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Emotion-reading Nursing Care Environment Based on Facial Expression Recognition

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The super-aged society is becoming a reality and maximizing the ability of the elderly to live independently and reducing the burden on caregivers have become urgent issues. In this study, we propose to establish an emotion-reading nursing care environment based on facial expression recognition to reduce the long-term work pressure of caregivers and achieve the goal of improving the quality of life of the elderly. The system automatically adjusts the environment through facial expression recognition to guide the emotions of the care recipient. It uses the expression images captured by a computer and a camera lens, and uses the Python-trained program for emotion recognition. The captured identification signal is transmitted to a LabVIEW platform via Transmission Control Protocol/Internet Protocol (TCP/IP). The LabVIEW control program can guide emotions and corresponding environmental conditions, including color, sound, smell, and temperature, in accordance with the different emotional events received, and output the processing results to the real-time embedded evaluation board MyRIO to link devices such as a liquid crystal display, a servomotor, and a full-color LED. In this study, we demonstrate the feasibility of an adaptive and optimized nursing care environment based on facial expression recognition. However, through experiment, we also understand the constraints of the system and differences from the theory.

1. Introduction

The super-aged society is becoming a reality and maximizing the ability of the elderly to live independently[(1)] and reducing the burden on caregivers have become urgent issues. To reduce the burden on relatives to take care of the elderly, in September 2016, the Taiwan Executive Yuan passed the Long-term Care 2.0 plan, which provides a multiservice, hierarchical community-based long-term care service system.[(2)] However, extensive services also mean that nursing manpower will be scarcer, and the workload of caregivers will become more serious and worse. Because of the above problems, the introduction of smart technology into the elderly welfare

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market has brought opportunities for addressing the manpower shortage and improving the service quality.[3] In this study, we propose to establish an adaptive nursing care environment based on facial expression recognition, which provides an optimized environment with an adaptive ability, to reduce the long-term work pressure of caregivers and achieve the goal of improving the quality of life of the elderly.

At the application level of science and technology, establishing an emotion-reading nursing care environment based on facial expression recognition involves theoretical discussions in the fields of intelligent environment, computer vision, deep learning, face recognition, and facial expression recognition. At the practical level of health care, it involves the health and emotional adjustments of the elderly and the professional service survey of home care attendants.

Big data computing technology accelerates machine learning calculations, implements deep learning, and promotes the successful application of convolutional neural networks (CNNs) to face recognition and facial expression recognition in the field of computer vision. The computer vision system includes six steps: image acquisition, preprocessing, feature extraction, associative storage, knowledge base, and recognition (Fig. 1).[4]

After 2012, big data operations implemented CNNs instead of manual algorithms, and the application of image recognition was able to be accelerated.[5] CNN-based computer vision uses unsupervised learning for feature extraction, simplified operations, and supervised learning for classification to achieve image recognition. The convolutional layer uses filters to generate one activation map after another for the original image to extract features. The pooling layer further controls the stride (s) parameter, so that the input activation map can obtain a large number of feature maps that reduce the resolution and simplify the amount of calculation through the operation. The second half of the CNNs is a fully connected layer, which is used for supervised learning and classification. The neurons in the fully connected layer are connected in pairs, and the number of neurons in the final output layer is consistent with that of classification problems to achieve classification (Fig. 2).[6–10] Since its development, computer vision has been widely used, from applying filter functions to improve image quality, animations, and film special effects to applying feature technology for size measurement, defect detection, counting, and positioning, especially in biometric technology where it has made a significant impact.[11] Biometrics is an anthropometric measurement and calculation method related to human

