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(19) **United States**(12) **Patent Application Publication**
Yi(10) **Pub. No.: US 2009/0176629 A1**(43) **Pub. Date: Jul. 9, 2009**(54) **AUTOMATIC VELOCITY CONTROL
TREADMILL USING PRESSURE SENSOR
ARRAY AND FUZZY-LOGIC****Publication Classification**(51) **Int. Cl.**
A63B 22/02 (2006.01)(52) **U.S. Cl.** **482/54**(57) **ABSTRACT**

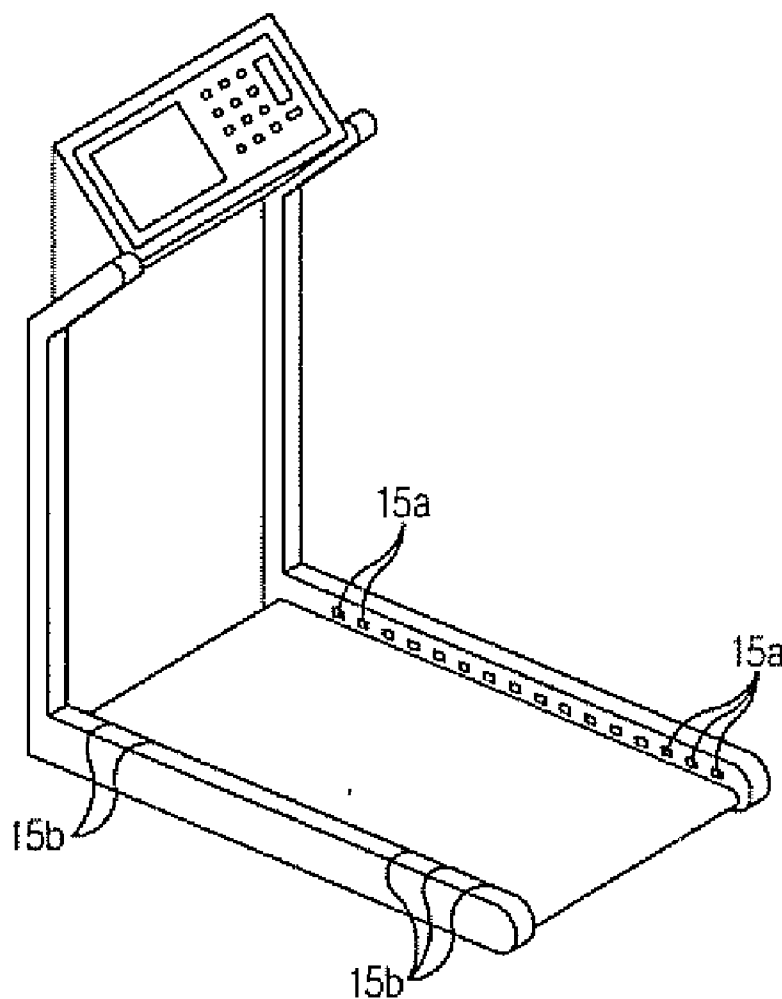
The present invention relates to an automatic speed-controlled treadmill using a pressure sensor array and a method of operating the same. The automatic speed-controlled treadmill includes a walking belt, a pressure sensor array including pressure sensors for detecting loads of the exerciser's feet and outputting the detected loads of the feet as load detection signals, a pace speed status storage unit for storing a pace speed and variation in pace speed of the exerciser, and a control unit provided with an algorithm for calculating a pace speed of the exerciser using the load detection signals, calculating a difference between a previous pace speed and a current pace speed as the variation in pace speed, calculating the exercise center of the exerciser, and proportionally accelerating/decelerating a driving speed of the walking belt in consideration of the variation in pace speed and the exercise center.

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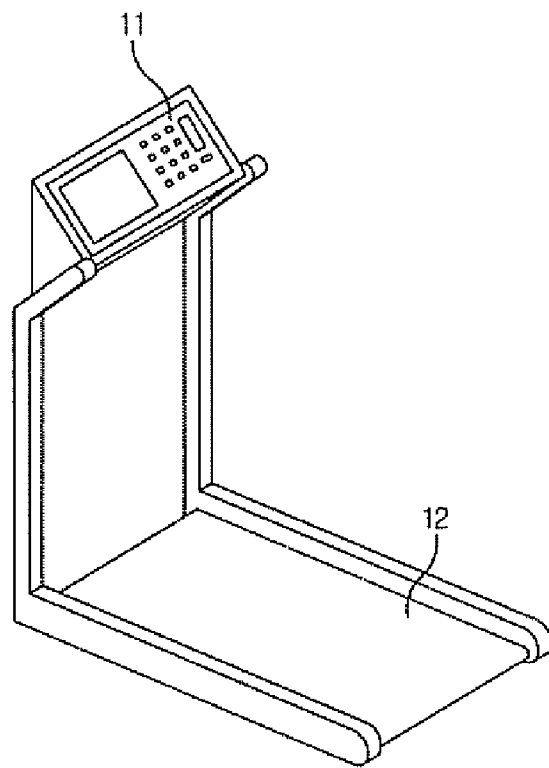
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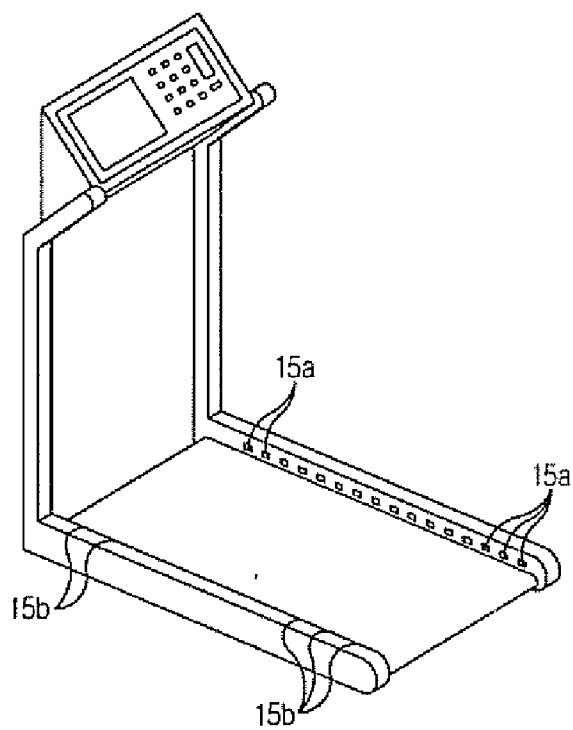
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[Fig. 1]

