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Tanaka et al.

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(54) **TERMINAL DEVICE, SERVER, DATA PROCESSING SYSTEM, DATA PROCESSING METHOD, AND PROGRAM**

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(51) **Int. Cl.**

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H04N 7/18	(2006.01)
H04L 9/00	(2006.01)
H04N 21/2187	(2011.01)
H04N 21/2347	(2011.01)
H04N 21/44	(2011.01)
H04N 21/4405	(2011.01)

(52) **U.S. Cl.**

CPC ***H04N 7/18*** (2013.01); ***H04L 9/008*** (2013.01); ***H04N 21/2187*** (2013.01); ***H04N 21/2347*** (2013.01); ***H04N 21/4405*** (2013.01); ***H04N 21/44008*** (2013.01)

(58) **Field of Classification Search**

CPC H04N 7/183; H04N 7/1675; H04N 5/77; H04L 9/08; H04L 63/0428; H04L 63/0442; H04L 9/00

USPC 713/149–153; 726/22

See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Sony Corporation

(57) **ABSTRACT**

A terminal device, which includes an encrypting section encrypting input data in a fully homomorphic encryption scheme to generate encrypted data. The terminal device includes an encrypted data transmission section transmitting the encrypted data generated by the encrypting section to a server. The terminal device includes an encrypted data reception section receiving the encrypted data on which the server implements a predetermined process and a decrypting section decrypting the encrypted data on which the predetermined process is implemented.

8 Claims, 12 Drawing Sheets

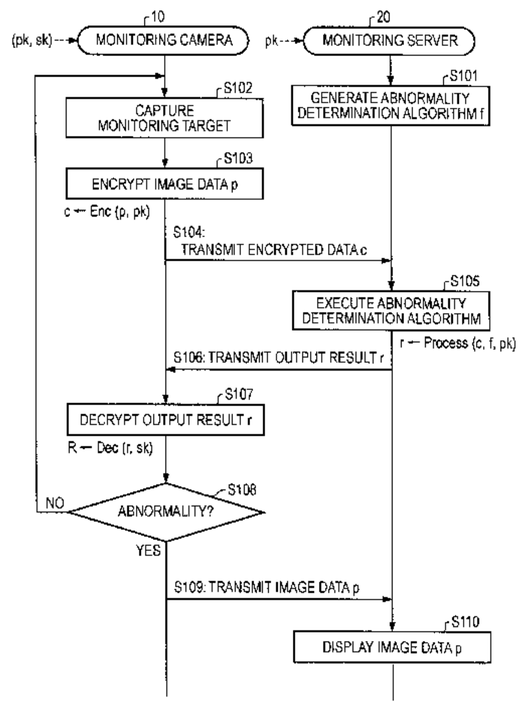

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FIG. 1

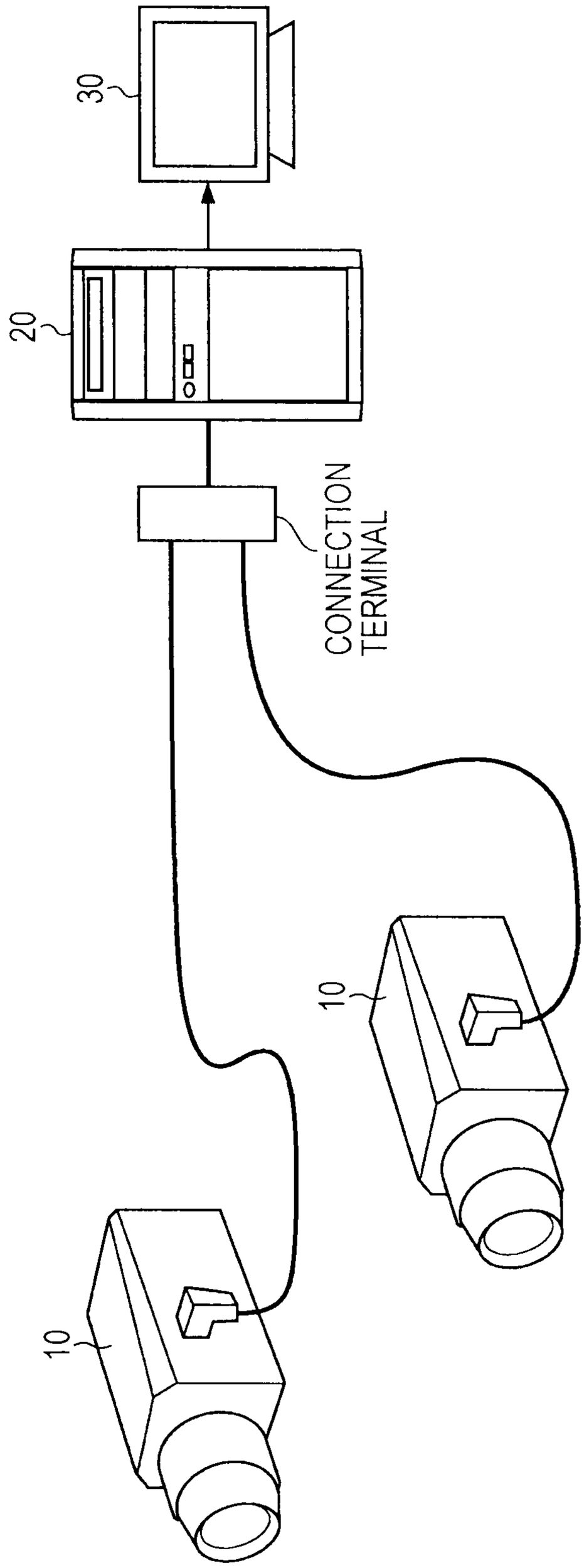


FIG. 2

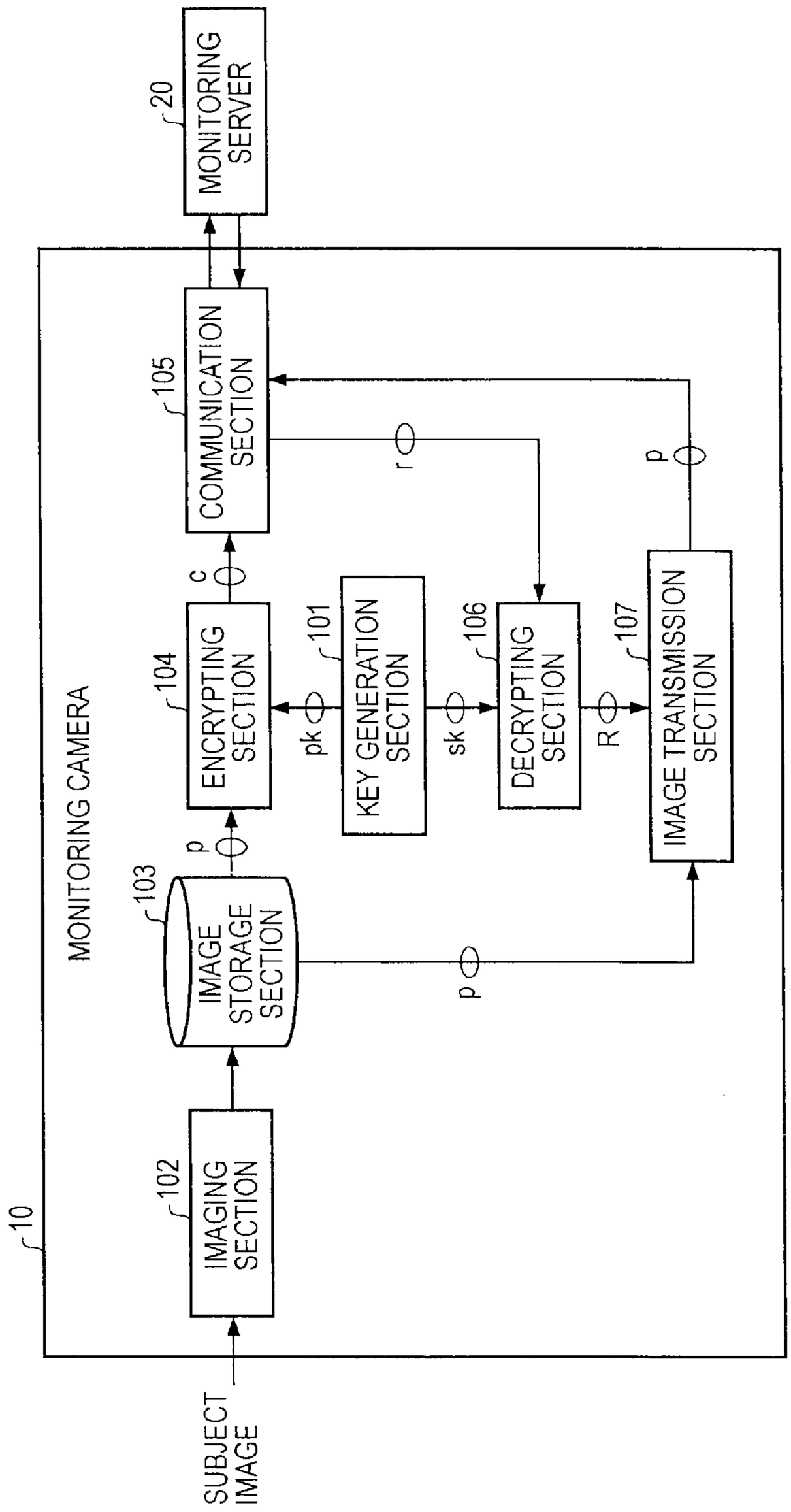

MONITORING SERVER
20
MONITORING CAMERA
COMMUNICATION SECTION
105
ENCRYPTING SECTION
104
KEY GENERATION SECTION
101
DECRYPTING SECTION
106
IMAGE TRANSMISSION SECTION
107
IMAGE STORAGE SECTION
103
IMAGING SECTION
102
10
c
r
p
pk
sk
R
p
p
SUBJECT IMAGE

FIG. 3

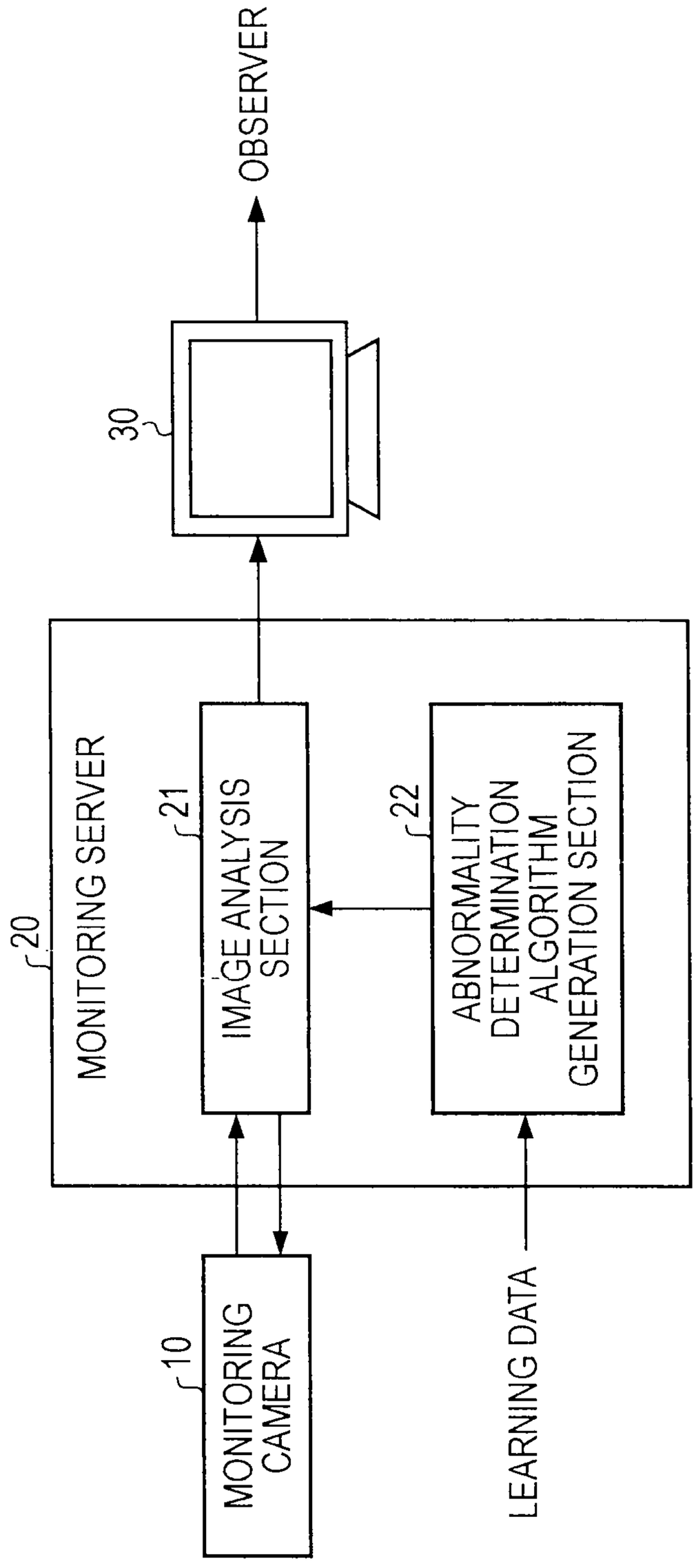

OBSERVER
30
MONITORING SERVER
20
IMAGE ANALYSIS SECTION
21
ABNORMALITY DETERMINATION ALGORITHM GENERATION SECTION
22
MONITORING CAMERA
10
LEARNING DATA

