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Stellenberg

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(45) **Date of Patent: Mar. 28, 2017**

(54) **PINBALL MACHINE WITH ANIMATED PLAYFIELD COMPONENTS AND AUTOMATIC LEVEL DETECTION**

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(73) Assignee: **Multimorphic Inc.**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 233 days.

(21) Appl. No.: **13/933,590**

(22) Filed: **Jul. 2, 2013**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 13/734,151, filed on Jan. 4, 2013, which is a continuation-in-part of application No. 13/777,865, filed on Feb. 26, 2013.

(60) Provisional application No. 61/632,002, filed on Jan. 17, 2012, provisional application No. 61/632,749, filed on Jan. 31, 2012, provisional application No. 61/633,559, filed on Feb. 14, 2012, provisional

(Continued)

(51) **Int. Cl.**

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G07F 17/32	(2006.01)
A63F 9/24	(2006.01)

(52) **U.S. Cl.**

CPC ***A63F 7/027*** (2013.01); ***G07F 17/323*** (2013.01); ***G07F 17/3211*** (2013.01); ***G07F 17/3216*** (2013.01); *A63F 2009/246* (2013.01); *A63F 2009/2442* (2013.01); *G07F 17/3297* (2013.01)

(58) **Field of Classification Search**

CPC A63F 9/24; G06F 19/00

USPC .... 463/1, 20; 273/118 R, 121 A

See application file for complete search history.

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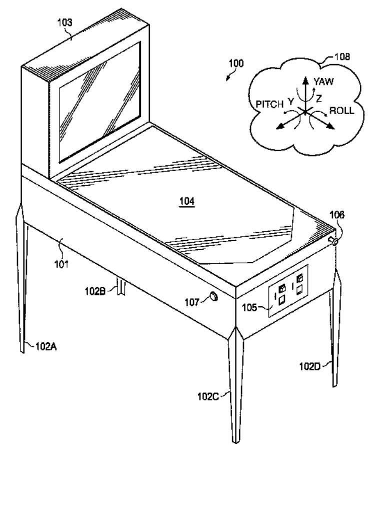
Assistant Examiner — Ankit Doshi
(74) *Attorney, Agent, or Firm* — Boisbrun Hofman, PLLC

(57) **ABSTRACT**

Pinball machines with animated playfield components and automatic level detection are described. In an illustrative, non-limiting embodiment, a method may include changing a visual appearance of a surface of a physical object within a pinball machine, the physical object configured to physically interact with a pinball during a pinball game. In another illustrative, non-limiting embodiment, a pinball machine may be configured to receive leveling information detected by one or more accelerometers, the leveling information selected from the group consisting of: pitch, roll, and yaw. In yet another illustrative, non-limiting embodiment, a pinball machine may be configured to periodically or continuously receive leveling information detected by one or more accelerometers during a pinball game, and then discourage the player from applying force to the pinball machine in response to the leveling information meeting a value and/or encourage a player to apply force to the pinball machine.

14 Claims, 17 Drawing Sheets



Related U.S. Application Data

application No. 61/634,352, filed on Feb. 28, 2012, provisional application No. 61/685,588, filed on Mar. 21, 2012, provisional application No. 61/685,644, filed on Mar. 22, 2012, provisional application No. 61/690,711, filed on Jul. 3, 2012, provisional application No. 61/741,126, filed on Jul. 13, 2012.

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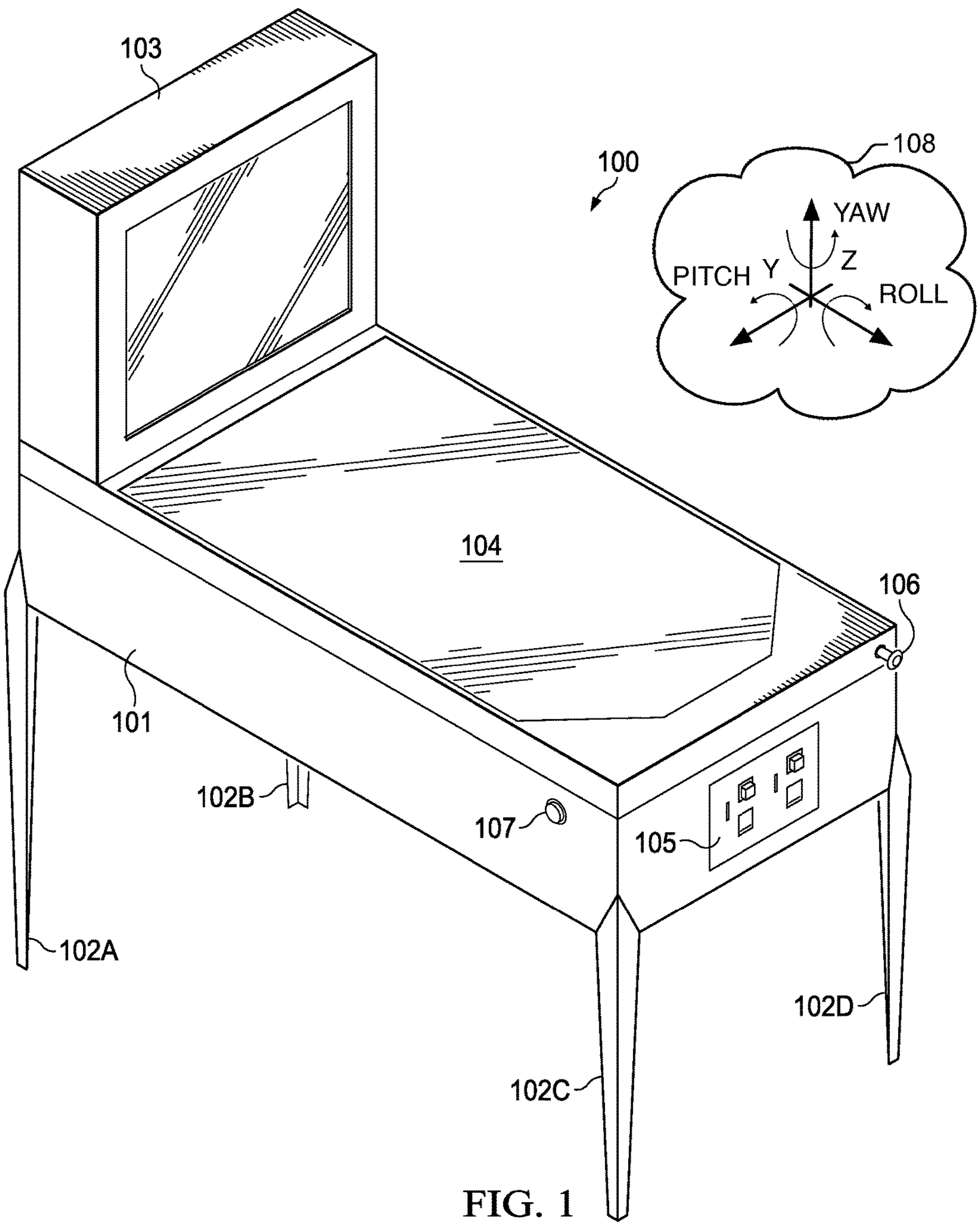

103
100
108
YAW
Z
Y
PITCH
ROLL
104
106
101
102B
107
105
102A
102D
102C

FIG. 1

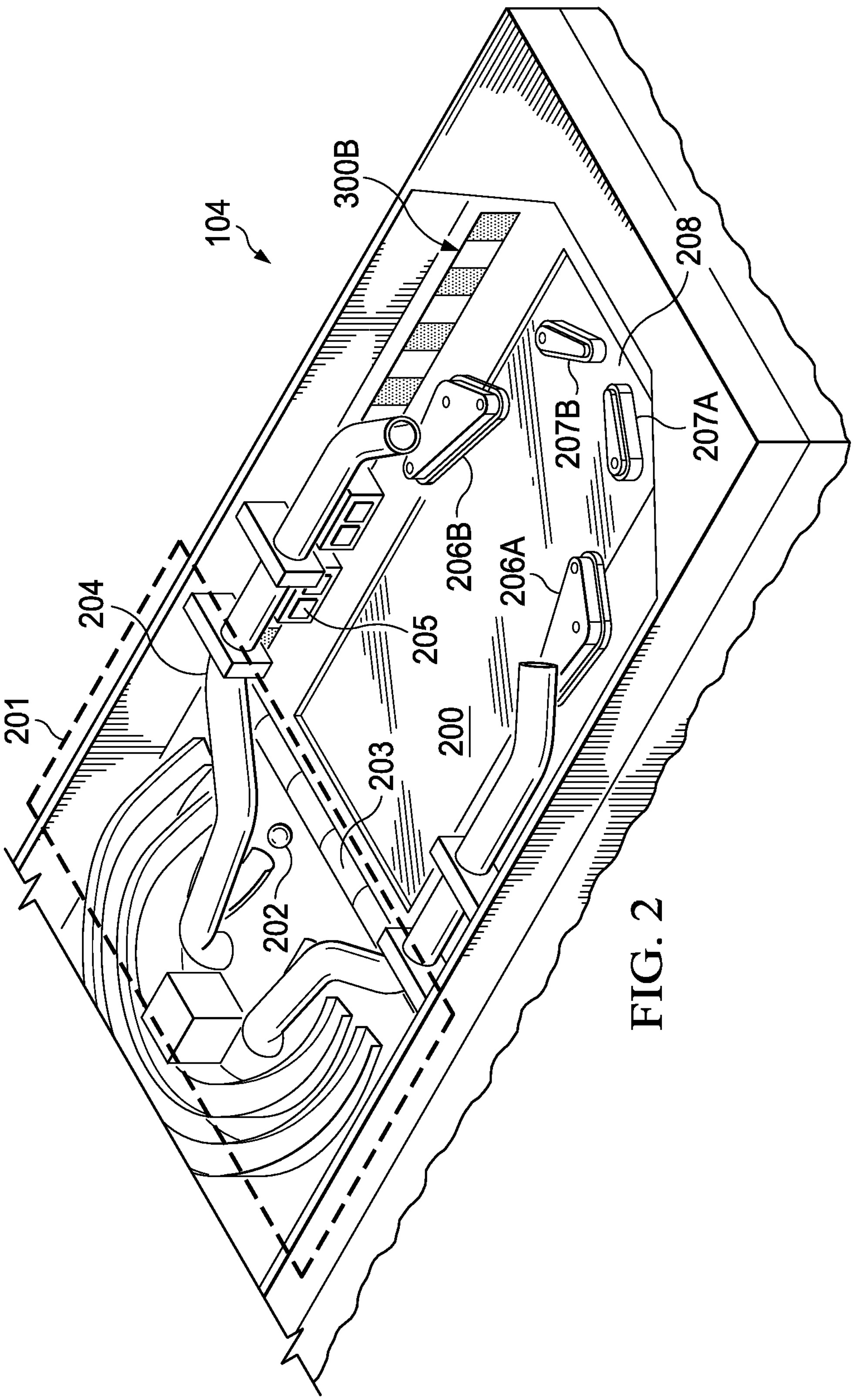


FIG. 2

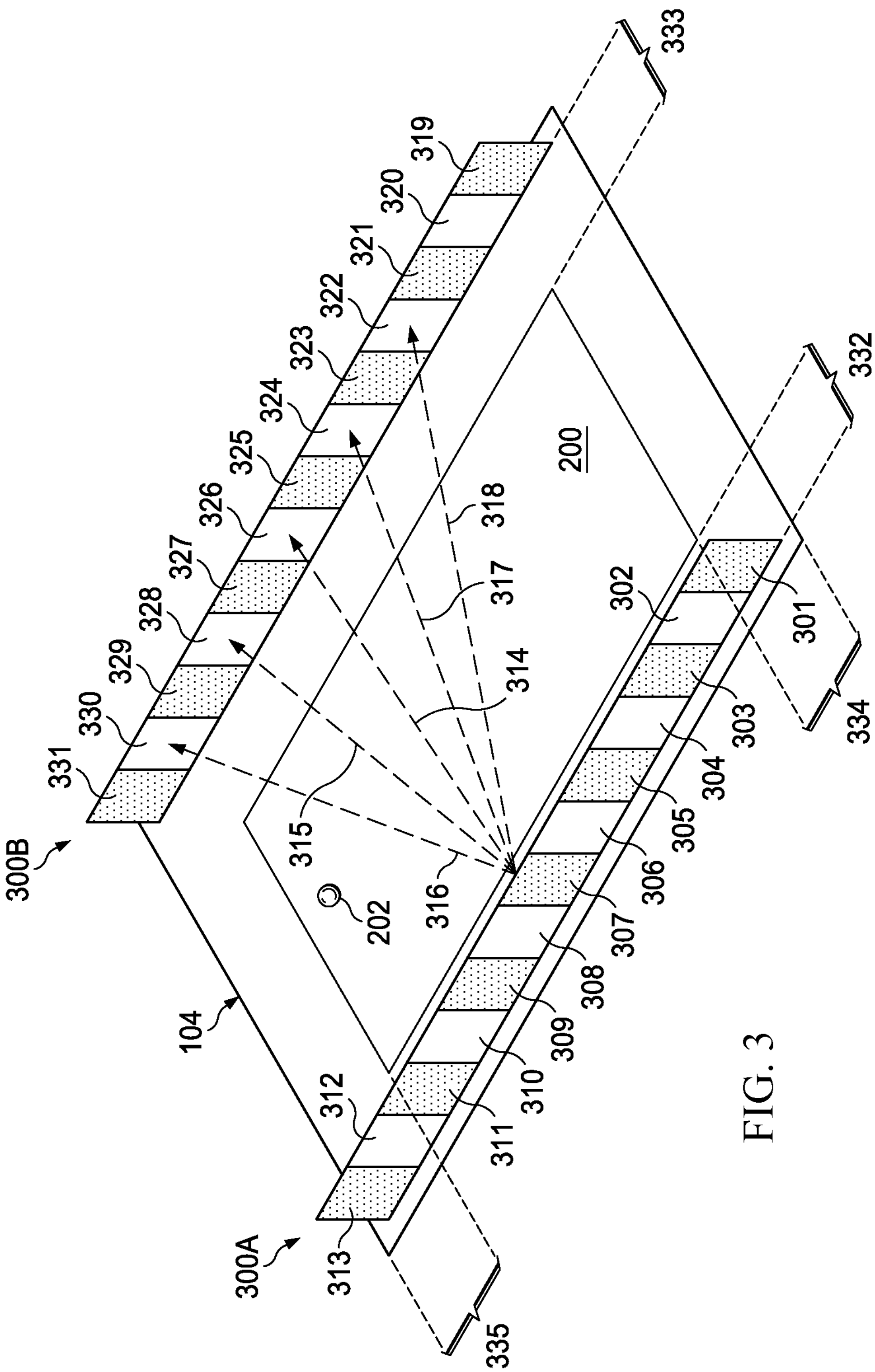

333
319
320
321
322
323
324
325
326
327
328
329
330
331
300B
200
318
317
314
315
316
202
104
332
302
301
303
304
305
306
307
308
309
310
311
312
313
300A
334
335

FIG. 3

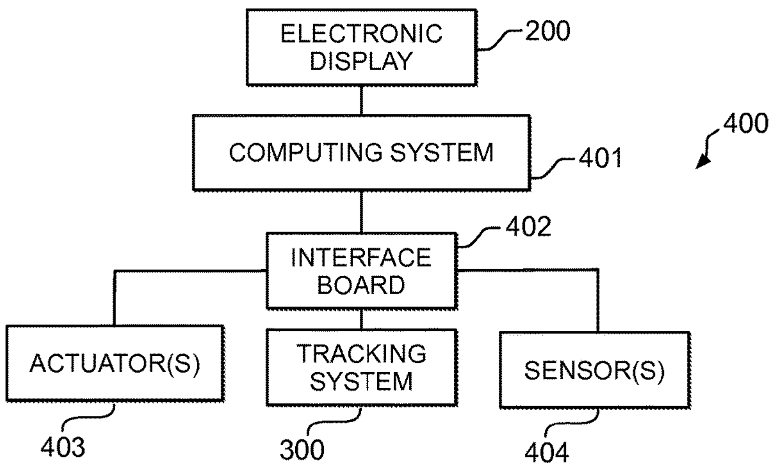

ELECTRONIC DISPLAY
200
COMPUTING SYSTEM
401
400
INTERFACE BOARD
402
ACTUATOR(S)
TRACKING SYSTEM
SENSOR(S)
403
300
404

FIG. 4

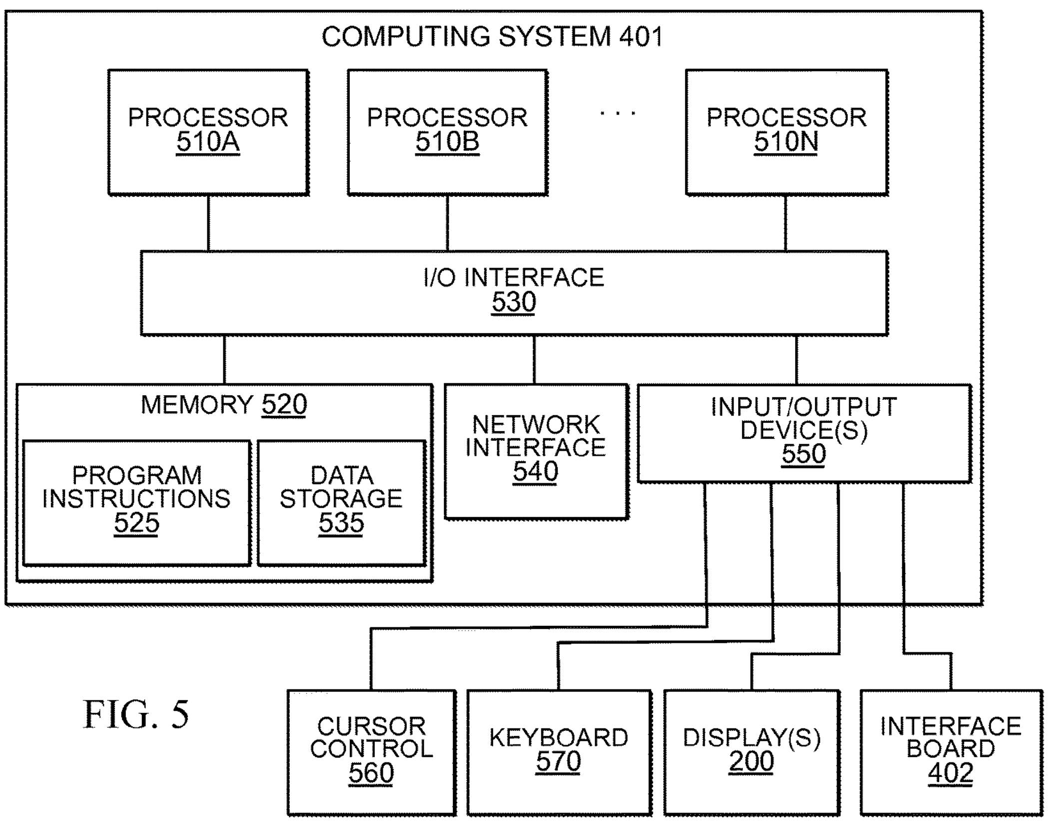

COMPUTING SYSTEM 401
PROCESSOR 510A
PROCESSOR 510B
. . .
PROCESSOR 510N
I/O INTERFACE 530
MEMORY 520
PROGRAM INSTRUCTIONS 525
DATA STORAGE 535
NETWORK INTERFACE 540
INPUT/OUTPUT DEVICE(S) 550
CURSOR CONTROL 560
KEYBOARD 570
DISPLAY(S) 200
INTERFACE BOARD 402

