

GEOMETRICALLY PAIRED LIVE INSTRUMENTATION TRAINING HAND GRENADE

[0001] This application claims the benefit of and is a non-provisional of co-pending US Provisional Application Serial Nos. 63/104,204 and 63/104,206 both filed on October 22, 2020,
5 which are both hereby expressly incorporated by reference in their entirety for all purposes.

[0002] This application expressly incorporates by reference US Application Serial No. 17/508,631, filed on October 22, 2021, entitled "AUTOMATED EQUIPMENT ASSOCIATION SYSTEM", in its entirety for all purposes.

BACKGROUND

10 [0003] This disclosure relates in general to battlefield simulation systems and, but not by way of limitation, to training munitions.

[0004] Conventional systems for simulating hand grenade threat effect simulation utilize laser and short-range radio to determine an affected area of the grenade blast. However, such solutions present problems that reduce the realism of the simulation. For example, laser relies on
15 line of sight, and as a result is unrealistically blocked by items (e.g. foliage, furniture, lightweight street scape, etc.) that would have limited and/or no effect on an operational grenade effect. For example, a thin plastic sheet can shield a laser detector from a laser emitted by a simulated grenade blast, but a blast from a real grenade would not be shielded by such a sheet of plastic. Short-range radio operates in a non-line of sight manner, which mitigates some disadvantages
20 associated with the use of lasers. However, the radio media has the unrealistic effect of diffracting (bending) around a surface and/or reflecting off adjacent surfaces resulting in a simulated effect onto an entity where an operational grenade would have had no effect. For example, one or more soldiers in a concrete-walled corridor can throw grenade(s) around the door into a room. While an operational grenade blast would not affect those soldiers, an RF
25 simulated threat effect is likely to, as the RF signal can bend and/or reflect off a surface to reach an RF detector worn by the soldier. Additionally, existing training grenades can be difficult to find after deployment.

SUMMARY

[0005] In one embodiment, the present disclosure provides method and apparatus for simulating a hand grenade in a training environment. The hand grenade includes dead reckoning to determine location after leaving a thrower. By knowing a location of the thrower and subsequent path after leaving the thrower, the explosion location and simulated damage to targets can be determined. The simulation can determine the effect of obstructions between the explosion location and nearby targets.

[0006] In another embodiment, a method of operating a simulated hand grenade is disclosed. A first location of deployment of the simulated hand grenade is determined. A second location of a simulated explosion of the simulated hand grenade is determined using dead reckoning. An explosion effect of the simulated explosion for a target within an explosion area of the simulated hand grenade is determined. The explosion effect is communicated to the target.

[0007] In another embodiment, a method of operating a simulated hand grenade is disclosed. A location of deployment of the simulated hand grenade is determined. A flight path of the simulated hand grenade is determined upon deployment. It is determined that a fuse duration of the simulated hand grenade has expired. An explosion location of the simulated hand grenade is identified after the fuse duration has expired. The explosion location being identified based at least in part on the location of deployment and the flight path. The explosion location is sent away from the simulated hand grenade for subsequent determination of an explosion result of the simulated hand grenade.

[0008] In another embodiment, a simulated hand grenade is disclosed that includes a trigger mechanism, an arming mechanism, a dead reckoning function, a communication interface, and a processing unit. The trigger mechanism that, when engaged, configures to activate a fuse timing mechanism. The arming mechanism that, when engaged, configures to maintain the trigger mechanism in a safety state in which the trigger mechanism cannot be engaged and, when disengaged, configures to place the trigger mechanism into a live state in which the trigger mechanism is engageable. The processing unit that is configured to:

- detect a location of deployment of the simulated hand grenade;
- determine a flight path of the simulated hand grenade upon deployment;
- determine that a fuse duration of the simulated hand grenade has expired;

- identify an explosion location of the simulated hand grenade after the fuse duration has expired, the explosion location being identified based at least in part on the location of deployment and the flight path; and
 - provide the explosion location to a remote computing system for subsequent
- 5 determination of an explosion result of the simulated hand grenade.

[0009] Further areas of applicability of the present disclosure will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating various embodiments, are intended for purposes of illustration only and are not intended to necessarily limit the scope of the disclosure.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present disclosure is described in conjunction with the appended figures:

FIG. 1 depicts a block diagram of an embodiment of operation of a simulated hand grenade;

FIG. 2 depicts a block diagram of an embodiment of a simulated hand grenade;

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FIG. 3 depicts a block diagram of an embodiment of a wireless module;

FIG. 4 illustrates a flowchart of an embodiment of a process for an association process for establishing a connection between a wireless module and other wireless modules and/or a grenade based on authorization;

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FIG. 5 illustrates a flowchart of an embodiment of a process for operating simulated hand grenade; and

FIG. 6 illustrates a flowchart of an embodiment of a process for simulated hand grenade deployment.

[0011] In the appended figures, similar components and/or features may have the same reference label. Where the reference label is used in the specification, the description is applicable to any

25 one of the similar components having the same reference label.

DETAILED DESCRIPTION

[0012] The ensuing description provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the disclosure. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling description for implementing a preferred exemplary embodiment. It is understood that various changes can be made in the function and arrangement of elements without departing from the spirit and scope as set forth in the appended claims.

