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Robotic Service Ontology (RoSO)

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Preface

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1 Scope

The Robotic Service Ontology (RoSO) defines vocabularies to describe functions and constraints of robotic functional components for deployment in robotic services. RoSO is intended to work with IEEE1872-2015 [IEEE1872] for robotic functions. RoSO also intended to work with other ontologies for Human-Robot or Human-Agent Interaction (HRI/HAI) and ontologies for the service domain.
Robotic systems have been used to provide interactive service in societies such as reception, navigation, and retails. The development of such robotic systems becomes modularized with component technologies. ROS and OMG RTC have provided component models for robotic technologies and have been used for more than a decade. Those component models are supported by distributed communication infrastructures such as CORBA, SDO, and DDS.
Functions to be provided by those components are issues on another side. OMG RoIS defines a framework focusing on robotic interaction services. RoIS bridges between component functions and the development of components and also service development and component development. The example use case described in RoIS contains an interaction between a messenger robot and a person that consists of a sequence of use of robotic functional components.

Though such robotic functional components have been developed upon component technologies and reuse of such components has been established with common programming interfaces, the functions of and the requirements for such components are not well described with formal definitions. About components, common API can only describe 'how to use them,' but 'what they are.' This is because of a lack of common ontology to describe features of robotic systems.

IEEE1872 [IEEE1872] is an ontology for the robotics domain focusing on the core (generic) concepts for use in robotic systems and automation. The standard, called Core Ontology for Robotics and Automation (CORA), however, does not include domain-specific vocabularies, such as vocabularies for human-robot interactions, or those for robotic interaction services, or those for environmental knowledge required to deliver such services. The IEEE Robotics and Automation Society (RAS) has several activities to define domain-specific ontologies for autonomous systems and industrial robots but has not addressed requirements specific to service robots. With common vocabularies to describe the kinds of services provided by service robots, their components, and interfaces, interoperability and composition of lower-level services to achieve greater functionality are possible. The description of protocols and syntax of function calls are in machine-readable formats; the lack of formal definitions and semantics may allow for the specification of some robotic services, such as OMG RoIS (Robotic Interaction Service) framework [RoIS], which describe prerequisites and effects of components' functions in natural languages that developers and users of components can understand, but that the systems themselves cannot.

Figure 1 depicts a map of current specifications relating to robotic services.

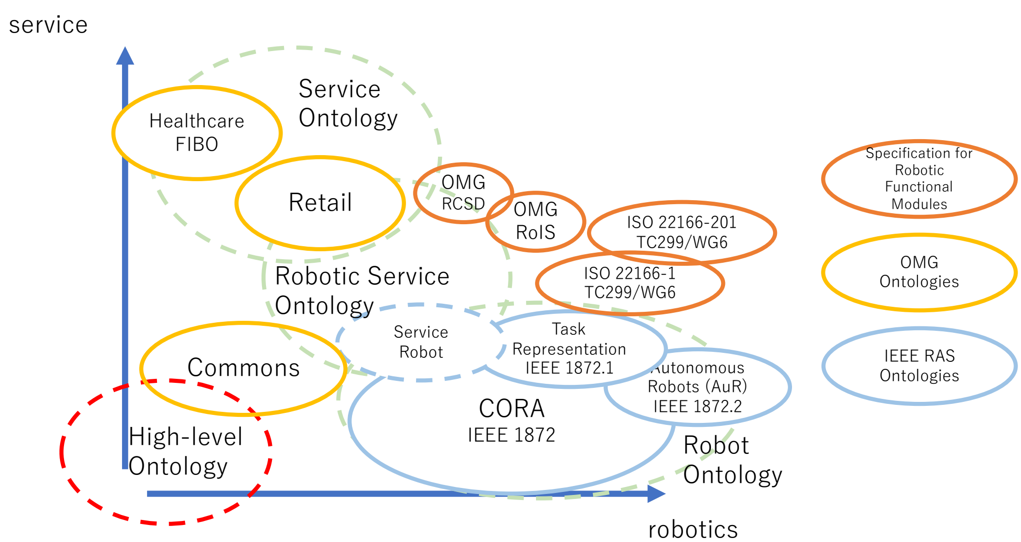

Figure 1 A map of current specifications that are related to robotic services.

This specification describes a new ontology for robotic services providing a foundation which existing robot services, such as those defined in OMG RoIS, can be clearly and consistently understood. Though RoIS provides a means to employ robotic functional components in a dynamic environment, the example use case described in the RoIS specification only describes statically configured robotic service without dynamic configuration. Recent developments in Cloud Networked Robotics (CNR) describe a robotic service environment in which numerous robotic components with various configurations can be combined and allocated to perform a variety of services dynamically and depending on the situation. As suggested in the RoIS, when robotic services and robotic components are developed independently in a loosely coupled fashion, a given service can be performed by various robots that are uniquely configured but are equally capable of executing the requested functions. Though the RoIS scenario does not explicitly describe how and when the robots are selected, the possibilities include dynamic or static configuration scenarios.

In the static configuration, given a request for a specific robotic service application, robotic service developers can deploy appropriate robots by composing existing or new components in advance of deployment. In this case, the matching between service requirements and component functions is designed by the developers who deeply understand both requirements and capabilities currently written in natural languages.

In the dynamic configuration, the allocation of robotic components is controlled by the running service itself or by robotic service platforms that configure and orchestrate the robotic services and robotic functional components on demand. Requirements from these services are not limited to the functional definition of components. As the services (through robotic components) interact with customers providing a range of capabilities in various environments, constraints of the execution environments and/or communication capabilities of individual customers can be taken into account and can inform the assignment of robotic components for a service customized for a specific customer in a particular environment. Well-defined vocabularies for robotic services enable such dynamic allocation scenarios of robotic service composition.

In this specification, RoSO (Figure 2) provides ontologies for robotic services including basic vocabularies to describe Human-Robot or Human-Agent Interaction (HRI/HAI) to be defined upon abstract ontologies (not concretely specified but depicted as “High-level Ontology” in Figure 1 and 2). The vocabularies constitute robotic services, vocabularies to describe functions and constraints of robotic functional components for deployment in robotic services; and vocabularies to describe functions and requirements of higher-level robotic services.
Those vocabularies are, partly from a physical viewpoint, classified under Agents, Services, Functions, and Environments. The ontology also incorporates common ontologies from OMG Commons Library.

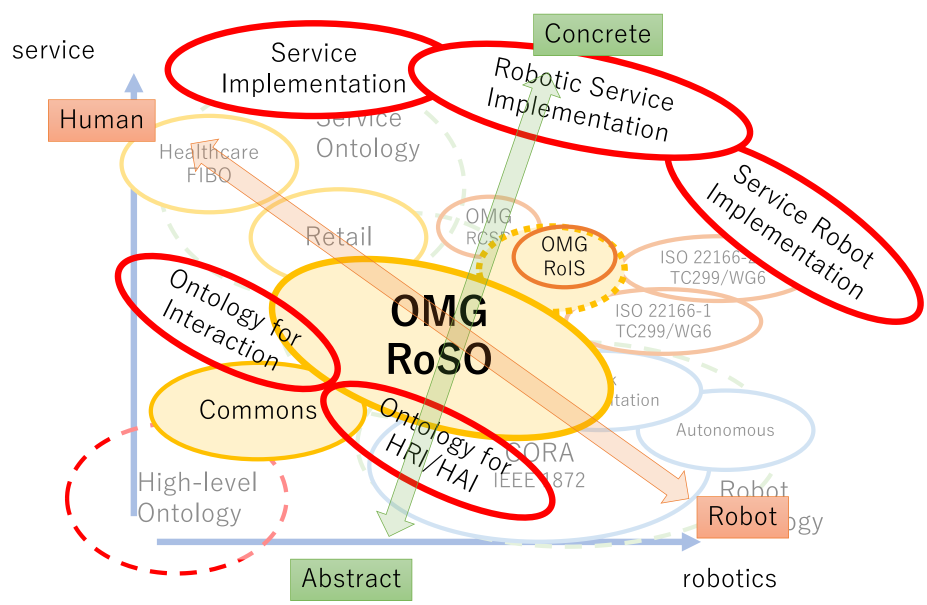

Figure 2 How RoSO supports and is supported by other standards.

2 Conformance

There are two conformance points with respect to the ontologies provided herein. These are as follows:

(1) Specification-level conformance with all of the OWL ontologies – which means that the subject application formally imports all of the ontologies (*i.e.*, through `owl:imports` statements in another ontology or via loading the full set of ontologies for reference in a knowledge base that supports OWL) with no resulting logical inconsistencies;

(2) Linked Data-level conformance – which means that the subject application references one or more of the ontologies but does not formally import them.

For either conformance point, any references to the elements defined in a given ontology must use, or provide a mapping to, the standard OMG URI for that element. Implementations that claim specification-level conformance with the ontologies must support all of them.

Users may choose to use or extend any of the RoSO ontologies needed to address their individual requirements.

3 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

[Commons] OMG Commons Ontology. Available at https://www.omg.org/spec/Commons/.

[CORA] IEEE Standard Ontologies for Robotics and Automation, IEEE1972-2015. Available at https://standards.ieee.org/ieee/1872/5354/.

[IPR] OMG, OMG Policy Statement Intellectual Property Rights. Available at https://www.omg.org/cgi-bin/doc.cgi?ipr.

[ISO 22166-1] ISO 22166-1:2021 Robotics – Modularity for service robots – Part 1: General requirements. Available at https://www.iso.org/standard/72715.html.

[ISO 22166-201] ISO 22166-201:2024 Robotics – Modularity for service robots – Part 201: Common information model for modules. Available at https://www.iso.org/standard/82334.html.

[LCC] OMG, Languages, Countries and Codes. Available at https://www.omg.org/spec/LCC.

[ODM] Ontology Definition Metamodel. Available at https://www.omg.org/spec/ODM/.

