Mini-Symposia Title:

Telemedicine enabling person-centered telecare

Theme:

- ○ 01. Biomedical Signal Processing
- ○ 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/Nano-bioengineering; Cellular/Tissue Engineering &
- ○ 04. Computational Systems & Synthetic Biology; Multiscale modeling
- ◉ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ○ 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic & Diagnostic Systems and Technologies
- ○ 10. Biomedical & Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Mini-Symposia Organizer Name & Affiliation:

Natividad Martinez Madrid (Reutlingen University) and Ralf Seepold (HTWG Konstanz)

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Mini-Symposia Speaker Name & Affiliation 6:

Mini-Symposia Synopsis— Max 2000 Characters

Technologic evolution in telemedicine is driving the development of person-centered medicine in many domains. The next-generation telemedicine systems need to focus on both the users´ needs and requirements, as well as the telecare infrastructure available. The session will present telemedicine approaches tuned to different domains and showing how they are embedded in the locally available care infrastructure. As a result, a telecare service is offered tailored to a patient´s needs and applicable at his living place. The examples presented demonstrate working prototypes, well-connected to care-giving bodies in their (inter-)national environment. The session covers approaches from the domain of sleep medicine, cardiovascular monitoring, e.g., stress detection, rehabilitation, and more.

Each contribution describes his advance over state of the art, the applicability and implementation in a working context with patients, and the results obtained.

International telemedicine support for assisted living

Natividad Martínez Madrid, Reutlingen University (Germany) and Sechenov University (Russia)

***Abstract*— Assisted living support is one of the main challenges in active aging for many European countries. The approach presents results from a study taking into account the situation from Germany, Austria, and Switzerland. This study tries to identify and lower barriers for national and cross-border telemedicine and gathers experience from a patient´s point of view.**

I. INTRODUCTION

This work presents the goals, methodology, and preliminary results of a project running in the Lake Constance region (Germany, Austria, and Switzerland) [1] to design telemedicine services for older adults. Such regions are particularly challenging from the health service perspective because companies can offer cross-border health services (especially within the European Union), or it is also possible for older adults to live abroad. The telemedicine services concentrate on some health areas that can be implemented through AAL approaches. The selected systems provide monitoring of stress [2] and sleep [3], as well as in-home rehabilitation [4].

II. METHODS

The goal of the project is to develop a telemedicine platform for elder people concentrating stress, sleep, and rehabilitation management. One goal is to address the challenge of usability and user experience by selecting appropriate devices and processes for its usage. The second main goal is to design an integration platform to visualize the results for users and health caregivers, as well as to statistically analyze the correlations between stress, sleep quality, and physical activity. The project is divided into two phases. In the first phase, three devices for the different areas addressed in the project have been selected and installed in the homes of elderly test persons. The devices were selected according to their functional characteristics as well as usability requirements. For the first experimental phase, nine test persons were selected in the age group 75+, without relevant health problems, and with homes having the necessary infrastructure. The duration of the experiment was two weeks. The sleep measurements were completely non-intrusive. They were asked to do specific exercises on the trainer and to use the heart-rate measuring device during the day, as well as filling standard questionnaires. In parallel to the first experimental phase, the specification for the integration platform has been completed.

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III. PRELIMINARY RESULTS AND DISCUSSION

The data from the first experiment are still under analysis, but some preliminary results can be gathered. The usage of the sleep monitoring device was unproblematic, and the measurements were correctly taken. The usage of the therapeutic trainer was also according to plan, with few exceptions. One problem detected was the length of the questionnaires. Especially problematic was the use of the heart rate armband. The test persons complained that they were often unsure whether they were using it correctly. The only visual feedback that the measurement was appropriately running was through an LED in the armband. We found quite a large amount of missing measurements

IV. CONCLUSION

The use of telemedicine for older adults in home environments faces several challenges. Elder people using AAL technology still need considerable support close to their homes to help them use the devices and systems correctly. The real potential is obtained when data from different devices can be integrated. An effort should be made in open-source platforms and devices supporting the standard, plug&play-like integration, to be able to guarantee affordable and qualitative services.

The preliminary results show that the current elder generation is very conscious about their health and want to participate in keeping a good quality of life.

