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(54) **AUTOMATIC TARGET ACQUISITION FOR A FIREARM**

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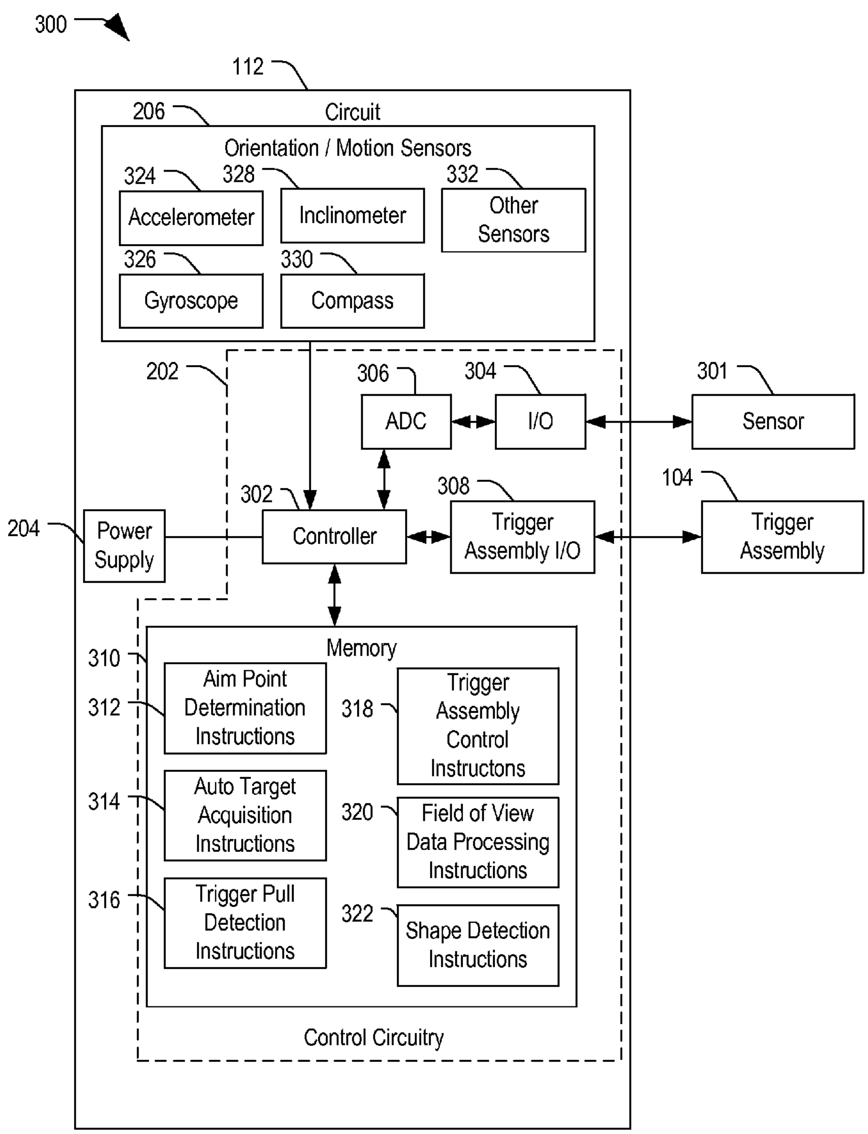
(57) **ABSTRACT**

A precision guided firearm includes a sensor configured to capture data associated with at least one of a view area and a firearm. The precision guided firearm further includes a controller coupled to the sensor and configured to detect an aiming event. The controller is configured to automatically acquire a target location within location based on the orientation data in response to detecting the aiming event.



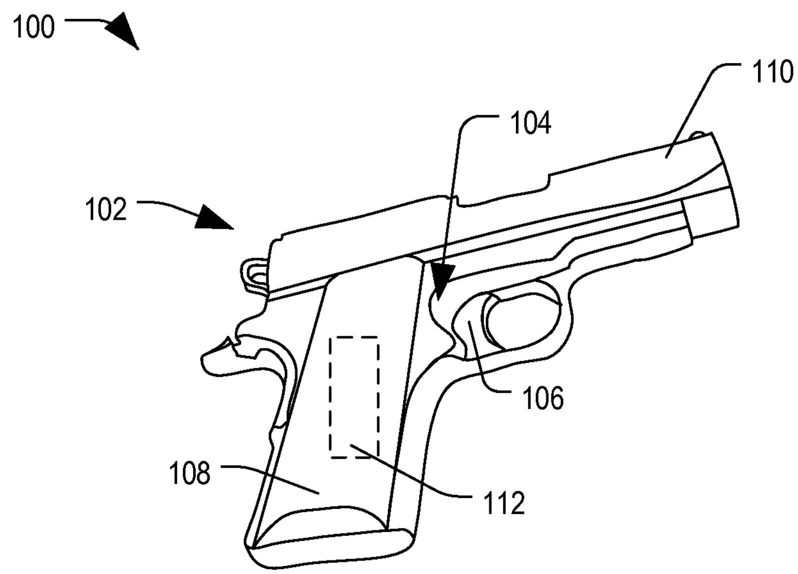

100
110
104
102
106
108
112

FIG. 1

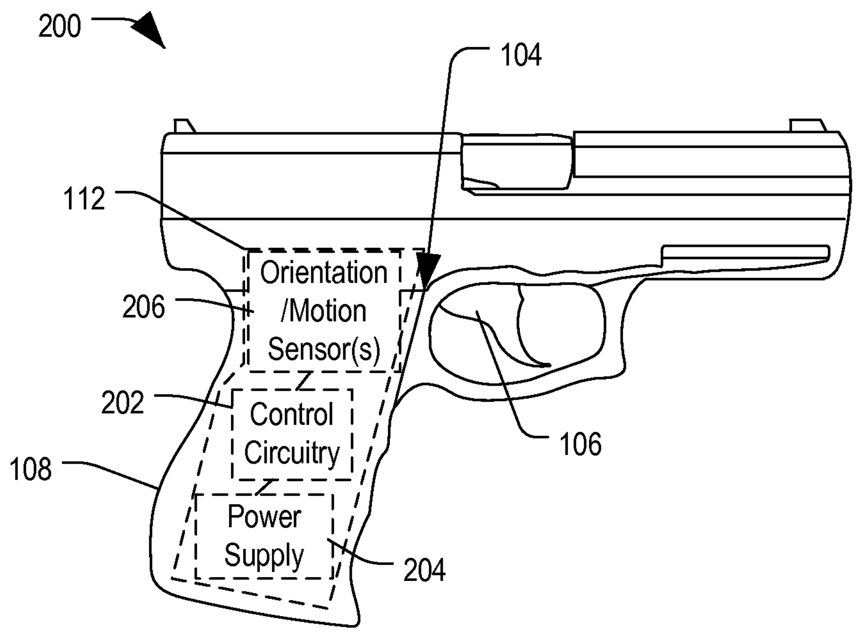

200
104
112
Orientation
/Motion
Sensor(s)
206
202
Control
Circuitry
108
Power
Supply
204
106

