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Selection of Motion Sensor for Smart Applications: A Characteristic Analysis

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***Abstract*— As most of the daily life applications turn smarter in the present scenario, the sensor technology defend itself a key role in it. In evidently, the motion detection serves a predominant role in smart applications. This paper presents a study on the characteristic features of some motion sensors that are been widely deployed in the smart applications. Sensor modalities, Working principle, Coverage pattern, RFI immunity, Applications, Operating voltage, current specifications and the deployment failure issues are been analyzed. So this paper brings a concise report on the motion sensors, a preliminary reference for the researcher indulged in motion sensing application.**

***Index Terms*— Acoustic, sensitivity, microwave, modality.**

I. INTRODUCTION

The low-power, ease of use, and ultra-compact nature of the motion sensors, addresses a wide- range of consumer and industrial applications from motion-activated user interfaces to vibration monitoring. And this justifies the vendors to extend the range of the motion sensors. In the recent years, motion sensing technologies have begun appearing everywhere viz., video consoles, smart mobile phones, multimedia applications control.

Some of the previous works that was focused in the human sensing modalities presented an in-depth survey on the human-sensing Taxonomy such as presence detection, count, location, tracking, and identity. Irrespective of the sensing modality, several challenges met in human-sensing such as noise, environmental variations, similarity to background signals, appearance variability and unpredictability, similarity to other people, and active deception were also been discussed in [1].

Among the several sensor modalities used for human intrusion detection, another work that was presented in [2], dealt with the power pack of Wireless sensor networks embedded to the human intrusion detection, which is been considered as an upper deck candidate in the current technology. Six types of passive sensors viz., magnetic, seismic, acoustic, optical, thermal, and chemical, were analyzed qualitatively based on certain criteria, and the comparison table was briefed in [2]. In this paper, the characteristic features such as Sensing Modality and Principle Operation, Coverage Pattern, Power Rating, Application and RFI Immunity, and the Practical complications and considerations are discussed, compared and analyzed qualitatively for different kinds of motion sensors. It is also proposed to find out the criteria that justify the selection of motion sensor for the various smart applications. 7

Motion detection is the method of detecting a change in position of an object relative to its environment or the change in the environment relative to an object. Motion can be detected by Infrared (Passive and active sensors), Optics (video and camera systems), Radio Frequency Energy (radar, microwave detection), Sound (microphones and acoustic sensors), Vibration (seismic, and inertia-switch sensors), Magnetism (magnetic sensors and magnetometers). Some of the motion sensors which finds the broader application that are been considered in this paper are IR sensor, LASER motion sensor, Microwave motion sensor**,** Acoustic emission sensor.

II. SENSING MODALITY AND PRINCIPLE OPERATION

A. Infra-Red Sensor

Sensing based on IR radiation is classified as active and passive IR sensor. Infrared radiation is the portion of electromagnetic spectrum having wavelengths longer than visible spectrum, but smaller than microwave spectrum, i.e., the region approximately from 0.75μm to 1000 μm is the infrared region which is invisible to human naked eyes. An active infrared detector includes a radiation source (IR LED) and an infrared sensor which is sensitive to interruptions in the radiation sensed. Such detectors are used to detect the human intrusion by providing a path of radiation from the source to the sensor in a place where the path is likely to be interrupted by an intruder. Passive infrared motion detection detects the heat energy radiated or emitted from a human body moving transversely in the field of vision of a heat sensing element on the system. As it senses the difference in ambient temperatures, it found to be apposite in detecting the movement of people from their body temperature. Fig. 1 and Fig. 2 show the clear picture of the construction and the principle working of the PIR sensor respectively.

B. Acoustic Emission Sensor

It houses a piezoelectric sensing element and a built-in impedance converter, where the sensing element made of piezoelectric ceramic mounted on a thin steel diaphragm. The impedance converter produces a low-impedance output voltage

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signal. Any characteristic variations in the propagating medium of the acoustic wave will be given as a voltage signal output, which will be processed further.

