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SATTERLEE, STEPHENS, BURKE & BURKE LLP
Mario Aieta
Robert Carrillo
230 Park Avenue, 11th Floor
New York, NY 10169
(212) 818-9200
Attorneys for ShotSpotter, Inc. and
The Johns Hopkins University

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

SHOTSPOTTER, INC., and THE JOHNS HOPKINS UNIVERSITY, Plaintiffs, v. SAFETY DYNAMICS, INC., Defendant.	Index No. 09-cv-7828 (GBD) SECOND AMENDED COMPLAINT JURY TRIAL DEMANDED

Plaintiffs ShotSpotter, Inc. ("ShotSpotter"), and The Johns Hopkins University, by counsel, for their Complaint against Defendant Safety Dynamics, Inc. ("Safety Dynamics") allege and state:

Parties

1. ShotSpotter is a corporation organized and existing under the laws of the State of Delaware, with its principal place of business at 1060 Terra Bella Avenue, Mountain View, CA 94043.

2. The Johns Hopkins University is a non-profit educational and research institution located at 34th and Charles Streets, Baltimore, Maryland 21218 and is organized and existing under the laws of the State of Maryland.

3. Upon information and belief, defendant Safety Dynamics is a corporation organized and existing under the laws of the State of Delaware, being headquartered at 9030 South Rita Road, Suite 100, Tucson, Arizona 85747.

Jurisdiction and Venue

4. This is an action for patent infringement of US. Patent No. 7,411,865 ("the '865 Patent") and U.S. Patent No. 6,965,541 ("the '541 Patent") arising under the Patent Laws of the United States, 35 U.S.C. §§ 1 *et seq.*, and for false advertising in violation of §43(a) of the Lanham Act, 15 U.S.C. §1125(a).

5. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331, 1338(a), and 1400(b).

6. This Court has personal jurisdiction over Safety Dynamics because, *inter alia,* Safety Dynamics has committed, or aided, abetted, contributed to, or participated in, acts of patent infringement in this judicial district.

7. Venue is proper in this judicial district pursuant to 28 U.S.C. §§ 1391 and 1400(b).

The Patents

8. ShotSpotter is the owner by assignment of the '865 Patent, entitled "System and Method for Archiving Data from a Sensor Array," which the United States Patent and Trademark Office duly and legally issued on August 12, 2008. A true and correct copy of the '865 Patent is attached hereto and incorporated by reference as Exhibit A. The claims of the '865 Patent are valid and enforceable. ShotSpotter owns by assignment all right, title and interest in the '865 Patent and has the right to sue for and obtain equitable relief and damages for infringement.

9. The Johns Hopkins University is the owner by assignment of the '541 Patent, entitled "Gun Shot Digital Imaging System," which the United States Patent and Trademark

Office duly and legally issued on November 15, 2005. A true and correct copy of the '541 Patent is attached hereto and incorporated by reference as Exhibit B. The claims of the '541 Patent are valid and enforceable. The Johns Hopkins University owns by assignment all right, title and interest in the '541 Patent.

10. The Johns Hopkins University licensed the '541 Patent to Planning Systems, Inc.

11. Planning Systems, Inc. is the exclusive licensee of the '541 Patent with respect to municipal markets for law enforcement.

12. Planning Systems, Inc. sublicensed to ShotSpotter its entire right and interest in the '541 Patent.

13. ShotSpotter has the right to sue for and obtain equitable relief and damages for infringement of the '541 Patent.

First Cause of Action

Infringement of the '865 Patent by Safety Dynamics

14. Plaintiffs reallege and incorporate by reference the allegations set forth in paragraphs 1-13 above.

15. Pursuant to 35 U.S.C. § 282, the '865 Patent is presumed valid.

16. Safety Dynamics is without authority making, using, offering to sell, or selling products or services within this judicial district, including a "gun shot detection system," that directly infringe, contributorily infringe, and induce infringement of one or more valid claims of the '865 Patent. The infringing "gun shot detection system" has been described by Safety Dynamics in proposals submitted to potential customers in this judicial district and elsewhere.

17. As a direct and proximate consequence of Safety Dynamics' direct infringement, contributory infringement, and inducement to infringe the '865 Patent, Plaintiffs have suffered

and will continue to suffer substantial and irreparable injury and damages in an amount not yet determined for which Plaintiffs are entitled to relief.

Second Cause of Action

Infringement of the '541 Patent by Safety Dynamics

18. Plaintiffs reallege and incorporate by reference the allegations set forth in paragraphs 1-17 above.

19. Pursuant to 35 U.S.C. § 282, the '541 Patent is presumed valid.

20. Safety Dynamics is without authority making, using, offering to sell or selling products and/or services within this judicial district, including a "gun shot detection system," that directly infringe, contributorily infringe, and induce infringement of one or more valid claims of the '541 Patent. The infringing "gun shot detection system" was described by Safety Dynamics in proposals submitted to potential customers in this judicial district and elsewhere.

21. As a direct and proximate consequence of Defendant Safety Dynamics' direct infringement, contributory infringement, and inducement to infringe of the '541 Patent, Plaintiffs have suffered and will continue to suffer substantial and irreparable injury and damages in an amount not yet determined for which Plaintiffs are entitled to relief.

Third Cause of Action

False Advertising in Violation of § 43(a) of the Lanham Act

22. Plaintiff ShotSpotter realleges and incorporates by reference the allegations set forth in paragraphs 1-21 above.

23. Safety Dynamics is a direct competitor with ShotSpotter in the market for gun shot detection systems for municipal law enforcement.

24. The market for gun shot detection systems for municipal law enforcement is very small. In the history of the industry, approximately 75 gun shot detection systems have been sold to municipal law enforcement customers.

25. Municipal law enforcement customers typically purchase gun shot detection systems for the purpose of installing those systems in a fixed geographic area, ranging from several city blocks to several square miles. An effective gun shot detection system must provide effective detection over the entire area sought to be monitored by the municipal law enforcement customer.

26. Safety Dynamics, either directly or through its agents, distributes to potential municipal law enforcement customers promotional materials containing literally false statements about the minimum number of sensors required by the Safety Dynamics gun shot detection system to provide effective detection over a given area.

27. Upon information and belief, Safety Dynamics, through its agent Sound & Optics Systems, Inc., has distributed and is distributing to potential municipal law enforcement customers promotional materials referred to as "Gun Shot and Sound Recognition Comparison Chart" that claim that 5 to 9 Safety Dynamics "Sentri II" sensors will provide effective gun shot detection over an area of one square mile. This claim is literally false.

28. Upon information and belief, Safety Dynamics, through its agent Secure Network Systems LLC, has distributed and is distributing to potential municipal law enforcement customers promotional materials referred to as "SENTRI Solution Overview" that claim that an installation consisting of 20 "SENTRI Systems" sensors, each of which "can listen for street-type weapons (.357, .45, 9mm) at an average distance of 600 feet in all directions," will provide

effective gun shot detection over "every square foot in a square mile." This claim is literally false.

29. Safety Dynamics distributes its literally false promotional materials, either directly or through its agents, for the purpose of influencing potential municipal law enforcement customers to buy its goods and services.

30. Safety Dynamics' literally false claims are material to the relevant purchasing public because the number of sensors required to provide effective gun shot detection over a given area directly and substantially determines the cost of the gun shot detection system.

31. Safety Dynamics' literally false claims have misled, and continue to mislead, members of the relevant purchasing public concerning the relative cost and effectiveness of gun shot detection systems installed by Safety Dynamics versus gun shot detection systems installed by ShotSpotter.

32. Safety Dynamics' distribution of promotional materials containing literally false claims concerning the number of sensors required to provide effective gun shot detection over a given area are part of an organized campaign to penetrate the relevant market of municipal law enforcement customers. Upon information and belief, this campaign includes oral statements made at trade shows and in face to face meetings with potential customers.

33. The false statements made by Safety Dynamics constitute false advertising in violation of § 43(a) of the Lanham Act, 15 U.S.C. § 1125(a).

34. ShotSpotter has been damaged and is likely to be damaged by the literally false claims made by Safety Dynamics and distributed in the promotional materials of Safety Dynamics.

Fourth Cause of Action

False Advertising in Violation of § 43(a) of the Lanham Act

35. Plaintiff ShotSpotter realleges and incorporates by reference the allegations set forth in paragraphs 22 to 35 above.

36. Beginning on or about December 28, 2009, Safety Dynamics incorporated into its website at http://www.safetydynamics.net/ a segment from a television news program broadcast by CNN on or about November 9, 2009. The segment is entitled "Gunshot Detection in Real Time" (hereinafter the "Segment").

37. Next to the Segment, Safety Dynamics' website included the following language:

> CNN's Mario Armstrong takes a look at technology being used by some cities to detect gunfire within seconds and pinpoint the location up to about 83 feet. The importance of technologies like Safety Dynamics' SENTRI gunshot location system was emphasized by the tragedy of the shootings at Fort Hood where gunshot location technology could have contributed significantly to the emergency first responders by generating and presenting data on the origin of gunfire. In the case of SENTRI, a fast PTZ video camera receives location data from the microphones and slews to the shooter's position while rolling digital video recordings. This combination of advanced acoustic recognition with digital video creates a highly-effective common operating picture [COP] for use across police departments and security personnel. It also manufactures evidence of the crime that can be used for legal proceedings in the form of digital video.

38. Upon information and belief, Safety Dynamics uses its website as a marketing tool for the purpose of influencing potential municipal law enforcement customers to buy its goods and services.

39. By using the Segment on its website in connection with the above-quoted text, Safety Dynamics makes the following literally false claims:

A. That Safety Dynamics can provide to potential municipal law enforcement customers the technology described in the Segment which has a track record of proven effectiveness in urban environments;
B. That Safety Dynamics can provide to potential municipal law enforcement customers the graphical user interface presented in the Segment; and

C. That the technology sold by Safety Dynamics is being used by over forty municipal customers.

40. Safety Dynamics' literally false claims are material to the relevant purchasing public because the proven effectiveness and ease of use of any new technology are material to any municipal law enforcement entity's decision to purchase and implement that technology.

41. Safety Dynamics' literally false claims have misled, and continue to mislead, members of the relevant purchasing public concerning the ease of use and proven effectiveness of gun shot detection systems installed by Safety Dynamics versus gun shot detection systems installed by ShotSpotter.

42. Safety Dynamics' use of the Segment on its website is part of an organized campaign to penetrate the relevant market of municipal law enforcement customers. Upon information and belief, this campaign includes oral statements made at trade shows and in face to face meetings with potential customers.

43. The false statements made by Safety Dynamics constitute false advertising in violation of § 43(a) of the Lanham Act, 15 U.S.C. § 1125(a).

44. ShotSpotter has been damaged and is likely to be damaged by the literally false claims made by Safety Dynamics and distributed in the promotional materials of Safety Dynamics.

Fifth Cause of Action

Unfair Competition Under New York Law

45. Plaintiff ShotSpotter realleges and incorporates by reference the allegations set forth in paragraphs 22 to 44 above.

46. ShotSpotter has invested millions of the dollars in the development and improvement of its gunshot detection systems and has generated enormous goodwill in the municipal law enforcement field due to the proven effectiveness of its systems.

47. Safety Dynamics has distributed to the relevant purchasing public literally false claims regarding its gunshot detection products with the intent to confuse and mislead the relevant purchasing public into believing that the capabilities and qualities unique to ShotSpotter's gunshot detection systems are available in the products of Safety Dynamics.

48. Safety Dynamic has acted in bad faith and without justification and has misappropriated ShotSpotter's goodwill by falsely associating itself and its products with ShotSpotter and its systems, and by distributing literally false statements regarding the capabilities of Safety Dynamics' products.

49. ShotSpotter has been damaged and is likely to be damaged by the distribution of literally false claims made by Safety Dynamics and distributed in the promotional materials of Safety Dynamics.

