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(72) Inventors:  
• **Semegen, Mateusz**  
**64-200 Komorowo (PL)**  
• **Rot, Maciej**  
**64-200 Komorowo (PL)**  
• **Kasperowicz, Rafal**  
**64-200 Komorowo (PL)**

(71) Applicant: **Heavy Kinematic Machines Sp. z o. o.**  
**64-200 Komorowo (PL)**

(74) Representative: **Blonski, Pawel**  
**EP-Patent**  
**Konstruktorow 30/2**  
**65-119 Zielona Gora (PL)**

(54) **SYSTEM AND METHOD FOR ASSISTING A WEIGHTLIFTING WORKOUT**

(57) System for assisting weightlifting workout having a plurality of weight plates, the system comprising: a memory; a controller; the system being characterized in that it comprises: at least three sensors each comprising an emitter/receiver pair managed by the controller; wherein each weight plate comprises a reflective marker configured to reflect a signal of the emitter and reflect it towards the receiver; wherein the three sensors are arranged with respect to an engaging movement vector, selectively applied to the weight plates, as follows: a middle sensor (S2) being the first sensor to detect the front weight plate, in the initial state, when considering the direction of said engaging movement; a top sensor (S1) being the sensor following the middle sensor (S2) when considering the direction of said engaging movement; a bottom sensor (S3) being the sensor preceding the middle sensor (S2) when considering the direction of said engaging movement.

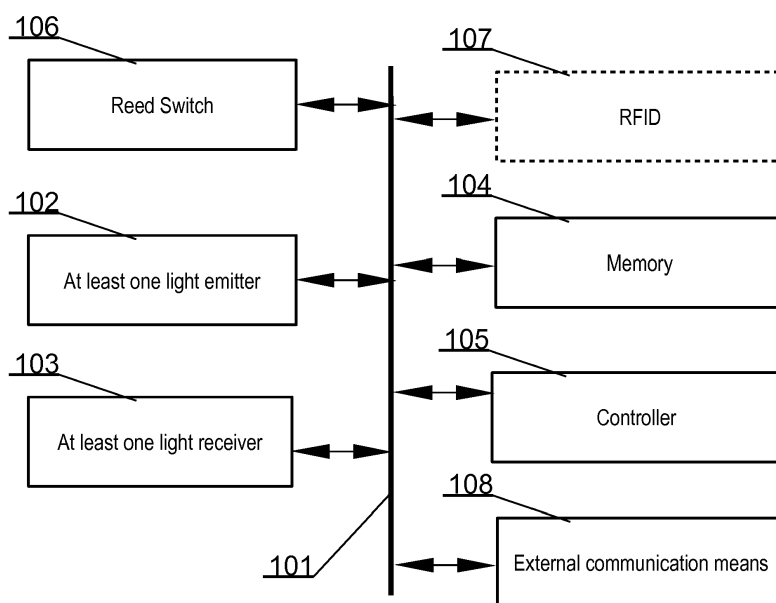


Fig. 1A

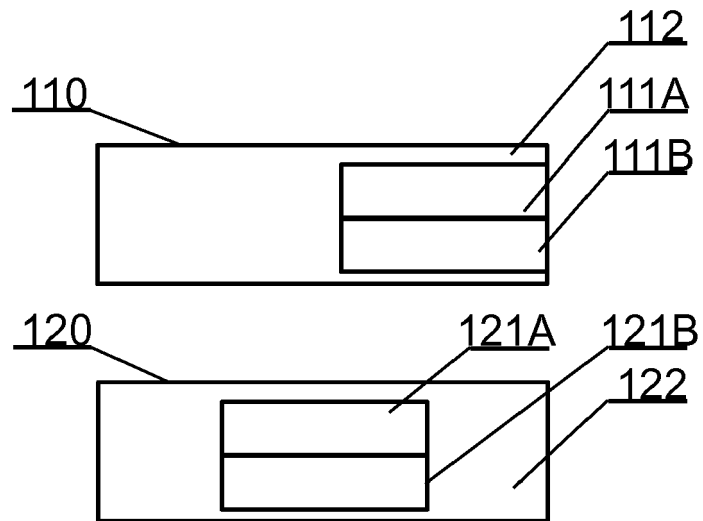


Fig. 1B

**Description****TECHNICAL FIELD**

5 [0001] The present invention relates to a system and method for assisting a weightlifting workout. In particular, the invention relates to counting repetitions and lifted weight when working out using a machine such as weight stack. This data may in turn be used for various summaries and statistical analysis of a plurality of workouts.

**BACKGROUND OF THE INVENTION**

10 [0002] Prior art of "Exercise monitoring system" US 8062182 B2 discloses an exercise-monitoring system including a static-stack light transmitter, a static-stack light reflector, and a static-stack light receiver. The static-stack light transmitter may be positioned to emit light towards the bottom of the weight stack where the static-stack light reflector is located, along an optical path having a length that is proportional to an amount of static weight in the weight stack. The exercise-monitoring system may further include an active-stack light transmitter, an active-stack light reflector, and an active-stack light receiver. The active-stack light transmitter may be positioned to transmit light to the active-stack light reflector located at the top of the weight stack. The active-stack reflector may extend from the top of the active stack in such a manner so as to be in the path of the light emitted from the active-stack light transmitter in order to reflect light to the active stack light receiver. The amount of reference light received by the active- and/or static-stack light receivers may be used by an analyzer to output information regarding various factors about the exercise being performed, such as range of motion, amount of weight lifted, and number of repetitions.

20 [0003] A drawback of this solution is that due to a requirement of very precise distance measurements (especially in case of the static-stack) the system requires very precise sensors that measure distance. This in turn requires appropriate expenses on such equipment.

25 [0004] A further publication of "Sensor arrays for exercise equipment and methods to operate the same" US 20070213183 A1, discloses a linear array of sensors. The array of sensors includes a plurality of sensors positioned adjacent and opposite the resting position of each weight plate, and at equally spaced locations above the example stack of weights up to the highest travel position attainable by the top weight plate of the example stack of weights. The example sensor array is enclosed in, covered and/or attached to any variety of housing and/or mounting bracket.

30 [0005] A drawback of this solution is that there must be present a lot of sensors wherein the number of sensors greatly exceeds the number of weight plates because the sensors must extend up to the highest travel position attainable by the top weight plate.

[0006] Therefore, due to the number of required sensors this solution is also ineffective with relation to cost.

35 [0007] It would be advantageous to present a solution where the cost would be decreased where a low number of relatively low complexity sensors would suffice to achieve the object of counting repetitions and lifted weight when working out using a machine such as weight stack.

[0008] The aim of the development of the present invention is therefore an improved and cost effective system and method for assisting weightlifting workout.

**SUMMARY AND OBJECTS OF THE PRESENT INVENTION**

40 [0009] An object of the present invention is a system for assisting weightlifting workout having a plurality of weight plates, the system comprising: a memory; a controller; at least three sensors each comprising an emitter/receiver pair managed by the controller; wherein each weight plate comprises a reflective marker configured to reflect a signal of the emitter and reflect it towards the receiver; wherein the three sensors are arranged with respect to an engaging movement vector, selectively applied to the weight plates, as follows: a middle sensor being the first sensor to detect the front weight plate, in the initial state, when considering the direction of said engaging movement; a top sensor being the sensor following the middle sensor when considering the direction of said engaging movement; a bottom sensor being the sensor preceding the middle sensor when considering the direction of said engaging movement.

50 [0010] Preferably, the system further comprises a proximity sensor configured to identify particular users operating the system.

[0011] Preferably, each emitter is configured to emit a signal detectable by the receiver.

55 [0012] Preferably, said reflective markers are such that they occupy only a section of the side area of a corresponding weight plate while the remaining side area of a corresponding weight plate is such that it reflects the emitted signal to a lesser extent than the reflective marker.

[0013] Preferably, wherein each reflective marker comprises two distinct elements: reflector A and reflector B, having different reflective properties.

[0014] Preferably, reflectors A reflect more light while reflectors B reflect less light whereas both reflectors A and B

reflect light to such an extent that it is possible to differentiate between said reflectors and the weight plate as well as an empty space, between weight plates, is present in front of a receiver.

[0015] Preferably, each sensor comprises an emitter as well as two receivers positioned such that there is a shift between them along the expected axis of movement of said markers positioned on the weight plates.

[0016] Preferably, the size of the respective reflectors B and the reflectors A is at least equal to a rectangle defined by vertices at the positions of the two receivers.

[0017] Preferably, there is more than one top sensor present in a group of top sensors and/or more than one bottom sensor present in a group of bottom sensors.

[0018] Preferably, wherein the system further comprises an external communication means configured to communicate workout parameters and statistics to external devices.

[0019] Another object of the present invention is a method for assisting weightlifting workout involving a plurality of weight plates in the system according to the present invention, the method being characterized in that weight counting comprises the steps of: activating all sensors except for the top sensor; awaiting for the middle sensor to detect a marker; determining the lowest sensor that has detected a marker; activating top sensor and, in case the top sensor has detected a presence of the first weight plate, determining a count of detected markers by the lowest sensor that has detected a marker; calculating a number of markers using the following equation:

$$\text{sensor's\_index} * \text{offset} + \text{count\_of\_step\_407}$$

wherein said offset is the number of weight plates between directly neighboring sensors; wherein said sensor's\_index is the number of sensors between the middle sensor and the lowest sensor that has detected a marker; summing the weight of all weight plates starting from the last until the weight plate indicated by the result of the equation.

[0020] Preferably, in case the lowest sensor that has detected a marker returns an empty result, there is be taken into account a number of markers detected by the middle sensor after detecting the first weight plate by the top sensor.

[0021] Another object of the present invention is a method for assisting weightlifting workout involving a plurality of weight plates in the system according to the present invention, the method being characterized in that repetitions counting comprises the steps of: setting a "Ready to notify repetition" flag to false; determining a direction of movement of the weight stack; in case the weight stack is moving downwards and the "Ready to notify repetition" flag is set to true, notifying a repetition while at the same time setting the "Ready to notify repetition" flag to false and otherwise, if the weight stack is moving upwards, setting the "Ready to notify repetition" flag to true.

[0022] Another object of the present invention is a computer program comprising program code means for performing all the steps of the computer-implemented method according to the present invention when said program is run on a computer.