FIG. 2

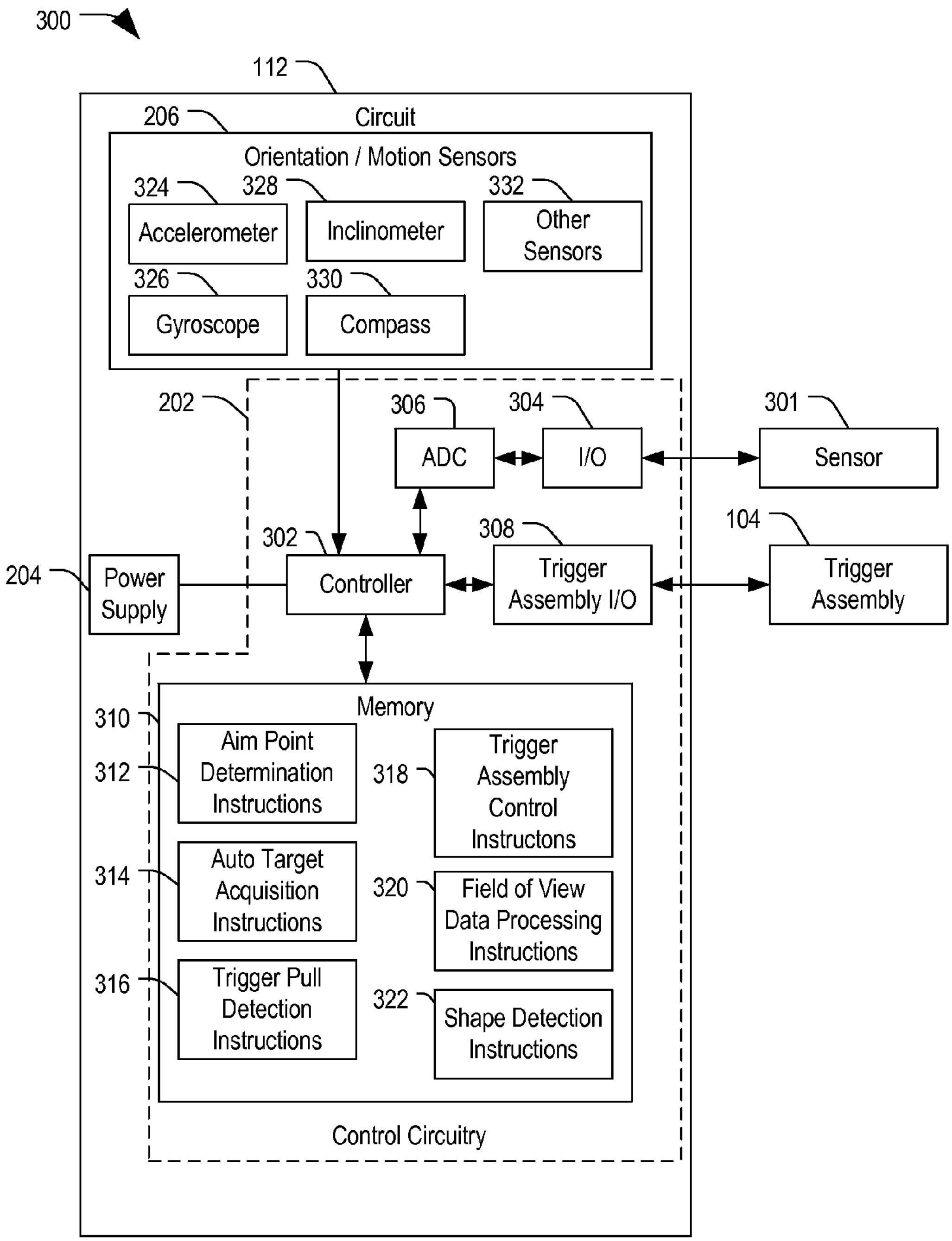

300
112
Circuit
206
Orientation / Motion Sensors
324
Accelerometer
328
Inclinometer
332
Other Sensors
326
Gyroscope
330
Compass
202
306
ADC
304
I/O
301
Sensor
302
Controller
308
Trigger Assembly I/O
104
Trigger Assembly
204
Power Supply
Memory
310
312
Aim Point Determination Instructions
314
Auto Target Acquisition Instructions
316
Trigger Pull Detection Instructions
318
Trigger Assembly Control Instructons
320
Field of View Data Processing Instructions
322
Shape Detection Instructions
Control Circuitry

