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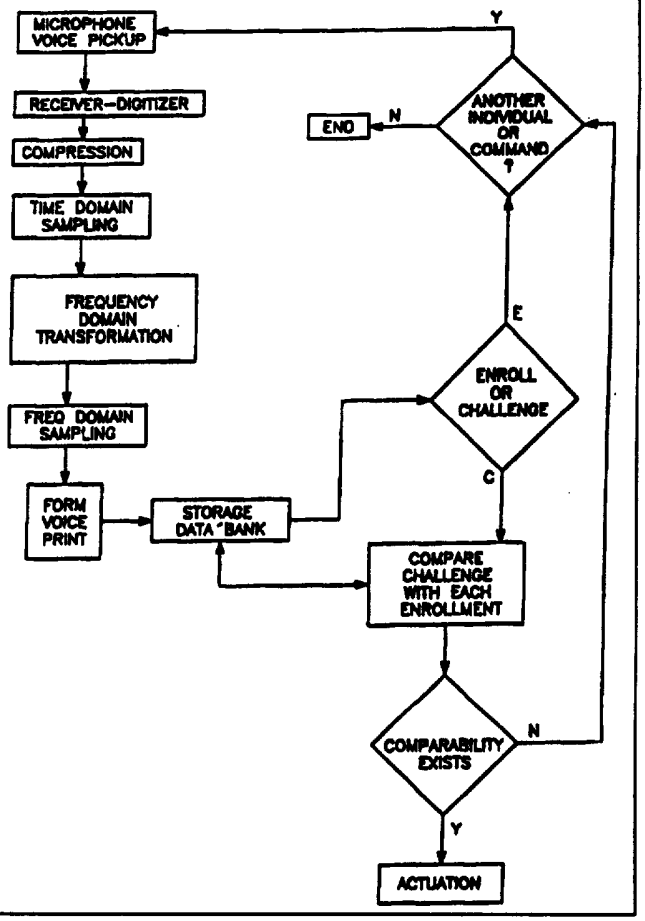
(54) Title: SPEAKER VERIFICATION METHOD

(57) Abstract

A method for comparing different electronic representations of sounds in an effort to determine a high level of confidence that the sounds, in fact, originated from the same source, is disclosed. Specifically, the method attempts to determine if two sounds were produced by the same human voice in an attempt to discriminate between allowed and non-allowed personnel seeking entry to a secure facility. A short word or phrase is converted into an electronic representation and is then compared with a data bank of stored similar representation of the same word or phrase made by the same person at some earlier time. Depending upon the comparison results, access is granted or denied. Sound prints comprising two portions; a time domain portion and a frequency domain portion are created and stored. The manner in which the sound prints are created, the manner in which the sound prints, once created, are compared and the admittance protocol are all the subject of the claims of this disclosure.



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TITLE: SPEAKER VERIFICATION METHOD

FIELD OF THE INVENTION

This invention relates generally to electronic security methods which provide for modeling or otherwise comparing human features such as fingerprints, voice patterns, and retina patterns, in order to distinguish between individuals, and, more particularly, to a security method and protocol for modeling and comparing voice prints by digital means.

BACKGROUND OF THE INVENTION

There is clearly a need for automated individual recognition in industry and elsewhere. The art is defined by Rabiner, Rosenberg and Soong of American Telephone and Telegraph Company in Canadian patent 1,252,567, entitled Individual Recognition by Voice Analysis. of interest also are Koristka, in DDR patent 201,524, and two Russian references, 518,512 and 522,512.

The prior art is characterized by methods for forming of a code book of word-grouping features that are independent of the temporal sequence of such features for each word, and then generating a set of acoustic feature signals from a test case for matching to the code book. However the disadvantages of the above methods include the difficulty in rigorously removing the temporal features from speech, problems with repetitive results within a statistically satisfactory confidence level, problems introduced by equipment variability, and environmental noise.

