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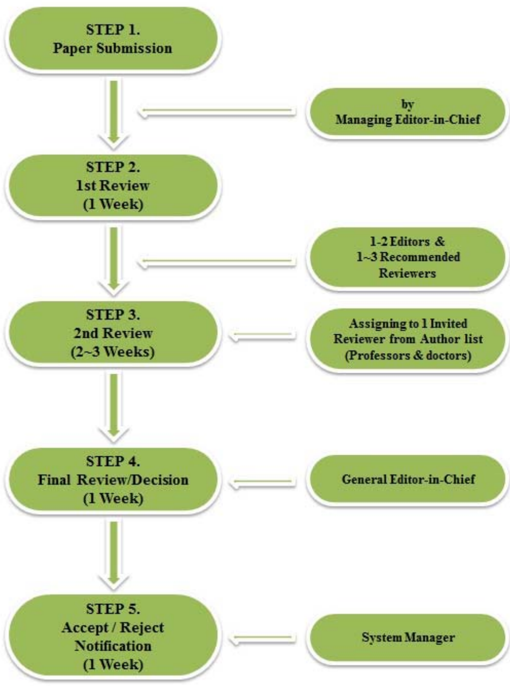

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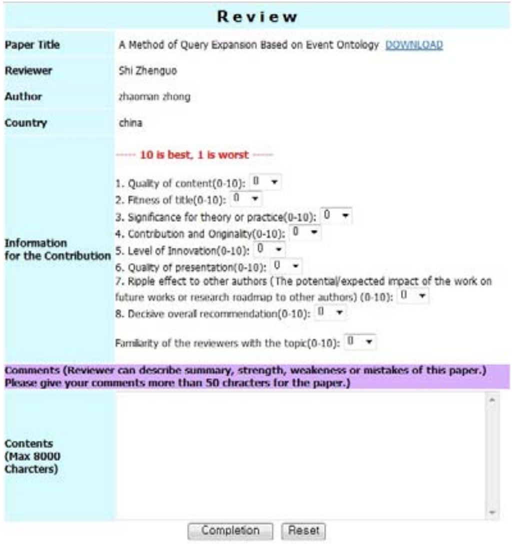

Review

Paper Title	A Method of Query Expansion Based on Event Ontology DOWNLOAD
Reviewer	Shi Zhenguo
Author	zhaoman zhong
Country	china
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Capacitive Sensor to Detect Fallen Humans in Conditions of Low Visibility

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Abstract

This paper examines the potential for a capacitive sensor to be used as part of a system to detect fallen humans at very close range. Previous research suggests that a robotic system incorporating a low cost capacitive sensor could potentially distinguish between different materials. The work reported in this paper stemmed from an attempt to determine the true extent to which such a system might reliably differentiate between fallen humans and other objects. The work is motivated by the fact that there are several different emergency circumstances in which such a system might save lives if it could reliably detect immobile humans. These scenarios include situations where older people have fallen and are unable to move or raise an alert, and circumstances where people have been overcome by smoke in a burning building. Current sensing systems are typically unsuitable in conditions of low visibility such as smoke filled rooms. This analysis focused specifically on the potential for a robot equipped with a capacitive sensing system to identify an immobile human in a low visibility emergency scenario. It is concluded that further work would be required to determine whether this type of capacitive sensing system is genuinely suitable for this task.

Keywords: Capacitive Sensor, Material-type Classification, Robot, Emergency, Fall, Fire, Health Alert System

1. Introduction

Researchers at the University of Technology Sydney are currently developing health monitoring systems intended to help determine when a person is experiencing health-related trauma [1, 2, 3, 4, 5]. A key objective of some of this research is to determine when a person is lying on the floor. This can occur when a person is incapacitated by a fall, smoke inhalation, heart attack, diabetic coma or other life-threatening event. Elderly people are particularly vulnerable to falls, and one third of falls among the elderly occur in the home environment [6, 7]. Factors that contribute to older people falling include wet surfaces, changes in floor levels (such as stairs), dimly lit areas around the home, and decreased levels of visual acuity and coordination.