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Domestic care of children with autism spectrum disorders

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Abstract— **Autism spectrum disorders (ASD) in children are often diagnosed too late, and it is difficult to personalize the care for this chronic disease. The presented approach allows the treatment of children in a domestic environment and works out the relationship between sleep and ASD.**

I. INTRODUCTION

Children with Autism spectrum disorders (ASD) benefit from an early diagnosis because the treatment can start quickly. Furthermore, sleep disorders are often related to ASD. Sleep disturbances show prevalence rates of about 80% and more [1]. Children who have insomnia show a high correlation to deficits in social skills, emotions, and an increased aggression level.

II. METHODOLOGY

The development of medical care at home for ASD children will include pre-diagnosis support through interactive methods and tests. Telemedicine-based automated workplace for supervising doctors though special equipment of a doctor's workplace and a home diagnostic system.

The mentioned correlation between sleep quality and a children's status concerning ASD needs to be analyzed in more detail. Reports in literature are based mostly on parents' reports about their children's sleep. They can be clustered in the following sets: sleep-on set and insomnia [2], sleep disturbance [3], or even sleep-wake problems, morning awakening, and poor routines [4]. The sleep problems are associated with several consequences like sensory over-responsivity [5], self-injury [6], etc.

Contact persons suffer from sleep diseases as studies show that parents stress has a negative influence on children with ASD, and thus these effects sleep diseases even more. The introduction of sleep quality measurement based on objective measures is key to eliminate the subjective factor and thus produce a more reliable dataset on the sleep quality; therefore, one task is to develop a sleep quality measurement system (hard and software) to extract all relevant data in order to replace.

A dynamic video surveillance system will be developed for the recognition of the child's behavior using deep learning. VR offers unique benefits for children with ASD by simulating real-world situations in a carefully controlled and safe environment. Medical and psychological services will be formed to monitor the health, behavior, and social adaptation of a child with ASD. An information resource will be developed, accumulating the developed technologies and providing communication between the child, parents (guardians), medical and social workers, medical and social institutions. A register of medical information technologies will be created to improve the availability and quality of medical care and social adaptation of children with ASD, which is a single online service for collecting and analyzing medical information.

III. CONCLUSION

This approach provides at a holistic approach for a medical and psychological service integrated in a communication platforms for the different actors (children, parents, doctors, psychiatrists, social workers, teachers, etc.), as well as an information platform for the whole community..

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Patient-tailored solutions for diabetes management

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***Abstract*— Perceived usefulness and ease of use are the key factors to patient's adherence to any diabetes management system, from mHealth apps to artificial pancreas systems. In this work we present an integrated diabetes management system that allows the patient to tailor the system to his/her needs and preferences. Patients will choose the devices (insulin pump, continuous glucose monitor, smart insulin pens, physical activity monitors, blood pressure monitor, etc.) and the degree of interaction with the system, from fully automated blood glucose control to recommender and coaching systems.**

I. INTRODUCTION

Despite current treatments, the majority of subjects with type 1 diabetes cannot achieve recommended glucose goals to prevent acute and long-term complications. Individuals with T1D face a lifelong challenge to maintain blood glucose (BG) within a safe range by reducing hyperglycemia without provoking hypoglycemic events. Continuous glucose monitoring (CGM) systems provide glucose levels in real-time, allowing patients to perform specific actions when necessary. The combination of insulin pumps with CGM into sensor-augmented pump systems (SAP) translated to the first automation features in commercial SAP. In a next step towards automation, integration of closed-loop glucose control algorithms into SAP gave birth to hybrid closed-loop control systems (CLC), the so-called artificial pancreas (AP). There is still much room for improvement regarding patient safety and prevention of hypoglycemia. In addition, some of these technologies may not be suitable for all people affected by T1D, and the costs and reimbursement barriers are also an impediment to their dissemination.

