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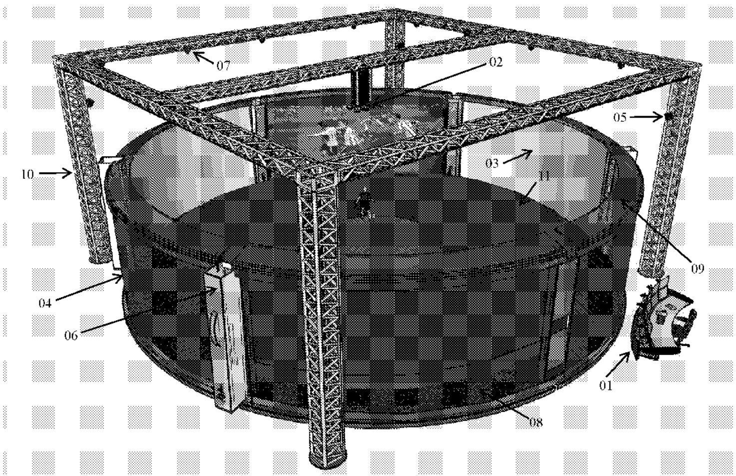
(54) **Title**: DEVICE FOR ASSESSING AND TRAINING THE PERCEPTUAL, COGNITIVE, AND MOTOR PERFORMANCE, AND METHOD THEREOF

Fig 1.



(57) **Abstract**: A simulator synchronized with a high-accuracy measurements system allowing continuous tracking of a ball and a player's movements. The simulator and the measurement system cooperate with ball launcher robotsin a fully automatized fashion, allowing the simulation of successive close-to-real game situations. Simulation of any type of signals (e.g. audio, tactile) or physical environments (temperature, humidity, indoor or outdoor surfaces) can also be integrated into this system in order to increase the immersion of the individuals into this environment. The Inventive system is supported by three types of validation / quality procedures relying on technological, scientific and sports-based considerations a) the accuracy of the system b) the discriminative power of the system in measuring the cognitive – motor performance and c) the improvement of the cognitive –motor performance after specific training sessions. It can be used in sports for talents identification, training, rehabilitation, to measure the effects of specific training programs, to monitor/train the recovery of motor and cognitive skills after neurological events in disabled people, and as an immersive virtual reality game.

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Device for Assessing and Training the Perceptual, Cognitive, and Motor Performance, and Method thereof

Field of the invention

[0001] The present invention relates, in embodiments, to the general fields of sport sciences (technologies), visual cognition and behavioural neurosciences and has specific application in the fields of sports and physical-cognitive rehabilitation.

Description of related art

[0002] The following references are related to the field of the present invention: US8480517; US20090091583; US20110300522; US20130266918; US4751642; US9474952; US20090281450; US20150164378. Relevant background can be found also in the following sources:

- Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. Journal of sports sciences. 2006;24:665-74.
- Bradley PS, Carling C, Gomez Diaz A, Hood P, Barnes C, Ade J, et al. Match performance and physical capacity of players in the top three competitive standards of English professional soccer. Hum Mov Sci. 2013;32:808-21.
- Svensson M, Drust B. Testing soccer players. J Sports Sci. 2005;23:601-18.
- Hulse MA, Morris JG, Hawkins RD, Hodson A, Nevill AM, Nevill ME. A field-test battery for elite, young soccer players. Int J Sports Med. 2013;34:302-11.
- Romo R, Lemus L, de Lafuente V. Sense, memory, and decision-making in the somatosensory cortical network. Current opinion in neurobiology. 2012;22:914-9.
- Sasaki Y, Nanez JE, Sr., Watanabe T. Recent progress in perceptual learning research. Wiley interdisciplinary reviews Cognitive science. 2012;3.

[0003] US4751642 discloses an interactive sports simulation system with physiological sensing and psychological conditioning. This system does not offer real-time training/testing possibilities and is not fully automated (balls shall be replaced manually by the user from one tested sequence to another).

[0004] US9474952 discloses a method and system for improving a user's reaction time and accuracy in propelling an object. Although the method includes detecting movement of the user using a sensor, it should be noticed here that the user propels the balls towards static targets displayed on a static rectangular goal, limiting the possibility to simulate realistic sport situations (real images or movies). This reference describes in detail neither the definition of the reaction time nor the nature of the motion detection module. Furthermore, the system is not fully automated (balls shall be replaced manually by the user from one tested sequence to another).

[0005] US20090281450 discloses a system and method for visual and cognitive testing or training, under stress conditions. In particular, this system allows subjecting a user to a stress condition and receives a response from the test subject using input device (manual device like a keyboard, joystick or foot-actuated device like pedals or buttons). Since the user does not respond using real sport gestures but via input devices, the ecological validity/relevance of the whole system and the possibility to accurately monitor and train the cognitive and motor performance are considerably impaired.

[0006] US8480517 discloses a training device where the user is fully immersed in a playfield, and can repeatedly kick a ball provided by ball dispensers to one of the ball receivers. This reference, however, fails to describe an accurate measurement of the cognitive-motor performance. No acquisition of well-defined reaction times is described and, nothing hints that such a measurement could be performed in real-time. In addition, the user has to send balls towards static rectangular targets, hence limiting the possibility to assess or train the performance in realistic, close-to-real game situations.

[0007] Although all of the aforementioned prior art relate to sports simulation/training systems is of interest, none of the systems found therein provide a fully-automated and real-time simulator/assessing system allowing accurate measurements and training of the cognitive and motor performance both in realistic sport-specific situations and using real sport gestures, as provided by the present invention. The physical training of individuals (in particular sportsmen) greatly benefited from sports sciences / exercise physiology studies performed over the twentieth century. In the following sections, examples will be detailed for sportsmen but they can also apply to other populations.

[0008] Many studies focused on physiological demands of a particular sport providing a large amount of information about match activities (for instance, distance covered or running intensity), aerobic and anaerobic energy production, substrate utilization or fatigue during a competition (see [Bangsbo] for a review). In team sports, data highlighted major individual differences related to players' training status, playing position or specific tactical roles [Bradley].

[0009] Based on these findings, specific physical training programs could be proposed to optimize players' physical development. To gain an understanding of the player's physiological abilities and to assess the effectiveness of physical training programs, laboratory and field tests were developed (see [Svensson] for a review).

[0010] Both laboratory and field tests were then progressively integrated in talents identification of young soccer players [Hulse]. Nowadays, many standardized methods and devices for assessing and training the physical performance of sportsmen exist but, performance in sports is not determined only by physical effort capacities.

[0011] In contrast with what exists at the physiological level, no standardized and widely accepted methods/devices for assessing and training the cognitive-motor skills of sportsmen exist.

[0012] On the one hand, scientific studies dedicated to studying the perceptual and cognitive skills of sportsmen suffer from their lack of ecological validity (most studies being realized in laboratory conditions), from their lack of accurate testing devices (when such studies are performed in close to real field situations) or from some combination thereof. For example, participants are often instructed to provide motor responses by pressing on keyboard buttons or by using a joystick (and not using a real sports gesture) in many laboratory-based studies. Part of the limited impact of sport sciences studies can also be explained by unclear definitions of a game situation, often restricted to a sports vocabulary.

