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Speech-controlled cloud-based wheelchair platform for disabled persons

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ABSTRACT

This paper describes the development of a prototype speech-controlled cloud-based wheelchair platform. The control of the platform is implemented using a low-cost WebKit Speech API in the cloud. The description of the cloud-based wheelchair control system is provided. In addition to the voice control, a GUI is implemented, which works in a web browser as well as on mobile devices providing live video streaming. Development was done in two phases: first, a small, initial prototype was developed and, second, a full size prototype was build. The accuracy of the speech recognition system was estimated as ranging from approximately 60% to up to 97%, dependent on the speaker. The speech-controlled system latency was measured as well as the latency when the control is provided via touch on a so-called smart device. Measured latencies ranged from 0.4 s to 1.3 s. The platform was also clinically tested, providing promising results of cloud-based speech recognition for further implementation. The developed platform is based on a Quad Core ARM Mini PC GK802 running Ubuntu Linux and an Arduino UNO Microcontroller. Software development was done in JavaScript/ECMA Script, applying node.js.

1. Introduction

The availability of the smart wheelchair solutions is often limited due to their high costs [1–5], making them inaccessible for most people. Furthermore, electric wheelchairs are becoming increasingly common, but the control systems are reduced mainly to joysticks that are generally suitable only for patients with motor disabilities in their lower limbs [6]. There are significant efforts in the field of smart wheelchair development guided by speech [7–9] based on SUMMIT speech recognizer or Sphinx [10] indicating the problems of Word Error Rate (WER). Since the technology of speech recognition is critical for the adequate operation of smart wheelchairs, the possibility of applying cloud technology in this field was researched with regard to the possibility of lowering the cost of the system development as well as providing higher accuracy of the speech recognition. By means of the emerging interdisciplinary discipline of cyber-physical systems [11], we propose a low-cost solution for a speech-controlled wheelchair platform, also suitable for the patients with severe disabilities. Cyber-physical systems are integrating the dynamic physical processes with processes of software and communications, providing abstraction and modeling, design and analysis for an integrated whole [12]. Such technology is based on several interconnected disciplines, i.e. embedded systems, computers, communications, software, and mechanical engineering. Technologies such as HTML5, JavaScript/ECMA Script in the context of Internet of Things provide the new possibilities in the field of the rehabilitation robotics platform development [13,14]. JavaScript/ECMA Script and HTML5 are becoming more valuable not only in the field of Internet programming but also in the hardware domain [15], blending into cyber-physical systems [13].

The wheelchair robotic platform presented in this paper has been designed in order to meet the following requirements:

- Control the movement of the wheelchair with speech recognition using available Web Speech Application Programming Interface (API) in the cloud.
- In addition to speech control, the control of the movements of a wheelchair should be possible wirelessly via a web-based GUI. Control should be made from anywhere as long as a local or internet connection is available.
- Control of the movement should be implemented in a web browser, mobile devices and other available devices such as SmartTV. The control should be possible in parallel, i.e. several controllers could be used at the same time in order to enable remote monitoring and control.
- Real time video streaming from the wheelchair platform should be provided in order to monitor and control the movements and ensure security.

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The developed platform should therefore also provide remote control for a tele-operated hospital transporter solution for patients. Since HTML5/JavaScript/ECMA Script technology will be applied, the wheelchair platform will also be suitable for the educational purposes.

2. System architecture

The proposed system was designed in order to benefit patients who cannot control their upper and lower extremities. Fig. 1 represents the overview of the system architecture. The main component of the system is a Mini ARM PC GK802 SOC i.MX 6 with a Quad-core CPU at 1.2 GHz Cortex-A9 running fully fledged Ubuntu Linux 12.04 [16]. A significant advantage of the Mini ARM PC is its integrated Wi-Fi. The Mini PC is connected to the Arduino UNO microcontroller [17] and a Logitech C210 video camera with 640 × 480 resolution. The input into the system is a smart device, e.g. a smartphone, which has become a ubiquitous device, incorporating a camera, a microphone and a speaker. The camera can be used to provide monitoring of movement, the speaker to provide the audio feedback of the wheelchair control system (WCS), while the microphone is available for speech control. One of the possible means of control is also using the touch screen with buttons for motion control. The smart device is connected to the WCS over the internet via a Wi-Fi router. In our case, the wireless functionality is provided by the LinkSys 54 WRT WiFi router with dd-WRT firmware installed, enabling smart device control. The Wi-Fi router is connected via Unshielded Twisted Pair (UTP) cable to the internet. This connection should be fast in order to provide quick access to the cloud-based speech recognition system. The command issued by speech or touch on the smart device is transmitted via Wi-Fi router to the Mini ARM PC and passed to the Arduino UNO Microcontroller. The priority of the voice and touch screen control is FIFO (First In First Out); in our case, both controllers are active in parallel, which is also convenient for assisting the movement of the wheelchair remotely. In the development phase, a monitor (HDMI link) as well as a USB keyboard and a USB mouse could be connected to the Mini PC. The Logitech C210 onboard mounted camera with 640 × 480 resolution is connected via USB to the Mini PC. To control the camera motion on the *z*-axis (up and down movement), a Hextronic HXT900 9GR Micro Servo is applied on the pan/tilt AI frame, driven by an Arduino UNO microcontroller PWM (Pulse Width Modulation). The Mini PC is connected to the Arduino UNO microcontroller [17] via USB. The DC Motor Controller is driven by Digital output (DIG) from the Arduino unit controlling both DC Motors. The wheelchair has a 24 V battery on board for powering its motors and electronics. The power for the Mini PC and Arduino Microcontroller comes from the batteries of the wheelchair over the voltage control providing +5 V. Regulated 5V is provided by a Pololu BEC (Battery Eliminator Circuit) Step-Down Voltage Regulator D15V35F5S3. In Fig. 1, the border that determines the parts of the system that are on wheels,

