US012386961B2

(12) **United States Patent**
Yamanaka et al.

(10) **Patent No.: US 12,386,961 B2**

(45) **Date of Patent: Aug. 12, 2025**

(54) FALSIFICATION DETECTION DEVICE, FALSIFICATION DETECTION METHOD, AND FALSIFICATION DETECTION PROGRAM

(71) Applicant: **NIPPON TELEGRAPH AND TELEPHONE CORPORATION**, Tokyo (JP)

(72) Inventors: **Yuki Yamanaka**, Tokyo (JP); **Manami Ito**, Tokyo (JP); **Ryota Sato**, Tokyo (JP); **Hiroyoshi Takiguchi**, Tokyo (JP); **Nobuhiro Chiba**, Tokyo (JP); **Yoshiaki Nakajima**, Tokyo (JP)

(73) Assignee: **NIPPON TELEGRAPH AND TELEPHONE CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 51 days.

(21) Appl. No.: **18/272,094**

(22) PCT Filed: **Jan. 13, 2021**

(86) PCT No.: **PCT/JP2021/000909**
§ 371 (c)(1),
(2) Date: **Jul. 12, 2023**

(87) PCT Pub. No.: **WO2022/153410**
PCT Pub. Date: **Jul. 21, 2022**

(65) **Prior Publication Data**
US 2024/0303332 A1 Sep. 12, 2024

(51) **Int. Cl.**
G06F 21/56 (2013.01)
G06F 21/57 (2013.01)

(52) **U.S. Cl.**
CPC ***G06F 21/565*** (2013.01); ***G06F 21/566*** (2013.01); *G06F 2221/033* (2013.01)

(58) **Field of Classification Search**
CPC G06F 21/565; G06F 21/566; G06F 2221/033; G06F 21/56; G06F 21/57
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,733,183	B2 *	8/2020	Parayatham	G06F 16/245
2020/0034534	A1 *	1/2020	Toley	G06F 16/182
2021/0216659	A1 *	7/2021	Kinoshita	G06F 16/1727
2022/0222342	A1 *	7/2022	Ma	G06F 21/565

FOREIGN PATENT DOCUMENTS

AU	2021419776	A1 *	7/2023	.... G06F 21/552
JP	2004013607	A *	1/2004	
JP	2010211453	A	9/2010	
JP	2019008376	A	1/2019	
JP	2019008732	A	1/2019	
JP	2019207661	A	12/2019	

* cited by examiner

Primary Examiner — Jayesh M Jhaveri

(57) **ABSTRACT**

A tampering detection device includes tampering detection circuitry configured to acquire an access frequency of a monitoring target file, calculate a number of times of scanning in a scan pattern for each monitoring target file on a basis of the access frequency acquired, and determine the scan pattern on a basis of the number of times of scanning calculated.

6 Claims, 8 Drawing Sheets

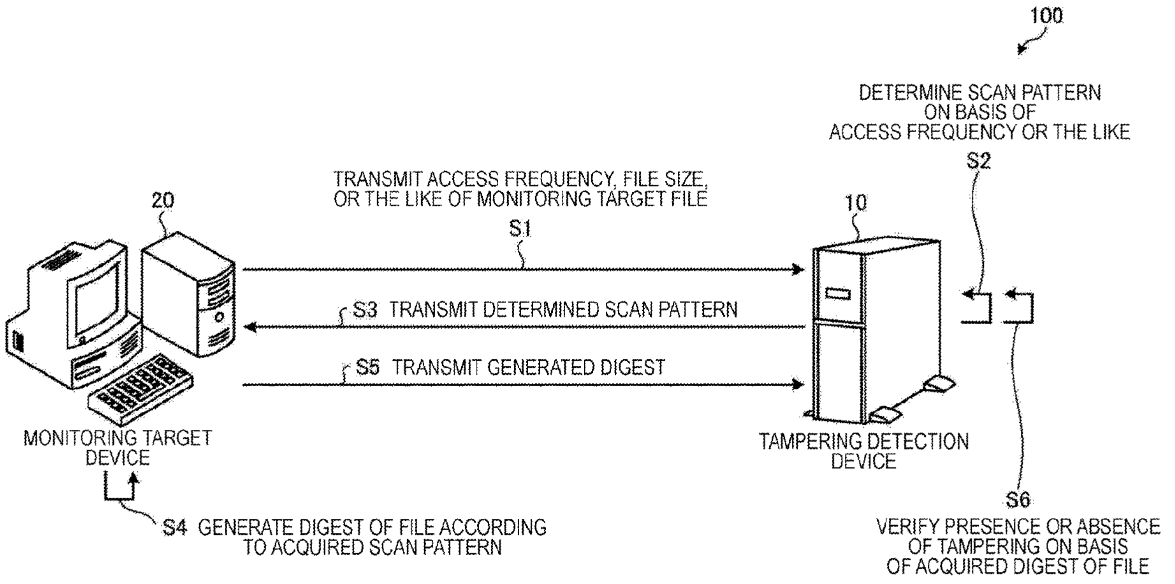

100
DETERMINE SCAN PATTERN ON BASIS OF ACCESS FREQUENCY OR THE LIKE
S2
TRANSMIT ACCESS FREQUENCY, FILE SIZE, OR THE LIKE OF MONITORING TARGET FILE
S1
20
10
S3 TRANSMIT DETERMINED SCAN PATTERN
S5 TRANSMIT GENERATED DIGEST
MONITORING TARGET DEVICE
TAMPERING DETECTION DEVICE
S4 GENERATE DIGEST OF FILE ACCORDING TO ACQUIRED SCAN PATTERN
S6
VERIFY PRESENCE OR ABSENCE OF TAMPERING ON BASIS OF ACQUIRED DIGEST OF FILE

Fig. 1

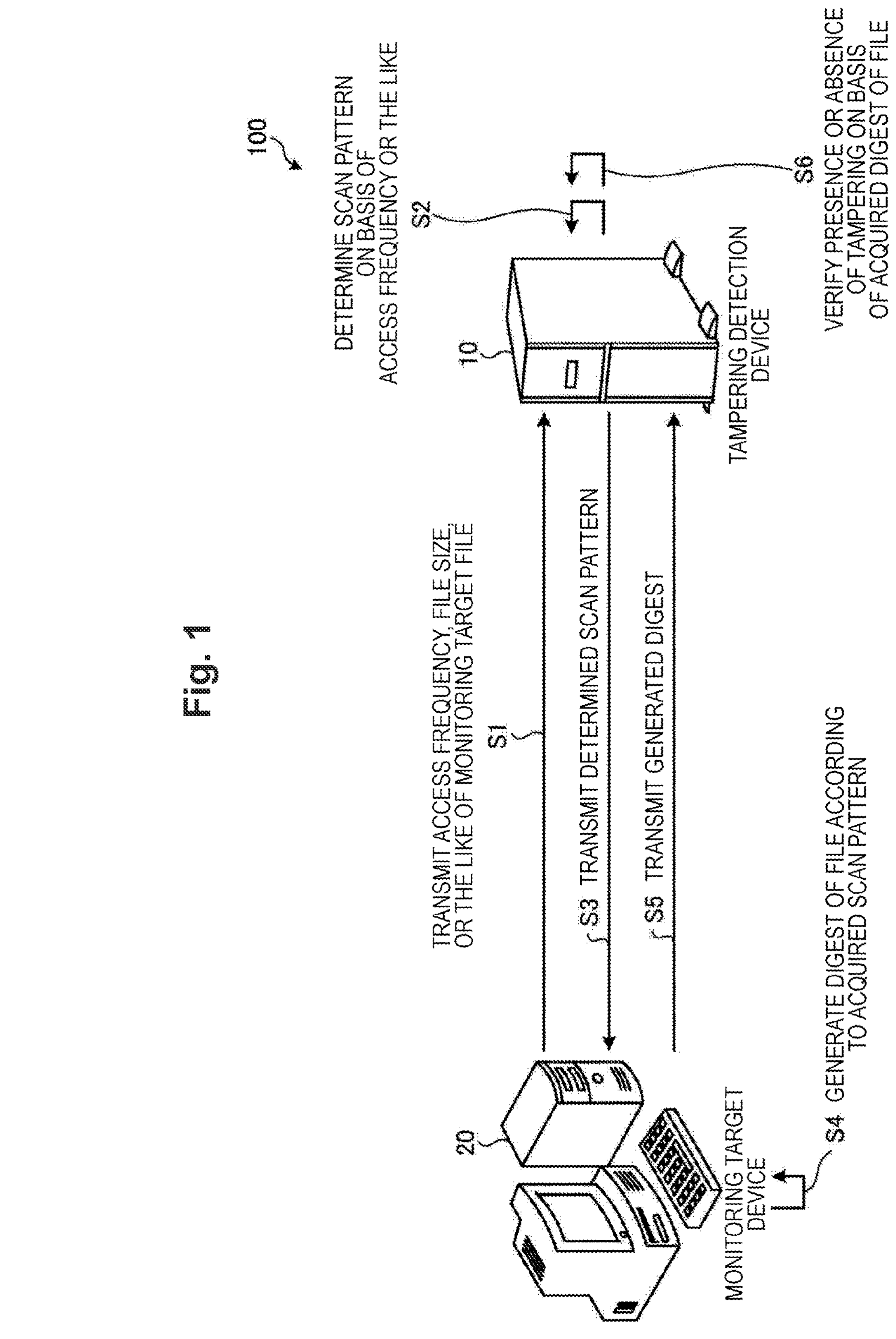

100
20
MONITORING TARGET DEVICE
10
TAMPERING DETECTION DEVICE
S1
TRANSMIT ACCESS FREQUENCY, FILE SIZE, OR THE LIKE OF MONITORING TARGET FILE
S2
DETERMINE SCAN PATTERN ON BASIS OF ACCESS FREQUENCY OR THE LIKE
S3 TRANSMIT DETERMINED SCAN PATTERN
S4 GENERATE DIGEST OF FILE ACCORDING TO ACQUIRED SCAN PATTERN
S5 TRANSMIT GENERATED DIGEST
S6
VERIFY PRESENCE OR ABSENCE OF TAMPERING ON BASIS OF ACQUIRED DIGEST OF FILE

