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Detection reliability for passive infrared detectors in intrusion and hold-up alarm systems and their ergonomics

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Abstract. Currently it is highly important for detectors to be able to achieve efficiency, reliability, and faultless operation, and to be ergonomic thanks to their assembly and being easy-to-fit. In the case of a proposal for the placement of detectors it is naturally important to determine position of the detector and the type of detector being used, but also to guarantee their capability to be able to detect anything when in use and their user and installation-friendliness. The problem of passive infrared (PIR) detectors affects a large proportion of intrusion and hold-up alarm systems (I&HAS). In a time of increasing property crime, it is highly important for PIR detector to actually be able to detect break-in attempts within the guarded area on a reliable basis and free of error. In the case of the installation of PIR detectors, it is naturally important not only to ensure correct installation, to gauge the external influences which may impact upon the detector and to ensure proper maintenance, but also to guarantee the capability of detection under more arduous conditions. The tests and comparisons which have been conducted examine both the normal operation of the PIR detectors and the ergonomics of these detectors. These tests are important both from an informative perspective and due to the opportunities to be able to develop potential counter-measures which could lead to their improvement.

Key words: security risks, ergonomic, intrusion and hold-up alarm systems, passive infrared detector.

INTRODUCTION

At a time of increasing property crime, it is very important for detectors to achieve efficiency, reliability, faultlessness, and ergonomic ease of assembly and assembly. Passive infrared detectors, known as PIR detectors, are the most commonly used space protection elements in alarm systems for intrusion and retention. They can, however, be used in many other applications than simply to provide space protection. PIR detectors are, as the name suggests, passive non-emitting motion detectors. For proper operation, these detectors are typically DC powered (using a low voltage). Movement is detected by a pyro element which detects a change in temperature with a pyroelectric effect in the background of the space that is under surveillance. In the case of installing PIR detectors, it is of course not only important to ensure proper installation, to measure external influences on the detector and to ensure proper maintenance, but also to ensure their detection capability in more demanding conditions (Cumming, 1994; Capel, 1999; Hart & Hartová, 2016).

PIR detectors are highly prone to poor installation and, as a result, it is very important to pay attention to these detectors. PIR detectors have in general the highest number of false alarms from all detectors. This high error rate is due mainly to incorrect installation. This is why we've defined a problem which should serve to compare the properties and parameters of the PIR detector with its suitability for installation (Staff & Honey, 1999; Powell & Shim, 2012; Malaťák et al., 2016; Choubisa et al., 2017).

MATERIALS AND METHODS

Measurements were made in order to determine the response of the PIR sensor (Fig. 1) in various situations. The PIR sensor is a basic feature of the PIR detector. These are sensors that are sensitive to infrared light irradiation. These are semiconductor devices and are made of crystalline materials such as tantalum and lithium compounds. They can respond to irradiation with infrared light. In the case of irradiation, an electrical charge occurs on the crystals. It works as a gradient drive, ie. it only detects changes of incident radiation on the sensor. In the case of usually more expensive and better quality sensors, two and four pyroelements are used.

Since the pyroelectric sensor is sensitive to the large wavelength range of electromagnetic waves, a radiation filter is inserted in front of the sensor. The purpose of the filter is to pass through only infrared radiation. The PIR sensor is a so-called pyroelectric phenomenon (the effect of temperature on the crystalline lattice -> electrical potential, electrical charge difference -> triggering of an alarm) (Petruzzellis, 1993; Upadrashta et al., 2015; Drga et al., 2016; Hart et al., 2016; Luo et al., 2016).

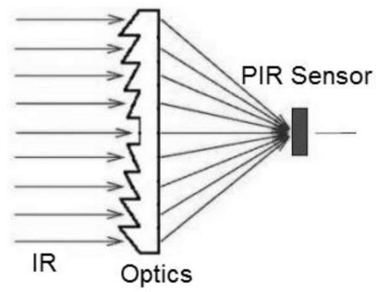

Figure 1. Schematic showing the PIR sensor function.

