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Sullivan et al.

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(54) **METHODOLOGY FOR BORE SIGHT ALIGNMENT AND CORRECTING BALLISTIC AIMING POINTS USING AN OPTICAL (STROBE) TRACER**

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F41G 3/00 (2006.01)

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(58) **Field of Classification Search** 89/41.06, 89/41.17, 41.19, 200, 203, 127, 28.2, 41.01; 356/4.01, 141.01
See application file for complete search history.

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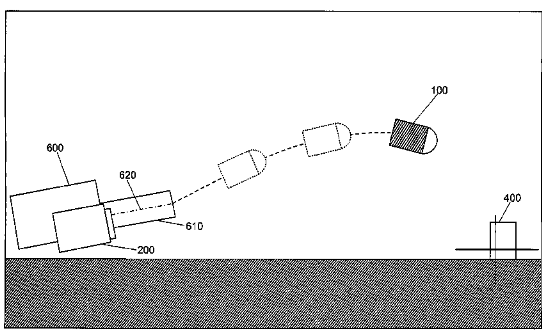
(57) **ABSTRACT**

A method and system for improving precision and accuracy of weaponry according to which angular position information of the fire control device and optical location information of the optical signals emitted during the flight of a projectile are processed in a computer using software to calculate and provide a precise aim point for firing one or more subsequent projectiles.

12 Claims, 12 Drawing Sheets



Time	Item
T0-o	Fire Control Displays Solution based on solution derived from algorithm (based on previous video measurement)
	Information recorded/measured for processing by computer algorithms.
T0-n	Measurement of (a) radial Azimuth/Elevation Barrel centerline and (b) elevation of barrel/fire control elevation)if not aligned)
T0-n	Firing Pin Trigger pull (or hammer fail sensor)
T0	Set Back/Cartridge Launch
Tz1	Measurement of projectile at Position A
Tz2	Measurement of projectile at Position B
T1	Video Image(x1, y1) of strobe 1 and video position (xx1,yy1)
T2	Video Image(x2, y2) of strobe 2 and video position (xx1,yy1)
T3	Video Image(x3, y3) of strobe 3 and video position (xx1,yy1)
Tx	Video Image(x4, y4) of strobe x and video position (xx1,yy1)
Txn	Video Image(x5, y5) of strobe xn (last strobe prior to impact) and video position (xx1,yy1)