Fig. 2

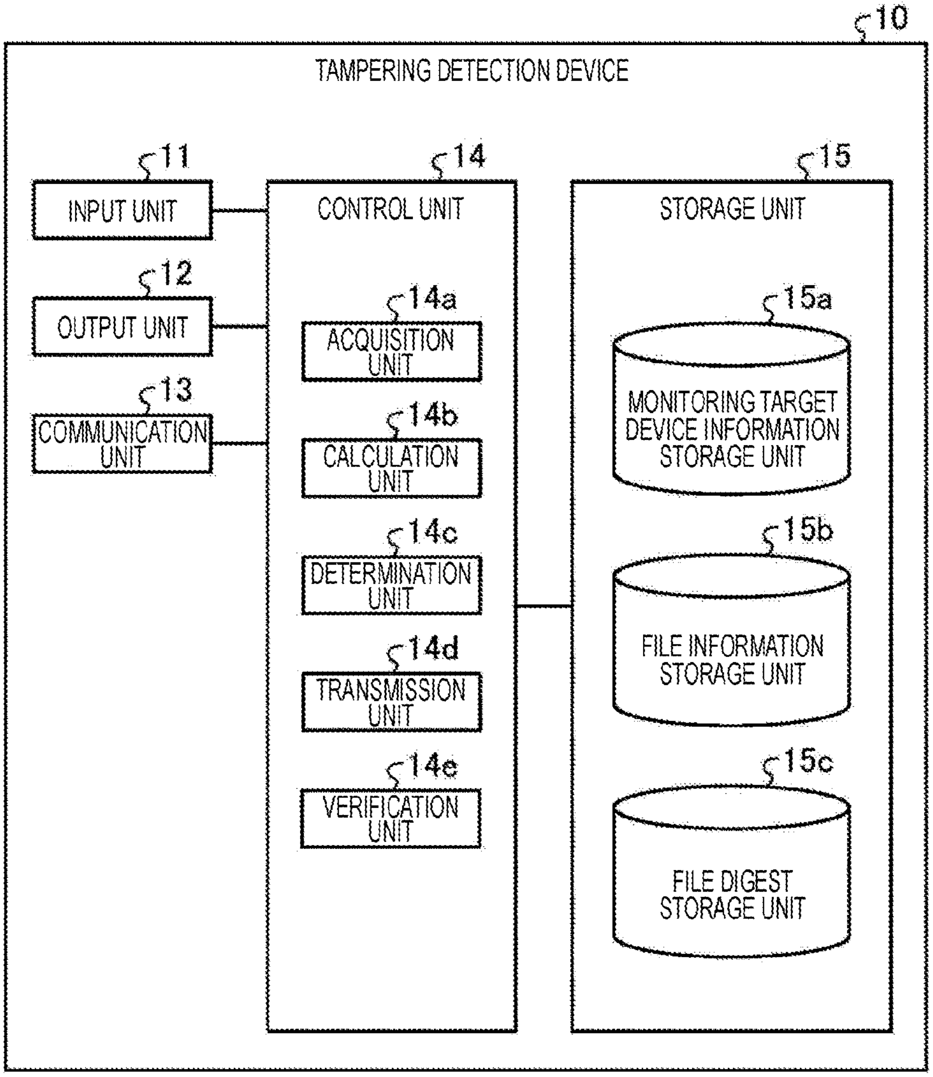

10
TAMPERING DETECTION DEVICE
11
INPUT UNIT
12
OUTPUT UNIT
13
COMMUNICATION UNIT
14
CONTROL UNIT
14a
ACQUISITION UNIT
14b
CALCULATION UNIT
14c
DETERMINATION UNIT
14d
TRANSMISSION UNIT
14e
VERIFICATION UNIT
15
STORAGE UNIT
15a
MONITORING TARGET DEVICE INFORMATION STORAGE UNIT
15b
FILE INFORMATION STORAGE UNIT
15c
FILE DIGEST STORAGE UNIT

Fig. 3

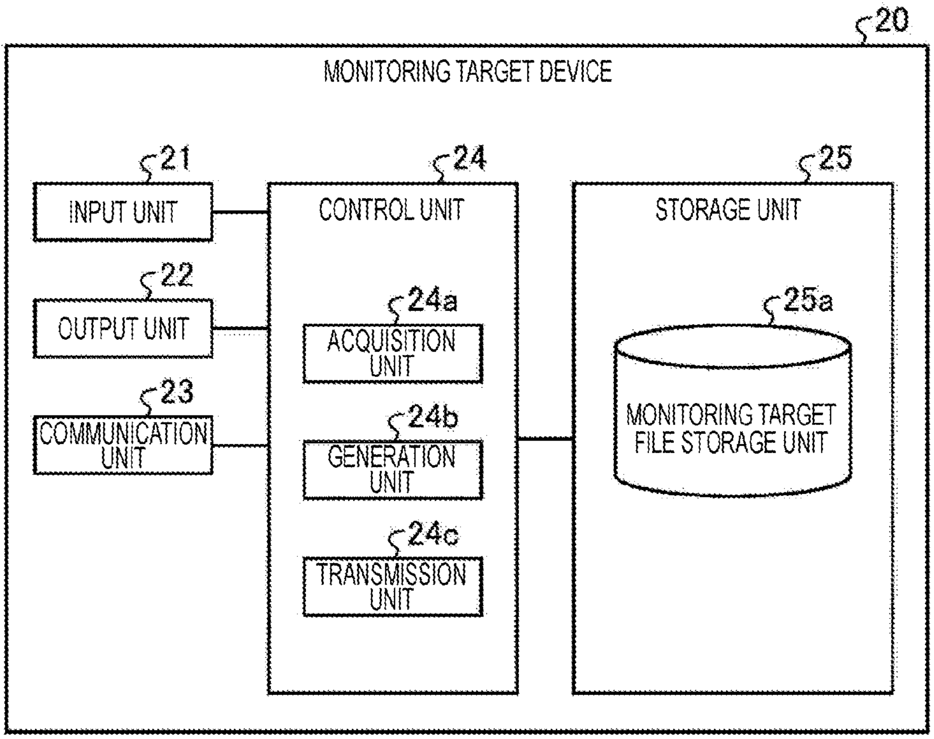

20
MONITORING TARGET DEVICE
21
INPUT UNIT
22
OUTPUT UNIT
23
COMMUNICATION UNIT
24
CONTROL UNIT
24a
ACQUISITION UNIT
24b
GENERATION UNIT
24c
TRANSMISSION UNIT
25
STORAGE UNIT
25a
MONITORING TARGET FILE STORAGE UNIT