For testing and comparison, digital PIR detectors were selected (see Fig. 2). These were detectors from Bosch, PARADOX, Satel, and Pyronix-Hikvision. PET Immunity detectors with the largest representation in the Czech Republic were selected. These detectors have met Security Level 2 standards (a low-to-medium risk). From each type of detector, five samples were tested and average values of all of the measured results were reported.

Figure 2. PIR detectors (from the left: ISC-BPR2-WP12; NV5; AQUA PET; KX10DP).

The following tests were carried out:

- Slow test passage
  - Walking speed – 1.5 km an hour^{-1} (simulating offender movement)
  - Distance from detector – 7 m.
- Range test (max)
  - Walking speed – 5 km an hour^{-1} (standard motion simulation)
  - Testing started at the maximum distance indicated by the manufacturer
  - The measurement is repeated cyclically ten times in succession
  - After a successful measurement, the distance of the drive was extended by half a metre
  - The alarm should have been triggered at least nine times out of ten attempts. If this did not happen then the test was unsuccessful and the test distance was defined as being the maximum distance.
- Detection angle test (max)
  - Walking speed – 5 km an hour^{-1} (standard motion simulation)
  - Distance from detector – 7 m
  - PIR sensors were monitored during the passage
  - The measurement is repeated cyclically ten times in succession
  - During these cycles, the subject's position and the first 'reliable' pulse were monitored
  - A reliable pulse was defined and these pulses had to occur so that at least eight out of ten cycles were triggered, otherwise the angle is defined as being the maximum permitted.
- Sampling Test (max)
  - During the activation of the detector (placing it in its alarm state) its current consumption was measured against the data provided by the manufacturer.

In addition, thirteen independent firms were approached. These companies had all of the selected detectors in their installation portfolio. All of these companies filled out a questionnaire, describing which of these detectors best suited their needs. They were to assign three points to the best of the detectors, two to their second choice, one to their third choice, and zero to the worst detector in their view.

The selection of the most appropriate (compromise) variant was carried out using a multi-criteria analysis. The difference in the price of the PIR detectors being compared is insignificant and therefore has not been counted. The difference between the cheapest and most expensive PIR detectors is only 2 €, which is not particularly crucial when investing in the security feature. For this reason, in the case of these particular detectors, their technical parameters are preferred over their cost. Table 1 shows the value of the judged criteria for individual PIR detectors (Hart et al., 2016).

Table 1. An average expression of detected PIR detector parameters

Type	Slow passage-triggered alarms	Range (max) [m]	Detection angle [°]	Current consumption [mA]	Installation friendliness
Bosch ISC-BPR2-WP12	48	13.5	98.0	10.5	21
Paradox NV5	46	13.5	92.0	11.2	17
Satel AQUA PET	50	16.0	90.5	10.5	16
Pyronix-Hikvision KX10DP	39	11.0	88.5	12.9	24

The priority of each parameter was expressed by means of weights. Weights were determined according to Table 2. The points assigned to the parameters of each PIR detector, the weights, the overall rating, and the PIR detector variant that was selected as the most appropriate are listed in Table 3 (Hart et al., 2016).

Table 2. Determination of weights for PIR detectors

Parameters	Scoring	Scales
Slow passage-triggered alarms	6	0.167
Range (max)	10	0.278
Detection angle	9	0.250
Current consumption	4	0.111
Installation friendliness	7	0.194
Total	36	1

Table 3. A selection of the most suitable PIR detector by multi-criteria analysis

Type	Slow passage-triggered alarms	Range (max) [m]	Detection angle [°]	Current consumption [mA]	Installation friendliness	**Points**
Bosch	6	8	10	9	8	**8.277**
Paradox	7	8	9	8	5	**7.501**
Satel	5	10	8	10	4	**7.501**
Pyronix	10	7	7	7	10	**8.083**
Scales	**0.167**	**0.278**	**0.250**	**0.111**	**0.194**	

RESULTS AND DISCUSSION

Of all four PIR detectors being compared, the Bosch ISC-BPR2-WP12 detector was selected as the best option, with a total score of 8.277 points. This means that the required criteria satisfied approximately 83% of the total possible score. The Pyronix-Hikvision KX10DP detector was placed in second position with 8.083 points (81%), and the Paradox NV5 and Satel AQUA PET detectors were placed in last position, both with 7.501 points (75%). The final order is shown in Fig. 3.