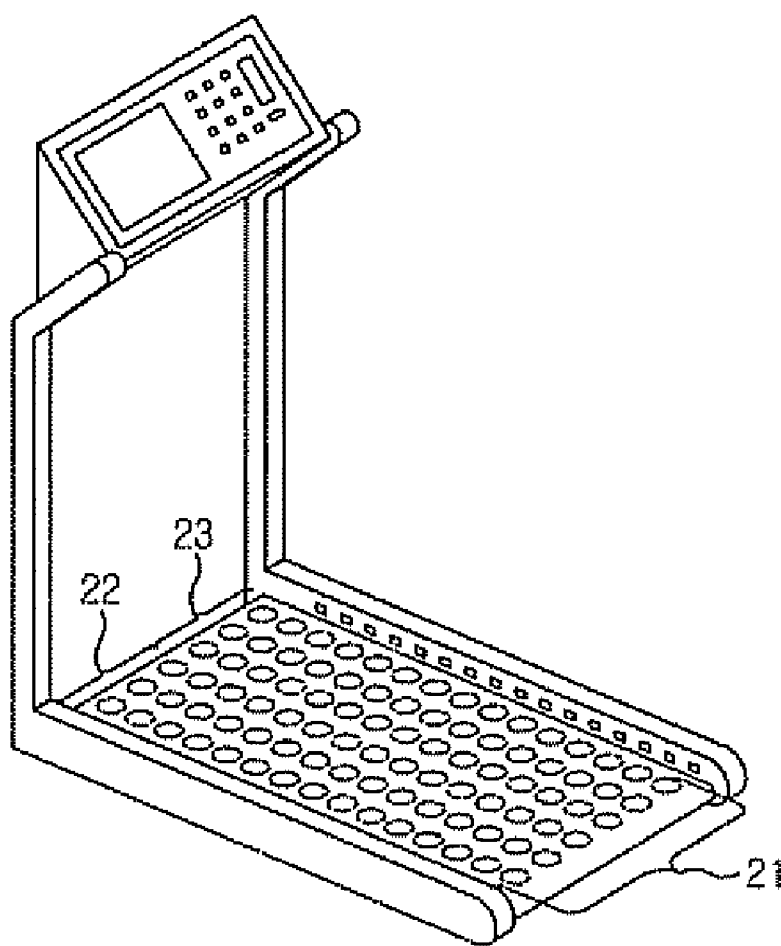


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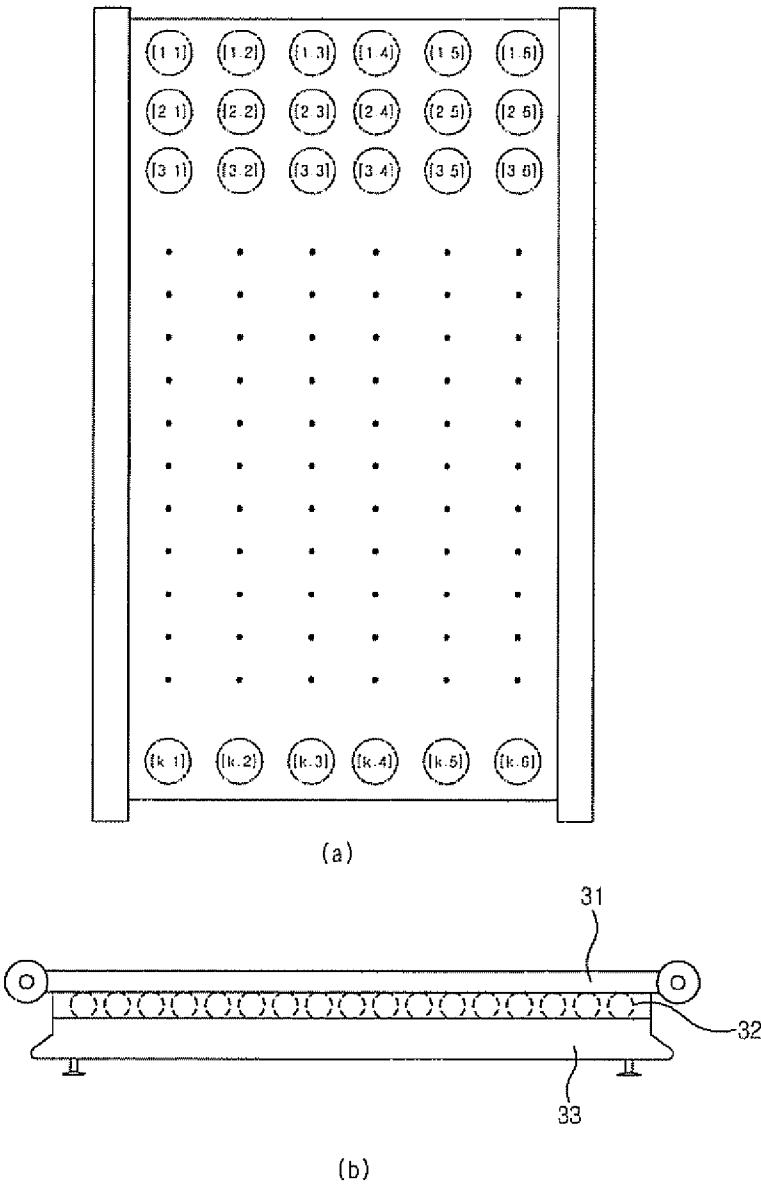


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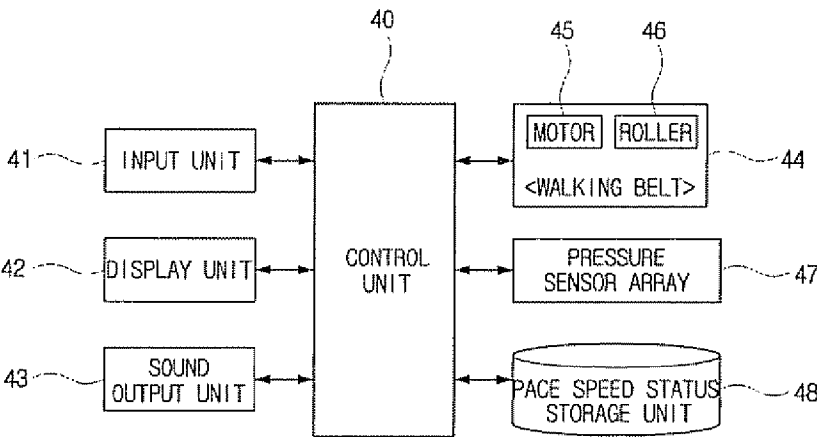
[Fig. 2]



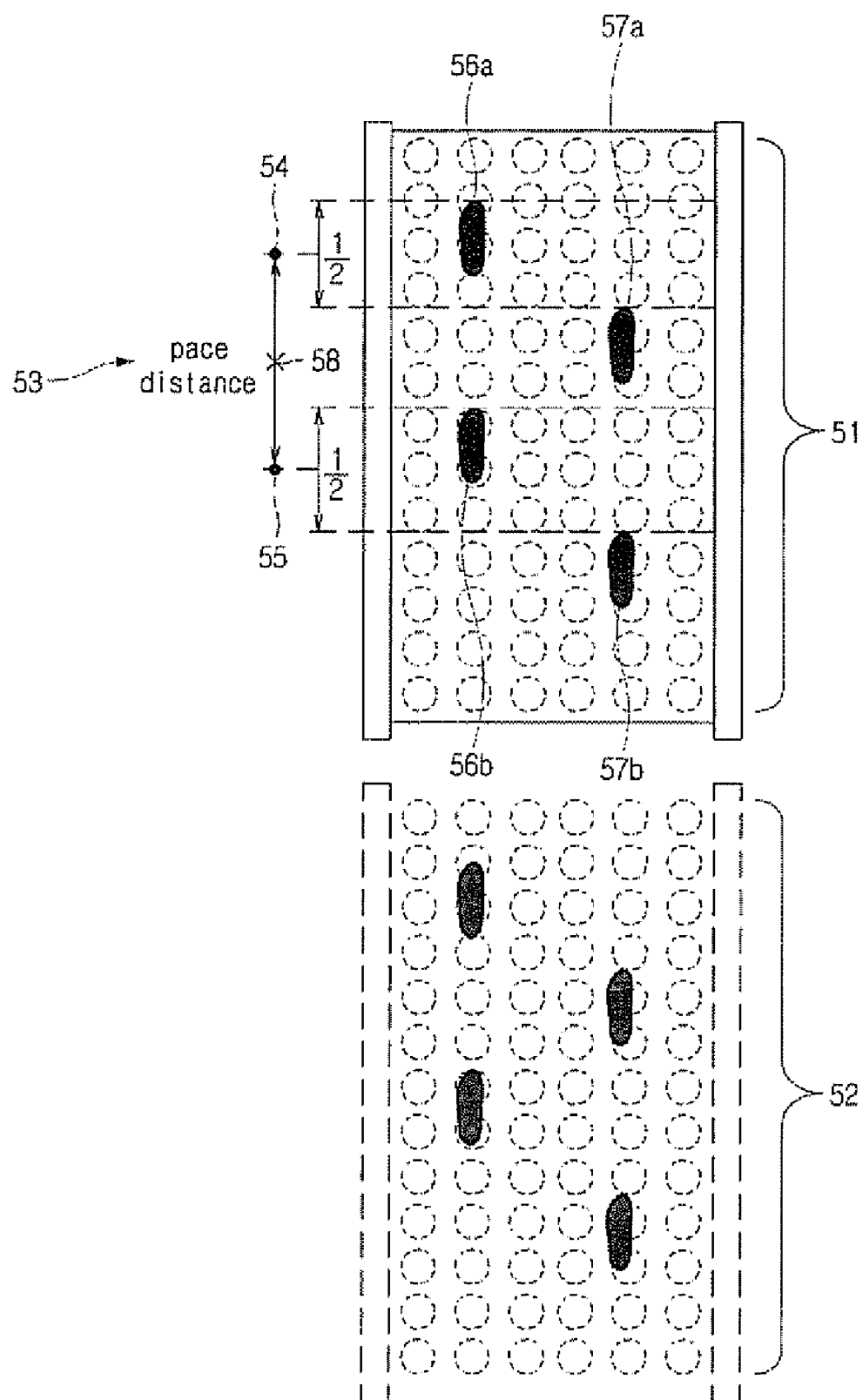
[Fig. 3]