[0023] Another object of the present invention is a computer readable medium storing computer-executable instructions performing all the steps of the computer-implemented method according to the present invention when executed on a computer.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0024] These and other objects of the invention presented herein, are accomplished by providing a system and method for assisting weightlifting workout. Further details and features of the present invention, its nature and various advantages will become more apparent from the following detailed description of the preferred embodiments shown in a drawing, in which:

Fig. 1A presents a diagram of the system according to the present invention;

Fig. 1B depicts examples of reflective markers according o the present invention;

Fig. 2 presents an example of a combined emitter/receiver pair;

Fig. 3 presents sensors positioning on a weight stack;

Fig. 4 presents a process diagram of weight counting;

Fig. 5 shows a process diagram of repetitions counting;

Fig. 6 shows a process diagram of setting threshold values responsible for determining which sensors to switch on or off;

Figs. 7A-B depict a process of switching the sensors during movement of the weight stack; and

Figs. 8A-E show system's state during movement of a weight stack.

## NOTATION AND NOMENCLATURE

**[0025]** Some portions of the detailed description which follows are presented in terms of data processing procedures, steps or other symbolic representations of operations on data bits that can be performed on computer memory. Therefore, a computer executes such logical steps thus requiring physical manipulations of physical quantities.

**[0026]** Usually these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a computer system. For reasons of common usage, these signals are referred to as bits, packets, messages, values, elements, symbols, characters, terms, numbers, or the like.

**[0027]** Additionally, all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Terms such as "processing" or "creating" or "transferring" or "executing" or "determining" or "detecting" or "obtaining" or "selecting" or "calculating" or "generating" or the like, refer to the action and processes of a computer system that manipulates and transforms data represented as physical (electronic) quantities within the computer's registers and memories into other data similarly represented as physical quantities within the memories or registers or other such information storage.

**[0028]** A computer-readable (storage) medium, such as referred to herein, typically may be non-transitory and/or comprise a non-transitory device. In this context, a non-transitory storage medium may include a device that may be tangible, meaning that the device has a concrete physical form, although the device may change its physical state. Thus, for example, non-transitory refers to a device remaining tangible despite a change in state.

**[0029]** As utilized herein, the term "example" means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms "for example" and "e.g." introduce a list of one or more non-limiting examples, instances, or illustrations.

## DESCRIPTION OF EMBODIMENTS

**[0030]** Fig. 1A presents a diagram of the system according to the present invention. The system is a set of modules aimed at monitoring workout activities on a weight stack system.

**[0031]** The electronic system may be realized using dedicated components or custom made FPGA or ASIC circuits. The system comprises a system bus (101) communicatively coupled to a memory (104). Additionally, other components of the system are communicatively coupled to the system bus (101) so that they may be managed by a controller (105). It will be evident that instead of a system bus (101) separate electrical connections may be used.

**[0032]** The memory (104) may store computer program or programs executed by the controller (105) in order to execute steps of the method according to the present invention. The memory (104) may store any configuration parameters of the system.

**[0033]** An external communication means (108) may be used in order to update operating instructions of the controller (105) as well as in order to communicate workout parameters and statistics to external devices, for example in the Internet. Such external communication means (108) may be, but are not limited to, Bluetooth LE or Wi-Fi.

**[0034]** A proximity sensor (107) such as an RFID sensor, may be used in order to identify particular users operating the system. Such user may be identified using a smartphone comprising an RFID functionality or a suitable workout garment, such as a glove, comprising an RFID functionality configured to identify a particular user.

**[0035]** The system may also comprise several modules positioned on the workout equipment such as on a weight-stack.

**[0036]** These modules may comprise at least one reed switch (106) (or a similar contact/proximity sensor such as a Hall effect sensor) providing operating current when two contacts are in proximity or directly connect to one another). Typically, a magnet will be used to activate the reed-switch. The function of such reed switch (106) is two-fold, first it may indicate a low power mode when such switch has not been activated for a longer period of time (a predefined time, e.g. 3 minutes), secondly such reed-switch may identify the first weight plate of a given weight stack.

**[0037]** According to the present invention, the system comprises at least one emitter/receiver pair (102, 103). Preferably, the at least one emitter is a light emitter (102) while the corresponding receiver (103) is configured to conditionally receive a signal from the corresponding emitter (102).

**[0038]** Said conditional reception requires a presence of an appropriate reflective marker as will be explained later. Thus, in a preferred embodiment each emitter (102) emits a signal in a given axis, for example horizontally or vertically, depending on the positioning of weight plates.

**[0039]** Each emitter (102) is configured to emit a signal detectable by the receiver (103), such as a beam of visible light, although other signals, such as radio signals and infrared signals may be used.

**[0040]** In a preferred embodiment, the emitter (103) is an infra-red diode while the receiver (102) is a photo-transistor.

**[0041]** As will become evident, from the subsequent figures, the at least one emitter/receiver pair (102, 103) is positioned on one side of the workout equipment. Therefore, each weight plate comprises a reflective marker configured to reflect said detectable signal of the emitter (102) and reflect it towards the receiver (103).

**[0042]** As is evident from Fig. 1A, the system may operate using just a single emitter/receiver pair (102, 103). However, embodiment with several emitter/receiver pairs (102, 103) are also possible as will be shown in the following parts of the specification.

**[0043]** Said reflective markers (111, 121) are preferably such that they occupy only a section of the side area of a corresponding weight plate (as shown in Fig. 1B) while the remaining side area of a corresponding weight plate (110, 120) is preferably matte (112, 122) and reflects the emitted signal to a much lesser extent than the reflective marker.

**[0044]** When a weight plate, having said reflective marker (111, 121) thereon, has passed by the photo-transistor (receiver), it will register a change in properties of received signal (light) from a given state to another state. Naturally, there may be set different thresholds for a high and low state.

**[0045]** The reflective marker (111, 121) preferably comprises two distinct elements (111A-B, 121A-B). Their color is in principle of no significance, but rather their reflective properties is what matters. To this end, two reflectors A (111A, 121A) and reflectors B (111B, 121B) are present, which have different reflective properties. For example, reflectors A (111A, 121A) reflect more light while reflectors B (111B, 121B) reflect less light. Nevertheless, both reflectors A and B reflect light to such an extent that it is possible to differentiate between said reflectors and the weight plate as well as between a situation where an empty space, between weight plates, is present in front of a receiver (103).

**[0046]** With reference to reflective parameters of the reflective markers (111, 121), it is most convenient to use a range of values provided by an analog to digital converter (ADC) responsible for converting signals received from the respective sensors.

**[0047]** In case of a 12-bit ADC the range is (0 - 4095). For the weight plate (when a typical matte, dark color is used e.g. black), the returned values are usually below 2000. Reflectors B (111B, 121B) usually return values in a range of 1300 to 3500 or reflect twice as much light as the weight plate. In case of ADC values above 3500, reflectors A (111A, 121A) may be assumed.

**[0048]** Particular values and ranges above depend on the ADC's resolution. A 0 denotes black while a maximum value denotes white. For example, a 14 - bit ADC will have a range of 0 to 16383 and the respective values of a 12-bit ADC will shift proportionally x4.

**[0049]** It is clear, to one skilled in the art, that the respective reflective properties may be defined in different ranges as long as it is possible to clearly differentiate between the weight plate, the reflectors B (111B, 121B) and finally the reflectors A (111A, 121A).

**[0050]** Fig. 2 presents an example of a combined emitter/receiver pair (102, 103). In this embodiment, an integrated sensor comprises an emitter (203) typically being an infra-red LED as well as two receivers (202, 204) positioned on a diagonal (e.g. top left side and bottom-right side).

**[0051]** Typically, the two receivers (202, 204) will be the same however an embodiment with different receivers (202, 204) is also possible but more difficult to manage by the controller (105).

**[0052]** Regarding said diagonal placement, other arrangements are possible as long as there is a shift along the expected axis of movement of said markers positioned on the weight plates (typically vertically along the Y axis). A shift between the two receivers (202, 204) in the other axis (typically X) allows to decrease a distance, on the axis of movement, between the two receivers (202, 204) and thus allows to decrease a size of the markers.

**[0053]** The receivers (202, 204) are configured to register the reflected light emitted by the emitter (203).

**[0054]** Additional electrical and/or digital components such as transistors and resistors required by said emitter (203) and receivers (202, 204) may be integrated in a form of a sensor controller (201) being controlled by and reporting to the main controller (105).

**[0055]** Now that the sensors arrangement has been presented, their method of operation will be described in details. The sensors, as well as their appropriate placement allow for proper detection of the weight plates as well as their direction of movement.

**[0056]** In theory, in order to detect a direction, there is one sensor sufficient with a single photo-transistor (Fig. 1) - when a weight plate moves upwards first the reflector A will be detected which reflects more light than the reflector B; in case of a downward movement first the reflector B will be detected which reflects less light than the reflector A.

**[0057]** The inventors however have found that in practice it is not that simple to obtain reliable results.

**[0058]** Data from a photo-transistor receiver (103, 202, 204) are typically in a form of a stream of numerical values (after being converted by an analog to digital converter preferably being a part of the controller (105)) and in order to detect whether a given photo-transistor receiver (103, 202, 204) detects a given marker's reflector (A or B) there must be experimentally set ranges of values, which may be received for each reflector.

**[0059]** For example, for a given reflector A a range of 3500 to 4095 may be assumed while for reflector B a range of 1300 (black color and colors in proximity to black are assumed below this value) to 3500 may be assumed. The values given apply to a 12-bit analog to digital converter.

**[0060]** Thus, when a marker is moved upwards on a weight plate, the reflector A approaches a photo-transistor receiver (103, 202, 204) and thus the received numerical values gradually increase (more and more light is reflected in comparison to the dark surface of the weight plate) and cross the threshold between the reflector A and B ranges (defined above) because finally the reading will reach for example the level of 4000 while starting from readings below the 1300 threshold.

**[0061]** Therefore, on this basis one may falsely report a reflector B first even though, in case of an upwards movement, it does not precede the reflector A. This potential false detection is corrected with a use of the second photo-transistor receiver (202, 204).

**[0062]** The above results in that the size of the respective reflectors B (111B, 121B) and the reflectors A (111A, 121A) should be at least equal to a rectangle defined by vertices at the positions of the two receivers (202, 204).

**[0063]** In other embodiment, the size of the respective reflectors B (111B, 121B) should be at least equal to a rectangle defined by vertices at the positions of the two receivers (202, 204) while the size of the respective reflectors A (111A, 121A) should be at least equal to 1/3 of said rectangle. It may be smaller due to higher reflective properties of the reflectors A (111A, 121A), which may already be detected in proximity to the reflectors A (111A, 121A).

**[0064]** In practice however, it is advantageous to set the size of the reflectors as larger than said rectangle.

**[0065]** Data from said two photo-transistor receivers (202, 204) are read simultaneously and in case both return values falling within a given range of a given reflector, it is certain that a given reflector (111A, 121A, 111B, 121B) is detected. Otherwise, the data may be ignored.

