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(54) **METHODS AND APPARATUS TO FINGERPRINT AN AUDIO SIGNAL VIA NORMALIZATION**

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G10L 25/18 (2013.01)
G10L 25/51 (2013.01)

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

CPC ***G10L 19/02*** (2013.01); ***G10L 25/18*** (2013.01); ***G10L 25/51*** (2013.01)

(58) **Field of Classification Search**

CPC G10L 19/02; G10L 25/18; G10L 25/51
See application file for complete search history.

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Primary Examiner — Thomas H Maung
(74) *Attorney, Agent, or Firm* — MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP

(57) **ABSTRACT**

Methods, apparatus, systems, and articles of manufacture are disclosed to fingerprint audio via mean normalization. An example apparatus for audio fingerprinting includes a frequency range separator to transform an audio signal into a frequency domain, the transformed audio signal including a plurality of time-frequency bins including a first time-frequency bin, an audio characteristic determiner to determine a first characteristic of a first group of time-frequency bins of the plurality of time-frequency bins, the first group of time-frequency bins surrounding the first time-frequency bin and a signal normalizer to normalize the audio signal to thereby generate normalized energy values, the normalizing of the audio signal including normalizing the first time-frequency bin by the first characteristic. The example apparatus further includes a point selector to select one of the normalized energy values and a fingerprint generator to generate a fingerprint of the audio signal using the selected one of the normalized energy values.

17 Claims, 9 Drawing Sheets

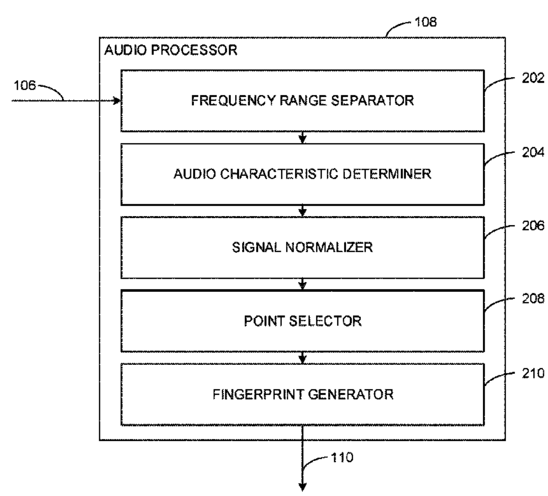

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FIG. 1

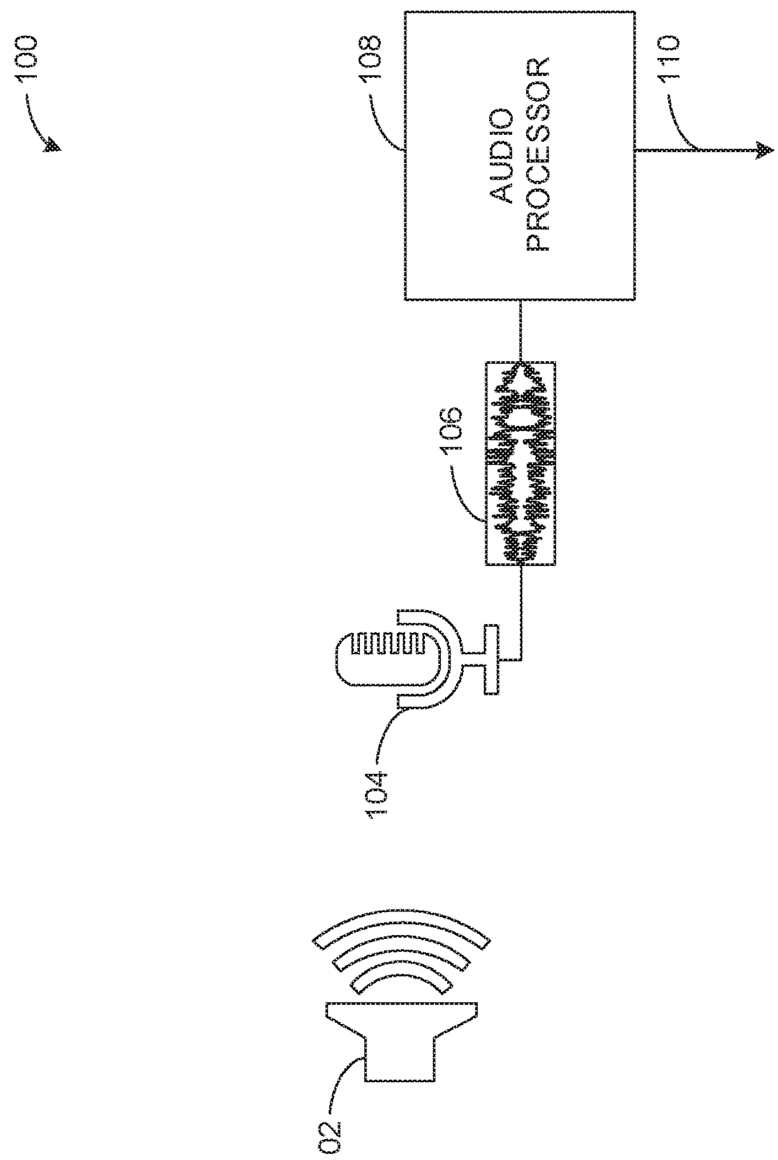
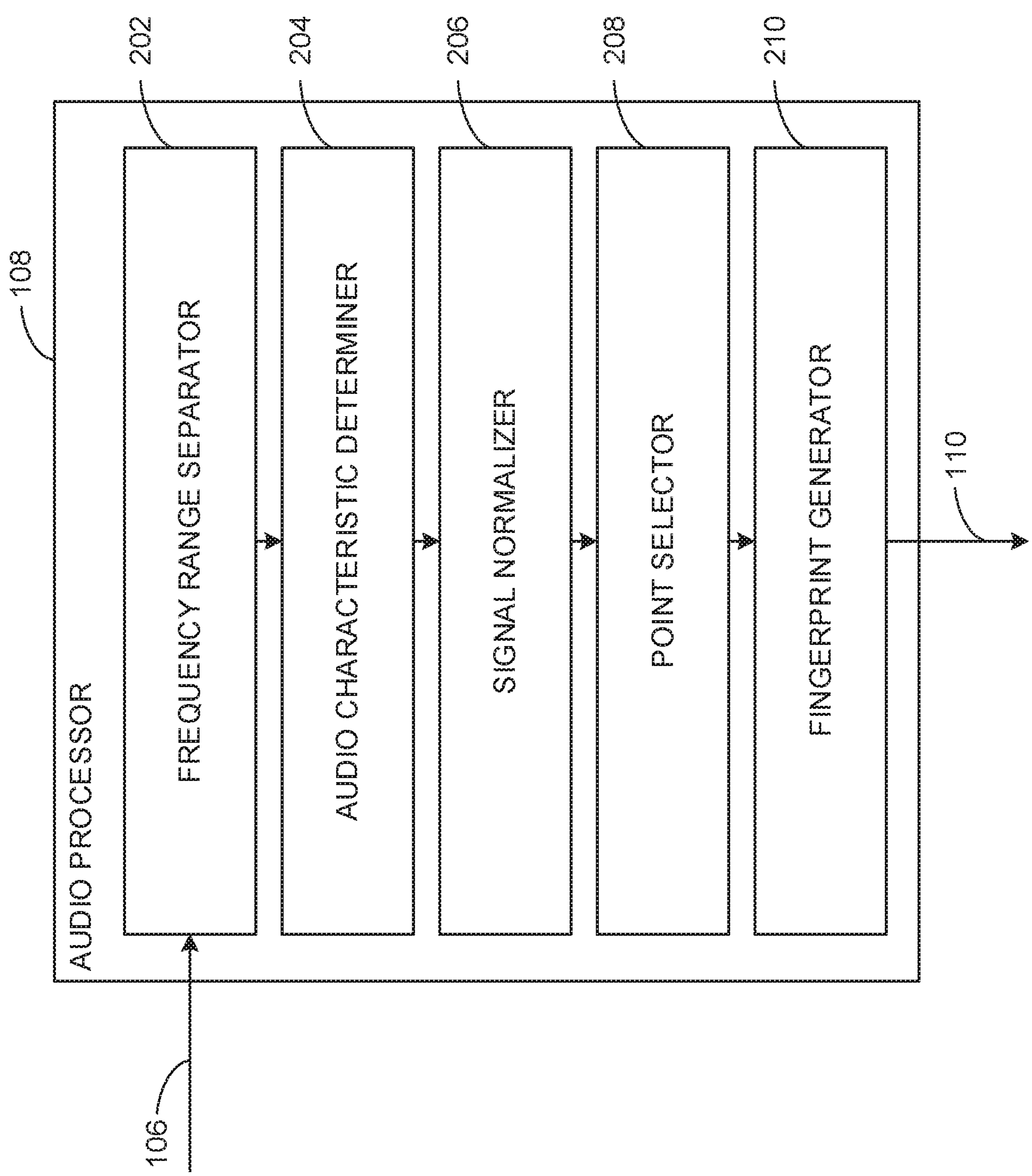


FIG. 2


AUDIO PROCESSOR
108
FREQUENCY RANGE SEPARATOR
202
AUDIO CHARACTERISTIC DETERMINER
204
SIGNAL NORMALIZER
206
POINT SELECTOR
208
FINGERPRINT GENERATOR
210
106
110

