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(54) **METHOD AND COMPUTER PROGRAM FOR
PERFORMING PROCESSING RELATED TO
CLASS DISCRIMINANT MODEL
INCLUDING GAP LAYER**

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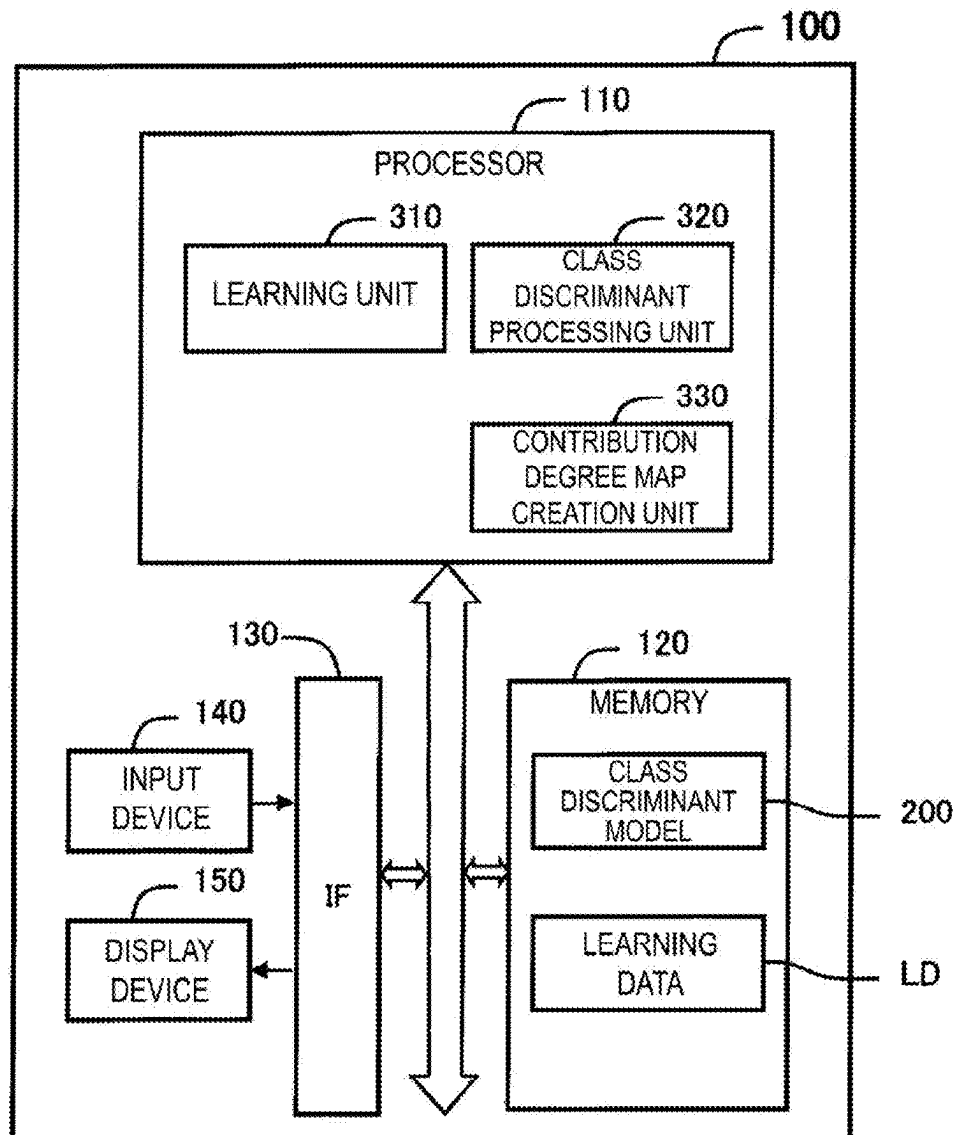
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(57) **ABSTRACT**

A method of the present disclosure includes (a) a step for inputting input data to a class discriminant model to obtain an operation result of the class discriminant model, (b) a step for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before a GAP layer, and a GAP layer vector being output of the GAP layer, and (c) a step for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.