Fig. 4

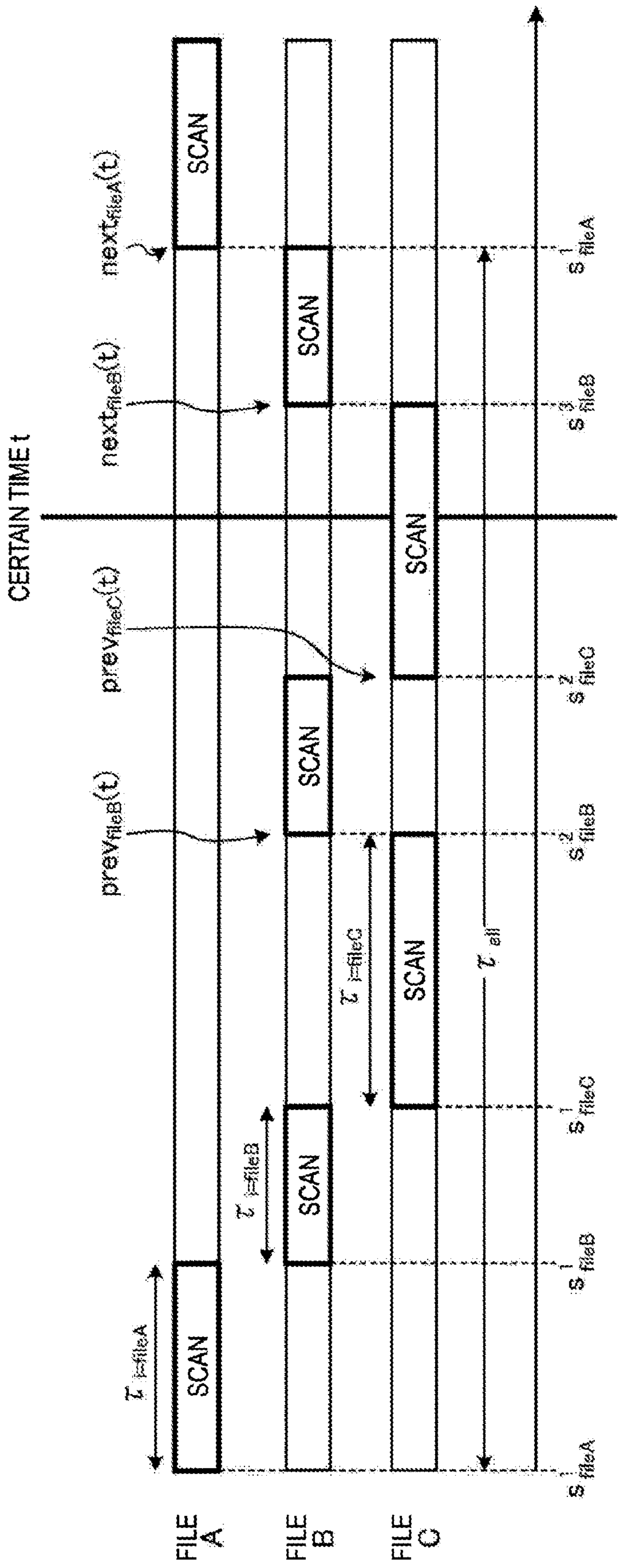

FILE A
FILE B
FILE C
CERTAIN TIME t
SCAN
$\tau_{j=fileA}$
$\tau_{j=fileB}$
$\tau_{j=fileC}$
τ_{all}
$prev_{fileB}(t)$
$prev_{fileC}(t)$
$next_{fileB}(t)$
$next_{fileA}(t)$
S^1_{fileA}
S^1_{fileB}
S^1_{fileC}
S^2_{fileB}
S^2_{fileC}
S^3_{fileB}
S^1_{fileA}

Fig. 5

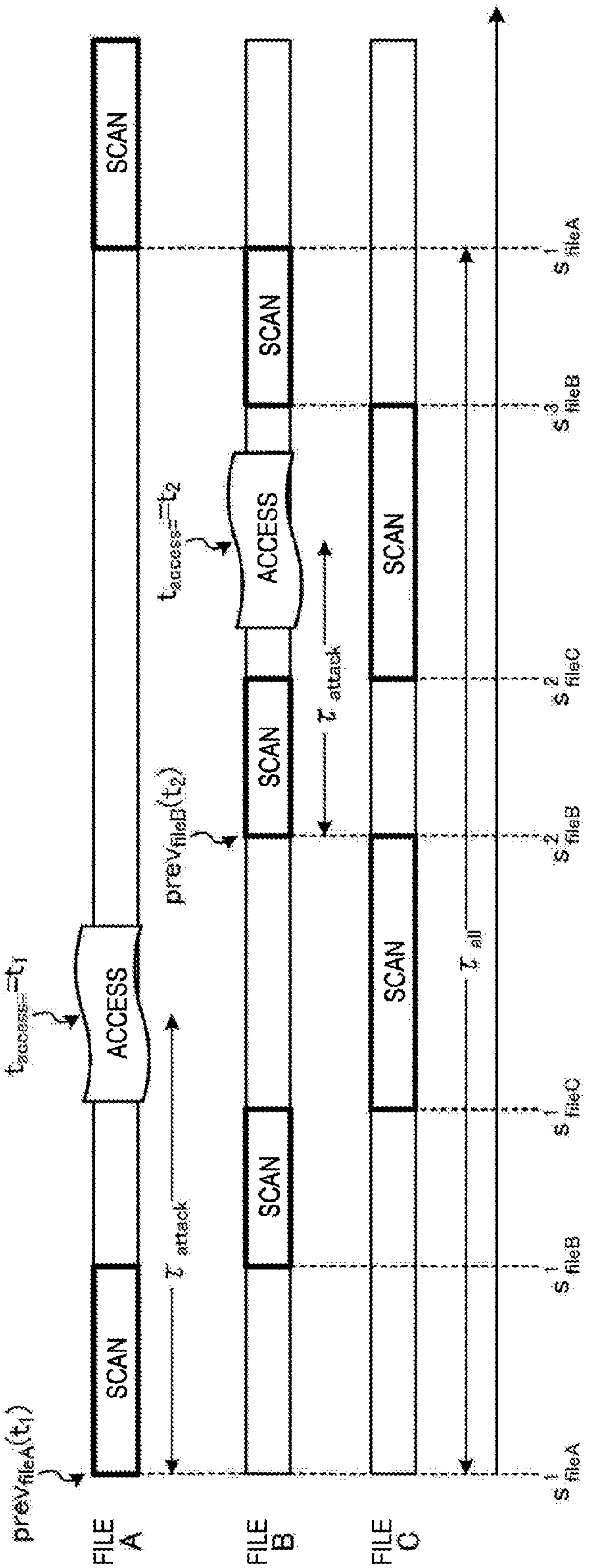

FILE A
FILE B
FILE C
prev$_{fileA}$(t$_1$)
t$_{access}$=t$_1$
ACCESS
SCAN
τ attack
prev$_{fileB}$(t$_2$)
t$_{access}$=t$_2$
τ all
S$^1_{fileA}$
S$^1_{fileB}$
S$^1_{fileC}$
S$^2_{fileB}$
S$^2_{fileC}$
S$^3_{fileB}$
S$^1_{fileA}$

Fig. 6

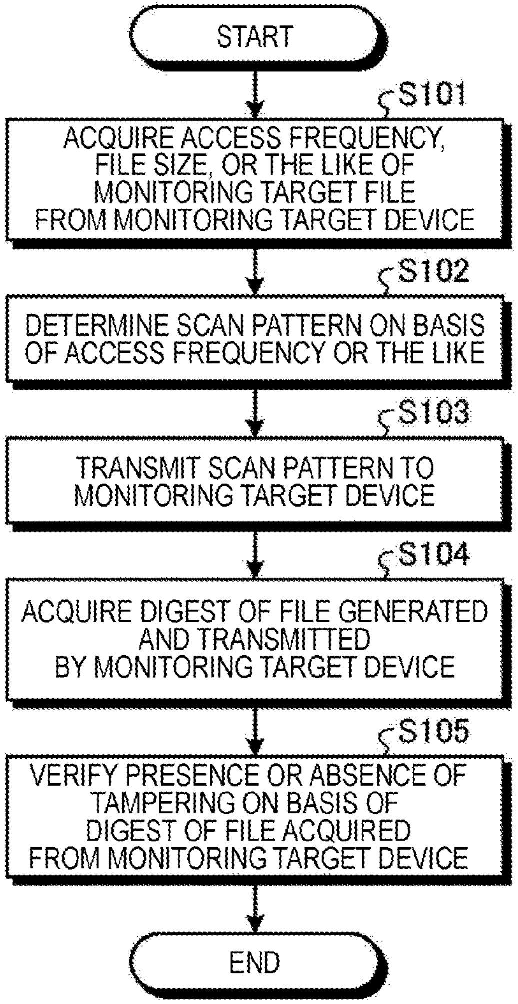

START
S101
ACQUIRE ACCESS FREQUENCY, FILE SIZE, OR THE LIKE OF MONITORING TARGET FILE FROM MONITORING TARGET DEVICE
S102
DETERMINE SCAN PATTERN ON BASIS OF ACCESS FREQUENCY OR THE LIKE
S103
TRANSMIT SCAN PATTERN TO MONITORING TARGET DEVICE
S104
ACQUIRE DIGEST OF FILE GENERATED AND TRANSMITTED BY MONITORING TARGET DEVICE
S105
VERIFY PRESENCE OR ABSENCE OF TAMPERING ON BASIS OF DIGEST OF FILE ACQUIRED FROM MONITORING TARGET DEVICE
END