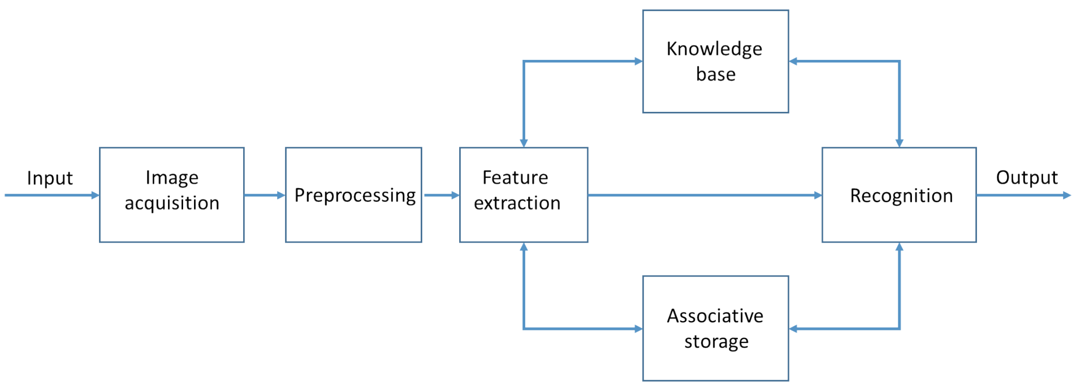

Fig. 1. (Color online) Computer vision system.[4]

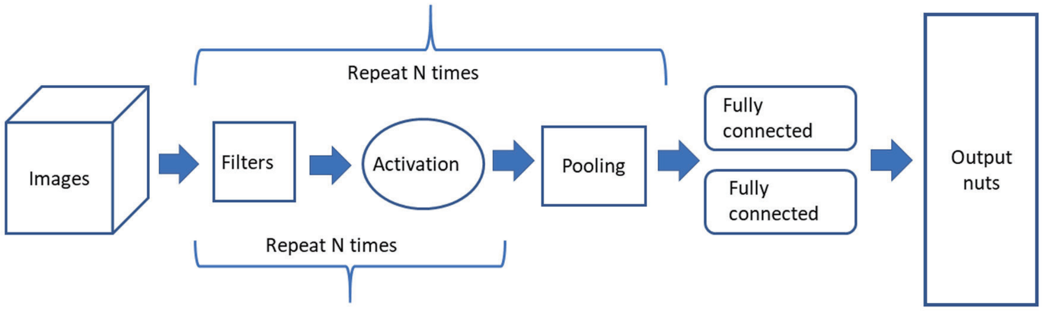

Fig. 2. (Color online) Convolution series combination.(9)

Fig. 3. (Color online) Bedridden state.(18)

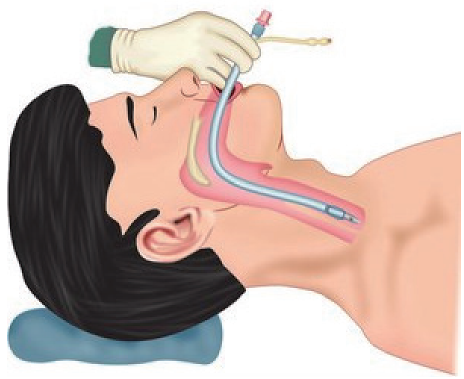

Fig. 4. (Color online) Intubation.(19)

characteristics, and among them, face recognition and facial expression recognition are the most developed artificial intelligence applications and have a new high penetration rate of the necessary technology.(12)

In this study, we propose the application of the principle of expression recognition to improve the environment of caring for the elderly, especially those who have difficulty expressing their true feelings to others. In medical care, facial expression recognition systems based on deep learning have been applied to diagnose cognitive impairment,(13) explore children's social cognitive abilities,(14) understand students' academic emotions,(15) and assist physicians in assessing pain in patients, especially those who are unable to properly report pain themselves.(16) In long-term care institutions, the elderly are basically in a passive adaptation state to the environment they inhabit,(17) and the institution needs to have the ability to actively read emotions. In addition, although long-term home care attendants can identify elderly participation in activities with their own eyes, it is difficult to identify the signs of poor mental health. It is also possible that owing to a lack of familiarity with the person being cared for, correct treatment and judgment cannot be made. Figure 3 shows a possible situation.(18) In the institution, the body and limbs of a bedridden person may be restricted by medical equipment. In addition, this is often because of anesthesia intubation during an operation, which causes discomfort in the throat after surgery, making it difficult to speak (Fig. 4);(19) therefore, emotions can only be expressed by facial expressions. Facial expression recognition can detect "what's going on?" and further predict "what to do?". Institutions set up an expression recognition system that will have the emotion-reading ability. According to Professor Ekman,[20] the eight basic human emotions are anger, sadness, fear, joy, love, surprise, disgust, and shame. From this basic model, more complex patterns such as Plutchik's wheel of emotions[21] are derived. In addition to this, Ekman and Friesen proposed a Facial Action Coding System (FACS) that was first published in 1978 and updated in 2002.[20,22] FACS enables the analysis of emotions by presenting the physiological responses of the human face and has become the basis of other facial expression recognition systems.[23]