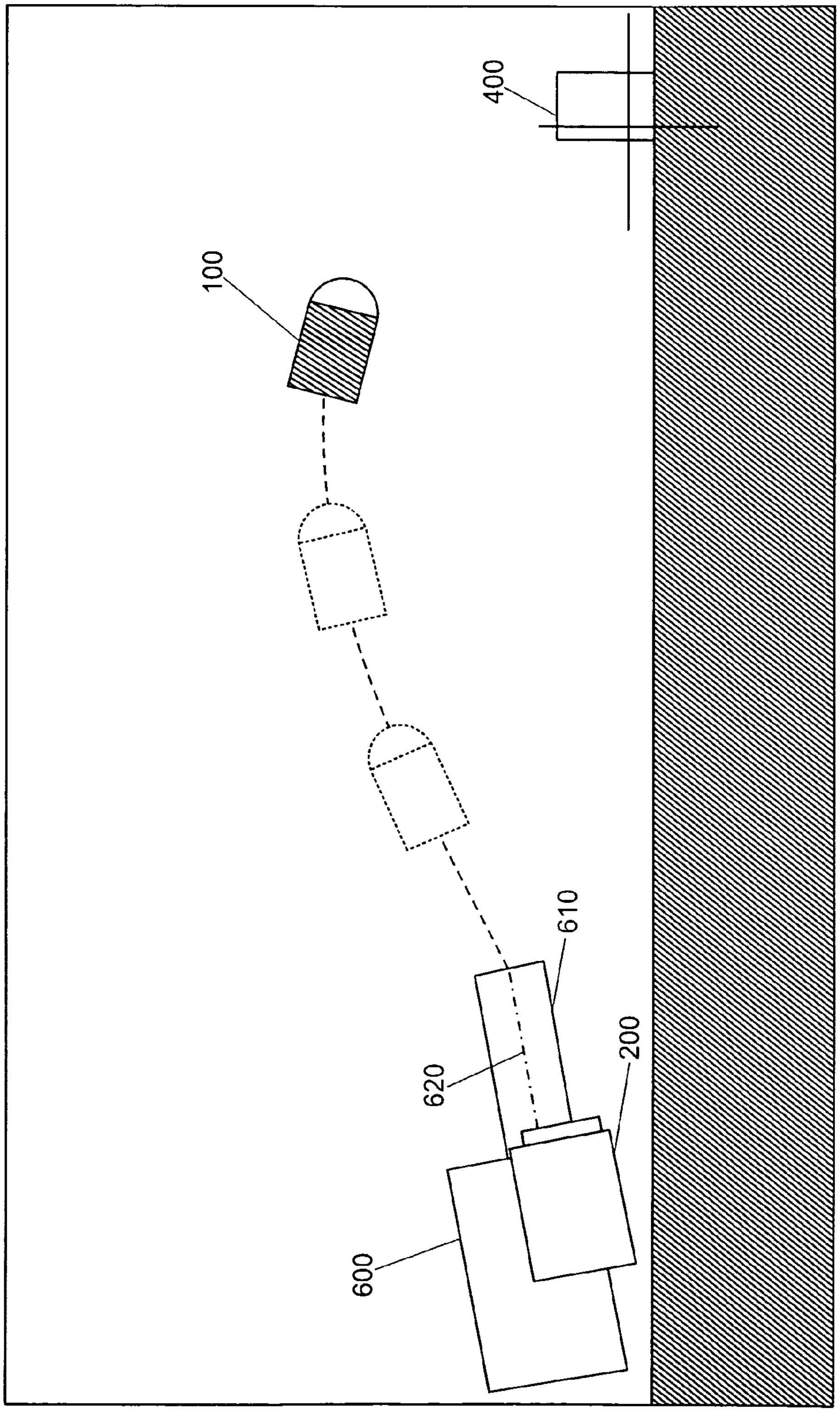


FIG. 1

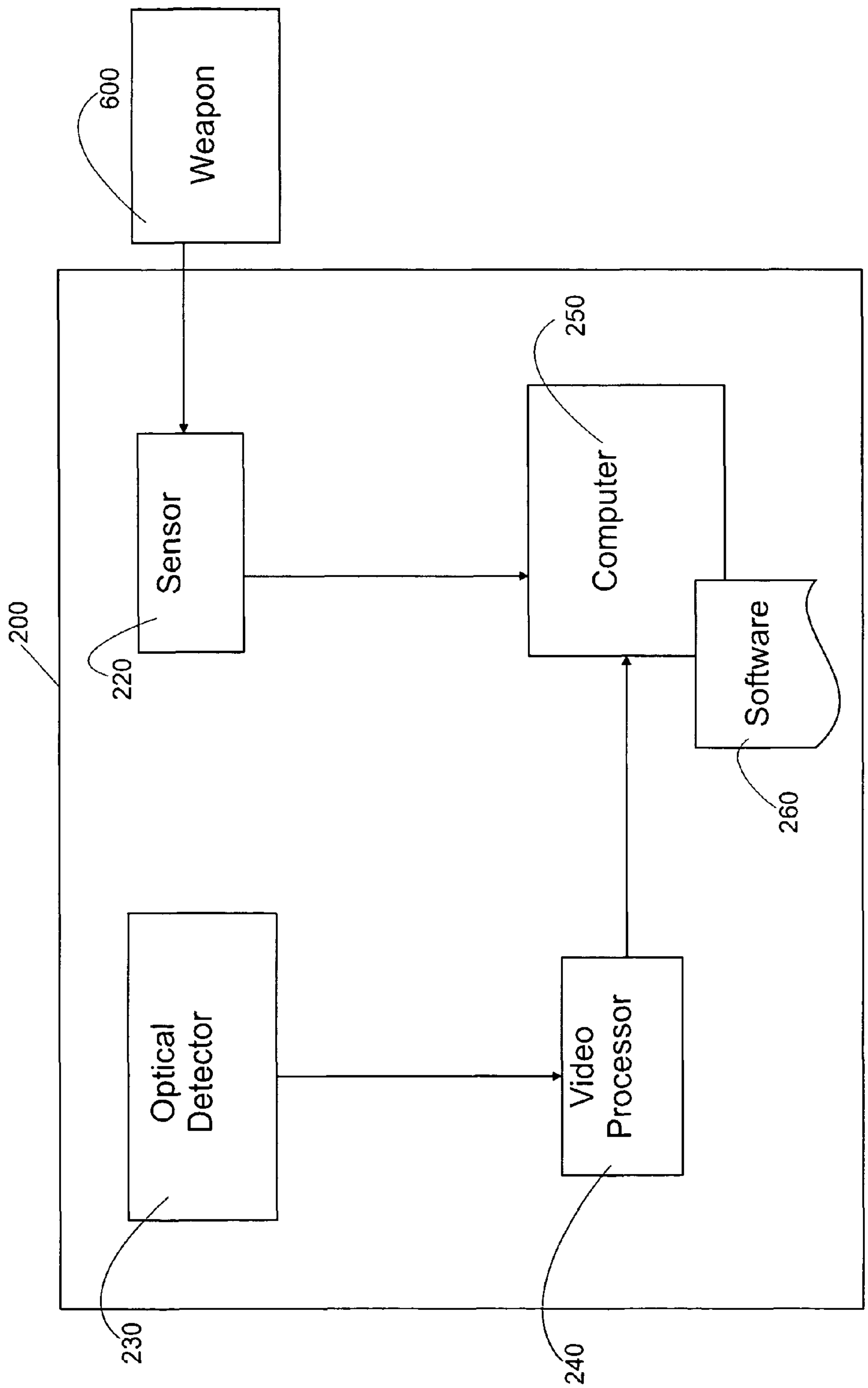

600
Weapon
200
220
Sensor
250
Computer
Software
260
Optical
Detector
Video
Processor
230
240

FIG. 2

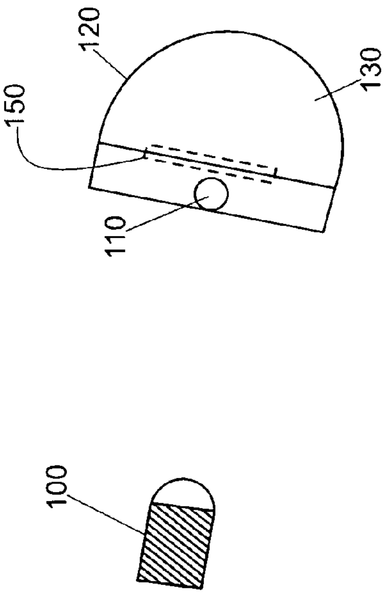


FIG. 3a

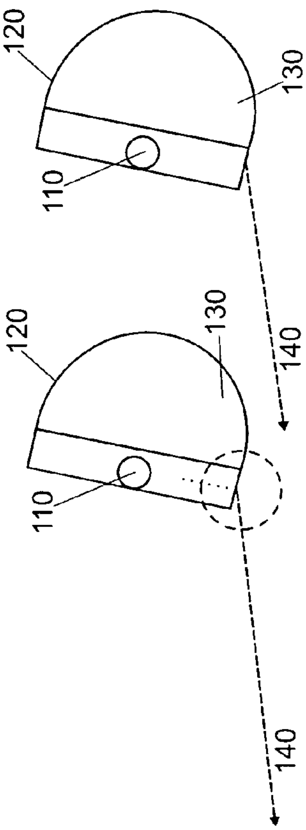