**[0066]** Because the movement of a weight stack is executed along the Y axis, the displacement of the photo-transistor receivers (202, 204) must also be on the Y axis.

**[0067]** An additional range, taken into account while detecting a marker, is a range defining the weight plate without a marker. Typically, this range falls between 0 and 650, because the weight plates are usually painted with black or other dark color (clearly, other definitions of such range are possible).

**[0068]** Having the aforementioned three ranges, there may be defined system states for photo-transistor receivers (202, 204) reading:

**UNKNOWN** - data from the photo-transistor receivers (202, 204) do not both fall into the same range (e.g. the first photo-transistor returns 2000 while the second photo-transistor returns 400). Such state is discarded;

**NONE** - data from the photo-transistor receivers (202, 204) both fall in the first range, for example 0 - 650 (i.e. a weight plate without marker has been detected - an assumption made for this range);

**REFLECTOR\_B** - data from the photo-transistor receivers (202, 204) both fall in the first range 1300 - 3500 (i.e. a weight plate with reflector B has been detected);

**REFLECTOR\_A** - data from the photo-transistor receivers (202, 204) both fall in the first range 3500 - 4095 (i.e. a weight plate with reflector A has been detected);

**[0069]** Subsequently, in two separate steps, there are detected directions of movement of a weight plate. The direction is detected based on the following changes of states (Previous state → Current state):

Upwards movement:

**NONE → REFLECTOR\_A** or

**REFLECTOR\_A → REFLECTOR\_B** or

**REFLECTOR\_B → NONE**

Downwards movement:

**NONE → REFLECTOR\_B** or

**REFLECTOR\_B → REFLECTOR\_A** or

**REFLECTOR\_A → NONE**

**[0070]** A presence of a weight plate is confirmed only when the following changes of states occur:

**REFLECTOR\_A → REFLECTOR\_B** or

**REFLECTOR\_B → REFLECTOR\_A**

**[0071]** This greatly simplifies internal operation of the system according to the present invention.

**[0072]** Having all the above information, the system is able to detect (separately on each of the sensors according to Fig. 2) how many weight plates have been moved in a given direction (each of the sensors may have its own counter of weight plates that are present above its location - it is a difference between weight plates count detected during an upwards movement and a weight plates count detected during a downwards movement).

**[0073]** This is crucial, because it eases installation since it allows lower precision during mounting of the sensors.

**[0074]** In the following section a general principle of weight counting and repetitions counting will be presented.

**[0075]** A preferred configuration, as shown in Fig. 3, comprises three sensors (S1, S2, S3) shown in Fig. 2. Each sensor (S1, S2, S3) shall be initially positioned such that it reports the NONE state.

**[0076]** Distances between the sensors (S1, S2, S3) are set during mounting and setup and are fixed for a given weight stack device. Nevertheless, these distances are preferably a multiplication of a height of a single weight plate (WPO - WP3), for example four weight plates distance equals 10 cm for a weight plate having 2,5 cm height.

**[0077]** In principle, the bottom sensor (S3) is responsible for counting weight while the top sensor (S1) is responsible for counting repetitions. The middle sensor (S2) is preferably positioned just above (level 301) the top weight plate of the weight stack at rest.

**[0078]** It will be evident, to one skilled in the art, that a weight lifting machine is a preferred example and references in the following description are made to such an arrangement where a weight is lifted vertically. Nevertheless, the present invention may be applied in case of machines that move weight in a different direction than vertical, for example horizontally (weight pulling/pushing). In such case, a top sensor will rather be a left/right sensor and a bottom sensor will be named accordingly as will be apparent to one skilled in the art.

**[0079]** In view of the above, one needs to differentiate between the engaging movement (vector (302) in Fig. 3), which requires application of an external force (e.g. weight lifting by a user), and a return movement, which typically does not require the external force and is effected by means of gravity.

**[0080]** An alternative naming scheme of the sensors may be as follows:

- the middle sensor (S2) → the first sensor to detect the front (i.e. first) weight plate, in the initial state, when considering the direction of said engaging movement e.g. a top weight plate in case of a vertical movement (WP3 in Fig. 3), leftmost weight plate in case of horizontal movement towards the left side or a rightmost weight plate in case of horizontal movement towards the right side;
- the top sensor (S1) → the sensor(s) following the middle sensor (S2) when considering the direction of said engaging movement;
- the bottom sensor (S3) → the sensor(s) preceding the middle sensor (S2) when considering the direction of said engaging movement.

**[0081]** As will be evident from the following specification, there may be only one top sensor (S1), only one middle sensor (S2) and at least one bottom sensor (S3) present in a group of bottom sensors.

**[0082]** Repetitions counting is executed by having a global state denoting a movement of the weight stack. Such state may be updated by each sensor except for the bottom sensor (S3). In practice however, only the top sensor (S1) updates said state, when it has detected at least one marker on a weight plate. When the top sensor (S1) has detected a change into UPWARDS state and subsequently detects a change into DOWNWARD state, the system (i.e. the controller (105)) signals a single repetition.

**[0083]** The above applies to a simple embodiment of 3 sensors, and in case of more sensors, the highest placed sensor that was reached by a marker present on the top weight plate, will trigger update of the repetitions counter.

**[0084]** Details of repetitions counting, in view of the general principles above, will be defined with reference to Fig. 5.

**[0085]** Kilograms (or weight in general) counting is effected differently. First, in order to properly detect a number of lifted weight plates (WPO - WP3), the system needs information from two sensors. In case when less than four weight plates are lifted (i.e. with reference to a distance multiplication factor of 4 referred to earlier), the total weight is detected based on data from sensors (S1, S2). Such case is present when the bottom sensor (S3) has not detected any marker, the middle sensor (S2) has detected fewer than 5 markers and the top sensor (S1) has detected at least one marker.

**[0086]** In the case described above, the number of detected markers by the middle sensor (S2) during an UPWARDS

movement it assumed as the weight of the series (after multiplication by a weight of a single weight plate) when the weight stack returns to its initial position (i.e. the number of weight plates above the middle sensor (S2) is zero) for a predefined minimum time threshold.

**[0087]** The predefined minimum time threshold (post repetition rest time) may be set during setup and be assigned to the weight stack machine or be set in a software application of a user (preferably takes precedence). The time may, for example, equal 500 ms or 1000ms.

**[0088]** In case more than four weight plates are lifted, the bottom sensor (S3) also reports state changes and hence a count of markers for the bottom sensor (S3) may be established. In this case, in order to correctly detect the number of weight plates in a given repetition, a further condition must be met: the middle sensor (S2) must detect at least four markers during UPWARDS movement. Then, there is certainty that the number of detected markers, by the bottom sensor (S3), is final. In this case, the total weight is calculated by using the number of markers detected by the bottom sensor (S3) summed with the four weight plates that are above it and multiplying it by the weight of a single weight plate.

**[0089]** Details of weight counting, in view of the general principles above, will be defined with reference to Fig. 4.

**[0090]** A general process of detecting weight for a greater number of weight plates will be the same whereas except for the bottom sensor (S3) there will be iteration present on a plurality of sensors assigned to a bottom sensors group. In such case there will be analyzed data detected by the sensor, which is the closest to the beginning of the weight stack (i.e. the lowest in case of a vertical weight stack).

**[0091]** To this end, the arrangement of the sensors (S1, S2, S3) in a sequence is preferably known and the sensors are all spaced by the same distance from one another. Nevertheless, for specific weight stack machines, there may be different distances between groups of sensors, for example in case when an exercise requires lifting a set of weight plates to a predefined initial level and subsequently exercising at this level.

**[0092]** In yet another embodiment, at least one top sensor (S1) may be present in a group of top sensors. This allows a more precise tracing of a weight stack. Naturally, this embodiment may also be combined with the embodiment with a group of bottom sensors (S3).

**[0093]** For example, assuming a spacing of 4 weight plates between sensors, a weight stack of 12 weight plates will require 5 sensors (3 sensors in the bottom sensors group) and a weight stack of 20 weight plates will typically require 7 sensors (5 sensors in the bottom sensors group).

**[0094]** Similarly, assuming a spacing of 5 weight plates between sensors, a weight stack of 10 weight plates will require 4 sensors (2 sensors in the bottom sensors group) and a weight stack of 20 weight plates will require 6 sensors (4 sensors in the bottom sensors group).

**[0095]** The spacing influences a minimum required movement in order to detect a repetition. Therefore, in principle, the more sensors, the greater the possible extent of movement (greater number of sensors in the top group (S1)). Further, increased number of sensors allows for detection of more weight plates or a greater accuracy of repetition detection due to decreased spacing between successive sensors.

**[0096]** Fig. 4 presents a process diagram of weight counting. The first, optional, step (401) is to detect a presence of a system start condition, for example using the Reed switch (106).

**[0097]** Subsequently, at step (402), the system powers on (activates in general) all sensors except for the top sensor (S1).

**[0098]** Next, at step (403) the system awaits for the middle sensor (S2) to detect a marker (111, 121). After that, there may be determined all sensors that have detected a marker. The lowest of these sensors may be determined (404), which may also be used in order to deactivate all bottom group's (S3) sensors (406) except for the sensor determined at step (404). This step is aimed at saving energy use and is the preferred embodiment. Nevertheless, deactivation of sensors may be omitted.

**[0099]** Subsequently, after activating top sensors group (405), in case a top sensor (S1) detects presence of the first (top) weight plate (WP3) there is determined a count (407) of detected markers (111, 121) by the sensor of the (404) step. The presence is detected by a complete pass from the REFLECTOR\_A state to the REFLECTOR\_B state as previously explained.

**[0100]** Next, at step (408), there are deactivated all sensors of the bottom sensors group (S3). Subsequently, at step (409), there may be calculated a number of markers (weight plates) using the following equation:

$$(\text{sensor's\_index}) * \text{offset} + \text{count\_of\_step\_407}$$

wherein said offset is the number of weight plates between directly neighboring sensors (four in the example of Fig. 3); and

wherein said sensor's\_index is the number of sensors between the middle sensor (S2) and the sensor of step (404).

**[0101]** This value needs to be multiplied by a weight of a single weight plate (410) or in more sophisticated systems, where weight plates have different weights, it may be a sum of a the weight of all weight plates starting from the back/last (WP0) until the weight plate indicated by the result of step (409).

**[0102]** The calculated weight is kept until the end of the series (i.e. the middle sensor (S2) has detected as many upwards moving markers as downwards moving markers and the predefined post repetition rest timeout has elapsed).

**[0103]** In case step (404) returns an empty result, there may be taken into account (411) a number of markers detected by the middle sensor (S2) after detecting the first weight plate (WP3) by the top sensor (S1). The bottom sensors (S3) may be deactivated in such case.