2. Theory and Method

To perform the care function of reading and guiding emotions, as shown in Fig. 5, we established a system of "an adaptive nursing care environment based on facial expression recognition." The system will automatically adjust the environment (including spatial ambience factors such as music, lighting, and flavor) through facial expression recognition to guide the negative emotions of a care recipient to become positive ones, reduce the long-term work and pressure of the caregiver, and improve the quality of the living environment of the care recipient (Fig. 5).

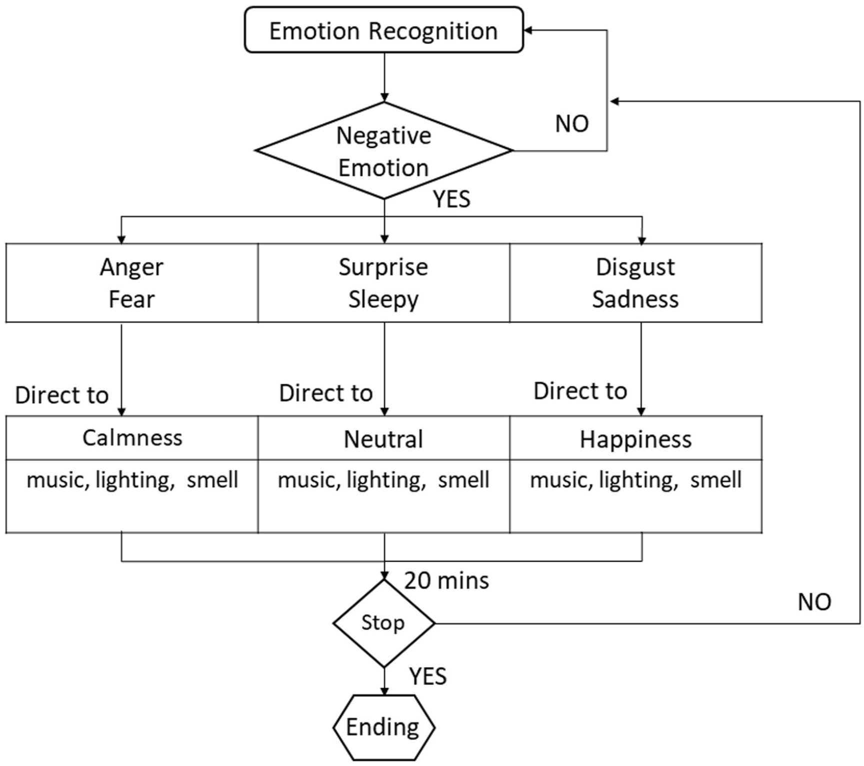

Fig. 5. System architecture.

FACS divides the face into upper and lower regions, decomposes its actions into basic action units (AUs), and encodes the corresponding action description: AU01–AU64. AUs are subdivided into (1) Main Action Units: AU01–46, (2) Head Movement Action Units: AU51–58, and (3) Eye Movement Action Units: AU61–64. These AUs show the different movements of the facial muscles. Certain combined movements of these facial muscles are associated with displayed emotions. Their combination represents emotions, for example, happiness, sadness, surprise, fear, anger, disgust, and contempt. For example, happiness is calculated on the basis of the combination of AU06 and AU12 (Table 1).[22]

On the basis of the above FACS, the facial expression is recorded by a camera and imported into a computer for calculation. It follows three steps to complete the expression muscle strength and emotion pairing analyses.

1) Face detection
   The engine detects faces in video frames and draws face boxes around them (Fig. 6).
2) Facial landmark detection and registration
   The engine recognizes facial landmarks and adjusts the position, size, and scale of a rather simplified facial model to match the respondent's actual face (Fig. 7).

Table 1
(Color online) Examples of basic action units.