[OWL2] OWL 2 Web Ontology Language Quick Reference Guide (Second Edition), W3C Rocommendation 11 December 2012. Available at https://www.w3.org/TR/2012/REC-owl2-quick-reference-20121211/.

[RDF Concepts] RDF 1.1 Concepts and Abstract Syntax. W3C Recommendation, 25 February 2014. Available at https://www.w3.org/TR/rdf11-concepts/.

[RDF Schema] RDF Schema 1.1 W3C Recommendation, 25 February 2014. Available at https://www.w3.org/TR/rdf-schema/.

[RLS] OMG Robotic Localization Service. Available at https://www.omg.org/spec/RLS/.

[RoIS] OMG Robotic Interaction Service Framework. Available at https://www.omg.org/spec/RoIS/.

[RTC] OMG Robotic Technology Component. Available at https://www.omg.org/spec/RTC/.

[SysML] OMG System Modeling Language. Available at https://www.omg.org/spec/SysML/.

[UML] OMG Unified Modeling Language. Available at https://www.omg.org/spec/UML/.

[XSD] XML Schema Part 2: Datatypes Second Edition. W3C Recommendation, 28 October 2004. Available at https://www.w3.org/TR/xmlschema-2/.

4 Terms and Definitions

For the purposes of this specification, the following terms and definitions apply.

Agent

An entity that provides or receives services such as a robot or a person.

Robot

An artificial agent that is used to provide robotic services.

Avatar Robot

A robot that represents a person who is operating the avatar robot remotely.

Robotic Service

A service provided by service robots.

Robotic Interaction Service

A robotic service that includes interaction between robot and human.

Robotic Functional Component

A component that is used to compose robots.

5 Symbols

CORA – Core Ontology for Robotics and Automation.

ISRO – Intelligent Service Robot Ontology.

LCC – Languages, Countries and Codes.

ODM – Ontology Definition Metamodel.

OWL – Web Ontology Language.

RDF – Resource Definition Framework.

RLS – Robotic Localization Service.

RoIS – Robotic Interaction Service.

ROS – Robot Operating System.

RTC – Robotic Technology Component.

UML – Unified Modeling Language.

W3C – World Wide Web Consortium.

XMI – XML Metadata Interchange.

XML – eXtensible Markup Language.

6 Additional Information

6.1 Acknowledgements

The following organizations submitted this specification:

- Japan Robot Association (JARA)
- Korea Association of Robot Industry (KAR)

The following additional organizations contributed to this specification:

- Shibaura Institute of Technology
- National Institute of Advanced Industrial Science and Technology, Japan (AIST)
- Université Sorbonne Paris Nord (UPSN)

The following additional companies and organizations are supporters of this specification:

- Advanced Telecommunication Research International (ATR)
- Electronics and Telecommunication Research Institute (ETRI)
- University of Seoul
- Université Paris-Est Créteil (UPEC)
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6.3 Reuse of the Ontologies

The Robotic Service Ontology (RoSO) uses and extends a number of the ontologies specified in the companion Commons Ontology Library specification. The Commons Ontology Library contains small but fundamental building block ontologies that are essential to RoSO. RoSO also uses ontologies included in the Languages, Countries, and Codes (LCC) specification for the identification of languages and geographic regions associated with vocabulary elements.

6.4 Notations

The notation used to represent description logic expressions (*i.e.*, the expressions in the Parent columns in class tables containing ontology details) is consistent with the notation defined in the Description Logic Handbook [DL Handbook]. The notation used in this specification, representing a subset of OWL 2, is described in Table 6.1, below.

Table 6.1: Description Logic Expressions Notation

Construct	***Description***	***Notation***

Boolean Connectives and Enumeration		
intersection	The intersection of two classes consists of exactly those individuals which are instances of both classes.	$C \cap D$
union	The union of two classes contains every individual which is contained in at least one of these classes.	$C \cup D$
enumeration	An enumeration defines a class by enumerating all its instances.	oneOf (i_1, i_2, i_3, … i_n)
Property Restrictions		
universal quantification	Universal quantification is used to specify a class of individuals for which all related individuals must be instances of a given class (*i.e.*, allValuesFrom in OWL).	$\forall$R.C, where R is the relation (property) and C is the class that constrains all values for related individuals
existential quantification	Existential quantification is used to specify a class as the set of all individuals that are connected via a particular property to at least one individual which is an instance of a certain class (*i.e.*, someValuesFrom in OWL).	$\exists$R.C, where R is the relation (property) and C is the class that constrains some values of related individuals
individual value	Individual value restrictions are used to specify classes of individuals that are related to one particular individual (*i.e.*, hasValue in OWL).	$\forall$R.I, where R is the relation (property) and I is the individual
exact cardinality	Cardinality (number) restrictions specify classes by restricting the cardinality on the sets of fillers for roles (relationships, or properties in OWL). Exact cardinality restrictions restrict the cardinality of possible fillers to exactly the number specified.	= n R (for unqualified restrictions) = n R.C (for qualified restrictions, i.e., including onClass or on DataRange)
maximum cardinality	Maximum cardinality restrictions restrict the cardinality of possible fillers to at most the number specified (inclusive).	$\leq$ n R (for unqualified restrictions) $\leq$ n R.C (for qualified restrictions)
minimum cardinality	Minimum cardinality restrictions restrict the cardinality of possible fillers to at least the number specified (inclusive).	$\geq$ n R (for unqualified restrictions) $\geq$ n R.C (for qualified restrictions)
Class Axioms		
equivalent classes	Two classes are considered equivalent if they contain exactly the same individuals.	$\equiv$ C
disjoint classes	Disjointness means that membership in one class specifically excludes membership in another.	$\neg$ C
Property Axioms		
complex role inclusions	Role inclusions allow [object] properties to be chained together in a sequence that is a subproperty of a higher-level property.	$R \circ R$

Note that in the case of complex restrictions, where there are nested elements in parentheses, the "dot notation" used as a separator between a property and the role filler is replaced with the embedded parenthetical filler definition. A "role" from a description logic perspective is essentially a property in OWL, and the role "filler" is the class or individual that provides the value for that role in a given axiom (*i.e.*, in a restriction or other logic expression).

7 Robotic Service Ontology

7.1 Robotic Service Ontology

An overview of the primitive entities for robotic service ontology is described in Figure 3 and Figure 4. In the following diagrams classes defined in OMG RoSO are represented in white box, classes imported from OMG Commons are represented in amber, and those imported from other ontology is represented in pink.

The metadata of the Robotic Service Ontology are provided in Table 7.1. The detailed annotations and axioms that comprise the Robotic Service Ontology are provided in Table 7.2.

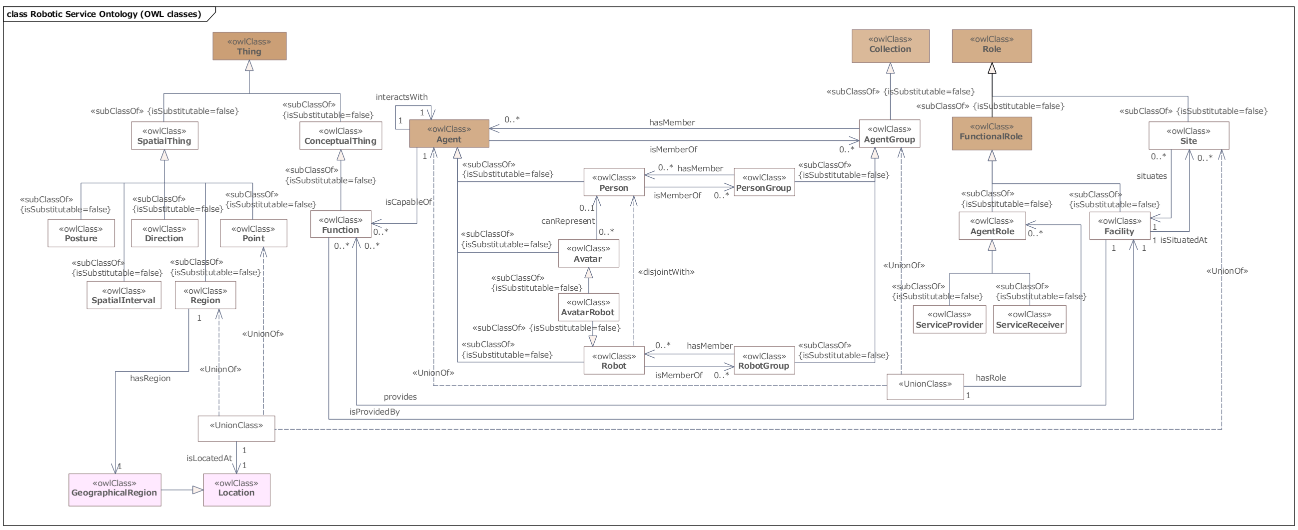

Figure 3 Robotic Service Ontology (OWL classes).

