International Journal of Information Technology Vol. 26 No. 1 2020

A Hybrid Framework for Smart and Safe Working Environments in the Era of COVID-19

Huiguo Zhang[1], Yundong Cai[1], Hao Zhang[1] and Cyril Leung[1,2]

[1]Joint NTU-UBC Research Centre of Excellence in Active Living for the Elderly, Nanyang Technological University
[2]Department of Electrical and Computer Engineering, The University of British Columbia
huiguo001@e.ntu.edu.sg, {yundong.cai, zhang.h}@ntu.edu.sg, cleung@ece.ubc.ca

Abstract

The COVID-19 pandemic has greatly changed the living and working lifestyles that we are familiar with. How can organisations ensure a safe working environment in the epidemic and post-epidemic periods? In this paper, we propose a hybrid framework of the Internet of Things (IoT), humanoid robots and artificial intelligence to establish a smart and safe working environment. The framework involves a list of modules in the functional hierarchy with guidelines and principles that give a structural description of the build-up in the working environment. Moreover, ethical concerns are highlighted for the framework setup.

Keywords: Smart Working Environment, COVID-19, IoT, Smart Robots, Ethics.

I. Introduction

COVID-19 is a severe infectious virus which has spread across most of the countries and territories in the world. The virus epidemic has totally changed the human lifestyle for living and working [10]. People need to wear masks in public spaces all the time and keep safe distances from each other, in order to minimise the potential risk of virus infection and ensure the self protection. Work-from-home (WFH) becomes a new trend for the daily working style and online

communication becomes dominant over the face-to-face communication. While the epidemic is still ongoing, a lot of organisations have requested some of their employees work in the offices (via team A/B rotation etc). A very critical problem for the organisations is how to ensure a safe working environment for the employees in the epidemic and post-epidemic periods without costing excessive human efforts and involvements.

With the development of the Internet of Things (IoT), robotics and artificial intelligence, a safe working environment becomes possible [14]. Ambient intelligence plays an important role for healthcare in the daily life spaces via sensors and underneath intelligence [15], which also inspires the possible adaptation of the working environment. Researchers propose the adoption of artificial intelligence and robotics to build smart working environment [5]. In fighting against COVID-19, a lot of IoT solutions have been proposed to monitor human activities via a wide spread of sensors, to enhance diagnosis and treatment, reduce mistakes and expenses and make control more effective [29].

For the working environment, "smart" and "safe" have become more and more important since the epidemic than ever. "Smart" working environment means that the environment is aware of the employees' activities and is able to spot the faults and misconducts of the employees at the early stage, without much burden in human efforts; meanwhile, "Safe" working environment means that the environment helps to ensure all the safety measures, especially in the epidemic period, e.g. wearing masks, human healthy and safe distance.

The main purposes of the smart and safe working environment design are to:

1. Ensure minimum and safe human contact;

2. Offload people's routine tasks;

3. Verify a user's identity to minimize risks from external;

4. Help employees to build up correct behavior norms.

In this paper, we propose a hybrid framework based on IoT, humanoid robots and artificial intelligence platform to achieve a smart and safe working environment. An overall architecture is built to cover all the necessary modules in the functional hierarchy, ranging from the infrastructure, to data, to AI models, to applications. Guidelines are provided to facilitate the organizations/companies/institutions to make a similar setup. Moreover, ethical issues are also highlighted for the smart working environment setup.

II. Framework

A. Identify Stakeholders

The working environment is different from the living environment and public environment, which involves people with close communications through a long day time and opportunities to interact with external people. Based on the size of organisation, the dynamics of human flow also varies. In order to design a safe and smart working environment, there is a need to identify the stakeholders who are interacting with the environment and their responsibilities first. The main stakeholders to be considered for the design include:

- *Management*: the management refers to the top executives who are responsible for the safety and welfare of all the people in the organisation, by setting the safety measures and ensuring that all personnel follow these measures. They should be aware of the ongoing events in the working environment, and act promptly via policy executions and actions.

- *Employees*: the employees are the majority in an organisation, who should follow all the required safety measures by themselves to keep safe and efficient while working.

