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(54) METHOD OF CONTROLLING A FORCE AND/OR RESISTANCE GENERATOR OF AN EXERCISE APPARATUS

(57) The invention relates to a method, in particular a computer implemented method, of controlling a force and/or resistance generator of an exercise apparatus (1), which apparatus comprises a plurality of physical transmission ratios (10, 4) between a user force input device (7-9) and the force and/or resistance generator and at least one shifter (12) to select a desired transmission ratio. The method comprises the steps of determining the engaged physical transmission ratio, mapping the engaged physical gear ratio onto a virtual transmission ratio, and adapting the generated force and/or resistance based on the virtual transmission ratio.

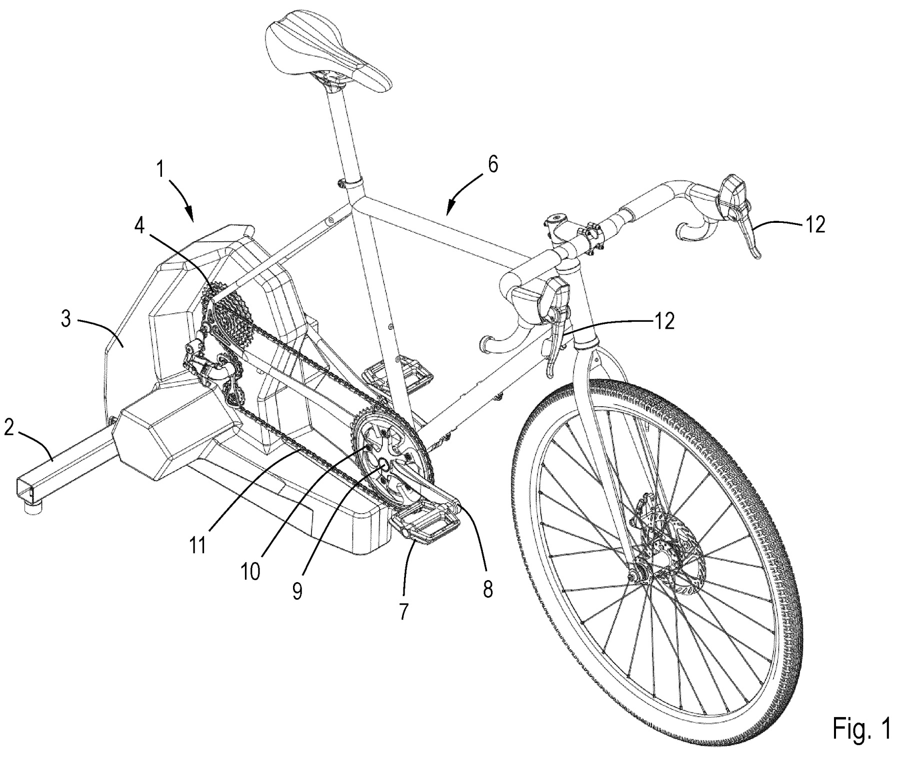

Fig. 1

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Description

[0001] The invention relates to a method, in particular a computer implemented method, of controlling a force and/or resistance generator of an exercise apparatus. The exercise apparatus comprises a plurality of physical transmission ratios between a user force input device, such as pedals and cranks rotatable about an axis, typically a bottom bracket, and fixed to one or more chain rings, and the force and/or resistance generator and at least one shifter to select a desired transmission ratio.

[0002] Exercise equipment mimics reality using a force-feedback system, wherein some form of force is generated to counter the motion and force of the athlete. The motion and force may be measured by sensors in terms of speed and force, in case of a trainer for cycling in terms of rotational or angular speed and torque. Based on the sensor information, a resistive force is calculated by a computer and used to control a device that is capable of generating a variable resistive force using mechanical, electrical and/or magnetic means. The resistive force can be applied directly or indirectly, e.g. by prescribing a desired speed of the user force input device.

[0003] WO2019/059759 relates to a bicycle trainer comprising a seat, handlebars and rotatable pedals, and an electronically variable brake acting directly or indirectly on the rotatable pedals with a braking resistance that depends on a predetermined setting of a computer-controller, which predetermined setting is variable and depends on selected parameters to reflect simulated cycling conditions comprising at least one of a road, wind conditions and a cyclist, wherein the bicycle trainer excludes a flywheel and includes a variable-ratio transmission system and that the predetermined setting of the braking resistance also depends on a setting or change of setting of the variable-ratio transmission system so as to simulate a level of inertia or change of inertia as experienced by an outdoor cyclist when changing the variable-ratio transmission system.