WHEREFORE, ShotSpotter and The Johns Hopkins University pray that this Court grant the following relief on their First and Second Causes of Action for Patent Infringement:

(a) A judgment that one or more claims of the '865 Patent is infringed by the Safety Dynamics "gun shot detection system," and that Safety Dynamics' making, using, offering to sell, or selling in the United States, or importing into the United States, the "gun shot detection system" infringes the '865 Patent either by direct infringement, contributory infringement and/or inducement to infringe;

(b) A judgment that one or more claims of the '541 Patent is infringed by the Safety Dynamics "gun shot detection system," and that Safety Dynamics's making, using, offering to sell, or selling in the United States, or importing into the United States, the "gun shot detection system" infringes the '541 Patent either by direct infringement, contributory infringement and/or inducement to infringe;

(c) An award of damages adequate to compensate Plaintiffs for Defendant Safety Dynamics' infringement of the '865 Patent and the '541 Patent pursuant to 35 U.S.C. § 284;

(d) An award increasing damages up to three times the amount found or assessed by the Court in Plaintiffs' favor and against Safety Dynamics for its infringement of the '865 Patent and the '541 Patent in view of the willful and deliberate nature of Safety Dynamics' infringement;

(e) An Order permanently enjoining Safety Dynamics, and its affiliates and subsidiaries, and each of their officers, agents, servants and employees, from making, using, offering to sell, or selling in the United States, or importing into the United States any "gun shot detection system" that infringes the '865 Patent either by direct infringement, contributory infringement and/or inducement to infringe until after the expiration date of the '865 Patent;

(f) An Order permanently enjoining Safety Dynamics, and its affiliates and subsidiaries, and each of their officers, agents, servants and employees, from making, using, offering to sell, or selling in the United States, or importing into the United States any "gun shot detection system" that infringes the '541 Patent either by direct infringement, contributory infringement and/or inducement to infringe until after the expiration date of the '541 Patent;

(g) That Plaintiffs be awarded their attorney fees, costs and expenses incurred in prosecuting this action; and

(h) Such further and other relief as this Court deems just, proper, and equitable under the circumstances.

AND WHEREFORE, ShotSpotter prays that this Court grant the following relief on its Third and Fourth Causes of Action for False Advertising in Violation of the Lanham Act:

(a) Permanently enjoining Safety Dynamics and those acting in concert with it from falsely representing the number of sensors needed to provide effective gun shot detection using gun shot detection systems manufactured or offered for sale by Safety Dynamics; and

(b) Permanently enjoining Safety Dynamics and those acting in concert with it from falsely representing the market penetration, history of effective installations, or graphical user interface of the gun shot detection systems manufactured or offered for sale by Safety Dynamics provide the ; and

(c) Awarding ShotSpotter the profits that Safety Dynamics obtained from the sale of its goods and services in connection with promotional materials containing literally false statements;

(d) Awarding ShotSpotter compensatory damages in the amount of the pecuniary loss resulting from the effect of Safety Dynamics' conduct on actual and potential customers;

(e) Awarding ShotSpotter compensatory damages in the amount of the expenditures necessary to counteract the false representations, including the costs and attorneys fees incurred therein;

(f) Awarding ShotSpotter treble damages and profits based upon defendants' knowing and willful infringement under the Lanham Act in an amount that this Court shall find to be just;

(g) Such further and other relief as this Court deems just, proper, and equitable under the circumstances.

AND WHEREFORE, ShotSpotter prays that this Court grant the following relief on its Fifth Cause of Action for Unfair Competition:

(a) Permanently enjoining Safety Dynamics and those acting in concert with it from falsely representing the number of sensors needed to provide effective gun shot detection using gun shot detection systems manufactured or offered for sale by Safety Dynamics; and

(b) Permanently enjoining Safety Dynamics and those acting in concert with it from falsely representing the market penetration, history of effective installations, or graphical user interface of the gun shot detection systems manufactured or offered for sale by Safety Dynamics provide the ; and

(c) Awarding ShotSpotter the profits that Safety Dynamics obtained from the sale of its goods and services in connection with promotional materials containing literally false statements;

(d) Awarding ShotSpotter compensatory damages in the amount of the pecuniary loss resulting from the effect of Safety Dynamics' conduct on actual and potential customers; and

(e) Awarding ShotSpotter compensatory damages in the amount of the expenditures necessary to counteract the false representations, including the costs and attorneys fees incurred therein; and

(f) Such further and other relief as this Court deems just, proper, and equitable under the circumstances.

JURY DEMAND

Plaintiffs demand a trial by jury on all issues in this case that may be properly submitted to a jury.

Dated: March 4, 2010

SATTERLEE STEPHENS BURKE & BURKE LLP

By: ______________________
Mario Aieta
Robert Carrillo
230 Park Avenue, 11th Floor
New York, NY 10169
(212) 818-9200
Attorneys for ShotSpotter, Inc. And The Johns Hopkins University

US007411865B2

(12) **United States Patent**
Calhoun

(10) **Patent No.: US 7,411,865 B2**
(45) **Date of Patent: Aug. 12, 2008**

(54) **SYSTEM AND METHOD FOR ARCHIVING DATA FROM A SENSOR ARRAY**

(75) Inventor: **Robert B. Calhoun**, Oberlin, OH (US)

(73) Assignee: **Shotspotter, Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 6 days.

(21) Appl. No.: **11/318,422**

(22) Filed: **Dec. 23, 2005**

(65) **Prior Publication Data**

US 2007/0230270 A1 Oct. 4, 2007

Related U.S. Application Data

(60) Provisional application No. 60/638,876, filed on Dec. 23, 2004.

(51) **Int. Cl.**
G01S 3/808 (2006.01)

(52) **U.S. Cl.** **367/124**; 367/127

(58) **Field of Classification Search** 367/906, 367/124, 127, 129; 707/1
See application file for complete search history.

(56) **References Cited**

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2006/0114749	A1 *	6/2006	Baxter et al.	367/128
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2006/0256660	A1 *	11/2006	Berger	367/124
2006/0280033	A1 *	12/2006	Baxter et al.	367/906
2006/0294164	A1 *	12/2006	Armangau et al.	707/205

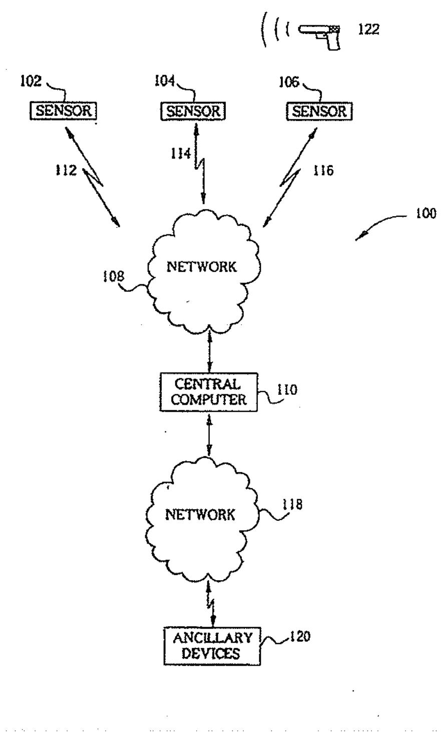
* cited by examiner

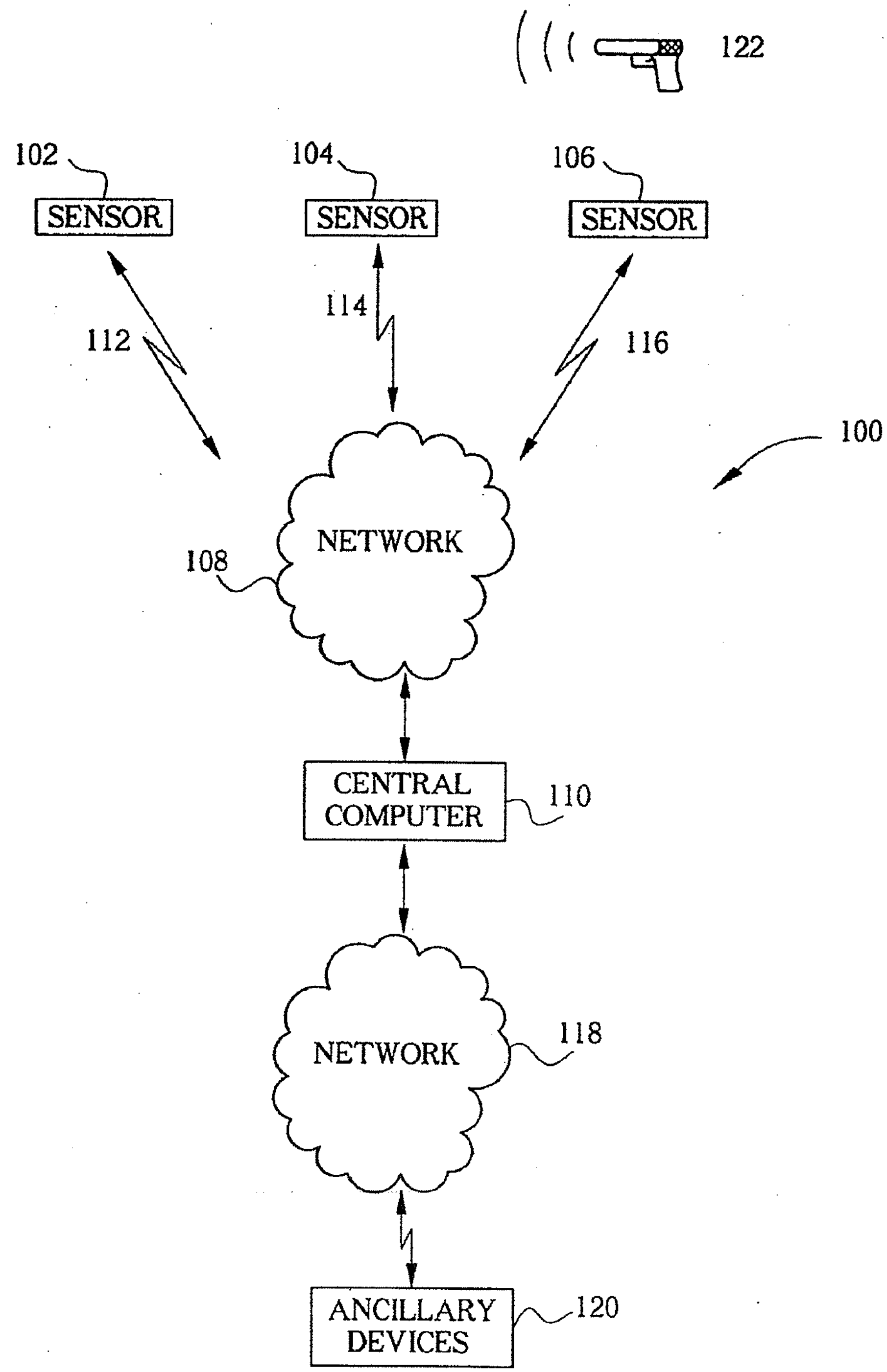
Primary Examiner—Dan Pihulic
(74) *Attorney, Agent, or Firm*—DLA Piper US LLP

(57) **ABSTRACT**

A system and method for archiving and retrieving information from an array of remote sensors. In a preferred embodiment the invention is incorporated in a gunshot detection and location system to preserve audio information surrounding a gunshot event for later review or analysis. In a preferred embodiment the system includes a plurality of acoustic sensors deployed in an array, a computer for processing gunshot information from the sensors, and a mass storage device for temporary archival of audio information. When a gunshot event is detected, the location of the audio information of the data within the spool is stored in an index to facilitate later retrieval of the information.

