

**FORM 2**

**THE PATENT ACT 1970**

(39 OF 1970)

AND

The patent rules, 2003

**COMPLETE SPECIFICATION**

(See section 10: rule 13)

**TITLE OF INVENTION**

Five bar mechanism based quadruped

**APPLICANTS**

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**PREAMBLE TO THE DESCRIPTION**

**COMPLETE**

The following specification particularly describes the invention and the manner in which it is to be performed.

## **DESCRIPTION**

### **Technical field of invention:**

[001] Present invention in general relates to the field of robotics and automation and more specifically to quadruped using five-bar mechanism with two possible distinct arrangements of actuator.

### **Background of the invention:**

[002] Conventionally, various self-moving robots have been developed, some of which have wheels, caterpillars and still others of which have leg sections. As a walking robot having leg sections, multi-legged walking robots such as a biped or two-legged robot, a three-legged robot, a quadruped or four-legged robot, a six-legged robot, etc., have been developed. In particular, various types of quadruped robots have recently been developed in view of high stability in walking motions. Thus few of the existing quadruped robots are discussed below.

[003] The "Scout" quadruped robot design demonstrated walking, turning, climbing and running capabilities, with one degree of freedom per leg. In the Scout design RC-Servo motors were used as rotary hip actuators for actuating four stiff legs (Scout I), and in a later design passive compliant prismatic legs (Scout H)[M. Buehler et al., "SCOUT: A simple quadruped that walks, climbs, and runs", Proc. of the 1998 IEEE Int. Conf. on Robotics & Automation, May 1998] [D. Papadopoulos and M. Buehler, "Stable Running in a Quadruped Robot with Compliant Legs", Proc. Of the 2000 IEEE Int. Conf. on Robotics & Automation, April 2000].

[004] WO2008084480A9 discloses a quadruped legged robot driven by linear actuators. The invention provides a legged robot, whose legs are actuated by means of linear actuators capable of applying leg movement within three allowable degrees of freedom, wherein each of the robot's legs is actuated by means of three linear actuators and wherein the robot's leg is constructed from a first linear actuator

attached to the body of the robot by means of a joint capable of providing two degrees of freedom to said leg, and wherein the second and third linear actuators are attached to said leg at points situated more or less at the same level along its length in selected angular positions with respect thereto, such that it may be moved within the two degrees of freedom provided by the joint.

**[005]** IN 201941019760 discloses the actuation of quadruped robot by shape memory alloy helical spring. A quadruped robot was developed and actuated using Shape Memory Alloy (SMA) helical springs. The robot uses four legs, with each leg uses SMA springs for achieving locomotion. The locomotion is achieved by using SMA springs which exhibit Shape Memory Effect (SME) to bring the spring to their original shape and thereby move the links which are connected to the springs. The SMA used for this purpose has a composition of 55% of Nickel and 45% of Titanium. The actuation of the links using Nitinol springs is performed only in one leg due to its symmetric nature. Analytical modeling of the SMA springs has been performed to determine the current required to actuate the SMA spring. Finite element modeling was carried out using a small portion of the spring to exhibit the SME. Then, the model of the leg was designed and the SME was applied on the attached spring to show the actuation of the leg. By performing the Finite element analysis, it showed that as the material reaches the phase transformation of 45°C, the spring returns to its original shape. The effect was experimentally verified by supplying the-calculated current to attain the desired-V: temperature.

**[006]** US20080252247A1 discloses quadruped walking robot. A quadruped walking robot comprises: a horizontal swivel portion disposed so as to freely swivel in the horizontal direction in the main body portion; a horizontal swivel driving portion for driving and turning the horizontal swivel portion in the horizontal direction; an upper side upper leg portion rotatably axially attached in the horizontal swivel portion so as to freely turn in the vertical direction; a lower side upper leg portion disposed roughly parallel to the lower part of the upper side upper leg portion; an upper leg driving and turning portion for driving and turning the upper side upper leg portion in the vertical direction; a lower leg portion in which the distal end part of the upper side upper leg

portion and the distal end part of the lower side upper leg portion are axially supported vertically at the upper end portion; and a grounding portion disposed at the lower end portion of the lower leg portion; and a resilient extension and contraction portion, disposed at an intermediate portion of the lower side upper leg portion, which resiliently extends and contracts in the lengthwise direction.