Fig. 7

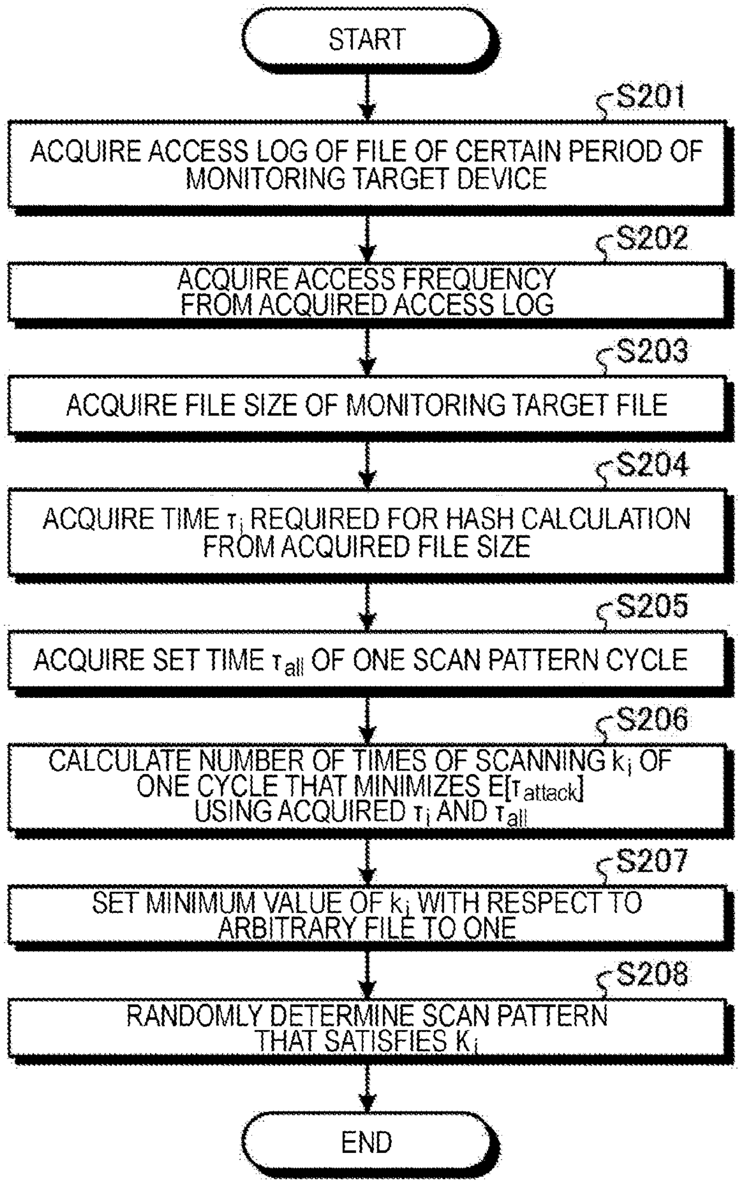
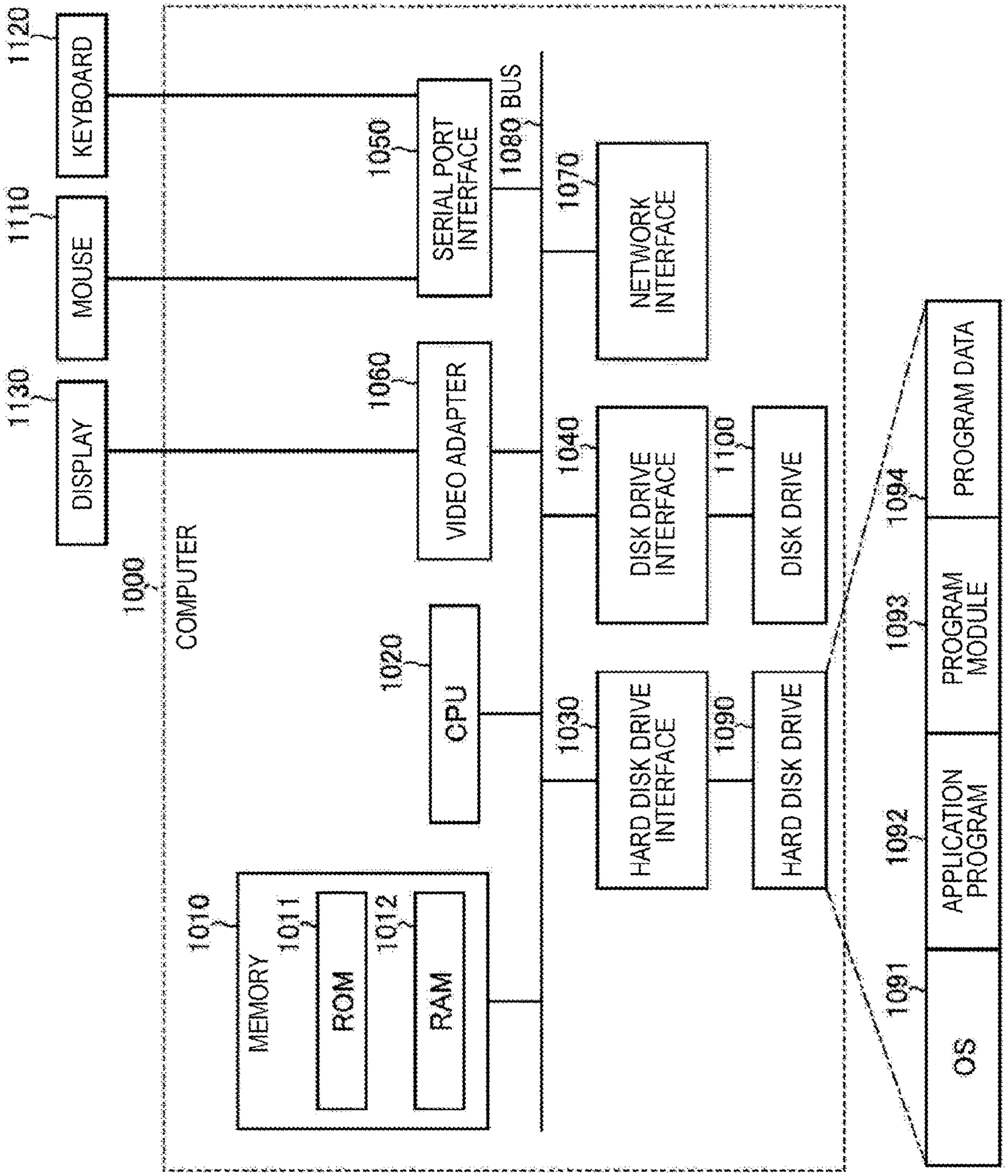

START
S201
ACQUIRE ACCESS LOG OF FILE OF CERTAIN PERIOD OF MONITORING TARGET DEVICE
S202
ACQUIRE ACCESS FREQUENCY FROM ACQUIRED ACCESS LOG
S203
ACQUIRE FILE SIZE OF MONITORING TARGET FILE
S204
ACQUIRE TIME τ_i REQUIRED FOR HASH CALCULATION FROM ACQUIRED FILE SIZE
S205
ACQUIRE SET TIME τ_{all} OF ONE SCAN PATTERN CYCLE
S206
CALCULATE NUMBER OF TIMES OF SCANNING k_i OF ONE CYCLE THAT MINIMIZES $E[\tau_{attack}]$ USING ACQUIRED τ_i AND τ_{all}
S207
SET MINIMUM VALUE OF k_i WITH RESPECT TO ARBITRARY FILE TO ONE
S208
RANDOMLY DETERMINE SCAN PATTERN THAT SATISFIES K_i
END

Fig. 8


1130
DISPLAY
1110
MOUSE
1120
KEYBOARD
1000
COMPUTER
1010
MEMORY
1011
ROM
1012
RAM
1020
CPU
1060
VIDEO ADAPTER
1050
SERIAL PORT INTERFACE
1080 BUS
1030
HARD DISK DRIVE INTERFACE
1040
DISK DRIVE INTERFACE
1070
NETWORK INTERFACE
1090
HARD DISK DRIVE
1100
DISK DRIVE
1091
OS
1092
APPLICATION PROGRAM
1093
PROGRAM MODULE
1094
PROGRAM DATA

FALSIFICATION DETECTION DEVICE, FALSIFICATION DETECTION METHOD, AND FALSIFICATION DETECTION PROGRAM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Stage Application filed under 35 U.S.C. § 371 claiming priority to International Patent Application No. PCT/JP2021/000909, filed on 13 Jan. 2021, the disclosure of which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to a tampering detection device, a tampering detection method, and a tampering detection program.

BACKGROUND ART

The software tampering detection technique is a technique of acquiring a digest (a hash value or the like) of a monitoring target file at a certain point of time when the file can be regarded as normal, and periodically comparing the acquired digest with the current digest of the monitoring target file to check whether or not the target file has been illicitly tampered with. In general, this tampering detection technique is installed in a certain device, and is used for the purpose of securing authenticity of the device by periodically scanning the entire monitoring target file in the device. As a method of this scanning, the three methods described below have been conventionally used.

The first method is a cyclic scan method. In this method, the entire monitoring target file is scanned in a fixed order based on a certain rule such as ascending order of path names and node number order.