21 Claims, 8 Drawing Sheets

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NETWORK
118
ANCILLARY DEVICES
120

Fig. 1

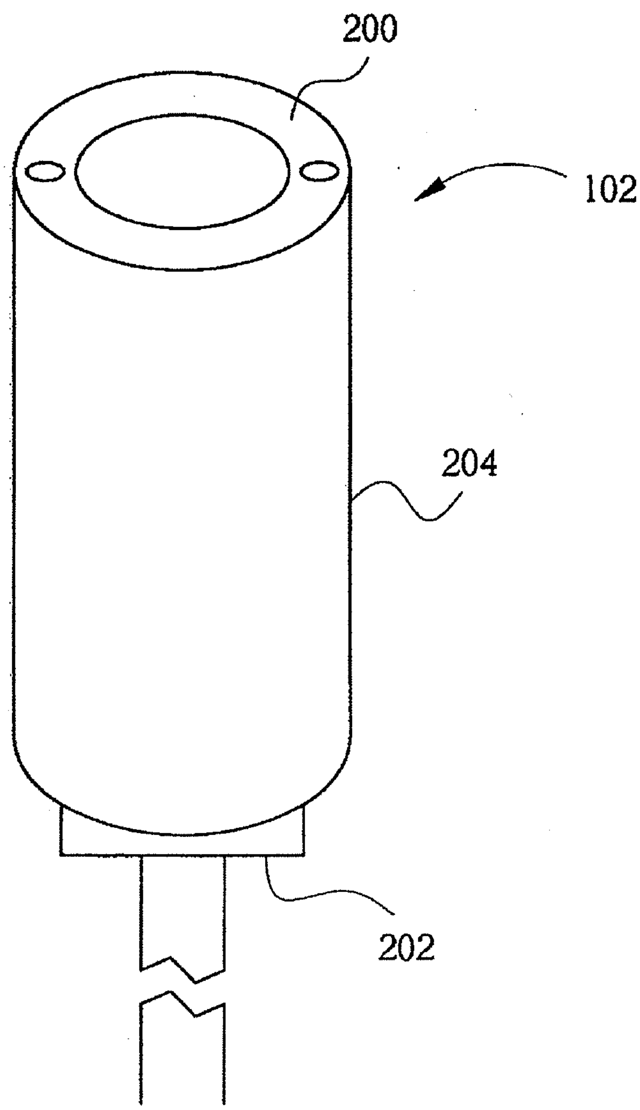

Fig. 2

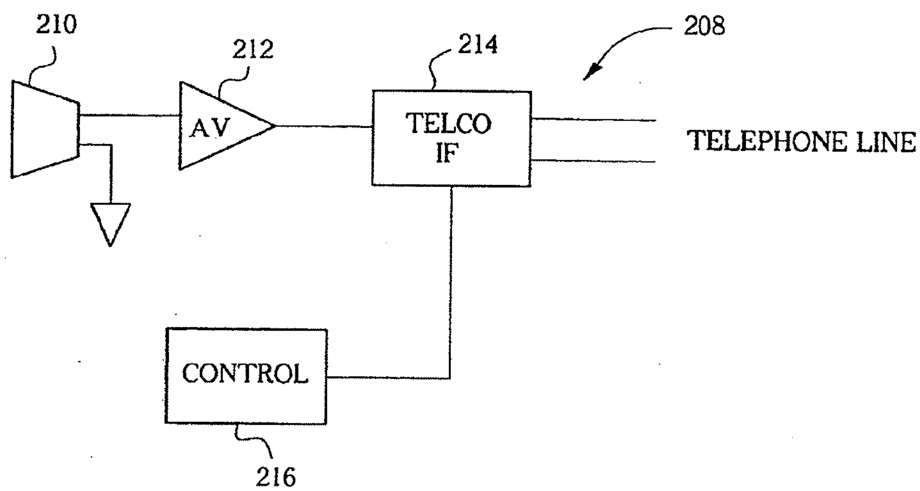

Fig. 3

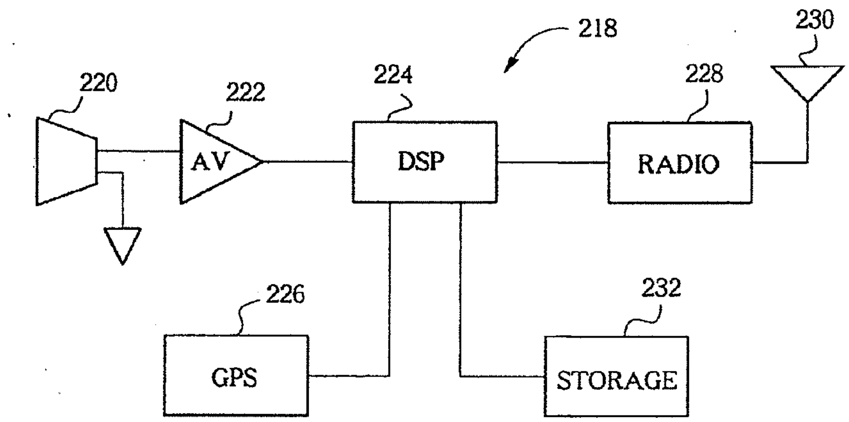
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Fig. 4

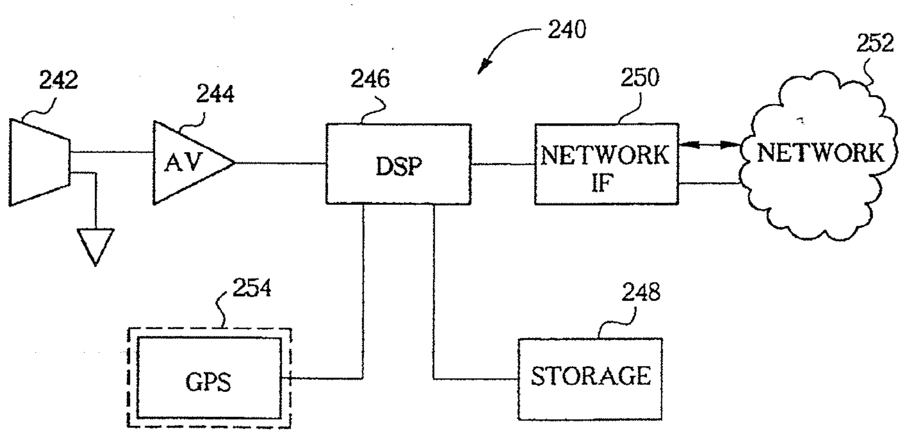
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Fig. 5

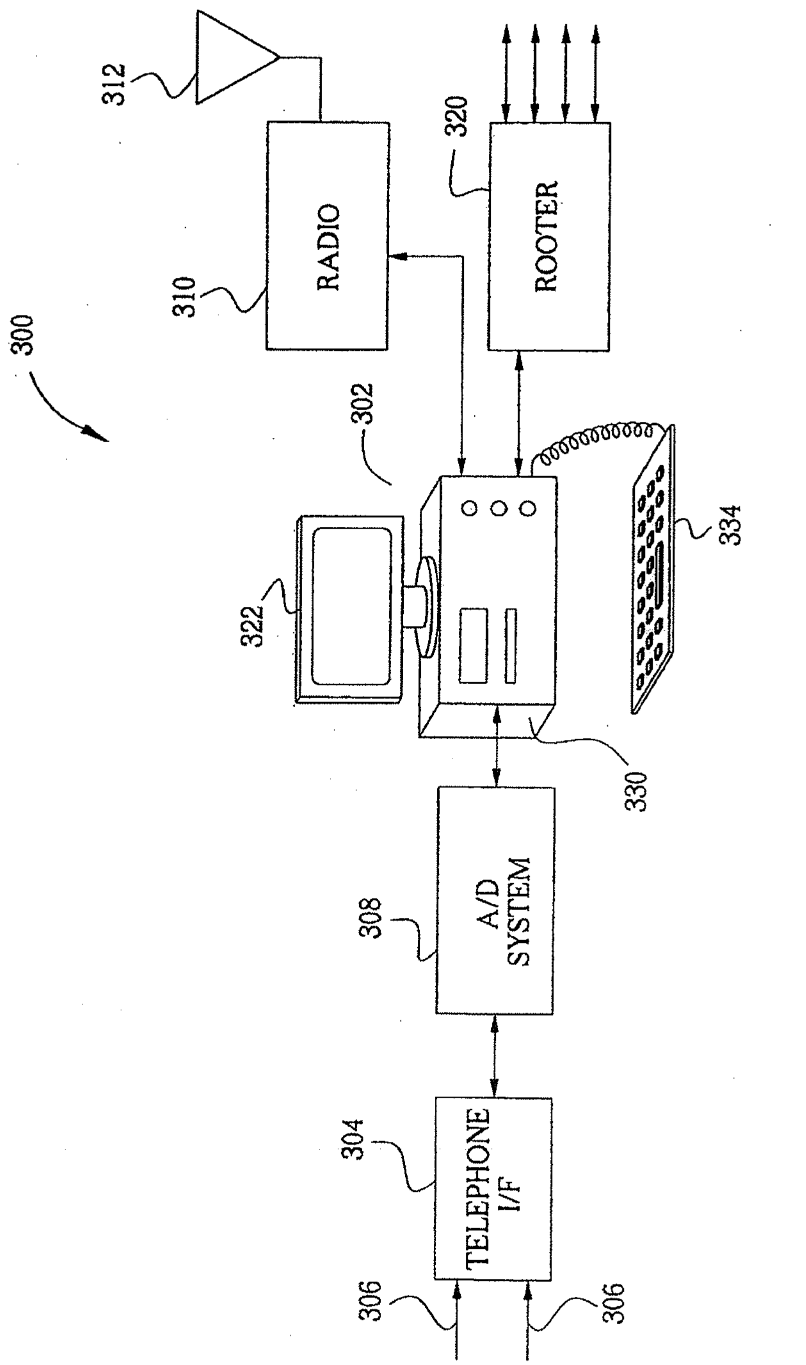
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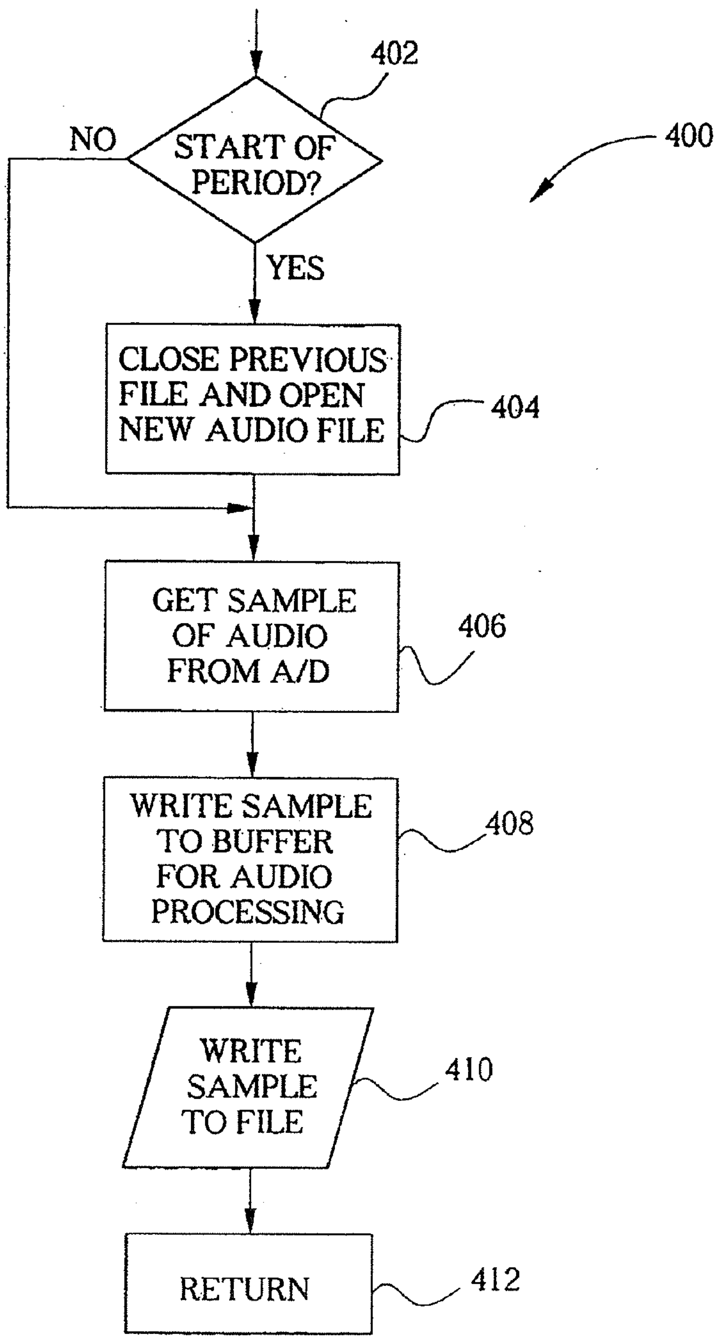
Fig. 6