[0013] Embodiments described herein are generally related to a system and method to improve fidelity of live ground simulation of hand grenade effect or other similar training munitions. In particular, some embodiments of the disclosure incorporate dead reckoning systems into simulated hand grenades, permitting the simulated hand grenade to determine the location at which a simulated detonation occurs. This location can be provided to another computing device, such as a host computer that is running a combat simulation remotely, in real-time, permitting the computing device to evaluate a result of the detonation based on knowledge of entities and their surroundings that are proximate to the simulated explosion (e.g., whether the detonation has an impact on one or more people or objects within an explosion radius of the simulated hand grenade). By permitting the computing device to analyze the effects of the explosion based on a known location of the simulated grenade, line of sight and RF diffraction/reflection issues associated with earlier systems can be eliminated. While discussed primarily in the context of simulated hand grenades for combat training purposes, alternative embodiments can vary from the embodiments discussed herein, and alternative applications can exist (e.g., tracking other thrown projectiles, such as sporting equipment).

[0014] To geometrically determine the location of the simulated explosion, embodiments of the disclosure use a known starting location and a determined travel path after release by a user to calculate a final location of the simulated grenade at the time of the simulated explosion. In particular, embodiments utilize the grenade thrower's location at the time of the release of the simulated grenade and a travel path of the simulated grenade between the pin/spoon release and simulated fuse timeout to determine a location of the simulated explosion. In some embodiments, the travel path of the simulated grenade can be determined based on

measurements from an inertial measurement unit (IMU) that is integrated into the simulated grenade. Such solutions permit for an accurate real-time determination of the location of the explosion of a simulated grenade to be made, without the need to know anything about the thrower, other than the location at which the thrower released the simulated grenade. This
5 differs from other projectile weapon simulations, which typically also include a launch platform attitude (bearing, elevation), such as the direction and position at which a barrel of a mortar or gun is aimed at when fired.

[0015] Embodiments can geometrically pair (thrower, grenade, target(s), etc.) without using attitude of deployment method (i.e., bearing or elevation of thrower/deployment platform).
10 Embodiments also permit a definition of grenade explosion location to be provided, even in the absence of an entity hit report. Embodiments further provide the ability to quickly recover grenade, as the grenade's actual location (in grass/corner/under equipment, etc.) is communicated to a remote computing device that can provide coordinates of the grenade, a display of where the grenade is, and/or output that can indicate an exact location of the grenade
15 once deployed. Additionally, embodiments provide the ability to reuse the same training grenade that is used during combat simulation exercises to teach correct throw technique by analyzing the path. This is due to the ability to measure the path of an arcing throw, from release through to fly out, to determine a final location of the simulated grenade. The path and location can all be measured, enabling detailed feedback to be provided to the trainee.

20 [0016] Referring initially to **FIG. 1**, the operation of a simulated hand grenade 102 according to one embodiment is shown. Here, a user 100 deploys a simulated hand grenade 102, such as by throwing the hand grenade 102. To throw the hand grenade 102, the user 100 must first remove a pin that permits an arming mechanism, such as a spoon, to be maneuvered into an engaged state, such as by the user 100 releasing the arming mechanism. Upon the user 100
25 releasing the hand grenade 102, the arming mechanism is engaged, which causes a communications interface of the hand grenade 102 to communicate with a wireless module 103 worn by the user 100. The wireless module 103 can communicate a location of the user 100, allowing the hand grenade 102 to know a starting position of its flight path. The hand grenade 102 can then track its flight path (which can involve bouncing and/or rolling against one or more

surfaces). The flight path tracking can be done using a dead reckoning system. In some embodiments, the dead reckoning system can include an IMU that is integrated into the electronics of the simulated hand grenade 102.

5 [0017] In addition to the determination of the starting location and flight path 124 of the hand grenade 102, the release of the hand grenade 102 (and engagement of the arming mechanism) also initiates a timer that simulates a fuse of the hand grenade 102, which has a preset duration. Upon the expiration of the fuse duration, the hand grenade 102 can determine its present location, which is the location of a simulated explosion 120, based on the starting location and the flight path 124 up until the expiration of the duration. As illustrated, the hand grenade 102
10 has come to rest between several exposed users 104. Also nearby are several protected users 106, who are positioned behind an armored vehicle 112 or some other obstruction such as a rock or reinforced wall.

[0018] The hand grenade 102 can communicate the location of the simulated explosion to one or more remote devices. For example, in some embodiments, the location of the explosion can
15 be communicated (such as via an RF signal) to each of the wireless modules 103 on users 100, 104, 106 and/or equipment 112 (e.g., armored car) within a blast radius 128 of the simulated explosion 120. One or more individual wireless modules 103 are mounted on each of the users 100, 104, 106 and/or equipment 112 communicate individually using personal area networks (PAN), local area networks (LAN) and wide area networks (WAN). In other embodiments, the
20 location of the explosion can be communicated to a host computer 114, such as a computer or server farm that is controlling the combat exercise by way of a LAN or WAN. In such embodiments, the host computer 114 can evaluate a pairing of an explosion effect to the targets (e.g., users and/or objects proximate the blast radius). The evaluation can involve the host computer 114 utilizing knowledge about the effects of the particular type of hand grenade 102
25 (fragmentary, flash, stun, gas, etc.), along with location information associated with the individual target, and/or knowledge of the environment/terrain proximate the blast radius of the location of the explosion. For example, for a fragmentary grenade 102, the host computer 114 can be programmed to determine that an exposed human target can be “killed” if within a five-meter unobstructed radius of the location of the explosion and can be injured in some manner if

within about a ten-meter radius of the location of the explosion. The host computer 114 can also factor in environment information, and thus can know that protected users 106, while possibly within one of the damage radii outlined above, are protected by the armored vehicle 112 or other obstruction. This permits the host computer 114 to determine that protected users 106 are safe from harm and/or should be subject to reduced injuries based on their shielded state. Similarly, the host computer 114 knows that unshielded users 104 can be deemed to be killed or injured based on their respective positions relative to the location of the explosion. The resulting explosion effects can then be communicated back to the wireless modules of the affected parties (e.g., users, vehicles, structures, etc.) to provide a realistic simulation experience.