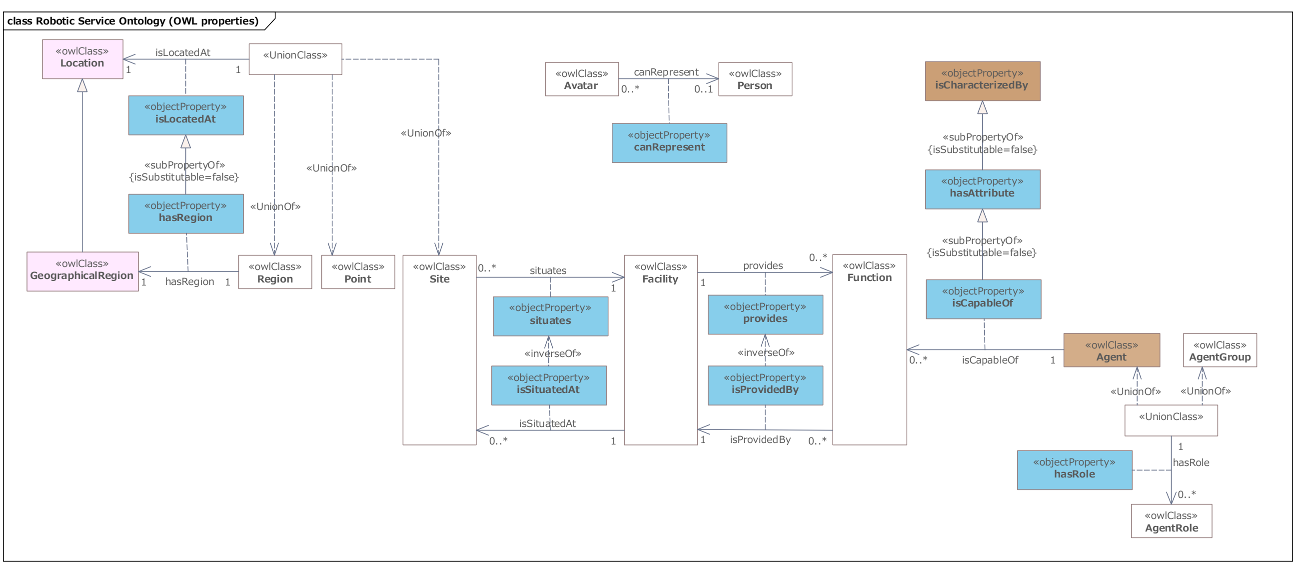

Figure 4 Robotic Service Ontology (OWL properties).

Table 7.1: Robotic Service Ontology Metadata

Metadata Term	Value
OntologyIRI	https://www.omg.org/spec/RoSO/RoboticServiceOntology/

rdfs:label	Robotic Service Ontology
dct:abstract	The Robotic Service Ontology (RoSO) ontology provides the core concepts required to integrate robotics services with other robotics ontologies, such as the IEEE Standard Ontologies for Robotics and Automation, IEEE1972-2015, also known as CORA.
cmns-av:copyright	Copyright © 2023-2024 Japan Robot Association
cmns-av:copyright	Copyright © 2023-2024 Korea Association of Robot Industry
cmns-av:copyright	Copyright © 2023-2024 Shibaura Institute of Technology
cmns-av:copyright	Copyright © 2023-2024 National Institute of Advanced Industrial Science and Technology, Japan
cmns-av:copyright	Copyright © 2023-2024 Université Sorbonne Paris Nord
cmns-av:copyright	Copyright © 2023-2024 Object Management Group
dct:references	http://purl.org/dc/terms/
dct:references	http://www.w3.org/2004/02/skos/core#
dct:title	Robotic Service Ontology
owl:versionIRI	https://www.omg.org/spec/RoSO/20241101/RoboticServiceOntology/

Table 7.2: Robotic Service Ontology Details

Properties

Name	Annotations	Property Axioms
canRepresent (can represent)	Definition: can represent a person	Domain: roso:Avatar Range: roso:Person
hasAttribute (has attribute)	Definition: has feature or is delimited by	Parent Property: cmns-cls:*isCharacterizedBy*
hasRegion (has region)	Definition: indicates a demarcated area on the surface of the Earth	Parent Property: roso:*isLocatedAt* Domain: roso:Region Range: lcc-cr:GeographicalRegion
hasRole (has role)	Definition: represents agent's (or agent group's) role in service	Parent Property: cmns-cls:*isCharacterizedBy* Domain: cmns-pts:Agent ∪ roso:AgentGroup Range: roso:AgentRole
isCapableOf (is capable of)	Definition: represents agent's capability to execute a role or function in service	Parent Property: roso:*hasAttribute* Domain: cmns-pts:Agent Range: roso:Function
isLocatedAt (is located at)	Definition: relates something to a location, which might be physical or virtual	Domain: roso:Point ∪ roso:Region ∪ roso:Site Range: lcc-cr:Location
isProvidedBy (is provided by)	Definition: is made available by	InverseOf: roso:*provides*
isSituatedAt (is situated at)	Definition: is placed at Note: something may be situated at some site, or in some setting, situation, or context.	InverseOf: roso:*situates*
provides (provides)	Definition: makes something available	Domain: roso:Facility Range: roso:Function
situates (situates)	Definition: indicates the place, setting, or context in which something is placed	Domain: roso:Site Range: roso:Facility

Classes

Name	Annotations	Class Expressions

AgentGroup (agent group)	Definition: collection of agents (people, organizations, software agents, robots, etc.) considered as a unit	Parent Class: cmns-col:Collection PropertyRestricton: ∀hasMember.Agent
AgentRole (agent role)	Definition: a role an agent can perform Note: The relationship between an agent or an agent group and an agent role is represented by a *hasRole* attribute	Parent Class: cmns-rlcmp:FunctionalRole
Avatar (avatar)	Definition: an agent that represents a person and provides the person functions of remote control and communication stream to interact with other agents in the robotic service environment	Parent Class: cmns-pts:Agent
Avatar Robot (avatar robot)	Definition: a robot that represents a person and provides the person functions of remote control and communication stream to interact with other agents in the robotic service environment	Parent Class: roso:Robot, roso:Avatar
ConceptualThing (conceptual thing)	Definition: a foundation to all classes that represents abstract concepts	Parent Class: owl:Thing
Direction (direction)	Definition: a spatial amount typically represented as a spatial vector that an object is moving	Parent Class: roso:SpatialThing
Facility (facility)	Definition: something established to serve a particular purpose, make some course of action or operation easier, or provide some capability or service	Parent Class: cmns-rlcmp:FunctionalRole
Function (function)	Definition: activity a component actuates something or senses status of or changes in the environment	Parent Class: roso:ConceptualThing
Person (person)	Definition: an agent that perform roles in interaction with other agents, but not a robot Note: a person in a service environment can be both a service provider and a service receiver as an agent	Parent Class:cmns-pts:Agent
PersonGroup (person group)	Definition: collection of persons considered as a unit	Parent Class: roso:AgentGroup PropertyRestricton: ∀hasMember.Person
Point (point)	Definition: a spatial point as a target of actuation or a spatial point where an event is observed	Parent Class: roso:SpatialThing
Posture (posture)	Definition: a spatial amount typically represented as a set of spatial vector to describe the posture of an object	Parent Class: roso:SpatialThing
Region (region)	Definition: a spatial area typically where a sensor can observe	Parent Class: roso:SpatialThing
Robot (robot)	Definition: a spatial amount typically represented as a set of spatial vector to describe the posture of an object	Parent Class: cmns-pts:Agent Class Axiom: ¬ roso:Person
RobotGroup (robot group)	Definition: collection of robots considered as a unit	Parent Class: roso:AgentGroup PropertyRestricton: ∀hasMember.Robot
ServiceProvider (service provider)	Definition: a role of an agent or agent group that provides services	Parent Class: roso:AgentRole
ServiceReceiver (service receiver)	Definition: a role of an agent or agent group that receives services	Parent Class: roso:AgentRole
Site (site)	Definition: place, setting, or context in which something, such as a facility, is situated	Parent Class: cmns-rlcmp:Role

	Note: A physical site has certain characteristics that contribute to the context it provides, including area, shape, accessibility, and in the case of a geographic site, landforms, soil and ground conditions, climate, and so forth	
SpatialInterval (spatial interval)	Definition: a spatial distance typically as a limit that actuators can work safely or that a sensor can distinguish targets	Parent Class: roso:SpatialThing
SpatialThing (spatial thing)	Definition: a foundation to all classes that represents spatial entities such as points and spatial amounts such as distances	Parent Class:owl:Thing

7.2 Robotic Service Interaction Ontology

Vocabularies to describe events and actions in interaction is defined in Figure 5 and Figure 6. Those vocabularies are used in service implementation in conjunction with entities in the primitive ontology.
The metadata of the Robotic Service Interaction Ontology are provided in Table 7.3. The detailed annotations and axioms that comprise the Robotic Service Interaction Ontology are provided in Table 7.4.

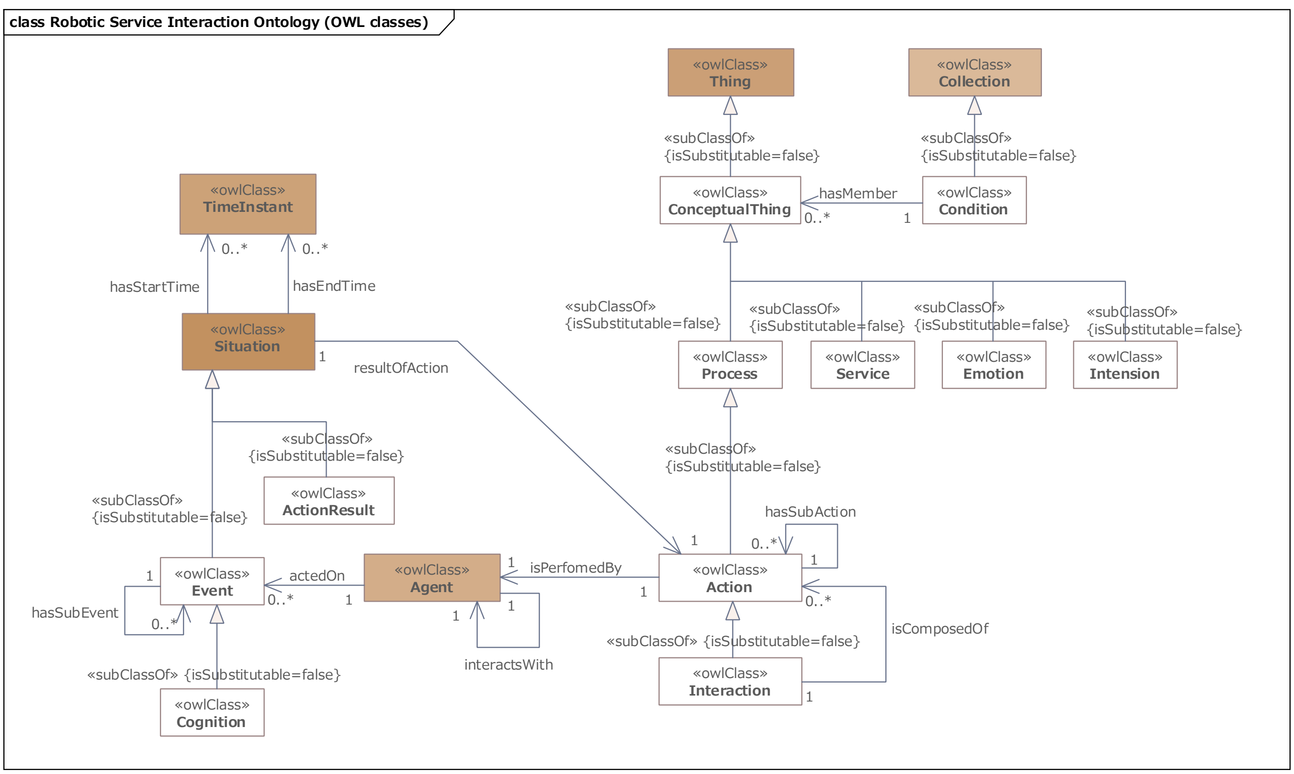

Figure 5 Robotic Service Interaction Ontology (OWL classes)