- *Support staff*: there are a number of supporting persons in the working environment (e.g. cleaner, security guard etc.), who will make routine but infrequent interactions with the employees.

- *Visitor*: there are visitors occasionally to the organisation, e.g. suppliers, customers, collaborators, who should be tracked in the normal procedures.

Each working environment of an organisation is different from others, so a generalized architecture might not be suitable for a specific organisation. By understanding the formation of the stakeholders who are involved in the working environment, the organisation can determine the modules/solutions to suit the organisation's requirements best.

B. Layered Architecture

Based on the functionalities, a generalized 4-layer architecture is constructed as shown in Figure 1, which includes Infrastructure Layer, Data Layer, Intelligence Layer, and Application Layer.

The four layers are organized in the sequence of data flow from bottom to top:

- *Infrastructure Layer*: this layer contains various IoT devices, sensors and robots. The continually connected physical world with computational elements forms a smart environment [1].

- *Data Layer*: the collected data from the elements in the Infrastructure Layer is processed for further analysis in intelligence layer. Privacy data is processed or encrypted in this layer.

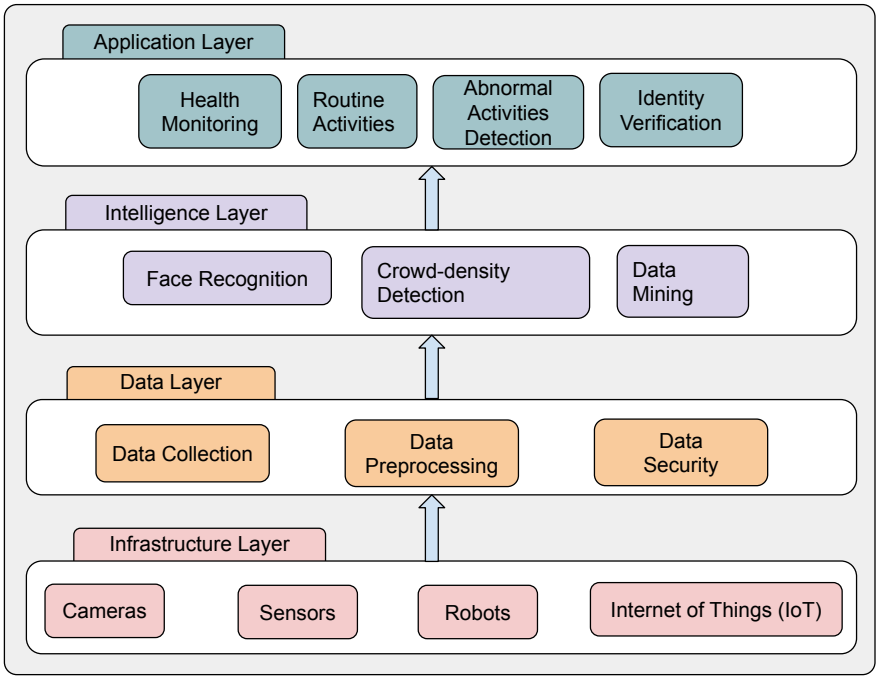

Fig 1 Architecture of the hybrid framework for smart and safe working environment

- *Intelligence Layer*: in this layer, many AI technologies such as computer vision (CV), Natural Language Processing (NLP), are used to solve specific problems for the smart workplace [5].

- *Application Layer*: based on the output from the intelligence layer, the application layer will provide a series of solutions to enable a smart and safe working environment.

B-1. Infrastructure Layer: A Hybrid of IoT, Robots for more complete data collection

To ensure a safe working environment, it is important to seamlessly monitor the working environment. Three approaches can be adopted by the organisations, including 1) using IoT systems only; 2) using mobile robots only; or 3) using a hybrid of IoT systems and navigating robots. A comparison between the IoT system and the robot system is depicted in Table 1.