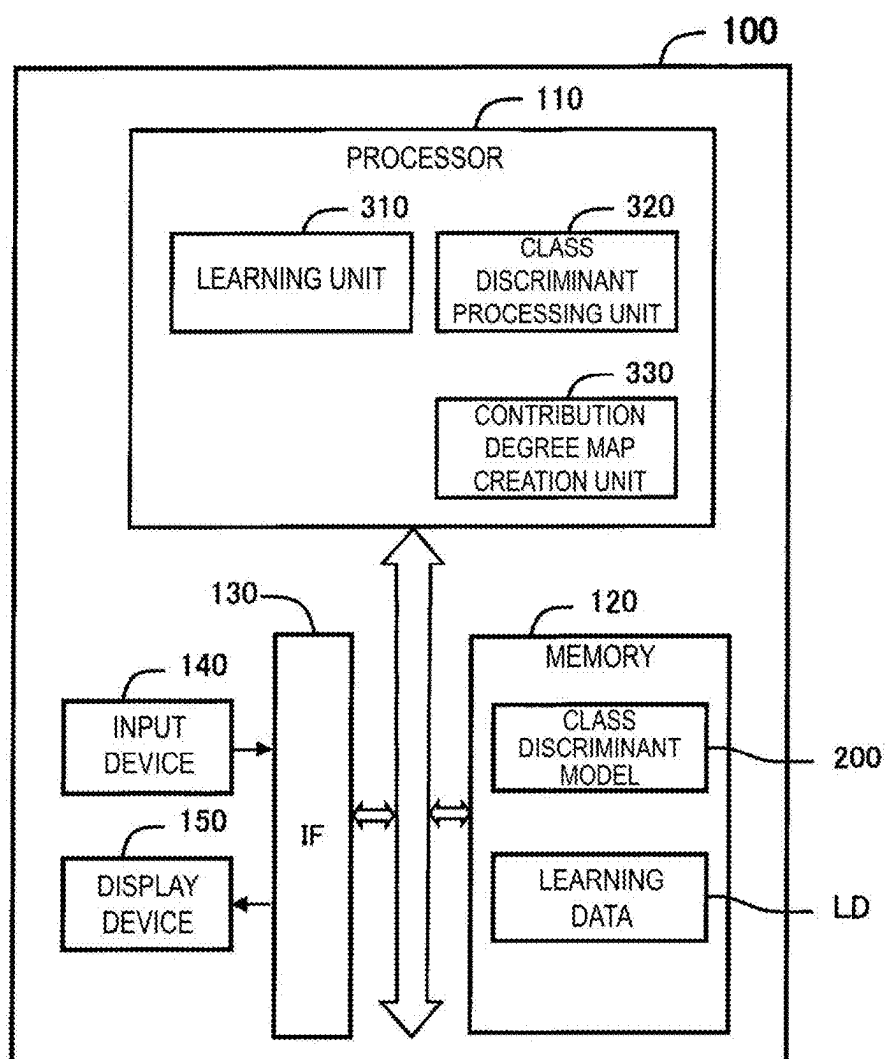


FIG. 1

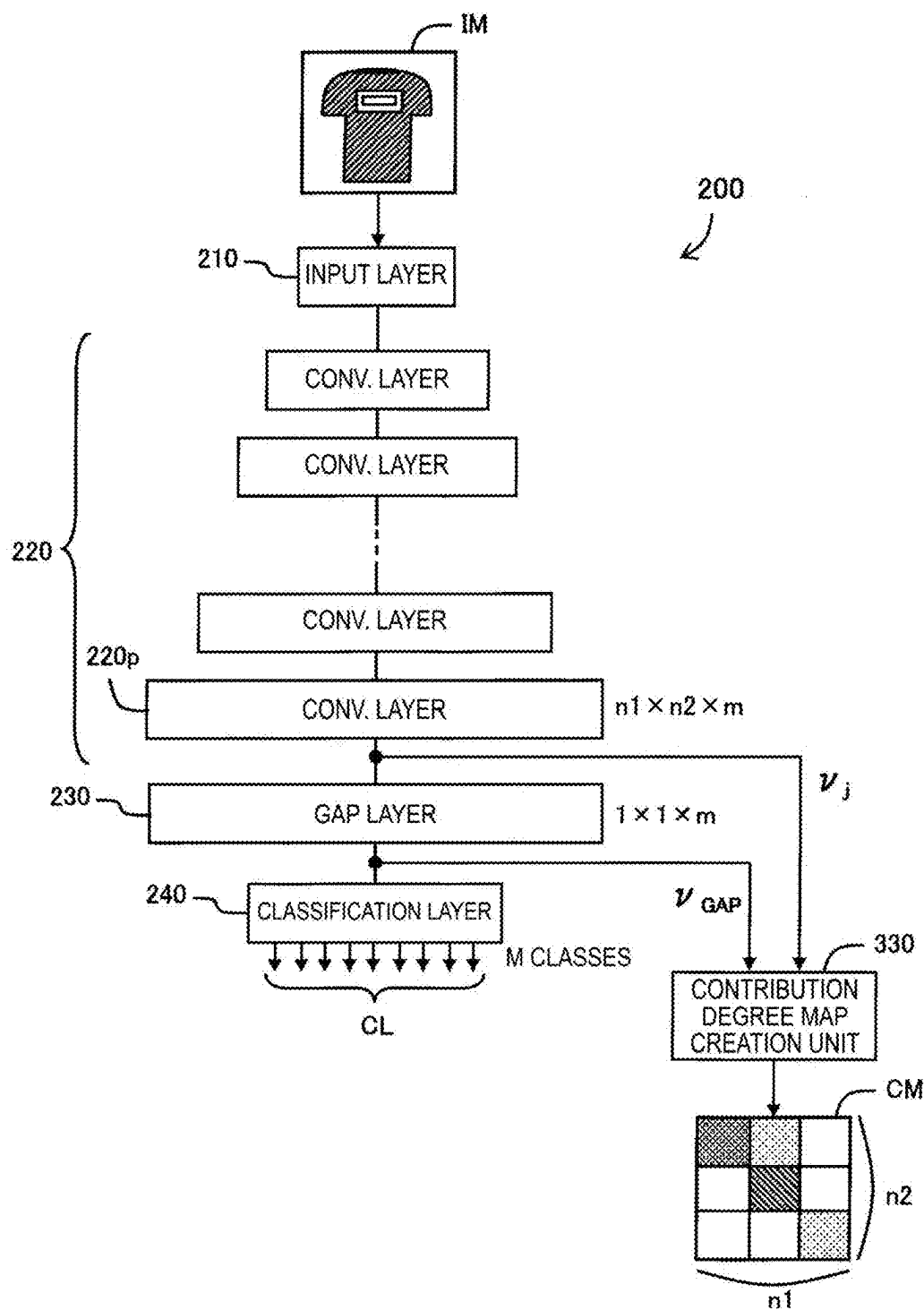


FIG. 2

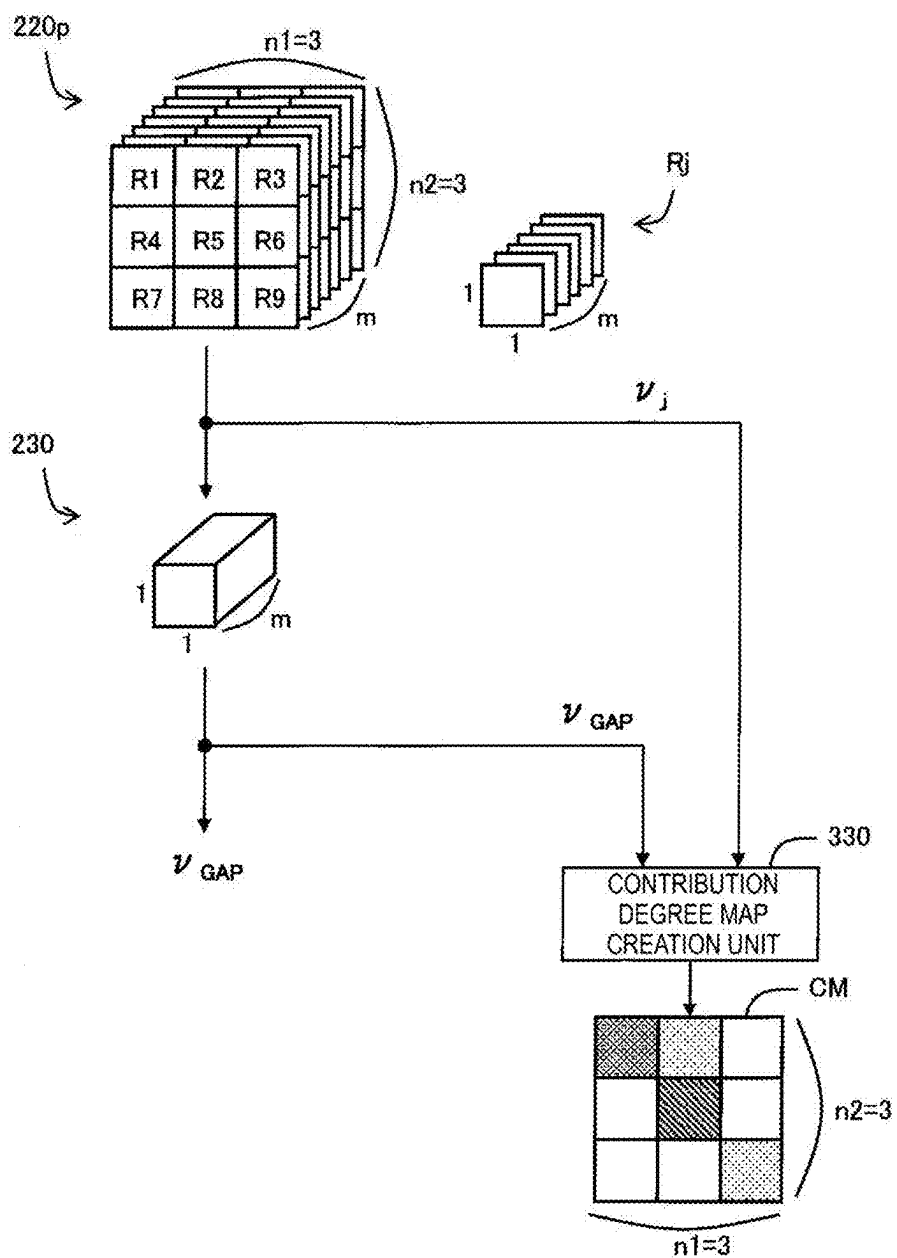


FIG. 3

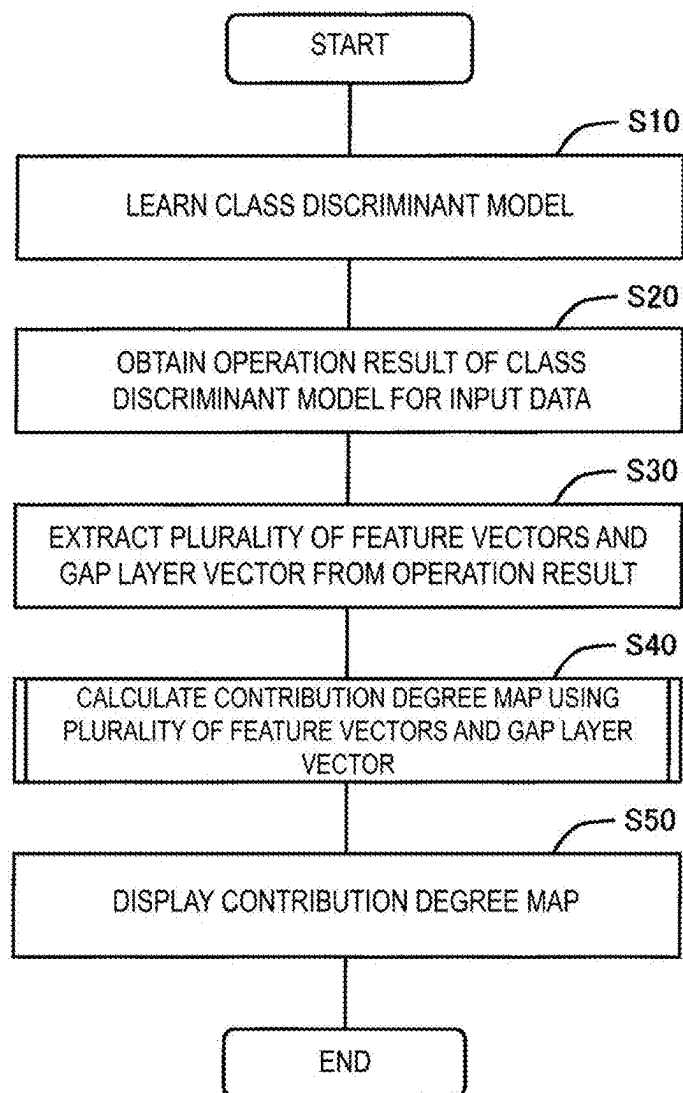


FIG. 4

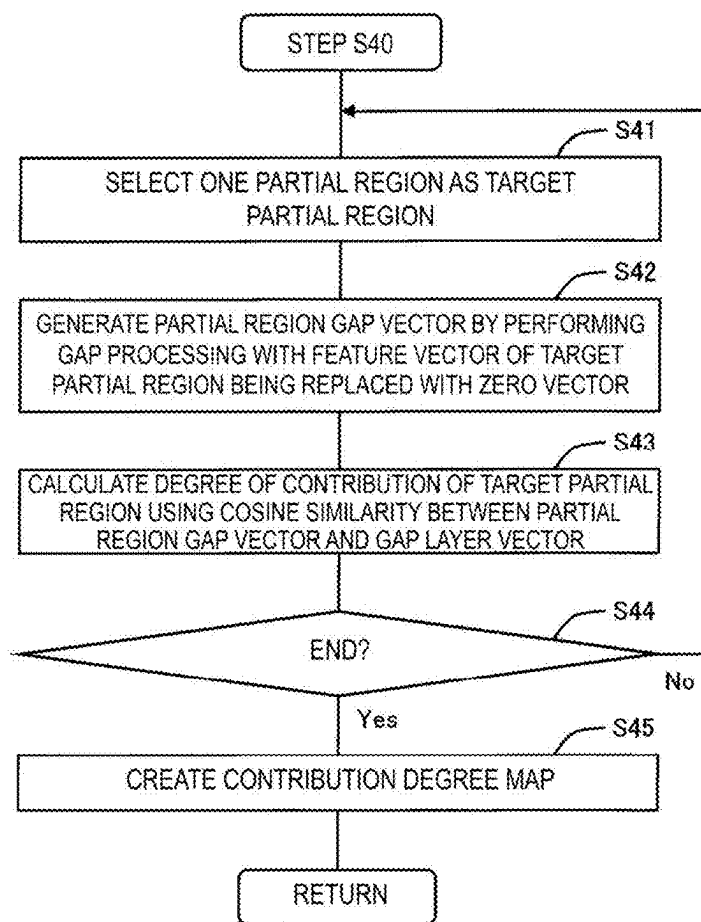


FIG. 5

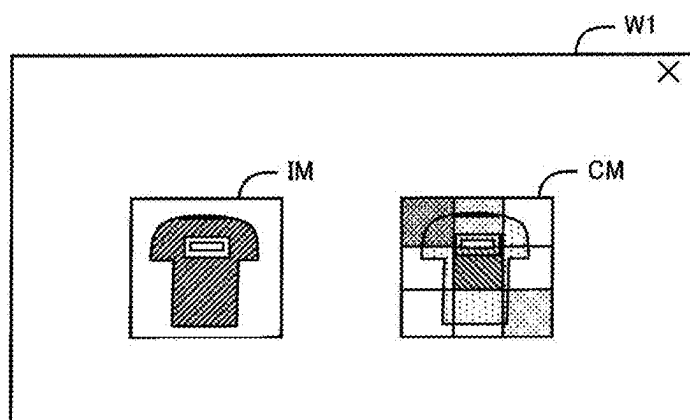


FIG. 6

METHOD AND COMPUTER PROGRAM FOR PERFORMING PROCESSING RELATED TO CLASS DISCRIMINANT MODEL INCLUDING GAP LAYER

[0001] The present application is based on, and claims priority from JP Application Serial Number 2024-019114, filed Feb. 13, 2024, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a method and a computer program for performing processing related to a class discriminant model including a GAP layer.

2. Related Art

[0003] W. Yang, et al., “Towards Rich Feature Discovery With Class Activation Maps Augmentation for Person Re-Identification”, in 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) discloses a method for calculating a degree of contribution of a feature vector in a preceding layer of a global average pooling (GAP) layer of a deep learning model to the GAP layer. In this existing technique, a tensor extracted from the preceding layer of the GAP layer is divided into a plurality of feature vectors corresponding to a plurality of portions constituting the layer. Then, a product of a cosine similarity between each feature vector and the GAP layer vector and a norm of each feature vector is calculated as a degree of contribution of a corresponding portion. This makes it possible to quantify a degree of contribution of a feature vector of each portion of the preceding layer to magnitude of the GAP layer vector.