FIG. 3

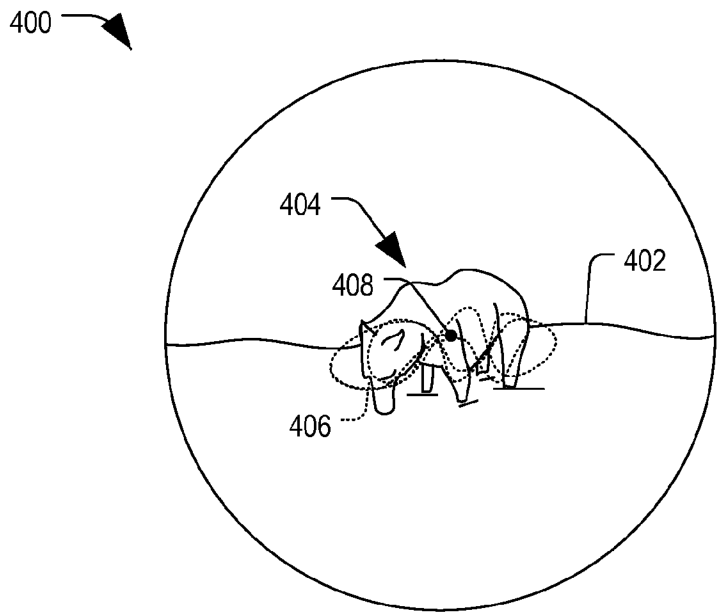

400
404
402
408
406

FIG. 4

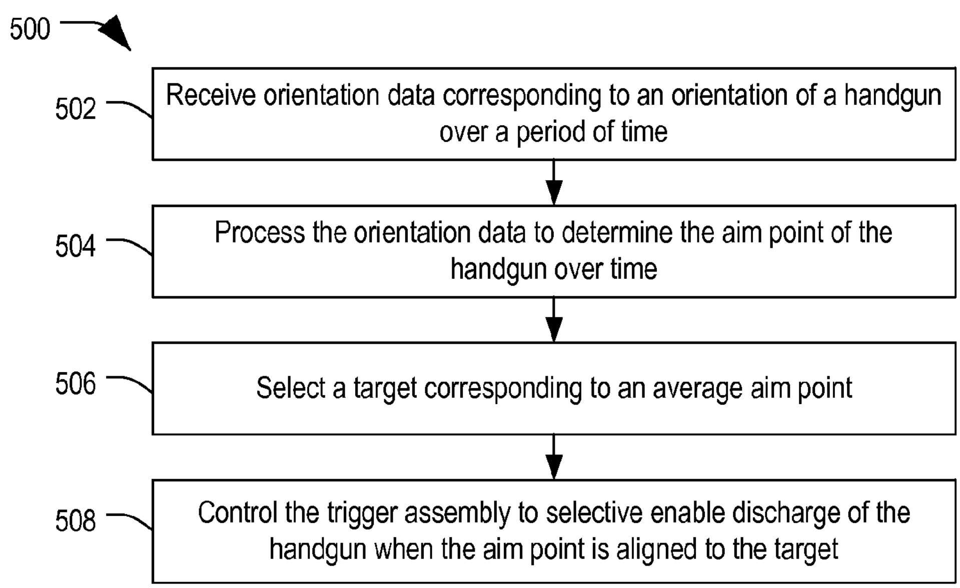

500
502
Receive orientation data corresponding to an orientation of a handgun over a period of time
504
Process the orientation data to determine the aim point of the handgun over time
506
Select a target corresponding to an average aim point
508
Control the trigger assembly to selective enable discharge of the handgun when the aim point is aligned to the target

FIG. 5

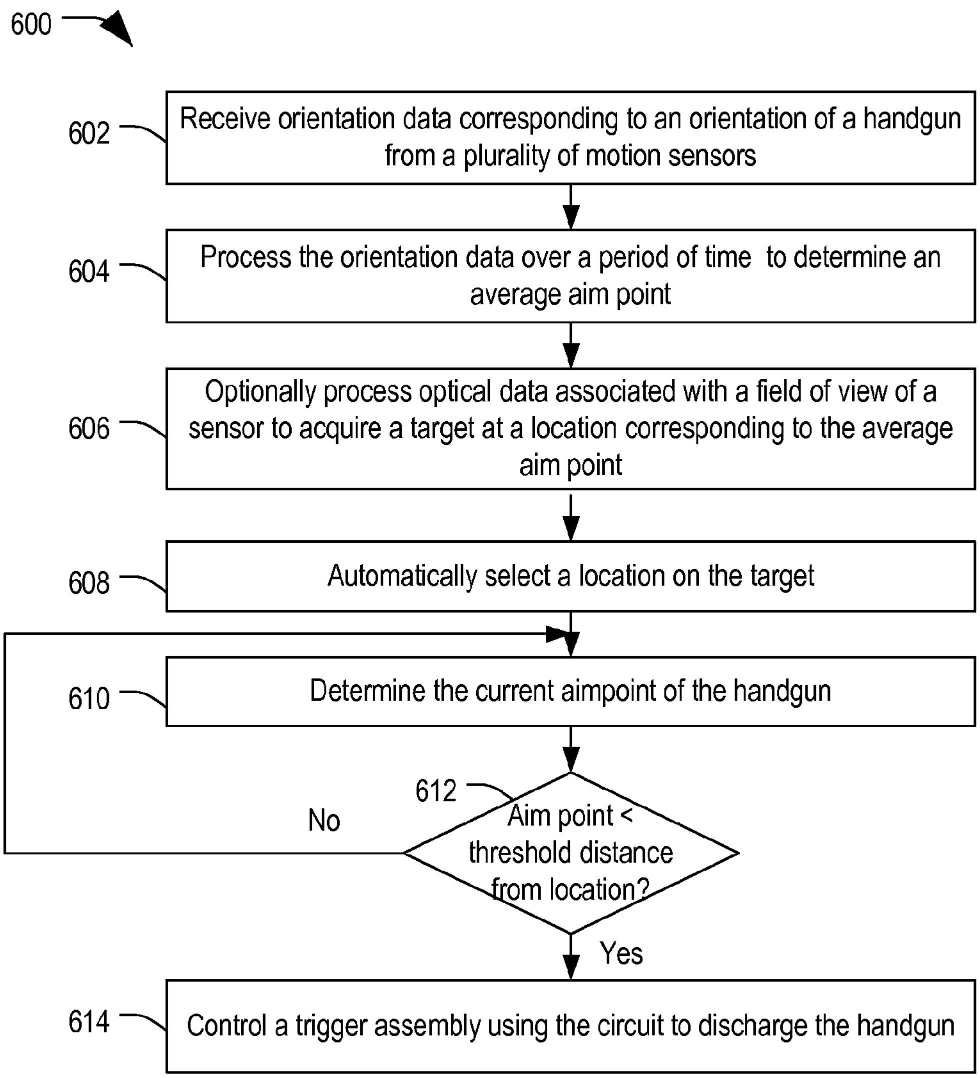

600
602
Receive orientation data corresponding to an orientation of a handgun from a plurality of motion sensors
604
Process the orientation data over a period of time to determine an average aim point
606
Optionally process optical data associated with a field of view of a sensor to acquire a target at a location corresponding to the average aim point
608
Automatically select a location on the target
610
Determine the current aimpoint of the handgun
612
Aim point < threshold distance from location?
No
Yes
614
Control a trigger assembly using the circuit to discharge the handgun