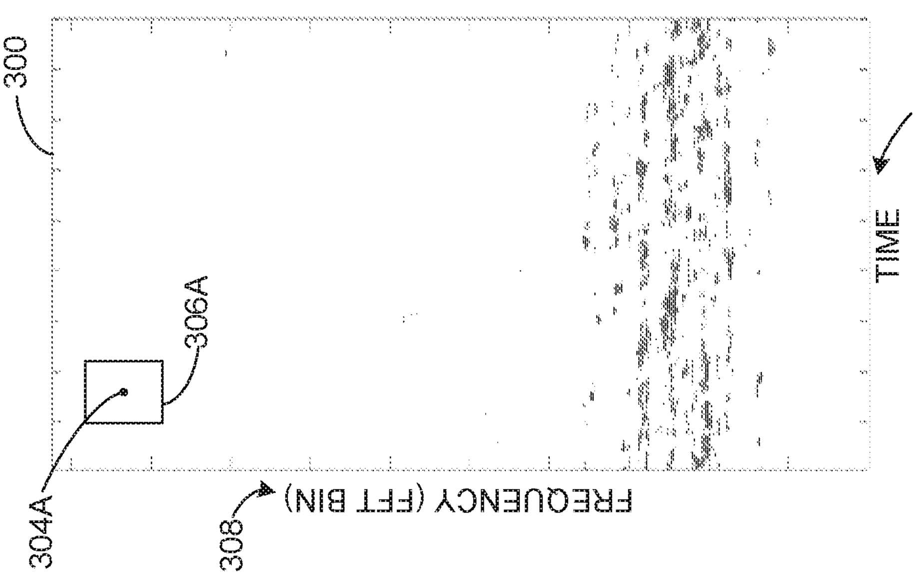


FIG. 3A

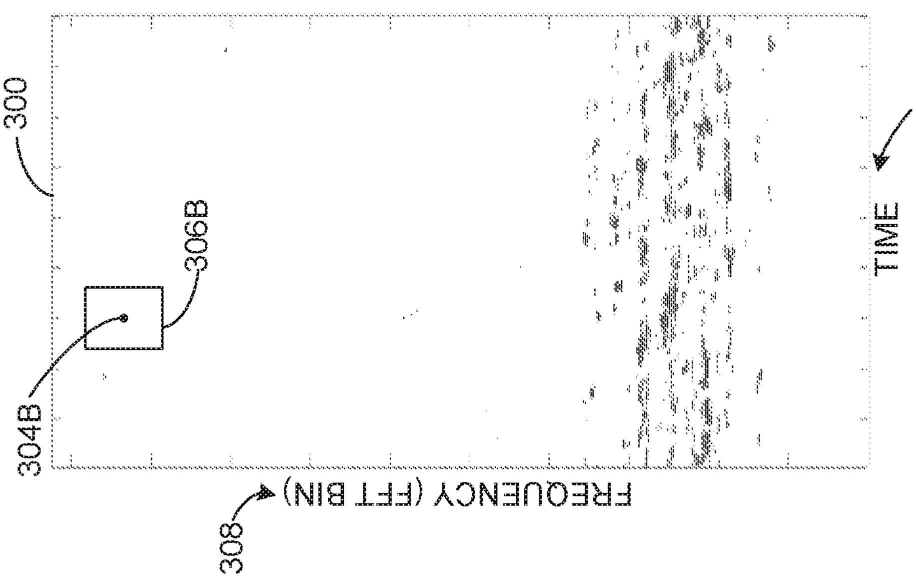


FIG. 3B

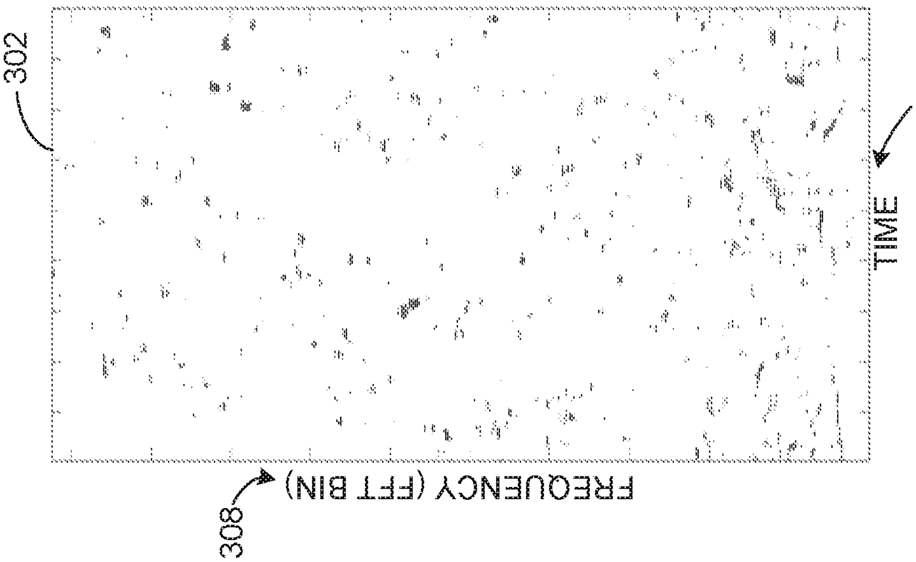


FIG. 3C

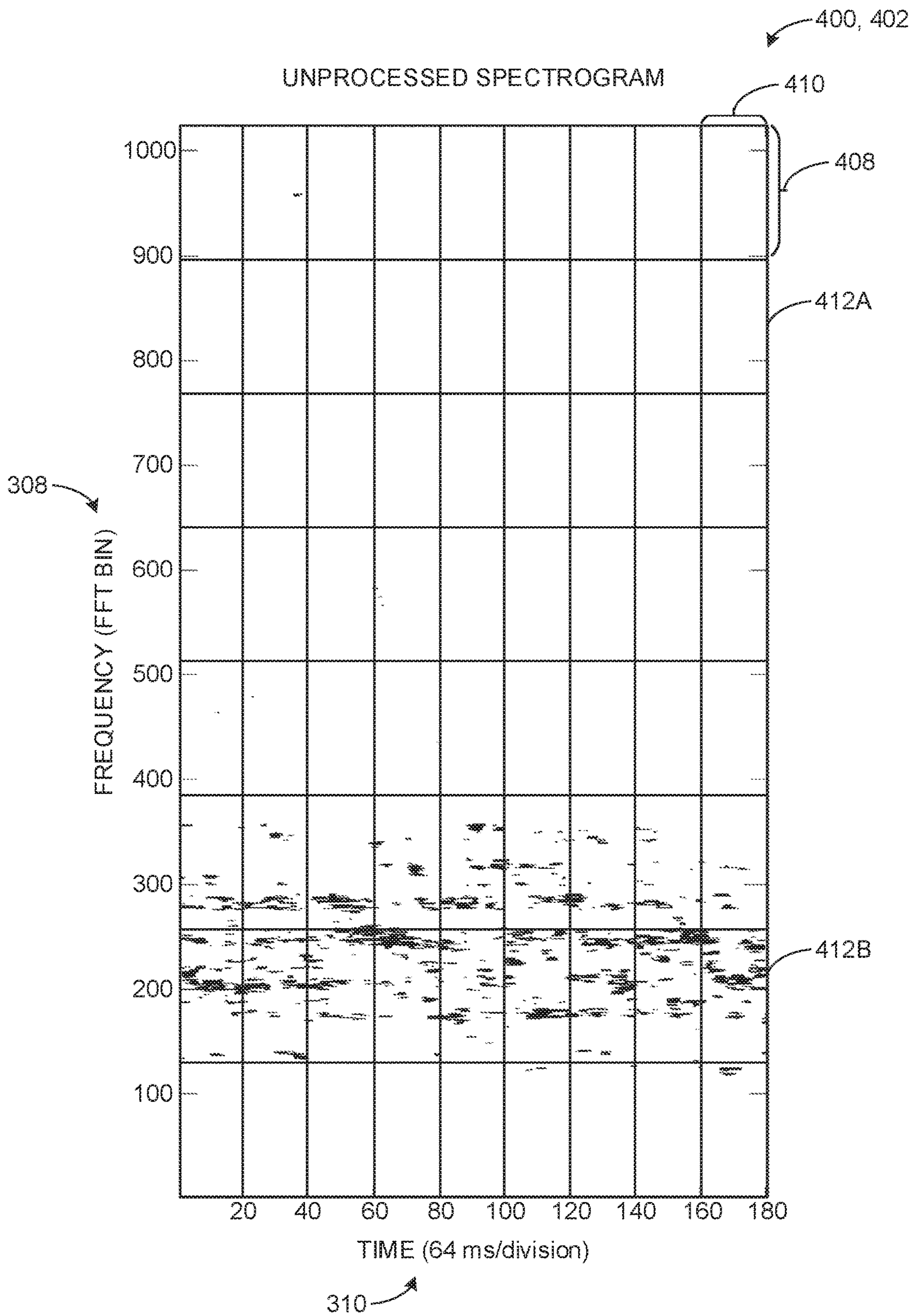
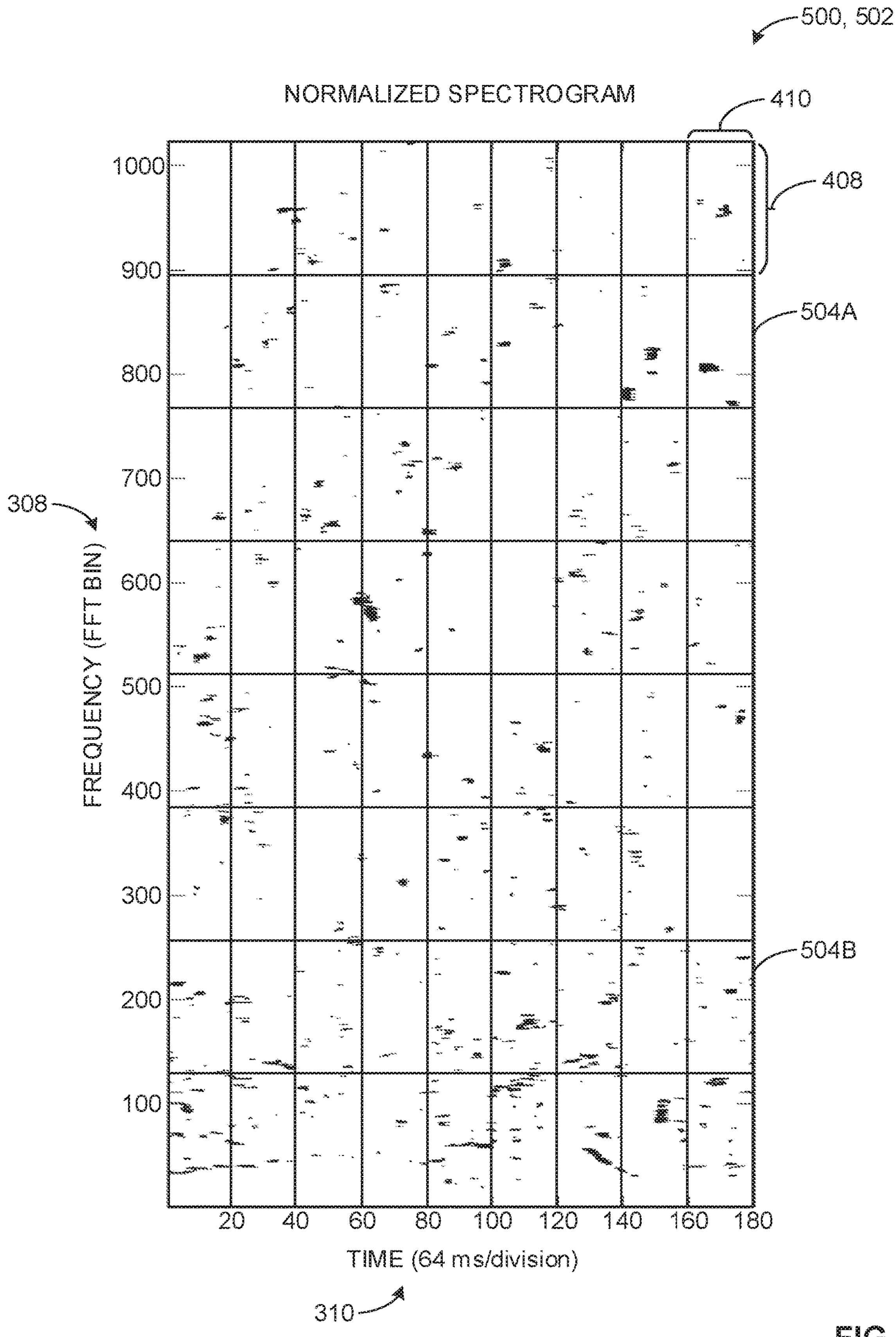

400, 402
UNPROCESSED SPECTROGRAM
410
408
412A
412B
308
310
FREQUENCY (FFT BIN)
1000
900
800
700
600
500
400
300
200
100
20
40
60
80
100
120
140
160
180
TIME (64 ms/division)

FIG. 4



500, 502
NORMALIZED SPECTROGRAM
410
408
504A
504B
308
FREQUENCY (FFT BIN)
1000
900
800
700
600
500
400
300
200
100
20
40
60
80
100
120
140
160
180
TIME (64 ms/division)
310