**[0104]** Fig. 5 shows a process diagram of repetitions counting. A default value of a "Ready to notify repetition" flag is false (501). Its purpose is to notify that a change from an upwards movement to downwards movement has been detected. Next, at step (502) there is determined a direction of movement of the weight stack (as previously defined with respect to Upwards movement and Downwards movement).

**[0105]** In case the weight stack is moving downwards and the "Ready to notify repetition" flag is set to true there is notified a repetition (503) while at the same time setting the "Ready to notify repetition" flag to false. Otherwise, at step (504) the "Ready to notify repetition" flag is set to true if the weight stack is moving upwards (505).

**[0106]** A presence and use of the "Ready to notify repetition" flag is required in case of systems having a plurality of repetition detection sensors (i.e. a top sensors group (S1) within which a repetition detection sensor is selectively identified). A repetition is detected on a sensor defined as a repetition\_detection\_sensor, the selection of which has been described in the following paragraphs. This process is preferably executed as a separate processing thread, wherein for each sensor there is stored information defining a direction of movement of the weight stack. If this direction differs from the currently reported direction, a notification is triggered, which is processed according to the method of Fig. 5

**[0107]** Fig. 6 shows a process diagram of setting threshold values responsible for determining which sensors to switch on or off. The top sensor (S1) or a group of top sensors in general, is used to detect repetitions. During this process there are sensors preferably switched on and off depending on their use in the repetitions counting. Alternatively, all sensors may be permanently active but at the expense of higher energy use, which is not beneficial in case of battery powered systems.

**[0108]** In general, when the vertical weight stack moves upwards, a higher sensor is switched on while when the vertical weight stack moves downwards, a lower sensor is switched on.

**[0109]** A decision, on which sensor (102, 103) to switch on, is taken based on a number of weight plates that have been counted by the active sensor. In order to take that decision two thresholds are used: previous\_sensor\_threshold and next\_sensor\_threshold.

**[0110]** In addition to these thresholds there are the following variables defined:

- current\_stack\_height - representing a current stack height determined during weight counting and expressed preferably in a number of weight plates (e.g. 5 weight plates);
- offset - a distance, between neighboring sensors, expressed in a number of weight plates (e.g. 4 weight plates);
- repetition\_detection\_sensor - an indicator of a sensor, which currently detects a change of direction of weight stack movement (it is a currently active sensor, which at the start is the lowest sensor of the top sensors group (S1). Typically, the sensors are numbered with increasing indicator values the higher a given sensor is located: for example 0, 1, 2, 3 or -2, -1, 0, 1, 2 in order to clearly indicate the middle sensor as 0.

**[0111]** Said two thresholds: previous\_sensor\_threshold and next\_sensor\_threshold, defining when to switch on a sensor below (preceding) the repetition\_detection\_sensor (next\_sensor\_threshold) or above (successive) the sensor indicated by the repetition\_detection\_sensor (previous\_sensor\_threshold) are calculated as defined in Fig. 7A and Fig 7B. The process of Fig. 6 is executed only once after the weight has been determined.

**[0112]** The process starts at step (601) from verifying whether the current\_stack\_height variable is greater than the offset variable. If it is, at step (602) the process sets the previous\_sensor\_threshold to offset - 1 value, which is followed by setting the next\_sensor\_threshold to current\_stack\_height - offset (604).

**[0113]** Otherwise, when the current\_stack\_height variable is equal of lower than the offset variable, at step (603) the previous\_sensor\_threshold is set to current\_stack\_height and at step (605) the threshold next\_sensor\_threshold is set to the 1.

**[0114]** Switching the sensors (during movement of the weight stack) is shown in Fig. 7A and 7B. Fig 7A shows sensors switching process when the current\_stack\_height > 1. At step (701) there is an update on the repetition detection sensor meaning that data are current and are read from the repetition detection sensor, which is currently active.

**[0115]** Next, at step (702), it is verified whether the number of weight plates counted by the repetition detection sensor >= previous\_sensor\_threshold. In case it is, data are obtained from successive (above) sensor (703). Subsequently, if

weight plates counted by sensor above are not equal to zero (704), at step (705) the indicator of the current sensor is increased:  $\text{repetition\_detection\_sensor} = \text{repetition\_detection\_sensor} + 1$ . This means that an upper (successive) sensor will be switched on (the weight stack is moving upwards). The current sensor may be switched off depending on the respective threshold values.

**[0116]** If condition of step (702) has not been met, at step (706), it is verified whether the number of weight plates, counted by the repetition detection sensor  $\leq \text{next\_sensor\_threshold}$ . In case it is, at step (707), data are obtained from the preceding sensor. Next, if weight plates count detected by the current repetition detection sensor is equal to zero (708) the indicator of the current sensor is decreased:  $\text{repetition\_detection\_sensor} = \text{repetition\_detection\_sensor} - 1$  (709). This means that a lower (preceding) sensor will be switched on (the weight stack is moving downwards). The current sensor may remain switched on (705), depending on the respective threshold values, in case of a rapid return of the weight stack.

**[0117]** If the  $\text{current\_stack\_height}$  is equal to 1, the process shown in Fig 7B is executed. At step (710) there is an update on the repetition detection sensor meaning that data are current and are read from the repetition detection sensor, which is currently active. Next, at step (711) is verified direction of moving stack. If the stack is moving upwards data are obtained from successive (above) sensor (712). Next, if weight plates count detected by the successive sensor is greater than zero (713), at step (714) the indicator of the current sensor is increased:  $\text{repetition\_detection\_sensor} = \text{repetition\_detection\_sensor} + 1$ .

**[0118]** If the condition of step (711) has not been met, at step (715), it is verified if the weight stack is moving downwards. In case it is, data are obtained from the preceding sensor, at step (716). Next, if weight plates count detected by the preceding sensor is equal to zero (717), the indicator of the current sensor is decreased:  $\text{repetition\_detection\_sensor} = \text{repetition\_detection\_sensor} - 1$  (718).

**[0119]** A need to have two thresholds i.e. the  $\text{next\_sensor\_threshold}$  and the  $\text{previous\_sensor\_threshold}$  is due to the fact that when counting weight plates by a sensor the number of weight plates increases (0, 1, 2, 3...) during an upward movement and decreases (3, 2, 1...) during a downward movement. Therefore, in order to maintain symmetry of intervals of switching on and off respective sensors during an upwards or downwards movement, there is a need to have two counters.

**[0120]** At that time, there may be switched on the sensor determined at step (404) of weight detection. When the middle sensor (S2) and the step (404) sensor reach a weight plates count of 0 (the number of weight plates counted by the given sensor decreases during a downwards movement) the system assumed its initial state.

**[0121]** Alternatively, in order to save energy the switching on of the (404) sensor may be omitted.

**[0122]** Said switching on and off the respective sensors during repetitions counting is separated from switching on and off the sensors during weight counting. These processes are separated such that weight counting is executed first (having its own rules of switching on and off the sensors as per Fig. 4) and after the weight has been determined there is executed repetitions counting (as per Fig. 5) (having its own rules of switching on and off the respective sensors - as per Fig. 7A-B).

**[0123]** On the basis of the above, two additional functions may be implemented i.e. time of a repetition as well as height of a weight lift.

**[0124]** A time of a repetition may be registered by calculating time elapsed from a moment of detection of a first/top weight plate by the middle sensor (S2) until the weight plates count on the middle sensor (S2) has returned to 0. In practice it may be a time between step (504) and (502).

**[0125]** A height of a weight lift may be determined from a known height if a highest sensor that has detected a weight plate plus a height of weight plates detected on that particular sensor (a height of weight plates is known as a configuration parameter and typically all weight plates have the same height even though they may have different weight).

**[0126]** Figs. 8A-E show system's state during movement of a weight stack. Fig. 8A presents 5 sensors of which S2 is the middle sensor, S1-2 and S1-1 belong to the top sensors group (S1) while S3-1 and S3-1 belong to the bottom sensors group (S3). The sensors are spaced by 3 weight plates as specified by the Offset variable. Other variables may be in their default state of unspecified state such as null.

**[0127]** There are 8 weight plates (WPO - WP7) wherein in its initial state the system activates sensors S3-2, S3-1 and S2.

**[0128]** In Fig. 8B the weight stack has moved upwards by 4 weight plates, which results in that the S1-1 sensor is switched on (because it was the next sensor to detect an upwards moving weight stack and it is additionally a sensor responsible for weight detection (a top sensor of step (407)) and in that the sensor S3-1 is switched off. The S2 sensor has detected movement, S1-1 awaits a marker.

**[0129]** The remaining variables are set as follows:

- The step (404) sensor = S3-2
- $(\text{sensor's\_index}) * \text{offset} + \text{count\_of\_step\_406} = 8$
- $\text{current\_stack\_height} = 8$
- $\text{repetition\_detection\_sensor} = \text{S1-1}$

- next\_sensor threshold= 3
- previous\_sensor threshold = 2

[0130] In Fig. 8C the weight stack has moved upwards by 1 weight plate, which results in that the S3-2 sensor has been switched off while the listed variables remain the same. The lifted weight has been detected and the (702) condition has been met resulting in switching on the S1-2 sensor (703).

[0131] Fig. 8D corresponds to Fig. 8B but because now a downwards movement has been detected, sensor S3-2 is not switched yet in comparison to Fig. 8B. The repetition\_detection\_sensor is now S2, because the condition of step (702) is not met for S1-1 and steps (706) and (708) are met.

[0132] In Fig. 8E the repetition\_detection\_sensor is set to S2, because it is the highest sensor detecting weight plates in this downwards movement. For S2 the condition of step (702) is met, therefore S1-1 remains active.

[0133] Lastly, in Fig. 8F the system returns to its initial state i.e. the number of weight plates counted by the middle sensor S2 is zero.

[0134] The present invention assists in weightlifting training and provides a device assisting in this task. This device has appropriate sensors of physical activities. Therefore, the invention provides a useful, concrete and tangible result.

[0135] Also due to the fact of using sensors and data processing, the machine or transformation test is fulfilled and that the idea is not abstract.

[0136] At least parts of the methods according to the invention may be computer implemented. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit", "module" or "system".

[0137] Furthermore, the present invention may take the form of a computer program product embodied in any tangible medium of expression having computer usable program code embodied in the medium.

[0138] It can be easily recognized, by one skilled in the art, that the aforementioned method for assisting weightlifting workout may be, fully or partially, performed and/or controlled by one or more computer programs. Such computer programs are typically executed by utilizing the computing resources in a computing device. Applications are stored on a non-transitory medium. An example of a non-transitory medium is a non-volatile memory, for example a flash memory while an example of a volatile memory is RAM. The computer instructions are executed by a processor. These memories are exemplary recording media for storing computer programs comprising computer-executable instructions performing all the steps of the computer-implemented method according to the technical concept presented herein.

