A robotic vehicle with Internet of Things (IoT) capabilities to verify the compliance of Law 7600 in Costa Rica

Arys Carrasquilla-Batista, Yeiner Arias-Esquivel
acarrasquilla@itcr.ac.cr, yarias@itcr.ac.cr

Mechatronics Engineering

Instituto Tecnológico de Costa Rica - ITCR

***Abstract*—Governmental entities worldwide are working towards equal opportunities environments, this principle recognizes the importance of the different needs that individuals have and of how these needs must serve as the basis for social planning, to ensure that resources are being used in ways that guarantee persons equal opportunities of access an participation in identical circumstances. In May 1996, the Legislative Assembly of Costa Rica approved the equal opportunities law for persons with disabilities, known as Law 7600. In this law there are mandatory technical specifications, issued by the corresponding public and private entities, that have to be fulfill in new building or changes in existing buildings, parks sidewalks, gardens, restrooms and other public spaces. The proposed system consists of electronic circuitry built with commercial-off-the-shelf components (COTS), affordable sensors, mobile communication, actuators and software running in the Internet. In the first iteration of the project a local computer was used to control a robotic vehicle and to process all data, in this paper an embedded system with Internet of Things (IoT) capabilities is to be implemented.**

***Index Terms*—COTS, Internet of Things, Law 7600, Robotic vehicle, Teleoperation, Embedded system.**

I. Introduction

In the past forty years, an increased awareness about people with disabilities and their rights has led to the creation of numerous pieces of legislation regarding the status of disabled people and their relationships to their environment. Beginning in 1973 with the Rehabilitation Act in the United States and continuing today at the United Nations with the Convention on the Rights of Persons with Disabilities, countries now look to each other when drafting legislation. With a national "Equal Opportunities Law for Persons with Disabilities", also known as Law 7600, and as a signatory to the United Nation Convention, Costa Rica is one of these such countries working to improve the rights of people with disabilities in all facets of life.

Costa Rica is located in Central America, bordering Panama and Nicaragua, has a population is 4.9 million and an advanced hospital system when compared with other Central American countries. Life expectancy at birth for the total population is 77.21 years, literacy rate is 96% and approximately 10% of the population is identified as having a disability, 6.09% are men and 5.76% are women.

Since 1996, Law 7600 [1] has been established in Costa Rica for the integral development of the population with disabilities, in order to provide equal opportunities to people with some type of disability and to enable them to reach full development, full social participation, as well as the exercise of rights and duties. In chapter IV of Law 7600 entitled "Access to physical space", specifically in article 41, are given all mandatory technical specifications about: new constructions or remodeling of existing buildings, parks, sidewalks, gardens, plazas, lanes, restrooms, and other public space.

According to [1], all private buildings destined for public use must comply with the same indications of the paragraph herein above. The same mentioned obligations must be meet for all housing projects which are partially or totally funded with public funds. In projects of this type, houses assigned to persons with disabilities or to families where one of their members has a disability, must be built on an accessible location.

How to verify the compliance of the Law in existing buildings, sidewalks, restrooms and other public sites is not an easy task. In order to solve this problem, some efforts have been developed in the search for technical initiatives and alternatives. Such is the case of the robotic vehicle called ACIA [2], shown in figure 1, implemented for verification of compliance with Law 7600, this first approach considered a local computer with blue-tooth communication. Some other initiatives were studied, as the one presented by Arce [3] in which an haptic interface with feedback forces was implemented to control ACIA robotic vehicle.

This paper is organized as follows: Section II describes the problems regarding the compliance of Law 7600 in old public buildings and public sites. Section III presents the general structure of the proposed embedded system along with the application specific software. Some explanations are given on the IoT software platform and how it is integrated to the acquisition and processing system. In section IV an IoT application that generates a graphical report about compliance

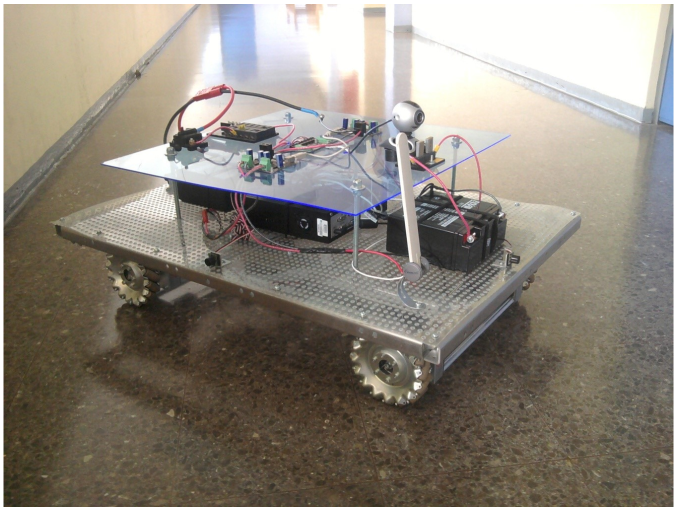

Figure 1. Robotic vehicle to verify the compliance of Law 7600.

or not with Law 7600 is described. A thorough discussion is given on how measured variables are co-related and evaluated in a IoT platform. Finally, some conclusions and perspectives are given in Section V.