FIG. 5

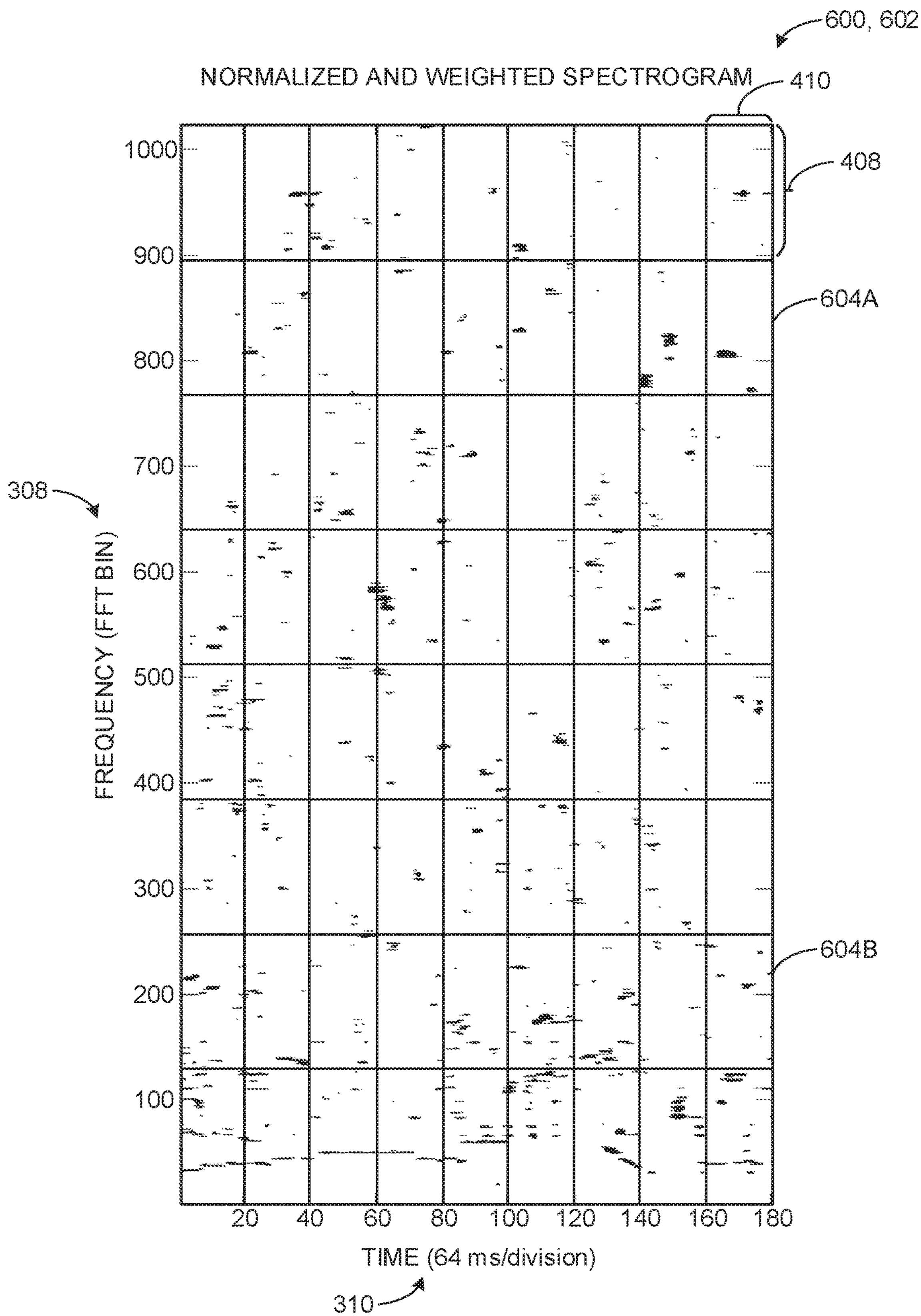

600, 602
NORMALIZED AND WEIGHTED SPECTROGRAM
410
408
604A
604B
308
FREQUENCY (FFT BIN)
1000
900
800
700
600
500
400
300
200
100
20
40
60
80
100
120
140
160
180
TIME (64 ms/division)
310

FIG. 6

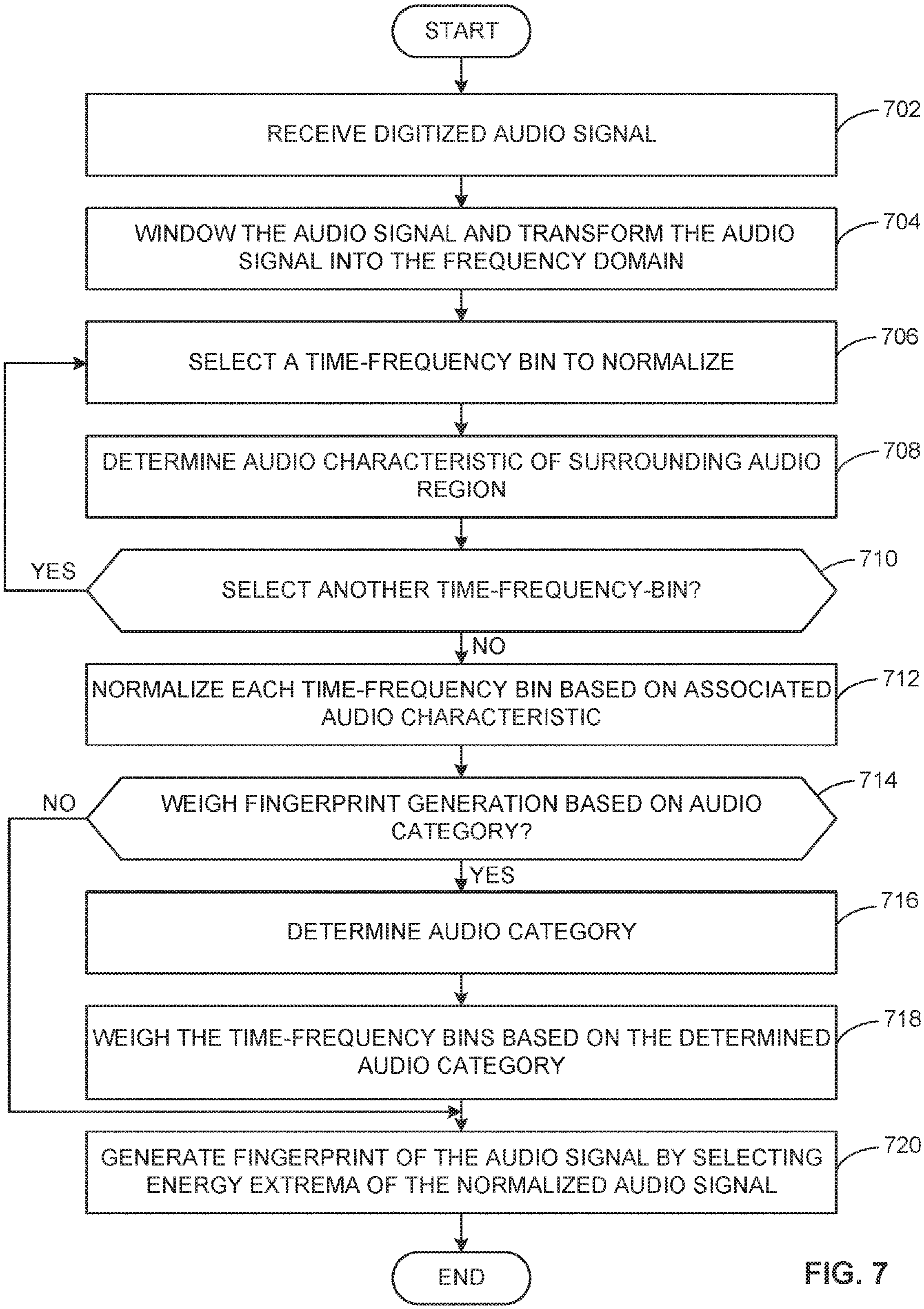

START
RECEIVE DIGITIZED AUDIO SIGNAL
702
WINDOW THE AUDIO SIGNAL AND TRANSFORM THE AUDIO SIGNAL INTO THE FREQUENCY DOMAIN
704
SELECT A TIME-FREQUENCY BIN TO NORMALIZE
706
DETERMINE AUDIO CHARACTERISTIC OF SURROUNDING AUDIO REGION
708
YES
SELECT ANOTHER TIME-FREQUENCY-BIN?
710
NO
NORMALIZE EACH TIME-FREQUENCY BIN BASED ON ASSOCIATED AUDIO CHARACTERISTIC
712
NO
WEIGH FINGERPRINT GENERATION BASED ON AUDIO CATEGORY?
714
YES
DETERMINE AUDIO CATEGORY
716
WEIGH THE TIME-FREQUENCY BINS BASED ON THE DETERMINED AUDIO CATEGORY
718
GENERATE FINGERPRINT OF THE AUDIO SIGNAL BY SELECTING ENERGY EXTREMA OF THE NORMALIZED AUDIO SIGNAL
720
END