Both the IoT system and mobile robot system have their own strengths and limitations in terms of deployment, cost, coverage, security. Thus, a hybrid of the two systems would enable a more

Table 1 Comparison between IoT System and Robot System for Data Collection

	IoT	**Robot**
Data Collection Mode	Continuously via Bluetooth low energy	Scheduled Collection
Deployment Method	Attached to physical assets	Place in the working environment
Detection Mode	Static/Fixed	Dynamic/Mobile
Security Concerns	Only at public areas	Program to limit the navigation
Cost of Deployment	Cheap	Expensive
Functions	Detection Only	Detection and Performing Tasks

complete coverage, which provides a better and balanced solution to ensure the safety of the working environment as well as privacy protection.

Fig 2 A hybrid system setup of IoT with mobile robots

A hybrid of an IoT setup with mobile robots in the working environment is shown in Figure 2. This approach is cost-effective without overwhelming IoT devices and has improved penetration for data collection. In order to make contact tracing more effective, the larger workplace should be

split into small areas [9]. For each space, the IoT setup contains one kind or more of the following devices or sensors:

- A camera is deployed at the entrance of the work area or public areas to capture the facial images of people entering this area [36]. Based on the facial images, people's identity is recognized by the face recognition modules [32, 3]. At the same time, whether the person is wearing a mask is being recognized [21] if wearing face mask is compulsory.

- A non-contact thermometer is also deployed at the entrance of the work area for measuring the body surface temperature of the person entering the area [11]. If the body surface temperature is higher than normal, the system will trigger an alarming message.

- Cameras are deployed for real-time crowd-density detection [37] at the hub of public areas such as lobby, meeting room, discussion room, food room etc. where people usually gather.

- Motion sensor: motion sensors are placed in the working environment (e.g. doors, corridors) to track people's moving activities. By analysis the people's movement information, the system can estimate the density of crowds and make a decision of disinfection frequency [2].

- Temperature sensor/humidity sensor: there are some supporting sensors to provide basic information about the working space.

As a complement to the IoT system, a mobile robot or a group of robots are suggested to be deployed in the work area, which have embedded on them the following sensors:

- A 2D laser for environmental mapping and construction, in turn supporting autonomous navigation [7, 28]. With the capability of autonomous navigation, the mobile robot can be

programmed to conduct a series of functions such as checking social distance, measuring staff body temperature, delivering items etc.

- Cameras are quite common embedded in a mobile robot. They serve a lot of functions in this framework such as measuring distances between staff and face mask detection [22].

- A non-contactable infrared thermometer for checking the body surface temperature of people in the area [18]. Based on the body surface temperature information, any abnormal health status will be recorded and the supervisors will be notified accordingly.

B-2. Data Layer: minimal data with the right purpose

Data is most critical for the success of the safe working environment.

The data collected via the IoT system and robot system in time sequence include:

- *Actions*: it represents the individual actions by a person, e.g. moving, gestures.

- *Interactions*: it represents the interactions between two or more people in the physical world.

- *Activity*: by understanding the actions and mutual interactions, the activity means the semantic events in a certain context

Besides the behavioral data collected in real-time, context-aware/organisation-related data are also collected. For example, in order to examine whether a person is an employee of the organisation, there is a need to store the person's information in the system in the first place. This part of data is strictly confidential within the organisation, and needs to be kept with the highest security (e.g. permissions, encryption, network isolation etc).

Some principles about the data are : 1) minimize the data to be used for the model training; 2) keep

the data safe for both storage and communication; and 3) keep the user information confidential. There are more detailed ethical issues about the data discussed in Section C.

B-3. Intelligence Layer: computational models from data to solution

The intelligence layer contains all the modules to ensure the working environment is "smart", which bridges the gap between the data and the applications.

Based on the data collected via the IoT system and robot system and context-aware data, artificial intelligence models in the intelligence layer can be used to interpret the data and induce the proper actions for different applications. Data mining models can be developed to classify whether a typical situation is proper or improper.

Some typical models involved in the intelligence layers include:

- Face Recognition: based on computer vision, face recognition is mainly used for identity verification. During the COVID period, one great challenge would be face recognition for human mask wearers [19, 24].

- Crowd-density detection: detection is mainly based on the IoT sensors together with computer vision by the robots, which aims to measure the distance between two or more persons.

