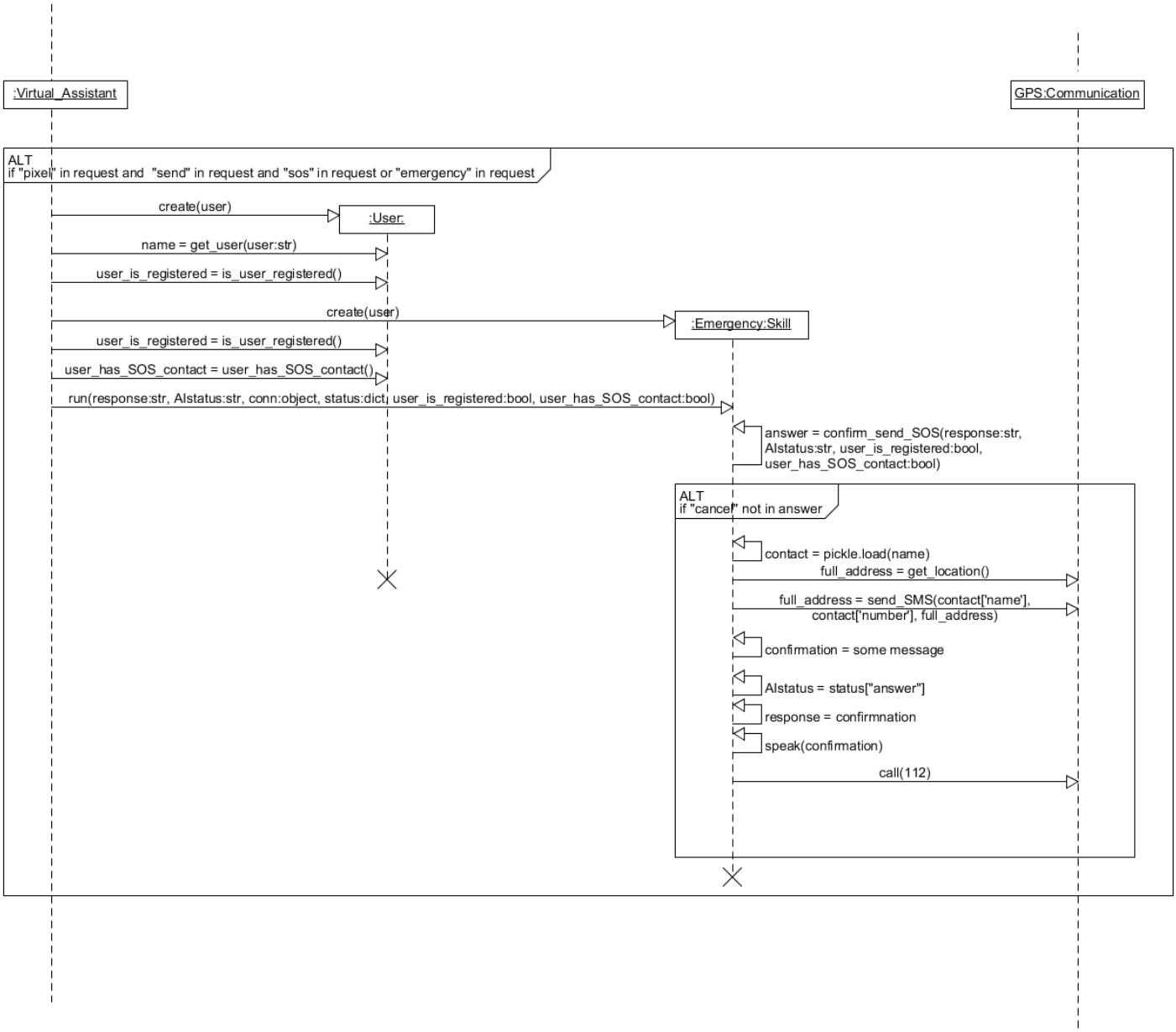


Figure 35 "Request send SOS - sequence diagram"