FIG. 3b

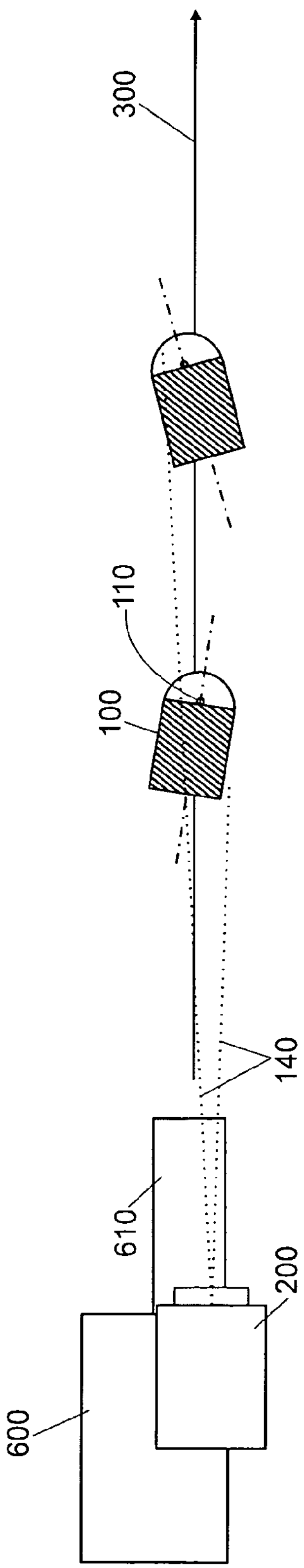


FIG. 4a

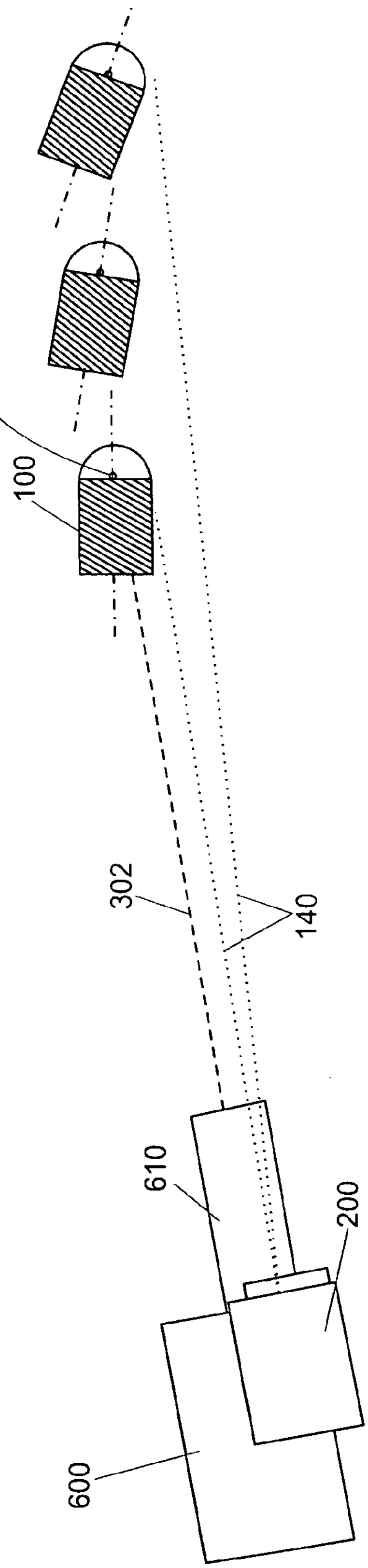


FIG. 4b

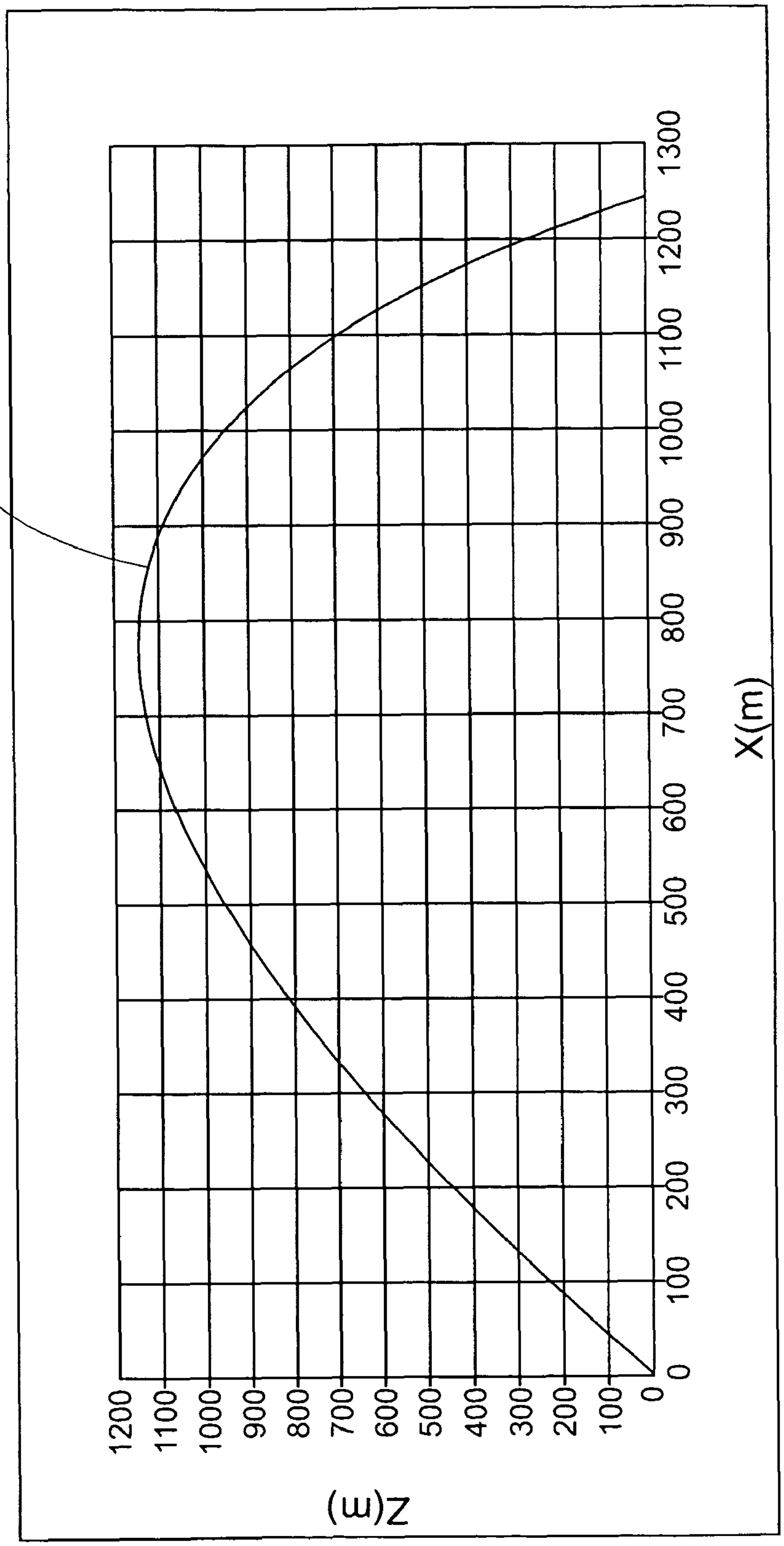

302
X(m)
Z(m)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

FIG. 4c