The second method is a random scan method. In this method, a file to be scanned next is uniformly and randomly selected from all monitoring target files, and the file is scanned.

The third method is an on-access scan method. In this method, a function of an operating system (OS) such as fanotify is utilized, an access to a file is detected and hooked, scanning is performed, and file access is permitted when tampering is not performed.

CITATION LIST

Patent Literature

Patent Literature 1: JP 2019-008376 A
Patent Literature 2: JP 2019-008732 A
Patent Literature 3: JP 2019-207661 A

SUMMARY OF INVENTION

Technical Problem

However, in the conventional technique, it is not possible to reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device. This is because the above-described three scan methods have the problems described below.

In the cyclic scan method, which is the first method, a file that has been scanned once is not scanned again until scanning of all the other files is completed. Therefore, in a situation where available resources such as a central processing unit (CPU) and memory are limited, a time taken until all the files are scanned in one cycle often becomes long. Thus, even when tampering is performed, it is difficult to immediately find the tampering, and there is a possibility that an authorized program executes an illicitly tampered file without noticing the tampering.

In the random scan method, which is the second method, since a file to be scanned is selected completely randomly, there is a possibility that it takes an enormous amount of time from when a certain file is scanned to when the file is scanned next.

In the on-access scan method, which is the third method, the possibility that an authorized program unintentionally executes an illicitly tampered file can be almost completely zeroed, but monitoring and file access hooking in the OS consume considerable memory and CPU resources, and a response of an input/output (I/O) is reduced, so that an operation of the device is considerably affected.

Solution to Problem

In order to solve the above-described problems and achieve the object, a tampering detection device according to the present invention includes: tampering detection circuitry configured to: acquire an access frequency of a monitoring target file; calculate a number of times of scanning in a scan pattern for each monitoring target file on the basis of the access frequency acquired; and determine the scan pattern on the basis of the number of times of scanning calculated.

In addition, a tampering detection method according to the present invention is a tampering detection method executed by a tampering detection device, the method including: acquiring an access frequency of a monitoring target file; calculating a number of times of scanning in a scan pattern for each monitoring target file on the basis of the access frequency acquired; and determining the scan pattern on the basis of the number of times of scanning calculated.

In addition, a non-transitory computer-readable recording medium storing therein a tampering detection program according to the present invention causes a computer to execute: acquiring an access frequency of a monitoring target file; calculating a number of times of scanning in a scan pattern for each monitoring target file on the basis of the access frequency acquired; and determining the scan pattern on the basis of the number of times of scanning calculated.

Advantageous Effects of Invention

The present invention can reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating a configuration example of a tampering detection system according to a first embodiment.

FIG. **2** is a block diagram illustrating a configuration example of a tampering detection device according to the first embodiment.

FIG. **3** is a block diagram illustrating a configuration example of a monitoring target device according to the first embodiment.

FIG. **4** is a diagram for describing a definition of each constant according to the first embodiment.

FIG. **5** is a diagram for describing an evaluation index of a scan pattern according to the first embodiment.

FIG. **6** is a flowchart illustrating an example of a flow of tampering detection processing according to the first embodiment.

FIG. **7** is a flowchart illustrating an example of a flow of scan pattern determination processing according to the first embodiment.

FIG. **8** is a diagram illustrating a computer that executes a program.

DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment of a tampering detection device, a tampering detection method, and a tampering detection program according to the present invention will be described in detail with reference to the drawings. Note that the present invention is not limited to the embodiment described below.

First Embodiment

Hereinafter, a configuration of a tampering detection system, a configuration of a tampering detection device, a configuration of a monitoring target device, the definition of each constant, an evaluation index of a scan pattern, a flow of tampering detection processing, and a flow of scan pattern determination processing according to the present embodiment will be described in order, and finally, the effects of the present embodiment will be described.

[Configuration of Tampering Detection System]

A configuration of a tampering detection system (appropriately referred to as the present system) **100** according to the present embodiment will be described in detail with reference to FIG. **1**. FIG. **1** is a diagram illustrating a configuration example of the tampering detection system according to the first embodiment. The tampering detection system **100** includes a tampering detection device **10** such as a server and a monitoring target device **20** such as various terminals. Here, the tampering detection device **10** and the monitoring target device **20** are connected to be communicable by wire or wirelessly via a predetermined communication network, which is not illustrated. Note that tampering detection system **100** illustrated in FIG. **1** may include a plurality of tampering detection devices **10** and a plurality of monitoring target devices **20**.

First, the monitoring target device **20** transmits an access frequency, a file size, or the like of the monitoring target file to the tampering detection device **10** as information for determining a scan pattern (step S**1**). Here, the information for determining the scan pattern is information regarding the monitoring target device ("monitoring target device information" as appropriate) and information regarding the monitoring target file ("file information" as appropriate).

The monitoring target device information is information regarding resources of the monitoring target device or the like, and is, for example, but is not particularly limited to, information regarding a processing speed and a use amount of the CPU, a memory capacity, a storage capacity, and hash calculation, information regarding communication, and the like. In addition, the monitoring target device information is basic information of the monitoring target file stored in the monitoring target device or the like, and is, for example, but is not particularly limited to, a file name, a file type, a file size indicating a data size of the file, a list thereof, the number of files stored in the monitoring target device, or the like.

The file information is information regarding access of the monitoring target file stored in the monitoring target device or the like, and includes, for example, information acquired or calculated by the tampering detection device **10** in addition to information such as the number of times of access, an access frequency, and an access source for each file included in an access log, but is not particularly limited thereto.

Next, the tampering detection device **10** determines a scan pattern on the basis of the acquired access frequency or the like (step S**2**). Here, the scan pattern indicates an order of one cycle of processing (scan processing) in which the monitoring target device **20** generates a digest of each file ("file digest" as appropriate) for the monitoring target file stored in the monitoring target device **20**, but is not particularly limited thereto. The scan pattern may indicate a time, an interval, or the like at which each scan processing is performed.

Note that the digest of the file generated by the monitoring target device **20** is, but particularly not limited to, data generated through hash calculation or the like. In addition, the tampering detection device **10** can determine the scan pattern not including a specific file by static or dynamic setting. Detailed scan pattern determination processing by the tampering detection device **10** will be described below in [Flow of Scan Pattern Determination Processing].

Subsequently, the tampering detection device **10** transmits the determined scan pattern to the monitoring target device **20** (step S**3**). Then, the monitoring target device **20** generates the digest of the file according to the acquired scan pattern (step S**4**). Further, the monitoring target device **20** transmits the generated digest of the file to the tampering detection device **10** (step S**5**).

Finally, the tampering detection device **10** verifies whether the file has been tampered with on basis of the acquired digest of the file (step S**6**). At this time, the tampering detection device **10** compares the digest of the correct file stored in the tampering detection device **10** with the acquired digest of the file, and determines that the file has been tampered with when the digests are different.

The tampering detection system **100** according to the present embodiment acquires a file access log and the file size of a monitoring target file from the monitoring target device, calculates a time required for scanning a target file (=digest acquisition) from the file size on the basis of these pieces of information, and generates a scan pattern in consideration of the time required for scanning for each file and the frequency of access to the target file. Therefore, it is possible to reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a device.

[Configuration of Tampering Detection Device]

A configuration of the tampering detection device **10** according to the present embodiment will be described in detail with reference to FIG. **2**. FIG. **2** is a block diagram illustrating a configuration example of the tampering detection device according to the present embodiment. The tampering detection device **10** includes an input unit **11**, an output unit **12**, a communication unit **13**, a control unit **14**, and a storage unit **15**.

The input unit **11** controls inputting various types of information to the tampering detection device **10**. The input unit **11** is, for example, a mouse, a keyboard, or the like, and accepts input of setting information or the like to the tampering detection device **10**. In addition, the output unit **12** controls outputting various types of information from the tampering detection device **10**. The output unit **12** is, for example, a display or the like and outputs the setting information or the like stored in the tampering detection device **10**.

The communication unit **13** controls data communication with other devices. For example, the communication unit **13** performs data communication with each communication device. In addition, the communication unit **13** can perform data communication with a terminal of an operator, which is not illustrated.

The storage unit **15** stores various types of information referred to when the control unit **14** operates and various types of information acquired when the control unit **14** operates. The storage unit **15** includes a monitoring target device information storage unit **15***a*, a file information storage unit **15***b*, and a file digest storage unit **15***c*. Here, the storage unit **15** is, for example, a semiconductor memory element such as random access memory (RAM) or flash memory, a storage device such as a hard disk, an optical disc, or the like. Note that, in the example of FIG. **2**, the storage unit **15** is installed inside the tampering detection device **10**, but may be installed outside the tampering detection device **10**, or a plurality of storage units may be installed.