C. Microwave motion sensor

Basic principle behind its working is the Doppler effect, when an electromagnetic wave is emitted from a source propagated towards an object, its wavelength seem to be changed when either or any of the two are moving relatively. A low energy microwave that is radiated form the sensor, usually in gigahertz produces a Doppler shift when it is reflected by an object moving relative to the sensor. Doppler Effect in light can be briefed as that a relative motion between the radiating source and the reflecting target will cause the changes in frequency that's propagated in space. Such a mixture of shifted and actual wave results in an output voltage.

D. LASER motion sensor

It contains a solid-state laser radiating source and a PSD or CMOS/CCD detector. A laser beam is projected on the object being measured and a portion of the rays is reflected through focusing optics on a detecting element. Motion of the target object provides the laser beam a proportional movement on the detector element.

The signal from the detector is used to find out the comparative distance to the object. This information is then characteristically obtained through an analog output. That is, they are able to accurately compute the position or displacement of an entity. Fig. 3 shows the understandable picture of the principle working of the PIR sensor.

E. Figures

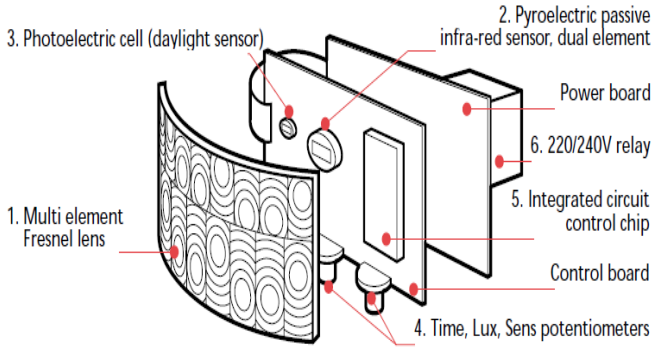

Fig. 1. Typical assembly of a PIR sensor.

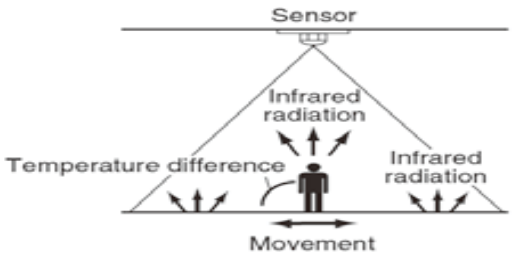

Fig. 2. Principle Working of a PIR sensor.

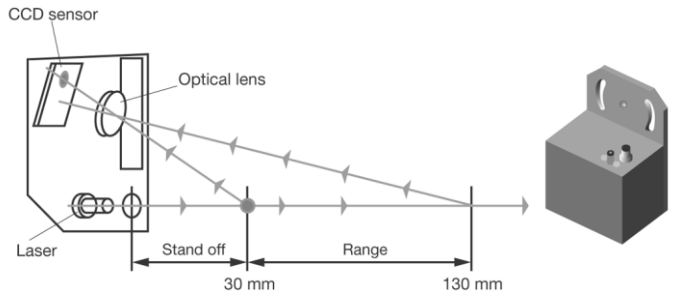

Fig. 3. Principle Working of a LASER motion sensor.

III. Coverage Pattern

A maximum outdoor distance cover of 300 meter and the axial beam spread of 3meter could be achieved in active IR, where as the PIR covers the distance of 12 m with almost 90^{o} beam spread.

Noise level measurement of the acoustic emission sensor ranges above 50 kHz to 900 kHz from the metallic components and machine structure. With its robust housing construction, it is highly sensitive to the acoustic emission of Rayleigh and longitudinal waves over a wide frequency range and have inherent high-pass characteristics.

Effective coverage of a 9.37 GHz and +2dBm power level microwave motion sensor goes up to a maximum of 5m distance and 45^{0} angle, without any intrusion of objects and the detection time of 4seconds.

