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Emotion determination device and emotion determination method

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Abstract

An emotion determination device includes a first estimator that estimates an emotion of a user based on a change in a facial expression of the user detected from a face image of the user, a second estimator that estimates the emotion of the user based on a change in a temperature of the user detected contactlessly from the user, and a determiner that determines the emotion of the user based on an estimation result obtained by the first estimator and an estimation result obtained by the second estimator.

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Background/Summary

TECHNICAL FIELD
(1) The present invention relates to a technique for determining the emotion of a user, such as calmness, anger, sadness, and joy.
BACKGROUND ART
(2) A technique has been developed for determining the emotion of a user for, for example, intended control. A correct determination of user emotions allows, for example, control of the operation (e.g., speech) of a communication robot for intended communication with the user.
(3) Techniques for determining emotions are described in, for example, Patent Literatures 1 to 3. Patent Literatures 1 to 3 describe techniques for determining emotions based on various sets of biometric data, such as brain waves and heartbeats measured with wearable devices.
CITATION LIST
Patent Literature
(4) Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2014-178970
Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2017-144222 Patent Literature 3: Japanese Unexamined Patent Application Publication No.
SUMMARY OF INVENTION
Technical Problem
(5) However, with the known techniques described in Patent Literatures 1 to 3, the user wears a wearable device and thus can have low usability. Such techniques also use numerous sets of biometric data, and involve a high processing load and a lengthy time for emotion determination.
(6) In response to the above issue, one or more aspects of the present invention are directed to a technique for determining emotions with high accuracy using a simple structure with high usability.
Solution to Problem
(7) The technique according to one or more aspects of the present invention has the structure described below.
(8) An emotion determination device according to a first aspect of the present invention includes a first estimator that estimates an emotion of a user based on a change in a facial expression of the user detected from a face image of the user, a second estimator that estimates the emotion of the user based on a change in a temperature of the user detected contactlessly from the user, and a determiner that determines the emotion of the user based on an estimation result obtained by the first estimator and an estimation result obtained by the second estimator. The face image is, for example, an image obtained by capturing an image of a face with an image sensor (camera) or a portion of an image captured with an image sensor including a face. The temperature is detected contactlessly with, for example, a thermal sensor.
(9) In the structure described above, the emotion can be determined with high accuracy using the simple structure based on the results of the emotion estimation using the face image and the temperature, without using numerous sets of biometric data. Further, both the face image and the temperature (detection value) are obtained contactlessly with high usability and without the user wearing any wearable device. Determining the emotion with high accuracy based on the facial

image alone is difficult due to individual differences in facial expression changes and in the correspondence between the emotion and the facial expression. Determining the emotion with high accuracy based on the temperature alone is also difficult due to the temperature of the user that varies greatly depending on the environment (season and location such as indoors or outdoors) and clothing. The structure described above estimates the emotion by combining the result of the emotion determination (emotion estimation) using the face image with the result of the emotion determination using the temperature and achieves higher accuracy than the emotion determination using one of the face image or the temperature.

(10) Each of the first estimator and the second estimator may calculate a score indicating a likelihood of the user holding an emotion of a plurality of emotions. The determiner may determine the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator. The scores are normalized by the same criteria and thus are in the same range for the emotion estimation using the face image and the emotion estimation using the temperature. For example, the maximum score is commonly a predetermined value of, for example, 100, in the emotion estimation using the face image and the emotion estimation using the temperature. The multiple emotions include calmness, anger, sadness, and joy.

(11) For example, the determiner may determine, as the emotion of the user, an emotion with a greatest score calculated by the first estimator matching an emotion with a greatest score calculated by the second estimator. The determiner may determine, in response to the emotion with a greatest score calculated by the first estimator not matching the emotion with a greatest score calculated by the second estimator, the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator.

(12) More specifically, in response to the emotion with a greatest score calculated by the first estimator not matching the emotion with a greatest score calculated by the second estimator, the determiner may determine, as the emotion of the user, an emotion with a greater calculated score for the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator. This structure yields a more reliable emotion as the determination result.

(13) In response to the emotion with a greatest score calculated by the first estimator not matching the emotion with a greatest score calculated by the second estimator, the determiner may determine, as the emotion of the user, an emotion with a greater sum of a score calculated by the first estimator and a score calculated by the second estimator of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator. This structure also yields a more reliable emotion as the determination result.

(14) In response to the emotion with a greatest score calculated by the first estimator not matching the emotion with a greatest score calculated by the second estimator, the determiner may determine, as the emotion of the user, an emotion with a greater score change amount of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator. This allows emotional changes to be detected more quickly.

(15) In response to the emotion with a greatest score calculated by the first estimator not matching the emotion with a greatest score calculated by the second estimator, the determiner may determine, as the emotion of the user, an emotion with a greater score variance value of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator. This structure also yields a more reliable emotion as the determination result. The variance value herein can be referred to as the degree of score prominence.

(16) The emotion determination device may further include an adjuster that detects a period with a

variance value, for the period up to a predetermined time, of scores indicating a likelihood of the user holding an estimated emotion being less than a predetermined threshold value and adjusts an estimation result obtained by the first estimator and an estimation result obtained by the second estimator to replace an estimation result from a first period with the variance value less than the predetermined threshold value backward up to a period immediately after a second period with the variance value less than the predetermined threshold value with an estimation result in the first period. The determiner may determine the emotion of the user based on the adjusted estimation result obtained by the adjuster. In this manner, the emotional changes can be smoothed for detection of the tendency with high accuracy. This allows intended control with, for example, emotional changes being predicted. When, for example, the emotion of the user tends to change from anger to sadness, the behavior (e.g., speech) of the communication robot can be controlled to communicate with an angry user while expecting that the emotion of the user may change to sadness.

(17) Each of the first estimator and the second estimator may estimate the emotion of the user in a first cycle. The determiner may use the estimation result obtained by the first estimator and the estimation result obtained by the second estimator updated in a second cycle longer than the first cycle. This can reduce the processing load for the emotion determination.

(18) An emotion determination method according to a second aspect of the present invention includes estimating an emotion of a user based on a change in a facial expression of the user detected from a face image of the user, estimating the emotion of the user based on a change in temperature of the user detected contactlessly from the user, and determining the emotion of the user based on an estimation result in the estimating based on the change in the facial expression and an estimation result in the estimating based on the change in the temperature.

(19) One or more aspects of the present invention may be directed to an emotion determination system including at least one of the components or functions described above. One or more aspects of the present invention may also be directed to an emotion determination method or a control method for an emotion determination system including at least part of the above processes, a program for causing a computer to implement the method, or a non-transitory computer-readable storage medium storing the program. The above structure and processes may be combined with one another unless any technical contradiction arises.

Advantageous Effects of Invention

(20) The technique according to the above aspects of the present invention allows determination of the emotion with high accuracy using the simple structure with high usability.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a block diagram of an emotion determination device according to one or more embodiments of the present invention.

