

## DESCRIPTION

### EARDRUM CLASSIFICATION APPARATUS, EARDRUM CLASSIFICATION SYSTEM, AND EARDRUM CLASSIFICATION PROGRAM

#### Technical Field

[0001]

The present invention relates to an apparatus for classifying the presence or absence of a pathological condition of an eardrum from an image of the eardrum.

#### Background Art

[0002]

Conventionally, the method of JP 2019-534723 A (Patent Literature 1), for example, is known as a method of classifying a pathological condition of an eardrum from an image of the eardrum. The conventional method determines whether the eardrum is normal or abnormal on the basis of an image obtained by capturing an image of the condition of the eardrum.

#### Citation List

##### Patent Literature

[0003]

Patent Literature 1: JP 2019-534723 A

#### Summary of Invention

Technical Problem

[0004]

However, the present inventors have found that the above-described conventional method has a point to be further improved. That is, there are cases where a normal eardrum is incorrectly determined as abnormal, an abnormal eardrum is incorrectly determined as normal, and determination as to whether otitis media is acute otitis media or otitis media with effusion is incorrect. Accurate diagnosis is therefore difficult, and the accuracy of the classifying (a classification accuracy) has room for improvement.

[0005]

In addition, there are many needs to get a diagnosis of an eardrum at midnight, on a Sunday, or on a holiday, when neither a doctor's office nor a clinic provides a medical examination. In particular, a parent who is busy with both work and child-care often fails to notice an abnormal condition in a deep portion of the ear cavity of an infant or child. This may worsen inflammation around the eardrum, and the parent may at last want a medical examination at midnight, on a Sunday, or on a holiday.

[0006]

In addition, medical services are not sufficient in rural areas. Getting a medical examination at a doctor's

office or a clinic may be difficult due to absence of a pediatrician and/or an ear-nose-throat doctor.

[0007]

Nevertheless, early detection of otitis media is essential for proper treatment. A delay in diagnosis leads to a delay in appropriate treatment.

[0008]

The present invention has been made in view of the above circumstances, and an object of the present invention is to provide a technique that enables simple and correct determination of a pathological condition of a region including an eardrum at a suitable time even when medical services in a doctor's office, a clinic, and the like are limited.

Solution to Problem

[0009]

For this purpose, an eardrum classification apparatus according to the present invention includes a communication unit to which image data including an image of an eardrum is input, a first classification unit that extracts a characteristic from the image data by an algorithm and performs classification of a condition of the eardrum as either acute otitis media or other than acute otitis media, and a second classification unit that

extracts a characteristic, by an algorithm, from the image data classified as other than acute otitis media and performs classification of the condition of the eardrum as either normal eardrum or otitis media with effusion, wherein the eardrum classification apparatus outputs a result indicating acute otitis media, normal eardrum, or otitis media with effusion from the communication unit on the basis of classification results of the first and second classification units.

[0010]

According to the present invention, two-stage binary classification is performed, thereby enabling a classification result to be obtained that provides the classification accuracy higher than that of the conventional technology. Therefore, even when a medical institution cannot be consulted, it is possible to get support almost equivalent to a medical examination, and to know the symptom at a suitable time. The eardrum classification apparatus of the present invention has a hardware configuration and a software configuration that are not particularly limited. The eardrum classification apparatus is implemented, for example, in a server on a network or in a cloud.

[0011]

A glitter or foreign matter appearing in the image

adversely affects the classification. It is difficult, in capturing an image of the eardrum, for an ordinary person who is unfamiliar with capturing an image, to adjust the amount of light emission required for capturing an image or to capture an image of the eardrum to prevent a glitter or foreign matter from appearing in the image. Therefore, as one aspect of the present invention, a clipping unit is included that clips out the eardrum from the image data input to the communication unit and provides image data of the eardrum to the first classification unit. According to such aspect, appearance of a glitter and foreign matter can be removed from the image to be classified, and the classification accuracy of classification is therefore improved. In addition, machine learning can be effectively performed. As another aspect of the present invention, the eardrum may be clipped out before being input to the communication unit, such as when an image of the eardrum is captured or when the image data is transmitted to the communication unit, and the area of the image data that has been clipped out may be input to the communication unit of the eardrum classification apparatus.

[0012]

As a preferred aspect of the present invention, a clipping unit is included that clips out a predetermined portion of the eardrum from the image data input to the

communication unit and provides the predetermined portion to the first classification unit. According to such aspect, at least one of the first classification unit and the second classification unit focuses on the predetermined portion of the eardrum rather than the entire eardrum, thereby enabling the classification accuracy of classification to be improved, and machine learning to be effectively performed. For example, clipping out the lower half of the eardrum enables correct classification of a case in which the lower half has a prominent lesion, such as otitis media with effusion, and enables machine learning to be effectively performed. Alternatively, for example, a central portion of the eardrum is clipped out.

[0013]

The eardrum classification apparatus of the present invention includes artificial intelligence (AI). The AI model of the algorithm of AI is not particularly limited. As a preferred aspect of the present invention, at least one of the first classification unit and the second classification unit reads labeled training data and performs supervised machine learning. According to such aspect, the eardrum classification apparatus repeats machine learning, thereby causing the classification accuracy to be further improved.

