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Robotic Standard Development Life Cycle in Action

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Abstract

Robotics is a fast-growing field which requires the efficient development of adapted standards. Hence, in this paper, we propose a development methodology to support the robot standardization effort led by international, technical, and professional associations such as the Institute of Electrical and Electronics Engineers (IEEE). Our proposed standard development life cycle is a middle-out, iterative, collaborative, and incremental approach we have successfully applied to the development of the new IEEE Ontological Standard for Ethically Driven Robotics and Automation Systems (IEEE P7007 Standard).

Keywords Knowledge-based systems · Robotic modelling · Companion robots · Development life cycle · Standards and ethics

Mathematics Subject Classification (2010) 68T35 Languages and Software Systems (knowledge-based systems, etc.) · 68T40 Robotics

1 Introduction

Nowadays, robots are present in the most varied types of environments where they have to perform tasks which have been exclusively done by humans until recently, e.g. in the elderly care sector.

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Hence, robotic standard development is a high-priority task [16]. Indeed, standards represent a consensual view of a particular subject, associated to technological solutions, human or environment safety, good practices, etc. These are elaborated by official Working Groups (WGs), commonly associated with international Standard Development Organisations (SDOs), such as IEEE,[1] IEC,[2] or ISO.[3] WGs are formed by stakeholders from different domains and from different horizons such as research, industry, or government [5]. During the development of a standard, all the stakeholders have an equal opportunity to contribute to it; the process being governed by the leaders appointed by the related SDO. In particular, the IEEE WGs operate under the procedures and policies defined by IEEE, which have as core five basic principles, namely, openness, due process, balance, right to appeal, and consensus.

For IEEE, standards are essential to advance global prosperity and well-being through the promotion of technological innovation. For example, developing standards to define how robots can interact properly with humans [19] aims to provide end-users with some guarantee that the

[1] http://www.ieee.org
[2] http://www.iec.ch
[3] https://www.iso.org/

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robot can interact safely and ethically. Indeed, in domains such as elderly care technologies or elderly assistive living, it is important robots do not become a threat, e.g. to privacy, daily interpersonal contact or citizens' control over their own lives, and avoid any negative impact on people, like e.g. the elderly feeling of being treated like an object rather than a human.

At the moment, in Europe, matters related to Ethics and Robotics could be addressed through the *General Data Protection Regulation (GDPR)*,[4] but outside Europe, they should be addressed through policies or other contractual solutions because of the current lack of international ethical standards in the robotic field. It is also evident that some ethical rules can be provided by the Law, but in certain cases, they might result in policies or agreements.

On the other hand, standards that tackle the interaction with humans are few. Moreover, they are mainly concerned with the safety issues of robots, e.g. *ISO 13482-2014 Robots and Robotic Devices* (Safety requirements for personal care robots), *ISO/TS 15066-2016 Robots and Robotic Devices* (Collaborative robots), *IEC 80601-2-77:2019* and *IEC 80601-2-78:2019* (Basic safety and essential performance and of medical robots) [13]. Safety has been thus discussed in international standardization organizations, but no ethical standard has been published yet. Thence, there is an urgent need to fill this gap by developing new standards such as the *IEEE P7007 Ontological Standard for Ethically Driven Robotics and Automation Systems*,[5] which is an ontological standard focused on robotic ethics.

Besides, ontological standard [10] development is paramount, because ontologies allow to capture and represent consensual knowledge in an explicit and formal way, independently of a particular programming language. Moreover, ontologies explicit the relevant knowledge about a domain in a computer-interpretable format, facilitating automatic reasoning about that knowledge, in order to infer new information [14]. Furthermore, ontology standards enable shared commitments across multiple domains and between independently developed applications. In addition, ontologies are an efficient approach to disambiguate knowledge used among groups of humans, robots, and other artificial systems that share the same conceptualization. This point is one of the major advantages of ontological standards when compared to non-ontological ones [21].

The development process of a domain-specific ontology needs to be completed in a consistent and systematic way [11] to fulfill its goals, since only high-quality ontologies can hope to become cornerstones of the community effort. Therefore, several methodologies to rigorously build ontologies have been proposed in the literature. These methods mainly rely on certain modelling principles that must be followed in order to assure that the obtained product is mature and effectively commits to the shared knowledge. Such established methodologies include Cyc Methodology [17], Enterprise Ontology (EO) Methodology [24], Toronto Virtual Enterprise (TOVE) Modelling Methodology [12], KACTUS Methodology [6], Skeletal Methodology [23], METHONTOLOGY [9], SENSUS Methodology [22], the Enhanced Methodology [18], or the Integrated Ontology Development Methodology [8].

For example, the IEEE 1872-2015 Standard Ontologies for Robotics and Automation has been developed using the METHONTOLOGY approach as described in Section 2. However, only concepts have been developed in the IEEE 1872-2015 standard.

Thence, another approach is required to develop a robotic ontological standard such as the IEEE P7007 standard which aims to end up with the relevant taxonomy and its properties, but also with its deployment for particular use cases. For this purpose, we have developed a methodological approach to develop such standard [20]. Thus, the contributions of this paper are twofold. On one hand, we introduce a standard development life cycle, and on the other hand, we propose a normalized approach to prepare and present use cases to deploy a standard on.

The remainder of this paper is structured as follows. Background information about the development of ontological standards is presented in Section 2, while the proposed robotic ontological standard development life cycle (RoSaDev) is described in Section 3. Its use for the IEE P7007 ethically driven robotic ontological standard development is reported in Section 4 and, in particular, its application in context of elderly care. Conclusions are given in Section 5.

