Electronic Sensors for Tampering Detection

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This overview of electronic sensors presents multiple options for using electronic means to detect tampering on a vessel. The functionality, advantages, and disadvantages are noted for accelerometers, gyroscopes, pressure sensors, and vision sensors. Multimodal sensing, one possible means of compensation for the disadvantages of any sensor, is presented.

Background

Problem Description

Drink tampering is a valid threat in today's society. A survey conducted in the U.K. in 2014 found that one in ten people have had their drinks spiked and another three in ten know someone who has had their drink spiked (Crime Week Poll, 2014). The danger for a drugged victim is the easy exploitation. They can be robbed, attacked, or worse: in the United States in 2007 alone, it is estimated that about 200,000 women were victims of drug facilitated rape (Kilpatrick, Resnick, Ruggiero, Conoscenti, & McCauley, 2007).

In designing a method of detecting tampering with drink containers or any vessel, one major decision for the Green Team to consider is the sensor implementation. Not only must we consider how the sensor will interface with other hardware elements, but also we must decide on a method for detecting tampering. This means examining different types, specifications, and applications of available sensors to determine the appropriate component to utilize in the design. Options include mechanical, chemical, and electrical sensors. This Note focuses on the electrical means of sensing (see the Tech Notes by Green Team members Matthew Kwan and Catherine Kravchenko for discussions on mechanical- and chemical-based applications).

Sensor Research

There are many types of electrical sensors that could be used to detect tampering. Accelerometers, gyroscopes, pressure sensors, and vision sensors are explored here.

Accelerometer

An accelerometer is a type of transducer, converting acceleration into an electrical signal (Mayo, 2009). Lifting the sensor up off of or out away from a vessel, a motion that would be required to tamper with the contents, is an acceleration, or change in velocity, that can be detected. Acceleration is measured in g forces, where one g force is the same as the acceleration due to gravity on earth, or 9.8 m/s^2. One important specification of an accelerometer is the sensitivity, or output to input ratio. This is a rating of the preciseness of the device in its measurement of g forces. Commercially available sensors range from ±1g to ±250g, with the lower end able to measure tabletop vibrations and the upper end able to measure rocket motion. An accelerometer with lower sensitivity can be more precise, but is also more prone to noise, or unwanted signal elements, because it may sense more than the intended vibration or acceleration (Corinne, n.d.). In this situation, this means that the sensor could detect not only the tampering movement, but also extraneous movement such as the shaking of a table. Choosing an accelerometer for detecting tampering, then, would most likely mean that a filter should be implemented in order to disregard the irrelevant movements. One example of such a filter is a linear Kalman filter (Czerniak, n.d.).

Gyroscope

A gyroscope measures angular velocity, so any tilting that might occur as it is removed from a vessel would be detected by the sensor. Angular velocity is the speed of rotation, measured in degrees or revolutions per second, and most gyroscopes can measure rotation speed around the three primary axes. Like an accelerometer, a gyroscope has a sensitivity rating with a lower sensitivity having better resolution (Ronzo, n.d.). However, unlike an accelerometer, a gyroscope's performance tends to vary significantly with temperature changes. Most have a built-in temperature monitor to compensate for this effect with a feedback control mechanism. One other potential problem is that gyroscopes can tend to drift, meaning that the sensor often has a non-zero output even when there is no rotation (Chen, Liu, Xiao, Cui, & Wang, 2014). The design can compensate for this issue, but it may require the user to calibrate the sensor every time they need to use it, which is not ideal.

Table 1. Sensor Cost Comparison

Sensor Type	Average Cost	Cost Index Source & Date
Accelerometer	$0.720	"Accelerometer Product Index," 2015
Gyroscope	$1.990	"Gyroscope Product Index," 2015
Pressure Sensor	$2.150	"Pressure Sensors, Transducers Product Index," 2015
Vision Sensor	$4.125	"Image Sensors, Cameras Product Index," 2015

Pressure Sensor

A pressure sensor measures force over the sensor's area, converting the input force into an output resistance. It could be used in this application because the sensor could detect a loss of contact with a vessel if the output resistance is monitored via a balanced circuit, such as a Wheatstone Bridge. Pressure sensors have a sensitivity ranging from 1 lb to 100 lbs, but, unlike accelerometers and gyroscopes, they also have varying areas of sensing. This impacts the design because a decision must be made of whether to include one large, more expensive sensor or manage several smaller, less expensive sensors ("Pressure Sensors, Transducers Product Index," 2015).

Vision Sensor

A vision sensor reads in input from a camera and processes the image to determine context or detect certain patterns. This could be used to detect tampering if the camera could detect the presence of a hand approaching the vessel. An important specification of this type of sensor is the speed at which it can process the image. The fastest products are PC-based systems that use a computer to process the data (Lecklider, 2005), so this may be a limiting factor when trying to design a device that could work remotely from a computer. Another limit is cost. As noted in Table 1, a vision sensor would be more expensive to implement than the other sensors as it, on average, costs two to four times more.

Other Considerations

Multimodal Sensing

Every potential electrical sensor has an associated movement that would be detected if the device were removed from its vessel. However, in order to ensure that a perpetrator cannot circumvent the sensor, these motions must be detectable for every possible way the sensor can be moved off of the glass. For example, a gyroscope can sense rotations, but if an attacker were to lift it carefully without any tilt, they could potentially still tamper with the contents of the vessel. The pressure and vision sensors also have vulnerabilities. The pressure sensor could be lifted off of the vessel while the attacker maintains the force where the vessel was previously on the sensor. The vision sensor could have one or multiple blindspots that an attacker could use to tamper with the contents of the container undetected.

One way to protect against these vulnerabilities is to utilize multimodal sensing. This requires aggregating data from multiple sensors to test against a variety of thresholds rather than one singular threshold. Han, The Vinh, Lee, and Lee (2012) proved that multimodal sensors in smart phones can distinguish contexts such as walking, jogging, riding a bus, and riding the subway. Their method can be applied to this project for two purposes. First, using two or three sensors to check for tampering ensures that where one sensor has deficiencies, the other sensor(s) will still detect interference. Second, it is possible that the method could be applied such that the contexts of tampering, table movement, music vibrations, and other likely scenarios can be distinguished.

Conclusion

Many options exist for sensors that can potentially detect tampering, including accelerometers, gyroscopes, pressure sensors, and vision sensors, among others. To further the selection process, preliminary testing could be done with each type of sensor to assess its performance as a detection method. These tests should include a means of evaluating how multiple sensors function together to determine if multimodal sensing will be a desirable option. It is important to note, however, that the "best" sensor or combination of sensors to use depends on many factors, including the reliability of the sensor's detection, cost, and the user interface in the final product. Only after considering all of these elements can the Green team make a decision about the best means of detecting tampering for our project.

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