[0014]

An eardrum classification system of the present invention includes the above-described eardrum classification apparatus, an earscope that captures an image of an eardrum, and a terminal that receives image data of the eardrum from the earscope and outputs the image data to the communication unit of the eardrum classification apparatus. According to such aspect, the symptom of the eardrum can be known by operating the earscope and the terminal of a household in a general household not skilled in medical technology. The terminal is capable of, for example, simply displaying a classification result and optionally displaying information related to the classification result. The earscope is not limited to a medical device as long as an image of the depths of the earhole can be captured, and it is sufficient that a sufficient resolution (DPI) can be managed with respect to the imaging unit and the image. Preferably, the earscope includes an imaging unit capable of capturing an image of preferably 4 million pixels or more. More preferably, the earscope includes an imaging unit capable of capturing an image of preferably 8 million pixels or more. The device and the hardware configuration of the terminal are not particularly limited.

[0015]

As one aspect of the present invention, the terminal

includes a screen that displays an image captured by the earscope, and guide means that provides guidance to allow the eardrum to be displayed in a central portion of the screen on the screen. The terminal outputs image data including the eardrum appearing in the central portion, to the eardrum classification apparatus. According to such aspect, the terminal includes the guide means, thereby enabling even a user who is not skilled in medical technology to easily capture an eardrum image D'. The guide means is not particularly limited, but is, for example, a frame having a circular shape displayed at the center of the screen of the terminal.

[0016]

As one aspect of the present invention, the earscope is a digital camera provided in an earhole cleaning structural unit. According to such aspect, the symptom of the eardrum can be known by using an earhole cleaning device including the digital camera.

[0017]

As a preferred aspect of the present invention, the eardrum classification system includes a medical institution terminal mutually communicable with the eardrum classification apparatus and with the terminal. According to such aspect, it is possible to get support that is almost equivalent to a medical examination from a medical

institution.

[0018]

A glitter or foreign matter appearing in the image adversely affects the classification. It is difficult, in capturing an image of the eardrum, for an ordinary person who is unfamiliar with capturing an image, to adjust the amount of light emission required for capturing an image or to capture an image of the eardrum to prevent a glitter or foreign matter from appearing in the image. Therefore, as a preferred aspect of the present invention, the earscope or the terminal includes a clipping unit that clips out the eardrum from the image including the eardrum to generate the image data. According to such aspect, appearance of a glitter and foreign matter can be removed from the image to be classified, and the classification accuracy of classification is therefore improved. In addition, machine learning can be effectively performed. The clipping operation is performed by a component on the earscope side as viewed from the eardrum classification apparatus. Alternatively, in another aspect, the clipping operation may be performed by a component on the eardrum classification apparatus side.

[0019]

As a preferred aspect of the present invention, the guide means indicates, on the screen, whether the image

displayed on the screen is suitable for classification. According to such aspect, even a user who is unfamiliar with capturing an image can capture an eardrum image.

[0020]

As a preferred aspect of the present invention, the terminal displays probabilities related to classification results of the first and second classification units, on the screen. According to such aspect, attention of the user can be attracted. As another aspect, a threshold value may be predetermined for the probability, and a notification prompting to go to a doctor's office or a clinic may be displayed on the screen when the probability is equal to or greater than the threshold value.

[0021]

Each operation (processing) in the classification method of the present invention can also be realized in a method using a computer-executable program stored in various types of machine-readable storage media. An eardrum classification program of the present invention is a program that causes a computer to classify image data including an image of an eardrum. The eardrum classification program causes a computer to perform a first classification step of extracting a characteristic from the image data by an algorithm and classifying a condition of the eardrum as either acute otitis media or other than

acute otitis media, a second classification step of extracting a characteristic, by an algorithm, from the image data classified as other than acute otitis media and classifying the condition of the eardrum as either normal eardrum or otitis media with effusion, and a step of outputting a result indicating acute otitis media, normal eardrum, or otitis media with effusion on the basis of classification results of the first and second classification steps.

[0022]

The present invention includes a program code that causes a computer to perform the classification, a computer-readable program product, and a storage medium that stores the program code. The storage medium may include, for example, but is not limited to, a magnetic disk, an optical disk, a magneto-optical disk, a semiconductor storage, and the like. The storage medium that stores the program code is directly or indirectly provided to a system or to an apparatus, and a computer, a ROM, a RAM, or a central processing unit (CPU) of the system or the apparatus reads and executes the program code. The method for realizing the present invention is not limited to use of the program, but can be implemented by other software and/or firmware. The present invention may be an apparatus or a method.

## Advantageous Effects of Invention

[0023]

As described above, according to the present invention, the pathological condition of an eardrum can be known with a high classification accuracy without consulting a medical institution, thereby enabling the pathological condition of a region including the eardrum to be known at a suitable time regardless of time and place, and enabling a situation of getting a diagnosis too late to be prevented. In addition, regional differences in medical services are eliminated. Furthermore, use in a medical site improves the efficiency of diagnosis, which contributes to labor saving in the site.