FIG. 5

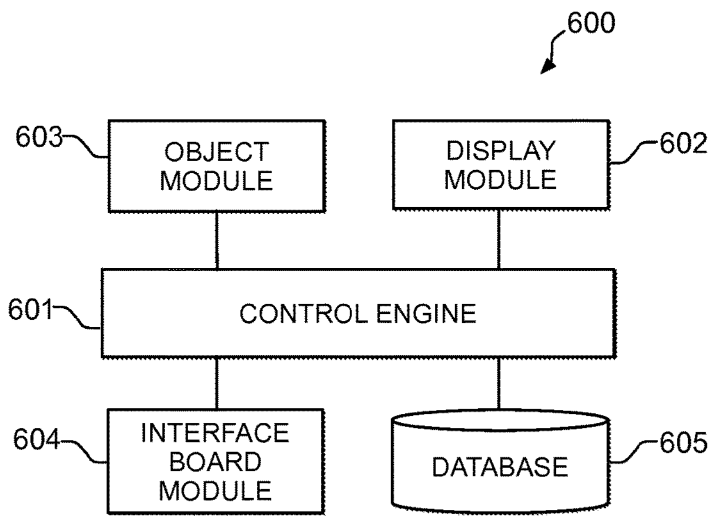

600
603
OBJECT MODULE
DISPLAY MODULE
602
601
CONTROL ENGINE
604
INTERFACE BOARD MODULE
DATABASE
605

FIG. 6

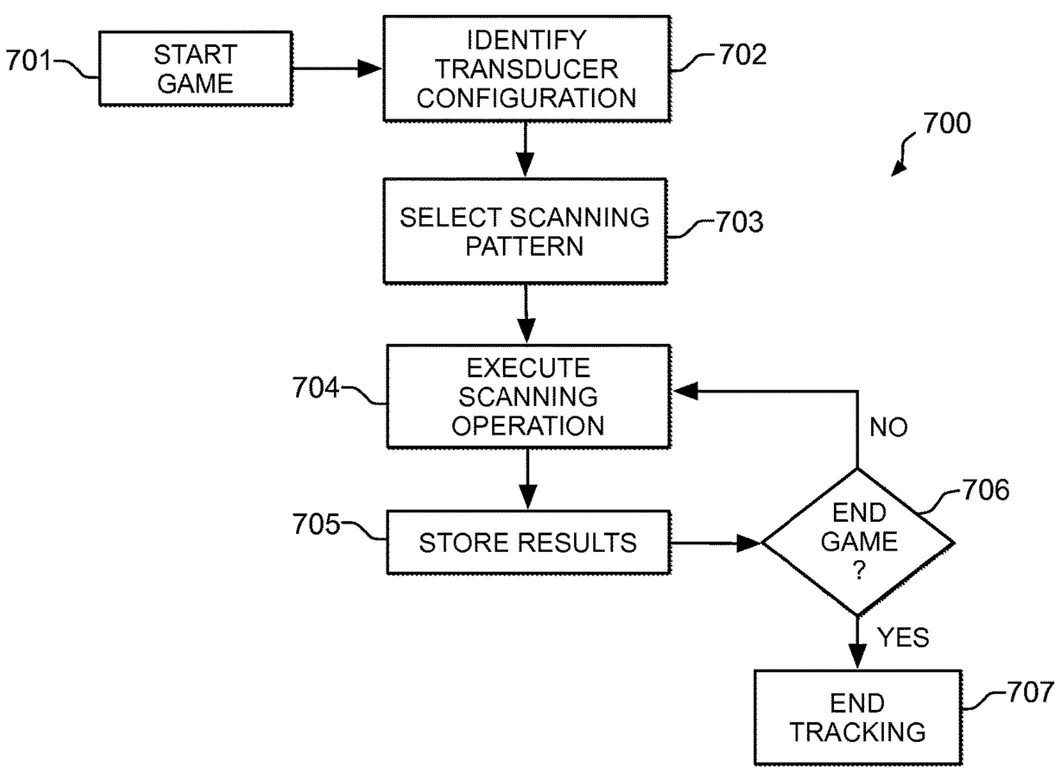

701
START GAME
IDENTIFY TRANSDUCER CONFIGURATION
702
700
SELECT SCANNING PATTERN
703
704
EXECUTE SCANNING OPERATION
NO
705
STORE RESULTS
END GAME ?
706
YES
END TRACKING
707

FIG. 7

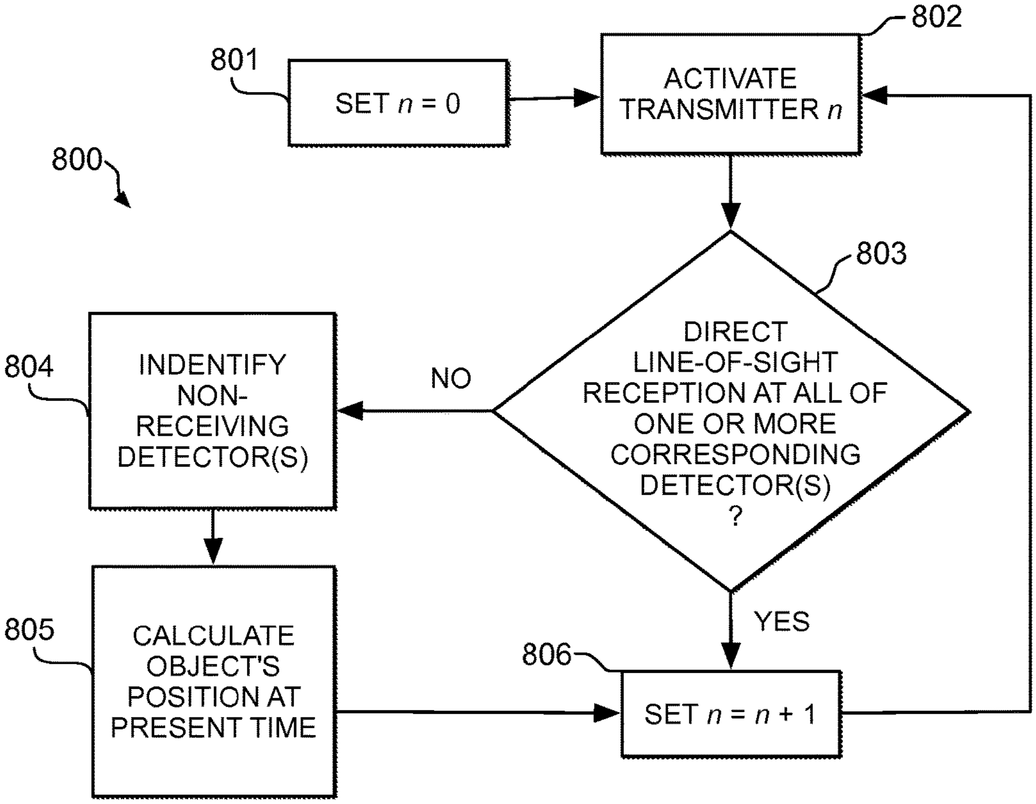

801
SET n = 0
802
ACTIVATE TRANSMITTER n
800
803
DIRECT LINE-OF-SIGHT RECEPTION AT ALL OF ONE OR MORE CORRESPONDING DETECTOR(S) ?
NO
804
INDENTIFY NON-RECEIVING DETECTOR(S)
805
CALCULATE OBJECT'S POSITION AT PRESENT TIME
YES
806
SET n = n + 1

FIG. 8

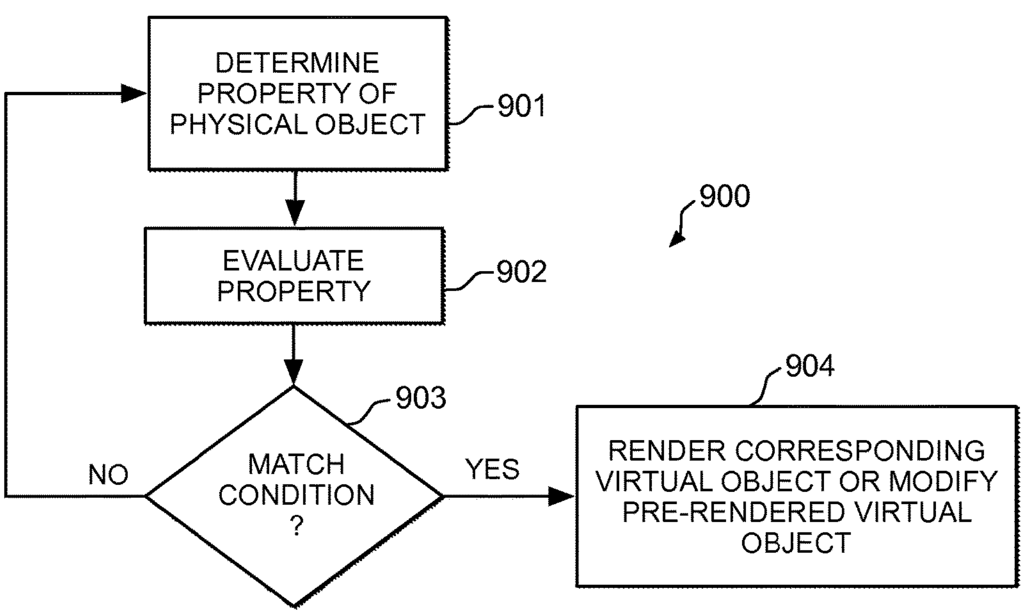

DETERMINE PROPERTY OF PHYSICAL OBJECT
901
900
EVALUATE PROPERTY
902
903
904
MATCH CONDITION ?
NO
YES
RENDER CORRESPONDING VIRTUAL OBJECT OR MODIFY PRE-RENDERED VIRTUAL OBJECT

FIG. 9

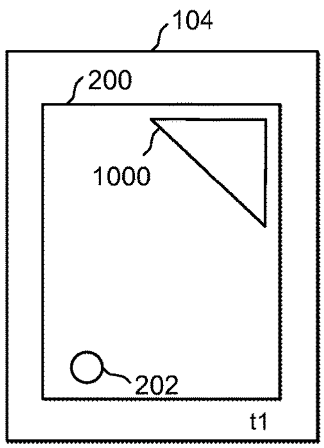


FIG. 10A

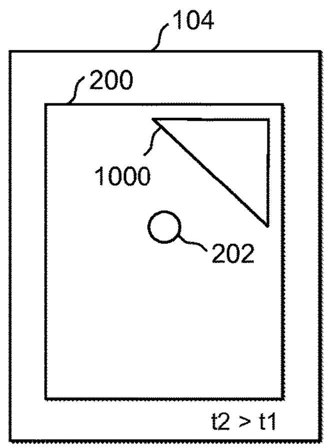


FIG. 10B

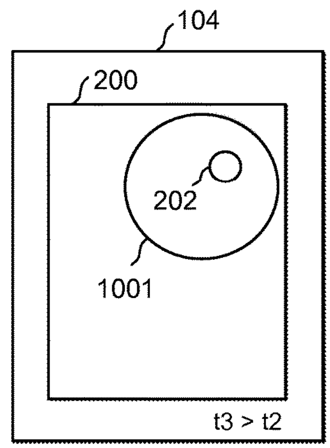


FIG. 10C

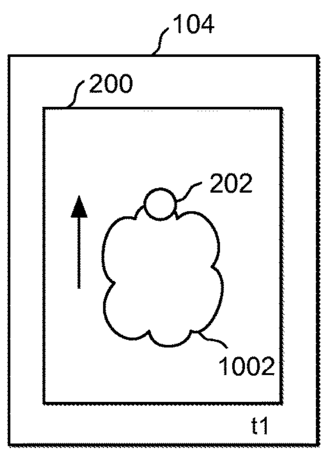


FIG. 10D

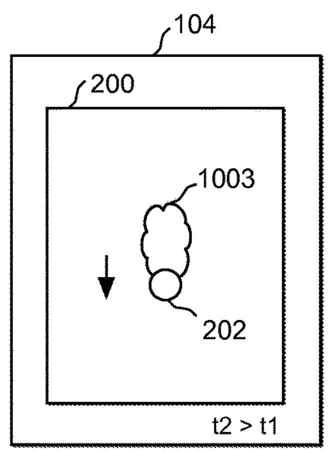


FIG. 10E

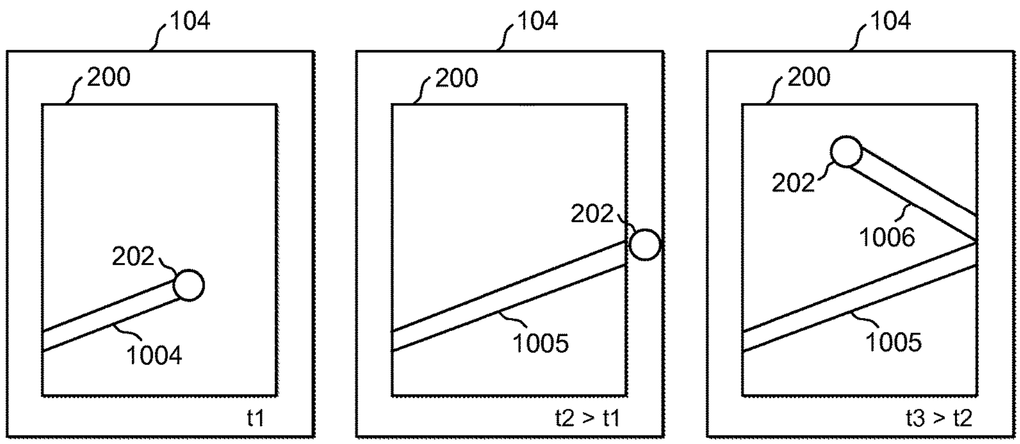


FIG. 10F FIG. 10G FIG. 10H

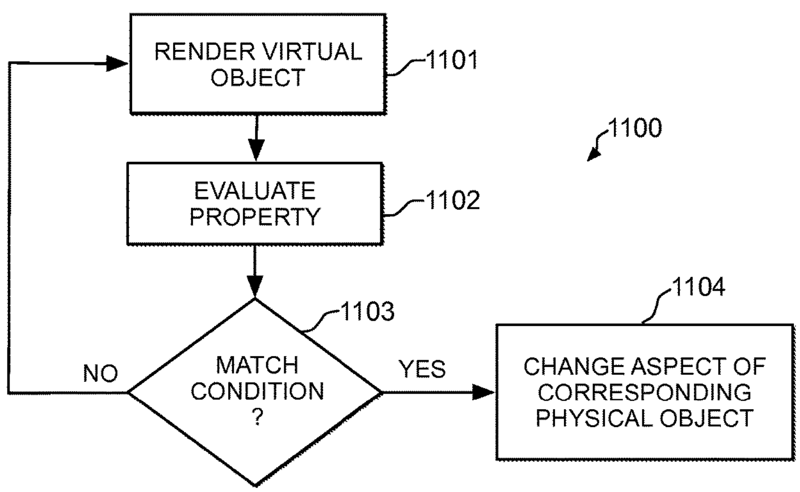


FIG. 11

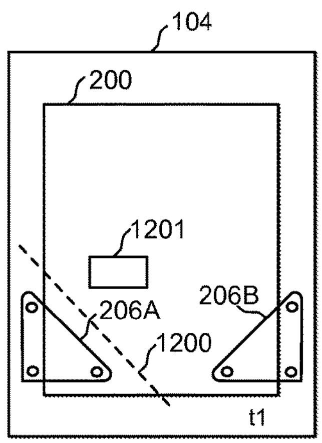


FIG. 12A

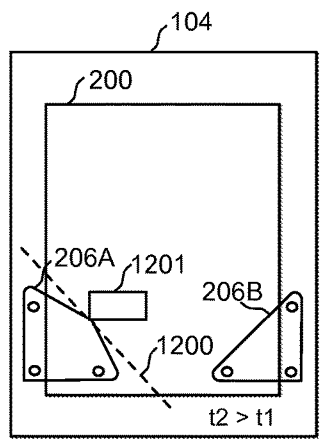


FIG. 12B

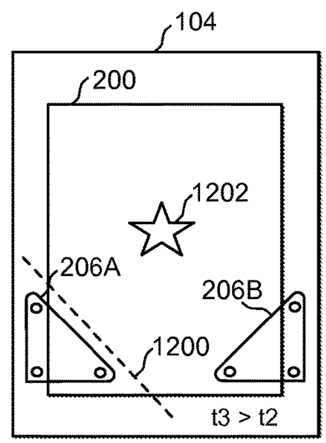


FIG. 12C

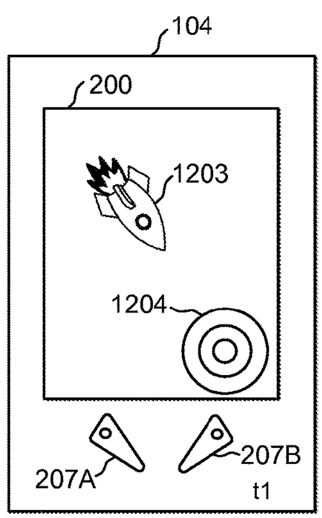


FIG. 12D

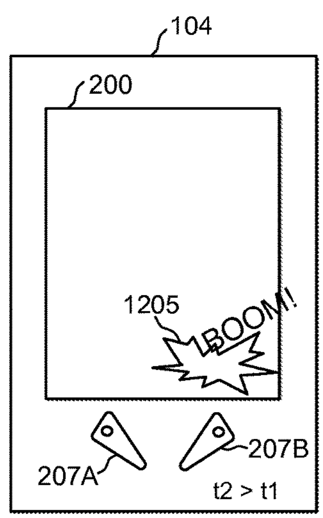


FIG. 12E

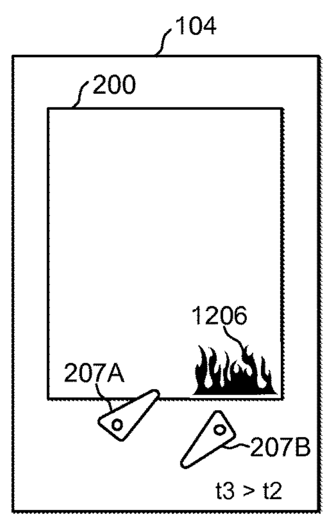


FIG. 12F

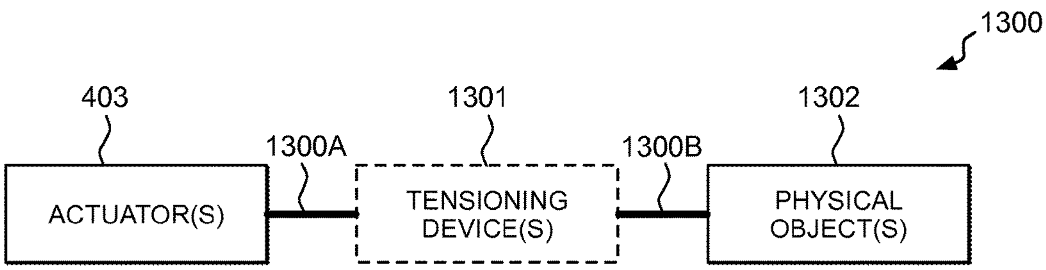

1300
403
1301
1302
1300A
1300B
ACTUATOR(S)
TENSIONING DEVICE(S)
PHYSICAL OBJECT(S)