- Data Mining: by mining the multi-modal data, we can analyse the people's actions and semantic activities, which provides the basis for the abnormal activities detection.

B-4. Application Layer: applications to ensure safe and smart

Function Modules in the framework include:

1. Identity Verification

   Different countries have implemented their own methods to track people's activities at a venue in a time slot. For example, the Singapore government implemented the SafeEntry to track the indoor activities [34]. Once a person is diagnosed with a COVID-19 infection, people with the same visiting history will be informed to stay at home and keep track of their health status. A total number of people can be recorded for a venue, so that some restriction rule can be applied (e.g. a gathering of 50 people is not allowed in the Circuit-breaker Phase 1 period). However, this can only be implemented at a large scale, e.g. a building, a company, which does not provide a small scale measurement in the working environment. For example, who has used the meeting room between 3pm-5pm? When a visitor arrives, who has ever contacted him/her? It can be done via the face recognition or sensor tracking at different areas (using RFID etc).

2. Detection of abnormal activities

   The available activity recognition could be conducted via the following non-contactable methods:

   - Computer vision: Computer vision is a powerful tool to check if a person wears mask when he/she is moving in the working environment; it can also detect if two persons have followed the safe-distance rule [4].
   - Radio Frequency Identification (RFID): RFID enables non-contactable communication, which has been implemented in a lot of commercial solutions [31].
   - QR Code: 2D barcodes have been widely used for tracking via simple scanning [17].
   - Sensor-based activity recognition [8, 20]: by deploying the sensors (e.g. motion sen-

sors), peoples' activities can be derived from understanding the actions detected under certain contexts.

Some safe measures should be followed in a safe working environment [34]. For example, people need to wear masks as necessary. People should keep a safe distance at communicating with each other face-to-face. People don't have symptoms, e.g. fever (high temperature), dry cough and tiredness.

3. Health Monitoring

   Health monitoring is very critical for the working environment to ensure that every person is healthy. Any person with potential symptoms (e.g. dry cough, high temperature) are advised to see a doctor.

4. Routine Activities

   In order to minimise human contact, some routine activities can be performed by the mobile robots, e.g. cleaning the working area, delivering some documents etc.

With the AI-empowered applications, the stakeholders are able to quickly respond to various abnormal situations and alarm/report to the management team. Meanwhile, the robot can sanitize the working place based on a routine schedule and provide on-the-spot intervention, e.g. inform the people who are not keeping safe distance and report abnormal temperature. The system can also generate a statistical or narrative report [35] for the decision-makers to mange the working environment.

C. Ethical Challenges

The main objective of this framework is to ensure a safe and comfortable working environment in the era of COVID-19. However, health monitoring technologies may raise various ethical issues for the stakeholders, such as data privacy and transparency [33]. Therefore, there is a requirement to ensure that ethical issues are well addressed in the hybrid framework. We summarized some of the ethical challenges in the smart working environment and proposed practical guidance for the decision-makers. These ethical considerations are grounded in the basic principles and moral considerations of public health ethics and data ethics [23, 27].

1. Protecting Privacy

   The IoT sensors and robot may impinge upon individual privacy by collecting users' information such as health status, behaviours, and current locations [12]. With the vast amount of data being gathered, managers or application developers must prevent down-stream reidentification through data linkage to protect privacy for each individual. It is also important to understand that the risks of privacy may change and accumulate over time, which highlights the need for strong legislative protection when applying the digital tools [26]. Privacy issues also disclose further concerns about fairness. Proper implementation of the IoT and robot technologies implies technical, legal, and ethical distinctions that must ensure trust and accountability [6]. Therefore, privacy risks relate to the vulnerability of individuals and groups in the working environment, inciting us to use the technologies to empower our working environment, instead of using their power to increase or perpetuate the vulnerabilities [30].