[0013] On the other hand, most of existing technological devices allowing testing and training close to real sporting/game situations suffer from their lack of scientific definition of the measured cognitive and/or motor variables (e.g. the reaction time), from their lack of scientific validity (with very few exceptions, the claims of performance improvement are not confirmed by any reproducible study) or from some combination thereof.

[0014] This invention is concerned with the field of measuring (assessing) and training the cognitive and motor skills of individuals (in particular sportsmen).

[0015] This invention is inspired by four types of requirements a) it must correspond to clearly identified needs of cognitive-motor assessing and training (in sports and/or in rehabilitation) b) it must be based on scientific knowledge and expertise on the brain mechanisms involved in the cognitive-motor performance c) it must be validated by reproducible tests run in cooperation with sport top-level experts (or rehabilitation medical doctors) and d) it must be supported by robust, easy-to-use and flexible technological devices/software.

[0016] The cognitivo-motor performance, defined here as the capacity to rapidly use sensory information and transfer it into efficient decisions and motor skills, represent a major contributor to performance in almost all sports.

[0017] For example, a player typically faces complex visual environments composed of static and moving - objects, teammate(s), opponent(s) and referee(s) - stimuli and he has to convert such information into efficient decisions/gesture(s) in a reduced amount of time (defined as temporal pressure) and in a reduced amount of space (defined as spatial pressure).

[0018] Importantly, the temporal pressure and the spatial pressure can each be decomposed into perceptual and motor components. For example, a) the temporal perceptual pressure can correspond to the amount of time during which visual information is available; b) the spatial perceptual pressure can correspond to the amount of visual objects/distractors contained in the visual information, c) the temporal motor pressure can correspond to the amount of time available to implement a particular gesture and d) the spatial motor pressure can correspond to the amount of space (defined for example by the number and proximity of potential opponent(s)) available for implementing a particular gesture.

[0019] The present invention allows for accurate control, measuring and training of each of these components, as detailed in the next sections. In fact, most of the sporting/game situations encountered in sports require interactions between the perceptual, memory, decisional and motor systems. These multiple and parallel processing stages begin with the transmission of information from sensory captors (conveying visual, proprioceptive/tactile and vestibular inputs) to primary sensory areas. The detection-to-perception stage is modulated by the influences of attention and memory on the processing of (static and dynamic) environmental features, which result in perceptual decisions (see [Romo], and [Sasaki] for reviews specific to the visual and somatosensory systems). Perception is thus an active, high-order process where part of the actual sensory flow is compared to memorized ones, resulting in a particular interpretation of the actual situation.

[0020] Following this definition, a decision corresponds to the selection/choice of the most appropriate gesture given this particular interpretation. The cognitive-motor performance therefore encompasses all these spatial and temporal features. Depending on the complexity of the sensory stimulus, this processing can involve mostly attentional or decisional mechanisms.

[0021] The output of this processing (for sports with a ball) can consist in different actions like i) intercepting the ball ii) keeping the ball iii) passing the ball iv) dribbling or v) kicking the ball.

The present invention allows for accurate simulation of these different sport scenarios in realistic and sport-specific situations, as detailed in the next sections.

Brief Description of the Drawings

[0022] The invention will be better understood with the aid of the following detailed description given by way of example and illustrated by the accompanying drawings in which:

Figure 1 shows a top view of the testing and training sport simulator.

Figure 2 shows the global architecture of the testing and training sport simulator.

Figure 3 depicts a particular embodiment of the system for soccer where the user is visually exposed to a virtual environment where he should pass or kicks the ball towards a salient (static or moving dark circle/sphere) visual target, as accurately (and/or) as quickly as possible.

Figure 4 depicts a particular embodiment of the system for soccer where the user is visually exposed to a realistic game situation and is instructed to deliver a pass towards a relevant location on the visual scene as accurately (and/or) as quickly as possible.

Figure 5 depicts a particular embodiment of the system for tennis where the user is visually exposed to a realistic game situation and is instructed to hit a passing shot towards a relevant location on the visual scene as accurately as possible.

Figure 6 depicts a particular embodiment of the system for soccer where multiple users are visually exposed to different game situations and are instructed to deliver a pass/kick the ball towards a relevant location on the visual scene as accurately (and/or) as quickly as possible.

Figure 7 depicts a particular embodiment of the system for soccer where one user is visually exposed to a 360 degrees visual environment and is instructed to deliver a pass/kick the ball towards the salient visual target (static or moving dark circle/sphere), as accurately (and/or) as quickly as possible.

Detailed Description of possible embodiments of the Invention

[0023] The following is a detailed description of exemplary embodiments to illustrate the principles of the invention. The embodiments are provided to illustrate aspects of the invention, but the invention is not limited to any embodiment. The scope of the invention encompasses numerous alternatives, modifications and equivalents.

[0024] Numerous specific details are set forth in the following description in order to provide a thorough understanding of the invention. However, the invention may be practiced according to the claims without some or all of these specific details. For the purpose of clarity, technical material that is known in the technical fields related to the invention has not been described in detail.

[0025] The present description will refer to the subject whose motor skill are tested or entrained as a "user" or a "player", the two terms being interchangeable.

[0026] In a preferred embodiment of the system, illustrated in figure 1, the user is located inside a playfield 11, circular in this example, and faces one or successive sporting situations projected onto a large screen. The surface of the playfield can be selected based on a particular sport. The main controller is located at a single location 01 together with the individual data recording systems. The video-projector 02 is fixed on another surrounding structure 10 together with the speakers 05 and the tracking devices 07. The visual environment is projected onto a large screen 03 (flat or curved) on the rear of which an ultra-shock absorbing tissue 04 is fixed. The tissue 04 is also fixed to the surrounding structure 09. Ball-launcher robots 06 are located along the surrounding structure 09. A ball recovery system 08 is visible via a section through the tissue 04 and allows for ball reception after ball impact on the screen 02. Balls are then displaced and recirculated, either passively or by active conveyance means, towards the ball-launcher robots 06.

[0027] The user has to respond as fast and as accurately possible to this simulated situation by sending the ball/object (by kicking/passing with his foot or by shooting/launching/passing with his hands) towards the most relevant spatial location.

[0028] The initial position of the ball can vary according to the desired simulation conditions. In one embodiment, the ball is static and is located near the user. In another embodiment, the ball is launched by one of the ball launcher robots 06 in the direction of the user. In this case, the instant when the ball is launched is fully controlled and can be set randomly/by the user before the testing/training session. This instant is fully synchronized with the visual simulator so that the ball can be sent before, during or after the presentation of the visual environment to the user.

[0029] The ball can be launched at predetermined speeds/heights, for example according to a program defined before the training/testing session. Partial or total randomization of the ball vector velocity is also possible.

[0030] The spatial location to be reached by the ball is either signalled to the user by a particular visual (salient) object or is freely chosen by the user (this freely chosen location can then be compared to pre-programmed correct spatial locations; for instance, when facing a penalty kick situation, left and right top corners of a soccer goal can be defined as correct spatial regions).

[0031] The user and ball movement are continuously tracked, preferably at sampling rates equal or superior to 240 images per second, throughout the whole "visual information presentation – ball impact on the screen" phase.