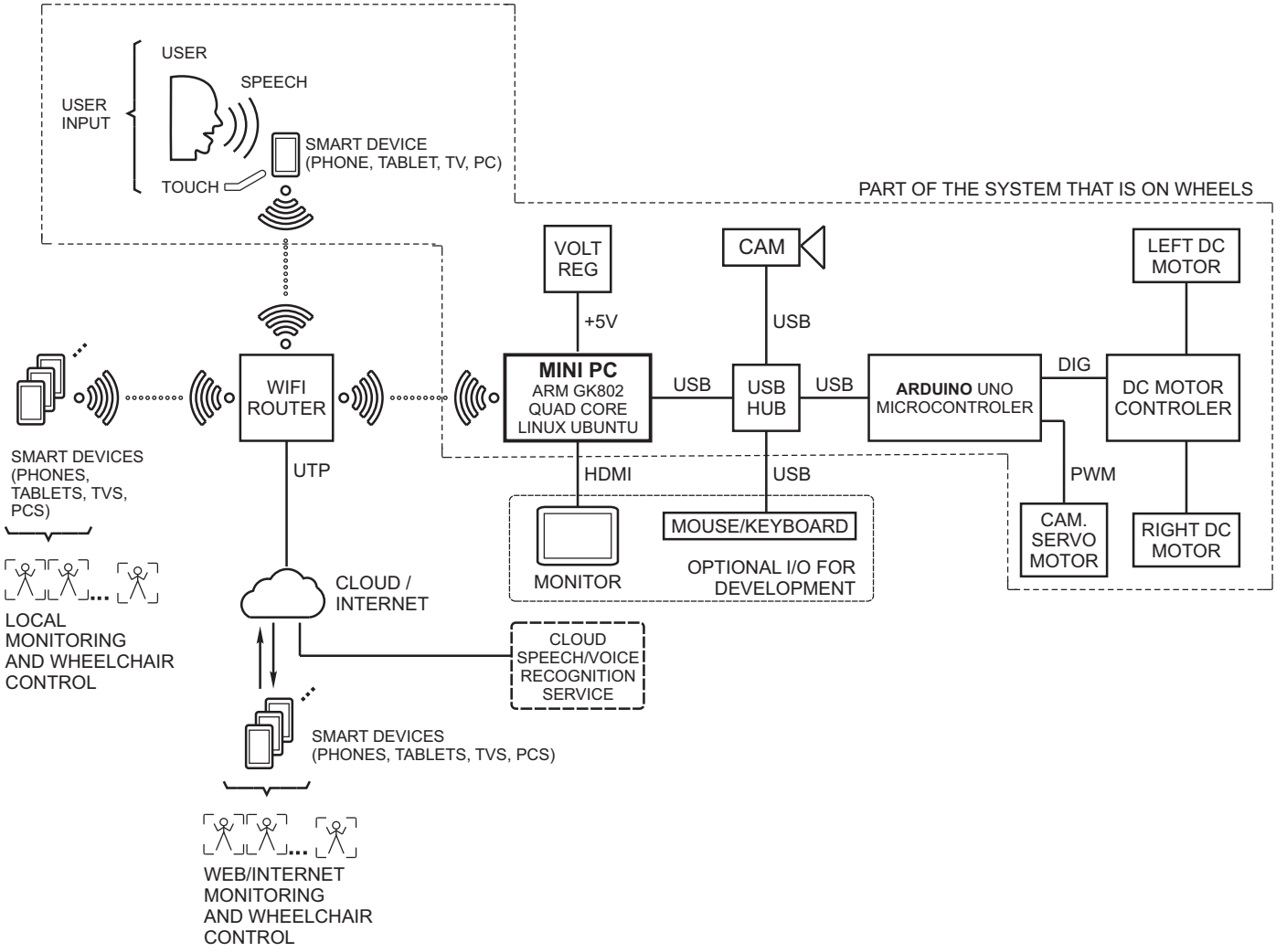

Fig. 1. Overview of the cloud speech-controlled wheelchair system architecture.