FIG. 4

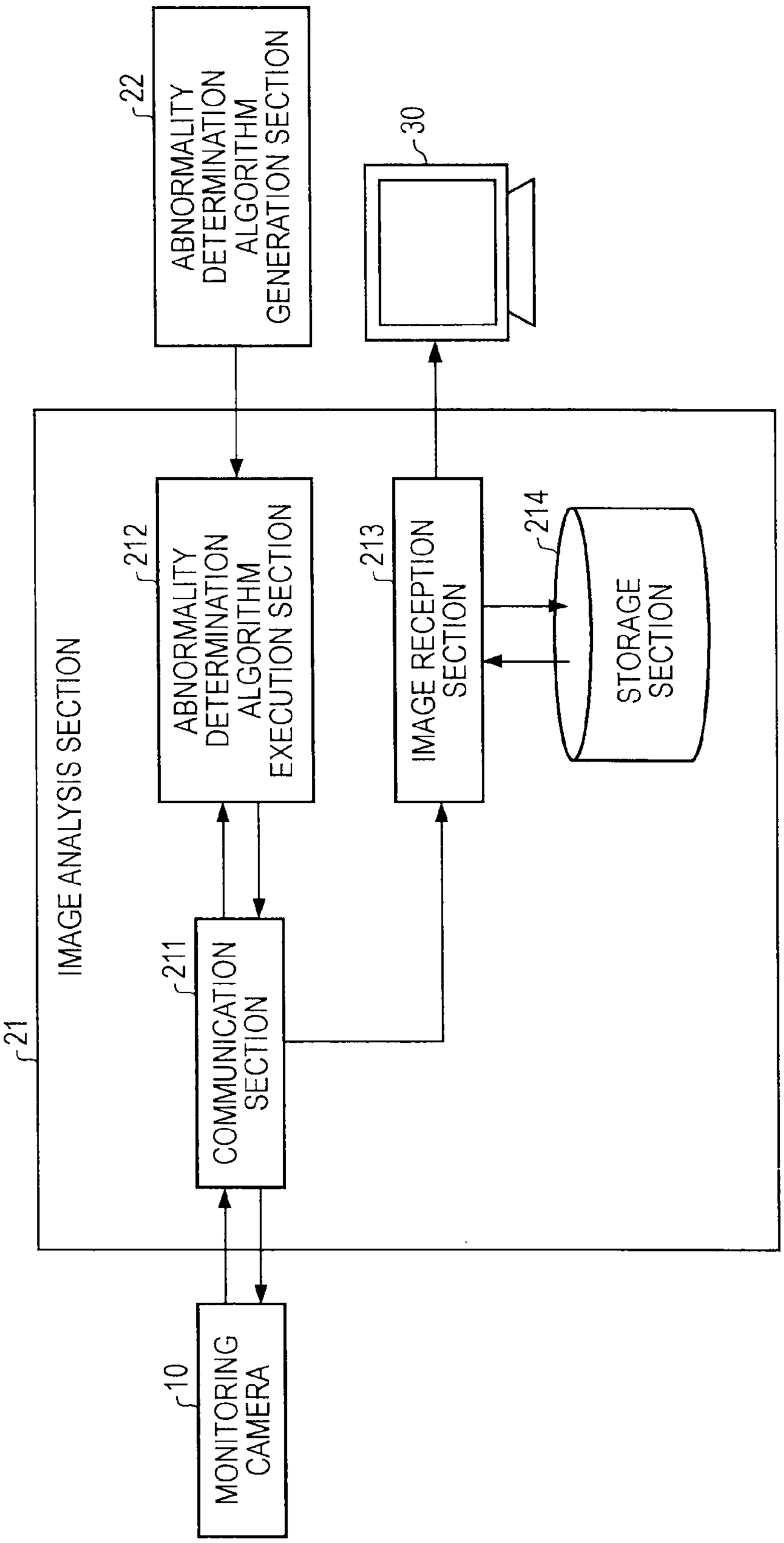

MONITORING CAMERA
10
IMAGE ANALYSIS SECTION
21
COMMUNICATION SECTION
211
ABNORMALITY DETERMINATION ALGORITHM EXECUTION SECTION
212
IMAGE RECEPTION SECTION
213
STORAGE SECTION
214
ABNORMALITY DETERMINATION ALGORITHM GENERATION SECTION
22
30

FIG. 5

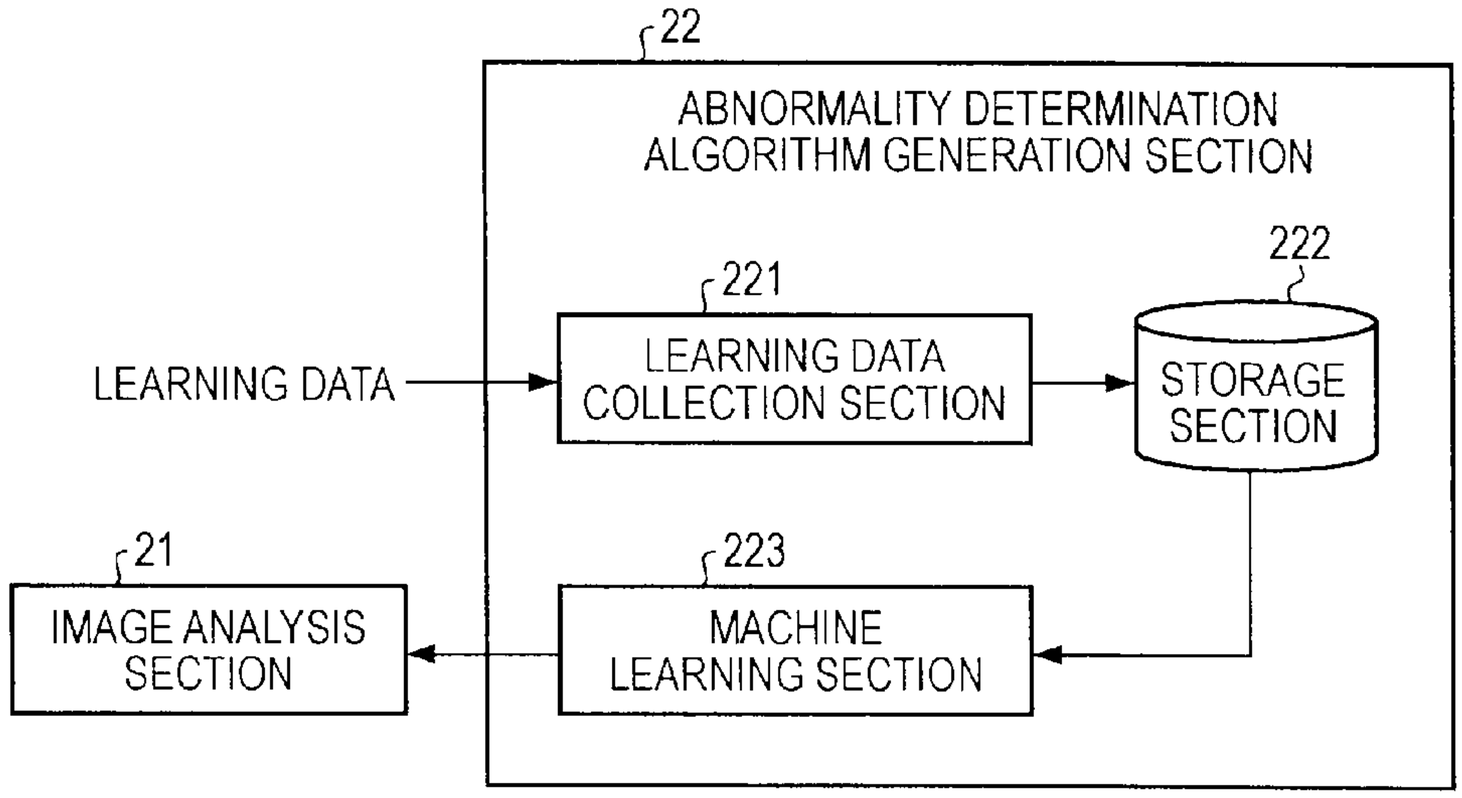


FIG. 6

CHARACTERISTICS OF FULLY HOMOMORPHIC ENCRYPTION SCHEME

(INPUT DATA: p, PUBLIC KEY: pk, SECRET KEY: sk, PROCESS FUNCTION: f)

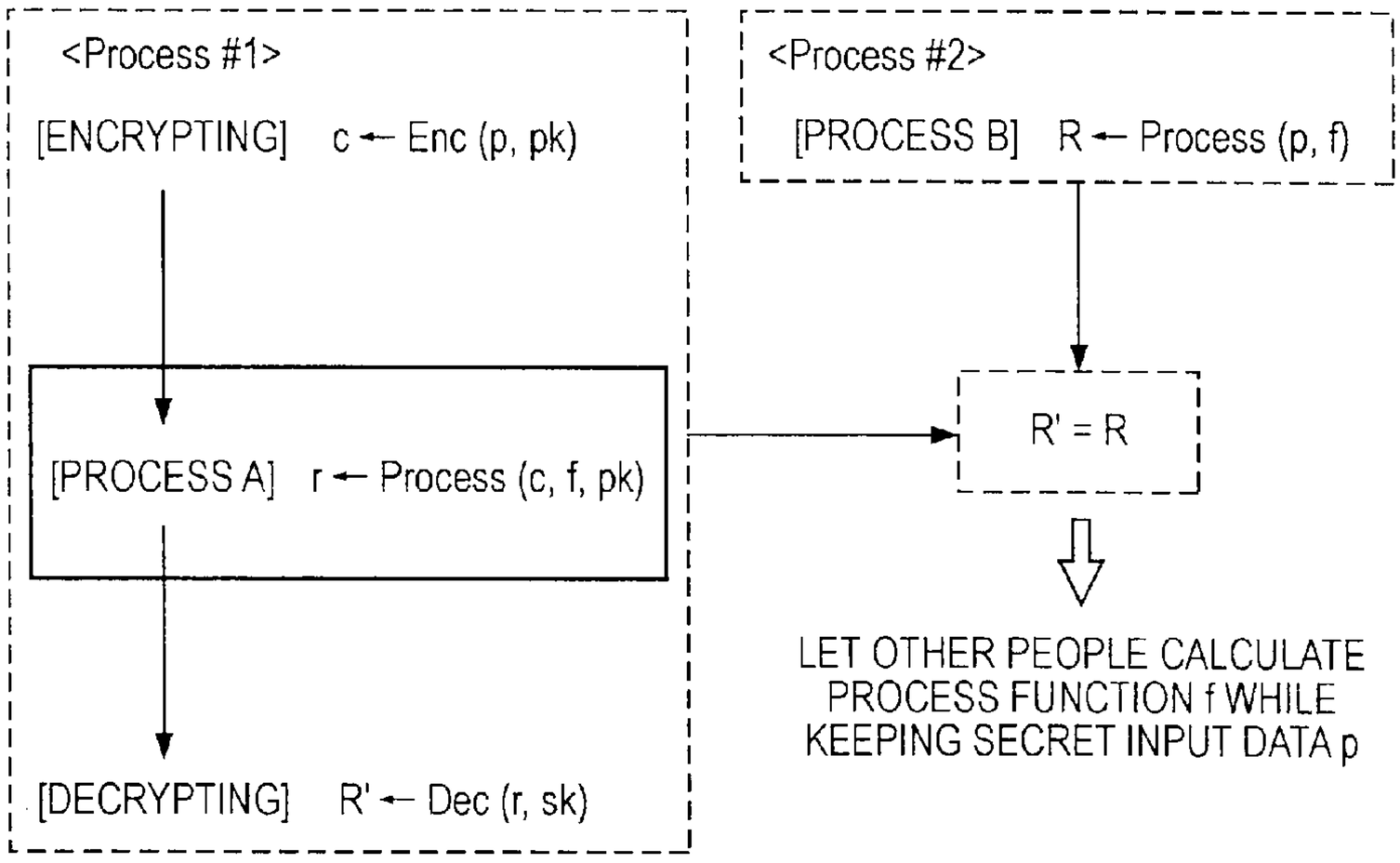


FIG. 7

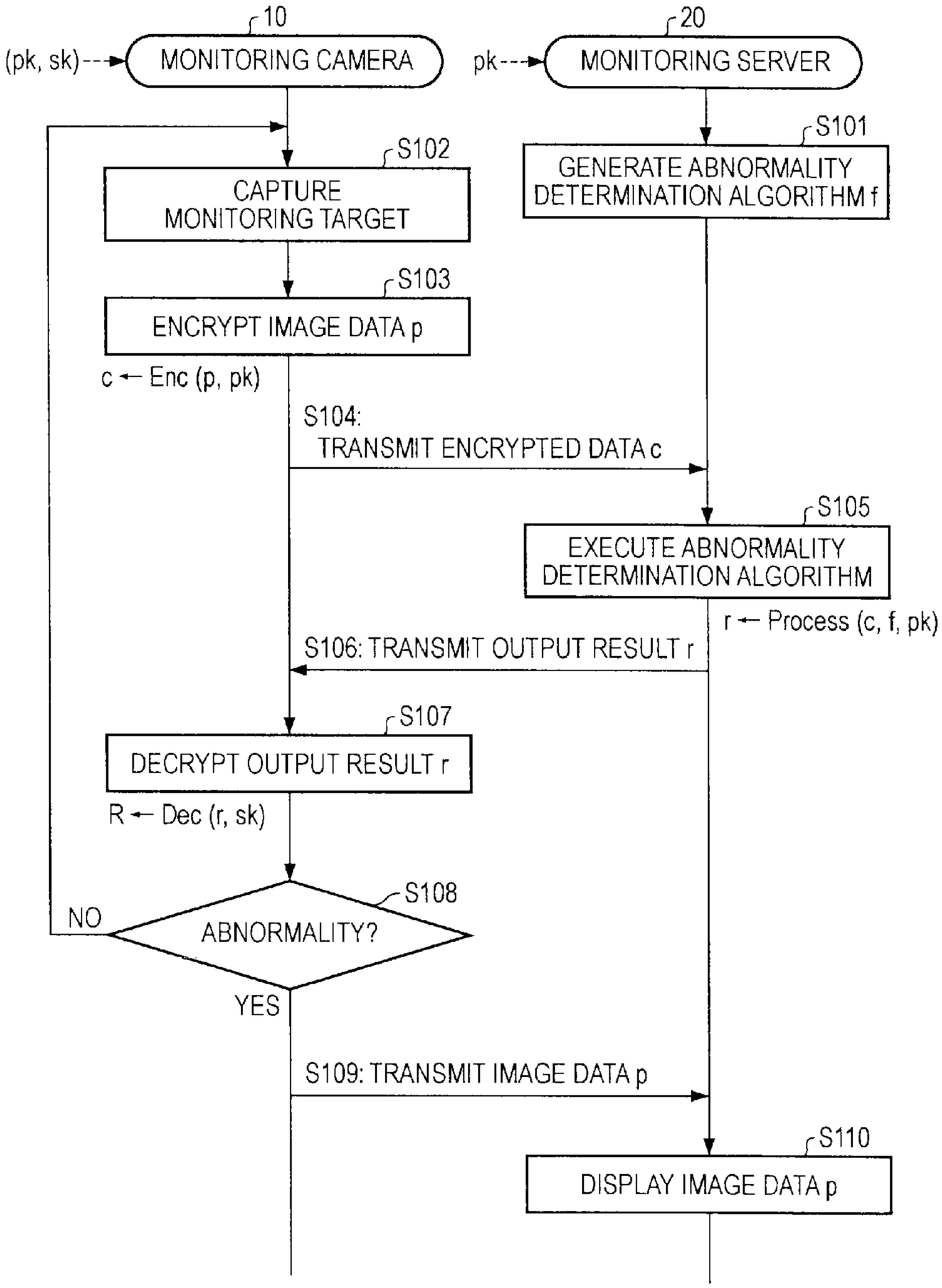

10
(pk, sk)
MONITORING CAMERA
20
pk
MONITORING SERVER
S101
GENERATE ABNORMALITY DETERMINATION ALGORITHM f
S102
CAPTURE MONITORING TARGET
S103
ENCRYPT IMAGE DATA p
c ← Enc (p, pk)
S104:
TRANSMIT ENCRYPTED DATA c
S105
EXECUTE ABNORMALITY DETERMINATION ALGORITHM
r ← Process (c, f, pk)
S106: TRANSMIT OUTPUT RESULT r
S107
DECRYPT OUTPUT RESULT r
R ← Dec (r, sk)
S108
NO
ABNORMALITY?
YES
S109: TRANSMIT IMAGE DATA p
S110
DISPLAY IMAGE DATA p