FIG. 7

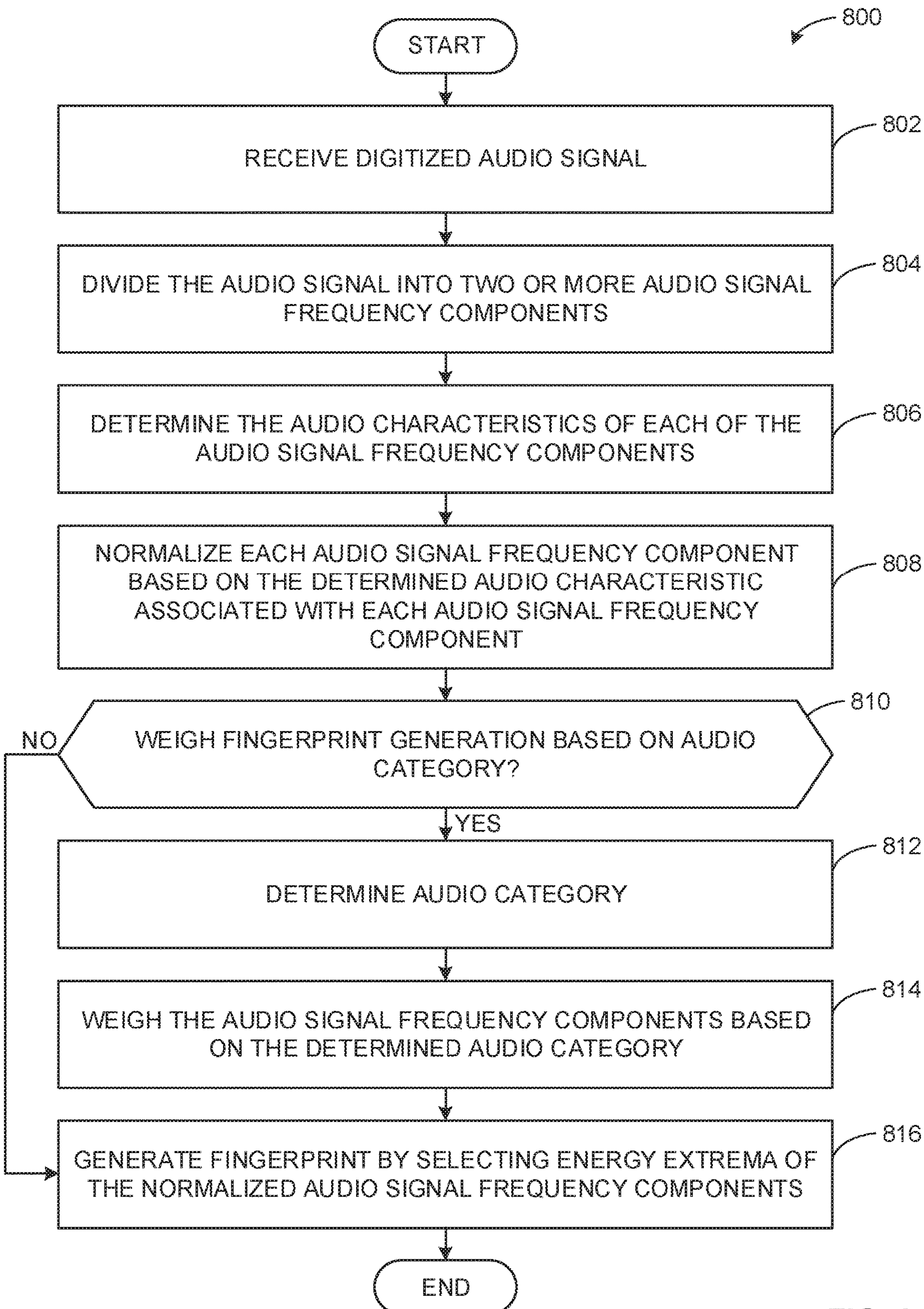

800
START
RECEIVE DIGITIZED AUDIO SIGNAL
802
DIVIDE THE AUDIO SIGNAL INTO TWO OR MORE AUDIO SIGNAL FREQUENCY COMPONENTS
804
DETERMINE THE AUDIO CHARACTERISTICS OF EACH OF THE AUDIO SIGNAL FREQUENCY COMPONENTS
806
NORMALIZE EACH AUDIO SIGNAL FREQUENCY COMPONENT BASED ON THE DETERMINED AUDIO CHARACTERISTIC ASSOCIATED WITH EACH AUDIO SIGNAL FREQUENCY COMPONENT
808
WEIGH FINGERPRINT GENERATION BASED ON AUDIO CATEGORY?
810
NO
YES
DETERMINE AUDIO CATEGORY
812
WEIGH THE AUDIO SIGNAL FREQUENCY COMPONENTS BASED ON THE DETERMINED AUDIO CATEGORY
814
GENERATE FINGERPRINT BY SELECTING ENERGY EXTREMA OF THE NORMALIZED AUDIO SIGNAL FREQUENCY COMPONENTS
816
END

FIG. 8

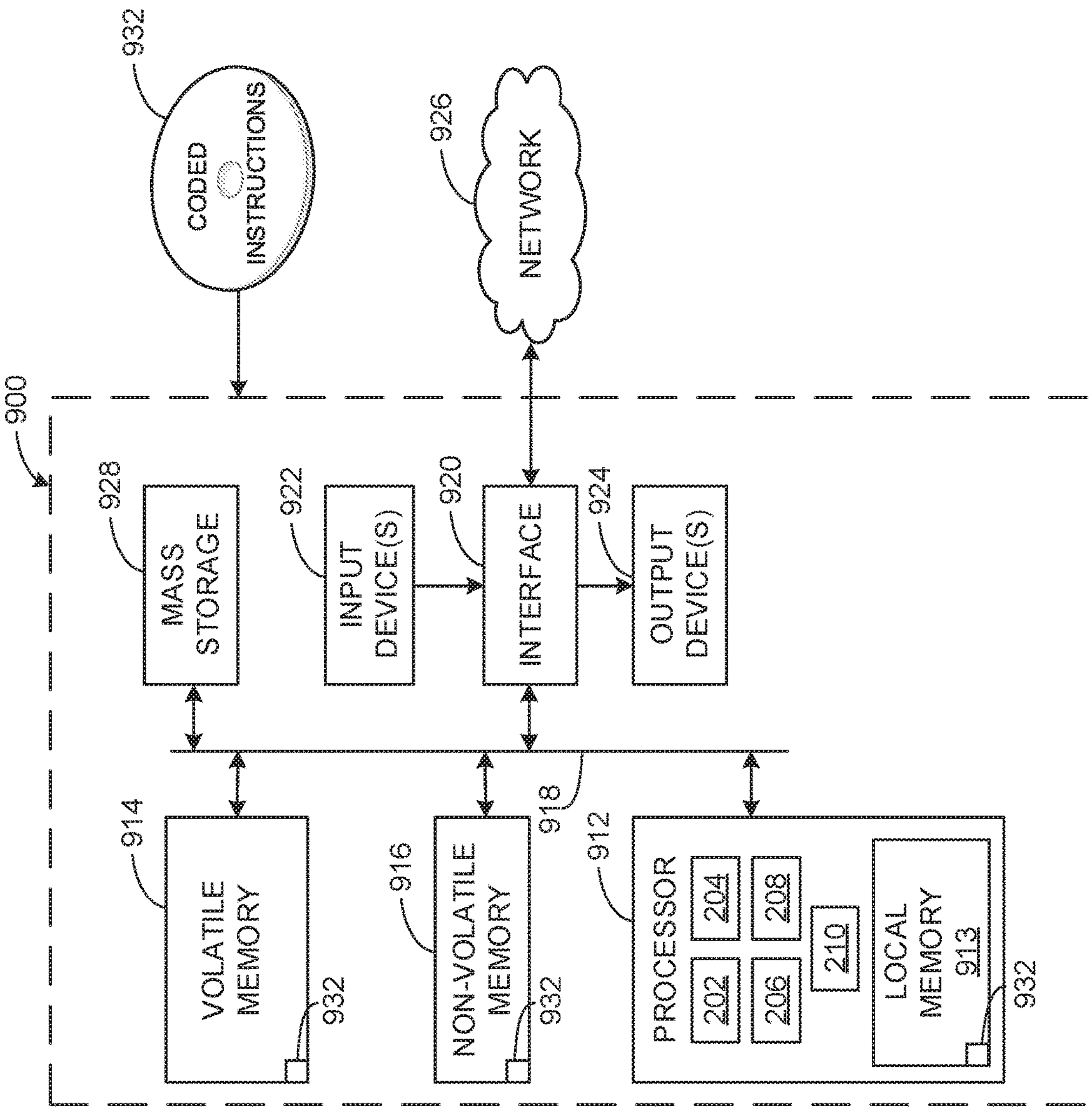

932
CODED INSTRUCTIONS
926
NETWORK
900
928
MASS STORAGE
922
INPUT DEVICE(S)
920
INTERFACE
924
OUTPUT DEVICE(S)
914
VOLATILE MEMORY
932
916
NON-VOLATILE MEMORY
932
918
912
PROCESSOR
202
204
206
208
210
LOCAL MEMORY
913
932

FIG. 9

METHODS AND APPARATUS TO FINGERPRINT AN AUDIO SIGNAL VIA NORMALIZATION

RELATED APPLICATION

This patent claims priority to, and benefit of, French Patent Application Serial No. 1858041, which was filed on Sep. 7, 2018. French Patent Application Serial No. 1858041 is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

This disclosure relates generally to audio signals and, more particularly, to methods and apparatus to fingerprint an audio signal via normalization.

BACKGROUND

Audio information (e.g., sounds, speech, music, etc.) can be represented as digital data (e.g., electronic, optical, etc.). Captured audio (e.g., via a microphone) can be digitized, stored electronically, processed and/or cataloged. One way of cataloging audio information is by generating an audio fingerprint. Audio fingerprints are digital summaries of audio information created by sampling a portion of the audio signal. Audio fingerprints have historically been used to identify audio and/or verify audio authenticity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an example system on which the teachings of this disclosure may be implemented.

FIG. **2** is an example implementation of the audio processor of FIG. **1**.

FIGS. **3**A and **3**B depict an example unprocessed spectrogram generated by the example frequency range separator of FIG. **2**.

FIG. **3**C depicts an example of a normalized spectrogram generated by the signal normalizer of FIG. **2** from the unprocessed spectrogram of FIGS. **3**A and **3**B.

FIG. **4** is an example unprocessed spectrogram of FIGS. **3**A and **3**B divided into fixed audio signal frequency components.

FIG. **5** is an example of a normalized spectrogram generated by the signal normalizer of FIG. **2** from the fixed audio signal frequency components of FIG. **4**.

FIG. **6** is an example of a normalized and weighted spectrogram generated by the point selector of FIG. **2** from the normalized spectrogram of FIG. **5**.

FIGS. **7** and **8** are flowcharts representative of machine readable instructions that may be executed to implement the audio processor of FIG. **2**.

FIG. **9** is a block diagram of an example processing platform structured to execute the instructions of FIGS. **7** and **8** to implement the audio processor of FIG. **2**.

The figures are not to scale. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts.

DETAILED DESCRIPTION

Fingerprint or signature-based media monitoring techniques generally utilize one or more inherent characteristics of the monitored media during a monitoring time interval to generate a substantially unique proxy for the media. Such a proxy is referred to as a signature or fingerprint, and can take any form (e.g., a series of digital values, a waveform, etc.) representative of any aspect(s) of the media signal(s) (e.g., the audio and/or video signals forming the media presentation being monitored). A signature can be a series of signatures collected in series over a time interval. The term "fingerprint" and "signature" are used interchangeably herein and are defined herein to mean a proxy for identifying media that is generated from one or more inherent characteristics of the media.

Signature-based media monitoring generally involves determining (e.g., generating and/or collecting) signature(s) representative of a media signal (e.g., an audio signal and/or a video signal) output by a monitored media device and comparing the monitored signature(s) to one or more references signatures corresponding to known (e.g., reference) media sources. Various comparison criteria, such as a cross-correlation value, a Hamming distance, etc., can be evaluated to determine whether a monitored signature matches a particular reference signature.

When a match between the monitored signature and one of the reference signatures is found, the monitored media can be identified as corresponding to the particular reference media represented by the reference signature that with matched the monitored signature. Because attributes, such as an identifier of the media, a presentation time, a broadcast channel, etc., are collected for the reference signature, these attributes can then be associated with the monitored media whose monitored signature matched the reference signature. Example systems for identifying media based on codes and/or signatures are long known and were first disclosed in Thomas, U.S. Pat. No. 5,481,294, which is hereby incorporated by reference in its entirety.

Historically, audio fingerprinting technology has used the loudest parts (e.g., the parts with the most energy, etc.) of an audio signal to create fingerprints in a time segment. However, in some cases, this method has several severe limitations. In some examples, the loudest parts of an audio signal can be associated with noise (e.g., unwanted audio) and not from the audio of interest. For example, if a user is attempting to fingerprint a song at a noisy restaurant, the loudest parts of a captured audio signal can be conversations between the restaurant patrons and not the song or media to be identified. In this example, many of the sampled portions of the audio signal would be of the background noise and not of the music, which reduces the usefulness of the generated fingerprint.

