POLITECNICO DI TORINO

Dipartimento di Automatica e Informatica

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Advisor

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Leveraging the Cloud to develop Service Robotics Applications

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1. Introduction

Cloud Robotics is a new research field in robotics. It was first introduced in 2010, and it aims at leveraging internet based technologies to open new possibilities in the development of service robotics applications. Thanks to the cloud, robots can offload part of their computation and storage resources remotely, or can share their knowledge and collaborate with other robots to perform tasks. Cloud Robotics takes strong advantages from the open source community: an important step in this direction has been done by the Robot Operating System (ROS), that is an open source framework designed to encourage collaboratively development of service robotics applications.

2. Objectives

Cloud Robotics aims at pushing the development of robotics applications to a new level of complexity, and it is a perfect technology to solve common issues in service robotics. However, the cloud introduces new open issues in real applications.

This work focuses on the design of general frameworks that enable the development of service robotics applications resorting on the cloud robotics paradigm. In details, it aims at analyzing common issues that appear in the development of cloud robotics applications and proposing frameworks to solve them. The main contributions of this work are introduced and discussed in Section 3, and have been applied in order to prototype working cloud robotics applications, presented in Section 4.

3. Technologies

3.1 Cloud Manager. Cloud Robotics developers need an infrastructure to deploy and run their applications, that is guaranteed by several available projects, such as the TIM Cloud Robotics Platform, which provides computational and storage resources on demand. However, it is important to provide some developing tools to enable fast prototyping of cloud robotics applications, especially when the developers have to deal with multiples machines. The Cloud Robotics Manager has been designed to be a powerful tool to develop robotic applications. The general architecture of the manager is depicted in Fig. 1. The cloud manager exposes a web Graphic User Interface (GUI) which enables entirely the deployment of a cloud robotics applications. Thanks to the *Cloud Interface* (CI) component, each machine involved in the application can be remotely configured: developers can configure machines (such as connectivity configuration, name, etc.), install, run, stop, compile and deploy ROS libraries and nodes. In addition, it enables the development of web GUIs that communicate with ROS thanks to *Rosbridge*.

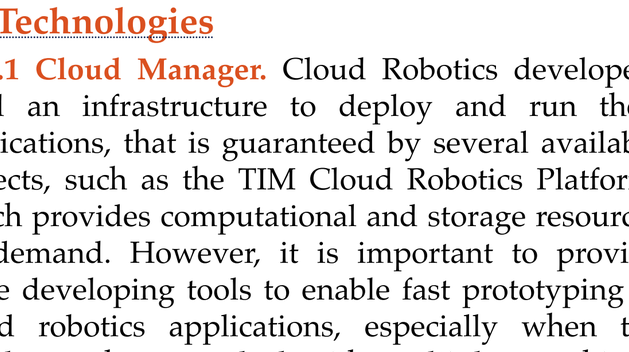

Figure 1: Cloud Manager Architecture

3.2 Virtual Sensor Networks. Sensor Networks (SNs) are a common application of IoT in Industry 4.0. They resort on a sparse set of sensors to collect localized measurements from the environment.

We propose the Virtual Sensor Networks (VSNs) approach, i.e., a novel alternative to SNs that relies on autonomous robots equipped with environmental sensors to solve the same task. We propose a new architecture (see Fig. 2) that enables the development of a VSN resorting on a cloud robotics platform. It is composed of 4 layers: the *Hardware Layer* groups sensors and actuators; the *Navigation Layer* guarantees autonomous navigation of the mobile base; the *Sensing Layer* groups preprocessing algorithm to apply to the raw data from sensors before storing them; the *Application Layer* enables the application itself resorting on the navigation and sensing layer, and exposes a web GUI to enable the user to access the collected data and configure the system. With respect to SNs, this system is simpler to configure, elastic and does not require physical intervention on the environment; on the other hand, it does not guarantee time dense measurements.

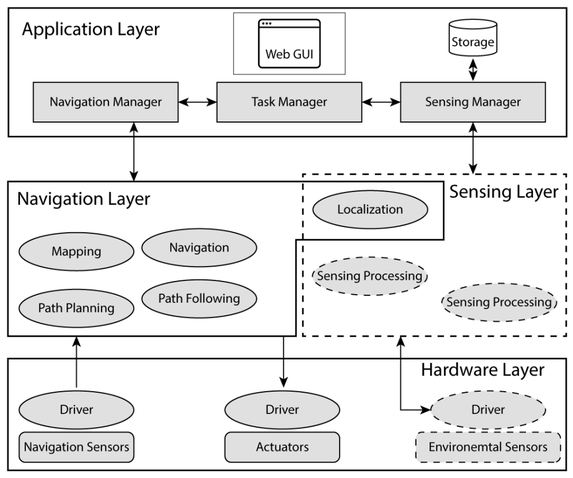

Figure 2: Virtual Sensor Networks

3.3 Telepresence with Natural Interfaces. Telepresence is an emerging application of Cloud Robotics: it enables a user to physically interact with a remote environment. Telepresence pushed the development of Natural Interfaces (NIs), i.e., intuitive Human/Computer Interfaces. NIs require a huge amount of computation resources and the access to a huge trained database to perform complex Computer Vision algorithms which process raw input data. We propose to offload the input processing capability to the cloud, according to the architecture depicted in Fig. 3.