The monitoring target device information storage unit **15***a* stores monitoring target device information such as information regarding resources of the monitoring target device acquired by an acquisition unit **14***a* of the control unit **14** and basic information of the monitoring target file. The monitoring target device information storage unit **15***a* stores, for example, information regarding a processing speed of the CPU, a memory capacity, a storage capacity, and hash calculation as information regarding resources of the monitoring target device, and stores a file name of the file, a file type, a file size indicating a data size of the file, a list thereof, the number of files stored in the monitoring target device, and the like as basic information of the monitoring target file.

The file information storage unit **15***b* stores, as file information, information included in the access log acquired by the acquisition unit **14***a* of the control unit **14**. For example, the file information storage unit **15***b* stores information such as the number of times of access, an access frequency, and an access source for each file as information included in the access log described above. Further, the file information storage unit **15***b* may store the time ("scan pattern set time" as appropriate) τ_{all} for one scan processing cycle acquired by the acquisition unit **14***a*.

In addition, the file information storage unit **15***b* stores information calculated by a calculation unit **14***b* of the control unit **14** as file information. For example, the file information storage unit **15***b* stores, as the information calculated by the calculation unit **14***b* described above, the time ("time required for hash calculation" as appropriate) τ_i required to calculate the hash value of a file i and the number of times of scanning k_i in the scan pattern for each monitoring target file that minimizes an evaluation index $E[\tau_{attack}]$ to be described below. Further, the file information storage unit **15***b* may store the scan pattern determined by a determination unit **14***c*.

The file digest storage unit **15***c* stores information regarding a correct monitoring target file for verifying tampering acquired by the acquisition unit **14***a* of the control unit **14**. For example, the file digest storage unit **15***c* stores a file digest generated using hash calculation from a file stored in the monitoring target device as information regarding a correct monitoring target file for verifying tampering.

The control unit **14** controls the entire tampering detection device **10**. The control unit **14** includes the acquisition unit **14***a*, the calculation unit **14***b*, the determination unit **14***c*, a transmission unit **14***d*, and a verification unit **14***e*. Here, the control unit **14** is, for example, an electronic circuit such as a CPU or a micro processing unit (MPU), or an integrated circuit such as an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA).

The acquisition unit **14***a* acquires the access frequency of the monitoring target file. For example, the acquisition unit **14***a* acquires the access frequency from the monitoring target device **20** that stores the monitoring target file. In addition, the acquisition unit **14***a* acquires the access frequency included in the access log of the monitoring target file of the monitoring target device **20**. In addition, the acquisition unit **14***a* acquires the file size of the monitoring target file and the scan pattern set time. In addition, the acquisition unit **14***a* calculates and acquires a time required for hash calculation for each file from the acquired file size. Further, the acquisition unit **14***a* acquires the digest of the file generated by the monitoring target device **20**.

On the other hand, the acquisition unit **14***a* stores the acquired monitoring target device information such as resources of the monitoring target device **20** in the monitoring target device information storage unit **15***a*. In addition, the acquisition unit **14***a* stores the acquired file information such as the access frequency in the file information storage unit **15***b*. Further, the acquisition unit **14***a* transmits the acquired digest of the file to the verification unit **15***e*.

The calculation unit **14***b* calculates the number of times of scanning in the scan pattern for each monitoring target file on the basis of the access frequency acquired by the acquisition unit **14***a*. For example, the calculation unit **14***b* calculates the number of times of scanning in the scan pattern for each monitoring target file on the basis of the access frequency, the file size, and the scan pattern set time acquired by the acquisition unit **14***a*. In addition, the calculation unit **14***b* calculates, for each monitoring target file, the number of times of scanning in the scan pattern that minimizes an average time from scanning of the monitoring target file to the latest access. On the other hand, the calculation unit **14***b* stores the file information such as the calculated number of times of scanning in the file information storage unit **15***b*. Note that detailed calculation processing of the information acquired by the tampering detection device **10** will be described below in [Flow of Scan Pattern Determination Processing].

The determination unit **14***c* determines a scan pattern on the basis of the number of times of scanning calculated by the calculation unit **14***b*. In addition, the determination unit **14***c* randomly determines a scan pattern in which all the monitoring target files are included at least once on the basis of the number of times of scanning calculated by the calculation unit **14***b*. At this time, the determination unit **14***c* refers to the monitoring target device information stored in the monitoring target device information storage unit **15***a*. In addition, the determination unit **14***c* refers to the file information stored in the file information storage unit **15***b*. Note that detailed scan pattern determination processing by the tampering detection device **10** will be described below in [Flow of Scan Pattern Determination Processing].

The transmission unit **14***d* transmits the scan pattern determined by the determination unit **14***c* to the monitoring target device **20**. In addition, the transmission unit **14***d* may transmit whether the file verified by the verification unit **14***e* has been tampered with to the monitoring target device **20** or another terminal.

The verification unit **14***e* verifies whether the file has been tampered with by using the digest of the file generated on the basis of the scan pattern by the monitoring target device **20**. At this time, the verification unit **14***e* refers to the file digest of the correct monitoring target file stored in the file digest storage unit **15***c*.

[Configuration of Monitoring Target Device]

A configuration of the monitoring target device **20** according to the present embodiment will be described in detail with reference to FIG. **3**. FIG. **3** is a block diagram illustrating a configuration example of a monitoring target device according to the present embodiment. The monitoring target device **20** includes an input unit **21**, an output unit **22**, a communication unit **23**, a control unit **24**, and a storage unit **25**.

The input unit **21** controls inputting various types of information to the monitoring target device **20**. The input unit **21** is, for example, a mouse, a keyboard, or the like, and accepts input of setting information or the like to the monitoring target device **20**. In addition, the output unit **22** controls outputting various types of information from the monitoring target device **20**. The output unit **22** is, for example, a display or the like and outputs the setting information or the like stored in the monitoring target device **20**.

The communication unit **23** controls data communication with other devices. For example, the communication unit **23** performs data communication with each communication device. In addition, the communication unit **23** can perform data communication with a terminal of an operator, which is not illustrated.

The storage unit **25** stores various types of information referred to when the control unit **24** operates and various types of information acquired when the control unit **24** operates. The storage unit **25** includes, for example, a monitoring target file storage unit **25***a*. Here, the storage unit **25** is, for example, a semiconductor memory element such as RAM or flash memory, or a storage device such as a hard disk or an optical disc. Note that, in the example of FIG. **3**, the storage unit **25** is installed inside the monitoring target device **20**, but may be installed outside the monitoring target device **20**, or a plurality of storage units may be installed. The monitoring target file storage unit **25***a* stores a monitoring target file that can be accessed from the outside or tampered with.

The control unit **24** controls the entire monitoring target device **20**. The control unit **24** includes an acquisition unit **24***a*, a generation unit **24***b*, and a transmission unit **24***c*. Here, the control unit **24** is, for example, an electronic circuit such as a CPU or an MPU, or an integrated circuit such as an ASIC or an FPGA.

The acquisition unit **24***a* acquires a scan pattern of files from the tampering detection device **10**. In addition, the acquisition unit **24***a* may acquire information regarding whether or not the file has been tampered with from the tampering detection device **10**.

The generation unit **24***b* generates the digest of the file according to the scan pattern of the file acquired by the acquisition unit **24***a*. In addition, the generation unit **24***b* may store the generated digest of the file in the storage unit **25**.

The transmission unit **24***c* transmits the digest of the file generated by the generation unit **24***b* to the tampering detection device **10**. In addition, the transmission unit **24***c* may transmit the digest of the file to a terminal other than the tampering detection device **10**.

[Definition of Each Constant]

The definition of each constant according to the present embodiment will be described in detail with reference to FIG. **4**. FIG. **4** is a diagram for describing a definition of each constant according to the first embodiment.

It is assumed that there are N files {1, 2, . . . , N} of a monitoring target file group in the monitoring target device **20**, and an i-th file is referred to as a file i. In addition, the symbol i is also used as a symbol indicating a file name of an arbitrary file as appropriate, such as "i=file A".

"τ_i" represents a time required for hash calculation of the file i, and a numerical value thereof is obtained by Formula (1). Here, the constant determined by the hash calculation method is a calculation amount for each byte of the file depending on the hash algorithm.

[Math. 1]

$$\tau_i = \frac{\text{[Constant determined by hash calculation method]}\,\text{[Size of file } i\text{]}}{\text{[Use amount of } CPU\text{]} + \text{[Delay by communication or the like]}} \tag{1}$$

Note that, in FIG. **4**, the time required for the hash calculation of "file A", "file B", and "file C" is illustrated.

"τ_{av}" represents an average time required for hash calculation of the file, and a numerical value thereof is obtained by Formula (2).

[Math. 2]

$$\tau_{av} = E[\tau_i] = \frac{1}{N}\sum\nolimits_{i=1}\tau_i \tag{2}$$

Formula (3) represents a scan pattern for the file i. Here, "s_i^j" represents a j-th scan start time for the file i, and "k_i" represents the number of times of scanning in the scan pattern for the file i, that is, the number of times of scanning per scan processing cycle.

