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Design of a Digital Twin of the Heart for the Management of Heart Failure Patients

Andrea SCOTTO[a,1], Noemi GIORDANO [a], Samanta ROSati [a] and Gabriella BALESTRA [a]
[a] *Department of Electronics and Telecommunication, Politecnico di Torino, Italy*
ORCiD ID: Andrea Scotto https://orcid.org/0000-0002-3317-3843
Noemi Giordano https://orcid.org/0000-0002-9265-6538
Samanta Rosati https://orcid.org/0000-0003-0620-594X
Gabriella Balestra https://orcid.org/0000-0003-2717-648X

Abstract. Heart failure poses a significant global health burden with high prevalence and mortality rates. A promising possibility in this context is the constant monitoring of the patients through telemedicine. The aim of this work is to present a digital twin of a patient at risk of heart failure. Applying machine learning to the recorded data of the patient, the system is able to early detect potential issues and improve the outcome.

Keywords. Digital Twin, personalized medicine, heart failure, telemedicine

1. Introduction

Heart failure (HF) is a complex clinical syndrome that results from any structural or functional impairment of ventricular filling or ejection of blood [1]. HF is associated with high morbidity, mortality [2] and hospital readmission rate [3]. In 2017 the estimated prevalence was around 64 million people worldwide [4], expected to grow even more due to overall aging of the population, thus, leading to more hospitalizations.

The Covid-19 pandemic resulted in a rapid-shift to "remote-by-default" healthcare, increasing interest in telemedicine. Its application in the HF context facilitates patients to rapidly access quality care when needed and minimizes the frequency of clinical visits [5], reducing the hospitalization rates.

Another emerging tool are digital twins, virtual replicas of a physical system that, constantly updates with real-time data, mimics its real-world counterpart.

The aim of this work is to present the main features of a Digital Twin, tailored to the characteristics of HF patients to remotely monitor them and improve their outcome.

2. The Digital Twin

In figure 1 the block diagram of the proposed Digital Twin (DT) is presented. The heart of the DT is a cloud, which stores the patient data captured either daily through wearable

[1] Corresponding Author: Andrea Scotto, Department of Electronics and Telecommunications, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino; E-mail: andrea.scotto@polito.it.

devices in a home environment, from clinical reports acquired during periodical visits or produced by the DT itself. On the top-left there is a coupled electro-mechanical (EM) model of the human heart, able to generate synchronous electrocardiograms (ECG) and phonocardiograms (PCG) based on the characteristics of the patients. Its role is to generate a theoretical ECG and each component of the associated acoustic signal to train a machine learning (ML) tool to automatically separate the two elements of each heart tone (i.e. M1 and T1 for the first tone and P2 and A2 for the second tone) from real PCGs. Eventually, the aim is to improve the accuracy in the detection of cardiac time intervals [6], proved to be associated with a worsening in the status of HF patients [7]. On the top right there is a second tool, which leverages ML algorithms to analyze the data collected in the cloud. Its aim is to forecast potential health issues, enabling preemptive measures to prevent hospital readmissions and adverse outcomes or to suggest if patients can be discharged successfully or not if they are already hospitalized. Another feature is the ability of the DT to send an alert whenever it detects a worsening in the condition of the patient, allowing the clinician to quickly react and help the patient.

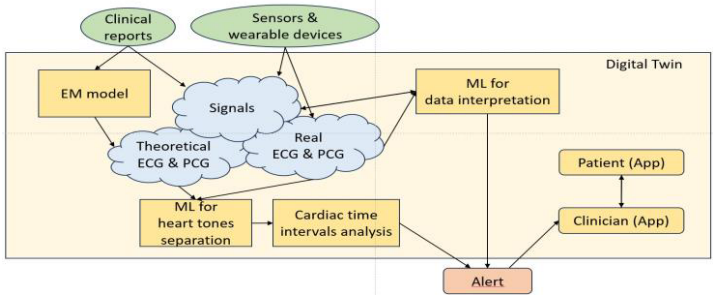

Figure 1. Block diagram of the Digital Twin.

3. Conclusions

In this work we introduce a Digital Twin. Its advantage is that it combines different tools to effectively monitor either at-risk patients or those who are already affected by the pathology to quickly detect a deterioration in their health and react promptly.

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