[Fig. 4]



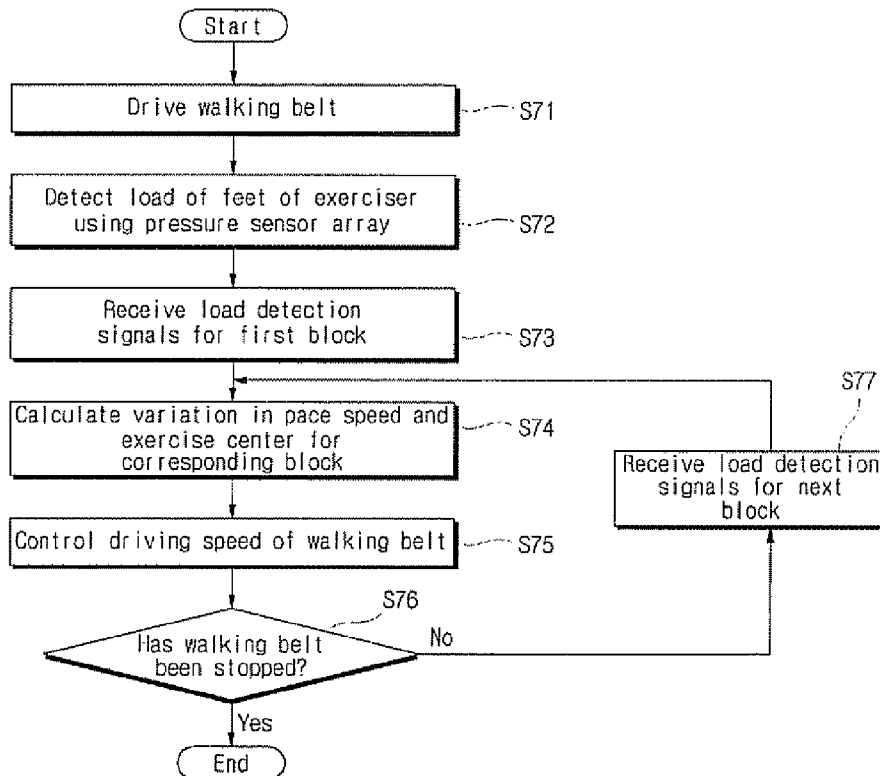
[Fig. 5]



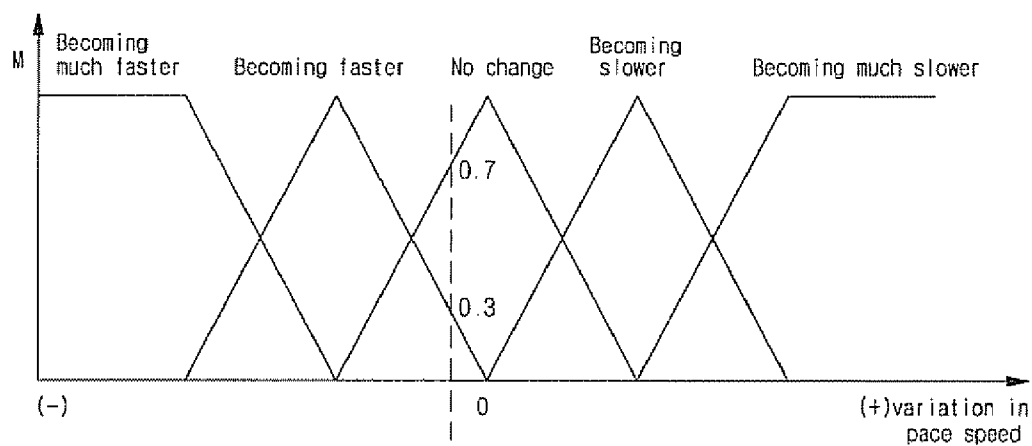
[Fig. 6]

Exercise center (P) Variation in pace speed (ΔV : km/h)	location of 4/5 of length of walking belt (frontmost end)	$\frac{4}{5}$ Position $\geq$ $P > \frac{3}{5}$ Position (Front end)	$\frac{3}{5}$ Position $\geq$ $P > \frac{2}{5}$ Position (Intermediate position)	$\frac{2}{5}$ Position $\geq$ $P > \frac{1}{5}$ Position (Rear end)	$\frac{1}{5}$ Position $\geq$ $P > 0$ Position (Rearmost end)
$0.8 \leq \Delta V$	3level (Highest acceleration)	2level (Normal acceleration)	1level (Lowest acceleration)	-1level (Lowest acceleration)	-1level (Lowest acceleration)
$0.6 \leq \Delta V < 0.8$	2level (Normal acceleration)	2level (Normal acceleration)	0level (Maintain speed)	-1level (Lowest acceleration)	-1level (Lowest acceleration)
$0.4 \leq \Delta V < 0.6$	1level (Lowest acceleration)	1level (Lowest acceleration)	0level (Maintain speed)	-2level (Normal acceleration)	-1level (Normal acceleration)
$0.2 \leq \Delta V < 0.4$	1level (Lowest acceleration)	0level (Maintain speed)	-1level (Lowest acceleration)	-3level (Highest acceleration)	-3level (Highest acceleration)
$0 \leq \Delta V < 0.2$	0level (Maintain speed)	0level (Maintain speed)	-2level (Normal acceleration)	-3level (Highest acceleration)	-3level (Highest acceleration)

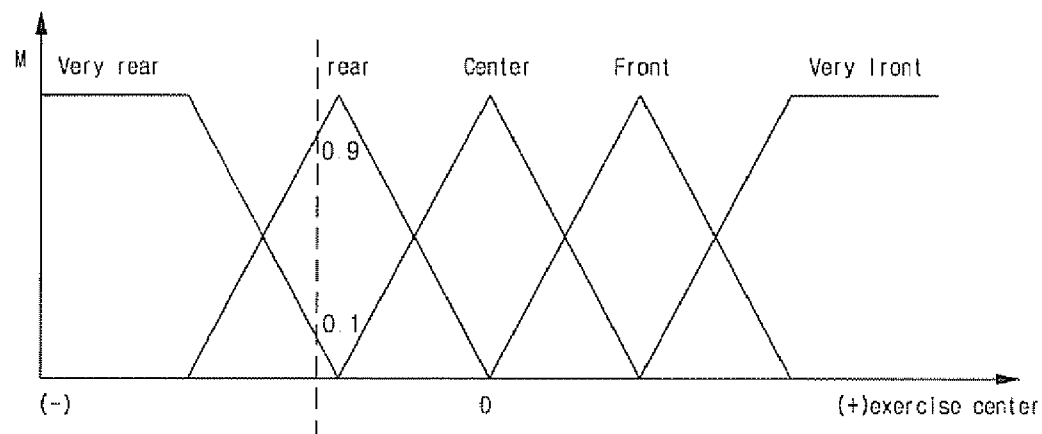
[Fig. 7]