[0004] EP 3 199 211 relates to a method for operating a bicycle trainer, and such a bicycle trainer comprising a stand with a seat, handlebars and rotatable pedals, or such a bicycle trainer comprising a stand for mounting a bicycle frame with a seat, handlebars and rotatable pedals, wherein the stand incorporates an electronically variable brake acting directly or indirectly on the rotatable pedals with a braking resistance that depends on a computer-controlled predetermined setting, wherein the pre-determined setting is variable and wherein said setting depends on selected parameters to reflect a simulated surface condition of a road.

[0005] It is an object of the present invention to provide an improved method of controlling a force and/or resistance generator of an exercise apparatus, as well as an improved exercise apparatus.

[0006] To this end, the method according to the invention comprises the steps of

determining the engaged physical transmission ratio,
mapping the engaged physical gear ratio onto a virtual transmission ratio, and
adapting the generated force and/or resistance based on, amongst other parameters such as mass, acceleration, slope, and wind, the virtual transmission ratio, e.g. on the difference between the virtual and physical transmission ratio's.

[0007] The engaged physical transmission ratio can be monitored continuously or only after a change has been detected.

[0008] The engaged physical transmission ration can be determined e.g. from the difference in rotational speed of the force input device on the one hand and the rotational speed of the force and/or resistance generator on the other, and preferably a lookup table.

[0009] The method may comprise the steps of detecting a physical transmission shift, determining the (newly) engaged physical transmission ratio, mapping the engaged physical transmission ratio onto a virtual transmission ratio, and adapting the generated force and/or resistance based on the virtual transmission ratio.

[0010] The engaged physical gears can be determined e.g. from the physical position of one or more of the transmission elements (e.g. a chain and/or derailleurs) or by means of a camera, ultrasonically, or by means of tactile switches or induction. The physical gearing ratio can be calculated or derived from one or more lookup tables that relate(s) the physical position of the transmission elements to the gearing ratio.

[0011] In a preferred method, the selected gears are determined from variations in the rotational speeds over a period of time. In a refinement, the gears that have been determined, in particular with one or more of the above methods, are entered in a lookup table and, optionally, linked to virtual ratios that had already been inputted. Also, the determined gears can be used to check and/or correct data entered by the user.

[0012] In an embodiment, the method comprises the steps of selecting a virtual transmission ratio, e.g. via an input device, such as electronic shifter preferably located on or near the handlebar e.g. on or near the physical shifters of the bicycle or an app on a smartphone or computer device, determining the (newly) selected virtual transmission ratio, and adapting the generated force and/or resistance based on the (newly) engaged virtual transmission ratio.

[0013] In another embodiment, the exercise device is a bicycle trainer, which trainer is coupled to a bicycle or parts of a bicycle, e.g. wherein the trainer takes the place of the rear wheel of a bicycle, the combination of the trainer and the bicycle or parts of a bicycle comprising one or more rear sprockets or pulleys, e.g. a plurality of rear sprockets or pulleys of different diameter and at least one front chainring or pulley, preferably two or three front chain rings or pulleys, coupled to or provided with a pair of pedals, and a transmission element, such as a chain or belt, passing over one of the rear sprockets or pulleys and a front chainring or pulley, defining a physical transmission gear ratio, i.c. a gear or pulley ratio.

[0014] The method may comprise the step of determining the number of teeth of the (engaged) rear sprocket or the diameter of the (engaged) rear sprocket or pulley and/or the number of teeth of the (engaged) front chainring or the diameter of the (engaged) front chainring or pulley.

[0015] With the present invention, the physical gearing ratio that is selected by the rider is determined, preferably automatically, and subsequently used to map the physical gears onto virtual gears that may or may not be the same as the physical gears on the bicycle trainer. By adapting the formulas that calculate the resistance of the bike, the rider experiences the resistance as if he was riding on the virtual gears. Thus, the effect of the physical gearing can be eliminated from the resistance. In an embodiment, the physical gears are effectively used only to detect current gearings and/or changes therein, i.e. as an index mechanism.

[0016] In an embodiment, mapping the physical transmission, e.g. gear, ratio onto a virtual transmission ratio comprises selecting the virtual transmission ratio from a look-up table.