2. Preserving Transparency and Autonomy

   The technologies for the smart working environment have the potential to undermine not

only privacy but also personal autonomy and transparency [29]. The most obvious form of violation of personal autonomy is the mandatory use of such technologies [13]. Therefore, the data collection must respect users' autonomy. Data and technology transparency is crucial for the users to voluntarily work in the smart environment to prevent them from the virus. Transparency in the form of provocative communication with all the key stakeholders—and where possible, active consultation and participation with them—is essential and needs to be an integral part of the system from beginning to end. It is necessary to establish a real-time feedback mechanism to ensure transparency during the technology deployment stage and continuously evaluate its usage and effects. Based on the goals set in the planning and selection phase, the risk assessment of the system should be constantly updated for all the stakeholders to keep transparency.

3. Protecting Data

   The system developers must take every effort to protect stakeholders' data, including ensuring sufficient security of any personal data collected and of any sensors, applications, networks, or services involved in the collection, transmission, processing, and storage [25]. The anonymization of the data should be carefully considered, and only anonymous data can be retrieved from the system. The collected data should be only used for the purposes of responding to the COVID-19 pandemic, which should be dismissed as soon as they are no longer relevant. The data collected, fed, and aggregated in response to the pandemic must be limited in scope, within the time frame related to the pandemic, and must not be used for commercial or any other purposes [16].

At the time of the COVID-19 pandemic, the development and deployment of digital health tech-

nologies in the working environment for pandemic management have increased. However, it must be ensured that the technologies are scientifically and ethically sound to receive broad public trust and acceptance. This section can help system developers and decision-makers consider the complex ethical challenges when designing the smart working environment.

III. Conclusion

In this paper, we have proposed a hybrid framework for a smart and safe working environment in the era of COVID-19, with IoT, robots and artificial intelligence. It lists out the modules in the framework to be used from the infrastructure to the data, security and application, and provides the guidelines/necessary modules for the organisations' reference. The organisations can build their own safe working environment with modules for their own requirements. Moreover, ethic issues are highlighted to raise any concern from such a system setup.

References

[1] Ejaz Ahmed, Ibrar Yaqoob, Abdullah Gani, Muhammad Imran, and Mohsen Guizani. Internet-of-things-based smart environments: state of the art, taxonomy, and open research challenges. *IEEE Wireless Communications*, 23(5):10–16, 2016.

[2] Manar Amayri, Abhay Arora, Stephane Ploix, Sanghamitra Bandhyopadyay, Quoc-Dung Ngo, and Venkata Ramana Badarla. Estimating occupancy in heterogeneous sensor environment. *Energy and Buildings*, 129:46–58, 2016.

[3] Stephen Balaban. Deep learning and face recognition: the state of the art. In Ioannis A. Kakadiaris, Ajay Kumar, and Walter J. Scheirer, editors, *Biometric and Surveillance Tech-*

nology for Human and Activity Identification XII, volume 9457, pages 68 – 75. International Society for Optics and Photonics, SPIE, 2015.

[4] Robert Bodor, Bennett Jackson, and Nikolaos Papanikolopoulos. Vision-based human tracking and activity recognition. In *Proc. of the 11th Mediterranean Conf. on Control and Automation*, volume 1, 2003.

[5] David Brougham and Jarrod Haar. Smart technology, artificial intelligence, robotics, and algorithms (stara): Employees' perceptions of our future workplace. *Journal of Management & Organization*, 24(2):239–257, 2018.

[6] GABRIELA ARRIAGADA BRUNEAU, MARK GILTHORPE, and VINCENT C MÜLLER. The ethical imperatives of the covid-19 pandemic: A review from data ethics. *Los imperativos éticos de la pandemia de COVID-19*, 46:13–35, 2020.

[7] Cesar Cadena, Luca Carlone, Henry Carrillo, Yasir Latif, Davide Scaramuzza, José Neira, Ian Reid, and John J Leonard. Past, present, and future of simultaneous localization and mapping: Toward the robust-perception age. *IEEE Transactions on robotics*, 32(6):1309–1332, 2016.

[8] Liming Chen, Jesse Hoey, Chris D Nugent, Diane J Cook, and Zhiwen Yu. Sensor-based activity recognition. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 42(6):790–808, 2012.

[9] Aaqib Bashir Dar, Auqib Hamid Lone, Saniya Zahoor, Afshan Amin Khan, and Roohie Naaz. Applicability of mobile contact tracing in fighting pandemic (covid-19): Issues, challenges and solutions. *Computer Science Review*, page 100307, 2020.