FIG. 6

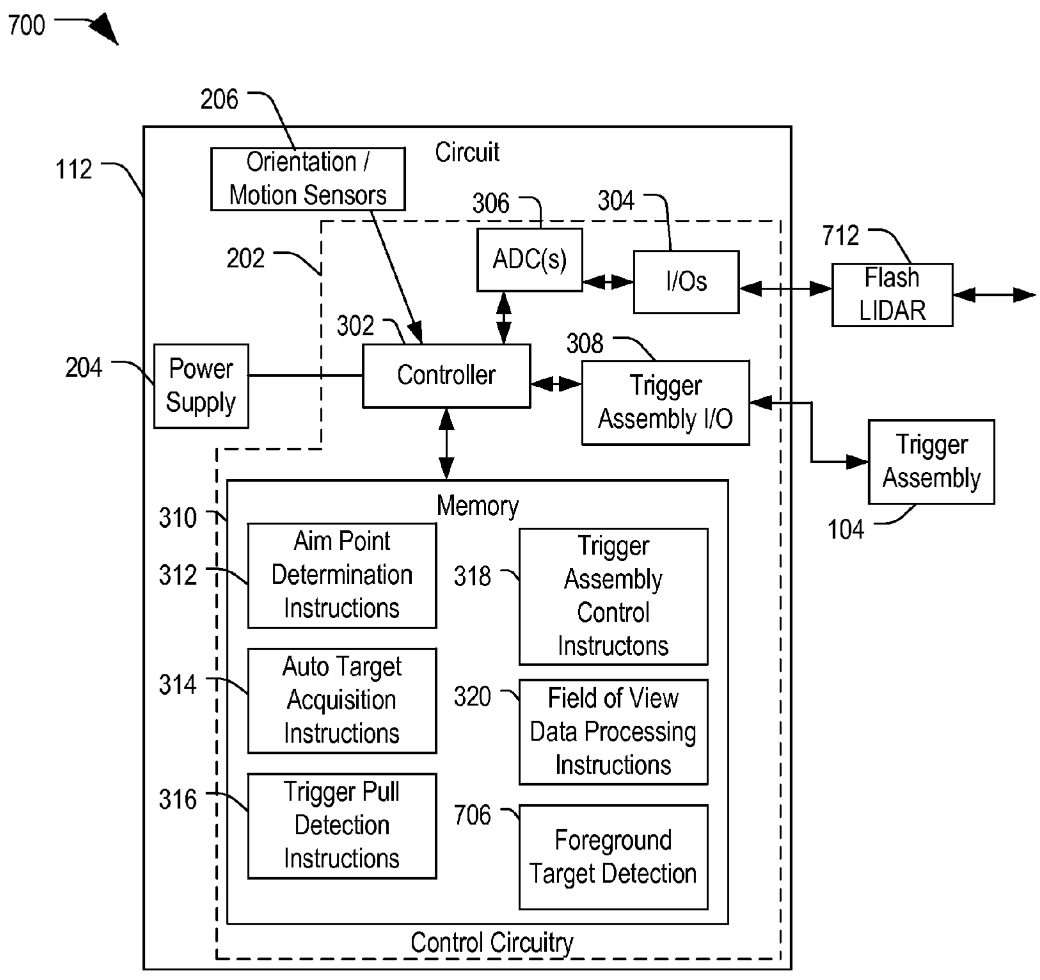

700
206
Orientation / Motion Sensors
Circuit
112
306
304
ADC(s)
I/Os
712
Flash LIDAR
202
302
308
204
Power Supply
Controller
Trigger Assembly I/O
Trigger Assembly
104
Memory
310
312
Aim Point Determination Instructions
318
Trigger Assembly Control Instructons
314
Auto Target Acquisition Instructions
320
Field of View Data Processing Instructions
316
Trigger Pull Detection Instructions
706
Foreground Target Detection
Control Circuitry

FIG. 7

AUTOMATIC TARGET ACQUISITION FOR A FIREARM

FIELD

[0001] The present disclosure is generally related to small arms firearms, and more particularly to firearms with discharge control.

BACKGROUND

[0002] Firearms including handguns (such as pistols), rifles, shotguns, and other small arms firearms are designed to be carried by a shooter and to be discharged toward a target. Conventionally, a shooter identifies a target and directs the gun toward the target by aligning the iron sight to the target or by aiming in the general direction of the target.

SUMMARY

[0003] In an embodiment, a precision guided firearm includes a sensor configured to capture data associated with at least one of a view area and a firearm. The precision guided firearm further includes a controller coupled to the sensor and configured to detect an aiming event. The controller is configured to automatically acquire a target location within location based on the orientation data in response to detecting the aiming event.

[0004] In another embodiment, a firearm includes a sensor circuit configured to capture orientation data corresponding to an orientation of a firearm. The firearm further includes a controller coupled to the sensor circuit and configured to automatically select a target location in response to the orientation data.

[0005] In still another embodiment, a method of automatically acquiring a target for a firearm includes receiving orientation data from a sensor circuit at a controller, the orientation data corresponding to an orientation of the firearm. The method further includes automatically selecting a target location based on the orientation data using the controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a perspective view of a precision guided firearm configured to select a target based on an aim point according to an embodiment.

[0007] FIG. **2** is a side-view of a precision guided firearm configured to select a target based on an aim point according to an embodiment.

[0008] FIG. **3** is a block diagram of a control system including a circuit configured to select a target based on an aim point according to an embodiment.

[0009] FIG. **4** is a diagram of a representative example of a target with an aim path and an average aim point superimposed thereon.

[0010] FIG. **5** is a flow diagram of a method of automatically acquiring a target according to an embodiment.

[0011] FIG. **6** is a flow diagram of a method of automatically acquiring a target according to a second embodiment.

[0012] FIG. **7** is a block diagram of a control system including a circuit configured to select a target based on a flash light detection and ranging (LiDAR) circuit according to an embodiment.

[0013] In the following discussion, the same reference numbers are used in the various embodiments to indicate the same or similar elements.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0014] Embodiments of a precision guided firearm may include a controller coupled to a plurality of motion/orientation sensors and configured to select automatically select a target within an "aim" area of the firearm based on data from at least one of the plurality of motion/orientation sensors. In an embodiment, the controller is configured to determine when a shooter is aiming the handgun toward a target based on orientation data from the sensors. When the shooter directs an aim point of the handgun toward a target for a period of time that is greater than a pre-determined time threshold, the controller may detect an aiming event and may select the aim point of the firearm as a target or target location.

[0015] As the shooter aims, the aim point may vary over time, tracing an aim point path across and around an intended location on a target, for example, due to human jitter. The controller may be configured to detect an aiming event based on the relative consistency of the orientation data over time and to infer an intended aim point based on the orientation data. In an embodiment, the controller may determine an average aim point based on the aim point path in response to detecting the aiming event. The controller may be configured to automatically select (infer or intuit) a target location corresponding to the average aim point. In response to a trigger pull, the controller may control timing of the discharge of the handgun by selectively enabling discharge when the aim point intersects the average aim point or passes within a range of the average aim point, where the range may be defined by a pre-determined threshold distance or minute of angle (MOA).

[0016] In one possible embodiment, in addition to utilizing orientation data to determine an intended aim point of the firearm, the controller may also be coupled to an optical sensor, an acoustic sensor, and/or a thermal sensor configured to capture data corresponding to a field of view that includes the aim point of the firearm. As used herein, the term "field of view" refers to an area from which the sensor receives data. This sensor may be a circuit that may include a single pixel camera, a thermal (infrared) sensor, an ultrasonic sensor, a light detection and ranging circuit, or other directional sensor. The controller may use data from the sensor to identify a foreground object in the field of view that corresponds to the aim path of the firearm, and to automatically refine the inferred or intuited target to correspond to the object. In an embodiment, the controller may use the shape detection and/or boundary detection algorithms to further refine the target selection (target location) to a location that is within the determined boundaries of the object. An embodiment of a precision guided firearm configured to automatically acquire a target is described below with respect to FIG. **1**.

[0017] FIG. **1** is a perspective view of a precision guided firearm (PGF) implemented as a precision guided handgun (PGH) **100** according to an embodiment. PGH **100** includes a handgun **102** including a trigger assembly **104** with a trigger shoe **106**. The handgun **102** further includes a grip **108** and a barrel **110**. PGH **100** further includes a circuit **112** that may be housed within or integrated into the grip **108**. In one embodiment, circuit **112** may be mounted within grip **108**. In another embodiment, circuit **112** may be integrated into a casing that is attached to handgun **102**, such as a textured grip. The circuit **112** may also be coupled to the trigger assembly **104** through a wired or wireless communications link (not shown).