402
400
NO
START OF PERIOD?
YES
CLOSE PREVIOUS FILE AND OPEN NEW AUDIO FILE
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GET SAMPLE OF AUDIO FROM A/D
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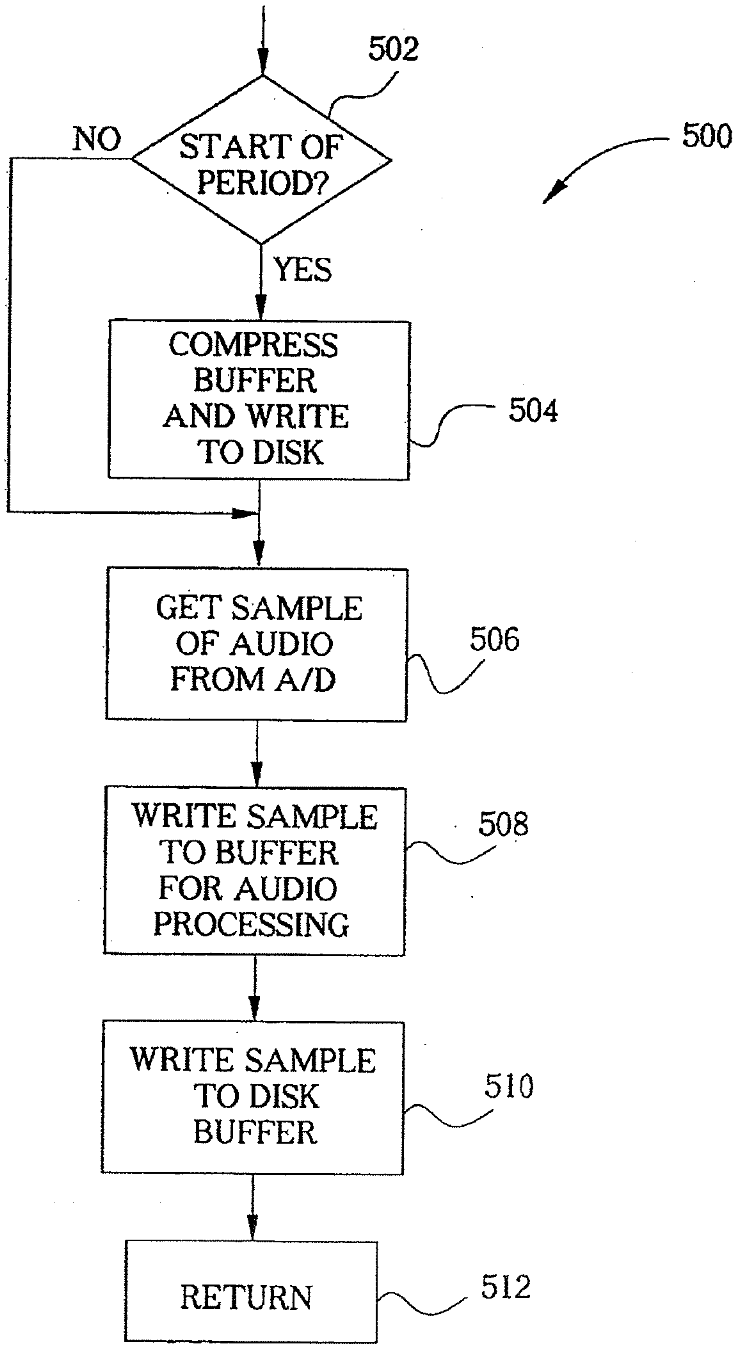
WRITE SAMPLE TO BUFFER FOR AUDIO PROCESSING
408
WRITE SAMPLE TO FILE
410
RETURN
412

Fig. 7



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500
NO
START OF PERIOD?
YES
COMPRESS BUFFER AND WRITE TO DISK
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GET SAMPLE OF AUDIO FROM A/D
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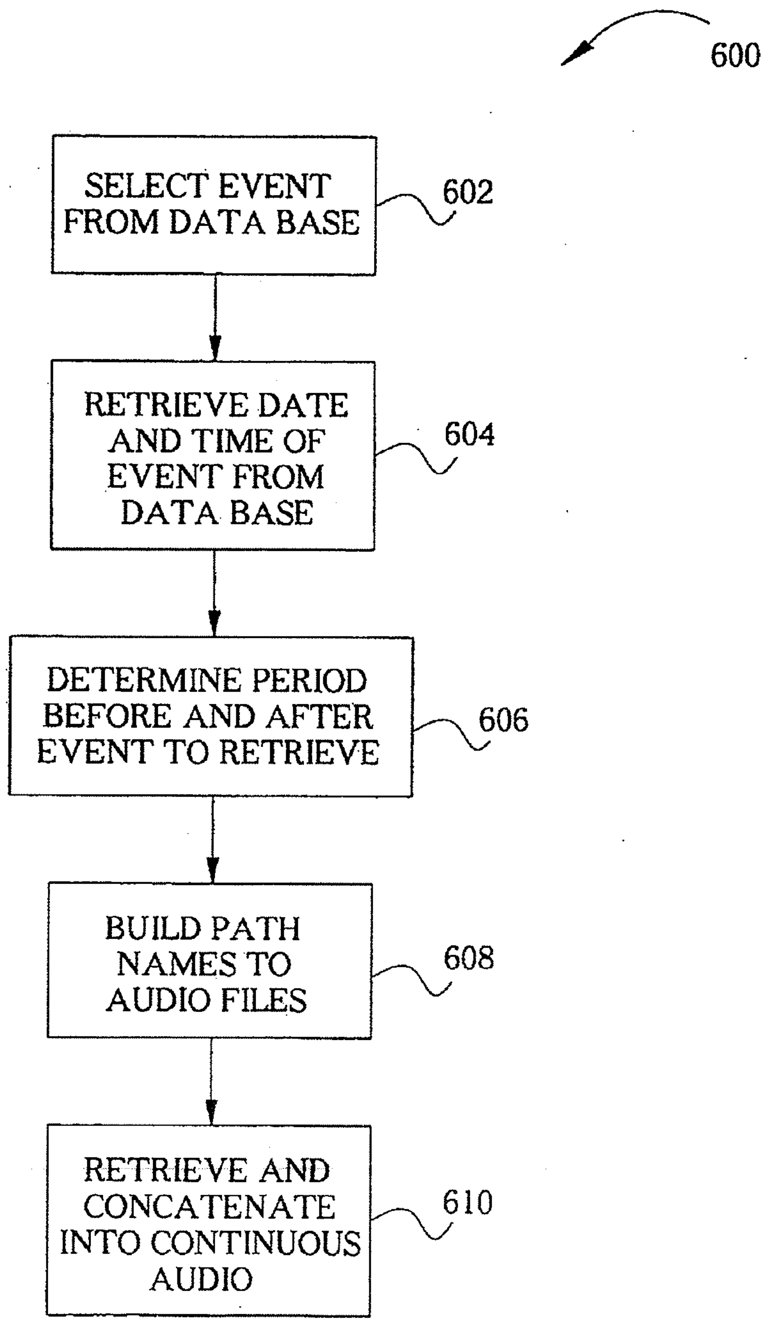
WRITE SAMPLE TO BUFFER FOR AUDIO PROCESSING
508
WRITE SAMPLE TO DISK BUFFER
510
RETURN
512

Fig. 8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SELECT EVENT FROM DATA BASE
602
RETRIEVE DATE AND TIME OF EVENT FROM DATA BASE
604
DETERMINE PERIOD BEFORE AND AFTER EVENT TO RETRIEVE
606
BUILD PATH NAMES TO AUDIO FILES
608
RETRIEVE AND CONCATENATE INTO CONTINUOUS AUDIO
610

Fig. 9

SYSTEM AND METHOD FOR ARCHIVING DATA FROM A SENSOR ARRAY

CROSS REFERENCE TO RELATED APPLICATION

This application claims benefit of provisional patent application No. 60/638,871 filed Dec. 23, 2004.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system and method for archiving data from a sensor array along with metadata that facilitates later retrieval of the archived data. More particularly, but not by way of limitation, in a system for identifying and locating an acoustic event, the present invention provides a system and method for collecting, storing, and indexing raw data from detected events for efficient subsequent review.

2. Background of the Invention

Gunfire and sniper detection systems are generally known in the art. Such systems can be broadly grouped into three categories: systems which pinpoint the precise location of the source of gunfire; azimuthal sensors which provide an indication of the radial direction to the source of gunfire; and proximity sensors which merely provide an indication that nearby gunfire was detected. While such systems have been demonstrated to perform well in both law enforcement and military applications, the entire field is presently an emerging technology.

In many large cities, gun-related violence has become a plague of epidemic proportions. Urban gunfire, whether crime-related or celebratory in nature, results in thousands of deaths per year in the United States alone. Gunfire location systems, such as those installed in the Redwood City, Calif., Glendale, Ariz., Willowbrook, Calif., City of Industry, Calif., and Charleston, S.C. areas, have proven to be effective in reducing law enforcement response time to detected gunfire, apprehending criminals, collecting evidence, and reducing the occurrence of celebratory gunfire. One such system is described in U.S. Pat. No. 5,973,998, issued to Showen, et al., which is incorporated herein by reference.

Showen, et al., discloses a system wherein sensors are placed at a density of roughly six to ten sensors per square mile. Audio information is sent to a computer at a central location and processed to: detect a gunshot; determine a time of arrival for the gunshot at each sensor; and calculate a location of the shooter from the difference in the times of arrival at three or more sensors. Showen, et al. takes advantage of the long propagation distance of gunfire to place sensors in a relatively sparse array so that only a few of the sensors can detect the gunfire. This permits the processor to ignore impulsive events which only reach one sensor—a concept called "spatial filtering." This concept of spatial filtering radically reduces the sensor density compared to predecessor systems, which require as many as 80 sensors per square mile.

Another gunshot location system is described in U.S. Pat. No. 6,847,587 issued to Patterson, et al., which is incorporated herein by reference. Patterson, et al. discloses a system wherein audio information is processed within each sensor to detect a gunshot and determine a time of arrival at the sensor. Time of arrival information, as determined from a synchronized clock, is then transmitted wirelessly by each sensor to a computer at a centralized location where a location of the shooter is calculated in the same manner as in the Showen, et al. system.

As yet, azimuthal systems have not been as widely accepted as, for example, the Showen, et al. system. Azimuthal sensors typically employ one or more closely-spaced sensors, where each sensor includes several microphones arranged in a small geometric array. A radial direction can be determined by measuring the differences in arrival times at the various microphones at a particular sensor. Presently such systems suffer from somewhat limited accuracy in the determination of the radial angle. When two or more azimuthal sensors are used to locate a source location by finding the intersection of indicated radial angles, angular error translates into positional error. Since errors in the radial angle result in ever increasing positional error as the distance from the sensor to the source increases, the reported position will be especially suspect toward the outer limits of the sensor's range.

While present gunshot detection systems provide nearly immediate information about an event, it has heretofore been overlooked that the audio data surrounding the event may provide investigative leads or be rich in evidentiary value. For example, the raw audio data might be used by an expert in weapon types to identify the specific model of weapon used, or by an automotive expert to gain information about the type of car used in a drive-by shooting. Further, it has also been overlooked that, if the audio data is stored along with time information, the data from mislocated, or unlocated, events can be later processed to determine a correct source location, and an exact time at which the event occurred.

Past inventions also do not allow the use of audio information to test the veracity of a witness. For example, a person may claim to have been shot in an area near a sensor at a time when an automated gunshot location system did not report any gunfire. This could be because of a failure of the gunshot location system or it could be because of inaccuracies in the story of the witness. To determine the truth of the situation, the data collected by the system could be rescanned over the period of interest to ensure that no gunshots were detected on any channel during this time.

Even if a time frame is narrowed down to an hour, or so, the task of reviewing data from each sensor of an array, would be daunting. Searching an hour of data from a sixteen sensor array would consume two man work days. Further, if data is stored remote from the user, the time required to retrieve hour long audio files from a plurality of sensors would require large amounts of time. As it is thus infeasible for a user to download and listen to even fairly short time periods of data across multiple sensor channels in a timely manner, there is a need for a method to facilitate the review of large amounts of remotely stored data.

It is thus an object of the present invention to provide a system and method for storing data from a sensor array which overcomes the problems and alleviates the needs discussed above.

SUMMARY OF THE INVENTION

The present invention provides a system and method for storing data from an array of remote sensors. In a preferred embodiment, the inventive system includes: a plurality of acoustic sensors dispersed throughout a monitored area; a communication network adapted to deliver information from the sensors to a host processor; and a storage system for storing acoustic information received at each sensor.

In another preferred embodiment, the inventive system includes: a plurality of acoustic sensors for receiving acoustic information from a monitored area; and a processor for discriminating acoustic events from other sounds. Upon detecting an acoustic event, the type of event and the precise time of arrival of the event are determined and acoustic data surrounding each detected event is stored in digital form and indexed such that the information may be easily retrieved at a later time. For example, the characteristics of each gunshot-like sound detected (its amplitude, the shape of its envelope, its frequency components, etc) may be stored along with the arrival time as audio metadata in a database such that data files may easily be searched with conventional database searching algorithms. By storing the absolute timing information for the audio data on each channel, the relative timing information from multiple channels may be ascertained with high precision.

