

## ECHOLOCATION 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 in close proximity on a land terrain. 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 navigation 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 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 a built environment including indoors in total darkness as we have set out to achieve.

#### STATEMENT OF DISCLOSURE

[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 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 of echolocation imaging and ranging of objects on land comprising: (i) generating

sound waves at objects in close proximity to be imaged and ranged; (ii) capturing sound waves echoed or reflected from said objects; (iii) transducing the captured sound 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.

10 [013] Preferably, the sonar waves are transmitted as ultrasonic waves are amplified or modulated based on feedback/input from the (v) display signal processing step.

[014] In a specific embodiment, the steps of capturing and transducing the sound 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 beamformed signals.

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[015] In a second aspect of our invention, an apparatus is disclosed for echolocation imaging and ranging of objects on land comprising (i) at least one sound wave transmitter capable of broadcasting said sound waves at objects in

close proximity 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 signals, including any one or combination of  
5 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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[016] The sonar wave transmitter is preferably provided with a power amplifier which may modulate the transmission of the sound wave transmitter based on feedback/input from the processor.

15 [017] 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.

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#### LIST OF ACCOMPANYING DRAWINGS

[018] To facilitate better understanding of our invention we shall refer to the following drawings by way of specific or preferred embodiments which are

exemplary and not limiting, in which:

[019] FIGURE 1 discloses an algorithm for the method according to our invention to produce 3-dimensional imaging from reflected ultrasound waves;  
5 and

[020] FIGURE 2 discloses a schematic diagram of the main components employed in the apparatus according to the invention.

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#### DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

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

20 [022] With reference to FIGURE 1 and FIGURE 2 collectively, the sound 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 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 affect the azimuth resolutions.

5 [023] 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'  
10 (30) layout of the display (32). In a preferred configuration, 400 microphones may be arranged in  $20 \times 20$  rectangular array at 2.4 mm apart from one another. Several echoes or reflections may be collected or received for processing.

15 [024] 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).

[025] One or more processors (40) may be used to process the conditioned  
20 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 according to its direction, range and magnitude of the echoed sound or ultrasound wave.

[026] Beamforming is a known signal processing technique using with arrays of transmitters or receivers (20) (such as microphones in our case) so 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.

[027] 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 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.

[028] 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 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.

[029] Matched filtering is a known technique in electronics signal  
5 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 ratio (SNR) in the presence of noise. 2-dimensional matched filters are  
10 commonly used in image processing. In our invention, matched filtering algorithm is used for ranging or estimating the distance of an object.

[030] Matched filtering (402) is performed on each of the direction of the beamformed signals to obtain the range information. Using direction and range  
15 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).

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[031] The ultrasound wave transmitter (10) may preferably be provided with 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 instance, if the resultant processed signals are weak, the processor may automatically send a feedback signal to the transmitter to increase the  
5 amplitude of the ultrasound wave generated.

[032] Another preferred embodiment of our invention is to include a Doppler frequency detector (34) wherein the differential frequencies of the sound waves transmitted and echoed from at least one of the objects (14) are processed to  
10 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. Given the Doppler frequency detected, we can calculate the velocity of the object moving relative to (i.e. away or towards) the observer.

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[033] 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  
20 integrated functions, the apparatus may be made into a compact or hand-held device such as a goggle and binoculars or monogle and monocular.

[034] 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 considered as different embodiments of our invention and are to be considered as falling within the scope and letter of the following claims.

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CLAIMS

1. A method of echolocation imaging and ranging of objects for use in a night vision device on land comprising:

- 5 (i) generating sound waves at objects in close proximity to be imaged and ranged;
- (ii) capturing sound waves echoed or reflected from said objects;
- (iii) transducing the captured sound waves into electronic signals;
- (iv) conditioning the electronic signals, including any one or combination  
10 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.

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2. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 1 wherein the sound waves are amplified or modulated based on feedback/input from the display signal processing step.

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3. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 1 wherein at least one of the steps of capturing and transducing the sound waves is achieved by a plurality of electro-acoustic means.

4. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 3 wherein the electro-acoustic means are provided in an array corresponding to imaging elements of displaying.

5. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 1 wherein beamforming technique is used to improve the signal to noise ratio.

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6. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 5 wherein matched filtering is applied on a beamformed signal to obtain the range information of an object.

15 7. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 6 wherein matched filtering is performed on each of the direction of the beamformed signals.

8. A method of echolocation imaging and ranging of objects for use in a night vision device on land according to Claim 1 whereby

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- successive ultrasonic wave bursts are transmitted at the objects in close proximity and surroundings to be imaged and ranged;
- 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 range information.

10 9. A night vision device for echolocation imaging and ranging of objects on land comprising:

- (i) at least one sound wave transmitter capable of broadcasting said sound waves at objects in close proximity to be imaged and ranged;

- (ii) a plurality of electro-acoustic transducers capable of transducing sound 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 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.

10. The night vision device for echolocation imaging and ranging on land according to Claim 9 wherein the power amplifier modulates the transmission  
5 of the sound wave transmitter based on feedback/input from the processor.

11. The night vision device for echolocation imaging and ranging on land according to Claim 9 wherein the electro-acoustic transducers are microphones arranged in an array corresponding to picture elements' layout of  
10 the display.

12. The night vision device for echolocation imaging and ranging on land according to Claim 11 wherein 400 microphones arranged in  $20 \times 20$  rectangular array at 2.4 mm apart from one another.

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13. The night vision device for echolocation imaging and ranging on land according to Claim 9 comprising  
- at least an ultrasonic wave transmitter capable of transmitting successive bursts of ultrasonic waves at objects in close proximity and  
20 surroundings to be imaged and ranged;

- a plurality of microphones arrayed in a 2-dimensional  $20 \times 20$  rectangular array at 2.4 mm apart from one another predisposed to receiving and transducing said ultrasonic waves reflected from said objects and surroundings;

- 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
- 5 echoed signals of each of the directions;
- match filtering is performed on each of the directions; and
- matched filter is applied on the beamformed signals to obtain the range information.