10 **[0019]** Referring next to **FIG. 2**, a block diagram of a simulated grenade 102 or be any projectile munition used in training simulations. Grenade 102 can include a housing 202 that is sized and shaped like a live grenade. The hand grenade 102 can further include an arming mechanism 204 and an arming mechanism 206 that are provided on and/or otherwise affixed to the housing 202. For example, the arming mechanism 204 is a sensor that detects the presence of a pin that is configured to be removed and/or otherwise disengaged from the housing 202. When engaged with the housing 202, the arming mechanism 204 maintains the arming mechanism 206 in a safety state, in which the arming mechanism 206 cannot be engaged. Once the arming mechanism 204 is disengaged, the arming mechanism 206 can be switched from the safety state to a live state in which the arming mechanism 206 can be engaged. The arming mechanism 206 can include a sensor to detect the presence, movement and/or absence of a spoon and/or other feature that can be actuated to engage a fuse timing mechanism 208. For example, a user can release the spoon to activate the hand grenade 102 and start the fuse timing mechanism 208 that counts down for a predetermined duration.

25 **[0020]** This embodiment includes a battery 220 to power the hand grenade 102. The battery 220 be charged through a port, wirelessly, and/or energy harvesting (e.g., solar). A hanging clip on the throwing user 100 could integrate the charging cable or wireless charger. When connected to either, the pairing to the PAN, LAN and/or WAN can be performed to permit communication to and from the hand grenade 102.

5 [0021] Embodiments can optionally include a tracking tag 224 associated with an indoor tracking system as location determination is commonly most accurate outdoors. The tracking tags 224 can use ultra-wide band (UWB) technology to determine location of the hand grenade 102 and/or wireless modules 103. Indoor beacons can be used with the tracking tag to allow indoor trilateration of location for the wireless modules 103 and/or tracking tag 224. In any event, the location of the hand grenade 102 prior to throwing is known throughout the training environment

10 [0022] The hand grenade 102 includes dead reckoning functionality in an inertial measurement unit (IMU) 212. Additionally, the IMU 212 can determine the surroundings while in movement using LIDAR, radar, ultrasonic, and/or camera sensors to develop a point cloud or other simulated reconstruction of the blast radius 128. Reconstruction information can be shared with wireless modules 103 to distribute the task of building an accurate simulation of the actual environment. Pattern recognition and machine learning can be used to estimate how the various obstructions would react to the simulated explosion 120.

15 [0023] The throwing technique of the user 100 can also be evaluated by the IMU 212. Use of hand grenades 102 entails recording of training including the throwing style, accuracy and distance for later evaluation of how each grenade simulation was done. The processing unit 214 stores this information for later analysis. Automated suggestions can be provided in real-time during the simulation to provide the user 100 timely feedback, for example, “grenade missed target”, “at that distance throw underhanded”, “use more force to reach that distance”, etc.

20 [0024] The hand grenade 102 can also include a communications interface 210, such as one or more RF antennae or laser / light communication sensors. The communications interface 210 can be armed, such as upon engagement of the arming mechanism 204, to communicate with the wireless modules 103 affixed to the person throwing the hand grenade 102 to retrieve position information of the user, and thereby the starting location of the hand grenade 102. For example, the communications interface 210 can poll and/or otherwise request the location from the IMU 212. In other embodiments, the hand grenade 102 can be passive without independent location determining functionality and can receive a location that is determined from an IMU 212 within the wireless modules 103. The hand grenade 102 is paired with the wireless modules 103 of a

PAN for the thrower using Bluetooth™ Low Energy, Zigbee™, LoWPAN™, WiFi, IrDA™, NFC, and/or any other short-range communication medium.

- 5 [0025] As the arming mechanism 204 is released, the IMU 212 can also be triggered to start detecting movement (the flight path 124) of the hand grenade 102, which can include a flight path 124, as well as any bouncing and/or rolling against objects during the countdown of the fuse timing mechanism 208. In some embodiments, the IMU 212 can include a dead reckoning device, which can include an accelerometer, magnetometer, digital compass, gyroscope, pressure sensor, and/or other sensors that enable the IMU 212 to track movement of the hand grenade 102 after deployment.
- 10 [0026] Once the fuse duration of the fuse timing mechanism 208 expires, the hand grenade 102 can determine its absolute position. This can be done using a processing unit 214, which can take the starting location from the communications interface 210 and the flight path as determined by the IMU 212 and use this information to calculate a position of the hand grenade 102 at the time of detonation. Once the detonation position is determined, the communications
- 15 interface 210 can send the location to a remote computing system, such as a host computer 114, for subsequent determination of a result of the explosion (such as whether any targets and/or friendlies were harmed by the simulated explosion). In other embodiments, the communications interface 210 can communicate a signal of the detonation to one or more sensors (such as RF and/or laser detection sensors worn by users and/or positioned on vehicles) that are in a blast
- 20 radius of the hand grenade 102. For example, the hand grenade 102 can transmit a detonation location to the target(s), which can evaluate their proximity (line of sight along with any obstructions from terrain and/or infrastructure) and resulting pairing and casualty / damage assessment (explosion result).
- [0027] In some embodiments, the hand grenade 102 can also include a detonation emitter 216
- 25 that can include a visual and/or audio emitter. For example, pyrotechnics, light elements, and/or speaker devices can be included in the detonation emitter 216 that allow for an audio and/or visual effect that can be triggered upon the expiration of the fuse timer. A piezo emitter, speaker, LED strobe or light, can be used for the detonation emitter 216. This permits the hand grenade 102 to more realistically simulate a real live grenade, while still providing a safe, reliable, and

