A FALL DETECTION SYSTEM BASED ON A WIRELESS ZIGBEE SENSOR NETWORK

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ABSTRACT
A sensor system for fall detection was subject of a research project at Fraunhofer Institute for Integrated Circuits. Starting with position analysis based on measured sensor data (3 axis acceleration sensor), various movement patterns had been tracked and analyzed (walking, climbing stairs, fall) with to develop simple and efficient algorithms in time domain. These algorithms had to be designed for microcontroller capabilitites to create a tiny, low power and intelligent sensor unit. Data acquisition, signal processing and wireless communication is all done by a single microcontroller inside ZigBee communication module

KEYWORDS
Fall Detection, Movement, Activity, Sensor Network, Wireless Sensors, ZigBee

INTRODUCTION

The situation for elder people has changed in many varieties in our times. While earlier several generations lived together in one house – grandparents, parents and children – and took care of each other, this former kind of common living today has nearly completely disappeared. Not only in big cities, even in rural regions most grandparents and parents live separately. Along with these sociological changes the demographic progression in our society aggravates the situation when special care is needed. With most parents being both employed, there is a huge problem of childcare, so who has the time to look for the grandparents?
More and more seniors are moving into elderly housings to spend their retirement. The atmosphere is familiar and a special daily schedule fits the seniors' needs. But even here the mentoring is limited. Nurses have many tasks to do all over the day, so part of the day the elderly are unattended.
If seniors in these unattended situations fall, they may be hurt and a person that directly could help is not present. Statistic analysis on falls in the Elderly show frightening results when looking to the high percentage of people not being able to stand up again without

help. Also the quantity and the heaviness of injures, mostly fractures of hip and tight, stress the need for immediate help when a senior fell down.
For these specific situations a helpful sensor system has been developed at Fraunhofer IIS (Institute for Integrated Circuits) that monitors persons' movements and detects possible falls. An alarm indication is automatically generated and sent to a nurse using wireless communication technology.

METHODS

The movement signals are measured using a tiny MEMS acceleration sensor (Micro Electro Mechanical System). This sensor derives from a sleep analysis system. In that use case it is used to determine the current position of a patient (e.g. patient lying on belly or back, lying on left or right side, number of turns per night).
In a first system concept all the raw data was sent to a PC using ZigBee radio technology. With a sampling frequency of 50 Hertz and a data resolution of 8 bit a data stream of 400 bit/s was generated for each channel, i.e. 1200bit/s for all three axes, which is equal to 150 bytes/s.
With the PC's powerful CPU and system resources the measurement data was processed and analyzed in several steps. Two main objectives had been pushed: an investigation on movement signals in general, but with a special focus on falls, and a stable algorithm for fall detects. Several measurement series have been accomplished and different algorithms have been tested.
Finally, the signal processing was implemented into for a microcontroller on the movement sensor. With this intelligent / smart sensor device only a single, coded byte is sent containing information about the patient's position and possible fall events. Using a predefined lookup table the receiving unit can decode this byte and either indicate visual information on a monitor in a nurse's station or even line up respective emergency procedures.