Clearly, then, there is a need for an improved protocol for management of voice prints in a system which is expandable to virtually any size, and a method for comparing a challenge print in a large data base, or in producing print matching of very high confidence. Such a needed method is described in the following summary and detailed description and is based upon principles which are defined

in the appended claims.

SUMMARY OF THE INVENTION

The present invention is a method for comparing different electronic representations of sounds in an effort to determine a high level of confidence that the sounds, in fact, originated from the same source, the source usually being human voice, the sounds being common speech. Specifically, the method attempts to determine if two sounds were produced by the same human voice in an attempt to discriminate between allowed and non-allowed personnel seeking entry to a secure facility. In the preferred embodiment of the method a short word or phrase is spoken into a microphone and is then converted into an electronic representation of the word or phrase. This representation is then compared with a stored similar representation of the same word or phrase made by the same person at some earlier time. If the two representations meet a given similarity criterion, then a door or other security device, as an example, is unlocked. If the criterion is not met, the security device is not unlocked. The technique could be used for access to doors, computer files, file cabinets or other things that must be kept under "lock and key".

In the method of the present invention each of the electronic representations are termed "sound prints" and consist of two portions; a time domain portion and a frequency domain portion. In the general case there are at least several different individuals which may be admitted, while possibly many others may not be. The method provides for the establishment of a data bank of "enrollment sound prints", one for each of the admittable individuals. The method further provides for the taking of a sample or challenge-sound print from a prospective individual seeking admittance. The challenge sound print is compared with each of those stored in the data bank to see if a match exists. If it does, the individual is admitted, if not he is withheld from admittance.

Sound prints, whether of the enrollment type, or of the challenge type, are

established in the same way so that they are able to be compared on a one-to-one basis. The manner in which the sound prints are created, the manner in which the sound prints, once created, are compared and the admittance protocol are all the subject of the claims of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawing, FIGURE 1, illustrates the invention. In such drawing is shown a method flow diagram summarizing the various steps of the invention method.

DETAILED DESCRIPTION OF THE DISCLOSURE

The method of creating any one of the sound prints in the invention includes, first, the step of converting a verbal utterance of a specific word or phrase of about two seconds duration into an electronic representation through the use of a microphone or other transducer. The representation is therefore a time domain analog signal. Next, this signal, which may contain pauses or portions with zero signal level, is reduced by eliminating the pauses. The reduced signal is then sampled to produce a sampling set. The sampling set of the reduced time domain signal is called the time domain sound print portion, and is one part of the total sound print. The time domain sound print portion is stored digitally for reference.

The electronic representation is also processed in an analog to digital converter and then into a series of Fast Fourier Transformation digital filters, to produce a frequency domain electrical signal representation. Again, a sampling set of this signal is stored digitally and is called the frequency domain sound print portion, a second part of the sound print. Together the time domain sound print portion and the frequency domain sound print portion make up the total sound print of the spoken word or phrase.

An important part of the method includes repeating the above at least twice, and

further, calculating the set of statistical variances for both the time domain and the frequency domain portions. A grand average of the variances is calculated and is used as a preliminary match criterion between each of the enrollment sound prints and the challenge sound print. The step of first calculating the grand average variance of the challenge sound print and comparing it with the grand average of each of tile enrollment sound prints is an initial step in determining if a match exists. If no variance grand average match exists, then no further comparison need be executed. If a set of variance grand average matches is found, then the further comparison may be limited to those enrollment sound prints which have met this first requirement. Of course, in a system whereby the challenger is first identified, one need not search all of the enrollment data bank for a preliminary match. In this case only the enrollment print of the identified individual need be matched with the challenge print.

In producing the frequency domain electrical signal representation, the total spectrum energy content is determined as well as the energy content of each of the filter subsets. Ratios of each of the subset energy contents to the total energy content are calculated. These ratio numbers are compared between the challenge and each of the enrollment sound prints as a further preliminary measure in determining if a match exists.

