Furhat Robotics
Technical Product Overview

Product Documentation

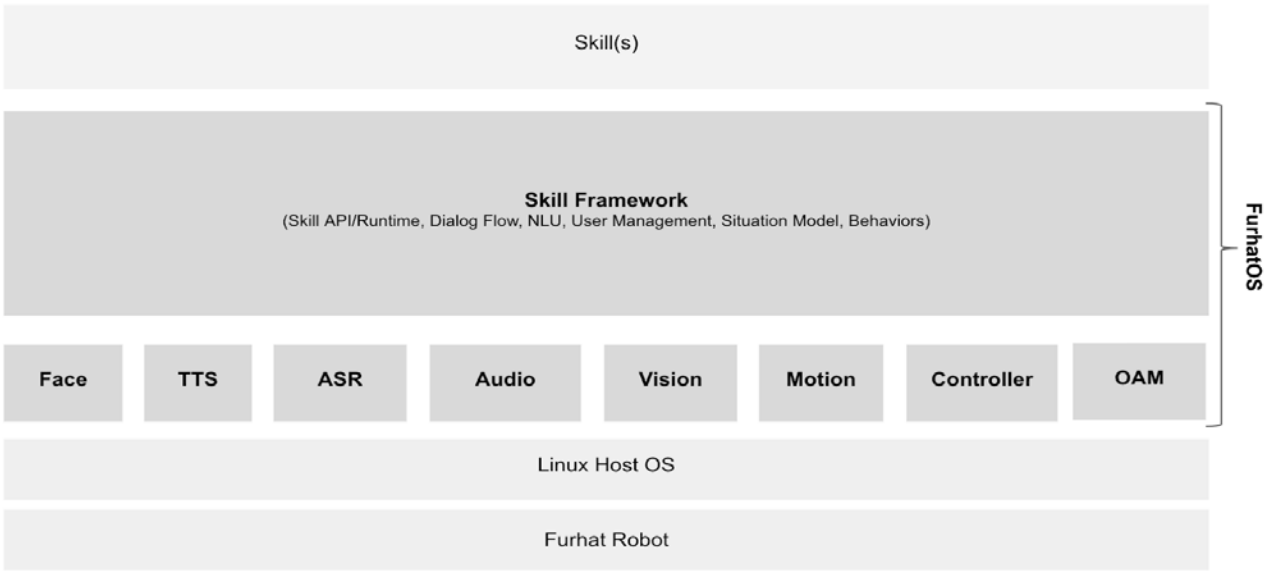
Version 1.2

Contents

Furhat Platform

The *Furhat Platform* is a powerful, unified set of products that combine to enable the *development* and *delivery* of breakthrough user experiences that advance the frontiers of human computer interaction via social robotics.

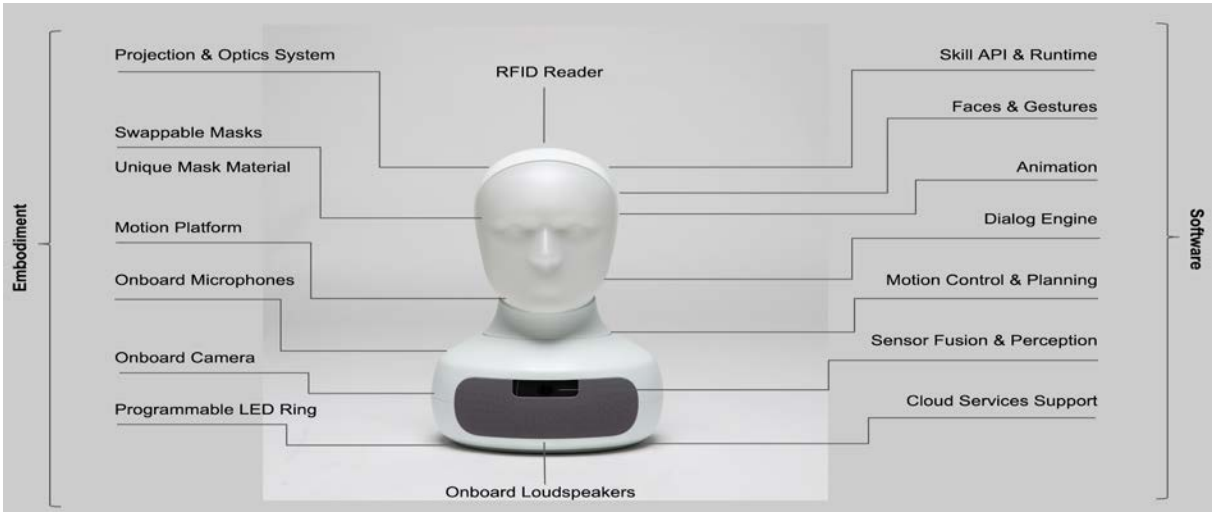
The *Furhat Robot* distills everything we have learned about embodiment design and engineering into a single, friendly, approachable package. The design emphasizes a powerfully expressive face powered by our unique projection architecture, and customizable via swappable face masks created from a unique material optimized for optical performance. The Robot is equipped with an advanced motion platform that enables the delivery of natural, human-like head movements. Onboard sensors for audio and visual perception complete this package along with ample computation, memory and storage capacity. Standardized I/O ports enable the extension of the robot system, as well as its inclusion into wider systems.