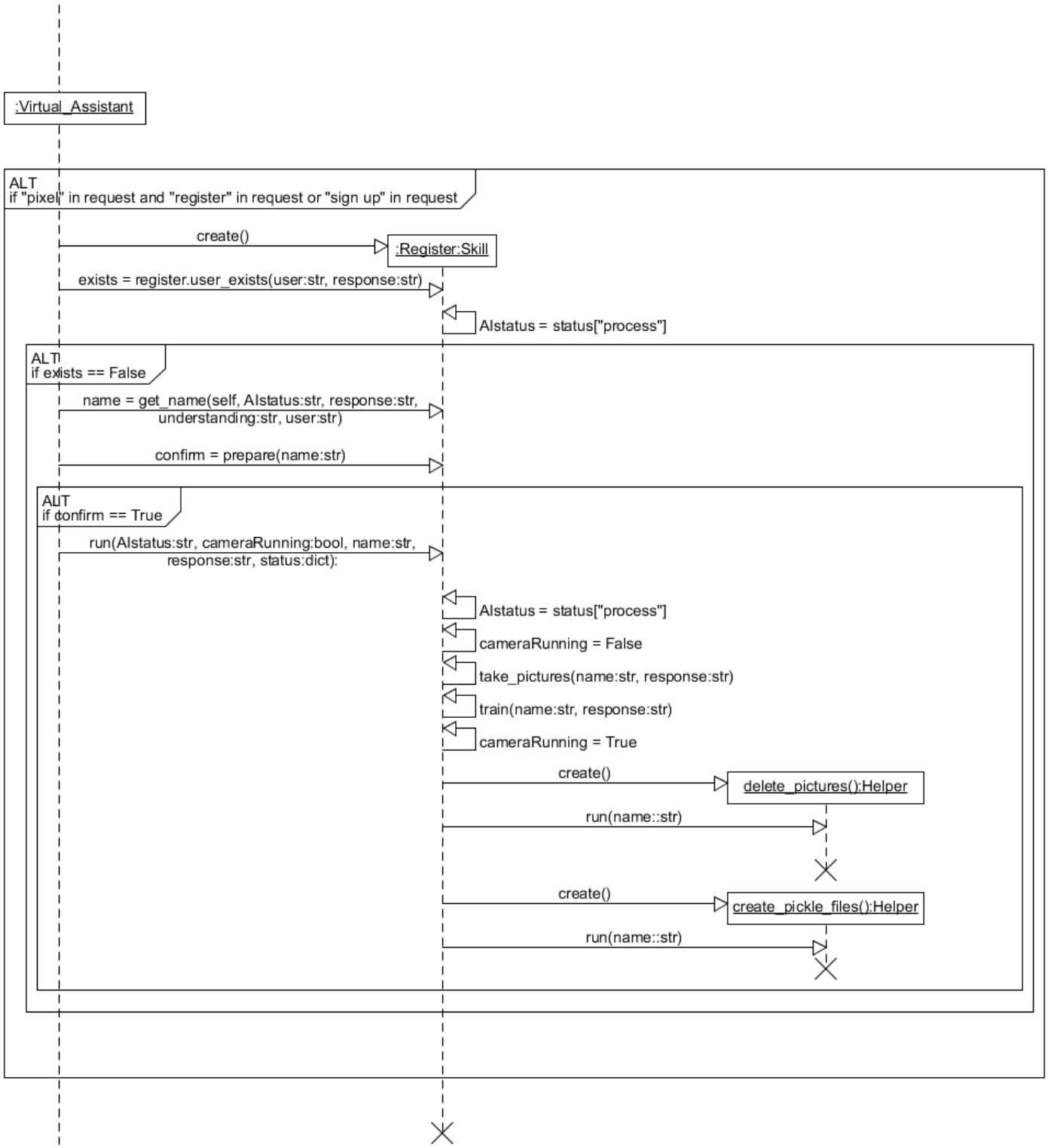


Figure 36 "Request registration - sequence diagram"

