A design and application of unobtrusive sensor system to support incontinence care of elderly nursing homes

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Abstract:

Patients in long-term care facilities often suffer from incontinence. Elderly people are burdened physically and mentally, but so are caretakers, who have to deal with an increased task. In order to alleviate the burden of caring for someone with incontinence, there are a variety of technological solutions available. Because of this, these systems are too expensive. Residents of nursing homes complain about the inconvenience of these facilities. To find a solution to address these issues, we've developed an attached sensor system.to a mattress equipped with incontinence detection and monitoring technology events. Bluetooth Low Energy and Influx DB were used to create a prototype. Using the sensor data, may be accessed by other systems in real-time so that it may be put through even more checks. There will be more safeguards in the future energy measurements and other components may be used to create the system is completely relocatable.

Keywords – Bluetooth Low Energy, incontinence, Grafana, InfluxDB, sensor system

I. INTRODUCTION:

More than half of the residents in nursing homes suffer from some form of incontinence, whether it be urinary or faecal. Elderly people with incontinence need to be taken to the bathroom on a frequent basis for incontinence management. Caregiver checks are often done too early or too late, leading to incontinence material being replaced too early or too late. As a result, residents suffer, and caregivers are burdened with extra labour [1], [2]. Incontinence occurrences account for 20% of the time spent on caring throughout the daytime [3]. As a result of current methods, not only are nursing homes dealing with more patients, but they are also having to pay more money.

In order to address these issues, a system that is both comfortable for the patient and capable of measuring parameters related to incontinence must be developed.

Sensors on the bed and in the room are used to showcase a novel sensor system for measuring incontinence-related metrics in an unobtrusive manner. A fast prototype was made utilising widely available components. As a starting point, we believe that incontinence incidents may be recognised by comparing temperature, humidity, and ammonia (NH3) concentrations surrounding the bed and in the room.

Below is a breakdown of the rest of this document: The shortcomings of today's cutting-edge systems are examined in Section II. Sensor technology is discussed in Section III. In this case, sensors are discreetly integrated into the room and the bed. Using Bluetooth Low Energy and off-the-shelf sensors, an example sensor system is shown in Section IV. Hardware and software components are included in this category. Sensor data may be retained and exported for further analysis in Section V. In Sections VI and VII, further research and conclusions are made.

II. BACKGROUND

In most modern systems, sensors implanted in incontinence products are used. These have a number of drawbacks [4]. Nursing home patients frequently complain that these items are too intrusive and unpleasant for them to use. Adding these sensors also raises the price of the incontinence product. This is compounded by the fact that the embedded sensors can only measure for a limited period of time and may not be monitored in real time. Instead, a urinary diary is used to keep track of a person's progress. This means that health care workers are unable to respond quickly when required. As a result, they put people on the toilet at certain periods based on information obtained over a short period of time, such as 72 hours. Because of the disparate nature of the systems' software, it is almost difficult for them to communicate with one another, for example, a nurse call system. The cost of this programme is also included. Connecting them to nurse call systems would allow for the suggestion of patients to be communicated directly to medical workers, saving them from learning and using a new system.

By combining sensors on the bed and sensors throughout the room, we want to create a new sensor system for use in nursing homes, one that is both interoperable and inconspicuous to nursing home residents with urine incontinence.

III. PROPOSED SYSTEM

A new sensor system is required to address the issues outlined in Section II. Figure 1 depicts a high-level representation of the proposed sensor system. Here is a rendering of a nursing home room with sensors installed around the space, even on the bed itself. To continue processing, the data is sent to a server through a gateway.

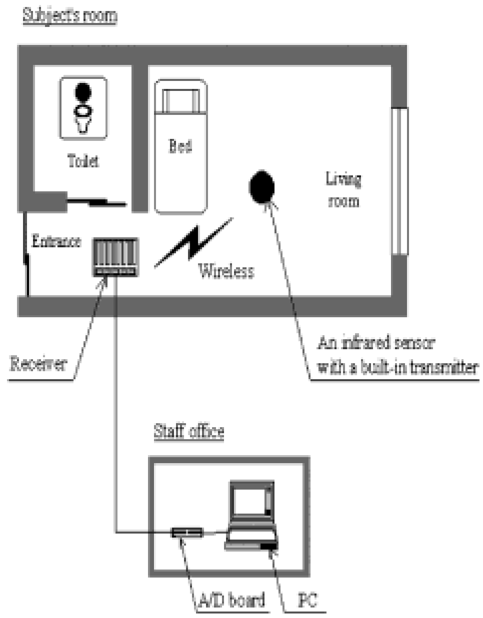

Figure 1. A room at a nursing home with the planned sensor system

Sensors may be built into the mattress or attached to the side of the bed. Detecting incontinence incidents may be achievable by integrating and comparing sensor readings from the bed itself and the surrounding environment. When an incontinence occurrence occurs, caregivers might be alerted to the situation. It is also cheaper than other systems since the sensors only need to be bought once, reducing the burden on carers. Sensors may be easily incorporated into the bed, making them less disruptive to nursing home residents.