FurhatOS is Furhat Robotics operating system for social robotics. The primary duty of *FurhatOS* is providing the runtime environment that enables sophisticated social robotics applications, that we call *Skills*. The *FurhatOS* skill runtime hooks the skill into the dialog flow, provides it with a

user attention model, natural language understanding functions, as well as access to other key robot functions such as motion and gesture expression. *FurhatOS* also includes a variety of face models and textures, and allows for the easy extension of these. Similarly, a wide array of voices, in over 40 different languages, and with both onboard and cloud based variants are supported by the system. A browser based Web-Console allows for full control and configuration of the robot, including remote Wizard-Of-Oz control. *FurhatOS* also includes the entire set of subsystems required in order to technically run the robot; these discrete modular subsystems handle functions such as facial animation, motion functions, visual perception, audio processing, vision, I/O, cloud service integration, and operations & maintenance functions.

The *Furhat SDK* includes all of the developer tools, API's, tutorials and documentation enabling developers to create skills for the Furhat platform. Developers can develop skills using the Kotlin programming language and hook into the rich API set offered by *FurhatOS*. One of the key development paradigms relates to dialog flow, which is based on the model of hierarchical state machines (HSM). This model is adapted to handle expressive low-latency interactions and is based on an event architecture that routes sensor input, as well as directing expressive output, making it easy to simplify, abstract and handle complex interactions. *Furhat SDK* also provides IDE integration, and a Virtual Furhat environment that enables skills to be developed, hosted, executed, and debugged on the developer's workstation before they are deployed to a physical robot system for final testing and/or production deployments.



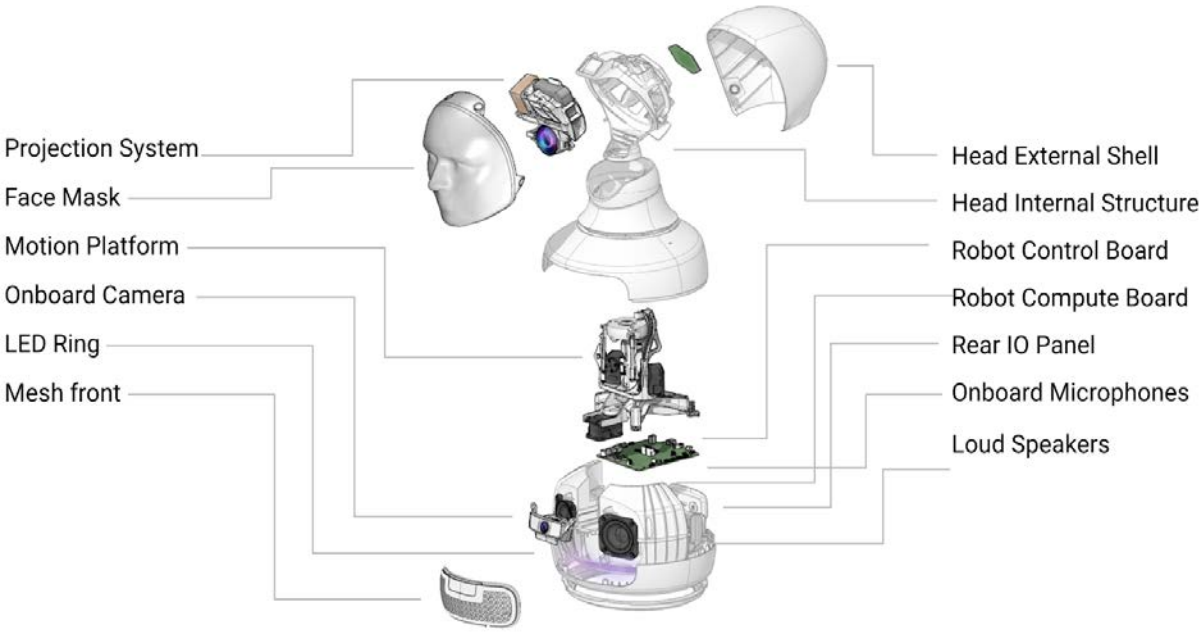
The contents of this document are subject to continuous improvement and revision, in line with the evolution of Furhat products. Please visit our website at furhatrobotics.com for the latest information, data, and software. For questions relating to this document please contact sales@furhatrobotics.com