[0032] The system is preferably capable of acoustic reproduction and can render pre-recorded sound content and/or synthesized sounds. Acoustic signals can be discretely emitted to signal the next sequence or can be continuously emitted to reproduce the sound environment of a competition game.

[0033] After the response of the user, the situation seen previously can be displayed again to him and/or to the trainer, and the result of his response (in terms of ball accuracy, response time, ball speed, and other possible types of feedbacks) can be displayed on the screen (or through positive or negative acoustic feedbacks). This augmented feedback possibility can be defined in terms of spatial accuracy, temporal reactiveness or as a combined spatial accuracy/temporal reactiveness feedback. This feedback stage is typically used in the training version of the system but is not displayed in the testing version of the system.

[0034] This whole procedure relies on the following architecture, units/devices and procedures.

Global architecture

[0035] A possible global architecture of the inventive system is represented schematically in figure 2.

[0036] The system is designed as an assembly of one or several (wired or wirelessly) interconnected individual unit controllers. Each unit controller is composed of mechanical structures, electronical and robotics devices and optical (or sound) tracking devices, and delivers synchronized command signals to each device. It must be understood, however, that the figure 2 is a functional, and not necessarily structural, representation of the invention. Some or several of the functional elements could in fact be implemented in a single physical unit. Some of the functions could also be embodied by suitable software means, or be carried out by external means, connected to the system by a data communication link, but not in physical proximity.

[0037] The whole system is installed in a playfield and can be configured differently depending on the geometry of the playfield and depending on the number of units / users.

[0038] The real-time control of all units is preferably performed using a single main controller (e.g. desktop computer, laptop), which can be activated/programmed using a remote controller (remote, smartphone or tablet).

[0039] Data acquisition is performed by dedicated data recording systems (e.g. desktop computer, laptop) and streamed/stored in real-time to/by the main controller through wired or wireless connections.

[0040] In the case of multi-users configuration, each individual unit can function independently of the other units. In this case, one main controller is connected to each individual unit controller.

[0041] The detailed description of the individual units constituting the integrated system is given in the following sections.

<u>Individual unit controllers</u>

[0042] Each unit allows for testing/training one or several users, and may include:

a) a playfield (of various sizes and floor textures, depending on the sport under consideration, and depending on the number of users);

b) a visual environment projected onto a screen with a high-performance beamer;

c) one or several ball launcher robots;

d) a playfield surface with surrounding metallic structures (09 in figure 1);

e) optical tracking devices (like optoelectronic motion capture systems) or other types of tracking devices connected to one data recording system;

f) a system for recovering/collecting balls after kicks;

g) devices for simulating non-visual environmental features - and receives commands from the main controller allowing both for the programing of all simulated scenarios and data storage. The real-time analysis of the response properties (spatial accuracy of the kick, reactiveness of the user), is performed with dedicated software platform on the main controller.

[0043] Each component of an individual unit is detailed below.

Playfield size and floor texture

[0044] The playfield can be configured in one of different spatial configurations, and using different types of surfaces (artificial or natural grass, indoor floors). In a preferred embodiment, rigid structures are placed at the limits of the playfield surfaces in order to support the screen (see next section).

Visual Environment

[0045] Typically, the user faces one large screen (flat or curved, for example, 4 meters width x 3 meters height for a flat screen) onto which images or movies are projected via a beamer.

[0046] These images or movies can represent object(s) with pre-defined properties integrated in a virtual environment (all characteristics of shape, colour, 2D or 3D, low of full HD resolution, contrast, transparency, and background…can be fixed in the main controller by the user). They can also correspond to real sporting/game situations of different types (sports, type of playfield, and type of stadium).

[0047] Importantly, these realistic images/movies were pre-filmed from the perspective of the user and calibrated to match the screen dimensions. These two types of images/movies will be referred to as virtual or realistic stimuli.

[0048] Importantly, new stimuli can be integrated into the visual environment by the user.

[0049] All parameters of the visual environment can be set randomly or set by the user using the remote controller or the main controller before the training/testing session. These include (but are not limited to)

a) the number of successive stimuli,

b) the inter-stimuli intervals,

c) the duration presentation of the stimuli,

d) the type and complexity of stimuli,

e) the type of simulated situations (for example a penalty kick or a pass to a teammate in a defensive or offensive soccer situation),

f) the presence, number and motion properties of the targets to reach,

g) the presence, number and motion properties of visual distractors,

h) the display of a visual feedback.

Screen Properties

[0050] This screen is made of shock absorbing tissue or cloth so that almost the whole amount of ball energy (due to a kick for example) is absorbed at impact.

[0051] In another embodiment, the screen is made of conventional screen canvas and the absorbing structure, constituted of the shock absorbing tissue, cloth, net, or any other type of absorbing matter, is rigidly attached to the screen canvas.

[0052] The screen can be flat or can be curved/cylindrical. Preferably, it is fixed to a rigid structure (04 and 09 in figure 1) and is tightened to ensure a regular surface of the desired shape, whether flat or cylindrical.

[0053] In one preferred embodiment, the images are projected onto the screen from front. In another embodiment, they can be projected from behind (rear projection). In this case, the screen properties shall allow for such rear projection.

Beamer Properties

[0054] The beamer must possess minimal requirements in terms of full resolution (HD), contrast, three-dimensional images projection, luminosity and zoom compatible with the ambient luminosity on the playfield and the beamer-screen distance. In particular, any technologies for simulating 3D environments can be used, including the ones based on the use of anaglyph glasses.

[0055] Such beamers are known in the technical field and will not be further detailed.

Ball launcher robots

[0056] The ball launcher robot or robots should be selected based on the specific ball-sport practiced by the user (from team sports like football, rugby, basketball… to individual sports like tennis, baseball…). It can also be a non-ball object like hockey pucks. It should be fully programmable in terms of instant at which the ball/object is launched, ball/object speed and height.

Tracking devices and data recording system

[0057] In a preferred embodiment, the tracking device is constituted of high-frequency motion capture cameras connected to the data recording system. Infra-red light reflective material is fixed on the ball and after a calibration procedure, the ball motion is recognized by the associated motion capture system software and delivers real-time information about the ball position and rotation in real-time.

[0058] This information is streamed in real-time to the main controller via wired or wireless connection: it is used for the on-line analysis of the ball motion prior to, during and after ball impact on the screen. This allows, in particular, computation of accurate response times (delay between the instant of visual information appearance and the instant of start of ball motion in the direction of the screen after foot impact).

[0059] In another embodiment, active detectors located into or onto the ball could send such positional/rotational information, without any need to use motion capture systems. Such detectors are known in the technical field and will not be further detailed.

[0060] In a preferred embodiment, the user's motion following ball reception can be analysed using the same type of motion capture systems, by a force platform (for foot movements) or by pressure detectors located on the fingers of users (for hand sports): in both cases, motion detection algorithms allow detecting the instant of kick/launch initiation by the user. This allows, in particular, computation of accurate reaction times (delay between the instant of visual information appearance and the instant of postural changes initiation prior to kick/launch initiation).

[0061] In a preferred embodiment, response times are used to measure reactiveness of the user which is defined as how fast users convert visual information into an action towards the ball (pass or kick initiation).

