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

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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 & 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 techno-logical advances in embedded systems hardware, software, and connectivity. The increasing availability of tiny, cheap, power-efficient micro-controllers and peripherals has spuna new category of computers: low-end IoT devices. Even though such devices cannot run traditional operating systems(e.g. Linux and equivalents) due to very constrained mem- ory, CPU, power resources, most low-end IoT devices haveenough resources to run newer operating systems [4] and cross-platform application code. Furthermore, recent net- work 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 in-dustrial 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, an- other class of robots (and applications) is expected to consistof mini-robots [10] approximatively of the size and comput-ing capabilities of current IoT devices. Mini-robots are ex- pected to become commodity and 1000 times cheaper than available robots (see for instance the AFRON Chal- lenge [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 do- mains 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) in- cluding 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 avail-ability and such a significant price drop for these compo- nents, 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 cre-ate custom parts with a high precision. The *Arduino commu- nity* lead to the availability of a wide range of affordable sen-sors (from inertial measurement units to full-blown laser dis-tance scanners), and a variety of actuators became availabledue 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 in- termittent activity scenarios, of small solar panels and othermeans of energy harvesting solutions.

Software Perspective: 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 ele- ments. The most popular software base for robots is the Robot Operating System (*ROS* [9]) a set of libraries and toolsrunning 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 typ- ically 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*).

Network Challenges: On the network side, IoT mini- robots need (i) enhanced algorithms and protocols, and (ii) novel/holistic network architectures. Aforementioned con- straints 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 Inter- net. 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 in- crease reliability. But these are not designed to accommo- date mobility, temporal loss of connectivity and topological changes, in addition to the classical radio interference, mul- tipath fading: they should be extended and adapted (see [11] for instance). Furthermore, IoT robotics combines embed- ded system constraints with the extreme complexity of some tasks IoT robot may have to carry out (e.g. grasping an un- known object/environment); thus, it will be necessary to de-port some of the logic and/or processing for robot control toremote server(s) i.e., the cloud. Elements of such an architec- ture already exist (protocols such as [5], publish/subscribe in *ROS*, or `rosserial`). But convergence/adaptation is neededbetween 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 architec- ture, 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 com- ponents including a low-power MCU (ARM Cortex-M0+), DC drive motor, power stage, steering server, and ultrasonicdistance sensor. The behavior of the mini-robot will be (i) reprogrammable on the fly from the cloud, (ii) simultane- ously 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 communica- tion with the cloud, the mini-robot will combine low-power wireless (IEEE 802.15.4) and IP protocols, providing end- to-end connectivity via standard access points, using RIOT's default network stack. The cloud component consists in a simple REST-based daemon using CoAP to communicate with the robot, and the web for user interaction (e.g. chang-ing the robot's behavior).

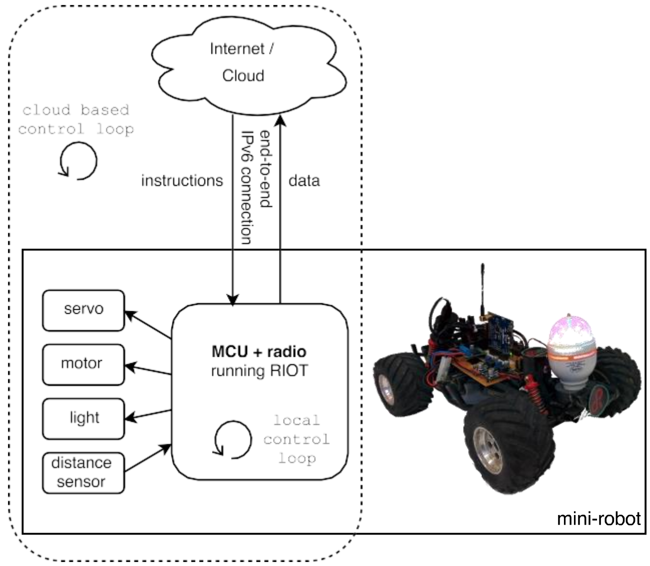

Figure 1. High-level architecture and image of low-cost 4-wheeled minirobot, cloud-controlled, using low-power wireless, IPv6 and RIOT.

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 pro-cessing, 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 ex-tended for a wide range of emerging applications mixing IoT and robotics. Our future work will focus on efficient portable software running on IoT minirobots, computation offloading schemes, and optimizing standard IoT protocols for reliabil-ity in face of mobility and multihop over low-power wireless.

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