The invention is not limited to the field of audio data recording or gunshot detection. For example, a remote sensor with data logging capability and a low-bandwidth radio telemetry link might be assigned to monitor the temperature of a process. Using the present invention, a message containing the time, temperature, fluid flow rates, etc. could be sent to a remote database every time some warning threshold (temperature or rate of temperature change, for example). Later, the temperature might exceed a certain alarm threshold, causing the sensor to send an alarm via radio telemetry to indicate a serious problem with the process. By storing the metadata for all measurements in a database, including those that do not trigger an alarm, an engineer later desiring to review the relevant data stream stored on the sensor can readily determine when the process began to have problems and extract the raw data from data point.

Further objects, features, and advantages of the present invention will be apparent to those skilled in the art upon examining the accompanying drawings and upon reading the following description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a preferred configuration of a gunshot detection system in which the inventive method is used.

FIG. **2** provides a perspective view of a preferred embodiment of a sensor as employed in the inventive system.

FIG. **3** provides a block diagram for a preferred embodiment of an analog wired sensor.

FIG. **4** provides a block diagram for a preferred embodiment of a wireless sensor.

FIG. **5** provides a block diagram for a preferred embodiment of a digital wired sensor.

FIG. **6** provides a block diagram of the server of FIG. **6** when used to collect information from an array of sensors.

FIG. **7** provides a flow chart for a preferred method for storing audio information received at the server of FIG. **6**.

FIG. **8** provides a flow chart for a preferred method for storing audio information at a sensor.

FIG. **9** provides a flow chart for a preferred method for using indexing information to retrieve audio data as stored in accordance with the method FIGS. **7** or **8**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before explaining the present invention in detail, it is important to understand that the invention is not limited in its application to the details of the construction illustrated and the steps described herein. The invention is capable of other embodiments and of being practiced or carried out in a variety of ways. It is to be understood that the phraseology and terminology employed herein is for the purpose of description and not of limitation.

Referring now to the drawings, wherein like reference numerals indicate the same parts throughout the several views, a representative gunshot detection system **100** is shown in its general environment in FIG. **1**. In a preferred embodiment, a plurality of sensors **102-106** are dispersed over a monitored area. Preferably, each sensor is placed such that it has a relatively unobstructed acoustic view around its immediate area. By way of example and not limitation, suitable sites include: placed atop a building; placed atop utility or light poles; on towers, etc. Typically sensors **102-106** communicate through a communications network **108** with a centralized processor **110** wherein information concerning acoustic events is processed to provide details of the event, such as the source location of a gunshot, time of the gunshot, the number of detected gunshots, the type of event, and the like. It should be noted that sensors **102-106** may be any combination of wired or wireless sensors, that communications paths **112-116** may carry either analog or digital information, and that network **108** may comprise any combination of sub-networks, such as, by way of example and not limitation: a telephone network; the internet; a private computer network; or even a collection of dedicated wires routed to the sensor array.

As will be appreciated by those skilled in the art, information about a detected acoustic event is typically output to a person of interest such as a police dispatcher or directly to individual officers, as through network **118** to display devices **120** or a computer console. When weapon **122** is fired, the muzzle blast reaches sensors **102-106** at different times based on the speed of sound and the distance of each sensor from the shooter. Whether the acoustic information is processed at the sensor, or at computer **110**, a time of arrival is determined for each sensor and the differences between the various times of arrival are processed to determine a location of the source of the gunshot. In response to the gunshot, information is provided at device **120**.

A preferred embodiment of a sensor **102** is shown in FIG. **2**. Typically sensor **102** includes a housing **200**, a support **202** for mounting sensor **102**, and a windscreen **204** for protecting internal elements from the environment, while allowing acoustic waves to pass through to the interior.

Turning to FIG. **3**, preferably a wired analog sensor **208** includes: a microphone **210**; an amplifier, and/or other signal conditioning, **212**; an interface to a communication network **214**, most preferably a telephone network; and control logic **216** to handle administrative tasks such as hook-switch. Optionally, sensor **208** may include other features such as, by way of example and not limitation: temperature sensing; gain control; phone line integrity monitoring; etc. In a system employing at least one wired sensor **208**, audio information is transmitted via communication network **215** to a central location where the audio information is digitized and processed to detect gunshots and determine a source location. It should be noted that a particular advantage of the wired analog sensor is that sensor circuitry may be powered by the loop current provided through the telephone line.

With reference to FIG. **4**, a preferred embodiment of a wireless sensor **218** includes: a microphone **220** for receiving acoustic information; an amplifier and/or other signal conditioning **222**; a processor **224**, typically a digital signal processor ("DSP"), as are well known in the art; a satellite positioning receiver, e.g. a GPS **226**; a radio **228** configured for wireless transmission and reception of digital signals; and antenna **230**. It should be noted that in such a sensor, GPS receiver **226** may play two roles, providing positional information as to the sensor's location and an exceptionally accurate real time clock. In one preferred embodiment, DSP **224** processes the received audio information to detect a gunshot and determine the time of arrival of the gunshot. As will be appreciated by those skilled in the art, since only the sensor location and time of arrival need to be transmitted to another location, the load placed on a wireless network by a single sensor 218 may be relatively small. With regard to the present invention, as discussed in more detail hereinbelow, it is most preferable that sensor 208 also includes mass storage device 232 for temporary archival of audio data. For purposes of this invention a "mass storage device" is a device for storage of digital information. By way of example and not limitation mass storage devices include: magnetic disk drives; optical disk drives; CD-ROM drives; DVD drives; flash storage devices such as memory sticks, CF cards, SD cards, MMX cards, and the like; floppy disk drives; as well as any other file oriented type storage device.

Turning next to FIG. 5, wherein is shown a preferred embodiment of a wired digital sensor 240. Sensor 240 preferably includes: microphone 242; amplifier and/or other signal conditioning 244; a processor 246, preferably a digital signal processor; a network interface 250 for communication via a digital network 252, such as by way of example and not limitation, an Ethernet. Like the wireless sensor, in the preferred embodiment of the wired digital sensor processing of the received audio is performed at the sensor and mass storage device 248 is provided for temporary storage of the audio signal.

Optionally, the wired digital sensor may also include a GPS receiver 254, however as will be apparent to those skilled in the art, a wired sensor does not have the same need to self-survey as exists with a wireless sensor. Further, while GPS receiver 254 may be used to provide synchronized clocks among an array of sensors, adequate synchronization may be achieved by periodically synchronizing sensor clocks via the network, or by acquiring data from all sensors using a data acquisition system in which a common sample clock is used to drive acquisition on each sensor.

With presently known gunshot detection systems, it is not possible to provide an accurate position of the shooter with a single sensor. As a result, the calculation of a shooter position requires computation based on the outputs of a plurality of sensors. In a preferred embodiment the sensors communicate with a computer or server 300 as shown in FIG. 6. Server 300 preferably comprises: CPU 302; when employed in a system having wired analog sensors, a telephone interface 304 supporting connection to a plurality of phone lines 306, typically one line for each wired analog sensor and analog to digital converter 308 providing at least one analog input channel for each incoming telephone line; when employed in a system having one or more wireless sensors, radio base station 310 and antenna 312; and, when employed in a system having one or more wired digital sensors, router 320.

As will be apparent to those skilled in the art, CPU 302 will usually include: an enclosure 330 housing the circuitry of the CPU, one or more disk drives for the nonvolatile storage of programs and data, as well as a host of commonly found features, such as a sound card, printer ports, serial ports, USB ports, a network interface, IEE-1394 ports, etc.; a monitor 332; and keyboard 334.

In practice, audio signals received from telephone lines 306 are digitized at a predetermined rate through A/D system 308. As will be appreciated by those familiar with the switched telephone network, audio which passes through the switched system is bandwidth limited to approximately 3000 Hz. Thus, a sample rate of 12 kHz at A/D 308 is more than adequate to record any details of the signal which have passed through the telephone line.

The digitized audio is then stored in a relatively short buffer and processed to determine: if a gunshot occurred; and, if so, a time of arrival of the gunshot. Techniques for making such determinations are well known in the art. If shots are received at a sufficient number of sensors, the differences in the times of arrivals are used to determine a source location of the gunshot.

When wireless or wired digital sensors are used, the gunshot detection and the time of arrival calculation are preferably performed at the sensor, rather than at CPU 302. The calculation of the source location based on differences in the times of arrival, however, is still preferably performed at CPU 302.

It has been observed that, even though in the preferred embodiment the sensors are widely separated, often other sounds made by perpetrators are received at a sensor and could provide investigative leads or have independent evidentiary value. It is, of course, impractical to attempt to listen to all of the audio received from all of the sensors and such an attempt would waste valuable manpower resources. Further, where digital sensors are used, the audio is not sent to CPU 302 as part of the detection process and, sending continuous audio to CPU 302 from every digital sensor would waste bandwidth of the network.

A practical solution is to save all of the audio from each sensor to nonvolatile memory, for example a hard drive, for a predetermined period of time. To reduce storage requirement, stale data is deleted as new data is stored. In one preferred embodiment audio information is stored for 72 hours. If a crime involving gunfire occurs on a Friday night, detectives can review audio surrounding the event on Monday morning and create a copy of any audio which may be of interest, thus avoiding the pending deletion of the data. In addition, the system may be programmed to provide "hints" as to the location of audio events which may not have produced a source location, perhaps because of environmental conditions, but which might be manually analyzed to determine the source location after the fact.

With further reference to FIGS. 3, 4, and 5, at CPU 302, in the case of wired analog sensors, bandwidth is not an issue since analog audio is sent to CPU 302 over a dedicated pair of wires for each sensor. In the case of digital sensors 218 or 240, however, attempting to return all of the audio from all of the sensors would likely tax the throughput of the network. Instead, the audio is stored locally along with such information as the position of the sensor, the temperature of the air, etc. at the sensor and only the hints and event information, known as metadata, are sent to, and stored at, CPU 302. When audio is reviewed, only the desired time from the desired sensors is actually transferred over the network.

The utility of computing this metadata in real time and storing it in a local or remote database becomes apparent when the raw data itself is stored at a remote site accessible only via a low-bandwidth communications link, as is typically the case with all remote sensors that use radio telemetry. Since the vast majority of the data stored remotely is of little or no interest, the desired information can be much more expeditiously obtained by searching the database of metadata to reveal those subsets of data which are most likely to be of interest. As will be apparent to those skilled in the art, when digital sensors are employed, this metadata can be stored locally in the sensor or at the host computer.

Also, in the case of wired sensors, providing sufficient disk space at CPU 302 to store 72 hours of audio from even dozens of wired analog sensors 208 is of little concern. At sensors 218 and 240, however, power consumption and size are important factors. In one preferred embodiment, audio data is stored on commonly available flash media such as SD cards, CF cards, MMX cards, USB memory device, or the like. As will be apparent to those skilled in the art, such mass storage devices are available which mimic a hard drive and provide significant amounts of storage.

In one preferred method of storing the audio data, a directory structure is written to the disk such that there is a dedicated directory for each month of the year. In each month directory there are subdirectories for each day of the month. In each day directory there are twenty four subdirectories, one for each hour of the day. Each hour directory contains sixty minute-subdirectories, and in each minute-subdirectory there are sixty second-subdirectories. At the beginning of each hour CPU **302** erases the data in the appropriate directory representing 72 hours in the past, while at the end of each second the CPU writes audio from that second in its appropriate directory. Each file contains one second of audio and the file names of all such files are generated from the sensor identifier and from the absolute time of that second. In this method, the directory structure provides the indexing to retrieve the desired audio from any start time to any stop time.

An index file is also produced having the times for every event detected by the system, as well as the times of other sounds which may be of interest (the hints). Thus, audio may also be retrieved relative to an event. This requires only one level of indirection, looking up the time of the event from the index file.

