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- **CHOI, Sang-Woo**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **KIM, Hyung-Woo**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **SON, Gi-Wan**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **PARK, Young-Do**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **JANG, Kil-Bong**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **SON, Sang-Han**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
- **BAE, Ho-Moon**
Pohang-si, Gyeongsangbuk-do 37877 (KR)

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(71) Applicant: **POSCO**
Gyeongsangbuk-do 37859 (KR)

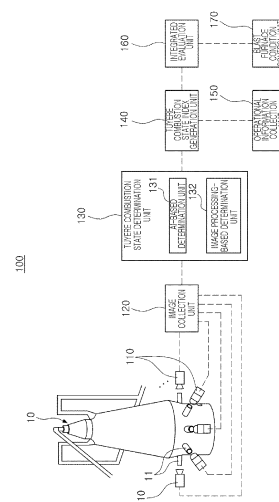
(72) Inventors:
• **SHIN, Kee-Young**
Pohang-si, Gyeongsangbuk-do 37877 (KR)
• **KIM, Young-Hyun**
Pohang-si, Gyeongsangbuk-do 37877 (KR)

(74) Representative: **Zech, Stefan Markus**
Meissner Bolte Patentanwälte
Rechtsanwälte Partnerschaft mbB
Postfach 86 06 24
81633 München (DE)

(54) **SYSTEM AND METHOD FOR EVALUATING OPERATIONAL CONDITIONS OF BLAST FURNACE**

(57) A system and method for evaluating the operational conditions of a blast furnace is disclosed. The system for evaluating the operational conditions of a blast furnace may comprise: an image capture unit for capturing image data according to multiple tuyeres disposed in a blast furnace; an image collection unit for collecting the image data captured according to the tuyeres by the image capture unit; a tuyere combustion state determination unit for classifying, on the basis of artificial intelligence, combustion states according to the tuyeres by using the image data according to the tuyeres; a tuyere combustion state index generation unit for generating combustion state indexes according to the tuyeres by using the result of classifying the combustion states according to the tuyeres by the tuyere combustion state determination unit; and an integrated evaluation unit for generating an integrated combustion state index on the basis of the combustion state indexes according to the tuyeres.

[FIG. 1]



Description

[Technical Field]

[0001] The present disclosure relates to a system and a method for evaluating operational conditions of a blast furnace.

[Background Art]

[0002] In order to evaluate operational conditions of a blast furnace, attempts have been made to determine a situation inside a furnace by analyzing image data captured through a tuyere of the blast furnace, or the like, or to determine a situation inside a furnace by monitoring operational data.

[0003] However, in the related art, an operator has merely qualitatively judged the blast furnace combustibility or the blast furnace condition simply through image data, or merely judged the situation inside the furnace by analyzing luminance of the image data.

[0004] In this regard, Japanese Patent Publication No. 2015-52148 (published date: March 19, 2015) discloses a control method based on determination of operational conditions of a furnace.

[Disclosure]

[Technical Problem]

[0005] In the technical field, a method for quantitatively evaluating a combustion state of a tuyere based on the tuyere image data, and based thereon, a method for integrally evaluating operational conditions of a blast furnace is required.

[Technical Solution]

[0006] In order to solve the above problems, an embodiment of the present disclosure is to provide a system for evaluating operational conditions of a blast furnace.

[0007] According to an embodiment of the present disclosure, a system and a method for evaluating operational conditions of a blast furnace includes: an image capturing unit for capturing image data according to each of a plurality of tuyeres disposed in a blast furnace; an image collection unit for collecting the image data captured according to each of the tuyeres by the image capturing unit; a tuyere combustion state determination unit for classifying, on the basis of artificial intelligence, combustion states according to each of the tuyeres by using the image data according to each of the tuyeres; a tuyere combustion state index generation unit for generating combustion state indices according to each of the tuyeres by using the result of classifying the combustion states according to each of the tuyeres by the tuyere combustion state determination unit; and an integrated evaluation unit for generating an integrated combustion state index

on the basis of the combustion state indices according to each of the tuyeres.

[0008] Meanwhile, another embodiment of the present disclosure is to provide a method for evaluating operating conditions a blast furnace.

[0009] According to another embodiment of the present disclosure, the method for evaluating operating conditions a blast furnace includes operations of: collecting image data according to a plurality of tuyeres provided in a blast furnace; classifying combustion states according to each of the tuyeres on the basis of artificial intelligence, by using the image data according to each of the tuyeres; generating combustion state indices according to each of the tuyeres by using the result of classifying the combustion state according to a plurality of tuyeres; and generating an integrated combustion state index on the basis of the combustion state indices according to each of the tuyeres.

[0010] In addition, not all features of the present disclosure are listed in the solution means of the above-mentioned problem. Various features of the present disclosure and the advantages and effects thereof may be understood in more detail with reference to specific embodiments below.

[Advantageous Effects]

[0011] According to an embodiment in the present disclosure, it is possible to classify a tuyere combustion state based on deep learning using the tuyere image data, in addition to the result of classifying the result of classifying the tuyere combustion state, and a result of analyzing the tuyere image data and a result of analyzing the blast furnace operational data may be additionally used to extract the tuyere combustion state indices according to each of the tuyeres, and an operational condition of a blast furnace may be integrally evaluated and controlled.

[0012] Accordingly, the blast furnace combustibility and the blast furnace condition may be quantitatively evaluated to enable stable blast furnace operations, and productivity may be improved.