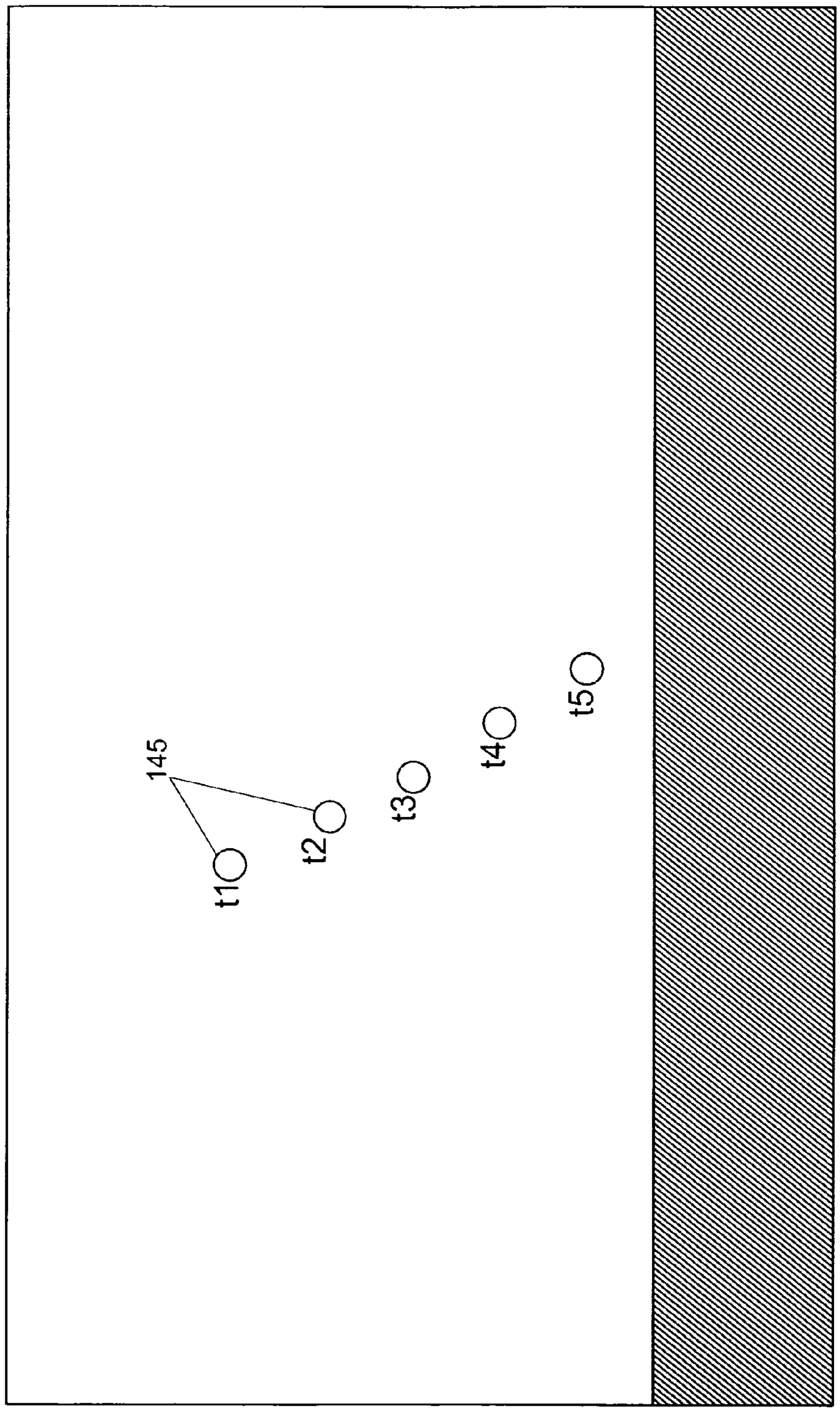


FIG. 5

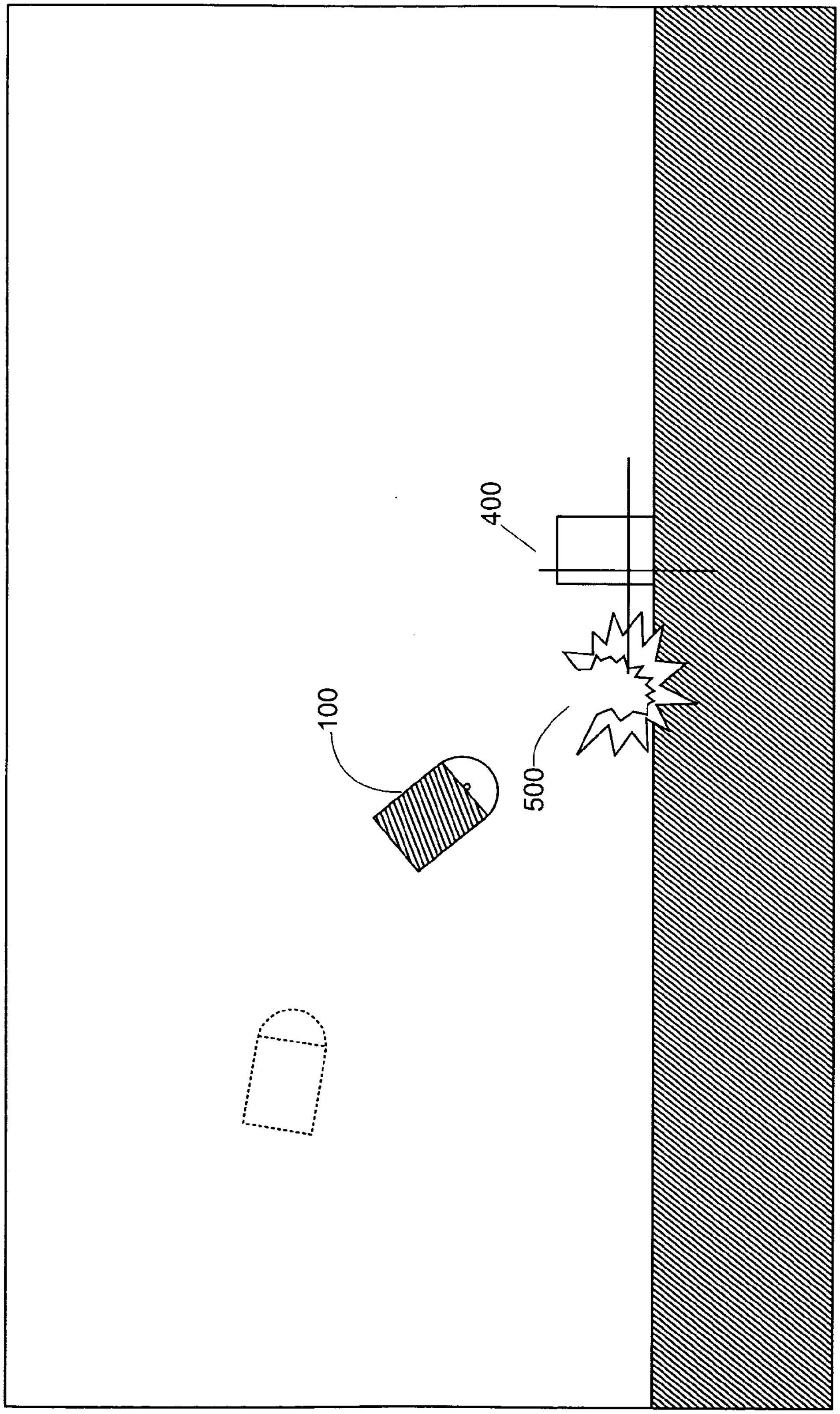


FIG. 6

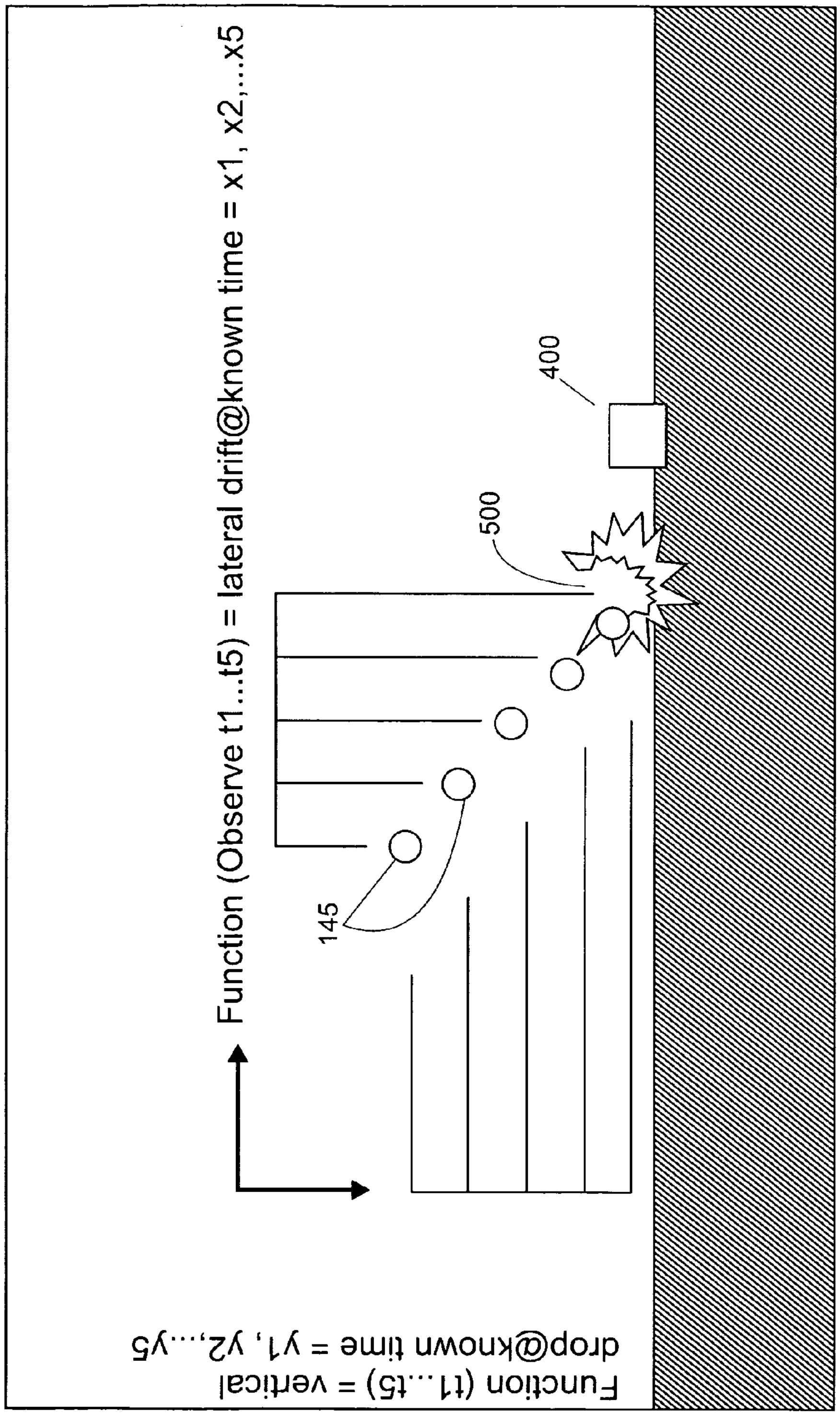

Function (Observe t1...t5) = lateral drift@known time = x1, x2,...x5
Function (t1...t5) = vertical drop@known time = y1, y2,...y5
145
500
400

