Towards a Taxonomy of Services for Developing Service-Oriented Robotic Systems

Lucas Bueno R. Oliveira*,†, Fernando S. Osório*, Flavio Oquendo†, and Elisa Yumi Nakagawa*

*Dept. of Computer Systems, University of São Paulo - USP, São Carlos, SP, Brazil
†IRISA Research Institute, University of South Brittany, Vannes, France
Email: {buenorlo, fosorio}@icmc.usp.br, flavio.oquendo@irisa.fr, and elisa@icmc.usp.br

Abstract—Robotic systems have been increasingly adopted in several sectors of the society. To cope with this demand and diversity, researchers have investigated the Service-Oriented Architecture (SOA) to develop such systems. SOA promotes interoperability between software modules and heterogeneous hardware devices, and a better reusability and flexibility for robotic systems. However, due to the lack of a common understanding on how services for robotic systems should be designed, described and also classified, these services are sometimes difficult to be used in other projects, reducing the potential of reuse provided by SOA. The main contribution of this paper is to propose a taxonomy of services for robotic systems that was based on results of a systematic review, reference architectures, and knowledge of specialists. Results have pointed out that our taxonomy is an important element to organize different types of services, what can promote reuse and productivity in the development of robotic systems.

Keywords: Taxonomy, Service-Oriented Architecture, Robotics.

I. INTRODUCTION

Robotics has currently become one of the most active fields for researchers and enterprise, significantly impacting the society and our daily lives [13]. Different types of robots have been developed and used in a wide variety of application areas, such as house cleaning, surveillance, and entertainment. In this perspective, the complexity of the robotic systems has been increasing, creating a considerable challenge for their development. To deal with this complexity and improve the productivity of the development, several researchers have adopted the Service-Oriented Architecture (SOA) to design robotic systems [10].

SOA is as a successful architectural style that uses services as the basic constructs to support the development of software systems [11]. Services are independent, self-contained, and well-defined software modules that can be dynamically composed to form more complex software solutions [11]. This architectural style intends to contribute with loosely-coupled systems, promoting reuse and productivity in the software development [11]. In robotics, SOA has been used to develop more flexible, scalable, and reconfigurable robotic systems built as a set of independent software modules. It has also been adopted to facilitate integration of heterogeneous hardware devices and reuse of complex software modules. In this perspective, companies and research institutes have created means to support the development of Service-Oriented Robotic System (SORS), i.e., robotic systems designed according to SOA. Two well-known examples of environments to develop these systems are Robot Operating System (ROS) [14] and Microsoft Robotic Developed Studio (MRDS) [8].

Due to the relevance of SOA for the robotics, several SORS have been developed in recent years [10]. These works not only have contributed to the consolidation of SOA in the domain, but also have produced a considerable amount of services for SORS. However, most of these SORS were developed using their own structures, without a common understanding about how and which software modules should be provided as services. This lack of consensus has reduced the reusability of the services and hampered the discovery of these services by developers of SORS. In this sense, identification and classification of the types of services that can be used in the development of SORS would contribute to facilitate the discovery and reuse of services.

The main contribution of this paper is to present a classification of services for SORS. For this, we have established a taxonomy, which is a form of classification widely accepted in different domains, such as software architecture [4] and robotics [5]. This taxonomy is based on the SORS available in the literature and identified in a systematic review [10], as well as a set of reference architectures of the domain [6] and knowledge of experts in robotics. Results obtained from a survey with domain experts have shown that the proposed taxonomy is representative and can be used to successfully classify the robotics services, as well as provides a good support to discovery such services to their future reuse.

The remainder of this paper is organized as follows. Section II describes the establishment of the taxonomy. Section III presents the survey used to evaluate the taxonomy. Section IV discusses on the results obtained from the survey and the perspectives of application of the taxonomy. Finally, Section V presents our conclusion and future work.

II. DESIGNING THE TAXONOMY OF SERVICES FOR SORS

To establish the taxonomy of services, we followed a well-defined, systematic set of steps, as illustrated in Figure 1. In short, in Step 1, we first elicited services from different sources of information. In Step 2, we grouped the
types (or sets) of services that have similar characteristics and purposes of use. In Step 3, these groups were described and organized in different abstraction levels, resulting in the types of services and the Robotics Services Dependency Stack (RSDS). Finally, in Step 4, the types of services and RSDS were evaluated in a survey applied to experts of robotics area. Following, each step used to establish our service taxonomy is presented in details.