Much of the previously reported fall detection work to date has focused on detecting the falling motion of the person by means of a device such as an accelerometer that is worn by the person [8-12]. Accelerometer-based approaches face significant drawbacks. First, such devices are typically not worn in the shower or during visits to the bathroom at night. Secondly, it can be difficult for many people to remember to wear such devices, and in the absence of supervision, wearable devices are unsuitable for people who have limited memory capacity due to conditions such as dementia. More pertinent is the fact that the vast majority of humans caught in house-fires or other emergency scenarios are unlikely to be wearing sensors on the body.

Cameras attached to walls or ceilings can be useful for determining if a person is immobile on a floor. However, systems involving fixed cameras in the home can be regarded as invasive, and even though such systems may be closed circuit, many people express concerns regarding privacy. The placement of pressure-switches within carpets or mats on the floor is a topic of considerable interest, and sensor mats are currently available for use with back-to-base home health monitoring systems. However, one difficulty with floor/mat sensors is that when they are used in hallways or living areas, they can be permanently “triggered” by moves of furniture, or the placement of a heavy object such as a bag.

In some of the systems that are currently being developed, fixed sensing devices such as sonar and passive infrared detectors (PID) are positioned in high-risk locations such as bathrooms and stairs. A PID is suitable for detecting the presence or absence of movement, but in itself is incapable of detecting when a person is lying on the floor.

Robots are becoming increasingly common in rescue and domestic settings, and work is being undertaken to equip future robots with improved capabilities. There are several different emergency circumstances in which robots might save lives if they were able to reliably detect immobile humans. These scenarios include situations where older people have fallen and are unable to move or raise an alert, and circumstances where people have been overcome by smoke in a burning building. Current sensing systems such as cameras are unable to operate reliably in conditions of low visibility such as smoke filled rooms.

Robots that are specially designed to perform search and rescue functions are ordinarily equipped with sensors that help determine distances from the robot to various objects. In addition, search and rescue robots are typically equipped with both vision cameras and thermal cameras [13-17]. Thermal cameras can be reliably used to differentiate humans from their surroundings, but thermal cameras are at present very expensive. Systems that rely on thermal cameras are thus beyond the reach of consumer-level in-home robots. Newer generations of in-home robots include functions suited to some basic in-home health care tasks such as reminding users to take pills. If current trends continue, it seems likely that in the near future an additional function of a domestic robot may be to try to detect (and summon help) when a person is immobile on the floor. One of the key objectives inherent in the task is for the robot to differentiate between an immobile person and other objects such as an item of furniture or a bag of clothes.

Recent work at the University of Technology Sydney has focused on the potential for a capacitive sensor to be used as part of a system that can identify different types of objects based on the materials of construction and the thicknesses or other properties of those materials [18, 19]. When used as range finders, capacitive sensors hold certain advantages over other sensors in situations where airborne particles (such as smoke) reduce the effectiveness of other sensors such as visual, laser, and infra-red (IR). In addition, capacitive sensors can be used to differentiate between different types of non-conductive materials [20]

A capacitor is made up of conductive plates separated by a dielectric medium. When a voltage is applied to a capacitor, positive charges collect on one plate, negative charges collect on the other, and an electric field is formed. Capacitive sensors include oscillators which rapidly alternate the voltage that is applied to the plates. Each oscillation causes the charges to start moving to reverse their positions, and this movement of charges forms an alternating current that can be amplified and continually measured by the sensor. The flow of current is affected by the electric field, and the electric field is affected by proximate objects that act upon that field.

Capacitive sensors are widely used as touch-switches or proximity sensors. The human body can tend to polarize electrons rather than conduct electrons freely, hence it can be considered as a dielectric medium. When the human body is placed in an electric field, it can have an effect on that field. The extent to which an object affects and is affected by an electric field is known as its *permittivity*. The dielectric nature of the human body is a characteristic that is used in many of the capacitive touch switches found on common household devices including kitchen appliances, bedside lamps and certain types of touch screen.

