

SONAR VISION METHOD AND APPARATUS

TECHNICAL FIELD

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[001] This invention concerns the use of sound waves, including ultrasound waves, in imaging an area or surroundings and the objects therein based on echo or reflected waves from the objects or surroundings. An apparatus using such methods is also disclosed.

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BACKGROUND ART

[002] One of the most useful general purpose instrument for military and law enforcement use is the night vision devices which allows human vision under conditions which does not normally allow the human eye to see, for example under very little or no ambient light. Thermal imaging devices may operate in complete darkness but requires thermal radiation to form images from heat radiation signatures, i.e. could only see for example thermally exposed bodies of humans and animals.

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[003] Conventional night vision devices rely on ambient light such as from the moon or stars and by detecting that small amount of light by photoelectric means and amplify the electron effect on a phosphor screen. Illumination may

also be provided actively such as radiating light beyond human visible spectrum such as infrared and use the same photoelectric amplification to provide vision.

5 [004] Night operations in urban warfare or under thick forest canopy night operations which occur in built-up areas, ambient light may not be available sufficiently or may even be in complete darkness rendering such night vision devices useless. Actively providing illumination such as infrared to enable convention night vision devices to work would give away one's position when
10 detected by opposing forces' night vision devices. As with all optical or light means, object ranging (estimating distance of an object from an observer) based on direct reflection is difficult due to the high speed of light.

[005] Hence, it is now proposed that sound waves be used for night vision
15 purposes in such close range atmospheric environment similar to echolocation practiced by animals such as bats, or sonar (sound naavigation and ranging) in underwater applications. As our invention also includes object ranging, in this specification, we are using the terms "**sound**", "**sonar**", "**echolocation**" or "**acoustic location**" and the like interchangeably in a loose manner to mean
20 the use of sound waves to provide a visual image of one's surroundings or field covered by the sound waves, including specific objects in the field.

[006] 3-dimensional imagery with sonar has been practiced for more than 20 years. Basically, sonar signals are emitted, reflected and/or radiated by

objects are sensed, focused and amplified. They are then recognized, interpreted & processed through algorithms and computing means into a user perceivable output or display.

5 [007] For example, in U.S. Patent No. **4,667,199** (Roberts), radar reflected from objects of non-uniform reflectivity such as clouds and other atmospheric bodies. Using object modeling algorithm, imaginary radial scan data are modulated to provide an image of the object for weather and storm imaging purposes. Although it claims to cover sonar, no description on sound wave
10 reflection or configuration is made and this prior art basically concerns the algorithm for providing a 3-dimensional imagery.

[008] In U.S. Patent No. **4,805,015** (Copeland), 3-dimensional imaging is achieved through the principle of differential sensing, i.e. widely spaced
15 sensors placed along the wing span of an aircraft. This configuration is thought to work with a wide range of medium - video, radar, sonar, infrared or laser – to produce stereo display despite the physical disparity between the waves of different media.

20 [009] U.S. Patent No. **5,077,704** (Tannas, Jr.) concerns solely sonic waves for 3-dimensional image display. This prior art is also configured to sense reflected sonic waves at spaced out or left and right displaced receivers. The wave differential in terms of time, space or both are modulated and processed

to produce different left and right images presented to the viewer to be fused by the viewer's own brain into a 3-dimensional image.

[010] These prior art teachings thus rely on a single point (at each of left or
5 right sensing) or a base line (1-dimension sensing along air plane wing span)
for sensing purposes and their respective applications are intended for
detecting well-defined and well-known objects far and wide apart such as other
flying aircrafts. There would be severe limitations on adapting these prior art
configurations for close-range imaging of many objects close to one another in
10 a built environment including indoors in total darkness as we have set out to
achieve.