[007] In existing quadruped leg mechanisms motion is achieved using two actuators. One actuator is mounted on the chassis and the second actuator is mounted on the output motion of the first actuator. Thus the motion of the first actuator will have its effect in the second actuator. Mounting an actuator on one another is difficult and taking electronic control and power connection via moving parts is difficult.

[008] To overcome the above-described conventional problems the present invention provides a five bar mechanism based quadruped with two possible distinct arrangements of actuator.

**Object of the invention:**

[009] Primary object of the present invention is to provide a five bar mechanism based quadruped having actuation along parallel axis and co-axial .(Modified)

[0010] Another object of the present invention is to provide a quadruped having no moving actuator that simplifies the assembly, manufacturing and control for both parallel axis and co-axial arrangements of the actuators.

[0011] Yet another object of the present invention is to provide high speed locomotion and ability to reposition itself after falling.

[0012] Other objects, features and advantages will become apparent from detailed description and appended claims to those skilled in art.

### **Summary of the invention:**

[0013] Accordingly following invention provides a five bar mechanism based quadruped. The proposed mechanism provides quadruped with two possible distinct arrangements of actuator i.e. mechanism with actuators being parallel to each other and mechanism with actuators being co-axial. In the proposed invention the leg of the quadruped is two upper links (1) and two lower links (2) and the fifth link is chassis (7). It has two upper and two lower links. The lower links (2) of the leg in the mechanism are held by two upper links (1). These two lower links (2) are connected with each other as well as the upper two links (1) by revolute joint. The two upper links (1) are connected to each of two motors respectively. These motors (6) are mounted on the chassis (7) of the quadruped robot. The lower links are connected with the respective upper links. The feedback of the position of the leg is taken in terms of its position and speed to control its motion. The microcontrollers and microprocessors are used for its overall movement and operations. The preferred embodiment comprises of upper link, lower link, coupling, motor shaft, bearing, bearing plate, motor block, DC motor, chassis, rotary actuator, nut and bolt.

### **Brief description of drawing:**

[0014] This invention is described by way of example with reference to the following drawing where,

[0015] Figure 1 of sheet 1 show five-bar mechanisms with actuators arranged parallel to each other.

Where,

1 denotes upper link,

2 denotes lower link,

3 denotes coupling,

4 denotes bearing plate,

5 denotes motor block,

6 denotes motors.

**[0016]** Figure 2 of sheet 1 shows the side view of quadruped with two legs on one side of the chassis.

Where,

7 denotes chassis.

**[0017]** Figure 3 of sheet 2 shows the arrangement of rotary actuators of quadruped facing each other.

Where,

1 denotes upper link,

2 denotes lower link,

3 denotes coupling,

4 denotes bearing plate,

5 denotes motor block,

6 denotes motors.

**[0018]** Figure 4 of sheet 2 shows the side view of one leg with co-axial (facing each other) actuator.

Where,

1 denotes upper link,

2 denotes lower link,

3 denotes coupling,

4 denotes bearing plate,

5 denotes motor block,

6 denotes DC motors.

**[0019]** Figure 5 of sheet 3 shows the top view of the chassis of the quadruped for parallel arrangement of the rotary actuators.

**[0020]** Figure 6 of sheet 3 shows the complete 3D view of the five-bar mechanism based quadruped and arrangement of its rotary actuators being parallel to each other.

[0021] In order that the manner in which the above-cited and other advantages and objects of the invention are obtained, a more particular description of the invention briefly described above will be referred, which are illustrated in the appended drawing. Understanding that these drawings depict only typical embodiment of the invention and therefore not to be considered limiting on its scope, the invention will be described with additional specificity and details through the use of the accompanying drawing.

**Detailed description of the invention:**

[0022] The present invention relates to a five bar mechanism based quadruped. Herein a five-link mechanism with five revolute joints is commonly called a five-bar mechanism. The quadruped using five-bar mechanism is proposed with two possible distinct arrangements of actuator, mechanism with actuators being parallel to each other and mechanism with actuators being co-axial.

[0023] The proposed five bar mechanism quadruped is a four legged robot which is driven by eight motors where each leg is driven by two motors. The two motors are arranged one next to another in case of parallel axes based arrangement and facing each other in case of co-axial arrangements.

