LIGHT BASED PROJECTILE DETECTION SYSTEM FOR A VIRTUAL FIREARMS TRAINING SIMULATOR

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims priority from co-pending U.S. Provisional Application Serial No. 61/162,498, filed on March 23, 2009, said application being relied upon and incorporated herein by reference.

FIELD OF INVENTION

[0002] The present invention relates to a system and method for determining the actual coordinates of a projectile impact in a screen and associating the point of impact with a firearms training simulation.

BACKGROUND OF THE INVENTION

[0003] A typical virtual firearms training simulator uses simulated weapons that do not fire real bullets to train students on the proper handling of a weapon during a simulated real life scenario. The training scenario includes a video, digital animation, or other virtual scenario of one or more situations requiring the user to react quickly and decisively, such as a hostage scenario, terrorist attack, or general malfeasance. This scenario is projected onto a screen using a video projector, with

the scenario being controlled by a simulation computer that also detects the point of aim at the instance the student pulls the trigger of the simulated weapon. The simulated weapon is equipped with either an invisible or visible laser that "fires" a laser pulse when the trigger is pulled. A camera, in electrical communication with the simulation computer, detects this pulse of light, and transmits the impact coordinates to the simulation computer. The simulation computer then determines the location of the hit relative to the scenario being broadcast by matching the coordinate system of the camera to the coordinate system of the projected image or target.

[0004] A drawback to this system is that the simulated weapon operated by the user often simply generates a laser pulse to imitate the firing of the weapon, which does not produce a realistic experience for the user. That is, the simulated weapon typically does not have the feel of an actual firearm, and often does not produce recoil action, or produces unrealistic recoil action for the user, such that the simulation lacks credibility for the user. Consequently, trainees that are not used to extensive target practice with live firearms may be disadvantaged when required to handle firearms in combat situations.

[0005] A variant of this virtual firearms training simulator is one that detects real bullets fired from an actual live weapon. Since a bullet is not a pulse of light, the camera detection method described above may not seem practical to use. Rather,

several alternative detection methods have been developed as an add-on to an existing simulator's laser detection system. They include detection of the visual image of the bullet as it passes an array of sensors, detection of the heat signature of the bullet as it penetrates the screen, detection of the acoustical waves generated by the bullet as it passes an array of acoustic sensors, or detection of the hole that the bullet makes when penetrating a screen material such as paper. While all of these methods may work to some degree, none of them are performed within desired parameters, such as at a low financial cost and having a high degree of accuracy.

BRIEF SUMMARY OF THE INVENTION

[0006] A light based projectile detection system for a firearm and a virtual firearms training simulator is described herein. The light based projectile detection system includes a self-sealing screen having a proximal side and a distal side. A scenario projector transmits a simulation onto the proximal side, and a light source (such as a flash) faces the distal side. The light source selectively projects light onto the distal side of the screen when the firearm is shot, such that light from the source traverses the screen after contact by a projectile. A camera monitors the light traversing the aperture created by the projectile to determine and associate the position of impact and transmit that information to a scenario computer.

[0007] The system may include an audio detection circuit to monitor the sound generated by the firearm and transmit a signal to a flash controller to cause the light source to illuminate. The screen will then re-seal around the hole so that the light no longer traverses the screen.

[0008] The system may additionally include a housing to support the screen, with the light source surrounded by the housing and screen to control the distribution of light from said light source. In such an embodiment, a reflective panel (such as paper with foil on one side) may be mounted in said housing diagonally, with the light source positioned between the reflective panel and the screen. This arrangement will project light directly onto the distal side of the screen as well as onto the reflector panel, which will assist in evenly projecting light on the distal side of the screen.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a block diagram of the light based projectile detection system for a virtual firearms training simulator;

[0010] Figure 2 is a second block diagram of the light based projectile detection system for a virtual firearms training simulator of Figure 1, the diagram showing the impact of a projectile with a screen; and

[0011] Figure 3 is a perspective view of the screen and light assembly incorporated into the system illustrated in Figures 1 and 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Referring to Figures 1-3, a light based projectile detection system **10** is illustrated. The light based projectile detection system **10** is able to monitor the impact of a projectile **18** fired by an actual firearm **16** on a self-sealing screen **14** using a laser detection system **12** similar to those described above and as used in a typical laser-based virtual firearms training simulator known in the art.