## Brief Description of Drawings

[0024]

Fig. 1 is a schematic overall diagram illustrating an eardrum classification system according to an embodiment of the present invention.

Fig. 2 is a diagram illustrating an example of classification results of classification performed by an eardrum classification apparatus of the embodiment.

Fig. 3 is a set of photographs showing an image including an eardrum and clipped-out images.

Fig. 4 is a schematic diagram illustrating a classification algorithm executed by the eardrum classification apparatus of the embodiment.

Fig. 5 is a schematic diagram illustrating classification performed by an eardrum classification apparatus of Comparative Example 1.

Fig. 6 is a screen displayed on a terminal of the embodiment, in which the screen of the terminal displays guide means.

Fig. 7 is a schematic diagram illustrating a classification algorithm executed by the eardrum classification apparatus of the embodiment together with probabilities [%].

Fig. 8 is a screen displayed on the terminal of the embodiment, in which a classification result displayed on the screen of the terminal is displayed with indication.

#### Description of Embodiment

[0025]

An embodiment of the present invention will hereinafter be described in detail with reference to the drawings. Fig. 1 is a schematic overall diagram illustrating an eardrum classification system according to an embodiment of the present invention. The eardrum classification system includes an earscope 10, a terminal

20, and an eardrum classification apparatus 30. The earoscope 10 includes a main body 11 having a bar shape, an earhole cleaning structural unit 12 provided at a distal end of the main body, and a light emitting unit 14 and an imaging unit 15 attached to the earhole cleaning structural unit 12. The imaging unit is, for example, a digital camera.

[0026]

The terminal 20 has a screen 21 and can mutually communicate with the earoscope 10. The screen 21 displays an image B captured by the imaging unit 15. The image B includes a frame C having a circular shape by way of example.

[0027]

The user of the earoscope 10 holds the main body 11 by hand, inserts the earhole cleaning structural unit 12 into an ear canal H of the subject (e.g., a child), and removes cerumen on the inner circumferential surface of the ear canal H. Alternatively, the user causes the light emitting unit 14 to emit light, captures an image of the inside of the ear canal H using the imaging unit 15, and displays the image of the inside of the ear canal H on the screen 21.

[0028]

It is advisable that the user move the earoscope 10

while checking the screen 21 to cause the image of the eardrum D (hereinafter referred to as eardrum image D') to be centered in the frame C. The frame C serves as a mark for guiding the user to capture the eardrum image D'. The image B captured by the imaging unit 15 is displayed on the screen 21 every moment. It is advisable that when the user moves the earscope 10 while checking the eardrum image D' included in the image B and the eardrum image D' is displayed in a large size at the center of the frame C, the user select and capture the eardrum image D' including fewer blown-out highlights due to light reflection, glare, and color blowout (glitter F) while avoiding blurring of the image and camera shake. Note that the user is not particularly limited, and does not need to be skilled in imaging technology or be a medical person. The user is an ordinary person.

[0029]

The terminal 20 can mutually communicate with the eardrum classification apparatus 30 (specifically, with a communication unit 33), which is provided externally, via wireless communication or wired communication such as network means NW (e.g., the Internet). The terminal 20 can be implemented in a widely and generally used mobile phone terminal (such as, for example, a smartphone), a tablet terminal, or a terminal having another communication

function such as Wi-fi (registered trademark) or bluetooth (registered trademark). The user provides the image B (strictly, image data of the image B) that has been captured to the eardrum classification apparatus 30, thereby enabling the eardrum D to be classified by the eardrum classification apparatus 30 as normal eardrum or suffering from acute otitis media or otitis media with effusion. Such classification can be translated as determination or diagnosis.

[0030]

The eardrum classification apparatus 30 includes a classification unit 31, which includes artificial intelligence (AI) that runs a unique algorithm, a memory unit 32, which stores a large amount of image data (which has the same meaning as images), and a communication unit 33, which mutually communicates with the outside world. The eardrum classification apparatus 30 of the present embodiment is a server connected to the Internet. The memory unit 32 stores a large amount of image data of normal eardrum labeled as normal eardrum. The memory unit 32 also stores a large amount of image data of acute otitis media labeled as acute otitis media. The memory unit 32 further stores a large amount of image data of otitis media with effusion labeled as otitis media with effusion. These pieces of data are used in machine learning of the

classification unit 31 as labeled training data. The classification unit 31 performs machine learning using a plurality of sets of training data as the training material to improve a classification accuracy of classification. Note that the classification accuracy is understood to have the same meaning as that obtained in such a manner that an external organization different from the eardrum classification apparatus 30 (e.g., a human doctor) scores classification results of the classification unit 31 on the basis of whether the classification results are correct or incorrect, and accumulates the results of scoring.

[0031]

When an image (which has the same meaning as image data, the same applies hereinafter) including the eardrum image D' is input, the classification unit 31 extracts a characteristic for classification from the eardrum image D', performs algorithm processing on the characteristic, classifies the eardrum image D' as one of normal eardrum, acute otitis media, and otitis media with effusion, and outputs the classification result. The term characteristic refers to the hue distribution of the eardrum image D', the size of the profile of the distribution, and/or the like, and is defined inside the classification unit 31 according to an algorithm.