[Description of Drawings]

[0013]

FIG. 1 is a configuration diagram of a system for evaluating operational conditions of a blast furnace according to an embodiment of the present disclosure.

FIG. 2 is a view illustrating a concept for primarily classifying a tuyere combustion state on the basis of deep learning according to an embodiment of the present disclosure.

FIGS. 3 and 4 are views diagrams illustrating a concept of determining classification of a tuyere combustion state on the basis of accumulating results primarily classified in time series based on deep

learning according to an embodiment of the present disclosure.

FIG. 5 is a flowchart of a method for evaluating operating conditions according to another embodiment of the present disclosure.

[Best Mode for Invention]

[0014] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The disclosure may, however, be exemplified in many different forms and should not be construed as being limited to the specific embodiments set forth herein, and those skilled in the art and understanding the present disclosure can easily accomplish retrogressive inventions or other embodiments included in the scope of the present disclosure by the addition, modification, and removal of components within the same scope, but those are construed as being included in the scope of the present disclosure. Like reference numerals will be used to designate like components having similar functions throughout the drawings within the scope of the present disclosure.

[0015] Throughout the specification, it will be understood that when an element is referred to as being "on," "connected to," or "coupled to" another element, it can be directly "on," "connected to," or "coupled to" the other element or indirectly "on," "connected to," or "coupled to" the other elements intervening therebetween may be present. In addition, when a component is referred to as "comprise" or "comprising," it means that it may include other components as well, rather than excluding other components, unless specifically stated otherwise.

[0016] FIG. 1 is a configuration diagram of a system for evaluating operational conditions of a blast furnace according to an embodiment of the present disclosure.

[0017] Referring to FIG. 1, a system 100 for evaluating operational conditions of a blast furnace according to an embodiment of the present disclosure may be configured to include an image capturing unit 110, an image collection unit 120, a tuyere combustion state determination unit 130, a tuyere combustion state index generation unit 140, an operational information collection unit 150, an integrated evaluation unit 160, and a blast furnace condition control unit 170.

[0018] The image capturing unit 110 may acquire image data according to each of the tuyeres 11 provided in the blast furnace 10.

[0019] For example, the image capturing unit 110 may include a plurality of cameras installed in each tuyere 11, and may acquire the image data according to each of the tuyeres in real time (e.g., in ms units) through each camera.

[0020] The image collection unit 120 may collect image data according to each of the tuyeres captured by the image capturing unit 110.

[0021] For example, the image collection unit 120 may collect image data obtained in real time according to each

of the tuyeres from a plurality of cameras included in the image capturing unit 110.

[0022] In addition, the image collection unit 120 may map the collected image data with collection environment information including a tuyere number, data capture time, and the like.

[0023] In addition, the image data, which has been mapped by the image collection unit 120, may be stored in a data storage (not shown) provided in a system for evaluating operational conditions of a blast furnace 100, or may be transmitted in real time to the tuyere combustion state determination unit 130.

[0024] The tuyere combustion state determination unit 130 is for classifying a combustion state according to each of the tuyeres using the image data according to each of the tuyeres transmitted from the image collection unit 120, and may be configured to include an AI-based determination unit 131 and an image processing-based determination unit 132.

[0025] The AI-based determination unit 1311 may classify the combustion state according to each of the tuyeres based on artificial intelligence using the image data according to each of the tuyeres. For example, the AI-based determination unit 131 may classify the combustion state according to each of the tuyeres based on deep learning.

[0026] According to an embodiment, the AI-based determination unit 131 may primarily classify the combustion state according to each of the tuyeres based on a convolutional neural network (CNN) using image data according to each of the tuyeres.

[0027] If necessary, the AI-based determination unit 131 may determine the tuyere combustion state classification based on results of accumulating the results of classifying the combustion states according to each of the tuyeres in time series, primarily classified, thereby further improving consistency of the combustion state classification.

[0028] The concept of classifying and determining the tuyere combustion state by the AI-based determination unit 131 will be described in more detail with reference to FIGS. 2 to 4.

[0029] FIG. 2 is a view illustrating the concept of primarily classifying a tuyere combustion state based on deep learning according to an embodiment of the present disclosure.

[0030] Referring to FIG. 2, the AI-based determination unit 131 may classify the combustion states based on the image deep learning, for example, CNN, for first tuyere image to the Nth tuyere image data (21 to 2N) captured according to each of the tuyeres, thereby obtaining the results of the first tuyere combustion state classification to the Nth tuyere combustion state classification (21'to 2N'). Here, N means the number of tuyere.

[0031] FIGS. 3 and 4 are diagrams illustrating a concept of determining a tuyere combustion state classification based on a result of accumulating a result primarily classified based on deep learning in time series accord-

ing to an embodiment of the present disclosure.

[0032] First, referring to FIG. 3, as a result of accumulating the result of classifying the combustion states in time series, primarily classified according to each of the tuyeres, that is, the AI-based determination unit 131 may determine a tuyere combustion state classification according to each of the tuyeres based on first tuyere combustion state classifications 31-1, 31-2, and 31-3, second tuyere combustion state classifications 32-1, 32-2, and 32-3, and Nth tuyere combustion state classifications 3N-1, 3N-2, and 3N-3, and may obtain determined tuyere combustion state classification results 31' to 33'.

