Tagung

Smart-Future-Living-Bodensee

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A review of health monitoring systems using sensors on bed or cushion

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Abstract— How technology can answer the challenge that currently population ageing is facing to the healthcare system? In this work, systems and devices related to “smart bed” and cushion, that are commercially available or matter of research works, are reviewed.

Keywords—smart bed; smart cushion; population ageing; smart-care.

I. INTRODUCTION

European people are living a longer and healthier life. The rapidly growing of the elderly population is also happening together a reduction in fertility rates that poses great challenge to the social protection systems in Europe [1].

Here we are most interest to the challenges that the population ageing is bringing up to the health care and long-term care programs in Europe. This is also a main focus of Horizon 2020 program, from the exact words of the Commissioner for Research, Innovation and Science, European Commission, Máire Geoghegan-Quinn: “Hundreds of millions of euros have been invested over recent years in health-related ageing research, neurodegenerative diseases, including Alzheimer’s, as well as in socioeconomic dimensions of ageing. The challenge-based approach of Horizon 2020 — the EU’s new programme for research and innovation — fits perfectly with the pressing need to address issues resulting from demographic change and ageing.” [1]. Then she concluded how it is important to “ensure the good quality of life and well-being of the elderly” [1].

While the prevision in [2] say that in 2015, in the whole Europe the over-60 population would be the 23.9% and will increase to 29.6% in 2030, from Fig. 1 we can see that in 2014 in Italy and Germany this percentage was just over the 30%.

Together to this world changing we witness the continuous progress of technology. Can these two facts combine to give some effective solutions for care? Does technology answer to the request for good quality of life and well-being of the elderly?

In this work, we will face these questions by making a review of commercial systems and components related to “smart” bed and cushion. Then a review of recently research works on the same topic will follow.

II. COMMERCIAL DEVICES

A. Novel pliance-HS

The Novel pliance-HS system [3] provides a dynamic quantification of the sitting pressure points of patients in wheelchairs. The system helps in selecting the appropriate cushions and correct adjustments of the wheelchair to fit the individual patient. It functions with Bluetooth® wireless telemetry systems in a wide measurement range.

Connects up to 1024 sensors to a desktop, notebook or handheld Pocket PC. Collected data can be stored on the
internal flash memory or transmitted via Bluetooth® telemetry. Although its high spatial resolution and advanced characteristic it is not meant to be used for a daily use as an anti-decubitus system. Fig. 2 shows a picture of the sensors part of the system.

Fig. 2. Novel pliance-HS. SOURCE: [3].

B. EMFIT SafeBed

1) Emfit Safebed

The Emfit Safebed [4] is a bed occupancy monitoring system for fall and wandering prevention. It consists of a monitor device and an under-mattress bed sensor, operates as a fall or bed exit monitor and monitors the presence or absence of a person in bed by detecting all the person's movements and micro movements, such as those caused by a person's heart beating.

The bed sensor uses Emfit’s patented, thin-film ferro-electret technology (Electroactive Polymer) and it is installed under the mattress. The monitor has an audible notification with adjustable volume and a dry-contact output for connection to nurse call systems or personal emergency phones.

Fig. 3 shows the Emfit Safebed system.

Fig. 3. The Emfit Safebed. SOURCE: [4].

2) Safebed with sleep tracking.

Emfit Safebed QS [5] is a health and wellness tracker designed with seniors' additional safety needs in mind. It improves the safety of seniors and helps maintain their independence, enabling them to live on their own for a longer time. Like in Safebed, a highly durable sensor is simply installed underneath the mattress and paired with Wi-Fi. Safebed tracks sleep quality and quantity, heart and breathing rates, and even heart rate variability. Changes in long-term trends can give very valuable information about health and wellbeing. It is provided in three different version, aimed respectively to improve the performances of sport amateurs or professionals, for assisted living & nursing homes, and as a clinical tool in sleep research studies. Fig. 4 shows an Emfit Safebed QS system.

Fig. 4. Emfit Safebed QS. SOURCE: [5].

C. Murata Contactless Bed Sensor SCA11H

It is a device aimed to patient monitoring and elderly care in hospitals, assisted living and even at homes. The signal processing of heart and respiration rate and beat-to-beat time enables patient monitoring from bed occupancy to condition quality analysis.