The primary comparison between prints is one in which each of the elements of each of the sampling sets, both time domain and frequency domain, are compared element to element, on a one to one basis, between the two prints being compared, whereby a prescribed number of elemental matches must be found or the match process is taken as a failure.

While the invention has been described with reference to a preferred embodiment, it is to be clearly understood by those skilled in the art that the invention is not limited thereto. Rather, the scope of the invention is to be interpreted only in conjunction with the appended claims.

CODE ENABLEMENT

The following machine language code provides the software enablement for the method of the invention:

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34 S9030000FC

CLAIMS

What is claimed is:

1. A method of creating and comparing voice prints for determining a level of comparability between the prints in order to provide an access step if the level of comparability is at least as great as a predetermined level, comprising the steps:

a) converting a verbal utterance of a specific word or phrase of about two seconds duration into an electronic representation through the use of a microphone or other transducer;

b) deleting portions of the electronic representation which have zero signal level;

c) sampling the electronic representation of the utterance with deleted portions to produce a time domain sampling set;

d) storing the time domain sampling set digitally;

e) converting the electronic representation from an analog to a digital form;

f) transforming the digital form of the electronic representation through a Fast Fourier transform device to produce a frequency domain electrical signal representation;

g) sampling the frequency domain electrical signal representation to produce a frequency domain sampling set;

h) forming a list voice print as a composite of the time domain and the frequency domain sampling sets;

i) repeating the steps (a) through (g) to form a second voice print as a composite of a second time and a second frequency domain sampling sets resulting from the repeated steps;

j) comparing corresponding elements from the first and the second sampling sets of the first with the second voice print to establish a level of comparability of the two prints;

k) enabling a security access if the level of comparability in step (j) is at least as great as a predetermined level of comparability, and denying said access otherwise.

2. The method of claim 1 including the further steps, after step (i) of:

j') calculating a first statistical variance of the elements of the time domain sampling set of the first voice print;

k') calculating a second statistical variance of the elements of the time domain sampling set of the second voice print;

1') taking the arithmetical difference between the first with the second statistical variances and continuing with steps (j) and (k) only if tile difference is less than a selected number, access being denied otherwise, whereby steps (j'), (k') and (1') provide a quick method of discriminating between the first and second voice prints before execution of more time consuming steps.

3. The method of claim 1 including the further steps, after step (i) of:

j") calculating a first total spectrum energy content, a first band pass energy content of each of the filtered subsets of the frequency domain sampling set of the first voice print, and a statistical variance of said first filtered subsets;

k'') calculating a second total spectrum energy content, a second band pass

energy content of each of the filtered subsets of the frequency domain sampling set of the second voice print, and a statistical variance of said second filtered subsets;

1'') taking the arithmetical difference between the first and the second total spectrum energy content, and the arithmetical difference between the variances of the first and the second filtered subsets, and continuing with steps (j) and (k) only if the difference is less than a selected number, access being denied otherwise, whereby steps (j"), (k'') and (1'') provide a quick method of discriminating between the first and second voice prints before execution of more time consuming steps.

4. A method of creating and comparing a challenge voice print with a collection of enrollment voice prints for determining if the challenge voice print meets a level of comparability with any one of the enrollment voice prints in order to provide an access step if the level of comparability is at least as great as a predetermined level, comprising the steps:

a) converting a verbal utterance of a specific word or phrase of about two seconds duration into an electronic representation through the use of a microphone or other transducer;

b) deleting portions of the electronic representation which have zero signal level;

c) sampling the electronic representation of the utterance with deleted portions to produce a time domain sampling set;

d) storing the time domain sampling set digitally;

e) converting the electronic representation from an analog to a digital form;

f) transforming the digital form of the electronic representation through a Fast

Fourier Transform device to produce a frequency domain electrical signal representation;

g) sampling the frequency domain electrical signal representation to produce a frequency domain sampling set;

h) forming an enrollment voice print as a composite of the time domain and the frequency domain sampling sets;

i) repeating the steps (a) through (h) a plurality of times by a corresponding plurality of individuals to form a data base of enrollment voice prints, each said voice print representing one said individual;

j) repeating the steps (a) through (g) to form a challenge voice print of an unknown individual;

k) comparing corresponding elements in turn from each of the enrollment sampling sets, in order, with the challenge sampling set to establish a level of comparability between each of the enrollment voice prints with the challenge voice print;

l) enabling a security access if the level of comparability in step (k) with any said comparing of elements is at least as great as a predetermined level of comparability and denying said access otherwise.