FIG. 8

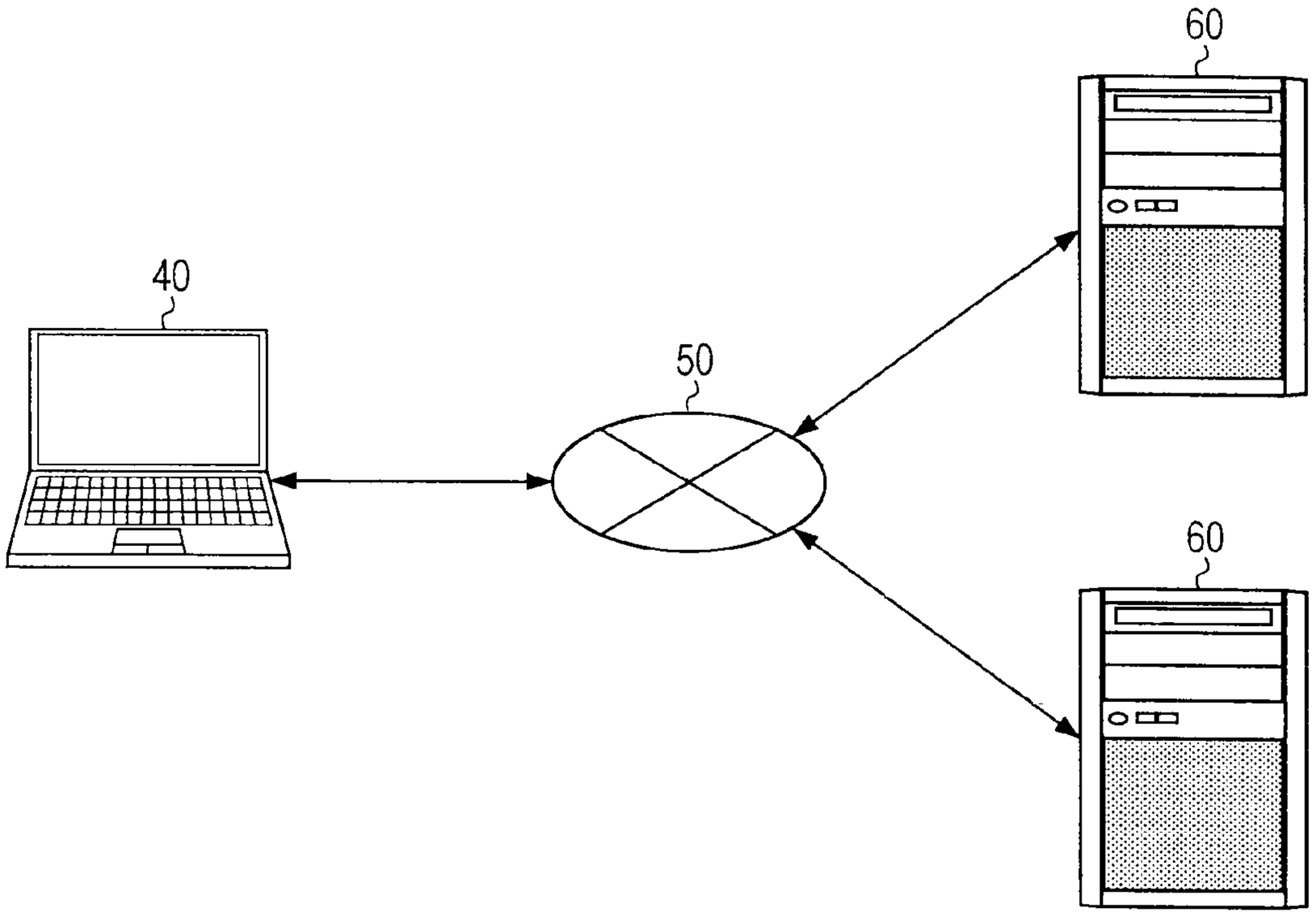


FIG. 9

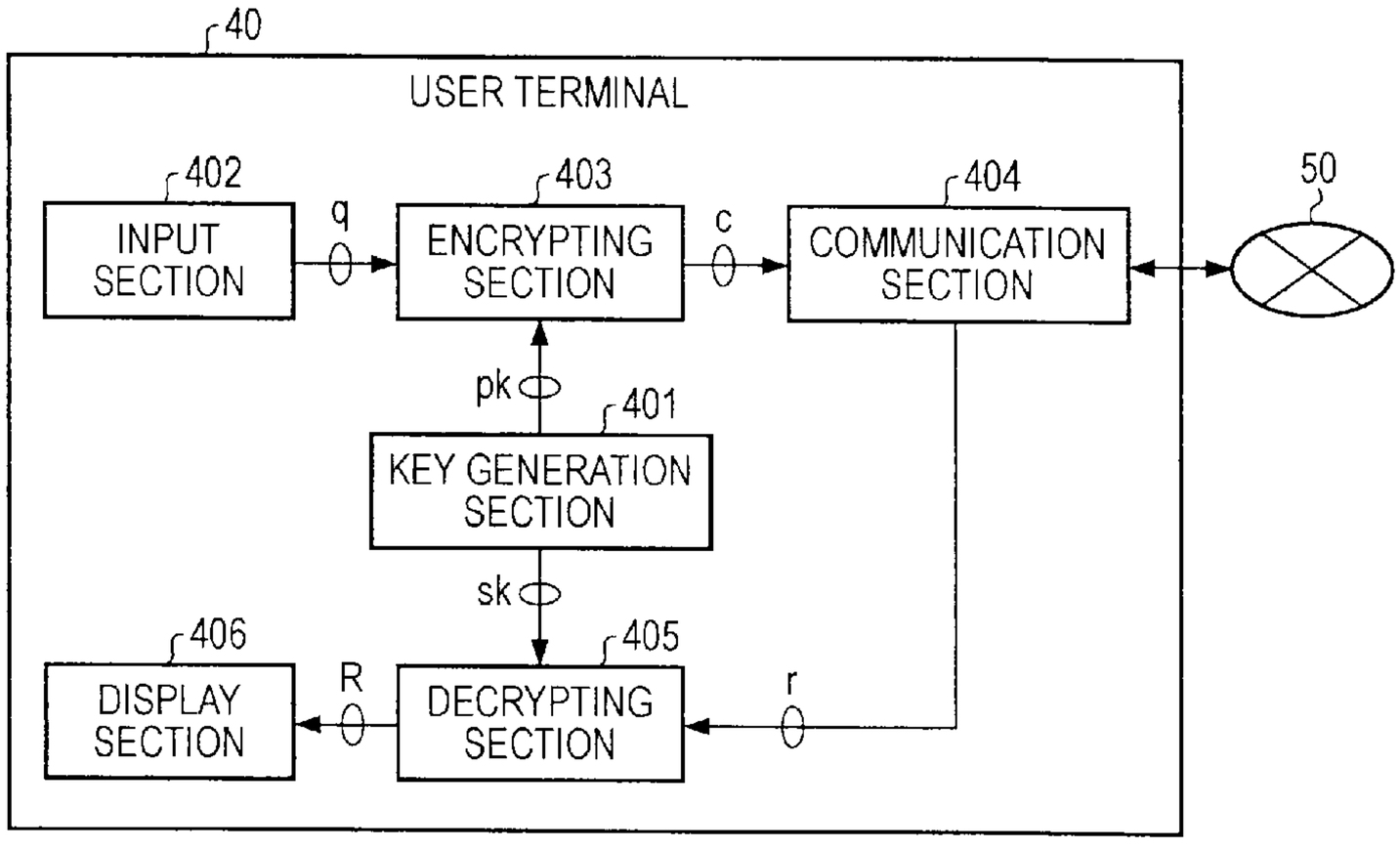

40
USER TERMINAL
402
INPUT SECTION
q
403
ENCRYPTING SECTION
c
404
COMMUNICATION SECTION
50
pk
401
KEY GENERATION SECTION
sk
406
DISPLAY SECTION
R
405
DECRYPTING SECTION
r

FIG. 10

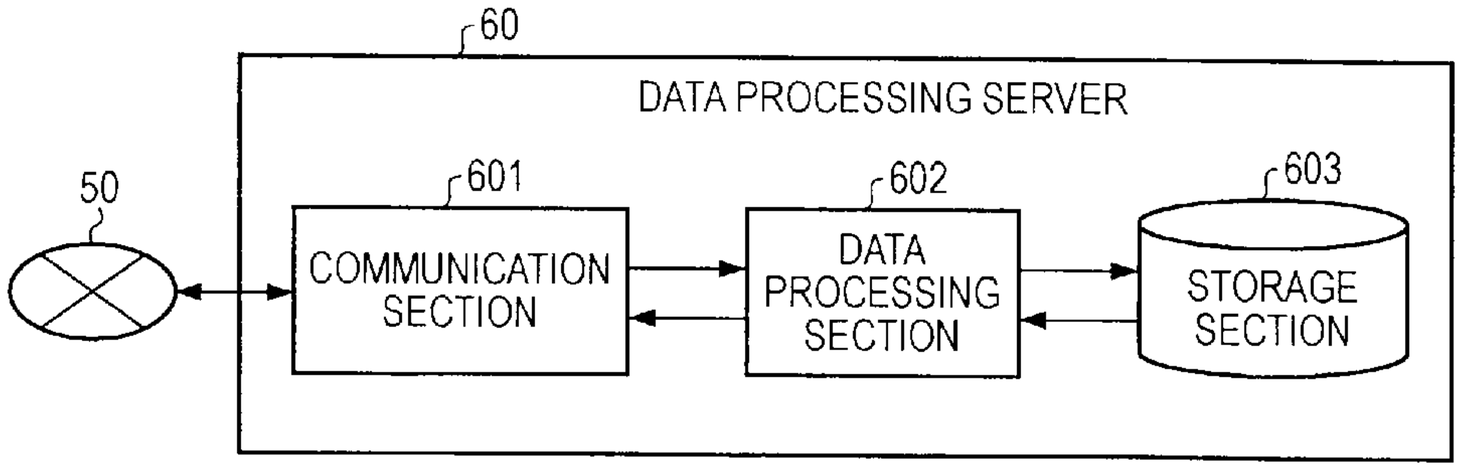

60
DATA PROCESSING SERVER
50
601
COMMUNICATION SECTION
602
DATA PROCESSING SECTION
603
STORAGE SECTION

FIG. 11

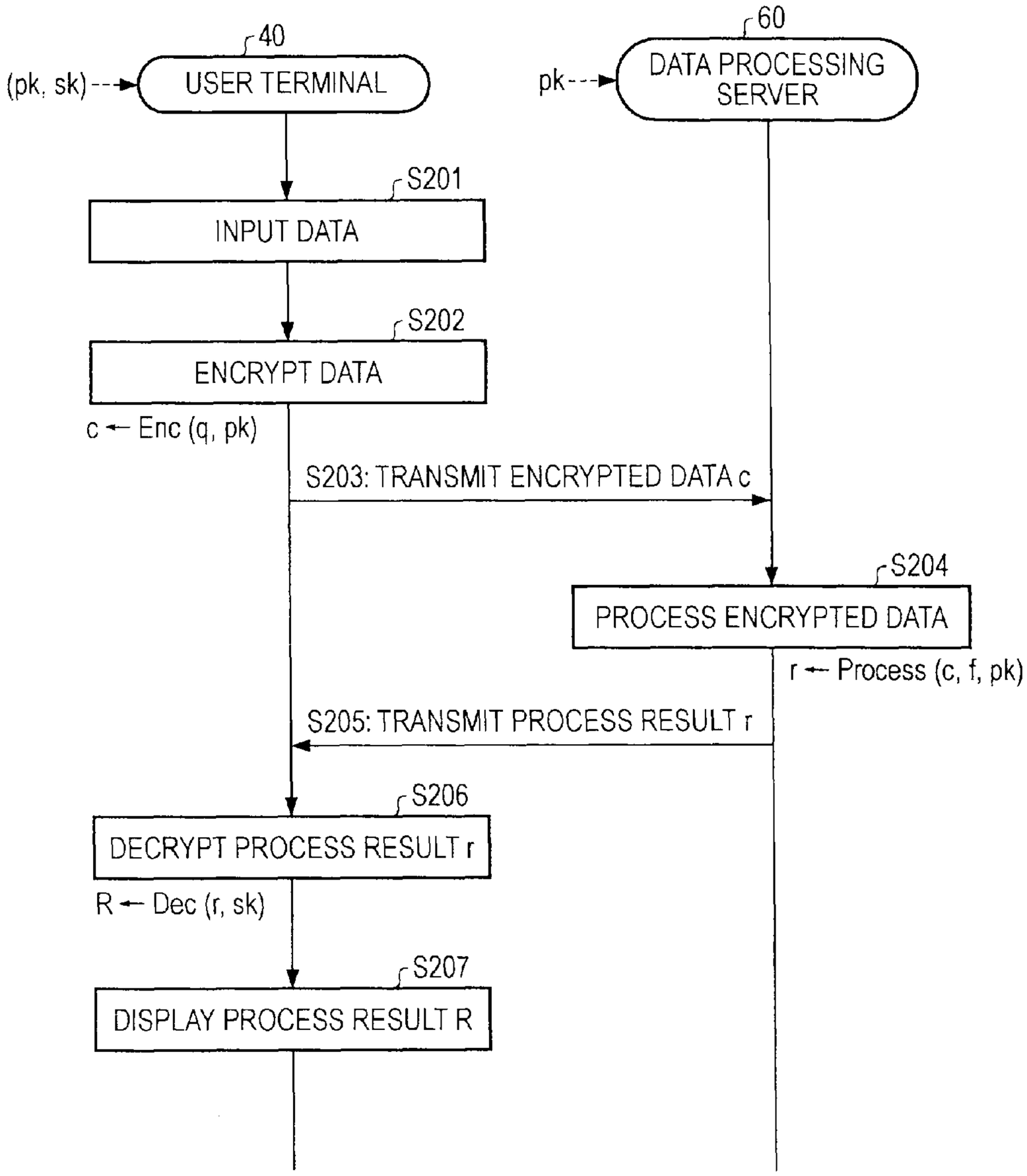

40
(pk, sk)
USER TERMINAL
60
pk
DATA PROCESSING SERVER
S201
INPUT DATA
S202
ENCRYPT DATA
c ← Enc (q, pk)
S203: TRANSMIT ENCRYPTED DATA c
S204
PROCESS ENCRYPTED DATA
r ← Process (c, f, pk)
S205: TRANSMIT PROCESS RESULT r
S206
DECRYPT PROCESS RESULT r
R ← Dec (r, sk)
S207
DISPLAY PROCESS RESULT R