Another potential limitation of previous fingerprinting technology is that, particularly in music, audio in the bass frequency range tends to be loudest. In some examples, the dominant bass frequency energy results in the sampled portions of the audio signal being predominately in the bass frequency range. Accordingly, fingerprints generated using existing methods usually do not include samples from all parts of the audio spectrum that can be used for signature matching, especially in higher frequency ranges (e.g., treble ranges, etc.).

Example methods and apparatus disclosed herein overcome the above problems by generating a fingerprint from an audio signal using mean normalization. An example method includes normalizing one or more of the time-frequency bins of the audio signal by an audio characteristic of the surrounding audio region. As used herein, "a time-frequency bin" is a portion of an audio signal corresponding to a specific frequency bin (e.g., an FFT bin) at a specific time (e.g., three seconds into the audio signal). In some examples, the normalization is weighted by an audio category of the audio signal. In some examples, a fingerprint is generated by selecting points from the normalized time-frequency bins.

Another example method disclosed herein includes dividing an audio signal into two or more audio signal frequency components. As used herein, "an audio signal frequency component," is a portion of an audio signal corresponding to a frequency range and a time period. In some examples, an audio signal frequency component can be composed of a plurality of time-frequency bins. In some examples, an audio characteristic is determined for some of the audio signal frequency component. In this example, each of the audio signal frequency components are normalized by the associated audio characteristic (e.g., an audio mean, etc.). In some examples, a fingerprint is generated by selecting points from the normalized audio signal frequency components.

FIG. **1** is an example system **100** on which the teachings of this disclosure can be implemented. The example system **100** includes an example audio source **102**, an example microphone **104** that captures sound from the audio source **102** and converts the captured sound into an example audio signal **106**. An example audio processor **108** receives the audio signal **106** and generates an example fingerprint **110**.

The example audio source **102** emits an audible sound. The example audio source can be a speaker (e.g., an electroacoustic transducer, etc.), a live performance, a conversation and/or any other suitable source of audio. The example audio source **102** can include desired audio (e.g., the audio to be fingerprinted, etc.) and can also include undesired audio (e.g., background noise, etc.). In the illustrated example, the audio source **102** is a speaker. In other examples, the audio source **102** can be any other suitable audio source (e.g., a person, etc.).

The example microphone **104** is a transducer that converts the sound emitted by the audio source **102** into the audio signal **106**. In some examples, the microphone **104** can be a component of a computer, a mobile device (a smartphone, a tablet, etc.), a navigation device or a wearable device (e.g., a smart watch, etc.). In some examples, the microphone can include an audio-to digital convert to digitize the audio signal **106**. In other examples, the audio processor **108** can digitize the audio signal **106**.

The example audio signal **106** is a digitized representation of the sound emitted by the audio source **102**. In some examples, the audio signal **106** can be saved on a computer before being processed by the audio processor **108**. In some examples, the audio signal **106** can be transferred over a network to the example audio processor **108**. Additionally or alternatively, any other suitable method can be used to generate the audio (e.g., digital synthesis, etc.).

The example audio processor **108** converts the example audio signal **106** into an example fingerprint **110**. In some examples, the audio processor **108** divides the audio signal **106** into frequency bins and/or time periods and, then, determines the mean energy of one or more of the created audio signal frequency components. In some examples, the audio processor **108** can normalize an audio signal frequency component using the associated mean energy of the audio region surrounding each time-frequency bin. In other examples, any other suitable audio characteristic can be determined and used to normalize each time-frequency bin. In some examples, the fingerprint **110** can be generated by selecting the highest energies among the normalized audio signal frequency components. Additionally or alternatively, any suitable means can be used to generate the fingerprint **110**. An example implementation of the audio processor **108** is described below in conjunction with FIG. **2**.

The example fingerprints **110** is a condensed digital summary of the audio signal **106** that can be used to the identify and/or verify the audio signal **106**. For example, the fingerprint **110** can be generated by sampling portions of the audio signal **106** and processing those portions. In some examples, the fingerprint **110** can include samples of the highest energy portions of the audio signal **106**. In some examples, the fingerprint **110** can be indexed in a database that can be used for comparison to other fingerprints. In some examples, the fingerprint **110** can be used to identify the audio signal **106** (e.g., determine what song is being played, etc.). In some examples, the fingerprint **110** can be used to verify the authenticity of the audio.

FIG. **2** is an example implementation of the audio processor **108** of FIG. **1**. The example audio processor **108** includes an example frequency range separator **202**, an example audio characteristic determiner **204**, an example signal normalizer **206**, an example point selector **208** and an example fingerprint generator **210**.

The example frequency range separator **202** divides an audio signal (e.g., the digitized audio signal **106** of FIG. **1**) into time-frequency bins and/or audio signal frequency components. For example, the frequency range separator **202** can perform a fast Fourier transform (FFT) on the audio signal **106** to transform the audio signal **106** into the frequency domain. Additionally, the example frequency range separator **202** can divide the transformed audio signal **106** into two or more frequency bins (e.g., using a Hamming function, a Hann function, etc.). In this example, each audio signal frequency component is associated with a frequency bin of the two or more frequency bins. Additionally or alternatively, the frequency range separator **202** can aggregate the audio signal **106** into one or more periods of time (e.g., the duration of the audio, six second segments, 1 second segments, etc.). In other examples, the frequency range separator **202** can use any suitable technique to transform the audio signal **106** (e.g., discrete Fourier transforms, a sliding time window Fourier transform, a wavelet transform, a discrete Hadamard transform, a discrete Walsh Hadamard, a discrete cosine transform, etc.). In some examples, the frequency range separator **202** can be implemented by one or more band-pass filters (BPFs). In some examples, the output of the example frequency range separator **202** can be represented by a spectrogram. An example output of the frequency range separator **202** is discussed below in conjunction with FIGS. **3**A-B and **4**.

The example audio characteristic determiner **204** determines the audio characteristics of a portion of the audio signal **106** (e.g., an audio signal frequency component, an audio region surrounding a time-frequency bin, etc.). For example, the audio characteristic determiner **204** can determine the mean energy (e.g., average power, etc.) of one or more of the audio signal frequency component(s). Additionally or alternatively, the audio characteristic determiner **204** can determine other characteristics of a portion of the audio signal (e.g., the mode energy, the median energy, the mode power, the median energy, the mean energy, the mean amplitude, etc.).

The example signal normalizer **206** normalizes one or more time-frequency bins by an associated audio characteristic of the surrounding audio region. For example, the signal normalizer **206** can normalize a time-frequency bin by a mean energy of the surrounding audio region. In other examples, the signal normalizer **206** normalizes some of the audio signal frequency components by an associated audio characteristic. For example, the signal normalizer **206** can normalize each time-frequency bin of an audio signal frequency component using the mean energy associated with that audio signal component. In some examples, the output of the signal normalizer **206** (e.g., a normalized time-frequency bin, a normalized audio signal frequency components, etc.) can be represented as a spectrogram. Example outputs of the signal normalizer **206** are discussed below in conjunction with FIGS. **3**C and **5**.

The example point selector **208** selects one or more points from the normalized audio signal to be used to generate the fingerprint **110**. For example, the example point selector **208** can select a plurality of energy maxima of the normalized audio signal. In other examples, the point selector **208** can select any other suitable points of the normalized audio.

Additionally or alternatively, the point selector **208** can weigh the selection of points based on a category of the audio signal **106**. For example, the point selector **208** can weigh the selection of points into common frequency ranges of music (e.g., bass, treble, etc.) if the category of the audio signal is music. In some examples, the point selector **208** can determine the category of an audio signal (e.g., music, speech, sound effects, advertisements, etc.). The example fingerprint generator **210** generates a fingerprint (e.g., the fingerprint **110**) using the points selected by the example point selector **208**. The example fingerprint generator **210** can generate a fingerprint from the selected points using any suitable method.

While an example manner of implementing the audio processor **108** of FIG. **1** is illustrated in FIG. **2**, one or more of the elements, processes, and/or devices illustrated in FIG. **2** may be combined, divided, re-arranged, omitted, eliminated, and/or implemented in any other way. Further, the example frequency range separator **202**, the example audio characteristic determiner **204**, the example signal normalizer **206**, the example point selector **208** and an example fingerprint generator **210** and/or, more generally, the example audio processor **108** of FIGS. **1** and **2** may be implemented by hardware, software, firmware, and/or any combination of hardware, software, and/or firmware. Thus, for example, any of the example frequency range separator **202**, the example audio characteristic determiner **204**, the example signal normalizer **206**, the example point selector **208** and an example fingerprint generator **210**, and/or, more generally, the example audio processor **108** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), programmable controller(s), graphics processing unit(s) (GPU(s)), digital signal processor(s) (DSP(s)), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)), and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example frequency range separator **202**, the example audio characteristic determiner **204**, the example signal normalizer **206**, the example point selector **208** and an example fingerprint generator **210** is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc., including the software and/or firmware. Further still, the example audio processor **106** of FIGS. **1** and **2** may include one or more elements, processes, and/or devices in addition to, or instead of, those illustrated in FIG. **2**, and/or may include more than one of any or all of the illustrated elements, processes, and devices. As used herein, the phrase "in communication," including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication and/or constant communication, but rather additionally includes selective communication at periodic intervals, scheduled intervals, aperiodic intervals, and/or one-time events.

FIGS. **3**A-**3**B depict an example unprocessed spectrogram **300** generated by the example frequency range separator of FIG. **2**. In the illustrated example of FIG. **3**A, the example unprocessed spectrogram **300** includes an example first time-frequency bin **304**A surrounded by an example first audio region **306**A. In the illustrated example of FIG. **3**B, the example unprocessed spectrogram includes an example second time-frequency bin **304**B surrounded by an example audio region **306**B. The example unprocessed spectrogram **300** of FIGS. **3**A and **3**B and the normalized spectrogram **302** each includes an example vertical axis **308** denoting frequency bins and an example horizontal axis **310** denoting time bins. FIGS. **3**A and **3**B illustrate the example audio regions **306**A and **306**B from which the normalization audio characteristic is derived by the audio characteristic determiner **204** and used by the signal normalizer **206** to normalize the first time-frequency bins **304**A and second time-frequency bin **304**B, respectively. In the illustrated example, each time-frequency bin of the unprocessed spectrogram **300** is normalized to generate the normalized spectrogram **302**. In other examples, any suitable number of the time-frequency bins of the unprocessed spectrogram **300** can be normalized to generate the normalized spectrogram **302** of FIG. **3**C.

The example vertical axis **308** has frequency bin units generated by a fast Fourier Transform (FFT) and has a length of 1024 FFT bins. In other examples, the example vertical axis **308** can be measured by any other suitable techniques of measuring frequency (e.g., Hertz, another transformation algorithm, etc.). In some examples, the vertical axis **308** encompasses the entire frequency range of the audio signal **106**. In other examples, the vertical axis **308** can encompass a portion of the audio signal **106**.

In the illustrated examples, the example horizontal axis **310** represents a time period of the unprocessed spectrogram **300** that has a total length of 11.5 seconds. In the illustrated example, horizontal axis **310** has sixty-four milliseconds (ms) intervals as units. In other examples, the horizontal axis **310** can be measured in any other suitable units (e.g., 1 second, etc.). For example, the horizontal axis **310** encompasses the complete duration of the audio. In other examples, the horizontal axis **310** can encompass a portion of the duration of the audio signal **106**. In the illustrated example, each time-frequency bin of the spectrograms **300**, **302** has a size of 64 ms by 1 FFT bin.

