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Cost Effective Immersive Room with Pressure Sensing Floor

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Abstract

This paper proposes the architecture of a pressure sensing floor divided in rigid tiles. The system is based on a network of flexible pad pressure sensors, used under all tile corners, connected to special local data acquisition circuits. Signals captured by the sensor units are transmitted to a system controller that process, display and store the information received. The proposed architecture was applied in an interactive room with a 64 tiles floor, providing a network weight measuring system that allows detecting, recording and tracking the movement of objects or people over the sensitive area.

The scalable modular network architecture allows the development of cost effective pressure sensing applications in several environments and sensing areas.

Keywords: Weight measuring network; pressure sensitive pads; detection of object movement; interactive rooms.

1. Introduction

In interactive room design several scanning technologies can be used to detect people or object movement, namely those using: laser and ultrasonic waves [0], radiofrequency [2], computer vision and radiofrequency [3], etc.

Some of these localization technologies require that the user needs to carry an identifiable badge (mobile node). By measuring the distance to anchored nodes (with known position) the user position can be obtained by triangulation.

Localization systems based on computer vision are sensitive to ambient light changes and usually require high ceiling rooms in order to have a good perspective of the room.

Floor weight sensitive systems present other problems such as portability and adaptability [0 - 0]. However, they can be considered as hidden user interfaces, since they free the user from having to carry any mobile node (badge).

To accurately track an object or person, inside a room, it may be necessary to use distance information gathered from several different measuring methods.

In this paper we present a network weight measuring system that provides weight distribution inside a room with a floating floor made by rigid tiles. It can be use to detect, record and track people or object movement over the sensitive area. This system is based on a grid of 256 sensors distributed by 64 tiles (8x8 array) each one measuring 60 cm by 60 cm.

Our system is organized as a wired network of modular acquisition and computational units that communicate wirelessly with a computer. In our approach we don't need to control the system timing, creating a more easily expandable system comparatively to already known solutions [0, 5]. Other alternative proposals for sensitive floors are known [0 - 0] but they envisage high resolution weight sensing applications and as a consequence are very expensive.

2. System Architecture

The architecture of the proposed system is scalable and highly modular allowing the design of applications simple to implement, Fig. 1.

The floor area is divided into sections independently controlled by a fixed node (FN) implemented with a microcontroller. The system network (SN) interconnects the system controller (SC) and all the fixed nodes (FN). Each fixed node gathers the data from the Sensors Pads (SP) accessed through the Pad Concentrators (PC). The connection between the pad concentrators and the fixed nodes within a section is done through a local bus (LB).

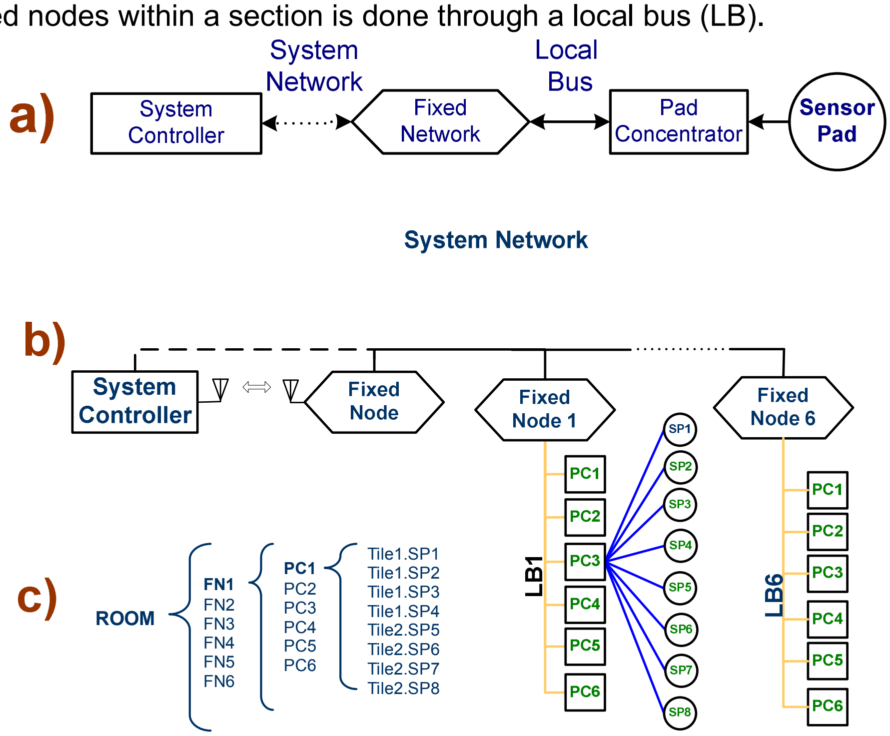

Fig. 1 – System architecture

a)- Overview; b) Detailed structure; c) Logical Room organization

The weight distribution data of all sections is transmitted to the system controller that can be implemented by a fixed node or by a mobile node.