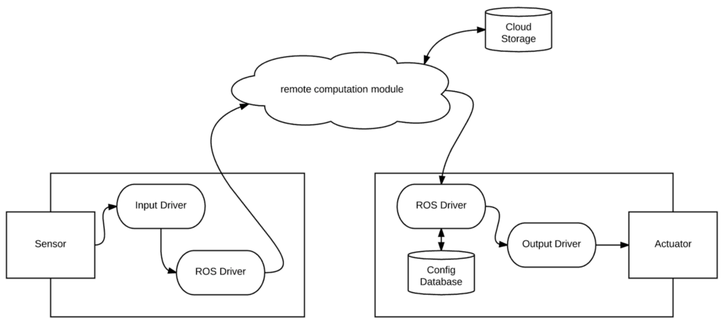

Figure 3: Telepresence with NI

4. Applications

4.1 Robot@CED. Thermal management is critical in data centers, Robot@CED [1] aims at developing a robot-based environmental monitoring system aimed at supporting managers to detect and solve anomalies in the server rooms. We developed a VSN to solve this goal. The hardware layer is equipped with a temperature/humidity probe and a thermal camera. The robot continuously inspects precise points (goals) in the map and store temperature/humidity measurements and thermal images. The system has been tested in one room of the data center of Politecnico di Torino (see Fig. 4).

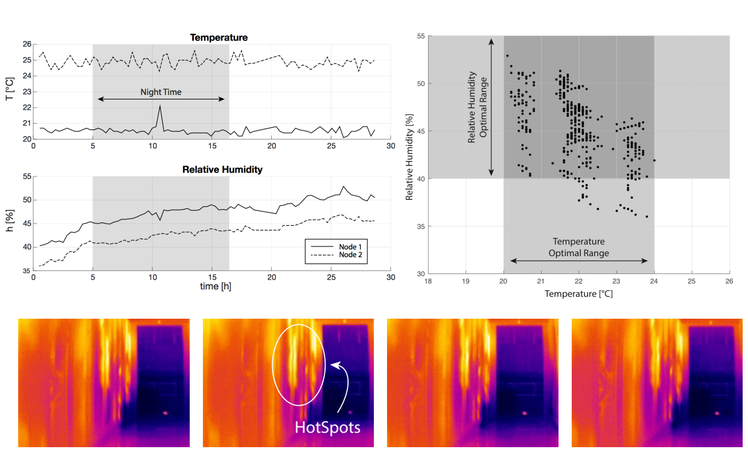

Figure 4: Robot@CED Collected Data

4.2 PARLOMA. PARLOMA [2,3] aims at developing a communication system for deafblind people, who communicate resorting on tactile Sign Languages (tSLs). Due to the needs to have a tactile output device, we developed an Open Source bioinspired robot hand controlled remotely from a NI device that is able to perform hand tracker on the signer. In this way, the "listener", is able to understand the message sent by the signer. Some experiments on the system are depicted in Fig. 5.

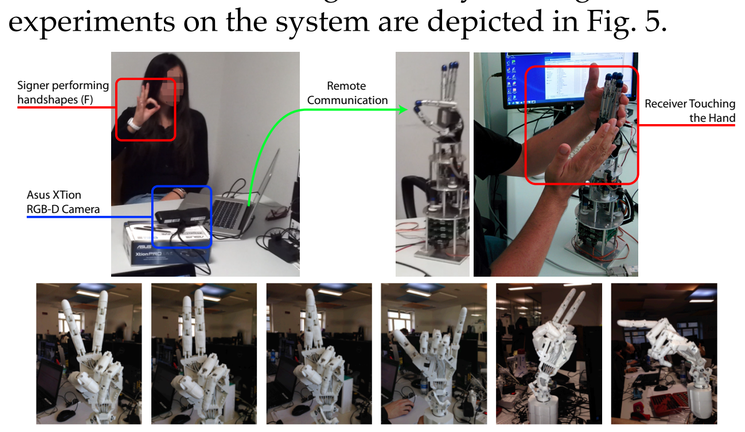

Figure 5: PARLOMA

4.3 DotBot. Didactic robotics is a powerful tool to help scientific teachers to enthuse students and transfer information easily. We believe that Cloud Robotics can open new possibilities for students and teachers. DotBot is an Open Source robot connected to a cloud robotics platform that can be programmed and configured remotely thanks to the cloud manager presented in Section 3.1. The system is actually used by several Italian schools.

5. Conclusions

In this work, we explored novel possibility in the field of service robotics powered by a cloud infrastructure. The designed frameworks have been applied to working applications in real case scenarios; however, there are still some issues are open and need investigation, such as IT security.

6. Relevant Publications

[1] Russo, Ludovico Orlando; Rosa, Stefano; Maggiora, Marcello; Bona, Basilio (2016) A Novel Cloud-Based Service Robotics Application to Data Center Environmental Monitoring. In: SENSORS, vol. 16 n. 8, 1255 ISSN 1424-8220

[2] Russo L.O.; Airò Farulla G.; Pianu D.; Salgarella A.R.; Controzzi M.; Cipriani C.; Oddo C.M.; Geraci C.; Rosa S.; Indaco M. (2015) PARLOMA - A Novel Human-Robot Interaction System for Deaf-blind Remote Communication. In: INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS, vol. 12 n. 57, pp. 1-13. - ISSN 1729-8806

[3] Bulgarelli, Andrea; Toscana, Giorgio; Russo, Ludovico Orlando; Farulla, Giuseppe Airo; Indaco, Marco; Bona, Basilio (2016) A Low-cost Open Source 3D-Printable Dexterous Anthropomorphic Robotic Hand with a Parallel Spherical Joint Wrist for Sign Languages Reproduction. In: INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS

7. Acknowledgements

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