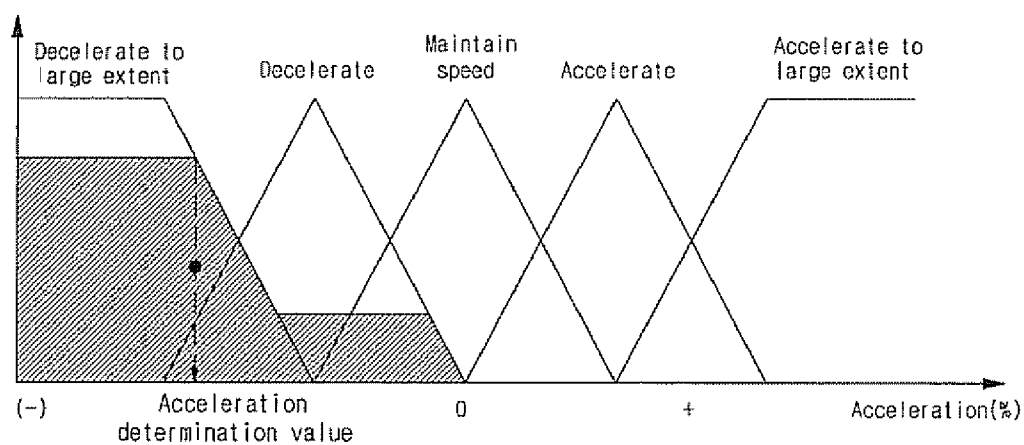
[Fig. 8]



[Fig. 9]



[Fig. 10]



[Fig. 11]

Exercise center Variation in pace speed	Very front(++)	Front(+)	Center(0)	Rear(-)	Very rear(—)
Becoming much faster(++)	Accelerate to large extent	Accelerate	Accelerate to small extent	Accelerate to small extent	Accelerate to small extent
Becoming faster(+)	Accelerate	Accelerate	Maintain speed	Accelerate to small extent	Accelerate to small extent
No change(0)	Accelerate to small extent	Accelerate to small extent	Maintain speed	Decelerate	Decelerate
Becoming slower(-)	Accelerate to small extent	Maintain speed	Decelerate to small extent	Decelerate to large extent	Decelerate to large extent
Becoming much slower(—)	Maintain speed	Maintain speed	Decelerate	Decelerate to large extent	Decelerate to large extent

AUTOMATIC VELOCITY CONTROL TREADMILL USING PRESSURE SENSOR ARRAY AND FUZZY-LOGIC

TECHNICAL FIELD

[0001] The present invention relates to an automatic speed-controlled treadmill that uses a pressure sensor array and a method of operating the same, and has a technical feature such that it detects the load of an exerciser, calculates variation in pace speed and an exercise center, and then automatically controls the driving speed of a walking belt.

BACKGROUND ART

[0002] In general, a treadmill is exercise equipment that enables running or walking exercise to be performed indoors. As shown in FIG. 1(a), the treadmill includes a walking belt 12, a driving device for moving the walking belt 12, and control means for controlling the driving device. The driving device includes a plurality of rollers for supporting the walking belt 12 and a motor for driving the rollers. The control means controls the driving device in association with the motor. According to such a typical treadmill, a user moves the walking belt 12 by driving the motor through an input module 11, and an exerciser steps on the walking belt 12 and walks or runs at the driving speed of the walking belt 12, thereby achieving exercise effects.

[0003] Therefore, in order to obtain appropriate exercise effects, the exerciser must run at the speed of rotation of the walking belt 12. When it is desired to change the rate of exercise, the exerciser must control the rotating speed by manipulating the button, knob, or the like of the input module 11 of the treadmill and then run in conformity with the rotating speed of the walking belt 12. That is, in order for the exerciser to change the running speed as desired while running, the exerciser must manually manipulate a speed change button or the like, which is located in the input module 11 of the treadmill.

[0004] However, in the case where the exerciser manually manipulates the speed of the treadmill using buttons during running exercise, there is inconvenience in manipulation. In particular, for the elderly, the weak and children, who have difficulty in maintaining their balance, and patients, who require rehabilitation, there is the concern that they may fall down due to the changed speed of the walking belt 12 after the change of the speed.

[0005] To solve this problem, there is a method of detecting the position of an exerciser by radiating ultrasonic waves toward the exerciser and calculating the arrival time of an ultrasonic wave reflected from the exerciser, and increasing or decreasing the rotating speed of a walking belt based on the detected position. However, this apparatus has many limitations to application to practical products in that reflectivity varies with the dress or movement of the body of an exerciser, which is the ultrasonic reflector, so that it is difficult to measure the position of the exerciser and a measured signal is disturbed, with the result that there are many limitations in the application thereof to practical products.

[0006] To overcome the limitations, an invention (Korean Unexamined Patent Publication No. 10-2002-0013649), entitled "Treadmill Capable of Detecting Position of Exerciser and Speed/Position-Adaptive Control Method for the Treadmill," which controls speed using optical sensors, rather than ultrasonic waves, has been proposed. That is, an appa-

ratus that detects the exercise position of an exerciser using optical sensors 15a and 15b, including light-emitting units 15a on one of two opposite sides of a walking belt and light-receiving units 15b on the other side thereof, and controls the speed of the walking belt, has been proposed, as shown in FIG. 1(b). In other words, the apparatus detects the position of an optical sensor, which is turned off by the leg of an exerciser who runs on the walking belt, increases the speed of the walking belt if the exerciser is positioned before the immediately previous position, and decreases the speed of the walking belt if the exerciser is positioned after the immediately previous position. However, the method of controlling the position of a walking belt using optical sensors has a problem in that speed is inaccurately controlled because only the position of a user's foot is detected using an optical sensor, regardless of whether it is the right or left foot, and then the speed is controlled. Furthermore, the apparatus has a problem in that the position of a user's foot is not accurately detected when light radiated from the light-emitting units is weak due to a problem, such as an excessive distance between the light-emitting units 15a and the light-receiving units 15b because the light-emitting units 15a and the light-receiving units 15b are disposed on either the left or right sides of the walking belt.

DISCLOSURE OF INVENTION

Technical Problem

[0007] Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to automatically control the speed of a walking belt in conformity with an exerciser's rate of exercise without requiring an exerciser to manually control the rate.

[0008] Another object of the present invention is to provide a scheme for controlling the speed of a walking belt without using the conventional ultrasonic waves and optical sensors.

Technical Solution

[0009] In order to accomplish the above objects, an automatic speed-controlled treadmill of the present invention an automatic speed-controlled treadmill using a pressure sensor array, including a walking belt disposed on the bottom of the treadmill and configured to function as a pace surface of an exerciser; a pressure sensor array including pressure sensors for detecting loads of the exerciser's feet and outputting the detected loads of the feet as load detection signals, the pressure sensors being disposed in a plurality of arrangements between the bottom of the treadmill and the walking belt; a pace speed status storage unit for storing a pace speed and variation in pace speed of the exerciser who takes exercise on the walking belt; and a control unit provided with an algorithm for receiving the load detection signals from the pressure sensors and then calculating a pace speed of the exerciser, calculating a difference between a previous pace speed and a current pace speed as the variation in pace speed, calculating the exercise center of the exerciser from unique position values of the pressure sensors, and proportionally accelerating/decelerating a driving speed of the walking belt in consideration of the variation in pace speed and the exercise center.