The raw sensor data is saved on a server in a time-based database for processing. As a result, all sensor data must be sent to the gateway, which then delivers the data to the database with the appropriate information. Extraction, visualisation, and processing of this data are all possible.

IV. SENSOR SYSTEM

The sensor system that has been suggested has already had a prototype produced. It is possible to collect data from patients at a nursing home. A simple attachment to a bed is all that is needed to test this device. It was built from commercially available parts in order to speed up the prototype process.

A. Sensor selection

Commercially available sensors were utilised to create a sensor system mounted to the bed. Click boards are breakout boards from MikroElektronica that employ the mikroBUSTM standard for its sensors.To rapidly prototype and develop a test system, this open standard lets you link the click board into the click shield without having to design a bespoke printed circuit board. A wide range of sensors may be connected to the mikroBUS standard, which supports a wide range of communication protocols. Here are the sensors that were used and why they were selected.

The Weather click is the first sensor to be introduced. The Bosch Sensortec BME280 environmental sensor is at the heart of this board's design. In addition to humidity and pressure, the sensor can also monitor temperature and humidity (+/-0.3% rh).It is feasible to detect changes in an incontinence episode by taking temperature and humidity measurements near to the bed and comparing them to ambient values.

Second temperature and humidity sensor, the Temp&Hum 2 click, is installed and may be used to monitor environmental data just close to the mattress. Silicon Labs' Si7034 sensor powers it. Moisture content (+/-4% rh) and temperature (+/-0.4°C) may both be measured by this device.

Additional sensors include the Accel 5 click, which collects data from the accelerometer in all three directions (x,y,z). The sensor used for this is the Bosh Sensortec BMA400 low power triaxial accelerometer. It is possible to observe when the patient gets out of bed, enters the bed, or leaves the bed by attaching this to the mattress. It's possible that a resident's pain is one reason for moving.

The Air quality 5 click sensor is the system's last piece of hardware. Using a MiCS-6814, three MOS sensors are integrated into this sensor board. All of these sensors are sensitive to certain gases. Various gases may be measured using these sensors. Carbon monoxide (CO), nitrogen dioxide (NO2), ethanol (C2H5OH), hydrogen (H2), ammonia (NH3), methane (CH4), propane (C3H8), and butane (C3H10) are some examples (C4H10). An incontinence sensor may be connected to the patient's bedside in order to detect gases. Incontinence episodes may be detected in the air using an NH3 dilution process, which was previously shown. In these studies, sensors like the commercially available MICS-6814 were shown to be capable of measuring NH3 concentrations that are comparable to urine's NH3 content [5]. The usual concentration ranges from 6 to 47 ppm. Custom boards with the same layout were made to measure minuscule changes in gas composition. The design has a 16-bit A/D converter instead of a 12-bit one. This improves the precision even more.

B. Bluetooth Low Energy (BLE)

Bluetooth low energy (BLE) was utilised to create a portable system that allows sensors to be added to the bed. As part of the Bluetooth standard stack with the release of Bluetooth 4.0 is the Bluetooth SIG's BLE technology. If you're looking for an energy-efficient device, this is the one for you! In this scenario, the "just works" connection is employed.

Connecting two devices is now easier since no security key has to be entered before they can be used together, Using Generic Attribute Profile (GATT) transactions, BLE devices may exchange data. Client-server model: GATT-server holds data and GATT-client may request particular data from the server based on the transaction type. Services, a term used to describe a collection of distinct features, are used to categorise this information. There is a single globally distinct identification for each service and attribute (UUID). Some of these services are established in the Bluetooth standard and may be addressed using 16-bit UUIDs. The Heart Rate Service (0x180D) features a feature called Heart Rate Measurement as an example of a predefined service (0x2A37).

You may create your own unique Bluetooth features and services that don't appear in the Bluetooth standard for your own personal usage. Using a 128-bit UUID, they may be categorised. As a GATT-server peripheral, a sensor might provide a variety of capabilities and services. In order to receive the data, a GATT-client must be installed on a gateway (central).