(2) FIG. **2**A is a schematic diagram of a communication system (emotion determination system) according to a first embodiment, showing an overall example structure, and FIG. **2**B is a block diagram of a personal computer (PC, or an emotion determination device) according to the first embodiment.

(3) FIG. **3** is a flowchart of an example procedure according to a first embodiment.

(4) FIGS. **4**A to **4**C are diagrams showing operation examples in the first embodiment.

(5) FIG. **5** is a flowchart of an example procedure according to a second embodiment.

(6) FIGS. **6**A to **6**C are diagrams showing operation examples in the second embodiment.

(7) FIG. **7** is a flowchart of an example procedure according to a third embodiment.

(8) FIGS. **8**A to **8**C are diagrams showing operation examples in the third embodiment.

(9) FIG. **9** is a flowchart of an example procedure according to a fourth embodiment.

(10) FIGS. **10**A to **10**C are diagrams showing operation examples in the fourth embodiment.

(11) FIG. **11** is a block diagram of a PC (emotion determination device) according to a fifth embodiment.

(12) FIGS. **12**A to **12**C are diagrams showing operation examples in the fifth embodiment.

(13) FIGS. **13**A and **13**B are diagrams showing operation examples in a sixth embodiment.

DESCRIPTION OF EMBODIMENTS

Example Use

(14) An example use of the present invention will now be described. With known techniques for determining the emotion of the user, such as calmness, anger, sadness, and joy, the user wears a wearable device and thus can have low usability. Such techniques also use numerous sets of biometric data, and involve a high processing load and a lengthy time for emotion determination.

(15) FIG. **1** is a block diagram of an emotion determination device **100** according to one or more embodiments of the present invention. The emotion determination device **100** includes a first emotion estimator **101**, a second emotion estimator **102**, and an emotion determiner **103**. The first emotion estimator **101** estimates the emotion of the user based on a change in the facial expression of the user detected in the face image of the user. The second emotion estimator **102** estimates the emotion of the user based on a change in the temperature of the user detected contactlessly from the user. The emotion determiner **103** determines the emotion of the user based on the estimation results obtained by the first emotion estimator **101** and the second emotion estimator **102**. The first emotion estimator **101** is an example of a first estimator in an aspect of the present invention, the second emotion estimator **102** is an example of a second estimator in an aspect of the present invention, and the emotion determiner **103** is an example of a determiner in an aspect of the present invention. The face image is, for example, an image obtained by capturing an image of a face with an image sensor (camera) or a portion of an image captured with an image sensor including a face. The temperature is detected contactlessly with, for example, a thermal sensor.

(16) The emotion determination device **100** with the above structure can determine the emotion with high accuracy using the simple structure based on the results of the emotion estimation using the face image and using the temperature without using numerous sets of biometric data. A correct determination of user emotions allows, for example, control of the operation (e.g., speech) of a communication robot for intended communication with the user. Further, both the face image and the temperature (detection value) are obtained contactlessly with high usability and without the user wearing any wearable device. Determining the emotion with high accuracy based on the facial image alone is difficult due to individual differences in facial expression changes and in the correspondence between the emotion and the facial expression. Determining the emotion with high accuracy based on the temperature alone is also difficult due to the temperature of the user that varies greatly depending on the environment (season and location such as indoors or outdoors) and clothing. In the structure described above, combining the result of the emotion determination (emotion estimation) using the face image with the result of the emotion determination using the temperature allows estimation of the emotion with higher accuracy than the emotion determination using one of the face image or the temperature.

First Embodiment

(17) A first embodiment of the present invention will now be described.

(18) (Structure)

(19) FIG. **2**A is a schematic diagram of a communication system (emotion determination system) according to the first embodiment, showing an overall example structure. The communication system according to the first embodiment includes a camera **10**, a temperature measurement device **20**, a personal computer (PC) **200** (emotion determination device), and a communication robot **30**. The camera **10** and the PC **200** are connected to each other with a wire or wirelessly. Similarly, the temperature measurement device **20** and the PC **200** are connected to each other with a wire or

wirelessly, and the PC **200** and the communication robot **30** are connected to each other with a wire or wirelessly.

(20) The camera **10** captures an image using an image sensor incorporated in the camera **10** and outputs the captured image to the PC **200**. In the first embodiment, the camera **10** outputs a face image obtained by capturing an image of the face of the user to the PC **200**. The temperature measurement device **20** measures temperature using a thermal sensor incorporated in the temperature measurement device **20** and outputs the measurement result (temperature information) to the PC **200**. In the first embodiment, the temperature measurement device **20** detects the temperature of the user (e.g., facial temperature) and outputs the temperature information indicating the detected temperature (detected value of the temperature) to the PC **200**. The PC **200** determines the emotion of the user based on the facial image and the temperature of the user, and outputs the result of the emotion determination to the communication robot **30**. The communication robot **30** communicates with the user based on the result of the determination of the emotion of the user.

(21) The camera **10** may capture a larger area than the face area. In this case, for example, the camera **10** or the PC **200** may perform a process for obtaining a face image from an image captured with the camera **10** (detecting a face from a captured image). The temperature measurement device **20** may also detect a temperature distribution over a larger area than the user (face) area. In this case, for example, the temperature measurement device **20** or the PC **200** may perform a process for obtaining the temperature of the user from the detected temperature distribution. The use of the result of the determination of the emotion of the user is not limited and may not be for the control of the communication robot **30**.

(22) In the first embodiment, the camera **10**, the temperature measurement device **20**, the PC **200**, and the communication robot **30** are separate devices, but are not limited to this structure. For example, at least two or more of the camera **10**, the temperature measurement device **20**, the PC **200**, and the communication robot **30** may be included in one device. More specifically, the camera **10**, the temperature measurement device **20**, and the PC **200** may be sensors incorporated in the communication robot **30**. The PC **200** may be at any location. For example, the PC **200** may or may not be located in the same room as the camera **10**, the temperature measurement device **20**, and the communication robot **30**. The PC **200** may or may not be a cloud computer.

(23) FIG. **2B** is a block diagram of the PC **200**. The PC **200** includes an image obtainer **210**, a temperature obtainer **220**, a controller **230**, a storage **240**, and an output unit **250**.

(24) The image obtainer **210** obtains a face image from the camera **10** and outputs the face image to the controller **230** (first emotion estimator **231**). In the first embodiment, the camera **10** captures a video, and the image obtainer **210** performs a process for obtaining one frame of the video from the camera **10** and outputting the frame to the controller **230** sequentially. Although the cycle of face image obtainment by the image obtainer **210** is not limited, the image obtainer **210** obtains a face image (one frame of a video) synchronously with the image capturing with the camera **10** in the first embodiment. In other words, the image obtainer **210** performs the process for obtaining the face image from the camera **10** and outputting the face image to the controller **230** at the frame rate of the image capturing with the camera **10** (e.g., 30 fps). The camera **10** may capture still images sequentially. The image obtainer **210** may then perform a process for obtaining still images from the camera **10** and outputting the still images to the controller **230** sequentially.