[0010] In addition, the present invention provides an automatic speed-controlled treadmill using a pressure sensor array, including a walking belt disposed on a bottom of a

treadmill and configured to function as a pace surface of an exerciser; a pressure sensor array comprising pressure sensors for detecting loads of the exerciser's feet and outputting the detected loads of the feet as load detection signals, the pressure sensors being disposed in a plurality of arrangements between the bottom of the treadmill and the walking belt; a pace speed status storage unit for storing a pace speed and variation in pace speed of the exerciser who takes exercise on the walking belt; and a control unit provided with an algorithm for receiving the load detection signals from the pressure sensors and then calculating the pace speed of the exerciser, calculating a difference between a previous pace speed and a current pace speed as the variation in pace speed, calculating an exercise center of the exerciser from unique position values of the pressure sensors, and proportionally accelerating/decelerating the driving speed of the walking belt based on a fuzzy theory using a fuzzifier, a rule base, a fuzzy inference engine, and a defuzzifier.

[0011] The pressure sensor array includes a right pressure sensor array provided on a right side of a longitudinal center line of the walking belt and configured to detect a load of a right foot of the exerciser; and a left pressure sensor array provided on a left side of the longitudinal center line of the walking belt and configured to detect a load of a left foot of the exerciser.

[0012] The pressure sensors have respective unique position values indicating positions thereof. The pace speed is obtained by dividing a pace distance, indicating a distance between paces of the exerciser, by a pace time period, indicating a time period of inter-pace movement of the exerciser (the pace=the pace distance/the pace time period).

[0013] Assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'an average stepping position=(a right foot stepping position+a left foot stepping position)/2', the pace distance is obtained by 'the pace distance=the average stepping position-the average lifting position'.

[0014] Assuming that 'an average lifting time point=(a right foot lifting time point+a left foot lifting time point)/2' and 'an average stepping time point=(a right foot stepping time point+a left foot stepping time point)/2', the pace time period is obtained by 'the pace time period=an average stepping time point-an average lifting time point'.

[0015] Assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'the average stepping position=(a right foot stepping position+a left foot stepping position)/2', the exercise center is obtained by 'the exercise center=(the average stepping position+the average lifting position)/2'.

[0016] The control unit accelerates the driving speed of the walking belt in steps as the variation in pace speed becomes higher and the exercise center becomes closer to a front portion of the walking belt, and decelerates the driving speed of the walking belt in steps as the variation in pace speed becomes lower and the exercise center becomes closer to a rear portion of the walking belt.

[0017] In addition, the present invention provides a method of controlling a driving speed of a treadmill using a pressure sensor array, the method including a first step of driving a walking belt of a treadmill through input manipulation of an exerciser; a second step of receiving load detection signals from pressure sensors for a first block, with a foot pace, including four positions (a left foot stepping position, a right foot stepping position, a left foot lifting position, and a left

foot stepping position), being set to each block; a third step of, for the first block, calculating a pace speed of the exerciser using the load detection signals, calculating a difference between a previous pace speed and a current pace speed as variation in pace speed, and calculating an exercise center using unique position values of the pressure sensors; a fourth step of proportionally accelerating/decelerating the driving speed of the walking belt in consideration of the calculated variation in pace speed and the calculated exercise center; and a fifth step of receiving the load detection signals from the pressure sensors for a next block until the walking belt is stopped, and repeating the third step and the fourth step.

Advantageous Effects

[0018] As described above, the present invention automatically controls the speed of a walking belt using pressure sensors, thereby solving the inconvenience in which an exerciser must manually control the speed. Furthermore, the pace speed and exercise center of an exerciser can be accurately calculated using pressure sensors, therefore there is an advantage in that detailed speed control is enabled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1(a) is a perspective view showing the appearance of a typical treadmill;

[0020] FIG. 1(b) is a perspective view showing the appearance of a treadmill in which the speed is controlled using conventional optical sensors;

[0021] FIG. 2 is a perspective view showing the appearance of a treadmill in which the speed is controlled using a pressure sensor array according to an embodiment of the present invention;

[0022] FIG. 3(a) is a plan view of a walking belt equipped with a pressure sensor array according to the present invention;

[0023] FIG. 3(b) is a side view of the walking belt equipped with a pressure sensor array according to the present invention;

[0024] FIG. 4 shows an automatic speed-controlled treadmill using a pressure sensor array according to an embodiment of the present invention;

[0025] FIG. 5 is a diagram showing a pace distance on a walking belt;

[0026] FIG. 6 is a control table used to control the speed of the walking belt based on an exercise center and variation in pace speed;

[0027] FIG. 7 is a flowchart showing a process of controlling the speed of the walking belt using the pressure sensor array according to an embodiment of the present invention;

[0028] FIG. 8 is a fuzzy membership function graph for variation in pace speed;

[0029] FIG. 9 is a fuzzy membership function graph for an exercise center;

[0030] FIG. 10 is a fuzzy membership function graph used to determine the acceleration of the walking belt using FIGS. 8 and 9; and

[0031] FIG. 11 shows a table showing the determination of acceleration using fuzzy theory according to the present invention.

MODE FOR THE INVENTION

[0032] Detailed descriptions of preferred embodiments of the present invention will be given in conjunction with the

accompanying drawings below. It should be noted that, in the assignment of reference numerals to the elements of respective drawings, the same elements are made to have the same reference numerals, even though the elements are shown in different drawings. Furthermore, in the description of the present invention, detailed descriptions of well-known functions or constructions will be omitted when it is determined that such descriptions would make the gist of the present invention obscure.

[0033] FIG. 2 is a perspective view showing the appearance of a treadmill in which the speed is controlled using a pressure sensor array according to an embodiment of the present invention.

[0034] Referring to FIG. 2, a pressure sensor array 21 is provided between the bottom surface of the treadmill and a walking belt, and thus can detect the load of an exerciser who takes exercise on the walking belt.

[0035] The pressure sensor array 21 is configured in such a manner that pressure sensors for detecting the loads of the feet of an exerciser and outputting them as load detection signals are disposed in arrangements between the bottom surface of the treadmill and the walking belt. On the basis of the longitudinal center line of a walking belt, a right pressure sensor array 23 (hereinafter referred to as a “right pressure sensor array”) detects the load of the exerciser’s right foot, and a left pressure sensor array 22 (hereinafter referred to as a “left pressure sensor array”) detects the load of the exerciser’s left foot.

[0036] Each pressure sensor of the pressure sensor array 21 has a unique position value, therefore a pressure sensor, when detecting the load of the exerciser, generates a load detection signal and sends it to the control unit of the treadmill. The control unit performs an operation using the received load detection signal and the unique position value of the pressure sensor, which sent the corresponding signal, and controls the speed of the walking belt. An example of the unique position values of the pressure sensors is illustrated in FIG. 3(a), wherein [1,1] indicates the unique position value of a pressure sensor located in a first row and a first column and [1,2] indicates the unique position value of a pressure sensor located in a first row and a first column. Furthermore, FIG. 3(b) is a side view of the treadmill, from which it can be seen that a pressure sensor array 32 is provided between the bottom surface 33 of the treadmill and a walking belt 31.

[0037] FIG. 4 is a block diagram showing the internal configuration of a treadmill according to an embodiment of the present invention.

[0038] An input unit 41 is a user interface that is equipped with selection buttons for receiving a desired speed and the type of image to be displayed and thus receives various requests for the control of the treadmill from a user. The treadmill may be implemented to have a Graphic User Interface (GUI), in addition to the selection buttons, and thus support selection using various menus in a touch screen manner. Furthermore, in the case of a treadmill having a remote control operation, the input unit 41 may be further provided with an infrared receiver for receiving infrared signals radiated through a remote controller and thus receive various requests for the control of the treadmill from a user through the remote controller.

[0039] A display unit 42 is a display device, such as a TFT-LCD, and displays various types of exercise information, such as heart rate during exercise, exercise distance, exercise time, calories consumed, and speed. An exerciser can

become aware of his current exercise status while viewing various types of exercise information displayed on the display unit.