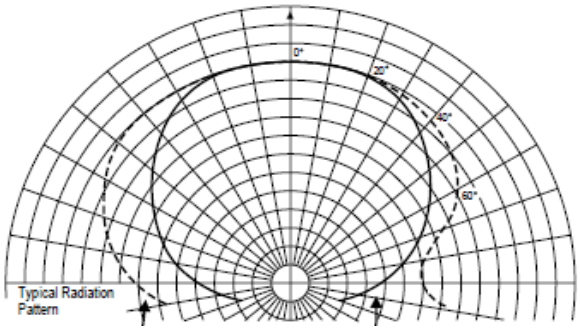

Fig. 4. Radiation pattern of a 9.37 GHz Microwave motion sensor.

Sensitivity of the laser motion sensor is generally defined by how much displacement occurs per unit of measurement, normally expressed in microns/milli-volt. At the standoff distance which is known as the Ideal operating point, the laser is at its sharpest focal point and the reflected spot is in the axis of the detector. As the object moves, the spot will shift to the ends of the detector allowing for measurements over a definite range of distance. Both the range of cover and standoff of a sensor are determined by its optical design. Fig. 4 shows the radiating pattern of a 9.37 GHz Microwave motion sensor.

IV. Practical Complications and Considerations

Strong beam of light should not fall on the receiver and its line of sight should be free from false sources such as trees, which may change seasonally.

Temperature difference between the target and the environment should exceed 4^{o}C. That implies the stable human body or with less variation cannot able to produce any temperature variations. Intrusion that occurs parallel to the Z-axis in the detection zone may not be detected.

Acoustic emission signal is very weak hence, the signal discrimination is extremely difficult under the very noisy

operating environment, yet it is important to rate the stability and reliability of the AE sensor.

Output of the microwave motion sensor is trustworthy without any discriminating object detected in its propagating path. The high frequency utility is been regulated in most countries. Certain frequencies that are subject to restrictions should be clarified with the relevant authorities in each country to ensure acquiescence with the customary legislation.

To obtain a better accuracy, the laser motion sensors require frequent cleaning as the dirt or other garbage can concern its precision. Since the laser heads comprise of sensitive electronic components their working temperature is limited and vacuum installations are not recommended without peripheral cooling arrangements.

V. Power Rating

Operates in supply voltage range of 3-5volt dc, PIR provides the output with voltage greater than or equal to V_{DD}-0.5v dc and current in the ranges of few hundred micro-amps. With the response time of 50 to 700 m/sec, the power consumption of active IR sensor ranges from 10.5to 28 V dc and the maximum current of 65mA.

The AE sensor need a bias range of 5Vdc to 36Vdc with the constant current of 6mA maximum and the nominal output values are 2.5Vdc with 4mA of current.

With an operating current of 25mA and input supply ranges from 8Vdc to 15Vdc, Microwave motion sensor produces the DC output voltage of 2.5V and 9.37GHz frequency with 50mV output signal voltage.

Maximum of 3vdc and operating current of 5.6mA is found to be power rating of an ultra-low power LASER motion sensor that is been deployed for computer mouse.

VI. Application and RFI Immunity

Commercial lighting, vending machine, Human occupancy sensor to find the presence detection, etc., is the few applications of the IR sensor.

Some of the well defined examples of AE sensor are process monitoring and testing, machines and tool in metal forming and cutting operations. This optimally suits measuring AE sourced from crack formation and growth, frictional noises and plastic deformation of materials. Since the sensing element is acoustically isolated, it is insensate to magnetic and electric noise fields.

In spite of its sensitive nature to the electrostatic discharges, the MW motion sensor finds several in domestic and industrial applications. Motion-activated lighting system, monitoring the motion and failure of belt conveyors, elevators and other machinery, and indication of product presence in conveyor belt are few of them.

With an ultra-low power rating such types of Laser motion sensor are mainly used in low cost wireless applications such as mouse. Also it finds the applications in measuring the curved targets and computing the surface reflectivity.

VII. Conclusion

The clear scope of this paper is to provide the valuable reference for the students, researcher those are engaged in the projects related to the motion detection for the smart applications. This would provide some key information about the motion sensors and will familiarize the optimal selection for a specific application. The future work may proceed to the motion sensing and human presence detection for framing an effective power saving algorithm in view of the energy conservation mainly for the corporate buildings.

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