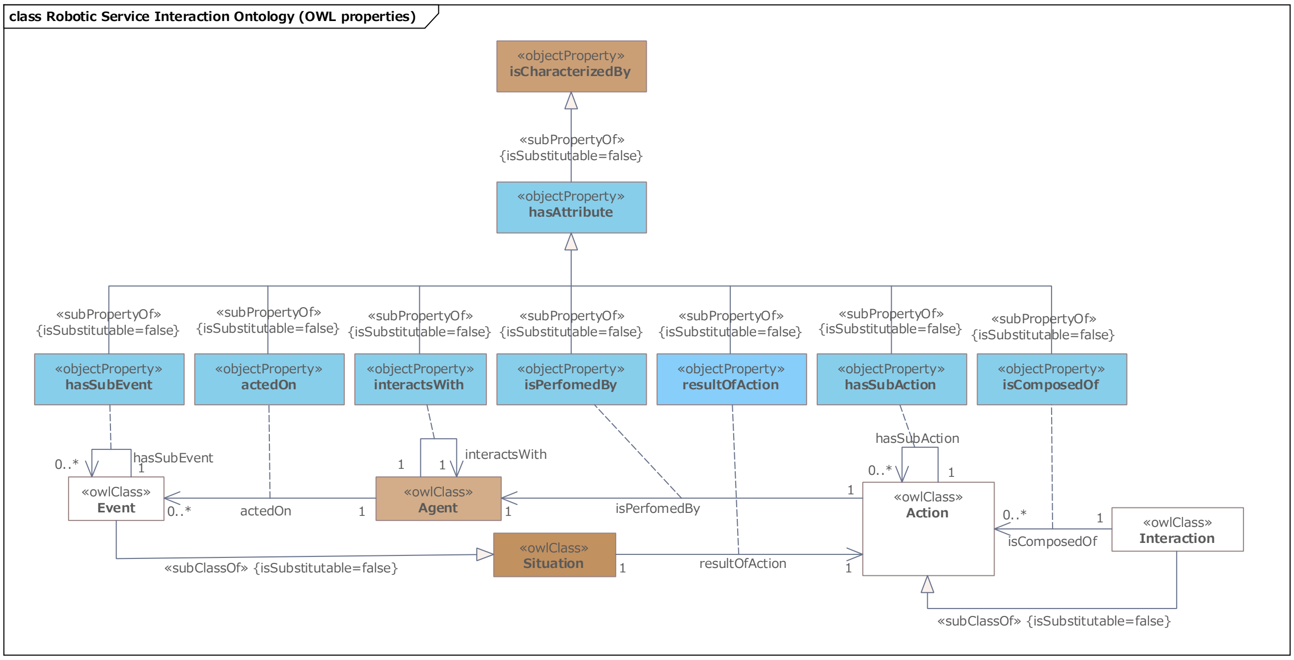

Figure 6 Robotic Service Interaction Ontology (OWL properties).

Table 7.3: Robotic Service Interaction Ontology Metadata

Metadata Term	Value
OntologyIRI	https://www.omg.org/spec/RoSO/RoboticServiceInteractionOntology/
rdfs:label	Robotic Service Interaction Ontology
dct:abstract	The Robotic Service Ontology (RoSO) interaction ontology extends the main RoSO ontology to define various interactions that a robotic service might have.
cmns-av:copyright	Copyright © 2023-2024 Japan Robot Association
cmns-av:copyright	Copyright © 2023-2024 Korea Association of Robot Industry
cmns-av:copyright	Copyright © 2023-2024 Shibaura Institute of Technology
cmns-av:copyright	Copyright © 2023-2024 National Institute of Advanced Industrial Science and Technology, Japan
cmns-av:copyright	Copyright © 2023-2024 Université Sorbonne Paris Nord
cmns-av:copyright	Copyright © 2023-2024 Object Management Group
dct:references	http://purl.org/dc/terms/
dct:references	http://www.w3.org/2004/02/skos/core#
dct:title	Robotic Interaction Ontology
owl:versionIRI	https://www.omg.org/spec/RoSO/20241101/RoboticServiceOntology/

Table 7.4: Robotic Service Interaction Ontology Details

Properties

Name	Annotations	Property Axioms
actedOn (acted on)	Definition: indicates an agent involved in an event	Parent Property: roso:*hasAttribute* Domain: roso:Event Range: cmns-pts:Agent
hasSubAction (has sub action)	Definition: indicates a subsequent action	Parent Property: roso:*hasAttribute* Domain: roso-inct:Action

		Range: roso-inct:Action
hasSubEvent (has sub event)	Definition: indicates a subsequent event	Parent Property: roso:*hasAttribute* Domain:roso-inct:Event Range: roso-inct:Event
interactsWith (interacts with)	Definition: indicates an agent as target of interaction	Parent Property: roso:*hasAttribute* Domain: cmns-pts:Agent Range: cmns-pts:Agent
isPerformedBy (is performed by)	Definition: indicates an agent that causes an action	Parent Property: roso:*hasAttribute* Domain: cmns-pts:Agent Range: roso-inct:Action
resultOfAction (results of action)	Definition: indicates a causal relationship between an action and a situation	Parent Property: roso:*hasAttribute* Domain: roso-inct:Action Range: cmns-pts:Situation

Classes

Name	Annotations	Class Expressions
Action (action)	Definition: an event that an agent causes to change the status of the environment or other agents Note: a sequence of actions is represented by using *hasSubAction* property	Parent Class: roso-inct:Process
ActionResult (action result)	Definition: a situation caused by an action performed by an agent or agent group	Parent Class: cmns-pts:Situation
Condition (condition)	Definition: collection of conceptual things such as actions, situations, and agents' internal status	Parent Class: cmns-col:Collection PropertyRestricton: ∀hasMember.ConceptualThing
Cognition (cognition)	Definition: agent's internal status that is caused by receiving events and changes its internal states such as Emotion or Intention or sometimes causes actions directly	Parent Class: roso:Event
Emotion (emotion)	Definition: agent's internal status that causes action and is changed by receiving events or cognitions	Parent Class: roso:ConceptualThing
Event (event)	Definition: a situation caused by something in the environment Note: a sequence of events is represented by using *hasSubEvent* property	Parent Class: roso:Situation
Intention (intention)	Definition: agent's internal status that causes action and is changed by receiving events, cognitions, or emotions	Parent Class: roso:ConceptualThing
Interaction (interaction)	Definition: an action that occurs between two or more agents that has a *performer* and one or more *targets* of the action	Parent Class: roso-inct:Action
Process (process)	Definition: structured set of activities involving various enterprise entities designed and organized for a given purpose	Parent Class: roso:ConceptualThing
Service (service)	Definition: intangible activity performed by some party for the benefit of another party	Parent Class: roso:ConceptualThing

7.3 Robotic Functional Components

Abstract part of the vocabularies to describe robotic functional component is described in Figure 7 and 8.
The metadata of the Robotic Service Ontology are provided in Table 7.5. The detailed annotations and axioms that comprise the Robotic Service Ontology are provided in Table 7.6.
Details of robotic functional components are to be defined in each implementation using this ontology as well as RoIS Person Detection examples in Annex A.