[0139] While the invention presented herein has been depicted, described, and has been defined with reference to particular preferred embodiments, such references and examples of implementation in the foregoing specification do not imply any limitation on the invention. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader scope of the technical concept. The presented preferred embodiments are exemplary only, and are not exhaustive of the scope of the technical concept presented herein.

[0140] Accordingly, the scope of protection is not limited to the preferred embodiments described in the specification, but is only limited by the claims that follow.

## Claims

1. System, for assisting a weightlifting workout, having a plurality of weight plates, the system comprising:

- a memory (104);
- a controller (105);

the system being **characterized in that** it comprises:

- at least three sensors each comprising an emitter/receiver pair (102, 103) managed by the controller (105);
- wherein each weight plate comprises a reflective marker (111, 121) configured to reflect a signal of the emitter (102) and reflect it towards the receiver (103);
- wherein the three sensors are arranged with respect to an engaging movement vector, selectively applied to the weight plates, as follows:
  - a middle sensor (S2) being the first sensor to detect the front weight plate, in the initial state, when considering the direction of said engaging movement;
  - a top sensor (S1) being the sensor following the middle sensor (S2) when considering the direction of said engaging movement;

- a bottom sensor (S3) being the sensor preceding the middle sensor (S2) when considering the direction of said engaging movement.

2. The system according to claim 1 further comprising a proximity sensor (107) configured to identify particular users operating the system.

3. The system according to claim 1 wherein each emitter (102) is configured to emit a signal detectable by the receiver (103).

4. The system according to claim 1 wherein said reflective markers (111, 121) are such that they occupy only a section of the side area of a corresponding weight plate while the remaining side area of a corresponding weight plate (110, 120) is such that it reflects the emitted signal to a lesser extent than the reflective marker.

5. The system according to claim 4 wherein each reflective marker (111, 121) comprises two distinct elements (111A-B, 121A-B): reflector A (111A, 121A) and reflector B (111B, 121B), having different reflective properties.

6. The system according to claim 5 wherein reflectors A (111A, 121A) reflect more light while reflectors B (111B, 121B) reflect less light whereas both reflectors A and B reflect light to such an extent that it is possible to differentiate between said reflectors and the weight plate as well as an empty space, between weight plates, is present in front of a receiver (103).

7. The system according to claim 5 wherein each sensor comprises an emitter (203) as well as two receivers (202, 204) positioned such that there is a shift between them along the expected axis of movement of said markers positioned on the weight plates.

8. The system according to claim 7 wherein the size of the respective reflectors B (111B, 121B) and the reflectors A (111A, 121A) is at least equal to a rectangle defined by vertices at the positions of the two receivers (202, 204).

9. The system according to claim 1 wherein there is more than one top sensor (S1) present in a group of top sensors and/or more than one bottom sensor (S3) present in a group of bottom sensors.

10. The system according to claim 1 wherein the system further comprises an external communication means (108) configured to communicate workout parameters and statistics to external devices.

11. A method for assisting weightlifting workout involving a plurality of weight plates in the system according to claim 1 or 9, the method being **characterized in that** weight counting comprises the steps of

- activating (402) all sensors except for the top sensor (S1);
- awaiting (403) for the middle sensor (S2) to detect a marker (111, 121);
- determining the lowest sensor that has detected a marker (404);
- activating top sensor (405) and, in case the top sensor (S1) has detected a presence of the first weight plate, determining a count (407) of detected markers (111, 121) by the lowest sensor that has detected a marker (404);
- calculating (409) a number of markers using the following equation:

sensor's\_index \* offset + count\_of\_step\_407

- wherein said offset is the number of weight plates between directly neighboring sensors;
- wherein said sensor's\_index is the number of sensors between the middle sensor (S2) and the lowest sensor that has detected a marker (404);

- summing the weight of all weight plates, starting from the last (WP0) until the weight plate indicated by the result of the equation (409).

12. The method according to claim 11 wherein in case the lowest sensor that has detected a marker (404) returns an empty result, there is be taken into account (411) a number of markers detected by the middle sensor (S2) after detecting the first weight plate (WP3) by the top sensor (S1).

13. A method for assisting weightlifting workout involving a plurality of weight plates in the system according to claim 1 or 9, the method being **characterized in that** repetitions counting comprises the steps of

- setting a "Ready to notify repetition" flag to false (501);
- determining (502) a direction of movement of the weight stack;
- in case the weight stack is moving downwards and the "Ready to notify repetition" flag is set to true, notifying a repetition (503) while at the same time setting the "Ready to notify repetition" flag to false and otherwise, if the weight stack is moving upwards (505), setting (504) the "Ready to notify repetition" flag to true.

14. A computer program comprising program code means for performing all the steps of the computer-implemented method according to claim 1 when said program is run on a computer.

15. A computer readable medium storing computer-executable instructions performing all the steps of the computer-implemented method according to claim 1 when executed on a computer.