Capacitive sensors can be divided into three types. First, there is a type of capacitive sensor that essentially consists of a single plate (or a number of "single" plates placed side by side). In this type (used in touch switches and touch screens), the touched object (for example, a person's finger) acts as the second plate. Second, there is a type of sensor that is made up of two shielded plates, and which measures changes in the electric field in front of the plates. Third, there is a type which has no active shielding, and which is affected by changes in the electric field around the whole sensor. These three types of sensor are illustrated in Figure 1.

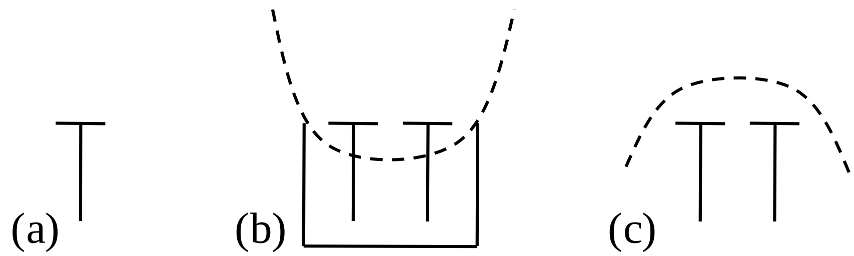

Figure 1. Three types of capacitive sensor: (a) a touch switch (which can be treated as a range finder with a resolution of 1 bit); (b) a shielded sensor; and (c) an unshielded sensor.

Prior research suggests that capacitive sensors can be used to distinguish between different types of material [20]. However, if the material is a conductor such as a steel plate, a capacitive sensor is unable to distinguish between thin plate and a thick plate because the thickness of the material has no effect on the electric field. In the special case where a grounded plate made of conductive material much larger than the sensor is placed in space parallel to the sensor plates, a model incorporating three capacitance variables and the distance from the grounded plate to the sensor plates can be adapted from [21:66] and [22:3].

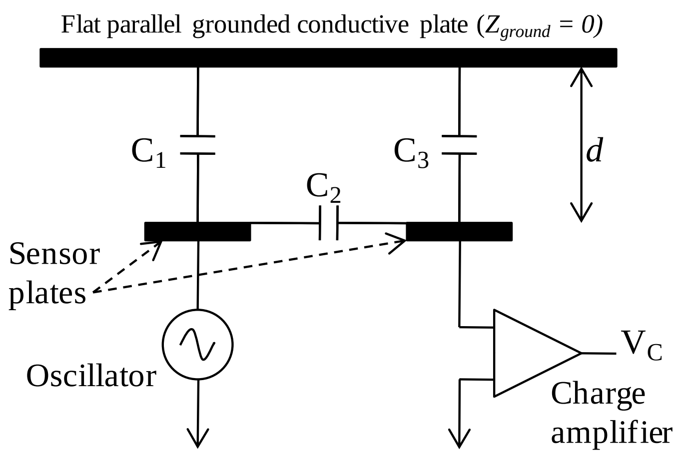

Figure 2. Special case where a large grounded conductive plate is parallel to the sensor plates at distance *d*.

Expressions for calculating the capacitances C_1, and C_3 are given in [21] and [22], and a method for estimating C_2 is given in [23], however the model may not be applicable when the sensor plates are surrounded by air, or when the grounded conductive plate is absent, or when impendence from the conductive plate to ground is not equal to zero.

If the object to be detected by the sensor is composed of a non-conductive material, the electric field can pass into the object and interact with charges inside the object. Wood, concrete, cotton and the human body differ from each other in permittivity, and will thus affect an electric field in different ways. Hence a capacitive sensor might be used as part of a system that is intended to distinguish between materials such as these. Alternatively, if the composition of the non-conductive material is held constant, the sensor could theoretically be used to measure the density or thickness of the material.

A capacitive sensor material classifier can be configured to operate either with or without a conductive back-plate. When configured to use a back-plate, the electric field between the sensor and back-plate is affected by an object that is inserted between the sensor and the back-plate. When configured to be used without a back plate, the electric field tends to wrap around the sensor when there is no proximate object. When an object is placed near-by, the electric field is affected by the presence of the object. The different configurations are shown in Figures 3 and 4.