reusable form factor. Additionally, not only does sending the detonation location allow the host computer 114 to evaluate explosion results, the detonation location allows the hand grenade 102 to be easily retrieved after completion of the training exercise. The detonation location along with any updates can be communicated with users 100, 104, 106 locally to allow one of them to easily retrieve the hand grenade 102. Where the hand grenade 102 communicates directly with wireless modules 103 for users 100, 104, 106 and/or equipment 112 within a blast radius 128 of the simulated explosion 120, it allows localized calculation in any of these devices of the resulting casualty / damage outcome to distribute evaluation of the hand grenade 102 effect. Some embodiments do not have a host computer 114 to distribute the simulation computing or as a backup when the host computer 114 is unavailable or excessively delayed.

[0028] The hand grenade 102 and/or the wireless modules 103 could have terrain and infrastructure information to simulate locally the resulting outcome without use of the remote host computer 114. Lidar, radar, sonic, camera, and/or other sensors in the hand grenade 102 and or wireless modules 103 could develop a point cloud of the environment along with an estimation of how the simulated explosion 120 would propagate in consideration of obstructions in the blast radius 128. For example, a cinder block wall can provide better cover than a tent wall. Pattern recognition could be used to tell the difference between various obstructions. For example, a camera or Lidar sensor on the hand grenade 102 could capture scene information in flight or as it rolled or bounced on the floor.

[0029] For retrieval, the communication interface receives a remote command to activate the detonation emitter 216 to permit easily finding it. Additionally, the location is known by either dead reckoning or through a location determining circuit in the IMU 212. The circuitry of the detonation emitter 216 could emit sounds and/or light to aid in quickly finding the hand grenade 102. Some embodiments could include a vibration transducer in the detonation emitter 216 for activation with the simulated explosion 120 or during recovery efforts.

[0030] With reference to **FIG. 3**, a block diagram of an embodiment of the wireless module 103 is shown. The wireless module 103 is attached to a part of a platform that can include other similar wireless modules 103. The platform can be a human body 100, 104, 106, a vehicle 112 such as a truck, combat system, transit system, warship, etc. The wireless module 103 is

configured to identify movements of the wireless module 103 and correlate the movements with the movements of other wireless modules 103 and the platform on which it is attached. The wireless module 103 includes a processing unit 214, an inertial measurement unit (IMU) 212 a laser detector 328, an Infrared radiation (IR) interface 338, a communications interface 210, a
5 battery/power supply 220, and a solar supply 342.

[0031] The processing unit 214 controls poll initiation, profile detection, correlation, and authorization. The processing unit 214 can include one or more processors, such as one or more special-purpose processors (such as digital signal processing chips, graphics acceleration processors, and/or the like), one or more input devices 330, and one or more output devices 332.
10 The processing unit 214 includes a data cache 334 that can include instructions and/or rules that are used by the processing unit 214 to establish PANs. For example, the data cache 334 can include gait information and/or other movement information such as vehicle acceleration, orientation, deceleration, and/or turning profiles that permit the processing unit 214 to properly determine whether a set of one or more other wireless modules 103 are attached to a same body
15 or platform. The processing unit 214 further includes a poll initiator 304, a profile detector 306, a correlator 308, an authorizer 310, a network organizer 312, and a network interface 336.

[0032] The poll initiator 304 performs a search for the wireless modules 103. The poll initiator 304 performs a network polling mode of the wireless modules 103. The network polling mode is initiated using the network interface 336. In an embodiment, the network polling includes the
20 wireless module 103 detecting a light source, such as a modulated laser.

[0033] The network interface 336 is a communication interface, which can include without limitation, a modem, a network card (wireless or wired), an infrared communication device, a wireless communication interface and/or chipset, and/or similar communication interfaces. The network interface 336 can permit data (such as movement data) to be exchanged with a network,
25 other computer systems, and/or any other devices. The network interface 336 can also be used to establish and communicate via the PANs.

[0034] The network interface 336 in the field communicates using the communications interface 210. Wireless protocols include Bluetooth™, IEEE 802.15.4, Zigbee, IEEE 802.11

(Wi-Fi), IEEE 802.16 (WiMAX), near-field communication (NFC), cellular, other short-range communications, etc.

5 **[0035]** The IR interface 338 is a communications interface, which includes an infrared communication using Infrared Data Association (IrDA) or other protocols. The IR interface 338 provides the infrared communication in the PAN or with devices seeking adoption.

[0036] The battery/power supply 220 provides power to the components of the wireless module 103 such as the processing unit 214, the laser detector 328, and the IMU 212. The battery/power supply 220 includes physical battery, and subsequent power supply. In some configurations, the wireless modules 103 is hardwired to the platform to avoid need for a battery.

10 **[0037]** The solar supply 342 is the energy harvesting component of the wireless module 103. The solar supply 342 is used to provide solar energy or other renewable source of energy to the processing unit 214, the laser detector 328, and the IMU 212 as an alternative source of energy. Where solar is not currently available, the battery 220 can provide power perhaps charged earlier with solar.