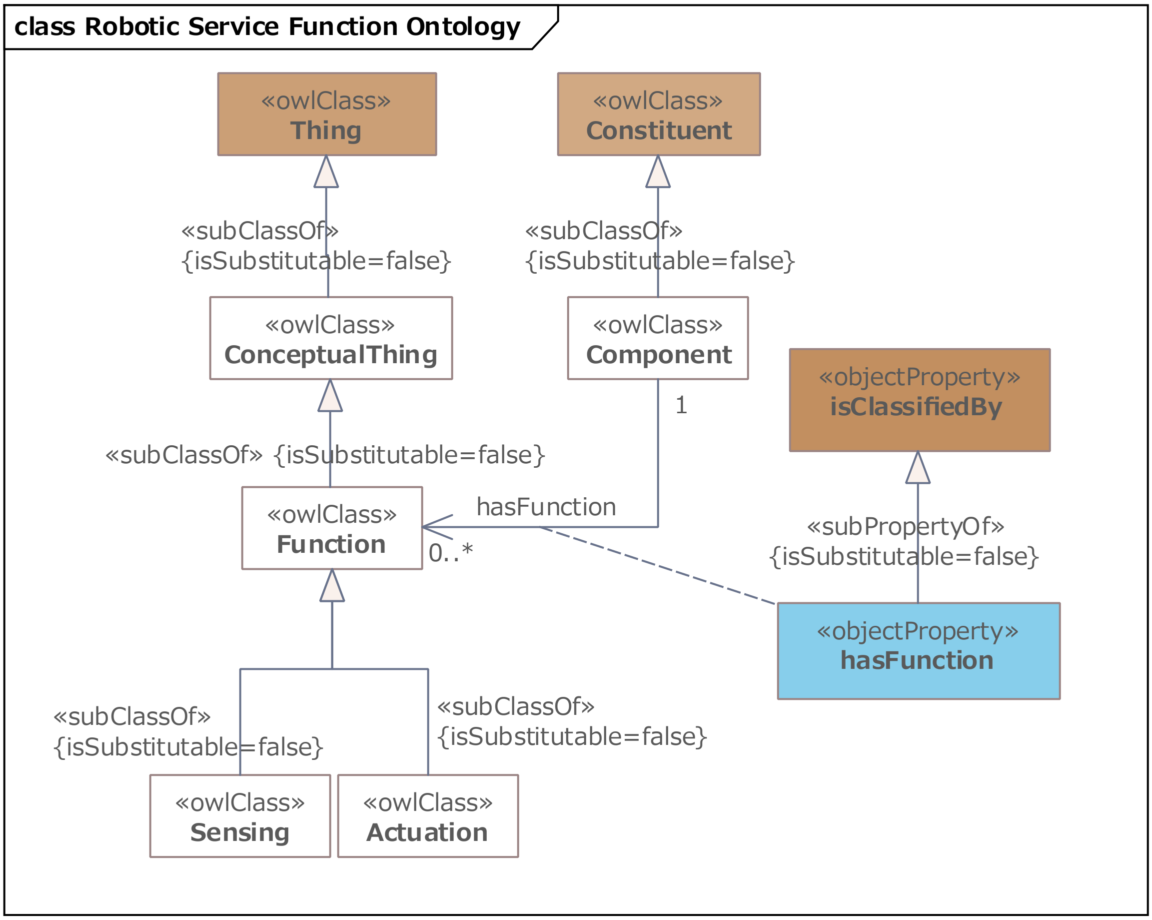

Figure 7 Robotic Service Function Ontology (OWL classes).

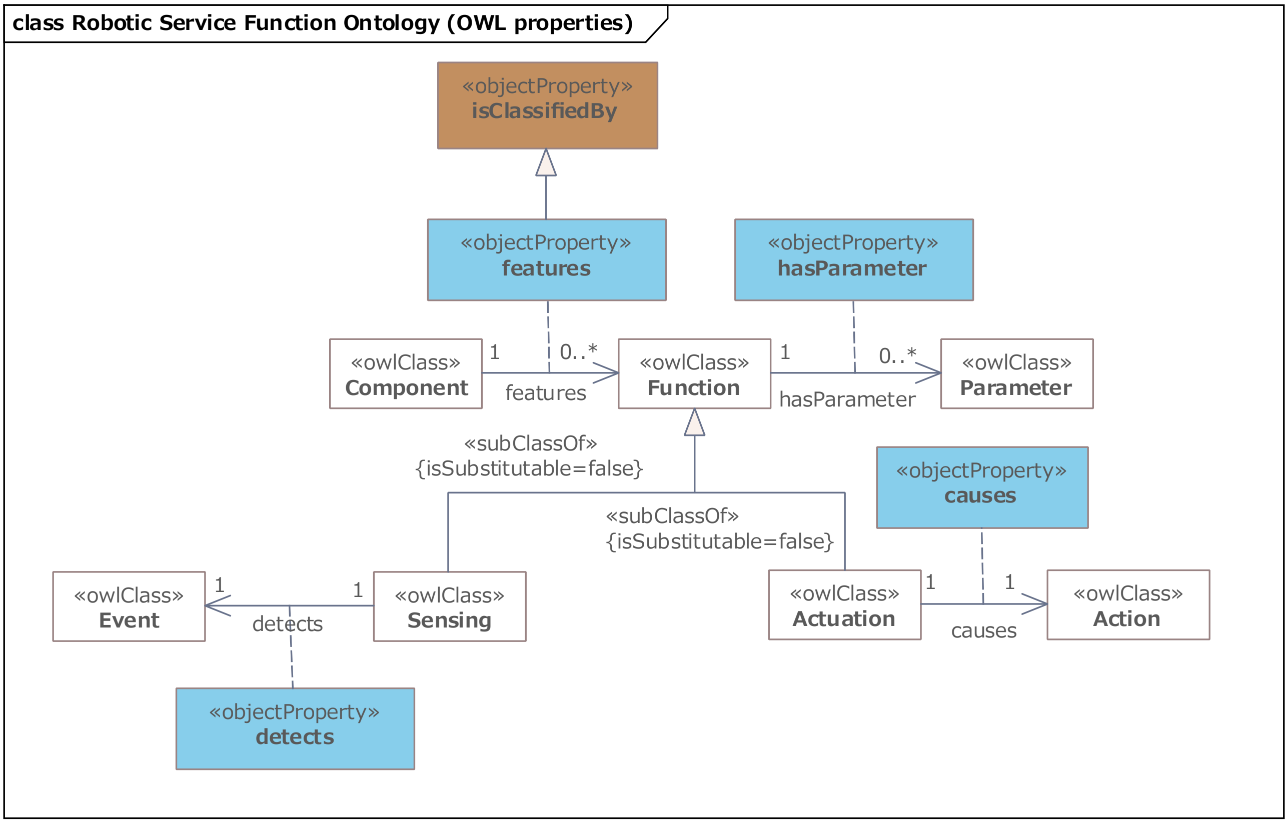

Figure 8 Robotic Service Function Ontology (OWL properties).

Vocabularies to describe the relationship between Component and Function are defined as follows.

Table 7.5: Robotic Service Function Ontology Metadata

Metadata Term	Value
OntologyIRI	https://www.omg.org/spec/RoSO/RoboticServiceFunctionOntology/
rdfs:label	Robotic Service Function Ontology
dct:abstract	The Robotic Service Ontology (RoSO) function ontology extends the main RoSO ontology to define various functions that a robotic service might perform.
cmns-av:copyright	Copyright © 2023-2024 Japan Robot Association
cmns-av:copyright	Copyright © 2023-2024 Korea Association of Robot Industry
cmns-av:copyright	Copyright © 2023-2024 Shibaura Institute of Technology
cmns-av:copyright	Copyright © 2023-2024 National Institute of Advanced Industrial Science and Technology, Japan
cmns-av:copyright	Copyright © 2023-2024 Université Sorbonne Paris Nord
cmns-av:copyright	Copyright © 2023-2024 Object Management Group
dct:references	http://purl.org/dc/terms/
dct:references	http://www.w3.org/2004/02/skos/core#
dct:title	Robotic Interaction Ontology
owl:versionIRI	https://www.omg.org/spec/RoSO/20241101/RoboticServiceFunctionOntology/

Table 7.6: Robotic Service Function Ontology Details

Properties

Name	Annotations	Property Axioms
causes (causes)	Definition: represents actions that a function can actuate	Domain: roso-fnct:Actuation Range: roso-inct:Action
detects (detects)	Definition: represents events that a function can sence	Domain: roso-fnct:Sensing Range: roso-inct:Event
features (features)	Definition: represents functions that a component can provide	Parent Property: cmns-cls:*isClassifiedBy* Domain: roso-fnct:Component Range: roso:Function
hasParameter (has parameter)	Definition: represents parameters that a function has	Domain: roso:Function Range: roso-fnct:Parameter

Classes

Name	Annotations	Class Expressions
Actuation (actuation)	Definition: a function to actuate something	Parent Class: roso:Function Disjoint With: roso-fnct:Sensing
Component (component)	Definition: a functional module that provides robotic functions such as actuation or sensing	Parent Class: cmns-col:Constituent
Parameter (parameter)	Definition: a value that have effects on a behavior of a component's function	
Sensing (sensing)	Definition: a function to sense something	Parent Class: roso:Function Disjoint With: roso-fnct:Actuation

Annex A: RoIS Functional Components

(informative)

This section describes example cases of definition with RoSO. The first example is definition of RoIS Basic Functional Components, in particular RoIS Person Detection Component, to demonstrate RoSO ontology usage. RoIS specific vocabularies are defined in Section A.1 and then RoIS functional components are defined using RoSO and extended ontology in Section A.2. Figure 9 and 10 describes classes and properties that describe RoIS Person Detection Component. Examples of robotic services as use case of RoSO description are described in Annex B and Annex C.