FIG. 13

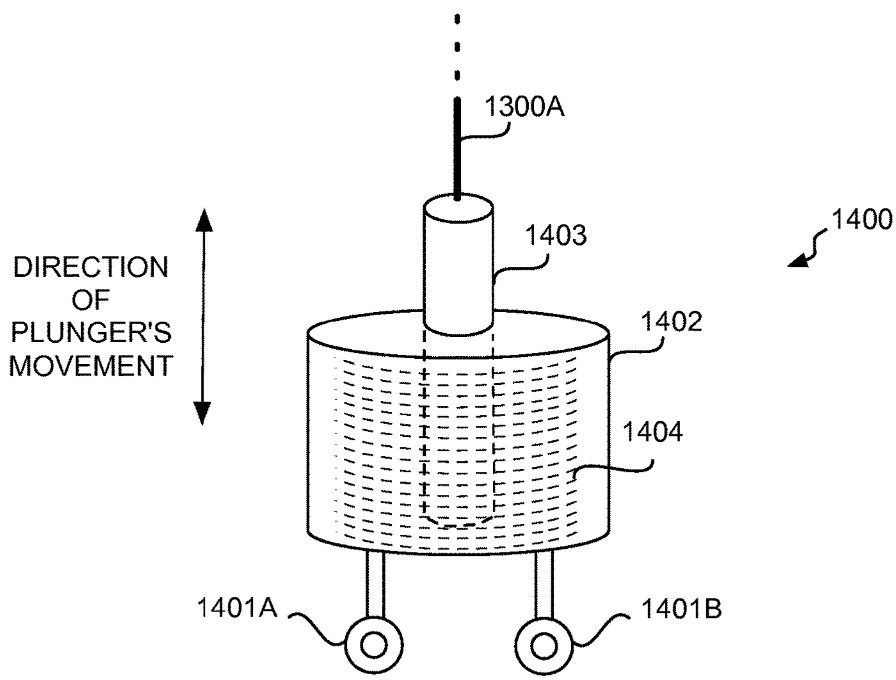

1300A
1400
1403
DIRECTION OF PLUNGER'S MOVEMENT
1402
1404
1401A
1401B

FIG. 14

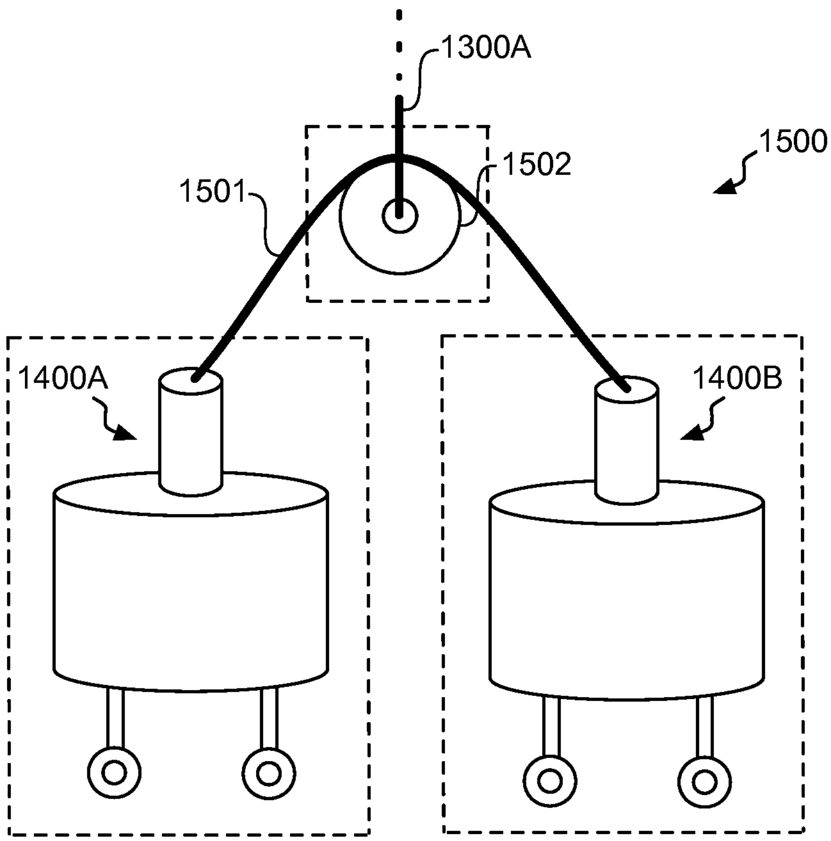

1300A
1500
1502
1501
1400A
1400B

FIG. 15

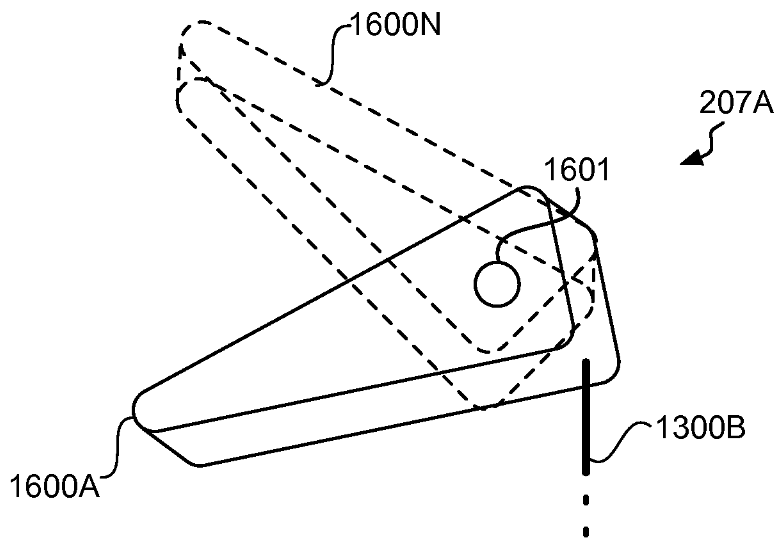

1600N
207A
1601
1300B
1600A

FIG. 16

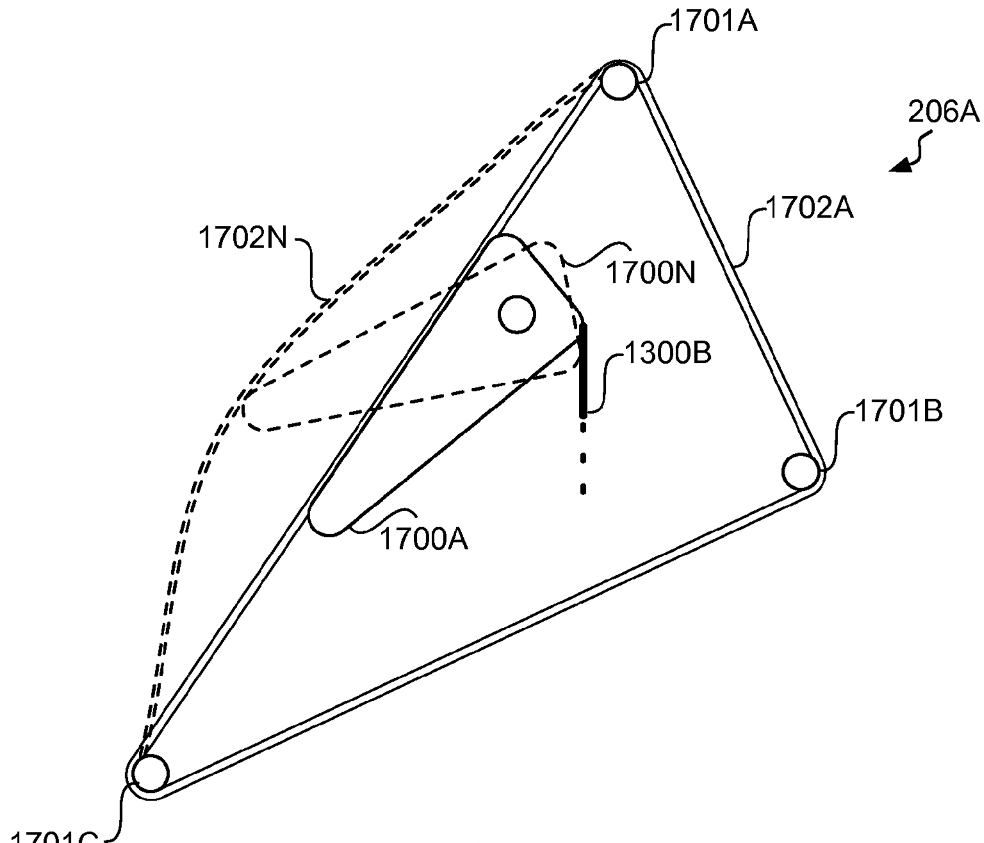

1701A
206A
1702A
1702N
1700N
1300B
1701B
1700A
1701C

FIG. 17

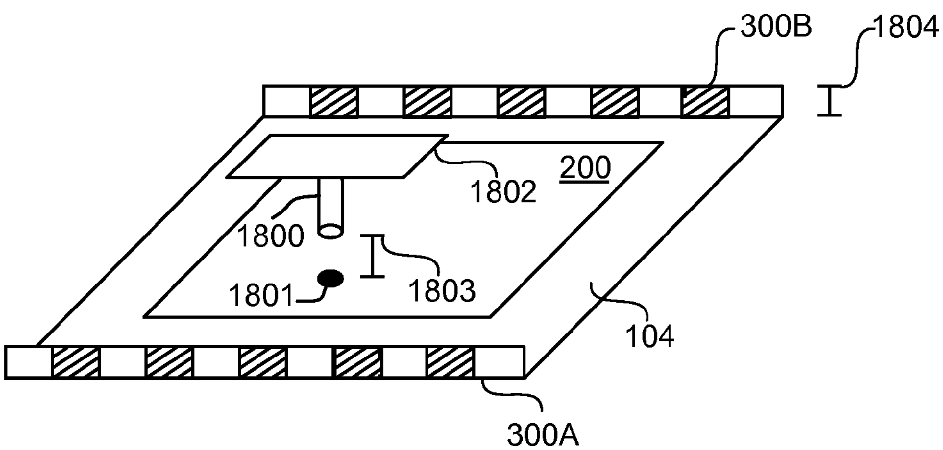
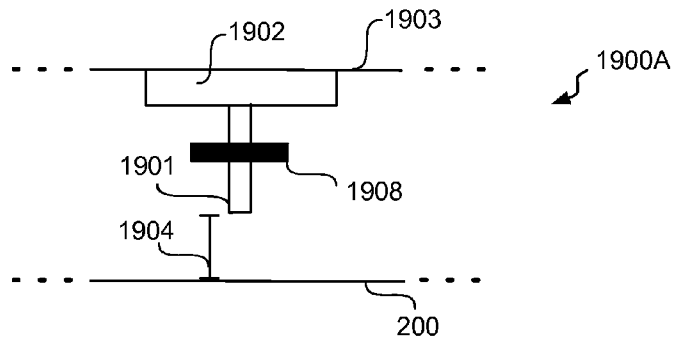

300B
1804
200
1802
1800
1803
1801
104
300A

FIG. 18

FIG. 19A



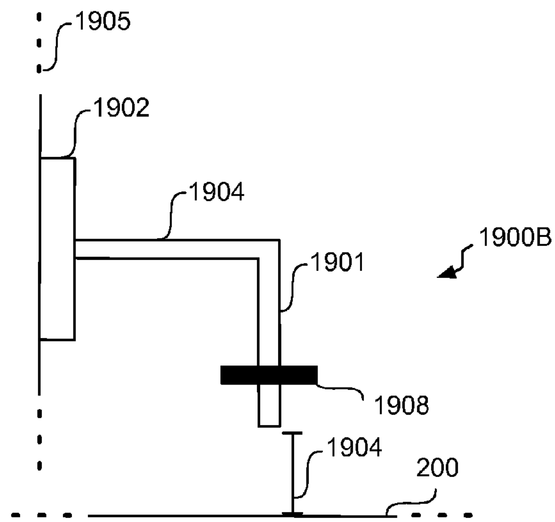


FIG. 19B

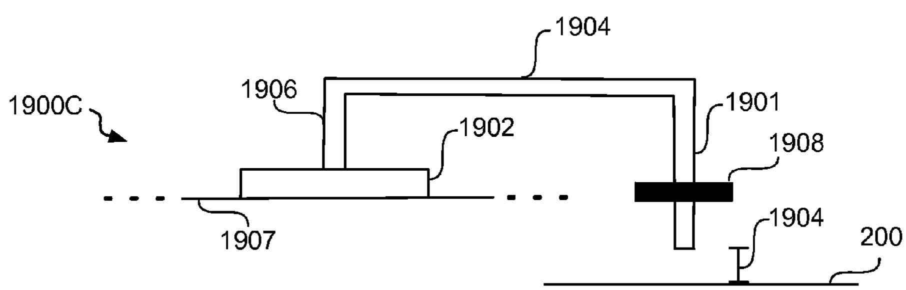


FIG. 19C

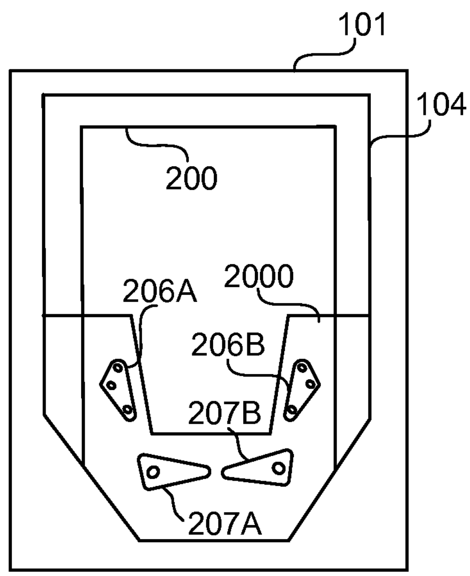


FIG. 20

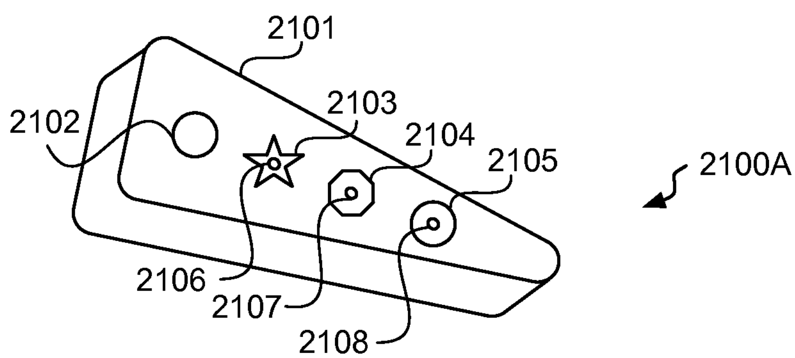


FIG. 21A

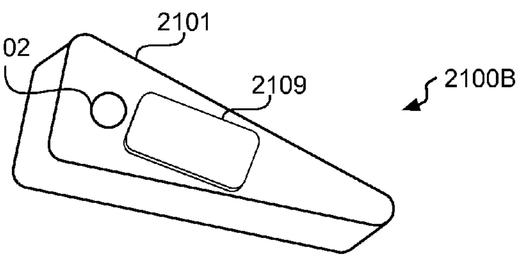


FIG. 21B

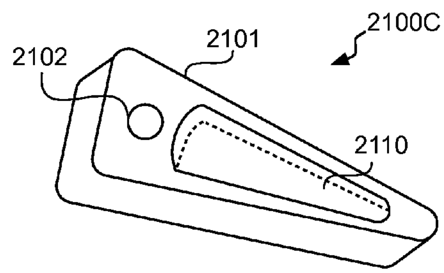


FIG. 21C

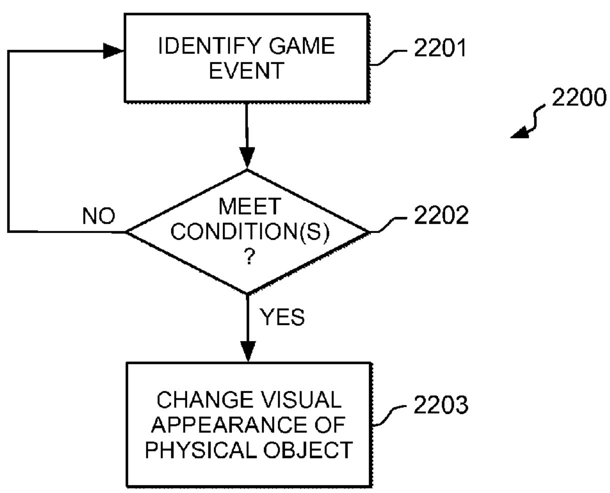


FIG. 22

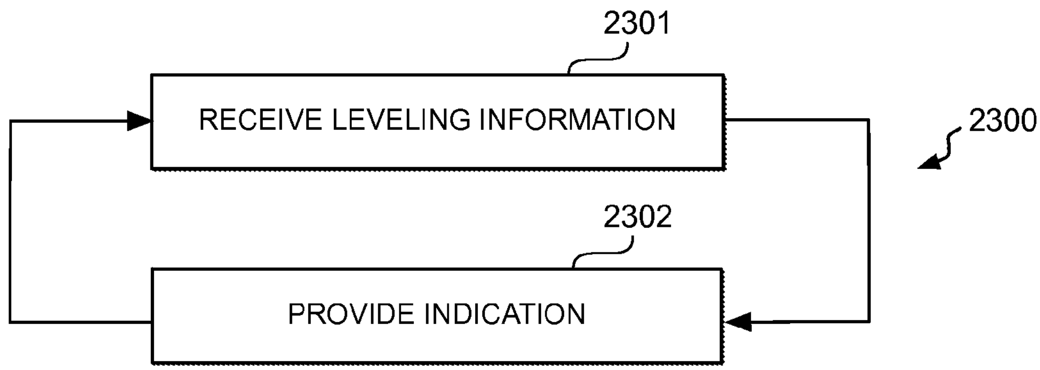

2301
RECEIVE LEVELING INFORMATION
2300
2302
PROVIDE INDICATION

FIG. 23

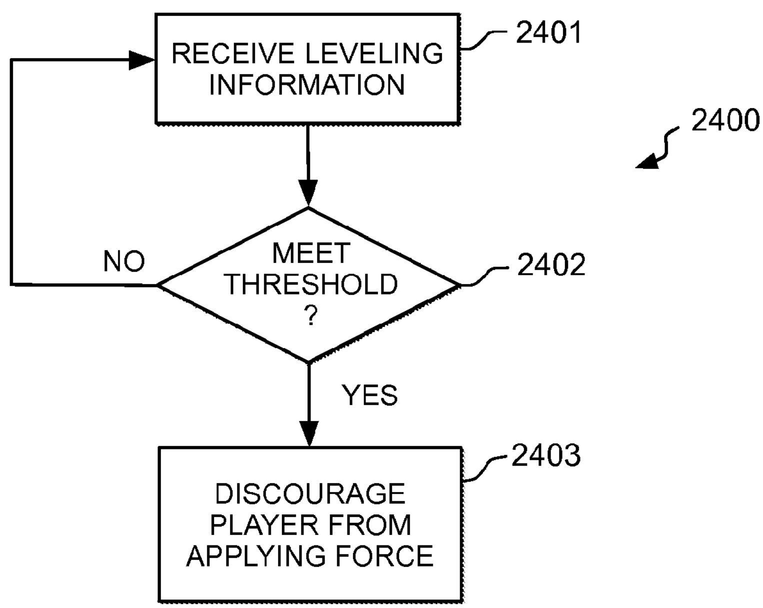

RECEIVE LEVELING INFORMATION
2401
2400
NO
MEET THRESHOLD ?
2402
YES
DISCOURAGE PLAYER FROM APPLYING FORCE
2403

FIG. 24

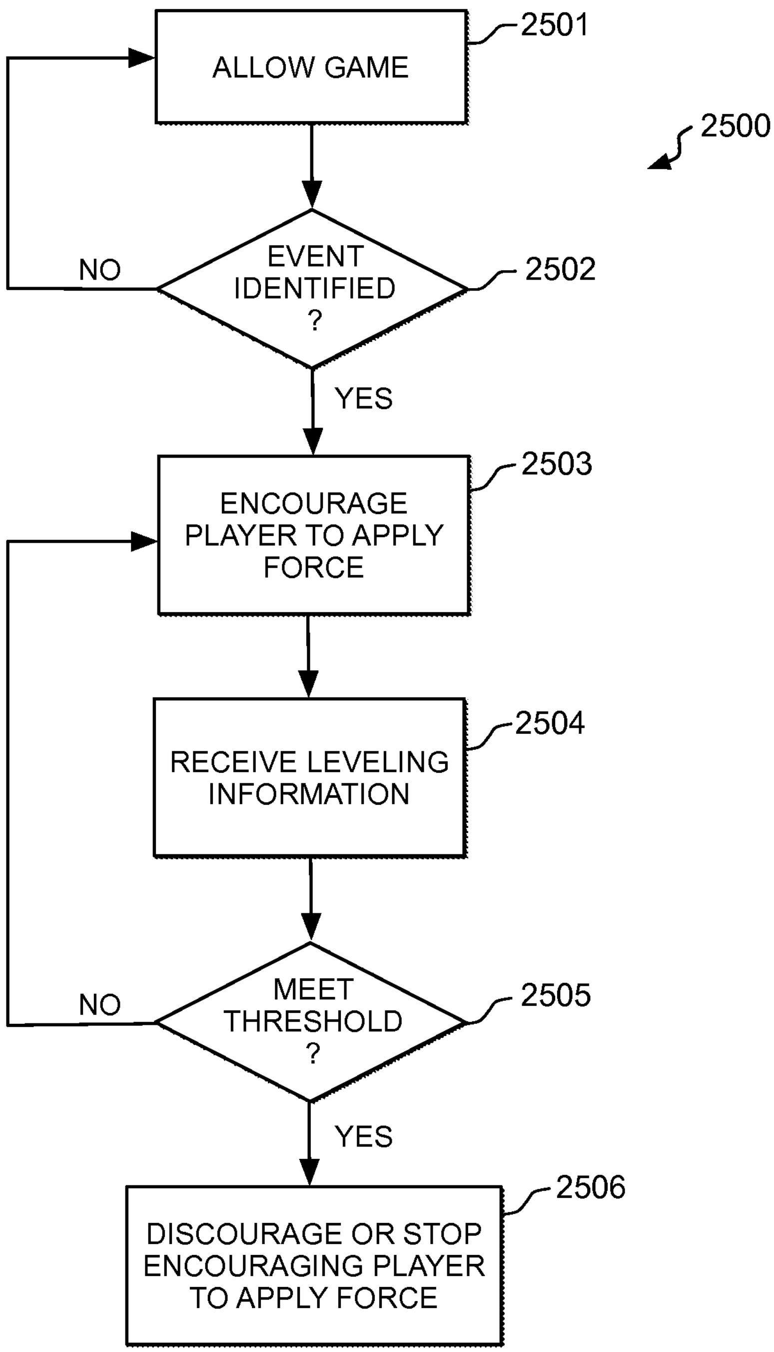

2500
ALLOW GAME
2501
EVENT IDENTIFIED ?
2502
NO
YES
ENCOURAGE PLAYER TO APPLY FORCE
2503
RECEIVE LEVELING INFORMATION
2504
MEET THRESHOLD ?
2505
NO
YES
DISCOURAGE OR STOP ENCOURAGING PLAYER TO APPLY FORCE
2506