A. Step 1: Service Elicitation

In this step, we selected different information sources to elicit the types of services used to develop SORS. These sources encompassed both theoretical and practical views of the robotic system development. The three sources were: (i) a systematic review addressing 39 studies that report on the development of SORS [10]; (ii) a set of reference architectures that encompass knowledge of how to structure robotic systems [6]; and (iii) expertise and knowledge of experts on how to develop robotic systems. By investigating these sources, we obtained a broad set of services.

B. Step 2: Service Analysis and Categorization

Given the services identified, we performed brainstorm meetings for analysis and classification. For this, we considered the expertise of specialists in software architecture, SOA, and robotics. These meetings were guided by reference architectures for robotics, since they contain modules and functionalities that should be considered in robotic systems. In this step, we have mitigated the following issues: (i) similar services with different names; (ii) services with the same name but providing different functionalities; (iii) services lacking cohesion; and (iv) modules that could be provided as services, but were not identified in the information sources. We also identified abstraction levels for the services. As a result, we obtained five groups of services: Device Driver, Knowledge, Task, Robotic Agent, and Application.

C. Step 3: Taxonomy Establishment

Based on the identified groups of services, we proposed a taxonomy of services for SORS. This taxonomy is composed by two main parts: (i) RSDS that links groups of services and (ii) description of all types of services of these groups. To define the dependency stack, we adopted the overall structure of the layered S3 reference architecture [1]. S3 is a widely accepted description of the relationships among services in SOA. Figure 2 presents RSDS and its layers, which represent the groups of services. In RSDS, less abstract services, for instance, services contained in Device Driver layer, provide functionalities for the higher ones, for instance, contained in Task layer. Besides that, services in lower layers are more fine grained and provide, for instance, software abstractions of hardware devices that can be used in different application domains. Services in higher level layers coordinate services in lower level layers to perform complete activities and are, therefore, more dependent of the application domain.

Device Driver layer encompasses services that control hardware devices, providing their functionalities to the higher layers. The Knowledge layer represents services that manage information used by the robotic system to make its decisions. Supported by Device Driver and Knowledge services, the Task layer groups services that provide tasks of robotics (e.g., mapping or localization) according to different behaviors. The Robotic Agent layer represent services that encapsulate the system that controls a robot as a service (i.e., Robot as a Service - RaS), which performs tasks – using Task services – based on information gathered from Knowledge services. Finally, the Application layer encompasses services that coordinate one or more Robotic Agents to perform more complex activities, such as surveillance and entertainment.

Notice that none of these five layers are mandatory and it is possible to develop robotic systems without using the lower level services, by designing a monolithic robotics service. However, we discourage this practice, since it may reduce flexibility and potential of reuse. A detailed description of each group of services is presented as follows.

1) Device Driver Services: This group includes services that encapsulate hardware drivers. Device driver services
are used as a design solution to provide better integration among heterogeneous off-the-shelf resources. There are two types of service in this group: Actuators and Sensors. Sensor services encapsulate drivers that coordinate hardware devices used to ‘feel’ the environment where the robot is. Actuator services are responsible for controlling the hardware used to interact with the environment. The services of this group are illustrated in Figure 3 and described as follows. Notice that some devices available nowadays can combine more than one type of service, such as for Position and Orientation. Interfaces of these services are therefore a composition of interfaces of provided services.

**Locomotion:** is responsible for providing mobility to the robot. There are different examples of locomotion driver services, such as for wheels, joints, helix, and so forth.

**Manipulation:** allows the robot to manipulate or hold objects of the environment. Drivers for controlling arms and grippers are considered as manipulation device services.

**Communication:** plays the role of both actuator and sensor. This is due to the fact that a communication is often bidirectional, i.e., a robotic system can use this service to feel the environment or interact with it. Different types of services can be considered as communication services, such as drivers for multimedia, network, and radio frequency.

**Position:** is used to obtain information of where the robot is in the environment. A well-known example of position service is the GPS device driver service.

**Orientation:** provides information about the orientation of the robot in the environment. Inclinometer driver and compass driver are both examples of orientation services.

**Movement:** measures the distance traveled by the robot. Encoder driver can be considered as a movement service.

**Contact:** controls sensors that detect whether the robot is in contact with objects in the environment. Drivers for barrier and bumper are examples of contact services.

**Distance:** is used to measure distance between the robot and the objects inside the environment. Drivers for lasers and sonars are examples of distance measuring services.

**Optical:** converts images of the environment into digital information that can be processed. Drivers for stereo cameras can be considered as examples of optical sensor services.