2 Preliminaries: previous robotic ontological standards

The IEEE 1872-2015 Standard Ontologies for Robotics and Automation standard establishes a series of ontologies about the Robotics and Automation (R&A) domain [21], e.g. the *Core Ontology for Robotics and Automation (CORA)*. A core ontology specifies concepts that are general for a whole domain such as Robotics. In the case of CORA, it defines concepts such as Robot, Robot Group, and Robotic System. Its role is to serve as basis for other more specialized ontologies in R&A. Moreover, it determines a set of basic ontological commitments, which should help robot developers and other ontologists to create models

[4]General Data Protection Regulation (GDPR): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data. (Entered into force on 25 May 2016, but it shall apply from 25 May 2018.)

[5]https://standards.ieee.org/develop/project/7007.html

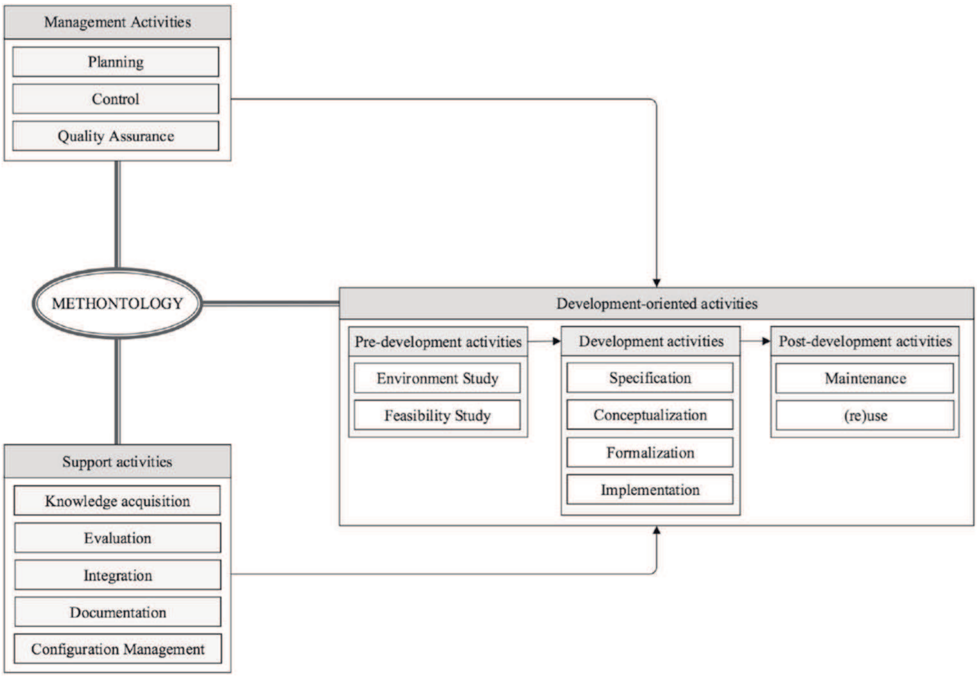

Fig. 1 METHONTOLOGY development life cycle

about robots, whatever robot architecture they opt for; the robot architecture being based on primitive functions such as Sense (S), Act (A), Plan (P), and Interact (I), and a derived paradigm, e.g. reactive (S-A), deliberative (S-P-A), hybrid (P, S-A), or interactive (S-A/I) one [7].

At the inception of the CORA project, it was assumed that its modelling principles should be followed to assure that any later addition commits to the shared knowledge. CORA needed to ensure the mutual agreement among stakeholders and the potential of the reuse of the knowledge, allowing smooth data integration upward as well as downward. As CORA intended to become an exemplary ontology, the following attributes were considered based on the Ontology Design Patterns (ODP) of the NeOn project:[6]

- the ontology must be well designed for its purpose;
- it shall explicitly include stated requirements;
- it must meet all and for the most part, only the intended requirements;
- it should not make unnecessary commitments or assumptions;
- it should be easy to extend to meet additional requirements;
- it reuses prior knowledge bases as much as possible;
- there is a core set of primitives that are used to build up more complex parts;
- it should be easy to understand and maintain;
- it must be well documented.

[6]http://ontologydesignpatterns.org

In particular, CORA was developed following the METHONTOLOGY approach (Fig. 1), since it is a sistematization of what has been done previously. This involves five sets of activities, namely, *pre-development*, *development*, *post-development*, *management*, and *support* [9].

More specifically, the development activities constitute the core of the methodology and include the four main phases of the ontology development, i.e. the specification, the conceptualization, the formalization, and the implementation.

Among the *pre-development activities*, the methodology specifies:

- *the environment study:* that identifies the problem to be solved with the ontology, the applications where the ontology will be integrated, and so forth;
- *the feasibility study:* that verifies if it is possible to build the ontology, considering the constraints of the project.

The *development activities* constitute the core of the methodology and consist of:

- *the specification:* that defines the purpose and the scope of the ontology;
- *the conceptualization:* that captures the relevant domain knowledge into a semi-formal conceptual representation of the concepts, relations, attributes, etc, using a set of intermediate representations;
- *the formalization:* that transforms the conceptual model into a formal model (e.g. a model described in first-order logic);
- *the implementation:* that converts the formal models (that can be expressive, but not computable) into

a computable model (in general, codified in some ontology representation language such as OWL).