II. Problem Description

To comply with the equal opportunities law for persons with disabilities there are technical specifications that require changes in public and private buildings. Since the promulgation of the Law new infrastructure plans require to include all technical needs to obtain permission to start the building. So usually the problem arise with old infrastructure that have to be modified accordingly. Thus, not only massive data collection becomes mandatory: if smart decisions are needed on the spot, a data processing system capable of giving answers in almost real time would most likely increase not only the speed but maybe the final quality of the decision that has to be taken. A multidisciplinary research group developed a project to improve expertise about the compliance with Law 7600, automatize data sampling and decision management by integrating IoT into their scientific research in order to convert data into information, information in knowledge and this into wisdom to manage decision making at the right time [5].

III. A General IoT system to verify the compliance of Law 7600

Internet of Things projects have find a niche in agriculture and forestry, this is caused for the high volume of data that have to be managed. The expertise generated in this field is now applied to propose a system with mobile communication to control locally and remotely ACIA robotic vehicle. Is important to mention that processed data include a web cam to visualize the physical space that is being analyzed. Is more than known that any modern embedded device has Internet access capabilities nowadays. And the acquisition and storage of multiple variables can be solved by any commercial data logger in the market. And yet, a fast perusal of the measurement instrumentation commonly used by professionals and researchers in fields such as agricultural sciences or forestry, typically surprises an electronics engineer, due to the startlingly high prices of this kind of equipment, and their awkward schemes of integration with other devices. In the case at hand, several researchers from security and architectural fields approached the authors with the mentioned problem: how to integrate the accurate measurement of variables such as pathways, ramps, bathrooms, sidewalks and other physical spaces that have to comply with the Law. How to measure from remote locations and in an affordable yet reliable way. For these researchers, the final approach should generate an easy to read and understand graphical report, giving a high precision technical tool for decision-making.

The authors then approached the design of this embedded system considering the use of COTS components under a severe pair of restrictions: affordable, and yet accurate enough compared to any commercial alternative technique. This requirements not only dictated the choosing of a COTS based system, but also promoted the use of online processing tools, that are commonly available at a low cost on the cloud. A first version was implemented on a laptop computer, and the following iteration considered the use of an Arduino ATmega-based processor with bare metal coding. In the third version, code was migrated to a Lanín 32-bit ARM-based board [8] running under an embedded Linux Buildroot distro, with interchangeable sensors and data acquisition, wireless and 3G communication interfaces and at least two electromechanical actuators, and open source software running on the cloud (for data fusion and post processing enabling accurate monitoring and decision making in agricultural and forestry applications). Using an embedded OS provided the system made it easier to configure depending on the final application (that usually means different sensors), via wired Ethernet, using a flexible HTML light web server running on the ARM board. System's performance has been tested in two different applications: greenhouse horticulture [6] and microalgae culture [7]. The proposal presented here is a system with COTS components and under a thousand American dollars (with all sensors and connectivity included), but with a precision comparable to high precision measurement equipment, and with data post processing available on the cloud.

IV. Methods and materials to verify the compliance of Law 7600

The approach of this document is to provide the ACIA robot with an Internet connection that allows control of the vehicle through a website and the processing of data in the cloud. This will reduce the information processing in the robot and use an embedded system with less performance as an interface between the vehicle and the cloud, as shown in figure 2, incorporating all the benefits of the *Internet of Things*.