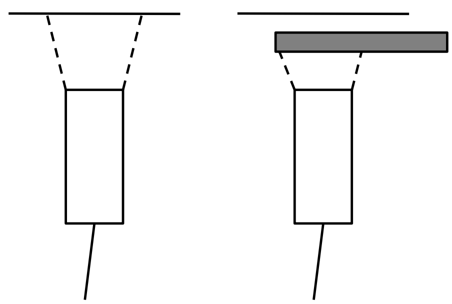

Figure 3. Capacitive material classifier sensor with back plate; the electric field is altered when an object is moved between the sensor and the back plate. Objects composed of different materials can alter the electric field in different ways

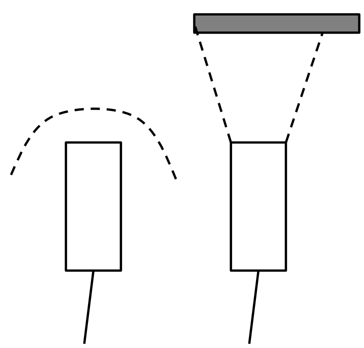

Figure 4. Capacitive material classifier sensor with no back plate: when no object is present, the electric field tends to wrap back around the sensor (a phenomenon known as *fringing*); when an object is present, the electric field may be drawn towards the object or altered in different ways depending of the composition of the object.

The effect on the electric field is proportional to the permittivity of the object, hence the sensor will tend to react more to objects of greater permittivity. For example, if an object such as a concrete block is placed within 5mm of a sensor, the capacitance can rise sharply [24, 25]. This is because concrete replaces the air in the sensor field, and concrete is a better dielectric than air. The sensitivity to permittivity gives rise to an important characteristic for detecting fallen humans. Given that the human body has a greater permittivity than that of many garments such as those made of cotton, it might be possible for a capacitive sensor material classifier system to detect a human body part “through” a cotton garment. The difference in permittivity might also allow a classifier to distinguish between a fallen human and a bag of clothes.

Another characteristic of capacitive sensors that makes them particularly promising for the application of detecting fallen humans is that they are not affected by airborne particles (such as smoke) in the same ways as other sensors. This makes capacitive sensors potentially attractive for situations where a person must be found within a building that is full of dense smoke (for example, in a house fire).

Airborne particles tend to reflect or diffract light and can have a debilitating effect on commonly used sensors such as cameras, lasers and IR. It is known that airborne particles can affect the accuracy of capacitive range finders [20, 26-28], however, recent work undertaken at the University of Technology Sydney suggests that a capacitive sensor can perform material classification even in extreme conditions such as in the presence of sandblasted airborne metallic particles [19]. This being the case, the project sought to explore the potential for capacitive-sensor-equipped robots to assist in the task of detecting fallen immobile humans in conditions such as smoke filled rooms.

2. Method

The work was undertaken in two parts. First, the results from experiments using a custom designed capacitive sensor [19] were re-analyzed. Second, an evaluation of the strengths and weakness of various alternative sensor systems was undertaken.

The circuit for the capacitive sensor has two halves, a sensor plate connected to each. The first half of was oscillated sequentially at three drive frequencies: 89.7 kHz, 96.6 kHz and 104.7 kHz. The specific frequencies were obtained using a microcontroller pulse width modulator, and the general range was chosen to be similar to frequencies used in previous studies – for example, a sensor used by Novak operated at 100 kHz and 153 kHz [25]. The oscillating current in the other half of the circuit was amplified and sampled in data sets each of 2ms duration.

The mean and standard deviation of each set of samples was calculated and probability distribution functions were formed. The re-analysis considered the operation of the system with four different materials (MDF, concrete, mild steel and human) and two conditions (clear air, and air laden with particles flowing at 100 grams per second).

3. Discussion

The re-analysis suggested that although the response curves for concrete and steel are similar, the response curves for MDF and human both appear to differ from the all of the other materials. The differences in position and shape of the curve relating to human objects are of particular relevance for the task of differentiating human objects from non-human objects.