FIG. 12

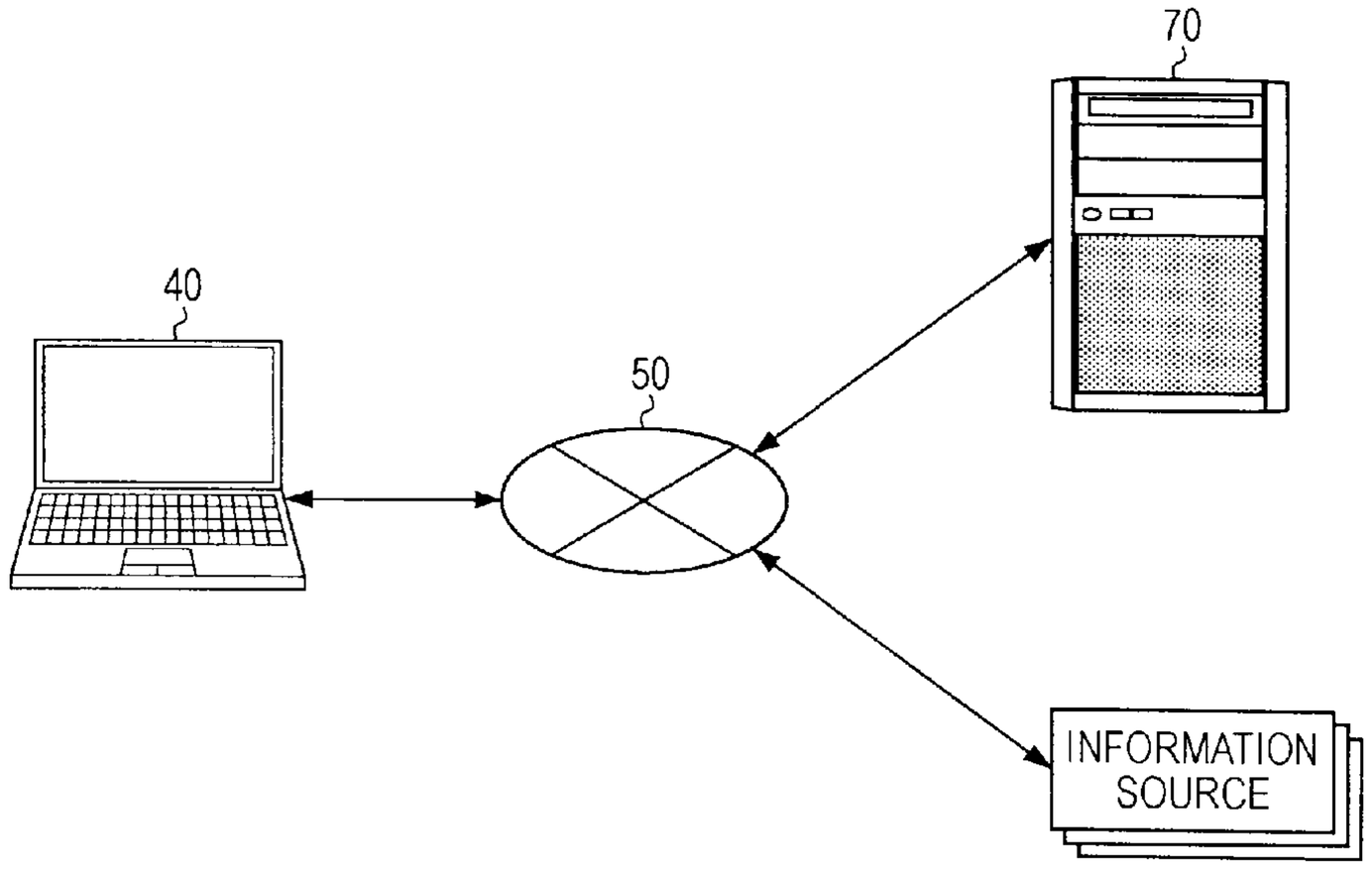

70
40
50
INFORMATION SOURCE

FIG. 13

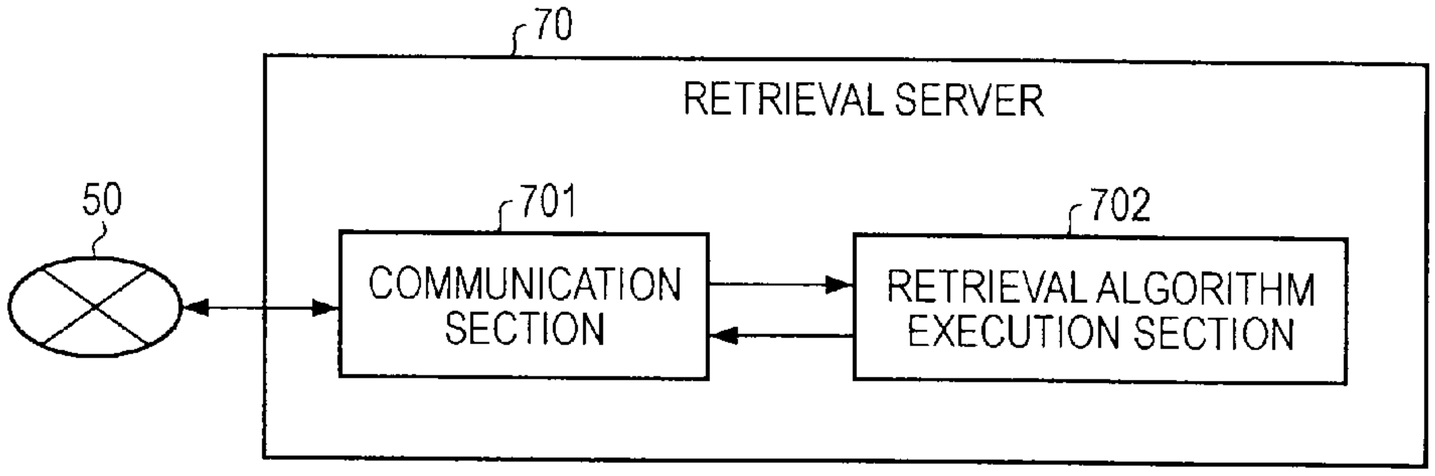

70
RETRIEVAL SERVER
50
701
COMMUNICATION SECTION
702
RETRIEVAL ALGORITHM EXECUTION SECTION

FIG. 14

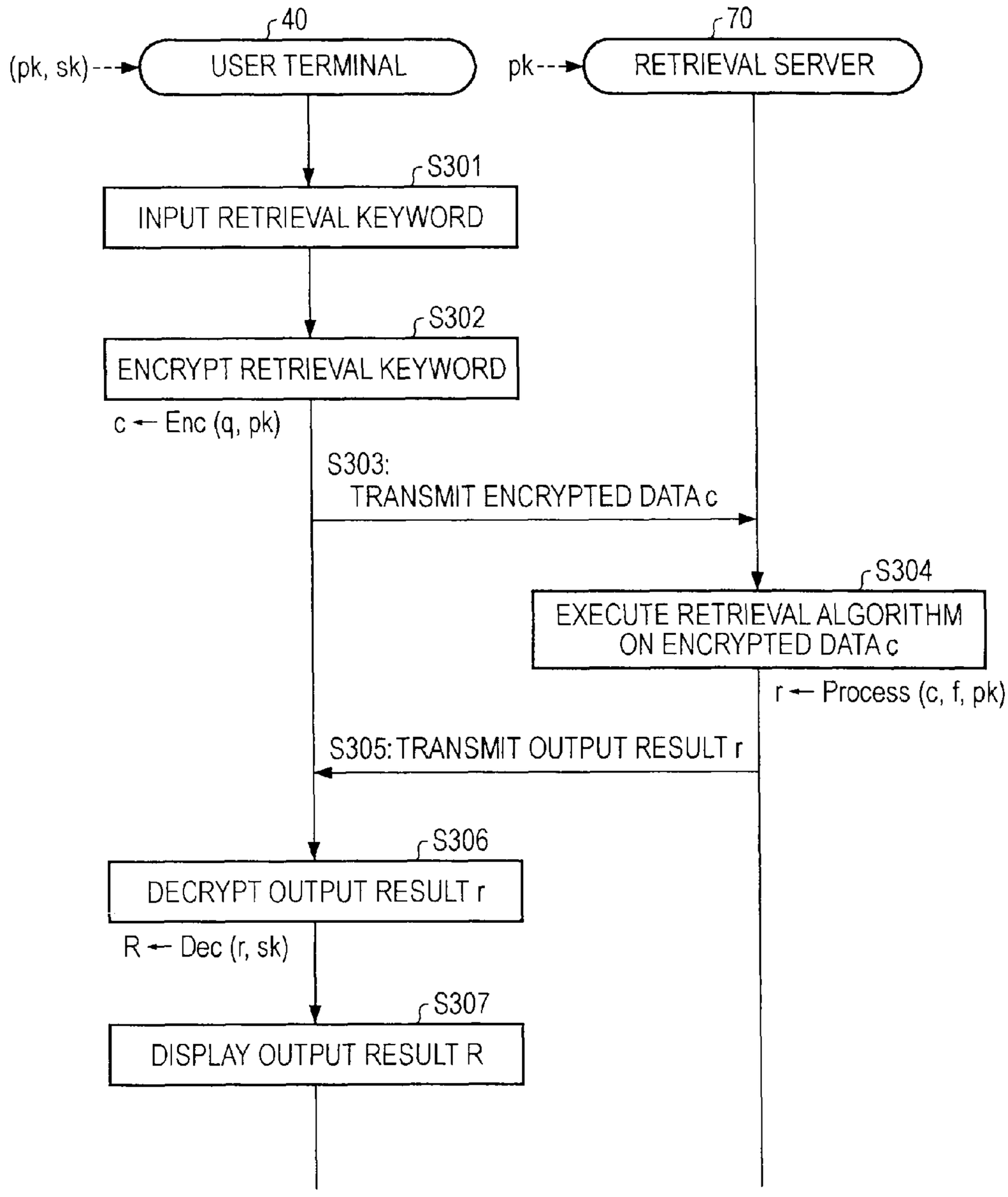
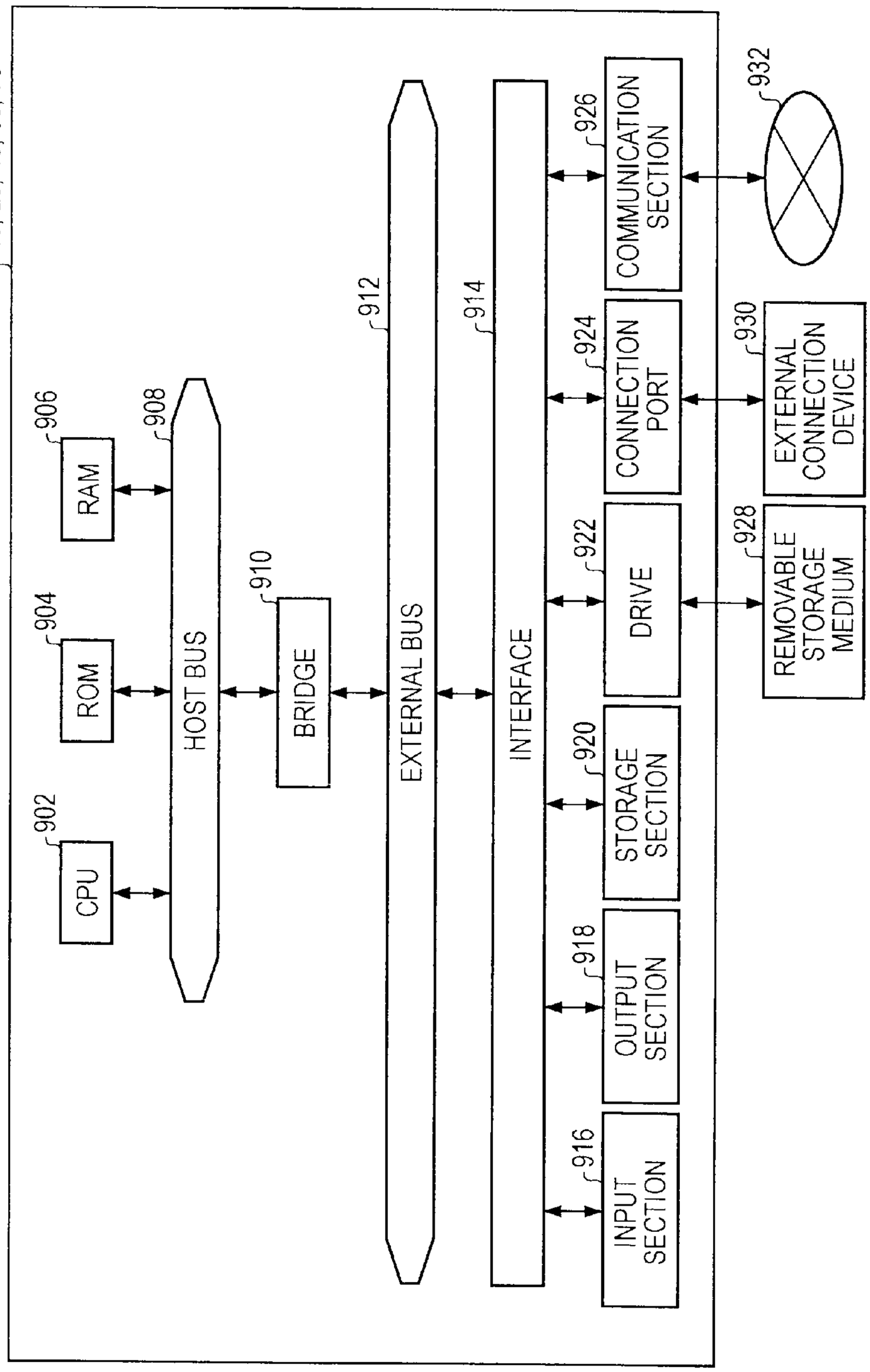

40
(pk, sk)
USER TERMINAL
70
pk
RETRIEVAL SERVER
S301
INPUT RETRIEVAL KEYWORD
S302
ENCRYPT RETRIEVAL KEYWORD
c ← Enc (q, pk)
S303:
TRANSMIT ENCRYPTED DATA c
S304
EXECUTE RETRIEVAL ALGORITHM ON ENCRYPTED DATA c
r ← Process (c, f, pk)
S305: TRANSMIT OUTPUT RESULT r
S306
DECRYPT OUTPUT RESULT r
R ← Dec (r, sk)
S307
DISPLAY OUTPUT RESULT R

FIG. 15


10, 20, 40, 60, 70
902
CPU
904
ROM
906
RAM
908
HOST BUS
910
BRIDGE
912
EXTERNAL BUS
914
INTERFACE
916
INPUT SECTION
918
OUTPUT SECTION
920
STORAGE SECTION
922
DRIVE
924
CONNECTION PORT
926
COMMUNICATION SECTION
928
REMOVABLE STORAGE MEDIUM
930
EXTERNAL CONNECTION DEVICE
932

TERMINAL DEVICE, SERVER, DATA PROCESSING SYSTEM, DATA PROCESSING METHOD, AND PROGRAM

BACKGROUND

The present disclosure relates to a terminal device, a server, a data processing system, a data processing method, and a program.