II. PROPOSED SOLUTION

This proposed solution is based on the integration of artificial intelligence and the internet of things (IoT). It will connect the devices to store the generated data in a centralized and integrated way and provide a framework for the management of chronic diseases using prediction, prevention and classification tools through machine learning models and other advanced algorithms that will run in the cloud. The first practical application of the platform is diabetes management. The resulting system extends the results and benefits of the AP to MDI therapy using a smart insulin pen and CGM, that "closes the loop" automatically guiding patient's manual actions when needed for an improved glycemic control. The system allows patients to decide which devices to use: including insulin pump or insulin pen, continuous glucose monitor and/or physical activity monitor. The software package can be embedded into any diabetes management solution. It includes: (1) Hypoglycemia minimizing tools; (2) Exercise management tools; (3) Missed bolus detection and compensation. The system can be adapted for any pump and for MDI. It will also be compatible with any CGM currently in the market.

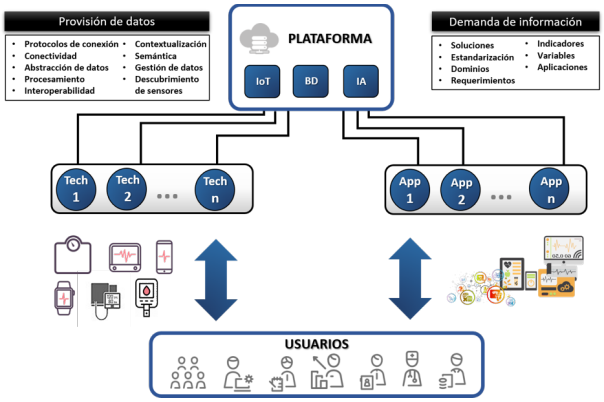

Figure 1. General scheme of the platform.

III. DISCUSSION & CONCLUSION

The proposed system is a disruptive technological novelty, including functionalities that doesn't exist in any other diabetes management system. The overall system covers the three main issues in diabetes management: hypoglycemia prevention, exercise management and missed meal management. Data mining allows the continuous monitoring of patient condition. The system addresses unmet needs in glycemic control in type 1 diabetes, and it will allow to advance towards patient-tailored solutions.

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Non-invasive ballistocardiography with accelerometric sensors placed under a mattress

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***Abstract*— The ballistocardiography is a technique that measures the heart rate from the mechanical vibrations of the body due to the heart movement. In this work a novel non-invasive device placed under the mattress of a bed that estimates the heart rate using the ballistocardiography.**

I. INTRODUCTION

The ballistocardiography is a technique that measures the heart rate from the mechanical vibrations of the body due to the heart movement. Many wearable devices used these techniques. Recent review papers in this field have been published [1-3]. Some non-invasive techniques use the ballistocardiography placing sensors in chair or in the bed where the patient is placed. Some of the commercially available devices are: SCA11H di MuRata tech. [4], QD+CLINICAL di EMFIT [5], BEDDIT [6]. They use accelerometric or piezoelectric sensors placed under the bed but they are mainly used it not used for apnea or sleep monitoring. The raw data are not available.

II. METHODS

This work presents a novel non-invasive device placed under the mattress of a bed that estimates the heart rate using the ballistocardiography. The low cost system developed is based on a single board Raspberry Pi 3B with Linux operating system and the low cost but accurate accelerometric sensor ADXL355Z of Analog Devices connected to the Raspberry with the SPI bus. The main features of ADXL355 are: ultra-low noise density 25 µg/√Hz; 20-bit analog-to-digital converter (ADC); maximum sensitivity 3.9µg/LSB at +/-2g; up to 4 KHz output data rate; programmable high- and low-pass digital filters. The Raspberry is able to store the data in its internal memory or send the data to PC via WiFi or a cloud storage system using a WiFi internet access point. The time synchronization is performed through an internet connection.

The sampling rate has been fixed to 50 Hz, enough for the bandwidth of the heart signal. The signal processing for the estimation of the heart rate from the accelerometric signal is performed in real time on the Raspberry using a python code. The ADXL355Z has been placed on the structure of the bed under the mattress, as shown in Figure 1. Structure of the bed and mattress are common ones available in IKEA. Different processing algorithms have been used based on autocorrelation or convolution with a reference signal. Figure 2 reports an example of the results obtained: the acceleration signal coming from the ADXL355Z, the convolution of the normalized acceleration signal with a pattern signal representing the QRS signal and the estimated heart rate period (sample/beat). The sample period is 20ms. The results have been compared in time interval of 30s with the wearable Huawei Watch CLassic: mean HR: 77.59 (our) 78 (Huawei).