[0062] Alternative methods might consist in computing the delay between visual information appearance and ball impact on the screen: such methods are used in some training systems and are erroneously considered as “reaction times”. Indeed, a ball kicked at a very slow speed may generate long “reaction times” because these would include the duration of ball displacement towards the target, which does not correspond at all to any reactiveness process.

Main controller

[0063] The main controller is the central hardware/software interface and may comprise

a) a computer (e.g. a laptop or a desktop equipped with one or several compatible operating system(s)) dedicated to hosting the software part necessary to send visual environment related commands / to receive data streamed by the data recording system / to perform real-time analysis of the recorded data / to data storage,

b) synchronization and data acquisition devices used to trigger/record data of the different devices (e.g. robots, tracking devices) (01 in figure 1 and figure 2).

[0064] The user interface of the software platform also allows settings of the user characteristics (name, age…), the visual environment, and the number of units at work. In particular, the physical size of the visual environment (covering all or part of the visual field of the user), the distance between the user and the screen (and comparable type of settings) can be fixed using this interface.

[0065] The results of individual testing/training sessions can be compared immediately (after the session) to other users or to the mean results across users, enhancing the interactivity of the whole system in case of multi users configurations.

[0066] In particular, these results can also be shared through wired or wireless connections to systems located in different locations.

[0067] Importantly, the main controller allows a full and effective automation of the (visual information presentation - user response - real-time measurements, analysis and storage - balls recovery) successive sequences with inter-sequences intervals as short as one second.

System for recovering/collecting

[0068] This system (08 in figure 1) may comprise ball recovery gutters located just below the screen. The internal part texture and the inclination of the gutters is chosen so as to ensure that balls, after impact on the screen, directly fall into the gutter and are conveyed towards to one of the gutters termination where they are collected into the ball launcher robots' collector.

[0069] In another embodiment, the gutter terminates below the user's position on the playfield. The ball is then brought at the floor level using a rotating platform. This embodiment corresponds to the configuration where users interact with a static ball (e.g. ball launchers would not be used in such configuration).

Augmented reality environment: devices for simulating non-visual environmental features.

[0070] In addition to the visual environment, specific sound (for example, crowd) environments can be simulated using any type of sound emitters.

[0071] Other external features (like temperature and humidity on the playfield) can be controlled by the main controller using devices that are known in the technical field and will not be further detailed.

Validation / Quality procedures

[0072] The present invention is supported by three types of quality measurements inspired by technological, scientific and sports-based considerations a) the accuracy of the system b) the discriminative power of the system in measuring the cognitive – motor performance and c) the improvement of the cognitive – motor performance after specific training sessions. These three types of measurements guarantee the performance of the system both as a testing and as a training device.

[0073] Some procedures described below can be specific to a certain sport or use particular devices. These are given as illustrations but they do not limit the scope or nature of the present invention.

Accuracy of the system measurements

[0074] As a multi-devices integrated system, the accuracy of the automatically generated spatial and temporal measurements has been verified using a video-based image-by-image control procedure. In particular, the simulated stimuli presentation durations, the automatically computed response times and the ball position at impact/speed have been compared to the physical counterparts of these variables.

[0075] This has been done manually using video images recorded with a high-speed camera (CASIO EXILIM, sampling rate: 600 frames per second). The films were taken from a point of view allowing viewing simultaneously the ball (in a configuration where the ball was static and near the user) and the visual environment.

[0076] In a soccer-like kicking test, a fully-identifiable piece of tape was located on the floor at the ball level. The frame by frame scroll of image was performed for 9 kicks. The user had to kick the ball towards the location of a visual target projected onto the screen.

[0077] At the temporal level, our accuracy quality procedure allowed estimating the frame of appearance of the visual stimulus, the frame at which the user' foot touched the ball and the frame of ball impact on the screen. These different instants were converted into response times (instant of first foot contact with the ball - instant of stimulus appearance), stimulus duration and ball speed and compared to the values automatically computed by the main controller. The manually computed and automatically computed temporal variables were strongly correlated ($r>0.98$).

[0078] At the spatial level, we designed a calibration grid on the screen where light-reflective markers were placed at 9 particular physical positions (e.g. screen corners, screen centre positions and mid-height/half-screen width). The 3D spatial positions of the light-reflective markers were transmitted by the tracking device connected to the data recording system to the main controller. These coordinates were then converted into screen units (pixels). Any projected object can thus be expressed in spatial coordinates (of the tracking device) and any physically tracked object position at impact can be expressed in screen units using this calibration procedure. Physical measurements were performed following this calibration procedure for a 6 meters distance between the beamer and the screen, using the same soccer kicking test: the position of the ball at impact was accurate within an error inferior to 0.01 meter.

Discriminative power of the system in measuring the cognitive – motor performance

[0079] The discriminative power of the system corresponds to the ability of the system to discriminate the performance level of individual (or group) users. In particular, the measured temporal and spatial variables correspond to well-defined sport skills, for instance reactiveness and short passes accuracy.

[0080] The following description is given for soccer but it can easily be adapted to other ball sports.

[0081] Fourty-eight young elite soccer players were tested in a typical situation of 5 meters distance-passes towards static visual targets (white circles projected onto a black background for short periods ranged between 0,2 and 0,5 second). Players had to deliver passes as fast and as accurately possible. The players belong to a youth soccer academy and practiced soccer for at least 5 times per week (training and competition). Importantly, they were all trained/followed by several highly-certified and experienced coaches on a quasi-nearly basis.

[0082] Before being informed about the results of their players using the system, the coaches had to provide quantitative judgments about each player in terms of reactiveness (via 5 points scale ranged between low reactiveness to high reactiveness) and pass accuracy (via a 5 point scale ranged between low pass accuracy to high pass accuracy).

[0083] The comparison between automatically-measured reactiveness and pass accuracy and the corresponding coaches' judgments revealed minimal differences between the system measurements and the coaches' judgments. On average, the differences between the two types of judgments were equal to 0.11 ± 0.26 and 0.32 ± 0.43 for the temporal reactiveness and the pass accuracy, respectively.

[0084] Thus, the system reproduced fairly the coaches' judgments. This can be considered as a relevant soccer-like validation of the system. Similar procedures could be adapted to different tasks/sports.

[0085] The comparison could be used to affine the type of visual stimulation presented to the players to further reduce the difference between coaches judgments and the system.

[0086] Alternatively, it could also serve as a way to detect inter-coaches differences in the judgments of players' reactiveness and pass accuracy, e.g. it can be used as a method to train coaches' judgment using objective and quantitative measurements about players.

The efficiency of the system in improving the cognitive – motor performance

[0087] The efficiency of the system in improving the cognitive-motor performance is tested using set-ups comparable to or different from the ones described earlier.

[0088] These should include training/cognitive-motor learning protocols where tested users would be judged before or after the training program.

[0089] The pre and post training measurements represent a measure of the efficiency of the system. However, possible lack of performance improvements may be due to incomplete/irrelevant training programs rather than a lack of efficiency of the system.

[0090] The ability of the system to accurately simulate/measure spatial and temporal components of the perceptual environment/motor responses is indeed guaranteed by the previous procedures.