[0033] In the present embodiment, if any combustion state classification occurs more than a predetermined number of times, a result of classifying the plurality of combustion states primarily classified for an arbitrary time period (t-1 to t+1) to determine the tuyere combustion state classification, may be determined as the corresponding combustion state classification. Thereby, it is possible to further improve the accuracy of the tuyere combustion state classification.

[0034] Next, referring to FIG. 4, as a result of accumulating the result of classifying the combustion states in time series, primarily classified according to each of the tuyeres, that is, the AI-based determination unit 131 may determine tuyere combustion state classification according to each of the tuyeres based on deep learning in time series on first tuyere combustion state classifications 41-1, 41-2, and 41-3, second tuyere combustion state classifications 42-1, 42-2, and 42-3, and Nth tuyere combustion state classifications 4N-1, 4N-2, and 4N-3, and may obtain determined tuyere combustion state classification results 41' to 43'.

[0035] For example, the AI-based determination unit 131 determine the tuyere combustion state classification according to each of the tuyeres based on a recurrent neural network (RNN) or a recurrent convolutional neural network (RCNN) by using the result of classifying a plurality of combustion states primarily classified according to each of the tuyeres for an arbitrary time period (t-1 to t+1).

[0036] Since the combustion state of the tuyere changes with continuity over time, the accuracy may be deteriorated to determine the combustion state of the tuyere only at a certain point in time.

[0037] Therefore, according to the present embodiment, in order to determine the combustion state classification of the tuyere by comprehensively considering the changes in the combustion state of the tuyere according to the time flow, an image time-series deep learning may be applied to further improve the accuracy of the tuyere combustion state classification.

[0038] Meanwhile, as illustrated in FIGS. 3 and 4, in determining the tuyere combustion state classification based on the results accumulated in time series, the accuracy of classification may be affected according to the time period (for example, t-1 to t+1) for accumulating the results primarily classified and a start time (t-1) of the

corresponding time period.

[0039] According to an embodiment, at the time of initial performance, starting from the time at which the classification of the combustion state of the corresponding tuyere is first detected, the tuyere combustion state classification may be determined by accumulating the results primarily classified for a time period set by a user.

[0040] In addition, when the determination result of the tuyere combustion state classification is accumulated, the above-described time period is adjusted according to the elapsed time information from the time at which the tuyere combustion state classification is first detected to the time at which the tuyere combustion state classification transitions to another state, such that the accuracy may be further improved.

[0041] The tuyere combustion state classified by the AI-based determination unit 131 may include, for example, a normal combustion state, a poor combustion state, pulverized coal non-injection, unreduced molten material falling(raw ore falling), coke turning, and the like.

[0042] Here, pulverized coal non-injection means that it is determined whether or not pulverized coal is injected, unreduced molten material falling(raw ore falling) means that it is determined whether or not an unreduced raw material in a molten state in which raw materials that need to be reduced in an upper part of the furnace are unreduced and fall, and coke turning means whether coke turns in a middle part of the coke.

[0043] The image processing-based determination unit 132 may diagnose a tuyere facility through image processing for image data according to each of the tuyeres, and determine the tuyere combustion state.

[0044] According to an embodiment, the image processing-based determination unit 132 may determine a tuyere facility abnormal condition including presence or absence of a curvature of a tuyere, presence or absence of a tuyere attachment, clogging or a tuyere, lance banding or burning, or the like, through image processing of the image data according to each of the tuyeres.

[0045] In addition, the image processing-based determination unit 132 may extract a combustion area and combustion brightness (i.e., luminance) through image processing of image data according to each of the tuyeres.

[0046] In addition, when the combustion state is normal, the image processing-based determination unit 132 may determine a pulverized coal flow rate through image processing of the image data according to each of the tuyeres.

[0047] Various image processing techniques known to a person skilled in the art may be applied to the image processing-based determination unit 132 for image processing of image data according to each of the tuyeres, and detailed description thereof will be omitted.

[0048] The determination by the AI-based determination unit 131 and the image processing-based determination unit 132 described above may be performed in parallel.

[0049] The combustion condition classification result according to each of the tuyeres classified by the tuyere combustion state determination unit 130 and the tuyere facility diagnosis result may be mapped and stored and managed together with image data and collection environment information according to each of the tuyeres.

[0050] The tuyere combustion state index generation unit 140 may generate a combustion state index according to each of the tuyeres by using the combustion state classification result according to each of the tuyeres classified by the tuyere combustion state determination unit 130.

[0051] According to an embodiment, the combustion state index according to each of the tuyeres generated by the tuyere combustion state index generation unit 140 may include a combustion state defect index, a pulverized coal non-injection index, an unreduced molten material falling(raw ore falling) index, a coke turning index, a combustion state level index, a pulverized coal flow rate index, a tuyere raceway index, and the like.

[0052] For example, the tuyere combustion state index generation unit 140 may count the number of times that an arbitrary classification result has occurred based on the combustion state classification results according to each of the tuyeres by the tuyere combustion state determination unit 130 for every predetermined period, and generate a related index by scoring it according to the number of times counted for each corresponding period.

[0053] In addition, the tuyere combustion state index generation unit 150 may score the combustion state level index according to a combustion area and combustion brightness (i.e., luminance) extracted by the tuyere combustion state determination unit 130, combine the calculated scores for a predetermined period to generate a combustion state level index. Here, reference information used to generate the combustion state level index can be updated according to the input signal by the administrator. Accordingly, the updated reference information may be reflected in real time to generate index information reflecting the blast furnace condition.