AU	Description	Facial muscles	Demonstration (happiness)
06	Cheek lift	Eye rotifer Eye socket	
12	Corners of lips pulled up	Main cheekbones	

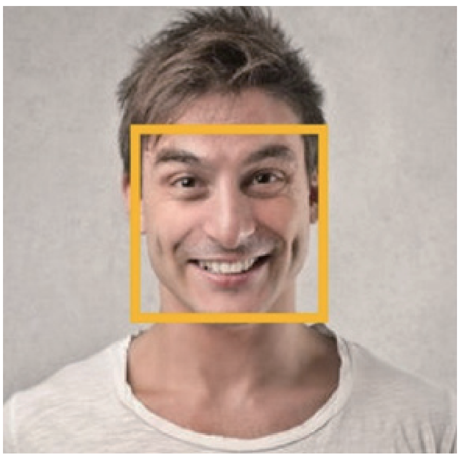

Fig. 6. (Color online) Face detection.[24]

Fig. 7. (Color online) Facial landmark detection and localization.[24]

3) Facial expression muscle analysis (Fig. 8) and emotion pairing analysis (Fig. 9)
   The classification algorithm numerically compares the actual appearance of the face and the configuration of features to a normative database of facial expressions, and then the features are converted into AU codes, emotional states, and other emotional indicators.[20]

3. Implementation

The experiment of the adaptable nursing care environment system based on facial expression recognition involves the use of expression images captured by the computer and camera lens and the Python-trained program for emotion recognition. The captured identification signal is transmitted to the LabVIEW platform via Transmission Control Protocol/Internet Protocol (TCP/IP). The LabVIEW control program can guide emotions and corresponding environmental conditions (including color, sound, smell, and temperature) in accordance with the different emotional events received and output the processing results to the real-time embedded evaluation board MyRIO that links devices such as a liquid crystal display (displaying repertoires and odors), a servomotor (representing temperature control), and a full-color LED (displaying light color) (Fig. 10).

In this study, we used a Python-trained emotion recognition application that can distinguish emotions including anger, fear, disgust, sadness, surprise, sleep, calmness, happiness, and neutral. The corresponding relationship between their attitude and energy are shown in the Fig. 11 and Table 2. The adaptive environmental control design of this study should be able to direct the detected negative emotions to become positive emotions (Fig. 11). The environmental factors of the linkage control of the adjustable device include lighting colors, repertoires, odors, air conditioning temperature, and the corresponding relationship between negative and positive emotions and the variable factors of the environment (Table 2).[27]

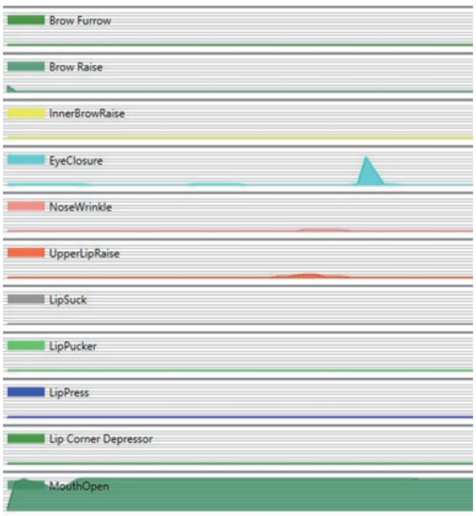

Fig. 8. (Color online) Facial expression muscle analysis.[25]

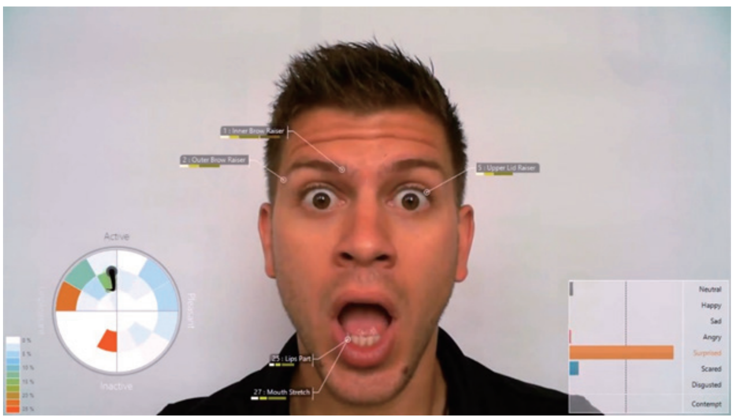

Fig. 9. (Color online) Emotion pairing analysis: surprise.[26]