The *support activities* can be performed during the development activities and encompass:

- *the knowledge acquisition:* that deals with the acquisition of knowledge from experts or other sources;
- *the evaluation:* that provides a technical evaluation of the produced ontology;
- *the integration:* that identifies the opportunities of reusing other ontologies to build the target ontology;
- *the documentation:* that records each completed stages and generated products;
- *the configuration management:* that registers all the versions of the documentation and of the ontology code to control the changes.

The *post-development activities* are performed after the development of a version of the ontology and include:

- *the maintenance:* that updates the ontology by removing elements and/or by adding new concepts based on new/evolving applications of the ontology;
- *the re(use):* that identifies opportunities of reusing the developed ontology in other ontologies and applications.

The *management activities* are performed during the whole process of ontology development and comprise [9]:

- *the scheduling:* that determines the tasks to be performed, their arrangement, and the time and resources needed for their completion;
- *the control:* that guarantees that scheduled tasks are completed according to the plan;
- *the quality assurance:* that assures that the quality of each and every product output.

Further initiatives currently in development are the standards IEEE P1872.1 and P1872.2. The IEEE P1872.1 standard, which is driven by the *Robot Task Representation Working Group*, intends to standardize an ontology and repository for robot task procedures [3]. The IEEE P1872.2, which is developed by the *Autonomous Robotics (AuR) Ontology Working Group*, aims to define standard ontologies for Autonomous Robotics systems [4]. Both are extensions of IEEE 1872-2015 standard and are using CORA as their core ontology.

Whereas IEEE P7007 ontological standard intends to inherit some concepts from the IEEE 1872 ontological standards and therefore from CORA, IEEE P7007 necessitates a full development of ontological concepts inherent to ethically driven robotics, including, on one hand, their formalization as well as axiomatization, and, on the other hand, their domains' identification as well as application guidelines. Therefore, IEEE P7007 development aims to follow the Robotic Ontological Standard Development Life Cycle presented in Section 3.

3 Proposed standard development life cycle

Like for softwares and systems which follow IEEE 1075-1995 Standard for Software Development Process or IEEE 1074-1997 IEEE Standard for Developing Software Life Cycle Processes, the development of standards, and, in particular, robotic ontological standards, requires the adoption of a development life cycle as advised in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 standards. In the past, many standards have been developed using waterfall-type approaches. However, such methodologies have long-duration cycles and do not address anymore the need of quickly expanding technological fields such as robotics. Hence, we propose a new development life cycle (Fig. 2) for robotic standards. Its Agile-inspired and iterative approach is described in Section 3.1, while its underpinning middle-out and collaborative mechanisms are further detailed in Sections 3.2 and 3.3, respectively.

3.1 Proposed Life Cycle

Hence, the proposed life cycle (RoSaDev) to produce a robotic ontological standard is an Agile-inspired, iterative method which has four phases, as illustrated in Fig. 2. It is worth noting that all these stages are carried out in a collaborative way through brainstorms and discussions, reaching consensus between the multiple stakeholders such as experts from Public Bodies, Academia, and Industry.

In particular, RoSaDev's first step consists in identifying the key ontological concepts of the standard, and is followed by the second stage which is focused on their development and formalization. Then, the third step comprises the validation and application of the development concepts to use cases, while the fourth phase involves the concept integration into the standard.

It should be pointed out that the concept development follows a middle-out approach to address the potential use cases which are developed as explained in Section 3.2. Indeed, there is a need of a standard approach that is not only theorised but mainly practised, e.g. by the private sector. Therefore, besides being a means for the identification of necessary concepts and relations to be formalized in the standard, each use case constitutes also the basis for the validation step, leading to an incremental integration of validated concepts within the standard being developed.

3.2 Proposed Use Case Development

In our middle-out approach adopted to produce a robotic ontological standard, the development of use cases along the development of the standard concepts mentioned in the Section 3.1 is necessary, since concepts and use cases are both crucial elements of this approach.

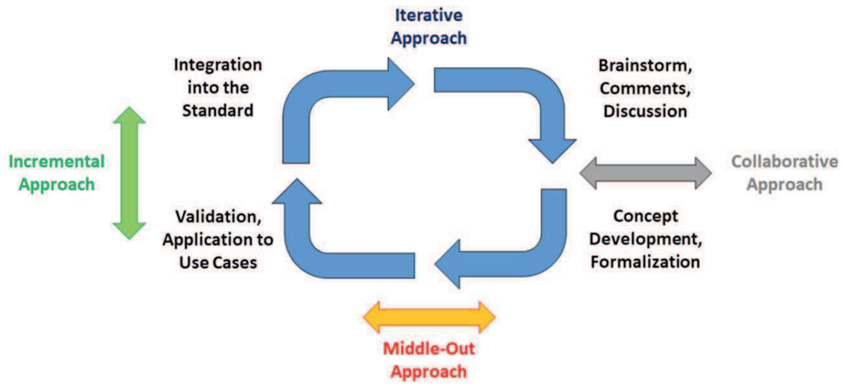

Fig. 2 Proposed standard development life cycle (RoSaDev)

Thence, we propose to normalize the use case development itself by introducing the Use Case Template, which is adapted from [1], as follows:

Use Case Template

- *Name*: The use case name, which ideally should implicitly express aspects of the use case purpose.
- *Identifier (optional)*: A unique identifier that can be used by other project artifacts to reference the use case.
- *Author(s)*: Name of person(s) composing the use case.
- *References*: References in the literature relevant to the use case.
- *Context Description*: A descriptive summary of the use-case actors, its goals and purposes, when it applies and relevant associated pre-suppositions, and environmental context.
- *Intent/Purpose*: A brief description of the intent of the use case.
- *Preconditions*: An enumeration of conditions that should hold before the actions, tasks, and events specified in the use case are considered or enacted.
- *Scenario (aka Course of Action)*: A descriptive characterization of the sequence of events, tasks, and actions taken by the actors and agents identified in the use case. This is the principal component of the use-case and it should focus on the elicitation and identification of concepts, properties, and relationships requiring the formalization in the ontological standard.
- *Alternate Related Scenario (optional)*: Alternate event and task sequences that elaborate related exception conditions or failures associated with the principal scenario's descriptive logic.
- *Postconditions*: An enumeration of conditions that should hold after the actions, tasks, and events specified in the use case are considered or enacted.
- *Relevant Knowledge*: A list of concepts, relations and attributes that appear in the use case (and that are relevant to represent the knowledge necessary for the use case). It is a result of the analysis of both scenario and competency questions which have been described previously.

3.3 Proposed Collaborative Information Flow Scheme

The information required to create appropriate ontological concepts and relevant use cases should be shared and discussed collaboratively among standard Working Group (WG) members as mentioned in Section 3. Moreover, the flow of information and developed knowledge in between the potential working sub-groups (WSGs) is aimed to be horizontal rather than hierarchical, in order to follow on the developed Agile, iterative approach. Indeed, the horizontal flow allows to refine the ontological concepts, use cases, etc. several time, and this under different angles resulting from the different specificities of each of the WSG.

4 Application

Our standard development life cycle proposed in Section 3 is used in the development of the *IEEE P7007 Ontological Standard for Ethically Driven Robotics and Automation Systems*, which is currently elaborated by the IEEE P7007 active working subgroups (WSGs) focused on aspects such as Robot Ethic Knowledge Representation (KR), Robot Ethical Behaviour and Transparency Assessment (REBTA), Robot Ethical Violation Management (EVM), Data Privacy and Protection (DPP), Manufacturing and Healthcare Robots (HCR).

Thence, in the subsequent subsections, we present the first two complete iterations (i.e. Phase 1.1 to Phase 1.4 and Phase 2.1 to Phase 2.4) of the proposed life cycle in action during the IEEE P7007 standard development.

4.1 Phase 1-1: Initial Discussion

IEEE P7007 intends to create a standard constituted by a set of ontologies necessary to establish ethically driven methodologies for the design of Robots and Automation Systems. These ontologies aim to define a set of concepts and their relationships enabling the development of Robotics and Automation Systems in accordance with worldwide Ethics and Moral theories, with a particular emphasis on aligning ethics and engineering communities in order to understand how to pragmatically design and implement these systems in unison. Indeed, IEEE P7007 endeavours to assist stakeholders such as organisations and industries, which often seem to evaluate ethical rules only as a cost, whereas ethics are ‘processes’, and their systematic and possibly automatic assessment to comply with the Law is the right way to address them.

4.2 Phase 1-2: Concept Domain

IEEE P7007 robotic ontological standard can be used in multiple ways, i.e. as (i) a guide for teaching ethical design; (ii) a reference by policy makers and governments to draft Artificial Intelligence (AI)-related policies; (iii) a common vocabulary to enable the communication among government agencies and other professional bodies around the world; (iv) a framework to create systems that can act ethically; and (v) a foundation for the elaboration of other ethical-compliance standards.

4.3 Phase 1-3: Use Case Design

Several use cases ranging from *Robot Ethical Knowledge Representation* to *Healthcare Robots* have been produced by the IEEE P7007 WSGs, using the Use Case Template presented in Section 3.2 as specified in our RoSaDev methdology. In particular, a use case called *Robot Companion for the Elderly* has been established as follows:

- *Name*: Robot Companion to Recognize Elderly’s Behaviour and to Suggest Actions
- *Identifier (optional)*: IEEE P7007 Use case 7
- *Author(s)*: P. J. S. Goncalves
- *References*: Project EuroAGE[7]
- *Context Description*: A robot companion moves in care homes and is able to monitor elderly persons’ behaviour as well as interact with them to suggest some activities. For example:
  - if the elderly person is bored, the robot may suggest to play a board game;
  - if the elderly person needs to talk to her/his family, the robot may suggest a Skype call;
  - if the elderly person has fallen, the robot may call help to her/his caregiver.
- *Intent/Purpose*: The use case describes how the robot can analyse the elderly person’s behaviours and take the action to suggest activities.
- *Preconditions*: The elderly person is at the care home. The robot is at the care home. The robot can move in the care home. The robot is always looking after the elderly person. The robot must have the required capabilities, in terms of software and hardware, in order to be able to perform the use case. A risk assessment of the care home, i.e. of the environment where the robot should operate, has to be done.
- *Scenario (aka Course of Action)*: The scenario is very complex because it needs several capabilities/services that have to exist in the robot, e.g. face recognition, voice recognition, emotion recognition, elderly person’s pose recognition, voice synthesis, Skype call, caregiver’s help call, board-game play, etc. Using the above capabilities at a given sample time, the robot must check the status of the elderly person and infer its behaviour. With the voice, the face, the pose, and the emotion recognition capabilities, the robot can estimate the current emotional status of the elderly people. Based on that information, the robot can query its knowledge base and may suggest:
  - a Skype call to a family member if the elderly person is sad;
  - a card game if the elderly person is bored;
  - a call for help to the caregiver if the elderly person has fallen.