[0040] A sound output unit 43 is implemented using a speaker for outputting sounds, and functions to output various types of exercise information, such as heart rate during exercise, exercise distance, an exercise time, calories consumed and speed, as well as manipulation prompts in voice form.

[0041] The treadmill of the present invention is characterized in that it further includes a walking belt 44, a pressure sensor array 47, a pace speed status storage unit 48, and a control unit 40 in addition to the general basic elements of a typical treadmill, such as the input unit 41, the display unit 42, and the sound output unit 43. The walking belt 44, the pressure sensor array 47, the pace speed status storage unit 48, and the control unit 40 will be described in detail below.

[0042] The walking belt 44 is the moving belt of the bottom portion of a treadmill bottom, on which the exercise of an exerciser is conducted. The walking belt 44 is driven through the rotating operation of rollers 46. The rollers 46 are rotating transfer elements for driving the walking belt 44 of the treadmill, and the walking belt 44 is driven through the rotating operation of the rollers 46. The motor 45 is a rotating driving element that is rotated by electromagnetic force. The motor 45 is connected to the rollers 46 through shafts, and is responsible for the rotation of the rollers. The RPM of the motor 45 varies in response to the driving power signal of the control unit 40. The control unit 40 performs an operation of conforming to the rate of activity of an exerciser in such a manner that it increases the RPM of the motor 45 when an exerciser runs on the walking belt at high speeds, and reduces the RPM of the motor 45 when the exerciser runs on the walking belt at low speeds. The rate of exercise of the exerciser is detected by the pressure sensor array 47 disposed under the walking belt 44. The control unit 40 performs a predetermined operation using a load detection signal detected by the pressure sensor array 47, and controls the RPM of the motor.

[0043] The pressure sensor array 47 is a device in which a plurality of pressure sensors is arranged, and detects the current position of an exerciser by detecting the foot load of the exerciser. The pressure sensors, constituting the pressure sensor array 47, are sensors that detect the load applied thereto by detecting variation in resistance when pressure is applied thereto. When the foot of the exerciser touches the walking belt 44, a pressure sensor at a corresponding location detects it.

[0044] In the pressure sensor array 47 formed of an arrangement of the pressure sensors, the right pressure sensor array 23, disposed on the right side of the reference line of the walking belt, detects the load of an exerciser’s right foot, and the left pressure sensor array 22, disposed on the left side of the reference line of the walking belt, detects the load of the exerciser’s left foot, as shown in FIG. 2. When the load of the exerciser is detected by the right pressure sensor array 23 or the left pressure sensor array 22, as described above, the corresponding pressure sensor of the pressure sensor array that detected the load generates a load detection signal and sends it to the control unit 40.

[0045] The pace speed status storage unit 48 is a temporary recording buffer medium, such as Random Access Memory (RAM), and functions to store a pace speed and variation in pace speed, which are calculated by the control unit 40. The control unit 40 controls the driving speed of the walking belt based on the variation in pace speed. A method of calculating

the pace speed and the variation in pace speed will be described in detail with reference to the following Equations 7 and 8 below.

[0046] The control unit **40** drives the walking belt by controlling the respective function units, and is provided with an algorithm for automatically controlling the speed of the walking belt in conformity with the rate of exercise of an exerciser. In other words, when each of the pressure sensors of the right and left pressure sensor arrays **23** and **22** detects a load and sends it to the control unit as a load detection signal, the control unit **40** calculates a pace distance and a pace time period based on load detection signals, and controls the speed of the walking belt based on the pace distance and the pace time period.

[0047] The pace distance is described with reference to FIG. 5, which shows the pace speed of an exerciser on the walking belt. The pace distance refers to the pace distance of an exerciser's foot when the exerciser runs on the walking belt, and, in greater detail, to a distance **53** (the pace distance=an average lifting position ? an average stepping position) from an average lifting position **55**, at which the exerciser's foot is lifted from the walking belt, to an average stepping position **54** in the next pace. The average lifting position **55** is the average value of the lifting positions of two feet **56b** and **57b**, and the average stepping position **54** is the average value of the stepping positions of two feet **56a** and **56b**. When the foot **56a**, **56b**, **56c**, or **56d** of the exerciser touches a plurality of pressure sensors, as shown in FIG. 5, the lifting position or stepping position is determined based on the frontmost of the pressure sensors that detected the exerciser's foot.

[0048] Meanwhile, the control unit **40** continuously calculates the average lifting position and the average stepping position for each block, with a foot pace, including four positions (a left foot stepping position, a right foot stepping position, a left foot lifting position, and a left foot stepping position), being set to a single block **51** or **52**, as shown in FIG. 5. Accordingly, the control unit **40** forms the block **51** or **52** using four pace positions detected on the walking belt, and calculates the average lifting position and the average stepping position for each block **51** or **52**.

[0049] An equation for calculating the average lifting position **55** is given as the following Equation 1, and an equation for calculating the average stepping position is given as the following Equation 2. Furthermore, an equation for obtaining the pace distance using the average lifting position and the average stepping position is given as the following Equation 3.

$$\text{Average lifting position} = (\text{Right foot lifting position} + \text{Left foot lifting position}) / 2 \quad \text{[Equation 1]}$$

[0050] (In the above Equation, the right foot lifting position is the position at which the right foot is lifted from the belt, and the left foot lifting position is the position at which the left foot is lifted from the belt)

$$\text{The average stepping position} = (\text{the right foot stepping position} + \text{the left foot stepping position}) / 2 \quad \text{[Equation 2]}$$

[0051] (In the above Equation, the right foot stepping position is the position at which the right foot touches the belt, and the left foot stepping position is the position at which the left foot touches the belt)

$$\text{The pace distance} = \text{the average stepping position} - \text{the average lifting position} \quad \text{[Equation 3]}$$

[0052] The control unit calculates the pace distance using Equation 3. In a similar way, the control unit can calculate a pace time period based on a stepping time point and a lifting time point. The pace time period refers to the time period of the movement of an exerciser's foot pace when the exerciser runs on the walking belt, and refers to a time period (the pace time period=the average lifting time point ? the average stepping time point), spanning from an average lifting time point, at which the exerciser's foot is lifted from the walking belt, to an average stepping time point, at which the exerciser's foot touches the walking belt for the next pace. The average lifting time point refers to the average value of the lifting time points of two feet, and the average stepping time point refers to the average value of stepping time points of two feet.

[0053] Meanwhile, the control unit continuously calculates the average lifting time point and the average stepping time point, with a foot pace, including four positions (the left foot stepping position **56a**, the right foot stepping position **57a**, the left foot lifting position **56b**, and the left foot stepping position **56a**) being set to one block **51** or **52**, as shown in FIG. 5. Accordingly, the control unit **40** forms the block **51** or **52** using four pace positions detected on the walking belt, and calculates the average lifting time point and the average stepping time point for each block.

[0054] An equation for calculating the average lifting time point is given as the following Equation 4, and an equation for calculating the average stepping time point is given as the following Equation 5. Furthermore, an equation for obtaining the pace time period using the average lifting time point and the average stepping time point is given as the following Equation 6.

$$\text{The average lifting time point} = (\text{the right foot lifting time point} + \text{the left foot lifting time point}) / 2 \quad \text{[Equation 4]}$$

[0055] (In the above Equation, the right foot lifting time point refers to the time point at which the right foot is lifted from the belt, and the left foot lifting time point refers to the time point at which the left foot is lifted from the belt)

$$\text{The average stepping time point} = (\text{the right foot stepping time point} + \text{the left foot stepping time point}) / 2 \quad \text{[Equation 5]}$$

[0056] (In the above equation, the right foot stepping time point refers to the time point at which the right foot touches the belt, and the left foot stepping time point refers to the time point at which the left foot touches the belt)

$$\text{The pace time period} = \text{the average stepping time point} - \text{the average lifting time point} \quad \text{[Equation 6]}$$

[0057] After the pace distance and the pace time period have been obtained using Equation 3 and Equation 6, the pace speed is obtained by dividing the pace distance by the pace time period, as in the following Equation 7.

$$\text{The pace speed} = \text{the pace distance} / \text{the pace time period} \quad \text{[Equation 7]}$$

[0058] With regard to the pace speed, after the pace speed has been obtained for the first block **51**, the pace speed for the second block **52** and then the pace speed for the third block are sequentially obtained continuously, as shown in FIG. 5.