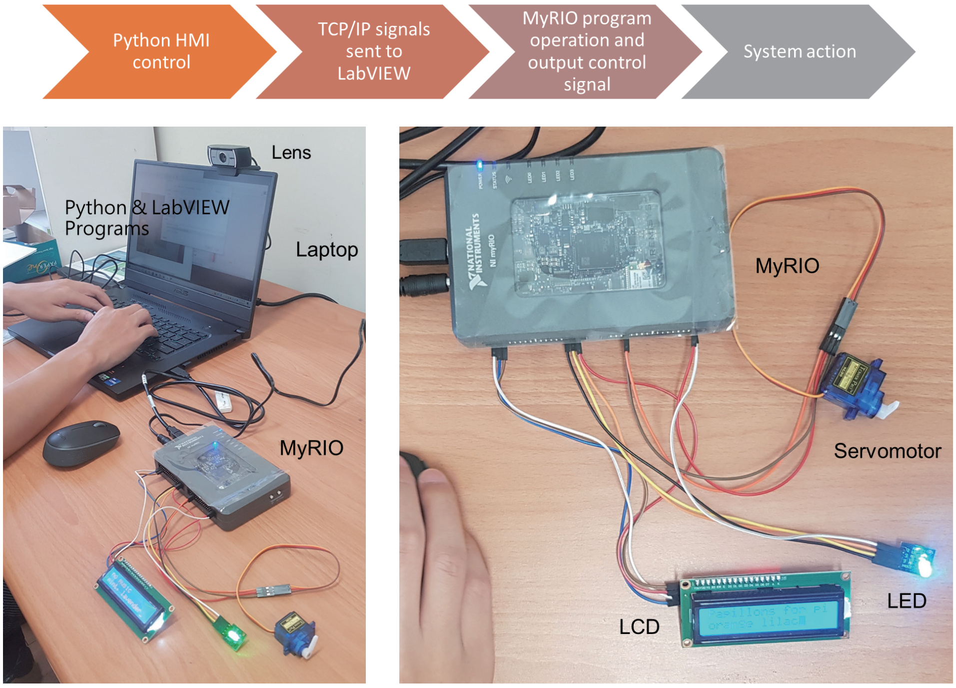

Fig. 10. (Color online) Software and hardware system integration with system operation flow.

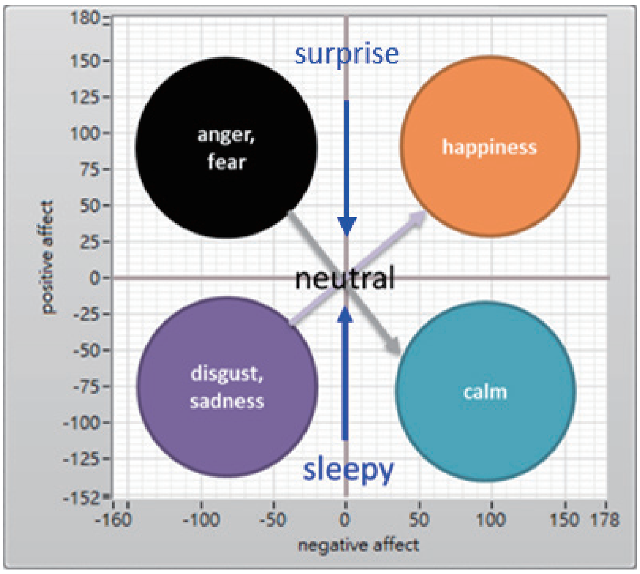

Fig. 11. (Color online) Guide negative emotions to become positive emotions.

As described above, in this research, we planned the LabVIEW control program flow chart, which is translated into the graphical program of LabVIEW in the function panel (Fig. 12) and is mainly composed of the stacked sequence structure describing the initialization state, receiving events (that is, the emotional recognition signals), case structure, and so forth, which constitute a while loop. The case structure includes processing procedures and settings for different

Table 2
Correspondence between emotions and environmental variables.[27]

Recipient	Direct to	Environmental variables			
Negative emotions with coding	Positive emotions with coding	Colors	Repertoires	Odors	Temperature
Anger (0) Fear (2)	Calmness (8)	Blue Pink	Papillons for Piano, Op.2: X-VIVO	Chamomile Bergamot	20–24
Disgust (1) Sadness (4)	Happiness (3)	Orange	Satie_ Gnossienne#1	Willow Lilac	26–28
Surprise (5) Sleepy (7)	Neutral (6)	Green	None	Mint Lavender	20