[0018] In an embodiment, the circuit **112** may include a battery or other power source, which may deliver power to the circuit **112** and to the trigger assembly **104**. The circuit **112** may further include a plurality of motion/orientation sensors and a controller configured to determine an aim point of the handgun **102** based on orientation data and/or motion/orientation data. The motion/orientation sensors may include an accelerometer, a gyroscope, an inclinometer, a compass, an attitude sensor, other sensors, or any combination thereof, which may provide orientation data to the controller. The controller may be further configured to detect an aiming event, calculate an average aim point over time and to automatically infer a target selection based on the orientation data. In an example, a shooter may attempt to maintain an aim point of the firearm on an object for a period of time. The circuit **112** may detect a directed aiming event when the orientation data varies by less than a pre-determined amount for a period of time that exceeds a pre-determined time threshold. In such an example, the circuit **112** may determine that the orientation data corresponds to a directed aiming event. In response to detecting an aiming event, the controller may process the orientation data and may select an average aim point over the period of time as the selected target, inferring a target location that corresponds to that average aim point.

[0019] In an embodiment, the controller may control the trigger assembly to selectively enable discharge of the handgun **102** when the aim point is aligned (within a margin of error) to the previously determined average aim point (i.e., to the inferred target location). In an embodiment, the margin of error may be defined by the user. The margin of error may be one or more minutes of angle or another threshold. In an embodiment, the trigger assembly **104** may include a solenoid or other circuit that is responsive to control signals from circuit **112** to control timing of the discharge of the handgun **102**, for example, by selectively enabling movement of the trigger shoe to release the hammer, bolt, or other discharge mechanism. In another embodiment, the trigger assembly **104** may include an electronic discharge mechanism responsive to an electrical signal to fire.

[0020] In some embodiments, circuit **112** may also be coupled to an optical or thermal sensor that may be coupled to the handgun **102**, such as to the barrel **110**. In a particular example, the optical or thermal sensor may capture image data, thermal data, reflected light, or other data associated with a field of view of the sensor and may provide the data to the controller. The controller may process the data to identify an object within the field of view that corresponds to the average aim point and may automatically refine (adjust) the selected aim point to correspond to a location within a boundary of the object. The controller may continue to monitor the aim point of the handgun (while the shooter is pulling the trigger) and may control the trigger assembly **104** to selectively enable discharge of the handgun **102** when the aim point as determined from the orientation data is aligned to the selected aim point.

[0021] In one embodiment, an optical sensor circuit may include one or more one or more single-pixel or small profile cameras configured to capture at least two optical views of the area and to determine a foreground object corresponding to the aim point based on the two views (parallax). In another embodiment, the sensor may include a flash light detection and ranging (LiDAR) circuit, which may be configured to illuminate objects within the view area, to receive reflected light, and to detect foreground and background objects based on the reflected light, which may be used to refine the aim point inferred based on the directed aiming event. In an example, the controller may use boundary detection or other algorithms or techniques to identify boundaries of an object and may refine the inferred aim point to fit within the boundaries. In an example, the controller may also adjust the threshold (i.e., the MOA or error) so that the discharge may occur when the aim point is within the boundaries of the object.

[0022] It should be understood that, in the illustrated example of FIG. **1**, the circuit **112** may be included in the grip or mounted to the handgun **102**. An example of one possible embodiment of a PGH that includes the circuit **112** within an enclosure defined by the grip **108** is described below with respect to FIG. **2**.

[0023] FIG. **2** is a side-view of a PGH **200** according to an embodiment. PGH **200** includes handgun **102** that includes a trigger assembly **104** including a trigger shoe **106**. Handgun **102** further includes a grip **108** and a barrel **110**. The circuit **112** is situated within the grip **108**. In this example, the circuit **112** includes control circuitry **202** that may be coupled to the trigger assembly **104**. The control circuitry **202** includes the controller and other circuitry. The circuit **112** includes a power supply **204** and one or more orientation/motion sensor **206** that are coupled to the control circuitry **202**. Further, as discussed above, the control circuitry **202** may be configured to process data from the one or more orientation/motion sensors **206** to determine a directed aiming event and to infer a target based on the orientation data of the handgun **102**.

[0024] In an embodiment, the control circuitry **202** may detect a directed aiming event based on a period of time in which the orientation data from orientation/motion sensors **206** varies by less than a pre-determined threshold. For example, a shooter may point the handgun **102** toward a particular target for a period of time, and the control circuitry **202** may detect that the orientation data changes by less than a threshold amount for the period of time, which can be used to infer that the shooter is aiming the handgun **102**. In response to detecting a directed aiming event, the control circuitry **202** may determine an average aim point and may automatically select a location corresponding to the average aim point as a target. In an example, the controller is configured to selectively enable discharge of the handgun **102** when the aim point of the handgun **102** is aligned to the average aim point (i.e., the inferred target location).

[0025] Further, in some embodiments, the control circuitry **202** may be coupled to an optical sensor and may utilize data corresponding to a field of view of the sensor to refine an inferred target location, refining the average aim point location to better align to a center of a target object (for example). In an example, in response to inferring a target based on the average aim point, the control circuitry **202** may activate the sensor to capture data associated with the view area (image data, thermal data, reflected light data, other data, or some combination thereof), may process the data to identify an object corresponding to the average aim point, and may automatically refine the aim point based on the optical data from the sensor. In an alternative embodiment, the control circuitry **202** may be coupled to an ultrasonic sensor configured to provide ultrasonic data corresponding to objects in an aim path of a firearm, which ultrasonic data may be used to refine the target location.

[0026] While the illustrated examples of FIGS. **1** and **2** have depicted a particular type of handgun, the circuit **112** may be used with other types of firearms to infer a target in response to a directed aiming event. Such other types of firearms may include, but is not limited to, rifles, shotguns, airsoft guns, pellet guns, snub-nosed shotguns, and other types of firearms.

[0027] Further, in an embodiment, the circuit **112** may include an interface (such as a Universal Serial Bus (USB) interface) or a wireless transceiver configured to allow a user to communicatively couple the handgun **102** to a computing device, such as a smart phone, a portable computer, a tablet computer, or other computing device. In an example, the user may couple the computing device to the handgun **102** and may configure settings, such as a threshold error (i.e., one or more MOA, a distance threshold, or other threshold), by interacting with an interface of the computing device. In an embodiment, the interface may be accessible by removing or opening a cover or by detaching a portion of the grip **108**, for example. In an example, once the threshold error is configured, the control circuitry **202** may determine a difference between the inferred target location and the aim point of the handgun **102** and may selectively enable discharge of the handgun **102** when the distance between the aim point and the target location is less than the threshold error. One possible example of the circuit **112** for use within a PGF or a PGH is described below with respect to FIG. **3**.

[0028] FIG. **3** is a block diagram of a control system **300** that may be mounted to or integrated with a handgun to provide a PGH, such as the PGFs of FIGS. **1** and **2**, according to an embodiment. The control system **300** includes the circuit **112**, a sensor **301**, and the trigger assembly **104**. The circuit **112** includes the control circuitry **202**, the power supply **204** (which may be a battery), and the orientation/motion sensors **206**.