15 **[0038]** The profile detector 306 determines the device profile of the wireless modules 103. The device profile includes two or more of an orientation of the wireless modules 103, the movement, acceleration, and timing associated with the wireless modules 103. The profile detector 306 also determines profiles such as movement, orientation, acceleration, and timing profiles of the platform on which the wireless module 103 is attached to or associated with. The
20 profiles also include pressure profiles or gait information associated with the platform.

[0039] The IMU 212 determines movement of the detected wireless module 103. The IMU 212 provides the processing unit 214 with movement data associated with the wireless module 103. For example, the IMU 212 can include a gyroscope 316, accelerometer 318, magnetometer 320, pressure sensor 322, GPS module 324, a digital compass 326, tracking tag 224, and/or other
25 sensors. The IMU 212 can provide information from these sensors to the processing unit 214 such that the processing unit 214 can identify other wireless modules 103 having similar movement profiles. The processing unit 214 can then determine that these wireless modules 103

are on a same platform and can establish a personal area network with the various wireless modules 103.

5 [0040] The hand grenade 102 includes a IMU 212 that can not include a GPS module 324 as could a wireless module 103. Where the GPS module 324 is missing, non-functional or powered down, the location of the hand grenade 102 or wireless module 103 can determine its location inferentially from another wireless module 103 on the same platform and PAN and nearby. The separation can be corrected for by the processing unit 214. Between synchronizations or when separated, dead reckoning can be used, for example when the hand grenade 102 is thrown. Dead reckoning can be calculated by the processing unit 214 using readings from the gyroscope 316, 10 accelerometer 318, magnetometer 320, and/or digital compass 326.

[0041] The correlator 308 receives the movement of the detected wireless modules 103 and other wireless modules 103. The correlator 308 compares the movement of the wireless modules 103 and other wireless modules 103. Based on the comparison of the movement of the wireless modules 103, the correlator 308 further compares the device profile of the detected wireless 15 module 103 with the profiles of the platform on which the wireless module 103 is attached to or associated with. The profiles include movement over time profile, acceleration profile, pressure profile and/or gait information associated with the platform. The correlation is provided to the authorizer 310 for processing.

20 [0042] The authorizer 310 validates the detected wireless module 103 for connecting with the other wireless modules 103 in a network based on the correlation. When it is determined that the detected wireless module 103 is placed on the same platform and is in correlation with the other wireless modules 103, then the detected wireless module 103 is authorized for connection. The authorization is necessary for the wireless modules 103 to connect.

25 [0043] The network organizer 312 establishes a PAN based on the authorization. The network organizer 312 establishes a network when the detected wireless module 103 correlates with the other wireless modules 103 and is associated with the same platform.

[0044] The wireless module 103 includes the laser detector 328 configured to detect a particular wavelength of light associated with an object such that the laser detector 328 can

determine when the wireless module 103 has been hit by the object. US MILES™ is one of several protocols that can be received.

5 [0045] Additional components of the wireless module 103 include a laser transmitter (not shown) with US MILES being one of several protocols that can be transmitted. Inclusion of the laser transmitter in the communication interface 210 gives bidirectional laser communication to the wireless module 103. The wireless module 103 can also include a precision orientation module (not shown) which senses weapon orientation, as next generation replacement for laser. Inclusion of the precision orientation module makes the wireless module-a weapon simulator.

10 [0046] Referring next to **FIG. 4**, a flowchart of an association process 400 for establishing a connection between a wireless module 103 and other wireless modules 103 and/or a hand grenade 102 based on authorization is shown, according to an embodiment of the present disclosure. For establishing an automatic association between several wireless modules 103 and/or hand grenades 102, an authorization of the wireless module 103 or hand grenade 102 based on the correlation is performed. The depicted portion of the association process 400 starts at block 402 where a network polling for the wireless module 103 or hand grenade 102 is initiated. Several wireless modules 103 within a predetermined distance from the unpaired wireless module 103 or hand grenade 102 are identified.

20 [0047] At block 404, based on the network polling, at least one additional wireless module 103 or hand grenade 102 is identified. The at least one additional wireless module 103 or hand grenade 102 being other than the unpaired wireless module 103. The wireless modules 103 or hand grenade 102 are attached on a same platform which is identified based on the correlation of movements of the wireless modules 103 and/or hand grenades 102 all experience.

25 [0048] At block 406, movements of the wireless modules 103 and/or hand grenades 102 are identified. The movements are identified for correlation to identify association between the wireless modules 103 and/or hand grenades 102. The movements correspond with the location, orientation, heading, pressure, acceleration, and/or timing of the wireless modules 103 or hand grenades 102 on the platform.

5 [0049] At block 408, the correlation between the unpaired wireless module 103 or hand grenade 102, and the others is identified. If there is a correlation between the wireless module 103 or hand grenade 102 and the others, then the correlation with the platform is identified at block 410. Else, at block 416, the unpaired wireless modules 103-1 are unauthenticated at block 416 if there is no correlation between the unpaired wireless module 103 or hand grenade 102 and others on the same PAN.

10 [0050] At block 410, the correlation of the wireless module 103 or hand grenade 102 with the profiles of the platform is identified. For example, the wireless module 103 or hand grenade 102 can be placed on a human body. Then the wireless module 103 or hand grenade 102 is correlated with a location of placement on the human body 100 along with the other wireless modules 103 or hand grenades 102. If it is determined that all the wireless modules 103 or hand grenades 102 are on the same platform then, at block 412, the unpaired wireless module 103 or hand grenade 102 is authorized for connection with the others, or else, at block 418, the wireless module 103 or hand grenade 102 is unauthorized and the correlation is considered a false positive and pairing to the PAN is reversed.