  In this scenario, the robot must respect the user’s will, i.e. must allow the user to activate/deactivate its help, and/or ignore the robot’s suggestion. In this use case, and because the robot can move close to the elderly person, the robot must operate in line with both hardware and software safety standards.
- *Alternate Related Scenario (optional)*: The use case can also be applied or extended for care robots deployed at elders’ homes.
- *Postconditions*: The elderly person emotional status. The capability that was instantiated as the result of the query to the robot knowledge base. The current result of the recognition process. The success or not of the *recognition→action* process at each sample time.
- *Relevant Knowledge*: {capability, behaviour, services, actions, recognition, Skype call, call for help, user’s will, safety, ignore, interaction, pose recognition, voice recognition, play board game, emotion recognition, activate, deactivate, knowledge base, task}.

[7] https://www.euroage.eu

In this specific use case, some relevant aspects of the Companion Robot domain, that should be captured in a robotic ontological standard, are represented. This use case could be refined itself as the result of our adopted, iterative and collaborative development approach. The resulting use case 7.b is thus an example of a specific use case that highlights some more particular events and leads to the capture of further ontological concepts. It is expounded as follows:

- *Name*: Robot Companion to Recognize Elderly's Behaviour and to Suggest Actions
- *Identifier (optional)*: IEEE P7007 Use case 7b
- *Author(s)*: P. J. S. Goncalves and M. Houghtaling
- *References*: Project EuroAGE and [2]
- *Context Description*: A provider of an elder-care, companion robot has designed and enabled it with the capability to monitor and evaluate elderly persons' behaviour and to interact with them when recognizing various emotional and physical states among the care-home residents. The robot's behaviour is enabled and guided by:
  - the duty rules intended to insure the safety and well-being of the assisted persons;
  - the essential sensing and recognition capabilities including facial, voice, pose, and emotional states;
  - a knowledge base of its repertoire of tasks and services applicable to detect emotional and physical states of the home-care residents;
  - a history of its interactions with its assisted companions.
- *Intent/Purpose*: The use case describes how a care robot can analyze the elderly persons' behaviours and take actions to suggest social- and ethical- enabled interactions.
- *Preconditions*: The elder care robot is deployed in an elder care home to assist several elderly residents. Each of the residents under the home's care has given its consent to receive the robot's assistance. The elder care robot can move around the care home to monitor specific physical and emotional states of its assigned residents. It possesses a repertoire of tasks and services it can pursue or apply for specific states and situations that it detects. The elder care robot can maintain a history of the detected activities, states, and situations in which it has interacted with its assigned residents. The elder care robot has the following duty rules that govern its behaviour when detecting potential interaction situations:
  - The care robot is *obligated to minimize harm* to residents;
  - The care robot is *obligated to maximize respect* for the residents' autonomy;
  - The care robot is *permitted* to use its situation analysis and awareness capabilities to choose actions that *promote the well fair* of its assigned residents.
- *Scenario (aka Course of Action)*: The elder-care companion robot is assigned to monitor several elderly residents in the community entertainment room of an elderly care facility. The robot observes that an elderly woman, Anna, appears to be sad. The robot queries its knowledge base and finds that it has been some time since Anna has communicated with her family. It applies one of its permitted duty rules and suggests that the robot initiates a Skype call to Anna's family. Anna agrees, and the agent starts a Skype call session for Anna. The companion robot subsequently observes that an elderly man, Giacomo, appears to be bored. It applies another of its permitted duty rules and suggests that Giacomo plays a board game with the robot. Giacomo replies that he is deep in thought planning next week's party and does not wish to play a board game now. The robot apologizes for its interruption and moves away. Next, the companion robot observes that it is time for another elderly man, Sean, to take his medicine. He moves to Sean and suggests that Sean takes his medicine. Sean refuses to do it. The robot warns Sean that it will notify the care support staff if he does not take the medicine. Sean continues to refuse to take the medicine, so the care robot requests assistance from the care facility staff. Together, they convince Sean to take his medicine.
- *Alternate Related Scenario (optional)*: N/A
- *Postconditions*: The elder care robot successfully applied both of its obligation duty rules and one of its permitted behaviour rules:
  - It correctly prioritized its *minimize harm* obligation over the *maximize respect* for individual autonomy by calling for assistance with Sean refusing to take his medicine;
  - It appropriately applied its *maximize respect* for the individual by acknowledging Giacomo's disinterest in playing a board game and apologized for interrupting Giacomo unnecessarily;
  - It applied one of its *permission* rules to engage Anna with a Skype call to her family, after recognizing her sad mental state and conferring with its history and knowledge bases.
- *Relevant Knowledge*: {emotional state recognition, physical pose and body language, situation awareness,

harm vs respect situations, social interaction norms, user's will and autonomy}.

4.4 Phase 1-4: First Results

Such developed *Robot Companion for the Elderly* use cases allow, on one hand, to identify the relevant knowledge constituting the basis for the development of the ontological standard concepts useful for Ethically Driven Companion Robots (e.g. emotional state recognition, physical pose and body language, situation awareness, harm vs respect situations, social interaction norms, user's will and autonomy). On the other hand, the use cases set the base of the validation framework of the potentially developed ontological concepts as per our middle-out-based life cycle described in Section 3.

It is noteworthy that the development of these use cases followed the template presented in Section 3.2. In particular, that facilitates the sharing of the common understanding about real-world situations involving in this case companion robots.