In order to carry out the work, it is proposed to use the platform Raspberry Pi 3, because in addition to complying with the requirements to perform the tasks of robot control and data acquisition, it also has an integrated wireless interface for

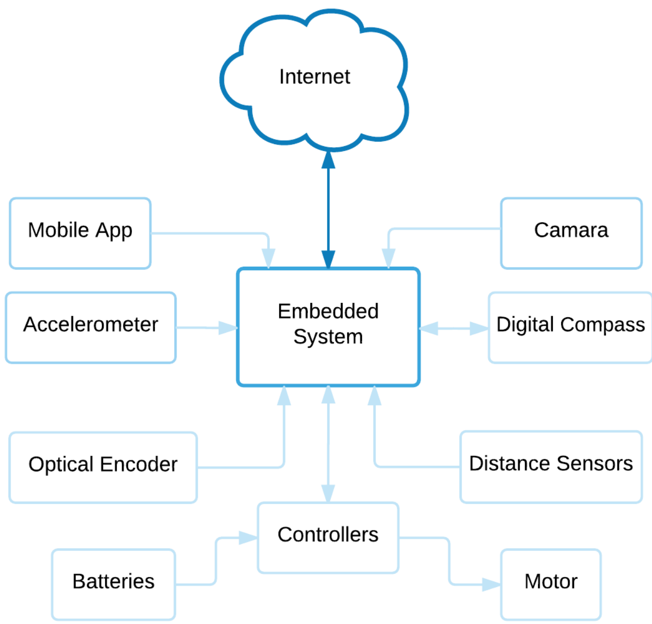

Figure 2. General diagram of interconnection.

the Internet connection. Some of the platform specifications are shown in table I.

Table I
SPECIFICATIONS OF RASPBERRY PI 3 MODEL B [4].

	Raspberry Pi 3 model B
SoC	BCM2837
CPU	1.2GHz 64/32-bit quad-core ARM Cortex-A53
RAM	1GB LPDDR2
Ethernet	10/100
Wireless	802.11n - Bluetooth 4.0

Nowadays, there is a growing need in various research fields and the produce and precision agricultural industry to record and process data from multiple sensors, sensors sometimes located in remote areas, miles apart from each other. The usual approach to sensor data recording implies separate measurement equipment for each variable, making difficult and expensive the integration and processing of joint data. An affordable solution is here proposed, providing with an integrated multivariable measurement environment, using commercial-off-the shelf (COTS) and taking advantage of the ubiquitous computing capabilities available today, in what is generally known as Internet of Things. The proposed system was successfully tested as a monitor of a microalgae culture used for biofuel research applications. Multiple variables (temperature, light, pH and dissolved oxygen) associated to microalgae kinetic growth are captured and sent to a remote database that is connected to Internet, where researchers can perform various data analysis online.

The emergence of wireless technologies for 3G and 4G on one side (coupled with the falling cost of these communication systems) and the rise of the Internet of Things (IoT) (Evans, 2011) , also refered as Internet of Everything (IoE), offer a

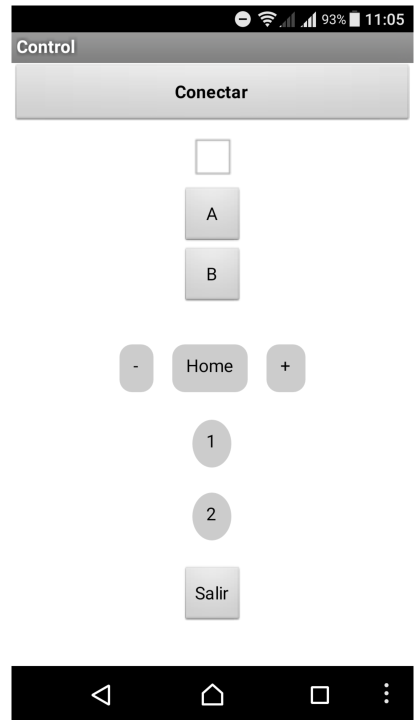

Figure 3. Bluetooth control application interface for the vehicle.

much more viable and practical solution for the integration of multiple sensors. Such integration allows for the exploitation of the huge processing and storage capacities available in the Internet, where data from multiple remote sites can take advantage of complex data processing techniques, usually known as ”multi-sensor data fusion”, to provide researchers not only with massive long range data series analysis, but also with the possibilities of process prediction and estimation. In Figure 3 is shown a mobile application to control locally ACIA robotic vehicle considering a Bluetooth interconection to Raspberry Pi 3 board.

To study the interaction between COTS and IoT, the proposed approach will include some variables that are related to the Law 7600, specifically should be measured: location, distance between robotic vehicle and walls, degrees of inclination of the ramp, batteries charge level, among others (see again Figure 2).