[0013] More specifically, the laser detection system **12** includes a scenario projector **20** and a camera **22** that are both in electrical communication with a simulation or hit detect computer **24**. The projector **20** may include any type of image-generating device, and receives a simulation scenario from the hit detect computer **24**. The projector **20** will then broadcast that scenario on one or more self-sealing screens **14**. In contrast, the camera **22** monitors the self-healing screen **14** for a light or laser pulse, which will correspond to the point of impact of the projectile **18** fired in during the simulation projected on the screen **14**. That is, the laser detection system **12** will monitor the actual live fire of the weapon **16** to determine the impact position of a fired projectile **18**, such as a bullet or slug, through the screen **14** during simulation scenarios projected on the screen **14**.

Once the light pulse is detected, the camera **22** will transmit the coordinates of the impact to the hit detect computer **24**. The computer **24** includes software that will be able to compute the impact coordinate relative to predetermined screen coordinates relative to the projected target.

[0014] To leverage the laser detection system **12** to determine the bullet position of impact on the screen **14**, the bullet **18** must generate a pulse of light at the specific location **L1** where the bullet **18** impacts the screen **14** after being fired by the weapon **16**. To generate this pulse of light, the projection screen **14** of the bullet detection system **10** is made of a self-healing elastomeric material, such as a natural gum rubber or other similar substance known in the art. The screen **14** has a proximal side **14p** and an opposite distal side **14d**. The proximal side **14p** faces and is closest to the laser detection system **12**, while the distal side **14d** opposite the proximal side **14p** faces and is closest to a light source **26**. The light source **26** outputs wavelengths of light **28** that can be detected by the same camera **22**.

[0015] When a projectile **18** penetrates the surface of the screen **14** at location **L1** (see Figure 1), it will create a hole **H1** at the location **L1** that creates a light valve to allow light **28** to travel through the screen **14** (see Figure 2). After a period of time, the self-healing material of the screen **14** will re-seal the hole **H1** so that the camera **22** will no longer monitor any light **28** through the screen **14**. As a result, the brief exposure of light **28** through the light valve **H1** in the screen **14**

will simulate a light pulse. Because the temporary hole **H1** is the position **L1** of the bullet **18** at impact, the accuracy for monitoring the light through the light valve **H1** by the camera **22** is the same as the laser pulse detection (as described above). Any calibration algorithm used by the hit detect computer **24** to match the coordinate system of the camera **22** to the coordinate system of the projected simulation of the hit detect computer **24** as projected by projector **20** may be used in the present system; that is, the calibration algorithm used by the simulation hit detect computer **24** to match the coordinate system of the camera **22** to the coordinate system of the projected simulation of the hit detect computer **24** will remain the same whether one uses a laser pulse in prior simulation systems or shoots a real bullet **18** in the training scenario of the present system.

[0016] A prototype of the design integrated with typical virtual small arms training simulator is illustrated in Figure 1. This prototype was tested for accuracy in matching the contact of the bullet **18** with the scenario, and the results were accurate within 1 to 3 mm, which is very similar to the laser-based system. It was determined the best way to get the most amount of light **28** for the camera **22** to detect the bullet **18** passing through the screen was to use a xenon flash **26** facing the distal side **14d** of the screen **14** that is selectively illuminated instead of a continuous light source. A xenon flash was selected for its desirable properties in light intensity while generating relatively lower heat. As a result, a flash triggering

system **30** is connected to the light source **26** to ensure proper timing of the light **28** with the firing event of the weapon **16**.