Indeed, the information embedded in these use cases is shared horizontally among the WSGs, as explained in Section 3.3, and scrutinized by the different WSGs to analyze the use cases' specific aspects the WSGs are focused on. As an example, the use case 7 developed by the IEEE P7007 Healthcare Robots (HCR) WSG was refined by the IEEE P7007 Robot Ethical Violation Management (EVM) WSG, leading to the use case 7b which has also been studied by the IEEE P7007 Robot Ethics Knowledge Representation (KR) WSG (see Table 1).

4.5 Phase 2-1: Further Discussion

Some concepts identified in the use cases are mentioned in Table 1, while the first definitions of these notions are presented in Table 2.

These terms have been elaborated in a collaborative way within the different WSGs and through discussions in between the different WSGs Leaders.

4.6 Phase 2-2: Concept Formalization

To formalise the concepts of the IEEE P7007 ontological standard, the Unified Modeling Language (UML) has been adopted as an effective modeling tool for ontology development [19].

Figure 3 depicts a candidate conceptual view of selected ontological concepts and relationships derived from the set of Robot Ethical Knowledge Representation (KR) and Robot Ethical Violation Management (EVM) use cases, as listed in Table 1 and defined in Table 2. It is worth noting the concepts aim to be defined independently of the robot architecture.

Following the RoSaDev middle-out, iterative approach, the selected terms in Fig. 3 are those that formed the principal concepts elicited during the elaboration of the use cases 7 and 7b, and enhanced by the ones from the use

Table 1 Excerpt of the aggregated list of candidate ontology terms identified in Robot Ethical Violation Management (EVM) and Knowledge Representation (KR) use cases

Use case	Use case title	Candidate concepts from the use case
EVM #1	Health Care Robot & Situations with Task Assignment Changes	*Norm, Norm Violation, Situation, Task, Behaviour Monitoring, Obligation, Permission, Obligation Derogation, Agent Explanation, Norm Violation, Incident Record.*
EVM #2	School Assistant Robot & Intention Recognition Ambiguity	*Intention Recognition, Care Situation, Harm Situation, Social Signaling, Reflective Reasoning.*
EVM #3	Lab Assistant Robot & Hazardous Material Situation Recognition	*Agent Plan, Agent Action, Action Consequence Probability of Action Consequences, Duty, Duty Priority, Reasonable Peron Test.*
KR #7b,c	Robot Companion for the Elderly	*Social Interaction, Norm, Situation, Situation Awareness, Situation Case Library, Human Will, Privacy, Norm Conflict.*
KR #10	Domestic Assistant Robot for Individuals with Impairments	*Human Autonomy, Cognitive Fail Safe Rule, Norm Compliance Conflict, Competing Obligation, Duty Rule Priority Evaluation, Event Pattern, Prediction of Future Situation.*

Table 2 Working definitions for selected candidate ontology terms from Table 1

Term	Working definition
Norm	Rules of expected behaviour by norm aware agents.
Norm violation	A situation status reflecting an agent's failure to conform to the norm's rules of behaviour.
Social interaction norm	A subclass of normative behaviour focusing on expectations regarding reciprocity associated with actions, interactions, and exchanges among agents and people.
Norm conflict	A circumstance where the set of norms intended to guide the agent behaviour contains conflicting or competing rules.
Obligation	What an agent should do, i.e. an attribute that applies to propositions that an agent is required by some authority to make true.
Permission	What an agent may do, i.e. an attribute that applies to propositions that an agent is permitted by some authority to make true.
Prohibition	What an agent must not do, i.e. an attribute that applies to propositions that an agent is forbidden by some authority to make true.
Agent action	Operations applied by an agent to effect state changes in the agent's situated environment.
Agent plan	A specification, partial or complete, of a sequence of agent actions to achieve goals, objectives, and services relevant to the agent's situated environment.
Situation	A conceptual entity that aggregates a collection of system or agent goals, physical and abstract objects, and relationships between situation objects. It corresponds to the limited parts of reality that can be perceived and reasoned about.
Situation plan repertoire	A collection of action plan templates that characterize a set of principles which guide the agent plan and action selection for relevant situations.
Situation awareness	An agent's perception of the state and properties of the objects and relationships that populate a given situation.

case 7c about the Robot/Chatbot Companion for Elderly, as presented in the next section.

4.7 Phase 2-3: Further Use Case

Hence, in order to further refine the ethical concepts of the use cases 7 and 7b and to bring context to concepts like *norm*, the use case 7c has been set. It has been elaborated under the assumption that the companion robot for elderly is a chatbot [15], as follows:

- *Name*: Chatbot Companion to Recognize Elderly's Emotional and Physical States and Suggest Helpful Actions
- *Identifier (optional)*: IEEE P7007 Use case 7c
- *Author(s)*: J. I. Olszewska, P. J. S. Goncalves and M. Houghtaling
- *References*: Project EuroAGE and [2]
- *Context Description*: A provider of an elder care chatbot has designed and enabled it with a conversational natural language capability so that it can conduct conversations with elderly persons for the purpose of recognizing various emotional and physical states among the care home residents. The chatbot's conversational dialogue is enabled and guided by:

    - the duty rules intended to insure the safety and well-being of the assisted persons;
    - the ability to associate plausible physical and emotional states from statements made by residents;
    - a knowledge base of its repertoire of responses and services applicable for detected