FIG. 7

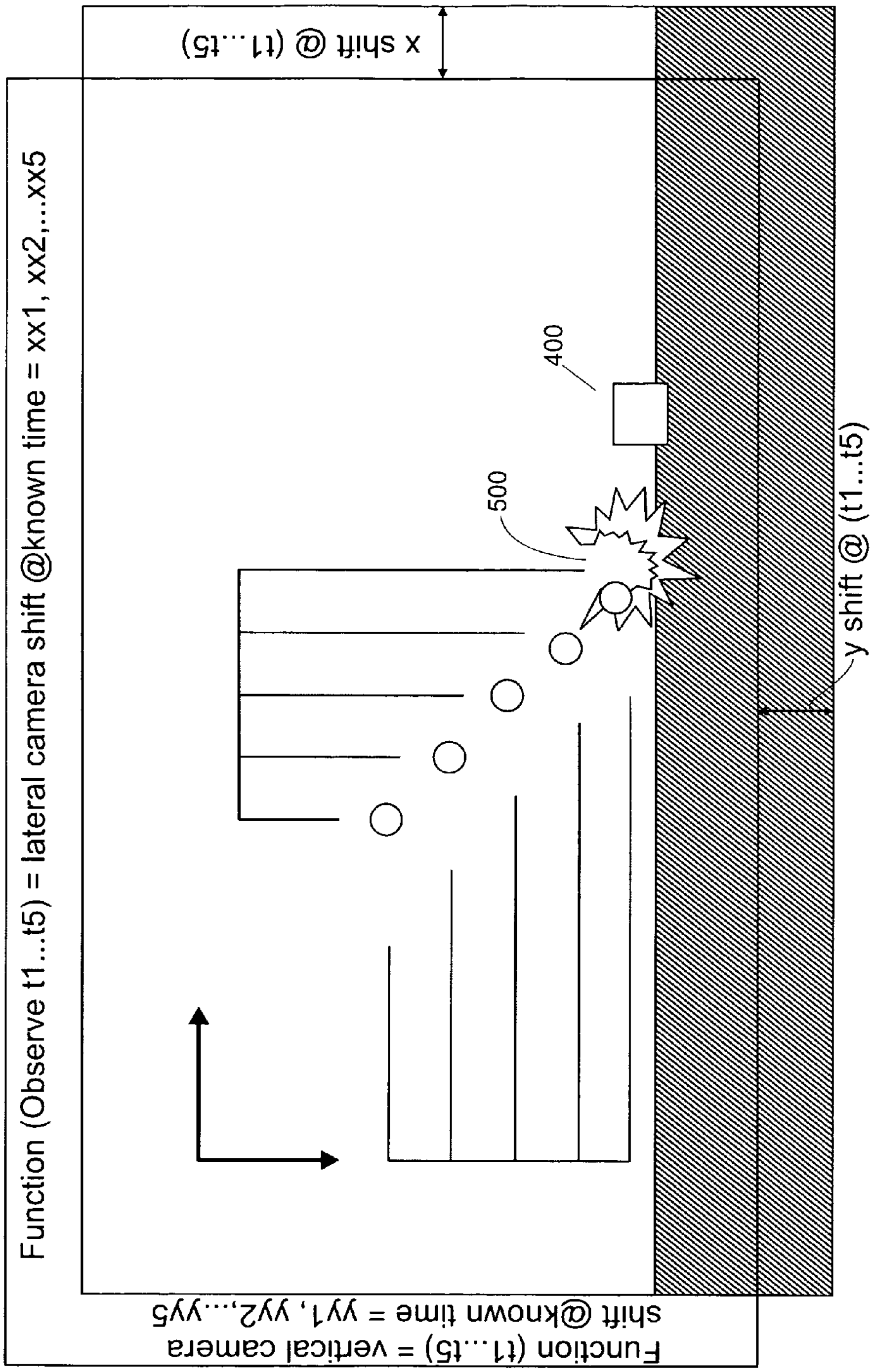

x shift @ (t1...t5)
Function (Observe t1...t5) = lateral camera shift @known time = xx1, xx2,...xx5
400
500
y shift @ (t1...t5)
Function (t1...t5) = vertical camera
shift @known time = yy1, yy2,...yy5

FIG. 8

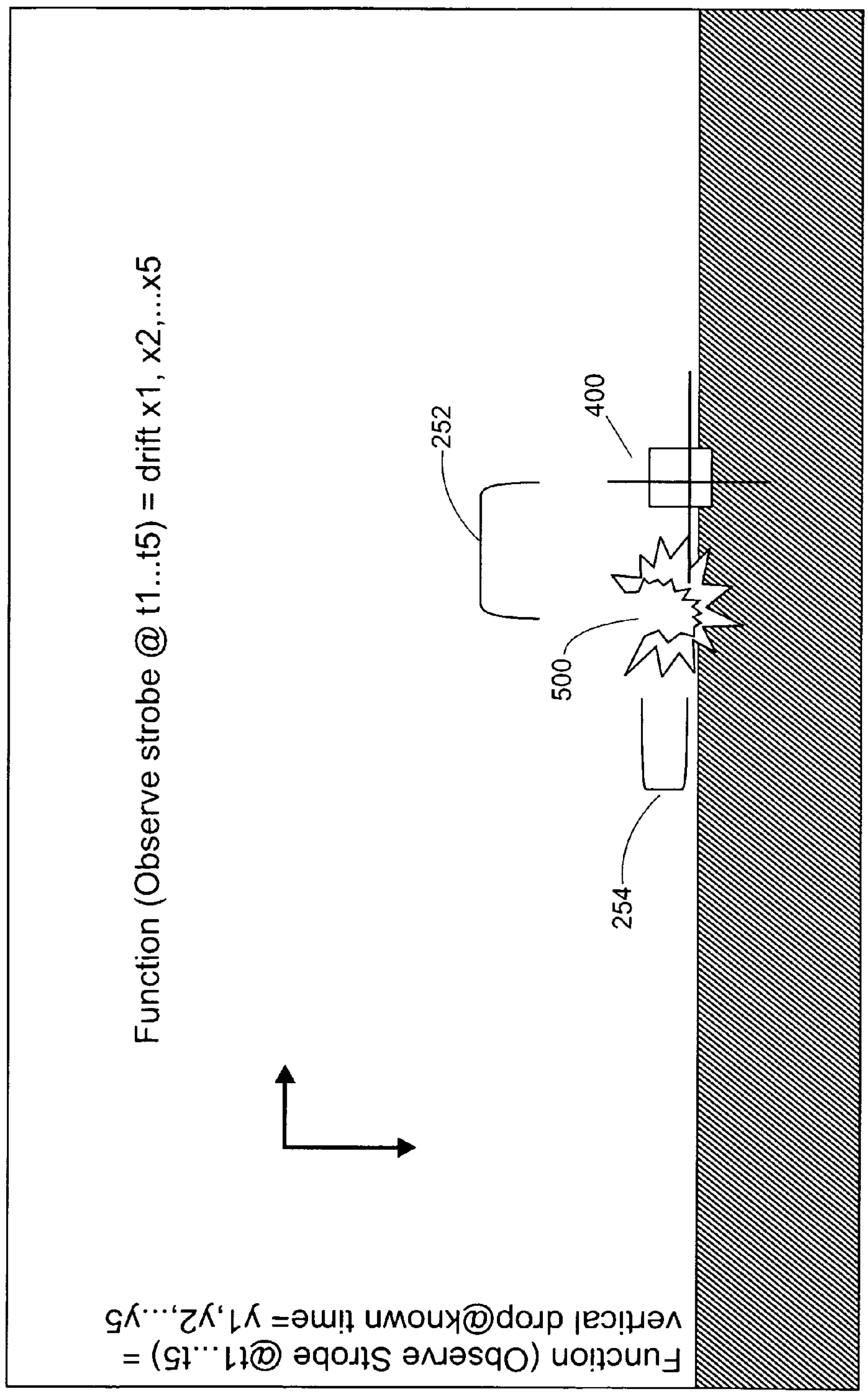

Function (Observe strobe @ t1...t5) = drift x1, x2,...x5
252
400
500
254
Function (Observe Strobe @t1...t5) =
vertical drop@known time= y1,y2,...y5