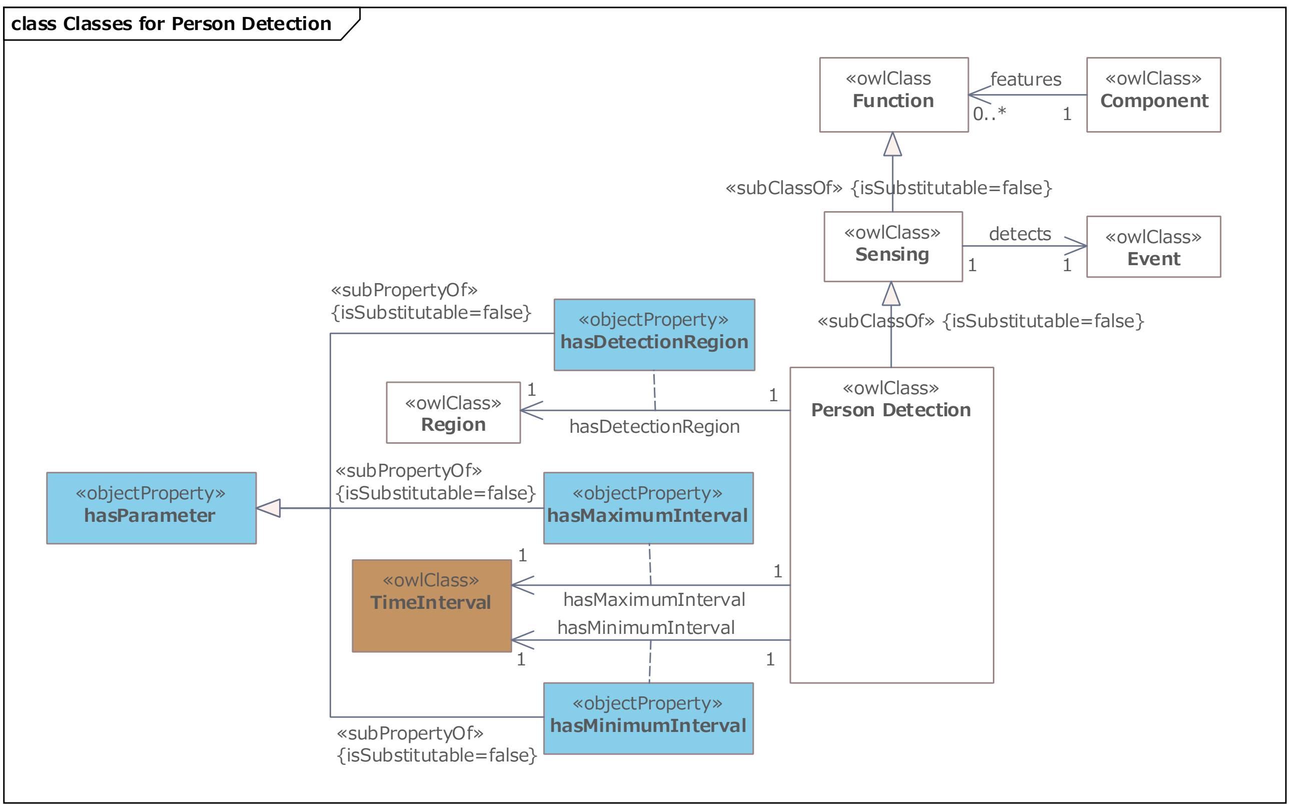

Figure 9 RoIS Person Detection Component (OWL classes).

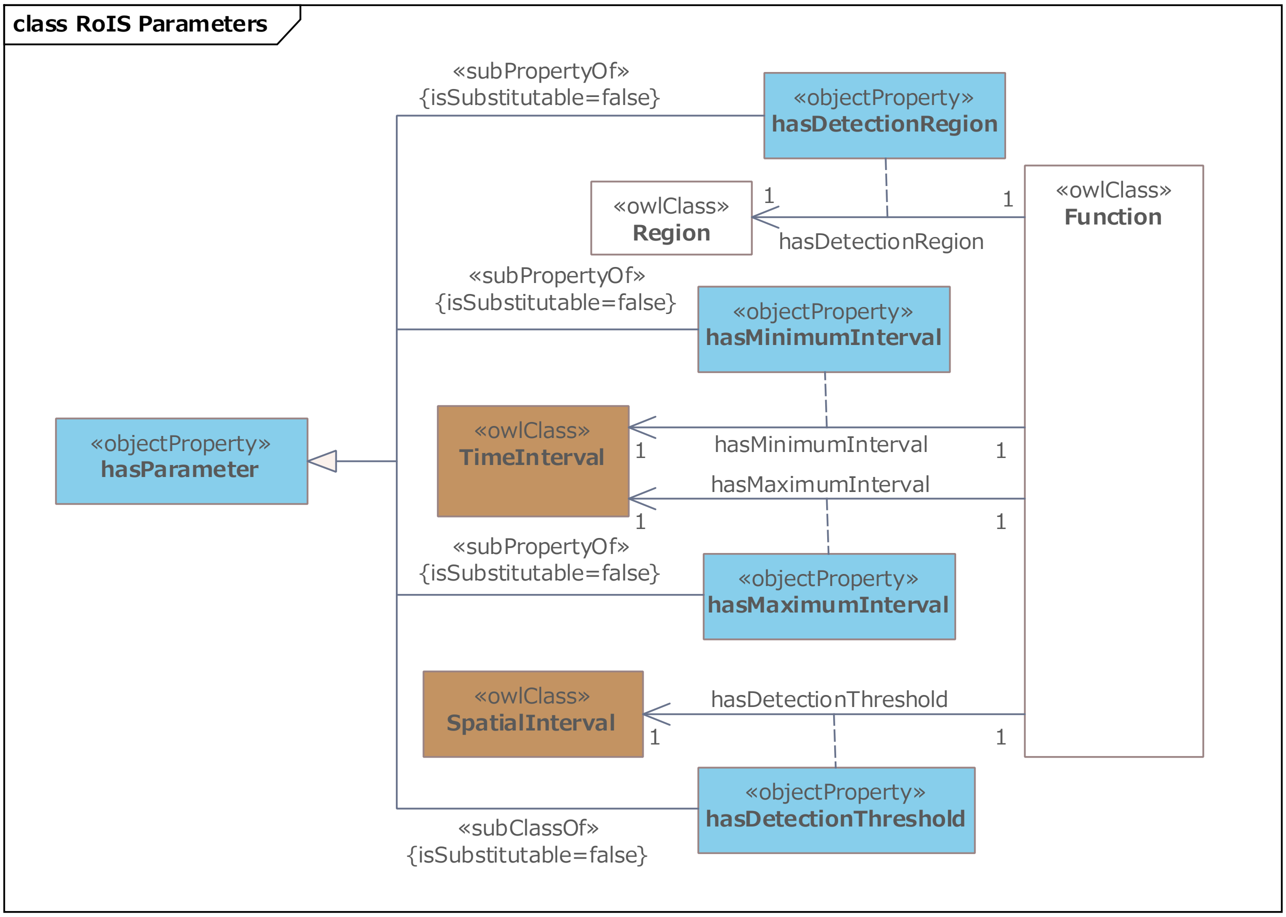

Figure 10 RoIS Person Detection Component (OWL properties)

A.1 RoIS Functional Component Ontology

Data types of parameters are statically defined as sub classes of RoSO data types. Parameters used in RoIS functional components are defined as properties and range of them are defined upon RoSO vocabularies. RoIS basic functional components are defined as subclasses of roso:Sensor or roso:Actuator.

Table A.1: Robotic Functional Service (RoIS) Component Ontology Metadata

Metadata Term	Value
OntologyIRI	https://www.omg.org/spec/RoSO/Example/RoboticInteractionServiceComponentOntology/
rdfs:label	Robotic Interaction Service (RoIS) Component Ontology
dct:abstract	The Robotic Interaction Service Components Ontology provides vocabularies to describe RoIS basic functional components
cmns-av:copyright	Copyright © 2022-2023 Japan Robot Association
cmns-av:copyright	Copyright © 2022-2023 Korea Association of Robot Industry
cmns-av:copyright	Copyright © 2023 Shibaura Institute of Technology

cmns-av:copyright	Copyright © 2023 Advanced Institute of Science and Technology, Japan
cmns-av:copyright	Copyright © 2023 Université Sorbonne Paris Nord
cmns-av:copyright	Copyright © 2023 Object Management Group
dct:references	http://purl.org/dc/terms/
dct:references	http://www.w3.org/2004/02/skos/core#
dct:title	Robotic Interaction Service Component Ontology
owl:versionIRI	https://www.omg.org/spec/RoSO/20230801/Example/RoboticInteractionServiceComponentOntology/

Table A.2: Robotic Functional Service (RoIS) Component Ontology Details

Properties

Name	Annotations	Property Axioms
hasDetectionRegion (has detection region)	Definition: indicates a region in which a component can detect targets	Domain: roso-fnct:Function Range: roso:Region
hasDetectionThreshold (has detection threshold)	Definition: indicates a spatial interval by which a component can distinguish detected targets	Domain: roso-fnct:Function Range: roso:SpatialInterval
hasMaximumInterval (has maximum interval)	Definition: indicates a periodic interval within which a component notifies events in maximum	Domain: roso-fnct:Function Range: cmns-dt:TimeInterval
hasMinimalInterval (has minimal interval)	Definition: indicates a periodic interval by which a component can detect targets	Domain: roso-fnct:Function Range: cmns-dt:TimeInterval
hasTimeLimit (has time limit)	Definition: indicates a time limit by which a component completes the function	Domain: roso-fnct:Function Range: cmns-dt:TimeInstant

Classes

Name	Annotations	Class Expressions
FaceDetection (face detection)	Definition: component function to count the number of faces detected in the detection region	Parent Class: roso:Sensing
FaceLocalization (face localization)	Definition: component function to localize positions of faces detected in the detection region	Parent Class: roso:Sensing
Follow (follow)	Definition: component function to move following a target agent	Parent Class: roso:Actuation
GestureRecognition (gesture recognition)	Definition: component function to recognize gestures represented by other agents	Parent Class: roso:Sensing
Move (move)	Definition: component function to move along the indicated path	Parent Class: roso:Actuation
Navigation (navigation)	Definition: component function to navigate another agent to the indicated goal point	Parent Class: roso:Actuation
SoundDetection (sound detection)	Definition: component function to count the number of sound sources detected in the detection region	Parent Class: roso:Sensing
SoundLocalization (sound localization)	Definition: component function to localize positions of sound sources detected in the detection region	Parent Class: roso:Sensing
SpeechRecognition (speech recognition)	Definition: component function to recognize speech sound to text	Parent Class: roso:Sensing
SpeecSynthesis (speech synthesis)	Definition: component function to synthesize speech sound from text	Parent Class: roso:Actuation
PersonDetection (person detection)	Definition: component function to count the number of persons detected in the detection region	Parent Class: roso:Sensing

PersoIdentification (person identification)	Definition: component function to identify persons detected in the detection region	Parent Class: roso:Sensing
PersonLocalization (person localization)	Definition: component function to localize positions of persons detected in the detection region	Parent Class: roso:Sensing
Reaction (reaction)	Definition: component function to perform motions to interact with other agents	Parent Class: roso:Actuation

Annex B: RoIS Use Case Example

(informative)

B.1 Overview

Figure 11 shows an example of a robot scenario for a robotic reception service. In the RoIS development model, though the robot service developers choose appropriate robotic functional components to compose their robotic systems and services, there is no description of how they can choose such components suitable for their purpose.