In the following we present a brief description of all the system components.

Sensor Pad (SP) – a rubber pad equipped with pressure sensors. It is fitted in each of the corners of the floor tiles and gives the weight information of each tile corner.

Pad Concentrator (PC) – a circuit that makes the connection between the SP and the fixed node. It concentrates the sensors from 2 tiles (8 SP) and simplifies the connection to the fixed node by establishing the routing with a Local Bus (LB).

Fixed Node (FN) – a circuit based on a microcontroller for gathering the information from the connected sensor pads and transmitting the corresponding data to the system controller.

System Controller (SC) – a software application running on a personal computer; it controls all the fixed nodes and is responsible for displaying and data logging all of the received information.

3. System Components

Sensor Pads - Force Sensing Resistors (FSR) [12] with a 6.4 mm of radius are used as the force (pressure) sensors. Their resistance changes with the applied pressure (10 kg/cm^2 maximum). To detect the presence of a person with an average weight of 80 kg over one foot, just positioned along one of the corners, it was necessary to increase the contact surface between the rigid tile and the pair Sensor-Base, to 7 cm^2 by introducing a compressible rubber cover which works as a pressure homogenizer over the sensor (see Fig. 2). Each set of 4 sensors is placed between two rubber layers over a steel plate supported by the base. This leads to an estimated worst case weight distribution of 52 kg, 17 kg, 8 kg and 3 kg for each tile corner.

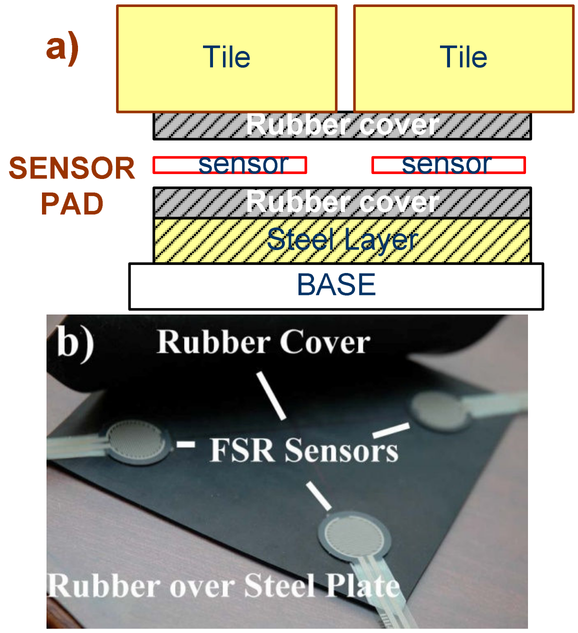

Fig. 2 - Sensor Pad
a)- Structure; b) Photography.

Pad Concentrator - This module provides the interface between the fixed nodes and the sensor pads, which actuates as voltage dividers, implementing sensor current limiting, signal conditioning and sensor addressing. All the pad concentrators and the fixed node circuit, within a section, are interconnected trough a Local Bus.

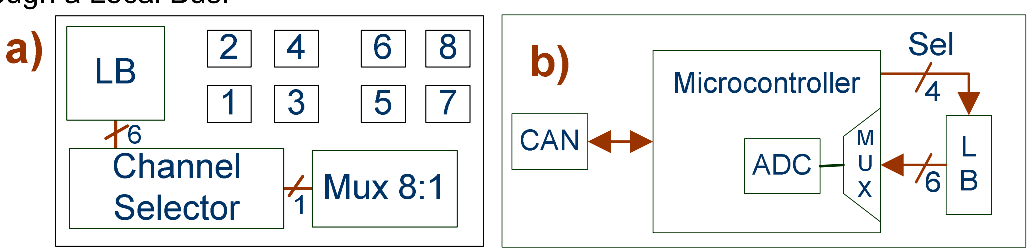

Fig. 3 – Diagrams of Pad Concentrator a) and Fixed Node b)

Pad concentrator includes an 8:1 analogue multiplexer that allows the microcontroller to access the intended sensor (4 wires: 3 bit selectors and 1 bit enable). The local bus has 12 lines, 4 dedicated to the microcontroller, 2 for power supply, and the remaining 6 lines are the analogue output line of each pad concentrator circuit. All pad concentrators share the sensor addressing lines, so when the microcontroller sets a sensor for accessing, all pad concentrators attached to the local bus will output the signal of the addressed sensor. The configurable channel selector allows that each pad concentrator has its own channel.