[0017] The look-up table may contain a plurality of virtual and user defined gears, e.g. corresponding to a 10-, 11- or 12- speed cassette. The number of virtual and user defined gears may exceed the number of physical gears enabling the user to train with more gears than physically available.

[0018] The invention further relates to an exercise apparatus, in particular a bicycle trainer, such as a smart trainer, which provides the benefit of allowing the resistance to be controlled by cycling apps, such as Zwift™ or Rouvy™ comprising:

a frame;
an axle, such as a bottom bracket, rotatably mounted in or to the frame;
a force input device, such as pedals and cranks, coupled to, preferably mounted on, the axle;
a force and/or a resistance generator coupled to the axle;
and means, such as a computer, e.g. a single board computer, or a controller, for carrying out the method of any one of the preceding claims.

[0019] The exercise apparatus may comprise sprockets, e.g. a cassette, a free hub body or freewheel for mounting sprockets, or a roller, to be placed in frictional contact with the rear wheel of a bicycle.

[0020] In an embodiment, the trainer takes the place of the rear wheel of a bicycle. In another embodiment, the rear wheel of a bicycle presses against and, during exercise, drives a roller.

[0021] In another embodiment, the bicycle trainer comprises an input device, such as one or more, e.g. two or four, electronic switches, which is/are preferably located on or near the handlebar e.g. on or near the physical shifters of the bicycle, or an app on a smartphone or computer device to electronically change the virtual gears.

[0022] The input device may comprise two sets of two switches, one set for shifting up and down the virtual rear sprockets and one set for shifting up and down the virtual front chain rings.

[0023] The input device enables virtual shifting beyond the available physical transmission ratios, e.g. to expand an installed physical 9-speed cassette to a virtual 11- or 12-speed cassette, or a single speed to a multiple speed.

[0024] The computer or controller is preferably configured to receive input, e.g. via a keypad, computer, or smartphone, from a user to enter and/or amend the virtual gears.

[0025] The invention further relates to a computer program comprising instructions to cause the system as described above to execute one or more of the steps of the method as described above, as well as to a computer-readable medium having the computer program stored thereon.

[0026] US2009/0011907 discloses a stationary exercise bike, comprising: a support structure; a pair of pedals rotatably mounted to the support structure; a force-generating device operably connected to the pedals and generating a variable resistance force to the pedals; a force sensor configured to measure a force applied to the pedals by a user, wherein the force sensor measures a relative displacement of first and second points on the stationary bike that are interconnected by a drive structure defining a stiffness whereby a force can be determined based on the relative displacement and the stiffness; and a controller operably connected to the force-generating device and the force sensor, wherein the controller varies the resistance force generated by the force-generating device to simulate inertial effects based, at least in part, on a force measured by the force sensor.

[0027] The invention will now be explained in more detail with reference to the Figures, which show preferred embodiments of the present invention.

Figure 1 is a perspective view of a bicycle trainer according to the present invention.
Figure 2 is diagram of a physical set of front and rear gears and a virtual set of front and rear gears.
Figure 3 is a diagram of a method for virtual shifting and force feedback in accordance with the present invention.

[0028] Figure 1 shows a smart trainer 1, comprising a frame 2 in a housing 3. A force generator, in this example an electric motor, is fixedly mounted to the frame and accommodated inside the housing. A cassette 4 of sprockets is mounted on the axle of the force generator or coupled to the axle of the force generator via a transmission, such as a belt drive. A computer 5 (Figure 3), e.g. a single board computer, for controlling the force generator as well as sensors for measuring the angular speed of and the torque exerted on the axle carrying the sprockets are also accommodated inside the housing. More details on these components can be found in WO 2020/071913 A1.

[0029] A road bike 6, with its rear wheel and cassette removed, is mounted in the frame in a manner known in itself. The bike 6 comprises a user force input device, i.c. pedals 7 and cranks 8 rotatable about and fixed to a bottom bracket and to one or more e.g. two chain rings. A chain extends over one of the chain rings and one of the sprockets. The bike comprises, in a usual manner, shifters 12 to derail the chain and move it to another chain ring or sprocket to change the physical transmission ratio.