[0054] In addition, the tuyere combustion state index generation unit 140 may generate a tuyere facility abnormality index by scoring the results of the tuyere facility diagnosis determined by the tuyere combustion state determination unit 130. Here, the tuyere facility abnormality index may include a tuyere curvature index, a tuyere attachment index, a tuyere blockage index, a lance damage index, and the like.

[0055] An operational information collection unit 150 is for collecting operational information generated during a blast furnace operation in real time. Here, the operational information may include, for example, a blast furnace body temperature, pressure, a cooling water flow rate, and the like.

[0056] The operational information collected in real time by the operational information collection unit 150 may be mapped with the tuyere combustion state index information generated by the tuyere combustion state

index information unit 140 described above and stored and managed.

[0057] An integrated evaluation unit 160 may be integrally evaluated in a circumferential direction of the blast furnace based on the tuyere operational state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140 and operational information collected by an operational information collection unit 150.

[0058] According to an embodiment, the integrated evaluation unit 160 may generate an integrated combustion state index by comprehensively considering the tuyere combustion state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140.

[0059] For example, the integrated combustion state index may include an integrated combustion state index, matched 1:1 to the integrated combustion state index generated according to each of the tuyeres such as an integrated combustion state defect index, an integrated pulverized coal non-injection index, an integrated unreduced molten material falling(raw ore falling) index, and the like.

[0060] In addition, the integrated evaluation unit 160 may generate a circumferential balance index based on tuyere raceway indices generated according to each of the tuyeres.

[0061] In addition, the integrated evaluation unit 160 may generate an integrated tuyere facility abnormality index based on the tuyere facility abnormality index generated according to each of the tuyeres.

[0062] A blast furnace condition control unit 170 may perform at least one of pulverized coal injection control, N₂ purge control, and blast furnace charge control, based on the tuyere combustion state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140 or the integrated combustion state index generated by the integrated evaluation unit 160 to control the blast furnace condition.

[0063] According to an embodiment, the blast furnace condition control unit 170 may perform pulverized coal injection control when a pulverized coal non-injection index for an arbitrary tuyere exceeds a predetermined reference value.

[0064] In addition, the blast furnace condition control unit 170 may perform blast furnace charging control when a unreduced molten material falling (raw ore falling) index exceeds a predetermined reference value due to occurrence of raw ore falling in any tuyere region.

[0065] According to another embodiment, the blast furnace condition control unit 170 may integrally control a plurality of tuyeres based on information of an integrated combustion state index or a circumferential balance index.

[0066] For example, the blast furnace control unit 170 may control a blast furnace charging, for example, by changing distribution of charges to change a direction in which the charges fall, when raw ore falling occurs in only

one direction.

[0067] The system for evaluating operational conditions of a blast furnace 100 described above with reference to FIG. 1 applies an artificial intelligence algorithm to input data and performs image processing, and may be implemented by combination of a processing device capable of calculating various indices, and a control device capable of performing blast furnace control.

[0068] FIG. 5 is a flowchart of a method for evaluating operational conditions of a blast furnace according to another embodiment of the present disclosure.

[0069] Referring to FIG. 5, according to a method for evaluating operational conditions of a blast furnace, image data according to each of the tuyeres provided in a blast furnace may be collected in real time by an image capturing unit 110 and an image collection unit 120 (S510).

[0070] Thereafter, by a tuyere combustion state determination unit 130, a combustion state according to each of the tuyeres may be classified using the image data according to each of the tuyeres (S520).

[0071] Specifically, by an AI-based determination unit 131, after primarily classifying the tuyere combustion state based on artificial intelligence using the image data according to each of the tuyeres (S521), the classification of the tuyere combustion state may be determined based on the result of classifying the combustion states (S522).

[0072] In addition, in parallel therewith, by an image processing-based determination unit 132, in addition to classifying the combustion state according to each of the tuyeres through image processing for the image data according to each of the tuyeres, a tuyere facility can be diagnosed (S525).

[0073] Thereafter, by a tuyere combustion state index generation unit 140, a combustion state index is generated based on the result of classifying the combustion state according to each of the tuyeres (S530), and by an integrated evaluation unit 160, an operational condition of a blast furnace may be integrally evaluated in a circumferential direction based on the generated combustion state index according to each of the tuyeres (S540).

[0074] Thereafter, by a blast furnace condition control unit 170, a blast furnace condition may be controlled based on the integrally evaluated operational condition (S550).

[0075] Since the detailed method of performing each operation described above with reference to FIG. 5 is the same as described above with reference to FIGS. 1 to 4, redundant description thereof will be omitted.

[0076] While embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A system for evaluating operational conditions of a blast furnace, comprising:

an image capturing unit for capturing image data according to each of a plurality of tuyeres provided in a blast furnace;
 an image collection unit for collecting the image data captured according to each of the tuyeres by the image capturing unit;
 a tuyere combustion state determination unit for classifying, on the basis of artificial intelligence, combustion states according to each of the tuyeres, by using the image data according to each of the tuyeres;
 a tuyere combustion state index generation unit for generating a combustion state index according to each of the tuyeres by using the result of classifying the combustion states according to each of the tuyeres by the tuyere combustion state determination unit; and
 an integrated evaluation unit for generating an integrated combustion state index on the basis of the combustion state index according to each of the tuyeres.

