Ontology for group of rescuing robots

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Annotation. In general, almost all fields of activities in the High North and the Arctic Region can be classified as either of high or extreme risks, as any kind of emergency at industrial site/object facility is very likely to lead to a large number of casualties. Rescuing people in distress is a complicated and challenging task. Having experience of numerous rescuing activities, it has shown that application of conventional rescue equipment in northern environments is not so effective: part of rescue facilities (such as medical aircrafts and ships) are based far from location of emergency, whereas the other part (floats, boats) have very limited capabilities. However, if arrived 48 hours after the catastrophe, there is almost zero possibility to find anyone alive, and the situation often becomes even worse because of the fact that rescuers have absolutely no idea about the actual situation and conditions within the emergency area or zone. Use of robotic groups in order to provide searching of survivors, lifting them up from either sea or ice surface, considering also further transporting of the people suffered - to stationary point-of-care or station of medical aid. Should tasks of robot group operation planning and of challenging situations complex analysis be considered, the most important is to implement standardized language with very clearly defined terminology. To solve this task, it is necessary to have appropriate ontology, i.e. it is ontology that determines core constructs, properties and connections. The article indicates core robotic ontologies, standardized and currently applied by international engineering community, as well as proposes extended solution of already existing IEEE standards (CORA, etc.), formulated with application of core SUMO ontology.

1. Introduction

Tasks of robotic group operation planning for several members, of situation analysis for making proper decision, of databases collection for practical experience analysis and their implementation for robot teaching require application of standardized language with clearly defined terminology. Ontology, as it formally provides core constructs, properties and connections, as well as determines basic axioms, is of the most significant issue. Ontologies are responsible for relevant knowledge in various fields, providing them in appropriate formats, as required, to be easily interpreted with SW tools. This provides the possibility to make programming for operations with application of standard conceptual constructs to generate conclusions, accommodate experience, interchange with information, etc. Ontologies are currently widely used in development of various SW tools for automatic translation instruments, enquiry systems, information requests, man-machine dialogues, etc.

Increasing complexity of tasks to be solved by more and more autonomous special-purpose robots requires more and more intelligent control methods. In order that robots be able to communicate both with each other and with human operator, it is necessary to implement into robot’s control system...
conceptual constructs, as appropriate, being also in compliance with level of knowledge of qualified operator. The requirement to have clear and understandable model of both collecting and using these knowledge is more than obvious. Moreover, technology of creating such model should be aimed to supporting SW tools development as well [1].

Group of rescuing robots belongs to extreme robotics field – that is to the field of creating robots meant for extreme conditions and hazard environments of both natural and man-caused character. Rescuing robots should autonomously follow one and the same common flexible algorithm in compliance with each other, and do this in challenging environments with continuously changing parameters [2]. Therefore, elaboration of ontology in this very field is of high priority task.

2. Core robotic ontologies

2.1. CORA Ontology

![CORA Concept Diagram]

**Figure 1.** Upper level of CORA concepts and their connection with SUMO taxonomy.

Elaboration of general ontologies to describe robotics specific areas is under active investigation recent years [3-5]. The most notable results are achieved by Work Group in Ontologies for Robotics and Automation (ORA WG). This Group works in close connection with industrial companies, scientific institutions and state organizations and focuses on developing set of ontologies coupled with associated modelling approach in order to use and implement these Robotics and Automation (R&A) standard, as suggested. ORA WG main efforts are currently concentrated in two fields – industrial and service robotics, and there are two basic reasons to do so. First and foremost, industrial and service robots prevail in the market of robotic means today, involving enormous amount of developers’ teams all over the world. In the next place, both service and industrial robots, as a rule, are operating and functioning in already known environments and in conditions of connection and communication stability. This
simplifies greatly the task of describing both the robot and its operation environment by means of conceptual constructs.