[0004] In the existing technique described above, the degree of contribution of the feature vector of each portion of the preceding layer to the magnitude of the GAP layer vector is obtained. However, in a class discriminant problem, since a direction of the GAP layer vector is reflected in a class discriminant result, it is desired to know not the degree of contribution to the magnitude of the GAP layer vector but a degree of contribution to the direction of the GAP layer vector.

SUMMARY

[0005] According to a first aspect of the present disclosure, there is provided a method for performing processing related to a class discriminant model including a GAP layer. This method includes (a) a step for inputting input data to the class discriminant model to obtain an operation result of the class discriminant model, (b) a step for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer, and (c) a step for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

[0006] According to a second aspect of the present disclosure, there is provided a computer program causing a processor to perform processing related to a class discriminant model including a GAP layer. This computer program causes the processor to perform (a) processing for inputting input data to the class discriminant model to obtain an

operation result of the class discriminant model, (b) processing for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer, and (c) processing for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a block diagram of an information processing device in an embodiment.

[0008] FIG. 2 is an explanatory diagram illustrating a relationship between a class discriminant model and a contribution degree map creation unit.

[0009] FIG. 3 is an explanatory diagram illustrating a configuration of an immediately preceding layer and a GAP layer.

[0010] FIG. 4 is a flowchart illustrating a processing procedure of the embodiment.

[0011] FIG. 5 is a flowchart illustrating a detailed procedure of step S40.

[0012] FIG. 6 is an explanatory diagram illustrating a display example of a contribution degree map.

DESCRIPTION OF EMBODIMENTS

[0013] FIG. 1 is a block diagram illustrating functions of an information processing device 100 in an embodiment. The information processing device 100 includes a processor 110, a memory 120, an interface circuit 130, and an input device 140 and a display device 150 coupled to the interface circuit 130. The processor 110 not only has a function of performing processing described in detail below, but also has a function of displaying data obtained by the processing and data generated in a process of the processing on the display device 150. The information processing device 100 can be achieved by a computer such as a personal computer.

[0014] The processor 110 achieves functions of a learning unit 310 that performs learning of a class discriminant model 200, a class discriminant processing unit 320 that performs class discriminant processing of input data using the class discriminant model 200, and a contribution degree map creation unit 330 that creates a contribution degree map to be described later. The functions of these units are achieved by the processor 110 executing a computer program stored in the memory 120. However, the functions of these units may be achieved by a hardware circuit. The processor in this specification is a term including such a hardware circuit. In addition, one or more processors that perform various kinds of processing may be processors included in one or more remote computers connected via a network.

[0015] The memory 120 stores the class discriminant model 200 and learning data LD thereof. The class discriminant model 200 is used for operation by the class discriminant processing unit 320. The learning data LD is labeled data used for learning of the class discriminant model 200.

[0016] FIG. 2 is an explanatory diagram illustrating a relationship between the class discriminant model 200 and the contribution degree map creation unit 330. The class discriminant model 200 includes an input layer 210 to which input data IM is input, a plurality of convolution layers 220, a global average pooling (GAP) layer 230, and a classifi-

cation layer **240**. The input data IM is typically image data. As the class discriminant model **200**, for example, ResNet, WideResNet or the like can be used. However, data other than an image may be used as the input data IM. For example, an audio signal, one-dimensional data such as a spectroscopic spectrum, surface spectroscopic data, or the like may be used as the input data IM. The surface spectroscopic data is an image having more than three channels.

[0017] Among the plurality of convolution layers **220**, a layer disposed immediately before the GAP layer **230** is referred to as an “immediately preceding layer **220p**”. When an output size of each layer is expressed as “width×height×channel depth”, the immediately preceding layer **220p** has a size of $n1 \times n2 \times m$, and the GAP layer **230** has a size of $1 \times 1 \times m$. Here, one of $n1$ and $n2$ is an integer equal to or greater than 1, and another is an integer equal to or greater than 2, and m is an integer equal to or greater than 2. For example, when the input data IM is one-dimensional data, one of $n1$ and $n2$ may be equal to 1. Note that the immediately preceding layer **220p** need not be a convolution layer, and may be, for example, a residual layer.

[0018] FIG. 3 is an explanatory diagram illustrating a configuration of the immediately preceding layer **220p** and the GAP layer **230**. The immediately preceding layer **220p** includes $n1 \times n2$ partial regions R_j . Here, j is an ordinal number from 1 to $n1 \times n2$. The individual partial regions R_j each have a size of $1 \times 1 \times m$. In the example of FIG. 3, since $n1 = n2 = 3$, the immediately preceding layer **220p** includes nine partial regions $R1$ to $R9$. Output of each partial region R_j is referred to as a “feature vector v_j ”. The feature vector v_j is an m -dimensional vector. In other words, a tensor of $n1 \times n2 \times m$, which is output of the immediately preceding layer **220**, includes $n1 \times n2$ feature vectors v_j .

