Multiple Sensor Fusion Technology for Non-contact Measurement of Vital Signs and its Application for Infection Screening

2021/03/04

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Agenda

Recent studies on non-contact bio-measurement
Non-contact measurement of vital signs (heart rate, respiration rate, body temperature) and its medical applications

Current Projects in SUN LAB@UEC
Infection Screening System for Prevention of Pandemic
Elderly Bedridden Hospitalized Patients Monitoring System

Elderly Bedridden Hospitalized Patients Monitoring System Sleep Monitoring (Sleep Apnea Syndrome) Mental Stress Monitoring (Major Depressive Disorder) Mobile Robot for Home Healthcare

• Future Plans



Remote Sensing of Vital Sign with Microwave Radar and Imaging Sensors



Non-contact, without attaching electrodes, long-term monitoring

Medical Applications



CURRENT PROJECTS

Fever-based Screening at Airport during Covid-19 Pandemic

Dennis Normile: Airport screening is largely futile, research shows. Science, (2020)

Fever-based Screening at a Hospital Entrance during Covid-19 Pandemic

Cornelius Dzien, et al.: Covid-19 screening: are forehead temperature measurements during cold outdoor temperatures really helpful?. Wiener klinische Wochenschrift, **(2020)**

Background --- Infectious Disease and Vital Signs



Included in the diagnostic criteria for the

Systemic Inflammatory Response Syndrome (SIRS)

Infection type	Temp (°C)	HR (bpm)	RR (bpm)	
Typhus	40~41	110~120	30~40	
Influenza	40~41	110~120	30~35	
Bloody flux	38~39	120~130	—	
Malaria	40~41	Above 100bpm	—	
Measles	40~41	120~140	35~40	
Tetanus	39~40	100~110	25~30	

Associated with inflammation

As a results of being **Infected**, not only body temperate, but also **Heart rate** and **Respiration rate** increase.

Our Vital-signs based Infection Screening System



(b) Neural network and the fuzzy clustering method

<u>Sun G</u>: An infectious disease/fever screening radar system which stratifies higher-risk patients within ten seconds using a neural network and the fuzzy grouping method. Journal of Infection, (2015)

System design: Non-contact vital-sign based infection screening system





10GHz microwave radar, Respiration rate

2013







2018





Image Processing to Extract Respiration and Heart beat

Respiration -Thermal image



Schematic representation of the image processing method



Sun G: Remote sensing of multiple vital signs using a CMOS camera-equipped infrared thermography system and its clinical application in rapidly screening patients with suspected infectious diseases. International Journal of Infectious Diseases, (2017) 12



- Laboratory testing -

• Subject : 10 students(23±1 years)

Measurement : twice per subject

• Ambient temperature : 25°C

- Correlation and Bland-Altman analysis -



Classification algorithm and clinical test

Classification algorithm



Linear Discriminate Analysis (LDA)



Neural Network Determines Optimal Screening Condition



Self-organizing Map (SOM) with k-means clustering method

- Competitive Learning Neural Network (unsupervised)
- Clustering method: Data of a similar property constitute a cluster

<u>Sun G</u>, Matsui T, et al. A novel infection screening method using a neural network and k-means clustering algorithm which can be applied for screening of unknown or unexpected infectious diseases. Journal of Infection. **2012**.

Clinical Tests on Seasonal Influenza and Dengue Fever



Japan Self-Defense Forces Central Hospital (2009, 2012, 2013)



Okinawa International Airport (2009)



Narita International Airport Clinic (2013)



National Hospital of Tropical Diseases (2017)

SUBJECTS

57 patients diagnosed to have A-type influenza by QuickVue Rapid SP influ kits (Quidel Corp., USA), (19-40 years old). Treated with an Oseltamivir or a Zanamivir hydrate $35.7 \degree C \leq Body$ Temperature $\leq 38.3 \degree C$