[0024] In the preferred embodiment the leg of the quadruped is two upper links (1) and two lower links (2) and the fifth link is chassis (7). This mechanism has two upper and two lower links. The lower links (2) of the leg in the mechanism are held by two upper links (3). These two lower links (2) are connected with each other as well as the upper two links (1) by revolute joint. The two upper links are connected to each of two motors respectively. These motors (6) are mounted on the chassis (7) of the quadruped robot. The lower links (2) are connected with the respective upper links (1). The feedback of the position of the leg is taken in terms of its position and speed to control its motion. The microcontrollers and microprocessors are used for its overall movement and operations in various stated applications.

**[0025]** In another embodiment, referring to figure 1, each leg of quadruped having five-bar mechanisms and actuators are arranged parallel to each other. One end of these upper links (1) is joined or fixed with the coupling in which the motor shaft is inserted and the other end has a revolute joint with the respective lower link (2). Whereas one end of these lower links (2) has a revolute joint with the respective upper link (1) and the other end of these lower links (2) have revolute joint among themselves. Couplings (3) are press fit in the bearings present in the bearing plates (4). A bearing is pressfit in the bearing plate (4) and in that bearing there is a coupling (3) which is also press fit. The motor block (5) is casing which holds the motor with a transition fit. These motor blocks (5) are mounted on the chassis using nuts and bolts. The DC motors (6) are used as rotary actuators. The motor shafts are inserted in the couplings (3). The motor (6) is fitted in the motor block (5) and this motor block (5) is mounted above or below the chassis (7) using nuts and bolts. A similar arrangement is made on the other side of the chassis as shown in figure 2.

**[0026]** Further by referring to figure 3, in the arrangement of rotary actuators of quadruped while facing each other a motor block (5) is used to hold DC motor (6). DC motor used as rotary actuator for five-bar mechanism and the couplings (3) for attaching upper link (1) to the motor shaft. Similarly one end of these upperlinks (1) is joined or fixed with the motor and the other end has a revolute joint with the respective lower link (2). All the parts are the same as parallel arrangement with the same functionality.

**[0027]** The proposed quadruped robot based on a five-bar mechanism walks on all types of surfaces (smooth, flat, uneven, dry, wet, moist, ploughed land etc.). The five bar mechanism quadruped provides the highest stability for uneven terrains and it can even climb all types of slopes.

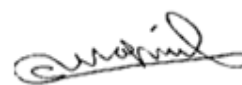
**[0028]** Consequently, for all the surfaces the input power from two rotary actuators is given to the two upper links (1) of each leg to obtain the best performance. An angular position sensor is used that gives feedback of angular position to the processor and accordingly the leg of the quadruped follows its gait. A similar



procedure is applied for all the four legs that uses the same five bar mechanism for locomotion. The locomotion of the five bar mechanism based quadruped makes use of various patterns like diagonal in which two diagonal legs performs the same action, three legs on ground in which only one leg is lifted at a time and hopping in which the front leg performs jump and rear legs follow them. Turning and running of the quadruped is performed using a diagonal pattern.

**[0029]** Additional advantages and modification will readily occur to those skilled in art. Therefore, the invention in its broader aspect is not limited to specific details and representative embodiments shown and described herein. Accordingly various modifications may be made without departing from the spirit or scope of the general invention concept as defined by the appended claims and their equivalents.

**Dated this 12<sup>th</sup> day of March 2020**



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## **CLAIMS**

### **We claim:**

1. A five bar mechanism based quadruped wherein five-bar mechanism is enabled with two possible distinct arrangements of actuator, mechanism with actuators being parallel to each other and mechanism with actuators being co-axial, comprising of;

a four legged robot is driven by eight motors where each leg is driven by two motors wherein two motors are arranged one next to another in case of parallel axes based arrangement and facing each other in case of co-axial arrangements;

characterized in that; said mechanism having two upper and two lower links and said two lower links (2) are connected with each other as well as the upper two links (1) by revolute joint and the two upper links are connected to each of two motors (rotary actuators) respectively;

these said motors (rotary actuator) (6) are mounted on the chassis (7) of the quadruped robot;

and microcontrollers and microprocessors are used for its overall movement and operations in various stated applications.

2. The five bar mechanism based quadruped as claimed in claim 1 wherein; each leg of quadruped having five-bar mechanisms and actuators are arranged parallel to each other and one end of these upper links (1) is joined with the coupling in which the motor shaft is inserted and the other end has a revolute joint with the respective lower link (2) whereas one end of these lower links

(2) has a revolute joint with the respective upper link (1) and the other end of these lower links (2) have revolute joint among themselves.

