

# Ontologies' definition for modeling the cabin comfort on cruise ships

D. Spoladore<sup>a,1</sup>, S. Arlati<sup>a,2</sup>, M. Nolich<sup>b,3</sup>, S. Carciotti<sup>b,4</sup>, A. Rinaldi<sup>b,5</sup>,  
D. Celotti<sup>c,6</sup>, and P. Guglia<sup>c,7</sup>

<sup>a</sup>*CNR-ITIA, Italy*

<sup>b</sup>*University of Trieste, Italy*

<sup>c</sup>*Fincantieri, Trieste, Italy*

**Abstract.** The evolution of sea cruiser research considers the possibility to provide more comfortable cabins to the passengers. This goal can be achieved by providing the sea cruiser with the possibility to acquire, manage, and reason over data deriving from the cabin environment, its passengers, and their activities. A promising approach to deal with the information belonging to these domains is represented by Semantic Web technologies, in particular the exploitation of ontologies. The use of these technologies can provide, from the one hand, a sound model of the comfort metrics to be enforced inside the cabin, while on the other hand it leverages the exploitation of reasoning processes in order to adjust comfort metrics to passengers' desires. This work describes a set of domain ontologies developed to address these purposes; starting from a motivating scenario, the paper illustrates how domain knowledge can be modelled to take into account the passenger's desires, limits and activities in relation to the comfort metrics provided by the cabin. Furthermore, the work provides some examples on how reasoning processes can infer new knowledge and provide changes in the cabin environment.

**Keywords.** Ontology, comfort, cabin, passengers, cruise ship.

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<sup>1</sup> Daniele Spoladore, Institute of Industrial Technologies and Automation (ITIA), Italian National Research Council, via Gaetano Prevati 1E, 23900, Lecco, Italy; E-mail: daniele.spoladore@itia.cnr.it.

<sup>2</sup> Sara Arlati, Institute of Industrial Technologies and Automation (ITIA), Italian National Research Council, via Gaetano Prevati 1E, 23900, Lecco, Italy; E-mail: sara.arlati@itia.cnr.it.

<sup>3</sup> Massimiliano Nolich, Department of Engineering and Architecture, via Alfonso Valerio 6/3 - 34127 Trieste, Italy; E-mail: mnolich@units.it.

<sup>4</sup> Sara Carciotti, Department of Engineering and Architecture, via Alfonso Valerio 6/3 - 34127 Trieste, Italy; E-mail: scarciotti@units.it.

<sup>5</sup> Alessandro Rinaldi, Department of Engineering and Architecture, via Alfonso Valerio 6/3 - 34127 Trieste, Italy; E-mail: alessandro.rinaldi@units.it.

<sup>6</sup> Daniel Celotti, Fincantieri, Trieste, Italy

<sup>7</sup> Paolo Guglia, Fincantieri, Trieste, Italy

## 1. Introduction

The evolution of sea cruisers' research considers the possibility to provide more comfortable cabins to the passengers. This goal can be achieved allowing the sea cruiser to acquire, manage and reason over data deriving from the cabin environment, its passengers and their activities. Although these domains of knowledge deal with heterogeneous data, they all cooperate toward the definition of comfort model. A promising approach to manage the information belonging to different domains is represented by Semantic Web technologies, and, in particular it can encompass the exploitation of ontologies. An ontology is a shared and explicit conceptualization of the knowledge and of the relationships of the concepts composing a domain [1] and it can be used to provide a formal representation of pieces of information and data relevant for a domain. Ontology development leverages the use of W3C-endorsed formalization languages, such as Resource Description Framework (RDF) [2] Ontology Web Language (OWL) [3] and Semantic Web Rule Language (SWRL) [4]. In addition, knowledge formalization using ontologies allows the discovery of new pieces of information through reasoning process, thus enriching the knowledge base with new derived facts. This feature is particularly interesting to trigger the adjustment of comfort metrics according to environmental conditions, passengers' needs and desires, and special circumstances. Therefore, the use of these technologies can provide, from the one hand, a sound model of the passengers' needs, cabin spaces and comfort metrics to be enforced inside the cruise's cabin, while on the other hand it leverages reasoning processes to adjust comfort metrics according to the passenger needs.

This work describes a set of domain ontologies developed to address these purposes; starting from the motivating scenario, the paper illustrates how domain knowledge can be modelled to take into account the passenger's desires, limits and activities in relation to the comfort metrics provided by the cabin. Furthermore, the work provides some examples on how reasoning processes can infer new knowledge and trigger comfort-related changes in the cabin environment.