2. The system for evaluating operational conditions of a blast furnace of claim 1, wherein the tuyere combustion state determination unit comprises an AI-based determination unit for classifying combustion states according to each of the tuyeres based on deep learning using the image data according to each of the tuyeres.

3. The system for evaluating operational conditions of a blast furnace of claim 2, wherein the AI-based determination unit determines the combustion state classification according to each of the tuyeres based on a result of accumulating a result of classifying the combustion states according to each of the tuyeres classified based on deep learning in time series for a predetermined time period.

4. The system for evaluating operational conditions of a blast furnace of claim 3, wherein the AI-based determination unit determines the combustion state classification if any combustion state classification occurs more than a predetermined number of times during the time period.

5. The system for evaluating operational conditions of a blast furnace of claim 3, wherein the AI-based determination unit determines the combustion state classification based on time-series deep learning on the results of classifying the combustion states according to each of the tuyeres accumulated during the time period.

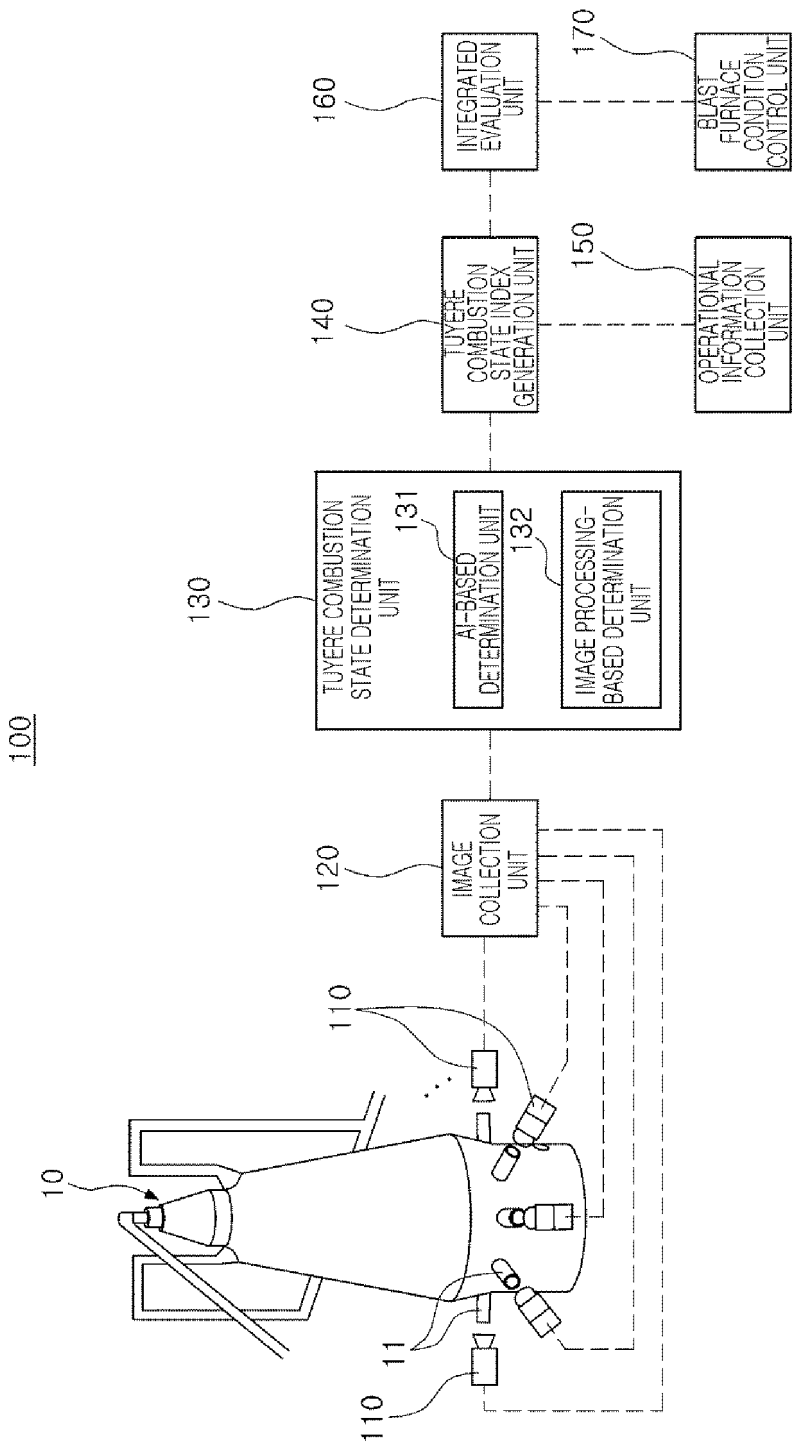
6. The system for evaluating operational conditions of a blast furnace of claim 3, wherein the time period is adjusted according to elapsed time information from a time at which the tuyere combustion state classification is first detected to a time at which the tuyere combustion state classification transitions to another state. 5
7. The system for evaluating operational conditions of a blast furnace of claim 2, wherein the tuyere combustion state determination unit further comprises an image processing-based determination unit for diagnosing a tuyere facility through image processing on the image data according to each of the tuyeres and determining the tuyere combustion state. 10 15
8. The system for evaluating operational conditions of a blast furnace of claim 1, wherein the combustion state classification comprises a normal combustion state, a poor combustion state, pulverized coal non-injection, unreduced molten material falling, and coke turning. 20
9. The system for evaluating operational conditions of a blast furnace of claim 1, further comprising a blast furnace condition control unit for performing at least one of pulverized coal injection control, N₂ purge control, and blast furnace charge control, based on the combustion state index according to each of the tuyeres or the integrated combustion state index. 25 30
10. The system for evaluating operational conditions of a blast furnace of claim 1, wherein the combustion state index according to each of the tuyeres comprises at least one of a combustion state defect index, a pulverized coal non-injection index, an unreduced molten material falling index, a coke turning index, a combustion state level index, a pulverized coal flow rate index, and a tuyere raceway index. 35 40
11. A method for evaluating operational conditions of a blast furnace comprising operations of:
 - collecting image data according to a plurality of tuyeres provided in a blast furnace; 45
 - classifying a combustion state according to each of the tuyeres based on artificial intelligence using the image data according to each of the tuyeres;
 - generating a combustion state index according to each of the tuyeres using the result of classifying the combustion state according to each of the tuyeres; and 50
 - generating an integrated combustion state index based on the combustion state index according to each of the tuyeres. 55