[0032]

The communication unit 33 receives image data from the outside world via wireless communication or wired communication such as the network means NW, and outputs the image data to the classification unit 31. In addition, the communication unit 33 can mutually communicate with a computer terminal of a medical institution 40 via similar communication means. Alternatively, the eardrum classification apparatus 30 may be a computer installed in a medical institution. In any case, the labeled training data is accumulated in the memory unit 32 over time. As a result, the learning amount of machine learning of the classification unit 31 increases, and the classification accuracy of the classification is improved. In addition, an eardrum image D' newly input from the terminal 20 to the eardrum classification apparatus 30 is labeled later by a doctor of the medical institution 40. As a result, training data is accumulated in the memory unit 32 over time.

[0033]

The classification unit 31 includes a clipping unit, a first classification unit, and a second classification unit. In the present embodiment, as illustrated in Fig. 3, the clipping unit in the classification unit 31 clips out the eardrum image D' from the image B illustrated in part (a) using an algorithm. As a result, the glitter F

appearing in the image B, separate from the eardrum image D', the color of the inner circumferential surface of the ear canal H, and foreign matter G such as hair and/or cerumen will have no effect on the classification. Part (b) illustrates image data related to the eardrum image D' that has been clipped out.

[0034]

Fig. 4 is a schematic diagram illustrating an algorithm sequentially executed by the first classification unit and by the second classification unit in the classification unit 31. Such algorithm is executed by a residual network (ResNet), VGG16 (Visual Geometry Group 16 layers), Densely Connected Convolutional Network (DenseNet), or other AI model.

[0035]

First, a first classification unit 31b in the classification unit 31 classifies the eardrum image D' as one of two groups. Specifically, the eardrum image D' is classified as either acute otitis media or other than acute otitis media. This binary classification is performed on the basis of the magnitude of the proportion of reddish pixels in the pixels of the entire eardrum image D', the size of the area of brownish pixels (also referred to as muddiness), and other characteristics.

[0036]

Second, a second classification unit 31c in the classification unit 31 classifies the eardrum image D' other than acute otitis media as one of two groups. Specifically, the eardrum image D' other than acute otitis media is classified as either normal eardrum or otitis media with effusion. This binary classification is performed on the basis of the magnitude of the proportion of brownish pixels in all the pixels and other characteristics. Such two-stage classification allows the eardrum image D' to be classified as one of the three groups with a classification accuracy higher than that of the conventional technology.

[0037]

Fig. 2 is a diagram illustrating an example of classification results of classification performed by the eardrum classification apparatus of the present embodiment. A classification result output by the eardrum classification apparatus 30 is transmitted to the terminal 20 via the network means NW and displayed on the screen 21. In addition, the probability [%] calculated by the eardrum classification apparatus 30 is also displayed for each classification result. Note that the probability [%] as used herein is a numerical value calculated by the classification unit 31.

[0038]

The terminal 20 can mutually communicate with the medical institution 40 via wireless communication or wired communication such as the network means NW. The user of the terminal 20 can ask and answer the personnel of the medical institution 40 about the classification result of the eardrum image D', reasonableness of the classification, future diagnosis and treatment, and the like.

[0039]

When the classification result is normal eardrum, a probability of X [%] of normal eardrum is also displayed together with the classification result. When the classification result is acute otitis media, a probability of Y [%] of acute otitis media is also displayed together with the classification result. When the classification result is otitis media with effusion, a probability of Z [%] of otitis media with effusion is also displayed together with the classification result. The probabilities of X, Y, and Z [%] are based on classification results of classification previously performed by the classification unit 31 and on comparison of the classification results with the labeling performed by a doctor, i.e., the classification accuracy.

[0040]

In addition, in Fig. 2, a warning may be issued in such a manner that the color of the peripheral edge of the

image B or of the background surrounding the image B is changed, the thickness or color of a character or characters is changed, a numerical value or a degree is represented by an indicator in which, for example, an indicator such as a scale having fine and rough marks is displayed, and/or a symbol or a marker is displayed together. For example, the image B classified as normal eardrum in Fig. 2(a) is displayed with a white border around the image B. In addition, when acute otitis media is suspected (i.e., the probability of  $Y [\%] < 50 [\%]$ ), the image B classified as acute otitis media in Fig. 2(b) is displayed with a border of a light color such as pink around the image B instead of displaying the probability of  $Y [\%]$ . Alternatively, when acute otitis media is highly probable (i.e., the probability of  $Y [\%] \geq 50 [\%]$ ), the image B is bordered with a dark color such as dark red. The same applies to the case of otitis media with effusion in Fig. 2(c). As a result, the viewer of the screen 21 can be reliably notified of imminence of the symptom of the eardrum D. Note that the probabilities of  $X$ ,  $Y$ , and  $Z [\%]$  may be displayed together with an indicator and/or a marker.