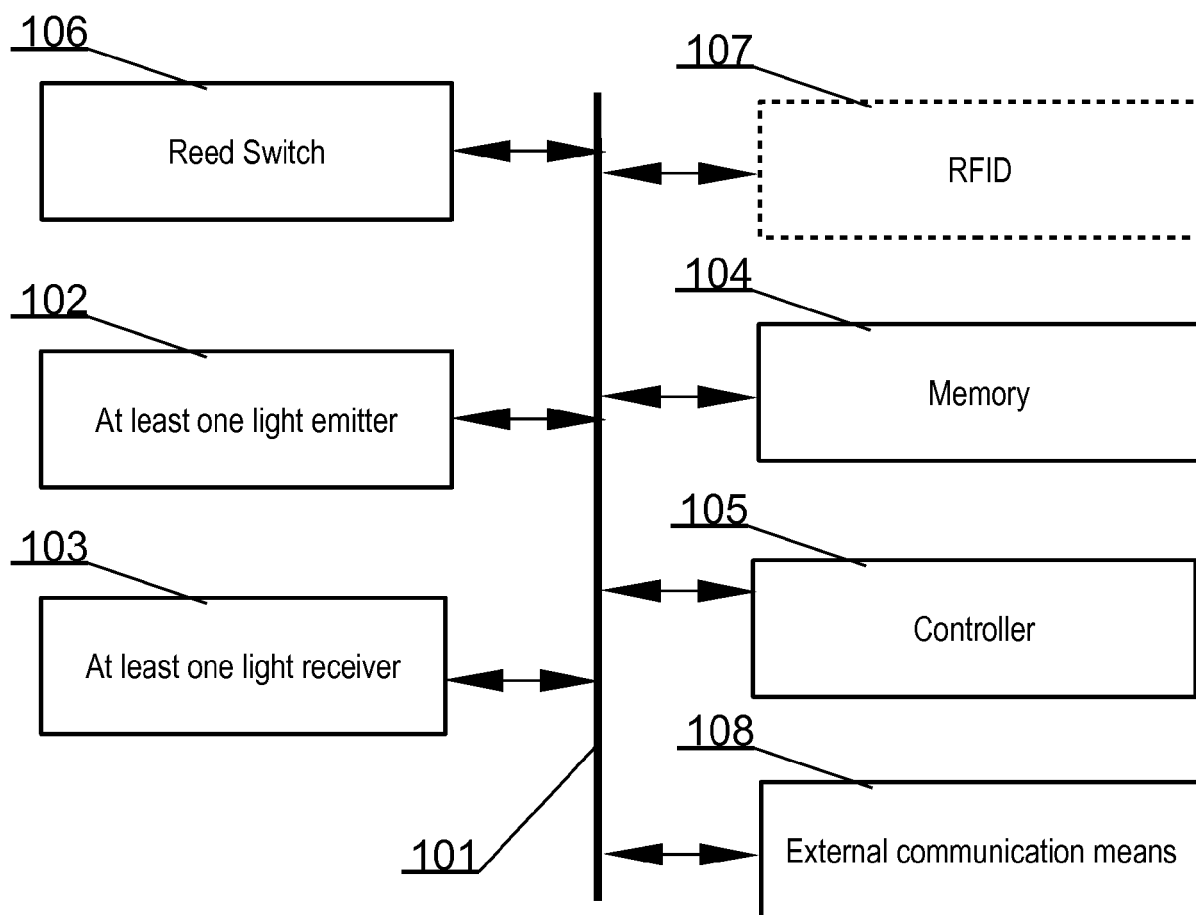


Fig. 1A

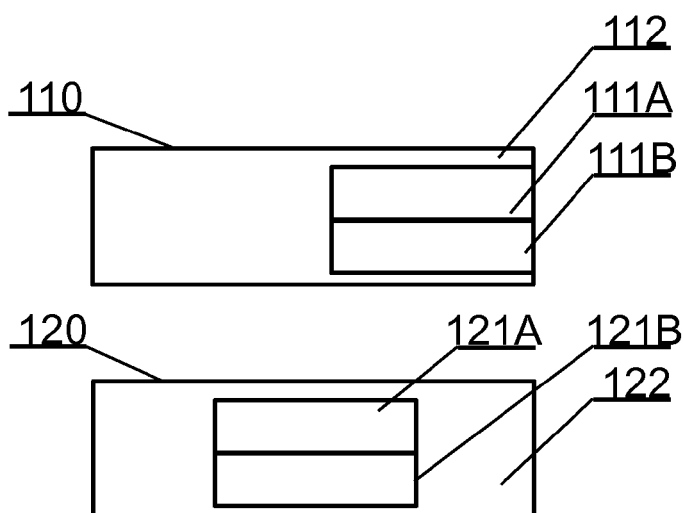


Fig. 1B

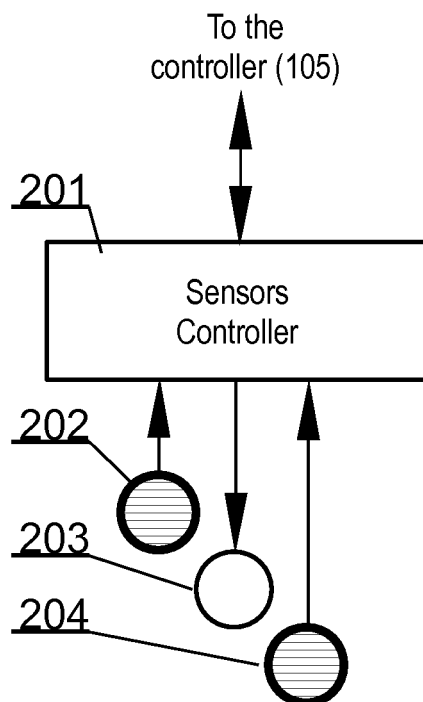


Fig. 2

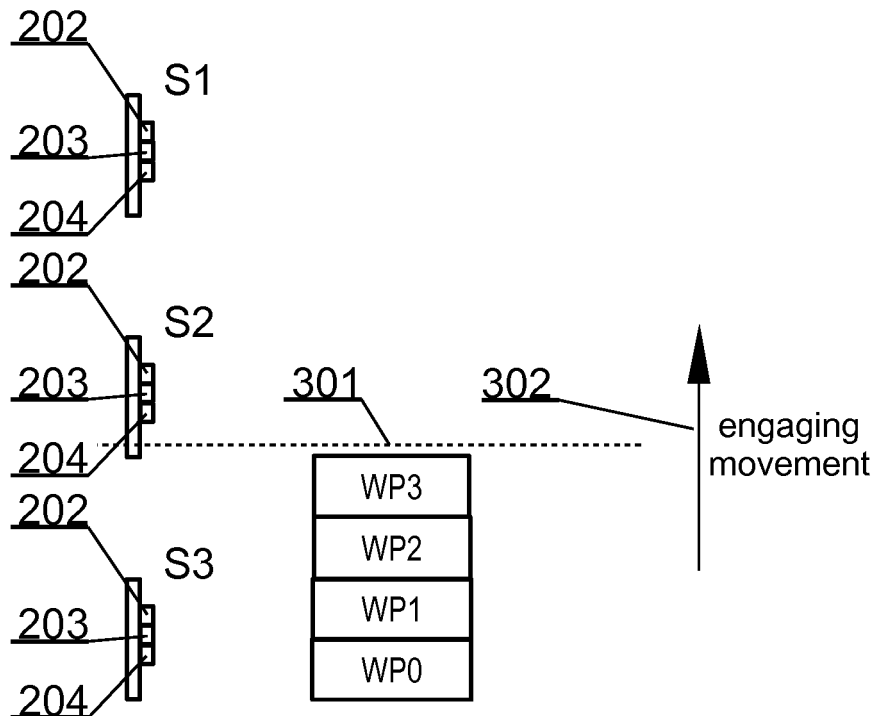


Fig. 3

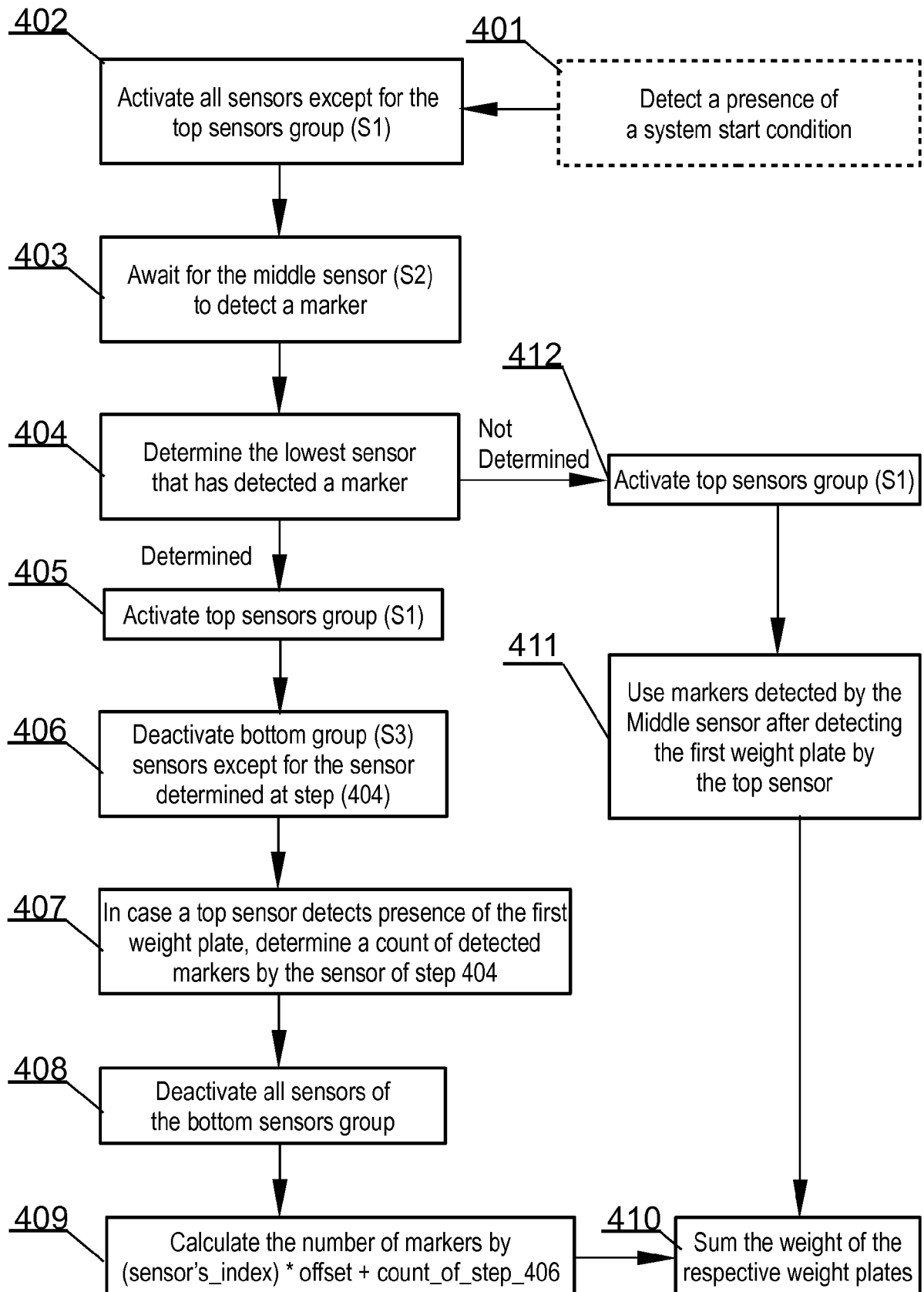


Fig. 4

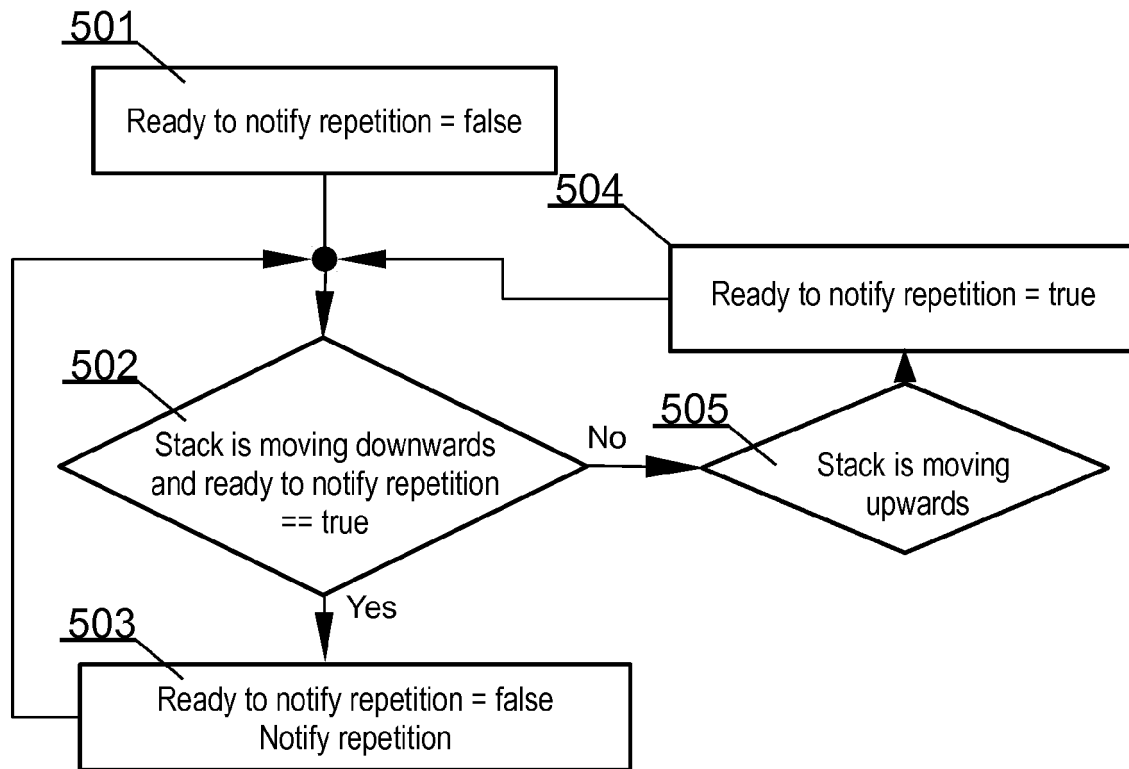


Fig. 5

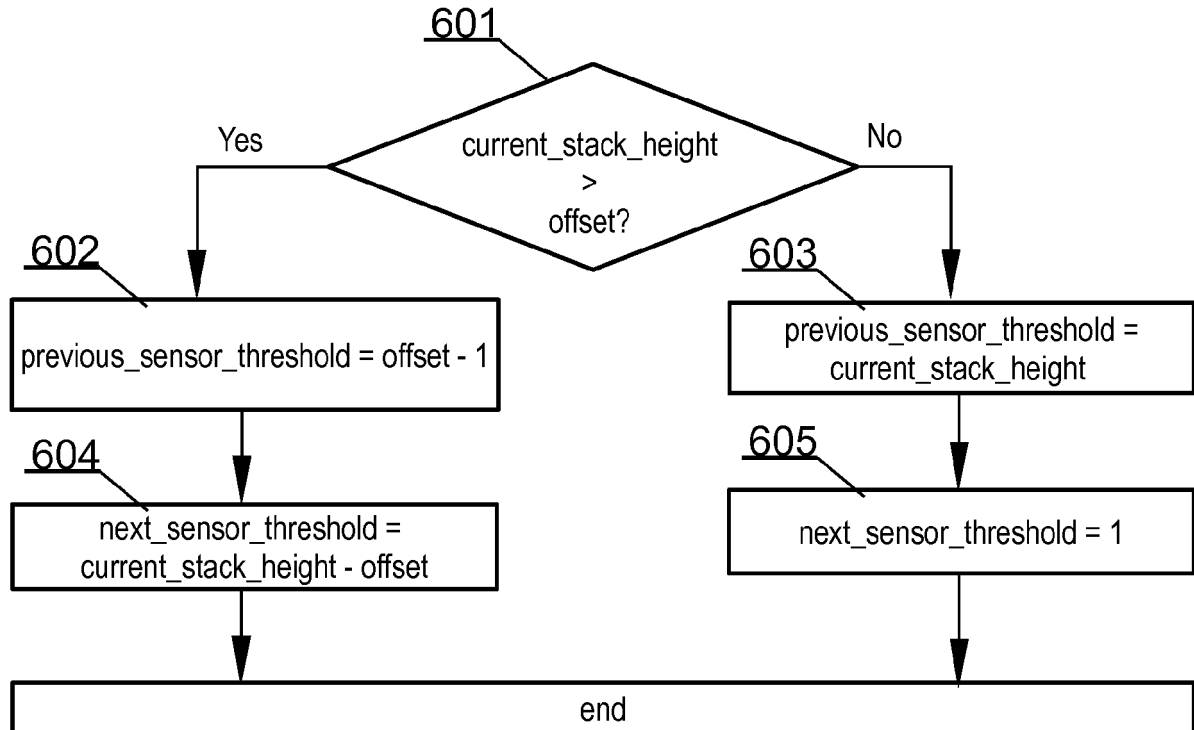


Fig. 6

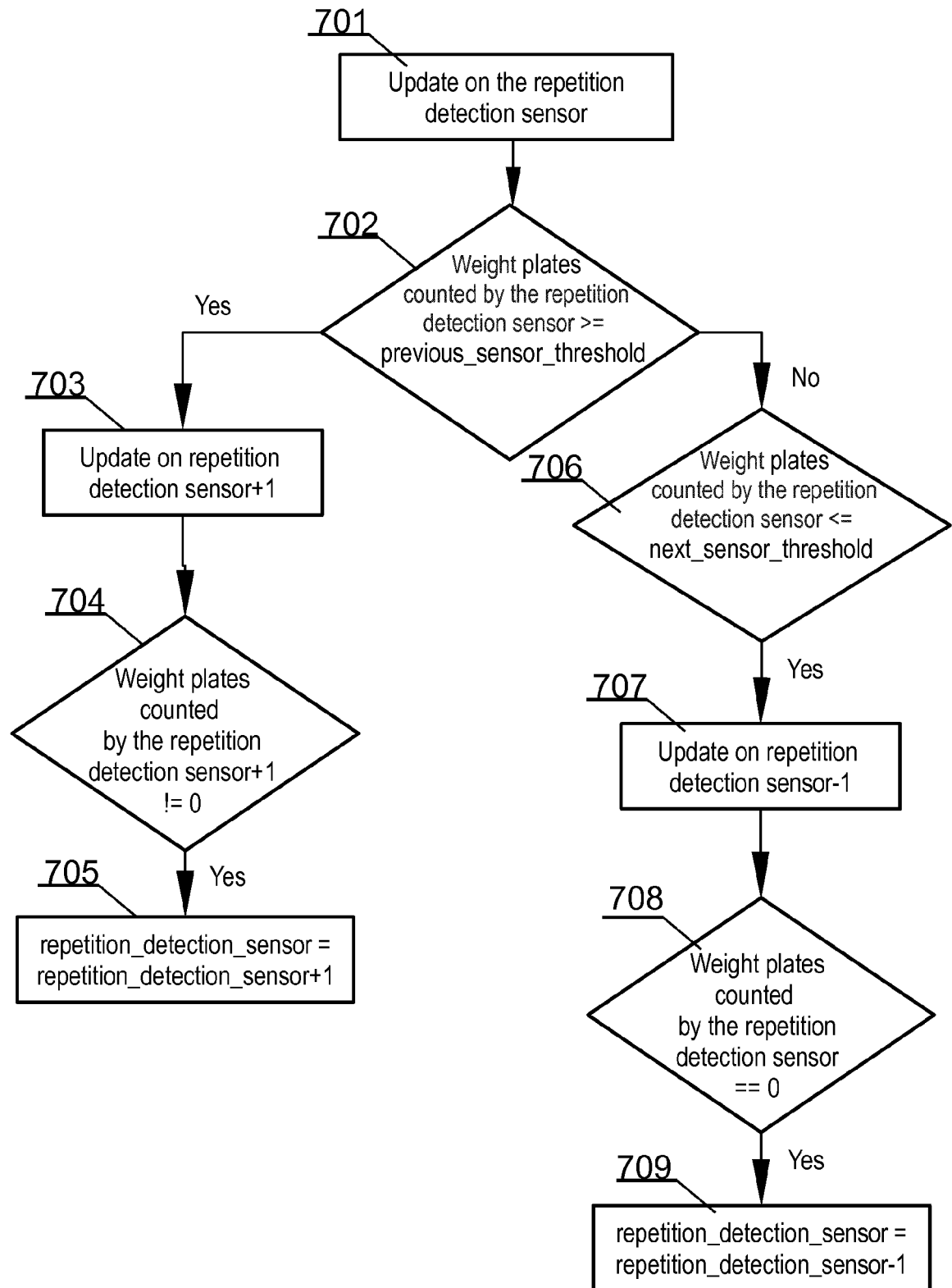


Fig. 7A

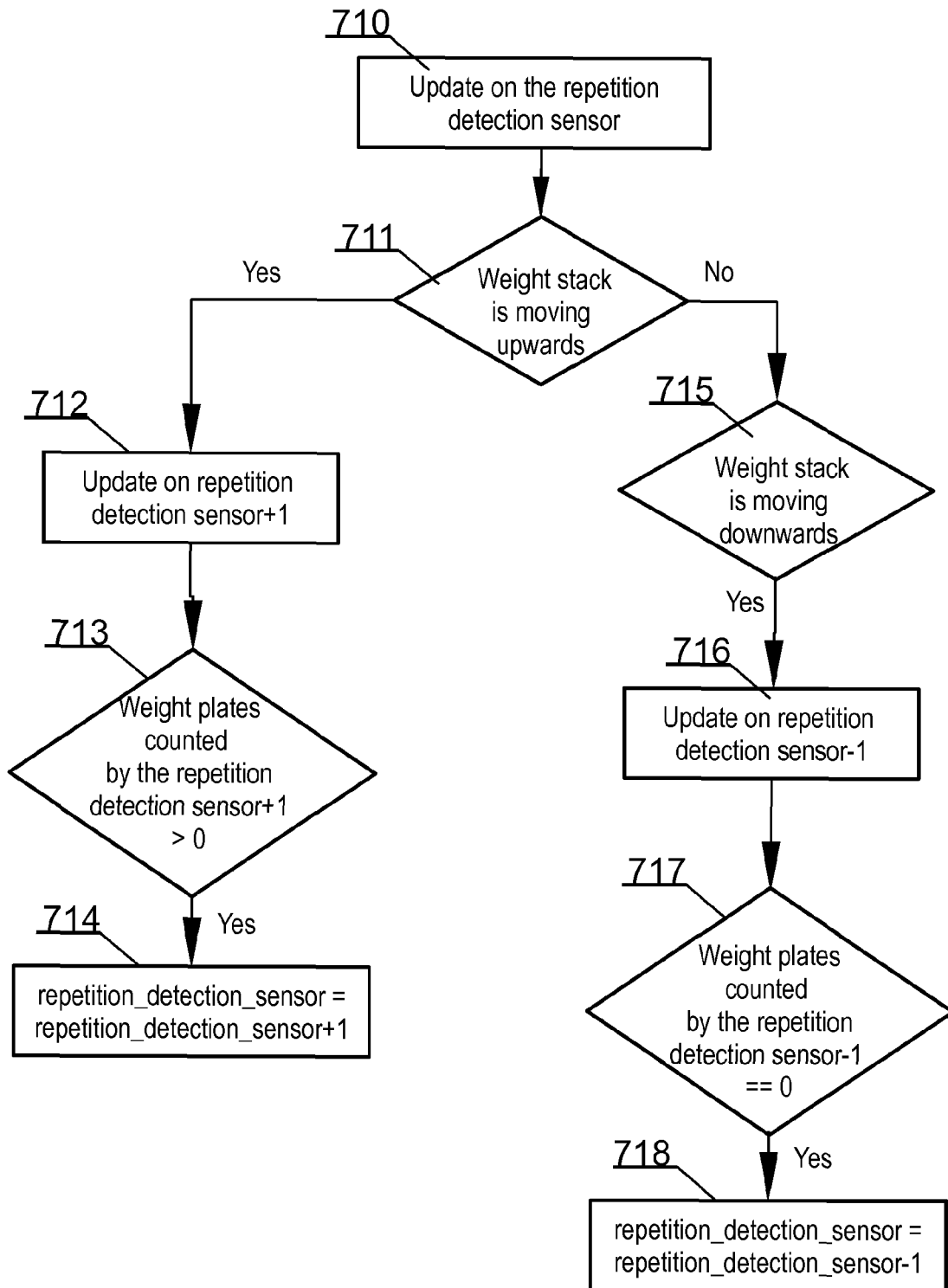


Fig. 7B

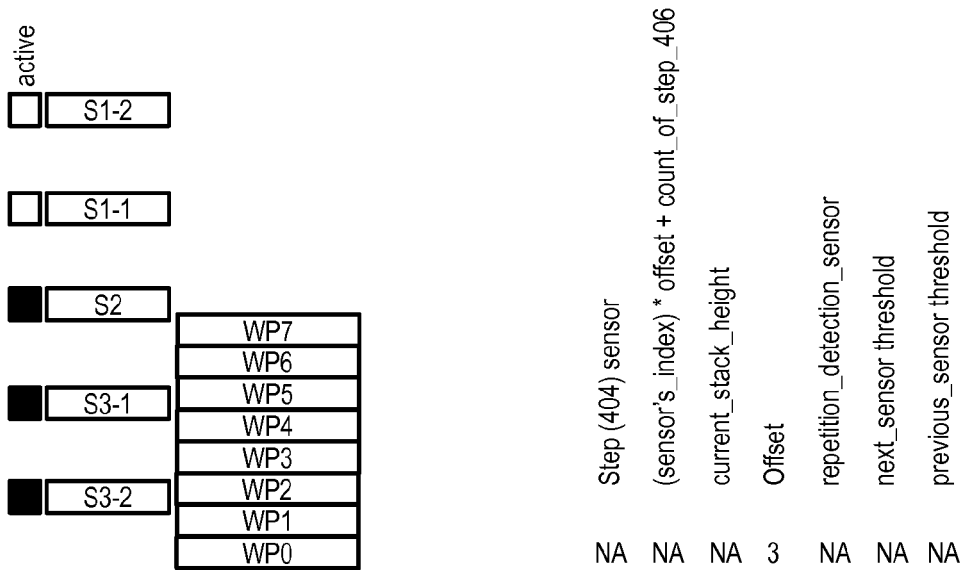


Fig.8A

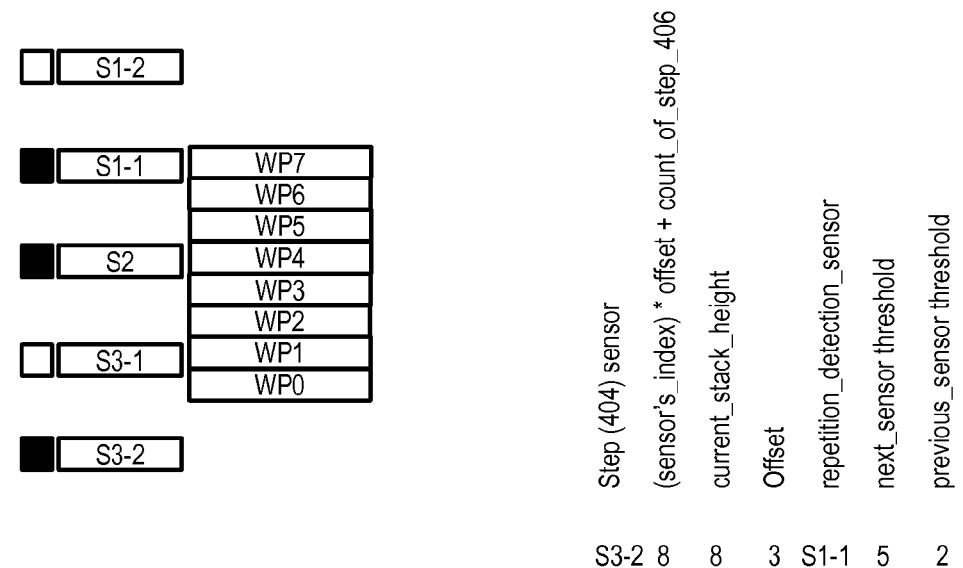


Fig. 8B

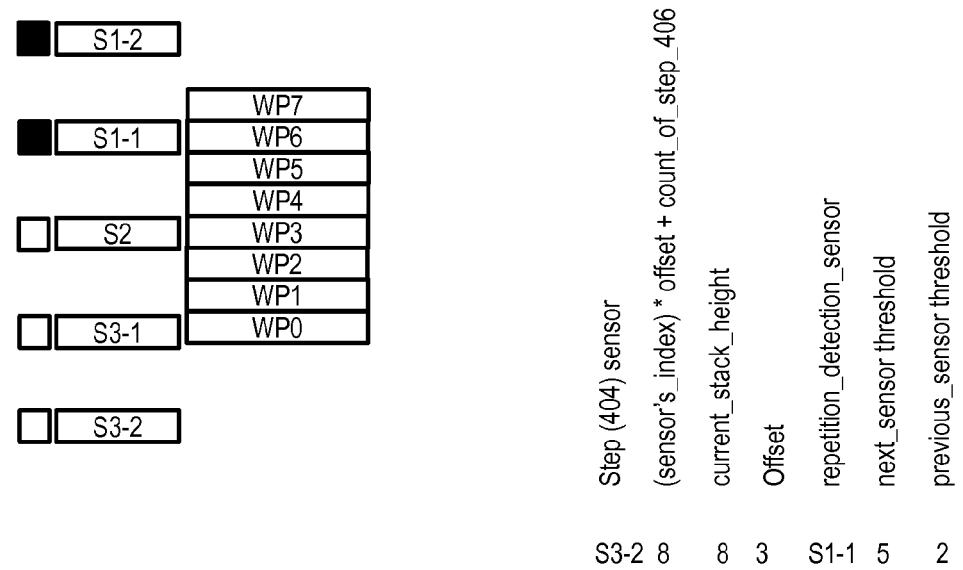


Fig. 8C

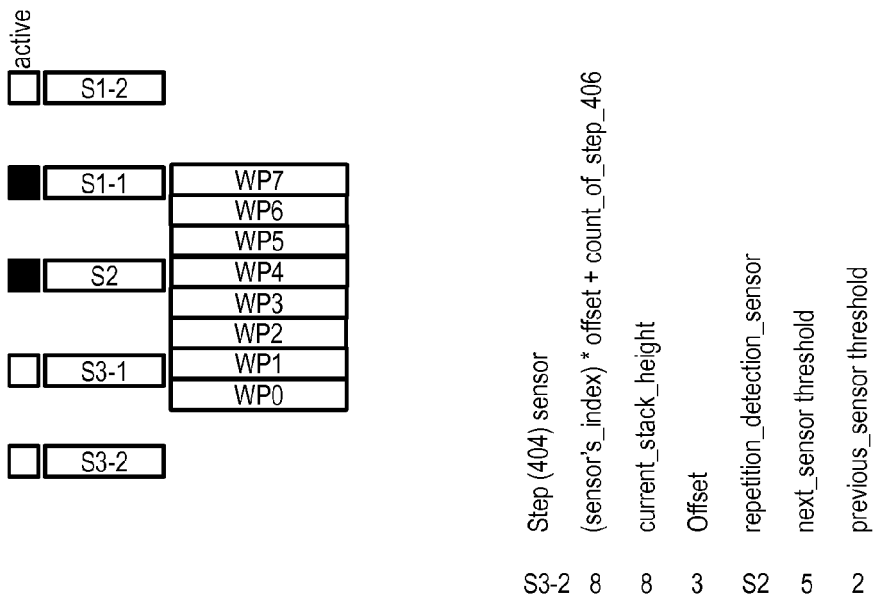


Fig8. D

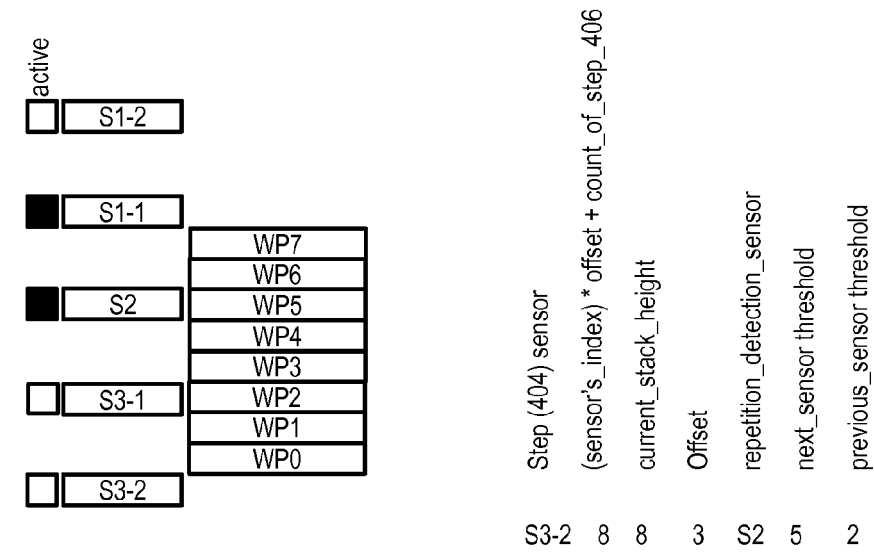


Fig. 8E

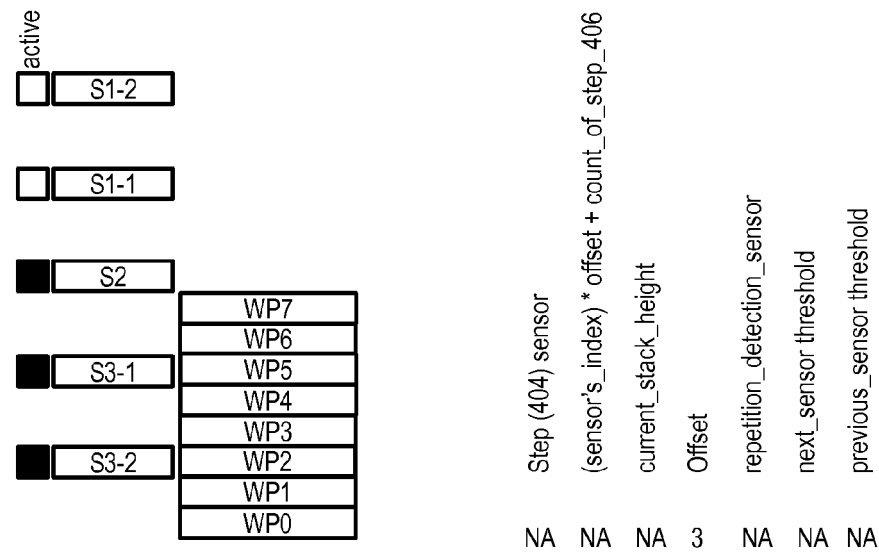


Fig. 8F



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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                 |                                                           |                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                                   | Relevant to claim                                         | CLASSIFICATION OF THE APPLICATION (IPC) |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | WO 