3. The five bar mechanism based quadruped as claimed in claim 1 wherein;

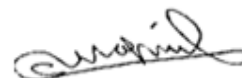
motor block (5) is casing which holds the motor with a transition fit which are mounted on the chassis and

DC motors (6) are used as rotary actuators and motor shafts are inserted in the couplings (3) and said motor (6) is fitted in the motor block (5) and this motor block (5) is mounted above or below the chassis and a similar arrangement is made on the other side of the chassis.

4. The five bar mechanism based quadruped as claimed in claim 1 wherein; in the arrangement of rotary actuators of quadruped while facing each other a motor block (5) is used to hold DC motor(6) which used as rotary actuator for five-bar mechanism and the couplings (3) for attaching upper link (1) to the motor shaft.
5. The five bar mechanism based quadruped as claimed in claim 1 wherein; for all the surfaces the input power from two rotary actuators is given to the two upper links (1) of each leg.
6. The five bar mechanism based quadruped as claimed in claim 1 wherein; an angular position sensor is enabled that gives feedback of angular position to the processor and accordingly the leg of the quadruped follows its gait.
7. The five bar mechanism based quadruped as claimed in claim 1 wherein; the locomotion of the five bar mechanism based quadruped makes use of various patterns as diagonal in which two diagonal legs performs the same action,

three legs on ground in which only one leg is lifted at a time, hopping in which the front leg performs jump and rear legs follow them, and other possible patterns.

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Sheet 3/1

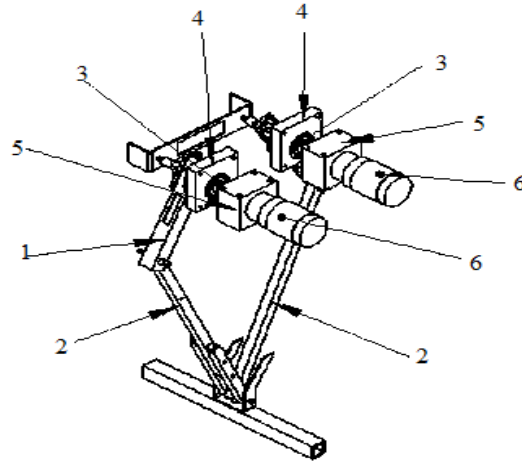


Figure 1

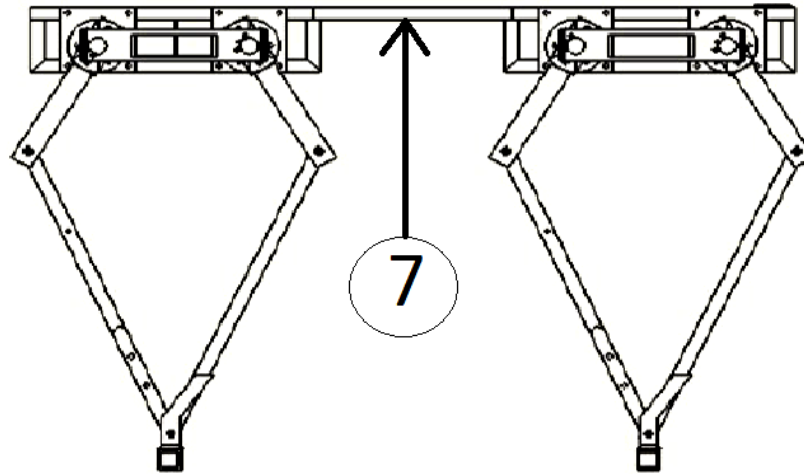
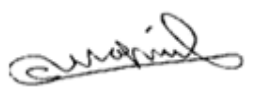


