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Passive Infrared (PIR) Sensors with Barker Code Lensing for Detecting Motion Direction

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ABSTRACT

Applications that require sensing presence or motion of people in a given physical area often employ passive infrared (PIR) sensors for these purposes. Commodity PIR sensors lack the spatial resolution to discern the direction of the person's movement. This disclosure describes a PIR sensor module that incorporates a Fresnel lenslet system based on Barker codes to provide the spatial resolution needed to detect the direction of motion by leveraging the autocorrelation property of Barker codes. Information on the direction of a user's motion opens up new possibilities for spatially intelligent applications and services.

KEYWORDS

- Passive Infrared (PIR) sensor
- Presence detection
- Motion detection
- Barker code
- Fresnel lens
- Spatial resolution
- Convolutional Neural Network (CNN)
- Smart home
- Lenslet pattern
- Correlational vector gap

BACKGROUND

Applications that require sensing presence or motion of people in a given physical area often employ passive infrared (PIR) sensors for these purposes. Detection of presence or motion

via PIR sensors can be used to support a variety of operations in these settings, such as triggering actions, monitoring security, etc. For instance, such sensors can be installed to support home intelligence operations within smart homes.

Typical PIR sensors include commodity hardware that generates a two-element plus alternating lenslet pattern to perform the presence or motion sensing. As shown in Fig. 1, such sensors incorporate a conventional Fresnel-patterned lens that has a few lenslets that focus the incident infrared radiation on the negative sensor channel and others that focus it on the positive sensor channel. Such a design results in the creation of several virtual cones in the open physical space in the proximity of the sensor.

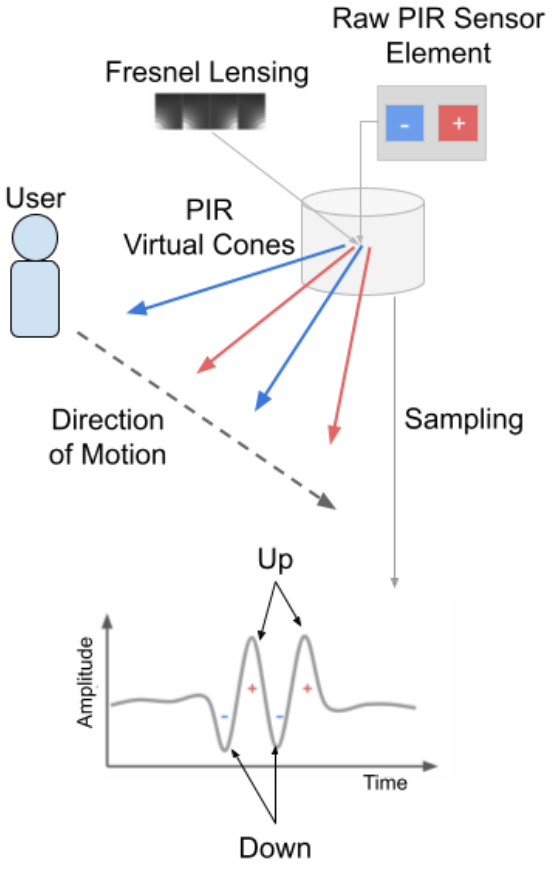

Fig. 1: Operation of a PIR sensor using conventional Fresnel lensing

A person crossing a particular virtual cone generates an appropriately signed signal. A person in motion leads to the generation of a signal with oscillations of down and up as the path taken by the person crosses various virtual cones in succession. For example, a person moving from left to right in front of the sensor with four virtual cones as shown in Fig. 1 will generate a signal with four oscillations of down → up → down → up.

Such a setup can thus detect presence and motion. For instance, the generated signal can be processed via a suitably trained binary classifier to indicate whether a person is present or moving within the spatial coverage of the sensor. However, the operation lacks the spatial resolution to discern the direction of the person's movement, e.g., left to right or right to left in relation to the sensor. As a result, such sensors are unsuitable when the direction of motion is essential for an application, e.g., counting people, detecting entry or exit into an area, providing virtual assistant services based on the direction of movement, etc.