[0017] The flash triggering system **30** includes an audio detection circuit **32** in electrical communication with a flash/trigger controller **34**. The audio detection circuit **32** may be any known in the art, such as a circuit including a microphone for converting audio energy (sound waves) into an electrical signal. Similarly, the flash/trigger controller **34** may be a conventional microcontroller that is in electrical communication with the audio detection circuit **32** and the light source **26**. The audio detection circuit **32** is positioned somewhat near the weapon **16**, and detects the sound associated when the weapon **16** is initially shot. The audio detection circuit **32** thereby transmits a signal to the flash controller **34** corresponding to the timing of the weapon **16** being fired.

[0018] The flash controller **34**, which is in electrical communication with the light source **26**, will use the signal transmitted from the audio detection circuit **32** to further send a signal triggering a bank of facing the distal side **14d** of the screen **14**. The xenon flash bulbs **26** will therefore be illuminated at the approximate time when the bullet **18** penetrates through the self-healing rubber front surface **14p**. This is accomplished by having the controller **34** turn the flash bulbs **26** on after a pre-determined time delay to ensure the camera **22** will detect or view the light **28** while there is a bullet hole **H1** in the screen **14**. This time delay will vary

depending on the speed of the bullet **18** used and the distance that the firearm **16** is from the screen **14**.

[0019] Looking to Figure 3, the screen **14** may be mounted in a housing or frame **36** (one side of the housing **36** is removed to view the screen **14**). The housing **36** and screen **14** define a casing that surrounds the light source **26**, such that the housing **36** and screen **14** will contain all light produced by light source **26** until the screen **14** is pierced by a bullet **18**. Although the present rectangular housing **36** is illustrated, other frames may be implemented for the housing **36** as desired by the user. Furthermore, a reflector panel **38** may be diagonally mounted within the housing **36** above the light source **26**, such that the light source **26** is positioned between the reflector panel **38** and the screen **14**. The reflector panel **38** may be made of a sheet of paper with foil on a side nearest the light source **26** or some other similar material that has a high reflectivity to effectively reflect and distribute the light produced by the light source **26**. The light source **26** will therefore project light directly onto the screen **14** as well as onto the reflector panel **38** to project light evenly on the distal side **14d** of the screen **14**.

[0020] As noted above, a prototype using xenon flash bulbs **26** was developed and tested to work as expected with accuracy to be within 1 to 3 mm.

[0021] Without knowing the properties of the rubber screen **14** (such as the stretch or hardness), an assumption is made that there is a finite amount of time

before the screen **14** will re-seal itself (return back to its original shape) depending on the distance and failure point of the stretch in the screen **14**. A further assumption of a worst case condition is that the re-seal time is zero (that is, that the screen **14** is a perfect material that reseals instantly). In other words, the screen **14** is sealed as soon as the bullet or slug **18** passes through the screen **14**. It is also assumed that the only time "light" **28** is allowed through the screen **14** is while the slug **18** is penetrating the screen **18** (i.e., the initial hole **H1** that the slug **18** makes is bigger than the slug **18** to allow this light **28** to come through as the slug **18** is passing through.) To determine how much light **28** is directly related to the speed of the slug **18** and how long the "light valve" is left on (that is, how long light passes through the screen **14** before it reseals), the following equation should be used:

[0022] Light valve on time = [(length of slug + thickness of screen + distance the screen stretch before initial penetration) / speed of slug] + [resealing time once the slug **18** passes], the following measurements are determined.

[0023] Assuming that the minimum distance of stretch in the screen **14** is half of the diameter of the slug **18** (but is most likely more) and is dependant of speed of the slug **18** and material property of the screen **14**, 5 mm as the screen thickness, 0 sec for the resealing time once the slug passes (this is somewhat dependant on how

far the material is stretched and the screen material property), the following calculations are made:

[0024] A typical spec for a 9mm NATO ball is: Speed of slug range from 950 ft/s to 1300 ft/s with a slug length of 0.610" or 15.5mm.