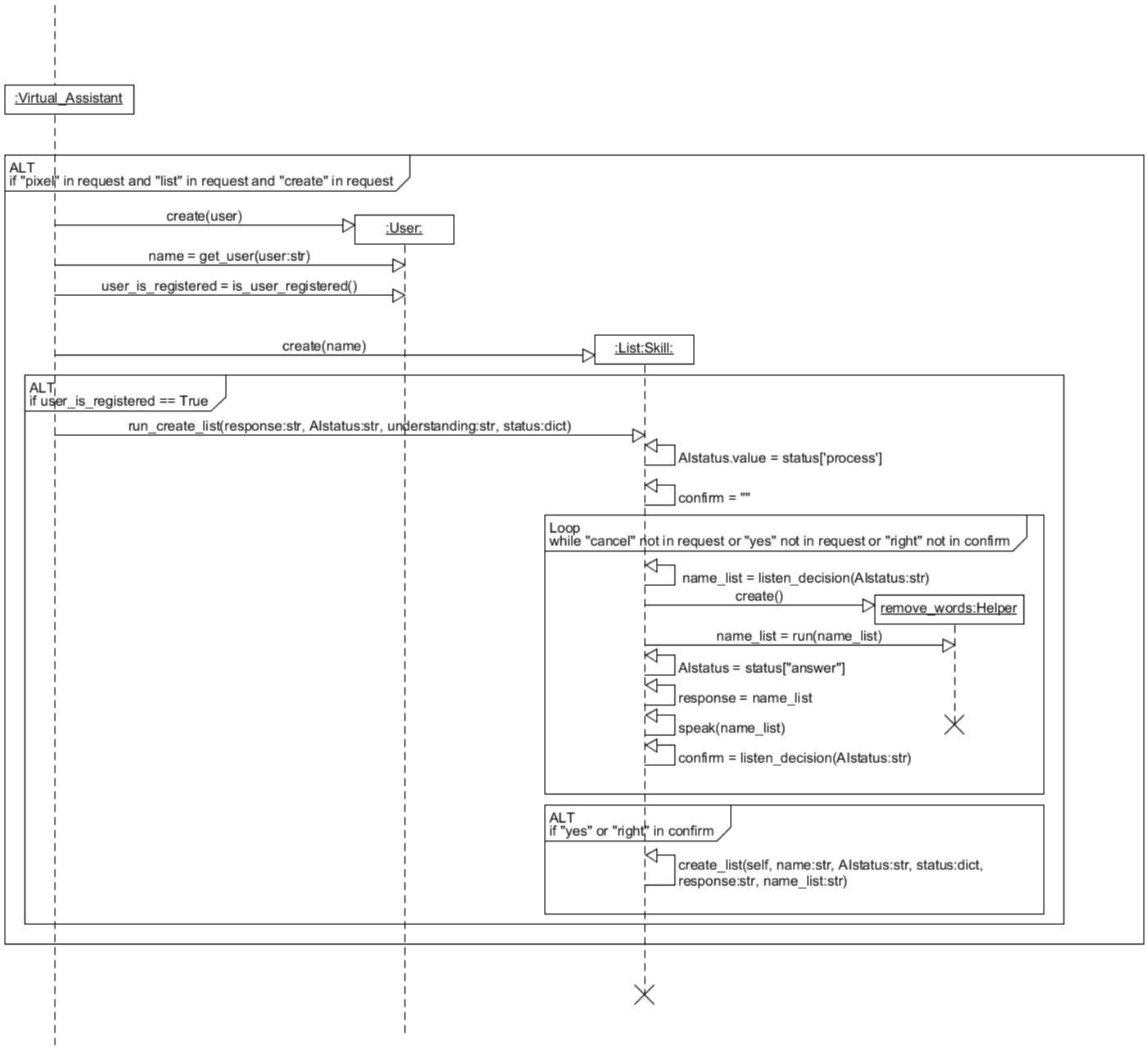


Figure 37 "Create a list - sequence diagram"