[0029] The control circuitry **202** includes a controller **302** coupled to sensor **301** through an input/output (I/O) interface **304** and through an analog-to-digital converter (ADC) **306**. In an embodiment, the ADC **306** may be integrated within sensor **301** or into I/O interface **304**. The control circuitry **202** further includes a trigger assembly I/O interface **308**, which may be coupled to the controller **302** and to the trigger assembly **104**. The control circuitry **202** also includes a memory **310** that may be coupled to the controller **302**. The orientation/motion sensors **206** and the power supply **204** may also be coupled to the controller **302**. The controller **302** may operate as a power management unit configured to distribute power to the memory **310**, the ADC **306**, the I/O interface **304**, the trigger assembly I/O interface **308**, the orientation/motion sensors **206**, and even to the sensor **301** and the trigger assembly **104**. In an embodiment, the controller **302** may include a processor, a microcontroller unit (MCU), a field programmable gate array (FPGA) or any combination thereof configured to process data and execute instructions stored in memory **310**.

[0030] The orientation/motion sensors **206** may include one or more accelerometers **324**, one or more gyroscopes **326**, one or more inclinometers **328**, a compass **330**, other sensors **332**, or any combination thereof. The orientation/motion sensors **206** may be configured to provide orientation data to the controller **302**. The orientation data may include motion data from the one or more accelerometers **324**, angular rotation rate from the one or more gyroscopes **326**, angle or incline data from the one or more inclinometers **328**, directional data from the compass **330**, and other movement, orientation or attitude data from the other sensors **332**.

[0031] The memory **310** may be a non-volatile memory configured to store thresholds and data, and/or to store instructions that, when executed, cause the controller **302** to perform a variety of functions. The memory **310** may include aim point determination instructions **312** that, when executed, cause the controller **302** to process the orientation data from the orientation/motion sensors **206** to determine an orientation of the handgun **102**. The aim point determination instructions **312** may cause the controller **302** to detect a directed aiming event when the aim point of the handgun **102** is substantially consistent over a period of time, which may indicate that the shooter is attempting to aim at a target. In an example, the period of time may be measured in milliseconds, such as 50 or 100 milliseconds. Alternatively, the period of time may be based on a pre-determined number of clock cycles. The directed aiming event may be detected when the orientation data varies by less than a threshold amount over a period of time that exceeds a time threshold (or clock pulse count). The threshold amount may be an angular variation (i.e., MOA) or angular distance.

[0032] In an example, the controller **302** may detect directed aiming by the shooter when the variation of the aim point (determined from the changing orientation data) over a predetermined period of time is less than a predetermined threshold. In a particular example, the predetermined period of time may be configurable by a user. Further, in an embodiment, the predetermined threshold range or threshold error may also be configured by a user. In an embodiment, the period of time may be less than 100 milliseconds and the threshold range or error may be two MOA. Alternatively, the predetermined threshold range may represent a change in the aim point reflecting a range of approximately 4 feet in an X-Y plane at a distance of 50 feet.

[0033] The memory **310** may also include auto target acquisition instructions **314** that, when executed, cause the controller **302** to automatically acquire a target corresponding to a location of an average of the aim point over a period of time. In an example, the controller **302** may determine an average aim point of the handgun over a period of time, and may select the average aim point as a target location. The memory **318** further includes trigger pull detection instructions **316** that, when executed, cause the controller **302** to detect a trigger pull event based on movement of the trigger shoe **106** coupled to the trigger assembly **104**. In an example, the trigger assembly **104** may include one or more sensors, such as an optical sensor, a Hall effect sensor, an electrical switch, or any combination thereof that can provide a signal in response to a trigger pull and/or that can be used to detect movement of the trigger shoe **106** and to communicate a signal indicating movement of the trigger shoe **106** to the controller **302** through the trigger assembly I/O interface **308**.

[0034] The memory **310** also includes trigger assembly control instructions **318** that, when executed, cause the controller **302** to selectively enable discharge of the handgun **102** when the aim point of the handgun **102** is aligned to the inferred target location corresponding to the average aim point. In an embodiment, the controller **302** may execute the trigger assembly control instructions **318** to selectively enable discharge of the handgun **102** when the aim point is within a threshold distance of the average aim point. The controller **302** may selectively enable discharge by providing a control signal to a solenoid of the trigger assembly **104**, where the solenoid is configured to block or otherwise prevent discharge of the handgun **102** until the control signal is received. The controller **302** may enable discharge by providing the control signal or by terminating the signal.

[0035] In some embodiments, the controller **302** may utilize field of view data from the sensor **301** to further refine the target selection. The memory **310** includes field of view data processing instructions **320** that, when executed, cause the controller **302** to process data received from the sensor **301**. The data may be image data, thermal data, ultrasonic data, light detection and ranging data, other data associated with the view area of the sensor **301**, or any combination thereof. In a particular example, the sensor **301** may include multiple sensors configured to capture different types of data. In one example, the field of view data processing instructions **320** may cause the controller **302** to assemble multiple single-pixel samples of a field of view to provide an image, a thermal snapshot, or two-dimensional representation of the field of view for further processing.

[0036] The memory **310** further includes shape detection instructions **322** that, when executed, cause the controller **302** to detect one or more objects within the data of the field of view. In some examples, the shape detection instructions **322** cause the controller **302** to detect regions in a set of digital data that differ in properties, such as brightness or color (image data) or intensity (thermal or acoustic data), as compared to areas surrounding those regions. In one example, the shape detection instructions **322** cause the controller **302** to identify one or more regions within a field of view of the sensor **301** in which some properties are constant or vary within a prescribed range of values, representing a shape or object within the field of view. As used herein, the term "field of view" refers to an area that is sensed by the sensor, whether the sensor is acoustic, optical, thermal, or another type of directional sensor. In one example, the shape detection instructions **322** cause the controller **302** to utilize differential methods, which are based on derivatives of a data processing function with respect to position. In another example, the shape detection instructions **322** cause the controller **302** to utilize methods based on local extreme, which are based on finding the local maxima and minima of the data processing function. In an example, the controller **302** may utilize the shape detection instructions **322** to detect boundaries of an object in the foreground or background of the field of view.

[0037] In an embodiment, the controller **302** executes the trigger pull detection instructions **316** until a trigger pull event is detected. Once a trigger pull event is detected, the controller **302** may execute the trigger assembly control instructions **318** to prevent discharge of the handgun **102** until other conditions are met. In conjunction with or simultaneous with the execution of the trigger assembly control instructions **318**, the controller **302** may execute the aim point determination instructions **312** to determine the aim point of the handgun **102** and to determine an average aim point over time. The controller **302** may also execute the auto target acquisition instructions **314** to determine an intended aim point based on the average aim point, and to control the trigger assembly **104** to prevent discharge of the handgun **102** until the current aim point of the handgun **102** is aligned to the average aim point (at least within a margin of error). In an alternative embodiment, the controller **302** may execute the aim point determination instructions **312** until the orientation data remains consistent within a threshold amount of variation for a period of time that is greater than a time threshold or until a trigger pull event is detected.