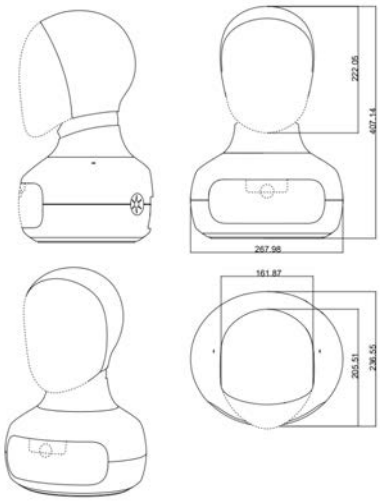
Furhat Robot

The *Furhat Robot* distills everything we have learned about embodiment design and engineering into a single, friendly, approachable package.

On the exterior, soft lines and matte smooth surfaces combined with a downward sloping front, signal approachability and openness. The design tones down the body in order to emphasize the bright projected face with it's geometry, textures, and lively gestures. The neck shape suggests movement with a visible sphere, the width of the front side curved mesh codes for the interaction space, suggesting where users should stand.

On the inside we have created our own unique architecture catering to the challenges and needs for *projection/optics*, *motion platform*, *robot control,* and *thermal/noise management*. We have also selected best in class components from vendors such as *Robotis* and *Intel* in order to deliver the very best performance and quality.





Physical Dimensions

Organic unibody design with fully enclosed neck section and cranium finished in Arctic White. Front grill in Dawncloud Grey.

- 410 mm x 270 mm x 240 mm (HxWxD)
- Eye Height: ~300[1] mm
- Robot Weight: 3.5 kg

Onboard Camera Sensor

- RGB Sensor Type
- 120° diagonal FOV
- 3.4 MP resolution (2304x1536 pixels)
- Fixed Focus for interaction space
- Automatic Exposure control

Onboard Microphones

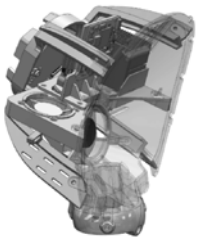
2 x 100Hz~10kHz digital, PDM stereoscopic digital MEMS omnidirectional microphones, set 180mm apart on the robots shoulders

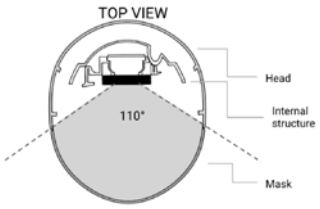
Bundled USB Microphone

- 4 x MEMS omnidirectional digital mics
- Far-field voice pick-up up to 5m
- 360° pick-up pattern
- DOA (Direction of Arrival)
- AEC (Automatic Echo Cancellation)
- AGC (Automatic Gain Control)
- NS (Noise Suppression)
- Sensitivity: -26 dBFS (Omnidirectional)
- Acoustic Overload Point: 120 dBSPL

Projection & Optics

- 100 lumens brightness[2]
- 854x480 Resolution[3]
- 1500:1 Contrast, 59Hz Frequency
- DLP SmartEngine





Furhat Mask

The mask is based on a Furhat proprietary polymer blend that is optimized for optical performance in conjunction with Furhat Projection & Optics system.

Masks can be RFID coded and detected by the robots RFID sensor.

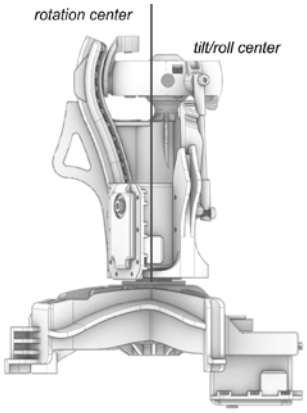
[1] Mask Geometry Dependent

[2] Next generation Furhat Projection System (available Q1 2020) adds 150 Lumen projection

[3] Next generation Furhat Projection System (available Q1 2020) resolution 1280x720 pixels

Motion Platform

- 3 Degrees Of Freedom (DOF)
- Pan/Tilt/Roll with silent off-axis panning
- 3 x high speed servos, active feedback
- 0.088° resolution
- 25 kg·cm stall torque
- Metallic gears



Pan: +/- 60°, Tilt/Roll: +/- 20°

LED Ring

Enables a *silver lining* effect, allowing the robot to signal a presence outside the container of its body, further increasing its presence in a space when needed. Uses 88 x RGB LED, controllable from *FurhatOS*/Skills

Rotary Controller

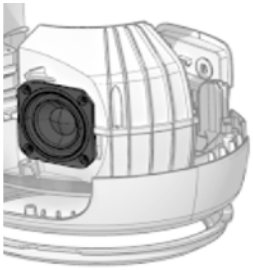
Rotary thumbwheel controller with click function controls volume & on face menu.