STATEMENT OF DISCLOSURE

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[011] Our present invention endeavours to provide an alternative night
vision device which avoids the inherent shortcomings of the prior art. Our
invention also endeavours to enable its methods and/or apparatus to be
combined with existing night vision equipment to extend their capabilities, as
20 well as to present sonar devices that are used mainly for underwater
applications to extend their use on land. In effect, our invention will better
equip tactical and reconnaissance personnel in their field operations.

[012] In a first aspect of our invention, it is provided a method for sonar imaging and ranging of objects comprising: (i) generating sonar waves at objects to be imaged and ranged; (ii) capturing sonar waves echoed or reflected from said objects; (iii) transducing the captured sonar waves into electronic signals; (iv) conditioning the electronic signals, including any one or combination of reducing distortion, biasing, noise filtering, amplifying and digitizing; (v) processing the conditioned electronic signals into display signals, wherein at least one of matched filtering and beamforming processes are performed, and (vi) displaying said display signals as visual images of said objects.

[013] Preferably, the sonar waves are transmitted as ultrasonic waves with suitable amplification whereby the sonar waves are amplified or modulated based on feedback/input from the (v) display signal processing step.

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[014] In a specific embodiment, the steps of capturing and transducing the sonar waves are achieved by a plurality of electro-acoustic means which may be provided in an array corresponding to imaging elements of displaying. Preferably, beamforming technique is used to improve the signal to noise ratio. Preferably still, matched filtering is applied on a beamformed signal to obtain the range information of an object, including on each of the direction of the echoed signals.

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[015] In another specific embodiment, the processing step may include processing the signals according to any one or combination of the direction, range and magnitude of said echoed sonar wave and displaying said processed signals as 3-dimensional image information.

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[016] As a preferred embodiment, the frequencies of the sonar waves transmitted and echoed from at least one of the objects are processed according to Doppler effect to estimate the relative velocity of said object. Alternatively, a plurality of the aforesaid electronic processes may be integrally
10 incorporated in an integrated circuit.

[017] In a second aspect of our invention, an apparatus is disclosed for sonar imaging and ranging of objects comprising (i) at least one sonar wave transmitter capable of broadcasting said sonar waves at objects to be imaged
15 and ranged; (ii) a plurality of electro-acoustic transducers capable of transducing sonar waves echoed or reflected from said objects into electronic signals; (iii) at least one of electronic circuits for conditioning the electronic signals, including any one or combination of electronic means for reducing distortion, biasing, noise filtering, amplifying and digitizing said electronic
20 signals; (iv) at least one processor for processing said electronic signals into display signals wherein at least one of matched filtering and/or beamforming processes are performed; and (v) a display capable of converting said display signals into visual images of said objects.

[018] The sonar wave transmitter is preferably provided with a power amplifier which may modulate the transmission of the sonar wave transmitter based on feedback/input from the processor.

5 [019] As a specific embodiment, the electro-acoustic transducers may be provided as microphones arranged in an array corresponding to picture elements' layout of the display. Preferably, 400 microphones are arranged in 20×20 rectangular array at 2.4 mm apart from one another.

10 [020] As another specific embodiment, the processor may further include logic and/or algorithm for processing the signals according to any one or combination of the direction, range and magnitude of said echoed sonar wave and displaying the processed signals as 3-dimensional image information via a suitable imaging or display device.

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[021] As an alternative embodiment, a Doppler frequency detector is included wherein the differential frequencies of the sonar waves transmitted and echoed from at least one of the objects are processed to estimate the relative velocity of the object. A plurality of the electronic circuits for
20 modulating, conditioning and/or processing the signals may also be alternatively provided integrally in an integrated circuit.

LIST OF ACCOMPANYING DRAWINGS

[022] To facilitate better understanding of our invention we shall refer to the following drawings by way of specific or preferred embodiments which are
5 exemplary and not limiting, in which:

[023] FIGURE 1 discloses an algorithm for the method according to our invention to produce 3-dimensional imaging from reflected ultrasound waves;
and
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[024] FIGURE 2 discloses a schematic diagram of the main components employed in the apparatus according to the invention.

