Short communication

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A new approach to contactless probing of vital signs

Abstract

Vital sign detection is used across ubiquitous scenarios in medical and health settings and contact and wearable sensors have been widely deployed. Contactless detection can be achieved using camera imaging, but it is susceptible to ambient light conditions along with privacy concerns. This brief report appraises a photonic radar for non-contact vital sign detection. The high resolution of the radar system enables accurate respiratory detection from breathing simulators and a cane toad as a human proxy. This could cater for contactless and high-resolution vital sign detection to meet the increasing demands of future medical and healthcare applications.

Keywords: vital sign, LiDAR, photonic radar, resolution

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Introduction

Vital signs, which encompass a collection of clinical measurements that indicate fundamental bodily functions, serve as diagnostic parameters for the purpose of monitoring medical and health conditions. Vital sign detection is extensively utilized throughout various domains. Various common situations involve the utilization of specific environments, such as intensive care units designed to cater to individuals with severe health conditions, aged-care facilities that provide continuous health monitoring to prevent medical emergencies in unsupervised patients, and vehicles equipped to detect instances of driver drowsiness.

Traditional methods for detecting vital signs basically involve the use of contact-based devices. As for example, pulse oximeters utilize electrodes to detect subtle electrical changes that occur during cardiac contractions. Similarly, smartwatches employ infrared probe light to measure variations in intensity caused by changes in blood flow and volume—known as photoplethysmography. Despite their widespread use, contact-based methods possess certain lacunae which prevents continuous monitoring mode. Despite advancements in user experience, wearable sensors are not prescribed for individuals with burn wounds or skin irritations, as well as with limited surface area specially for infants.[1–6]

Non-contact methods utilizing optical sensors have been investigated, such as employing cameras to monitor specific areas of interest. Nevertheless, camera-based systems, such as infrared and conventional cameras, exhibit sensitivity to variations in skin color and lighting conditions. These systems commonly depend on intricate computational algorithms and thermal videos generated by infrared cameras, often exhibiting restricted resolution. Furthermore, the considerable level of detail provided by certain camera-based systems is another cause of concern. In such scenario, the search for a non-contact approach for monitoring vital signs is painstaking and researchers really did it. This short communication appraises a photonic radar for non-contact vital sign detection.

Background and principle

Monitoring vital signs is achieved through the utilization of contact-based instruments. oximeters and smart watches. Camera imaging offers a noncontact alternative; however, this approach is susceptible to fluctuations in ambient light conditions and skin pigmentation, thereby giving rise to privacy apprehensions. To do away with all these shortcomings, researchers in Australia have recently announced the successful development of a novel system that integrates photonic radar and Light Detection and Ranging [LiDAR] technologies. This innovative system has the capability to monitor vital signs remotely and accurately with a high level of precision. This hybrid configuration combines the strengths of both approaches, offering a potential solution for a noncontact vital-sign detection system that is both cost-effective and capable of high-resolution.[1]

Radar systems employing radio frequency (RF) waves have the capability to non-invasively retrieve a patient's vital signs, thereby presenting a viable option for contactless monitoring. Nevertheless, conventional electronic radars exhibit limited bandwidth and diminished range resolution, thereby impeding their ability to differentiate between closely positioned targets and detect subtle human vital signs, such as respiration. The developed prototype utilizes photonic generation of the radar signal instead of electronic means. The photonic-radar system commences by utilizing a laser source to emit a seed pulse, which is then directed into a fiber loop containing an acousto-optical frequency shifter. During each iteration of the loop, which has a duration of 162 nanoseconds, the pulse frequency undergoes a shift of 100 megahertz.

The inclusion of an erbium-doped fiber amplifier within the loop sustains the pulse power over multiple circulations. The outcome of conducting 250 round trips in the fiber loop yields a stepped-frequency (SF) optical signal characterized by a wide bandwidth (reaching up to 30 MHz) and a high level of time-frequency linearity. These attributes are deemed crucial for ensuring accuracy and achieving precise range resolution in a radar sensing setup designed for vital-signs monitoring. The signal originating from the source, which is transmitted through fiber optics, undergoes a conversion process to be transmitted in the radio frequency (RF) domain. This conversion is achieved through heterodyne mixing, where the signal is combined with a reference laser. Subsequently, the converted signal is transmitted to the desired destination using a transmitting antenna. The radar signal that has undergone reflection is subsequently detected by a receiving antenna which is subsequently transformed into the optical domain through the utilization of an electro-optical modulator and recorded using a photo detector Figure 1.