[0059] After the pace speed has been obtained, variation in speed is obtained by obtaining the difference between the pace speed for a current block **N** and the pace speed for a previous block **N-1**. That is, the variation in pace speed is obtained using the following Equation 8.

$$\text{The variation in pace speed} = \text{the pace speed for an 'N' block} - \text{the pace speed for an 'N-1' block} \quad \text{[Equation 8]}$$

[0060] The pace speed and the variation in pace speed, which have been measured for each block as described above, are stored in the pace speed status storage unit. An example of the storage of the pace speed status storage unit is shown in the following Table 1.

TABLE 1

Block [N]	Pace speed [V_i]	Variation in pace speed ($V_i - V_{i-1}$)
First block	2.432 km/h [V_1]	—
Second block	2.633 km/h [V_2]	0.201 ($V_2 - V_1$)
...	...	...
(N - 1)th block	3.320 km/h [V_{N-1}]	0.171 ($V_{N-1} - V_{N-2}$)
Nth block	3.751 km/h [V_N]	0.431 ($V_N - V_{N-1}$)

[0061] Meanwhile, the control unit 40 calculates an exercise center for each block. The exercise center refers to a value indicating the position of an exerciser for each block, and is obtained using the following Equation 9. The exercise center 58 is the average value of the average stepping position 54 and the average lifting position 55, as shown in FIG. 5, and can be obtained using the unique position value of each pressure sensor for detecting the exerciser's foot, which is shown in FIG. 3(a).

$$\text{The exercise center} = (\text{the average stepping position} + \text{the average lifting position}) / 2 \quad [\text{Equation 9}]$$

[0062] Meanwhile, the control unit 40 controls the driving speed of the walking belt using the pace speed obtained by Equation 7, the variation in pace speed obtained by Equation 8, and the exercise center obtained by Equation 9. The control unit 40 proportionally controls the driving speed of the walking belt in consideration of the exercise center and variation in the rate of exercise of the exerciser. That is, when the exercise center is detected on the front portion of the walking belt and the variation in the rate of exercise is high, the control unit 40 accelerates the walking belt so that it can be driven at a higher speed. In contrast, when the exercise center is detected on the rear portion of the walking belt and the variation in the rate of exercise is low, the control unit 40 decelerates the walking belt so that it can be driven at a lower speed.

[0063] An example of the control method is shown in the table of FIG. 6.

[0064] Referring to FIG. 6, when the exercise center is detected at a location equal to or before the location of $\frac{1}{3}$ of the total length of the walking belt, it indicates that the exerciser exercises at the frontmost end of the walking belt, and thus the acceleration of the walking belt is controlled accordingly. For example, when the exerciser takes exercise at the frontmost end of the walking belt, the driving speed of the walking belt is controlled in proportion to the variation in pace speed in such a way as to set the driving speed of the walking belt to the highest acceleration (level 3) when the variation in pace speed is highest, set the driving speed of the walking belt to normal acceleration when the variation in pace speed is normal, and set the driving speed of the walking belt to the lowest acceleration (level -3) when the variation in pace speed is lowest.

[0065] Meanwhile, although the table of FIG. 6 is a table that is implemented such that the exercise center has five levels, the variation in the rate of exercise has five levels, and the speed of the walking belt has 7 levels (level 3, level 2, level 1, level 0, level -1, level -2, and level -3), the table is only an

embodiment, and it will be apparent that the driving speed of the walking belt can be controlled at various levels.

[0066] FIG. 7 is a flowchart showing the walking belt driving speed control process of the control unit according to an embodiment of the present invention.

[0067] When a user drives the walking belt through manipulation of the input unit at step S71, the pressure sensor array detects the load of the exerciser's foot at step S72. When respective pressure sensors of the pressure sensor array detect the load of the exerciser's foot and continue to output load detection signals, the control unit receives load detection signals corresponding to the first block of the foot pace of the exerciser at step S73, and calculates the variation in pace speed using Equation 8 and the exercise center using Equation 9 at step S74.

[0068] The control unit proportionally controls the driving speed based on the calculated variation in pace speed and the calculated exercise center at step S75. For example, assuming that the driving speed is controlled based on the table of FIG. 6, while the exerciser exercises at the frontmost end of the walking belt, the driving speed of the walking belt is controlled proportionally in such a way that the driving speed is set to the highest acceleration when the variation in pace speed is highest, the driving speed is set to the normal acceleration when the variation in pace speed is normal, and the driving speed is set to the lowest acceleration when the variation in pace speed is lowest.

[0069] After the control of the driving speed of the walking belt has been completed at step S75, a process in which variation in pace speed and the exercise center are calculated using load detection signals (S77) for the next block at step S74 and then the driving speed of the walking belt is controlled at step S75 is repeated until the walking belt is stopped through the user's manipulation.

[0070] Meanwhile, although the speed of the walking belt may be controlled as in the flowchart of FIG. 7, the rate of exercise may also be controlled using fuzzy theory, as in another embodiment of the present invention. Fuzzy theory is a theory of mathematically dealing with vague and unclear situations, and fuzzy control is performed using a fuzzifier, a rule base, a fuzzy inference engine and a defuzzifier. In another embodiment of the present invention, the speed of the walking belt is controlled according to fuzzy theory using a control unit, including the fuzzifier, the rule base, the fuzzy inference engine, and the defuzzifier. The speed control of the walking belt using fuzzy theory is described with reference to FIGS. 8, 9, and 10.

[0071] FIG. 8 is a fuzzy membership function graph for variation in pace speed, FIG. 9 is a fuzzy membership function graph for an exercise center, and FIG. 10 is a fuzzy membership function graph used to determine the acceleration of the walking belt using FIGS. 8 and 9. The speed control of the walking belt using the fuzzy theory is described in brief with reference to FIGS. 8, 9, and 10.

[0072] As shown in a fuzzy membership function graph for variation in pace speed of FIG. 8, a membership function is determined according to the pace speed. For example, in the case of a pace speed indicated by a dotted line, a weight of 0.7 is assigned to a 'no change' member, and a weight of 0.3 is assigned to a 'becoming slower' member. In a similar way, as shown in the fuzzy membership function graph at the exercise center of FIG. 9, in the case of an exercise center indicated by a dotted line, a weight of 0.9 is assigned to a 'forward' member, and a weight of 0.1 is assigned to a 'very backward' member.

member. When non-fuzzification (a weight center method in the present invention) is performed on the accelerations of the walking belt using the member values, acceleration can be determined using the weight center method, as shown in FIG. 10.

[0073] The determination of the acceleration of the walking belt based on the above fuzzy theory is shown in the table of FIG. 11. Referring to FIG. 11, in the speed control of the walking belt using fuzzy theory, the exercise center may be adjusted such that a larger amount of acceleration is not performed at a position behind the center in consideration of safety. The exercise centers may be adjusted somewhat in consideration of the exercise center and the variation in pace speed.

[0074] Although, in the above detailed description of the present invention, specific embodiments have been described, various modifications are possible without departing from the scope of the invention. Accordingly, the range of the patent of the present invention is not to be determined based on the above-described embodiments, but extends over the claims and equivalents of the claims.