(25) The temperature obtainer **220** obtains the temperature information about the user from the temperature measurement device **20** and outputs the temperature information to the controller **230** (second emotion estimator **232**). The cycle of the temperature measurement by the temperature measurement device **20** and the cycle of the temperature information obtainment by the temperature obtainer **220** are not limited. In the first embodiment, the temperature measurement device **20** measures the temperature synchronously with the image capturing with the camera **10**, and the temperature obtainer **220** obtains the temperature information synchronously with the

image capturing with the camera **10** (obtainment of the face image by the image obtainer **210**). In other words, the temperature obtainer **220** performs the process for obtaining the temperature information from the temperature measurement device **20** and outputting the temperature information to the controller **230** at the frame rate of the image capturing with the camera **10**.

(26) The controller **230** includes, for example, a central processing unit (CPU), a random-access memory (RAM), and a read-only memory (ROM) to control each unit and perform various information processes. As described in detail later, in the first embodiment, the controller **230** determines the emotion of the user based on the face image obtained by the image obtainer **210** and the temperature information obtained by the temperature obtainer **220** and outputs the emotion determination result to the output unit **250**.

(27) The storage **240** stores a program executable by the controller **230** and various sets of data usable by the controller **230**. For example, the storage **240** is an auxiliary storage device, such as a hard disk drive or a solid-state drive.

(28) The output unit **250** outputs the determination result (determination result of the emotion) output by the controller **230** to the communication robot **30**.

(29) The storage **240** will now be described in more detail. The storage **240** includes a first emotion estimation dictionary **241** and a second emotion estimation dictionary **242**. The first emotion estimation dictionary **241** stores the correspondence between the change in the facial expression and the emotion registered in advance. The second emotion estimation dictionary **242** stores the correspondence between the change in the temperature and the emotion registered in advance.

(30) The controller **230** will now be described in more detail. The controller **230** includes the first emotion estimator **231**, the second emotion estimator **232**, and an emotion determiner **233**.

(31) The first emotion estimator **231** sequentially performs a process for detecting the facial expression of the user from the face image output by the image obtainer **210** (expression detection). The first emotion estimator **231** refers to the first emotion estimation dictionary **241** to estimate the emotion of the user from a change in the detected facial expression. The first emotion estimator **231** then outputs the emotion estimation result to the emotion determiner **233**. The first emotion estimator **231** is an example of the first estimator in an aspect of the present invention.

(32) Any algorithm may be used for the facial expression detection and the emotion estimation (both processing based on the face image) performed by the first emotion estimator **231**. For example, the facial expression of the user may be detected through existing facial expression detection, or specifically with a detector (discriminator) that combines an image feature such as a histogram of oriented gradients (HoG) or a Haar-like feature and boosting. The facial expression may be detected using a trained model generated through existing machine learning, or specifically using a trained model generated by deep learning, examples of which include a region-based convolutional neural networks (R-CNN), Fast R-CNN, you only look once (YOLO), or a single shot multibox detector (SSD). Similarly, the emotion of the user may be estimated through existing emotion estimation or using a trained model generated by existing machine learning. More specifically, a trained model generated by deep learning (e.g., R-CNN, Fast R-CNN, YOLO, and SSD) may be used to estimate the emotion of the user.

(33) The second emotion estimator **232** sequentially obtains the temperature information output by the temperature obtainer **220**, refers to the second emotion estimation dictionary **242**, and estimates the emotion of the user from the change in the obtained temperature information (change in the temperature of the user). The second emotion estimator **232** then outputs the emotion estimation result to the emotion determiner **233**. The second emotion estimator **232** is an example of the second estimator in an aspect of the present invention.

(34) Any algorithm may be used for emotion estimation (emotion estimation based on the temperature) performed by the second emotion estimator **232**. For example, the emotion of the user may be estimated through existing emotion estimation or using a trained model generated by existing machine learning. More specifically, a trained model generated by deep learning (e.g., R-

CNN, Fast R-CNN, YOLO, and SSD) may be used to estimate the emotion of the user.

(35) The emotion determiner **233** determines the emotion of the user based on the estimation results obtained by the first emotion estimator **231** and the second emotion estimator **232** and outputs the emotion determination result to the output unit **250**. The emotion determiner **233** is an example of the determiner in an aspect of the present invention.

(36) In the first embodiment, each of the first emotion estimator **231** and the second emotion estimator **232** calculates a score indicating the likelihood of the user holding the emotion for each of the multiple emotions, and outputs the score for each emotion as the estimation result. The emotion determiner **233** then determines the emotion of the user based on the scores for each emotion calculated by the first emotion estimator **231** and of each emotion calculated by the second emotion estimator **232**.

(37) The scores are herein normalized by the same criteria in the emotion estimation using the face image (emotion estimation performed by the first emotion estimator **231**) and the emotion estimation using the temperature (emotion estimation performed by the second emotion estimator **232**), and the range of the scores is common. For example, the maximum score is commonly a predetermined value of, for example, 100, in the emotion estimation using the face image and the emotion estimation using the temperature. In the first embodiment, the score for each emotion is calculated to cause the sum of the respective multiple scores corresponding to the multiple emotions to be 100 in each of the emotion estimation using the face image and the emotion estimation using the temperature. Although the number of multiple emotions and their types are not limited, four emotions of calmness, anger, sadness, and joy are used in the first embodiment.

(38) When the emotion with the greatest score calculated by the first emotion estimator **231** matches the emotion with the greatest score calculated by the second emotion estimator **232**, the user is highly likely to hold the emotion. The emotion determiner **233** thus determines the emotion with the greatest scores calculated by the first emotion estimator **231** and the second emotion estimator **232** as the emotion of the user.

(39) The emotion with the greatest score calculated by the first emotion estimator **231** may not match the emotion with the greatest score calculated by the second emotion estimator **232**. In such a case, the emotion determiner **233** determines the emotion of the user based on the score for each emotion calculated by the first emotion estimator **231** and the score for each emotion calculated by the second emotion estimator **232**. More specifically, the emotion determiner **233** determines the emotion with the greater calculated score for the emotion with the greatest score calculated by the first emotion estimator **231** and the emotion with the greatest score calculated by the second emotion estimator **232** as the emotion of the user. A greater score is expected to indicate a higher reliability (a higher likelihood of the user holding the corresponding emotion), thus yielding a more reliable emotion as the determination result.

(40) (Operation)

(41) FIG. **3** is a flowchart of an example procedure according to the first embodiment. The PC **200** repeats the procedure in FIG. **3**. Although the repetition cycle of the procedure in FIG. **3** is not limited, the procedure in FIG. **3** is repeated at the frame rate of the image capturing with the camera **10** (e.g., 30 fps).