[0019] The GAP layer **230** performs global average pooling processing on the output of the immediately preceding layer **220p** to obtain a GAP layer vector v_{GAP} which is output of the GAP layer **230**. The global average pooling processing is processing for obtaining an average of $n1 \times n2$ outputs for each of the m channels of the immediately preceding layer **220**. The GAP layer vector v_{GAP} is an average vector of the $n1 \times n2$ feature vectors v_j , and is an m -dimensional vector.

[0020] When the number of discriminable classes is M , the classification layer **240** outputs a class discriminant result CL indicating which of the M classes a class is. The number of classes M is equal to or greater than 2, and may be equal to or greater than 3. The classification layer **240** includes a fully coupled layer, and converts elements $\{v1, v2, \dots, vm\}$ of the GAP layer vector v_{GAP} into M values by linear conversion using weight of the fully coupled layer to generate the class discriminant result CL. Therefore, there is a tendency that a ratio of magnitude of each of the elements $\{v1, v2, \dots, vm\}$ of the GAP layer vector v_{GAP} has a larger influence on the class discriminant result CL than magnitude of a norm of the GAP layer vector v_{GAP} . This tendency is the same when the class discriminant result CL is generated by applying a softmax function to a result of the linear conversion using the weight of the fully coupled layer. The ratio of the magnitude of each of the elements $\{v1, v2, \dots, vm\}$ of the GAP layer vector v_{GAP} corresponds to a direction of the GAP layer vector v_{GAP} . In this way, the direction of the GAP layer vector v_{GAP} has a larger influence on the class discriminant result CL than the magnitude of the norm of the GAP layer vector v_{GAP} , thus in the embodiment,

a degree of contribution of each partial region R_j of the immediately preceding layer **220p** to the direction of the GAP layer vector v_{GAP} is obtained.

[0021] The contribution degree map creation unit **330** creates a contribution degree map CM representing a degree of contribution of each of the plurality of partial regions R_j with respect to the direction of the GAP layer vector v_{GAP} by using a plurality of feature vectors v_j which are output of the plurality of partial regions R_j and the GAP layer vector v_{GAP} which is output of the GAP layer **230**. The contribution degree map CM has a size of $n1 \times n2$.

[0022] As described above, the output of the immediately preceding layer **220p** includes the $n1 \times n2$ feature vectors v_j , and the GAP layer vector v_{GAP} is an average vector of the $n1 \times n2$ feature vectors v_j . Therefore, when the degree of contribution of the feature vector v_j of the individual partial region R_j to the direction of the GAP layer vector v_{GAP} is known, the degree of contribution can be read as a degree of contribution of a specific portion of the input data IM corresponding to the partial region R_j . The degree of contribution of each partial region R_j is calculated as follows.

[0023] The GAP layer vector v_{GAP} is given by the following equation.

[Math 1]

[Math. 1]

$$v_{GAP} = \frac{1}{N} \sum_{V} v_j \quad (q1)$$

[0024] Here, v_j is the feature vector of the partial region R_j , V is a set of the feature vectors v_j corresponding to all the partial regions R_j of the immediately preceding layer **220p**, N is the number of partial regions R_j , and $N = n1 \times n2$.

[0025] In the embodiment, in order to calculate an extent of contribution of the individual partial region R_j to the direction of the GAP layer vector v_{GAP} , a partial region GAP vector v_{SR-i} with respect to an i -th partial region R_i is calculated according to the following equation.

[Math 2]

[Math. 2]

$$v_{SR-i} = \frac{1}{N} \sum_{V \setminus v_i} v_j \quad (q2)$$

[0026] Here, a symbol “ $V \setminus v_i$ ” attached to a summation symbol Σ means a set obtained by excluding an i -th feature vector v_i from the set V of all the feature vectors of the immediately preceding layer **220p**.

[0027] In other words, the partial region GAP vector v_{SR-i} is calculated by performing the global average pooling processing on output of the immediately preceding layer **220p** in a state where the i -th feature vector v_i is replaced with a zero vector.

[0028] A degree of contribution C_i of the i -th partial region R_i to the direction of the GAP layer vector v_{GAP} can be calculated, for example, as follows.

[Math 3]

[Math. 3]

$$c_i = 1 - D \quad (q3)$$

$$D = \frac{v_{GAP} \cdot v_{SRi}}{\|v_{GAP}\| \|v_{SRi}\|} \quad (q4)$$

[0029] Here, D is a cosine similarity between the GAP layer vector v_{GAP} and the partial region GAP vector v_{SR-i} . In other words, the degree of contribution C_i of the i-th partial region R_i can be calculated by subtracting the cosine similarity degree D between the GAP layer vector v_{GAP} and the partial region GAP vector v_{SR-i} from 1.

[0030] The cosine similarity D between the GAP layer vector v_{GAP} and the partial region GAP vector v_{SR-i} serves as an index indicating how much the partial region GAP vector v_{SR-i} obtained when the feature vector v_i of the i-th partial region R_i is replaced with the zero vector has changed from the GAP layer Vector v_{GAP} . When the i-th partial region R_i has no influence on the class discriminant result CL, the partial region GAP vector v_{SR-i} is equal to the GAP layer vector v_{GAP} , and the cosine similarity D is 1, so that the degree of contribution C_i is 0. On the other hand, when the information of the i-th partial region R_i is all of the GAP layer vector v_{GAP} , the partial region GAP vector v_{SR-i} becomes the zero vector and the cosine similarity D becomes 0, so that the degree of contribution C_i becomes 1. Therefore, the degree of contribution C_i serves as an index indicating an extent of contribution of the i-th partial region R_i to the direction of the GAP layer vector v_{GAP} .