15 DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[025] The general embodiment of a sonar imaging and ranging apparatus implementing a method according to our invention comprises of one or more sonar wave transmitter that is capable of broadcasting sonar waves at a field or
20 area wherein are present objects to be imaged and ranged before being displayed to the user. Preferably, the sonar wave transmitted is ultrasound waves.

[026] With reference to FIGURE 1 and FIGURE 2 collectively, the sonar wave transmitter (10) will emit sound signals (12) in short bursts. On each burst a “chirp” wave from 30 kHz – 40 kHz is transmitted. This signal wave will provide for a range resolution of about 17 cm. The range of the transmission
5 may be designed to be 4 m. The selection of range of frequency transmitted will affect the type of transmitter (10) and receiver (20) selected. It will also influence the performance of range resolution and spacing between the receivers (20) which indirectly affects the azimuth resolutions.

10 [027] A plurality of electro-acoustic transducers (20) which are capable of detecting sonar or ultrasound waves (12) echoed from or reflected (13) off the objects (14) and converting the waves (12) into electronic signals are then deployed. The electro-acoustic transducers (20) may be provided as microphones (20) arranged in an array (22) corresponding to picture elements’
15 (30) layout of the display (32). In a preferred configuration, 400 microphones may be arranged in 20×20 rectangular array at 2.4 mm apart from one another. Several echoes or reflections may be collected or received for processing.

20 [028] The electronic signals may then be conditioned by any one or combination of circuits (24) designed to reduce distortion, biasing, noise filtering and amplifying before digitizing the signals by a digitizer (26).

[029] One or more processors (40) may be used to process the conditioned and digitized electronic signals using one or more of the processing algorithm or techniques which may include at least matched filtering (402) and/or beamforming (401) techniques or algorithm wherein the signals are processed
5 according to its direction, range and magnitude of the echoed sonar or ultrasound wave.

[030] Beamforming is a known signal processing technique using with arrays of transmitters or receivers (20) (such as microphones in our case) so
10 that, with the differential between each of the receivers (20), the direction of and sensitivity to the signals may be controlled. Upon receiving a signal wave, the beamforming algorithm may increase the sensitivity of those receivers (20) in the direction of the signals and decrease the sensitivity of the other receivers or those that are in direction of unwanted signals, interference or noise.

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[031] In other words, beamforming technique 'steer' the directivity and sensitivity of the receiver electronically. It enhances the signal from a particular location (where we want to see/hear) and suppressing signals from others (reducing the influence of noise from other directions). Say, there is a hard
20 object in the field or space to be "visualized" that is of our interest, there will be a strong signal detected from that point. If there is nothing at that point/position, there will be no signal. In order to obtain the outline and texture of the object, you have to perform beamforming over the field or space of interest.

[032] In employing beamforming technique in our present invention to find direction, the aforesaid echo or reflected signals (13) as transduced from the microphones (20) may be processed by the beamforming algorithm whereby
5 the signals received in the direction of the echo or reflected ultrasound signal are enhanced while echo from other directions are reduced. A hard and rough object will give a stronger echo and based on the intensity of the signal, the texture and shape of object can be visualized or shown in a display.

10 [033] Matched filtering is a known technique in electronics signal processing, particularly in telecommunication and radar, whereby a matched filter is obtained by correlating a known signal, which is taken as a template, with an unknown signal to detect the presence of the template in the unknown signal. The matched filter is the optimized for maximizing the signal to noise
15 ratio (SNR) in the presence of noise. 2-dimensional matched filters are commonly used in image processing. In our invention, matched filtering algorithm is used for ranging or estimating the distance of an object.

[034] Matched filtering (402) is performed on each of the direction of the
20 beamformed signals to obtain the range information. Using direction and range information to give 3-dimensional image of the surrounds thus help to discriminate the object's form and size. The processed information on each direction is then plotted to give data having 3-dimensional image information

and magnitude which may then be fed into a display (32) which is capable of converting the display signals into visual images of the object (14).