Fixed Nodes - perform acquisition and transmission of the sensor data to the system controller. Fixed nodes are based on a small microcontroller, sensor signal processing circuitry and an analogue to digital converter (ADC) with a multiplexed input, Fig. 3b). FN's are placed under the floor, near the pad concentrators and the sensor pads; they are interconnected by a network based on a CAN bus and a power bus.

Each FN can be connected up to 6 pad concentrators, addressing 48 sensors, by using the internal multiplexer to access the output channel of the pad concentrator and the Sel bus to access each sensor (Fig 3b)).

A 1 kHz refresh rate per section can be easily achieved with the microcontroller internal ADC.

The CAN protocol provides a reliable connection (error detection, differential communication), allows broadcast, collisions arbitration (CSMA with collision detection with non-destructive arbitration) and is suitable for long distance communication.

The broadcast and the collision arbitration will free the System Controller from having to manage the bus access of the different modules, making this an easily expandable system.

To be able to determine which section sent the information it is necessary to assign a unique identification number (P_ID) to each fixed node. The P_ID identification is one byte long and serves as the individual address.

Each fixed node processes messages sent over to the CAN bus that have is own P_ID or have been broadcast (P_ID=0x00). It should discard messages sent to a node wit a different P_ID.

The threshold value is set by the system controller. This can be done by sending a broadcast message with the Set_Threshold command. It can also be done by sending the command to a specific FN using its P_ID; this allows the user to set different threshold values for each system section.

Fixed nodes are programmed to send their P_ID upon receiving a Show_PID command, by this way the system controller is able to “see” all nodes connected to the system network.

All sensor data sent to the system controller is stored in the microcontroller internal memory. In order to reduce the traffic of messages in the CAN bus, each FN is programmed, so that the gathered data is only forwarded to the system controller when any of the sensor readings change beyond a threshold level relatively to the last sent sensor level.

System Controller - This module controls the entire system. Some of the functions associated with this module are: setting sensor threshold values, starting and stopping acquisition, and discovery of the P_ID of the connected nodes. To be able to run the system and to display correctly the information received, the system controller needs to know the P_ID of all connected nodes and the room position of every fixed node, pad concentrator and sensor pad.

All the FN’s have a serial port, so the system controller can be connected with the common bus through a wireless solution (Bluetooth) or a wired solution (RS232/USB), using an off-the-shelf communication module (Fig. 1).

4. System Implementation

The 64 floor tiles of the room were divided in six sections, Fig. 4. Each section is controlled by one FN module accessing to 12 tiles (48 sensor pads).

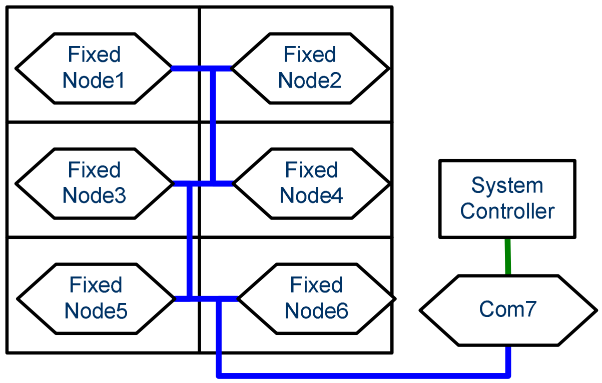

Fig. 4 - Layout of the FN nodes inside the room

As seen in Fig. 4 the P_ID=0x01 is assign to FN1 and so on. To implement the communication between the application running in the personal computer and the system we added an additional fixed node, that we assigned with the P_ID 0x07. This node was designated by 'Com' and it was programmed and fitted with an RS232 module to establish communications with the application running in the system controller.

To cover the entire room fixed nodes FN5 and FN6 only need to be connected to 8 tiles each, so we decided that they would only use pad concentrators PC1 to PC4. The program of the fixed nodes microcontroller wasn't change, so they will send the information has they were connected but the data is discarded in the application side.

The Fig. 5a) represents the layout of the connections within each section and Fig. 5b) displays the address of all sensor pads and the pad concentrator within the section.