(42) First, the image obtainer **210** obtains the face image of the user from the camera **10** (step S**301**). The first emotion estimator **231** then detects the facial expression of the user from the face image obtained in step S**301**, and calculates each score for calmness, anger, sadness, and joy based on a change in the detected facial expression (change in the facial expression from the past to the present) (step S**302**).

(43) The temperature obtainer **220** then obtains the temperature information about the user (temperature of the user) from the temperature measurement device **20** (step S**303**). The second emotion estimator **232** then calculates each score for calmness, anger, sadness, and joy based on a change in the temperature of the user (change in the temperature from the past to the present) (step

S**304**).

(44) The emotion determiner **233** then determines whether an emotion E1 with the greatest score calculated by the first emotion estimator **231** matches an emotion E2 with the greatest score calculated by the second emotion estimator **232** (step S**305**). The emotion E1 has the greatest score of the four scores (respectively corresponding to calmness, anger, sadness, and joy) calculated in step S**302** based on the change in the facial expression. The emotion E2 has the greatest score of the four scores (respectively corresponding to calmness, anger, sadness, and joy) calculated in step S**304** based on the change in the temperature. Once the emotion E1 matches the emotion E2 (Yes in step S**305**), the processing advances to step S**306**, and when the emotion E1 does not match the emotion E2 (No in step S**305**), the processing advances to step S**307**.

(45) In step S**306**, the emotion determiner **233** determines the emotion E1=the emotion E2 as the emotion Eresult (final determination result) of the user. The PC **200** then ends the procedure in FIG. **3**.

(46) In step S**307**, the emotion determiner **233** determines whether the score for the emotion E1 (score based on the change in the facial expression) matches the score for the emotion E2 (score based on the change in the temperature). When the score for the emotion E1 does not match the score for the emotion E2 (No in step S**307**), the processing advances to step S**308**. Once the score for the emotion E1 matches the score for the emotion E2 (Yes in step S**307**), the PC **200** ends the procedure in FIG. **3**. The same emotion as the previous emotion is then used as the emotion Eresult of the user.

(47) In step S**308**, the emotion determiner **233** determines whether the score for the emotion E1 is greater than the score for the emotion E2. When the score for the emotion E1 is greater than the score for the emotion E2 (Yes in step S**308**), the processing advances to step S**309**. When the score for the emotion E1 is less than the score for the emotion E2 (No in step S**308**), the processing advances to step S**310**.

(48) In step S**309**, the emotion determiner **233** determines the emotion E1 (emotion estimated based on the change in the facial expression) as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **3**.

(49) In step S**310**, the emotion determiner **233** determines the emotion E2 (emotion estimated based on the change in the temperature) as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **3**.

(50) (Specific Operation Example)

(51) FIGS. **4**A to **4**C show operation examples in the first embodiment. FIG. **4**A shows an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator **231**. In FIG. **4**A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold frames. FIG. **4**B shows an example temporal change of the score for each emotion (score based on the change in the temperature) calculated by the second emotion estimator **232**. In FIG. **4**B, the emotion E2 (emotion estimated based on the change in the temperature) is shown in bold frames. FIG. **4**C shows an example temporal change of the emotion (emotion Eresult) determined by the emotion determiner **233**.

(52) In the examples in FIGS. **4**A to **4**C, both the emotions E1 and E2 are calmness for the period from frame 0 to frame 2, and calmness is thus determined as the emotion Eresult. For frame 3, the emotion E1 is anger, and the emotion E2 is calmness. The emotions E1 and E2 are different. The score for the emotion E1 (anger) is 55. The score for the emotion E2 (calmness) is 52. Based on the score (**55**) for the emotion E1 (anger) greater than the score (**52**) for emotion E2 (calmness), anger is determined as the emotion Eresult. Similarly in the other frames, the emotion Eresult is determined based on, for example, the match or mismatch between the score for the emotion E1 and the score for the emotion E2, and on the relationship between the score for the emotion E1 and the score for the emotion E2.

(53) (Overview)

(54) In the first embodiment as described above, the emotion can be determined with high accuracy using the simple structure based on the result of the emotion estimation using the face image and the temperature, without using numerous sets of biometric data. Further, both the face image and the temperature (detection value) are obtained contactlessly with high usability and without the user wearing any wearable device. In addition, determining the emotion with the greater calculated score for the emotion estimated based on the face image and the emotion estimated based on the temperature as the emotion of the user can yield a more reliable emotion as the determination result.

Second Embodiment

(55) A second embodiment of the present invention will now be described.

(56) (Structure)

(57) The structures of the communication system and the PC **200** according to the second embodiment are substantially the same as in the first embodiment. In the second embodiment, the processing performed by the emotion determiner **233** differs from the processing in the first embodiment for the emotion with the greatest score calculated by the first emotion estimator **231** not matching the emotion with the greatest score calculated by the second emotion estimator **232**. In the second embodiment, the emotion determiner **233** determines, as the emotion of the user, the emotion with the greater sum of a score calculated by the first estimator **231** and a score calculated by the second estimator **232** of the emotion with the greatest score calculated by the first estimator **231** and the emotion with the greatest score calculated by the second estimator **232**. This structure also yields a more reliable emotion as the determination result.

(58) (Operation)

(59) FIG. **5** is a flowchart of an example procedure according to the second embodiment. The PC **200** repeats the procedure in FIG. **5**. Although the repetition cycle of the procedure in FIG. **5** is not limited, the procedure in FIG. **5** is repeated at the frame rate of the image capturing with the camera **10** (e.g., 30 fps).

(60) The processing in steps S**501** to S**507** is the same as the processing in steps S**301** to S**307** in the first embodiment. When the score for the emotion E1 (score based on the change in the facial expression) does not match the score for the emotion E2 (score based on the change in the temperature) (No in step S**507**), the processing advances to step S**508**.

(61) In step S**508**, the emotion determiner **233** calculates a total score S1 corresponding to the emotion E1. The total score S1 is calculated by adding the score for the emotion E1 (score calculated by the first emotion estimator **231**, or specifically, the score based on the change in the facial expression) and the score calculated by the second emotion estimator **232** (score based on the change in the temperature) for the same emotion as the emotion E1.

(62) In step S**509**, the emotion determiner **233** calculates a total score S2 corresponding to the emotion E2. The total score S2 is calculated by adding the score for the emotion E2 (score calculated by the second emotion estimator **232**, or specifically, the score based on the change in the temperature) and the score calculated by the first emotion estimator **231** (score based on the change in the facial expression) for the same emotion as the emotion E2.

(63) In step S**510**, the emotion determiner **233** determines whether the total score S1 calculated in step S**508** matches the total score S2 calculated in step S**509**. When the total score S1 does not match the total score S2 (No in step S**510**), the processing advances to step S**511**. Once the total score S1 matches the total score S2 (Yes in step S**510**), the PC **200** ends the procedure in FIG. **5**. The same emotion as the previous emotion is then used as the emotion Eresult of the user.