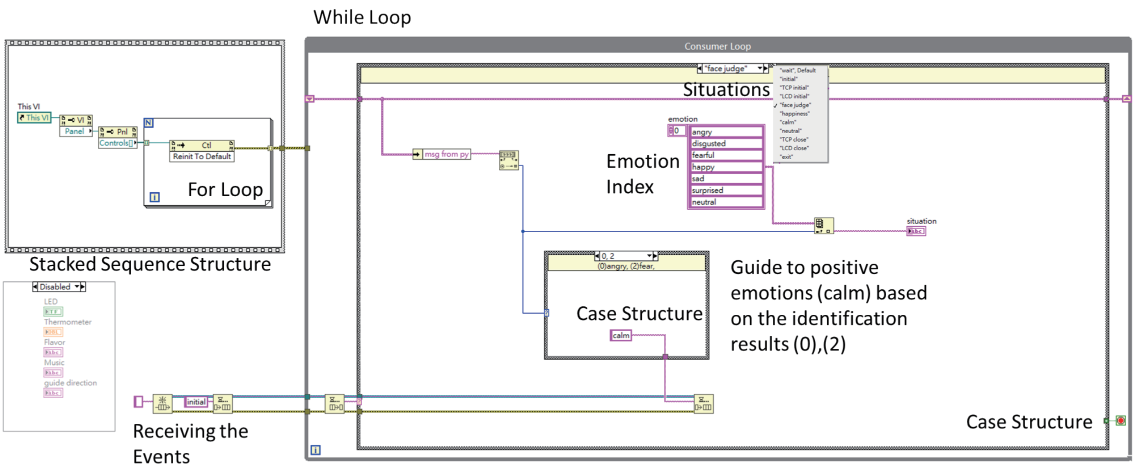

Fig. 12. (Color online) LabVIEW's function panel: in the state of "face judge".

situations, such as the initialization state, receiving emotional signals, and program end. When the system is in the process of receiving and identifying emotional signals, the program can guide negative emotional signals to become positive emotional signals (including calm, happy, and neutral) in accordance with the received emotional signals (Table 1). In the case structure, the lens, computer, and Python generate signals that link environmental control devices to change the color, music, smell, and temperature of the environment (Fig. 13). The right side of Fig. 14 is the simulation result of the system in the control panel of the graphical program LabView, and the bottom of Fig. 14 is the Python-trained emotion recognition application, which recognizes the negative emotion "angry" through a computer lens (left side of Fig. 14). Thus, the system directs anger to become "calm" and drives the device to adjust to an ambient state that promotes calmness, including color (blue), smell (orange lilac), music (Papillons for piano), and temperature (24 degrees) (shown on the right side of Fig. 14).

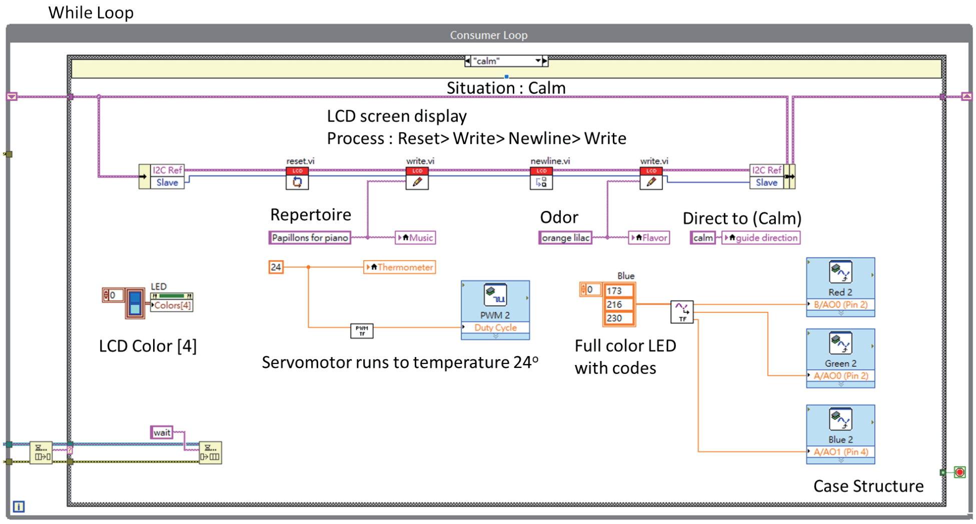

Fig. 13. (Color online) Depending on the situation: the emotion is led to calmness by the signal that causes the environmental control device to be linked and adjusted.