[0025] A typical specification for a 5.56 mm, ball is: Speed of slug is 3250 ft/s with the slug length of 19.3 mm to 23mm.

[0026] So minimum light valve on time for a 9 mm slug is (15.5 + 5 + 4.5)/(1300*304.8) = 63.1 μsec, and the minimum light valve on time for a 5.56 mm is (19.3 + 5 + 2.28)/(3250*304.8) = 26.8 μsec.

[0027] In a charged coupled device (CCD) in the camera **22** for capturing images, there is a photoactive region (an epitaxial layer of silicon), and a transmission region made out of a shift register. An image is projected by a lens on the capacitor array (the photoactive region), causing each capacitor to accumulate an electric charge proportional to the light intensity at that location. The exposure time for the light valve **H1** is calculated at a minimum from 26.8 to 63.1 μsec (based on the calculations for the above-noted assumptions). Consequently, it is possible to detect the charge if the intensity is large enough using the CCD sensor as long as the noise level in the CCD sensor is not larger than the charge. Since this is really an absolute minimum in an ideally perfect

situation, the actual time the light valve **H1** will be open will be greater, if not significantly greater.

[0028] In addition, there is a blanking time between the shifting of data out of the register where the CCD sensor cannot accumulate charges. This blanking needs to be as small as possible. The current camera **22** has about a 2 msec blank time. This is more of a function determined by the camera manufacturer. For example, the current camera **22** being evaluated for the system **10** has a blank time between frames of 35 μsec out of the box and can be adjusted even lower.

[0029] The calculations support the theory that the capabilities of CCD sensor can allow it to detect a bullet slug **18** traveling through a re-sealable rubber screen **14** with a back-lit light source **26**.

[0030] The design above was initially tested using a rubber live fire screen as a proof of concept, some incandescent light bulbs, a standard 100 D-P (small arms virtual system) with the standard hit camera **22** and a filter (an infrared filter used to monitor the desired light) and a TV monitor. The back side or distal side **14d** of the screen **14** was lit using about two 100W light bulbs, with the rear rubber screen removed so that only the front rubber screen was separating the light **26** and the shooter. The hit camera **22** was pointed on the screen **14** as usual and the TV monitor connected to "see" the output of the hit camera **22**. The design was tested with both 9 mm and 5.56 mm rounds **18**. In all cases, the users were able to

visually see the light **28** come through the screen **14** momentarily before the screen **14** would reseal after the slug **18** passed through.

[0031] The 5.56 slug **18** did leave a pinhole and did not completely reseal like the 9 mm slug **18**. A small piece of the screen **14** had been torn off from the back or distal side **14d** when the 5.56 mm slug **18** was shot, which did not occur with the 9 mm. A momentary faint blurry light appeared on the TV monitor indicating where the slug **18** went through the screen **14**, which showed that detection is possible and, with the right combination of filters, camera, screen material, and lighting source, it is possible to design a system to detect the brief pulse of light **28** caused by the penetration of the bullet slug **18**.

[0032] A high speed camera **22** was also used to determine the approximate on time of the material (how long the light valve **H1** appears to be open) once a 9 mm slug has penetrated the screen **18**. The frame rate of the camera **22** was approximately 8000 frames per sec. The hole **H1** appeared to be open for at least 4 frames or 4/8000 or 0.5 msec which is more 9 times longer than calculated for the worst case scenario. These test results further demonstrated that the proposed device will operate as desired.

[0033] Having thus described exemplary embodiments of a LIGHT BASED PROJECTILE DETECTION SYSTEM FOR A VIRTUAL FIREARMS TRAINING SIMULATOR, it should be noted by those skilled in the art that the

within disclosures are exemplary only and that various other alternatives, adaptations, and modifications may be made within the scope of this disclosure. Accordingly, the invention is not limited to the specific embodiments as illustrated herein, but is only limited by the following claims.