**Thermal:** is used to measure temperature of objects inside the environment. Drivers for thermal cameras are well-known examples of thermal sensor services.

2) **Knowledge Services:** This group comprises services that are responsible for gathering, interpreting, storing, and sharing information that is necessary to perform tasks and control the robot as a whole. This information allows the robotic system to learn about characteristics of its environment and objects inside it. Knowledge services can use not only data from sensors but also semantic information from a wide range of sources, such as ontologies or machine learning datasets. Services that belong this group are presented in Figure 4 and detailed as follows.

**External:** is concerned with gathering, storing, and sharing information from inside the environment. This information can be obtained from both sensors and databases hosted in a back-end server. Information obtained from sensors is generally produced by Task services and then stored in internal knowledge service to be shared among robots. Two examples of internal knowledge service are: (i) a robot learning how to deal with a given object by accessing a service hosted in a back-end server; and (ii) a robot sharing with another one its optimal path for a given position.

**Internal:** is responsible for obtaining and interpreting general purpose information from sources that are outside of the environment. By using this type of service, a web-enabled robot can search, access, and obtain information from machine-readable content on the Internet or even ordinary web sites, portals, and wikis. These external sources allow the robot to learn procedures, semantic concepts, and relationships that were not considered during the design of the robotic system. An example of this type of service is an autonomous robot learning how to make pancakes using information from the web, as shown in [15].

3) **Task Services:** This group encompasses services that provide functionalities considered as fundamental tasks of robotics. Task services allow the robot to perform basic activities, such as move from a position to another. These services can be implemented according to different behaviors, i.e., a robot can move to another position either by following a wall or keeping the distance between walls. This group can be divided in seven main types, as presented in Figure 5. Details of such services are discussed as follows.

**Mapping:** encapsulates algorithms used to estimate and build representations of the environment where the robot is. There are two types of mapping services, those that use Metric Maps and those that use Non-metric Maps. Metric maps are 2D/3D representations that use coordinates – Geometric or in a Grid – to describe the real location of
objects inside an environment. Non-metric maps are logical representations that can be Topological (e.g., an adjacency graph) or Sensorial, such as a sequence of images.

**Localization:** is used to estimate the position of the robot. For this, localization services use sensor data, previous knowledge about the environment, or both. There are two types of localization services: Probabilistic and Deterministic. Kalman filter [9] is a well-known algorithm that can be provided as a Probabilistic localization service to be executed and accessed by multiple robotic agents, as presented in [12]. Besides that, a Deterministic localization service can be any localization algorithm based solely on data from a GPS device or other type of position service.

**Path Planning:** is used to defined good (or optimal) paths between two or more positions in the environment. These services are often supported by mapping services and are developed based on two main strategies: (i) Heuristic Search (e.g., A-Star (A*) [7]) and (ii) Exhaustive Search (any kind of services that provide a path examining all possible paths).

**Navigation/Control:** is used by the robot to navigate in the environment. Navigation can be done based on a predefined path or not. There are two types of navigation/control services: Deliberative or Reactive. A service based on Deliberative navigation performs a path according to a predefined plan. Reactive navigation service controls the robot based on their current sensory data, e.g., using a Potential Fields [3]. Notice that a robotic system can combine these two types of service to provide a more robust hybrid behavior, combining reactive and deliberative control.

**Interaction:** allows the robot to work together with the Environment, Other Robots, or to accomplish an interaction with a User. Interaction services are responsible for supporting data exchange and procedures invocation between the robotic system and these elements. These services can be used, for instance, for requesting to an environment controller to open a door in a room.

**Object Manipulation:** provides algorithms to support physical interactions with objects inside the environment. Object manipulation services provide control algorithms that coordinate actuator devices, such as arms and grippers.

**Support:** provides general purpose functionalities that support the development of robotic systems. These functionalities generally involve data filtering, data fusion, math calculations, point cloud processing, and segmentation of images from cameras. As support services are not only from robotics domain, it is not possible to determine a finite number of subtypes of services that belong to this group.

4) **Robotic Agent Services:** This group encompasses services responsible for coordinating other services located in less abstract layers, such as Task and Device Driver. Providing a robotic agent as a service allows the robot to be remotely controlled and eases the coordination of multi-robotic systems. As presented in Figure 6, there are two types of Robotic Agent services: Non-mobile and Mobile.

**Non-mobile:** provides functionalities of a robot without mobility capability. An example of non-mobile service is a robotic system that controls an industrial robot designed to manipulate objects.