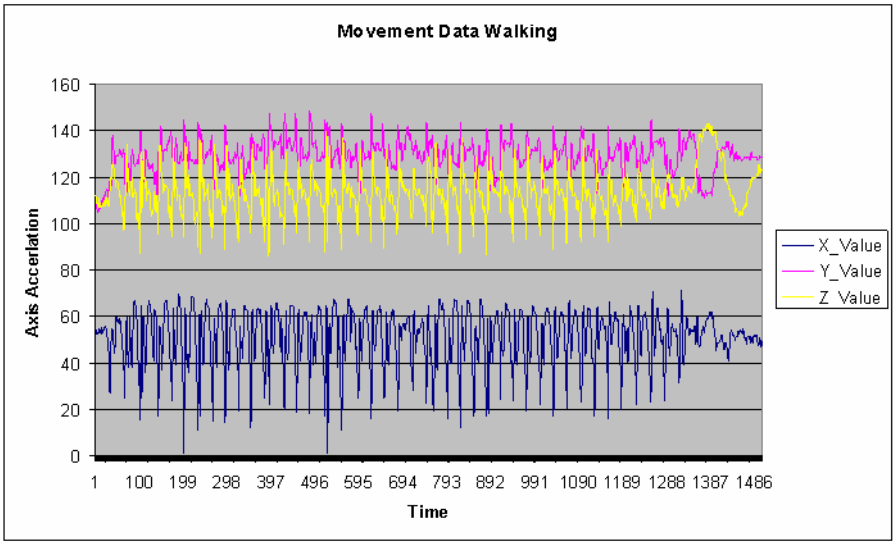

Figure 1 – Movement Data: Person walking

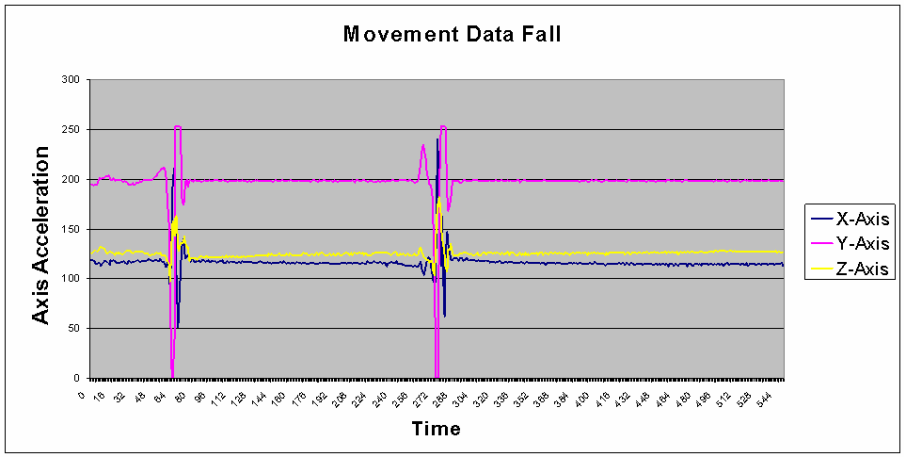

Figure 2 – Movement Data: Fall

TECHNOLOGICAL ADVANTAGE

The usage of the radio technology ZigBee – a low power technology based on IEEE standard 802.15.4 and with specifications from the promoting industry consortium ZigBee-Alliance – enables a very low power system for three reasons:

- The technological concepts for channel access (CSMA-CA: Carrier Sense Multiple Access with Collision Avoidance) and spread spectrum (DSSS: Direct Sequence Spread Spectrum) cause a very low power consumption over the time. Unlike some other wireless technologies, the ZigBee RF circuitry – which has a current draw of approximately 27 mA when active – must only be activated for sensing the channel and sending the data. When no data is pending, the RF circuitry can remain in a power saving state. This is a big advantage compared to systems using Frequency Hopping Spread Spectrum (FHSS), which have to continuously participate in frequency hops and synchronization procedures and thus continuously consuming a higher level of energy.

- Due to the special design of the ZigBee protocol stack, a microcontroller inside a ZigBee module can perform two main objectives: realizing the communication with according to ZigBee protocol routines and driving one or even several user applications. In this way only one processing unit has to be placed on a sensor board lowering energy consumption, form factor and costs for components at the same time!
  For this special project the user's movement data is processed directly on the sensor. The result coded into a single byte is sent to a receiver. Compared to the first system concept (with data rate of 150 bytes per second, see above) the data volume could be reduced to just a single byte. The less data is sent over the air,

the more energy could be saved for longer operating time.

FURTHER IMPROVEMENTS

Besides a ultra low power implementation of the sensor module another technological feature brings out the usability of the whole sensor system:
While most ZigBee applications currently are realized with microcontroller based modules (e.g. sending data from a stand alone sensor module to receiving module connected to a PC), a mobile system unit has been integrated at Fraunhofer IIS. Using a ZigBee SDIO card a portable PDA (Personal Digital Assistant) now is able to receive ZigBee data packages. With a special implementation of the protocol stack for operating systems in mobile devices (e.g. Pocket PC 2003, Windows Mobile 5.0) the user application on the PDA is able to extract data from received packages and process it according to the user's needs.
This system enhancement now allows nurses, currently working in a patient's room, to be informed about a nurse call or emergency situation from other patients in other sections of the building.

DISCUSSION AND CONCLUSIONS

With the ZigBee technology basically aiming for large sensor networks in industrial environment the implementation of the Fall Detection System at Fraunhofer IIS proves this communication concept to be suitable also in medical applications. In this special case the Fall Detection System makes a great contribution to everyday's life of the Elderly in both, home area and residential homes. The low power features provide a long operating time with large area coverage and stable signal transmission, all at the same time.
Current and future research projects focus on larger sensor networks with a higher number of network nodes, deeper analysis of movement data (going, walking, steps) and the combination of several vital signs (such as heart rate and temperature) to suggest activity and effort.

REFERENCES

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