[0030] Figure 2 shows, on the left-hand side, an example of a typical configuration for flat terrain and/or advanced level cyclists, namely two chain rings, one with 53 teeth and one with 39 teeth, in the front, and eleven sprockets having 11, 12 ... 21, 23 and 25 teeth in the rear, providing a fixed number of physical transmission ratios. The present invention enables the cyclist to use, with the physical setup described above, a different number and/or different transmission ratios on the smart trainer, e.g. to train at a different (virtual) terrain, e.g. via provider such as Zwift™ and Rouvy™ or a different level. An example of virtual gears is shown on the right-hand side of Figure 2 and comprises two virtual chain rings, one with 50 teeth and one with 34 teeth in the front, and eleven sprockets having 12, 14 ... 30, 33 and 36 teeth in the rear.

[0031] Figure 3 schematically shows a scheme for controlling the force generator. When a force, F_{ped}, is applied to the padels, the cyclist will experience a resistive force, F_{res}, from the force generator. The computer includes a kinetic model of the exercise apparatus, e.g. in the form of a software program, that is configured to receive an input and to generate a control signal for the force generator as an output. The kinetic model may be based on the equations of motions describing the behavior of the exercise apparatus and may further include external parameters relating to road conditions, e.g. wind and slope angle of the road in case of an exercise bike. This way, the kinetic model may accurately control the force generator to simulate certain exercise conditions, examples of such kinetic models are for example described in WO 2020/071913 and WO 2021186083.

[0032] Input from the sensors for angular speed and torque determine the force the athlete applies to the exercise apparatus and a computer may use this information as an input to the kinetic model of the exercise apparatus to generate the control signal for the force generator to generate a resistive force F_{res} that opposes the force of the athlete, i.e. $F_{ped} \approx F_{res}$.

[0033] Mapping of the virtual gears can be carried out as follows: power at the pedals, P_{ped}, is equal to power at the axle of the force generator, P_{wheel}

$$P_{ped} = P_{wheel}$$

$$F_{ped} \,.\, R_{ped} \,.2\pi \,.\omega_{ped} = F_{Res} \,.\, R_{wheel} .2\pi \,.\omega_{wheel}$$

[0034] The angular speed of the axle, ω_{wheel}, is proportional to the angular speed of the pedals, ω_{ped}, conform the ratio of the physical gears:

$$\omega_{wheel} = \frac{Gear_{front}}{Gear_{rear}} \cdot \omega_{ped}$$

yielding

$$F_{ped} = \frac{F_{Res} \,.\, R_{wheel} \,.2\pi \,.\, \frac{Gear_{front}}{Gear_{rear}} \,.\, \omega_{ped}}{R_{ped} \,.\, 2\pi \,.\, \omega_{ped}}$$

$$F_{ped} = \frac{F_{Res} \cdot R_{wheel} \cdot \dfrac{Gear_{front}}{Gear_{rear}}}{R_{ped}}$$

[0035] Note: required resistance is calculated in a manner known in itself, by adding forces resulting from wind, climbing, roll resistance, acceleration, etc., as mentioned above:

$$F_{Res} = F_{wind} + F_{climb} + F_{roll} + \dots\dots + m.a$$

[0036] In a trainer, force at the pedals is defined by an overall virtual gear ratio, as follows:

$$F_{ped} = F_{Res} \cdot \frac{R_{wheel}}{R_{ped}} \cdot \frac{Virt_{Front}}{Virt_{Rear}}$$

[0037] In accordance with the present invention, mapping virtual gears onto physical gears is achieved e.g. by including 1) the physical transmission ratio between the front chain ring and the rear sprocket and 2) the reciprocal transmission ratio, as follows:

$$F_{ped} = F_{Res} \cdot \underbrace{\frac{R_{wheel}}{R_{ped}} \cdot \frac{Real_{Front}}{Real_{Rear}}}_{\text{Physical Gearing}} \cdot \underbrace{\frac{Real_{Rear}}{Rear_{Front}} \cdot \frac{Virt_{Front}}{Virt_{Rear}}}_{\text{Virtual Impact}}$$

which yields front and rear mapping:

$$F_{ped} = F_{Res} \cdot \underbrace{\frac{R_{wheel}}{R_{ped}} \cdot \frac{Real_{Front}}{Real_{Rear}}}_{\text{Physical Gearing}} \cdot \underbrace{\frac{Virt_{Front}}{Real_{Front}}}_{\text{Front Mapping}} \cdot \underbrace{\frac{Real_{Rear}}{Virt_{Rear}}}_{\text{Rear Mapping}}$$

[0038] Operation is illustrated in Figure 3 and involves measuring force and angular speed of the axle, determining the number of physical gear teeth in the front (e.g. 53, see Figure 2)) and in the rear (e.g. 21), for example from variations in the rotational speeds over a period of time, update the physical gearing map, find the front ring index (e.g. index 2), find the rear sprocket index (e.g. index 9), lookup virtual front ring from index (index 2 corresponds to 50 virtual teeth, in Figure 2), lookup virtual rear sprocket from index (index 9 corresponds to 30 virtual teeth, in Figure 2), update force and angular speed, and adjust the force provided by the generator.