(64) In step S**511**, the emotion determiner **233** determines whether the total score S1 calculated in step S**508** is greater than the total score S2 calculated in step S**509**. When the total score S1 is greater than the total score S2 (Yes in step S**511**), the processing advances to step S**512**. When the total score S1 is less than the total score S2 (No in step S**511**), the processing advances to step S**513**.

(65) In step S**512**, the emotion determiner **233** determines the emotion E1 corresponding to the total score S1 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **5**.

(66) In step S**513**, the emotion determiner **233** determines the emotion E2 corresponding to the total score S2 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **5**.

(67) (Specific Operation Example)

(68) FIGS. **6**A to **6**C show operation examples in the second embodiment. FIG. **6**A shows an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator **231**. In FIG. **6**A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold frames. FIG. **6**B shows an example temporal change of the score for each emotion (score based on the change in the temperature) calculated by the second emotion estimator **232**. In FIG. **6**B, the emotion E2 (emotion estimated based on the change in the temperature) is shown in bold frames. FIG. **6**C shows an example temporal change of the emotion (emotion Eresult) determined by the emotion determiner **233**.

(69) In the examples in FIGS. **6**A to **6**C, both the emotions E1 and E2 are calmness for the period from frame 0 to frame 2, and calmness is thus determined as the emotion Eresult. For frame 3, the emotion E1 is anger, and the emotion E2 is calmness. The emotions E1 and E2 are different. For the emotion E1 (anger), the sum (total score S1) of the score (**55**) calculated by the first emotion estimator **231** and the score (**20**) calculated by the second emotion estimator **232** is 75. For the emotion E2 (calmness), the sum (total score S2) of the score (**22**) calculated by the first emotion estimator **231** and the score (**52**) calculated by the second emotion estimator **232** is 74. With the total score S1 (**75**) corresponding to the emotion E1 (anger) is greater than the total score S2 (**74**) corresponding to the emotion E2 (calmness), anger is determined as the emotion Eresult. Similarly in the other frames, the emotion Eresult is determined based on, for example, the match or mismatch between the score for the emotion E1 and the score for the emotion E2, and on the relationship between the total score S1 and the total score S2.

(70) (Overview)

(71) In the second embodiment as described above, the highly accurate emotion determination can be achieved using the simple structure with high usability, as in the first embodiment. In addition, determining the emotion with the greater sum of the score based on the face image and the score based on the temperature of the emotion estimated based on the face image and the emotion estimated based on the temperature as the emotion of the user can yield a more reliable emotion as the determination result.

Third Embodiment

(72) A third embodiment of the present invention will now be described.

(73) (Structure)

(74) The structures of the communication system and the PC **200** according to the third embodiment are substantially the same as in the first embodiment. In the third embodiment, the processing performed by the emotion determiner **233** differs from the processing in the first embodiment for the emotion with the greatest score calculated by the first emotion estimator **231** not matching the emotion with the greatest score calculated by the second emotion estimator **232**. In the third embodiment, the emotion determiner **233** determines the emotion with the greater score change amount from the previous score for those emotions as the emotion of the user. In this manner, the emotional change can be detected more quickly.

(75) (Operation)

(76) FIG. **7** is a flowchart of an example procedure according to the third embodiment. The PC **200** repeats the procedure in FIG. **7**. Although the repetition cycle of the procedure in FIG. **7** is not limited, the procedure in FIG. **7** is repeated at the frame rate of the image capturing with the camera **10** (e.g., 30 fps).

(77) The processing in steps S**701** to S**707** is the same as the processing in steps S**301** to S**307** in

the first embodiment. When the score for the emotion E1 (score based on the change in the facial expression) does not match the score for the emotion E2 (score based on the change in the temperature) (No in step S**707**), the processing advances to step S**708**.

(78) In step S**708**, the emotion determiner **233** calculates a change amount D1 from the previous score for the emotion E1 (score based on the expression change) to the present score for the emotion E1 (score based on the expression change). The change amount D1 is a difference value obtained by subtracting the previous score for the emotion E1 from the present score for the emotion E1.

(79) In step S**709**, the emotion determiner **233** calculates a change amount D2 from the previous score for the emotion E2 (score based on the change in the temperature) to the present score for the emotion E2 (score based on the change in the temperature). The change amount D2 is a difference value obtained by subtracting the previous score for the emotion E2 from the present score for the emotion E2.

(80) In step S**710**, the emotion determiner **233** determines whether the change amount D1 calculated in step S**708** matches the change amount D2 calculated in step S**709**. When the change amount D1 does not match the change amount D2 (No in step S**710**), the processing advances to step S**711**. Once the change amount D1 matches the change amount D2 (Yes in step S**710**), the PC **200** ends the procedure in FIG. **7**. The same emotion as the previous emotion is then used as the emotion Eresult of the user.

(81) In step S**711**, the emotion determiner **233** determines whether the change amount D1 calculated in step S**708** is greater than the change amount D2 calculated in step S**709**. When the change amount D1 is greater than the change amount D2 (Yes in step S**711**), the processing advances to step S**712**. When the change amount D1 is less than the change amount D2 (No in step S**711**), the processing advances to step S**713**.

(82) In step S**712**, the emotion determiner **233** determines the emotion E1 corresponding to the change amount D1 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **7**.

(83) In step S**713**, the emotion determiner **233** determines the emotion E2 corresponding to the change amount D2 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **7**.

(84) (Specific Operation Example)

(85) FIGS. **8**A to **8**C show operation examples in the third embodiment. FIG. **8**A shows an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator **231**. In FIG. **8**A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold frames. FIG. **8**B shows an example temporal change of the score for each emotion (score based on the change in the temperature) calculated by the second emotion estimator **232**. In FIG. **8**B, the emotion E2 (emotion estimated based on the change in the temperature) is shown in bold frames. FIG. **8**C shows an example temporal change of the emotion (emotion Eresult) determined by the emotion determiner **233**.

(86) In the examples in FIGS. **8**A to **8**C, both the emotions E1 and E2 are calmness for the period from frame 0 to frame 2, and calmness is thus determined as the emotion Eresult. For frame 3, the emotion E1 is anger, and the emotion E2 is calmness. The emotions E1 and E2 are different. For the emotion E1 (anger), the change amount D1 from the previous score calculated by the first emotion estimator **231** (**23**, or specifically, the score for frame 2) to the present score calculated by the first emotion estimator **231** (**55**, or specifically, the score for frame 3) is 32 (=55−23). For the emotion E2 (calmness), the change amount D2 from the previous score calculated by the second emotion estimator **232** (**61**, or specifically, the score for frame 2) to the present score calculated by the second emotion estimator **232** (**52**, or specifically, the score for frame 3) is −9 (=52−61). With the change amount D1 (**32**) corresponding to the emotion E1 (anger) is greater than the change amount D2 (−9) corresponding to the emotion E2 (calmness), anger is determined as the emotion

Eresult. Similarly in other frames, the emotion Eresult is determined based on, for example, the match or mismatch between the score for the emotion E1 and the score for the emotion E2, and on the relationship between the change amount D1 and the change amount D2.