[0041]

Classification accuracies were investigated with respect to the eardrum classification apparatus 30 of the present embodiment and with respect to an eardrum

classification apparatus of a comparative example. Results of the classification accuracies of these eardrum classification apparatuses are shown in Table 1.

[0042]

[Table 1]

| No. | Verification details                                                                                     | Classification type | Data content          | First (current) classification accuracy | Second classification accuracy |
|-----|----------------------------------------------------------------------------------------------------------|---------------------|-----------------------|-----------------------------------------|--------------------------------|
| 1   | Three-class classification into "normal eardrum", "acute otitis media", and "otitis media with effusion" | Multiclass          | Around eardrum        | 68.26%                                  | 91.12%                         |
| 2   | Three-class classification into "normal eardrum", "acute otitis media", and "otitis media with effusion" | Multiclass          | Lower half of eardrum | 62.41%                                  | 65.74%                         |
| 3   | Binary classification into "acute otitis media" and "other than acute otitis media"                      | Binary              | Around eardrum        | 99.88%                                  | —                              |
| 4   | Binary classification into "normal eardrum" and "otitis media with effusion"                             | Binary              | Around eardrum        | 95.50%                                  | —                              |
| 5   | Binary classification into "normal eardrum" and "otitis media with effusion"                             | Binary              | Lower half of eardrum | 96.07%                                  | 100%                           |

[0043]

First, machine learning was performed using training data for a plurality of cases (a plurality of persons and a plurality of ears thereof). Next, the eardrum classification apparatus 30 was caused to classify a

plurality of eardrum images D' (current case). Machine learning was further performed using training data for a plurality of cases (a plurality of persons and a plurality of ears thereof). Next, the eardrum classification apparatus 30 was caused to classify a plurality of eardrum images D' (second time). In a case where the second classification was not performed and only the first (current) classification was performed, the second classification accuracies are not displayed.

[0044]

The classification accuracies of the classification results of the present embodiment are shown in No. 3 and No. 4 of Table 1. It has been found that the two-stage binary classification of the present embodiment provides a classification accuracy higher than that of the conventional technology, in which the classification accuracy is 99.98 [%] in the first stage and 99.50 [%] in the second stage. This is thought to be because an eardrum D suffering from acute otitis media is more reddish than an eardrum D in a condition other than acute otitis media, and an eardrum D suffering from otitis media with effusion has a more noticeable muddy area than an eardrum D in a condition other than otitis media with effusion.

[0045]

Classification accuracies of the comparative example

were also investigated. The classification step of the comparative example is shown in Fig. 5.

[0046]

The eardrum classification apparatus of the comparative example includes a one-stage multiclass classification (three-class classification) algorithm that classifies an input eardrum image, in one stage, as one of normal eardrum, acute otitis media, and otitis media with effusion. According to the one-stage three-class classification of the comparative example, the classification accuracies were, as shown in No. 1 of Table 1, 68.26 [%] in the first time (current case) and 91.12 [%] in the second time. As described above, the classification accuracies (No. 1) of the eardrum classification apparatus of the comparative example were worse than the classification accuracies (No. 3 and No. 4) of the eardrum classification apparatus of the present embodiment. This shows that a method in which a binary classification is performed in a plurality of stages as performed in the present embodiment increases the classification accuracy as compared with that of the conventional technology.

[0047]

A modification of the present embodiment will next be described. The eardrum classification apparatus 30 of the modification clips out an approximate lower half of the

eardrum D as illustrated in Fig. 3. Then, a semicircular image D" that has been clipped out is classified as described above. Otitis media with effusion presents a noticeable muddy area in the lower half of the eardrum D. Therefore, clipping out an approximate lower half of the eardrum D (for example, the lower half of a central area of the eardrum D) provides improvement of the classification accuracy of the classification result. In addition, labeling the lower half image of the eardrum D and causing the classification unit 31 to perform machine learning on the labeled data as training data enables the classification accuracy of the classification unit 31 itself to be improved.

[0048]

The classification accuracy of the modification of the present embodiment is, as shown in No. 5, 96.07 [%] in the first time (current case), which is higher than the result in the case of the eardrum image D' (No. 4). In addition, the classification accuracy has increased to 100 [%] in the second time.

[0049]

The classification accuracy of the modification of the comparative example is, as shown in No. 2, 62.41 [%] in the first time (current case), which is rather less than the result in the case of the eardrum image D' (No. 1). In

addition, the classification accuracy is 65.74 [%] in the second time. The classification accuracy has indeed been improved, but has not exceeded the classification accuracy of the present embodiment (No. 5).

[0050]

Referring to Fig. 1, the eardrum classification apparatus 30 of the present embodiment includes a communication unit 33 to which an eardrum image D' including an image of an eardrum D is input, a first classification unit 31b (Fig. 3), which extracts a characteristic from the eardrum image D' by an algorithm and classifies a condition of the eardrum D as either acute otitis media or other than acute otitis media, and a second classification unit 31c, which extracts a characteristic, by an algorithm, from the eardrum image D' classified as other than acute otitis media by the first classification unit 31b and classifies the condition of the eardrum D as either normal eardrum or otitis media with effusion. The eardrum classification apparatus 30 outputs a result indicating acute otitis media, normal eardrum, or otitis media with effusion from the communication unit 33 on the basis of classification results of the first classification unit 31b and of the second classification unit 31c. The eardrum classification apparatus 30 provides a classification accuracy of classification higher than that

of the conventional technology, due to the two-stage binary classification illustrated in Fig. 4.