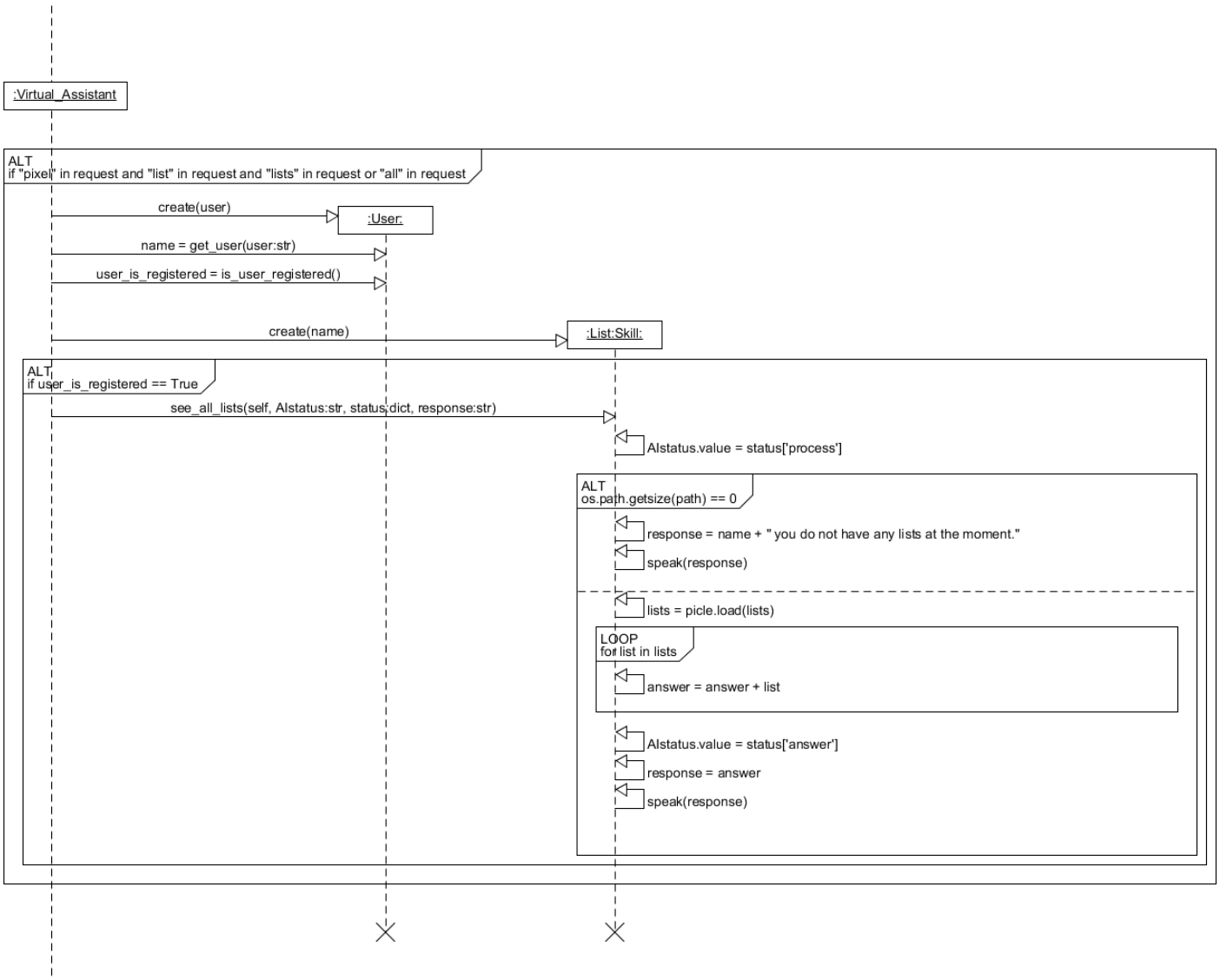


Figure 38 "See all lists - sequence diagram"