It had previously been thought that differences in the variability of the readings for each material may also be potentially useful for a system that seeks to distinguish human from non-human. However, it remains to be seen whether such results can be replicated. This is especially the case given that the results reported in [19] appeared to suggest that the sensor linked with a trained automatic classifier could distinguish between plates of painted mild steel, aluminum and thick mild steel with 99% accuracy. This re-analysis suggests that some of the findings of [19] may be attributable to uncontrolled variables such as differing surface textures, or noise, at least to a greater extent than was previously thought.

Subsequent work undertaken at Stanford refers to [19] as describing "a stray capacitance signal which may be useful in a proximity sensor … but in a force sensor it is effectively noise." [29:2]. This re-analysis would tend to agree with view of the Stanford researchers so far as the described capacitive sensing approach may be useful for proximity detection. However, in relation to material-type classification, it remains to be seen whether noise was a greater factor than the previously reported results might suggest.

Given findings such as these, it seems an open question as to whether capacitive sensors may hold some potential to increase the capacity of robots to detect fallen immobile humans. Depending on the cost and complexity of the system, it is likely that capacitive sensors, if they are used at all, would be used together with other sensors – considerations relating to alternative sensor systems are given in Table 1.

Table 1. Considerations relating to some potentially viable alternative sensor systems

Camera	Visual cameras can be used to detect immobile on-floor humans. However cameras are not effective in thick smoke, regardless of whether they are attached to robots or fixed to walls/ceilings. In addition, some people are unwilling to attach cameras to the walls or ceilings of their home for various reasons including the appearance of the camera, and concerns about how the signal might be used.
Thermal camera	Thermal cameras are currently common on search and rescue robots because they can reliably assist in the detection of a living human (where human is at different temperature to the surroundings), even in the presence of thick smoke. Thermal cameras are however relatively expensive, so it seems unlikely that thermal cameras will become commonly used on in-home domestic robots until this type of camera becomes less expensive.
Ultrasonic	Ultrasonic sensors are ordinarily used for range finding. Ultrasonics could be used by a robot to help determine if an object on the floor is roughly the size of a person, but they cannot provide information that can be used to classify the composition (material-type) of an object.
Scanning laser rangefinders	Scanning laser rangefinders are ordinarily used for range finding, but can also be used to provide information about an object's surface texture, size and shape. Scanning laser rangefinders are relatively expensive but dropping in price rapidly. They can be scattered by airborne particles, are less-suitable in smoke-filled environments.
Floor mat switches	Pressure-switches can be placed under carpets or within floor mats. When they are used in hallways or living areas, their effectiveness can be negated by moves of furniture, or the presence of heavy objects such as bags.
Near infra-red	Near infra-red is used in laboratory settings for material classification. The technique relies on light reflected from the surface of the object. Near IR would be unable to distinguish between a person wearing a cotton shirt and a piece of cotton covered furniture.
PID	PID sensors are suitable for detecting the presence or absence of movement, but in themselves are incapable of detecting when a person is lying on the floor. Certain types of PID sensor can be used to measure temperature at very close range, and would presumably be potentially useful in detecting humans if the human was at a different temperature to that of the surroundings.

Table 1 shows that several other types of sensors are potentially useful for helping to detecting fallen humans. However, it is apparent that none of the alternatives offer the same combination of cost and features as capacitive sensors. Hence, if capacitive sensors can be made to work reliably in this application domain, it seems there may be a role for capacitive sensors to be used alongside other sensors. This being the case, it seems likely that further exploration of the potential roles for capacitive sensors may be a fruitful area of further research.

4. Conclusions

This analysis looks at the potential for a relatively low cost capacitive sensor to be used to help a mobile robot identify a fallen immobile human. Previous work had suggested that a sensor currently in development may be potentially suitable for this task. The sensor had been coupled with firmware running relatively well understood learning algorithms, and prior reports suggested that the sensor could distinguish between humans and other materials. This report, however, suggests that further work is required to determine whether such a sensor could be suitable for the task of detecting fallen humans.

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