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Bio-compatible cyber-physical system for cloud-based customizable sensor monitoring of pressure conditions

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Abstract

The use of cloud computing for medical research is still in the beginning stages, which means there's much more progress to be made. As researchers become more familiar with the technology's advantages and capabilities, they'll be able to use it in more unique, innovative ways. Expect cloud computing to play a prominent role in many major medical breakthroughs in the future. This paper aims to study of a new design, implementation and validation of a cyber-physical system for the monitoring of stomatognathic system functioning comprising a platform grounded on cloud web services (MoSSy platform) for cognitive decision making based on advanced processing of signals from WiFi and biocompatible multiple sensors for the treatment of muscular-skeletal disorders.

Keywords: Cyber-physical system, cloud computing, clinical decision support

1. Introduction

This paper aims at designing, implementing and validating a cyber physical system (CPS) for the real time monitoring and analysis of diverse static and dynamic aspects during the functioning of the stomatognathic system. The main focus of the proposed paper relates to the understanding of the most important aspects of what happens in the oral cavity during physiological and non physiological tasks, before, during and after orthodontic treatments and how this could influence malocclusions, orofacial pain, masticatory muscles pain and respiratory problems, with the ultimate scope to support clinicians/researchers in their decision making process. To achieve these goals, a highly multidisciplinary approach based on established scientific expertise related to the stomatognathic system, advanced sensor monitoring techniques, cognitive decision making systems as well as a substantial knowledge of CPS and cloud computing (CC) paradigms. This body of knowledge can be achieved through the involvement of 2 Research Units of the University of Naples Federico II, the Dept. of Chemical, Materials and Industrial Production Eng. and the Dept. of Neuroscience, Reproductive Sciences & Stomatological Sciences which are able to provide complementary expertise in diverse fields: role of the muscles and articulation during functioning; etiology of malocclusion, temporomandibular disorders, respiratory problems and cephalea; multiple-sensor monitoring; knowledge based systems for decision making; CPS and CC.

The distinctive feature of this work is the study of a new design, implementation and validation of a CPS for the monitoring of stomatognathic system functioning comprising a platform grounded on cloud web services (MoSSy platform) for cognitive decision making based on advanced processing of signals from WiFi and biocompatible multiple sensors provided by customized monitoring systems applied to diverse clinical fields for the treatment of muscular-skeletal disorders that are associated with temporomandibular joint disorders, occlusal changes, and tooth loss.

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2. WiFi and biocompatible sensor system

2.1. State of the art

Measurement and sensor system solutions suitable to develop a CPS for monitoring and control of stomatognathic system functioning has to be identified. The sensor system solutions will be based on the characteristics of the signals to be detected and on their sensitivity to the functioning environment (oral cavity), and will be evaluated in terms of performance, cost, robustness, long term reliability and suitability for integration in the oral cavity.

Advances in Wireless Sensor Technologies (WST) are moving these technologies in a new phase with huge opportunities for research and development. This phenomenon is due to the decreasing costs of ownership, the engineering of increasingly smaller sensing devices and the achievements in radio frequency technology and digital circuits.

WST refers to Wireless Sensor Networks (WSN) and radio frequency identification (RFID) based sensor devices. WSN is one of the most valuable technologies of the latter century. RFID was developed for identification purposes, but growing interest in the many other possible applications has led to the development of a new range of wireless sensor devices based on RFID. The main difference between a WSN and a RFID system is that RFID devices have no cooperative capabilities, while WSN allow different network topologies and multihop communication.

Since 1980s there was an interest on WSNs but it is only since 2001 that WSNs has attracted a lot of attention from industrial and research perspectives. The increasing interest on this topic is bound to the availability of inexpensive, low powered miniature components like processors, radios and sensors that were often integrated on a single chip (system on a chip (SoC)). The miniaturization technology of WSN nodes based on microelectromechanical systems (MEMS) has made remarkable progress in recent years. The core technology of MEMS is to realize the combination of microelectronics technology, micromachining technology and the packaging technology. Different levels of 2D and 3D microsensitive structures can be produced based on microelectronics and micro-machining technology, which can be the miniature sensing elements. These miniature sensing elements, associated power supply and signal conditioning circuits can be integrated and packaged as a miniature MEMS sensor. At present, there are already many types of miniature MEMS sensors in the market which can be used to measure a variety of physical, chemical and biomass signals, including displacement, velocity, acceleration, pressure, stress, strain, sound, light, electricity, magnetism, heat, pH value, etc. Monitoring applications have been developed in medicine, agriculture, environment, military, machine/building, toys, motion tracking and many other fields. Architectures for sensor networks have been changing greatly over the last 50 years, wireless sensors decrease wiring needs, providing new opportunities for distributed-intelligence architectures [1-3].

WST allows MEMS to be integrated with signal conditioning and radio units to form "motes" – all for a low cost, a small size, and with low power requirements. Available MEMS include inertial, pressure, temperature, humidity, strain-gage, and various piezo and capacitive transducers for proximity, position, velocity, acceleration and vibration measurements [3]; and according to several research works, connecting wires to these devices can be more problematic than doing it by means of wireless designs [4,5].

Motes can form networks and co-operate according to various models and architectures. They came with miniaturized sensors mounted, that allow, in a small space (2.5 × 5 × 5cm), the gathering of data not only just about temperature, but also relative humidity, acceleration, shock and light [6].

Another advantage for wireless sensor devices is the feasibility of installation in places where cabling is impossible, such as large concrete structures [7] or embedded within the cargo, which brings their readings closer to the true in situ properties of perishable products [8].

Furthermore, smart sensors, which are created by combining sensing materials with integrated circuitry, are being considered for several biomedical applications such as a glucose level monitor or blood pressure monitors. These devices require the capability to communicate with an external computer system (base station) via a wireless interface. The limited power and computational capabilities of smart sensor based biological implants present research challenges in several aspects of wireless networking due to the need for having a bio-compatible, fault-tolerant, energy-efficient, and scalable design. Further, embedding these sensors in humans add additional requirements. For example, the wireless networking solutions should be ultra-safe and reliable, work trouble-free in different geographical locations (although implants are typically not expected to move; they shouldn't restrict the movements of their human host), and require minimal maintenance. This necessitates application-specific solutions which are vastly different from traditional solutions.

The recent development of high-performance microprocessors and novel sensing materials has stimulated great interest in the development of smart sensors physical, chemical, or biological sensors combined with integrated circuits. It is not uncommon to place multiple sensors on a single chip, with the integrated circuitry of the chip controlling all these sensors.

The many challenges for wireless communication with biomedical sensor networks that are unique or fundamentally different from other sensor network application domains. Although some subset of these requirements may be shared by other problem domains, the combination of these requirements makes wireless networking of biomedical sensors significantly different from other types of sensor networks. Due to their peculiarities WST both used in biomedical or industrial field show some challenges [9].

Firstly, the possible power restrictions and limited computation strongly associated to the necessity, above all in biomedical field, of small sensors that should not interfere with the normal day life of the subjects. Hence, without wires that could supply energy to the sensor and with small batteries also the possibility of computation is reduced.

Secondly, in biomedical field the material of the sensors must be biocompatible. Biocompatibility understood as the