In the illustrated example of FIG. **3**A, the first time-frequency bin **304**A is associated with an intersection of a frequency bin and a time bin of the unprocessed spectrogram **300** and a portion of the audio signal **106** associated with the intersection. The example first audio region **306**A includes the time-frequency bins within a pre-defined distance away from the example first time-frequency bin **304**A. For example, the audio characteristic determiner **204** can determine the vertical length of the first audio region **306**A (e.g., the length of the first audio region **306**A along the vertical axis **308**, etc.) based by a set number of FFT bins (e.g., 5 bins, 11 bins, etc.). Similarly, the audio characteristic determiner **204** can determine the horizontal length of the first audio region **306**A (e.g., the length of the first audio region **306**A along the horizontal axis **310**, etc.). In the illustrated example, the first audio region **306**A is a square. Alternatively, the first audio region **306**A can be any suitable size and shape and can contain any suitable combination of time-frequency bins (e.g., any suitable group of time-frequency bins, etc.) within the unprocessed spectrogram **300**. The example audio characteristic determiner **204** can then determine an audio characteristic of time-frequency bins contained within the first audio region **306**A (e.g., mean energy, etc.). Using the determined audio characteristic, the example signal normalizer **206** of FIG. **2** can normalize an associated value of the first time-frequency bin **304**A (e.g., the energy of first time-frequency bin **304**A can be normalized by the mean energy of each time-frequency bin within the first audio region **306**A).

In the illustrated example of FIG. **3**B, the second time-frequency bin **304**B is associated with an intersection of a frequency bin and a time bin of the unprocessed spectrogram **300** and a portion of the audio signal **106** associated with the intersection. The example second audio region **306**B includes the time-frequency bins within a pre-defined distance away from the example second time-frequency bin **304**B. Similarly, the audio characteristic determiner **204** can determine the horizontal length of the second audio region **306**B (e.g., the length of the second audio region **306**B along the horizontal axis **310**, etc.). In the illustrated example, the second audio region **306**B is a square. Alternatively, the second audio region **306**B can be any suitable size and shape and can contain any suitable combination of time-frequency bins (e.g., any suitable group of time-frequency bins, etc.) within the unprocessed spectrogram **300**. In some examples, the second audio region **306**B can overlap with the first audio region **306**A (e.g., contain some of the same time-frequency bins, be displaced on the horizontal axis **310**, be displaced on the vertical axis **308**, etc.). In some examples, the second audio region **306**B can be the same size and shape of the first audio region **306**A. In other examples, the second audio region **306**B can be a different size and shape than the first audio region **306**A. The example audio characteristic determiner **204** can then determine an audio characteristic of time-frequency bins contained with the second audio region **306**B (e.g., mean energy, etc.). Using the determined audio characteristic, the example signal normalizer **206** of FIG. **2** can normalize an associated value of the second time-frequency bin **304**B (e.g., the energy of second time-frequency bin **304**B can be normalized by the mean energy of the bins located within the second audio region **306**B).

FIG. **3**C depicts an example of a normalized spectrogram **302** generated by the signal normalizer of FIG. **2** by normalizing a plurality of the time-frequency bins of the unprocessed spectrogram **300** of FIGS. **3**A-**3**B. For example, some or all of the time-frequency bins of the unprocessed spectrogram **300** can be normalized in a manner similar to how as the time-frequency bins **304**A and **304**B were normalized. An example process **700** to generate the normalized spectrogram is described in conjunction with FIG. **7**. The resulting frequency bins of FIG. **3**C have now been normalized by the local mean energy within the local area around the region. As a result, the darker regions are areas that have the most energy in their respective local area. This allows the fingerprint to incorporate relevant audio features even in areas that are low in energy relative to the usual louder bass frequency area.

FIG. **4** illustrates the example unprocessed spectrogram **300** of FIG. **3** divided into fixed audio signal frequency components. The example unprocessed spectrogram **300** is generated by processing the audio signal **106** with a fast Fourier transform (FFT). In other examples, any other suitable method can be used to generate the unprocessed spectrogram **300**. In this example, the unprocessed spectrogram **300** is divided into example audio signal frequency components **402**. The example unprocessed spectrogram **400** includes the example vertical axis **308** of FIG. **3** and the example horizontal axis **310** of FIG. **3**. In the illustrated example, the example audio signal frequency components **402** each have an example frequency range **408** and an example time period **410**. The example audio signal frequency components **402** include an example first audio signal frequency component **412**A and an example second audio signal frequency component **412**B. In the illustrated example, the darker portions of the unprocessed spectrogram **300** represent portions of the audio signal **106** with higher energies.

The example audio signal frequency components **402** each are associated with a unique combination of successive frequency ranges (e.g., a frequency bin, etc.) and successive time periods. In the illustrated example, each of the audio signal frequency components **402** has a frequency bin of equal size (e.g., the frequency range **408**). In other examples, some or all of the audio signal frequency components **402** can have frequency bins of different sizes. In the illustrated example, each of the audio signal frequency components **402** has a time period of equal duration (e.g., the time period **410**). In other examples, some or all of the audio signal frequency components **402** can have time periods of different durations. In the illustrated example, the audio signal frequency components **402** compose the entirety of the audio signal **106**. In other examples, the audio signal frequency components **402** can include a portion of the audio signal **106**.

In the illustrated example, the first audio signal frequency component **412**A is in the treble range of the audio signal **106** and has no visible energy points. The example first audio signal frequency component **412**A is associated with a frequency bin between the 768 FFT bin and the 896 FFT bin and a time period between 10,024 ms and 11,520 ms. In some examples, there are portions of the audio signal **106** within the first audio signal frequency component **412**A. In this example, the portions of the audio signal **106** within the audio signal frequency component **412**A are not visible due to the comparatively higher energy of the audio within the bass spectrum of the audio signal **106** (e.g., the audio in the second audio signal frequency component **412**B, etc.). The second audio signal frequency component **412**B is in the bass range of the audio signal **106** and visible energy points. The example second audio signal frequency component **412**B is associated with a frequency bin between 128 FFT bin and 256 FFT bin and a time period between 10,024 ms and 11,520 ms. In some examples, because the portions of the audio signal **106** within the bass spectrum (e.g., the second audio signal frequency component **412**B, etc.) have a comparatively higher energy, a fingerprint generated from the unprocessed spectrogram **300** would include a disproportional number of samples from the bass spectrum.

FIG. **5** is an example of a normalized spectrogram **500** generated by the signal normalizer of FIG. **2** from the fixed audio signal frequency components of FIG. **4**. The example normalized spectrogram **500** includes the example vertical axis **308** of FIG. **3** and the example horizontal axis **310** of FIG. **3**. The example normalized spectrogram **500** is divided into example audio signal frequency components **502**. In the illustrated example, the audio signal frequency components **502** each have an example frequency range **408** and an example time period **410**. The example audio signal frequency components **502** include an example first audio signal frequency component **504**A and an example second audio signal frequency component **504**B. In some examples, the first and second audio signal frequency components **504**A and **504**B correspond to the same frequency bins and time periods as the first and second audio signal frequency components **412**A and **412**B of FIG. **3**. In the illustrated example, the darker portions of the normalized spectrogram **500** represent areas of audio spectrum with higher energies.

The example normalized spectrogram **500** is generated by normalizing the unprocessed spectrogram **300** by normalizing each audio signal frequency component **402** of FIG. **4** by an associated audio characteristic. For example, the audio characteristic determiner **204** can determine an audio characteristic (e.g., the mean energy, etc.) of the first audio signal frequency component **412**A. In this example, the signal normalizer **206** can then normalize the first audio signal frequency component **412**A by the determined audio characteristic to the create the example audio signal frequency component **402**A. Similarly, the example second audio signal frequency component **402**B can be generated by normalizing the second audio signal frequency component **412**B of FIG. **4** by an audio characteristic associated with the second audio signal frequency component **412**B. In other examples, the normalized spectrogram **500** can be generated by normalizing a portion of the audio signal components **402**. In other examples, any other suitable method can be used to generate the example normalized spectrogram **500**.

In the illustrated example of FIG. **5**, the first audio signal frequency component **504**A (e.g., the first audio signal frequency component **412**A of FIG. **4** after being processed by the signal normalizer **206**, etc.) has visible energy points on the normalized spectrogram **500**. For example, because the first audio signal frequency component **504**A has been normalized by the energy of the first audio signal frequency component **412**A, previously hidden portions of the audio signal **106** (e.g., when compared to the first audio signal frequency component **412**A) are visible on the normalized spectrogram **500**. The second audio signal frequency component **504**B (e.g., the second audio signal frequency component **412**B of FIG. **4** after being processed by the signal normalizer **206**, etc.) corresponds to the bass range of the audio signal **106**. For example, because the second audio signal frequency component **504**B has been normalized by the energy of the second audio signal frequency component **412**B, the amount of visible energy points has been reduced (e.g., when compared to the second audio signal frequency component **412**B). In some examples, a fingerprint generated from the normalized spectrogram **500** (e.g., the fingerprint **110** of FIG. **1**) would include samples from more evenly distributed from the audio spectrum than a fingerprint generated from the unprocessed spectrogram **300** of FIG. **4**.

FIG. **6** is an example of a normalized and weighted spectrogram **600** generated by the point selector **208** of FIG. **2** from the normalized spectrogram **500** of FIG. **5**. The example spectrogram **600** includes the example vertical axis **308** of FIG. **3** and the example horizontal axis **310** of FIG. **3**. The example normalized and weighted spectrogram **600** is divided into example audio signal frequency components **502**. In the illustrated example, the example audio signal frequency components **502** each have an example frequency range **408** and example time period **410**. The example audio signal frequency components **502** include an example first audio signal frequency component **604**A and an example second audio signal frequency component **604**B. In some examples, the first and second audio signal frequency components **604**A and **604**B correspond to the same frequency bins and time periods as the first and second audio signal frequency components **412**A and **412**B of FIG. **3**, respectively. In the illustrated example, the darker portions of the normalized and weighted spectrogram **600** represent areas of the audio spectrum with higher energies.

The example normalized and weighted spectrogram **600** is generated by weighing the normalized spectrogram **600** with a range of values from zero to one based on a category of the audio signal **106**. For example, if the audio signal **106** is music, areas of the audio spectrum associated with music will be weighted along each column by the point selector **208** of FIG. **2**. In other examples, the weighting can apply to multiple columns and can take on a different range from zero to one.

Flowcharts representative of example hardware logic, machine readable instructions, hardware implemented state machines, and/or any combination thereof for implementing the audio processor **108** of FIG. **2** are shown in FIGS. **7** and **8**. The machine readable instructions may be an executable program or portion of an executable program for execution by a computer processor such as the processor **912** shown in the example processor platform **900** discussed below in connection with FIG. **9**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a DVD, a Blu-ray disk, or a memory associated with the processor **912**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **912** and/or embodied in firmware or dedicated hardware. Further, although the example programs are described with reference to the flowchart illustrated in FIGS. **7** and **8**, many other methods of implementing the example audio processor **108** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, an FPGA, an ASIC, a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware.

As mentioned above, the example processes of FIGS. **7** and **8** may be implemented using executable instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory, and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media.