Compute Platform

- Intel Core i5 CPU, up to 3.40 GHz
- 8GB RAM
- 120 GB SSD mass storage
- Iris Plus 640 GPU

Speaker System

Dual speakers are optimised For human voice frequencies and angled to support the interaction space



- 2.5"
- 30W Power
- Full range type
- Magnetic type
- Aluminium cone

RFID Sensor

13.56MHz (Mifare) RFID Reader

Rear I/O Panel

- Power On/Off Switch
- 19[4] Volt / 90 Watt power input jack
- 802.11ac Wifi, 2.4/5.0 Ghz
- Wired Ethernet Port - 10/100/1000
- 2 x USB A supporting USB 3.0
- 1 x USB-C[5]
- Bluetooth 4.2

Product Packaging

The product ships as standard in a protective, hard shelled, wheeled, case

Environmental & Installation

Ambient Temperature: 5-25° C / 41-77° F
200 mm ventilation clearance behind unit

Certification(s)

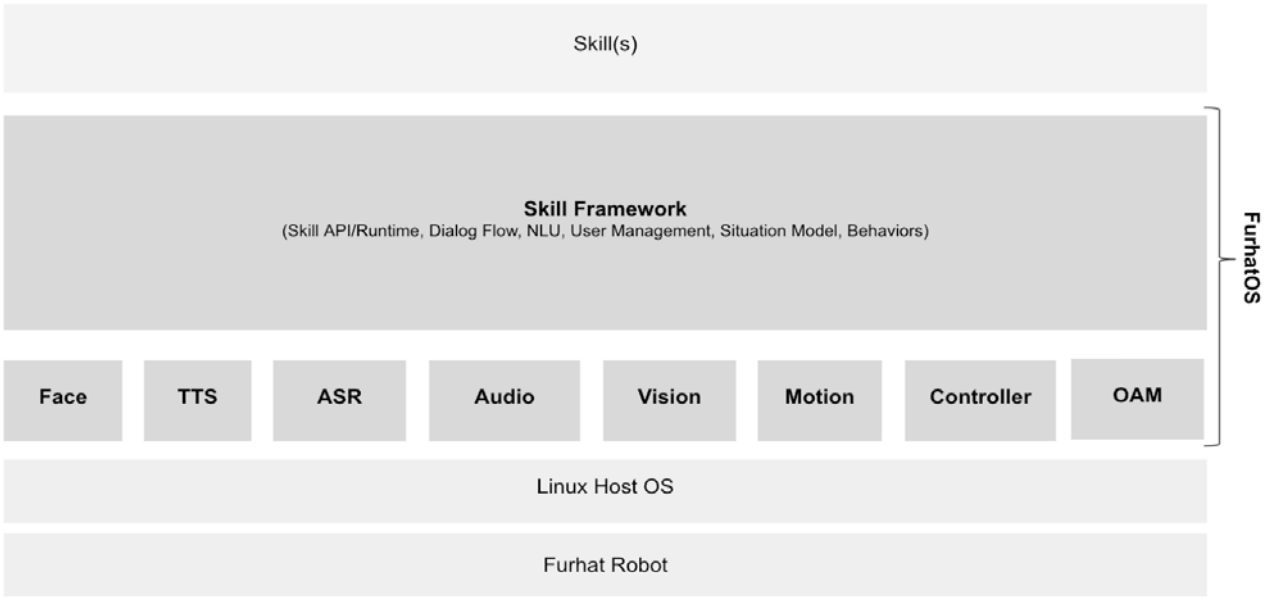
CE Certification expected Q1 2020

[4] 12V power supply on units up to unit 224, 19V power supply on units numbered 225 and later

[5] Thunderbolt 3 (40Gbps), USB 3.1 Gen 2 (10Gbps) & DP 1.2

FurhatOS

FurhatOS is Furhat Robotics operating system for social robotics. The primary duty of FurhatOS is providing the runtime environment that enables sophisticated social robotics applications, that we call *Skills*. The *FurhatOS* skill runtime hooks the skill into the dialog flow, provides it with a user attention model, natural language understanding functions, as well as access to other key robot functions such as motion and gesture expression.