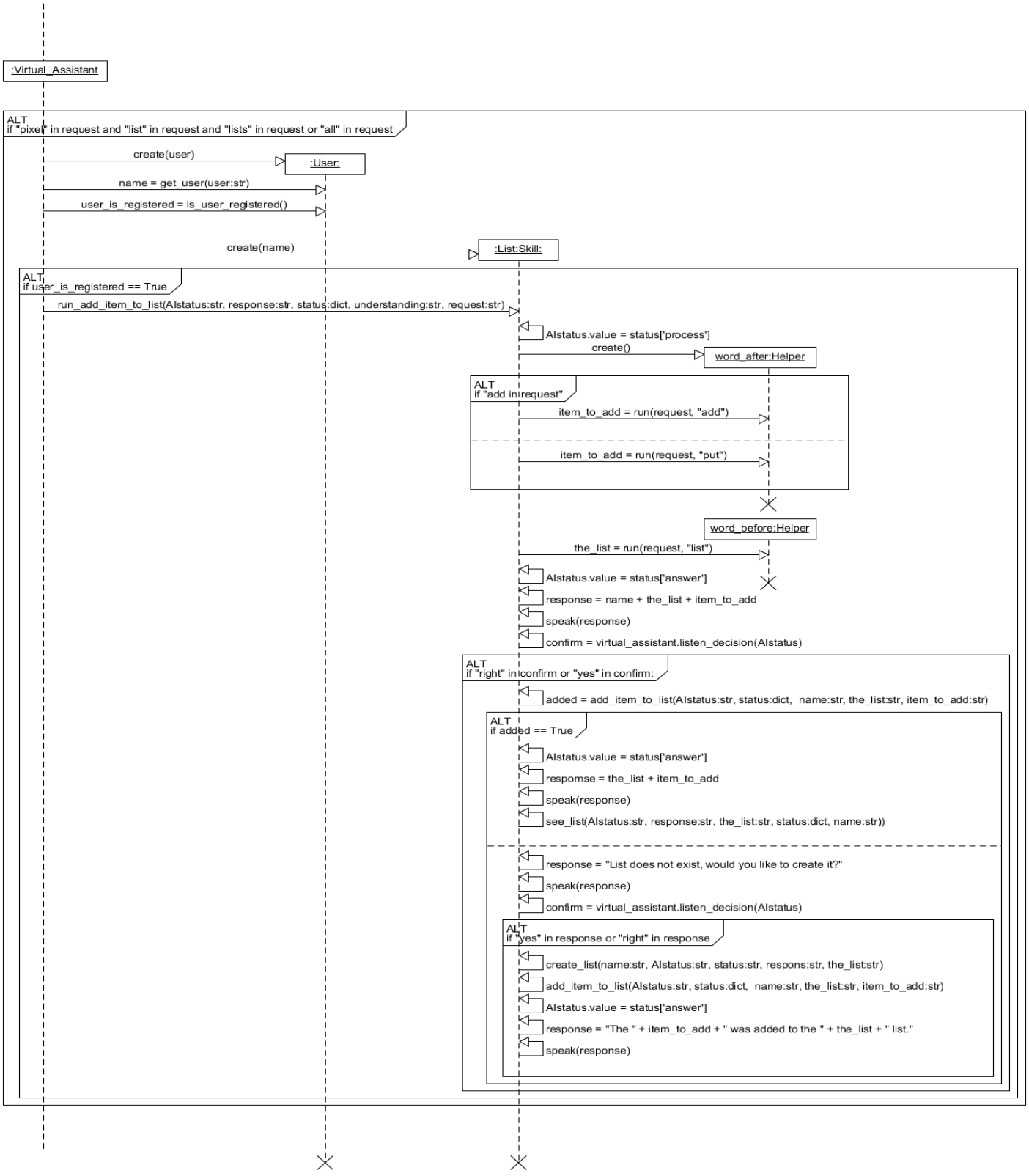


Figure 39 "Add item to list - sequence diagram"