FIG. 25

PINBALL MACHINE WITH ANIMATED PLAYFIELD COMPONENTS AND AUTOMATIC LEVEL DETECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to, and is a Continuation-In-Part (CIP) of, U.S. patent application Ser. No. 13/734,151 filed on Jan. 4, 2013, which claims the priority of U.S. Provisional Patent Application No. 61/632,002 filed on Jan. 17, 2012, of U.S. Provisional Patent Application No. 61/632,749 filed on Jan. 31, 2012, and of U.S. Provisional Patent Application No. 61/633,559 filed on Feb. 14, 2012, the disclosures of which are hereby incorporated by reference herein in their entirety. This application also claims priority to, and is a Continuation-In-Part (CIP) of, U.S. patent application Ser. No. 13/777,865 filed on Feb. 26, 2013, which claims the priority of U.S. Provisional Patent Application No. 61/634,352 filed on Feb. 28, 2012, of U.S. Provisional Patent Application No. 61/685,588 filed on Mar. 21, 2012, and of U.S. Provisional Patent Application No. 61/685,644 filed on Mar. 22, 2012, the disclosures of which are hereby incorporated by reference herein in their entirety. This application further claims priority to U.S. Provisional Patent Application No. 61/690,711 filed on Jul. 3, 2012, and U.S. Provisional Patent Application No. 61/741,126 filed on Jul. 13, 2012, the disclosures of which are hereby further incorporated by reference herein in their entirety.

FIELD

This document relates generally to gaming devices, and more specifically, to pinball machines with animated playfield components and automatic level detection.

BACKGROUND

A pinball machine is an entertainment or amusement device usually found in a variety of public places such as arcades, restaurants, bars, clubs, etc., but sometimes also present in private residences and other environments. Generally speaking, a conventional or traditional pinball machine allows players to play a game in which points are earned by physically manipulating one or more steel balls on a slightly inclined playfield within a glass-covered cabinet.

The pinball machine's playfield typically includes one or more physical targets. When a ball strikes a particular physical target, an electromechanical switch coupled to (or otherwise integrated into) the target detects the mechanical impact, which then triggers a change in some aspect of the game. For example, in some cases, when a ball hits a given target, a player may score a predetermined amount of points.

In most pinball implementations, a "hole" or "drain" is located at the bottom portion of the playfield. Usually, if the ball falls into the drain, the game ends or another ball is provided to the player. Mechanical "flippers" capable of at least partially covering the drain may allow a skilled player to hit the ball at an appropriate time so as to prevent it from falling into the drain, thus putting that same ball back in play and extending the duration of the game.

SUMMARY

Pinball machines with animated playfield components and automatic level detection are described. In an illustrative, non-limiting embodiment, a method may include

changing a visual appearance of a surface of a physical object within a pinball machine, the physical object configured to physically interact with a pinball during a pinball game. For example, the physical object may include a flipper, slingshot, or target. Also, changing the visual appearance of the surface may include causing the surface to convey at least one of: a text, a graphic, or a color.

In some implementations, the surface may include a display, and changing the visual appearance of the surface may include rendering an image on the display. In other embodiments a playable surface accessible to the pinball during the pinball game may include a display, the physical object may be located above the display, the surface of the physical object may include a transparent or translucent portion, and changing the visual appearance of the surface of the physical object may include rendering an image on the display, the image being visible to a player through the transparent or translucent portion.

As such, the method may include changing the visual appearance of the surface while the physical object moves during the pinball game or over a time interval. In some cases, the surface may have a first physical appearance when a given pinball is being played, and a second physical appearance when a subsequent pinball is being played. Moreover, changing the visual appearance of the surface may include conveying leveling information, the leveling information being detected by one or more accelerometers coupled to the pinball machine.

In another illustrative, non-limiting embodiment, a pinball machine may include a memory configured to store instructions and processing circuitry operably coupled to the memory, the processing circuitry configured to execute the instructions to cause the pinball machine to receive leveling information detected by one or more accelerometers, the leveling information selected from the group consisting of: pitch, roll, and yaw. The processing circuitry may be further configured to execute the instructions to cause the pinball machine to provide at least one of: a textual, graphical, or audio indication of the leveling information. In some cases, the indication may be provided to a computing device remotely located with respect to the pinball machine, at least in part, via a telecommunications network.

For instance, the instructions may be executable as part of a setup procedure of the pinball machine, and the indication may be provided to an installer. Additionally or alternatively, the indication may be provided to a prospective player of the pinball machine.

In some implementations, the processing circuitry may be further configured to execute the instructions to cause the pinball machine to allow a player to start a game in response to the leveling information meeting a threshold value. Additionally or alternatively the instructions may be executable as part of a pinball game, and the one or more accelerometers may be configured to determine that a player has physically moved the pinball machine. For instance, the one or more accelerometers may be coupled to a playfield surface of the pinball machine.

In yet another illustrative, non-limiting embodiment, a non-transitory computer-readable storage medium may have instructions stored thereon that, upon execution by a processor within a pinball machine, cause the pinball machine to periodically or continuously receive leveling information detected by one or more accelerometers during a pinball game, and perform at least one of: discourage the player from applying force to the pinball machine in response to the leveling information meeting a value, or encourage a player to apply force to the pinball machine.

In some cases, to encourage the player to apply force, the instructions may cause the pinball machine to perform at least one of: award a point, award a credit, award an extra pinball, render a virtual object on a display, stop rendering the virtual object on a display, or animate a virtual object on the display. The instructions may further cause the pinball machine to stop encouraging the player to apply force in response to the leveling information meeting a value. In other cases, to discourage the player from applying force, the instructions may cause the pinball machine to perform at least one of: take away a point, take away a credit, take away a pinball, increase the speed of a countdown timer, present an additional target to shoot, or disable a control.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention(s) is/are illustrated by way of example and is/are not limited by the accompanying figures, in which like references indicate similar elements. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale.

FIG. **1** is a three-dimensional, auxiliary view of an example of a pinball machine according to some embodiments.

FIG. **2** is a three-dimensional, auxiliary view of an example of a hybrid playfield according to some embodiments.

FIG. **3** is a three-dimensional, auxiliary view of an example of a tracking system in a hybrid playfield according to some embodiments.

FIG. **4** is a block diagram of an example of hardware elements of a pinball machine with a hybrid playfield according to some embodiments.

FIG. **5** is a block diagram of an example of a computing system or controller configured to implement aspects of a pinball machine with a hybrid playfield according to some embodiments.

FIG. **6** is a block diagram of an example of a software program configured to implement aspects of a pinball machine with a hybrid playfield according to some embodiments.

FIG. **7** is a flowchart of an example of a method of operating a tracking system in a hybrid playfield according to some embodiments.

FIG. **8** is a flowchart of an example of a method of obtaining an object's position in a hybrid playfield using a tracking system according to some embodiments.

FIG. **9** is a flowchart of an example of a method of enabling physical object(s) to interact with virtual object(s) in a hybrid playfield according to some embodiments.

FIGS. **10**A-H are diagrams illustrating examples of physical object(s) initiating interaction(s) with virtual object(s) according to some embodiments.

FIG. **11** is a flowchart of an example of a method of enabling virtual object(s) to interact with physical object(s) in a hybrid playfield according to some embodiments.

FIGS. **12**A-F are diagrams illustrating examples of virtual object(s) initiating interaction(s) with physical object(s) according to some embodiments.

FIG. **13** is a block diagram of an example of a remote actuator system according to some embodiments.

FIG. **14** is a three-dimensional diagram of an example of a single actuator according to some embodiments.

FIG. **15** is a three-dimensional diagram of an example of a dual actuator according to some embodiments.

FIG. **16** is a three-dimensional diagram of an example of a remotely actuated flipper according to some embodiments.

FIG. **17** is a top-view diagram of an example of a remotely actuated slingshot according to some embodiments.

FIG. **18** is a three-dimensional, auxiliary view of an example of a suspended physical object in a hybrid playfield according to some embodiments.

FIGS. **19**A-C are side-view diagrams of components configured to suspend a physical object in a hybrid playfield according to some embodiments.

FIG. **20** is a top-view diagram of an example of a surface configured to suspend physical objects in a hybrid playfield according to some embodiments.

FIGS. **21**A-C are a three-dimensional, auxiliary views of examples of animated playfield components according to some embodiments.

FIG. **22** is a flowchart of an example of a method of animating a playfield component according to some embodiments.

FIG. **23** is a flowchart of an example of a method of processing leveling information according to some embodiments.

FIG. **24** is a flowchart of an example of a method of discouraging a player from applying force to a pinball machine according to some embodiments.

FIG. **25** is a flowchart of an example of a method of encouraging a player to apply force to a pinball machine according to some embodiments.

DETAILED DESCRIPTION

Systems and methods disclosed herein are directed to pinball machines with hybrid playfields and methods of operating the same. Generally speaking, some of these systems and methods may be incorporated into, or otherwise combined with, a wide range of other entertainment or amusement devices, including, but not limited to, video games, electro-mechanical games, redemption games, merchandisers, billiards, shuffleboards, table football ("Foosball"), table tennis ("Ping-Pong"), air hockey tables, etc. These systems and methods may also be incorporated into gambling devices, such as slot machines, pachinko machines, or the like. It should be noted, however, that some of the techniques discussed herein may be uniquely applicable to devices that allow a player to manipulate a physical object within a playfield without directly touching that physical object (e.g., pinball machines).

Turning to FIG. **1**, a three-dimensional, auxiliary view of an example of pinball machine **100** is depicted according to some embodiments. As illustrated, cabinet **101** stands on legs **102**A-D, although in other implementations legs **102**A-D may be absent and cabinet **101** may sit on a stand, desk, table, countertop, or the like. Cabinet **101** includes hybrid playfield **104**, where a game of pinball may take place. Examples of hybrid playfield **104** are discussed in more detail below. In some cases, legs **102**A and **102**B may be slightly longer than legs **102**C and **102**D, such that playfield **104** may have an angle of approximately 3.5° to 10.5° with respect to the ground ("pitch"). Accordingly, playfield **104** may be said to have an approximately horizontal surface. In other cases, legs **102**A-D may each have the same length, and cabinet **101** may be constructed so as to provide a suitable pitch to hybrid playfield **104**.

Vertical portion **103** may include one or more electronic displays, video cameras, loudspeakers, etc. Generally speaking, vertical portion **103** may include or otherwise present certain audio-visual information, whether related or unrelated to a pinball game playable on machine **100** (e.g., promotional or marketing materials, etc.).

To enable a player to play a pinball game, front control(s) **105** may allow the user or player to deposit money or tokens into machine **100**. As such, front control(s) **105** may include, for example, a credit, coin or token receiver, a magnetic card reader, a Radio Frequency Identification (RFID) scanner, or the like. Front control(s) **105** may also include one or more buttons that allow a user to select a number of players for a particular game, or to simply to start a pinball game. Meanwhile, side control(s) **107** and playfield control(s) **106** allow the user to operate one or more physical objects within hybrid playfield **104**. As an example, side control(s) **107** (and/or a corresponding control on the opposite side of cabinet **101**, not shown) may include one more buttons that allow a player to control mechanical "flippers." As another example, playfield control(s) **106** may include one or more buttons or mechanisms that allow the player to control a "plunger" element configured to put a steel ball in play during a pinball game.

Here it should be noted that pinball machine **100** is provided by way of illustration only. In different applications, machine **100** may assume a variety of shapes and forms. Furthermore, one or more components discussed above may be absent or different from what is depicted in FIG. **1**. For example, in some cases, front control(s) **105** may be located elsewhere on machine **100**, and, in other cases, may include more or fewer elements than shown. For instance, when designed for residential or personal use, machine **100** may not be credit, coin or token-operated. Similarly, side control(s) **107** and/or playfield control(s) **106** may be replaced with motion detection devices (e.g., integrated into vertical portion **103**), or may not be necessary for certain games. For example, if steel balls are provided within playfield **104** via an internal mechanism within machine **100**, then playfield control(s) **106** may not be necessary.

To facilitate understanding of some of the systems and methods introduced below, a three-dimensional (XYZ) coordinate system **108** is also shown in FIG. **1**. As illustrated, an angle and/or rotation around the x axis is referred to as "roll," an angle and/or rotation around the y axis is referred to as "pitch," and an angle and/or rotation around the z axis is referred to as "yaw." As discussed in more detail below, in some implementations, pinball machine **100** and/or playfield **104** may include one or more accelerometers configured to evaluate leveling information based, at least in part, upon pitch, roll, and/or yaw measurements. Here, for ease of explanation, the lateral portion of pinball machine **100** is disposed along the x axis and the front portion of pinball machine **100** is disposed along the y axis.

FIG. **2** is a three-dimensional, auxiliary view of an example of hybrid playfield **104** according to some embodiments. Generally speaking, a "playfield" is a mostly flat surface over which one or more objects, such as pinball **202**, move in an amusement game, such as a pinball game. Hybrid playfield **104** is a playfield comprising a "physical space" and a "virtual space." The physical space may include one or more mechanical or electromechanical elements, also referred to herein as "physical objects." Electronic display **200** may provide the virtual space portion of hybrid playfield **104** by rendering one or more graphical elements referred to herein as "virtual objects."

In the case of a pinball machine, examples of hybrid playfield **104**'s physical objects include, but are not limited to, ball(s), plunger(s), bumper(s), kicker(s), bullseye target(s), drop target(s), variable point target(s), roll(s), saucer(s), spinner(s), rollover(s), switch(es), gate(s), stopper(s), ramp(s), toy(s), electromagnet(s), etc. Meanwhile, virtual objects may include any graphical or digital element that may be rendered on electronic display **200**, such as, for example, artwork, colors, images, animations, photographs, designs, etc.

In various implementations, systems and methods described herein may allow certain physical objects to cause changes to certain virtual objects and/or vice-versa. Accordingly, these systems and methods may create an impression or an illusion upon a player that physical and virtual elements are interacting during a game, for example, in a physical or mechanical manner.

In the illustrated embodiment, hybrid playfield **104**'s physical objects include modular portion **201** configured to deploy one or more ball(s) **202** onto the playfield during a game. In this example, modular portion **201** includes barrier element(s) **203** and pipe element(s) **204**. Barrier element(s) **203** may include one or more walls that can pop-up and at least partially block pinball **202** from transiting between modular portion **201** and other portion(s) of hybrid playfield **104**. In some cases, barrier element(s) **203** may act as a "trap" to cause pinball **202** to fall under the surface of hybrid playfield **104** or become more or less static for a predetermined amount of time (e.g., by including an electromagnet or the like), for example. Meanwhile, pipe element(s) **204** may allow pinball **202** to travel through predetermined paths or "shortcuts" when traveling within hybrid playfield **104**.

Once deployed, pinball **202** may tend to roll towards drain **208** depending upon the pitch of playfield **104** and absent action by a player operating flippers **207**A and/or **207**B. Flippers **207**A and/or **207**B are mechanically or electromechanically-controlled levers used for redirecting pinball **202** up playfield **104**, preventing pinball **202** from falling into drain **208**. Through the use of careful, skillful timing, a player may also be to manipulate flippers **207**A and/or **207**B to intentionally direct pinball **202** in a selected direction with a given speed, thus causing pinball **202** to hit various types of scoring targets, such as, for example, one or more trigger elements **205** and/or slingshots **206**A and **206**B.

With respect to hybrid playfield **104**'s virtual objects, electronic display **200** may be any suitable display or monitor (e.g., a Liquid Crystal Display (LCD) or the like) configured to present graphical designs and/or animations to a player. These virtual objects are configurable depending upon the design of a game, and may interact with certain physical objects in hybrid playfield **104**. In some implementations, electronic display **200** may be capable of rendering 2D virtual objects on a flat screen. Additionally or alternatively, electronic display **200** may be capable of producing 3D and/or holographic virtual objects.

Although shown as a single display in FIG. **2**, in other embodiments two or more electronic displays **200** may be disposed in playfield **104**. For example, in some cases, a first electronic display and a second electronic display may be positioned side-by-side. In other cases, four electronic displays may be arranged such that each occupies a different quadrature of playfield **104**. Furthermore, in some cases, electronic display **200** may be at least in part co-extensive with the surface of hybrid playfield **104**.

As discussed in more detail below, pinball **202** may cause one or more virtual objects rendered by electronic display **200** to appear, disappear, or change depending upon its position on hybrid playfield **104**. Similarly, when pinball **202** physically interacts with trigger element **205** and slingshots **206**A and **206**B, for example, one or more virtual objects presented on electronic display **200** may change their behavior in an appropriate manner. Conversely, virtual objects rendered on electronic display **200** may also behave in a way so as to cause a change in one or more of trigger element **205** and slingshots **206**A and **206**B, for example, thus appearing to a player as if a physical interaction between the virtual object and the physical object has taken place.

In some cases, in order to enable one or more of the foregoing operations, a tracking system may be disposed within machine **100** to determine a position of pinball **202** and/or other physical objects. For instance, one or more arrays of infrared (IR) transducers may be disposed immediately above the surface of hybrid playfield **104** along one or more sides of electronic display **200**.

Turning now to FIG. **3**, a three-dimensional, auxiliary view of an example of tracking system **300** in hybrid playfield **104** is depicted according to some embodiments. As illustrated, tracking system **300** includes first IR transducer array **300**A and second IR transducer array **300**B. Arrays **300**A and **300**B are disposed immediately above the surface of playfield **104** on opposite sides of electronic display **200**, and may be positioned such that other playfield components (e.g., trigger element **205**, slingshots **206**A and **206**B, flippers **207**A and **207**B, etc.) do not interfere with its operations—that is, so that array **300**A may have a least a partial direct line-of-sight with respect to array **300**B. For instance, one or more of these playfield components may be "floating" with respect to electronic display **200** (e.g., attached or coupled to the top or cover of hybrid playfield **104**).