FurhatOS includes the entire set of subsystems required in order to technically run the robot. These discrete modular subsystems handle functions such as facial animation, motion functions, sensory perception, audio processing, vision, I/O, cloud service integration, and operations & maintenance functions.

Furhat subsystems are written in the *Java* and *C++* programming languages, with subsystems intercommunicating using a structured event system, supported by a messaging bus, and fulfilling soft real-time characteristics.

FurhatOS uses *Linux* as its host OS, and via a Hardware Abstraction Layer (HAL) integrates fully with the Furhat embodiment architecture via that *Robot Control Board*, enabling full native control of robot capabilities like *motion platform*, *projection system*, *LED ring*, and *RFID reader*.

FurhatOS updates are available via the software update feature in the settings panel of the robot's web console. Furhat Robotics releases *FurhatOS* updates on a monthly cadence.

Faces

FurhatOS ships with a standard set of face models, rigged with 40 custom blendshapes, to which a standard set of artist-created textures can be applied. Face models and textures can be selected in the Web-Console. Furhat Robotics will extend the standard set of face models over time[6].

We currently ship one adult face model to which we can apply 10 individual textures, which allows for a wide array of male and female character faces.

We ship one child mask model, and matching textures which requires[7] a matching physical mask.

We ship one animal mask model, and matching textures, which requires[8] a matching animal physical mask.

Furhat Robotics plans to release additional tools that enable robot owners and designers to create their own mask models and textures and easily deploy these to robots.

This will also extend to services enabling the ordering and production of matching physical masks where required.

Gestures

FurhatOS supports a number of expressive built in gestures which can be triggered from skills as well as in Wizard-Of-Oz style remote control scenarios. Furhat Robotics will extend the standard set of gestures over time.

The following gestures are supported:

- Big Smile
- Blink
- Frown
- Brow Raise
- Close Eyes
- Open Eyes
- Express Anger
- Express Disgust
- Express Fear
- Express Sad
- Gaze Away
- Nod
- Oh!
- Roll
- Shake
- Smile
- Surprise
- Thoughtful
- Wink

Custom gestures can also be created by skills developers using the Kotlin DSL.

Furhat Robotics plans to release additional tools that enable robot owners and designers to create their own custom gestures and easily deploy these to robots

[6] All geometry & texture assets can be produced and edited using standard 3D graphics production tools such as Maya and Zbrush

[7] Available as an accessory from Furhat Robotics

[8] Available as an accessory from Furhat Robotics

Speech Synthesis	Speech Recognition
FurhatOS has support for a continuously growing (currently 40+) spoken languages including male, female and (in selected cases) child variants. *FurhatOS* supports both onboard voices (from Acapela & Cereproc), as well as cloud based voices from Amazon Polly[9]. *FurhatOS* has specific pluggability support which enables us to easily extend to additional cloud based voices as needed. The following languages are supported: ● Arabic ● Catalan ● Chinese (Mandarin) ● Czech ● Danish ● Dutch ● English (5 variants) ● Faroese ● Finnish ● French (French/Canadian) ● German ● Greek ● Hindi ● Icelandic ● Italian ● Japanese ● Korean ● Norwegian ● Polish ● Portuguese (Portuguese/Brazilian) ● Romanian ● Russian ● Sami ● Spanish (European/Mexican/US) ● Swedish ● Turkish ● Welsh	*FurhatOS* has support for a continuously growing (currently 120+) spoken languages and variants. *FurhatOS* includes out of the box support for both *Google Cloud Speech-To-Text* as well as *Microsoft Azure Cognitive Services Speech-to-Text* services. The following languages are recognized: ● Afrikaans ● Arabic (17 variants) ● Armenian ● Bahasa Indonesian ● Bahasa Melayu (Malaysia) ● Basque (Spain) ● Bengali (Bangladesh/India) ● Bulgarian ● Catalan ● Chinese (Chinese Mandarin zh-CN) ● Chinese (Chinese Mandarin Simplif. - zh) ● Chinese (HK Mandarin Simplif. - zh-HK) ● Chinese (TW Mandarin Trad. - zh-TW) ● Chinese (Cantonese/Traditional - HK) ● Croatian ● Czech ● Danish ● Dutch (Netherlands, Belgium) ● English (11 variants) ● Faroese ● Filipino ● Finnish ● French (3 variants) ● Galician (Spain) ● German ● Greek ● Gujarati (Indian) ● Hebrew ● Hindi ● Hungarian ● Icelandic ● Indonesian ● Italian ● Japanese

[9] Including *Neural* and *Newscaster* style voices

Animation Capabilities

The *FurhatOS* animation system allows for real time, high-fidelity rendering of dynamic facial expressions and visual speech, rendered through an optimized 3D graphics engine that leverages OpenGL 4.0 hardware acceleration. The animation system is built from the ground up to emphasize customisation via *blendshapes*, *textures*, *lighting* and *shading*.