[Math. 3]

$$[s_i^1, s_i^2, \ldots, s_i^{k_i}] \tag{3}$$

Note that FIG. **4** illustrates first scan start times of the first and second cycles for "file A", first to third scan start times of the first cycle for "file B", and first and second scan start times of the first cycle for "file C".

"τ_{all}" represents the time required to execute the scan pattern, that is, the time for one scan processing cycle, and is expressed by Formula (4).

[Math. 4]

$$\tau_{all} = \sum\nolimits_i k_i\tau_i \tag{4}$$

Note that, in FIG. **4**, the time from the first scan start time for "file A" to the third scan end time for "file B" corresponds to "τ_{all}".

"$\text{next}_i(t)$" is a time at which scanning of the file i is started for the first time after a certain time t, and is determined by a scan pattern. Note that, in FIG. **4**, "next$_i$(t)" is illustrated for each of scans of "file A" and "file B" after a certain time t.

"prev$_i$(t)" is a time at which scanning of the file i is started immediately before a certain time t, and is determined by a scan pattern. Note that, in FIG. **4**, "prev$_i$(t)" is illustrated for each of scans of "file B" and "file C" immediately before a certain time t.

[Evaluation Index of Scan Pattern]

The evaluation index of the scan pattern according to the present embodiment will be described in detail with reference to FIG. **5**. FIG. **5** is a diagram for describing an evaluation index of a scan pattern according to the first embodiment. In the present embodiment, E[τ_{attack}] is introduced as an evaluation index for determining whether a scan pattern is good or bad in order to formulate a "possibility that an authorized program unintentionally executes an illicitly tampered file". Hereinafter, the definition and optimization of the evaluation index E[τ_{attack}] will be described.

(Definition of Evaluation Index E[τ_{attack}])

First, the definition of the evaluation index E[τ_{attack}] will be described. "τ_{attack}" represents a time until another process uses the file i after the file i is scanned, that is, a time from scanning to the latest access, and a numerical value thereof is obtained by Formula (5). Here, "t_{access}" is a time at which the file i is read by another process, that is, a time at which the file i is accessed, and it is assumed that all accesses occur instantaneously without time width.

[Math. 5]

$$\tau_{attack} = t_{access} - prev_i(t_{access}) \tag{5}$$

Note that, in FIG. **5**, an access to "file A" occurs at time t_1, and time T_{attack} until "file A" is accessed after scanning is illustrated. In addition, an access to "file B" occurs at time τ_2, and time τ_{attack} until "file B" is accessed after scanning is illustrated.

In addition, "q$_i$(t)" represents a probability that an access to the file i occurs at a certain time t.

As described above, the evaluation index E[τ_{attack}] represents an average time until another process reads the monitoring target file after scanning, that is, an average time from scanning of the monitoring target file to the latest access, and is expressed by Formula (6). Note that the evaluation index E[τ_{attack}] can also be defined as "an unprotected time of the monitoring target file" or "a tamperable time of the monitoring target file".

[Math. 6]

$$E[\tau_{attack}] = \frac{1}{N}\sum_i \int (t - prev_i(t))q_i(t)dt \tag{6}$$

When the evaluation index E[τ_{attack}] is reduced, even if tampering occurs, scanning is performed before the file is used. Note that, in the on-access scan method, this index is zero.

(Optimization of Evaluation Index E[τ_{attack}])

Next, optimization of the evaluation index E[τ_{attack}] according to the present embodiment will be described. First, at the time of tampering detection, it is desired to generate a scan pattern that reduces the evaluation index E[τ_{attack}]. However, in general, a probability q$_i$(t) that an

access from an authorized program occurs to the file i at a certain time t is unknown. Therefore, in Formula (6) above, various optimization methods are conceivable depending on how to handle q$_i$(t). Hereinafter, an optimization method in which q$_i$(t) is constant without depending on the time t and only the access frequency of each file is taken into account will be described.

In Formula (6), when q$_i$(t) is constant without depending on the time t and is set to "q$_i$", it can be expressed as Formula (7).

[Math. 7]

$$E[\tau_{attack}] = \frac{1}{N}\sum_i q_i \int (t - prev_i(t))dt \tag{7}$$

In addition, in above Formula (7), "f$_i$(t)" (integration calculation part) related to the time t is expressed as in Formula (8).

[Math. 8]

$$f_i(t) = \int (t - prev_i(t))dt \tag{8}$$

Here, assuming that the monitoring target file is randomly scanned, f$_i$(t) can be approximated to "proportional to a reciprocal (1/k$_i$) of the number of times of accessing the file i in one scan processing cycle". Therefore, E[τ_{attack}] can be expressed as Formula (9).

[Math. 9]

$$E[\tau_{attack}] \propto \frac{1}{N}\sum_i \frac{q_i}{k_i} \tag{9}$$

k$_i$ that minimizes E[τ_{attack}] of above Formula (9) is obtained under the constraint conditions represented by Formulae (10) and (11) below.

[Math. 10]

$$\frac{1}{N}\sum_i q_i = 1 \tag{10}$$

[Math. 11]

$$\sum_i \tau_i k_i = \tau_{all} \tag{11}$$

When it is assumed that the time τ_i required for the hash calculation is constant regardless of the file, Formula (12) is a solution.

[Math. 12]

$$k_i \propto q_i \tag{12}$$

As described above, since k$_i$ is proportional to the scan frequency for the file i, the optimization of the evaluation index E[τ_{attack}] according to the present embodiment is a method of "generating a random scan pattern in which scan is performed more frequently as access frequency of file is higher in consideration of time required for scan according to file size".

[Flow of Tampering Detection Processing]

A flow of the tampering detection processing according to the present embodiment will be described in detail with reference to FIG. **6**. FIG. **6** is a flowchart illustrating an example of a flow of tampering detection processing according to the first embodiment. First, the acquisition unit **14***a* of the tampering detection device **10** acquires information such as information of an access frequency and a file size of a monitoring target file from the monitoring target device **20** (step S**101**). At this time, the acquisition unit **14***a* may acquire the information from a device other than the monitoring target device **20**. In addition, the acquisition unit **14***a* may acquire information directly input via the input unit **11**.

Next, the determination unit **14***c* determines an optimum scan pattern on the basis of the information acquired from the monitoring target device **20** such as access frequency (step S**102**). At this time, the calculation unit **14***b* may perform calculation processing for information necessary for the determination unit **14***c* to determine the scan pattern. In addition, when there is a scan pattern created in advance, the determination unit **14***c* can also adopt this scan pattern. Further, when a plurality of scan patterns can be determined, the determination unit **14***c* can adopt one or a plurality of scan patterns from the scan patterns.

Subsequently, the transmission unit **14***d* transmits the scan pattern to the monitoring target device **20** (step S**103**). At this time, the transmission unit **14***d* may transmit the scan patterns in bulk (collectively) or may transmit the scan patterns one by one. In addition, the transmission unit **14***d* may transmit a plurality of scan patterns.

Then, the acquisition unit **14***a* acquires a digest of a file generated by the generation unit **24***b* of the monitoring target device **20** and transmitted by the transmission unit **24***c* (step S**104**). Finally, the verification unit **14***e* verifies whether the file has been tampered with on the basis of the digest of the file acquired by the acquisition unit **14***a* (step S**105**), and the tampering detection processing ends. Note that the transmission unit **14***d* may transmit whether the file has been tampered with verified by the verification unit **14***e* to the monitoring target device **20** or another terminal.

[Flow of Scan Pattern Determination Processing]

The flow of the scan pattern determination processing according to the present embodiment will be described in detail with reference to FIG. **7**. FIG. **7** is a flowchart illustrating an example of a flow of scan pattern determination processing according to the first embodiment.

First, the acquisition unit **14***a* of the tampering detection device **10** acquires an access log of a monitoring target file in the monitoring target device **20** for a certain period from the monitoring target device **20** (step S**201**), and acquires an access frequency for each monitoring target file from the access log (step S**202**).

At this time, the acquisition unit **14***a* may acquire the access log from a device other than the monitoring target device **20**. In addition, the acquisition unit **14***a* may acquire the access log directly input via the input unit **11**. Note that in a certain period regarding the acquisition of the access log, the monitoring target device **20** may perform the scan processing by an arbitrary method or may not perform the scan processing.

Next, the acquisition unit **14***a* of the tampering detection device **10** acquires the file size of the monitoring target file from the monitoring target device **20** (step S**203**). At this time, the acquisition unit **14***a* may acquire the file size from a device other than the monitoring target device **20**. In addition, the acquisition unit **14***a* may acquire the file size directly input via the input unit **11**.

Then, the acquisition unit **14***a* calculates and acquires a time τ_1 required for hash calculation for each file from the file size described above and the like (step S**204**). Note that the acquisition unit **14***a* uses above Formula (1) when calculating τ_i described above. In addition, the acquisition unit **14***a* may calculate and acquire an average time τ_{av} required for hash calculation of the file represented by Formula (2) described above.