DESCRIPTION

This disclosure describes a PIR sensor module that provides sufficient spatial resolution to support detection of the direction of motion of a person within the spatial range of the sensor. The sensor incorporates a Fresnel lenslet system based on Barker codes. The direction of motion is detected by leveraging the autocorrelation property (i.e., pseudorandomness) of Barker codes that results in breaking the symmetry of the response signal in a signal-optimized manner.

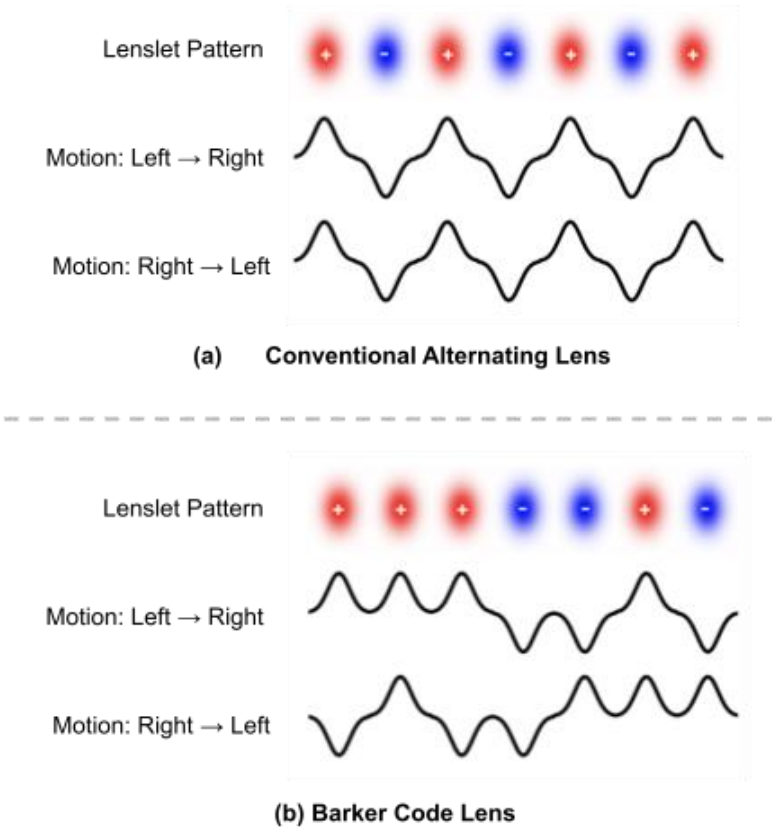

Fig. 2: Signal responses of PIR sensors with conventional and Barker Code lensing

For instance, a comparison of signal responses generated by a person moving in opposite directions is shown in Fig. 2 - a PIR sensor with a conventional alternating lens (Fig. 2a) and a PIR sensor that incorporates a Barker code lens as described in this disclosure (Fig. 2b). The asymmetry in the response signal as observed in Fig. 2b is indicative of the direction in which the person is moving in relation to the sensor.