In recent years, there has been increasing demand for monitoring camera systems for security reasons. The monitoring camera system includes mainly a monitoring camera for capturing a monitoring target and a monitoring server for analyzing video data which is captured by the monitoring camera. An observer checks the video data captured by the monitoring camera through a display connected to the monitoring server. In addition, as the analysis result of the video data, when there is an abnormality in the monitoring target, the monitoring server issues an alarm or explicitly shows the observer abnormality portions in the video data. Recently, the analysis technology of the video data has been advanced, so that the observer can effectively detect the abnormality of the monitoring target with high probability.

On the other hand, since the observer may check the video data even when there is no abnormality in the monitoring target, there is concern of an invasion of privacy. In order to remove such concerns, a mechanism in which the observer is not able to see the portions having no abnormality of the monitoring target in the video data is being considered. For example, in the following Japanese Unexamined Patent Application Publication No. 2005-269489, a masking technology is disclosed in which the portions having no abnormality of the monitoring target are masked in the video data. According to the technology, an abnormality detection mechanism and a masking mechanism are installed in the monitoring camera, so that the monitoring camera generates the video data in which the portions having no abnormality are masked, and transmits it to the monitoring server. Using the technology, the observer is not able to see the portions in which abnormality is not detected, so that an invasion of privacy can be avoided.

SUMMARY

In the technology described in Japanese Unexamined Patent Application Publication No. 2005-269489, installing the abnormality determination mechanism in the monitoring camera is the premise. However, in the case that the abnormality determination mechanism is installed in the monitoring camera, when the monitoring camera is reverse-engineered, there may be a risk of an abnormality detection logic of the abnormality detection mechanism being exposed. For this reason, on the premise that the abnormality detection mechanism is installed in the monitoring server, a mechanism for transmitting only the video data in which there is an abnormality to the monitoring server is sought. In other words, the mechanism, in which the abnormality detection of the video data is implemented by the monitoring server without letting the monitoring server know the contents of the video data, is sought.

In addition, though different from the monitoring camera system, in a server-client system in which data is processed by the server, the same mechanism is requested even when the data input from a client terminal is processed by the server without letting the server know the contents of the data. For example, in a retrieval system, it may be considered that a retrieval process is implemented by the retrieval server without letting the retrieval server know the retrieval keyword input from the client terminal. In addition, in a cloud system, it may be considered that a predetermined process is implemented by the cloud server without letting the cloud server know the input data from the client terminal.

The present disclosure has been made to address the above-mentioned problems, and it is desirable to provide: a novel and improved data processing system, which can make the server implement a process against the input data without letting the server know the contents of the processing input data; a terminal device and the server which are included in the data processing system; a data processing method used in the data processing system; and a program.

In order to solve the above-mentioned problems, according to an embodiment of the disclosure, there is provided a terminal device including: an encrypting section encrypting input data in a fully homomorphic encryption scheme to generate encrypted data; an encrypted data transmission section transmitting the encrypted data generated by the encrypting section to a server; an encrypted data reception section receiving the encrypted data on which the server implements a predetermined process; and a decrypting section decrypting the encrypted data on which the predetermined process is implemented.

In addition, the terminal device may further include an imaging section capturing a subject to generate image data. In this case, the encrypting section encrypts the image data generated by the imaging section to generate encrypted data, and the predetermined process is a process in which the encrypted data is input to an abnormality determination algorithm for determining an abnormality in the subject based on the image data and a determination result output from the abnormality determination algorithm is output as encrypted data on which the predetermined process is implemented.

In addition, the terminal device may further include: an abnormality determination section determining whether there is an abnormality in the determination result after the encrypted data on which the decrypting section implements the predetermined process is decrypted and the determination result is output from the abnormality determination algorithm; and an image data transmission section transmitting the image data generated by the imaging section to the server when there is an abnormality in the determination result of the abnormality determination section.

In addition, the terminal device may further include a key holding section holding a public key and a secret key based on the fully homomorphic encryption scheme. In this case, the encrypting section encrypts input data using the public key which is held by the key holding section; and the decrypting section decrypts the encrypted data on which the predetermined process is implemented, using the secret key which is held by the key holding section.

In addition, the predetermined process may be implemented using the public key.

In addition, the terminal device may further include an input section inputting retrieval data, and a display section displaying a retrieval result based on the retrieval data. In this case, the encrypting section encrypts the retrieval data, which is input by the input section, to generate encrypted data; the predetermined process is a process in which the encrypted data is input to a retrieval algorithm for retrieving information based on the retrieval data and outputs the retrieval result output from the retrieval algorithm as the encrypted data on which the predetermined process is implemented; and after the encrypted data on which the predetermined process is implemented is decrypted by the decrypting section and the

retrieval result output from the retrieval algorithm is obtained, the display section displays the retrieval algorithm.

According to an embodiment of the disclosure, to solve the above-mentioned problems, there is provided a server including: an encrypted data reception section receiving encrypted data from a terminal device, the encrypted data being obtained by encrypting input data in a fully homomorphic encryption scheme; a process section implementing a predetermined process on the encrypted data; and an encrypted data transmission section transmitting the encrypted data to the terminal device, the predetermined process being implemented on the encrypted data.

According to still another embodiment of the disclosure, to solve the above-mentioned problems, there is provided a data processing system including: a terminal device which includes an encrypting section encrypting input data in a fully homomorphic encryption scheme to generate encrypted data, a first transmission section transmitting the encrypted data to a server, the encrypted data being generated by the encrypting section, a first reception section receiving the encrypted data on which the server implements a predetermined process, and a decrypting section decrypting the encrypted data on which the predetermined process is implemented; and a server which includes a second reception section receiving the encrypted data transmitted from the first transmission section, a process section implementing the predetermined process on the encrypted data, and a second transmission section transmitting the encrypted data to the terminal device, the predetermined process being implemented on the encrypted data.

According to still another embodiment of the disclosure, to solve the above-mentioned problems, there is provided a data processing method including: causing a terminal device to encrypt input data in a fully homomorphic encryption scheme to generate encrypted data, and to transmit the encrypted data to a server, the encrypted data being generated in the encrypting of the input data; causing the server to receive the encrypted data which is transmitted in the transmitting of the encrypted data to the server, to implement a predetermined process on the encrypted data, and to transmit the encrypted data to the terminal device, the predetermined process being implemented on the encrypted data; and causing the terminal device to receive the encrypted data on which the server implements the predetermined process, and to decrypt the encrypted data on which the predetermined process is implemented.

According to still another embodiment of the disclosure, to solve the above-mentioned problems, there is provided a program causing a computer to execute: an encrypting function of encrypting input data in a fully homomorphic encryption scheme to generate encrypted data; an encrypted data transmission function of transmitting the encrypted data generated by the encrypting function to a server; an encrypted data reception function of receiving the encrypted data on which the server implements a predetermined process; and a decrypting function of decrypting the encrypted data on which the predetermined process is implemented.

According to still another embodiment of the disclosure, to solve the above-mentioned problems, there is provided a program causing a computer to execute: an encrypted data reception function of receiving encrypted data from a terminal device, the encrypted data being obtained by encrypting input data in a fully homomorphic encryption scheme; a process function of implementing a predetermined process on the encrypted data; and an encrypted data transmission function of transmitting the encrypted data to the terminal device, the predetermined process being implemented on the encrypted data.

In addition, according to still another embodiment of the disclosure, to solve the above-mentioned problems, there is provided a computer readable recording medium in which the program is recorded.

According to the present disclosure as described above, the processing of the input data can be performed by the server, without revealing the contents of the input data to be processed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an explanatory diagram illustrating the system configuration of a monitoring camera system according to a first embodiment of the present disclosure;

FIG. **2** is an explanatory diagram illustrating the functional configuration of a monitoring camera according to the first embodiment;

FIG. **3** is an explanatory diagram illustrating the functional configuration of a monitoring server according to the first embodiment;

FIG. **4** is an explanatory diagram illustrating the functional configuration of an image analysis section according to the first embodiment;

FIG. **5** is an explanatory diagram illustrating the functional configuration of an abnormality determination algorithm generation section according to the first embodiment;

FIG. **6** is an explanatory diagram illustrating the characteristics of a fully homomorphic encryption;

FIG. **7** is an explanatory diagram illustrating an abnormality determination processing flow of the monitoring camera system according to the first embodiment;

FIG. **8** is an explanatory diagram illustrating the system configuration of a data processing system according to a second embodiment of the present disclosure;

FIG. **9** is an explanatory diagram illustrating the functional configuration of a user terminal according to the second embodiment;

FIG. **10** is an explanatory diagram illustrating the functional configuration of a data processing server according to the second embodiment;

FIG. **11** is an explanatory diagram illustrating a data processing flow of the data processing system according to the second embodiment;

FIG. **12** is an explanatory diagram illustrating the system configuration of a retrieval system according to a third embodiment of the present disclosure;

FIG. **13** is an explanatory diagram illustrating the functional configuration of the retrieval server according to the third embodiment;

FIG. **14** is an explanatory diagram illustrating the flow of a retrieval process of the retrieval system according to the third embodiment; and

FIG. **15** is an explanatory diagram illustrating the hardware configuration for implementing functions of the monitoring camera, the monitoring server, the user terminal, the data processing server, and the retrieval server according to the embodiments of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, preferred embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. Further, in the present specification and the drawings, the components having substantially the same

functional configurations are designated by the same reference numerals, and the description already given will be omitted.

Description Flow

Here, the flow of descriptions of the embodiments of the disclosure will be briefly stated below. First, referring to FIG. **1**, a system configuration of a monitoring camera system according to a first embodiment of the present disclosure will be described. Next, referring to FIG. **2**, a functional configuration of a monitoring camera **10** according to the first embodiment will be described. Next, referring to FIG. **3**, a functional configuration of a monitoring server **20** according to the first embodiment will be described.

Then, referring to FIG. **4**, a functional configuration of an image analysis section **21** according to the first embodiment will be described. Next, referring to FIG. **5**, a functional configuration of an abnormality determination algorithm generation section **22** according to the first embodiment will be described. Next, referring to FIG. **7**, the flow of an abnormality determination process in the monitoring camera system according to the first embodiment will be described. Further, referring to FIG. **6**, the characteristics of a fully homomorphic encryption in the above description will be described.

Then, referring to FIG. **8**, a system configuration of a data processing system according to a second embodiment of the present disclosure will be described. Next, referring to FIG. **9**, a functional configuration of a user terminal **40** according to the second embodiment will be described. Next, referring to FIG. **10**, a functional configuration of a data processing server **60** according to the second embodiment will be described. Next, referring to FIG. **11**, the flow of data processing in the data processing system according to the second embodiment will be described.

Then, referring to FIG. **12**, a system configuration of a retrieval system according to a third embodiment of the present disclosure will be described. Next, referring to FIG. **13**, a functional configuration of a retrieval server **70** according to the third embodiment will be described. Further, since the functional configuration of the user terminal **40** included in the retrieval system according to the third embodiment is substantially equal to the functional configuration of the user terminal **40** according to the second embodiment, the description of the functional configuration of the user terminal **40** will be omitted. Next, referring to FIG. **14**, the flow of the retrieval process according to the third embodiment will be described.

Then, referring to FIG. **15**, an example of the hardware configurations for implementing the functions of the monitoring camera **10**, the monitoring server **20**, the user terminal **40**, the data processing server **60**, and the retrieval server **70** according to the embodiments of the present disclosure will be described. Finally, the technical ideas according to the embodiments of the present disclosure will be summed up, and operational advantages which can be obtained from the technical ideas will be described in brief.

DESCRIPTION CONTENTS

1: First Embodiment

The first embodiment of the present disclosure will be described. The first embodiment relates to the monitoring camera system which is devised to not invade privacy unnecessarily.

1-1: System Configuration of Monitoring Camera System

First, referring to FIG. **1**, the system configuration of the monitoring camera system according to the first embodiment will be described. FIG. **1** is a diagram illustrating the system configuration of the monitoring camera system according to the first embodiment.

As shown in FIG. **1**, the monitoring camera system includes mainly the monitoring camera **10**, the monitoring server **20**, and a display **30**. Further, in FIG. **1**, the monitoring camera system is illustrated to have two monitoring cameras **10** (#**1**, #**2**), but the number of monitoring cameras **10** is not limited to two. For example, the technology of the embodiment may either be applied to the monitoring camera system having only one monitoring camera **10**, or to the monitoring camera system having three or more monitoring cameras **10**.

The monitoring camera **10** is an imaging device to capture a monitoring target. Further, the monitoring camera **10** is connected to the monitoring server **20**. The monitoring camera **10** and the monitoring server **20** may be connected through a transmission cable, a network, or a radio communication network. However, in the following, the description will proceed assuming that the monitoring camera **10** and the monitoring server **20** are connected through the transmission cable.

When capturing a monitoring target, the monitoring camera **10** encrypts the captured image data. Then, the monitoring camera **10** transfers the encrypted data, which is obtained by encrypting the image data, to the monitoring server **20**. If the image data is transferred to the monitoring server **20** without the encryption, even though there is no abnormality in the monitoring target, the image data obtained by capturing the monitoring target will be shown to an observer. In other words, the privacy of the monitoring target is invaded unnecessarily. In the configuration of the embodiment, when the image data is transferred to the monitoring server **20**, the image data is encrypted. Of course, it is assumed that the encrypted data may not be decrypted by the monitoring server **20**. In addition, the monitoring camera **10** encrypts the image data based on a fully homomorphic encryption scheme to be described later.

