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An infectious disease/fever screening radar system which stratifies higher-risk patients within ten seconds using a neural network and the fuzzy grouping method

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Summary *Objectives:* To classify higher-risk influenza patients within 10 s, we developed an infectious disease and fever screening radar system.
Methods: The system screens infected patients based on vital signs, i.e., respiration rate measured by a radar, heart rate by a finger-tip photo-reflector, and facial temperature by a thermography. The system segregates subjects into higher-risk influenza (HR-I) group, lower-risk influenza (LR-I) group, and non-influenza (Non-I) group using a neural network and fuzzy clustering method (FCM). We conducted influenza screening for 35 seasonal influenza patients and 48 normal control subjects at the Japan Self-Defense Force Central Hospital. Pulse oximetry oxygen saturation (SpO_2) was measured as a reference.
Results: The system classified 17 subjects into HR-I group, 26 into LR-I group, and 40 into Non-I group. Ten out of the 17 HR-I subjects indicated SpO_2 <96%, whereas only two out of the 26 LR-I subjects showed SpO_2 <96%. The *chi-squared* test revealed a significant difference in the ratio of subjects showed SpO_2 <96% between HR-I and LR-I group ($p < 0.001$). There were zero and nine normal control subjects in HR-I and LR-I groups, respectively, and there was one influenza patient in Non-I group.

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Conclusions: The combination of neural network and FCM achieved efficient detection of higher-risk influenza patients who indicated SpO_2 96% within 10 s.

Introduction

The highly pathogenic avian influenza virus subtype H5N1 causes severe respiratory disease in humans, inducing threats of pandemic to increase.[1] Such a severe influenza infection elevates the risks of developing influenza-related complications, which is one of the leading causes of death during the epidemic season.[2,3] When a pandemic occurs, the rapid screening of infected patients with a severe infection can help clinicians make better medical decisions and provide improved patient care.[4] To conduct mass screenings of people with higher-risk influenza, we developed a radar system based on a neural network and the fuzzy clustering method for screening of influenza.

Infrared thermography has been applied as a means of fever screening at airports for almost 10 years, having been implemented after the severe acute respiratory syndrome outbreak of 2003.[5–8] However, the taking of an antifebrile drug results in the rapid modification of the body temperature and directly affects the efficacy of the thermography. Some recent studies have indicated that fever screening using thermography does not provide a satisfactory method of detecting febrile passengers.[9] Considering the defective fever screening method, we previously developed a non-contact screening system for performing medical examinations within 10 s using measured vital signs (i.e. heart rate, respiration rate, and facial temperature).[10] As a result of being infected, not only body temperature but also heart and respiration rates will invariably increase. Therefore by adding heart and respiration rates as new screening parameters, the system provided a higher screening sensitivity than using thermography alone.

Infection screening using multiple vital signs presents a multi-dimensional data classification problem, given that it is complex and exhibits non-linear boundaries. Since a neural network provides an efficient method of classifying multi-dimensional data, we have proposed a method that uses a neural network to distinguish influenza patients from normal control subjects. This method was developed in our previous study, which uses Kohonen's self-organizing map[11] (SOM) and the k-means clustering algorithm[12] (a non-linear clustering algorithm).[13] The advantage of using SOM together with the non-linear clustering algorithm is that it allows the specification of any number of classification groups, not just two. Therefore, it is rational to increase the number of groups to three to investigate whether the higher-risk patients can be gathered together into a newly created group.

In present study, we enhanced the SOM by incorporating a fuzzy clustering method (FCM) to cluster the subjects into three groups, i.e. a higher-risk influenza (HR-I) group, a lower-risk influenza (LR-I) group, and a non-influenza (Non-I) group. FCM is a non-linear clustering method that is used in a wide range of fields, including biometric recognition, pattern recognition, and medical data mining.[14–16] Unlike the k-means clustering method, FCM supports the use of classified data, which may belong to more than one group but with different degrees of membership. The membership represents the probability that the data belongs to a specific group based on fuzzy logic. Therefore, FCM is suitable for classifying multi-dimensional data without clearly defined boundaries, such as our multiple vital-signs data. The aim of this study was to evaluate the efficacy of the radar screening system for detecting higher-risk influenza patients in clinical settings. We tested the system at the Japan Self-Defense Forces Central Hospital during the 2012–2013 influenza season.

Patients and methods

The neural-network-based infectious disease screening radar system

We redesigned our previously developed system[10,17] to improve its portability and stability. The main advantage of this portable system is that it can be used in confined spaces such as inside an aircraft.[18] The system consists of three biosensors, namely, a thermograph to monitor facial temperature (NEC/AVIO Infrared Technologies Co., Ltd., C-200, Japan), a 10-GHz microwave radar for the non-contact determination of the respiration rate[19] (new-JRC, NJR-4175, Japan), and a finger-tip photo-reflector to measure the heart rate (Rohm, RPR-220, Japan). All of the

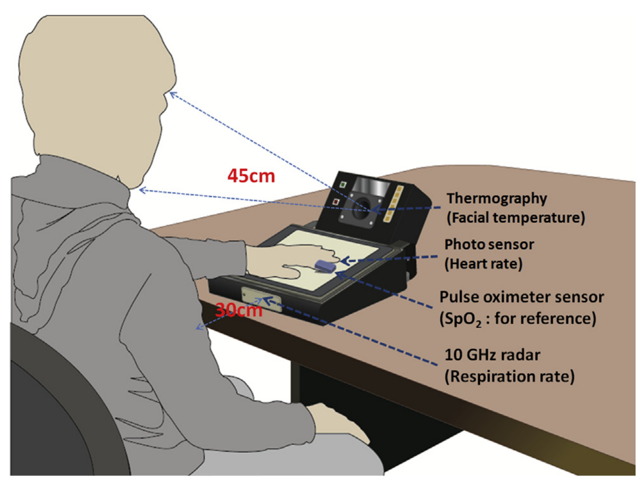

Figure 1 A pulse oximeter module was used to measure the SpO_2 levels. The respiration rate was measured using the 10-GHz respiration radar by monitoring the respiratory motion of the chest, the heart rate was measured by a finger-tip photo-reflector, and the facial temperature was measured by means of thermography. The thermograph was placed 45 cm from the subject's face, and the respiration radar was placed 30 cm from the subject's chest.