However, despite limitations indicated, it makes sense to implement ORA WG obtained results as the basis for further elaboration of ontologies for groups of autonomous special-purpose robots. Considering ORA WG involvement and participation, a special standard IEEE Std 1872-2015 (IEEE Standard Ontologies for Robotics and Automation) has been developed [6]. The standard is released as a referenced material for representation of both knowledge and reasoning in this subject area (domain): it describes Core R&A Ontology CORA and gives information on some more extending ontologies. CORA is the core ontology that determines core constructs, properties and connections, as well as axioms in terms of Robotics and Automation area. When being developed, CORA has implemented Standard Upper Merged Ontology (SUMO) [7], as developed in the frames of IEEE SUO (IEEE Standard Upper Ontology) project, to be its basis. CORA determines main constructs (such as robot, robot part, robot interface, robotic group, robotic system) in SUMO terminology, as represented in Fig. 1 above.

2.2. CORA extending ontologies

As per standard IEEE Std 1872-2015, it also includes some additional ontologies, extending CORA core ontology: CORAX, RPARTS, POS.

CORAX ontology is representing constructs and connections that are more general than as described in CORA. The most significant extensions for conceptual constructs are as follows: Physical Environment, Robot Move-on and Interaction.

RPARTS ontology contains constructs that are very useful to represent parts of the robot, as described: sensors, executives, communication, processor. Navigation subsystem seems to be out of RPARTS classification, however it is highly necessary and required to perform the operations in actual environments. Navigation system can be considered as intelligent sensor.

POS ontology includes main constructs and connections to describe robot’s position and orientation. These are of critical necessity to work with information related to robot-and-environments.

3. Ontology for group of rescuing robots

Analysis in terms of applicability of general robotic ontologies, as described, to solve the identified task shows that a number of key properties of rescuing robots can be described in terms and definitions of constructs as given by CORA, CORAX, POS n RPARTS. It should be noted, however, that these ontologies do not determine such feature and robot’s behavior. Having no such feature formalized, it is impossible to describe technologies of artificial intelligence, as required in order to organize autonomous interaction for group of rescuing robots [8].

To formalize the construct of behavior, the concept of three-level planning is taken as follows: mission – scenario – technological operation (TOP). The upper level is for mission. This is a formalized description of the task the group is to perform. Mission planning is performed by specifying a sequence of standard scenarios, and so scenario is of the second level. Scenario describes the algorithm of solving a functionally completed task. Should scenario be represented as a block diagram, the action blocks in this diagram will be typical TOPs, also connected with solution blocks (the switches). Each standard scenario has a certain set of parameters, prescribed during the planning. The third level of planning is a technological operation. This is a sequence of actions to perform a particular functional task. The TOP level allows to describe the logic of system functioning without excessive detail, and under operation planning it is the TOP that is an indivisible unit (similar to atomic nature).

Such approach provides flexibility for operation planning, as well as possibility to implement combinations as complicated as need be. At the same time single items of the plan are considered as reliable (proven) try-and-tested procedures.

Let us consider the example of one of the most challenging options of rescuing operation – rescuing people from the objects and facilities in environments and conditions of High North and Arctic. If there is a special robotic group for this task, it should include [9]:
1) Robots for reconnaissance for the purposes of searching suffered people and identifying potentially hazard zones/areas and objects (fire zones, collapsed structures, etc.);
2) Escape robots, as of fire- and explosion-proof 2-3 seats capsule capable of transporting persons to be rescued from the heart of emergency area to relatively safe zone nearby;
3) Robots for transportation to provide safe evacuation to the stationary point-of-care or station of medical aid.