[0051]

An operation and effect of the eardrum classification apparatus 30 will next be described for each of the following phases.

[0052]

In the first phase, the eardrum classification apparatus 30 classifies the eardrum D by the unique AI algorithm described above. This eliminates the need for going to the medical institution 40 himself or herself to get a medical examination of an ear-nose-throat doctor, and enables the symptom of the eardrum D to be determined. For example, in a general household not skilled in medical technology, a family member captures an image of the eardrum D of a child and uses the image to determine a disease of the eardrum D.

[0053]

In the second phase, the medical institution 40 includes the earscope 10 and the terminal 20 as instruments for use in medical examination, and is mutually communicably connected with the eardrum classification apparatus 30. As a result, the eardrum classification apparatus 30 is used by an ear-nose-throat doctor of the medical institution 40 as a diagnosis support tool for

diagnosing the eardrum image D' captured by the earscope 10. In addition, the image B is used by the ear-nose-throat doctor. Alternatively, for example, this enables, in a general household not skilled in medical technology, a family member to capture an image of the eardrum D of a child to get support almost equivalent to a medical examination from an ear-nose-throat doctor of the medical institution 40, such as an advice of consulting a doctor, and the symptom to be known at a suitable time.

[0054]

In the third phase, the eardrum classification apparatus 30 in the first phase and in the second phase described above is used as a diagnosis support tool or as a medical device. The eardrum classification apparatus 30 becomes capable of providing a classification at a same level as an ear-nose-throat doctor by repeating AI machine learning. For example, a medicine prescription program is incorporated into an AI algorithm to allow prescription of a prescription medicine on the basis of the diagnosis support tool of the present embodiment. For example, the eardrum classification apparatus 30 is mutually communicably connected with (a computer of) a pharmacy (not illustrated).

[0055]

Furthermore, referring to Figs. 3(a) and 3(b), the

eardrum classification apparatus 30 of the present embodiment includes a clipping unit that clips out an image portion corresponding to the eardrum D from the image B input to the communication unit 33 from the outside world and provides the image portion to the first classification unit 31b. When the light emitting unit 14 (Fig. 1) illuminates the ear canal H, the glitter F and/or the foreign matter G are likely to appear in a portion near the exit of the ear canal H. According to the present embodiment, the image in the portion near the exit of the ear canal H is removed, thereby causing the glitter F and/or the foreign matter G to be also removed from the image. Machine learning can therefore be effectively performed.

[0056]

In addition, referring to Figs. 3(a) and 3(c), the eardrum classification apparatus 30 of the modification of the present embodiment includes a clipping unit that clips out the lower half of the image of the eardrum D from the image B input to the communication unit 33 and provides the lower half of the image to the first classification unit 31b. This enables correct classification of a case in which the lower half has a prominent lesion, such as otitis media with effusion, and enables machine learning to be effectively performed.

[0057]

In addition, the eardrum classification apparatus 30 of the present embodiment stores the image B to be classified in the memory unit 32, and the image B is labeled for a correct classification by the medical institution 40 later. At least one of the first classification unit 31b and the second classification unit 31c reads labeled training data and performs supervised machine learning. As a result, the eardrum classification apparatus 30 repeats machine learning, and the classification accuracy is further improved.

[0058]

In addition, the eardrum classification system of the present embodiment includes the eardrum classification apparatus 30, the earscope 10, which captures an image of the eardrum D, and the terminal 20, which receives the image B of the eardrum D from the earscope 10 and outputs the image B to the communication unit 33 of the eardrum classification apparatus 30. Thus, the symptom of the eardrum D can be known by operating the earscope 10 and the terminal 20 in a general household not skilled in medical technology.

[0059]

In addition, the terminal 20 of the present embodiment includes the screen 21, which displays an image

captured by the earscope 10, displays the frame C, which provides guidance to allow the eardrum D to be displayed in a central portion of the screen on the screen 21, and inputs, to the communication unit 33, the image B including the eardrum D appearing in the frame C in the central portion. As a result, even a user who is not skilled in medical technology can appropriately capture the eardrum image D'.

[0060]

In addition, the imaging unit 15 of the present embodiment is a digital camera provided in the earhole cleaning structural unit 12. As a result, the symptom of the eardrum can be known using the digital camera provided on the earhole cleaning structural unit that is commodity for daily use.

[0061]

Moreover, the communication unit 33 and the terminal 20 of the present embodiment can mutually communicate with the medical institution 40, thereby enabling the user to get support almost equivalent to a medical examination and to know the symptom at a suitable time even when a medical institution cannot be consulted.