In this example, arrays **300**A and **300**B are positioned at distances **332** and **333** from the sides of electronic display **200**, and are longer than the height of electronic display **200** by lengths **334** and **335**. In some implementations, distances and lengths **332**-**335** may be selected to avoid interfering with gameplay (i.e., without blocking pinball **202**'s access to modular portion **201** or drain **208**). Also, in cases where electronic display **200** extends to the edge of hybrid playfield **104**, one or more of distances and lengths **332**-**335** may be zero and/or transducer arrays **300**A and **300**B may be positioned outside of hybrid playfield **104**.

In this embodiment, IR transducer array **300**A includes transmitter elements **301**, **303**, **305**, **307**, **309**, **311**, and **313** alternating with receiver or detector elements **302**, **304**, **306**, **308**, **310**, and **312**. Second IR transducer array **300**B includes transmitter elements **319**, **321**, **323**, **325**, **327**, **329**, and **331** alternating with receiver or detector elements **320**, **322**, **324**, **326**, **328**, and **330**. It should be noted, however, that this particular configuration is provided for ease of explanation only, and that many other suitable configurations with a different number of arrays, transmitter elements, and detector elements may be used, sometimes in the same pinball machine **100**. For instance, in other embodiments, tracking system **300** may include RF triangulation systems, video based motion tracking systems, capacitive systems, or other electro-mechanical position detection systems.

Tracking system **300** may be configured to scan hybrid playfield **104**, for example, as explained in FIGS. **7** and **8**. Briefly, each of transmitter elements **301**, **303**, **305**, **307**, **309**, **311**, and **313** of first array **300**A may transmit IR signals in succession such that one or more of detector elements **320**, **322**, **324**, **326**, **328**, and/or **330** of second array **300**B receives these signals. Then, each of transmitter elements **319**, **321**, **323**, **325**, **327**, **329**, and **331** of second array **300**B may transmit IR signals in succession such that one or more of detector elements **302**, **304**, **306**, **308**, **310**, and/or **312** of first array **300**A receives those signals. By determining which of detector elements **302**, **304**, **306**, **308**, **310**, **312** **320**, **322**, **324**, **326**, **328**, and/or **330** were expected to receive their respective signals but did not, for example, because pinball **202** was blocking that detector's line-of-sight, tracking system **300** may determine the position of pinball **202** as it moves across hybrid playfield **104**.

In some embodiments, tracking system **300** may be configured to determine the position, speed, and/or direction of movement of a physical object over hybrid playfield **104** with a margin of error no larger than the size of the physical object itself. Tracking system **300** may also be configured to determine the identification of a particular physical object, for example, when two balls **202** occupy hybrid playfield **104** simultaneously (e.g., via a chip or tag included in each pinball **202**, by maintaining a record of which ball gets deployed at what time and their respective trajectories, etc.). In some implementations, two or more tracking systems **300** may be used in the same hybrid playfield **104**, and each of the two or more tracking systems **300** may be of a different type (e.g., an IR system and an RFID system, etc.).

FIG. **4** is a block diagram of an example of hardware elements **400** in pinball machine **100** with hybrid playfield **104** according to some embodiments. As shown, computing system or controller **401** is coupled to electronic display **200** of FIG. **2**. Computing system **401** is also coupled to (or otherwise includes) interface board **402**, which in turn is coupled to tracking system **300**, actuator(s) **403**, and/or sensor(s) **404**.

In operation, computing system **401** may be configured to control electronic display **200** by providing one or more video signals capable of being rendered by electronic display **200** to create one or more 2D or 3D virtual objects in hybrid playfield **104** during a pinball game. Also, through interface board **402**, computing system **401** may be configured to control the behavior of and/or to receive information related to physical objects in hybrid playfield **104** through interface board **402**.

In some embodiments, interface board **402** may be any suitable pinball controller device such as, for example, the "Pinball—Remote Operations Controller" or "P-ROC" controller available from Multimorphic, Inc., which enables a computer to control a pinball machine over Universal Serial Bus (USB). It should be noted, however, that other pinball controller devices may be used as interface board **402**, and that such a device may communicate with computing device **401** using any suitable bus and/or communication protocol.

In some cases, interface board **402** may be configured to control actuator(s) **403**, such as, for example, coils, motors, etc. to thereby affect the behavior or status of physical elements, such as, for example, pinball **202**, barrier element **203**, pipe element **204**, trigger element **205**, slingshots **206**A and **206**B, flippers **207**A and **207**B, or the like. Moreover, interface board **402** may be configured to receive information from sensor(s) **404** such as, for example, switches, optical sensors, accelerators, etc., to determine the status of those physical objects. With regard to certain physical objects, such as, for example, pinball **202**, interface board **402** may also be configured to control tracking system **300** to obtain position and other information about those elements.

FIG. **5** is a block diagram of an example of computing system **401** configured to implement aspects of pinball machine **100** with a hybrid playfield **104**. In some embodiments, computing system **401** may be a server, a mainframe computer system, a workstation, a network computer, a desktop computer, a laptop, or the like. In other embodiments, one or more of the components described in connection with computing system **401** may be provided as a System-On-Chip (SoC), Application Specific Integrated Circuit (ASIC), or the like. More generally, however, computing system **401** may be any system, device, or circuitry capable of implementing or executing one or more of the various operations described herein.

In some implementations, computer system **401** may include one or more processors **510**A-N coupled to a system memory **520** via an input/output (I/O) interface **530**. Computing system **401** may further include a network interface **540** coupled to I/O interface **530**, and one or more input/output devices **550**, such as cursor control device **560**, keyboard **570**, electronic display(s) **200**, and interface board **402**.

In various embodiments, computing system **401** may be a single-processor system including one processor **510**A, or a multi-processor system including two or more processors **510**A-N (e.g., two, four, eight, or another suitable number). Processor(s) **510**A-N may be any processor capable of executing program instructions. For example, in various embodiments, processor(s) **510**A-N may be general-purpose or embedded processors implementing any of a variety of instruction set architectures (ISAs), such as the x86, POWERPC®, ARM®, SPARC®, or MIPS® ISAs, or any other suitable ISA. In multi-processor systems, each of processor(s) **510**A-N may commonly, but not necessarily, implement the same ISA. Also, in some embodiments, at least one processor(s) **510**A-N may be a graphics processing unit (GPU) or other dedicated graphics-rendering device.

System memory **520** may be configured to store program instructions and/or data accessible by processor(s) **510**A-N. In various embodiments, system memory **520** may be implemented using any suitable memory technology, such as static random access memory (SRAM), synchronous dynamic RAM (SDRAM), nonvolatile/Flash-type memory, or any other type of memory. As illustrated, program instructions and data implementing certain operations, such as, for example, those described herein, may be stored within system memory **520** as program instructions **525** and data storage **535**, respectively. In other embodiments, program instructions and/or data may be received, sent or stored upon different types of computer-accessible media or on similar media separate from system memory **520** or computing system **401**. Generally speaking, a computer-accessible medium may include any tangible, non-transitory storage media or memory media such as magnetic or optical media—e.g., disk or CD/DVD-ROM coupled to computing system **401** via I/O interface **530**.

The terms "tangible" and "non-transitory," are intended to describe a computer-readable storage medium (or "memory") excluding propagating electromagnetic signals, but are not intended to otherwise limit the type of physical computer-readable storage device that is encompassed by the phrase computer-readable medium or memory. For instance, the terms "non-transitory computer readable medium" or "tangible memory" are intended to encompass types of storage devices that do not necessarily store information permanently, including for example, random access memory (RAM). Program instructions and data stored on a tangible computer-accessible storage medium in non-transitory form may further be transmitted by transmission media or signals such as electrical, electromagnetic, or digital signals, which may be conveyed via a communication medium such as a network and/or a wireless link.

In an embodiment, I/O interface **530** may be configured to coordinate I/O traffic between processor **510**, system memory **520**, and any peripheral devices in the device, including network interface **540** or other peripheral interfaces, such as input/output devices **550**. In some embodiments, I/O interface **530** may perform any necessary protocol, timing or other data transformations to convert data signals from one component (e.g., system memory **520**) into a format suitable for use by another component (e.g., processor(s) **510**A-N). In some embodiments, I/O interface **530** may include support for devices attached through various types of peripheral buses, such as a variant of the Peripheral Component Interconnect (PCI) bus standard or the Universal Serial Bus (USB) standard, for example. In some embodiments, the function of I/O interface **530** may be split into two or more separate components, such as a north bridge and a south bridge, for example. In addition, in some embodiments some or all of the functionality of I/O interface **530**, such as an interface to system memory **520**, may be incorporated directly into processor(s) **510**A-N.

Network interface **540** may be configured to allow data to be exchanged between computing system **401** and other devices attached to network **115**, such as other computer systems, or between nodes of computing system **401**. In various embodiments, network interface **540** may support communication via wired or wireless general data networks, such as any suitable type of Ethernet network, for example; via telecommunications/telephony networks such as analog voice networks or digital fiber communications networks; via storage area networks such as Fiber Channel SANs, or via any other suitable type of network and/or protocol.

Input/output devices **550** may, in some embodiments, include one or more display terminals, keyboards, keypads, touch screens, scanning devices, voice or optical recognition devices, or any other devices suitable for entering or retrieving data by one or more computing system **401**. Multiple input/output devices **550** may be present in computing system **401** or may be distributed on various nodes of computing system **401**. In some embodiments, similar input/output devices may be separate from computing system **401** and may interact with one or more nodes of computing system **401** through a wired or wireless connection, such as over network interface **540**.

As shown in FIG. **5**, memory **520** may include program instructions **525**, configured to implement certain embodiments described herein, and data storage **535**, comprising various data accessible by program instructions **525**. In an embodiment, program instructions **525** may include software elements of embodiments illustrated in FIG. **2**. For example, program instructions **525** may be implemented in various embodiments using any desired programming language, scripting language, or combination of programming languages and/or scripting languages (e.g., C, C++, C#, JAVA®, JAVASCRIPT®, PERL®, etc.). Data storage **535** may include data that may be used in these embodiments. In other embodiments, other or different software elements and data may be included.

A person of ordinary skill in the art will appreciate that computing system **401** is merely illustrative and is not intended to limit the scope of the disclosure described herein. In particular, the computer system and devices may include any combination of hardware or software that can perform the indicated operations. In addition, the operations performed by the illustrated components may, in some embodiments, be performed by fewer components or distributed across additional components. Similarly, in other embodiments, the operations of some of the illustrated components may not be performed and/or other additional operations may be available. Accordingly, systems and methods described herein may be implemented or executed with other configurations.

FIG. **6** is a block diagram of an example of software program **600** configured to implement aspects of pinball machine **100** with a hybrid playfield **104**. In some embodiments software **600** may be executed by computing system **401** described above. For example, in some cases, software program **600** may be implemented as program instructions **525** of FIG. **5**. Generally speaking, control engine **601** may include one or more routines configured to implement one or more of the various techniques described herein. For instance, control engine **601** may include one or more routines configured to allow a user to select a game stored in database **605**. Control engine **601** may also include one or more routines configured to allow a user to start or terminate a game, as well as one or more routines configured to manage progress of a game.

Display module **602** may provide a software interface between computing device **401** and electronic display **200** such that images produced by display module **602** are rendered in electronic display **200** under control of control engine **401**. Interface board module **604** may provide a software interface between computing device **401** and interface board **402**. Through interface board module **402**, control engine **401** may determine that one or more sensor(s) **404** have been activated and/or it may control, via actuator(s) **403**, a physical aspect of a physical object in hybrid playfield **104**. Control engine **401** may also receive tracking information from tracking system **300** via interface board module **402**.

Object module **603** may keep track of one or more graphical elements or virtual objects being displayed (or yet to be displayed) on electronic display **200** via display module **602**, including, for example, a virtual object's characteristics such as the object's identification, boundaries, shape, color, size, texture, position (on electronic display **200**), speed, direction of movement, etc. Object module **603** may also keep a record of the received tracking information for one or more physical objects including, for example, an identification of the physical object, its position (above electronic display **200**), speed, direction of movement, shape, etc.

In some embodiments, the modules or blocks shown in FIG. **6** may represent processing circuitry and/or sets of software routines, logic functions, and/or data structures that, when executed by the processing circuitry, perform specified operations. Although these modules are shown as distinct logical blocks, in other embodiments at least some of the operations performed by these modules may be combined in to fewer blocks. For example, in some cases, object module **603** may be combined with display module **602** and/or with interface board module **604**. Conversely, any given one of modules **601-605** may be implemented such that its operations are divided among two or more logical blocks. Although shown with a particular configuration, in other embodiments these various modules or blocks may be rearranged in other suitable ways.

FIG. **7** is a flowchart of an example of method **700** of operating tracking system **300** in hybrid playfield **104**. In some embodiments, method **700** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with interface board **402** and tracking system **300**. At block **701**, method **700** may include determining that a pinball game has started or is about to start. At block **702**, method **700** may include identifying a transducer configuration to be used by tracking system **300**. As previously noted, different transducer configurations may be used in a single machine **100**, and, depending upon the specific game being played, a particular configuration may be more suitable for tracking certain physical objects.

At block **703**, method **700** may include selecting a scanning pattern to be used during a tracking operation. For example, in the configuration shown in FIG. **3**, the selected scanning pattern assigns detector elements **322**, **324**, **326**, **328**, and **330** to receive signals **318**, **317**, **314**, **315**, and **316** emitted by transmitter element **307**, respectively. In some cases, a scanning pattern may be such that each of transmitter elements **301**, **303**, **305**, **307**, **309**, **311**, **313**, **319**, **321**, **323**, **325**, **327**, **329**, and **331** is activated in rapid succession and in this order. In other cases, a transmitter element of first transducer array **300**A may be activated followed by a transmitter element of second transducer array **300**B in an alternating manner (e.g., **301**, **319**, **303**, **321**, and so on). In yet other cases, two or more transmitter elements may be activated simultaneously.

In some implementations, more or fewer detectors may be assigned to receive more or fewer signals from a given transmitter element at a given time. Moreover, the position of the transmitter element may dictate how many and which detector elements are assigned for a given scanning pattern. For instance, using the pattern illustrated in FIG. **3**, when transmitter **301** is active, only detectors **320** and **322** (i.e., two detectors) may be configured to receive its signals. When transmitter **303** is active, detectors **320**, **322**, **324**, and **326** (i.e., four detectors) may be configured to receive its signals. And, when transmitter **305** is active, detectors **320**, **322**, **324**, **326**, and **328** (i.e., five detectors) may be configured to receive its signals. In other implementations, however, a 1:1 relationship between transducer elements may be established such that a given detector is assigned to a single corresponding transmitter and vice-versa.

More generally, any suitable scanning pattern may be selected that creates a mesh such that, when a physical object such as pinball **202** is traveling between transducer arrays **300**A and **300**B therefore blocking the line-of-sight between a transmitter and an assigned detector, tracking system **300** and/or computing system **401** is capable of determining the position, speed, and/or direction of movement of the physical object. In various embodiments, signals are transmitted and received between transducer arrays **300**A and **300**B at angles other than a right angle.

At block **704**, method **700** may execute scanning operation(s) using the identified configuration and/or selected pattern and, at block **705**, method **700** may store results of those operation(s). At block **706**, method **700** may determine whether the game has ended. If not, control returns to block **704**. Otherwise, tracking may end at block **707**.

It should be noted that, in some embodiments, one or more of the operations described above may be conducted independently of whether a game is in progress. For example, in some cases, tracking may be active for purposes of touchscreen interactions when pinball machine **100** is in "service mode" (e.g., testing, debugging, etc.). More generally, electronic display **200** in conjunction with tracking system **300** may allow an operator to interface with aspects of computing system **401** at any time, for instance, to change the machine's configuration, select a new pinball game, test one or more of the machine's components, etc.

FIG. **8** is a flowchart of an example of method **800** of obtaining an object's position in hybrid playfield **104** using tracking system **300** according to some embodiments. Again, in some embodiments, method **800** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with interface board **402** and tracking system **300**. At block **801**, method **800** may include initializing or setting an integer or counter n to a zero value and, at block **802**, method **800** may include activating transmitter element n.

At block **803**, method **800** may include determining whether there is a direct line-of-sight reception at all of the one or more assigned detector elements. If so, then block **806** increments the value of n and control returns to block **802**, where a subsequent transmitter element following the selected scanning pattern is selected. Otherwise, at block **804**, method **800** may include identifying which of the assigned detector elements had its light-of-sight blocked by a physical object. Then, at block **805**, method **800** may include calculating the physical object's position based, at least in part, upon the result of block **804**.

To illustrate operations **802-806**, consider the following example. Assume, hypothetically, that pinball **202** shown in FIG. **3** is now at a position such that it blocks the light-of-sight of detector **330** when transmitter **307** is activated. Because the relative position between arrays **300**A and **300**B is known, it may be inferred that, at the time of the scan, pinball **202** was located somewhere along the path of signal **316**. As n is incremented, subsequent transmitter elements are activated and other detectors may have their light-of-sight blocked, such that the position of pinball **202** may be determined to be at the intersection(s) of two or more of these signals.

In some embodiments, the frequency of the scanning operation may be such that a sufficient number of transmitters are activated in series to resolve the position of pinball **202** prior to pinball **202** having moved to another position that is significantly distant from the resolved position. For example, in some cases, the position of pinball **202** may be identified with a margin of error no larger than the diameter of pinball **202**.

Computing system **401**, interface board **402**, and/or object module **403** may also maintain a historical record of the positions of pinball **202** at different times. Therefore, computing system **401** and/or interface board **402** may be configured to calculate a speed of pinball **202** and/or a direction of movement of pinball **202** based on that historical record. In some cases, computing system **401** and/or interface board **402** may be further configured to predict the position of pinball **202** at a future time based upon its present and/or past behavior.

Physical Objects Causing Changes in Virtual Objects

In some embodiments, hybrid playfield **104** may provide the illusion that one or more physical objects, such as one or more balls **202**, interact with one or more virtual objects, such as one or more images rendered on electronic display **200**. This may take place, for example, when a physical object is detected via tracking system **300** to be moving over an area of hybrid playfield **104** containing the virtual objects. In other examples, the interaction with virtual objects may be triggered upon detection, via tracking system **300**, that a physical object has a certain speed or moves in a particular direction (e.g., toward a virtual object) across hybrid playfield **104**.

In some cases, interactions between a physical object and a first virtual object may cause that first virtual object to move, change its shape, disappear, etc. on electronic display **200**. The same interactions between the physical object and the first virtual object may also cause a second virtual object to move, change its shape, appear, disappear, etc. on electronic display **200**. Other game-related interactions resulting from the interaction of physical and virtual objects in hybrid playfield **104** may include, but are not limited to, game scores being adjusted, sound and video devices being played, lamps being turned on and off individually or in pre-defined sequences, etc.

FIG. **9** is a flowchart of an example of a method of enabling physical object(s) to interact with virtual object(s) in hybrid playfield **104**. In some embodiments, method **900** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with electronic display **200**, interface board **402**, and tracking system **300**. At block **901**, method **900** may include determining a property of a physical object (e.g., pinball **202**). For instance, in some cases, method **900** may include determining a position of the physical object on hybrid playfield **104**, a speed of the physical object over hybrid playfield **104**, and/or a direction of movement of the physical object across hybrid playfield **104**.

At block **902**, method **900** may evaluate the property. At block **903**, if the property does not match any preselected conditions, control returns to block **901**. Otherwise, control passes to block **904**, where method **900** may include rendering a corresponding virtual object on display **200** or modifying a previously rendered virtual object. The conditions referred to in block **903** may include any programmable statement(s) that, when executed, give the appearance that the physical object's property or behavior has affected one or more virtual objects.

In some implementations, a player may indirectly manipulate the physical object described in block **901**. For example, when the physical object is pinball **202**, the player may briefly hit that object with another physical object, such as flippers **207**A and **207**B. Manipulation of flippers **207**A and **207**B may itself be indirect, for example, via side control(s) **107**. After being hit, pinball **202** may travel along playfield freely and outside of the user's control.

It should be noted that determination of a property of a physical object in block **901** is different from the detection of a player's own finger or stylus on a capacitive touchscreen of a tablet computer, which the user directly controls. For example, in the tablet scenario, if the touchscreen does not respond as expected by the user, the user may simply repeat his or her gesture; whereas in the case of a pinball machine, because pinball **202** moves on its own, it would be much more difficult to make pinball **202** repeat the exact same trajectory at a later time and, in any event, a game opportunity would be lost.