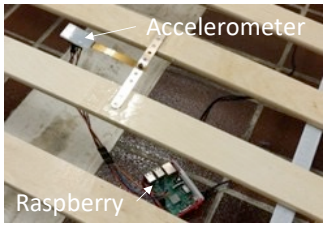

Figure 1. Position of the accelerometer under the matress.

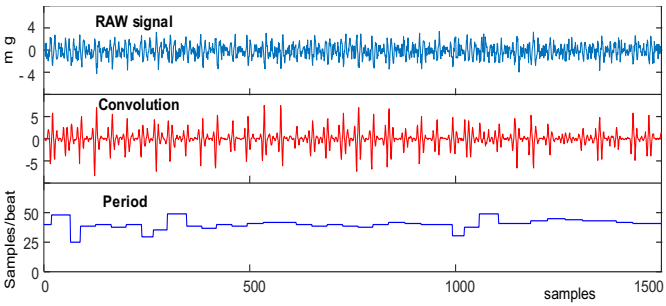

Figure 2. Example of a figure caption.

III. DISCUSSION & CONCLUSION

The system developed allows the estimation of the heart rate using a low-cost non-invasive device placed under a common mattress of a common bed. Preliminary results show good agreement with commercial devices that measure the heart rate. New experimental results are under development with a comparison with electrocardiogram signal in order to have a statistically relevant results and improve the processing algorithm.

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Research on the evolution of digital twins in healthcare

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***Abstract*— Digital Twins is a very promising technique, as well as an ongoing research topic, imported from the Industry domain in order to develop Personalized Healthcare around the behavior of either patients' disease or users' health profile. The objective of this paper is to present and discuss the advances in this important topic, Digital Twins, in the generation of knowledge. We advocate that this paper will proportionate an important state of art about this topic related to healthcare domain.**

I. INTRODUCTION

In this paper, a proposal to orchestrate an ecosystem of manipulation of reliable and safe data, applied to the field of health, is introduced by proposing the creation of digital twins for personalized healthcare [1]. Digital twin are defined as a digital representation of an entity, including attributes and behaviors, sufficient to meet the requirements of a set of use cases. In this context, the entity in the definition of digital representation are patients instead of an asset, process or system.

The elements to be considered are: (1) *Data privacy for ethical issues*. Medical data in health services need to comply to privacy and legal issues. However, an accurate diagnosis will depend on the quantity and quality of the information about a patient. Anonymization can mitigate the risks of obtaining and massively processing personal data [2]. We propose an initial GAN-based anonymization [3] phase. (2) *Knowledge generation in the health domain.* One of the most important advantages of digital twins is to test decision in a simulated real" environment to check how the simulated environment behaves or obtain some kind of feedback about how good the decision was. Hence a bidirectional communication is established between medical doctors and data analysts in a lifelong learning system. (3) *Lifelong learning*. We model the behavior of diseases in patients by continuous learning and reshaping the behavioral model. (4) *General purpose service.* The complete system should be designed as a general purpose service to be used in multiple domains.

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II. OUR APPROACH

The approach of this project focuses on:

• Digital twins will contain computational or analytic models to describe, understand and predict the real disease of the patient, its operational states and behaviors, as well as models to prescribe actions based on medical. Generative Adversarial Networks on health data information will allow both, anonymizing data and generating fake patients that health professionals can use to study more on the disease.

• Behavioral models allows both experimenting new health treatments with simulated `real' patients and extracting knowledge from regular data science research to be implemented in the form of a decision support system.

• A decision support system developed in a bidirectional form would allow both, a dyadic dialogue between health professionals and data scientists in order to work in a lifelong learning paradigm and to drive to an AI explainable system able to generate decision rules.

III. DISCUSSION & CONCLUSION

The proposed architecture aims to provide a clinical information integration model in the form of a digital twin of the behavior of some diseases in patients under treatment.
Data from patients will be approached from a novel perspective, the GAN machines, allows a complete anonymization of health records. Interpretable models will be obtained that will lead to the generation of `fake' patients serving as both, training patients for novel doctors and a source of new insights about the disease for expert doctors.

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