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Demo: IoT Meets Robotics - First Steps, RIOT Car, and Perspectives

Hauke Petersen
FU Berlin
hauke.petersen@fu-berlin.de

Cedric Adjih
INRIA
cedric.adjih@inria.fr

Oliver Hahm
INRIA
oliver.hahm@inria.fr

Emmanuel Baccelli
INRIA
emmanuel.baccelli@inria.fr

Abstract

We present a cloud-enhanced, four-wheeled, mobile mini-robot, assembled from low-cost, off-the-shelf hardware parts, and open-source software building blocks. These building blocks provide a reusable and extensible base for emerging applications mixing robotics with the Internet of Things.

Keywords

IoT, Robotics, Cloud Computing

1 Introduction

The recent years have seen wide interest and innovation in the field of Internet of Things (IoT), triggered by technological advances in embedded systems hardware, software, and connectivity. The increasing availability of tiny, cheap, power-efficient micro-controllers and peripherals has spun a new category of computers: low-end IoT devices, which include motes, sensors, actuators, etc. Even though such devices cannot run traditional operating systems (e.g. Linux and equivalents) due to very constrained memory, CPU, power resources, most low-end IoT devices have enough resources to run newer operating systems [4] and cross-platform application code. Furthermore, recent network technology and protocol standardization efforts have enabled new interconnection capabilities for such devices, such as low-power, end-to-end IPv6 based networking.

Simultaneously, robotics is experiencing a dramatic growth, not only in their traditional applications, such as industrial automation, but also in other domains such as self-driving cars, and personal robots such as drones, vacuum cleaning robots, and other types in the making. While ever smaller robots are targeted by the field of nanorobotics, another class of robots (and applications) is expected to consist of mini-robots [10] approximatively of the size and computing capabilities of current IoT devices. Mini-robots are expected to become commodity and 1000 times cheaper than currently available robots (see for instance the AFRON Challenge [7]). Leveraging a number of emerging techniques, such as 3D printed robots (see for instance Poppy [8]), and network connectivity enabling new paradigms ranging from fog computing [3] to cloud robotics [6], such robots are likely to be massively deployed in a variety of application domains in the near future. The encounter of IoT and robotics thus promises to open a fascinating new field.

2 IoT meets Robotics

An emerging class of mini-robots will inherit from the same constraints as current IoT devices (e.g. actuators) including very limited memory, finite processing power, and strong energy limitations. In the following, we focus on three important aspects in IoT robotics: hardware aspects, software aspects, and network aspects.

Hardware Aspects: From a hardware perspective, a robot consists in (i) structural and mechanical components, e.g. carcass, frame, wheels, (ii) sensor and actuators, e.g. motors, distance sensors, (iii) computational elements and electronics, e.g. micro-controllers, motor controllers, and (iv) power supply, e.g. batteries. Recently, the rise of open source hardware and the maker scene lead to increased availability and such a significant price drop for these components, that mini-robots under $10 are becoming a reality [7]. Popular examples of structural components include *Lego*, while 3D printers allow virtually anyone to conveniently create custom parts with a high precision. The *Arduino community* lead to the availability of a wide range of affordable sensors (from inertial measurement units to full-blown laser distance scanners), and a variety of actuators became available due to the *scale modeling community.* The market around low-power, low-cost micro-controllers is currently booming. Basing robots on these low-power platforms conveniently allows the use of standard off-the-shelf batteries, or, in intermittent activity scenarios, of small solar panels and other means of energy harvesting solutions.

Software Aspects: The software running on IoT mini-robots consists in (i) hardware abstraction and device drivers, (ii) control software, (iii) communication software, and (iv) a systems layer that glues together all these elements. The most popular software base for robots is the Robot Operating System (*ROS* [9]) a set of libraries and tools running on top of a host operating system (i.e. a traditional OS such as Linux, Windows). *ROS* is thus not intended to run on mini-robot hardware, whose constrained resources (memory, CPU, power) won't match traditional OS resource requirements. Instead, newer and more compact operating systems [4] must be used as base on such hardware. For instance, *RIOT* [2] provides real-time capabilities, hardware abstraction, multi-threading, and full IPv6 networking while fitting the tight memory constraints of micro-controllers typically found on low-end IoT devices. However, contrary to *ROS*, *RIOT* does not provide specific libraries targeting robotics. Nevertheless, this shortcoming could be overcome by porting light-weight robotics libraries [1] to *RIOT*. This task is simplified by RIOT providing common developer APIs, such as BSD sockets or POSIX thread (*pthread*) functionalities.