FIG. 9

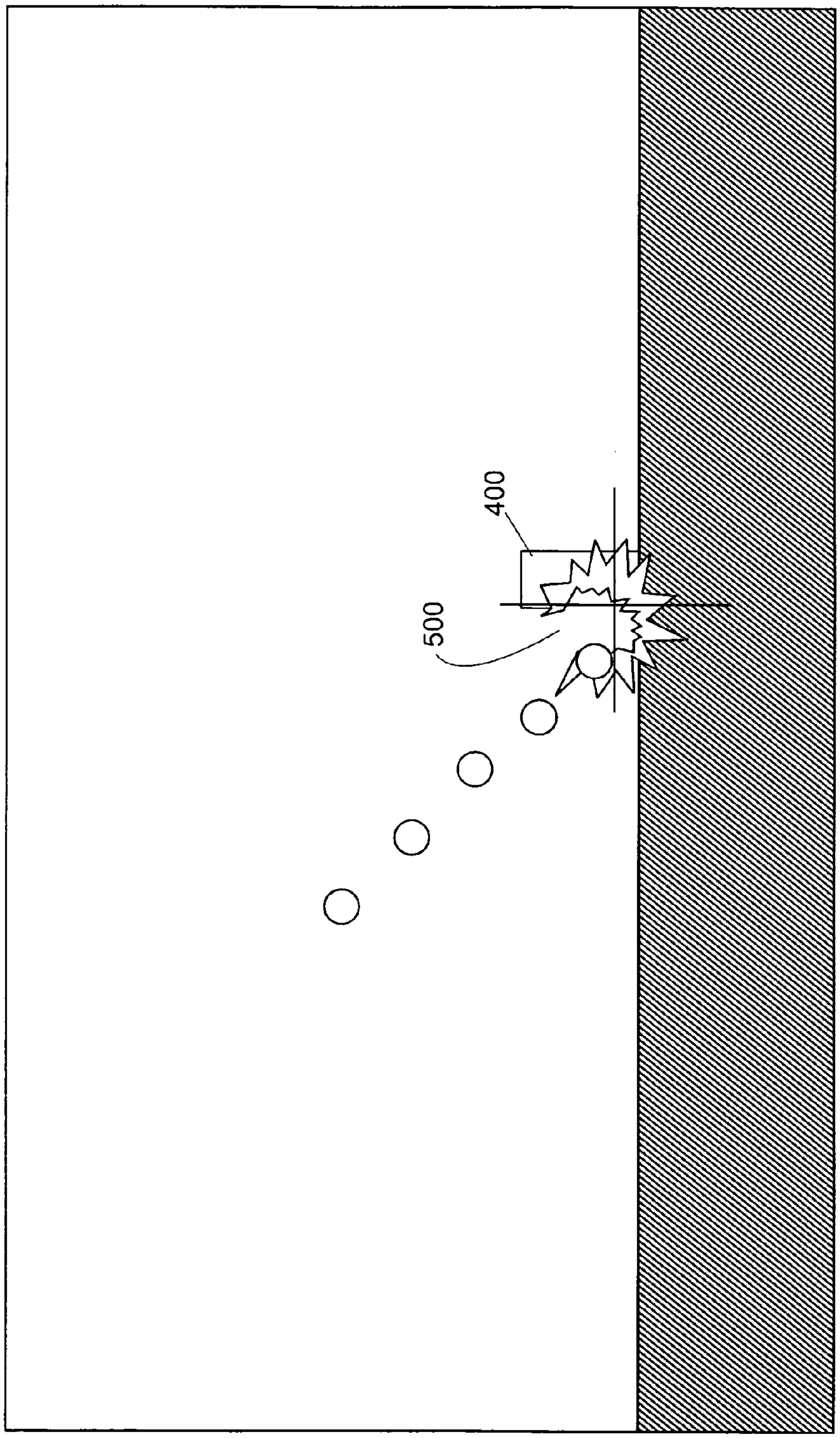


FIG. 10

Time	Item
T0-o	Fire Control Displays Solution based on solution derived from algorithm (based on previous video measurement)
	Information recorded/measured for processing by computer algorithms.
T0-n	Measurement of (a) radial Azimuth/Elevation Barrel centerline and (b) elevation of barrel/fire control elevation)if not aligned)
T0-n	Firing Pin Trigger pull (or hammer fall sensor)
T0	Set Back/Cartridge Launch
Tz1	Measurement of projectile at Position A
Tz2	Measurement of projectile at Position B
T1	Video Image(x1, y1) of strobe 1 and video position (xx1,yy1)
T2	Video Image(x2, y2) of strobe 2 and video position (xx1,yy1)
T3	Video Image(x3, y3) of strobe 3 and video position (xx1,yy1)
Tx	Video Image(x4, y4) of strobe x and video position (xx1,yy1)
Txn	Video Image(x5, y5) of strobe xn (last strobe prior to impact) and video position (xx1,yy1)

FIG. 11

METHODOLOGY FOR BORE SIGHT ALIGNMENT AND CORRECTING BALLISTIC AIMING POINTS USING AN OPTICAL (STROBE) TRACER

FIELD OF THE INVENTION

The present invention relates to weaponry systems, more specifically, it relates to a method and arrangement for improving precision and accuracy of weaponry and their fire control devices.

BACKGROUND OF THE INVENTION

There are several real time factors that influence the accuracy of weaponry and their fire control devices.

Existing fire control devices use ballistic tables and metrological sensors to calculate a predicted hit point (gunner aiming point). Also, some fire control devices allow for users to input manual drift and elevation offsets, but these offsets are generally linear offsets. Further, fire control devices often provide inaccurate aim points because a limited number of inputs are taken into consideration while calculating the aim points.

Existing wind sensing methodologies such as LIDAR and Doppler radar are too expensive to be incorporated into ground combat systems. Also, during the flight of the projectile, different wind conditions exist at different elevations, thus it is not effective to use a wind sensor at the fire control device as the wind conditions at the firing location are different from wind conditions on the in-flight projectile. Further, the trajectory of some projectiles makes it problematic to use wind sensors.

Chemical tracers have been used in ammunition for many years, but use of chemical tracers induces drag that negatively affects projectile ballistics. Further, chemical tracers do not allow precise measurement of the projectile time-location.

The U.S. Pat. No. 4,152,969 discloses a wind and target motion correction method for an airborne fire control system; however, the patent does not describe any method for correcting wind errors in ground combat systems.

The U.K. patent number GB 2,107,835 relates to a method and a device for correcting subsequent firing of a projectile from a weapon. However, the disclosed system is limited to the firing of the projectiles having a flat trajectory only, excluding its use for long range firing, and it does not take into account certain factors, such as errors due to gun jump or the like.

The U.S. Pat. No. 7,239,377 relates to a method and a device for determining a second range to a target based on data observed from a first range to the target. The method uses computer programs to calculate second range to the target using sensors such as a laser range sensor and a tilt sensor. However, practical considerations, such as atmospheric conditions, limit the accuracy of calculated solutions. Thus, there is a need to take into account real time observed data to improve the precision and accuracy of a fire control device.

In summary, there is a need for using real time data in weaponry systems to provide an improved ballistic control.

SUMMARY OF THE INVENTION

The principal object of the present invention is to improve the precision and accuracy of weaponry systems by taking into account all the factors that affect the actual flight of a projectile.

It is another object of the present invention to use a projectile with an optical emitter that emits short and intense optical signals at pre-determined time intervals to trace the path followed by the projectile. These optical emissions include but may not be restricted to light in ultraviolet, infra red and visual wavelengths.