FIGS. **10**A-H are diagrams illustrating examples of physical object(s) initiating interaction(s) with virtual object(s) according to some embodiments. Particularly, FIG. **10**A shows pinball **202** (i.e., a physical object) at t=t1 traveling along hybrid playfield **104** while electronic display **200** renders virtual object **1000** in the shape of a triangle. At FIG. **10**B, pinball **202** has moved closer to virtual object **1000** at t=t2 (t2>t1), but has not yet reached it. Then, at FIG. **10**C, pinball **202** has reached the position of virtual object **1000** on electronic display **200** at t=t3 (t3>t2), thus causing virtual element **1000** to change into virtual element **1001**, which now has a circular shape. Referring back to FIG. **9**, the predetermined condition expressed in block **903** in this case may be such as:

if position of <pinball **202**>==position of <virtual object **1000**>;

then change <virtual object **1000**> into <virtual object **1001**>

Thus, in this case, the operations of method **900** may help create a visual impression that pinball **202** has physically interacted with virtual object **1000** upon reaching its location in hybrid playfield **104** and effectively changed the virtual object's shape and/or other visual characteristic.

As another example, FIG. **10**D illustrates pinball **202** traveling upwards (shown by an arrow pointing up) across hybrid playfield **104** at t=t1 (e.g., after being hit by flipper(s) **207**A or **207**B), thus acquiring a first speed. FIG. **10**E shows pinball **202** traveling in a downwards direction (shown by an arrow pointing down) at t=t2 (t2>t1) with a second speed which, in this case, is smaller than the first speed. Accordingly, in FIG. **10**D, virtual object **1002** represents a graphical image or visual animation of fire or smoke following pinball **202** and having a first size proportional to the first speed, whereas in FIG. **10**E virtual object **1003** represents the fire or smoke with a second size proportional to the second speed, such that the first size is larger than the second size.

As yet another example, FIG. **10**F shows pinball **202** traveling across hybrid playfield **104** at t=t1 in a first direction thus leaving trail or mark **1004**. FIG. **10**G shows pinball **202** leaving the surface of electronic display **200** and reaching the boundary of hybrid playfield **104** at t=t2 (t2>t1), from which pinball **202** bounces back. As such, trail or mark **1005** is longer than trail or mark **1004**. Then, FIG. **10**H shows pinball **202** traveling across hybrid playfield **104** in a second direction at t=t3 (t3>t2), thus creating trail or **1006** in the second direction.

It should be noted that the examples of FIGS. **10**A-H are provided for sake of illustration. More generally, any virtual object(s) rendered on electronic display **200** may be affected by any physical property (or combination of physical properties) of any physical object(s) within hybrid playfield **104** in any suitable manner. In the examples above, the physical properties used are position, speed, and direction; although in other embodiments, other physical properties may be used such as shape, size, sound, color, etc. In various implementations, the type of virtual object and how that object is affected by the behavior of a physical object normally depends upon the specific game being played, and as such may vary from game to game.

Moreover, in some embodiments, the behavior of a physical object may be detected other than through tracking system **300**. For instance, pinball **202** may physically reach trigger element **205**, and electronic display **200** may in response render an animation such that it appears that a first virtual object such as an image of a laser beam or projectile is shot by trigger element **205** into hybrid playfield **104**. The first virtual object may then interact with other virtual objects on electronic display **200**; for example, the virtual laser beam or projectile may cause a second virtual object (e.g., an image of a building, etc.) to explode on electronic display **200**.

Virtual Objects Causing Changes in Physical Objects

In some embodiments, hybrid playfield **104** may present the illusion that one or more virtual objects, such as one or more images rendered on electronic display **200**, interact with one or more physical objects, for example, when the virtual object exhibits a predetermined behavior. For instance, when a virtual element is animated on display **200** in a particular way, it may trigger a software-initiated modification to an aspect of a physical object.

In that regard, FIG. **11** is a flowchart of an example of a method of enabling virtual object(s) to interact with physical object(s) in hybrid playfield **104**. In some implementations, method **1100** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with electronic display **200**, interface board **402**, and tracking system **300**. At block **1101**, method **1100** may include rendering a virtual object on electronic display **200**. At block **1102**, method **1100** may include evaluating a property of the virtual object. At block **1103**, if the property does not match a programmed condition, control returns to block **1101**. Otherwise, at block **1104**, method **1100** may include changing an aspect of a corresponding physical object.

FIGS. **12**A-F are diagrams illustrating examples of virtual object(s) initiating interaction(s) with physical object(s) according to some embodiments. In FIG. **12**A, virtual object **1201** is animated on display **200** to move at t=t1 toward slingshot **206**A, a physical object. FIG. **12**B shows virtual object **1201** reaching threshold line **1200** at t=t2 (t2>t1), thus triggering a deformation of slingshot **206**A such that, to an observer, it appears as if slingshot **206**A is reacting physically to the behavior of virtual object **1201** on display **200**. The deformation of slingshot **206**A is a physical response initiated by software because, in this case, virtual object **1201** is in a specific position relative to slingshot **206**A. In an embodiment, the shape of slingshot **206**A may be controlled by a solenoid mechanism that, when activated by software, pushes against a side of slingshot **206**A, thus causing it to mechanically expand. Then, FIG. **12**C shows slingshot **206**A returning to its original shape at t=t3 (t3>t2), and electronic display **200** changes the shape of virtual element **1201** into virtual element **1202**, which now travels away from slingshot **206**A on display **200** as if it had physically bounced off of slingshot **206**A and now appears to be moving further away from slingshot **206**A.

By drawing virtual element **1202** such that it appears to be moving away from slingshot **206**A, this technique may cause observer, such as the player, to believe that a virtual element **1201** (i.e., a graphical image) actually represents a physical object that interacted mechanically or physically with another (but actual) physical object (i.e., slingshot **206**A). More specifically, it may appear as if virtual element **1201** actually collided with slingshot **206**A, causing a solenoid mechanism to activate, in turn causing slingshot **206**A to "push" virtual element **1202** away from it.

In other embodiments, a virtual element does not need to appear to come into contact with a physical object, but it may still affect the operation of that physical object. An example of this technique is shown in FIGS. **12**D-E. In FIG. **12**D, a first virtual object **1203** (a rendering of a missile) is animated to move toward a second virtual element **1204** (a rendering of a target) on electronic display **200** at t=t1. FIG. **12**E shows that first virtual object **1203** and second virtual object **1204** have been replaced by third virtual object **1205** (a rendering of an explosion) upon first virtual object **1203**'s reaching of second virtual object **1204** at t=t2 (t2>t1). At this moment, operation of flipper **207**B (i.e., a physical object) may be changed such that, when a player activates side control(s) **107**, only flipper **207**A is capable of moving upwards while flipper **207**B is stuck in a down position as a result of the collision between virtual element **1203** and virtual element **1204**. In some cases, a fourth virtual object **1206** (e.g., a rendering of fire or smoke) may indicate that flipper **207**B is not operational such that, when virtual object **1206** disappears of fades from electronic display **200**, flipper **207**B returns to its normal operation under control of the player.

In other words, when the first virtual object reaches a specific point on electronic display **200**, it may cause a specific, predetermined reaction in a physical object, such as one or more flippers **207**A and **207**B. An example of such a reaction may be to cause the one or more of flippers **207**A and **207**B to flip, as if the missile pressed a "virtual flipper" button. Another reaction may be causing flippers **207**A and **207**B to "lose power," such that when the player next activates the flippers, they do not have as strong a pulse as they did prior to the missile reaching the specific location on electronic display **200**. Because the length of the flipper pulse, and therefore the power of the pulse, is controlled by software, control engine **601** may effectively weaken flippers **207**A and/or **207**B in response to missile **1203** reaching the specific location on the electronic display **200**. This technique may make it appear that the graphical, virtual object (i.e., missile **1203**) represented a physical element, such as a real missile, and was therefore capable of affecting physical object (i.e., flippers **207**A and **207**B).

Similarly as explained above, here it should also be noted that the examples of FIGS. **12**A-F are provided for sake of illustration. More generally, any physical object(s) in hybrid playfield **104** may have its propert(ies) modified in response to the behavior of one or more virtual object(s). Properties of the physical objects that may be subject to being changed include its shape, operation, color, sound, etc. Again, in various implementations, the type of physical object and how that object is affected by the behavior of a virtual object normally depends upon the specific game being played, and as such may vary from game to game.

Physical objects that can be affected by virtual objects include, but are not limited to, lamps, light emitting diodes (LEDs), magnets, motors, and solenoid assemblies, all of which may be found on pinball machine **100**. Virtual objects that may interact with physical objects include, but are not limited to, shapes or combination of shapes drawn on a display element, projected from a projection device, or otherwise displayed in a way that they appear to be part of or on pinball machine **100**. The location of virtual objects can be anywhere on machine **100**, oftentimes, but not always, close to the physical objects with which they appear to interact. In the example above where the missile is described to press a virtual flipper button, the spatial proximity of the missile and virtual button relative to the flippers is not relevant. As such, the graphical elements (missile and virtual button) can be located anywhere on electronic display **200**.

Deploying Physical Objects

In some embodiments, one or more of the aforementioned physical objects such as, for example, ball(s), plunger(s), bumper(s), kicker(s), bullseye target(s), drop target(s), variable point target(s), roll(s), saucer(s), spinner(s), rollover(s), switch(es), gate(s), stopper(s), ramp(s), toy(s), electromagnet(s), etc., or other physical objects, may be located in pinball machine **100**. At least in part due to the presence of electronic display **200**, tracking system **300**, and/or other components, one or more of these physical objects may be deployed within hybrid playfield **104** as described in more detail below.

There are many places in a pinball machine where the systems and methods described herein may be used. Common situations involve places where there is not enough room for all of the components required to strike and apply an acceleration to other objects. In such cases, the components may be separated into connected components, one or more components being remotely located with respect to another component(s), two or more components connected to each other or linked in a suitable manner.

In that regard, FIG. **13** is a block diagram of an example of a remote actuator system according to some embodiments. As illustrated, one or more actuator(s) **403** are operably coupled to one or more physical object(s) **1302** via one or more links. Particularly, in this example, link portion **1300**A couples actuator(s) **403** to tensioning device(s) **1301**, and link portion **1300**B couples tensioning device(s) **1301** to physical object(s) **1302**. It should be noted, however, that link portions **1300**A and **1300**B may in fact constitute a single, continuous link (collectively referred to as "link") and that, in some cases, tensioning device(s) **1301** may be absent. Tensioning device(s) **1301**, when present, may be located somewhere along the link.

Generally speaking, movement of actuator(s) **403** creates a force applied to physical object(s) **1302** via the link. Particularly, link portions **1300**A and **1300**B coupled between actuator(s) **403** and physical object(s) **1302** ensure that the movement of actuator(s) **403**, or component(s) within actuator(s) **403**, is translated into the movement of physical object(s) **1302**.

In some implementations, actuator(s) **403** may include an electric motor, plunger, or the like having a coil or solenoid element. When actuator(s) **403** (or one or more components within actuator(s) **403**) moves, link portions **1300**A and **1300**B also move. The movement of link portions **1300**A and **1300**B cause physical object(s) **1302** to move as well. In some implementations, the specific nature of the movement of actuator(s) **403** and physical object(s) **1302** may be to cause physical object(s) **1302** to strike and apply an accelerating force to another physical object (e.g., pinball **202**) in the pinball machine.

In some embodiments, tensioning device **1301** may be used to adjust the position and/or movement of physical object(s) **1302**. For example, tensioning device may include a knob and a bracket or mount such that the link goes through both the knob and the bracket or mount. The bracket or mount may be coupled to a portion of the pinball machine to keep the knob from moving when a force is applied by actuator(s) **403** to the link, whereas the knob may increase the tension on the link when turned in one direction, and it may decrease the tension on the link when turned in the other direction. In other implementations, tensioning device **1301** may include a turnbuckle, a ratcheting device, or another suitable tensioning mechanism.

Link portions **1300**A and **1300**B may be used to translate the movement of actuator(s) **403**, or component(s) of actuator(s) **403**, into the movement of physical object(s) **1302** and may be made of any suitable material that is easy to bend and reshape, for example, at room temperature. The shapes of link portions **1300**A and **1300**B may also be dynamically adjusted when a force is applied to it by the movement of actuator(s) **403**.

In some implementations, the material used for link portions **1300**A and/or **1300**B may include a flexible material that is readily capable of assuming various curved or bent configurations or paths within hybrid playfield **104**, such as wire, rope, malleable steel cable, etc. For instance, link portions **1300**A and **1300**B may assume different configurations (e.g., bend around different points along their lengths) during the course of a pinball game as actuator(s) **403** and/or physical object(s) **1302** are operated. In other implementations, the material used for link portions **1300**A and/or **1300**B may be include a rigid material such as a steel rod, metal bar or arm, hard plastic (e.g., thermosetting plastics, etc.), or the like.

The lengths of link portions **1300**A and **1300**B may be determined by the positions at which actuator(s) **403** and physical object(s) **1302** are placed, as well as the path that the link needs to take to connect to actuator(s) **403** and physical object(s) **1302**. For instance, when actuator(s) **403** are located in close proximity to physical object(s) **1302**, the link may be short. Conversely, when actuator(s) **403** are located far away from physical object(s) **1302**, the link may be long. As such, through the use of link portions **1300**A and

1300B, actuator(s) **403** and physical object(s) **1302** may be located anywhere in the pinball machine, even large distances apart from each other.

In some embodiments, a housing or pipe may be used to provide a more rigid and consistent guide for the link's movement. Such housing may be a hollow tube or other material through which link portions **1300**A and/or **1300**B is routed. Further, the housing may be mounted in a way that it does not move relative to the pinball machine when actuator(s) **403** (and therefore the link) moves. Rather, link portions **1300**A and/or **1300**B move through it. Therefore, in some implementations, a cable housing may provide a well-defined and unchanging path that the link may follow when translating the movement of actuator(s) **403** to the movement of physical object(s) **1302**.

FIG. **14** shows a diagram of an example of a single actuator **1400**. In some embodiments, single actuator **1400** may be used as actuator(s) **403** in FIG. **13**. In this illustration, single actuator **1400** includes of one or more components that may be made to move in order to exert a force on link portions **1300**A and/or **1300**B. Particularly, casing **1402** includes electromagnet solenoid **1404** made up of a wire coupled to terminal **1401**A, the solenoid being wrapped dozens or hundreds of times around a hollow core, and then coupled to another terminal **1401**B. When a predetermined voltage is applied across terminals **1401**A and **1401**B, electrical current flows through solenoid **1404**, thus creating a magnetic field inside the core around which the wire is wrapped. When the magnetic field is active, metal plunger **1403** is pulled into casing **1402** (a "first direction").

Link portion **1300**A is coupled to plunger **1403** such that, when plunger **1403** is pulled in the first direction, link portions **1300**A and/or **1300**B are pulled along with it. Therefore, the movement of plunger **1403** translates into the movement of link portions **1300**A and/or **1300**B, and that movement translates into the movement of physical object(s) **1302**. When the magnetic field is inactive—i.e., when no voltage is applied across terminals **1401**A and **1401**B—the force applied to plunger **1403**, and therefore link portions **1300**A and/or **1300**B, disappears. In some cases, plunger **1403** may then move in a direction opposite to the first direction (a "second direction") to return to its original position. To move plunger **1403** back to its original position, a spring may be employed as described below. Additionally or alternatively, if physical object(s) **1302** is pushing against another component with some tension (e.g., a rubber ring), that component may exert a force back on physical object(s) **1302**, thereby moving it back to its original position, and, by extension, forcing plunger **1403** back to its original position as well.

In some embodiments, a spring may be placed within casing **1402** to help return plunger **1403** to its original position outside of the solenoid's core. Such a spring may be compressed when plunger **1403** is pulled into casing **1402**, and its subsequent decompression may force plunger **1403** back out of casing **1402**. The force applied to plunger **1403** by the spring may be in the second direction. Accordingly, when the magnetic field within casing **1402** ceases, link portion **1300**A moves outwardly from casing **1402**, thus causing physical object(s) **1302** to also move in the second direction.

FIG. **15** is a diagram of an example of a dual actuator **1500** according to some embodiments. In this illustration, two single actuators **1400**A and **1400**B may make up actuator(s) **403** of FIG. **13**. More generally, however, any number N of single actuators may be used. Here actuators **1400**A and **1400**B are connected together by cable **1501**, which is distinct from link portions **1300**A and **1300**B of FIG. **13**. Cable **1501** is routed through pulley **1502**, which is in turn coupled to link portion **1300**A.

Similarly as before, link portions **1300**A and/or **1300**B couple actuator(s) **403** to physical object(s) **1302**, and are therefore configured to translate movement between actuators **1400**A/B and physical object(s) **1302**. More specifically, when either of actuators **1400**A and **1400**B's plungers is pulled into its respective solenoid core, pulley **1502** is also pulled closer to respective one(s) of actuator(s) **1400**A and/or **1400**B. This movement of pulley **1502** exerts a force on link portion **1300**A, and that force translates to movement of link portions **1300**A and **1300**B, and therefore movement of physical object(s) **1302**.

In some embodiments, either or both of actuators **1400**A and **1400**B may be activated at any given time. Activating actuators **1400**A and **1400**B may simultaneously translate into more movement of pulley **1502** than when only one of actuators **1400**A or **1400**B is activated at a time. A larger movement of pulley **1502** translates into more movement of the link, and therefore faster movement of physical object(s) **1302**. Accordingly, in some implementations, the use of N actuators may enable different lengths and/or speeds of movement in physical object(s) **1302**.

FIG. **16** is a diagram of an example of a remotely actuated flipper **207**A. In some embodiments, flipper **207**A may be used as physical object(s) **1302** of FIG. **13**. Here, flipper **207**A pivots or rotates around point or post **1601** to assume one of two or more positions **1600**A-N (or any other position in between) depending upon the force applied by link portion **1300**B, which in turn depends upon the operation of actuator(s) **403**, also shown in FIG. **13**.

In some embodiments, post **1601** may be used to mount flipper **207**A to a portion of hybrid playfield **104** that does not move when flipper **207**A rotates around post **1601**. This mounting can include, for example, a metal cylinder connected to a surface of pinball machine **101**. In some cases, flipper **207**A may be made of a single material, such as plastic, wood, metal, or any other suitable material. In other embodiments, however, flipper **207**A may include multiple components and/or multiple materials. For example, flipper **207**A may have a plastic body with a ball bearing mounted such that it fits around post **1601**.

Here, link portion **1300**B is coupled to a portion of flipper **207**A other than post **1601** (that is, the actual flipper bat) and in such a way that movement of link portion **1300**B translates to flipper **207**A rotating around post **1601**. When link portion **1300**B moves towards the bottom of FIG. **16**, flipper **207**A rotates clockwise, potentially reaching position **1600**N or any other intermediate position. When link portion **1300**B moves towards the top of FIG. **16**, flipper **207**A rotates counterclockwise, potentially returning to position **1600**A.

In some implementations, flipper **207**A may be controlled by a user operating side control(s) **107** to strike and/or apply an acceleration to another object, such as pinball **202**. The acceleration may be applied to pinball **202** directly or indirectly (e.g., in cases where flipper **207**A is surrounded by a rubber ring or the like; in which case, the rubber ring applies the force to pinball **202**). For example, if pinball **202** is at a location where part of flipper **207**A resides when traveling between positions **1600**A and **1600**N, flipper **207**A may strike pinball **202** and therefore apply an acceleration to it by rotating around post **1601** due to the movement of link portion **1300**B.

FIG. **17** is a diagram of an example of remotely actuated slingshot **206**A. In some embodiments, posts **1701**A-C hold rubber ring **1702**A or the like in place, and bat **1700**A (similar to flipper **207**A shown in FIG. **16**) may be configured to push against ring **1702**A. In that scenario, bat **1700**A may be configured to rotate as described in connection with FIG. **16** to assume position **1700**N (or any position in between), in which case rubber ring **1702**A may assume shape **1702**N (or any shape in between). Thus, rubber ring **1702**N may strike pinball **202** upon control of actuator(s) **403** shown in FIG. **13**.