The remainder of this paper is organized as follow: Section 2 surveys the existing works in the fields of semantic modelling for comfort. Section 3 introduces the motivating scenario and the implied knowledge domains. Section 4 focuses on the description of the set of domain ontologies, while Section 5 illustrates salient examples of the reasoning process.

## 2. Related works

Research on comfort has acquired a growing importance in the last decade with the spreading of Context-Aware (CA) systems and Ambient Intelligence (AmI). Although semantic formalization of the knowledge with ontologies has been exploited in several works, only few of these tackled the issue of modelling comfort metrics. Tila et al. [5] described an indoor environmental comfort system taking advantage of a context ontology, in which concepts for the description of sensors and actuators were modelled with RDF. In [6], ontology is used as a decision support system to improve quality of some comfort metrics (temperature, humidity and CO<sub>2</sub> concentration) in indoor environments; reasoning processes leverage on data acquired by sensors to suggest the actions that could improve the quality of one or more comfort metrics in the environment. Adeleke et al. [7] proposed an ontology for indoor air quality monitoring

and control, formalizing some of the knowledge of the standard ISO 7730:2005. Stavropoulos et al. [8] developed an ontology for smart building and AmI, mainly focusing on services, hardware energy management, and some concepts regarding the context. Similarly, in [9] the authors developed an ontology to represent the whole smart-home ecosystem, thus encompassing some comfort-related concepts. Finally, in [10] the authors relied on ontologies to provide a description of the inhabitants, comfort metric (luminance, CO<sub>2</sub> concentration, temperature and humidity rate) and the services provided by a smart-home.

### **3. Motivating scenario**

In order to describe how the various actors intervening in a cabin can interact, motivating scenarios were developed with the support of domain experts – such as ship owner, cruise providers, context-awareness experts. In this work, a representative scenario is reported with the aim of underlining the interactions among: the passenger, his/her specific needs, comfort metrics and adaptive logics.

In the scenario, a passenger afflicted by a mild light sensitivity impairment (John) leaves his cabin to meet a friend; when he comes back to his cabin, the cabin system sets back the comfort metrics as they were before the inhabitant left. Once back, John decides to read: he selects on an ad-hoc application the type of reading he wants to dedicate to (relax, study or work) and the type of reading support (tablet, laptop, book or newspaper). John also selects the position inside the cabin where he wants to read: he selects the bed. The cabin system, aware of John's impairment, adapts the comfort metrics according to his need, his activity and his the position. The lightning (illuminance, light tone, light direction, flash blindness) and the thermo-hygrometric metrics (humidity rate, temperature, air flow rate) are automatically set as soon as the passenger declares to start the activity via the application.

The scenario requires a cabin environment equipped with environmental sensors (luminance sensors, thermos-hygrometric sensors), devices for detecting the passenger's presence in the cabin, and an application acting as an interface and allowing the passenger to input data in the system. The scenario was formalized with Unified Modelling Language [11] and the output of this formalization was exploited to produce the Ontology Requirements Specification Document [11], which allows to specify the domains of interest that need to be modeled into the ontology and facilitates the reuse of already existing knowledge bases.

### **4. Ontology description**

The motivating scenario highlights the domains of knowledge that need to be formalized into a set of ontologies. The cornerstone of the scenario is the cabin, in which the passenger performs some activities and expects comfort metrics to adapt accordingly. All these features need to be represented into specific domain ontologies, each formalizing specific aspects: the passenger, the comfort metrics involved in a cabin, the cabin, and the activities a passenger can perform inside a cabin.

#### 4.1. Passengers and their health condition module

The module describing the passenger needs to account for his/her Registry Records and can also be used to determine relationships among passengers – whether a passenger is travelling with his/her partner, friend and/or children. In order to provide tailored services to its passengers, a cabin should be “aware” of their health conditions, so that the services it provides can adapt. This information can be modeled resorting to the International Classification of Functioning, Disability and Health (ICF) [13]; it conceptualizes the functioning of an individual and has already been proved to be a promising tool to describe health-related data [14]; moreover, ICF is also provided in the form of a standard ontology [15]. The classification is organized in four components: *Body functions (b)*, *Body structures (s)*, *Activities and participation (d)*, *Environmental factors (e)*. Each component is further deepened into Chapters, which identify the addressed domain, and using components’ letter and adding digits (Fig. 1). The number of digits following the letter, indicates the level of granularity – up to five digits – of the code.

|  |  |
|--|--|
| <b>B2</b> «Sensory functions and pain» | Component and chapter – first level item |
| <b>B210</b> «Seeing functions»         | Second level item                        |
| <b>B2102</b> «Quality of vision»       | Third level item                         |
| <b>B21020</b> «Light sensitivity»      | Fourth level item                        |

Fig. 1. An example of ICF code.

