Integrating Ontological Modelling, IoT and Humanoid Robotics for Motor Rehabilitation Systems

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Abstract

The difficulties of healthcare infrastructure, further highlighted by the Covid-19 pandemic, push to develop tailored and sustainable healthcare systems that exploit the integration of different methodologies and technologies. Here, we present projects I-TROPHYTS and SORTT which aim to develop an innovative framework for the real-time and semi-autonomous supervision of motor rehabilitation activities in dedicated facilities or at home. I-TROPHYTS leverages the use of ontological modelling, IoT communications and humanoid robotics to dispense with the physical presence of the physiotherapist. SORTT leverages on the use of ontological modelling and IoT to remotely monitor the rehabilitation activities of patients at home. The ontology-based modelling of the patient is central to control health and safety during the physiotherapy session, as well as to verify the quality of the patient's exercise execution. An important challenge in these projects is the integration and evaluation of individual qualities describing the human body state and the human body movements.

Keywords

Formal Ontology, Internet of Things, Rehabilitation, Humanoid Robotics, Human modeling, Smart Spaces

1. Introduction

The difficulties of healthcare infrastructure, further highlighted by the Covid-19 pandemic, push to develop tailored and sustainable healthcare systems that exploit new methodologies and technologies. We present the Italian MUR PRIN/PNRR research projects I-TROPHYTS (P20224TAETP) and SORTT (P2022H74YP) that aim to develop an innovative framework for the real-time and semi-autonomous supervision of motor rehabilitation activities in dedicated facilities or at home. I-TROPHYTS leverages on the use of ontological modelling, IoT communications and humanoid robotics to dispense with the physical presence of the physiotherapist. SORTT leverages on the use of ontological modelling and IoT to remotely monitor the rehabilitation activities of patients (either at home or in rehabilitation facilities), and give rise to a sort of digital twin of the subject. The ontology-based modelling of the patient is central to control health and safety during the physiotherapy session, as well as to verify the quality of the patient's exercise execution. An important challenge in these projects is the integration and evaluation of individual qualities describing the human body state and the human body movements. Details on the personnel, Units, Third Partners, tasks, and funding agencies are in continuous update on the websites https://site.unibo.it/itrophyts/en and https://www.loa.istc.cnr.it/sortt.

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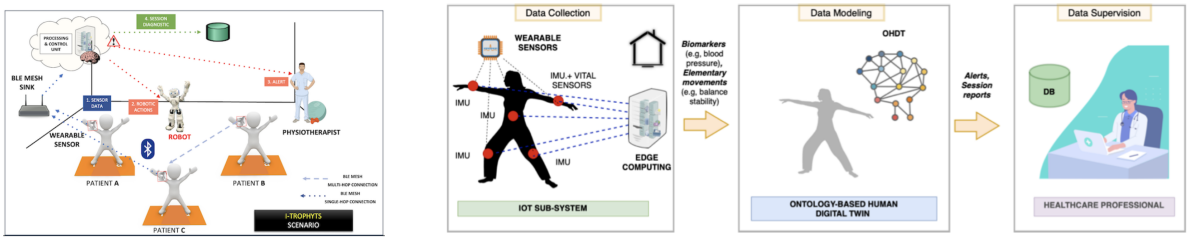

(a) (b)

Figure 1: (a) The I-TROPHYTS scenario; (b) the SORTT scenario.

2. Structure of the project, expected results, and current status

European Healthcare Systems are under pressure due to disorders related to ageing of the population, and spreading of unhealthy lifestyles. To face the problem, medical guidelines endorse preventive and/or adapted motor rehabilitation. Programs of this kind require specialised centres, and the constant presence of healthcare professionals, thus implying a large array of human professional resources, and their availability. Improvements in Human–Machine Interactions can provide alternative solutions to widen the access of patients with chronic disorders to motor rehabilitation programs, including type-2 diabetics (both obese and non-obese), pregnant women (both normal and diabetic), and individuals with Parkinson's disease. These patients would get advantages from balance, stretching, and posture routines. The I-TROPHYTS and SORTT projects investigate "intelligent" frameworks based on IoT solutions [1, 2] and ontological modelling [3, 4, 5] integrated in a robotic architecture. Healthcare professionals would be able to remotely track patients' motor performance and physiological parameters during rehabilitation sessions. By modelling heterogeneous information into a single ontological scaffold, adequate supervision and monitoring of the patient's health status is expected, and correct motor and cardiometabolic performance of the patients can be assessed. Also, in I-TROPHYTS, the use of humanoid robotics enters as a primary resource in the management of the rehabilitation programs [6, 7, 8]. As a result, patients are engaged in activities without the on-site presence of the healthcare professional (e.g. physiotherapist). The two research projects offer an homogeneous and partly shared bulk of technologies and aims including (i) a common approach to the physical performance (ii) a common funding agency (the Italian MUR/PRIN/PNRR); (iii) a common group of researchers; and (iv) solutions for health care problems typically involving families and social communities (I-TROPHYTS aiming at increasing the number of patients followed by a single medical professional; SORTT at involving patients that cannot reach medical facilities, see Fig. 1). The research framework is conceptually and operationally structured in three layers: (1) A sensing layer: the end-to-end IoT monitoring system for patients capturing both biometric and motor data via Bluetooth Mesh stack, leading to construction of dynamic multi-hop sensor networks within indoor scenarios; (2) A knowledge layer: a set of models for physical protocols and exercises, also comprising the ongoing patient's health status, quality of exercise execution, and history of patient's health; (3) A planning and actuation layer: the course of action based on the current state, goals, and preconditions. It includes the possibility to trigger alerts in response to potentially hazardous situations, and may involve humanoid robot's actions finalised to obtain the best patient's response to the alert. The projects started in late 2023, last 2 years, involve researchers with expertise in formal ontology, IoT, medicine, rehabilitation, and humanoid robotics. Current activities include: tuning the IoT system; selecting information for the ontological module; applying machine learning techniques to row sensors' data for generation of ontologically-meaningful information.

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