5. The method of claim 4 including the further steps, after step (i) of:

j') calculating a first statistical variance of the elements of the time domain sampling set of each of the enrollment voice prints;

k') calculating a second statistical variance of the elements of the time domain sampling set of the challenge voice print;

1') taking the arithmetical difference between the each of the first with the second statistical variances and continuing with steps (j) and (k) only if the difference is less than a selected number for at least one of the arithmetical differences, access being denied otherwise, whereby steps (j'), (k') and (1') provide a quick method of discriminating between the enrollment prints and the challenge voice prints before execution of more time consuming steps.

6. The method of claim 4 including the further steps, after step (i) of:

j") calculating a first total spectrum energy content, a first band pass energy content of each of the filtered subsets of the frequency domain sampling set of each of the enrollment voice prints, and a statistical variance of said first filtered subsets;

k'') calculating a second total spectrum energy content, a second band pass energy content of each of the filtered subsets of the frequency domain sampling set of the challenge voice print, and a statistical variance of said second filtered subsets;

l'') taking a first arithmetical difference between the first and the second total spectrum energy content, and a second arithmetical difference between the variances of the first and the second filtered subsets, and continuing with steps (j) and (k) only if each of the first and the second differences is less than selected numbers respectively, access being denied otherwise, whereby steps (j"), (k") and (l") provide a quick method of discriminating between the first and second voice prints before execution of more time consuming steps.