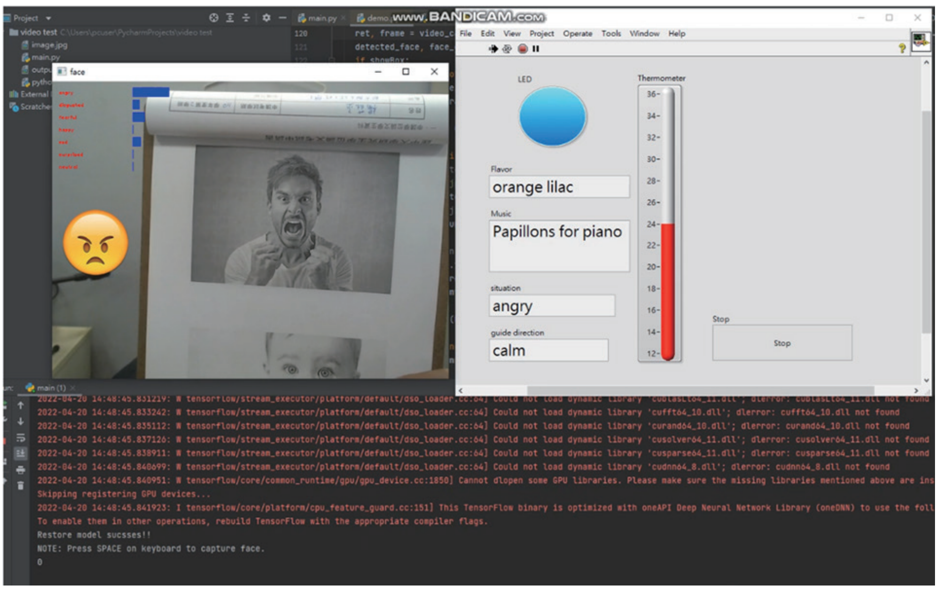

Fig. 14. (Color online) Integration of Python training program and LabVIEW human–machine interface.

4. Conclusions

We proposed the application of the principle of facial expression recognition to improve the environment of caring for the elderly, especially those who have difficulty expressing their true feelings to others. We expanded the facial expression recognition systems that address cognitive impairment and used it that create an adaptable care environment that can guide emotions. However, its differences and constraints are as follows.

(1) The Python-trained emotion recognition application can recognize a person's three-dimensional facial expressions. However, a single facial expression action cannot be long-lasting, which affects the signal reading of LabVIEW and the actions of its subsequent devices. Therefore, during testing, we replaced facial expressions with flat expression images. In the next phase, specific emotions and their frequency of occurrence during a period should be considered at the same time as the identification and threshold values of the system reaction.
(2) The system cannot normalize group expressions and can only react on a single test subject at present. However, for the care space used by multiple people, the system must have the ability to normalize the calculation of group emotions in the next phase.
(3) During the study period, owing to the impact of the COVID-19 epidemic, the original plan to conduct long-term close observations and analyses of the activities and behaviors of the elderly in an institution could not be carried out. Therefore, the task was changed to statistically analyzing the relevant literature and records, supplemented by institutional visits.