[0039] With the present invention, the physical gearing ratio that is selected by the rider is determined, preferably automatically, and subsequently used to map the physical gears onto virtual gears that may or may not be the same as the physical gears on the bicycle trainer. By adapting the formulas that calculate the resistance of the bike, the rider experiences the resistance as if he was riding on the virtual gears. Thus, the effect of the physical gearing can be eliminated from the resistance.

[0040] The invention is not restricted to the embodiments described above and can be varied in numerous ways within the scope of the claims. For example, in addition to direct drive trainers, the present invention is equally suitable for so-called wheel on trainers.

Claims

1. Method, in particular a computer implemented method, of controlling a force and/or resistance generator of an exercise apparatus (1), which apparatus comprises a plurality of physical transmission ratios (10, 4) between a user force input device (7-9) and the force and/or resistance generator and at least one shifter (12) to select a desired transmission ratio,

the method comprising the steps of
determining the engaged physical transmission ratio,
mapping the engaged physical gear ratio onto a virtual transmission ratio, and
adapting the generated force and/or resistance based on the virtual transmission ratio.

2. Method according to claim 1, wherein the engaged physical transmission ratio (10, 4) is determined from the difference in rotational speed of axles on both sides of the physical transmission.

3. Method according to claim 1 or 2, comprising the steps of detecting a physical transmission shift, determining the engaged physical transmission ratio (7-9), mapping the engaged physical transmission ratio onto a virtual transmission ratio, adapting the generated force and/or resistance based on the virtual transmission ratio.

4. Method according to any one of the preceding claims, comprising the steps of selecting a virtual transmission ratio, determining the selected virtual transmission ratio, and adapting the generated force and/or resistance based on the engaged virtual transmission ratio.

5. Method according to any one of the preceding claims, wherein the exercise device is a bicycle trainer, which trainer is coupled to a bicycle or parts of a bicycle, the combination of the trainer and the bicycle or parts of a bicycle comprising one or more rear sprockets or pulleys, a front chainring or pulley, and a chain or belt passing over one of the rear sprockets or pulleys and a front chainring or pulley, defining a physical transmission gear ratio.

6. Method according to claim 5, comprising the step of determining the number of teeth of the rear sprocket (4) or the diameter of the rear sprocket (4) or pulley and/or the number of teeth of the front chainring (10) or the diameter of the front chainring (10) or pulley.

7. Method according to any one of the preceding claims, wherein mapping the physical transmission ratio (10, 4) onto a virtual transmission ratio comprises selecting the virtual transmission ratio from a look-up table.

8. Method according to claim 7, wherein the look-up table contains a plurality of virtual and user defined gears.

9. Exercise apparatus, in particular a bicycle trainer, such as a smart trainer (1), comprising:

a frame (2);
an axle rotatably mounted in or to the frame (2);
a force input device (7-9) coupled to, preferably mounted on, the axle;
a force and/or a resistance generator coupled to the axle via a transmission (10, 11, 4);
and means, such as a computer (5), e.g. a single board computer, or a controller, for carrying out the method of any one of the preceding claims.

10. Bicycle trainer (1) according to claim 9, comprising sprockets (4), a free hub body or freewheel for mounting sprockets (4), or a roller, to be placed in frictional contact with the rear wheel of a bicycle, which sprockets, free hub body, freewheel, or a roller are coupled to the force and/or a resistance generator.

11. Bicycle trainer (1) according to claim 9 or 10, comprising an input device to electronically change the virtual gears.

12. Bicycle trainer (1) according to claim 11, wherein the input device comprises two sets of two switches, one set for shifting up and down the virtual rear sprockets and one set for shifting up and down the virtual front chain rings.

13. Bicycle trainer (1) according to any one of claims 9-12, wherein the means (5) for carrying out the method are configured to receive input, e.g. via a keypad, computer, or smartphone, from a user to enter and/or amend the virtual gears.