FurhatOS ships with a wide variety of blendshapes, containing targets for visual speech (lip- jaw and tongue motion), emotion expression, detailed control over eyebrow, eye and nose region, as well as gaze target control (eyeball rotation). The use of a standard blendshape set makes it possible to easily design entirely new face models and deploy them on the robot as drop-in replacements for existing models

FurhatOS also provides a range of textures that are applied to face models and can be easily switched to create entirely new appearances. Creating a new texture is the quickest way to modify the robot appearance and can be done with simple image editing software or by using texture painting tools in a 3D modelling software such as *Maya*

FurhatOS's rendering pipeline enables light sources to be adjusted in order to customize rendering. Programmable shaders make it possible to combine multiple textures to perform texture blending, enabling dynamic expressions such as dynamically appearing wrinkles and creases around the eyes or forehead. Shaders can also be used to incorporate other information such as bumpmaps or specularity maps. Finally shaders offer means for warping the geometry, which is used to ensure that the projection aligns perfectly with the mask.

Speech Recognition

The following languages are recognized:

- Korean (South Korea)
- Khmer (Cambodia)
- Lao (Laos)
- Latvian
- Lithuanian
- Malay (Malaysia)
- Malayalam (India)
- Marathi (India)
- Nepali
- Norwegian (Bokmål)
- Persian (Iran)
- Polish
- Portuguese (Portugal/Brazil)
- Romanian
- Russian
- Sami
- Serbian
- Slovak
- Slovenian
- Spanish (20 variants)
- Sudanese
- Swahili (Tanzania/Kenya)
- Swedish (4 variants)
- Tamil (India/Malaysia)
- Tamil (Singapore/Sri Lanka/Malaysia)
- Telegu (India)
- Thai
- Turkish
- Ukranian
- Vietnamese
- Urdu (Pakistan/India)
- Welsh
- Zulu

Cloud Services

FurhatOS has support for supported external service providers as follows:

- *Amazon Polly* speech synthesis
- *Google Speech to text* speech recognition
- *Microsoft Azure Cognitive Services Speech-to-Text*

Motion Capabilities

FurhatOS performs motion planning and orchestrates the combined actions of the motion platform servos in order to achieve smooth natural head/neck motion.

The motion capabilities can also be used to compose higher level motion expressions/gestures such as *Head Nods*, *Head Shake*s etc. These are available to Skills Developers via the SDK.

The motion capabilities are also used in conjunction with the situation modelling and visual perception capabilities to attend to users by facing the user and also by dynamically tracking the user with head movements and gaze as the user moves within the field of view of the robot.

Dialog Flow/Control

The *FurhatOS* dialog flow model is based on hierarchical state charts that are defined using a Kotlin DSL.

The flow provides support for high-level user management, as well as the storage of user-specific data. High-level control of speech, gestures and robot attention is also provided for.

Dialog flow also supports the definition of complex, reusable behaviours and integration with Java/Kotlin or web-based API

Natural Language Understanding (NLU)

FurhatOS provides a context-sensitive NLU engine that is integrated with the dialog flow DSL. The engine can detect multiple intents in utterances.

Skills developers can define custom intents and entities by using a Kotlin DSL in any spoken language supported by the ASR.

FurhatOS also provides a set of built-in intents and entities for English & Swedish

- Common entities, including `Date`, `Time`, `Number`, `Ordinal`, `Name`, `Color`
- Common intents, including `Yes`, `No`, `Don't Know`, `Maybe`, `Greeting`, `Goodbye`, `Thanks`, `RequestRepeat`

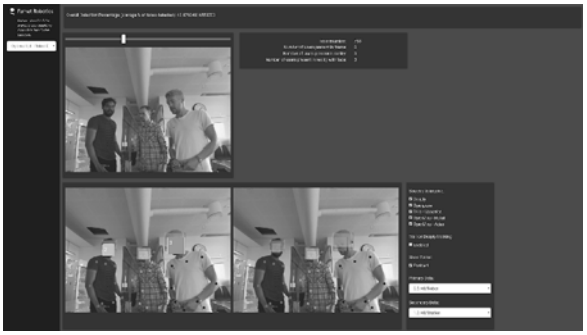
External Monitor Support

FurhatOS provides support for an external monitor connected via the robots USB-C port. The officially supported monitors are:

- ELO 1502L – Full HD (1080p version)
- Dell P2418HT 24" Touch

Visual Perception

FurhatOS supports a host of visual perception capabilities using the onboard camera. The visual perception capabilities are based on deep learning and support efficient execution on both robot CPU and GPU compute units.