Particularly, when actuator(s) **403** pull link portions **1300**A and/or **1300**B, bat **1700**A may move to position **1700**N, thus causing ring **1702**A to assume configuration **1702**N. Therefore, if pinball **202** meets the rubber ring while the rubber ring is traveling between positions **1702**A and **1702**N, slingshot **206**A may strike pinball **202** and therefore apply an acceleration to it. Then, when actuator(s) **403** stop pulling link portions **1300**A and/or **1300**B, bat **1700**N returns to its original position **1700**A.

As described, FIGS. **16** and **17** present embodiments of physical object(s) **1302** of FIG. **13**. It should be noted, however, that these embodiments are shown only by way of illustration, and that numerous other embodiments and variations are contemplated. In some cases, physical object(s) **1302** may move in a single direction, whether along a straight line or around a point. In other cases, physical object(s) **1302** may move in multiple directions, sometimes simultaneously, and other times only one direction at a time. It should also be noted that movement of physical object(s) **1302** is often, but not always, intended to strike and apply an acceleration to another object (e.g., pinball **202**).

In some implementations, physical object(s) **1302** may contain one or more springs or other tensioning devices to help apply movement to component(s) coupled to link portions **1300**A and/or **1300**B. For example, in FIGS. **16** and **17**, a spring may be added to help return flipper **207**A and/or slingshot **206**A to its original position once the force being exerted by link portions **1300**A and/or **1300**B goes away. The force therefore being applied by the spring may subsequently cause flipper **207**A and/or slingshot **206**A to exert a force on link portions **1300**A and/or **1300**B, which translates to a force on components actuator(s) **403**. In this manner, the system may be reversed in that physical object(s) **1302** now act to provide a force on link portions **1300**A and/or **1300**B in order to produce movement in actuator(s) **403**. However, components of actuator **403** may not necessarily be moved in order to strike and apply an acceleration to another object. In various embodiments, the movements caused in actuator(s) **403** by the movements of physical object(s) **1302** are to return components within actuator(s) **403** to their original positions.

Generally speaking, it should be noted that components within actuator(s) **403** or components within physical object(s) **1302** need not be located in the same general vicinity or be directly attached to each other. In other words, actuator(s) **403** and physical object(s) **1302** may be made up of many components that are located far apart from each other.

Furthermore, in some embodiments, one or more physical object(s) **1302** may be deployed within hybrid playfield **104**. As such, the presence of electronic display **202** and/or tracking system **300** may prevent physical object(s) **1302** from being directly coupled to the playing surface of playfield **104**. To address these and other concerns, FIGS. **18-20** describe systems and methods of suspending or floating physical object(s) **1302** within hybrid playfield **104**.

In that regard, FIG. **18** is a diagram of an example of a suspended or floating physical object **1800** in hybrid playfield **104** according to some embodiments. Specifically, object **1800** may be a metal post used to prevent pinball **202** from traveling into a part of playfield **104** that is blocked by object **1800**. In some cases, object **1800** may include a rubber ring or the like. In order to keep the assembly from moving or breaking when pinball **202** hits it, traditional mounting techniques would involve screwing directly into playfield **104** or screwing into a nut located underneath playfield **104**; thus causing object **1800** to appear to rise up from playfield **104**.

In contrast, here object **1800** is suspended within playfield **104** above electronic display **200**, thus appearing to be floating above the surface of playfield **104**. Particularly, object **1800** is mounted onto surface **1802**, which in this case may be a portion of a playfield cover or some other non-playable area, and hangs down from surface **1802**. Point **1801** indicates the location of playfield **104** where object **1800** would touch electronic display **200** were it long enough to do so; and gap **1803** illustrates the distance between the tip of object **1800** and point **1801**.

There may be a number of reasons why one may want object **1800** to appear as if it were floating in a pinball machine. For example, it may not be possible to mount the assembly in the desired location on playfield **104**. In FIG. **18**, for instance, electronic display **200** makes it impossible to mount object **1800** assembly in the desired location on playfield **104**. In other cases, components other than an electronic display may block object **1800**.

Also, one may wish to allow certain items to pass below the assembly, closer to the surface of playfield **104**. Still referring to FIG. **18**, tracking system components **300**A and **300**B may include transmitters and receivers that transmit and receive beams of light, for example, as described in FIG. **3**. Thus, the height **1804** of components **300**A and **300**B may be smaller than the gap **1803** between object **1800** and point **1801** so as to allow components **300**A and **300**B to communicate with each other while still blocking pinball **202** from entering a specific part of playfield **104** (e.g., the diameter of pinball **202** may be greater than gap **1803**). In contrast, if object **1800** had been mounted directly on the surface of playfield **104**, object **1800** would at least partially block communications between components **300**A and **300**B, thus creating a blind spot around which tracking system **300** would be unable to track the movement of pinball **202**.

There are a number of ways to mount floating pinball assemblies to provide the illusion that objects or assemblies are floating, for example, by keeping surface **1802** out of view from the player's perspective. In that regard, FIGS. **19**A-C are diagrams of components configured to suspend object **1901** in hybrid playfield **104** according to some embodiments.

In example **1900**A of FIG. **19**A, mount **1902** holds object **1901** having rubber ring **1908** above electronic screen **200** with gap **1904**. Mount **1902** may be attached to cover **1903**. In some cases, at least mount **1902** and/or cover **1903** may be made of glass, plastic, LEXAN, PLEXIGLAS, acrylic or other transparent or translucent materials so as to give the impression that object **1902** is floating. As to example **1900**B of FIG. **19**B, mount **1902** is vertically positioned and mounted against side wall **1905** of pinball machine cabinet **101**. Thus, arm **1904** may extend horizontally away from side wall **1905** to object **1901**. In some cases, at least mount **1902**, side wall **1905**, and/or arm **1904** may be made of glass, plastic, LEXAN, PLEXIGLAS, acrylic or other transparent or translucent materials. With respect to example **1900**C of FIG. **19**C, mount **1902** is horizontally positioned and mounted against horizontal surface **1907** of the pinball machine distant from electronic display **200**, out of sight from the player's perspective. Thus, vertical arm **1906** is coupled to horizontal arm **1904**, which in turn is coupled to object **1901**. Again, at least mount **1902**, vertical arm **1906**, and/or horizontal arm **1904** may be made of glass, plastic, LEXAN, PLEXIGLAS, acrylic or other transparent or translucent materials.

It should be noted that, in the foregoing examples, the assembly that includes object **1901** and ring **1908** (i.e., the object(s) with which pinball **202** makes contact) are directly coupled to non-playable surfaces of the pinball machine (e.g., side wall **1905**, etc.), that is, surfaces other than the playable surfaces that are accessible to pinball **202** during the normal course of a pinball game, and where the pinball game is actually played (e.g., including a surface immediately above electronic display **200**). Moreover, the mounting is done in such a way that the items in the assembly appear to be hanging or floating from the player's perspective. In some cases, object **1901** may itself be made of glass, plastic, LEXAN, acrylic or other transparent or translucent materials, thus giving the impression that ring **1908** is floating.

Floating assemblies may have few items, such as posts and rubber rings, or may be very complex with numerous items, including combinations of fixed and moving parts. For example, flipper **207**A may be made into a floating assembly by inverting the typical installation and mounting it from above, similar to how the post **1901** is mounted in FIGS. **18** and **19**A. Slingshot assembly **206**A may also be suspended or mounted from above.

FIG. **20** is a diagram of an example of intermediate surface **2000** configured to suspend physical objects in hybrid playfield **104** according to some embodiments. Particularly, flippers **207**A and **207**B, as well as slingshots **206**A and **206**B, are mounted on intermediate surface **2000**, which may be located at an intermediary height between a cover or lid of the machine, and the playable surface of playfield **104**. In some embodiments, components of flippers **207**A/B and/or of slingshot posts **206**A/B, as well as intermediate surface **2000**, may be made of transparent or translucent materials. Intermediate surface **2000** may also hang over the playable surface of playfield **104**, anchored to either the side of pinball machine cabinet **101** or to other items out of view from the player.

In the example of FIG. **20**, electronic display **200** is embedded into playfield **104** directly below assemblies **206**A/B and/or **207**A/B. Because traditional non-floating assemblies **206**A/B and/or **207**A/B would need to be mounted directly to playfield **104**, having electronic display **200** in the playfield makes it impractical to use the traditional non-floating assemblies. Floating assemblies **206**A/B and/or **207**A/B provide similar characteristics to non-floating ones, but are mounted in a way that does not interfere with electronic display **200**. Further, by making most of the items in the assembly out of acrylic, or other transparent or semi-transparent material, the player can still see graphics and other items being displayed on electronic display **200**, even directly under the floating assemblies **206**A/B and/or **207**A/B.

Another embodiment may contain some or all of the following items floating near one or both sides of playfield **104**: posts, rings, switch targets, guide rails, and other items otherwise used in pinball machines. Once again, a floating assembly with these items may be used due to the inability to mount the items directly to playfield **104**, such as in the case of the playfield containing electronic display **200** or other items. It might also be used so that they do not obstruct the path of infrared beams going across the playfield, near the playable surface of playfield **104**. Such infrared beams may be used to detect the position of pinball **202** as it moves across the surface of playfield **104**. Using traditional non-floating assemblies mounted into the playfield itself would not work, because assemblies would block infrared beams, rendering the tracking system at least partially useless.

In summary, floating pinball assemblies may generally operate as their non-floating pinball counterparts, but they present the illusion, from the player's perspective, that they are floating above the playable surface of playfield **104** or above other items mounted to the playfield. They therefore enable the use of features that would not otherwise be usable in a pinball machine, such as electronic display **200** embedded into playfield **104** in areas that are typically used for assembly mounting, or tracking systems whose infrared beams need to travel through areas generally populated by traditional non-floating assemblies.

Animated Playfield Components

Flippers, slingshots, targets, and other physical objects may be used as playfield components configured to physically interact with a pinball during a pinball game. For instance, referring to FIG. **2**, playfield components such as flippers **207**A/B, slingshots **206**A/B, and targets **205** may be disposed within playfield **104** and may be used to perform different gameplay operations. Although some of the examples of animated playfield components discussed below refer specifically to flippers, it should be understood that the same principles may be applied to any other of the aforementioned physical objects and components.

Generally speaking, flippers **207**A/B may be manipulated by a player in order to prevent pinball **205** from falling in drain **208**, and/or to otherwise control pinball **205**. Flipper manipulation may be achieved via software, direct hardware wiring, etc. Usually, but not always, pinball machines have two flippers near the bottom of the playfield, as shown in FIG. **2**. Certain machines may have fewer flippers. Other machines have additional flippers in other areas of playfield **104** to give players the ability to control pinball **202** at other locations of the playfield.

As noted in connection with FIG. **16**, a flipper may pivot or rotate around a point or post to assume one of two or more predetermined positions under control or a player. When flippers are activated, typically by the player hitting a button (e.g., side control **107** in FIG. **1**) corresponding to the flipper, the flipper rotates into another position. The changing of the flipper's position may be used to redirect the motion of a pinball. Flippers may also be used for other gameplay operations. Examples include, but are not limited to, holding a pinball in place, allowing a pinball to bounce from one flipper to another, and stopping the motion of a pinball.

Conventional flippers are typically made out of plastic, and they are usually opaque and single-colored. Examples of conventional flipper colors include white and yellow. Similarly, other playfield components (e.g., slingshots, etc.) are also usually made of opaque materials.

In contrast, in some embodiments described herein, a flipper (or any other pinball component) may be animated, such that the visual appearance of its surface (e.g., its top surface) changes over time. For example, in some implementations, a flipper may display one color at one time and a different color at another time. In other implementations, the opacity of the flipper may change. In yet other implementations, text, shapes or other graphical objects may be drawn or rendered (or appear to be drawn or rendered) on the flipper.

To illustrate these features, FIGS. **21**A-C show three-dimensional, auxiliary views of examples of animated flippers according to some embodiments. In each of FIGS. **21**A-C, flipper bat portion **2101** is configured to rotate around post **2102** during a pinball game, typically (although not exclusively) under control of a user or player.

With respect to FIG. **21**A, the surface of flipper **2100**A has different shapes **2103-2105** (e.g., each shape may have a different color), and each shape includes or is optically coupled to a corresponding one of light sources **2106-2108**. For example, each of light sources **2106-2108** may include one or more LEDs or the like (e.g., each of light sources **2106-2108** may include a white LED or an array of red, green, and blue LEDs) built or embedded within flipper **2100**A, and shapes **2103-2105** may be painted, drawn, carved, and/or inlaid (e.g., plastic or glass) onto the surface of flipper bat portion **2101**. As such, when a particular one of light sources **2106-2108** is turned on (or set to a particular color), a corresponding one of shapes **2103-2105** is visible to the user or player. Non-illuminated shapes are not visible, or are at least less visible (e.g., opaque) to the player.

For flipper **2100**A to be animated, different ones of light sources **2106-2108** may illuminate corresponding ones of shapes **2103-2105** at a given time. For instance, a particular pinball game may begin without any of light sources **2106-2108** being turned on—thus rendering all of shapes **2103-2105** opaque—and one or more of those light sources may be turned on later during the game, for example, in response to a game event.

For example, if all of elements **2103-2105** have the same shape, turning each of lights **2106-2108** on and off sequentially may give the impression that the shape is moving to different positions across the surface of flipper bat portion **2101**. As another example, shape **2103** (or any other shape(s)) may be illuminated when flipper **2100**A is in a down position, and shape **2105** (or any other shape(s)) may be illuminated when flipper **2100**A is in an up position. As yet another example, shape **2104** (or any other shape(s)) may be caused to "blink" in response to the player reaching a predetermined point or stage in a pinball game (e.g., a bonus round, etc.). As still another example, a first one of shapes **2103-2105** may be lit when a first pinball is being played, a second one of shapes **2103-2105** may be lit when a second pinball is being played, and a third one of shapes **2103-2105** may be lit when a third pinball is being played.

In some of the foregoing examples, when a given one of shapes **2103-2105** is not said to be lit, it may be deemed to be opaque—that is, a corresponding one of light sources **2106-2108** is turned off. Moreover, it should be understood that any number of light sources **2106-2108** and shapes **2103-2105** may be used, and that a one-to-one correspondence between light sources and shapes is not needed. Also, shapes **2103-2105** may have any suitable design, and may match a theme of the game or machine.

In FIG. **21**B, the surface of flipper **2100**B includes display **2109**. For example, display **2109** may include an LCD display similar to electronic display **200** of FIG. **2**, but smaller in size to fit the surface of flipper bat portion **2101**. In some embodiments, display **2109** may render one or more images during a pinball game. These images may include text, shapes or other graphical objects.

In some cases, display **2109** may provide graphical or textual instructions that teach a player certain aspects of the game such as, for instance, an instant in time when to activate flipper **2100**B. This may be achieved, for example, by tracking the position of the pinball across playfield **104**, determining a time at which flipper **2100**B should be activated in order to prevent the pinball from falling in the drain, accounting for a player reaction time (the time it should take for the player to see an instruction and control the flipper in response), and presenting the instruction to the player via display **2109** so that he or she has a sufficient amount of time to activate flipper **2100**B and hit the pinball.

In other cases, display **2109** may indicate a timer countdown, a number or credits left to the player, etc. In yet other cases, display **2109** may provide colorful animations with the goal to entertain the player during the game. For example, display **2109** may show images of fireworks, explosions, etc. matching the theme of the game or machine. In some implementations, the images displayed on display **2109** may be synchronized with images displayed on electronic screen **200** such that flipper bat portion **2101** appears to be at least partially invisible to a player—that is, image(s) on display **2109** appear to be part of the image(s) on electronic screen **200**—when flipper bat portion **2101** is static and/or rotating around pivot point **2102**.

Here it should be noted that display **2109** may assume any suitable shape and does not need to be rectangular. Display **2109** may, in some cases, cover the entirety of the surface of flipper bat portion **2101**. In other cases, display **2109** may be located inside of flipper **2100**B and covered with a transparent or translucent materials. Additionally or alternatively, display **2109** may be flush with the surface of flipper bat portion **2101** so that flipper **2100**B appears to be a monolithic component.

In FIG. **21**C, flipper bat portion **2101** of flipper **2100**C includes a hollow, transparent, and/or translucent gap **2110** surrounded by solid or opaque boundary **2111**. When flipper **2100**C is mounted on playfield **104**, gap **2110** allows a player or onlooker to see a portion of electronic display **200** ("flipper portion") directly under gap **2110** and within boundary **2111**. The flipper portion of display **200** may, in some cases, comprise a set of pixels having a shape that follows the contour of boundary **2111**. Hence, any of the aforementioned types of animation, or any other animation, although actually rendered on electronic display **200** below flipper **2100**C, may appear to an onlooker as if rendered on the surface of flipper **2100**C.

When flipper bat portion **2101** rotates, gap **2110** moves relative to electronic display **200**. In some implementations, by periodically or continually tracking the motion and/or activation of flipper **2100**C, graphical renderings in the flipper portion of electronic display **200** may be made to appear to move in a corresponding fashion, thus matching or tracking the movement of gap **2110**. As such, different physical portions of electronic display **200** (i.e., different sets of pixels) may provide the surface animation of flipper **2100**C when flipper **2100**C moves.

For instance, when flipper **2100**C is in a first position, the flipper portion of display **200** may consist of a first set of pixels corresponding to the portion of display **200** that a player sees through gap **2110**, and that appears (to that player) to be at the surface of flipper **2100**C. When flipper **2100**C is in a second position, the flipper portion of display **200** may correspond to a second set of pixels that a player then sees. Upon flipper **2100**C's return to the first position, the flipper portion of display **200** may change to again encompass the first set of pixels. In some cases, any number of positions may be interpolated so that flipper portions encompass different sets of pixels at different times. Furthermore, at any given time, portions of electronic display **200** that are not directly under gap **2110** at that time may continue to render other images (e.g., background graphics, etc.) that are not intended to appear as if part of the surface of flipper **2100**C.

Players of different heights and/or body types may see playfield **104** at different angles, and therefore may have different perspectives on images seen through gap **2110**. In some embodiments, a camera or other sensor (e.g., mounted on vertical portion **103**, etc.) may be coupled to interface board **402** and may be configured to identify a player's height and/or to track the location of a player's head and/or eyes. Accordingly, the location of a flipper portion of electronic display **200** under gap **2110** that displays images appearing to be rendered on the surface of flipper **2100**C may be adjusted to accommodate the player's vision, in some cases in real time, depending upon the player's height, distance from playfield **104**, head positioning, and/or eye positioning, such that the images produced by the flipper portion of electronic display **200** during a game appear to be directly under flipper **2100**C, regardless of perspective.

Additionally or alternatively, the level (roll, pitch, and/or yaw) of playfield **104** may be used when determining where to position the flipper portion of electronic display **200**. To that end, one or more accelerometers used as part of the automatic level detection systems and methods described in more detail below may be used here in order to adjust the location of flipper portions of electronic display **200**, and so that the images produced by those flipper portions appear to be directly under flipper **2100**C, regardless of the angle(s) with which pinball machine **100** and/or playfield **104** is set up.

In various embodiments, shapes, texts, and/or colors that represent the animations may either be drawn or displayed on the flipper themselves, or may be drawn or displayed in such a way that they appear to be in or on the flippers, even if those animations are not in or on the flippers. In an embodiment, colors that represent animations may be created by LEDs that are placed inside of the flippers or whose light is directed onto the flippers. In another embodiment, small screens such as LCD screens may be attached to the flippers and animations may be drawn or displayed on the screens. In another embodiment, animations may be projected onto the flippers from another source, such as a video projector. In yet another embodiment, flippers may be transparent or semi-transparent, and animations may be drawn or displayed on a screen or screens that are underneath the flippers.