Rescuing operation with application of group of rescuing robots requires performance of the following missions:
1) Reconnaissance and continuous monitoring of environments by means of reconnaissance robots. The result of such mission is environments evaluation summary represented as digital map built on the basis of a priori known site plan, card of sensory data and meteorological data. The map is generated on the basis of object-oriented classification method, which allows to form a comprehensive evaluation of environmental situation and conditions to be further used in multi-factor optimization procedure for robotic group plans.
2) Search and collecting of people suffered from either the sea or ice surface.
3) Staff/Personnel escape from the emergency area/object/facility, including high-priority tasks of life-supporting and survival systems.
4) Transportation of people rescued to the stationary point-of-care (rescue ship) or ground-based station of medical aid.

To perform missions as listed above, the following standard scenarios are proposed:
1) To alert/activate robotic group in case of emergency.
2) To observe the area/zone with reconnaissance robots and collect data on current situation and conditions. On-the-fly route selection is performed on the basis of comprehensive analysis of actual environments in compliance with given criteria for robotic group plan optimization.
3) To continue observing/surveying the area till a person to be rescued is targeted, identified and localized.
4) To move towards identified person/destination, trying to reach nearest possible distance. Message on targeting/identifying a person can be made by either one or several robotic group members, any group member can try reaching a man. Decision on what member suits best to proceed with this task is made on the basis of comprehensive analysis of actual environments in compliance with given criteria for robotic group plan optimization.
5) To perform decontamination of person’s location area (fire extinguishing, debris removal, etc.) by means of attachable equipment in automatic mode. Decision on tool/operation for the task is made on the basis of object-oriented analysis of sensory data [10], also considering equipment units that members of robotic group have.
6) To load people to be rescued inside the escape capsule (lifting from the water/ice surface, aid and support if person is injured and has limited mobility).
7) To move escape robots to a relatively safe distance from the emergency area object/facility and their further transfer to the point of location of the transport. Evacuation zone, evacuation (escape) routes and point of location of the transport are defined on the basis of comprehensive analysis of actual environments in compliance with given criteria for robotic group plan optimization.
8) To transport rescued people to the stationary point-of-care or station of medical aid.
9) To provide exceptional scenario to be implemented only in cases of errors and failures of the equipment of robotic group.

It is of crucial importance that all scenarios, as described above, can be implemented with limited amount of technological operations (TOPs). TOPs for means of transportation can be described as follows: moving straight ahead for \( n \) meters, turnaround for \( a \) degrees, moving to destination targeted (defined in coordinates) and obstacle avoidance, trajectory following considering also return to the initial trajectory after the obstacle avoidance operation is performed. TOP for executives can be described as: placing in transport position, placing in operational position, scanning environments to search for
potential object of interest/destination, installing attachable equipment unit as required, TOP performance using the selected tool/instrument.

It should be noted that in SUMO/CORA terminology both TOP and scenario are considered as physical processes while task performance. Therefore they are treated as abstract concepts when robot’s logic for functioning and operation is developed.

![Extended ontology description for rescuing robots](image)

**Figure 2.** Extended ontology description for rescuing robots.

In the light of stated above the authors of this article propose their ontology description for rescuing robots, as represented in Fig. 2 above. The ontology is introduced as extension for ontologies described in the previous section, implementing new concept constructs on the basis of SUMO taxonomy. If in terms of core ontologies it is possible to describe robot’s operations at common elementary level, the new constructs, as proposed in the paper, are to provide connection between robot physical description and mission to be performed suggesting that robot’s behavior is generated on the basis of situation analysis (the latter to be made using Knowledge Database).
4. Conclusions
The paper proposes extending of core robotic ontology if applied to the field of rescuing robots operation. Basing on three-level group operation planning description (considered as mission – scenario – TOP), the conceptual concept of Robotic Behavior is introduced, also in compliance of current applicable taxonomy. Common elementary technological operations are indicated, however it is necessary to understand that list of TOPs is defined by robot’s functional and operation abilities, as required. Further study will be focused on extending the proposed ontology to provide description of specialized subclasses and connections that can characterize both behavior and interactions of special-purpose autonomous robots being the robotic group-members for rescuing operations. For this purpose, concept map of associated objects and procedures will be further developed.

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