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Cutting-edge healthcare technologies for monitoring, care and coaching in elderly residential facilities: the perspective of the Italian project "Age-it"

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Summary:

An innovative healthcare ecosystem was developed to enhance care and coaching in elderly residential facilities. It integrates minimally invasive sensors, AI-based analysis and adaptive decision-making for continuous health tracking and early detection of conditions like falls or sarcopenia. Through vital signs monitoring and surface electromyography, the system enables personalized care, while high detection accuracy and Transfer Learning schemes ensure robust generalization in real-world settings. Scalable and workflow-compatible, it lays the groundwork for next-generation data-driven models in residential care facilities.

Keywords: healthcare, wearable sensors, transfer learning, fall detection, sarcopenia.

Motivation

Wearable and portable technologies enable continuous, non-invasive monitoring of physiological parameters, providing real-time health data such as heart rate (HR), respiratory rate (BR) and physical activity. When integrated into a connected ecosystem, this data benefits patients, healthcare professionals, caregivers and institutions. The work addresses the need to improve healthcare models in residential care facilities, where the aging population poses challenges in resource allocation and timely intervention. Traditional monitoring relies on manual data collection and reactive approaches, delaying interventions and increasing costs. A scalable cloud platform has been developed to collect and analyze data from heterogeneous wearable devices, offering real-time actionable insights. The platform supports timely interventions, reduces healthcare staff workload and promotes a proactive, data-driven approach to elderly care, improving diagnostic accuracy and optimizing healthcare resources.

Healthcare Ecosystem Overview

The proposed system (Fig.1) is a modular, cloud-based healthcare platform designed for continuous health monitoring. It integrates minimally invasive, wireless and low-power wearable devices, including the surface EMG device (FREEMG1000, BTS Bioengineering [1]), the Fitbit Versa 4 [2] for fall detection and the Samsung Galaxy A35 [3] for both vital signs estimation through remote photoplethysmographic paradigm (rPPG) and gateway capabilities.

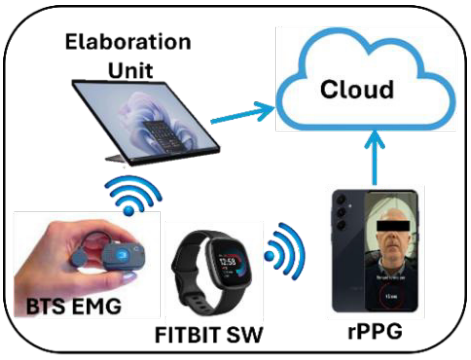

Fig. 1. Overview of the proposed healthcare ecosystem.

The platform aims to improve usability and efficiency compared to existing smart monitoring systems through a hardware-software-services ecosystem tailored for real-world deployment. Intelligent data fusion and hybrid edge/cloud processing ensure high-accuracy monitoring and early detection of health anomalies, even with consumer-grade sensors. The system focuses on detecting falls, anomalies in vital signs, postural imbalances, and early signs of sarcopenia. User-centered design guided the development of intuitive interfaces for both healthcare staff and caregivers. The system automatically generates alerts, daily summaries, and long-term

trend reports, enhancing responsiveness and overall care quality. High detection accuracy is achieved through an AI architecture with strong generalization capabilities via Transfer Learning (TL). Then, an intelligent decision support system (Combined deductiOn and abduCtiOn (COCO)) inspired by the cognitive theories of dual process was integrated into the platform, which, using automatic planning, generates personalised intervention plans based on expert knowledge and predefined objectives, while a reactive rules-based engine continuously adapts actions in response to real-time data. This dynamic feedback loop supports informed, flexible decision-making and personalized care strategies. Designed for scalability and seamless workflow integration, the system (see Fig. 2) offers a forward-looking, data-driven approach to elderly care enhancing monitoring, reducing staff burden and improving residents' well-being.

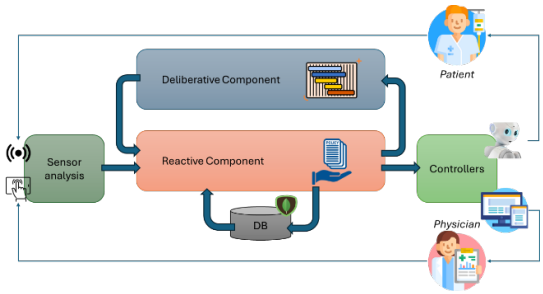

Fig. 2. Overview of the reasoning system.

Moreover, a field trial in a residential care facilities has recently been launched to evaluate the system's performance in a real-world elderly care setting. This study named "Multidomain Interventions to Improve the COgnitive and FUNctional Well-being of Elderly Individuals in Residential Structures" aims to evaluate the feasibility, acceptability and effects of a multidomain intervention for older adults in Long-Term Care Facilities. The intervention includes cognitive stimulation, physical activity, a Mediterranean diet enriched with functional foods, and vaccination recommendations. The sEMG protocol is validated against EWGSOP2 standards, including bioelectrical impedance analysis (BIA) and handgrip strength testing.

Results

This section briefly reports the performance of the three previously introduced technologies in controlled laboratory environments. Specifically, 20 participants were involved in rPPG. Each was equipped with ground truth instruments, allowing comparison with estimated HR, BR and SpO2 values from our system. To evaluate the performance of the system, Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) were used as metrics and, the obtained results are shown in Table 1, fixing the ambient light intensity (51-100 Lux) and the distance (20 cm) between the user and the smartphone camera.

Tab. 1: MAE and RMSE for rPPG system.

Metrics	HR	BR	SpO2
MAE	4.47	2.4	0.57
RMSE	7.83	4.11	0.95

Finally, for the sEMG platform, analyses were carried out on gait monitoring, for the early detection of abnormalities, such as toe walking. Different TL architectures were used to limit the problem of large training data for the CNN architecture. For brevity, the achieved results with the best tested architectures for fall detection (DenseNet201 (DN201)) and sEMG platform (InceptionResNetV2(IRNV2)) are reported in Table 2 considering Accuracy (Acc), Precision (Pr), Recall (Re) and F1-score (F1) as metrics.

Tab. 2: Performance of the fall detection (DN121) and normal/toe walking classification (IRNV2).

Model	Acc	Pr	Re	F1
DNet201	0.9756	0.9743	0.9674	0.9741
IRNV2	0.9525	0.9519	0.9440	0.9519

The achieved accuracies are comparable to the literature [4,5] for both fall detection and normal/toe walking classification, but with the advantage of a greater degree of generalization of the approach due to the use of TL and, consequently, greater adaptability in real-world contexts and without supervised learning technique that requires a large amount of labelled training data with the complexity to classify new data.

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