[035] The ultrasound wave transmitter (10) may preferably be provided with
5 a power amplifier (42) so that the sound wave may be first modulated or amplified before being transmitted at a suitable amplitude or frequency. The pre-transmission modulation may be automatically made based on feedback or input from the processor (40) upon assessing the strength and clarity of the display signals resulting from the previous echoed ultrasound waves. For
10 instance, if the resultant processed signals are weak, the processor may automatically send a feedback signal to the transmitter to increase the amplitude of the ultrasound wave generated.

[036] Another preferred embodiment of our invention is to include a Doppler
15 frequency detector (34) wherein the differential frequencies of the sonar waves transmitted and echoed from at least one of the objects (14) are processed to estimate the relative velocity of the object or target. The frequency domain information of the echoes or reflected waves may thus be processed to determine the relative velocity between the observer or transmitter and object.
20 Given the Doppler frequency detected, we can calculate the velocity of the object moving relative to (i.e. away or towards) the observer.

[037] It will be obvious for a person skilled in the art that some or all of the above electronic circuits for modulating, conditioning and/or processing the

signals may be integrally provided in the form of an integrated circuit (IC) so that they all appear in a single component or IC. With the use of devices of integrated functions, the apparatus may be made into a compact or hand-held device such as a goggle and binoculars or monogle and monocular.

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[038] Other applications for which a skilled person, upon being taught of our invention, may adapt or modify therefrom include applying it in situation awareness purposes such as installation perimeter observation or monitoring against intrusion. These variations and other modifications are to be
10 considered as different embodiments of our invention and are to be considered as falling within the scope and letter of the following claims.

CLAIMS

1. A method for sonar imaging and ranging of objects comprising:
 - 5 (i) generating sonar waves at objects to be imaged and ranged;
 - (ii) capturing sonar waves echoed or reflected from said objects;
 - (iii) transducing the captured sonar waves into electronic signals;
 - (iv) conditioning the electronic signals, including any one or combination of reducing distortion, biasing, noise filtering, amplifying and digitizing;
 - 10 (v) processing the conditioned electronic signals into display signals, wherein at least one of matched filtering and beamforming processes are performed, and
 - (vi) displaying said display signals as visual images of said objects.
- 15 2. A method for sonar imaging and ranging of objects according to Claim 1 wherein the sonar waves are transmitted as ultrasonic waves with suitable amplification.
- 20 3. A method for sonar imaging and ranging of objects according to Claim 2 wherein the sonar waves are amplified or modulated based on feedback/input from the display signal processing step.

4. A method for sonar imaging and ranging of objects according to Claim 1 wherein at least one of the steps of capturing and transducing the sonar waves is achieved by a plurality of electro-acoustic means.

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5. A method for sonar imaging and ranging of objects according to Claim 4 wherein the electro-acoustic means are provided in an array corresponding to imaging elements of displaying.

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6. A method for sonar imaging and ranging of objects according to Claim 1 wherein beamforming technique is used to improve the signal to noise ratio.

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7. A method for sonar imaging and ranging of objects according to Claim 6 wherein matched filtering is applied on a beamformed signal to obtain the range information of an object.

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8. A method for sonar imaging and ranging of objects according to Claim 6 wherein matched filtering is performed on each of the direction of the echoed signals.

9. A method for sonar imaging and ranging of objects wherein the processing step includes processing the signals according to any one or combination of the direction, range and magnitude of said echoed sonar wave and displaying said processed signals as 3-dimensional image information.

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10. A method for sonar imaging and ranging of objects according to Claim 1 wherein the frequencies of the sonar waves transmitted and echoed from at least one of the objects are processed according to Doppler effect to estimate the relative velocity of said object.

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11. A method for sonar imaging and ranging of objects according to any one of Claims 1 – 10 wherein a plurality of the electronic processes are integrally incorporated in an integrated circuit.