(87) (Overview)

(88) In the third embodiment as described above, the highly accurate emotion determination can be achieved using the simple structure with high usability, as in the first embodiment. In addition, determining the emotion with the greater score change amount from the previous score for the emotion estimated based on the face image and the emotion estimated based on the temperature as the emotion of the user can capture the emotional change more quickly.

Fourth Embodiment

(89) A fourth embodiment of the present invention will now be described.

(90) (Structure)

(91) The structures of the communication system and the PC **200** according to the fourth embodiment are substantially the same as in the first embodiment. In the fourth embodiment, the processing performed by the emotion determiner **233** differs from the processing in the first embodiment for the emotion with the greatest score calculated by the first emotion estimator **231** not matching the emotion with the greatest score calculated by the second emotion estimator **232**. In the fourth embodiment, the emotion determiner **233** determines the emotion with the greater score variance value among the multiple emotions of those emotions as the emotion of the user. The variance value herein can be referred to as the degree of score prominence. A greater score variance value among multiple emotions, or in other words, a more prominent greatest score indicates a higher reliability (likelihood of the user holding the corresponding emotion), and thus a more reliable emotion as the determination result. A variance value V of n scores Xi (i is an integer from 1 to n inclusive) can be calculated using, for example, Formula 1 described below. In Formula 1, Xave is the average of the n scores Xi.

Formula1

(92)
$$V = \tfrac{1}{n} \cdot \underset{i=1}{\overset{n}{\text{Math.}}} (Xi - Xave)^2 \quad (1)$$

(Operation)

(93) FIG. **9** is a flowchart of an example procedure according to the fourth embodiment. The PC **200** repeats the procedure in FIG. **9**. Although the repetition cycle of the procedure in FIG. **9** is not limited, the procedure in FIG. **9** is repeated at the frame rate of the image capturing with the camera **10** (e.g., 30 fps).

(94) The processing in steps S**901** to S**907** is the same as the processing in steps S**301** to S**307** in the first embodiment. When the score for the emotion E1 (score based on the change in the facial expression) does not match the score for the emotion E2 (score based on the change in the temperature) (No in step S**907**), the processing advances to step S**908**.

(95) In step S**908**, the emotion determiner **233** calculates each variance value of multiple scores (multiple scores based on the change in the facial expression) calculated by the first emotion estimator **231** for multiple emotions (calmness, anger, sadness, and joy) as a variance value V1 corresponding to the emotion E1.

(96) In step S**909**, the emotion determiner **233** calculates each variance value of multiple scores (multiple scores based on the change in the temperature) calculated by the second emotion estimator **232** for multiple emotions (calmness, anger, sadness, and joy) as a variance value V2 corresponding to the emotion E2.

(97) In step S**910**, the emotion determiner **233** determines whether the variance value V1 calculated in step S**908** matches the variance value V2 calculated in step S**909**. When the variance value V1 does not match the variance value V2 (No in step S**910**), the processing advances to step S**911**. Once the variance value V1 matches the variance value V2 (Yes in step S**910**), the PC **200** ends the procedure in FIG. **9**. The same emotion as the previous emotion is then used as the emotion Eresult

of the user.

(98) In step S**911**, the emotion determiner **233** determines whether the variance value V1 calculated in step S**908** is greater than the variance value V2 calculated in step S**909**. When the variance value V1 is greater than the variance value V2 (Yes in step S**911**), the processing advances to step S**912**. When the variance value V1 is less than the variance value V2 (No in step S**911**), the processing advances to step S**913**.

(99) In step S**912**, the emotion determiner **233** determines the emotion E1 corresponding to the variance value V1 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **9**.

(100) In step S**913**, the emotion determiner **233** determines the emotion E2 corresponding to the variance value V2 as the emotion Eresult of the user. The PC **200** then ends the procedure in FIG. **9**.

(101) (Specific Operation Example)

(102) FIGS. **10**A to **10**C show operation examples in the fourth embodiment. FIG. **10**A shows an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator **231**. In FIG. **10**A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold frames. FIG. **10**B shows an example temporal change of the score for each emotion (score based on the change in the temperature) calculated by the second emotion estimator **232**. In FIG. **10**B, the emotion E2 (emotion estimated based on the change in the temperature) is shown in bold frames. FIG. **10**C shows an example temporal change of the emotion (emotion Eresult) determined by the emotion determiner **233**.

(103) In the examples in FIGS. **10**A to **10**C, both the emotions E1 and E2 are calmness for the period from frame 0 to frame 2, and calmness is thus determined as the emotion Eresult. For frame 3, the emotion E1 is anger, and the emotion E2 is calmness. The emotions E1 and E2 are different. For the emotion E1 (anger), the variance value V1 calculated from the four scores (**22**, **55**, **12**, and **11**) calculated by the first emotion estimator **231** is 319. For the emotion E2 (calmness), the variance value V2 calculated from the four scores (**52**, **20**, **8**, and **20**) calculated by the second emotion estimator **232** is 267. The variance value V1 (**319**) corresponding to the emotion E1 (anger) is greater than the variance value V2 (**267**) corresponding to the emotion E2 (calmness), and anger is thus determined as the emotion Eresult. Similarly in other frames, the emotion Eresult is determined based on, for example, the match or mismatch between the score for the emotion E1 and the score for the emotion E2, and on the relationship between the variance value V1 and the variance value V2.

(104) (Overview)

(105) In the fourth embodiment as described above, the highly accurate emotion determination can be achieved using the simple structure with high usability, as in the first embodiment. In addition, determining the emotion with the greater score variance value among multiple emotions of the emotion estimated based on the face image and the emotion estimated based on the temperature as the emotion of the user can yield a more reliable emotion as the determination result.

Fifth Embodiment

(106) A fifth embodiment of the present invention will now be described.

(107) (Structure)

(108) The structure of the communication system according to the fifth embodiment is substantially the same as in the first embodiment. FIG. **11** is a block diagram of the PC **200** according to the fifth embodiment. In the fifth embodiment, the PC **200** also includes the image obtainer **210**, the temperature obtainer **220**, the controller **230**, the storage **240**, and the output unit **250** as in the first embodiment. However, the controller **230** in the fifth embodiment further includes an estimation result adjuster **234**. In the fifth embodiment, the processing other than those described below are the same as in the first embodiment.

(109) In the fifth embodiment, each of the first emotion estimator 231 and the second emotion estimator 232 stores (records, or specifically, accumulates) the estimation result of the emotion of the user into the storage 240.