[0038] In another embodiment, in addition to determining the average aim point, the controller **302** may capture field of view data from the sensor **301** and may execute the field of view data processing instructions **322** to process the field of view data, such as by assembling multiple samples of the sensor data. In addition, the controller **302** may execute the shape detection instructions **322** to identify objects within the data from the field of view and to identify a target corresponding to the average aim point. In this example, the controller **302** may automatically acquire the target corresponding to the average aim point and may select a location on the target based on the shape detection. The controller **302** may then track the aim point of the handgun **102** using the aim point determination instructions **312** and may control the trigger assembly **104** to control the timing of discharge of the handgun **102** to prevent discharge until the aim point is aligned to the location on the target.

[0039] In the above discussion of FIGS. **1-3**, a handgun implementation of a PGF was described; however, it should be appreciated that the techniques and circuitry for automatic target acquisition may be implemented in rifles, shotguns, and other types of firearms. Further, in the above discussion, the controller may be configured to intuit a target base on an average aim point of the firearm over time as the shooter attempts to aim the firearm at a target. The controller may automatically acquire a target at a location corresponding to the average aim point. A representative example of the aim path corresponding to the changing aim point of the firearm over time and the intuited target location derived from the aim path of the firearm is described below with respect to FIG. **4**.

[0040] FIG. **4** is a diagram **400** of a representative example of a target **404** with an aim path **406** and an average aim point **408** superimposed thereon. The diagram **400** further includes a horizon **402**. The user may direct the aim point of the handgun **102** toward the target **404**. In many instances, the user may have difficulty maintaining a constant aim point, and thus the user may continuously correct the aim point over time to try to keep the aim point aimed at the target, sometimes passing back and forth across the target as represented by the aim path **406**. The controller **302** may determine the aim path **406** based on the orientation data from orientation/motion sensors **206**. The controller **302** may calculate an average aim point, such as average aim point **408** based on the orientation data over time.

[0041] While the illustrated example depicts an animal target **404**, other types of targets are also possible. In an example, the controller **302** may process the field of view data from the sensor **301** to determine foreground objects within a field of view and may select a foreground object within the field of view as a selected target based on the orientation data from orientation/motion sensors **206**. By utilizing the average aim point **408**, the controller **302** can select a target without data from sensor **301**. However, sensor **301** may be used to further refine the target selection. In particular, the controller **302** may process the field of view data to determine boundaries of the target **404**, making it possible for the controller **302** to select a target location within the boundaries of the target **404**, so that, for example, the shooter does not miss under the target, such as between the target's legs.

[0042] The illustrated example of FIG. **4** shows the changing aim path of the firearm over time. One possible example of a method of automatically acquiring a target from such an aim path is described below with respect to FIG. **5**.

[0043] FIG. **5** is a flow diagram of a method **500** of automatically acquiring a target according to an embodiment. The method **500** includes receiving orientation data corresponding to an orientation of a firearm over a period of time, at **502**.

In an embodiment, the orientation data is received by a controller from one or more orientation/motion sensors within a grip of a handgun or a butt of a rifle, for example. In an embodiment, the orientation data may be received after detection of a trigger pull event and the average aim point may be determined thereafter.

[0044] Advancing to **504**, the orientation data is processed using the circuit to determine the aim point of the firearm over time. Continuing to **506**, the controller selects a location corresponding to an average aim point as a target. The controller may determine an average aim point from the orientation data and may select the location of the average aim point as an intended target. Thus, the controller may automatically acquire a target in response to determining that the user is aiming the handgun.

[0045] Proceeding to **508**, the controller controls the trigger assembly to prevent discharge of the firearm until the aim point is aligned to the location of the average aim point. The circuit may provide a control signal to a solenoid to block discharge and/or may send an enable signal to enable discharge, depending on the implementation. In an example, the controller may allow for a margin of error, such as a distance threshold representing an acceptable margin of error or distance between the selected target location and the aim point within which the handgun can fire and still hit the target (e.g., one MOA). In an example, the average aim point may represent an area or target location, and the controller may include a distance threshold corresponding to a range or distance from the location that is within an acceptable margin of error. In a particular example, the average aim point may be larger than a bullet hole or point, and the average aim point plus the MOA error may define a target area. In an example described below with respect to FIG. **6**, the controller may determine a distance between the aim point and a selected location on a target (such as a center of the target object), and may prevent discharge until the distance is less than a threshold distance.

[0046] FIG. **6** is a flow diagram of a method **600** of automatically acquiring a target according to a second embodiment. At **602**, the controller receives orientation data corresponding to an orientation of a firearm from a plurality of sensors, such as orientation/motion sensors. Proceeding to **604**, the controller processes the orientation data over a period of time to determine an aim path of the firearm and to determine an average aim point. Continuing to **606**, the controller processes data associated with a field of view of the sensor to acquire a target at a location corresponding to the average aim point. In an example, the controller may process image, thermal, ultrasonic, reflected light, or other data to identify objects within the field of view and may select one of the objects as a target.

[0047] Advancing to **608**, the controller automatically selects a location on the target. In an example, the controller may process the field of view data to determine boundaries of an object corresponding to the average aim point of the firearm. Once the boundaries are determined, the controller may select a location on the target that is within the boundaries.

[0048] Continuing to **610**, the controller determines the current aim point of the firearm. Proceeding to **612**, if the aim point is greater than a threshold distance from the location on the target, the method **600** returns to **610** and the controller determines the current aim point of the firearm. If, at **612**, the aim point is less than the threshold distance from the location on the target, the method **600** advances to **614** and the circuit including the controller controls the trigger assembly to discharge the firearm.

[0049] It should be noted that the particular arrangement of blocks in the method of FIG. **6** may be altered without departing from the teachings of the present disclosure. For example, the method **600** may be initiated by detection of a trigger pull. Further, blocks **604** and **606** may be executed in a different order or substantially simultaneously. In one example, the sensor **301** and the orientation/motion sensor **206** are activated by the controller **302** in response to detection of a trigger pull. Further, other steps may also be added without departing from the spirit of the disclosure.

[0050] FIG. **7** is a block diagram of a control system **700** including a circuit **112** configured to select a target based on a flash light detection and ranging (LiDAR) circuit **712** according to an embodiment. Control system **700** includes all of the elements of control system **300** in FIG. **3**. Further, control system **700** includes flash LiDAR circuit **712** coupled to I/O interfaces **304**. In an embodiment, the flash LiDAR circuit **712** may be part of the circuit **112**. Further, memory **310** includes foreground target detection instructions **706** that, when executed by controller **302** (which may be a processor), causes controller **302** to utilized flash LiDAR circuit **712** to illuminate a view area, receive reflected light, and detect one or more foreground objects within the view area. In an embodiment, target detection instructions **706** may be in addition to or may include shape detection instructions **322** in FIG. **3**.