While the above described method is well-suited for CPU **302**, it is somewhat problematic for sensors **218** and **240**. In order to minimize the amount of storage required at the sensor, it is important that the audio information is stored in a manner which makes full use of the drive, in light of its file structure. For example, the file structure of the drive may group sixty four, 512 byte sectors into a cluster such that each cluster contains 32,768 bytes. Files stored in such a file system thus consume disk space in 32 kilobyte chunks. If a digital sensor is sampling audio at 40,000 samples per second where each sample uses two bytes, each second requires 80,000 bytes of storage, which, in turn requires three clusters, or 98,304 bytes. If this storage system is used without adjustment, 18,304 bytes per second of disk space would be wasted. Instead, each minute is subdivided into periods of time which make virtually full use of the drive. Conversion of time in seconds to the period employed in the sensor may be performed either at CPU **302** or at the sensors **218** or **240**, in a manner which is transparent to the person requesting the data.

Yet another issue which arises with regard to distributed storage with digital sensors **218** and **240** is the possibility of compressing the data to make best use of the disk space. As will be apparent to those skilled in the art, compression schemes can be broadly divided into two classes: lossy schemes and non-lossy schemes. Lossy schemes compress audio in such a way that decompressed audio will faithfully reproduce the original sound but the actual reconstructed waveform may not be identical to the original. In contrast, non-lossy schemes exactly reconstruct the original waveform. While non-lossy schemes are always acceptable for use with the present invention, the manner in which the data may be used requires that a lossy scheme faithfully reproduce impulsive events without imparting variable delay and that the modification of the data will not impact its effectiveness as evidence in a court of law.

In a preferred embodiment, audio information received at microphone **220** or **242** is converted into digital information by a twelve bit A/D converter integrated into DSP **224** or **246**. One non-lossy scheme takes advantage of the fact that, since data is stored in a byte-wide fashion, two samples can be compressed to occupy three bytes, as opposed to four bytes. To reconstruct the original waveform, the middle byte is simply split in half with one sample claiming the upper nibble and the other sample claiming the lower nibble. There are numerous non-lossy compression techniques which are well known in the art and suitable for use with the present inventive method.

Referring to FIG. **7**, to save audio from an analog sensor to a hard drive of a server, a process **400** runs in communication with the periodic sampling of an audio signal. At step **402**, if the interval to be stored is complete, the file for the previous interval is closed and the file for the next interval is opened in step **404**. If a system of directories and subdirectories is employed as discussed hereinabove, the process of opening a file for the next interval would include the steps of building a path name based on the current time and date. At step **406**, a new sample of digitized audio is input from the A/D system and written to a buffer for audio processing at step **408**. At step **410**, the sample is also written to the currently opened file before the process ends at step **412**. As will be apparent to those skilled in the art, if the A/D system includes a provision for direct memory access, portions of process **400** may be performed by hardware.

Referring to FIG. **8**, to save audio information at a digital sensor, a process **500** preferably runs in communication with an A/ID interrupt routine. Thus, at step **502**, if a predetermined interval has passed, a file buffer is compressed, preferably in accordance with a non-lossy scheme, and written to a file at step **504**. An audio sample is then input from the A/D converter at step **506** and saved in a buffer for processing the audio at step **508**. The audio data is also saved to a file buffer at step **510** before process **500** ends at step **512**. It should be noted that, if the processing of audio to detect an acoustic event does not modify the data, the buffers of step **510** and **512** may be the same buffer, and a single save operation may be sufficient.

Turning to FIG. **9**, once audio information is saved in a file, preferably a system is in place to facilitate review of any portion of the audio information. As discussed above, the directory structure of the disk can be used to facilitate access based on one characteristic, such as time. Preferably the data may also be accessed through other characteristics which are stored in a data base. For example, process **600** describes a method for accessing an audio event where the type of event and the time and date of the event are stored in a data base. Beginning at step **602**, a user first selects a particular event, preferably through a user interface with access to an event data base. In step **604**, the system retrieves the data and time of the event from the data base. At step **606** the system gets the amount of time bracketing the event which the user wishes to review. At step **608**, the pathnames are built for each audio segment to be retrieved and the audio is retrieved and concatenated into a single audio stream at step **610**.

Since computer memory buffers and disk buffers are of finite size, it is necessary to store the data in a way that older data that is no longer of interest can be erased from the disk. Preferably, the data should be stored in a hierarchical file system organized by date so that obsolete files can most easily be found and erased by the recording system. Most preferably, each directory should be broken down into sub-directories by time so that the total number of files does not become too large and reduce the performance of the file system.

It should be noted that while preferred embodiments of the present invention have been described in connection with gunshot location systems, the spooling, archiving, logging of sensor metadata to a file or database, and other concepts described herein could be applied to many systems having large distributed data sets from disparate sources, such as those sensors monitoring temperature, pressure, strain, or concentration of certain chemicals. In particular it should be noted that the inventive method is particularly well suited to video data. Video transmission is even a greater consumer of network bandwidth than audio. Thus video could be archived remotely at, or near a camera, if an event is detected in the video, an index to the event may be stored and the information later transmitted for visual review of the event. In fact, in one preferred embodiment, a gunshot detection system is coupled to cameras which may be directed to pan, tilt, and zoom. When a gunshot is detected, cameras proximate the event are directed to the point indicated by the gunshot detection system. If video data is spooled to a mass storage device at or near the cameras, law enforcement personnel may use the stored index to quickly locate and retrieve the stored video from the remote location using minimal bandwidth.

As will also be apparent to those skilled in the art, the calculation of a shooter's position may be performed at one or more sensors and the index stored at any of the sensors involved in locating the gunshot event.

Thus, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned above as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, numerous changes and modifications will be apparent to those skilled in the art. Such changes and modifications are encompassed within the spirit of this invention as defined by the appended claims.

What is claimed is:

1. A method for archiving audio information in a gunshot detection system of a type having array of acoustic sensors placed over a geographic area; wherein said array of sensors detects gunshots which occur proximate to the array, the method comprising the steps of:

providing a mass storage device;

periodically sampling an audio signal from each sensor;

detecting an impulsive noise event including a start time;

storing samples of audio data in said mass storage device wherein audio signals detected by each sensor can be selected using time data, wherein the audio signals may be reproduced with the relative timing between the audio signals of each sensor preserved; and

creating a searchable database wherein audio signals containing the impulsive noise event are indexed, with each audio signal being indexed as a function of a sensor that detected the audio signal and the start time.

2. The method for archiving audio information of claim 1 further comprising:

providing a file structure on said mass storage device, said file structure having a plurality of files, each file having an absolute time associated therewith.

3. The method for archiving audio information of claim 2 the samples of audio data are stored in a file having an appropriate absolute time associated therewith.

4. The method for archiving audio information of claim 3 wherein each file of said plurality of tiles represents one second of sampled audio.

5. The method for archiving audio information of claim 4 wherein said files representing one second of sampled audio are organized into minute directories, each minute directory having sixty said files representing one second of sampled audio.

6. The method for archiving audio information of claim 1 further including the step of

when a gunshot is detected, storing an index to the location of the stored samples in said mass storage device corresponding to said gunshot.

7. The method for archiving audio information of claim 6 further including the step of reproducing the audio surrounding said gunshot by using said index to locate said stored samples corresponding to said gunshot.

8. The method for archiving audio information of claim 1, wherein the audio signals are further indexed according to metadata so as to provide a metadata index.

9. The method for archiving audio information of claim 8, wherein the metadata index parses the searchable database into subsets which comprise impulsive noise events.

10. A method for archiving audio information in a gunshot detection system of a type having an array of acoustic sensors placed over a geographic area, wherein said array of sensors detects gunshots which occur proximate the array, the method comprising the steps of:

providing a mass storage device;

obtaining, from data storage elements on remote sensors, information indicative of audio signal samples that contain impulsive noise components;

creating a searchable database wherein the information is indexed as a function of a sensor and a time associated with capture of each audio signal;

processing data in the searchable database to identify an impulsive noise component or an audio signal sample of interest; and

downloading, from a remote sensor, audio data associated with the impulsive noise component or the audio signal sample of interest.

11. The method for archiving audio information of claim 10, wherein the information in the searchable database is further indexed according to metadata so as to provide a metadata index.

12. The method for archiving audio information of claim 11, wherein the metadata index parses the information in the searchable database into subsets of information which comprise impulsive noise components.

13. The method for archiving audio information of claim 10 further comprising providing a file structure on said mass storage device, said file structure having a plurality of files, each file having an absolute time associated therewith.

14. The method for archiving audio information of claim 13 the samples of audio data are stored in a file having an appropriate absolute time associated therewith.

15. The method for archiving audio information of claim 14 wherein each file of said plurality of files represents one second of sampled audio.

16. The method for archiving audio information of claim 10 further including the step of, when a gunshot is detected, storing an index to the location of the stored samples in said mass storage device corresponding to said gunshot.

17. The method for archiving audio information of claim 16 further including the step of reproducing the audio surrounding said gunshot by using said index to locate said stored samples corresponding to said gunshot.

18. The method for archiving audio information of claim 17, wherein a permanent recording is made of said later reproduction.

19. The method for archiving audio information of claim 10 further comprising identifying a non-gunshot event storing an index to the location of the stored samples in said mass storage device corresponding to said non-gunshot event.

20. The method for archiving audio information of claim 19 further including the step of reproducing the audio surrounding said non-gunshot event by using said index to locate said stored samples corresponding to said non-gunshot event.

21. The method for archiving audio information of claim 17, wherein determination of a source location of said gunshot event is performed from said later reproduction.

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(12) United States Patent

Lapin et al.

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(45) Date of Patent: Nov. 15, 2005

(54) **GUN SHOT DIGITAL IMAGING SYSTEM**

(75) Inventors: **Brett D. Lapin**, Alexandria, VA (US); **Nicholas D. Beser**, Owings Mills, MD (US)

(73) Assignee: **The Johns Hopkins University**, Baltimore, MD (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**^{7} **G01S 3/80**
(52) **U.S. Cl.** **367/118**
(58) **Field of Search** 367/118, 121, 367/123, 124, 125, 127, 129, 96, 136

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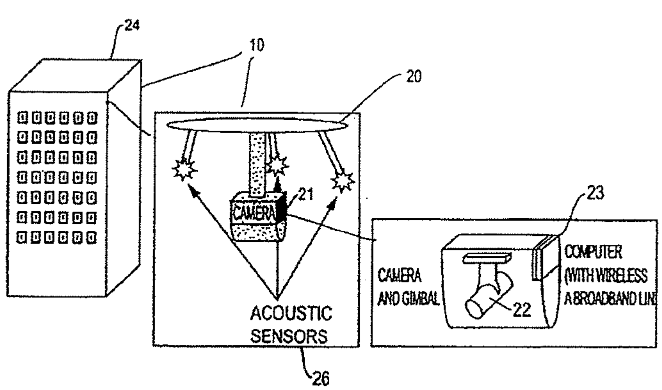
Primary Examiner—Daniel Pihulic
(74) *Attorney, Agent, or Firm*—Benjamin Y. Roca, Esq.

(57) **ABSTRACT**

Disclosed is a method for recording one or more images of a source area where an impulse sound has initiated. The recording is performed by at least one of a plurality of units that include a camera, a computing device, and a connection to a network. The method comprises the steps of detecting and calculating a range and direction of the impulse sound source; slewing the camera to align its optical axis with a direction of the impulse sound; determining whether the impulse sound was a gunshot; recording images of the source area; and alerting a plurality of neighboring units to perform the recording step.