[0091] Thus, it is recommended to design and test any training program using this system before using it in a training mode for users.

[0092] In particular, the use and definition of augmented-feedback (visual, auditory, visuo-auditory and so on) procedures should be considered. In the same vein, the specification of the training program characteristics (duration, frequency of training with the system…) should also be carefully monitored.

[0093] Thus, the system efficiency testing is determined largely by the user.

<u>Definitions.</u>

A. Cognitivo-motor performance: The ability to rapidly use sensory information and transfer it into efficient decisions and motor skills.

B. Reactiveness: Quality of being reactive to a sensory (visual, auditory…) stimulus.

C. Main Controller: Computer dedicated to controlling the different simulating / recording devices in a synchronized way for both single and multiple individual units.

D. Individual Unit Controller: Local computer dedicated to data acquisition and data streaming to the main controller.

E. Tracking device: Device dedicated to tracking and reconstruct in real-time the player/ball motion (positions and orientations in three dimensions) in the playfield.

F. Ball-launching robots: Device dedicated to launch the ball inside the playfield using parameters (speed, position) defined in the main controller.

G. Ball-recovery system: Device allowing recovery of the ball (after ball impact on the screen) and ball transmission towards the ball-launching robots.

[0094] The disclosed embodiments are illustrative, not restrictive. While specific configurations of the system have been described for particular sports (e.g. soccer), it is understood that the present invention can be applied to a wide variety of sports and non-sports tasks. There are many alternative ways of implementing the invention.

Claims

1. A real-time testing/training simulator comprising:

- a main controller simulating a multi-sensory environment;
- at least one video rendering unit, such as a video projector or beamer ;
- at least one screen, onto which a visual channel of the multi-sensory environment is reproduced by the video rendering unit;
- one, two or more audio rendering unit or units, for delivering an audio channel of the multi-sensory environment;
- at least one tracking device operationally arranged to track continuously the movement of the ball and/or the movement of the user;
- a data recording system connected to the tracking device and operationally arranged to stream data to the main controller;
- an analysis unit, operationally arranged to analyse in real-time cognitive-performances of the user, such as temporal reactiveness of the user, spatial accuracy of the user and spatio-temporal features of the user's actions;
- a visualization platform operationally arranged to display the cognitive-motor performance of the user.

2. The real-time testing/training simulator of the preceding claim, further comprising at least one ball-launcher robot or robots delivering a ball to the user, wherein a ball recovery system is operationally arranged to recirculate the balls to the ball-launcher robot or robots.

3. The real-time testing/training simulator of any one of the preceding claims, wherein the main controller is further arranged to control in real time multi-sensory environmental features such as, duration of the presentation, resolution, luminosity.

4. The real-time and testing/training simulator of any one of the preceding claims, wherein the visual environment includes real or virtual images or movies designed as planar (two-dimensional) or three-dimensional (3D) visual objects.

5. The real-time and testing/training simulator of any one of the preceding claims, wherein the video rendering unit projects high-definition and 3D-compatible visual scenes using passive (glasses-mediated) or active (holographic) technologies.

6. The real-time and testing/training simulator of any one of the preceding claims, wherein the video rendering unit includes one beamer or multiple beamers and covers all the visual field of the user, preferably including multiple beamers projecting an all-around (360 degrees) scene.

7. The real-time and testing/training simulator of any one of the preceding claims, wherein the controller is operationally arranged to cause a visual target to be displayed to the user, who has to throw/kick/pass the ball toward said visual target, or wherein the controller is arranged to analyse a throw/kick/pass of the ball towards a location in the visual environment chosen by the user, and evaluate the chosen location.

8. The real-time and testing/training simulator of any one of the preceding claims, wherein screen includes a shock absorbing tissue, canvas, or cloth, fixed to a metallic structure and allowing a full ball-energy absorption at impact.

9. The real-time and testing/training simulator of any one of the preceding claims, wherein auditory signals are delivered together with visual signals in a synchronized way by said audio rendering unit or units.

10. The real-time and testing/training simulator of any one of the preceding claims, wherein audio rendering unit or units include speakers or earphones.

11. The real-time and testing/training simulator of any one of claims 2-10, wherein the ball-launching robot or robots are arranged to send the ball to the user at predetermined positions/heights/speeds/instants.

12. The real-time and testing/training simulator of any one of the preceding claims, wherein the movement of the ball (and of the user) is continuously tracked at a frequency rate equal or superior to 240 Hz.

13. The real-time and testing/training simulator of any one of the preceding claims, wherein the cognitive-motor performance is assessed via the computation of the most relevant spatial (e.g. accuracy of the kick/pass, postural configuration of the user at last ball contact with the user) and temporal (e.g. reactiveness of the user as defined by the visual environment appearance instant minus the last ball contact with the ball instant, ball speed and kicking foot speed before the last ball contact) parameters.

14. The real-time and testing/training simulator of any one of the preceding claims, wherein the performance of the user is displayed at predetermined instants (after one action or after a sequence of actions) on the large screen.

15. The real-time and testing/training simulator of any one of the preceding claims, further arrange to provide positive or negative visual/auditory augmented feedback signals the user , such as feedbacks aiming to to enhance the spatial accuracy/temporal reactiveness of the user when facing very short-duration sporting/game situations.

16. A testing/training method for athletes using the real-time testing/training simulator of any of the preceding claims.

17. The testing/training method of the preceding claim including a procedure of validating the spatial and temporal accuracy of the simulator, in which the parameters automatically computed by the simulator (e.g. spatial accuracy at ball impact and temporal reactiveness of the user) are correlated with corresponding manually computed parameters obtained by a visual frame-by-frame analysis of a record taken by an external device, such as a high-speed camera sampling at 600 frames per second or better.

18. The testing/training method of claim 16, including causing a visual target to be displayed to the user on the screen of the real-time testing/training simulator; tracking and recording the movements of a ball and/or of the user while the user attempts to throw/kick/pass the ball to the visual target; determine cognitive-performances of the user, such as the reactiveness and/or the precision, based on said tracked and recorded movements.

19. The testing/training method of the previous claim, in which the ball is either placed at a fixed position or delivered to the user by a ball-launcher robot of the real-time testing/training simulator.

20. The testing/training method of any one of claims 18-19 wherein the visual target is stationary or in motion.

21. The testing/training method of any one of claims 18-20, wherein the steps of causing a visual target to be displayed, tracking and recording the movements, and determining cognitive performance are repeated for a set of different users, or for the same user at a different points in time, and the respective cognitive performances are compared.

Fig 1.