[0051] At block 414, based on the authorization of the wireless module 103 or hand grenade 102, the PAN is established between all the wireless modules 103 and hand grenades 102. The wireless modules 103 and/or hand grenades 102 all start communicating with each other and an association between the wireless modules 103 and hand grenades 102 is established.

20 [0052] The network polling continues to identify wireless modules 103 and hand grenades 102. The determination of whether the PAN includes nodes that are not on the platform enables the PAN to be reestablished to include the wireless modules 103 and hand grenades 102 that are determined to be on the same platform. Each platform can develop its own PAN with multiple wireless modules 103 and/or hand grenades 102 in this way. Communication between different PANs can occur by way of a LAN or WAN connection by one or more wireless modules 103 in each PAN.

[0053] With reference to **FIG. 5**, a flowchart of a process 500 for operating simulated hand grenade is shown. Process 500 can be performed by a computing device, such as host computer

114, that is controlling a combat exercise. Process 500 can begin at block 502 by determining a location of a simulated explosion 120 of a simulated hand grenade 102. In some embodiments this can be done by receiving a position of the simulated hand grenade 102 (which can calculate this position as described above) at a time of expiration of a fuse duration of the simulated hand
5 grenade 102, possibly via an RF signal. In other embodiments, determining the location can include determining that a fuse duration of the simulated hand grenade 102 has expired and/or receiving a location of deployment and a flight path 124 from the simulated hand grenade 102. The computing device can then determine the location based on the starting location and the flight path 124. In yet other embodiments, determining the location of the explosion can include
10 receiving signals from a plurality of sensors that have detected the simulated hand grenade 102 at a time of expiration of a fuse duration of the simulated hand grenade 102 and calculating the location of the simulated explosion 120 based on the signals from the plurality of sensors. For example, an RF tracking tag 224 can be incorporated into the hand grenade 102 and can be in communication with one or more beacons. The beacon signals can be used to triangulate and/or
15 otherwise determine a location of the hand grenade 102. In some embodiments, optical sensors, such as cameras and/or IR sensors that can track a location of the hand grenade 102 and transmit a location to the host computer 114. It will be appreciated that any combination of the above tracking techniques can be combined to track the location of a simulated hand grenade 102.

[0054] At block 504, the computing device can evaluate an explosion effect of the simulated
20 explosion 120 for one or more users 100, 104, 106 within a blast radius 128 (an explosion area) of the simulated hand grenade 102. For example, the computing device or host computer 114 can utilize positions of one or more targets 104, 106, 112 (which can be provided by the targets themselves) and/or knowledge about the environment (buildings, land, vehicles, trees, other structures, etc.) and the like. For example, in building simulations, the buildings and/or other
25 structures can be effectively modeled by the host computer 114, allowing for complex analysis of the explosion result based on how the structure would impact (e.g., at least partially protect) any of the targets. This data can be used to determine whether a target 104, 106 is hit, killed, injured, damaged, protected, etc. In some embodiments, the explosion effect can be based at least in part on a status of the user 100 who deployed the hand grenade 102. For example, if the
30 user 100 is marked as killed and/or has a simulated injury that would prevent the user 100 from

deploying the hand grenade in real combat, the computing device 114 can disregard the deployment of the hand grenade 102. In other instances, the user 100 can be injured and/or killed attempting to deploy the hand grenade 102. In such instances, the computing device 114 can determine that the simulated explosion 120 is at the location of the user 100, as if the user
5 100 had dropped the hand grenade 102 upon being shot, rather than at the actual location of the deployed hand grenade 102 or alternatively, not simulate the explosive effect. In instances in which the user 100 is deemed healthy and/or otherwise capable of deploying the hand grenade 102, the explosion effect can be simulated normally.

[0055] At block 506, the computing device 114 can communicate the explosion effect to the
10 one or more entities (i.e., users / platforms). This can include sending a signal to a wireless modules 103 of a user 104, 106 and/or vehicle 112 that indicates that the entity (such as a target and/or friendly or user that deployed the hand grenade) was harmed, killed, unscathed, and/or otherwise affected by the detonation. In some embodiments, it will be appreciated that some of all of the exercise simulation control can be integrated into user equipment, such as laser
15 detection sensors, rather than a centralized combat exercise control computer 114. For example, wireless modules 103 can simulate explosive effect with a model that includes the detonation location and any obstructions. Data from the hand grenade 102 and/or wireless devices 103 can be shared among each other to distribute the computational load among the nearby wireless devices 103 in communication with each other without use of a computing device 114.

20 [0056] Referring next to **FIG. 6**, a flowchart 600 for an embodiment of the hand grenade 102 deployment is shown. The depicted portion of the process begins in block 604 where the training grenade 102 is paired to the platform, which is a user 100 in this case. The hand grenade 102 joins the user's PAN with one or more wireless modules 103 in block 608. In block 612, the user activates the hand grenade 102 by pulling the arming mechanism 204 (for example, pin) and
25 triggering the timer by releasing the spoon 206. Even if the hand grenade 102 has no native location determining circuit, location can be determined implicitly by receiving location information from a wireless module 103 on the same platform / user. A correction can be made by estimating range and direction of separation between the hand grenade and the location from the wireless module 103.