Fig. 5. Murata Contactless Bed Sensor. SOURCE: [6].

The balistocardiography (BCG) technology [6] allows to output vital signs and bed occupancy information such as: Heart rate, Respiration rate, Heart rate variability (correlates to stress level), Relative stroke volume (how much blood the heart pumps), Bed status indicator (is the bed empty, is patient in bed, is patient moving in bed).

The product is not meant for sale to the end user but is targeted for software solution- and service providers and OEM system integrators. Fig. 5 shows the Murata device.
D. Early sense

Early sense system [7] was designed with the aim to provide continuous patient monitoring by mean if the measurements of heart rate, respiratory rate and motion of a patient in bed. These data potentially allow the clinical team to manage fall prevention, patient health state and pressure ulcers prevention.

The system has been developed specifically for medical surgical, general care patients who are usually monitored by nurses once every four to six hours. Skilled nursing facilities are emerging as important centres of care and attention for elderly people. All data came from a sensing plate with an integrated piezo-electric sensor that is easily placed under the mattress. Utilizing a piezoelectric technology integrated into a membrane plate, the sensor detects mechanical vibrations of the heart cardio ballistic (motion) effect, respiratory and patient motion. The signal is sent to a bedside monitor.

The positioning of the sensing plate it is shown in Fig. 6, while Fig. 7 shows a detailed view of the sensing plate itself.

Table I summary the main features of the reviewed systems, highlighting the measured quantity and the type of sensor used for. In the last column are also summarized the main application topics of each device.

![Fig. 6. Positioning of the Early sense sensing plate. SOURCE: [7].](image)

![Fig. 7. A Detail of the Early sense sensing plate. SOURCE: [7].](image)

### TABLE I. SUMMARY OF COMMERCIAL DEVICES.

| Device               | Quantity     | Sensor                  | Application                          |
|----------------------|--------------|-------------------------|--------------------------------------|
| Novel pliance-HS     | pressure     | capacitive transducer   | Cushion selection; wheelchair-personalization |
| Emfit safebed        | pressure     | quasi-piezoelectric     | Bed occupancy; sleep tracking         |
| Murata bed sensor    | Ballistocardiography (acceleration) | MEMS | HR, HRV, BR, RSV, measurements; bed occupancy |
| Early sense          | Ballistocardiography (acceleration) | piezoelectric | HR, BR, Motion; fall and pressure ulcers prevention |

III. RESEARCH WORKS

The reviews papers are recent papers on smart bed and cushion published in international journal or conferences. They present sensors, systems and also methodology to improve system performances.

In Table II to each of the two research topics, smart bed or cushion, are assigned the corresponding references that are dealing with. We can see that there is an overwhelming presence of works about cushion among scientific literature, reflecting the fact that the commercial systems mainly are devoted to the smart bed.

Table III summarizes the results about the main aims of the research of each work. We can see that six works are devoted to sleep tracking, a topic still of interest especially regarding the correct matching between measurements and signal features extracted from measurements and the correct sleep phases. Always from Table III we can see that only one research work is devoted to bed fall detection, a topic currently covered by many commercial systems. Five works are devoted to the crucial problem for bedridden or wheelchair-bound people of pressure ulcer prevention. This is still an open and challenging topic. Six among the reviews papers are devoted to a topic that is gaining more and more attention that is the posture tracking. Finally, we can find five works generally devoted to the monitoring of vital signs.

### TABLE II. SUMMARY OF DIFFERENT RESEARCH TOPICS OF RESEARCH WORKS LISTED IN REFERENCES.

| Research topic | Smart bed | Smart cushion |
|----------------|-----------|---------------|
| 9, 11, 24, 27, 28, 29, 30, 31 | 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 |

### TABLE III. MAIN AIMS OF RESEARCH WORKS LISTED IN REFERENCES.

| Aim of the research | 11, 27, 28, 29, 30, 31 |
|---------------------|-----------------------|
| sleep tracking      | 10                    |
| fall detection      | 12, 14, 15, 18, 20    |
| ulcer prevention    | 8, 13, 16, 19, 21, 23 |
| posture tracking    | 10, 21, 22, 27, 28    |
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