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References

1 W. C. Mann: Smart Technology for Aging, Disability, and Independence: The State of the Science, W. C. Mann Ed. (John Wiley & Sons, New Jersey, 2005) 1st ed., Chap. 1
2 Ministry of Health and Welfare: https://1966.gov.tw/LTC/cp-3636-42415-201.html (accessed March 2023).
3 Y. L. Hsu: J. Gerontechnol. Service Manage. **2** (2014) 83. https://doi.org/10.6283/JOCSG.2014.2.1.83
4 A. D. Kulkarni: Computer Vision and Fuzzy-Neural Systems (PH PTR, New Jersey, 2001) 1st ed., Chap. 1.
5 D. Ghimire, D. Kil, and S. H. Kim: Electronics **11** (2022) 945. https://doi.org/10.3390/electronics1106094
6 Y. LeCun, L. Bottou, Y. Bengio, and P. Haffner: Proc. IEEE **86** (1998) 2278–2324. https://doi.org/10.1109/5.726791
7 A. Krizhevsky, I. Sutskever, and G. E. Hinton: ImageNet Classification with Deep Convolutional Neural Networks, http://www.cs.toronto.edu/~hinton/absps/imagenet.pdf (accessed March 2023).
8 J. J. Huang: Artificial Intelligence and Deep Learning—Theory and Practice with Python (GOTOP Information Inc, Taipei, Taiwan 2020) 1st ed., Chap. 3.
9 P. Miao: CV+Deep Learning: AI's Most Complete Cross-Suite Python Artificial Intelligence Computer Vision (Deep mind Digital, Taipei, 2019) 1st ed., Chap. 1.
10 S. Haykin: Neural Networks a Comprehensive Foundation (Prentice Hall, New Jersey, 1999) 2nd ed., Sect. 4.19.
11 T. Acharya and A. K. Ray: Image Processing Principles and Applications (Wiley, 2005) 1st ed., Chap.1.
12 Spark Big Data Development: https://kknews.cc/zh-tw/tech/l9zoqqz.html (accessed March 2023).
13 Z. Fei, E. Yang, L. Yu, X. Li, H. Zhou, and W. Zhou: Neurocomputing **468** (2022) 306. https://doi.org/10.1016/j.neucom.2021.10.038
14 S. Ogoshi, T. Takezawa, Y. Ogoshi, H. T. Yanaka, and Y. Mitsuhashi: Sens. Mater. **26** (2014) 505. https://doi.org/10.18494/SAM.2014.1003
15 S. Y. Lin, C. M. Wu, S. L. Chen, T. L. Lin, and Y. W. Tseng: Sens. Mater. **32** (2020) 3243. https://doi.org/10.18494/SAM.2020.2863
16 D. Fontaine, V. Vielzeuf, P. Genestier, P. Limeux, S. Santucci-Sivilotto, E. Mory, N. Darmon, M. Lanteri-Minet, M. Mokhtar, M. Laine, and D. Vistoli for the DEFI study group: Artificial Intelligence to Evaluate Postoperative Pain Based on Facial Expression Recognition (the Centre Hospitalier Universitaire de Nice (CHUN) and Orange SA. 2022) 1st ed. https://doi.org/10.1002/ejp.1948

17 C. J. Hsieh, Y.-L. Hsiao, and S.-J. Liu: Long Term Care **11** (2007) 109. https://doi.org/10.6317/LTC.200706_11(2).0001
18 Bedridden State: https://doqvf81n9htmm.cloudfront.net/data/crop_article/94326/101204.jpg_1140x855.jpg (accessed March 2023).
19 Intubation: https://www.ems1.com/ems-products/medical-equipment/airway-management/articles/the-great-airway-debate-EHiXB9bZo1FPXhnp/ (accessed March 2023).
20 P. Ekman and W. V. Friesen: Manual for the Facial Action Code (Consulting Psychologist Press, Palo Alto, CA, 1978) 1st ed.
21 R. Plutchik: Emotions, and Life: Perspectives from Psychology, Biology, and Evolution (American Psychological Association, Washington, DC., 2002) 1st ed.
22 B. Farnsworth: https://imotions.com/blog/facial-action-coding-system/ (accessed March 2023).
23 I. A. Essa and A. P. Pentland: Proc. 1997 IEEE Trans. Pattern Analysis and Machine Intelligence Conf. **19** (1997) 757–763. https://doi.org/10.1109/34.598232
24 IMotions: https://imotions.com/blog/learning/best-practice/facial-expression-analysis/ (accessed March 2023).
25 J. Wilson: https://imotions.com/blog/automated-facial-coding-vs-femg/ (accessed March 2023).
26 FaceReader: https://www.noldus.com/facereader (accessed March 2023).
27 H. J. Wu: Emotion Regulation System and Database Establishment in Smart Environment—Base on Elderly Care (Thesis, Master of Architecture, Feng Chia University, Taichung, 2021). https://hdl.handle.net/11296/7bngv7

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