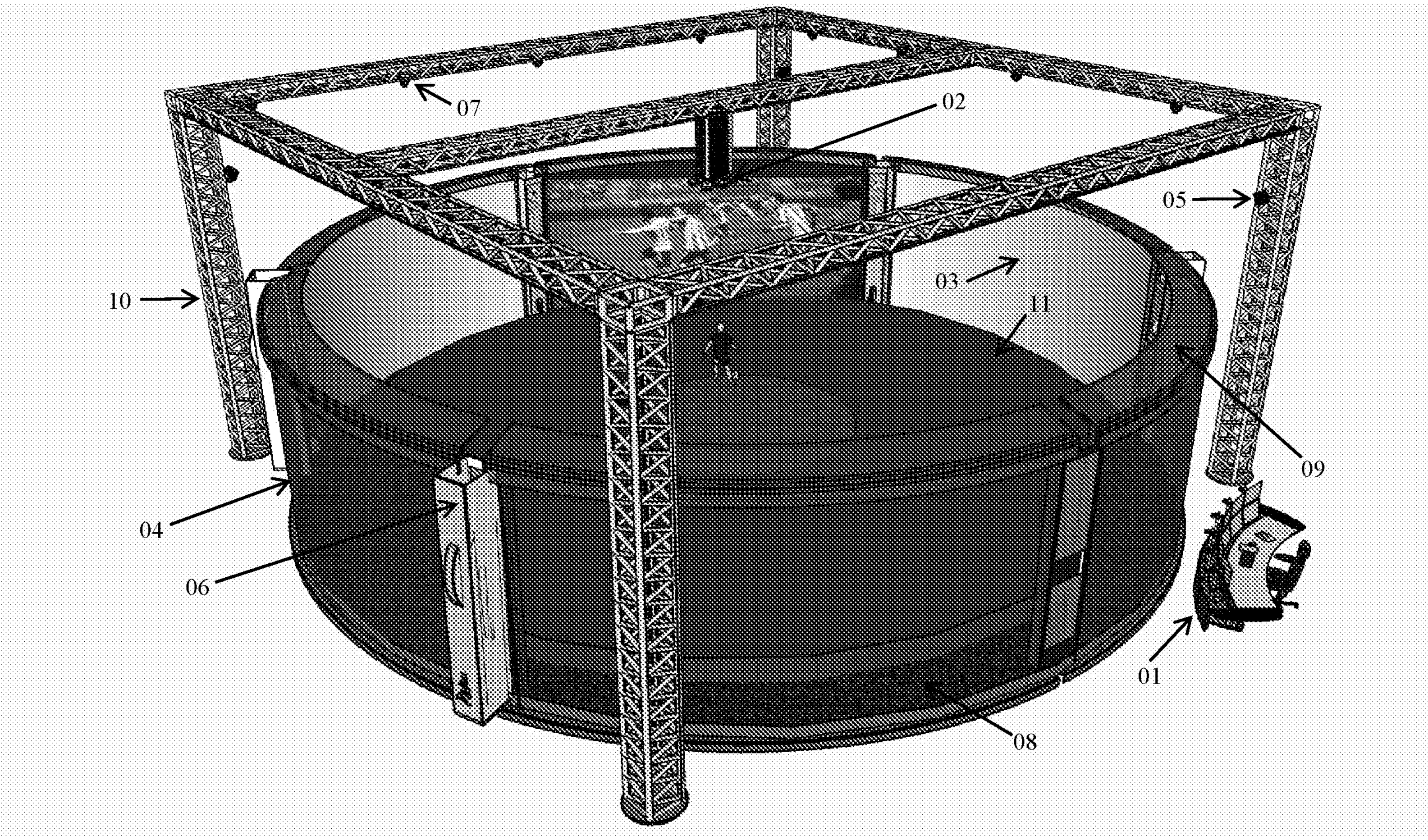


Fig 2.

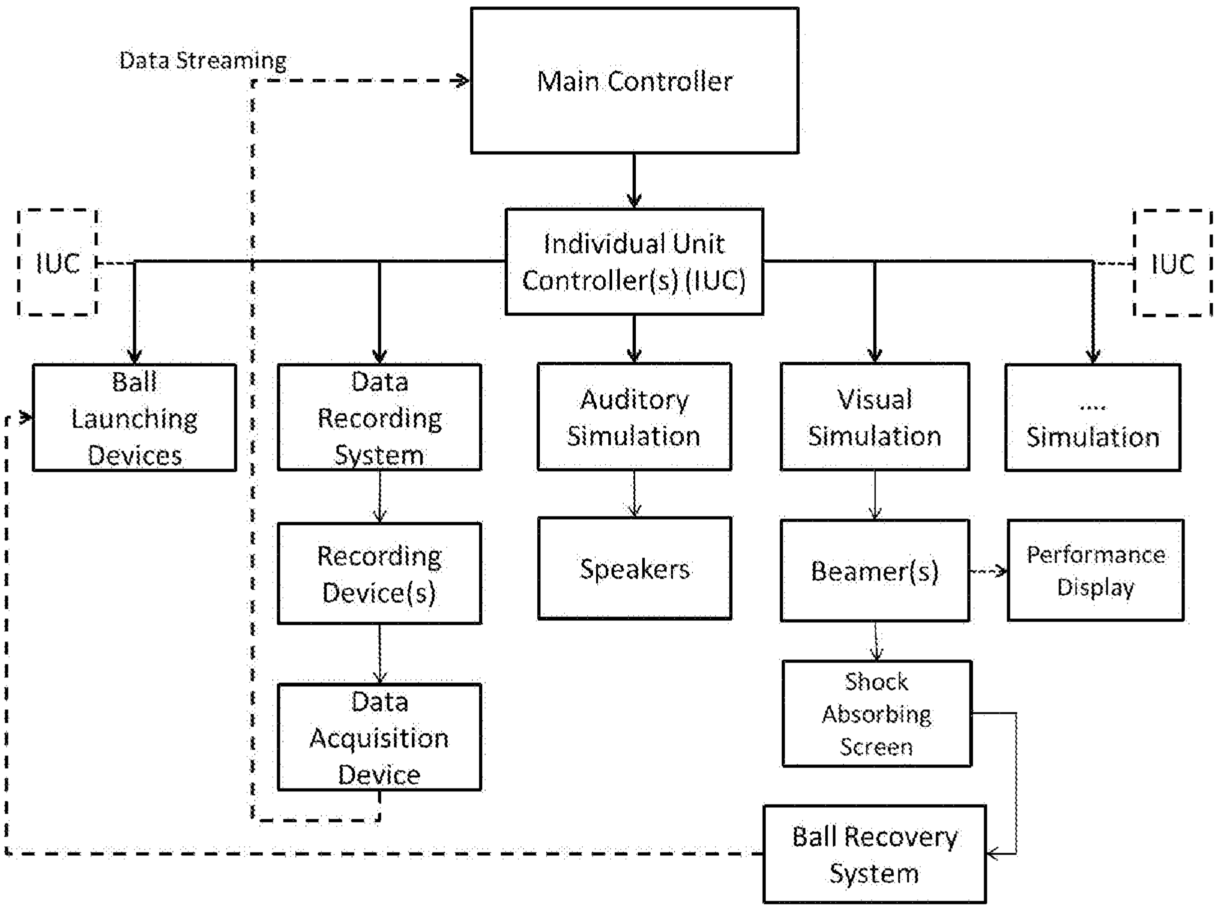

Data Streaming
Main Controller
IUC
Individual Unit Controller(s) (IUC)
IUC
Ball Launching Devices
Data Recording System
Auditory Simulation
Visual Simulation
.... Simulation
Recording Device(s)
Speakers
Beamer(s)
Performance Display
Data Acquisition Device
Shock Absorbing Screen
Ball Recovery System

Fig 3.

