SensFloor® and NaviFloor®: Robotics Applications for a Large-Area Sensor System

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ABSTRACT

The following chapter describes two systems, which both are perfect examples for ambient intelligence: sensor electronics, which is invisibly integrated into the floor. The first system comprises active sensors with high spatial resolution. It is able to detect people walking across the floor and recognizes peoples’ location and movement behavior. While the main application domains are Ambient Assisted Living (AAL), health care, security systems and home automation, several robotics applications are possible and have been investigated already. The second system serves for localizing moving objects such as robots, wheelchairs or hospital beds by means of passive RFID tags in the floor and an active RFID reader attached to the moving object. In the following, we describe the technical details of the two systems and robotics applications, which have already been realized or are under development.

SENSFLOOR®: A LARGE-AREA CAPACITIVE SENSOR SYSTEM

Conventional functions of room floors range from mechanical support, convenience, heating and noise reduction to the expression of individual style and design. However, considering the fact that during the day we are mostly in direct contact with the floor one may ask whether it is possible to exploit this close relationship for even more advanced functions.

In the following, we will introduce a sensor system called SensFloor®, which transforms a room’s floor into a sensor plane that detects and monitors peoples’ behavior and allows for a collection of novel supportive functions (Steinhage & Lauterbach, 2011). Although the result of these functions is obvious to the user, the sensor system itself remains invisible and does not interfere with the material or design of the floor covering in any way. In this respect, the technology we present here is an example for a new class of systems summarized under the expression Ambient Assisted Living (AAL). As this expression indicates, these systems’ main purpose is to assist people with limited mobility in their daily life (Lauterbach, Steinhage & Techmer, 2013, Lauterbach & Steinhage, 2012). An example is the recognition of falls and the following automatic activation of an alarm call. However, in combination with a mobile camera robot at home, the SensFloor® could

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simultaneously direct the robot to the location of the fall such that an external nursing service could directly communicate with the user by means of a videophone on the robot (Michaud, Boissy, Labonte, Corriveau, Grant, Lauria, Cloutier, Roux, Iannuzzi & Royer, 2007). Another robotics application is an advanced obstacle avoidance: in a dynamic environment where humans and robots are present simultaneously, the floor can convey the location and walking direction of people to the robots such that they can prevent collisions even when their on-board sensors are not able to see the obstacles in time. The latter can occur in a hospital equipped with transport robots when a person and a robot approach the crossing of two corridors from opposite directions, for instance.

For security applications, the same principle can be implemented in watchdog robots (see e.g. Gueaieb and Miah (2009)) that receive the information about the location of intruders directly from the SensFloor®. Another robotics application of SensFloor® is security fencing of industrial robots in the sense that when the distance between a robot and a person falls under a critical value, the robot becomes slower or is completely switched off. The latter two examples involve machine-to-machine communication (MMC) as the floor transmits its information directly to the robot without human interference.

The basis for the functions offered by the sensor system is the detection and tracking of people moving around within the room. Whereas the general movement is detected with conventional infrared or ultrasonic motion sensors, for instance, the acquisition of peoples’ exact location requires more advanced systems usually based on camera image processing or wireless identification tags. In addition to the technical problems caused by varying lighting conditions, blind spots caused by furniture in the room and the still unsolved computational task of robustly detecting arbitrarily dressed persons in a video image, cameras installed in every room may interfere with the inhabitant’s desire for privacy. The latter does also hold for wireless identification tags as they allow for a labelled behavioural protocol of individuals. In addition, systems like these are not ambient as either they require a visible installation, which interferes with the room’s design or the user is forced to carry around specific sensor- or identification tags.

In particular, in the case of elderly or handicapped persons knowing their current location or behavioural status is crucial. Many wearable sensor systems have been developed for this purpose already. There exist alarm buttons, for instance, which can be pressed in emergencies. This requires, however, that the person is conscious and still able to press the button. Automatic sensors, such as accelerometers, can detect specific situations such as a fall, for instance. All these wearable sensor require, however, that the user carry them all the time, even in the bathroom. This may become cumbersome for the user and in addition, other people might directly associate these devices with disabilities of their carriers.

SensFloor® relies on a much more direct way of detection: a grid of sensors underneath the flooring detects local capacitive changes in the environment brought about by humans walking on the floor. By design, this method does not allow for an identification of individuals. However, the persons’ locations is acquired very accurately based on the spatial resolution of the sensor grid. By collecting and processing, the sensor patterns over time it is possible to assign movement trajectories to the persons based on which several applications are realized.

The capacitive measurement principle has a unique advantage compared to conventional pressure sensors. Which, for instance, are used in fall detection mats or several other smart floor projects (Richardson, Paradiso, Leydon & Fernstrom, 2004, UKARI project Website, 2013): as the sensors within the SensFloor® underlay react from a certain distance without direct touch, there is nearly no restriction on the material that covers the sensors. SensFloor® works under carpet, linoleum, laminate, wood and even tiles or stone floors except for conductive material. However, the system is not restricted to the floor alone: it dissolves seamlessly into any
Kinova Modular Robot Arms for Service Robotics Applications

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