FIG. **22** is a flowchart of an example of method **2200** of animating a playfield component. In some embodiments, method **2200** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with electronic display **200**, interface board **402**, and/or tracking system **300**. At block **2201**, method **2200** includes identifying a game event. Examples of events include, but are not limited to, a game having not yet begun, a game having started, a number of credits being available, a stage or a predetermined point in a game being reached, a particular target being hit, a number of pinballs having been used or being available, a number of points being earned, a position of a physical object in the playfield, a speed or direction of the physical object, etc.

At block **2202**, method **2200** includes determining whether the event meets a predetermined condition. For example, the position of a physical object may have changed by an amount meeting a threshold value, a minimum number of points may have been earned, and so on. If so, then at block **2203** method **2200** includes changing the visual appearance and/or animating a physical object within the playfield in a preprogramed manner. Otherwise, method **2200** returns to block **2201**.

The shapes and colors that comprise animations on physical objects can change over time, often as a result of changing circumstances in gameplay. In some embodiments, text may be displayed on the flipper indicating the shot at which a player should aim, or counting down a timer, or any number of other possibilities. In other embodiments, the animations may appear as lightning bolts, morphing shapes, moving characters, or any number of other possibilities. In yet other embodiments, animations may include all of the previously described items.

The foregoing examples represent but only a few of the numerous ways the flippers or other playfield components may be animated using the systems and method described herein. The term animation applies broadly to the items being displayed on the playfield components that change over time, whether simple colors, shapes, texts, or other graphical objects.

Automatic Level Detection

The manner in which a pinball interacts with the playfield and/or physical objects on the playfield in a pinball machine during a game may be dependent upon the level at which the machine rests. The front-to-back level of a pinball machine, referred to herein as the pitch and illustrated in FIG. **1**, determines the speed at which one or more pinballs roll up or down the playfield when not subject to forces other than natural forces imposed by gravity, friction, and/or air resistance. The side-to-side level of a pinball machine, referred to herein as the "roll" and also shown in FIG. **1**, determines to which side one or more pinballs rolling on the playfield will be pulled when not under any force other than the aforementioned natural forces. Although the "yaw" of the machine, further shown in FIG. **1**, does not often directly affect gameplay, it may provide additional insight into how a pinball machine is installed or whether it is being moved.

Pinball machine manufacturers may sometimes provide instructions as to the pitch and roll levels with which the machine should be set up for optimal play. The roll is typically, but not always, 0 degrees, which means that the side-to-side surface of the playfield is parallel to the surface of the earth or exactly perpendicular to the force of gravity exerted by the earth. Having a side to side level of 0 degrees means any ball rolling on the playfield will not be pulled to either side by the force of the earth's gravity.

Generally speaking, assuming that the ground surface upon which machine **100** sits is flat, the roll of machine **100** is 0 degrees so long as leg **102**A has the same length of leg **102**B, and leg **102**C has the same length as leg **102**D, resulting in cabinet **101** resting parallel to the earth (also assuming that the cabinet is the same height on each side and, mounting holes or brackets are provided such that the legs are attached to the cabinet in the same spot on each side). The pitch of machine **100** varies from machine to machine, but it is approximately 6.5 degrees for most pinball machines manufactured in the last twenty years. A pitch of 6.5 degrees means the back of playfield **104** is taller than the front of the playfield **104** by an amount that makes the angle between the surface of the earth and the surface of the playfield 6.5 degrees. In FIG. **1**, the pitch of the machine **100** is determined by the lengths of the legs **102**A-D. If back legs **102**A/B were much longer than front legs **102**C/D, the pitch would be greater than if back legs **102**A/B had approximately the same length/height as front legs **102**C/D.

Setting up a pinball machine to a specific roll and to a specific pitch has traditionally been a very manual process.

Some pinball machine manufacturers include small bubble levels mounted onto machines to aid their owners in setting up the pitch of the machine; although this mechanism does not aid with side-to-side, "roll" leveling. Whether an installer setting up the machine uses the integrated bubble levels or another device, such as his or her own bubble levels, to measure the side to roll level and pitch, setting up the roll and pitch is an iterative and manual process. Generally, a person makes an adjustment to the leveling of the machine, visually checks the bubble level or other device to see the current angle of the side-to-side level and/or pitch, and repeats the process until the machine is set up as desired.

Because the side-to-side and front-to-back levels of a machine have a direct impact on how pinballs roll on the surface of the playfield, the roll and pitch may also very likely affect whether or not a player would want to play the machine. If the roll is non-zero, pinballs will be pulled to one side of the other by the force of gravity, making the game undesirable to play. If the pitch is significantly more or less than the recommended pitch, pinballs will likely roll up and down the playfield far too fast or far too slow, thus also making the game undesirable to play. Moreover, players may not realize that the roll and/or pitch of the machine is not set properly until they start playing the game.

To address these, and other problems, systems and methods described herein provide automatic level detection in pinball machines. In some embodiments, a pinball machine, through a combination of sensors and software code configured to process sensor data, may automatically identify the roll, pitch, and/or yaw at which it rests. In some cases, a pinball machine may provide feedback, whether visual or audible, to the person setting it up (such as an installer) in order to make the setup process less iterative and less manual. Additionally or alternatively, a pinball machine with automatic level detection may be configured to inform prospective players the roll, pitch, and/or yaw of the machine so that they know that information before deciding whether to play the machine. Additionally or alternatively, automatic level detection may be used to detect force applied to the pinball machine by a player.

In some embodiments, one or more accelerometers may be provided within (or mounted onto) a pinball machine by its manufacturer, or may be installed in the machine by a third-party after manufacturing. Referring to FIG. **4**, these one or more accelerometers may be communicatively coupled to interface board **402** as one or more of sensors **404**. As such, computing system **401** may be configured to retrieve values measured by the accelerometer(s). Also, in some embodiments, the accelerometer(s) may be mechanically coupled to playfield **104**, as opposed to cabinet **101**, in order to provide a more accurate reading of actual game conditions.

In some implementations, an accelerometer configured to measure the force of gravity in one, two, or three axes may measure the roll, pitch, and/or yaw of the pinball machine to which it is coupled. If two or more single-axis accelerometers are used, each accelerometer may measure the force of gravity on a respective axis, and therefore measure either the roll, pitch, or yaw the machine. For example, two single-axis accelerometers may be arranged orthogonally with respect to each other to measure the roll and pitch of a machine. A third single-axis accelerometer may be used to measure the yaw of the machine. Conversely, a single two- or three-axis accelerometer may be used.

Accelerometers suitable for use as sensor(s) **404** may include piezoelectric, piezoresistive, and/or capacitive components. In some cases, MicroElectro-Mechanical System (MEMS) accelerometers may be used that include an electronic package having cantilever beam(s) with a proof or seismic mass, or the like. As the proof mass is deflected from its neutral position due to the influence of external accelerations, the capacitance between a set of beams changes in a manner proportional to the deflection of the mass, which in turn may be correlated to an acceleration and/or ultimately to the orientation of the pinball machine. More generally, however, the exact device or devices used to measure the leveling of a pinball machine may vary.

FIG. **23** is a flowchart of an example of method **2300** of processing leveling information. In some embodiments, method **2300** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with interface board **402** and/or sensor(s) **404**. At block **2301**, method **2300** includes receiving leveling information, for example, from one or more accelerometers used as sensor(s) **404**. Then, at block **2302**, method **2300** includes providing an indication of the leveling information to an installer, player, prospective player, etc.

In some implementations, leveling information may be rendered on electronic display **200**. In other implementations, leveling information may be converted to audio signals and played through speakers (e.g., a human voice, beeps, etc.). In yet other implementations, leveling information may be displayed on electronic display **200** and converted to audio signals. In still other implementations, leveling information may be provided via other components within playfield **104**. For example, in some cases, a surface of a component (e.g., an animated flipper) may change its visual appearance to convey the leveling information.

In other embodiments, other forms of communication including, but not limited to, network-based communication via email and/or text messages, may be used by computing system **401** to convey leveling measurement data. A pinball machine configured to communicate roll-pitch and/or yaw information may greatly help a person or entity in adjusting the leveling of the machine. A person manually adjusting the side-to-side level, for instance, can continue making adjustments until the audio signal representing the roll of the machine indicates the desired leveling has been achieved.

Moreover, a pinball machine with automatic level detection may also be configured to inform prospective players of the roll and/or pitch of the machine before the prospective players decide to play. By displaying measurements on a display device, by playing audio representing these measurements through speakers, or by providing the measurement information to the prospective player through network communications, the player can understand what the measurements are before deciding whether or not to play a game on that machine.

In some embodiments, software **600** may be configured to disallow a player from playing if the roll and/or pitch of the pinball machine is outside of certain constraints. For example, a pinball machine may be configured to disallow a prospective player from playing if the side-to side-level is more than 1 degree off of 0. A pinball machine may also be configured to disallow somebody from playing if the pitch is more than 2 degrees off of a recommended pitch (e.g., 6.5 degrees).

Furthermore, a pinball machine with automatic level detection may be configured to inform its owner or operator when the roll or pitch of the machine is not ideal. For instance, the machine may notify the owner in any number of ways, such as by displaying a message on electronic display **200** or by playing an audio message through speakers. A network-enabled pinball machine may also notify the owner or operator by sending an email or text message or by some other form of electronic message.

In some embodiments, the automatic level detection systems and methods described above may be used to determine when a player is physically moving the pinball machine. When a player applies a sideways force to the machine, the measured roll level changes briefly, allowing the machine to identify the force being applied by the player. The same is true for front-to-back forces briefly affecting the pitch, and up-and-down forces affecting the yaw. A machine using a two or more axis accelerometer for its automatic level detection, or multiple single-axis accelerometers, may be configured to sense player-applied forces in any or all directions. By identifying these forces, the pinball machine may offer gameplay features that relate the player-created forces to gameplay objectives. Oftentimes a player may apply forces to the machine in an attempt to manipulate a pinball or other object on the machine.

FIG. **24** is a flowchart of an example of method **2400** of discouraging a player from applying force to a pinball machine. In some embodiments, method **2400** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with interface board **402** and/or sensor(s) **404**. At block **2401**, method **2400** includes receiving leveling information, for example, from one or more accelerometers. At block **2402**, method **2400** includes determining whether the leveling information meets one or more threshold values. For instance, block **2402** may determine whether a rate and/or magnitude of change of the leveling information meets the threshold value(s). If so, then at block **2403** method **2400** includes discouraging the player from applying force to the pinball machine. Otherwise, method **2400** returns to block **2401**.

In some implementations, in order to discourage the player from applying force to the pinball machine, block **2403** may include deducting points, reducing the number of pinballs available, taking away credits, increasing the speed of a countdown timer, reducing the length of a game, ending the game early, making it harder for the player to complete an objective (e.g., presenting additional targets to shoot), disabling a control (e.g., a flipper), etc. In some cases, by negatively affecting gameplay in a suitable manner, method **2400** may discourage the player from physical moving the pinball machine (and potentially damaging the machine). In other implementations, in order to discourage the player from applying force to the pinball machine, block **2403** may include acknowledging, via audio, video, or some other interaction with the player, that the machine knows the player is applying forces to the machine. In yet other implementations, block **2403** may include notifying an owner or operator (e.g., via network communications) that force is being applied to the machine.

FIG. **25** is a flowchart of an example of method **2500** of encouraging a player to apply force to a pinball machine. In some embodiments, method **2500** may be performed, at least in part, by computing system **401** executing software **600** in cooperation with interface board **402** and/or sensor(s) **404**. At block **2501**, method **2500** may include allowing a game to be played. At block **2502**, method **2500** may include identifying a game event. Again, examples of game events include, but are not limited to, a stage or a predetermined point in a game being reached, a particular target being hit, a number of pinballs having been used or being available, a number of points being earned, a position of a physical object in the playfield, a speed or direction of the physical object, etc. If not, method **2500** returns to block **2501**. Otherwise, method **2500** proceeds to block **2503**.

At block **2503**, method **2500** includes encouraging a player to apply force to the pinball machine. For example, method **2500** may include providing an indication via audio, video, etc., that the player should apply external forces to the machine. At block **2504**, method **2500** includes receiving leveling information, for example, from one or more accelerometers. At block **2505**, method **2500** includes determining whether the rate and/or magnitude of change of the leveling information meets threshold value(s). If so, method **2500** may reward the player by awarding point, credits, or extra pinballs, or by rendering a virtual object, stop rendering the virtual object, or animating the virtual object on an electronic display (e.g., shaking a fruit out of a tree, shaking a box off of a table, etc.). The method may then proceed to block **2506**. Otherwise, if the rate and/or magnitude of change of the leveling information does not meet the threshold value(s), method **2500** returns to block **2503** where the player is again encouraged to apply forces, or greater forces, to the machine.

At block **2506**, method **2500** includes discouraging or stop encouraging the player from applying forces to the machine. For example, once a game objective has been reached, method **2500** may warn or notify the player to stop moving the machine. Additionally or alternatively, if the rate and/or magnitude of change of the leveling information meets another (higher) threshold value(s), thus indicating that the player is making use of excessive force that can damage the machine, method **2500** may begin penalizing the player (e.g., by deducting points, available pinballs left, etc.) if he or she continues to move the machine.

In some embodiments, automatic level detection may also help handicap machines in multi-machine tournaments. For example, assume a tournament using two machines with otherwise the same pinball game, except that one is set up with a 6-degree pitch and the other with an 8-degree pitch. In this case, the 8-degree machine will have a faster playfield and therefore will be more difficult to play. Similarly, different rolls may also cause one machine to be harder to play than the other. Accordingly, in some cases, game software executed by computing system **401** may take the machine's automatically detected level into account to adjust scoring or some other aspect of gameplay. For instance, in the foregoing example, if it is determined that a given target in the 8-degree machine is twice as hard to hit than a corresponding target in the 6-degree machine, the 8-degree machine may be set up to award twice the amount of points than the 6-degree machine when that target is hit. Alternatively, the 6-degree machine may be set up to award half the amount of points than the 8-degree machine when the target is hit. In other cases, the 8-degree machine may allow a player more time to complete an objective than the 6-degree machine, the 8-degree machine may provide an additional bonus round or pinball(s) than the 6-degree machine, etc.

Also, still referring to multi-machine tournaments, the automatic level detection techniques discussed herein may be particularly useful when the machines are set up in different geographical or physical locations (e.g., connected via a network) so that an organizer can determine whether the various machines are set up similarly.

It should be understood that the various operations described herein, particularly in connection with FIGS. **7-12** and **22-25**, may be implemented in software executed by processing circuitry, hardware, or a combination thereof. The order in which each operation of a given method is performed may be changed, and various elements of the systems illustrated herein may be added, reordered, combined, omitted, modified, etc. It is intended that the invention(s) described herein embrace all such modifications and changes and, accordingly, the above description should be regarded in an illustrative rather than a restrictive sense.

Although the invention(s) is/are described herein with reference to specific embodiments, various modifications and changes can be made without departing from the scope of the present invention(s), as set forth in the claims below. For example, although presented in the context of pinball machines, various systems and methods described herein may be implemented in other types of amusement games. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of the present invention(s). Any benefits, advantages, or solutions to problems that are described herein with regard to specific embodiments are not intended to be construed as a critical, required, or essential feature or element of any or all the claims.

Unless stated otherwise, terms such as "first" and "second" are used to arbitrarily distinguish between the elements such terms describe. Thus, these terms are not necessarily intended to indicate temporal or other prioritization of such elements. The terms "coupled" or "operably coupled" are defined as connected, although not necessarily directly, and not necessarily mechanically. The terms "a" and "an" are defined as one or more unless stated otherwise. The terms "comprise" (and any form of comprise, such as "comprises" and "comprising"), "have" (and any form of have, such as "has" and "having"), "include" (and any form of include, such as "includes" and "including") and "contain" (and any form of contain, such as "contains" and "containing") are open-ended linking verbs. As a result, a system, device, or apparatus that "comprises," "has," "includes" or "contains" one or more elements possesses those one or more elements but is not limited to possessing only those one or more elements. Similarly, a method or process that "comprises," "has," "includes" or "contains" one or more operations possesses those one or more operations but is not limited to possessing only those one or more operations.

The invention claimed is:

1. A pinball machine comprising a physical playfield, wherein the pinball machine is configured to allow a user to cause a physical ball to move within the physical playfield over the playfield's surface, the pinball machine further comprising:

a memory configured to store instructions; and

processing circuitry operably coupled to the memory, the processing circuitry configured to execute the instructions to:

receive information regarding the leveling of the playfield's surface with respect to the ground during a pinball game, wherein the information includes at least one of pitch, roll, or yaw detected by one or more accelerometers coupled to the physical playfield, and

actively discourage, during the pinball game, a player from applying force to the physical playfield in response to the received information, and/or actively encourage, during the pinball game, the player to apply force to the physical playfield in response to an event occurring during the pinball game.

2. The pinball machine of claim **1**, wherein the processing circuitry is further configured to execute the instructions to cause the pinball machine to provide at least one of: a textual, graphical, or audio indication of the received information.

3. The pinball machine of claim **2**, wherein the indication is provided to a computing device remotely located with respect to the pinball machine, at least in part, via a telecommunications network.

4. The pinball machine of claim **1**, wherein the processing circuitry is configured to execute the instructions to:

actively encourage, during the pinball game, the player to apply force to the physical playfield in response to the event occurring during the pinball game.

5. The pinball machine of claim **4**, wherein to encourage the player to apply force, the processing circuitry is configured to execute the instructions to perform at least one of: award one or more points, award a credit, award an extra pinball, render a virtual object on a display, stop rendering the virtual object on a display, or animate a virtual object on the display.

6. The pinball machine of claim **1**, wherein the processing circuitry is configured to execute the instructions to:

actively discourage, during the pinball game, the player from applying force to the physical playfield in response to the received information meeting a value.

7. The pinball machine of claim **4**, wherein the processing circuitry is configured to execute the instructions to stop encouraging the player to apply force in response to the information meeting a value.

8. The pinball machine of claim **6**, wherein to actively discourage the player from applying force, the processing circuitry is configured to execute the instructions to perform at least one of: take away one or more points, take away a credit, take away a pinball, increase a speed of a countdown timer, present a target to shoot, or disable a control.

9. A pinball machine comprising:

a physical playfield;

one or more accelerometers mechanically coupled to the physical playfield;

a memory configured to store instructions; and

processing circuitry operably coupled to the memory and operable to execute the instructions to:

receive information regarding a positioning of a surface of the physical playfield relative to a gravitational force, wherein the information includes at least one of pitch, roll, or yaw detected by the one or more accelerometers, and

actively discourage, during a pinball game, a player from applying force to the physical playfield in response to the received information, and/or actively encourage, during the pinball game, the player to apply force to the physical playfield in response to an event occurring during the pinball game.

10. The pinball machine of claim **9** further comprising an output device, the processing circuitry being operable to execute the instructions to cause the output device to provide at least one of: a textual, graphical, or audio indication of the information.

11. The pinball machine of claim **9**, wherein the processing circuitry is operable to execute the instructions to allow the player to start the pinball game on the physical playfield in response to the received information meeting a threshold value.

12. The pinball machine of claim **9**, wherein the processing circuitry is configured to execute the instructions to:

actively encourage, during the pinball game, the player to apply force to the physical playfield in response to the event occurring during the pinball game.

13. The pinball machine of claim **9**, wherein the processing circuitry is configured to execute the instructions to:

actively discourage, during the pinball game, the player from applying force to the physical playfield in response to the received information meeting a value.

14. A pinball machine comprising:

a physical pinball playfield;

one or more accelerometers mechanically coupled to the physical pinball playfield, the one or more accelerometers being configured to detect at least one of pitch, roll, or yaw of a surface of the physical pinball playfield relative to a gravitational force;

a memory configured to store instructions; and

processing circuitry operably coupled to the memory and operably coupled to the one or more accelerometers, the processing circuitry being operable to execute the instructions to:

receive the detected at least one of pitch, roll, or yaw during a pinball game,

identify an occurrence of a predetermined event during a pinball game,

actively encourage, during the pinball game and in response to the predetermined event occurring, a player to apply force to the physical pinball playfield until the detected at least one of pitch, roll, or yaw meets a threshold value, and

actively discourage, during the pinball game and in response to the detected at least one of pitch, roll, or yaw meeting the threshold value, the player from applying a force to the physical pinball playfield.

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