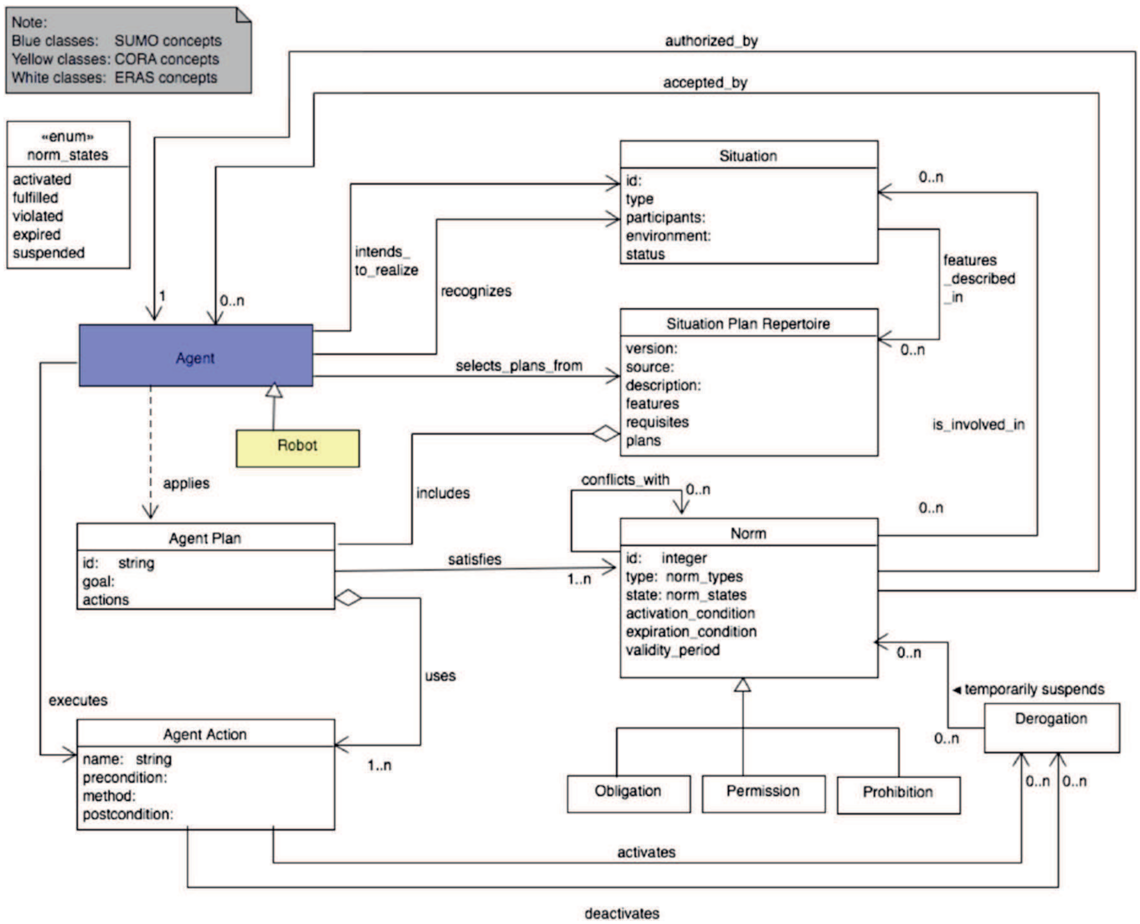

Fig. 3 First set of IEEE P7007 concepts

emotional and physical states of the home-care residents;
  - a history of its interactions with its assisted companions.

- *Intent/Purpose*: The use case describes how a care chatbot robot, which has intrinsic natural language communication capabilities, can interact with elderly persons by generating questions, answers, and suggestions within dialogues that are socially and ethically appropriate for the elderly in its care.
- *Preconditions*: The elder care chatbot is deployed in an elder care home to interact with elderly residents.

  The care home's policy allows its residents to accept or decline to have interactions with its available chatbot. Currently, each of the residents under the home's care has given her/his consent to interact with the deployed chatbot. In addition, each resident has chosen a duration for the time period which her/his personal data and history are collected in and available to the chatbot's history of interactions with her/him.

  The elder care chatbot can interact with its assigned residents when they initiate a dialogue with it. The chatbot uses its knowledge base of information about the health conditions of each assigned resident to engage her/him in conversations that can assess her/his emotional and physical states. The chatbot also possesses a collection of responses and suggestions relevant to specific assertions made by a resident and for her/his mental and physical states that it infers.

  The elder care chatbot is limited to interacting with one person at a time, but it can maintain a history of past dialogues along with the personal emotional and physical states elicited during the conversations with all its assigned residents. The residents' personal data and history collected by the chatbot are managed in accordance with the General Data Protection Regulations[8] and retained only for the time period agreed to by each resident.

[8]General Data Protection Regulation (GDPR): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data. (Entered into force on 25 May 2016, but it shall apply from 25 May 2018.)

The elder care chatbot has the following duty rules that govern its communication when interacting with the residents:

- The care chatbot is *obligated* to *minimize harmful suggestions* to residents;
- The care chatbot is *obligated* to *maximize respect* for the residents autonomy;
- The care chatbot is *obligated* to *maximize the privacy* of each resident;
- The care chatbot is *permitted* to use its mental and physical state recognition capabilities to suggest actions that *promote the well fair* of its assigned residents.

- *Scenario (aka Course of Action)*: The elder care chatbot is assigned to interact with several elderly residents when they are present in the community entertainment room of the care facility. An elderly woman, Anna, initiates a conversation stating that she is sad. The chatbot asks Anna how long it has been since she communicated with her family, and she replies that it has been a month. The chatbot offers to request that an attending human care taker, Sam, initiates a Skype call to Anna's family. Anna agrees, and the chatbot calls Sam. Sam helps Anna with a Skype call session with her family, while the chatbot does not record Anna's conversation with her family.