[10] Yogesh K Dwivedi, D Laurie Hughes, Crispin Coombs, Ioanna Constantiou, Yanqing Duan, John S Edwards, Babita Gupta, Banita Lal, Santosh Misra, Prakhar Prashant, et al. Impact of covid-19 pandemic on information management research and practice: Transforming educa-

tion, work and life. *International Journal of Information Management*, page 102211, 2020.

[11] Ahmed G. Ebeid, Enas Selem, and Sherine M. Abd El-kader. Early detection of covid-19 using a non-contact forehead thermometer. In Aboul Ella Hassanien, Adam Slowik, Václav Snášel, Hisham El-Deeb, and Fahmy M. Tolba, editors, *Proceedings of the International Conference on Advanced Intelligent Systems and Informatics 2020*, pages 314–323, Cham, 2021. Springer International Publishing.

[12] Urs Gasser, Marcello Ienca, James Scheibner, Joanna Sleigh, and Effy Vayena. Digital tools against covid-19: taxonomy, ethical challenges, and navigation aid. *The Lancet Digital Health*, 2020.

[13] Urs Gasser, Marcello Ienca, James Scheibner, Joanna Sleigh, and Effy Vayena. Digital tools against covid-19: taxonomy, ethical challenges, and navigation aid. *The Lancet Digital Health*, 2(8):e425–e434, 2020.

[14] Maria Grazia Gnoni, Paolo Angelo Bragatto, Maria Francesca Milazzo, and Roberto Setola. Integrating iot technologies for an "intelligent" safety management in the process industry. *Procedia Manufacturing*, 42:511–515, 2020.

[15] Albert Haque, Arnold Milstein, and Li Fei-Fei. Illuminating the dark spaces of healthcare with ambient intelligence. *Nature*, 585(7824):193–202, 2020.

[16] Laura P Hartman. Technology and ethics: Privacy in the workplace. *Business and Society Review*, 106(1):1–27, 2001.

[17] Shazi Iqbal, Shiraz Iqbal, II Merrill S Ross, Jeffrey S Ross, and Shahin Iqbal. Method of specimen tracking via barcode and rfid correlation at accession time, October 9 2018. US Patent 10,095,898.

[18] Chen-Chang Jang. Forehead thermometer for hygienic measurement, September 28 2006.

US Patent App. 11/089,924.

[19] Langford Lane. Nist finds flaws in facial checks on people with covid masks. *Biometric Technology Today*, 2020.

[20] Ye Liu, Liqiang Nie, Li Liu, and David S Rosenblum. From action to activity: sensor-based activity recognition. *Neurocomputing*, 181:108–115, 2016.

[21] Mohamed Loey, Gunasekaran Manogaran, Mohamed Hamed N Taha, and Nour Eldeen M Khalifa. A hybrid deep transfer learning model with machine learning methods for face mask detection in the era of the covid-19 pandemic. *Measurement*, 167:108288, 2020.

[22] Toshanlal Meenpal, Ashutosh Balakrishnan, and Amit Verma. Facial mask detection using semantic segmentation. In *2019 4th International Conference on Computing, Communications and Security (ICCCS)*, pages 1–5. IEEE, 2019.

[23] Brent Mittelstadt, Ben Fairweather, Neil Mcbride, and Mark Shaw. Ethical issues of personal health monitoring: A literature review. In *ETHICOMP 2011 Conference Proceedings*, pages 313–321, 01 2011.

[24] Mei L Ngan, Patrick J Grother, and Kayee K Hanaoka. Ongoing face recognition vendor test (frvt) part 6a: Face recognition accuracy with masks using pre-covid-19 algorithms. 2020.

[25] Alessandra Pierucci and Jean-Philippe Walter. Joint statement on the right to data protection in the context of the covid-19 pandemic. *Council of Europe*, 30, 2020.

[26] Lisa Rosenbaum. Facing covid-19 in italy — ethics, logistics, and therapeutics on the epidemic's front line. *New England Journal of Medicine*, 382(20):1873–1875, 2020. PMID: 32187459.