**Mobile:** provides functionalities related to both locomotion and object manipulation. Due to the different types of mobile robots – as well as their distinct representations of position and orientation – mobile robotic services can be divided into three categories: Aerial, Grounded, and Aquatic.

5) **Application Services:** Services in this group are responsible for managing robots to perform more complex activities. Application services are orchestrators that acquire knowledge through the robotic agent services, process it, and then request a set of tasks that satisfy a given activity. Figure 7 shows the three different types of Application services: Single Robot Application, Multi-robot Application, and Swarm Application.

**Single Robot Application:** is used to describe, coordinate, and monitor high level robotic activities. Applications such as for robotic vacuum cleaning and intrusion detection are examples of this type of service.

**Multi-robot Application:** is used to describe, coordinate,
and monitor multiple robotic agents (i.e., multiple robots) for a given application. This type of service is also responsible to allocate tasks for robots according to their specific features and availability. Coordination of multiple robotic arms in a factory line is an example of this type of service.

Swarm Application: coordinates and monitors a great amount of simple robots to perform cooperative applications. In a swarm application, all robots have the same service interface and provide the same functionalities. Measurement of temperature of an environment using a robotic swarm is an example of this type of service.

III. TAXONOMY EVALUATION

In Step 4, we evaluated our taxonomy by performing a survey with experts of the robotics domain. A group of ten experts was asked to read the taxonomy documentation and then answer questions in an on-line form. This group was formed by software architects, software engineers, software developers, and research team leaders from six different institutions from five countries, from both academy and industry. Results obtained from the survey are presented as follows and discussions are made in Section IV.

A. Evaluating Acceptance of the Taxonomy

In order to evaluate acceptance of our taxonomy, three aspects were evaluated during the survey: (i) RSDS, (ii) groups of services, and (iii) overall acceptance of the proposed taxonomy. For each aspect, we proposed statements that the experts had to answer using the following options: Strongly Agree (SA), Agree (Ag), Tend to Agree (TA), Neutral (Ne), Tend to Disagree (TD), Disagree (Di), and Strongly Disagree (SD). A Neutral answer means that the interviewee does not feel confident to accept or deny a given statement.

Regarding the acceptance of RSDS, three statements were made: ST1 - “The layers of RSDS are sufficient to describe the main parts and organization of a robotic system”; ST2 - “The dependencies between layers of RSDS are coherent”; ST3 - “Layers of RSDS are disjoint, i.e., there is a clear separation among layers”. Table I reports the answers for each of these statements. Notice that RSDS is considered (or tends to be considered) complete and coherent by more than 70% of the experts (i.e., more than 70% of answers about ST1 and ST 2 were SA, Ag, or TA). Besides that, 60% of the experts were in favor (strongly agreed, agreed, or tended to agree) and 30% were neutral about the statement that there is a clear separation between layers of RSDS.

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>Ag</th>
<th>TA</th>
<th>Ne</th>
<th>TD</th>
<th>Di</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1</td>
<td>30%</td>
<td>20%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>ST3</td>
<td>20%</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
</tr>
</tbody>
</table>

To evaluate the types of services identified in the taxonomy, we made three statements for each of the five groups of services: ST1 - “The group of services is complete.”; ST2 - “The group of services is correct.”; and ST3 - “The group of services has an adequate level of abstraction.”. Table II presents the results. It is possible to note a high degree of acceptance in the groups Device Driver, Task, Robotic Agent, and Application, where an average of 87.5% of answers were positive (i.e., SA, Ag, and TA). In group Knowledge, we observed positive answers from most experts, albeit few disagreements were also observed. It is due to the fact we adopted a classification using only two different types, since a deeper classification probably would lead to an incomplete set of subcategories, i.e., it is not possible to identify all subtypes of internal and external services. Notice that a similar classification was also adopted elsewhere [2].

<table>
<thead>
<tr>
<th>Type</th>
<th>SA</th>
<th>Ag</th>
<th>TA</th>
<th>Ne</th>
<th>TD</th>
<th>Di</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Driver</td>
<td>ST1</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST3</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Knowledge</td>
<td>ST1</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST3</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Task</td>
<td>ST1</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST3</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Robotic Agent</td>
<td>ST1</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST3</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Application</td>
<td>ST1</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>ST3</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

To measure the overall acceptance of the proposed taxonomy, we made four statements: ST1 - “I believe the taxonomy is clear and well-described”; ST2 - “I believe the taxonomy was defined adequately”; ST3 - “I believe the taxonomy is useful for describing services for diverse types of robotic applications”; and ST4 - “I believe the taxonomy is useful for describing services of different types of robotic systems”. Table III presents the results. It can be observed that an average of 80% have strongly agreed, agreed or tended to agree with all statements. Moreover, none of them have disagreed with the statements aforementioned. These facts indicate that the proposed taxonomy could be used as a first step to describe and classify services currently available for the development of SORS.