12. The method for evaluating operational conditions of

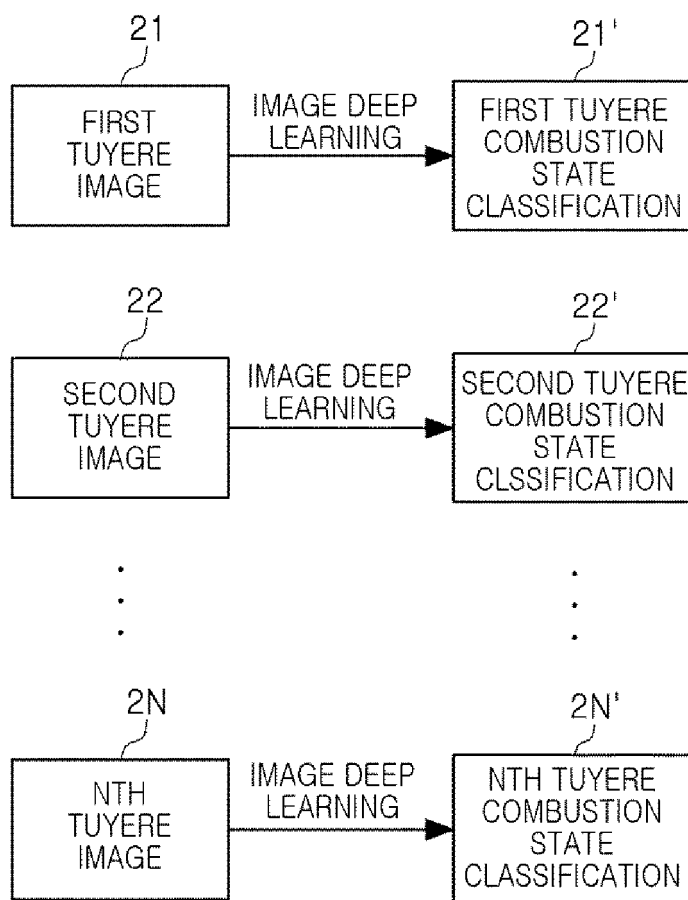
a blast furnace of claim 11, wherein the operation of classifying the combustion state according to each of the tuyeres comprises operations of:

classifying the combustion state according to each of the tuyeres based on deep learning using the image data according to each of the tuyeres; and
 determining a combustion state classification according to each of the tuyeres based on a result of accumulating the result of classifying the combustion state according to each of the tuyeres classified based on the deep learning for a predetermined time period.