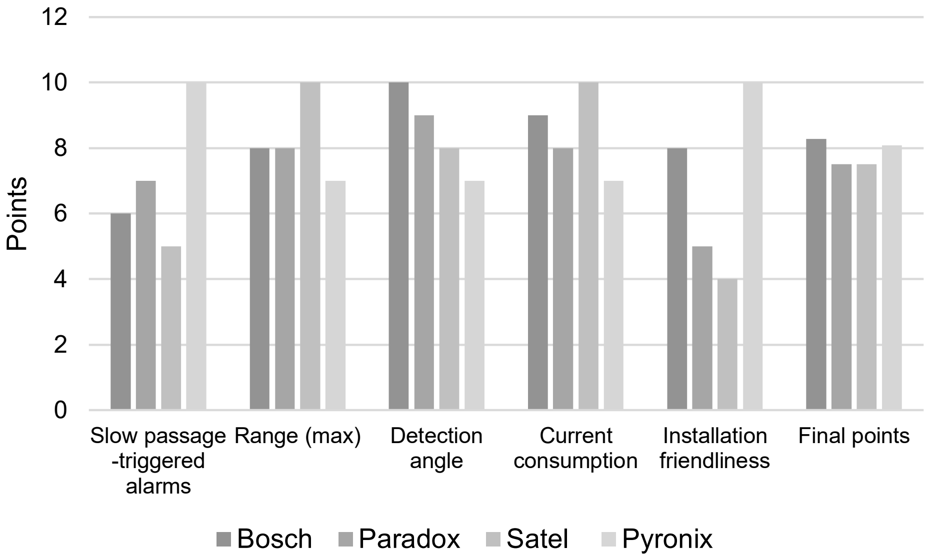

Figure 4. Overall standings for PIR detectors.

Until all of the systems have been tested, it is possible only to ask how many detectors and systems are at all secure. A further question is whether any system exists which could provide reliable protection for a reasonable price.

Although manufacturers are constantly attempting to develop systems, the majority copy old errors in the technical design into new products of a higher class, even despite the endeavours of customers to ensure manufacture is modified. Without innovative approaches and user feedback, this array will career into a blind alley (Upadrashta et al., 2015; Hart & Hartová, 2016; Drga et al., 2016; Luo et al., 2016; Choubisa et al., 2017).

This testing is also appropriate because PIR sensors are beginning to be used to monitor the movement of persons in the smarthome, as reported by authors in these articles: 'An Optical-Camera Complement to a PIR Sensor Array for Intrusion Detection and Classification in an Outdoor Environment' (Choubisa et al., 2017); 'ALPAS: Analogue-PIR-sensor-based Activity Recognition System in the Smarthome' (Kashimoto et al., 2017); 'Health Checking System Using a Wearable Health Device and PIR Sensors' (Miyazaki et al., 2016); 'Machine-to-machine Communication-Based Smart Home Security System by NFC, Fingerprint, and PIR Sensor with Mobile Android Application' (Morsalin et al., 2016); and 'Human Daily Activity Recognition Using Ceiling Mounted PIR Sensors' (Luo et al., 2016).

CONCLUSIONS

The technical design of security systems is unique for the majority of manufacturers. In the case of every manufacturer it is possible to find some degree of poor technical design which requires modification. This deficiency can be resolved through the technical development of the given product and adaptation to customer requirements.

The practical tests which have been conducted on PIR detectors delivered a level of insight into their functionality and usability in practice. Using multi-criteria analysis of variants, an optimal PIR detector was selected. In the research, the measured values of the PIR detector and installation convenience were compared. The PIR detector, ISC-BPR2-WP12 from the manufacturer Bosch, has emerged as being the best choice out of the comparison detectors.

The other detectors did not fare much worse than the ISC-BPR2-WP12. The second-placed one was the Pyronix-Hikvision KX10DP detector. In joint third position, the Paradox NV5 and Satel AQUA PET ended up with the same number of points. The difference between worst placed and best placed detector was only 10%.

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