Figure 2

Dated this 12<sup>th</sup> day of March 2020

  
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Sheet 3/2

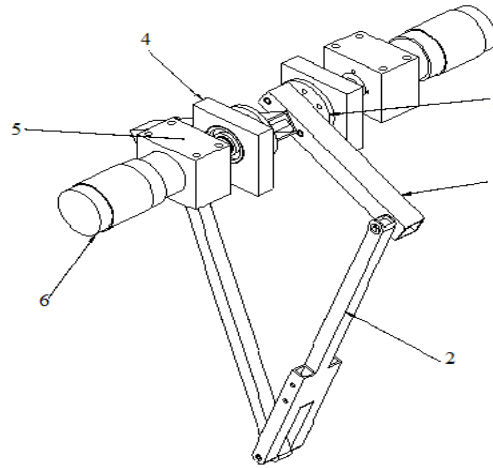


Figure 3

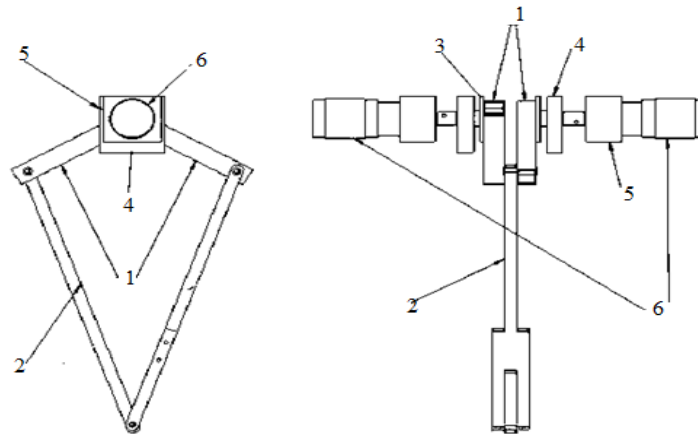
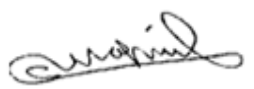


Figure 4

**Dated this 12<sup>th</sup> day of March 2020**

  
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Sheet 3/3

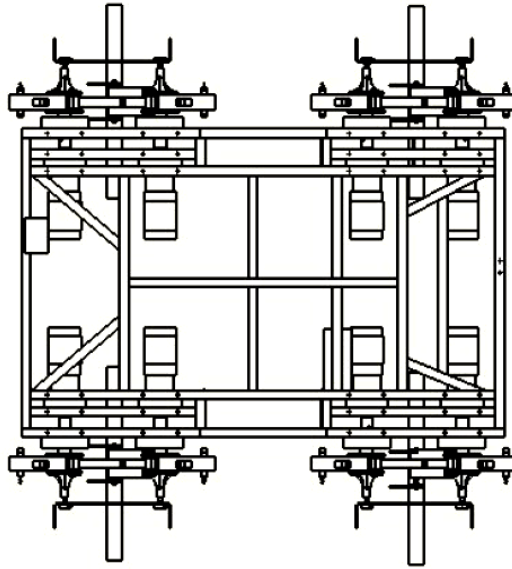


Figure 5

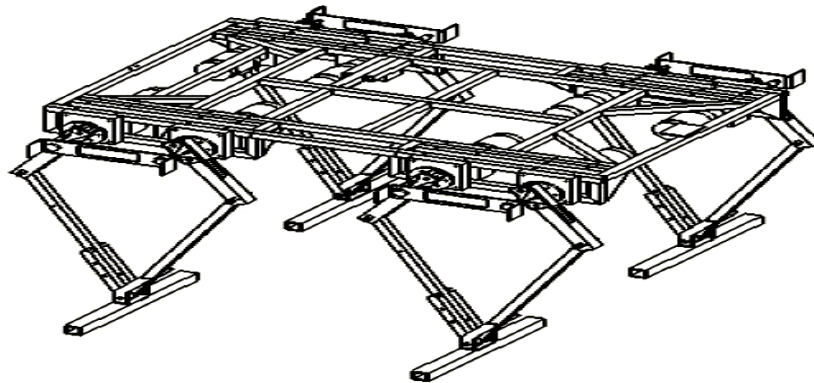
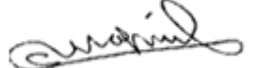


Figure 6

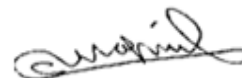
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## **ABSTRACT**

The present invention relates to a five bar mechanism based quadruped. The proposed invention has five bar mechanisms for each leg of quadruped and arranged in two ways, actuators being parallel to each other and with actuators being co-axial. The quadruped is driven by eight motors where each leg is driven by two motors (6) which are arranged one next to another in case of parallel axes based arrangement and facing each other in case of co-axial arrangements. The leg of the quadruped is basically two upper links (1) and two lower links (2) and the fifth link is chassis (7). The lower links (2) of the leg are held by two upper links (1). These two lower links (2) are connected with each other and the upper two links (1) by revolute joint. Following invention is described in detail with the help of Figure 1 of sheet 1 showing five bar mechanism based quadruped.

**Dated this 12<sup>th</sup> day of March 2020**



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