The functioning or disability of an individual can be assessed selecting the suitable category and its corresponding code and then adding a qualifier (from 0-no impairment to 4-complete impairment). The result of this modeling process is, for each passenger, a set of properties specifying his/her Registry Records and – according to ICF – the limits and/or disabilities he/she has.

#### 4.2. Comfort module

This section presents thermo-hygrometric, luminous and acoustic comfort metrics for different activities performed by passengers inside the cabin unit.

The evaluation of the thermo-hygrometric, luminous and acoustic comfort inside the cabin is strictly related both to the constructive characteristics and to Heating, Ventilation and Air Conditioning (HVAC) system of the cabin-unit. Furthermore, these metrics are influenced by the actions that can be performed inside the cabin. In particular, according to the scenario depicted above, the comfort conditions inside the cabin can be evaluated by monitoring the following parameters: environmental parameters (temperature, relative humidity, illuminance, CO<sub>2</sub> level, indoor noise level); HVAC system status (on/off, set point temperature); opening/closing status of the window; lighting status (on/off) due to the various punctual and diffused lights; electrical equipment status (on/off). These data and reports constitute the input data, necessary to identify the actions to be carried out by a reasoner process in order to adjust comfort metrics to passengers’ desires (see Sect. 5).

#### 4.3. Activity in the cabin module

The ontology must also provide a description of the activities a passenger can perform inside the cabin. According to the scenario, “Reading” is an activity that can be performed in the cabin and that can be conditioned by comfort metrics. It is indeed an activity that can be further specified selecting the type of reading a passenger wants to perform, the position inside the cabin where he performs “Reading” and the type of media he chooses as a reading support. Considering the possibility to represent passengers with disabilities, some activities (such as “Reading”) can be mapped into the component *Activity and Participation* of the ICF of the Passenger Module. This module allows to provide some comfort-related parameters to each activity (see further Sect. 5); for instance, “Reading” is an activity with metabolic rate equal to 1,0 met (considering a seated and quiet position) and clothing insulation index equal to 0,5 (for light clothing) [16]. Therefore, each activity can also represent some comfort-related parameters that are essential to determine the behavior of the cabin’s comfort system.

#### 4.4. Cabin module

This section presents the cabins' characteristics and its furniture. The cabin structure is designed for optimizing the space by utilizing modular elements; however, a univocal structural classification does not exist. The ontology defines three openings types: entrance door, bathroom door, and the door that divide the indoor cabin area with the balcony.

The cabin has been divided in the following functional areas: entrance, bathroom, living area, sleeping area, balcony and corridor – which is not classified as a cabin area. Fig. 2 shows the five functional areas associated with different furniture and services. In particular, for the ontology's definition, worth the following:

- Living area: wardrobe, sofa, chair1, TV, make up desk, minibar;
- Sleeping area: bed 1, bed 2, bedside table 1, bedside table 2, curtain 1, curtain 2 and TEL;
- Balcony: chair 2, table.

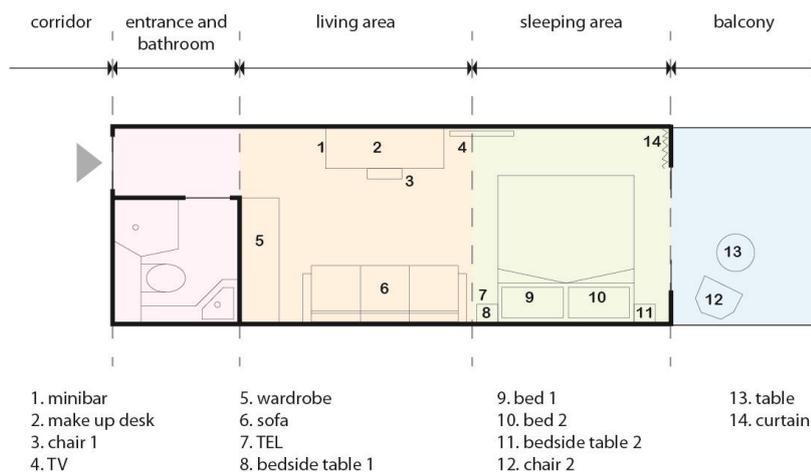
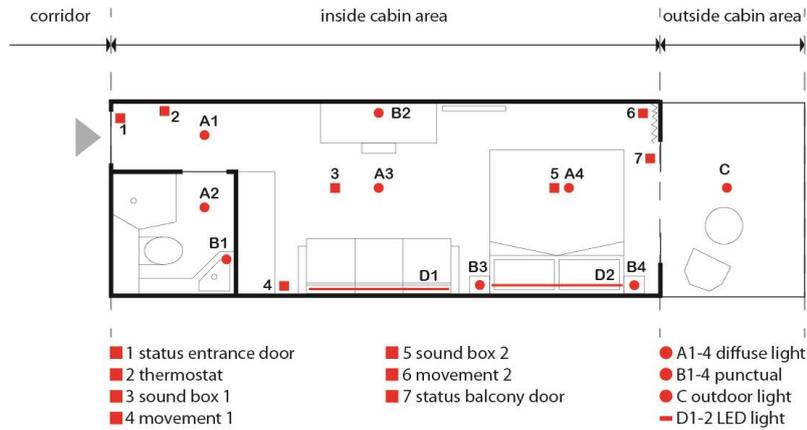