[0062]

A supplementary description will next be given about the screen 21 provided on the terminal 20. The terminal 20

communicates with the earscope 10 and displays the image B captured by the earscope 10 on the screen 21 in real time. [0063]

Fig. 6 is a view illustrating an example of the terminal screen of the embodiment, and illustrates the screen 21 provided as guide means. The image B of the ear canal H captured by the user inserting the earscope 10 into the ear of the subject is output in real time from the terminal 20 to the eardrum classification apparatus 30 via the network NW (Fig. 1). The classification unit 31 of the eardrum classification apparatus 30 includes a program (imaging guide program) as guide means that determines in real time whether the image B includes the entire eardrum D and is usable in eardrum classification. Specifically, the imaging guide program determines whether the image B includes the eardrum image D' illustrated in Fig. 3 described above. At the start of insertion of the earscope 10 into the ear of the subject, the imaging guide program determines that the image B does not include the eardrum image D' and that the image B is not usable in eardrum classification, and thus causes a circular ring 22 having a blue color to be displayed on the screen 21. The circular ring 22 has a diameter half of the diameter of the frame C of the image B. In addition, an outer area J of the frame C has, for example, a solid color such as light gray in the

screen 21.

[0064]

When the imaging guide program to which the image B is input determines that the eardrum D is displayed in the area surrounded by the circular ring 22 having a blue color, the imaging guide program determines that the image B is usable in eardrum classification, and changes the color of the circular ring 22 from blue to green. Then, the imaging guide program displays a determination operation button 23 in the outer area J. As a result, an appropriately captured eardrum image is bordered by the circular ring 22.

[0065]

According to the imaging guide program of the present embodiment, a user unfamiliar with capturing an image of the eardrum D can be assisted in capturing an image of the eardrum D. Note that the size and the circular shape of the circular ring 22 described above and the color thereof are merely by way of example, and it is sufficient that whether the image B is usable in eardrum classification is indicated by a visual change.

[0066]

When the user touches the determination operation button 23 with a finger, the terminal 20 outputs a classification command to (the communication unit 33 of) the eardrum classification apparatus 30. The eardrum

classification apparatus 30 performs two-stage binary classification on the image data input from the terminal 20 and displays the classification result on the screen 21.

[0067]

Fig. 7 is a diagram illustrating an example of probabilities [%] given as classification results in the two-stage binary classification performed by the classification unit 31.

[0068]

Fig. 8 is a diagram illustrating an example of a classification result displayed on the screen 21.

[0069]

In the above-described binary classification performed by the first classification unit 31b illustrated in Fig. 4, more specifically, by the algorithm, probabilities (numerical values) [%] of the two classifications are calculated as illustrated in Fig. 7. A similar description applies to the second classification unit 31c.

[0070]

When the classification results of the first classification unit 31b are, by way of example, 10 [%] for acute otitis media and 90 [%] for a condition other than acute otitis media, the process further proceeds to the determination of the second classification unit 31c, and a

result is output that indicates that the classification results are 70 [%] for normal eardrum and 30 [%] for otitis media with effusion. As a result, as shown in Table 2, the proportion of 90 [%] corresponding to the condition other than acute otitis media in the classification results of the first classification unit 31b is divided with respect to the classification results of the second classification unit 31c to obtain, as the final probabilities of the classification results, a probability of normal eardrum of  $X = 63$  [%], a probability of acute otitis media of  $Y = 10$  [%], and a probability of otitis media with effusion of  $Z = 27$  [%]. The screen 21, which serves as a classification result display unit, displays the magnitudes of these probabilities with indication using indicators such that the probabilities of  $X$ ,  $Y$ , and  $Z$  [%] for the respective three classifications sum to 100 [%].

[0071]

[Table 2]

| Classification | Binary classification | Formula                      | Percentage | Remarks                                 |
|----------------|-----------------------|------------------------------|------------|-----------------------------------------|
| Acute          | 10%                   | Proportion shown on the left | 10%        | Proportion in binary classification (1) |
| Normal         | 70%                   | $90 \times 0.7$              | 63%        | Proportion in binary classification (2) |
| Effusion       | 30%                   | $90 \times 0.3$              | 27%        | Proportion in binary classification (2) |
|                |                       | Total                        | 100%       |                                         |

[0072]

Furthermore, as illustrated in Fig. 8, the screen 21 serving as the classification result display unit displays the probabilities [%] for the respective classifications with indication using indicators having three different colors in the frame C having a circular ring shape surrounding the image B.

[0073]

In the eardrum image D' of normal eardrum illustrated as an example in Fig. 8, a blue indicator Cx (63 [%]) representing normal eardrum is displayed in a largest proportion, an orange indicator Cz (27 [%]) representing otitis media with effusion is displayed in a small proportion, and a red indicator Cy (10 [%]) representing acute otitis media is displayed to a very small extent, in the circular ring of the frame C for displaying the classification results of the eardrum image

D'. The indicators Cx, Cy, and Cz are reordered as appropriate in order of the magnitudes of the probabilities.