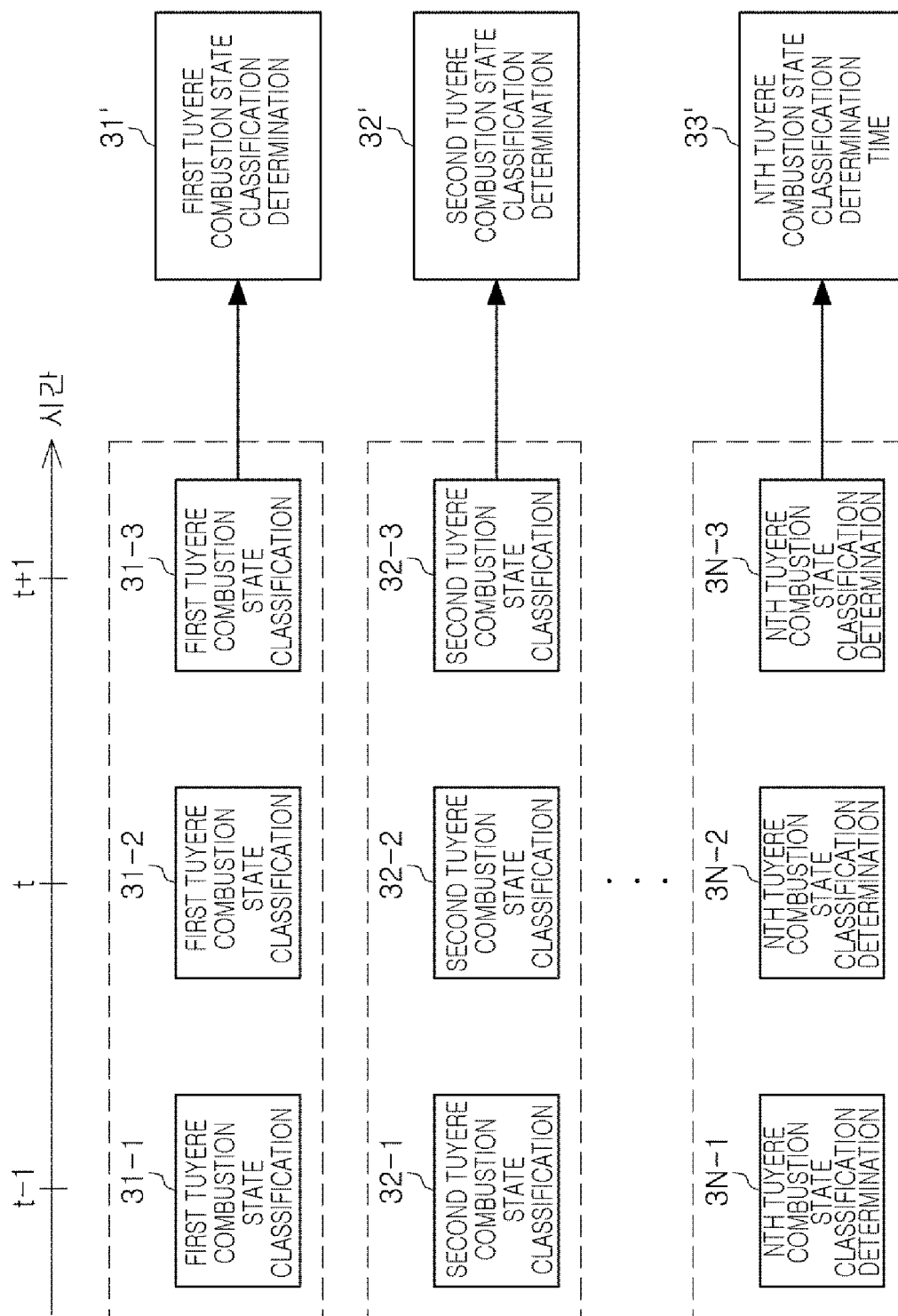
【FIG. 1】



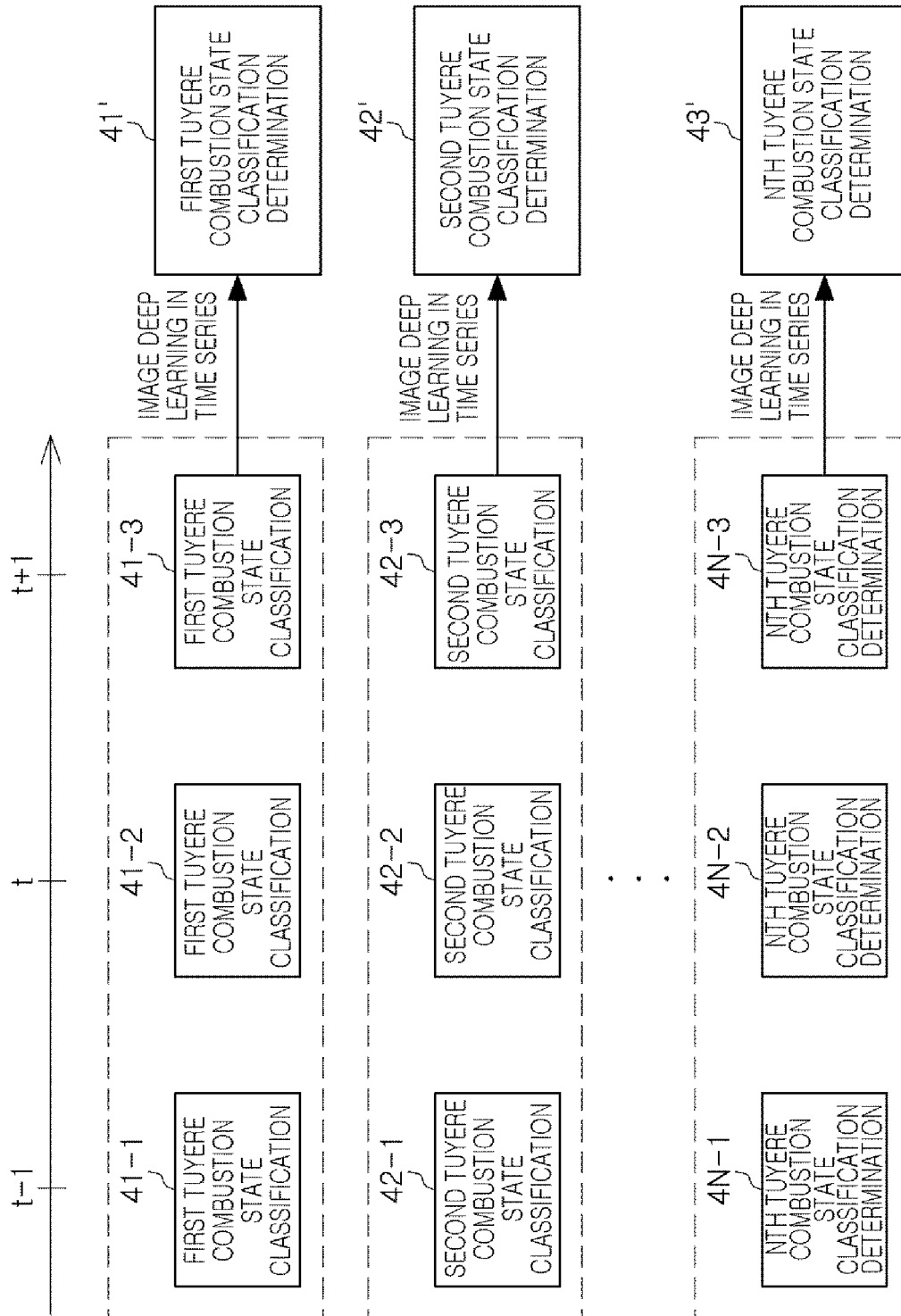
【FIG. 2】



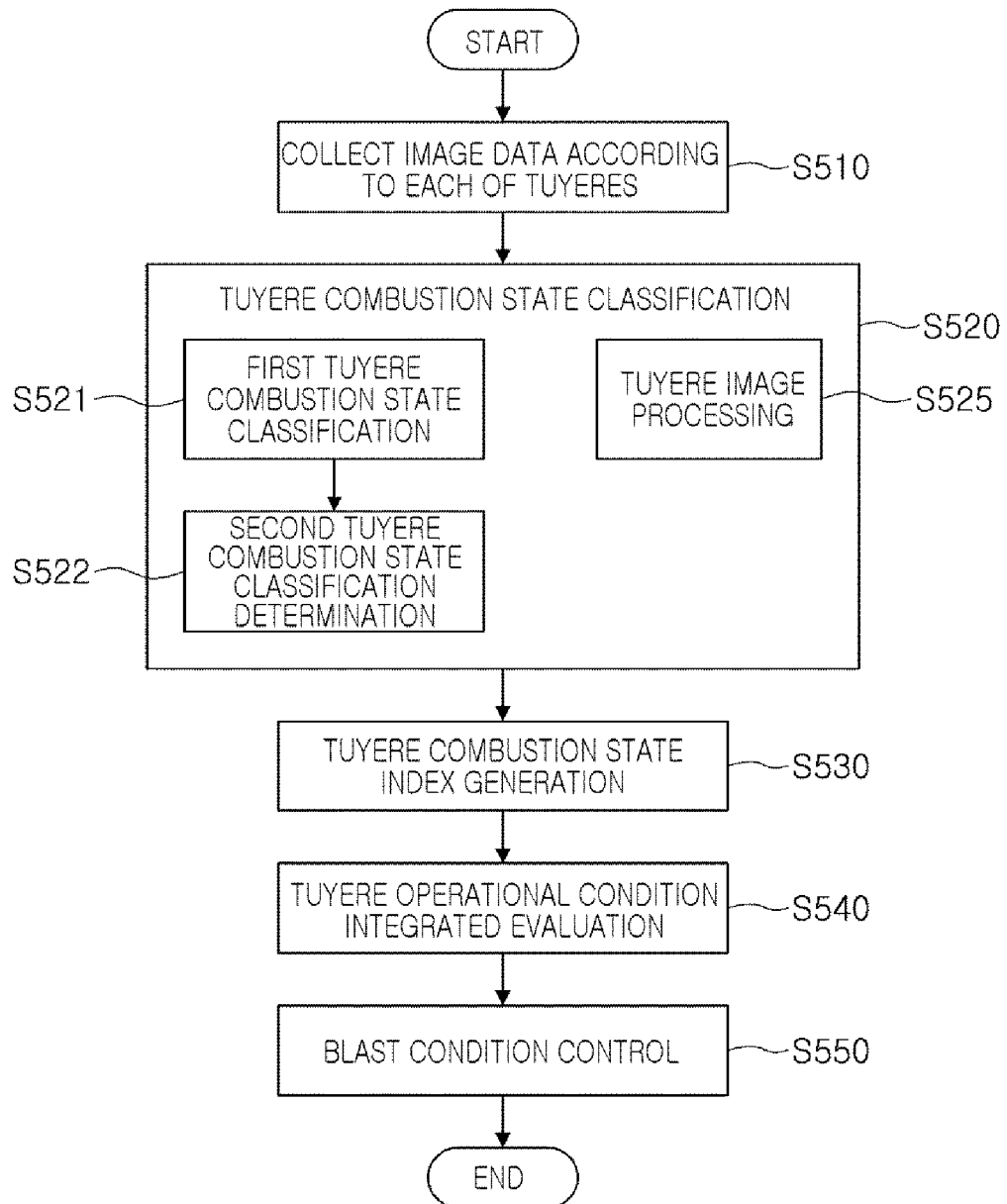
【FIG. 3】



【FIG. 4】



【FIG. 5】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2018/016580

A. CLASSIFICATION OF SUBJECT MATTER

C21B 5/00(2006.01)i, C21B 7/16(2006.01)i, F27D 21/02(2006.01)i, C21B 7/24(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21B 5/00; C21B 7/00; C21B 7/24; C22B 1/20; F23N 5/00; F27B 21/14; C21B 7/16; F27D 21/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models: IPC as above

Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & Keywords: artificial intelligence, neural network, deep learning, combustion state, blast furnace, blast furnace, image data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Further documents are listed in the continuation of Box C.



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 Korean Intellectual Property Office
 Government Complex Daejeon Building 4, 189, Cheongsu-ro, Seo-gu,
 Daejeon, 35208, Republic of Korea
 Facsimile No. +82-42-481-8578

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