Fig. 2. Functional areas associated with furniture and services.



**Fig. 3.** Devices' position in the cabin.

#### 4.5. Device module

The ontology has to provide a representation of devices associated to the cabin. The devices have the following properties: subclass (environmental, energy consumption, physiological), type (sensor, actuator, sensor – actuator), dimension (temperature, humidity, brightness, color, movement, beat, etc.), and units (degrees Celsius, % Relative Humidity, lux, etc.). Furthermore, for each device the ID, the date-time value and the measurement values are also identified. The selected devices are the following: a presence sensor; two Thermostats (internal and external) with the relative actuators to (de)activate devices of the HVAC system; date and time device; two Infrared motion devices (movement 1 and movement 2); a sensor for environmental parameters monitoring humidity, CO<sub>2</sub> concentration, noise; sensors for detecting the status of doors/windows (entrance and balcony); a luminance sensor; a microphone and two loudspeakers (sound box 1 and sound box 2); a webcam; lights.

### 5. Example of use of the proposed ontology

The information modelled in the ontology and the rules can be fed to a reasoner to infer new pieces of knowledge; for this ontology, the Pellet reasoner [17] was chosen for its ability to process SWRL rules. With reference to the motivating scenario, the whole cabin system can be aware of John's presence inside the stateroom and of his impairment, (ICF code b21020). When John leaves the cabin, the cabin detects the passenger's absence and deactivates the HVAC system, turns the light off and closes the window (if opened). Once John decides to get back to the cabin, he taps the proper option in the application on his smartphone; the system then begins the activities to reinstate all the comfort conditions of the cabin according to the moment the passenger left the cabin. Once he's back, John decides to perform the "Reading" activity, which may be compromised by John's mild visive impairment. Aware of the kind of impairment of the passenger, the position where John wants to read (on the bed) and the type and support of reading (leisure, book), the system calculates the suitable

luminous intensity also taking into account the natural daylight coming from the external environment. The system firstly acquires the measurement of illuminance coming from the window, then the measurement of indoor luminance in the bed position. These two data are combined and then compared with the minimum visive comfort requirement of 500 lux (according to UNI 12464-1) for reading activities. Considering John's light impairment, the minimum requirement value is reduced of 30% (350 lux) [20]; the lamps near the bed area then are set by the system to contribute to reach the amount of 350 lux in the reading area, if necessary.

The same logic can be applied to the other comfort metrics (indoor temperature, CO<sub>2</sub> level, relative humidity level); if any of them is not in the comfort ranges defined by the standard Fanger's theory [18] and the "Guide for Passenger Comfort on Ships" [19], the system automatically activates remedial actions. The system can also acquire and elaborate passenger's feedback for each comfort metric (measured according to a Likert scale from "1=very comfortable" to "7=totally uncomfortable"); if a metric is judged as partially or completely uncomfortable, the cabin system intervenes by asking the passenger if the comfort metrics need to be increased or decreased. Uncomfortable comfort metric's values are then modified to meet the passenger request.

## **6. Conclusions**

This paper describes the ontology definitions for an ontology-based context-aware system able to provide sea-cruiser' passengers with customized comfort metrics. Leveraging on the ontological approach, the system can be used as a tool to adjust comfort for impaired passengers. A motivating scenario guides the identification of the domains of knowledge involved, which are modelled into domain ontologies regarding the passenger and his/her health condition, the cabin, the devices deployed in the cabin and the comfort metrics. An example of reasoning is then proposed, illustrating the possibility to infer new knowledge and to adapt the cabin environment to the passenger's needs and desires. Future works foresees a refinement phase for the developed domain ontologies and validation of the whole framework in a real sea-cruiser's cabin.

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