[0031] Note that the degree of contribution C_i may be calculated by an equation other than the above equation (q3), and may be calculated by any one of the following equations, for example.

[Math 4]

[Math. 4]

$$c_i = a(1 - D) \quad (q5)$$

$$c_i = -aD \quad (q6)$$

$$c_i = a \left(\frac{2}{1+D} - 1 \right) \quad (q7)$$

[0032] Here, a is a positive coefficient, and D is the cosine similarity between the GAP layer vector v_{GAP} and the partial region GAP vector v_{SR-i} . The above equation (q3) corresponds to an equation when $a=1$ in the above equation (q5).

[0033] Generally, the degree of contribution C_i may have a negative correlation with the cosine similarity D between the GAP layer vector v_{GAP} and the partial region GAP vector v_{SR-i} . Further, the degree of contribution C_i may be represented by a function uniquely determined according to the cosine similarity degree D. Any of the degrees of contribution C_i given by the above equations (q3) to (q7) has a negative correlation with the cosine similarity degree D and is represented by a function uniquely determined according to the cosine similarity degree D. However, it is sufficient that the degree of contribution C_i has a negative correlation with the cosine similarity degree D, and the degree of

contribution C_i may be calculated using an equation other than the above equations (q3) to (q7). In this way, the degree of contribution C_i indicating the extent of contribution of the i-th partial region R_i to the direction of the GAP layer vector v_{GAP} can be obtained.

[0034] FIG. 4 is a flowchart illustrating a processing procedure of the embodiment. In step S10, the learning unit 310 performs machine learning of the class discriminant model 200 using the learning data LD. In step S20, the class discriminant processing unit 320 inputs the input data IM to the class discriminant model 200 to obtain an operation result of the class discriminant model 200.

[0035] In step S30, the contribution degree map creation unit 330 extracts the feature vectors v_j of the plurality of partial regions R_j constituting the immediately preceding layer 220p and the gap layer vector v_{GAP} which is the output of the gap layer 230 from the operation result of the class discriminant model 200. At this time, the correspondence relationship between the feature vector v_j and the partial region R_j is also stored. In step S40, the contribution degree map creation unit 330 calculates a contribution degree map using the plurality of feature vectors v_j and the GAP layer vector v_{GAP} .

[0036] FIG. 5 is a flowchart illustrating a detailed procedure of step S40. In step S41, the contribution degree map creation unit 330 selects one partial region R_i as a target partial region. In step S42, the contribution degree map creation unit 330 generates the partial region GAP vector v_{SR-i} by performing the global average pooling processing on output of the immediately preceding layer 220p in a state where the feature vector v_i of the target partial region R_i is replaced with the zero vector. This processing is performed in accordance with the above equation (q2). In step S43, the contribution degree map creation unit 330 calculates the degree of contribution C_i of the target partial region R_i using the cosine similarity D between the partial region GAP vector v_{SR-i} and the GAP layer vector v_{GAP} . This processing is performed in accordance with, for example, the above equation (q3). In step S44, the contribution degree map creation unit 330 determines whether the processing in steps S41 to S43 is completed for all the partial regions R_j or not. When the processing is not completed for all the partial regions R_j , the processing returns to step S41, a new partial region R_j is selected as the target partial region R_i , and the processing in steps S42 to S43 is performed again. On the other hand, when the processing is completed for all the partial regions R_j , the processing proceeds to step S45, and the contribution degree map creation unit 330 creates the contribution degree map CM illustrated in FIG. 3.

[0037] When the processing of step S40 is completed in this way, the processing proceeds to step S50 in FIG. 4, and the contribution degree map creation unit 330 displays the contribution degree map CM on the display device 150.

[0038] FIG. 6 is an explanatory diagram illustrating a display example of the contribution degree map CM. In this example, an image of the input data IM and the contribution degree map CM are displayed in a display window W1. The contribution degree map CM has a size of $n1 \times n2$, which is the same size as that of the immediately preceding layer 220p. Although the input data IM has a larger planar size than that of the immediately preceding layer 220p, size adjustment may be performed at the time of display such that visual sizes of both the input data IM and the immediately preceding layer 220p are equal to each other.

[0039] In the example of FIG. 6, the contribution degree map CM is displayed as a heat map, and the image of the input data IM is displayed in a state of being superimposed on the contribution degree map CM. At this time, by setting a transmittance for the input data IM, it is possible to check a state in which the contribution degree map CM and the input data IM are superimposed on each other. A user can visually recognize which portion of the image of the input data IM has a large influence on the class discriminant result CL by observing such a contribution degree map CM.

[0040] As described above, in the embodiment, the degree of contribution C_i of each of the plurality of partial regions R_j with respect to the direction of the GAP layer vector v_{GAP} is calculated using the plurality of feature vectors v_j of the plurality of partial regions R_j constituting the immediately preceding layer 220p of the GAP layer 230 and the GAP layer vector v_{GAP} which is the output of the GAP layer 230. Therefore, the degree of contribution C_i that contributes to the direction of the GAP layer vector v_{GAP} can be obtained for each of the plurality of partial regions R_j constituting the immediately preceding layer 220p.