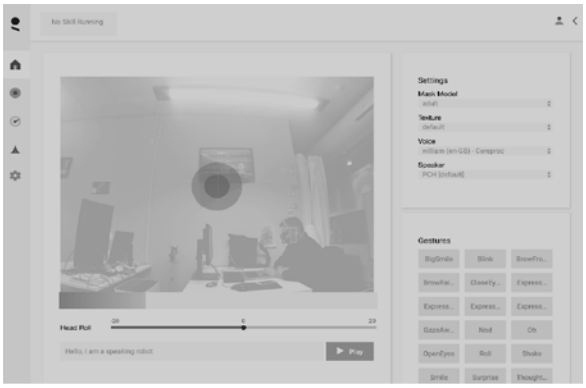


The visual perception capabilities support:

- 120° diagonal FOV
- Face Detection
- Face Recognition[10] using faceprint
- User Tracking of users in robot FOV
- User Tracking radius 0.5-3.0 Meters
- Head Pose Estimation (°Pitch/°Yaw/°Roll)
- Gesture[11] Recognition
- Body Pose Detection[12]
    - Head & Neck
    - Shoulders
    - Elbows
    - Wrists
    - Hips
    - Knees
    - Ankles

Web-Console

FurhatOS has a hosted browser based web interface that can be used to configure and manage many aspects of the system's setup



FurhatOS Web-Console supports:

- Live video feed from robot POV
- Live audio feed from robot[13]
- Wizard Of Oz[14] remote control capability
- Telepresence[15] capability
- Face Mask & Texture Selection
- Output Voice Selection
- Skill Install/Start/Stop/Uninstall
- Situation Model Dashboard
- Skill Activity Log
- Face Calibration
- Microphone Selection & Configuration
- Cloud Speech Recognizer Configuration
- Cloud Speech Synthesizer Configuration
- Face Mask & Texture Asset Management
- Network Settings Configuration
- System Password Management
- System Support Mode Initiation
- System Upgrade
- System Restart

[10] Not yet public in Furhat SDK or Kotlin API set
[11] Not yet public in Furhat SDK or Kotlin API set
[12] Not yet public in Furhat SDK or Kotlin API set
[13] Available 2020
[14] Remote control of *speech*, *gaze*, *head motion*, *gesture expression*, *face*, *texture* and *voice* selection
[15] Available 2020

Operations & Maintenance	Distribution
FurhatOS supports remote upgrade using the system update feature available from the web-console. *FurhatOS* enables robot owners to authorize Furhat Robotics support personnel to access the robot system and both view and change the installation, configuration, and state of the robot system. *FurhatOS* has a telemetry feature that enables it to send basic system level data to Furhat Cloud on a periodic basis. This data can be used by Furhat support personnel to expedite the handling of support cases from robot owners.	*FurhatOS* is distributed as a structured set of Linux packages supporting standard Linux package management operations and commands. Each version of *FurhatOS* is numbered using standard release notations including `major`, `minor` and patch level numbers. New minor releases of *FurhatOS* containing new features and fault corrections are released on a monthly basis.

Furhat SDK

The *Furhat SDK* (Software Development Kit) includes all of the developer tools, API's, tutorials and documentation enabling developers to create skills for the Furhat platform.

Developers can develop skills using the *Kotlin* programming language and hook into the rich API set offered by *FurhatOS*. *Furhat SDK* also provides IDE integration, and a virtual Furhat environment that enables skills to be developed, hosted, executed, and debugged on the developer's workstation before they are deployed to a physical robot system for final testing and/or production deployments.

Developer Experience With Virtual Furhat	**IDE Integration**
The *Furhat SDK* enables a developer to create, debug, and simulate skills on their developer workstation. A Virtual Furhat provides a simulated environment in which the skill can be run, and where all of it's features can be exercised and viewed. The Virtual Furhat has the same web-console as the real robot, and the developer can configure & control the virtual robot just as they do a real robot.	*Furhat SDK* supports integration with the *IntelliJ IDEA* IDE and *Gradle* based builds. **Supported Developer Workstation OS** The *Furhat SDK* supports developer workstations using *Linux*, *MacOS* and *Windows* as SDK host OS.