[0074]

According to the present embodiment, the classification results are displayed using indicators in the frame C of the screen 21 and the image B is bordered by the indicators Cx, Cy, and Cz, thereby enabling the user to be brought to attention.

[0075]

Note that the three different colors described above are examples, and each color can be changed and selected as appropriate. Optionally, a date and time and an indication of left or right ear relating to the image used for classification may be displayed.

[0076]

An embodiment of the present invention has been described above with reference to the drawings, but the present invention is not limited to the illustrated embodiment. Various modifications and variations can be made to the illustrated embodiment within the same scope as the present invention or within an equivalent scope.

[0077]

As a modification not illustrated, the eardrum classification apparatus 30 illustrated in Fig. 1 may be a program installed in the terminal 20 instead of the

configuration illustrated in Fig. 1 in which the eardrum classification apparatus 30 and the terminal 20 are communicably connected to each other via the network means NW. The program is, for example, application software stored in the terminal 20, and performs the above-described algorithm processing in the terminal 20.

[0078]

As a modification not illustrated, the screen 21 of the terminal 20 can present various additional options and/or change an option to another as a classification result display unit. Various displays using the color coding and the shape described above may be displays using voice and/or light.

Industrial Applicability

[0079]

The present invention is advantageously utilized in the medical industry.

#### Reference Signs List

[0080]

- 10 Earscope
- 11 Main body
- 12 Earhole cleaning structural unit
- 14 Light emitting unit
- 15 Imaging unit

|            |                                         |
|------------|-----------------------------------------|
| 20         | Terminal                                |
| 21         | Screen                                  |
| 22         | Circular ring (guide means)             |
| 30         | Eardrum classification apparatus        |
| 31         | (First and second) classification units |
| 32         | Memory unit                             |
| 33         | Communication unit                      |
| 40         | Medical institution                     |
| B          | Image                                   |
| C          | Frame (guide means)                     |
| Cx, Cy, Cz | Indicator of classification result      |
| D          | Eardrum                                 |
| D'         | Eardrum image                           |
| H          | Ear canal                               |

## CLAIMS

[Claim 1]

An eardrum classification apparatus comprising:

a communication unit to which image data including an image of an eardrum is input;

a first classification unit that extracts a characteristic from the image data by an algorithm and performs classification of a condition of the eardrum as either acute otitis media or other than acute otitis media; and

a second classification unit that extracts a characteristics, by an algorithm, from the image data classified as other than acute otitis media and performs classification of the condition of the eardrum as either normal eardrum or otitis media with effusion, wherein

the eardrum classification apparatus outputs a result indicating acute otitis media, normal eardrum, or otitis media with effusion from the communication unit on a basis of classification results of the first and second classification units.

[Claim 2]

The eardrum classification apparatus according to claim 1, comprising: a clipping unit that clips out the eardrum from the image data input to the communication unit

and provides image data of the eardrum to the first classification unit.

[Claim 3]

The eardrum classification apparatus according to claim 1, comprising: a clipping unit that clips out a predetermined portion of the eardrum from the image data input to the communication unit and provides the predetermined portion to the first classification unit.

[Claim 4]

The eardrum classification apparatus according to claim 1, wherein at least one of the first classification unit or the second classification unit reads labeled training data and performs supervised machine learning.

[Claim 5]

An eardrum classification system comprising:  
the eardrum classification apparatus according to claim 1;  
an earscope that captures an image of an eardrum;  
and  
a terminal that receives image data of the eardrum from the earscope and outputs the image data to the eardrum classification apparatus.

[Claim 6]

The eardrum classification system according to claim 5, wherein the terminal includes a screen that displays an

image captured by the earscope, and guide means that provides guidance to allow the eardrum to be displayed in a central portion of the screen on the screen, and the terminal outputs image data including the eardrum appearing in the central portion, to the communication unit.

[Claim 7]

The eardrum classification system according to claim 5, wherein the earscope is a digital camera provided in an earhole cleaning structural unit.

[Claim 8]

The eardrum classification system according to claim 5, comprising: a medical institution terminal mutually communicable with the eardrum classification apparatus and with the terminal.

[Claim 9]

The eardrum classification system according to claim 5, wherein the earscope or the terminal includes a clipping unit that clips out the eardrum from the image including the eardrum to generate the image data.

[Claim 10]

The eardrum classification system according to claim 6, wherein the guide means indicates, on the screen, whether the image displayed on the screen is suitable for the classifications.

[Claim 11]

The eardrum classification system according to claim 5, wherein the terminal displays probabilities related to classification results of the first and second classification units, on the screen.

[Claim 12]

An eardrum classification program that causes a computer to classify image data including an image of an eardrum, wherein the eardrum classification program causes the computer to perform:

a first classification step of extracting a characteristic from the image data by an algorithm and classifying a condition of the eardrum as either acute otitis media or other than acute otitis media;

a second classification step of extracting a characteristic, by an algorithm, from the image data classified as other than acute otitis media and classifying the condition of the eardrum as either normal eardrum or otitis media with effusion; and

a step of outputting a result indicating acute otitis media, normal eardrum, or otitis media with effusion on a basis of classification results of the first and second classification steps.