INDUSTRIAL APPLICABILITY

[0075] According to the present invention, the speed of the walking belt is automatically controlled according to the rate of exercise of an exerciser without requiring an exerciser to manually control the speed, thereby increasing the exercise's convenience. Furthermore, the speed of the walking belt is automatically controlled without using conventional ultrasonic waves or optical sensors, therefore the fabrication of the treadmill can be simplified and the manufacturing cost thereof can be reduced.

1. An automatic speed-controlled treadmill using a pressure sensor array, comprising: a walking belt disposed on a bottom of the treadmill and configured to function as a pace surface of an exerciser; a pressure sensor array comprising pressure sensors for detecting loads of the exerciser's feet and outputting the detected loads of the feet as load detection signals, the pressure sensors being disposed in a plurality of arrangements between the bottom of the treadmill and the walking belt; a pace speed status storage unit for storing a pace speed and variation in pace speed of the exerciser who takes exercise on the walking belt; and a control unit provided with an algorithm for receiving the load detection signals from the pressure sensors and then calculating a pace speed of the exerciser, calculating a difference between a previous pace speed and a current pace speed as the variation in pace speed, calculating the exercise center of the exerciser from unique position values of the pressure sensors, and proportionally accelerating/decelerating a driving speed of the walking belt in consideration of the variation in pace speed and the exercise center.

2. (canceled)

3. The automatic speed-controlled treadmill according to claim 1, wherein the pressure sensor array comprises:

a right pressure sensor array provided on a right side of a longitudinal center line of the walking belt and configured to detect a load of a right foot of the exerciser; and a left pressure sensor array provided on a left side of the longitudinal center line of the walking belt and configured to detect a load of a left foot of the exerciser.

4. The automatic speed-controlled treadmill according to claim 1, wherein the pressure sensors have respective unique position values indicating positions thereof.

5. The automatic speed-controlled treadmill according to claim 1, wherein the pace speed is obtained by dividing a pace distance, indicating a distance between paces of the exerciser, by a pace time period, indicating a time period of inter-pace movement of the exerciser (the pace=the pace distance/the pace time period).

6. The automatic speed-controlled treadmill according to claim 5, wherein, assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'an average stepping position=(a right foot stepping position+a left foot stepping position)/2', the pace distance is obtained by 'the pace distance=the average stepping position-the average lifting position'.

7. The automatic speed-controlled treadmill according to claim 5, wherein, assuming that 'an average lifting time point=(a right foot lifting time point+a left foot lifting time point)/2' and 'an average stepping time point=(a right foot stepping time point+a left foot stepping time point)/2', the pace time period is obtained by 'the pace time period=an average stepping time point-an average lifting time point'.

8. The automatic speed-controlled treadmill according to claim 1, wherein, assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'the average stepping position=(a right foot stepping position+a left foot stepping position)/2', the exercise center is obtained by 'the exercise center=(the average stepping position+the average lifting position)/2'.

9. The automatic speed-controlled treadmill according to claim 1, wherein the control unit accelerates the driving speed of the walking belt in steps as the variation in pace speed becomes higher and the exercise center becomes closer to a front portion of the walking belt, and decelerates the driving speed of the walking belt in steps as the variation in pace speed becomes lower and the exercise center becomes closer to a rear portion of the walking belt.

10. A method of controlling a driving speed of a treadmill using a pressure sensor array, the method comprising:

a first step of driving a walking belt of a treadmill through input manipulation of an exerciser; a second step of receiving load detection signals from pressure sensors for a first block, with a foot pace, including four positions (a left foot stepping position, a right foot stepping position, a left foot lifting position, and a left foot stepping position), being set to each block; a third step of, for the first block, calculating a pace speed of the exerciser using the load detection signals, calculating a difference between a previous pace speed and a current pace speed as variation in pace speed, and calculating an exercise center using unique position values of the pressure sensors; a fourth step of proportionally accelerating/decelerating the driving speed of the walking belt in consideration of the calculated variation in pace speed and the calculated exercise center; and a fifth step of receiving the load detection signals from the pressure sensors for a next block until the walking belt is stopped, and repeating the third step and the fourth step.

11. The speed control method according to claim 10, wherein the pace speed is obtained by dividing a pace distance, indicating a distance between paces of the exerciser, by a pace time period, indicating a time period of inter-pace movement of the exerciser (the pace speed=the pace distance/the pace time period).

12. The speed control method according to claim 11, wherein, assuming that 'an average lifting position=(a right

foot lifting position+a left foot lifting position)/2' and 'an average stepping position=(a right foot stepping position+a left foot stepping position)/2', the pace distance is obtained by 'the pace distance=the average stepping position-the average lifting position'.

13. The speed control method according to claim 11, wherein, assuming that 'an average lifting time point=(a right foot lifting time point+a left foot lifting time point)/2' and 'the average stepping time point=(a right foot stepping time point+a left foot stepping time point)/2', the pace time period is obtained by 'the pace time period=the average stepping time point-the average lifting time point'.

14. The speed control method according to claim 10, wherein, assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'the average stepping position=(a right foot stepping position+a left foot stepping position)/2', the exercise center is obtained by 'the exercise center=(the average stepping position+the average lifting position)/2'.

15. The speed control method, according to claim 10, wherein the control unit accelerates the driving speed of the walking belt in steps as the variation in pace speed becomes higher and the exercise center becomes closer to a front portion of the walking belt, and decelerates the driving speed of the walking belt in steps as the variation in pace speed becomes lower and the exercise center becomes closer to a rear portion of the walking belt.

16. An automatic speed-controlled treadmill using a pressure sensor array, comprising: a walking belt disposed on a bottom of a treadmill and configured to function as a pace surface of an exerciser; a pressure sensor array comprising pressure sensors for detecting loads of the exerciser's feet and outputting the detected loads of the feet as load detection signals, the pressure sensors being disposed in a plurality of arrangements between the bottom of the treadmill and the walking belt; a pace speed status storage unit for storing a pace speed and variation in pace speed of the exerciser who takes exercise on the walking belt; and a control unit provided with an algorithm for receiving the load detection signals from the pressure sensors and then calculating the pace speed

of the exerciser, calculating a difference between a previous pace speed and a current pace speed as the variation in pace speed, calculating an exercise center of the exerciser from unique position values of the pressure sensors, and proportionally accelerating/decelerating the driving speed of the walking belt based on a fuzzy theory using a fuzzifier, a rule base, a fuzzy inference engine, and a defuzzifier.

17. The automatic speed-controlled treadmill according to claim 16, wherein the pressure sensor array comprises:

a right pressure sensor array provided on a right side of a longitudinal center line of the walking belt and configured to detect a load of a right foot of the exerciser; and a left pressure sensor array provided on a left side of the longitudinal center line of the walking belt and configured to detect a load of a left foot of the exerciser.

18. The automatic speed-controlled treadmill according to claim 16, wherein the pressure sensors have respective unique position values indicating positions thereof.

19. The automatic speed-controlled treadmill according to claim 16, wherein the pace speed is obtained by dividing a pace distance, indicating a distance between paces of the exerciser, by a pace time period, indicating a time period of inter-pace movement of the exerciser (the pace=the pace distance/the pace time period).

20. The automatic speed-controlled treadmill according to claim 16, wherein, assuming that 'an average lifting position=(a right foot lifting position+a left foot lifting position)/2' and 'the average stepping position=(a right foot stepping position+a left foot stepping position)/2', the exercise center is obtained by 'the exercise center=(the average stepping position+the average lifting position)/2'.

21. The automatic speed-controlled treadmill according to claim 16, wherein the control unit accelerates the driving speed of the walking belt in steps as the variation in pace speed becomes higher and the exercise center becomes closer to a front portion of the walking belt, and decelerates the driving speed of the walking belt in steps as the variation in pace speed becomes lower and the exercise center becomes closer to a rear portion of the walking belt.

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