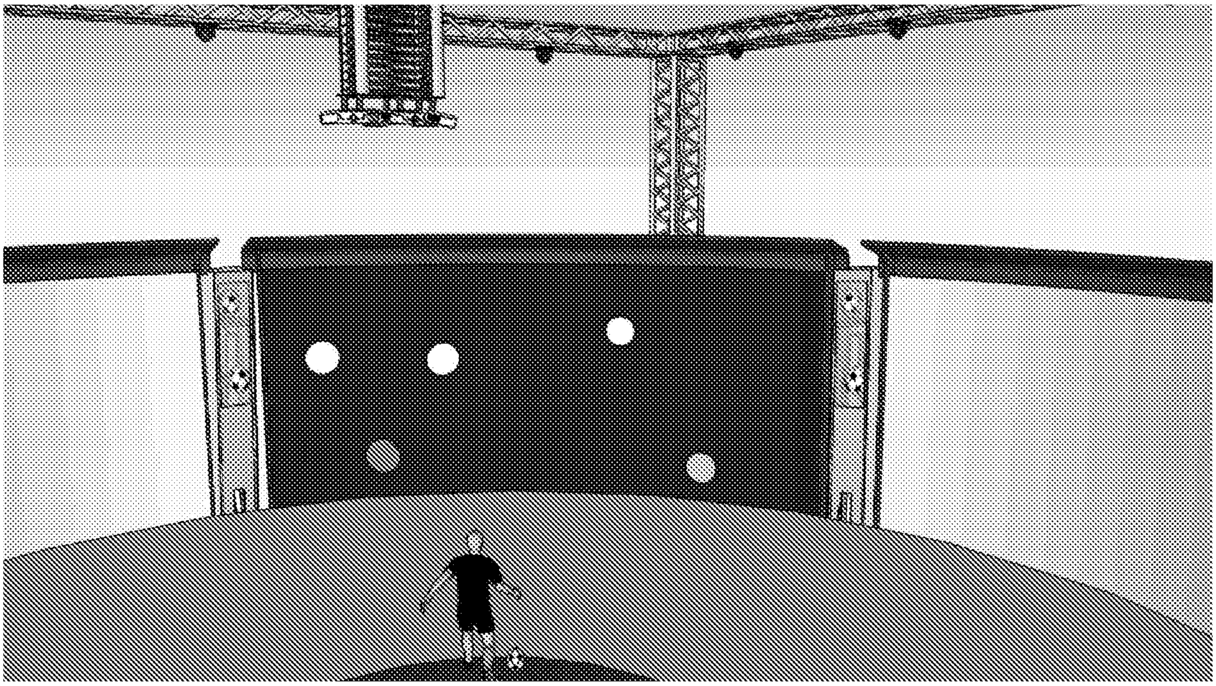


Fig 4.

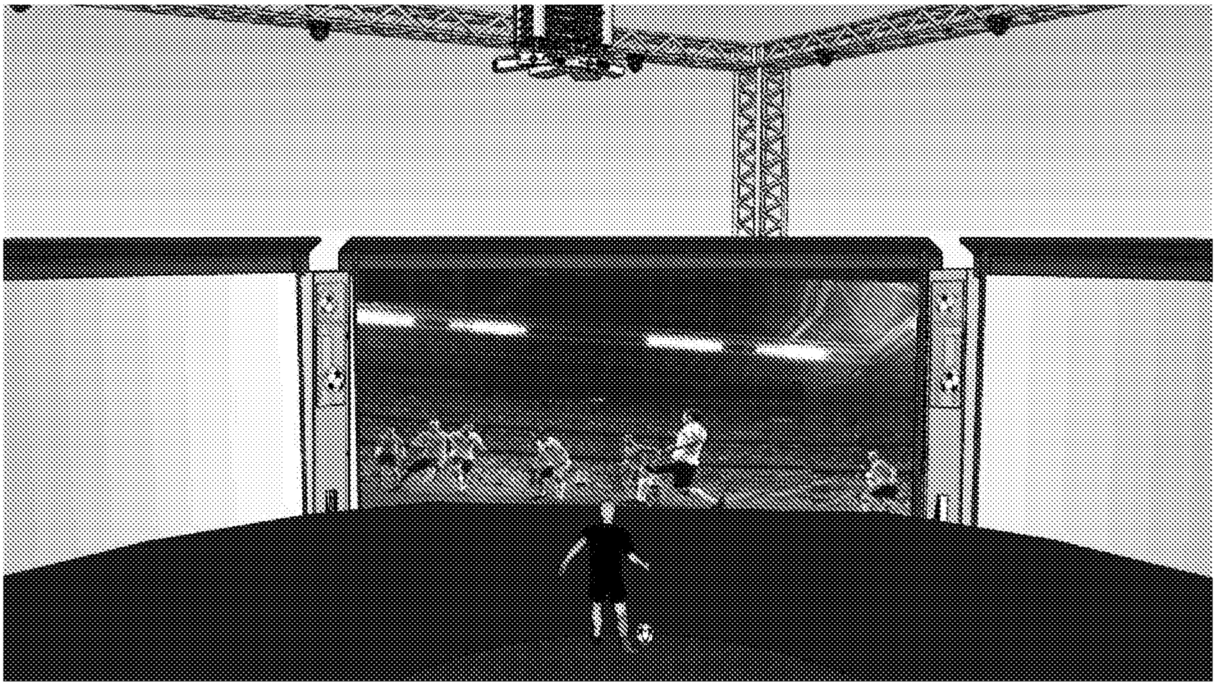


Fig 5.