Academic institutions and research centers have to join these efforts to find equitable solutions in their fields and promote the most drastic emissions' reduction possible. Now, several recent studies have been carried out regarding wireless sensor networks applied to agriculture and greenhouses which point out in the promising direction of exploiting IoT capabilities to carry out production decision-making on the cloud (see [5] for more on this). This has motivated the development of a general embedded system on an affordable platform, featuring Internet of Things (IoT) capabilities general enough for a wide span of potential applications. The developed system is based on a modular board, where different commercial sensors and actuators are plugged in or out depending on the

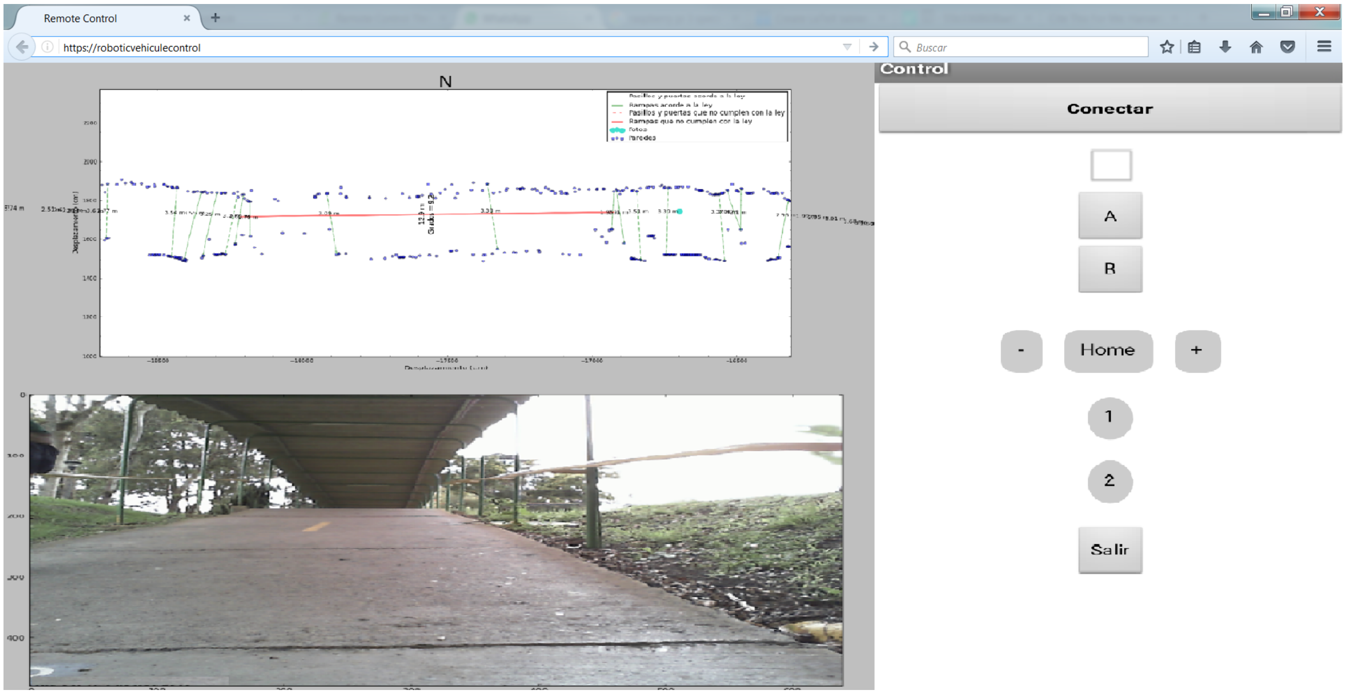

Figure 4. Website for robot control.

application, and where data gathering is shared via the cloud, for post processing and decision making depending on the final application. As an example of how such a system may help in the fight against climate change negative effects, two specific applications were tested and validated: the first one oriented to horticulture production in protected environments, [6], better known as greenhouses; the second application aimed at improving the biomass yield of a microalgae culture with potential uses in biofuel production (see [7]).

The expertise generated about IoT motivated to change the first approach given to ACIA robotic vehicle. In Figure 4 is shown the proposed website where users will have the possibility to control remotetly, visualize the physical space that is been analyzed and have a graphical view with color that indicate the compliance or not with Law 7600. The red line shown in Figure 4 indicates that this ramp (the one seen in the image) those not comply with the technical specification given by the Law.

V. Conclusions

A multivariable measurement prototype system with IoT capabilities, built with COTS components, has been developed and tested for agriculture and forestry applications, these expertise is now proposed to be implemented in a robotic vehicle to supervise the compliance of Law 7600.

The developed system can be used for many other applications, such as: greenhouse monitoring, forests and open air plantation monitoring, and even electrical smart grid monitoring. Only the sensors need be replaced for the intended application, and the data processing capabilities of the cloud can be used even for more specific applications, such as remote control and intelligent decision platforms.

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