(110) The estimation result adjuster 234 adjusts the estimation result obtained by the first emotion estimator 231 and the estimation result obtained by the second emotion estimator 232 stored in the storage 240. For clarity, in FIG. 11, arrows from the first emotion estimator 231 and the second emotion estimator 232 point to the estimation result adjuster 234 instead of arrows for writing or reading estimation results in the storage 240. More specifically, the estimation result adjuster 234 detects a period when the variance value of the scores (estimated emotion scores) for the period preceding a predetermined time is less than a predetermined threshold value. Such a period can be determined as the period with a stable estimation result of the emotion of the user. The estimation result adjuster 234 then replaces the estimation result from a first period with the variance value less than the predetermined threshold value backward up to the period immediately after a second period with the variance value less than the predetermined threshold value with the estimation result in the first period. The estimation result adjuster 234 adjusts the estimation result obtained by the first emotion estimator 231 and the estimation result obtained by the second emotion estimator 232 to detect such a period and replace the estimation result. The estimation result adjuster 234 is an example of an adjuster in an aspect of the present invention.

(111) The emotion determiner 233 determines the emotion of the user based on the adjusted estimation result obtained by the estimation result adjuster 234. For example, the emotion of the user is determined by any method described in the first to fourth embodiments.

(112) In this manner, the emotional changes can be smoothed for detection of the tendency with high accuracy. This allows intended control with, for example, emotional changes being predicted. When, for example, the emotion of the user tends to change from anger to sadness, the behavior (e.g., speech) of the communication robot 30 can be controlled to communicate with an angry user while expecting that the emotion of the user may change to sadness.

(113) (Specific Operation Example)

(114) FIGS. 12A to 12C show operation examples in the fifth embodiment. An example process for adjusting the estimation result of the first emotion estimator 231 will now be described below. The estimation result of the second emotion estimator 232 is also adjusted in the same manner as described below.

(115) FIG. 12A shows an example temporal change of the score before being changed by the estimation result adjuster 234, and an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator 231. In FIG. 12A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold frames.

(116) First, the estimation result adjuster 234 calculates the variance value of the emotion E1 estimated by the estimation result adjuster 234 for the period up to a predetermined time based on the temporal change in FIG. 12A. The predetermined time is not limited, but is herein to be the time for three frames. For example, the emotion E1 (emotion with the greatest score) is calmness for frame 2. The estimation result adjuster 234 thus calculates the variance value (16.9) from the calmness score for frame 2 (56), the calmness score for frame 1 (50), and the calmness score for frame 0 (60). The emotion E1 (emotion with the greatest score) is anger for frame 3. The estimation result adjuster 234 thus calculates the variance value (251) from the anger score (55) for frame 3, the anger score (23) for frame 2, and the anger score (20) for frame 1. The estimation result adjuster 234 calculates the variance values for other frames in the same manner. FIG. 12B shows an example temporal change of the calculated variance values.

(117) The estimation result adjuster 234 then detects the period (frame) with the variance value less than the predetermined threshold value. The predetermined threshold value is not limited, but is herein to be 50. In FIG. 12B, variance values less than the predetermined threshold (50) are shown

in bold frames. More specifically, frames 2, 7, 13, and 14 are detected.

(118) Finally, the estimation result adjuster **234** replaces the estimation result from the first period with the variance value less than the predetermined threshold value (**50**) backward up to the period immediately after the second period with the variance value less than the predetermined threshold value (**50**), with the estimation result in the first period. As described above, frames 2, 7, 13, and 14 are detected as periods with the variance value less than the predetermined threshold (**50**) in FIG. **12**B. Thus, the estimation result adjuster **234** replaces the scores for frames 0 to 2 with the score for frame 2, the scores for frames 3 to 7 with the score for frame 7, and the scores for frames 8 to 13 with the score for frame 13. FIG. **12**C shows an example temporal change of the score after being changed by the estimation result adjuster **234**.

(119) Although FIG. **12**C shows the score for the emotion E1 alone (emotion estimated to be held by the user), the above replacement may be performed for scores other than the emotion E1. For a series of multiple frames with the same emotion E1, the scores may be replaced for matching the scores among the multiple frames. In FIGS. **12**A to **12**C, for example, both the emotions E1 for frame 13 and for frame 14 are sadness. The estimation result adjuster **234** may thus replace the scores for frames 8 to 14 with the score for frame 13 or frame 14.

(120) (Overview)

(121) In the fifth embodiment as described above, the highly accurate emotion determination can be achieved using the simple structure with high usability, as in the first embodiment. In addition, the result of the emotion estimation is adjusted to detect smoothed emotional changes for detection of the tendency with high accuracy.

Sixth Embodiment

(122) A sixth embodiment of the present invention will now be described.

(123) (Structure)

(124) The structures of the communication system and the PC **200** according to the sixth embodiment are substantially the same as in the first embodiment. In the sixth embodiment, each of the first emotion estimator **231** and the second emotion estimator **232** estimate the emotion of the user in a first cycle. The emotion determiner **233** uses the estimation result obtained by the first emotion estimator **231** and the estimation result obtained by the second emotion estimator **232**, updated in a second cycle that is longer than the first cycle. For example, the second cycle is three times the first cycle. When the frame rate of the image captured with the camera **10** is 30 fps, and the first cycle corresponds to the frame rate, the second cycle corresponds to ⅓ of the frame rate (10 fps). The structure (processing) other than these is the same as in any of the first to fourth embodiments.

(125) This can reduce the frequency of the processing performed by the emotion determiner **233**, for example, in updating the estimation result obtained by the first emotion estimator **231** and the estimation result obtained by the second emotion estimator **232** to reduce the processing load for the emotion determination. The emotion determiner **233** may perform the emotion determination and output the results in the first cycle or in the second cycle. When the determination and the output are performed in the second cycle, the processing load in the emotion determiner **233** can be reduced further.

(126) (Specific Operation Example)

(127) FIGS. **13**A and **13**B show operation examples in the sixth embodiment. An example process for the emotion determiner **233** updating the estimation result obtained by the first emotion estimator **231** will now be described below. The emotion determiner **233** also updates the estimation result obtained by the second emotion estimator **232** in the same manner as described below.

(128) FIG. **13**A shows an example temporal change of the score for each emotion (score based on the change in the facial expression) calculated by the first emotion estimator **231**. In FIG. **13**A, the emotion E1 (emotion estimated based on the change in the facial expression) is shown in bold

frames.

(129) FIG. **13**B shows an example temporal change of the score for each emotion (score based on the change in the facial expression) used in the emotion determiner **233**. In FIG. **13**B, the emotion E1 (emotion estimated based on the change in the facial expression) is also shown in bold frames.