In a closed environment, such as a flat 20m-by-20m square entrance lobby space, when a messenger robot finds a person in the environment, it then approaches the person. After identifying the person, the robot looks up if there are messages to the person, and then, if some messages are found, it tells the messages to the person.

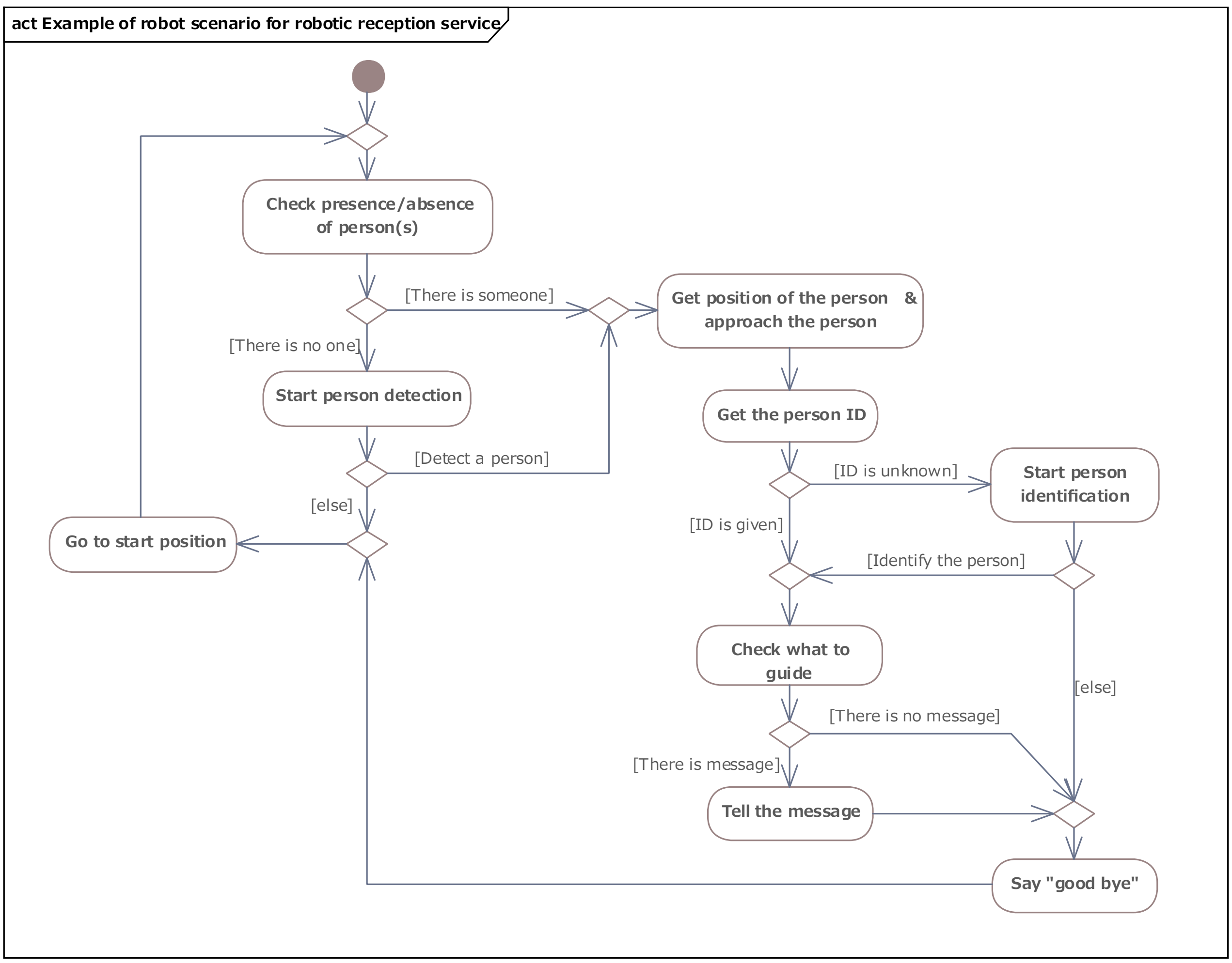

Figure 11 An example of Robotic Reception Service.

B.2 Description of Service Entities

Figure 12 illustrates an RDF graph of the example of robotic reception serivice described with RoSO/RoIS ontologies.

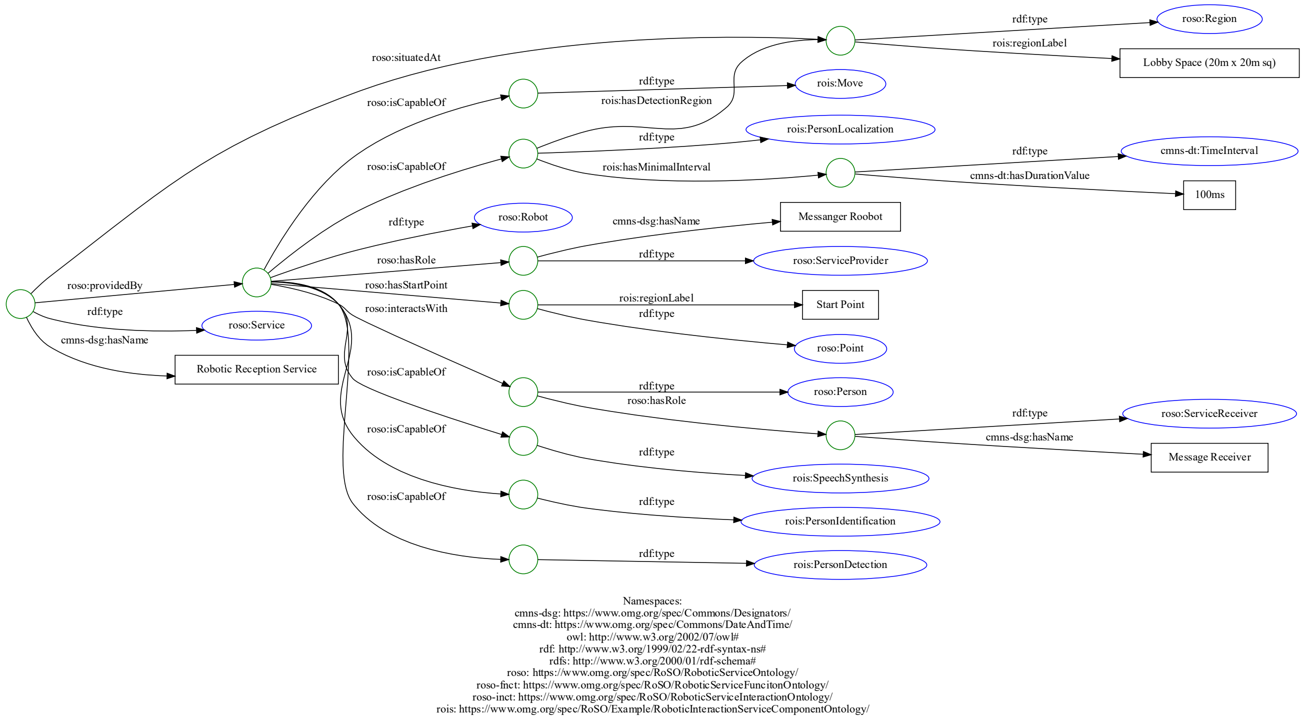

Figure 12 Description of Robotic Reception Service

Annex C: Cybernetic Avatar Service Use Case Example

(informative)

C.1 Product explanation at large stores

C.1.1 Overview

A store clerk remotely operates a semi-autonomous tele-operated robot (CA) to explain/recommend products to customers who come to the store. Regarding the location-fixed type CA, the CA is installed next to the product to be explained/recommended, and when the customer comes near the CA, the CA automatically plays the prepared explanation/recommendation contents. When a customer verbally asks a question to the CA, the question is transmitted to the clerk who is the tele-operator, and the clerk answers verbally or by selecting prepared answer contents with U/I. Regarding the movable type CA, in addition to the location-fixed type service, it will approach the customer to start the service, guide the customer to the location of the product.

C.1.2 Benefit

For the store clerk, since it is possible to respond without going to the site, it is not only possible to save the physical strength to stand all day for explanation and save travel time, and it is not necessary to be in the same store. It is possible to respond from other store or home. It will also be possible to provide services such as complying with the customer's national language from other country.

For customers, it is difficult to ask about products in stores with few store clerks or in stores where store clerks are busy. CA makes easier to ask about products. In addition, it is difficult to find what you want to ask from predetermined question items such as reading product advertisements or interactive digital signage, but with CA you can ask directly verbally, so stress is reduced.

Another advantage is that it can prevent infection such as COVID-19 for both clerks and customers.

C.1.3 Deployment Example

[Service from a location-fixed type CA]

A location-fixed type semi-autonomous tele-operated robot (CA) is installed on a shelf next to a product which is to be recommended to customers.

The CA is capable to find customers around the shelf by using a person detection component that can detect up to 10 persons in 150 cm from the CA.

The CA tries to connect to one of the CA's tele-operators when it detects customers within the range.

The CA is also capable to detect the position (direction and distance) of customers within the same detection range so that the CA can turn to the near-by customer (or a group of customers) before starting recommendation.

The CA is not capable of autonomous conversation that means it does not have any facility for speech recognition.

The CA is capable to transmit the customers speech (audio and video signal) to the tele-operator of the CA.

When a customer stops by the CA for more than 0.3 seconds (that requires the location of persons are to be updated 0.1 second frequency), the CA initiates interaction with the customer automatically just playing a pre-defined motion and speech. A reaction component and a speech synthesis component are required on the CA.

After the tele-operator clerk is ready connected, the CA receives commands for reaction and speech from the clerk.