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>Ag</th>
<th>TA</th>
<th>Ne</th>
<th>TD</th>
<th>Di</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>ST2</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>ST3</td>
<td>50%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>ST4</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

B. Assessing the Comprehension about the Taxonomy

We also assessed the understanding of the experts about our taxonomy. They were asked to classify services using the taxonomy to answer different questions (e.g., in which group a collision avoidance service should be classified). Table IV summarizes the topics that were evaluated, the number of multi-choice questions for each topic (Questions (#)), the
number of choices that has each of these questions (Choices (\#)), and the average of correct answers (Avg. score).

<table>
<thead>
<tr>
<th>Topic</th>
<th>Questions (#)</th>
<th>Choices (#)</th>
<th>Avg score</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSOS</td>
<td>8</td>
<td>5</td>
<td>78.75%</td>
</tr>
<tr>
<td>Device Driver</td>
<td>6</td>
<td>5</td>
<td>90.00%</td>
</tr>
<tr>
<td>Knowledge</td>
<td>4</td>
<td>2</td>
<td>80.25%</td>
</tr>
<tr>
<td>Task</td>
<td>6</td>
<td>4</td>
<td>88.33%</td>
</tr>
<tr>
<td>Application</td>
<td>4</td>
<td>2</td>
<td>80.00%</td>
</tr>
</tbody>
</table>

Notice that 78.75% of the questions made about the RSDS were correctly answered. Besides that, from 80% to 90% of the 20 questions made about the types of service in the five groups were correctly answered. These results evidence a good comprehension of our taxonomy and its use to classify services of SORS.

IV. A BRIEF DISCUSSION

Defining a widely accepted classification of elements of a given domain is a difficult task. Aiming at establishing a representative taxonomy of services for SORS, we considered a broad amount of information sources, including a systematic review and specialists in robotics. We also submitted the taxonomy to evaluation by the robotics community, intending to observe both its acceptance and understanding. The received feedback indicates that the taxonomy can be used for classifying services available to develop SORS. Moreover, there is a good comprehension about the taxonomy and its service groups. Minor issues were pointed out, mainly related to the Knowledge group and the completeness of the Device Driver group. Regarding the Knowledge services, we identified that sometimes there is a misunderstanding about the role played by services in this group. Knowledge services are specially dedicated to manage and share information useful for robotic systems, which sometimes is produced by services from Task group. Regarding the completeness of the Device Driver group, it is important to highlight that this taxonomy does not encompass all types of drivers for sensors and actuators available for embedded systems, but the most important and used in the development of SORS. It is also worth mentioning that this taxonomy is not final. Thus, as this research area evolves, new types of services may arise, requiring to update the taxonomy.

The proposed taxonomy moves the first step to a better communication among developers of SORS. As a consequence, its use can also contribute to improve the reusability and productivity in the SORS development, since services described using a well-defined terminology can be more easily found by other developers. Nowadays, service repositories for SORS do not support the discovery of services through categories and the identification of services that could be reused is sometimes a hard and time-consuming. Thus, based on our taxonomy, we have proposed a service management system\(^1\) that supports publication and discovery of services in a more productive way. In this system, services can be published and described according to one or more service types defined in the taxonomy and, then, discovered by developers using a desktop interface integrated to ROS.

V. CONCLUSION AND FUTURE WORK

SOA has been increasingly adopted for the development of SORS, getting considerable advantages of SOA and resulting in more flexible robotic systems. In this scenario, the main contribution of this paper was to present a taxonomy that intends to adequately classify all services of the robotics domain and improve the understanding about them. Results of our work have presented good perspective of this taxonomy to become an important element in SORS development processes. As future work, we plan to conclude the development of our service management system, which will allow services to be published, classified, and discovered based on the taxonomy. By disseminating our taxonomy we intend to contribute to the reuse of services and, as a consequence, increase the productivity of SORS development.

Acknowledgments: This work is supported by CNPq, Capes, and grants 2011/06022-0 and 2011/23516-8, São Paulo Research Foundation (FAPESP).

REFERENCES


\(^1\) www.labes.icmc.usp.br:8595/RegistroServicoWeb/