Network Aspects: On the network side, IoT mini-robots need (i) enhanced algorithms and protocols, and (ii) novel/holistic network architectures. Aforementioned constraints on software and hardware translate into challenges for network technologies, which are expected to operate with low memory foot-print, low energy consumption, and high reliability over wireless, and to interoperate with the Internet. For instance, the IETF is currently standardizing the use of IPv6 (with protocols as 6LoWPAN, RPL, CoAP) over low-power wireless link layers in IoT, e.g. BLE, or IEEE 802.15.4 using TDMA and frequency hopping to increase reliability for the exchange of critical information. However, such protocols are not well equipped to accommodate mobility. Additional to the challenges of radio interference and multi-path fading at the physical level, MAC and routing protocols have to deal with more frequent topological changes and temporal loss of connectivity. Therefore algorithms and protocols should be extended and adapted (see [11] for example work in this direction). Furthermore, as IoT robotics combine embedded system constraints on one hand, and on the other hand to the extreme complexity of some tasks IoT robot may have to carry out (e.g. grasping an unknown object/environment), it will be necessary to deport some of the logic and/or processing for robot control to remote server(s) i.e., the cloud. Elements of such an architecture already exist (protocols such as [5], publish/subscribe mechanisms in *ROS*, or `rosserial`). However, convergence/adaptation is needed between such elements and standard IoT protocols in the making, such as CBOR, COAP, MQTT, or ICN. The goal being to provide a fully integrated communication architecture, from IoT mini-robots up to the cloud

3 Demo

We will present a four-wheeled, mobile mini-robot (see Fig. 1) we have built assembling low-cost, off-the-shelf components including a low-power MCU (ARM Cortex-M0+), DC drive motor, power stage, steering server, and ultrasonic distance sensor. The behavior of the mini-robot will be (i) reprogrammable on the fly from the cloud, (ii) simultaneously subject to local and cloud-based control loops. For local control the mini-robot will run RIOT, an open source real-time operating system which fits resource constrained and low-cost micro-controller platforms. For communication with the cloud, the mini-robot will combine low-power wireless (IEEE 802.15.4) and IP protocols, providing end-to-end connectivity, using RIOT's standard network stack.

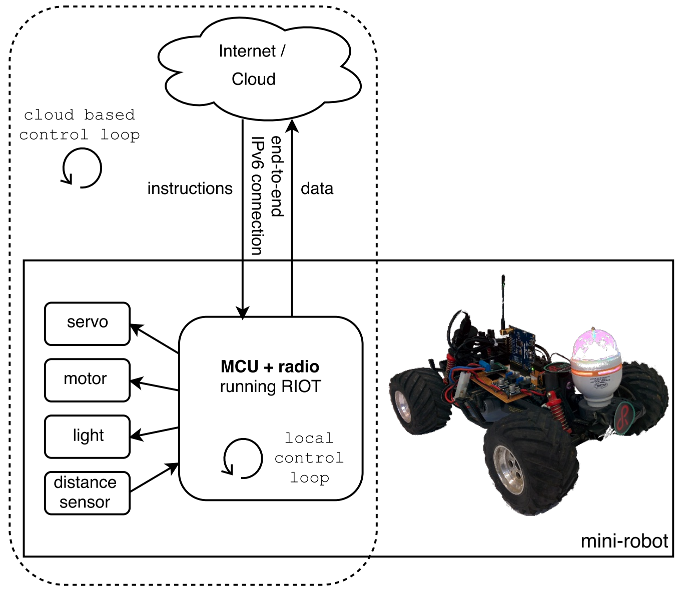

Figure 1. High-level architecture and image of low-cost 4-wheeled minirobot, cloud-controlled, using low-power wireless, IPv6 and RIOT.

4 Conclusion and Future Work

The demo we present decomposes into cleanly separated building blocks, using open-source software and off-the-shelf hardware. In particular, care was taken to make it straightforward to (i) substitute the local real-time control loop on the mini-robot with more advanced motor control, local sensor data fusion and short-term decision making, (ii) relocate and/or enhance the cloud-based control loop with more advanced computational offloading for sensor data processing, remote decision making, and mid- to long-term planning, or (iii) add/substitute sensors and actuators on the mini-robot. Thus, this work can be easily reused and extended for a wide range of emerging applications mixing IoT and robotics.

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