Subsequently, the acquisition unit **14***a* acquires a set time τ_{all} of one scan processing cycle (step S**205**). Here, τ_{all} is a numerical value given as a set value from the outside, but is not particularly limited. The acquisition unit **14***a* may acquire Tau from the monitoring target device **20** or another terminal, or may acquire τ_{all} directly input via the input unit **11**.

Note that the order of the processing of steps S**201** to S**205** is exemplary, and the acquisition unit **14***a* can also perform the processing in a different order. In addition, the acquisition unit **14***a* can omit part of the processing of steps S**201** to S**205**.

Thereafter, the calculation unit **14***b* calculates the number of times of scanning k_i of one cycle that minimizes the evaluation index $E[\tau_{attack}]$ using acquired τ_i and τ_{all} (step S**206**). At this time, when it is desired to generate a scan pattern so as to scan all the files at least once in one cycle, the calculation unit **14***b* sets the minimum value of k_i for an arbitrary file to one (step S**207**). Finally, the determination unit **14***c* randomly determines a scan pattern that satisfies k_i(step S**208**), and the processing ends.

[Effects of First Embodiment]

First, in the tampering detection processing according to the present embodiment described above, the access frequency of the monitoring target file is acquired, the number of times of scanning in the scan pattern is calculated for each monitoring target file on the basis of the acquired access frequency, and the scan pattern is determined on the basis of the calculated number of times of scanning. Thus, in the present processing, it is possible to reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device.

Second, in the tampering detection processing according to the present embodiment described above, the file size of the monitoring target file and the scan pattern set time are further acquired, and the number of times of scanning is calculated on the basis of the access frequency, the file size, and the set time. Thus, in the present processing, it is possible to more efficiently reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device.

Third, in the tampering detection processing according to the present embodiment described above, the number of times of scanning that minimizes an average time from scanning of the monitoring target file to the latest access is calculated. Thus, in the present processing, it is possible to more effectively reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device.

Fourth, in the tampering detection processing according to the present embodiment described above, a scan pattern in which all the monitoring target files are included at least once is randomly determined on the basis of the number of times of scanning. Thus, in the present processing, it is possible to more comprehensively reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in a monitoring target device.

Fifth, in the tampering detection processing according to the present embodiment described above, the access frequency is acquired from the monitoring target device that stores the monitoring target file, the scan pattern is transmitted to the monitoring target device, and whether or not the file has been tampered with is verified using the digest of the file generated on the basis of the scan pattern by the monitoring target device. Thus, in the present processing, in software tampering detection, it is possible to optimally and comprehensively monitor all the files, and it is possible to reduce the possibility that an authorized program executes an illicitly tampered file while suppressing use resources in the monitoring target device.

[System Configuration or the Like]

Each component of each device that has been illustrated according to the embodiment described above is functionally conceptual and does not necessarily have to be physically configured as illustrated. In other words, a specific form of distribution and integration of individual devices is not limited to the illustrated form, and all or part of the configuration can be functionally or physically distributed and integrated in any unit according to various loads, usage conditions, and the like. Further, all or any part of each processing function performed in each device can be implemented by a CPU and a program to be analyzed and executed by the CPU or can be implemented as hardware by wired logic.

In addition, among the individual processing described in the embodiment described above, all or part of the processing described as being automatically performed can be manually performed, or all or part of the processing described as being manually performed can be automatically performed by a known method. Additionally, the processing procedures, the control procedures, the specific names, and the information including various data and parameters illustrated in the specification and the drawings can be arbitrarily changed unless otherwise specified.

[Program]

In addition, it is also possible to create a program in which the processing executed by the tampering detection device **10** described in the foregoing embodiment is described in a language which can be executed by a computer. In this case, the computer executes the program, and thus, the effects similar to those of the embodiment described above can be obtained. Further, the program may be recorded in a computer-readable recording medium, and the program recorded in the recording medium may be read and executed by the computer. Thereby, processing similar to the embodiment described above may be realized.

FIG. **8** is a diagram illustrating a computer that executes a program. As illustrated in FIG. **8**, a computer **1000** includes, for example, memory **1010**, a CPU **1020**, a hard disk drive interface **1030**, a disk drive interface **1040**, a serial port interface **1050**, a video adapter **1060**, and a network interface **1070**. These units are connected by a bus **1080**.

As exemplified in FIG. **8**, the memory **1010** includes a read only memory (ROM) **1011** and a RAM **1012**. The ROM **1011** stores, for example, a boot program such as a basic input output system (BIOS). The hard disk drive interface **1030** is connected to a hard disk drive **1090** as exemplified in FIG. **8**. The disk drive interface **1040** is connected to a disk drive **1100** as exemplified in FIG. **8**. For example, a removable storage medium such as a magnetic disk or an optical disk is inserted into the disk drive **1100**. As exemplified in FIG. **8**, the serial port interface **1050** is connected to, for example, a mouse **1110** and a keyboard **1120**. As exemplified in FIG. **8**, the video adapter **1060** is connected to, for example, a display **1130**.

Here, as exemplified in FIG. **8**, the hard disk drive **1090** stores, for example, an OS **1091**, an application program **1092**, a program module **1093**, and program data **1094**. In other words, the above program is stored, for example, in the hard disk drive **1090** as a program module in which a command to be executed by the computer **1000** is described.

In addition, various data described in the embodiment described above is stored as program data in, for example, the memory **1010** and the hard disk drive **1090**. Then, the CPU **1020** reads out the program module **1093** and the program data **1094** stored in the memory **1010** and the hard disk drive **1090** to the RAM **1012** as necessary and executes various processing procedures.

Note that the program module **1093** and the program data **1094** related to the program are not limited to being stored in the hard disk drive **1090** and may be stored in, for example, a removable storage medium and may be read by the CPU **1020** via a disk drive, or the like. Alternatively, the program module **1093** and the program data **1094** related to the program may be stored in another computer connected via a network (such as a local area network (LAN) or a wide area network (WAN)) and may be read by the CPU **1020** via the network interface **1070**.

The embodiment described above and modifications thereof are included in the inventions recited in the claims and the equivalent scope thereof, similarly to being included in the technique disclosed in the present application.

Reference Signs List	
10	Tampering detection device
11	Input unit
12	Output unit
13	Communication unit
14	Control unit
14a	Acquisition unit
14b	Calculation unit
14c	Determination unit
14d	Transmission unit
14e	Verification unit
15	Storage unit
15a	Monitoring target device information storage unit
15b	File information storage unit
15c	File digest storage unit
20	Monitoring target device
21	Input unit
22	Output unit
23	Communication unit
24	Control unit
24a	Acquisition unit
24b	Generation unit
24c	Transmission unit
25	Storage unit
25a	Monitoring target file storage unit
100	Tampering detection system

The invention claimed is:

1. A tampering detection device comprising: tampering detection circuitry configured to:

acquire information on resources of a monitoring target device, an access frequency and a file size of a monitoring target file in the monitoring target device, and a scan pattern set time;

calculate a time required for hash calculation using the information on resources and the file size acquired by the acquisition step, and calculate a number of times of scanning in a scan pattern for each monitoring target file on a basis of the time required for hash calculation and the access frequency; and determine the scan pattern on a basis of the number of times of scanning calculated.

2. The tampering detection device according to claim **1**, wherein the tampering detection circuitry configured to

calculate the number of times of scanning thereby minimizing an average time lapse between an occurrence of scanning the monitoring target file and a first-time occurrence of an access to the monitoring target file subsequent to the occurrence.

3. The tampering detection device according to claim **1**, wherein the tampering detection circuitry configured to

randomly determine a scan pattern in which all the monitoring target files are included at least once on a basis of the number of times of scanning.

4. The tampering detection device according to claim **1**, wherein the tampering detection circuitry configured to

acquire the access frequency from a monitoring target device that stores the monitoring target file, and

the tampering detection device further comprises: tampering detection circuitry configured to:

transmit the scan pattern to the monitoring target device; and

verify whether or not the file has been tampered by using a digest of a file generated on a basis of the scan pattern by the monitoring target device.

5. A tampering detection method executed by a tampering detection device, the method comprising:

acquiring information on resources of a monitoring target device, an access frequency and a file size of a monitoring target file in the monitoring target device, and a scan pattern set time;

calculating a time required for hash calculation using the information on resources and the file size acquired by the acquiring process, and calculating a number of times of scanning in a scan pattern for each monitoring target file on a basis of the time required for hash calculation and the access frequency; and

determining the scan pattern on a basis of the number of times of scanning calculated.

6. A non-transitory computer-readable recording medium storing therein a tampering detection program causing a computer to execute a process comprising:

acquiring information on resources of a monitoring target device, an access frequency and a file size of a monitoring target file in the monitoring target device, and a scan pattern set time;

calculating a time required for hash calculation using the information on resources and the file size acquired by the acquisition step, and calculating a number of times of scanning in a scan pattern for each monitoring target file on a basis of the time required for hash calculation and the access frequency; and

determining the scan pattern on a basis of the number of times of scanning calculated.

* * * * *