If there aren’t any operators assigned, the CA plays pre-recorded recommendation without interacting with the customers.

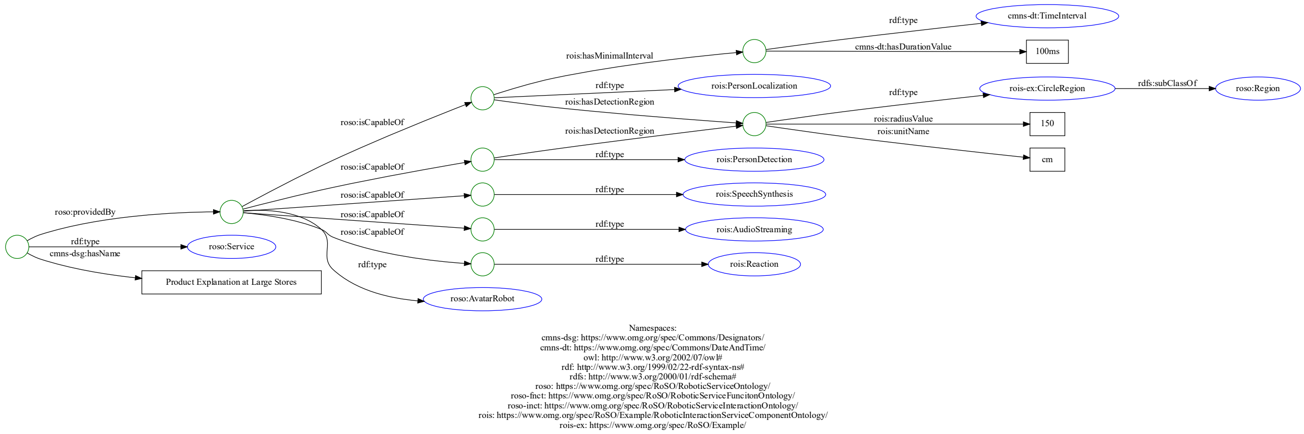

Figure 13 Cyberneic Avatar Shopping Service.

C.2 Reception at a company entrance

C.2.1 Overview

Receptionist remotely controls a semi-autonomous tele-operated robot (CA) to give reception guidance to customers who come to the company entrance. Regarding the location-fixed type CA, the CA is installed at the company entrance, and when a customer comes near the CA, the CA automatically reproduces a pre-prepared standard greeting. When a customer verbally asks a question to the CA, the question is transmitted to the receptionist of the tele-operator, and the receptionist answers verbally or by selecting the answer content prepared in advance with the U/I. Regarding the movable type CA, in addition to the installation type service, it will approach the customer to start the service, guide the customer to the meeting place or the place customer are looking for.

C.2.2 Benefit

For the receptionist, since it is possible to respond without going to the site, the stress of being exposed to crowds can be alleviated, travel time can be saved. It can be handled from home or even from overseas. It will also be possible to provide services complying with the customer's national language.

For customers, it is easier to ask questions in companies where CAs are located at reception entrances or where many mobile type CAs are in operation. Also, unlike interactive digital signage, it is difficult to search for what you want to ask from predetermined question items, but with CA you can ask directly verbally, so stress is alleviated.

Another advantage is that it can prevent infection such as COVID-19 for both receptionist and customers.

C.2.3 Deployment Example

The service from a movable-type CA is described here as an example though the service from a location-fixed CA is also available but similar to the previous example.

[Service from a movable-type CA]

A movable-type semi-autonomous tele-operated robot (CA) is put near a receptionist desk at the entrance of the company which is to be greeted and guided to visitors.

The CA is capable to find visitors around the receptionist desk by using a person detection component that can detect up to 10 persons in 150 cm from the CA.

The CA tries to connect to one of the CA's tele-operators when it detects visitors within the range.

The CA is also capable to detect the position (direction and distance) of visitors within the same detection range so that the CA can move to the near-by visitor (or a group of visitors) before start greeting or guiding.

The CA is not capable of autonomous conversation that means it does not have any facility for speech recognition.

The CA is capable to transmit the visitors speech (audio and video signal) to the tele-operator of the CA.

When a visitor stops by the CA for more than 0.3 seconds (that requires the location of persons are to be updated 0.1 second frequency), the CA initiates interaction with the visitor automatically just playing a pre-defined motion and speech. A reaction component and a speech synthesis component are required on the CA.

After the tele-operator receptionist is ready connected, the CA receives commands for reaction and speech from the operator.

If there aren't any operators assigned, the CA plays pre-recorded greeting or guiding without interacting with the visitors.

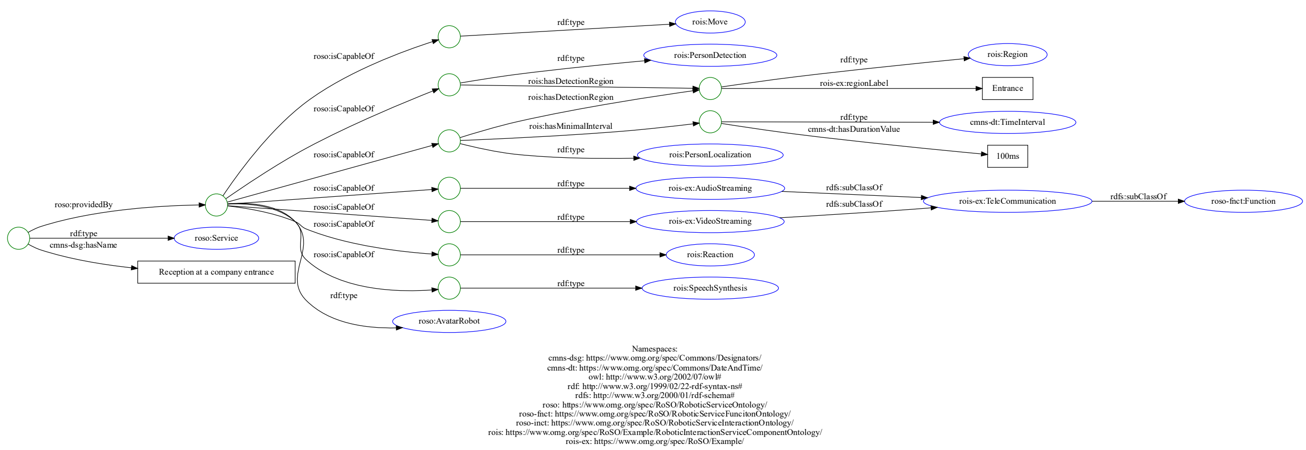

Figure 14 Cybernetic Avatar Reception Service.

C.3 Take a lesson in a class room

C.3.1 Overview

It is a service that allows students who cannot attend school for some reason to remotely operate a semi-autonomous tele-operated robot (CA) to participate in classes at school from home. A student who is a remote operator can check the surroundings with video and audio through the CA. Student can also verbally speak through CA. Regarding the location-fixed type CA, install the CA on the student's desk in the classroom. Recognize the behavior of teachers and other students through CA, and participate in lessons with other students in the classroom. Regarding the movable-type CA, they can move around the school, participate in classes in other classrooms, and chat with other students during breaks.

C.3.2 Benefit

If a student cannot attend school due to a physical disability, CA allows them to continue their studies at school. Many cases have been reported in which, for those who cannot attend school due to a mental disorder such as autism spectrum disorder (ASD), the use of CA reduces the stress of communicating with others or enables them to communicate with others.

For students who attend school as usual, communication with students who cannot come to school can be continued using CA.

Teachers will no longer need to provide special classes for students who cannot come to school.

C.3.3 Deployment Example

The service from a location-fixed CA is described here as an example though the service from a movable-type CA is also available but similar to each other.

[Service from a location-fixed CA]

A location-fixed type semi-autonomous tele-operated robot (CA) is put in a classroom at school which represents a student who is learning from home.

The CA is capable to pay and represent attention to the teachers and students who are talking to the CA by using a sound localization component that can detect sounds direction from the CA and a reaction component so that the CA can turn to the near-by students or teachers (or a group of students, or a group of teachers) while learning in the classroom.

The CA is capable to transmit the student speech (audio and video signal) to the tele-operating student.

The CA is not capable of autonomous conversation that means it does not have any facility for speech recognition.

The CA is capable to synthesize speech voice for students who may not want to represent their own voice.

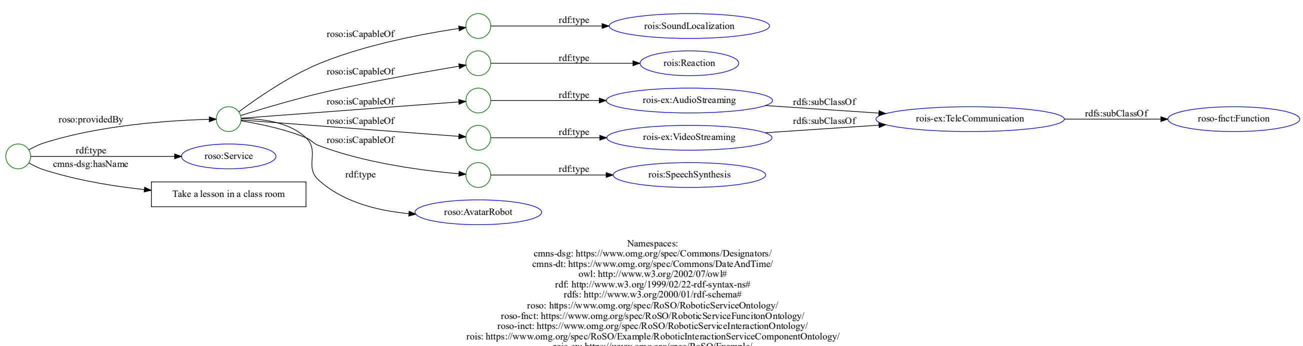

Figure 15 Cybernetic Avatar Class Room Service.

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