[0057] As the hand grenade travels from the user 100 to where the timer expires, dead reckoning within the hand grenade calculates the travel in block 616 before a detonation location is determined in block 620. Telemetry from the hand grenade 102 including the detonation location is reported over any wireless networks such as PANs or a LAN in block 624. The hand
5 grenade 102 can include LIDAR scanning without any moving parts to develop a point cloud in flight. Some embodiments can use a camera in the hand grenade 102 to develop the point cloud. The simulated effect can be modeled on a computing device 114 or in a distributed fashion using one or more wireless modules 103 in block 628. Some embodiments could use other troop mounted computing devices for the simulation or even handheld tablets or smartphones. In
10 block 632, the effect determined in the simulation is communicated to nearby wireless modules 103 so that they can react accordingly to disable or impede the user in the training exercise and/or stimulate audio/visual effects (such as augmented or mixed reality overlay) at target and observer entities.

[0058] Specific details are given in the above description to provide a thorough understanding
15 of the embodiments. However, it is understood that the embodiments can be practiced without these specific details. For example, circuits can be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques can be shown without unnecessary detail in order to avoid obscuring the embodiments.

[0059] Also, it is noted that the embodiments can be described as a process which is depicted
20 as a flowchart, a flow diagram, a swim diagram, a data flow diagram, a structure diagram, or a block diagram. Although a depiction can describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations can be re-arranged. A process is terminated when its operations are completed, but
25 could have additional steps not included in the figure. A process can correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

[0060] For a firmware and/or software implementation, the methodologies can be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. Any machine-readable medium tangibly embodying instructions can be used in implementing the methodologies described herein. For example, software codes can be stored in a memory.

5 Memory can be implemented within the processor or external to the processor. As used herein the term “memory” refers to any type of long term, short term, volatile, nonvolatile, or other storage medium and is not to be limited to any particular type of memory or number of memories, or type of media upon which memory is stored.

[0061] In the embodiments described above, for the purposes of illustration, processes can have been described in a particular order. It should be appreciated that in alternate embodiments, the methods can be performed in a different order than that described. It should also be appreciated that the methods and/or system components described above can be performed by hardware and/or software components (including integrated circuits, processing units, and the like), or can be embodied in sequences of machine-readable, or computer-readable, instructions, which can be used to cause a machine, such as a general-purpose or special-purpose processor or logic circuits programmed with the instructions to perform the methods. Moreover, as disclosed herein, the term "storage medium" can represent one or more memories for storing data, including read only memory (ROM), random access memory (RAM), magnetic RAM, core memory, magnetic disk storage mediums, optical storage mediums, flash memory devices and/or other machine readable mediums for storing information. The term "machine-readable medium" includes, but is not limited to portable or fixed storage devices, optical storage devices, and/or various other storage mediums capable of storing that contain or carry instruction(s) and/or data. These machine-readable instructions can be stored on one or more machine-readable mediums, such as CD-ROMs or other type of optical disks, solid-state drives, tape cartridges, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, flash memory, or other types of machine-readable mediums suitable for storing electronic instructions. Alternatively, the methods can be performed by a combination of hardware and software.

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[0062] Implementation of the techniques, blocks, steps and means described above can be done in various ways. For example, these techniques, blocks, steps and means can be implemented in hardware, software, or a combination thereof. For a digital hardware

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implementation, the processing units can be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to
5 perform the functions described above, and/or a combination thereof. For analog circuits, they can be implemented with discrete components or using monolithic microwave integrated circuit (MMIC), radio frequency integrated circuit (RFIC), and/or micro electro-mechanical systems (MEMS) technologies.

[0063] Furthermore, embodiments can be implemented by hardware, software, scripting
10 languages, firmware, middleware, microcode, hardware description languages, and/or any combination thereof. When implemented in software, firmware, middleware, scripting language, and/or microcode, the program code or code segments to perform the necessary tasks can be stored in a machine readable medium such as a storage medium. A code segment or machine-executable instruction can represent a procedure, a function, a subprogram, a program, a routine,
15 a subroutine, a module, a software package, a script, a class, or any combination of instructions, data structures, and/or program statements. A code segment can be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, and/or memory contents. Information, arguments, parameters, data, etc. can be passed, forwarded, or transmitted via any suitable means including memory sharing, message
20 passing, token passing, network transmission, etc.

[0064] The methods, systems, devices, graphs, and tables discussed herein are examples. Various configurations can omit, substitute, or add various procedures or components as appropriate. For instance, in alternative configurations, the methods can be performed in an order different from that described, and/or various stages can be added, omitted, and/or
25 combined. Also, features described with respect to certain configurations can be combined in various other configurations. Different aspects and elements of the configurations can be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims. Additionally, the techniques

discussed herein can provide differing results with different types of context awareness classifiers.

[0065] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly or conventionally understood. As used herein, the articles “a” and “an” refer to one or to more than one (i.e., to at least one) of the grammatical object of the article. By way of example, “an element” means one element or more than one element. “About” and/or “approximately” as used herein when referring to a measurable value such as an amount, a temporal duration, and the like, encompasses variations of $\pm 20\%$ or $\pm 10\%$, $\pm 5\%$, or $+0.1\%$ from the specified value, as such variations are appropriate to in the context of the systems, devices, circuits, methods, and other implementations described herein. “Substantially” as used herein when referring to a measurable value such as an amount, a temporal duration, a physical attribute (such as frequency), and the like, also encompasses variations of $\pm 20\%$ or $\pm 10\%$, $\pm 5\%$, or $+0.1\%$ from the specified value, as such variations are appropriate to in the context of the systems, devices, circuits, methods, and other implementations described herein.

