A Portable Infection Screening System Designed for Onboard Entry Screening Based on Multi-Parameter Vital Signs

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ABSTRACT

After outbreak of severe acute respiratory syndrome (SARS) in 2003, many international airport quarantines adopted fever-based screening to identify infected individuals using infrared thermography to control global pandemic. Unfortunately, the sensitivity of fever-based screening system did not exceed 70.4% at Narita International Airport. In order to achieve accurate onboard entry screening for highly contagious infectious diseases, the authors developed a portable system designed for onboard entry screening with linear discriminant analysis. Within several tens of seconds, the system automatically discriminates infected individuals from normal subjects using measured heart rate, respiratory rate, as well as facial surface temperature determined by thermography. The size of system is small enough to be placed on airplane tray tables. The authors tested on 68 subjects including 12 influenza patients to evaluate the system. The result showed sensitivity of 91.7% and specificity of 92.9%. The system seems to be promising for onboard infection screening to safeguard public health.

Keywords: Bio-Measurement, Infectious Disease, Pandemic, Public Health, Vital Signs

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1. INTRODUCTION

Since the rapid spread of severe acute respiratory syndrome (SARS) and a novel influenza A virus (N1H1) throughout the world in 2003 and 2009, mass screening for infectious passengers at the airport checkpoints have become standard procedure (Chiu et al., 2005; St John et al., 2005). Infrared thermography is adopted for febrile passenger screenings by monitoring their skin surface temperatures (Chan, Cheung, Lauder, & Kumana, 2004). Measuring the temperature of the skin surface is affected by many factors, such as taking antifebrile, alcohol drinking and ambient temperatures (Hausfater, Zhao, Defrenne, Bonnet, & Riou, 2008; Ng, Kaw, & Chang, 2004). Moreover, the body temperature also tends to be readily modified by taking antifebrile, which directly affects the accuracy of fever-based screening. For instance, a recent study showed that 55.6% of the H1N1-2009 passengers were under antipyretic medications upon arrival, and the sensitivity of fever-based screening system using thermography alone did not exceed 70.4% at Narita International Airport, Japan (Nishiura & Kamiya, 2011). Also, some previous studies revealed the limitation of effectiveness in detecting early-stage infectious symptoms (Bitar, Goubar, & Desenclos, 2009; Liu, Chang, & Chang, 2004). Moreover, the body temperature also tends to be readily modified by taking antifebrile, which directly affects the accuracy of fever-based screening. For instance, a recent study showed that 55.6% of the H1N1-2009 passengers were under antipyretic medications upon arrival, and the sensitivity of fever-based screening system using thermography alone did not exceed 70.4% at Narita International Airport, Japan (Nishiura & Kamiya, 2011). Also, some previous studies revealed the limitation of effectiveness in detecting early-stage infectious symptoms (Bitar, Goubar, & Desenclos, 2009; Liu, Chang, & Chang, 2004). In order to improve the accuracy, we developed a screening system which monitors infection-induced alternation of heart and respiratory rates as well as facial temperature in our previous study (Matsui et al., 2009). By adding those two new parameters, i.e., respiratory and heart rates, the system had a higher screening accuracy than the system with thermography alone (Matsui et al., 2010; Sun, Hakozaki, Abe, Vinh, & Matsui, 2012).

The idea of adding the two parameters to the system comes from the fact that infectious diseases accompany with inflammation, when they become symptomatic (Gauldie, Lamontagne, & Stadnyk, 1985). As is widely recognized, heart and respiratory rates are included in the diagnostic criteria of the systemic inflammatory response syndrome (SIRS). SIRS has the following criteria: (1) Body temperature greater than 38 °C or less than 36 °C. (2) Heart rate greater than 90 Beats per Minute (bpm). (3) Respiratory rate greater than 20 bpm or hyperventilation with a PaCO2 less than 32 mmHg. (4) White blood cell count ≥ 12,000 or ≤ 4,000 cells/mm³ (Berger & Chiolero, 2007). Our screening system does not measure PaCO2 and white blood cell count which require blood sampling. However, considering the fact that PaCO2 considerably correlate with respiratory rate (McNulty, Roy, Torjman, & Seltzer, 1990), in this sense our system covers three major indicators of SIRS (1) (2) (3) as above.

Due to the spread of pandemic influenza in 2009, Narita International Airport implemented strict screening measures including fever screening of onboard passengers (Nishiura & Kamiya, 2011). For this type of implementation, there is a pressing need of automatic screening system which reduces time and effort of quarantine officers. In order to meet this need, we developed a portable screening system with three parameters as described above.

The proposed new system is composed of a small size thermography to measure facial temperature, a reflective photo sensor to measure heart rate and microwave radar to measure respiratory rate. In order to make the system a portable size, a laser Doppler blood-flow meter was replaced by a compact size reflective photo sensor. The system dimensions are 0.27 meter long, 0.28 meter wide and 0.1 meter thickness, with its size being small enough to be placed on airplane tray tables. In this study, we demonstrated the effectiveness of this portable system in clinical tests. The tests were conducted on 12 influenza patients (36.8 °C < body temperature ≤ 38.4 °C, 16-42 years), and 56 healthy volunteers (35.9 °C < body temperature < 37.5 °C, 18-28 years) at Takasaka Clinic, Fushima, Japan in 2011.

This paper is organized as follows. The next section introduces our portable screening system hardware setup, signal processing techniques for multiple biosensors and discriminant method with linear discriminant analysis. To verify the
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