As described above, when the monitoring target is captured, the encrypted data is transferred from the monitoring camera **10** to the monitoring server **20**. When the encrypted data is transferred, the monitoring server **20** performs a process of determining whether there is an abnormality in the monitoring target using the encrypted data. Specifically, the monitoring server **20** inputs the encrypted data, which is

transferred from the monitoring camera **10**, to an abnormality determination algorithm for the determination of the abnormality in the input image data. In this case, the abnormality determination algorithm is assumed to be included in the monitoring server **20** in advance. Then, when the abnormality determination algorithm outputs an operation result, the monitoring server **20** transfers the operation result output from the abnormality determination algorithm to the monitoring camera **10**.

Further, since the fully homomorphic encryption scheme is used for encrypting the image data, the operation result output from the abnormality determination algorithm corresponds to an encrypted operation result which is obtained when the image data is input to the abnormality determination algorithm. When the operation result output from the abnormality determination algorithm is transferred from the monitoring server **20** to the monitoring camera **10**, the monitoring camera **10** decrypts the operation result to obtain an operation result (hereinafter, referred to as an abnormality determination result) which is obtained when the image data is input to the abnormality determination algorithm. When the abnormality determination result is obtained, if there has been an abnormality in the monitoring target, the monitoring camera **10** transfers an unencrypted image data to the monitoring server **20** with reference to the abnormality determination result.

When the unencrypted image data is transferred to the monitoring server **20**, the monitoring server **20** displays the image data onto the display **30**. When the image data is displayed in the display **30**, the observer checks the image data displayed onto the display **30** to visually determine whether there is an abnormality in the monitoring target. As described above, the abnormality determination algorithm remains maintained in the monitoring server **20**. In addition, when there is no abnormality in the monitoring target, the image data of the monitoring target captured by the monitoring camera **10** is not transferred to the monitoring server **20**. For this reason, when there is no abnormality in the monitoring target, the image data of the monitoring target is not shown to the observer, so that the unnecessary invasion of privacy can be avoided.

Fully Homomorphic Encryption Scheme

Here, the description of the fully homomorphic encryption scheme will be supplemented. The fully homomorphic encryption has the characteristics as shown in FIG. **6**. Further, in the following, input data is denoted by "p", a public key and a secret key of the fully homomorphic encryption scheme by "pk" and "sk" respectively, and a processing function of implementing a predetermined processing algorithm by "f".

First, take note of the process designated by Process #**1** of FIG. **6**. Process #**1** includes the three steps of the encrypting, the process A, and the decrypting. In the encrypting, the input data p is encrypted using the public key pk to generate the encrypted data c (c←Enc(p, pk)). In the subsequent process A, a predetermined process is implemented on the encrypted data c using the process function f and the public key pk, and obtains the process result r (r←Process(c, f, pk)). In the subsequent decrypting, the decrypting process is implemented on the process result r using the secret key sk, and the decrypting result R' is generated (R'←Dec(r, sk)).

Next, take note of the process designated by Process #**2** of FIG. **6**. Process #**2** includes the process B. In the process B, a predetermined process is implemented on the input data p using the process function f, and the process result R is obtained (R←Process(p, f)). As described above, Process #**1** is the process in which the input data p is encrypted and then the process function f is implemented thereon, and Process #**2** is the process in which the process function f is implemented while the input data p is not encrypted.

The characteristics of the fully homomorphic encryption consist in something that the results R and R' obtained from these two processes are equivalent to each other. Further, for the detailed description of the fully homomorphic encryption scheme, refer to the documents, for example, "Fully Homomorphic Encryption Using Ideal Lattices" (Craig Gentry), and "Fully Homomorphic Encryption over the Integers" (Marten van Dijk, Craig Gentry, Shai Halevi, and Vinod Vaikuntanathian).

Using the characteristics of the fully homomorphic encryption, the process of the process function f on the input data p shown in Process #**2** can be replaced with three steps such as those in the case of Process #**1**. In addition, in the case of Process #**1**, since the process A is implemented in a state where the input data p is encrypted, even if another person implements the process A, they are not able to know the contents of the input data p. In other words, by using the characteristics of the fully homomorphic encryption, the process on the input data p (the processing of the process function f) can be implemented by other people without letting them know the contents of the input data p.

As for the description of the correspondence with the monitoring camera system, the encrypting corresponds to a process of encrypting the image data in the monitoring camera **10**. In addition, the process A corresponds to a process of the monitoring server **20** implementing the abnormality determination algorithm in which the encrypted data is input. The decrypting corresponds to a process in which the monitoring camera **10** obtains the abnormality determination result. In other words, with the characteristics of the fully homomorphic encryption, the abnormality determination process on the image data can be performed by the observer without letting the observer show the image data.

Hereinbefore, the system configuration of the monitoring camera system according to the embodiment has been described. In the following, the function of the respective components included in the monitoring camera system will be described in more detail.

1-2: Functional Configuration of Monitoring Camera **10**

First, referring to FIG. **2**, the functional configuration of the monitoring camera **10** according to the embodiment will be described. FIG. **2** is a diagram illustrating the functional configuration of the monitoring camera **10** according to the embodiment.

As shown in FIG. **2**, the monitoring camera **10** includes mainly a key generation section **101**, an imaging section **102**, an image storage section **103**, an encrypting section **104**, a communication section **105**, a decrypting section **106**, and an image transmission section **107**.

The key generation section **101** is a part which generates the public key pk and the secret key sk of the fully homomorphic encryption scheme. The public key pk generated by the key generation section **101** is input to the encrypting section **104**. On the other hand, the secret key sk generated by the key generation section **101** is input to the decrypting section **106**. The public key pk input to the encrypting section **104** is maintained by the encrypting section **104**. In addition, the secret key sk input to the decrypting section **106** is maintained by the decrypting section **106**. Further, the public key pk generated by the key generation section **101** is also supplied to the monitoring server **20**. In addition, the public key pk supplied to the monitoring server **20** is maintained by the monitoring server **20**.

The imaging section **102** is a part which captures the monitoring target to generate the image data p. The image data p

generated by the imaging section **102** is sequentially stored in the image storage section **103**. Then, the image data p stored in the image storage section **103** is read by the encrypting section **104**. The encrypting section **104** having read the image data p encrypts the image data p using the public key pk to generate the encrypted data c (c←Enc(p, pk)). The encrypted data c generated by the encrypting section **104** is input to the communication section **105**. When the encrypted data c is input, the communication section **105** transfers the input encrypted data c to the monitoring server **20**.

When the encrypted data c is transferred to the monitoring server **20**, the monitoring server **20** implements the process f based on the abnormality determination algorithm for the encrypted data c (r←Process(c, f, pk)), and then transfers the process result r to the monitoring camera **10**. The process result r transferred from the monitoring server **20** is received by the communication section **105**, and then input to the decrypting section **106**. The decrypting section **106**, having received the process result r, implements a decrypting process on the input process result r using the secret key sk to obtain the abnormality determination result R (R←Dec(r, sk)). The abnormality determination result R obtained by the decrypting process of the decrypting section **106** is input to the image transmission section **107**.

When the abnormality determination result R is input, the image transmission section **107** determines whether the abnormality determination result R represents "Abnormality", and if so, the image data p is read from the image storage section **103**. When the abnormality determination result R represents "Abnormality", the image transmission section **107** inputs the image data p read from the image storage section **103** to the communication section **105**. When the image data p is input, the communication section **105** transfers the input image data p to the monitoring server **20**. Further, when the abnormality determination result R represents "No Abnormality", the image transmission section **107** does not read the image data p from the image storage section **103**. For this reason, when there is no abnormality in the monitoring target, the image data p is not transferred to the monitoring server **20**.

Hereinbefore, the functional configuration of the monitoring camera **10** has been described.

1-3: Functional Configuration of Monitoring Server **20**

Next, referring to FIG. **3**, the functional configuration of the monitoring server **20** according to the embodiment will be described. FIG. **3** is a diagram illustrating the functional configuration of the monitoring server **20** according to the embodiment.

As shown in FIG. **3**, the monitoring server **20** includes mainly the image analysis section **21** and the abnormality determination algorithm generation section **22**.

The image analysis section **21** is a part which analyzes the image data transferred from the monitoring camera **10** to detect the abnormality of the monitoring target included in the image data. In addition, the abnormality determination algorithm generation section **22** is the part which generates the abnormality determination algorithm for determining whether there is an abnormality in the monitoring target included in the image data. The abnormality determination algorithm generated by the abnormality determination algorithm generation section **22** is input to the image analysis section **21**. Then, the image analysis section **21** analyzes the image data input from the monitoring camera **10**, using the abnormality determination algorithm generated by the abnormality determination algorithm generation section **22**.

However, in the embodiment, the image data is not transferred from the monitoring camera **10** to the monitoring server **20** until the monitoring target is determined to be abnormal. Alternatively, when the determination of whether there is an abnormality in the monitoring target is implemented, the encrypted data generated by encrypting the image data is input to the image analysis section **21**. Then, the image analysis section **21** inputs the encrypted data to the abnormality determination algorithm, and transfers the determination result output from the abnormality determination algorithm to the monitoring camera **10**. Further, the analysis process itself of the image analysis section **21** is substantially the same as the analysis process on the image data. The difference is the kind of data which is input to the abnormality determination algorithm.

On the other hand, when there is an abnormality in the monitoring target, the image data is transferred from the monitoring camera **10** to the monitoring server **20**. In this case, the image analysis section **21** receives the image data which is transferred from the monitoring camera **10**, and then displays the image data in the display **30**. When the image data is displayed in the display **30**, the observer refers to the image data displayed in the display **30** to visually determine whether there is an abnormality in the monitoring target. In addition, the image analysis section **21** maintains the image data which is transferred from the monitoring camera **10**.

1-3-1: Functional Configuration of Image Analysis Section **21**

Here, referring to FIG. **4**, the functional configuration of the image analysis section **21** will be described in more detail. FIG. **4** is a diagram illustrating the functional configuration of the image analysis section **21** according to the embodiment.

As shown in FIG. **4**, the image analysis section **21** includes a communication section **211**, an abnormality determination algorithm execution section **212**, an image reception section **213**, and a storage section **214**.

The communication section **211** is a part which receives the encrypted data or the image data from the monitoring camera **10**, or transfers the determination result to the monitoring camera **10**. In addition, the abnormality determination algorithm execution section **212** is the part which inputs the encrypted data to the abnormality determination algorithm generated by the abnormality determination algorithm generation section **22** and implements the process based on the abnormality determination algorithm. The process result based on the abnormality determination algorithm is transferred to the monitoring camera **10** via the communication section **211**. The image reception section **213** is a part which receives the image data transferred from the monitoring camera **10** when it is determined that there is an abnormality in the monitoring target. The image reception section **213** having received the image data, stores the received image data in the storage section **214**, and displays the image data in the display **30**.

1-3-2: Functional Configuration of Abnormality Determination Algorithm Generation Section **22**

Next, referring to FIG. **5**, the functional configuration of the abnormality determination algorithm generation section **22** will be described in more detail. FIG. **5** is a diagram illustrating the functional configuration of the abnormality determination algorithm generation section **22** according to the embodiment.

As shown in FIG. **5**, the abnormality determination algorithm generation section **22** includes mainly a learning data collection section **221**, a storage section **222**, and a machine learning section **223**.

The learning data collection section **221** is a part which collects learning data used when the abnormality determination algorithm is generated. The learning data used for the

generation of the abnormality determination algorithm includes, for example, the image data and determination result data which represents whether there is an abnormality in the monitoring target included in the image data. The learning data may either be collected from the monitoring camera **10** or from an information source (not shown), and alternatively be given by the observer in advance. The learning data collected by the learning data collection section **221** is stored in the storage section **222**.

The learning data stored in the storage section **222** is read by the machine learning section **223**. The machine learning section **223** having read the learning data uses the read learning data to generate the abnormality determination algorithm by machine learning. The abnormality determination algorithm generated by the machine learning section **223** is provided to the image analysis section **21**.

Further, a machine learning method used by the machine learning section **223** is arbitrary. For example, the machine learning method, which is capable of generating a determiner for receiving the image data as an input and outputting whether there is an abnormality (for example, if there is no abnormality, outputting "0"; if there is an abnormality, outputting "1"), is conceivable. In addition, a machine learning method, which is capable of generating a determiner for receiving the image data as an input, combining a plurality of weak determiners which output "0" or "1", and finally outputting whether there is an abnormality based on the results output from all the weak determiners, is conceivable. For example, the machine learning method, which generates a determiner for determining the abnormality when the number of the weak determiners outputting "1" exceeds a predetermined ratio, is conceivable.

As described above, the monitoring server **20** according to the embodiment has a function of inputting the encrypted data to the abnormality determination algorithm, which can determine the abnormality of the monitoring target from the image data, and of transferring the output to the monitoring camera **10**. In addition, the monitoring server **20** has a function of maintaining the image data and of displaying the image data in the display **30** when the image data is transferred from the monitoring camera **10**.

Further, in the example of FIG. **3**, the configuration of the monitoring server **20** which generates the abnormality determination algorithm has been illustrated, but the abnormality determination algorithm may be provided from the outside to the monitoring server **20** in advance. In addition, the abnormality determination algorithm may be used which is generated by a method different from the machine learning. Furthermore, the abnormality determination algorithm generation section **22** may be configured to use the checking result of the image data, which is performed by the observer, in the generation process of the abnormality determination algorithm.

1-4: Flow of Abnormality Determination Process

Next, referring to FIG. **7**, the flow of the abnormality determination process according to the embodiment will be described. FIG. **7** is a diagram illustrating the flow of the abnormality determination process according to the embodiment. Further, the abnormality determination process shown in FIG. **7** is implemented by the monitoring camera **10** and the monitoring server **20**. In addition, the monitoring camera **10** is assumed to include the public key pk and the secret key sk of the fully homomorphic encryption scheme. Furthermore, the monitoring server **20** is assumed to include the public key pk of the fully homomorphic encryption scheme.

As shown in FIG. **7**, first, the monitoring server **20** generates the abnormality determination algorithm f (S**101**). In addition, the monitoring camera **10** captures the monitoring target and generates the image data p (S**102**). The monitoring camera **10** having generated the image data p encrypts the image data p using the public key pk, and generates the encrypted data c (S**103**). In other words, the monitoring camera **10** implements c←Enc(p, pk). Next, the monitoring camera **10** transfers the encrypted data c to the monitoring server **20** (S**104**).

The monitoring server **20** having received the encrypted data c inputs the received encrypted data c to the abnormality determination algorithm f, and implements the abnormality determination algorithm f using the public key pk (S**105**). In other words, the monitoring server **20** implements r←Process (c, f, pk), and obtains the output result r of the abnormality determination algorithm f. Next, the monitoring server **20** transmits the output result r of the abnormality determination algorithm f to the monitoring camera **10** (S**106**).