14. A computer program comprising instructions to cause the system of any one of the claims 9 to 13 to execute the steps of the method of any one of the claims 1 to 8.

15. A computer-readable medium having stored thereon the computer program of claim 14.

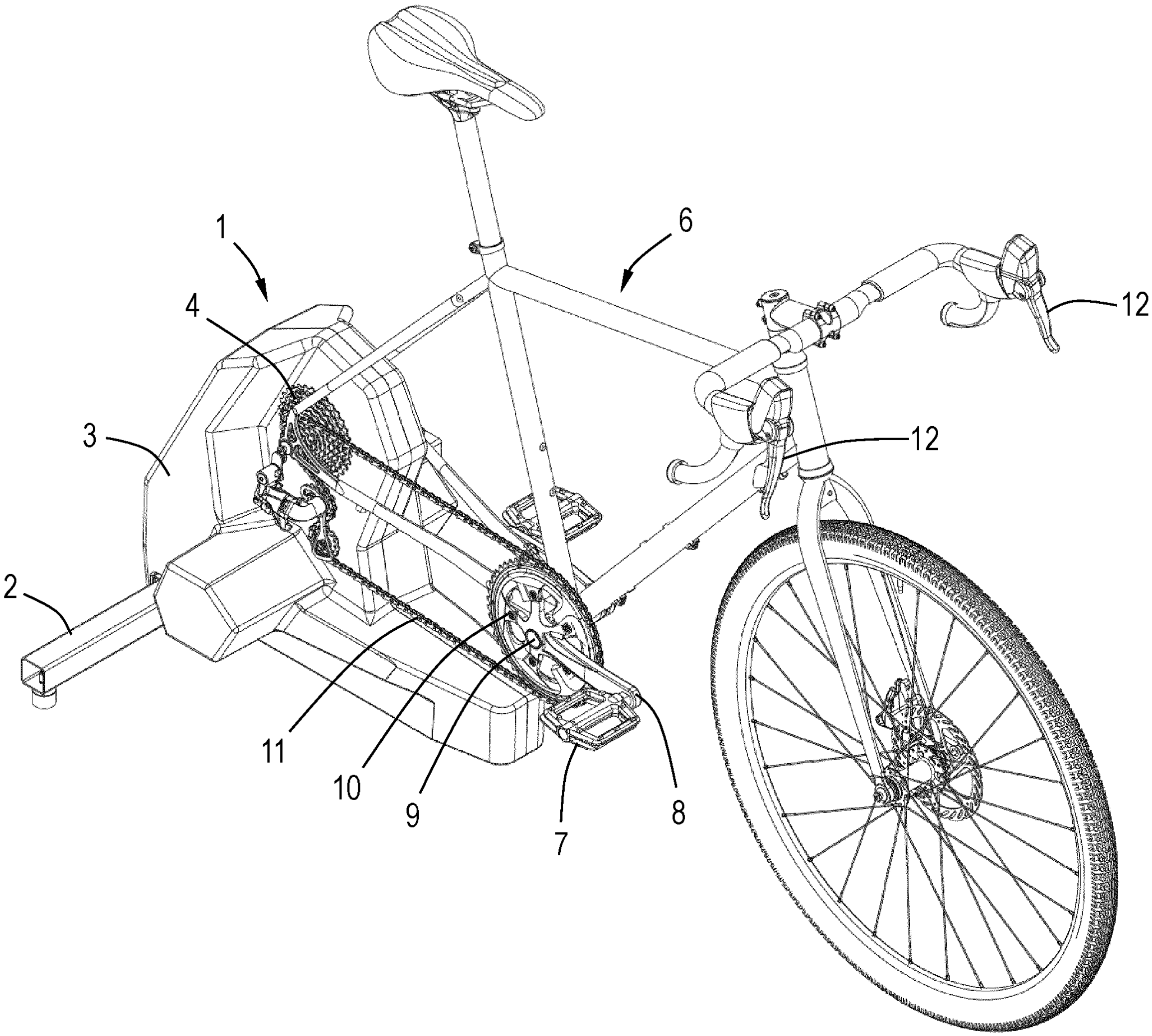

Fig. 1

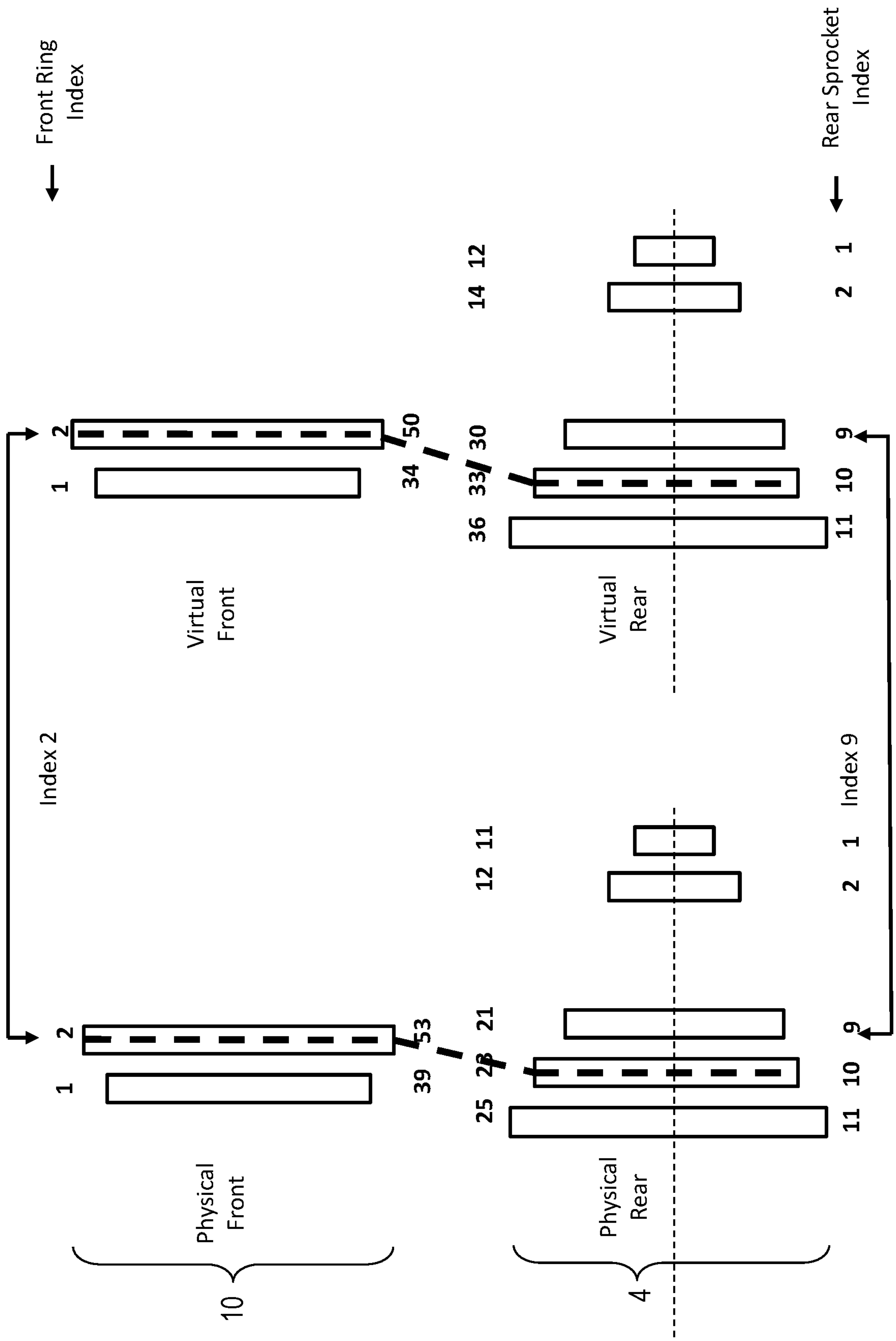
Front Ring Index
Rear Sprocket Index
Virtual Front
Virtual Rear
Physical Front
Physical Rear
Index 2
Index 9
10
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Fig. 2