[0051] Controller **302** may utilize aim point determination instructions **312** and auto target acquisition instructions to automatically select one of the foreground objects within the view area as a target. Controller **302** may then control timing of discharge of the firearm based on the trigger assembly control instructions **318** to prevent discharge until the aim point of the firearm is aligned to the selected target.

[0052] While the illustrated example uses a flash LiDAR circuit **712** to detect a target object within a view area of the firearm, it is also possible to use one or more cameras to detect foreground objects within the view area. In one possible example, the camera may be a single-pixel camera that captures images of the view area for processing by the controller **302** to detect objects. In another example, two or more cameras may be used to provide a parallax implementation configured to detect foreground objects based on differences in the position of the objects in the images from the two or more cameras.

[0053] In conjunction with the circuits, systems, and methods described above with respect to FIGS. **1-7**, a precision guided firearm is described that includes one or more orientation/motion sensors configured to produce orientation data corresponding to an orientation of a firearm, and includes a controller coupled to the orientation/motion sensors. The controller is configured to automatically acquire a target based on the orientation data. In one embodiment, the controller is configured detect an average aim point over a period of time and to automatically select a target corresponding to an average aim point. In another embodiment, the controller may be coupled to one or more sensors configured to capture data associated with a view area, such as a thermal sensor, one or more optical sensors, a flash LiDAR circuit, or other types of sensors. The controller may automatically select a target in the view area based on the data from the sensor. The controller may be coupled to a trigger assembly and may be configured to control the trigger assembly to prevent discharge of the handgun until the current aim point of the firearm (as determined from the orientation/motion data) is aligned to the selected target and the trigger shoe is pulled.

[0054] In accordance with various embodiments, the methods described herein may be implemented as one or more software programs running on a computer processor or controller. Dedicated hardware implementations including, but not limited to, application specific integrated circuits, programmable logic arrays, and other hardware devices can likewise be constructed to implement the methods described herein. Further, the methods described herein may be implemented as a computer readable storage medium or device including instructions that when executed cause a processor to perform the methods.

[0055] The illustrations, examples, and embodiments described herein are intended to provide a general understanding of the structure of various embodiments. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other embodiments may be apparent to those of skill in the art upon reviewing the disclosure. Other embodiments may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. Moreover, although specific embodiments have been illustrated and described herein, it should be appreciated that any subsequent arrangement designed to achieve the same or similar purpose may be substituted for the specific embodiments shown.

[0056] This disclosure is intended to cover any and all subsequent adaptations or variations of various embodiments. Combinations of the above examples, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the description. Additionally, the illustrations are merely representational and may not be drawn to scale. Certain proportions within the illustrations may be exaggerated, while other proportions may be reduced. Accordingly, the disclosure and the figures are to be regarded as illustrative and not restrictive.

What is claimed is:

1. A precision guided firearm comprising:

a sensor configured to capture orientation data associated with a firearm; and

a controller coupled to the sensor and configured to detect an aiming event and to automatically acquire a target location within location based on the orientation data in response to detecting the aiming event.

2. The precision guided firearm of claim **1**, wherein:

the sensor comprises an orientation/motion sensor configured to capture the orientation data to determine an aim path of the firearm over time; and

the controller is configured to determine an average aim point of the firearm and to automatically select the target location based on the average aim point.

3. The precision guided firearm of claim **1**, further comprising:

a trigger assembly coupled to the controller; and

wherein the controller is configured to control the trigger assembly to selectively enable discharge when an aim point of the firearm is aligned to the target location.

4. The precision guided firearm of claim **3**, wherein:

the controller defines a threshold error relative to the average aim point; and

the controller selectively discharge when a difference between the aim point of the firearm and the target location is less than the threshold error.

5. The precision guided firearm of claim **3**, wherein:

the controller detects a trigger pull based on signals received from the trigger assembly; and

the controller processes the orientation data in response to detecting the trigger pull.

6. The precision guided firearm of claim **1**, wherein the controller detects the aiming event when variation of the aim point is less than a threshold variation for a period of time.

7. The precision guided firearm of claim **1**, further comprising:

an optical sensor coupled to the controller and configured to capture optical data associated with a field of view including the aim point; and

wherein the controller is configured to determine boundaries of an object in the optical data that corresponds to the average aim point and to refine the target location to an adjusted location within the boundaries of the object.

8. The precision guided firearm of claim **7**, wherein the optical sensor comprises a single pixel camera configured to capture image data corresponding to the view area.

9. The precision guided firearm of claim **1**, further comprising:

a thermal sensor coupled to the controller and configured to capture thermal data corresponding to the view area of the firearm; and

wherein the controller is configured to process the thermal data to detect a foreground object corresponding to the average aim point and to refine the target location to an adjusted location at a center of the foreground object.

10. The precision guided firearm of claim **1**, further comprising:

a flash light detection and ranging circuit coupled to the controller and configured to illuminate a view area and to detect foreground objects within the view area based on reflected light; and

wherein the controller is configured to refine the target location to an adjusted location at a center of one of the foreground objects that corresponds to the target location.

11. The precision guided firearm of claim **1**, further comprising:

at least one camera configured to capture two different views of a view area of the firearm; and

a controller configured to process the two different views to detect at least one foreground object within the view area based on relative displacement of the object within the images and to automatically refine the target location to a center of the foreground object.

12. A firearm comprising:

a sensor circuit configured to capture orientation data corresponding to an orientation of a firearm;

a controller coupled to the sensor circuit, the controller configured to automatically select a target location in response to the orientation data.

13. The firearm of claim **12**, wherein the controller is configured to detect an aiming event based on the orientation data over time.

14. The firearm of claim **13**, wherein the controller is configured to determine an average aim point from the orientation data and to automatically select the average aim point as the target location in response to detecting the aiming event.

15. The firearm of claim **12**, further comprising:

a trigger assembly coupled to the controller; and

wherein the controller is configured to determine an aim point of the firearm based on the orientation data and to control the trigger assembly to selectively enable discharge when the aim point is aligned to the target location.

16. The firearm of claim **12**, wherein:

the sensor circuit further includes at least one of a camera and an optical ranging circuit configured to capture light associated with a view area of the firearm, and

the controller is configured to adjust the target location based on the captured light.

17. A method of automatically acquiring a target for a firearm, the method comprising:

receiving orientation data from a sensor circuit corresponding to an orientation of the firearm; and

automatically selecting a target location based on the orientation data using a controller.

18. The method of claim **17**, wherein automatically selecting the target location comprises:

processing the orientation data to determine an average aim point of the firearm over a period of time; and

selecting the target within the view area in response to determining the average aim point.

19. The method of claim **17**, further comprising detecting an aiming event when the orientation data changes by less than a threshold amount for a period of time that exceeds a time threshold.

20. The method of claim **17**, further comprising:

detecting a trigger pull event; and

selectively enabling a trigger assembly of a firearm in response to the trigger pull event when the orientation data indicates that a difference between the aim point and the target location is less than a threshold error.

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