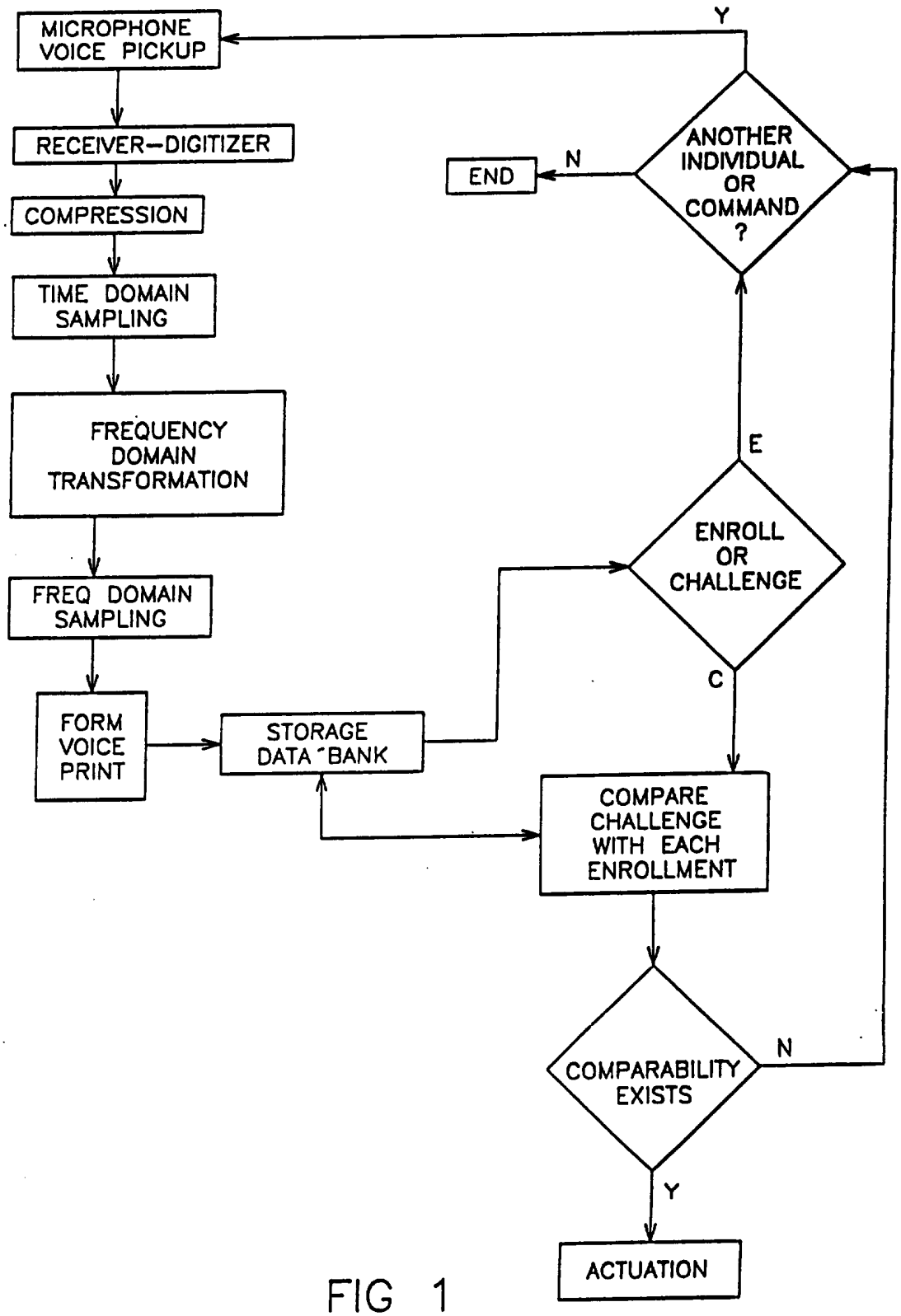
MICROPHONE VOICE PICKUP
RECEIVER–DIGITIZER
COMPRESSION
TIME DOMAIN SAMPLING
FREQUENCY DOMAIN TRANSFORMATION
FREQ DOMAIN SAMPLING
FORM VOICE PRINT
STORAGE DATA BANK
ENROLL OR CHALLENGE
E
C
COMPARE CHALLENGE WITH EACH ENROLLMENT
COMPARABILITY EXISTS
N
Y
ACTUATION
ANOTHER INDIVIDUAL OR COMMAND ?
Y
N
END

FIG 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/00709

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G10L 5/06, G10L 5/00, G01L 1/06, G10L 3/00, G06K 5/00
US CL : 381/41-43, 45; 395/2, 2.55, 2.56, 2.6-2.63, 2.82; 235/380
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/41-43, 45; 395/2, 2.55, 2.56, 2.6-2.63, 2.82; 235/380

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

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

APS, MAYA
search terms: (voiceprint or voice print) (P) (compar? or match?); time and frequency domain;

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,673,331 (HAIR ET AL) 27 June 1972, Abstract, column 3, lines 34-63, column 11, lines 8-35 and lines 60-73, column 12, lines 1-14.	1-6
Y	US, A, 3,896,266 (WATERBURY) 22 July 1975, Abstract, column 3, lines 24-47, column 4, lines 1-45, column 18, lines 13-26, column 22, lines 50-67, column 23, lines 56-67, column 24, lines 1-13.	1-6
Y	US, A, 4,449,189 (FEIX ET AL) 15 May 1984, Abstract, column 5, lines 34-56	1, 3
Y	US, A, 4,833,713 (MUROI ET AL) 23 May 1989, Abstract, Figure 6, columns 7-8, lines 50-68.	1-3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
29 MARCH 1996

Date of mailing of the international search report
23 APR 1996

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Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/00709

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A, 5,313,556 (PARRA) 17 May 1994, Abstract, column 3, lines 12-25, column 4, lines 11-19, column 6, lines 37-50, column 8, lines 37-58, column 9, lines 3-19.	1, 4 ----- 2, 3, 5, 6