19 Claims, 2 Drawing Sheets



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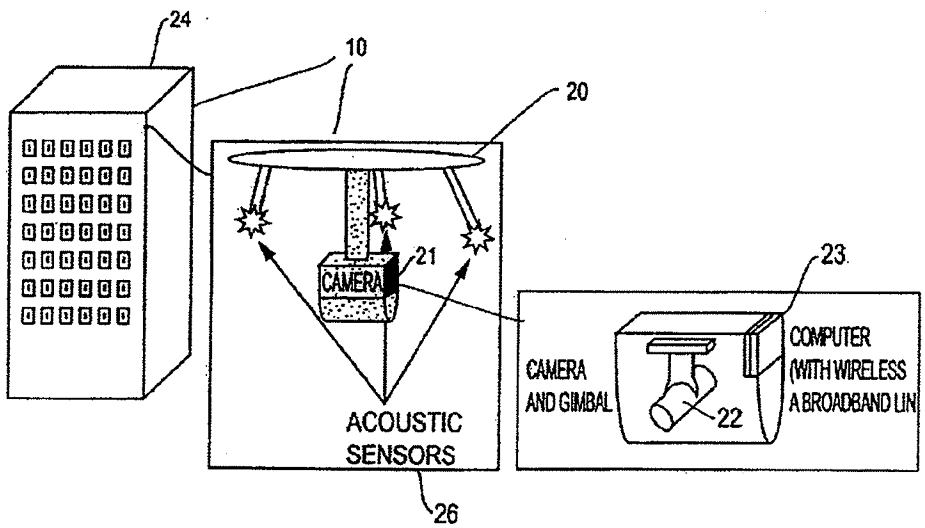
24
10
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23
CAMERA
COMPUTER
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A BROADBAND LIN
CAMERA
AND GIMBAL
22
ACOUSTIC
SENSORS
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FIG. 1

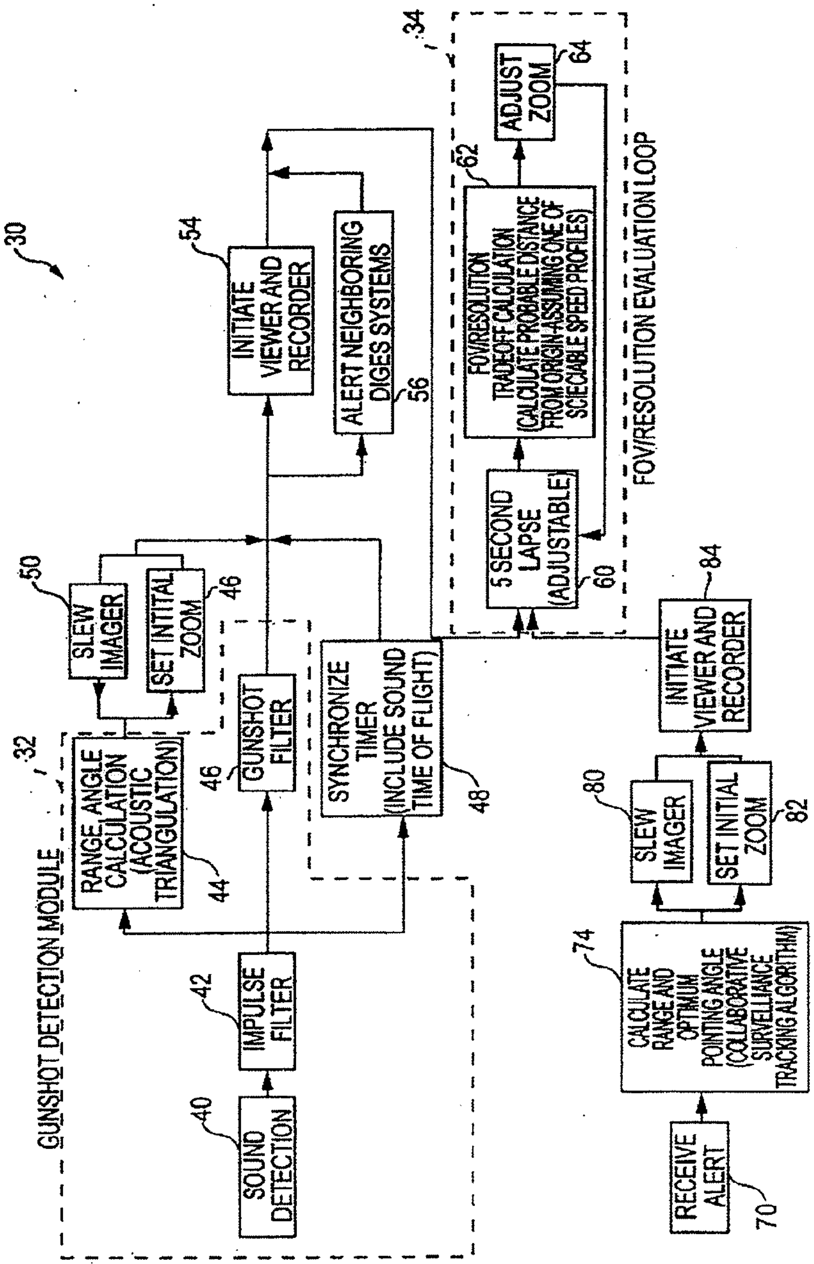

FIG. 2
BLOCK DIAGRAM FOR NORMAL OPERATIONS AND ALERT MODE

GUN SHOT DIGITAL IMAGING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/436,271 filed Dec. 24, 2002, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to gunshot detection. More particularly, the present invention is directed to using multiple installations of sound detection an recording devices for detecting firing of a gun or an explosion, identifying of a location of such firing or explosion, and recording images of an area of a source of the firing or explosion and of a possible suspect of such firing or explosion.

2. Description of the Related Art

Violence and criminal activity involving firearms is a significant problem for most metropolitan areas in the United States, and numerous suburban areas as well. Two of the problems facing law enforcement authorities when handling these types of crimes are (1) the speed at which the violence begins and ends and (2) the relative ease and speed at which the perpetrators can disappear into the urban landscape.

At no time have these problems been emphasized more than during the sniper killings of October 2002 in the greater Washington, D.C. area. With killings occurring almost at will, local and federal law enforcement agencies were being constantly stifled by the lack of reliable descriptions of exactly who and what they were looking for.

All law enforcement agencies agree that having reliable, accurate intelligence of who and what took part in a violent crime can enormously enhance their ability to apprehend the perpetrators. Similarly, counter-terrorism efforts of sovereign governments abroad and the Department of Homeland Security would be greatly helped in their fight against organized crime and terrorism if they had at their disposal a network of systems to detect, pinpoint, and record an event e.g., a shooting or an explosion, immediately upon the event occurring, as well as those involved in carrying out the crime.

Presently, technology has no capability to image the origin of a gunshot event immediately upon its detection. Existing technology is only able to report the location of such event. Certain existing infrared (IR) systems can detect a muzzle flash from a gunshot and subsequently localize the presence of the gun. However, these systems are extremely limited, because the imaging system must have the muzzle of the gun being fired in the field of view and much more often than not the muzzle is hidden.

There are also numerous systems that utilize acoustic triangulation technology to locate the origin of gunshot events, these include AAI Corporation's PDCue Counter Sniper Systems, Trilon Technology's Shot Spotter, and Tag-It. Similarly, digital imaging systems are plentiful. There is, however, no known system that integrates the two technologies, i.e., acoustic triangulation, and reporting the location of an event.

Gunshot Range and Direction Detection

Gunshot range and direction indicators have been developed for the military to help in locating snipers. Six different phenomenologies have been exploited in developing different systems to accomplish this task: (1) muzzle blast; (2) bullet shockwave; (3) muzzle flash; (4) bullet-in-flight heat signature; (5) optical laser reflection; and (6) vortex gradients in atmospheric refractive index.

However, all but one of the most promising of these phenomenologies are contingent on aspects of the military application that are different from the civilian law enforcement/Homeland Security application. In the military environment, gunshots are being aimed in the general direction of the friendly forces, and hence in the general direction of the detection system itself. The law enforcement application cannot make a determination of the direction of the criminal perpetrator's actions before the event, and hence there exists a need for a system designed for near omni-directional detection and image gathering.

In the urban setting, the range and direction of the gunshot can only be determined reliably by triangulating the acoustic sound wave produced by the firearm's muzzle blast. Current versions of these types of systems use acoustic sensors separated by sufficient distances so as to enable accurate calculations. Upon each sensor detecting the gunshot's sound wave, a computing device records the times of sound arrival and subsequently triangulates the source location and direction of the sound. Initial testing of current systems by the companies developing them, has indicated that accurate responses at the desired range, e.g., about one kilometer, are feasible, although the accuracy is heavily conditioned on sensor separation.

It would therefore be desirable to provide a system to detect a gunshot, determine the direction from which it was fired, identify the ground zero location of the gunshot event, and initiate recording of the area of the event immediately upon the event occurring.

SUMMARY OF THE INVENTION

Using acoustic triangulation technology, the present invention spatially localizes a gunshot. Such localization yields direction and range from the sensors of the source to be observed, subsequently triggering a digital imaging system to acquire the location of the gunshot in the field of view and begin recording. Zooming parameters and subsequent resolution of the imaging system is automatically set by the detected range. The most likely moving candidates or initiators of the gunshot origin will be identified, and multiple cameras of the inventive system located in the vicinity of the gunshot will be triggered to begin recording also.

Digital motion imagery, either multiple digital still images or digital video stream, will be recorded in the computing device embedded in the inventive system and locally stored. Total duration of digital motion imagery and image resolution will be determined according to system resources. Although one image may suffice in apprehending the perpetrator, a minimum duration of no less than about 30 seconds is preferred.

Units of the system of the present invention are positioned around a region. These units are able to communicate with each other to alert each to an event detected by one of the units. Subsequently, the units within a predefined distance of the initial event will respond to the alert by orienting itself in accordance with received information by using it onboard Global Positioning System (GPS), and will begin recording digital imagery. Additionally, the system of the present invention will communicate pertinent imagery data to those in control of the installation, e.g., a local law enforcement agency, a private security organization, an authorized concerned citizen's organization, etc. The system of the present invention can also be remotely accessible via secure wired or wireless network technology for imagery downloads on command.

The present invention advantageously integrates acoustic detection and digital imaging technologies yielding rapid detection, imaging, and tracking of gunshot origins. The acoustic sensing creates an omni-present detection system, triangulating the location of the gunshot without any limitations except range due to sensor sensitivity. The digital imaging system is mounted on a high-slew rate gimballed (ball jointed) system that reacts immediately and slews the imager to point in the direction of the detected acoustic input, hence the field of view of the cameras of the invention is not static but dynamic. The system of the present invention uses an acoustic triangulation algorithm for gunshot localization, and a tracking algorithm for imager field of view management.

Another feature of the present invention is a method for recording one or more images, or video, of a source area where an impulse sound has initiated. The recording is performed by at least one of a plurality of units that include a camera, a computing device, and a connection to a network. The method comprises the steps of (a) detecting and calculating a range and direction of the impulse sound source; (b) stewing the camera to align its optical axis with a direction of the impulse sound; (c) determining whether the impulse sound was a gunshot; recording images of the source area; and (d) alerting a plurality of neighboring units to perform the recording step.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, aspects, and advantages of the present invention will be better understood from the following detailed description of preferred embodiments of the invention with reference to the accompanying drawings that include the following:

FIG. 1 is a diagram a preferred embodiment of inventive components and a manner of installation of the inventive system; and,

FIG. 2 is a block diagram showing normal and alert mode operation steps of the inventive system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to a system for detecting and imaging gunshot events. The system of the present invention records still and/or motion imagery of locations of gunshot events immediately upon occurrence of the events. The system of the present invention performs as follows:

1. Upon detecting an impulse sound, the system
   a) Calculates a range and direction of the impulse sound source when it occurs within a specified distance, for example a distance of about one kilometer from the installation of the apparatus of the inventive system. (All target requirements are dependent on constraints of existing technology.)
   b) Slews a digital imaging system to align its optical axis with the direction of the impulse sound within a specified response time for detection, for example, about 500 milliseconds and preferably about 100 milliseconds. A 'slewing' motion may be described as a typically sharp pivoting or turning motion about an axis. For a camera it would be a rapid pan and/or tilt.
   c) Determines whether the impulse sound was a gunshot and upon that determination the system will
      i) begin viewing and recording the source area; and,
      ii) alert any neighboring installations of the inventive systems to the event, which will use onboard global positioning system (GPS) receivers in concert with transmitted direction data to slew their imagers to view areas neighboring the gunshot location.
2. Once correctly oriented, a time-synchronized digital motion imagery is recorded and stored within each system unit.
3. The system may be addressable by a direct connection, a telephone and wireless links to enable inter-system communication and for downloading stored motion imagery to authorized central servers, located for example in a local police precinct, or to various authorized computing devices seeking stored information, for example police cruisers.

Imagery Subsystem

Decisions that must be made during imagery subsystem design include phenomenology, e.g., infrared (IR) vs. visual; modality, e.g., high definition video vs. high resolution still sequencing; and compression, e.g., digital video, Moving Picture Experts Group (MPEG-2), or National Television System Committee (NTSC). Candidate camera and mount systems must be reviewed for both the visible and IR domains. High definition images are necessary to maximize the detail at high distances. The IR approach also supports low light level image collection conditions.