Skills Development with Kotlin

The *Furhat SDK* supports the development of skills using *Kotlin*. *Kotlin* is a popular cross-platform, general purpose programming language with type inference and is designed to interoperate fully with Java and it's JVM.

The *Furhat SDK Kotlin* DSL uses concepts such as *Flow*, *Intents* and *Entities* as it's key abstractions.

A *Flow* is a state chart implementation with additional functionality such as inheritance, global variables and dynamic states providing a powerful base for building complex interactions and reusing code. The *State* is the fundamental building block of the flow. A flow is always in one particular state, and makes transitions between states. The state defines *Triggers*, which in turn contain actions to be performed.

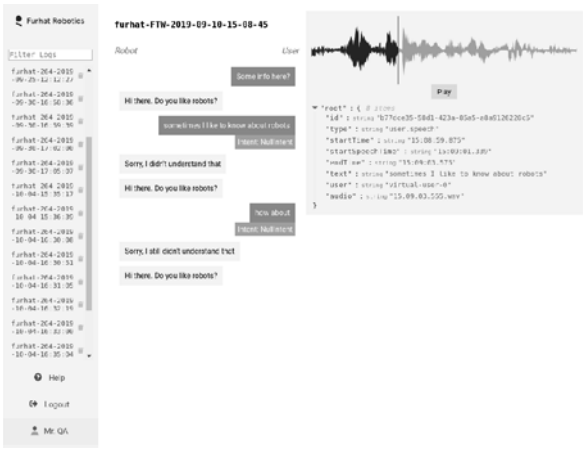
Intents relate to NLU. Every user utterance can be classified according to its *Intent*. For example, the *Intent* of an utterance could be a `Greeting` ("hello there"), a `RequestRepeat` ("could you repeat that") or a `BuyFruit` ("I want to buy an apple"). Each intent can be expressed using many different combinations of words.

Utterances can similarly contain *Entities*, that is, parts of the utterance that represent concepts such as City, Color, Time or Date. Thus, the `BuyFruit` *intent* may have an entity `Fruit` that specifies the fruit to be bought.

A full set of tutorials, API guides, and sample code is available on *Furhat.io.*

Dialog Logging

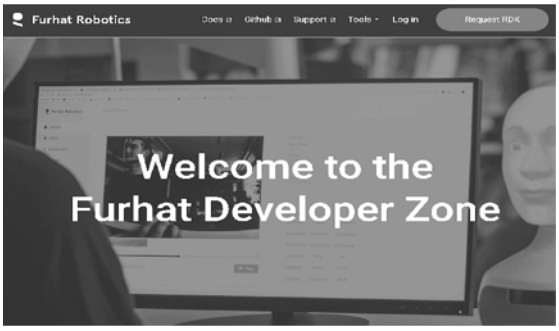
The *Furhat SDK* enables developers to activate logging in their skills.



The dialog states, timing, as well as the speech output, input, and the related audio data for the skill session are logged and can be inspected in a cloud based log viewer tool.

Developer Accounts

A Developer Account is required in order to download the *Furhat SDK* and also enables access to all of the documentation and tutorials on *Fuhat.io*



Developer accounts are allocated a developer token that can be used in conjunction with specific workflows and services such as Cloud Dialog logging.

Furhat Skills

Furhat Robotics has a number of skills, including a demonstrator skill, that can be used to explore and showcase our products. Please contact sales@furhatrobotics.com for further information on Furhat Skills.

Warranty & Support

Furhat Robotics offers both a standard *Furhat Limited Warranty* as well as an optional *Furhat Care package*. Please contact sales@furhatrobotics.com for further information.

Revision History

Revision	Date	Related SW & HW Versions	Description
1.2	20200304	FurhatOS Versions 1.17.0 & later Furhat Robot Generation 2, Rev A & later	Initial release of this document

Glossary

API	Application Programming Interface
ASR	Automatic Speech Recognition
DSL	Domain Specific Language
EOL	End Of Life
EOS	End Of Support
FOV	Field Of View
HSM	Hierarchical State Machine
HW	Hardware
IDE	IntegratedDevelopment Environment
I/O	Input Output
JVM	Java Virtual Machine
LED	Light Emitting Diode
LTS	Long Term Support
NLP	Natural Language Processing
NLU	Natural Language Understanding
OS	Operating System
POV	Point Of View
RFID	Radio Frequency Identification
RGB	Red Green Blue
SDK	Software Development Kit