99/43393 A1 (GYM IN LTD [IL]; BEN YEHUDA RAM [IL]; BEN YEHUDA SHARON [IL])<br>2 September 1999 (1999-09-02)<br>* page 11, paragraph 3 - page 13, paragraph 2; claims 1,8,17,32,33; figures 5-7 *                                                                                             | 1-6,<br>10-15                                             | INV.<br>A63B21/062<br>A63B24/00         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | * page 11, paragraph 3 - page 13, paragraph 2; claims 1,8,17,32,33; figures 5-7 *                                                                                                                                                                                                               | 7,8                                                       |                                         |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -----<br>CN 106 267 732 A (AIPAObU SPORTS EQUIPMENT CO LTD)<br>4 January 2017 (2017-01-04)<br>* From Annex I : "With reference to Fig. 12, one embodiment of the invention...it is also possible to be the mobile phone of client oneself."; paragraph [0025] - paragraph [0030]; figures 1-2 * | 1-3,9-12                                                  |                                         |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -----<br>US 6 793 607 B2 (KINETIC SPORTS INTERACTIVE [US])<br>21 September 2004 (2004-09-21)<br>* column 5, line 63 - column 6, line 63 *<br>* column 8, line 34 - column 9, line 3; figures 5-8 *                                                                                              | 1,3,4,<br>9-12                                            | TECHNICAL FIELDS SEARCHED (IPC)<br>A63B |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                 |                                                           |                                         |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                 | Date of completion of the search<br><b>22 August 2018</b> | Examiner<br><b>Lundblad, Hampus</b>     |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                                                                                 |                                                           |                                         |

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
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