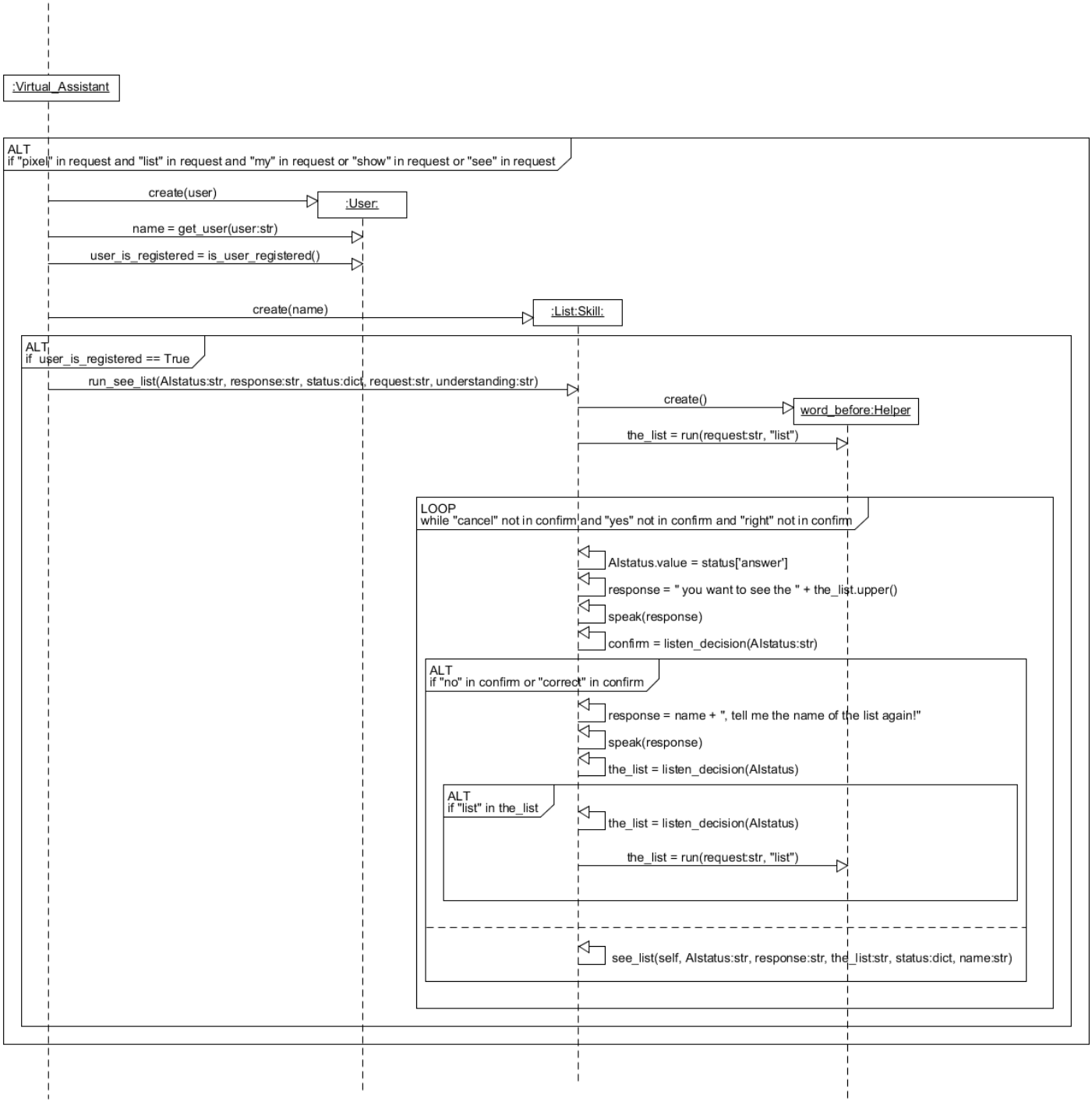


Figure 40 "See a list - sequence diagram"

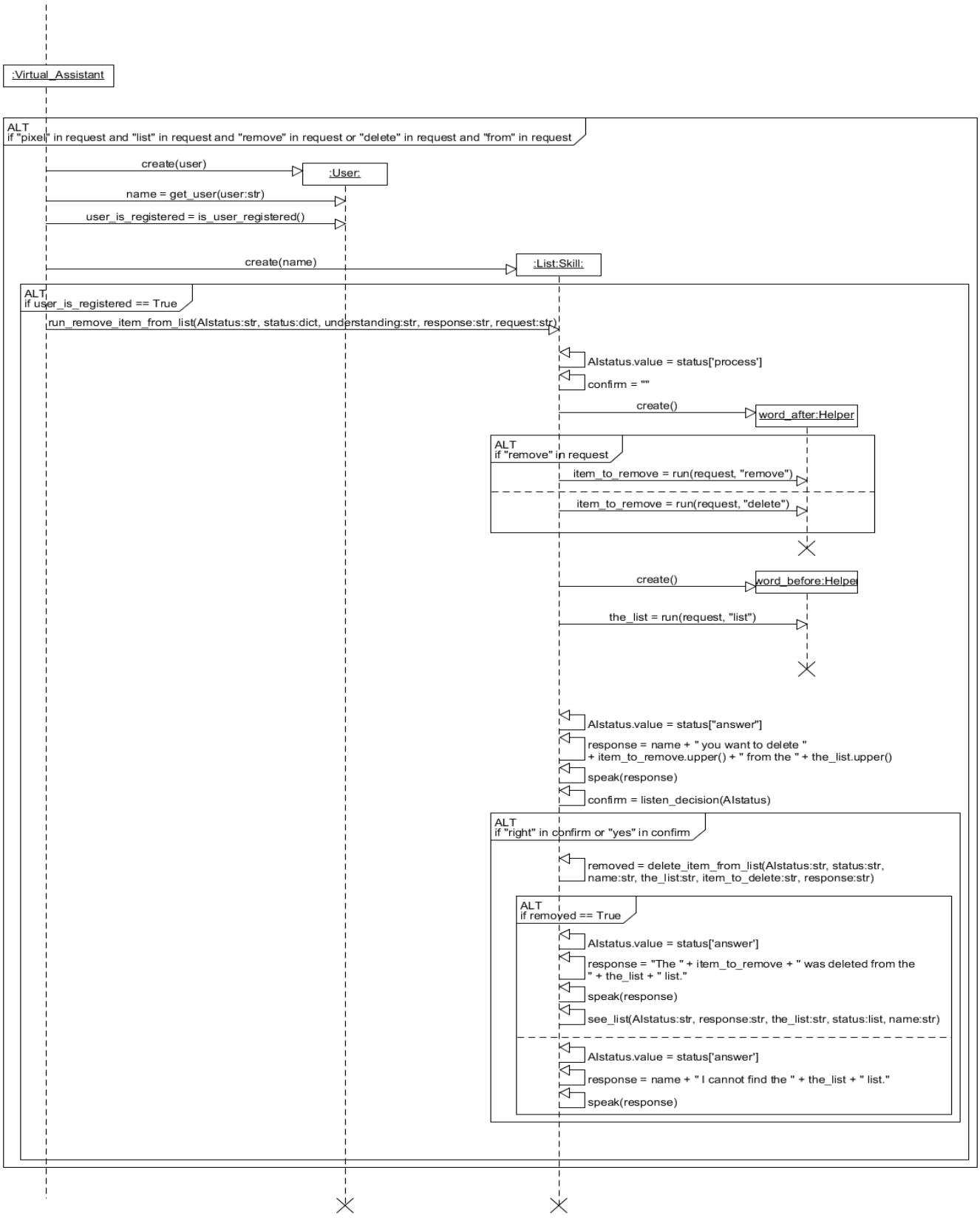


Figure 41 "Delete an item - sequence diagram"