[0066] As used herein, including in the claims, “and” as used in a list of items prefaced by “at least one of” or “one or more of” indicates that any combination of the listed items can be used. For example, a list of “at least one of A, B, and C” includes any of the combinations A or B or C or AB or AC or BC and/or ABC (i.e., A and B and C). Furthermore, to the extent more than one occurrence or use of the items A, B, or C is possible, multiple uses of A, B, and/or C can form part of the contemplated combinations. For example, a list of “at least one of A, B, and C” can also include AA, AAB, AAA, BB, etc.

[0067] While illustrative and presently preferred embodiments of the disclosed systems, methods, and machine-readable media have been described in detail herein, it is to be understood that the inventive concepts can be otherwise variously embodied and employed, and that the appended claims are intended to be construed to include such variations, except as limited by the prior art. While the principles of the disclosure have been described above in connection with specific apparatuses and methods, it is to be clearly understood that this description is made only by way of example and not as limitation on the scope of the disclosure.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of operating a simulated hand grenade, comprising:
determining a first location of deployment of the simulated hand grenade;
5 determining a second location of a simulated explosion of the simulated hand
grenade using dead reckoning;
evaluating an explosion effect of the simulated explosion for a target within an
explosion area of the simulated hand grenade; and
communicating the explosion effect to the target.
- 10 2. The method of operating the simulated hand grenade of claim 1, further
comprising:
determining that a fuse duration of the simulated hand grenade has expired; and
receiving a location of deployment and a flight path from the simulated hand
grenade, wherein determining the second location of the simulated explosion is based on the first
15 location of deployment and the flight path.
3. The method of operating the simulated hand grenade of claim 1, wherein:
determining the second location of the simulated explosion comprises receiving a
position of the simulated hand grenade at a time of expiration of a fuse duration of the simulated
hand grenade.
- 20 4. The method of operating the simulated hand grenade of claim 1, wherein:
determining the second location of the simulated explosion comprises:
receiving signals from a plurality of sensors that have detected the simulated hand
grenade at a time of expiration of a fuse duration of the simulated hand grenade; and
calculating the second location of the simulated explosion based on the signals
25 from the plurality of sensors.

5. The method of operating the simulated hand grenade of claim 1, further comprising:
receiving location information from a troop-mounted device attached to a thrower.
- 5 6. The method of operating the simulated hand grenade of claim 1, wherein:
the explosion effect is evaluated based on whether the target is at least partially obstructed from the second location of the simulated explosion.
7. The method of operating the simulated hand grenade of claim 1, wherein:
the explosion effect is evaluated based on information about an area proximate the
10 second location of the simulated explosion.
8. The method of operating the simulated hand grenade of claim 1, wherein:
the explosion effect is based on a status of a user who deployed the simulated hand grenade.
9. The method of operating the simulated hand grenade of claim 1, wherein:
15 a trigger mechanism is engaged by a thrower releasing a spoon of the simulated hand grenade.
10. A method of operating a simulated hand grenade, comprising:
detecting a location of deployment of the simulated hand grenade;
determining a flight path of the simulated hand grenade upon deployment;
20 determining that a fuse duration of the simulated hand grenade has expired;
identifying an explosion location of the simulated hand grenade after the fuse duration has expired, the explosion location being identified based at least in part on the location of deployment and the flight path; and
sending the explosion location away from the simulated hand grenade for
25 subsequent determination of an explosion result of the simulated hand grenade.
11. The method of operating the simulated hand grenade of claim 10, wherein:

detecting the location of deployment comprises receiving a position of a user of the simulated hand grenade from one or more sensors associated with the user.

12. The method of operating the simulated hand grenade of claim 10, wherein: the flight path is determined using an inertial measurement unit.

5 13. The method of operating the simulated hand grenade of claim 10, wherein: a computing device within a blast radius of the simulated hand grenade determines the explosion location.

14. The method of operating the simulated hand grenade of claim 10, wherein: detecting the location of deployment and determining the flight path of the
10 simulated hand grenade are initiated based on engagement of an arming mechanism.

15. A simulated hand grenade, comprising:
a trigger mechanism that, when engaged, is configured to activate a fuse timing mechanism;

an arming mechanism that, when engaged, is configured to maintain the trigger
15 mechanism in a safety state in which the trigger mechanism cannot be engaged and, when disengaged, is configured to place the trigger mechanism into a live state in which the trigger mechanism is engageable;

a dead reckoning function;

a communications interface; and

20 a processing unit that is configured to:

detect a location of deployment of the simulated hand grenade;

determine a flight path of the simulated hand grenade upon deployment;

determine that a fuse duration of the simulated hand grenade has expired;

25 identify an explosion location of the simulated hand grenade after the fuse duration has expired, the explosion location being identified based at least in part on the location of deployment and the flight path; and

provide the explosion location to a remote computing system for subsequent determination of an explosion result of the simulated hand grenade.

16. The simulated hand grenade of claim 15, wherein:
the dead reckoning function comprises an inertial measurement unit.

17. The simulated hand grenade of claim 15, wherein:
the arming mechanism comprises a pin that is disengageable from the simulated
5 hand grenade.

18. The simulated hand grenade of claim 15, wherein:
the trigger mechanism is engaged by a user releasing a spoon of the simulated
hand grenade.

19. The simulated hand grenade of claim 15, wherein:
the deployment comprises a time and position at which the arming mechanism is
10 engaged.

20. The simulated hand grenade of claim 15, wherein:
the location of deployment is detected based on a position of a user of the
simulated hand grenade received from one or more sensors associated with the user.