The microcontroller in this device is a nRF52840 chip. The Nordic Semiconductors chip includes a variety of ways to transmit wirelessly. Bluetooth 5, Thread, and Zigbee are all supported by its multiprotocol system on chip. This implies that data may be sent and received using the eco-friendly Bluetooth low energy standard.

The nRF52840 chip is housed in a nRF52 Development Kit. The configuration of this board is comparable to that of an Arduino Uno board, which is a benefit. Arduino Uno shields may now be attached to the board using this feature. The Arduino Uno Click Shield is available from MikroElektronika. This shield can hold all of the click boards. Many click sensors may be found connected to this kind of development kit, as seen in Figure 2.

Figure.2. Image of nRF52 measuring equipment with click sensor

The nRF sensor board's expandability and power control are made easier with Zephyr RTOS. In addition to Intel, NXP, Texas Instruments, and Nordic Semiconductor, it is an open source Real Time Operating System [6]. It is because Nordic Semiconductor is actively involved in the Bluetooth stack that Zephyr is picked above other Real-time operating system options. Additionally, drivers for SPI, UART, CAN/I2C, and more are included. As a result, the Click sensor drivers may be easily integrated.

A special BLE GATT service, the Bed Service, has been developed to deliver data via Bluetooth Low Energy. f364adc9-00b0-4240-ba50- 05ca45bf8abc is the UUID assigned to this service. This is a 128-bit UUID created at random.

For each of the click boards, the service base address is used to generate a unique identifier (UUID) for each board. The 'XX' bytes represent a sensor board's particular code. It's shown in Table 1 that every characteristic code has a matching MikroE sensor.

TABLE 1. CHARACTER CODES LIST

Characteristic code	Corresponding click sensor
0x01	Weather
0x02	Accelerometer 5
0x03	Air quality 5
0x04	Temp & hum 2

There are permissions in place for all of the attributes to be read or alerted. A client may subscribe to a feature if it performs a notify action. The sensor provides a notification to the client who has subscribed to it when that characteristic changes.

There is a requirement for a gateway since the sensor does not have direct internet connectivity. As a room gateway, a Raspberry Pi is used. To connect to the Bed sensor, a BLE central is built on the Raspberry Pi. The central will scan for advertising BLE peripherals, while the Bed sensor will begin advertising. Afterwards, the Raspberry Pi will attempt to establish communication with the Bed device. After the connection is formed the

Raspberry Pi will subscribe to all the characteristics in the bed service. A notice is sent to the Raspberry Pi central every time a value on the peripheral side is modified. An InfluxDB database gets notified every time this notification is received.

V. DATA STORAGE AND USAGE

Data must be saved in a database before it can be analysed.The use of a time series database, such as InfluxDB [7], is necessary since the data must be taken into account throughout the course of time. Open source time series database that can store enormous volumes of data in real-time with their accompanying timestamps is available.

An open source library is used to deliver data to the InfluxDB data storage. The gateway will use this library to transfer data received over BLE to the InfluxDB datastore. When the data is imported, it produces a timestamp automatically.

To do data analysis, it is necessary to see and export all of the data. For this, we'll be using Grafana [8], an open source data visualisation tool. Using Grafana's tight connection with InfluxDB, you can see all of the data saved in the InfluxDB datastore.

VI. FUTURE WORK

There is currently a power source for all of the sensors and the microcontrollers. We need to know how much energy a sensor system uses in order to make future sensor systems more portable. In order to save battery life and lessen the load on the network, it will be necessary to conduct data aggregation given that only raw data is transferred.

Because the sensors were transmitting biological data, they needed to be secure. However, under the existing system, there has been no addition of security. Authentic and private data must be sent to the server in a secure way at all times.

For the time being, the data is merely being kept and shown. Incontinence occurrences may still be detected and perhaps predicted using machine learning utilising that data. Additional BLE-enabled sensors may be added to a room or a bed to collect additional data if necessary.

VII. CONCLUSION

An inconspicuous method of supporting continence care has been explored in this research. In the first place, we've explained why a sensor system is necessary. Present-day tactics are often pricey, intrusive, and unpleasant for nursing home patients. Using sensors placed in the bed or connected to the mattress, we then presented a system that could detect incontinence incidents without being intrusive.

Next, a sensor system that can be connected to a bed was shown using commercially available components. Sensors may be quickly and affordably added by using a Bluetooth Low Energy microcontroller. All sensors in a single room are connected to a single gateway, which then sends the data to a server for further processing. This is where the data is kept in order to be used in the future.

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