It is another object of the present invention to improve the fire control device of the weaponry system by observing the angular position information of ammunition at known time points.

It is still another object of this invention to improve fire control solutions and allow for fire control computers to observe and calculate precise aim points and, in particular to correct errors due to (a) bore sight misalignment, (b) lot-to-lot errors, (c) occasion-to-occasion errors, (d) wind action on the projectile, and (e) several other local factors that contribute to error in fire control devices.

It is still another object of the present invention to use real time observed data to calculate new and improved fire control solutions for subsequent firing of projectiles.

It is still another object of the present invention to transmit optical signals in short form, thereby minimizing power consumption of reserve batteries and field generators used in the projectile fuzes.

It is still another object of the present invention to transmit optical signals in discrete bursts, thereby avoiding continuous processing of sensor inputs by processors of the computer disposed in the fire control device.

In the present invention, the weapon's ammunition tracer strobe, which is normally located with the fuze in the projectile ogive, provides time-location data and the fire control device observes the angular position of the projectile.

These objects, as well as still further objects which will become apparent from the discussion that follows, are achieved, in accordance with the present invention, by a method including the following steps:

(a) measuring angular position information between the weapon's barrel centerline and a fire control device;
(b) use of one or more sensors to identify possible parameters affecting the flight of the projectile;
(c) generating optical signals at predetermined time intervals using an optical emitter disposed in a housing of a projectile;
(d) receiving the optical signals generated in step (c) using an optical detector attached to the fire control device and measuring angular shift of the fire control device using sensors to detect gun jump or other post firing movement;
(e) processing the optical signals in a video processor for identifying optical location information of the flight of the projectile;
(f) using the angular position information, the aforesaid parameters, the angular shift and the optical location information to calculate a precise aim point, wherein the said calculation is carried out using software in a computer; and
(g) identifying the precise aim point to a user for firing one or more subsequent projectiles.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates a weaponry system for firing a projectile.

FIG. **2** illustrates different components of a fire control device.

FIG. **3**(*a*) illustrates the projectile and an exploded view of its nose.

FIG. **3**(*b*) illustrates the transmission of optical signals.

FIG. **4**(*a*) illustrates an induced yaw in the projectile in a flat trajectory.

FIG. **4**(*b*) illustrates the axis of rotation of the projectile for ballistic trajectory.

FIG. **4**(*c*) illustrates a ballistic profile of an in-flight projectile.

FIG. **5** illustrates an optical strobe images of the projectile at pre-determined time intervals (viewed from the fire control or position of the fire control).

FIG. **6** illustrates an actual hit point of the projectile fired without any correction.

FIG. **7** illustrates a lateral drift and vertical drop of the fired projectile.

FIG. **8** illustrates a lateral camera shift and vertical camera shift caused by gun jump at pre-determined time intervals.

FIG. **9** illustrates a lateral correction factor and vertical correction factor.

FIG. **10** illustrates a subsequently fired projectile hitting the intended target.

FIG. **11** shows a table for a sequence of measurements at different points of time to calculate an improved fire control solution.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention provide a method and arrangement for bore sight alignment and correcting ballistic aiming points using an optical strobe tracer. In the description of the present invention, numerous specific details are provided, such as examples of components and/or mechanisms, to provide a thorough understanding of the various embodiments of the present invention. One skilled in the relevant art will recognize, however, that an embodiment of the present invention can be practiced without one or more of the specific details, or with other apparatus, systems, assemblies, methods, components, materials, parts, and/or the like. In other instances, well-known structures, materials, or operations are not specifically shown or described in detail to avoid obscuring aspects of embodiments of the present invention.

FIG. **1** illustrates a weaponry system comprising one or more projectiles **100**, a weapon **600** and a fire control device **200**. The weapon **600** can be a gun, launcher, firearms, cannons, rocket pods, aircraft and the like.

The projectile **100** aimed at a target **400** is fired through a barrel **610** of the weapon **600** in response to a shoot command generated manually by a user. The shoot command can also be generated automatically by the fire control device **200** of the weaponry.

FIG. **2** illustrates the weapon **600** and the fire control device **200** comprising one or more sensors **220**, one or more optical detectors **230**, one or more video processors **240** and a computer **250** having a software **260**.

The sensors **220** are used in the present invention for identifying signals or any other parameters. Such sensors can be of various types, for example, position sensors, sensors for gun elevation, optical sensors and the like.

The optical detector **230** can be a camera or any image capturing device, for example video camera, infrared camera or the like.

The fire control device **200** measures angular position information of the weapon **600**, when the weapon **600** fires the projectile **100** aimed at the target **400**. The angular position information includes radial azimuth/elevation barrel centerline **620** and elevation of barrel/fire control elevation, wherein the angular position information is measured by using the sensors **220** and the information is recorded by the computer **250**.

FIG. **3**(*a*) illustrates the projectile **100** and an exploded view of the nose **130** of the projectile **100**. The projectile **100** comprises an optical strobe emitter **110**, which is disposed in a translucent housing **120** of the projectile **100**. Optical emitter **110** of the projectile **100** is a light generating source which can be a light emitting diode, laser or the like.

In one embodiment of the present invention, an electronic fuze **150** is disposed in the projectile **100**. The fuze **150** is programmed to relay precise position information of the projectile **100** to the fire control device **200**.

FIG. **3**(*b*) illustrates the transmission of optical signals **140** from the optical emitter **110** of the projectile **100** in the direction of the fire control device **200**, these optical signals **140** being generated at pre-determined time intervals during flight of the projectile **100**. A 360 degree refractive lens (not shown in the figure) is disposed in the translucent housing **120** of the projectile **100**. This lens allows optimized transmission of optical signals **140** from the emitter **110** in the direction of the fire control device **200**.

The optical emitter **110** emits optical signals **140** of high intensity and for very short period of time during the flight of the projectile **100**. Various types of optical emissions such as emissions in ultraviolet, infra red and visual spectrum of various frequencies and intensities can also be used without altering the scope of the invention.

In another embodiment of the present invention, it is possible to code the emissions of the optical signal **140** with a time code pulse.

In still another embodiment of the present invention, the optical emission (signal) **140** may include embedded signals corresponding to the precise time function.

FIG. **4**(*a*) and FIG. **4**(*b*) illustrate an arrangement for effectively transmitting the optical signal **140** generated from the optical emitter **110** toward the fire control device **200** during the flight of the projectile **100**.

FIG. **4**(*a*) illustrates firing of the projectile **100** aimed at a short range target (not shown in the figure). The path followed by the projectile **100** is relatively flat **300**. Yaw enables the projectile **100** to rotate about its vertical axis so as to optimally position the projectile **100** to emit optical signals **140** more effectively in the direction of the fire control device **200**. This yaw can be induced on projectiles **100** through a number of well known mechanical factors.

As shown in FIG. **4**(*b*), the projectile **100** is fired at an angle for a long range target (not shown in the figure). The axis of the in-flight projectile **100** changes relative to the position of the fire control device **200**; thereby allowing the emitter **110** to transmit optical signals **140** in the direction of the fire control device **200**. The path followed by the projectile **100** is ballistic **302** as shown in FIG. **4**(*c*). This figure shows the ballistic profile of 40 mm×53 HV grenade by using a PRODAS (PROjectile Design and Analysis System) cross plot.

The optical signals **140** generated by the optical emitter **110** of the projectile **100** are detected by the fire control device **200** using the optical detector **230**. The optical detector **230** of the fire control device **200** collects the optical emissions (signals) **140** at the pre-determined time intervals after firing. The optical signals **140** emitted by the optical emitter **110** of the projectile **100** at the discrete time intervals (t**1**, t**2**, t3, t4 and t5) are received by the optical detector **230** and digitally recorded as strobe images **145**, as illustrated in FIG. **5**.