[27] Alex Rosenblat, Tamara Kneese, and Danah Boyd. Workplace surveillance. *Open Society Foundations' Future of Work Commissioned Research Papers*, 2014.

[28] Ali Siadat, Axel Kaske, Siegfried Klausmann, Michel Dufaut, and René Husson. An optimized segmentation method for a 2d laser-scanner applied to mobile robot navigation. *IFAC Proceedings Volumes*, 30(7):149–154, 1997.

[29] Ravi Pratap Singh, Mohd Javaid, Abid Haleem, and Rajiv Suman. Internet of things (iot) applications to fight against covid-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(4):521 – 524, 2020.

[30] Christopher Slobogin. Public privacy: camera surveillance of public places and the right to anonymity. *Miss. lJ*, 72:213, 2002.

[31] Joshua R Smith, Kenneth P Fishkin, Bing Jiang, Alexander Mamishev, Matthai Philipose, Adam D Rea, Sumit Roy, and Kishore Sundara-Rajan. Rfid-based techniques for human-activity detection. *Communications of the ACM*, 48(9):39–44, 2005.

[32] Yi Sun, Xiaogang Wang, and Xiaoou Tang. Hybrid deep learning for face verification. In *Proceedings of the IEEE international conference on computer vision*, pages 1489–1496, 2013.

[33] Anthony M Townsend and James T Bennett. Privacy, technology, and conflict: emerging issues and action in workplace privacy. *Journal of Labor Research*, 24(2):195–205, 2003.

[34] JJ Woo. Policy capacity and singapore's response to the covid-19 pandemic. *Policy and Society*, 39(3):345–362, 2020.

[35] Zheng Xu, Yunhuai Liu, Hui Zhang, Xiangfeng Luo, Lin Mei, and Chuanping Hu. Building the multi-modal storytelling of urban emergency events based on crowdsensing of social media analytics. *Mobile Networks and Applications*, 22(2):218–227, 2017.

[36] Kaipeng Zhang, Zhanpeng Zhang, Zhifeng Li, and Yu Qiao. Joint face detection and alignment using multitask cascaded convolutional networks. *IEEE Signal Processing Letters*,

23(10):1499–1503, 2016.

[37] Shugang Zhang, Zhiqiang Wei, Jie Nie, Lei Huang, Shuang Wang, and Zhen Li. A review on human activity recognition using vision-based method. *Journal of healthcare engineering*, 2017, 2017.

Huiguo Zhang received the M.S. degree in computer application from Xiangtan University, Xiangtan, China in 2006. He is currently a PhD student in School of Computer Science and Engineering, Nanyang Technological University. His current research interests include high performance computing, edge computing and technologies to support ageless aging.

Yundong Cai received his Ph.D degree in computer engineering from Nanyang Technological University in 2011. He is currently a research project manager in Joint NTU-WeBank Research Centre of FinTech. His main research interests are serious game, fuzzy cognitive maps, artificial intelligence in education.

Hao Zhang received his Ph.D degree in computer engineering from Nanyang Technological University in 2020. He is currently a research associate in Joint NTU-WeBank Research Centre of FinTech. His research interests include human computer interactions and gerontechnology.

Cyril Leung received the B.Sc. degree (first class Hons.) from Imperial College, University of London, London, U.K., and the M.S. and Ph.D. degrees in electrical engineering from Stanford University, Stanford, CA, USA. He has been an Assistant Professor with the Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, MA, USA, and the Department of Systems Engineering and Computing Science, Carleton University, Ottawa, ON, Canada. Since July 1980, he has been with the Department of Electrical and Computer Engineering, The University of British Columbia (UBC), Vancouver, BC, Canada, where he is a Professor and currently holds the PMC-Sierra Professorship in Networking and Communications. He served as the Associate Dean, Research and Graduate Studies, in the Faculty of Applied Science, UBC from 2008 to 2011. His research interests include wireless communication systems and technologies to support active aging for the elderly. He is a member of the Association of Professional Engineers and Geoscientists of British Columbia, Canada.