"Including" and "comprising" (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim employs any form of "include" or "comprise" (e.g., comprises, includes, comprising, including, having, etc.) as a preamble or within a claim recitation of any kind, it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim or recitation. As used herein, when the phrase "at least" is used as the transition term in, for example, a preamble of a claim, it is open-ended in the same manner as the term "comprising" and "including" are open ended. The term "and/or" when used, for example, in a form such as A, B, and/or C refers to any combination or subset of A, B, C such as (1) A alone, (2) B alone, (3) C alone, (4) A with B, (5) A with C, (6) B with C, and (7) A with B and with C. As used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. As used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B.

The process of FIG. **7** begins at block **702**. At block **702**, the audio processor **108** receives the digitized audio signal **106**. For example, the audio processor **108** can receive audio (e.g., emitted by the audio source **102** of FIG. **1**, etc.) captured by the microphone **104**. In this example, the microphone can include an analog to digital converter to convert the audio into a digitized audio signal **106**. In other examples, the audio processor **108** can receive audio stored in a database (e.g., the volatile memory **914** of FIG. **9**, the non-volatile memory **916** of FIG. **9**, the mass storage **928** of FIG. **9**, etc.). In other examples, the digitized audio signal **106** can transmitted to the audio processor **108** over a network (e.g., the Internet, etc.). Additionally or alternatively, the audio processor **108** can receive the audio signal **106** by any other suitable means.

At block **704**, the frequency range separator **202** windows the audio signal **106** and transforms the audio signal **106** into the frequency domain. For example, the frequency range separator **202** can perform a fast Fourier transform to transform the audio signal **106** into the frequency domain and can perform a windowing function (e.g., a Hamming function, a Hann function, etc.). Additionally or alternatively, the frequency range separator **202** can aggregate the audio signal **106** into two or more time bins. In these examples, time-frequency bin corresponds to an intersection of a frequency bin and a time bin and contains a portion of the audio signal **106**.

At block **706**, the audio characteristic determiner **204** selects a time-frequency bin to normalize. For example, the audio characteristic determiner **204** can select the first time-frequency bin **304**A of FIG. **3**A. In some examples, the audio characteristic determiner **204** can select a time-frequency bin adjacent to a previously selected first time-frequency bin.

At block **708**, the audio characteristic determiner **204** determines the audio characteristic of the surrounding audio region. For example, if the audio characteristic determiner **204** selected the first time-frequency bin **304**A, the audio characteristic determiner **204** can determine an audio characteristic of the first audio region **306**A. In some examples, the audio characteristic determiner **204** can determine the mean energy of the audio region. In other examples, the audio characteristic determiner **204** can determine any other suitable audio characteristic(s) (e.g., mean amplitude, etc.).

At block **710**, the audio characteristic determiner **204** determines if another time-frequency bin is to be selected, the process **700** returns to block **706**. If another time-frequency bin is not to be selected, the process **700** advances to block **712**. In some examples, blocks **706-710** are repeated until every time-frequency bin of the unprocessed spectrogram **300** has been selected. In other examples, blocks **706-710** can be repeated any suitable number iterations.

At block **712**, the signal normalizer **206** normalizes each time-frequency bin based on the associated audio characteristic. For example, the signal normalizer **206** can normalize each of the selected time-frequency bins at block **706** with the associated audio characteristic determined at block **708**. For example, the signal normalizer can normalize the first time-frequency bin **304**A and the second time-frequency bin **304**B by the audio characteristics (e.g., mean energy) of the first audio region **306**A and the second audio region **306**B, respectively. In some examples, the signal normalizer **206** generates a normalized spectrogram (e.g., the normalized spectrogram **302** of FIG. **3**C) based on the normalization of the time-frequency bins.

At block **714**, the point selector **208** determines if fingerprint generation is to be weighed based on audio category, the process **700** advances to block **716**. If fingerprint generation is not to be weighed based on audio category, the process **700** advances to block **720**. At block **716**, the point selector **208** determines the audio category of the audio signal **106**. For example, the point selector **208** can present a user with a prompt to indicate the category of the audio (e.g., music, speech, sound effects, advertisements, etc.). In other examples, the audio processor **108** can use an audio category determining algorithm to determine the audio category. In some examples, the audio category can be the voice of a specific person, human speech generally, music, sound effects and/or advertisement.

At block **718**, the point selector **208** weighs the time frequency bins based on the determined audio category. For example, if the audio category is music, the point selector **208** can weigh the audio signal frequency component associated with treble and bass ranges commonly associated with music. In some examples, if the audio category is a specific person's voice, the point selector **208** can weigh audio signal frequency components associated with that person's voice. In some examples, the output of the signal normalizer **206** can be represented as a spectrogram.

At block **720**, the fingerprint generator **210** generates a fingerprint (e.g., the fingerprint **110** of FIG. **1**) of the audio signal **106** by selecting energy extrema of the normalized audio signal. For example, the fingerprint generator **210** can use the frequency, time bin and energy associated with one or more energy extrema (e.g., an extremum, twenty extrema, etc.). In some examples, the fingerprint generator **210** can select energy maxima of the normalized audio signal **106**. In other examples, the fingerprint generator **210** can select any other suitable features of the normalized audio signal frequency components. In some examples, the fingerprint generator **210** can utilize any suitable means (e.g., algorithm, etc.) to generate a fingerprint **110** representative of the audio signal **106**. Once a fingerprint **110** has been generate, the process **700** ends.

The process **800** of FIG. **8** begins at block **802**. At block **802**, the audio processor **108** receives the digitized audio signal. For example, the audio processor **108** can receive audio (e.g., emitted by the audio source **102** of FIG. **1**, etc.) and captured by the microphone **104**. In this example, the microphone can include an analog to digital converter to convert the audio into a digitized audio signal **106**. In other examples, the audio processor **108** can receive audio stored in a database (e.g., the volatile memory **914** of FIG. **9**, the non-volatile memory **916** of FIG. **9**, the mass storage **928** of FIG. **9**, etc.). In other examples, the digitized audio signal **106** can transmitted to the audio processor **108** over a network (e.g., the Internet, etc.). Additionally or alternatively, the audio processor **108** can receive the audio signal **106** by any suitable means.

At block **804**, the frequency range separator **202** divides the audio signal into two or more audio signal frequency components (e.g., the audio signal frequency components **402** of FIG. **3**, etc.). For example, the frequency range separator **202** can perform a fast Fourier transform to transform the audio signal **106** into the frequency domain and can perform a windowing function (e.g., a Hamming function, a Hann function, etc.) to create frequency bins. In these examples, each audio signal frequency component is associated with one or more frequency bin(s) of the frequency bins. Additionally or alternatively, the frequency range separator **202** can further divide the audio signal **106** into two or more time periods. In these examples, each audio signal frequency component corresponds to a unique combination of a time period of the two or more time periods and a frequency bin of the two or more frequency bins. For example, the frequency range separator **202** can divide the audio signal **106** into a first frequency bin, a second frequency bin, a first time period and a second time period. In this example, a first audio signal frequency component corresponds to the portion of the audio signal **106** within the first frequency bin and the first time period, a second audio signal frequency component corresponds to the portion of the audio signal **106** within the first frequency bin and the second time period, a third audio signal frequency component corresponds to the portion of the audio signal **106** within the second frequency bin and the first time period and a fourth audio signal frequency portion corresponds to the component of the audio signal **106** within the second frequency bin and the second time period. In some examples, the output of the frequency range separator **202** can be represented as a spectrograph (e.g., the unprocessed spectrogram **300** of FIG. **3**).

At block **806**, the audio characteristic determiner **204** determines the audio characteristics of each audio signal frequency component. For example, the audio characteristic determiner **204** can determine the mean energy of each audio signal frequency component. In other examples, the audio characteristic determiner **204** can determine any other suitable audio characteristic(s) (e.g., mean amplitude, etc.).

At block **808**, the signal normalizer **206** normalizes each audio signal frequency component based on the determined audio characteristic associated with the audio signal frequency component. For example, the signal normalizer **206** can normalize each audio signal frequency component by the mean energy associated with the audio signal frequency component. In other examples, the signal normalizer **206** can normalize the audio signal frequency component using any other suitable audio characteristic. In some examples, the output of the signal normalizer **206** can be represented as a spectrograph (e.g., the normalized spectrogram **500** of FIG. **5**).

At block **810**, audio characteristic determiner **204** determines if fingerprint generation is to be weighed based on audio category, the process **800** advances to block **812**. If fingerprint generation is not to be weighed based on audio category, the process **800** advances to block **816**. At block **812**, the audio processor **108** determines the audio category of the audio signal **106**. For example, the audio processor **108** can present a user with a prompt to indicate the category of the audio (e.g., music, speech, etc.). In other examples, the audio processor **108** can use an audio category determining algorithm to determine the audio category. In some examples, the audio category can be the voice of a specific person, human speech generally, music, sound effects and/or advertisement.

At block **814**, the signal normalizer **206** weighs the audio signal frequency components based on the determined audio category. For example, if the audio category is music, the signal normalizer **206** can weigh the audio signal frequency component along each column with a different scaler value from zero to one for each frequency location from treble to bass associated with the average spectral envelope of music. In some examples, if the audio category is a human voice, the signal normalizer **206** can weigh audio signal frequency components associated with the spectral envelope of a human voice. In some examples, the output of the signal normalizer **206** can be represented as a spectrograph (e.g., the spectrogram **600** of FIG. **6**).

At block **816**, the fingerprint generator **210** generates a fingerprint (e.g., the fingerprint **110** of FIG. **1**) of the audio signal **106** by selecting energy extrema of the normalized audio signal frequency components. For example, the fingerprint generator **210** can use the frequency, time bin and energy associated with one or more energy extrema (e.g., twenty extrema, etc.). In some examples, the fingerprint generator **210** can select energy maxima of the normalized audio signal. In other examples, the fingerprint generator **210** can select any other suitable features of the normalized audio signal frequency components. In some examples, the fingerprint generator **210** can utilize another suitable means (e.g., algorithm, etc.) to generate a fingerprint **110** representative of the audio signal **106**. Once a fingerprint **110** has been generate, the process **800** ends.

FIG. **9** is a block diagram of an example processor platform **900** structured to execute the instructions of FIGS. **7** and/or **8** to implement the audio processor **108** of FIG. **2**. The processor platform **900** can be, for example, a server, a personal computer, a workstation, a self-learning machine (e.g., a neural network), a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, a DVD player, a CD player, a digital video recorder, a Blu-ray player, a gaming console, a personal video recorder, a set top box, a headset or other wearable device, or any other type of computing device.

The processor platform **900** of the illustrated example includes a processor **912**. The processor **912** of the illustrated example is hardware. For example, the processor **912** can be implemented by one or more integrated circuits, logic circuits, microprocessors, GPUs, DSPs, or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor **912** implements the example frequency range separator **202**, the example audio characteristic determiner **204**, the example signal normalizer **206**, the example point selector **208** and an example fingerprint generator **210**.

The processor **912** of the illustrated example includes a local memory **913** (e.g., a cache). The processor **912** of the illustrated example is in communication with a main memory including a volatile memory **914** and a non-volatile memory **916** via a bus **918**. The volatile memory **914** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory

(DRAM), RAMBUS® Dynamic Random Access Memory (RDRAM®), and/or any other type of random access memory device. The non-volatile memory **916** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **914**, **916** is controlled by a memory controller.