OTHER EMBODIMENTS

[0041] The present disclosure is not limited to the embodiments described above, and may be achieved in various aspects without departing from the spirits of the disclosure. For example, the present disclosure can also be achieved by the following aspects. Appropriate replacements or combinations may be made to the technical features in the above-described embodiments which correspond to the technical features in the aspects described below to solve some or all of the problems of the disclosure or to achieve some or all of the advantageous effects of the disclosure. Furthermore, when the technical characteristics are not described as being essential in the present specification, the technical characteristics can be deleted as appropriate.

[0042] (1) According to the first aspect of the present disclosure, there is provided a method for performing processing related to a class discriminant model including a GAP layer. This method includes (a) a step for inputting input data to the class discriminant model to obtain an operation result of the class discriminant model, (b) a step for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer, and (c) a step for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

[0043] According to this method, the degree of contribution to the direction of the GAP layer vector can be obtained for each of the plurality of partial regions constituting the immediately preceding layer of the GAP layer.

[0044] (2) In the above method, when one of $n1$ and $n2$ is an integer equal to or greater than 1 and another is an integer equal to or greater than 2, m is an integer equal to or greater than 2, and a size of output of the immediately preceding layer is expressed by “width×height×channel depth”, the immediately preceding layer may have a size of $n1 \times n2 \times m$, each of the plurality of partial regions may have a size of $1 \times 1 \times m$, and each of the plurality of feature vectors and the GAP layer vector may be an m -dimensional vector.

[0045] According to this method, the degree of contribution to the direction of the GAP layer vector can be obtained for each partial region having the size of $1 \times 1 \times m$.

[0046] (3) In the above method, step (c) may include (c1) a step for sequentially selecting one of the plurality of partial regions as a target partial region, (c2) a step for generating a partial region GAP vector by performing global average pooling processing on output of the immediately preceding layer in a state where the feature vector in the target partial region is replaced with a zero vector, and (c3) a step for calculating the degree of contribution of the target partial region using a cosine similarity between the partial region GAP vector and the GAP layer vector.

[0047] According to this method, the degree of contribution of each partial region can be calculated using the cosine similarity between the partial region GAP vector and the GAP layer vector.

[0048] (4) In the above method, the degree of contribution may have a negative correlation with the cosine similarity, and may be represented by a function that is uniquely determined in accordance with the cosine similarity.

[0049] According to this method, it is possible to obtain the degree of contribution that indicates an extent of contribution of the individual partial region to the direction of the GAP layer vector.

[0050] (5) In the above method, step (c3) may include a step for obtaining the degree of contribution by subtracting the cosine similarity from 1.

[0051] According to this method, the degree of contribution having a value in a range of 0 to 1 can be obtained.

[0052] (6) According to the second aspect of the present disclosure, there is provided a computer program causing a processor to perform processing related to a class discriminant model including a GAP layer. This computer program causes the processor to perform (a) processing for inputting input data to the class discriminant model to obtain an operation result of the class discriminant model, (b) processing for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer, and (c) processing for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

[0053] The present disclosure may also be achieved by various aspects other than the above. For example, the present disclosure can be achieved by aspects such as a class classification device, a computer program for achieving functions thereof, and a non-transitory storage medium storing the computer program.

What is claimed is:

1. A method for performing processing related to a class discriminant model including a GAP layer, comprising:

- (a) inputting input data to the class discriminant model to obtain an operation result of the class discriminant model;
- (b) extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer from the operation result; and

(c) calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

2. The method according to claim 1, wherein

when one of $n1$ and $n2$ is an integer equal to or greater than 1 and another is an integer equal to or greater than 2, m is an integer equal to or greater than 2, and a size of output of the immediately preceding layer is expressed by “width×height×channel depth”, the immediately preceding layer has a size of $n1 \times n2 \times m$, each of the plurality of partial regions has a size of $1 \times 1 \times m$, and

each of the plurality of feature vectors and the GAP layer vector is an m -dimensional vector.

3. The method according to claim 2, wherein

(c) includes

(c1) sequentially selecting one of the plurality of partial regions as a target partial region,

(c2) generating a partial region GAP vector by performing global average pooling processing on output of the immediately preceding layer in a state where the feature vector in the target partial region is replaced with a zero vector, and

(c3) calculating the degree of contribution of the target partial region using a cosine similarity between the partial region GAP vector and the GAP layer vector.

4. The method according to claim 3 wherein

the degree of contribution has a negative correlation with the cosine similarity, and is represented by a function that is uniquely determined in accordance with the cosine similarity.

5. The method according to claim 3, wherein

(c3) includes obtaining the degree of contribution by subtracting the cosine similarity from 1.

6. A non-transitory computer-readable storage medium storing a computer program causing a processor to perform processing related to a class discriminant model including a GAP layer, the computer program being configured to cause the processor to perform:

(a) processing for inputting input data to the class discriminant model to obtain an operation result of the class discriminant model;

(b) processing for extracting a plurality of feature vectors in a plurality of partial regions constituting an immediately preceding layer disposed immediately before the GAP layer, and a GAP layer vector being output of the GAP layer; and

(c) processing for calculating a degree of contribution of each of the plurality of partial regions related to a direction of the GAP layer vector using the plurality of feature vectors and the GAP layer vector.

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