The monitoring camera **10**, which has received the output result r of the abnormality determination algorithm f, implements the decrypting process on the output result r of the abnormality determination algorithm f using the secret key sk to obtain the abnormality determination result R (S**107**). In other words, the monitoring camera **10** implements R←Dec (r, sk). The monitoring camera **10** that has obtained the abnormality determination result R determines whether the abnormality determination result R represents "Abnormality", and if so, the procedure proceeds to step S**109**. On the other hand, when the abnormality determination result R represents "No Abnormality", the monitoring camera **10** causes the procedure to proceed to step S**102**.

When the procedure proceeds to step S**109**, the monitoring camera **10** transmits the image data p generated in step S**102** to the monitoring server **20** (S**109**). The monitoring server **20** that has received the image data p displays the received image data p in the display **30** (S**110**). At this time, the monitoring server **20** maintains the image data p received from the monitoring camera **10**. When the image data p is displayed in the display **30**, the observer refers to the image data p displayed in the display **30** to visually determine whether there is an abnormality in the monitoring target.

Hereinbefore, the flow of the abnormality determination process according to the embodiment has been described. Further, in transmitting the image data p in step S**109**, an encryption key for communication may be used to encrypt the image data p. The encryption key for communication may either be an encryption key in a public key encryption scheme, or an encryption key in a common key encryption scheme. In addition, in the example of FIG. **7**, the abnormality determination algorithm f is described to be generated in step S**101**, but the abnormality determination algorithm f may be provided from the outside to the monitoring server **20** in advance.

Hereinbefore, the first embodiment of the present disclosure has been described. By applying the technology according to the embodiment, the abnormality determination algorithm may not necessarily be loaded on the monitoring camera **10**, and it is not necessary to transmit the image data having no abnormality to the monitoring server **20**. As a result, the risk of revealing the abnormality determination algorithm is avoided, and the unnecessary invasion of privacy can be prevented. In addition, even when the abnormality determination algorithm is updated, it is sufficient to update the abnormality determination algorithm in the monitoring server **20**, so that the cost for updating the algorithm can be suppressed to a low level. In other words, the observer does not have to go to the trouble of visually checking the image

data of the monitoring target having no abnormality, and the labor cost in monitoring can be suppressed to a low level.

2: Second Embodiment

Next, the second embodiment of the present disclosure will be described. The second embodiment relates to a data processing system in which the server performs the data processing. For example, the technology according to the embodiment may be applied to a cloud system, a thin client system, and the like.

2-1: System Configuration of Data Processing System

First, referring to FIG. **8**, the system configuration of the data processing system according to the embodiment will be described. FIG. **8** is a diagram illustrating the system configuration of the data processing system according to the embodiment.

As shown in FIG. **8**, the data processing system according to the embodiment includes mainly a user terminal **40** and a data processing server **60**. In addition, the user terminal **40** and the data processing server **60** are assumed to be connected to each other via a network **50**. Further, in FIG. **8**, the configuration of the data processing system having two data processing servers **60** (#**1**, #**2**) is illustrated as an example, but the number of the data processing servers **60** is not limited to two. For example, the technology of the embodiment may either be applied to the data processing system having only one data processing server **60**, or to the data processing system having three or more data processing servers **60**.

The user terminal **40** is a part through which a user inputs data, or which displays the data. For example, the user terminal **40** displays the execution screen of the application such as a web browser, a word processor, spreadsheet software, or image editing software, or receives a data input for the application. Further, display data for displaying the execution screen of the application may be provided from the data processing server **60** to the user terminal **40**, or may be generated by the user terminal **40**.

The data processing server **60** is a part which processes data transmitted from the user terminal **40**. In receiving the data to be processed from the user terminal **40**, the data processing server **60** implements a predetermined process on the received data, and transmits the processed data to the user terminal **40**. As an example of the predetermined process, a letter type conversion process, a keyword retrieval process, a calculation process using various functions, an information retrieval process for targeting an information source connected to the network **50**, various image processes, and processes related to various kinds of applications are exemplified.

However, the embodiment is to provide a mechanism in which the data processing server **60** implements the data processing, while the processing data is not informed to the data processing server **60**. In other words, the embodiment is to provide the configuration in which the contents of the processing data input to the user terminal **40** is not revealed to the data processing server **60**, so as not to invade user privacy. For the purpose of realizing the above configuration, in order not to transmit the processing data as it is to the data processing server **60**, the user terminal **40** encrypts the processing data in the fully homomorphic encryption scheme, and transmits the encrypted data (hereinafter, referred to as encrypted data) to the data processing server **60**.

In addition, the data processing server **60** having received the encrypted data implements a predetermined process on the received encrypted data, and transmits the data obtained after the process (hereinafter, referred to as processed data) to the user terminal **40**. Then, the user terminal **40** that has received the processed data decrypts the processed data which has been received. As described above, with the characteristics of the fully homomorphic encryption, the data obtained by the decrypting process of the user terminal **40** becomes the same as the data obtained by implementing a predetermined process on the original data to be processed. In other words, the user terminal **40** makes the data processing server **60** process the processing data.

As described above, by encrypting the processing data in the fully homomorphic encryption scheme, and by making the data processing server **60** process the encrypted data, the contents of the processing data may not necessarily be known to the data processing server **60**. As a result, the unnecessary invasion of user privacy can be avoided. For example, an electronic mail application or the document contents input by the user in a word processor does not become known to the data processing server **60**, and an invasion of user privacy is prevented.

Hereinbefore, the system configuration of the data processing system according to the embodiment has been described. In the following, the functions of the respective components which are included in the data processing system will be described in more detail.

2-2: Functional Configuration of User Terminal **40**

First, referring to FIG. **9**, the functional configuration of the user terminal **40** according to the embodiment will be described. FIG. **9** is a diagram illustrating the functional configuration of the user terminal **40** according to the embodiment.

As shown in FIG. **9**, the user terminal **40** includes mainly a key generation section **401**, an input section **402**, an encrypting section **403**, a communication section **404**, a decrypting section **405**, and a display section **406**.

The key generation section **401** is a part which generates the public key pk and the secret key sk of the fully homomorphic encryption scheme. The public key pk generated by the key generation section **401** is input to the encrypting section **403**. On the other hand, the secret key sk generated by the key generation section **401** is input to the decrypting section **405**. The public key pk input to the encrypting section **403** is maintained by the encrypting section **403**. In addition, the secret key sk input to the decrypting section **405** is maintained by the decrypting section **405**. Further, the public key pk generated by the key generation section **401** is also provided to the data processing server **60**. In addition, the public key pk provided to the data processing server **60** is maintained by the data processing server **60**.

The input section **402** is an input part which is used to input the processing data (hereinafter, referred to as the input data q). The input data q, which is input by using the input section **402**, is sequentially input to the encrypting section **403**. When the input data q is input, the encrypting section **403** encrypts the input data q using the public key pk, and generates the encrypted data c ($c \leftarrow Enc(q, pk)$). The encrypted data c generated by the encrypting section **403** is input to the communication section **404**. When the encrypted data c is input, the communication section **404** transmits the input encrypted data c to the data processing server **60**.

The data processing server **60** having received the encrypted data c implements a predetermined process f on the encrypted data c ($r \leftarrow Process(c, f, pk)$), and transmits the process result r to the user terminal **40**. The process result r transmitted from the data processing server **60** is received by the communication section **404**, and input to the decrypting section **405**. The decrypting section **405** having received the process result r implements the decrypting process on the

received process result r using the secret key sk, and obtains the process result R (hereinafter, referred to as a decrypted process result R) with respect to the input data q (R←Dec(r, sk)). The decrypted process result R obtained in the decrypting process of the decrypting section **405** is input to the display section **406**. The display section **406** having received the decrypted process result R displays the decrypted process result R which has been received.

Hereinbefore, the functional configuration of the user terminal **40** has been described.

2-3: Functional Configuration of Data Processing Server **60**

Next, referring to FIG. **10**, the functional configuration of the data processing server **60** according to the embodiment will be described. FIG. **10** is a diagram illustrating the functional configuration of the data processing server **60** according to the embodiment.

As shown in FIG. **10**, the data processing server **60** includes mainly a communication section **601**, a data processing section **602**, and a storage section **603**.

The communication section **601** is a communication part which receives data from the user terminal **40** via the network **50**, and transmits the data to the user terminal **40**. When the encrypted data is transmitted from the user terminal **40**, the communication section **601** receives the encrypted data. The encrypted data received by the communication section **601** is input to the data processing section **602**. When the encrypted data is input, the data processing section **602** implements a predetermined process on the input encrypted data. The processed data obtained by the data processing section **602** is input to the communication section **601**. When the processed data is input, the communication section **601** transmits the input processed data to the user terminal **40**. Further, the data processing section **602** appropriately stores the input encrypted data and the processed data in the storage section **603**.

Hereinbefore, the functional configuration of the data processing server **60** according to the embodiment has been described.

As described above, in the embodiment, the processing data is not transmitted without any change to the data processing server **60**. For this reason, by applying the mechanism of the data processing system according to the embodiment, the content of the data input to the user terminal **40** may not necessarily be known to the data processing server **60**, and the user privacy can be protected.

2-4: Flow of Data Processing

Next, referring to FIG. **11**, the flow of the data processing according to the embodiment will be described. FIG. **11** is a diagram illustrating the flow of the data processing according to the embodiment. Further, the data processing shown in FIG. **11** is performed by the user terminal **40** and the data processing server **60**. In addition, the user terminal **40** is assumed to include the public key pk and the secret key sk of the fully homomorphic encryption scheme. Furthermore, the data processing server **60** is assumed to include the public key pk of the fully homomorphic encryption scheme.

As shown in FIG. **11**, first, the processing data (hereinafter, referred to as the input data q) is input to the user terminal **40** (S**201**). When the input data q is input, the user terminal **40** encrypts the input data q using the public key pk, and generates the encrypted data c (S**202**). In other words, the user terminal **40** implements c←Enc(q, pk). Next, the user terminal **40** transmits the encrypted data c to the data processing server **60** (S**203**).

The data processing server **60**, which has received the encrypted data c, inputs the received encrypted data c to a predetermined process algorithm f, and implements the process algorithm f using the public key pk (S**204**). In other words, the data processing server **60** implements r←Process (c, f, pk), and obtains the process result r through the process algorithm f. Next, the data processing server **60** transmits the process result r to the user terminal **40** (S**205**).

The user terminal **40**, which has received the process result r, implements the decrypting process on the process result r using the secret key sk, and obtains the decrypted process result R (S**206**). In other words, the user terminal **40** implements R←Dec(r, sk). When the decrypted process result R is obtained, the user terminal **40** displays the decrypted process result R for the user (S**207**).

Hereinbefore, the flow of the data processing according to the embodiment has been described.

Hereinbefore, the second embodiment of the present disclosure has been described. By applying the technology according to the embodiment, the processing data is not known to the data processing server **60**, and the process thereof can be performed by the data processing server **60**. As a result, the content of the data input by the user may not necessarily be known to the data processing server **60**, and the user privacy is protected.

For example, in a system which collects information from a plurality of terminals placed respectively in a plurality of stores, sums up and processes the information, there is a situation in which each store wishes to share the information but does not want to let the other stores gain unique information relating to its own store. In this case, by applying the technology of the embodiment, the information of the respective stores is encrypted for protection, and on the other hand, each piece of information can be processed as in the case when no encrypting is implemented. In addition, the technology of the embodiment can be applied even in a case when medical institutions share information. For example, without letting the other medical institutions know the patient information, the medical information can be shared. In other words, while protecting patient privacy, a plurality of medical institutions can share the information.

3: Third Embodiment

Next, the third embodiment of the present disclosure will be described. The embodiment relates to a retrieval system for retrieving information which is contained in an information source connected to the network **50**. Further, the retrieval system according to the embodiment is an example of the application of the data processing system according to the second embodiment. For this reason, the description already given to the components having substantially the same functions as those of the second embodiment will be omitted, and the same reference numerals are designated to omit detailed description.

3-1: System Configuration of Retrieval System

First, referring to FIG. **12**, the system configuration of the retrieval system according to the embodiment will be described. FIG. **12** is a diagram illustrating the system configuration of the retrieval system according to the embodiment.

As shown in FIG. **12**, the retrieval system according to the embodiment includes mainly the user terminal **40** and the retrieval server **70**. In addition, the user terminal **40** and the retrieval server **70** are connected to each other via the network **50**. Further, in FIG. **12**, the configuration of the retrieval system having one retrieval server **70** is illustrated as an example, but the number of retrieval servers **70** is not limited to one. For example, the technology of the embodiment can

be applied even to the data processing system having two or more retrieval servers **70** for load distribution.

The user terminal **40** has substantially the same functions as those of the user terminal **40** according to the second embodiment. However, the description will be made by specifically focusing on the retrieval process. The user terminal **40** includes the function of performing the application such as a web browser. In addition, the user terminal **40** includes the function of receiving a retrieval keyword as an input through the application. When the retrieval keyword is input to the user terminal **40**, the user terminal **40** transmits the input retrieval keyword to the retrieval server **70**.

The retrieval server **70** is a part which retrieves information including the retrieval keyword, which is transmitted from the user terminal **40**, from the information source connected to the network **50**. When the retrieval keyword is received from the user terminal **40**, the retrieval server **70** accesses the information source connected to the network **50**, and retrieves the information having the received retrieval keyword. As an information source, for example, a homepage, a blog, and a message board which are opened to the public on the web may be considered. Of course, in addition to these, a database in which information is accumulated may be considered as the information source. In addition, the information source is assumed to be connected to the network **50**, but the database stored in a storage device (not shown) connected to the retrieval server **70** may be used as the information source.

The embodiment is to make the retrieval process implemented based on the retrieval keyword while not letting the retrieval server **70** know the retrieval keyword. For this purpose, in the embodiment, the user terminal **40** does not transmit the retrieval keyword as it is to the retrieval server **70**, but encrypts the retrieval keyword in the fully homomorphic encryption scheme and then transmits it to the retrieval server **70**. On the other hand, the retrieval server **70** having received the encrypted retrieval keyword implements the retrieval process using the encrypted retrieval keyword, and transmits the retrieval result to the user terminal **40**. Then, the user terminal **40** having received the retrieval result decrypts the received retrieval result, and obtains the original form of information which has been provided from the information source.

As described above, the retrieval keyword is encrypted in the fully homomorphic encryption scheme, and the retrieval server **70** implements the retrieval process based on the encrypted retrieval keyword, thereby not letting the retrieval server **70** know the retrieval keyword. As a result, the unnecessary invasion of user privacy can be prevented.