35 Normal control subjects No symptoms of fever, (10-35 years old). 35.5 °C \leq Body temperature \leq 36.9 °C

Vital-signs based infection screening V. S. Fever screening



Vital-signs based infection screening V. S. Fever screening

Normal Control						Influenza					
Body Temperat	Heart ure Rate(X ₁)	Respiratory Rate(X ₂)	Average Facial Temperature(X	Z (x ₁ , x ₂ , x ₃)	x ₃)	Body Temperati	Heart ure Rate(X ₁)	Respiratory Rate(X ₂)	Average Facial Temperature(X ₃)	Z(x ₁ , x ₂ , x	< ₃)
35.5	50	13	32.6	7.1		35.7	78	20	32.6	-2.5	
36.2	63	15	33.1	3.3		36.7	105	18	32.9	-6.9	
36.4	66	14	32.8	3.0		36.8	97	15	33.3	-4.0	
36.5	54	13	33.2	6.0		36.9	82	16	33.6	-1.4	
36.7	72	15	32.0	1.7		37.9	106	13	34.9	-5.6	
36.8	60	13	33.2	4.8		38.2	93	15	34.4	-3.7	
36.9	54	11	33.4	6.9		38.3	108	15	34.4	-6.9	
Conta	ct	Non-c	contact			Contac	t	Non-co	ntact		

Comparing and Optimizing Classification Algorithms

Method Error Sensitivity Specificity Average Average classification time training time rate [%] [%] [%] [ms] [ms] ODA 9.8 93 3.9 85.7 34.9 ODA* 10.9 89.5 88.6 LDA 10.9 91.2 85.7 30.7 3.4 LDA* 13 88.6 86 85.7 15.4SVM 9.8 93 0.7**kNN** 10.9 93 82.9 6 LR 12 89.5 85.7 24.51.3 NB 14.189.5 80 7.3 1.4 25 87.7 54.3 thr₁ _ _ 29.461.4 85.7 thr_2

TABLE I CLASSIFICATION RESULTS AND AVERAGE RUNNING TIME.

Yao Y & Sun G: Multiple Vital-sign Based Infection Screening Outperforms Thermography Independent of the Classification Algorithm. IEEE Transactions on Biomedical Engineering, 2016.

Future Plans --- Networked System for Infection Surveillance



<u>Sun G</u>: Visualisation of epidemiological map using an Internet of Things infectious disease surveillance platform. Critical Care, **2020.**

Guanghao Sun, Nguyen Vu Trung, Takemi Matsui, Koichiro Ishibashi, Tetsuo Kirimoto, Hiroki Furukawa, Le Thi Hoi, Nguyen Nguyen Huyen, Quynh Nguyen, Shigeto Abe, Yukiya Hakozaki, Nguyen Van Kinh <u>Field evaluation of an infectious disease/fever screening radar system during the 2017 dengue fever</u> <u>outbreak in Hanoi, Vietnam: A preliminary report</u>. *Journal of Infection*, 75(6), 590-593, 2017.

Guanghao Sun, Yosuke Nakayama, Sumiyakhand Dagdanpurev, Shigeto Abe, Hidekazu Nishimura, Tetsuo Kirimoto, Takemi Matsui <u>Remote sensing of multiple vital signs using a CMOS camera-equipped infrared thermography system</u> <u>and its clinical application in rapidly screening patients with suspected infectious diseases</u>. *International Journal of Infectious Diseases*, 55, 113-117, 2017.

Yu Yao, **Guanghao Sun**, Takemi Matsui, Yukiya Hakozaki, Stefan van Waasen, Michael Schiek <u>Multiple Vital-sign Based Infection Screening Outperforms Thermography Independent of the</u> <u>Classification Algorithm.</u>

IEEE Transactions on Biomedical Engineering, 63(5), 1025-1033, 2016.

Guanghao Sun, Takemi Matsui, Yukiya Hakozaki, Shigeto Abe <u>An infectious disease/fever screening radar system which stratifies higher-risk patients within ten</u> <u>seconds using a neural network and the fuzzy grouping method.</u> *Journal of Infection*, 70(3), 230-236, 2015.

Thank You!

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