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12. A method for sonar imaging and ranging of objects according to Claim 1 whereby

- successive ultrasonic wave bursts are transmitted at the objects and surroundings to be imaged and ranged;
- 20 - successive bursts of wave signals are reflected or echoed off the objects and surroundings signals are received and transduced in a 2-dimensional array to correspond with arrangement of display imaging elements;
- beamforming algorithm is performed on all directions of the echoed signals received by the 2-dimensional array;

- signal processing is performed to enhance the reflected or echoed signals of each of the directions;
- match filtering is performed on each of the directions;
- matched filter is applied on the beamformed signals to obtain the
5 range information;
- the range information is plot processed on each direction;
wherein the direction information and range information provide a 3-
dimensional image of the object; and wherein the Doppler effect frequencies of
the sonar waves transmitted and echoed from at least one of the objects are
10 processed to estimate the relative velocity of said object.

13. An apparatus for sonar imaging and ranging of objects comprising:
- (i) at least one sonar wave transmitter capable of broadcasting said
15 sonar waves at objects to be imaged and ranged;
 - (ii) a plurality of electro-acoustic transducers capable of transducing
sonar waves echoed or reflected from said objects into electronic
signals;
 - (iii) at least one of electronic circuits for conditioning the electronic
20 signals, including any one or combination of electronic means for
reducing distortion, biasing, noise filtering, amplifying and digitizing
said electronic signals;

- (iv) at least one processor for processing said electronic signals into display signals wherein at least one of matched filtering and/or beamforming processes are performed; and
- (v) a display capable of converting said display signals into visual images of said objects.

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14. An apparatus for sonar imaging and ranging according to Claim 13 wherein the sonar wave transmitter is provided with a power amplifier.

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15. An apparatus for sonar imaging and ranging according to Claim 14 wherein the power amplifier modulates the transmission of the sonar wave transmitter based on feedback/input from the processor.

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16. An apparatus for sonar imaging and ranging according to Claim 13 wherein the electro-acoustic transducers are microphones arranged in an array corresponding to picture elements' layout of the display.

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17. An apparatus for sonar imaging and ranging according to Claim 16 wherein 400 microphones arranged in 20×20 rectangular array at 2.4 mm apart from one another.

18. An apparatus for sonar imaging and ranging according to Claim 13 wherein the processor further includes logic and/or algorithm for processing the signals according to any one or combination of the direction, range and
5 magnitude of said echoed sonar wave and displaying said processed signals as 3-dimensional image information via a suitable imaging or display device.

19. An apparatus for sonar imaging and ranging according to Claim 12
10 further including a Doppler frequency detector wherein the differential frequencies of the sonar waves transmitted and echoed from at least one of the objects are processed to estimate the relative velocity of said object.

15 20. An apparatus for sonar imaging and ranging according to any one of Claims 13 – 19 wherein a plurality of the electronic circuits for modulating, conditioning and/or processing the signals are integrally provided in an integrated circuit.

21. An apparatus for sonar imaging and ranging according to Claim 13 comprising

- at least an ultrasonic wave transmitter capable of transmitting successive bursts of ultrasonic waves at objects and surroundings to be
5 imaged and ranged;
 - a plurality of microphones arrayed in a 2-dimensional 20×20 rectangular array at 2.4 mm apart from one another predisposed to receiving and transducing said ultrasonic waves reflected from said objects and surroundings;
 - 10 - a processor capable of performing
 - beamforming algorithm on all directions of the echoed signals received by the 2-dimensional array;
 - enhancement of the signal to enhance the reflected or echoed signals of each of the directions;
 - 15 - match filtering is performed on each of the directions;
 - matched filter is applied on the beamformed signals to obtain the range information;
 - the range information is plot processed on each direction;
- wherein the direction information and range information provide a 3-
20 dimensional image of the object; and wherein the Doppler effect frequencies of the sonar waves transmitted and echoed from at least one of the objects are processed to estimate the relative velocity of said object.