An optical injection of a temporal square envelope is applied to the FS fiber loop. The output signal reveals the resulting optically synthesized stepped-frequency signal.[1]

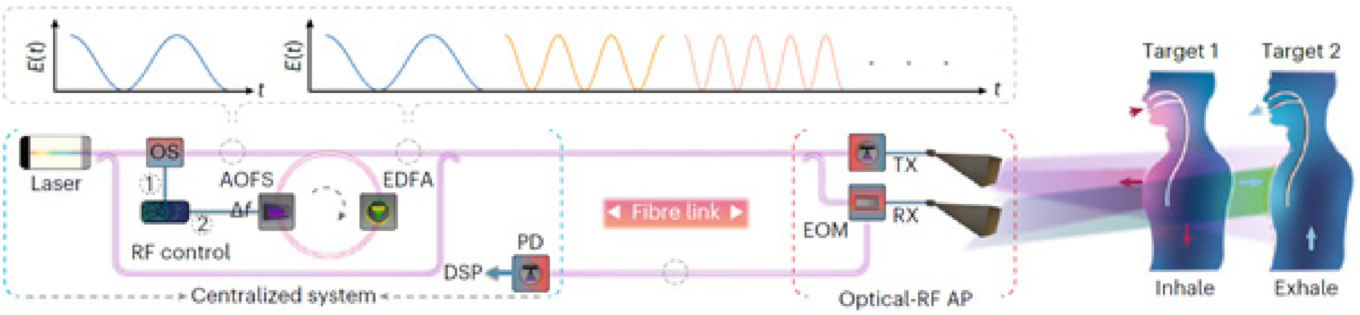

Figure 1 The photonic radar system used for detecting vital signs. It is based on a frequency-shifting (FS) fiber cavity, with the optical input and output signals depicted at the top of the diagram. A seed pulse, characterized by a singular frequency that is modulated by a gating mechanism. [Reproduced from (1) with permission].

Pros of the prototype

The additional benefit of utilizing radar signals for vital-sign detection, namely the ability to leverage the microwave signal's origin in the optical domain is to facilitate LiDAR sensing of vital signs. This is achieved by directly tapping a portion of the SF optical signal, bypassing the need for conversion to the RF domain. The integration of LiDAR and radar sensing capabilities within a single source could provide a significant advantage. This limitation arises from the fact that LiDAR, despite offering enhanced range and resolution, is unable to effectively penetrate objects like clothing, thereby restricting its ability to detect subtle vital-sign activity. By integrating both methods, the team was able to leverage the complementary features of the two approaches, resulting in enhanced sensing accuracy and resilience of the overall system. This hybrid approach resulted in the development of a vital-sign detection system that achieved a resolution as fine as six millimeters, demonstrating accuracy at the micrometer level.[1]

Implementation

During the experiment, the system successfully differentiated the respiratory patterns of two closely positioned human respiration simulators, which were approximately 10 cm apart, in real-time. The researchers assert that the system demonstrated its capacity to accurately detect or predict respiratory abnormalities associated with various medical conditions by effectively identifying irregular respiration through subtle movements at the millimeter level in the devices. Subsequently, it has been applied to the buccal region, which can be understood as the anatomical area corresponding to the cheek, of a cane toad, serving as a representative model for human physiology. The experimental conditions in this region present a greater level of difficulty compared to human trials due to its radar cross section being smaller than that of the human chest. The data obtained from the photonic radar yielded a precise record of the buccal movement of the toad, exhibiting a displacement of approximately 5 mm.[1]

Way forward

It is envisioned that the system will be utilized within a clinical environment to enable continuous and noncontact monitoring of vital signs. Via low-loss optical fiber to transmit signals to various sensing access points, it is possible to employ a centralized photonics-assisted radar platform for the noninvasive tracking of multiple targets. However, more in situ as well as in vivo experiments are required to make it fully functional. Additionally, the processing of colossal data generated during the process is another point of concern. With advancements in secure encryption as well as transmission, it can be predicted that these issues can be overcome. Apart from this, validation form gold standard protocol could be another viable option of attesting the efficacy of this novel technique. In summary, this methodology could potentially facilitate continuous surveillance of uncooperative targets, including those facing away or to the side, in contrast to the limitations of relying on a singular radar access point.[1–6]

Acknowledgments

None.

Conflicts of interest

Authors declare that there is no conflict of interest exists.

References

1. Zhang Z, Liu Y, Stephens T, et al. Photonic radar for contactless vital sign detection. *Nat Photon.* 2023;17:791–797.
2. Hannah Lanford. *Monitoring Vital Signs with Photonic Radar*. Optics and Photonics News. 2023.
3. Liu Y, Zhang Z, Burla M, et al. 11-GHz-bandwidth photonic radar using MHz electronics. *Laser Photon. Rev.* 2022;16(4):2100549.
4. Zhang Z, Liu Y, Eggleton B. Photonic generation of 30 GHz bandwidth stepped-frequency signals for radar applications. *J. Light. Technol.* 2022;40(14):4521–4527.
5. Lyu Y, Yihan Li, Chunlong Yu, et al. Photonic generation of highly-linear ultra-wideband stepped-frequency microwave signals with up to $6\square10^{6}$ time-bandwidth product. *J. Light. Technol.* 2022;40(4):1036–1042.
6. Liu Y, Zheru Qiu, Xinru Ji, et al. A photonic integrated circuit-based erbium-doped amplifier. *Science*. 2022;376(6599):1309–1313.