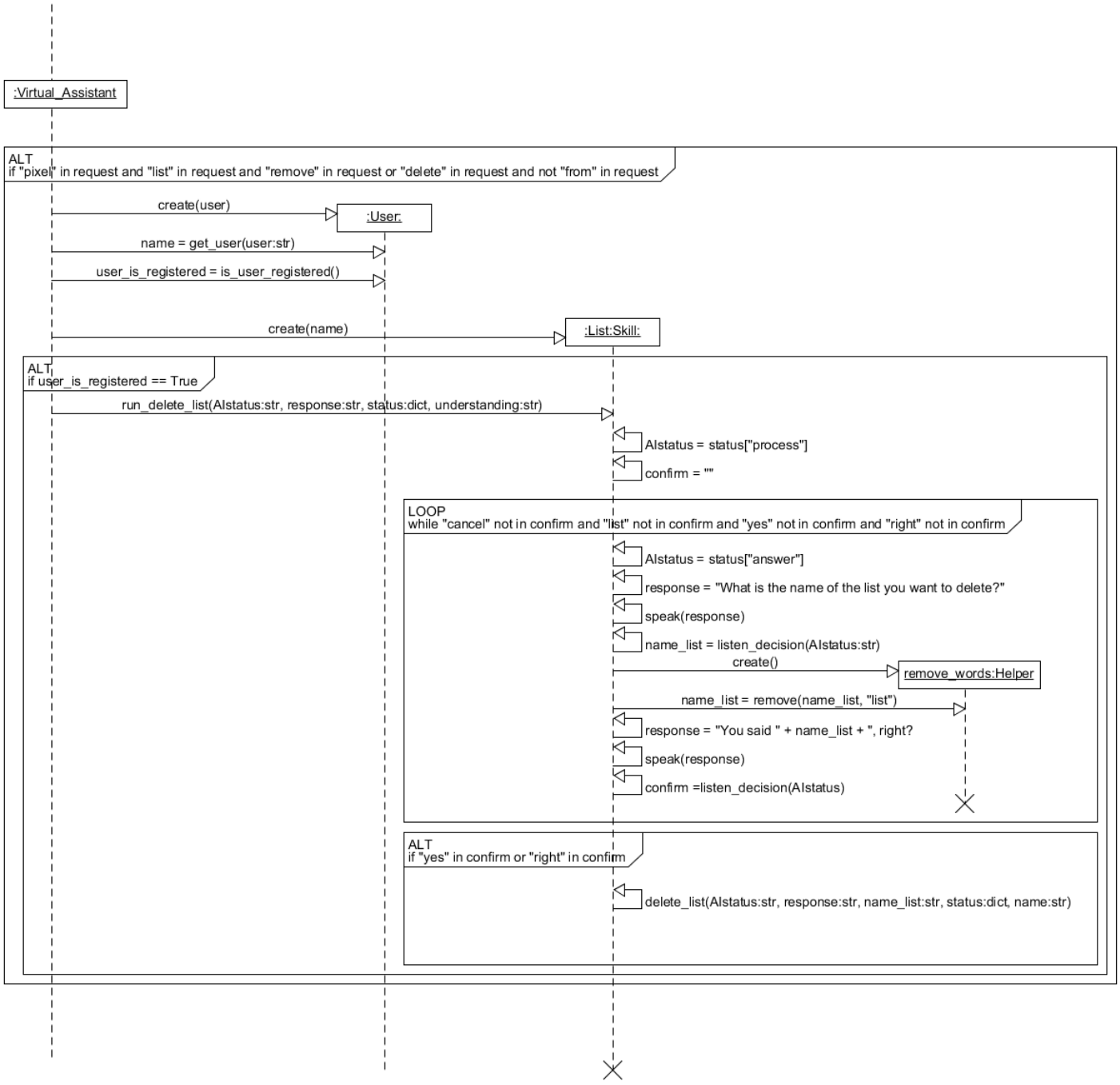


Figure 42 "Delete list - sequence diagram"