The processor platform **900** of the illustrated example also includes an interface circuit **920**. The interface circuit **920** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), a Bluetooth® interface, a near field communication (NFC) interface, and/or a PCI express interface.

In the illustrated example, one or more input devices **922** are connected to the interface circuit **920**. The input device(s) **922** permit(s) a user to enter data and/or commands into the processor **912**. The input device(s) **922** can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), and/or a voice recognition system.

One or more output devices **924** are also connected to the interface circuit **920** of the illustrated example. The output devices **924** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display (LCD), a cathode ray tube display (CRT), an in-place switching (IPS) display, a touchscreen, etc.), a tactile output device, a printer, and/or speaker. The interface circuit **920** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip, and/or a graphics driver processor.

The interface circuit **920** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem, a residential gateway, a wireless access point, and/or a network interface to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **926**. The communication can be via, for example, an Ethernet connection, a digital subscriber line (DSL) connection, a telephone line connection, a coaxial cable system, a satellite system, a line-of-site wireless system, a cellular telephone system, etc.

The processor platform **900** of the illustrated example also includes one or more mass storage devices **928** for storing software and/or data. Examples of such mass storage devices **928** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, redundant array of independent disks (RAID) systems, and digital versatile disk (DVD) drives.

The machine executable instructions **932** to implement the methods of FIG. **6** may be stored in the mass storage device **928**, in the volatile memory **914**, in the non-volatile memory **916**, and/or on a removable non-transitory computer readable storage medium such as a CD or DVD.

From the foregoing, it will be appreciated that example methods and apparatus have been disclosed that allow fingerprints of audio signal to be created that reduces the amount noise captured in the fingerprint. Additionally, by sampling audio from less energetic regions of the audio signal, more robust audio fingerprints are created when compared to previous used audio fingerprinting methods.

Although certain example methods, apparatus, and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus, and articles of manufacture fairly falling within the scope of the claims of this patent.

What is claimed is:

1. An apparatus for audio fingerprinting, comprising:

a frequency range separator to transform an audio signal into a frequency domain, the transformed audio signal including a plurality of time-frequency bins, each of the time-frequency bins corresponding to an intersection of a frequency bin and a time bin and contains a portion of the audio signal;

an audio characteristic determiner to:

select a first time-frequency bin;

determine a group of the plurality of time-frequency bins based on the first time-frequency bin and time-frequency bins within a pre-defined distance of the first time-frequency bin;

determine an audio characteristic for an audio region comprising the group of the plurality of time-frequency bins, wherein the determined audio characteristic for the audio region includes at least one of: (i) a mean energy value; (ii) a mode energy value (iii) an average power value; (iv) a mode power value; or (v) a mean amplitude of the group of the plurality of time-frequency bins;

select a second time-frequency bin;

determine a second group of the plurality of time-frequency bins based on the second time-frequency bin and time-frequency bins within a pre-defined distance of the second time-frequency bin, wherein at least a portion of the group of time-frequency bins overlaps at least a portion of the second group of time-frequency bins; and

determine a second audio characteristic for a second audio region comprising the second group of the plurality of time frequency bins;

a signal normalizer to:

normalize the audio region to generate normalized energy values, wherein normalizing the audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the group of the plurality of time-frequency bins based on the determined audio characteristic associated with the audio region; and

normalize the second audio region to generate second normalized energy values, wherein normalizing the second audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the second group of the plurality of time-frequency bins based on the determined second audio characteristic associated with the second audio region;

a point selector configured to:

determine a category of the audio signal;

weigh each of the time-frequency bins of the group of the plurality of time-frequency bins based on the determined category of the audio signal; and

weigh the selecting of the one of the normalized energy values by the category of the audio signal; and

select one of the normalized energy values; and

a fingerprint generator to generate a fingerprint of the audio signal using the selected one of the normalized energy values.

2. The apparatus of claim **1**, wherein the frequency range separator is further configured to perform a fast Fourier transform of the audio signal.

3. The apparatus of claim **1**, wherein the category of the audio signal includes at least one or music, human speech, sound effects, or advertisement.

4. The apparatus of claim 1, wherein the point selector selects the one of the normalized energy values based on an energy extrema of the normalized audio region.

5. The apparatus of claim 1, wherein each time-frequency bin of the plurality of time-frequency bins is a unique combination of (1) a time period of the transformed audio signal and (2) a frequency bin of the transformed audio signal.

6. A method for audio fingerprinting, comprising:
- transforming an audio signal into a frequency domain, the transformed audio signal including a plurality of time-frequency bins, each of the time-frequency bins corresponding to an intersection of a frequency bin and a time bin and contains a portion of the audio signal;
- selecting a first time-frequency bin;
- determining a group of the plurality of time-frequency bins based on the first time-frequency bin and time-frequency bins within a pre-defined distance of the first time-frequency bin;
- determining an audio characteristic for an audio region comprising the group of the plurality of time-frequency bins, wherein the determined audio characteristic for the audio region includes at least one of: (i) a mean energy value; (ii) a mode energy value (iii) an average power value; (iv) a mode power value; or (v) a mean amplitude of the group of the plurality of time-frequency bins;
- selecting a second time-frequency bin;
- determining a second group of the plurality of time-frequency bins based on the second time-frequency bin and time-frequency bins within a pre-defined distance of the second time-frequency bin, wherein at least a portion of the group of time-frequency bins overlaps at least a portion of the second group of time-frequency bins;
- determining a second audio characteristic for a second audio region comprising the second group of the plurality of time frequency bins;
- normalizing the audio region to generate normalized energy values, wherein normalizing the audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the group of the plurality of time-frequency bins based on the determined audio characteristic associated with the audio region;
- normalizing the second audio region to generate second normalized energy values, wherein normalizing the second audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the second group of the plurality of time-frequency bins based on the determined second audio characteristic associated with the second audio region;
- selecting one of the normalized energy values, wherein selecting one of the normalized energy values comprises:
  - determining a category of the audio signal;
  - weighing each of the time-frequency bins of the group of the plurality of time-frequency bins based on the determined category of the audio signal; and
  - weighing the selecting of the one of the normalized energy values by the category of the audio signal; and
- generating a fingerprint of the audio signal using the selected one of the normalized energy values.

7. The method of claim 6, wherein the transforming the audio signal into the frequency domain includes performing a fast Fourier transform of the audio signal.

8. The method of claim 6, wherein the category of the audio signal includes at least one of music, human speech, sound effects, or advertisement.

9. The method of claim 6, wherein the selecting the one of the normalized energy values is based on an energy extrema of the normalized audio region.

10. The method of claim 6, wherein each time-frequency bin of the plurality of time-frequency bins is a unique combination of (1) a time period of the transformed audio signal and (2) a frequency bin of the transformed audio signal.

11. A non-transitory computer readable storage medium comprising instructions which, when executed, cause a processor to at least:
- transform an audio signal into a frequency domain, the transformed audio signal including a plurality of time-frequency bins, each of the time-frequency bins corresponding to an intersection of a frequency bin and a time bin and contains a portion of the audio signal;
- select a first time-frequency bin;
- determine a group of the plurality of time-frequency bins based on the first time-frequency bin and time-frequency bins within a pre-defined distance of the first time-frequency bin;
- determine an audio characteristic for an audio region comprising the group of the plurality of time-frequency bins, wherein the determined audio characteristic for the audio region includes at least one of: (i) a mean energy value; (ii) a mode energy value (iii) an average power value; (iv) a mode power value; or (v) a mean amplitude of the group of the plurality of time-frequency bins;
- select a second time-frequency bin;
- determine a second group of the plurality of time-frequency bins based on the second time-frequency bin and time-frequency bins within a pre-defined distance of the second time-frequency bin, wherein at least a portion of the group of time-frequency bins overlaps at least a portion of the second group of time-frequency bins;
- determine a second audio characteristic for a second audio region comprising the second group of the plurality of time frequency bins;
- normalize the audio region to generate normalized energy values, wherein normalizing the audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the group of the plurality of time-frequency bins based on the determined audio characteristic associated with the audio region;
- normalize the second audio region to generate second normalized energy values, wherein normalizing the second audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the second group of the plurality of time-frequency bins based on the determined second audio characteristic associated with the second audio region;
- select one of the normalized energy values, wherein selecting one of the normalized energy values comprises:
  - determining a category of the audio signal;
  - weighing each of the time-frequency bins of the group of the plurality of time-frequency bins based on the determined category of the audio signal; and
  - weighing the selecting of the one of the normalized energy values by the category of the audio signal; and

generate a fingerprint of the audio signal using the selected one of the normalized energy values.

12. The non-transitory computer readable storage medium of claim **11**, wherein the transformation of the audio signal into the frequency domain includes performing a fast Fourier transform of the audio signal.

13. The non-transitory computer readable storage medium of claim **11**, wherein the category of the audio signal includes at least one of music, human speech, sound effects, or advertisement.

14. An apparatus comprising:

at least one memory;

programmable circuitry; and

instructions to cause the programmable circuitry to:

transform an audio signal into a frequency domain, the transformed audio signal including a plurality of time-frequency bins, each of the time-frequency bins corresponding to an intersection of a frequency bin and a time bin and contains a portion of the audio signal;

select a first time-frequency bin;

determine a group of the plurality of time-frequency bins based on the first time-frequency bin and time-frequency bins within a pre-defined distance of the first time-frequency bin;

determine an audio characteristic for an audio region comprising the group of the plurality of time-frequency bins, wherein the determined audio characteristic for the audio region includes at least one of: (i) a mean energy value; (ii) a mode energy value (iii) an average power value; (iv) a mode power value; or (v) a mean amplitude of the group of the plurality of time-frequency bins;

select a second time-frequency bin;

determine a second group of the plurality of time-frequency bins based on the second time-frequency bin and time-frequency bins within a pre-defined distance of the second time-frequency bin, wherein at least a portion of the group of time-frequency bins overlaps at least a portion of the second group of time-frequency bins;

determine a second audio characteristic for a second audio region comprising the second group of the plurality of time frequency bins;

normalize the audio region to generate normalized energy values, wherein normalizing the audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the group of the plurality of time-frequency bins based on the determined audio characteristic associated with the audio region;

normalize the second audio region to generate second normalized energy values, wherein normalizing the second audio region comprises normalizing each portion of the audio signal of each time-frequency bin of the second group of the plurality of time-frequency bins based on the determined second audio characteristic associated with the second audio region;

select one of the normalized energy values, wherein selecting one of the normalized energy values comprises:

determining a category of the audio signal;

weighing each of the time-frequency bins of the group of the plurality of time-frequency bins based on the determined category of the audio signal; and

weighing the selecting of the one of the normalized energy values by the category of the audio signal; and

generate a fingerprint of the audio signal using the selected one of the normalized energy values.

15. The apparatus of claim **14**, wherein the transformation of the audio signal into the frequency domain includes performing a fast Fourier transform of the audio signal.

16. The apparatus of claim **14**, wherein the category of the audio signal includes at least one of music, human speech, sound effects, or advertisement.

17. The apparatus of claim **14**, wherein each time-frequency bin of the plurality of time-frequency bins is a unique combination of (1) a time period of the transformed audio signal and (2) a frequency bin of the transformed audio signal.

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