CLAIMS

What is claimed is:

1. A light based projectile detection system for use with a firearm firing a projectile and a virtual firearms training simulator having a scenario projector, a camera, and a scenario computer, said projectile detection system comprising:

a self-sealing screen having a proximal side and a distal side, the scenario projector transmitting a simulation onto said proximal side; and

a light source facing said distal side of said screen to selectively project light onto said distal side of said screen;

wherein light from said light source traverses said self-sealing screen to be monitored by the camera at the point of contact of the projectile with said self-sealing screen.

2. The projectile detection system as described in claim 1, further comprising:

an audio detection circuit positioned proximate the firearm, said audio detection circuit having a microphone to monitor the sound of the firing of the firearm; and

a flash controller in electrical communication with said audio detection circuit and said light source to illuminate said light source corresponding to the firing of the firearm.

3. The projectile detection system as described in claim 1 further comprising a housing supporting said screen, said housing controlling the distribution of light from said light source proximate said screen.

4. The projectile detection system as described in claim 3 wherein said light source includes a xenon flash.

5. The projectile detection system as described in claim 3 further comprising a reflective panel mounted in said housing, said light source positioned between said reflective panel and said screen.

6. A training system to detect impact coordinates of one or more projectiles fired by one or more firearms, the system comprising:

a self-sealing screen having a proximal side and a distal side;

a light source facing said distal side of said screen to selectively project light onto said distal side of said screen;

a simulation computer generating a simulation;

a projector in electrical communication with said computer, said projector broadcasting a simulation on said proximal side of said screen;

a camera in electrical communication with said computer to detect a light pulse on said screen;

wherein light from said light source traverses said self-sealing screen to be monitored by said camera at the point of contact of the projectile with said self-sealing screen upon impact of the projectile through said screen.

7. The training system as described in claim 6 further comprising:

means for generating a signal corresponding to the firing of the firearm; and

means for controlling the illumination of said light source corresponding to said signal.

8. The training system as described in claim 7 wherein said signal generating means comprises an audio detection circuit positioned proximate the firearm, said audio detection circuit including a microphone to monitor the sound of the firing of the firearm.

9. The training system as described in claim 7 wherein said control means comprises a flash controller in electrical communication with said audio detection circuit and said light source to illuminate said light source corresponding to the signal generated by said audio detection circuit.

10. The training system as described in claim 7 further comprising a housing supporting said screen, said housing controlling the distribution of light from said light source proximate said screen.

11. The training system as described in claim 10 further comprising a reflective panel mounted in said housing, said light source positioned between said reflective panel and said screen.

12. The training system as described in claim 7 wherein said light source comprises a xenon flash.

13. A method for determining the position of impact on a target of a projectile launched by a firearm, said method comprising the steps of:

a) providing a self-sealing screen having a proximal side and a distal side;

b) generating the target on the proximal side of said screen using a projector in electrical communication with a simulation computer;

c) monitoring the proximal side of the screen for a light pulse with a camera in electrical communication with said simulation computer;

d) selectively illuminating said distal side of said screen with a light source;

e) generating a light pulse in said screen with said light source when the projectile traverses said screen; and

f) registering the point of contact of the projectile with said screen with said camera connected to said simulation computer.

14. The method as described in claim 13 wherein step d) further comprises the steps of:

generating a signal corresponding to the discharge of the projectile from the firearm; and

transmitting said signal to said light source to selectively illuminate said distal side of said screen.

15. The method as described in claim 14 further comprising the step of monitoring the sound of the discharge of the firearm using a audio detection circuit.

16. The method as described in claim 13 further comprising the step of:

supporting said screen and said light source in a housing to control the distribution of light from said light source proximate said screen.

17. The method as described in claim 16 further comprising the step of:

distributing light from said light source along said distal side of said screen with a reflective panel mounted in said housing, said light source positioned between said reflective panel and said screen.

18. The projectile detection system as described in claim 13 further comprising the step of:

providing a xenon flash for said light source.