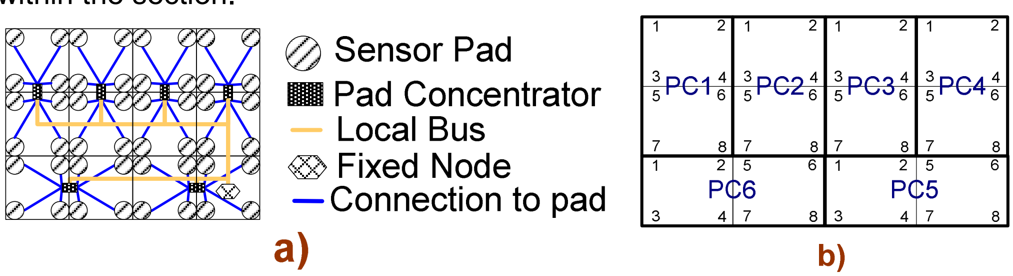

Fig. 5 –Room Sections a) Connection Layout; b) SP and PC channels position.

System controller is done by a software application running in a personal computer and

access any sensor pad, by addressing the section node by its P_ID, setting the Sel to access the sensor pad and setting the node internal multiplexer to read the pad concentrator channel that is connected to the intended sensor pad, see Fig. 1c).

To be able to reflect on screen the deployment of the system, it is necessary form the application to access a configuration file which relates the P_ID of the nodes and deployment of the sensor pad and pad concentrators with the on screen position. This is the configuration file is created using a map of the deployment as indicated in Fig. 5 a) and Fig 5b). The microcontrollers of the fixed nodes are programmed to execute the acquisition cycle represented in Fig. 6. After receiving the Start command each microcontroller executes the acquisition cycle continuously until the Stop command is received.

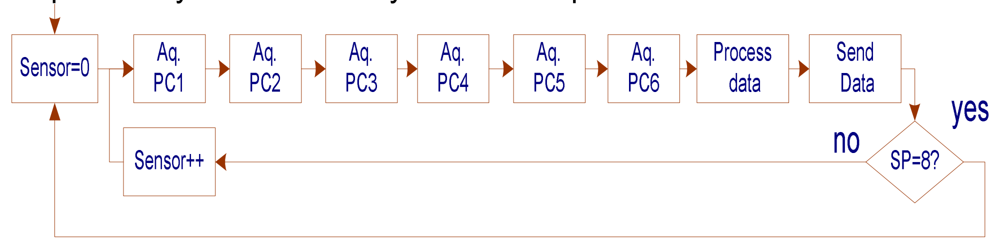

Fig. 6 – Fixed Node FN signal acquisition cycle

Nodes start by setting all the pad concentrator to output the variable of sensor pad1, then it will use the internal multiplexer of the ADC to sequentially read the sensor pad1 of all the pad concentrator connected to the local bus.

Then, each node processes the data and creates a message with the information and sends it to the CAN bus. Every time the node sends a message with the information gathered from the sensors to the CAN bus it updates the internal memory with the new values. It then repeats the acquisition cycle by updating the setting of pad concentrators to the next sensor pad. Every time it reaches the sensor pad 8 it has done a section sweep.

The message sent to the CAN bus is received by the COMS node that forwards it to system controller in the form of a Raw_Data command (see
Table 1).

Raw_Data	09	P_ID	SEL_{MUX}	PC1	PC2	PC3	PC4	PC5	PC6

Table 1 – System control commands and messages received

The Raw_Data is the message that SC receives with the information gathered from the SP by the FN. The P_ID is the identifier of the FN who sent this message; SEL_{MUX} indicates what was the SP (1… 8) accessed; the remaining data is the values read from the different PC (1…6) in that order.

When the application receives the Raw Data message it refreshes the colour of the corresponding sensor pad to reflect the current weight distribution of the tiles and saves the message in a file together with a time stamp, this creates a data archive that enables the tracking function.

In order to use this system to track the movement of persons over tiles, it is necessary to calibrate the system. This is done by making a few sweeps of all the sections, prior to the person entering the floor. This early data acquisition is used to get a base value of the weight distribution.

After conducting the calibration, the user is free to enter the floor sensible area;

by comparing the received data with the base values it is possible to indicate the persons position, the tiles with weight distribution different than the obtained during the calibration are represented with different colour.

This approach takes in account the case where the person steps in the corners of several tiles, trying to distribute the weight for as many tiles as possible. To be able to detect this situation the application look not only to the total weight applied in each tile, but also the weight applied to the surrounding tiles.

5. Conclusions

In this paper presents a flexible modular network of weight measuring system applied under a room floor. The system is used to obtain the position and to do movement detection of persons or objects. Due to high modularity of the design quick detection and replacement of damaged modules is possible. The system cost is kept very low due to the type of sensors chosen and to the decision to use only a single microcontroller per floor section. If necessary the system can achieve higher refresh rates by downsizing the sensor pads per section, leading to an increase of the number of Fixed nodes and higher occupancy of the CAN bus.

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