FIG. 1 illustrates an exemplary installation of one unit and details of the individual unit **10** installation of the inventive system. The controllable mount **20** may be selected from commercially available units after considering the requirements of slew accuracy, slew speed, and size and weight constraints of the mount **20**. The mount's slew accuracy will determine if the mount **20** can accurately point to a selected location after moving at high speeds. A computer-controlled mount **20** with optical positioning that will permit directed movement of the image recorder or camera **22** to a selected location within 0.1 second, as a target requirement is obtained in the present example. Initial product surveys indicate that slew rates of 50–250 degrees per second are readily available, these rates approach those of desired system flexibility and speed. Mounts **20** that are capable of 0.5 degree accuracy are also available commercially. It is to be understood that the system of the present invention envisions adapting and using a commonly available gunshot ranging and direction detector/calculator that uses acoustic triangulation.

Depending on the optics of the sensor, a 30 degree field of view (FOV) camera 22 can zoom to a 1 degree FOV. The extreme or very long range of the unit **10** of the system of the present invention will also determine the type of forensic imaging data that can be obtained. Although it is unlikely, given the state of optical technology, that a car license plate may be read by the system from a small image at maximum specified distances, the shape, color, model, and model year of the car can be easily determined, as well as cursory details of the perpetrators themselves. Also, if the event occurs at ranges closer than maximum, then discerning license plates is certainly a possibility.

The exact selection of the camera mount **20** will depend on the selection and availability of a high resolution visible and IR camera **22**. The mount features are determined by the weight of the camera/lens system **22** and an option of mounting two or more cameras **22** together. Higher weight systems may have reduced slew rates and potentially lower accuracy.

Integration

FIG. 2 illustrates a block diagram of a method **30** of the present invention in a normal mode of operations and in an alert mode. Integration of the gunshot detection, described above in the "Gunshot Range and Direction Detection" section, and the imagery subsystems described above, involve logic 32 that controls the stewing of the camera mount 20 (FIG. 1) to the required direction, and direct the zoom setting to the required ranges. As the timeline increases from the gunshot event, the zoom setting will shift outward in order to increase the FOV.

In the normal mode of operations, the logical sequence 32, detects a signal from acoustic sensors 26 (FIG. 1) mounted on the mount 20 of individual unit 10 of the invention, which signal is provided to a sound detection module 40. The detected sound signal is then provided to an impulse filter module 42, which forwards it to (1) a range and angle calculation module 44 to perform acoustic triangulation, (2) a gunshot filter module for identification of the received sound as that of a gunshot and (3) a Synchronization Timer module 48, whose calculation includes the sound's time of flight. Module 44 processes sound impulse data and forwards its range and direction calculations to the Slewing Imager 50 and Zoom Setting 52 modules which generate appropriate mount and camera settings.

Once the above-described modules have completed their tasks (the imager is at the correct pointing angle, and the timer has been synchronized), and if the sound is determined to be a gunshot, then an Initialization module 54 initiates recording (be it still or motion imagery) and the system enters the FOV/Zoom Adjustment loop 34. Also, an Alert module 56 alerts neighboring duplicate sister units 10 (FIG. 1).

When alerted the sister units 10 do not need to determine whether the sound is a gunshot, instead the Receive Alert module 70 forwards the source location information received by the Alert module 56 to the Range and Angle Calculation module 74 to perform collaborative surveillance by determining best range and angle data for each corresponding sister unit. Module 74 forwards the resultant range and angle to the Slewing Imager 80 and Zoom Setting 82 modules, which generate appropriate mount and camera settings. Once these tasks have been completed (the imager is at the correct pointing angle), then an Initialization module 84 initiates recording (be it still or motion imagery) and the system enters the FOV/Zoom Adjustment loop 34.

The logical sequence 34 constantly re-balances the FOV with the resolution needed to obtain the greatest amount of event details. That is, a larger FOV yields a lower resolution, and hence less details, but a smaller FOV doesn't cover as much area. Hence, a balance must be kept between FOV and resolution. The combined accuracy of the direction and angle of the gunshot source will dictate what the starting (highest) zoom, and starting (narrowest) FOV of the imager will be.

After receiving the initiation signal from modules 54 or 84 the delay module 60 allows a short user adjustable delay before the zoom is readjusted. After the lapse, a module 62 calculates a probable distance from origin of the gunshot perpetrator. The module 62 allows various perpetrator speed profiles for the FOV adjustment. After the calculation is made, zoom adjustment module 64 utilizes it in adjusting the camera 22 lens and passes control to the delay module 60 for the resolution adjustment recalculation process to iterate.

Communications between a command and control center on each of the installed systems are accomplished on a variety of levels.

1. An installed landline modem allows not only remote downloads of recorded imagery, but also will enable each system to communicate with the other systems on its network. This enables the alert mechanism to direct nearest neighbor installations 10 (FIG. 1) of the system of the present invention to respond to an event out of their sensing zones, and record imagery of possible escape routes of perpetrators. Onboard GPS receivers will allow each system to have a frame of reference for networked responses.

2. Wireless links will be incorporated to also allow remote downloads, but in addition will enable mobile downloads. This latter capability will allow law enforcement officers to download imagery while en route, and could also be configured to allow officers to obtain live feeds of criminal activities once authorization is granted.

3. All installations of the inventive system 10 (FIG. 1) can be connected to a network cable, such as the Ethernet cable, T1–T3 lines, fiber-optic cables, etc. installed in a building or structure 24 (FIG. 1) on which the system is installed.

Finally, the onboard central computer 23, responsible for conducting the integrated operations of the gunshot detection and imaging subsystems of the inventive system 10 (FIG. 1), is also responsible for performing all time-dependent operations. These include synchronizing elapsed time with the recorded imagery, adjusting the time-dependent zoom setting, and also determining the size of the area that the imager should be interested in, which expands as elapsed time increases.

While the invention has been shown and described with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A method of recording one or more images of a source area of an impulse sound by at least one of a plurality of units including a camera, a computing device, and a connection to a network, said method comprising the steps of:

detecting the impulse sound;

calculating a range and direction of the impulse sound source;

slewing the camera to align its optical axis with a direction of the impulse sound

determining whether the impulse sound was a gunshot;

recording images of the source area; and,

alerting a plurality of neighboring units to perform the recording step.

2. The method of claim 1, wherein the impulse sound occurs within a distance of a desired requirement from an installation of the units.

3. The method of claim 2, wherein said desired requirement is a distance not to exceed about one kilometer.

4. The method of claim 1, wherein the camera is a selected from one of a still and video digital imaging system and images are stored on storage media of a computing device.

5. The method of claim 4, wherein the step of alerting further comprises aligning the camera of the plurality of alerted neighboring units.

6. The method of claim 1, wherein the slewing step is performed within a response time of a desired requirement of a sound detection.

7. The method of claim 6, wherein the desired requirement is a response time not to exceed about 500 milliseconds.

8. The method of claim 1, further comprising receiving direction data and using onboard global positioning system (GPS) receivers to select those cameras of neighboring units to be slewed and record images of the source area.

9. The method of claim 1, wherein said step of recording further comprises storing a time-synchronized digital motion imagery within each unit.

10. The method of claim 9, wherein the plurality of units are connected via a hardwired network.

11. The method of claim 9, wherein each unit is connected to the network via wireless means.

12. The method of claim 10, further comprising downloading stored motion imagery to an authorized reporting system in reply to a request.

13. A system for recording one or more images of a source area emitting an impulse sound comprising:

a) one or more detection observation units including a plurality of acoustic sensors, at least one camera, a microphone, a computing device having storage media and a connection to a network;

b) a gunshot detection module for receiving acoustic sensors' data and calculating a range and an angle at which the camera of the unit is to record images;

c) a slew and zoom setting module for accepting the range and angle information and providing instructions for slewing and zooming the camera;

d) an initiating and alerting module for initiating recording of images by the current detection observation unit and for alerting and passing coordinates to other detection observation units located in a vicinity of source area to initiate recording of images; and,

e) a field of view (FOV) resolution evaluation module for continuously readjusting the focus of the camera.

14. The system of claim 13, wherein the camera is selected from one of still or video imaging devices.

15. The system of claim 13, further comprising a global positioning system (GPS) for allowing neighboring units to direct their cameras to the source area of the impulse sound.

16. The system of claim 13, further comprising a receive alert module for receiving an alert signal from an alerting module of another detection observation unit and performing steps (b)-(e).

17. The system of claim 13, further comprising a synchronization module for coordinating image recordation by the plurality of units.

18. A computer program device readable by a machine, tangibly embodying a program of instructions executable by the machine to perform method steps for a method of recording one or more images of a source area of an impulse sound by at least one of a plurality of units including a camera (still or video), a computing device, and a connection to a network, said method comprising the steps of:

detecting the impulse sound;

calculating a range and direction of the impulse sound source;

stewing the camera to align its optical axis with a direction of the impulse sound

determining whether the impulse sound was a gunshot;

recording images of the source area; and

alerting a plurality of neighboring units to perform the recording step.

19. The device of claim 18, wherein the camera is selected from one of still or video imaging devices.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,965,541 B2
DATED : November 15, 2005
INVENTOR(S) : Brett D. Lapin and Nicholas D. Beser

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 8,
Line 11, delete "stewing" and insert -- slewing --.

Signed and Sealed this

Eleventh Day of April, 2006

JON W. DUDAS
Director of the United States Patent and Trademark Office

AFFIDAVIT OF SERVICE BY ELECTRONIC MEANS

STATE OF NEW YORK)
) ss.:
COUNTY OF NEW YORK)

The undersigned, being duly sworn, deposes and says:

1. I am not a party to this action, am over 18 years of age and reside at Brooklyn, NY.

2. That on March 19, 2010, as per Judge Dollinger's March 19, 2010 Order (attached) granting leave to file a Second Amended Complaint, the annexed Second Amended Complaint was deemed served upon:

HAYES SOLOWAYP.C.
Robert A. Matson
Stephen B. Mosier
3450 E. Sunrise Drive, Suite 140
Tucson, Arizona 85718
Attorneys for Defendant

Leo Kailas, Esq.
Reitler Kailas & Rosenblatt
885 3rd Avenue, 20th Floor
New York, NY 10022
Attorneys for Defendant

as of that date.

David Gerard

Sworn to before me this
26th day of April, 2010.

Notary Public

MARILYN JUDA
Notary Public, State of New York
No. 01JU4759632
Qualified in Queens County
Commission Expires June 30, 20 10

3/19/10

SATTERLEE, STEPHENS, BURKE & BURKE LLP
Mario Aieta
Robert Carrillo
230 Park Avenue, 11th Floor
New York, NY 10169
(212) 818-9200
Attorneys for ShotSpotter, Inc. and
The Johns Hopkins University

COPY
MAR - 9 2010

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

SHOTSPOTTER, INC., and THE JOHNS HOPKINS UNIVERSITY, Plaintiffs, v. SAFETY DYNAMICS, INC., Defendant.	09 cv 7828 (GBD)(MHD) PLAINTIFFS' NOTICE OF MOTION FOR LEAVE TO FILE THE SECOND AMENDED COMPLAINT

PLEASE TAKE NOTICE that, upon the Declaration of Robert C. Carrillo, dated March 4, 2010, and the exhibit attached thereto, the accompanying Memorandum of Law; and on all prior papers and pleadings filed herein, Plaintiffs ShotSpotter, Inc. and The Johns Hopkins University, by and through their undersigned attorneys, Satterlee Stephens Burke & Burke LLP, hereby move this Court before the Honorable Magistrate Judge Michael H. Dolinger, United States Courthouse, 500 Pearl Street, New York, New York 10007, for leave, pursuant to Fed. R. Civ. P. 15(a), to file a Second Amended Complaint, and for such other and further relief as the Court may deem just and proper.

Plaintiffs do not request oral argument at this time.

ENDORSED ORDER

Plaintiffs's motion for leave to serve and file a Second Amended Complaint in the form submitted to the court is granted. The new complaint is deemed served. The current pretrial schedule remains in effect.

[signature] 3/19/10

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Dated: New York, New York
March 4, 2010

SATTERLEE STEPHENS BURKE & BURKE LLP

By: /S/Robert Carrillo
Mario Aieta
Robert C. Carrillo
230 Park Avenue
New York, New York 10169
(212) 818-9200
Attorneys for ShotSpotter, Inc. and The Johns Hopkins University

To: Stephen Mosier, Esq.
Nick Soloway, Esq.
Hayes Soloway
3450 East Sunrise Drive
Suite 140
Tucson, AZ 85718

Leo Kailas, Esq.
Reitler Kailas & Rosenblatt
885 3rd Avenue, 20th Floor
New York, NY 10022