Hereinbefore, the system configuration of the retrieval system according to the embodiment has been described. Next, the functions of the respective components included in the retrieval system will be described in more detail. However, since the functional configuration of the user terminal **40** is substantially equal to that of the user terminal **40** according to the second embodiment, the description thereof will be omitted.

3-2: Functional Configuration of Retrieval Server **70**

Referring to FIG. **13**, the functional configuration of the retrieval server **70** according to the embodiment will be described. FIG. **13** is a diagram illustrating the functional configuration of the retrieval server **70** according to the embodiment.

As shown in FIG. **13**, the retrieval server **70** includes mainly a communication section **701** and a retrieval algorithm execution section **702**.

The communication section **701** is a communication part which receives data via the network **50** from the user terminal **40**, and transmits the data to the user terminal **40**. When the encrypted retrieval keyword is transmitted from the user terminal **40**, the communication section **701** receives the encrypted retrieval keyword (hereinafter, referred to as the encrypted data). The encrypted data received by the communication section **701** is input to the retrieval algorithm execution section **702**.

When the encrypted data is input, the retrieval algorithm execution section **702** implements the retrieval algorithm in which the encrypted data is input. When the retrieval result is output from the retrieval algorithm, the retrieval algorithm execution section **702** inputs the retrieval result (hereinafter, referred to as an output result) output from the retrieval algorithm to the communication section **701**. The communication section **701**, which has received the output result, transmits the received output result to the user terminal **40**.

Hereinbefore, the functional configuration of the retrieval server **70** according to the embodiment has been described.

As described above, in the embodiment, the retrieval keyword is not transmitted as it is to the retrieval server **70**. For this reason, by applying the mechanism of the retrieval system according to the embodiment, the content of the retrieval keyword input to the user terminal **40** may not necessarily be known to the retrieval server **70**, and the user privacy can be protected.

3-3: Flow of Retrieval Processing

Next, referring to FIG. **14**, the flow of the retrieval process according to the embodiment will be described. FIG. **14** is a diagram illustrating the flow of the retrieval process according to the embodiment. Further, the retrieval process shown in FIG. **14** is implemented by the user terminal **40** and the retrieval server **70**. In addition, the user terminal **40**, is assumed to include the public key pk and the secret key sk of the fully homomorphic encryption scheme. Furthermore, the retrieval server **70** is assumed to include the public key pk of the fully homomorphic encryption scheme.

As shown in FIG. **14**, first, the user terminal **40** receives a retrieval keyword q (S**301**). When the retrieval keyword q is received, the user terminal **40** encrypts the retrieval keyword q using the public key pk, and generates the encrypted data c (S**302**). In other words, the user terminal **40** implements c-Enc(q, pk). Next, the user terminal **40** transmits the encrypted data c to the retrieval server **70** (S**303**).

The retrieval server **70**, which has received the encrypted data c, inputs the received encrypted data c to the retrieval algorithm f, and implements the process by the retrieval algorithm f using the public key pk (S**304**). In other words, the retrieval server **70** implements r←Process(c, f, pk), and obtains the retrieval result r (hereinafter, referred to as the output result r) output from the retrieval algorithm f. Next, the retrieval server **70** transmits the output result r to the user terminal **40** (S**305**).

The user terminal **40**, which has received the output result r, implements the decrypting process on the output result r using the secret key sk, and obtains the output result R (which corresponds to the retrieval result by the retrieval keyword q) (S**306**). In other words, the user terminal **40** implements R←Dec(r, sk). When the output result R is obtained, the user terminal **40** displays the output result R for the user (S**307**).

Hereinbefore, the flow of the retrieval process according to the embodiment has been described.

Hereinbefore, the third embodiment of the present disclosure has been described. By applying the technology according to the embodiment, the retrieval process can be implemented without letting the retrieval server **70** know the retrieval keyword. As a result, the content of the retrieval keyword input by the user may not necessarily be known to the retrieval server **70**, and user privacy can be protected.

4: Hardware Configuration

The functions of the respective components included in the monitoring camera **10**, the monitoring server **20**, the user terminal **40**, the data processing server **60**, and the retrieval server **70** may be implemented using, for example, the hardware configuration of an information processing device shown in FIG. **15**. In other words, the functions of the respective components are realized by controlling the hardware shown in FIG. **15** using computer programs. Further, the form of the hardware is arbitrary, and for example, a portable information terminal such as a personal computer, a portable telephone, a PHS, and a PDA, a game machine, or various information appliances are included. Herein, the PHS is the abbreviation of "Personal Handy-phone System". In addition, the PDA is the abbreviation of "Personal Digital Assistant".

As shown in FIG. **15**, the hardware includes mainly a CPU **902**, a ROM **904**, a RAM **906**, a host bus **908**, and a bridge **910**. Further, the hardware includes an external bus **912**, an interface **914**, an input section **916**, an output section **918**, a storage section **920**, a drive **922**, a connection port **924**, and a communication section **926**. Herein, the CPU is the abbreviation of "Central Processing Unit". In addition, the ROM is the an abbreviation of "Read Only Memory". Further, the RAM is the abbreviation of "Random Access Memory".

The CPU **902**, for example, serves as an arithmetic processing unit or a control unit, and controls all or a part of the operations of the respective components based on various programs stored in the ROM **904**, the RAM **906**, the storage section **920**, or a removable storage medium **928**. The ROM **904** is a part which stores the programs read by CPU **902** or data used for an arithmetical process. In the RAM **906**, for example, the programs read by the CPU **902** or various parameters which vary as appropriate according to the execution of the programs are stored temporarily or permanently.

These components, for example, are connected to each other via the host bus **908** which is capable of transmitting data at a high rate. On the other hand, the host bus **908** is connected, for example, via the bridge **910** to the external bus **912** of which data transmission rate is relatively low. In addition, as the input section **916**, for example, a mouse, a keyboard, a touch panel, buttons, switches, and levers may be used. Furthermore, as the input section **916**, a remote controller may be used which can transmit a control signal using infrared or other radio waves.

As the output section **918**, devices which can inform acquired information visually and auditorily to the user, for example, a display device such as a CRT, an LCD, a PDP, or an ELD; an audio output device such as a speaker and a headphone; a printer; a portable telephone; or a facsimile are exemplified. Herein, the CRT is the abbreviation of "Cathode Ray Tube". In addition, the LCD is the abbreviation of "Liquid Crystal Display". Then, the PDP is the abbreviation of "Plasma Display Panel". Furthermore, the ELD is the abbreviation of "Electro-Luminescence Display".

The storage section **920** is a device for storing various types of data. As the storage section **920**, for example, a magnetic-storage device such as an HDD, a semiconductor memory device, an optical memory device, or a magneto-optical memory device may be used. Herein, the above HDD is the abbreviation of "Hard Disk Drive".

The drive **922** is a device which reads out information recorded in the removable storage medium **928** such as a magnetic disc, an optical disc, a magnetic-optical disc, or a semiconductor memory, or writes the information to the removable storage medium **928**. The removable storage medium **928** may include, for example, DVD media, Blu-ray media, HD DVD media, and various kinds of semiconductor media. Of course, the removable storage medium **928** may be, for example, an IC card on which a contactless IC chip is mounted, or an electronic device. Herein, the IC is the abbreviation of "Integrated Circuit".

The connection port **924** is a port for connecting an external connection device **930** such as a USB port, an IEEE1394 port, a SCSI, an RS-232C port, and an optical audio terminal. The external connection device **930** may be, for example, a printer, a portable music player, a digital camera, a digital video camera, an IC recorder, or the like. Herein, the USB is the abbreviation of "Universal Serial Bus". In addition, the SCSI is the abbreviation of "Small Computer System Interface".

The communication section **926** is a communication device for the connection to the network **932**, and a wired or wireless LAN, Bluetooth (Registered Trademark), or a communication card for a WUBS, a router for an optical communication, a router for an ADSL, and various MODEMs for communication are exemplified. In addition, the network **932**, which is connected to the communication section **926**, includes a wired or wireless connection network, for example, the Internet, a home LAN, infrared communication, visible light communication, broadcasts, satellite communication, and the like. Herein, the LAN is the abbreviation of "Local Area Network". In addition, the WUSB is the abbreviation of "Wireless USB". Then, the ADSL is the abbreviation of "Asymmetric Digital Subscriber Line".

5: Summary

Finally, the technology content according to the embodiments of the present disclosure will be summed up briefly.

The technology according to the above-mentioned embodiments relates to the data processing system which includes the terminal device and the server as follows. The terminal device includes the encrypting section, the encrypted data transmission section, the encrypted data reception section, and the decrypting section. The encrypting section encrypts the input data in the fully homomorphic encryption scheme to generate the encrypted data. In addition, the encrypted data transmission section transmits the encrypted data generated by the encrypting section to the server. Then, the encrypted data reception section receives the encrypted data on which a predetermined process is implemented by the server. Furthermore, the decrypting section decrypts the encrypted data on which the predetermined process is implemented.

By employing the fully homomorphic encryption scheme as an encryption scheme, the decrypting result of data obtained by implementing a predetermined process on the encrypted data is equal to that of data obtained by implementing a predetermined process on input data. For this reason, even though the encrypted data is processed in the server, the terminal device can obtain substantially the same processing result as in the case when the input data is processed in the server. Furthermore, since the contents of the input data is not revealed to the server at all, the terminal device can make the server perform the process of the input data without letting the server know the contents of the input data.

Remarks

The monitoring camera **10** and the user terminal **40** are examples of the terminal device. The communication sections **105** and **404** are examples of the encrypted data transmission section, the encrypted data reception section, a first transmission section, and a first reception section. The image

transmission section **107** is an example of the abnormality determination section and the image data transmission section. The encrypting sections **104**, **403** and the decrypting sections **106**, **405** are examples of the key holding section. The monitoring server **20**, the data processing server **60**, and the retrieval server **70** are examples of the server. The communication sections **211**, **601**, and **701** are examples of the encrypted data reception section, the encrypted data transmission section, a second reception section, and a second transmission section. The abnormality determination algorithm execution section **212**, the data processing section **602**, and the retrieval algorithm execution section **702** are examples of the process section. The monitoring camera system and the retrieval system are examples of the data processing system.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2010-188128 filed in the Japan Patent Office on Aug. 25, 2010, the entire contents of which are hereby incorporated by reference.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A terminal device comprising:

one or more hardware processors operable to:

encrypt input image data of a monitoring target in a fully homomorphic encryption scheme to generate encrypted image data;

transmit the encrypted image data to a server;

receive the encrypted image data on which the server implements a predetermined process, wherein the predetermined process is a process in which the encrypted image data is input to an abnormality determination algorithm;

retrieve an abnormality determination result by decrypting an output obtained from the abnormality determination algorithm after the predetermined process is implemented by the server on the encrypted image data;

determine an abnormality in the monitoring target included in the input image data based on the abnormality determination result; and

transmit unencrypted image data to the server in case the abnormality is determined in the monitoring target.

2. The terminal device according to claim **1**, wherein the one or more hardware processors are operable to capture the monitoring target to generate the input image data.

3. The terminal device according to claim **1**, wherein the one or more hardware processors are further operable to hold a public key and a secret key based on the fully homomorphic encryption scheme,

wherein the input image data is encrypted using the public key, and

wherein the output obtained from the abnormality determination algorithm is decrypted using the secret key.

4. The terminal device according to claim **3**, wherein the predetermined process is implemented using the public key.

5. A server comprising:

one or more hardware processors operable to:

receive encrypted image data of a monitoring target from a terminal device, wherein the encrypted image data is obtained by encrypting input image data in a fully homomorphic encryption scheme;

implement a predetermined process on the encrypted image data, wherein the predetermined process is a process in which the encrypted image data is input to an abnormality determination algorithm;

transmit an output, obtained from the abnormality determination algorithm after the predetermined process is implemented on the encrypted image data, to the terminal device,

wherein an abnormality determination result is retrieved at the terminal device by decrypting the output obtained from the abnormality determination algorithm, and

wherein an abnormality in the monitoring target included in the image data is determined based on the abnormality determination result at the terminal device; and

receive unencrypted image data from the terminal device in case the abnormality is determined in the monitoring target.

6. A data processing system comprising:

a terminal device which includes:

a first set of hardware processors operable to:

encrypt input image data of a monitoring target in a fully homomorphic encryption scheme to generate encrypted image data,

transmit the encrypted image data to a server,

receive the encrypted image data on which the server implements a predetermined process, wherein the predetermined process is a process in which the encrypted image data is input to an abnormality determination algorithm,

retrieve an abnormality determination result by decrypting an output obtained from the abnormality determination algorithm after the predetermined process is implemented by the server on the encrypted image data,

determine an abnormality in the monitoring target included in the input image data based on the abnormality determination result, and

transmit unencrypted image data to the server in case the abnormality is determined in the monitoring target; and

the server which includes:

a second set of hardware processors operable to:

receive the encrypted image data transmitted from the terminal device,

implement the predetermined process on the encrypted image data,

transmit the output, obtained from the abnormality determination algorithm after the predetermined process is implemented by the server on the encrypted image data to the terminal device, and

receive the unencrypted image data from the terminal device case the abnormality is determined in the monitoring target.

7. A non-transitory computer-readable storage medium having stored thereon, a computer program having at least one code section executable by a computer, thereby causing the computer to execute steps comprising:

encrypting input image data of a monitoring target in a fully homomorphic encryption scheme to generate encrypted image data;

transmitting the encrypted image data to a server;

receiving the encrypted image data on which the server implements a predetermined process, wherein the pre-

determined process is a process in which the encrypted image data is input to an abnormality determination algorithm;

retrieving an abnormality determination result by decrypting an output obtained from the abnormality determination algorithm after the predetermined process is implemented by the server on the encrypted image data;

determining an abnormality in the monitoring target included in the input image data based on the abnormality determination result; and

transmitting unencrypted image data to the server in case the abnormality is determined in the monitoring target.

8. A non-transitory computer-readable storage medium having stored thereon, a set of computer-executable instructions which when executed by a computer, causes the computer to execute steps comprising:

receiving encrypted image data of a monitoring target from a terminal device, wherein the encrypted image data is obtained by encrypting image data in a fully homomorphic encryption scheme;

implementing a predetermined process on the encrypted image data, wherein the predetermined process is a process in which the encrypted image data is input to an abnormality determination algorithm;

transmitting an output, obtained from the abnormality determination algorithm after the predetermined process is implemented on the encrypted image data, to the terminal device,

wherein an abnormality determination result is retrieved at the terminal device by decrypting the output obtained from the abnormality determination algorithm, and

wherein an abnormality in the monitoring target included in the image data is determined based on the abnormality determination result at the terminal device; and

receiving unencrypted image data from the terminal device in case the abnormality is determined in the monitoring target.

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