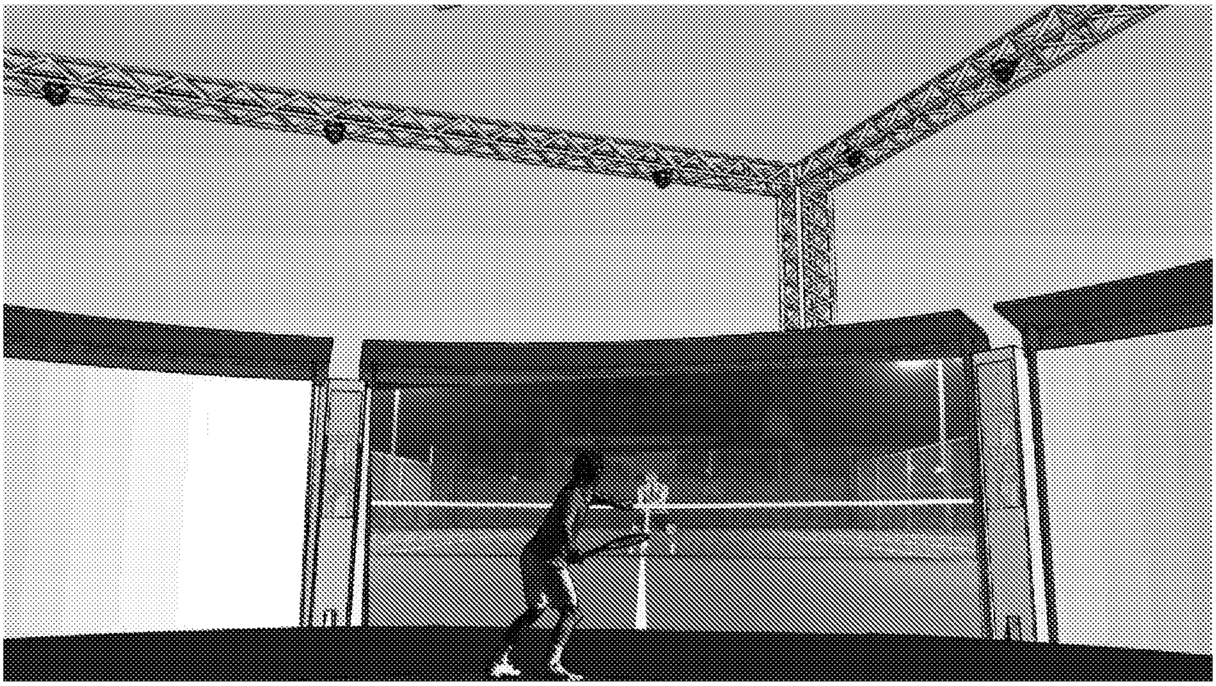


Fig 6.

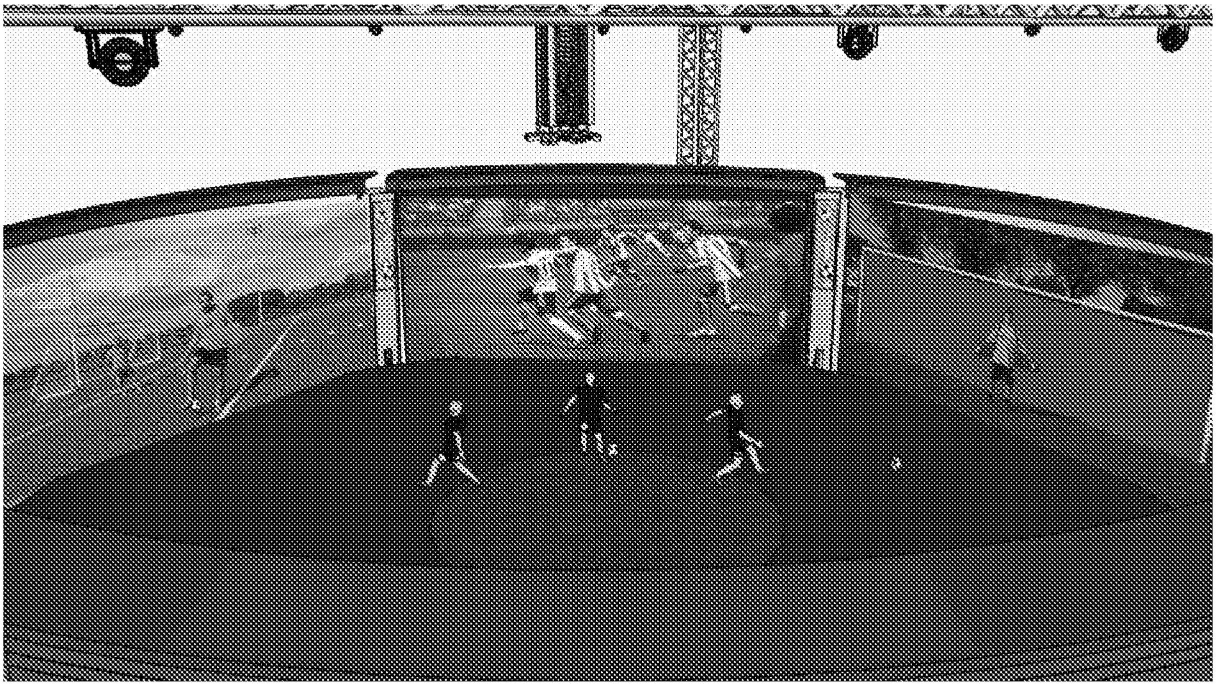
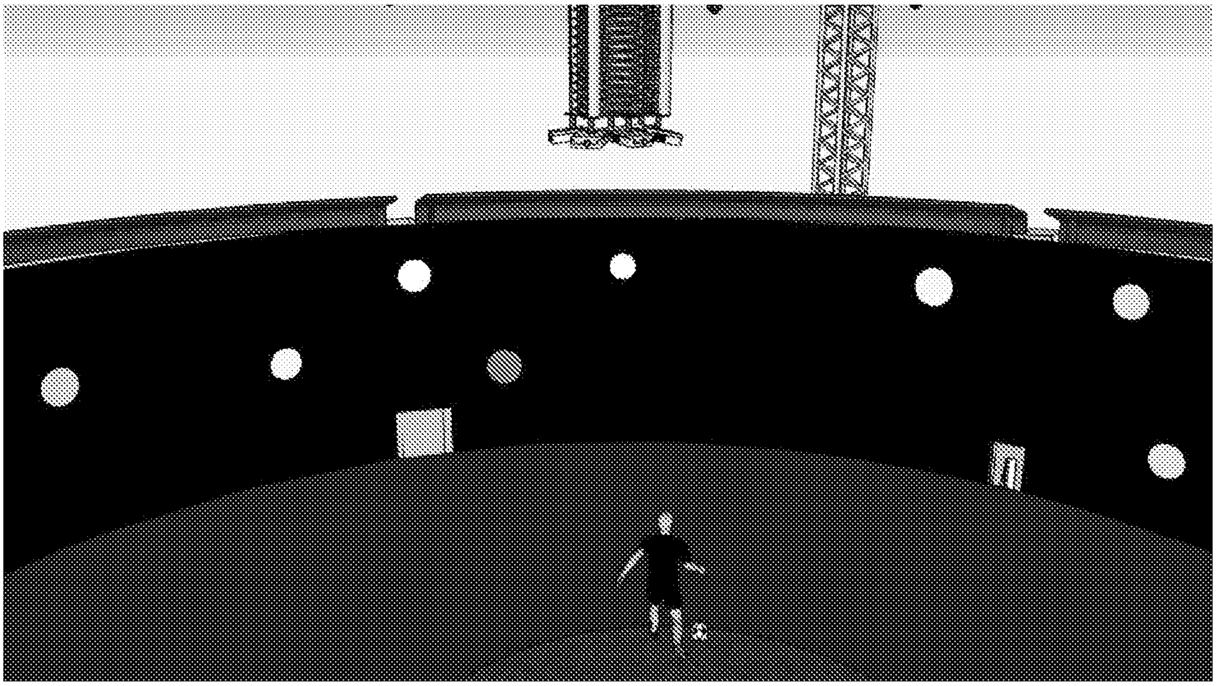


Fig 7.



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/050835

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F19/00 A63B69/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F A63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 751 642 A (SILVA JOHN M [US] ET AL) 14 June 1988 (1988-06-14) abstract column 1, line 63 - column 2, line 64 column 3, line 32 - column 4, line 60 claims 1-7 figures 1,2 -----	1-21
X	US 2014/094326 A1 (FUCCILLO RALPH C [US] ET AL) 3 April 2014 (2014-04-03) abstract paragraph [0014] - paragraph [0026] claims 1-4,11-18 figures 1,2 -----	1-21
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 May 2017	17/05/2017

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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