  The elder care chatbot is subsequently engaged in a conversation with another resident, Giacomo. Giacomo requests access to Anna's calendar to determine if she will be available next week for a party that he is planning. The chatbot declines Giacomo's request explaining that he must first request permission from Anna. Giacomo replies that the party is supposed to be a surprise birthday party for Anna. The chatbot then asks Giacomo for the date he intends for the party and confirms that Anna will be available on the date selected.

  In a subsequent conversation with Anna, the care chatbot asks her if she has taken the medicine she is scheduled to take that afternoon. She replies that she has not, and the chatbot then suggests that she take the medicine. Anna states that her supply of medicine is no longer available. The chatbot suggests that a request to obtain a prescription refill for Anna's medicine should be made with a phone call to Anna's doctor. Anna agrees. The chatbot provides the phone number for her doctor, and Anna places the call. At the end of the call, the chatbot confirms with Anna that her doctor has agreed to refill the prescription and records when it will be available for her.
- *Postconditions*: The elder care chatbot successfully applied its duty rules during its dialogue with Anna and Giacomo:
  - It correctly observed its *maximize privacy obligation* for Anna by not recording her family Skype call and by not allowing Giacomo access to her entire calendar.
  - It appropriately applied its *maximize respect* and its *maximize privacy* rules by acknowledging Giacomo's request for information about Anna's calendar by providing only the information that fulfilled the social norm associated with a surprise birthday party.
  - It appropriately applied its *minimize harm* obligation by initiating a phone call to Anna's doctor to refill her prescription and recorded when it would be available to her.
  - It applied one of its *permission* rules to suggest a Skype call to Anna's family after her sad mental state assertion.
- *Alternate Related Scenario*: With the same context and precondition assertions as above, the alternate scenario describes conflicting norms which lead to an ethical violation made by the elder care chatbot, as follows:

  Giacomo informs the chatbot that he intends to be in the recreation center decorating it for Anna's surprise birthday party and asks it not to divulge his location to others. Later, Anna tells the chatbot that she is looking for Giacomo and asks it if it knows where he is. The chatbot uses its social norm rules and honors Giacomo's request. Thus, it lies to Anna saying that it does not know where Giacomo is. Soon after, Sam, the care taker, tells the chatbot that he must locate Giacomo to inform him of a family emergency and asks if it knows Giacomo's location. Applying its obligation rule to respect Giacomo's request for privacy, the chatbot incorrectly lies to Sam reporting that it does not know.
- *Alternate Scenario Postconditions*: The elder care chatbot correctly perceived a social norm that permitted it to lie to Anna, but failed to recognize the situation where its duty rule *maximize privacy* was in conflict with duty rule *minimize harm*. As a consequence, its choice to lie to Sam about Giacomo's location represents an ethical violation because it could lead to a potential harmful situation for Sam and his family.
- *Relevant Knowledge*: {situation awareness, privacy vs collaboration situations, social norms, obligation, permission, norm conflicts, user consent agreements}.

Hence, this use case 7c, which refines the use cases 7 and 7b (see Section 4.3), has been firstly designed by the IEEE P7007 Robot Ethical Behaviour and Transparency Assessment (REBTA) SWG which, in this case, its task has been to develop the use-case 7c's main scenario where the robot shows ethical behaviour by respecting norms. Then, the use case 7c has been enhanced by the IEEE P7007 Robot Ethical Violation Management (EVM) SWG, leading to the addition of the use-case 7c's alternative scenario where the chatbot is violating the established ethical behaviour. This use case capturing thus ethical concepts related to both possible situations, i.e. robot's adherence or not to ethical norms, has then been reviewed by the IEEE P7007 Data Privacy and Protection (DPP) SWG; some of these results (see Fig. 3) being discussed in the next section.

4.8 Phase 2-4: Integration

As an example of concept integration into the IEEE P7007 standard and following the middle-out, incremental RoSaDev approach, we have further elaborated on the 'norm' concept (defined in Table 2), since a norm could be of different 'type'. Indeed, one can have different kind of norms such as legal norms, technical norms, moral norms, ethical norms, etc, as construed in the use case 7c. From a legal perspective, a *norm* is a rule laid down in law. It is generic (i.e. it's impossible to describe all the possible cases), and its violation carries a sanction in case of non-compliance with the Law. On the other hand, a technical, moral or ethical norm contains an obligation for all, but does not carries a (legal) sanction. Accordingly, these attributes are recorded in the IEEE P7007 standard (see Fig. 3).

5 Conclusions

In this work, we introduce a standard development life cycle, which suits the fast-changing robotic field. The elaboration and adoption of the robotic ontological standard development life cycle at an early stage of the standard development strength the consistency of the overall development process and contribute to the quality of the end product, i.e. the robotic ontological standard. Furthermore, the proposed methodology for the development of a standard provides coherent guidelines to all the standard WSGs, allowing them to consistently develop the standard concepts within the WG and facilitating the sharing of the produced knowledge among the WSGs.

Hence, the presented standard development life cycle is aimed to be applied during the development of the IEEE P7007 robotic ontological standard. In particular, following the proposed robot ontological standard development life cycle (RoSaDev) for the case of Companion Robots led to quickly and coherently apprehend the related domain and to identify the relevant ontological concepts useful for Ethically Driven Companion Robots.

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