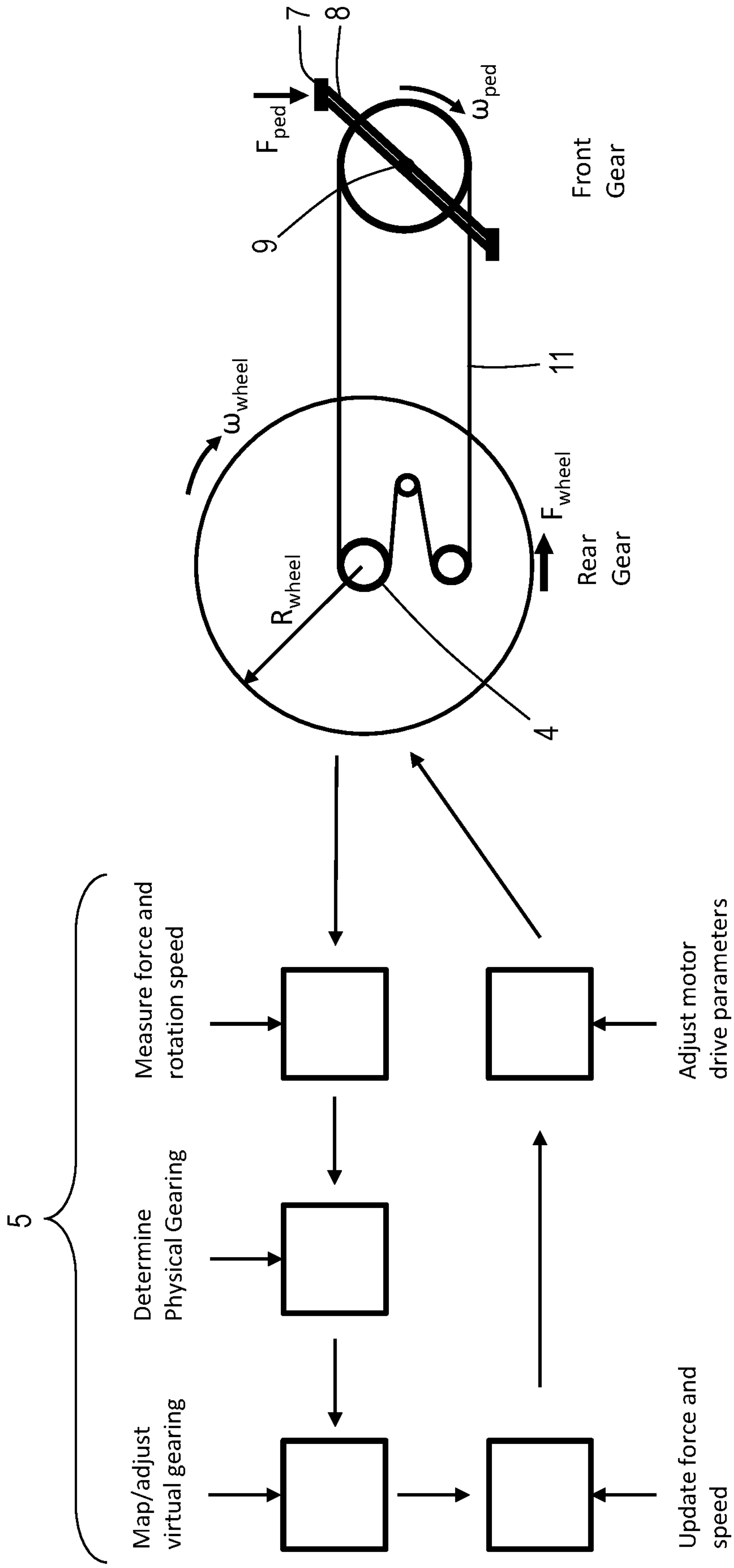
7
8
F_{ped}
ω_{ped}
9
Front Gear
11
ω_{wheel}
F_{wheel}
R_{wheel}
Rear Gear
4
5
Measure force and rotation speed
Determine Physical Gearing
Map/adjust virtual gearing
Adjust motor drive parameters
Update force and speed

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 4578

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,D	WO 2021/186083 A1 (TRUEKINETIX B V [NL]) 23 September 2021 (2021-09-23) * page 11, line 24 - page 33, line 3; figures 1-14 *	1-15	INV. A63B69/16 A63B21/005 A63B21/00 A63B22/06 A63B24/00
A	WO 2009/003170 A1 (BLAU D A) 31 December 2008 (2008-12-31) * paragraph [0053] - paragraph [00199]; figures 1-37 *	1-15	
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TECHNICAL FIELDS SEARCHED (IPC)

A63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	13 September 2022	Jekabsons, Armands

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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L : document cited for other reasons
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 16 4578

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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13-09-2022

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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- US 20090011907 A **[0026]**
- WO 2020071913 A1 **[0028]**
- WO 2020071913 A **[0031]**
- WO 2021186083 A **[0031]**