FIG. **6** illustrates an actual hit point **500** of the fired projectile **100** and the intended target **400**. The projectile **100** misses the intended target **400** because of some real time errors such as, for example, occasion to occasion errors, lot-to-lot errors, bore sight misalignment and errors resulting from varying environmental conditions such as wind direction, wind speed and the like. The present invention facilitates in correcting these errors for firing subsequent projectiles **100** to hit the intended target **400** by processing the real time observed data.

The digitally recorded strobe images **145** are processed by the video (or image) processor **240** of the fire control device **200** to identify actual drift and drop of the fired projectile **100** as observed from the fire control device **200**.

The video processor **240** of the fire control device **200** detects the strobe images **145** at pre-determined time intervals (t**1**, t**2**, t**3**, t**4** and t**5**) after firing of the projectile **100**. Video processing software of the video processor **240** distinguishes the optical signal **140** from the collected strobe image **145** and measures angular changes that are used to calculate optical location information, wherein the optical location information comprises lateral drift (i.e. x**1**, x**2**, x**3**, x**4** and x**5**) and vertical drop (i.e. y**1**, y**2**, y**3**, y**4** and y**5**) of the projectile at the predetermined time intervals (i.e. t**1**, t**2**, t**3**, t**4** and t**5**) as illustrated in FIG. **7**.

At each pre-determined time interval (t**1**, t**2**, t**3**, t**4** and t**5**), the fire control device **200** also records angular shift in the optical detector **230** using one or more sensors **220** disposed in the fire control device **200**. This angular shift is determined by measuring shift in the horizontal (x) direction (i.e. xx**1**, xx**2**, xx**3**, xx**4** and xx**5**) and shift in the vertical (y) direction (i.e. yy**1**, yy**2**, yy**3**, yy**4** and yy**5**) of the optical detector **230** at the pre-determined time intervals (t**1**, t**2**, t**3**, t**4** and t**5**), as illustrated in FIG. **8**. The angular shift occurs due to gun jump or other post firing movements. "Gun jump" refers to the movement of the fire control device **200** or weapon **600** at the time of firing the projectile **100**. Errors due to gun jump can be solved in a number of ways such as, but not restricted to using software algorithms that detect the image shift or by using sensitive accelerometers or measuring equipment that detects relative change in position of the sensors.

The angular shift information along with the observed actual lateral drift and vertical drop data are provided to the computer **250** of the fire control device **200**. The computer **250** uses this information and the angular position information of the weapon **600**, recorded at the time of firing the projectile **100**, with software **260** to calculate lateral correction **252** and vertical correction **254** as illustrated in FIG. **9**. The lateral correction **252** is a function of the total observed lateral drift in the x coordinate (i.e., sum of the observed lateral drift x**1**, x**2**, x**3**, x**4** and x**5**) and vertical correction **254** is a function of the total observed vertical drop in the y coordinate sum of the observed vertical drop y**1**, y**2**, y**3**, y**4** and y**5**) of the initially fired projectile **100** that misses the target **400**. These corrections are used to calculate a new and improved fire control solution for subsequent firing. This solution takes into account the errors resulting from factors such as wind speed, wind direction or the like.

In one embodiment of the present invention, the fire control device **200** resets subsequent fire control solutions by using the actual observed drift and drop of the improved fire control solution, thereby providing a precise aim point for firing the subsequent projectiles **100**.

In another embodiment of the present invention, the fire control device **200** establishes a correction factor to modify the calculated fire control solution, thereby providing a more precise aim point for firing a subsequent projectile **100**.

The fire control device **200** uses the new and improved fire control solution to adjust the azimuth and elevation of aim point of the weapon **600** for firing subsequent projectiles **100**, so that they hit the intended target **400** as illustrated in FIG. **10**. Adjustment in azimuth corresponds to angle adjustment of the weapon **600** in the horizontal (left or right) direction to hit the intended target **400**. Adjustment in elevation corresponds to angle adjustment of the weapon **600** in the vertical (up and down) direction to hit the intended target **400**. These adjustments provide a precise aim point which is identified to the user for firing subsequent projectiles **100**.

Further, when subsequent projectiles **100** are fired, the fire control device **200** repeatedly measures the adjustments in the azimuth and elevation of the aim point and uses commonly known mathematical algorithms to improve the precision and accuracy of the corrected aim point by repositioning the weapon **600**.

FIG. **11** identifies various measurement parameters at different points of time during the flight of the projectile. Further, the measurements allow for optional measurement of muzzle velocity variation if needed.

The variables that may be used for calculating the improved fire control solution are described below.

T**0**-*o*: Time duration that fire control solutions are displayed and the weapon is physically positioned (aimed).

T**0**-*n*: Time when operator initiates firing.

T**0**: Moment ammunition is fired (set-back).

z**1**: Position of 1st time measurement (Position A barrel mouth).

z**2**: Position at 2nd time measurement (Position B Tz**2**−Tz**1**=Time/known distance=Muzzle Velocity)

x: Horizontal position.

y: Vertical Position.

Thus, the weaponry of the invention uses real time data and observations to calculate precise aim point solutions interrupting that help in removing errors; for example, errors resulting from varying environmental conditions such as wind direction, wind speed and the like, occasion-to-occasion errors, lot-to-lot errors, bore sight misalignment and the like.

While embodiments of the present invention have been illustrated and described, it will be clear that the present invention is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions and equivalents will be apparent to those skilled in the art, without departing from the spirit and scope of the present invention, as described in the claims.

What is claimed is:

1. An improved weaponry system comprising:

(a) a projectile having a housing, an optical emitter, disposed in the housing, for producing optical signals at pre-determined time intervals following firing of the projectile;

(b) a weapon for firing said projectile;

(c) a fire control device coupled to said weapon and comprising:

i. one or more sensors for measuring angular shift caused by gun jump;

ii. one or more sensors for measuring angular position information; and

iii. an optical detector for receiving said optical signals;

(d) a video processor for processing said optical signals to calculate optical location information comprising lateral drift and vertical drop of the projectile at predetermined times (T**1**, T**2**, T**3** . . .) following firing of the projectile (at time T**0**); and

(e) a computer having software which identifies a precise aim point for firing subsequent projectiles by determining parameters, said parameters comprising:

i. said angular shift;

ii. said angular position information; and

iii. said optical location information;

wherein the optical signals produced at the pre-determined time intervals (at times T**1**, T**2**, T**3** . . .) following firing of the projectile (at time T**0**) have a time code pulse corresponding to the precise time with respect to time T**0**, thereby to distinguish the projectile, which was fired at time T**0**, from any other projectiles viewed by the video processor; and

wherein said sensors measure angular shift of the optical detector in the horizontal direction and vertical direction at the predetermined time intervals (T**1**, T**2**, T**3** . . .), thereby to correct for errors due to gun jump.

2. The system according to claim **1**, wherein said projectile further comprises a fuze which is programmed to relay position information of the projectile to the fire control device.

3. The system according to claim **2**, wherein said fuze is an electronic time fuze.

4. The system according to claim **1**, wherein said optical emitter is light emitting diode.

5. The system according to claim **1**, wherein said optical emitter emits said optical signals at discrete frequencies in the UV, visual or IR spectrums.

6. The system according to claim **1**, wherein said video processor is attached to said fire control device.

7. The system according to claim **1**, wherein said video processor processes strobe image data collected by said optical detector.

8. The system according to claim **7**, wherein said optical detector is a camera.

9. The system according to claim **1**, wherein said computer is attached to said fire control device.

10. The system according to claim **1**, wherein the optical emitter includes a 360 degree lens, disposed in the housing, for transmitting the optical signals in the direction of the fire control device.

11. The system according to claim **10**, wherein said lens is refractive.

12. The system according to claim **10**, wherein said housing includes a translucent portion for the passage of said optical signals.

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