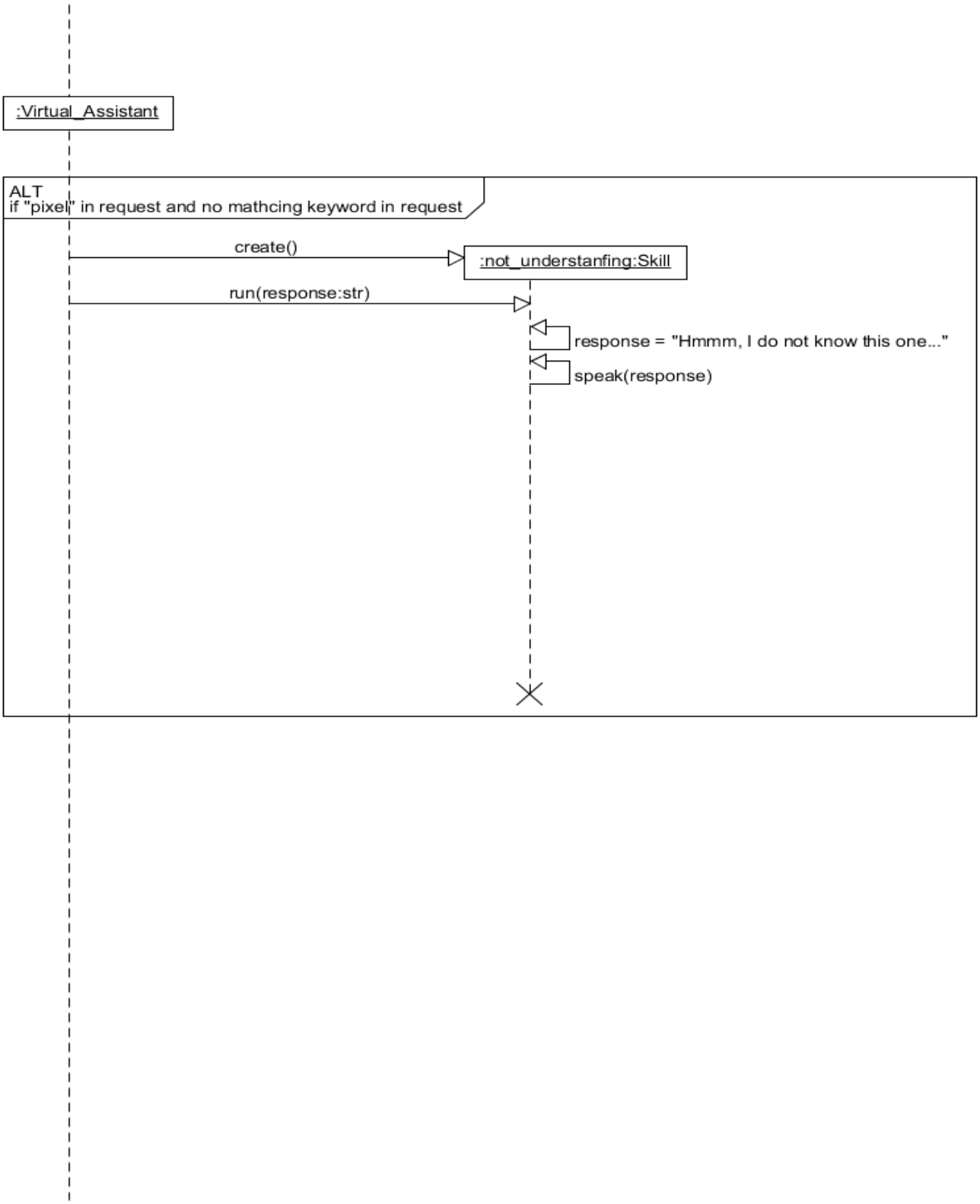


Figure 43 "Not understanding - sequence diagram"

BACKUP

This project requires backup storage dedicated to backup files such as XML files used for face detection and recognition and pickle files. These files are read and written on the device itself, but backing up these files is crucial if the device is malfunctioning and needs to be reset.

The reading and writing processes are happening on the device, as the speed and performance are increased and do not require a continuous internet connection. Reading and writing data directly from a database is a strong option, but for this project, the approach implemented is to process the files on the device itself.

CLOUD STORAGE

When saving static files and media files into the cloud is required for different purposes, App Engine Cloud Storage is one of the best and popular choices.

App Engine generates a default bucket. This bucket contains a free limit for Cloud Storage I/O operations as well as 5 GB of storage. Other Cloud Storage buckets can be created, but only the default bucket offers free storage for the first 5GB.

Unfortunately, due to the time constraints for developing the software, the backup functionality was not implemented.

CONCLUSION

This document detailed Pixel Virtual Assistant's design, a smart speaker dedicated to people with hearing deficiencies and people with low computer skills.

The document includes the hardware and software architecture, describing in detail the system flow, hardware schema, class diagram and sequence diagrams. Each sequence diagram is based on the detailed use case described in the “Functional Document”.

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