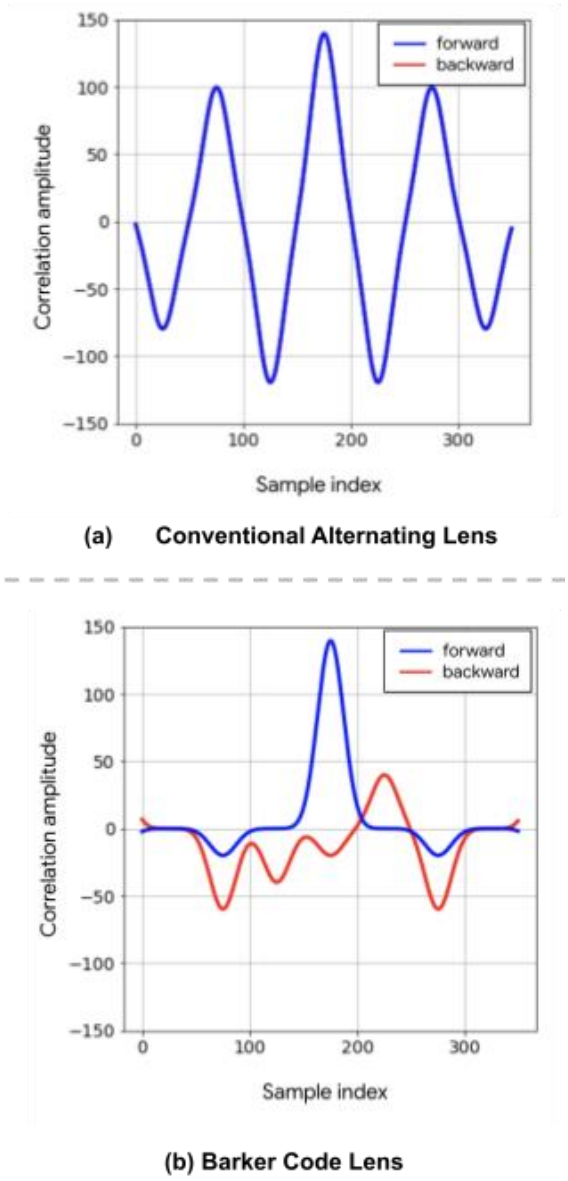

Fig. 3: Correlational vectors of PIR sensors with conventional and Barker Code lensing

As shown in Fig. 3, PIR sensors with a lens that incorporates Barker codes (Fig. 3b) result in a correlational vector gap that is sufficient to disambiguate directionality of motion compared to a conventional PIR sensor (Fig. 3a). The direction of motion relative to the sensor can be detected with an appropriate machine learning model, such as a three-class convolutional neural network. The three classes can correspond to the absence of a person, the presence of a person moving from left to right, and the presence of a person moving from right to left,

respectively. Training the model with suitable data, such as observed patterns of a user in motion in the vicinity of the sensor, can help achieve nearly errorless and efficient detection of the direction of motion.

With user permission, the techniques described in this disclosure can be incorporated within any PIR sensor and the output of the detected direction of the motion can be made available to applications and services in a suitable format, such as an application programming interface (API).

Information on the direction of a user's motion can enhance the capabilities of current applications to provide motion-related functionality. For example, applications that provide intelligent services within a smart home can be set to perform different actions, such as adjusting the temperature or controlling the lights, based on whether a user is entering or exiting an area. Moreover, the direction of motion can enable additional uses and functionalities that are not feasible with current PIR sensors that lack information about the direction of the detected motion. For instance, deployment of such sensors in a public setting can help understand movement patterns by counting the number of people moving in specified directions. Implementation of the described techniques can thus open up new possibilities for spatially intelligent applications and services.

Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs or features described herein may enable collection of user information (e.g., information about a user's social network, social actions or activities, profession, a user's preferences, or a user's current location), and if the user is sent content or communications from a server. In addition, certain data may be treated in one or more ways before it is stored or used, so that personally identifiable information is removed.

For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level), so that a particular location of a user cannot be determined. Thus, the user may have control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

This disclosure describes a passive infrared (PIR) sensor module that incorporates a Fresnel lenslet system based on Barker codes that provides sufficient spatial resolution to detect the direction of a person's motion by leveraging the autocorrelation property of Barker codes. The pseudorandomness results in breaking the symmetry of the response signal in a signal-optimized manner. A trained machine learning model can leverage the asymmetry in the response signal for accurate and efficient detection of the direction in which a person is moving. Information on the direction of a user's motion can enhance the capabilities of current applications to provide motion-related functionality and enable additional uses and functionalities.

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