(130) As shown in FIG. **13**A, the first emotion estimator **231** calculates and updates the score for each frame. In contrast, as shown in FIG. **13**B, the emotion determiner **233** updates the score every three frames. More specifically, the emotion determiner **233** also uses the score for frame 0 as the scores for frames 1 and 2. The emotion determiner **233** can thus perform the processing for frames 1 and 2 for a period preceding frames 1 and 2. In other words, the result of the emotion determination can be obtained more quickly. The score is updated for frame 3, and the score for frame 3 is also used as the scores for frames 4 and 5. After that as well, the score is updated in the same manner.

(131) (Overview)

(132) In the sixth embodiment as described above, the highly accurate emotion determination can be achieved using the simple structure with high usability, as in the first embodiment. In addition, reducing the frequency of updating the emotion estimation result used for the emotion determination can reduce the processing load for the emotion determination and increase the processing speed of the emotion determination (the time taken to obtain the emotion determination result can be reduced).

(133) <Others>

(134) The embodiments described above are mere examples of the present invention. The present invention is not limited to the embodiments described above, but may be modified variously within the scope of the technical ideas of the invention. The processing in the first to sixth embodiments may be combined as appropriate.

(135) <Appendix 1>

(136) An emotion determination device (**100**, **200**), comprising:

(137) a first estimator (**101**, **231**) configured to estimate an emotion of a user based on a change in a facial expression of the user detected from a face image of the user;

(138) a second estimator (**102**, **232**) configured to estimate the emotion of the user based on a change in a temperature of the user detected contactlessly from the user; and

(139) a determiner (**103**, **233**) configured to determine the emotion of the user based on an estimation result obtained by the first estimator and an estimation result obtained by the second estimator.

(140) <Appendix 2>

(141) An emotion determination method, comprising: (S**302**, S**502**, S**702**, S**902**) estimating an emotion of a user based on a change in a facial expression of the user detected from a face image of the user; (S**304**, S**504**, S**704**, S**904**) estimating the emotion of the user based on a change in temperature of the user detected contactlessly from the user; and (S**305** to S**310**, S**505** to S**513**, S**705** to S**713**, S**905** to S**913**) determining the emotion of the user based on an estimation result in the estimating based on the change in the facial expression and an estimation result in the estimating based on the change in the temperature.

REFERENCE SIGNS LIST

(142) **100**: Emotion determination device **101**: First emotion estimator **102**: Second emotion estimator **103**: Emotion determiner **10**: Camera **20**: Temperature measurement device **30**: Communication robot **200**: PC (Emotion determination device) **210**: Image obtainer **220**: Temperature obtainer **230**: Controller **240**: Storage **250**: Output unit **231**: First emotion estimator **232**: Second emotion estimator **233**: Emotion determiner **234**: Estimation result adjuster **241**: First emotion estimation dictionary **242**: Second emotion estimation dictionary

Claims

1. An emotion determination device, comprising: a memory configured to store computer-executable instructions; and a processor configured to execute the computer-executable instructions stored in the memory to implement: a first estimator configured to estimate an emotion of a user based on a change in a facial expression of the user detected from a face image of the user; a second estimator configured to estimate the emotion of the user based on a change in a temperature of the user detected contactlessly from the user; a determiner configured to determine the emotion of the user based on an estimation result obtained by the first estimator and an estimation result obtained by the second estimator; and an adjuster configured to detect a period with a variance value, for the period up to a predetermined time, of scores indicating a likelihood of the user holding an estimated emotion being less than a predetermined threshold value and adjust the estimation result obtained by the first estimator and the estimation result obtained by the second estimator to replace an estimation result from a first period with the variance value less than the predetermined threshold value backward up to a period immediately after a second period with the variance value less than the predetermined threshold value with an estimation result in the first period, wherein the determiner determines the emotion of the user based on the adjusted estimation result obtained by the adjuster.

2. The emotion determination device according to claim 1, wherein each of the first estimator and the second estimator calculates a score indicating a likelihood of the user holding an emotion of a plurality of emotions, and the determiner determines the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator.

3. The emotion determination device according to claim 2, wherein the determiner determines, as the emotion of the user, an emotion with a greatest score calculated by the first estimator matching an emotion with a greatest score calculated by the second estimator, and the determiner determines, in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator.

4. The emotion determination device according to claim 3, wherein in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the determiner determines, as the emotion of the user, an emotion with a greater calculated score for the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator.

5. The emotion determination device according to claim 3, wherein in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the determiner determines, as the emotion of the user, an emotion with a greater sum of a score calculated by the first estimator and a score calculated by the second estimator of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator.

6. The emotion determination device according to claim 3, wherein in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the determiner determines, as the emotion of the user, an emotion with a greater score change amount of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator.

7. The emotion determination device according to claim 3, wherein in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the determiner determines, as the emotion of the user, an

emotion with a greater score variance value of the emotion with the greatest score calculated by the first estimator and the emotion with the greatest score calculated by the second estimator.

8. An emotion determination method, comprising: estimating an emotion of a user based on a change in a facial expression of the user detected from a face image of the user; estimating the emotion of the user based on a change in temperature of the user detected contactlessly from the user; determining the emotion of the user based on an estimation result in the estimating based on the change in the facial expression and an estimation result in the estimating based on the change in the temperature; detecting a period with a variance value, for the period up to a predetermined time, of scores indicating a likelihood of the user holding an estimated emotion being less than a predetermined threshold value; and adjusting the estimation result in the estimating based on the change in the facial expression and the estimation result in the estimating based on the change in the temperature to replace an estimation result from a first period with the variance value less than the predetermined threshold value backward up to a period immediately after a second period with the variance value less than the predetermined threshold value with an estimation result in the first period, wherein the determining determines the emotion of the user based on the adjusted estimation result.

9. A non-transitory computer readable medium storing a program for causing a computer to perform operations included in the emotion determination method according to claim 8.

10. An emotion determination device, comprising: a memory configured to store computer-executable instructions; and a processor configured to execute the computer-executable instructions stored in the memory to implement: a first estimator configured to estimate an emotion of a user based on a change in a facial expression of the user detected from a face image of the user; a second estimator configured to estimate the emotion of the user based on a change in a temperature of the user detected contactlessly from the user; and a determiner configured to determine the emotion of the user based on an estimation result obtained by the first estimator and an estimation result obtained by the second estimator, wherein, each of the first estimator and the second estimator calculates a score indicating a likelihood of the user holding an emotion of a plurality of emotions, the determiner determines the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator, the determiner determines, as the emotion of the user, an emotion with a greatest score calculated by the first estimator matching an emotion with a greatest score calculated by the second estimator, and the determiner determines, in response to the emotion with the greatest score calculated by the first estimator not matching the emotion with the greatest score calculated by the second estimator, the emotion of the user based on a score for each of the plurality of emotions calculated by the first estimator and a score for each of the plurality of emotions calculated by the second estimator.

11. The emotion determination device according to claim 10, wherein each of the first estimator and the second estimator estimates the emotion of the user in a first cycle, and the determiner uses the estimation result obtained by the first estimator and the estimation result obtained by the second estimator updated in a second cycle longer than the first cycle.