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Recent Developments in Pantographic Leg Mechanisms of Robot: A Review

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ABSTRACT

Study of different pantograph type robot leg mechanisms which are recently designed and analyzed is presented in this paper. Main focus is kept on the way of actuation of these pantographic mechanisms. Different designs of these mechanisms are explained. Simultaneously their efficiencies in terms of energy consumption and in terms of stated pattern generation are compared. Based on that study few remarks are made. These remarks are very important for designing an efficient walking mechanism for any kind of walking robot which may be a biped or quadruped robot. Concept of aperiodic motion and its importance is described. For actuating these mechanisms different actuation ways are elaborated.

Keywords— Pantograph, Mechanism, Robot, Gait.

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I. Introduction

Recently tremendous developments and useful modifications was done in the field of robot design. Because of their ability of working in unconditional way made them very popular and interesting. By the invention of rotating wheel the story of machines has been started and after several developments these machines are now becoming automated. Robots are trying to become backbone of this automation. So many type of robots are there like wheeled robots, walking robots, industrial robots etc.Because of desired capabilities that the walking robots have they made themselves a special class of robots and now a days becoming more popular. Walking robots have several advantages over wheeled robots like off road working capability and so they have capacity to cove about one third portion of the entire earth. So in future these walking robots are going to become more popular and essential part of human life.

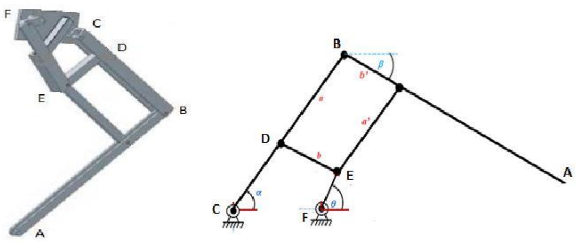

Fig.1 Pantographic leg mechanism [4]

Pantograph mechanism is one of the most common mechanism used in designing legs for robots. Several modifications are made in pantograph mechanism for using them in legs of robot. Pantograph mechanism has capability to produce one to up to three degree of freedom leg mechanism. Simultaneously it produce a suitable gait required for walking of robots. Simple pantograph type walking mechanism is shown in fig.1.Pantograph type leg mechanisms are also used for designing biped robot legs. We called these robots as humanoid robots. For designing biped robots stability is the major issue because biped robots tip over easily due to unbalanced forces. There are mainly three possible positions of walking we consider to be occur during walking of biped robots as shown in fig. 2.

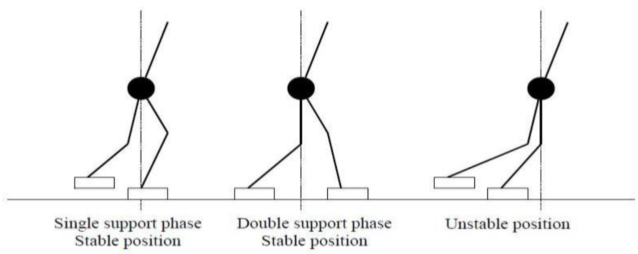

Fig.2 Possible Positions during Walking [7]

Out of these three positions first two are stable and desired positions and last one is unstable and undesired. During design main aim is to avoid this last position.

II. IMPORTANT POINTS REGARDING ROBOT WALKING

A. Static Walk

Leg should generate straight line trajectory for foot with respect to body of robot; if the use of robot is special for special purpose then we need that it should possess minimum number of DOFs for its smooth movement; leg mechanism must be statically and dynamically stable; require minimum maintenance, noise free operation and have capacity to tolerate any unavoidable effects like unbalanced force, unbalanced torque, shocks etc.In static walking we know that the robot is perfectly stable statically. This means that, when motion is stopped at any time the robot will stay indefinitely in a single position. It is necessary that the projection of the centre of gravity of the robot on the ground must be always within the foot support area also shown in fig. 2. The support area is either the foot in position of one leg supporting or the minimum convex area which has both feet surfaces in case of both feet are on the ground.These are referred to be as single and double support conditions, respectively. Also, walking speed should be as low as possible so the inertial forces are negligible.

B. Dynamic Walk

Biped dynamic walking allows the centre of gravity to be outside of the support region for limited amounts of time. There is no absolute criteria that determines whether the dynamic walking action is stable or not. As a walker is designed to recover the different kinds of unbalances. If robot has stable and acting ankle base joint and always it keeps at least one foot at on the ground surface then the ZMP (Zero Moment Point) can be used as a stability criteria. The ZMP is a point contact where the robot's total moment and unbalanced force at the ground is zero. As long as the ZMP (Zero Moment Point) is inside the foot support region the walking is considered dynamically and statically stable because it is the only condition where the foot can control the robot's structure. It is clear that robots which do not continuously put at least one foot on the ground or that do not have active ankle joints, the motion of support area does not exist, so that’s why the ZMP criterion cannot applied.

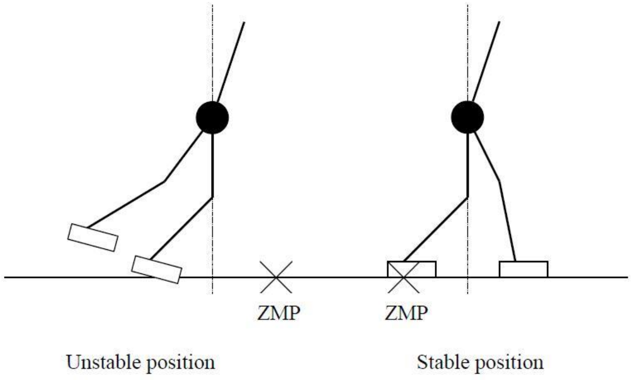

Fig.3 Dynamic Walking [7]

Dynamic walking is achieved by ensuring that the robot always supposed to be rotating around a point in the support region fig.3. If the robot rotates around a point outside the support region then it means that the support foot will tend to get off the ground support or get compressed against the ground surface. Both the conditions lead to instability in mechanism posture.

C. Zero Moment Point (ZMP)

To achieve dynamic walking the centre of gravity (or centre of mass) can be outside of the support area of the robot, but the zero momentum point (ZMP), cannot.At ZMP resultant momentum is zero. The position of the ZMP is computed by finding the point where the total torque is zero. Since ground plane study is important so we assume that height of ZMP is zero.

III. HIGHLIGHTS OF RECENT WORK DONE ON PANTOGRAPHIC LEG MECHANISM

Several authors proposed their designs of leg mechanism based on pantograph mechanism for robots. Highlighted points of their research work are listed below in front of their research topic.

A. The Development of a Mechanical Quadruped Robot with Animal-like Muscle Arrangement

In this paper author proposed a leg mechanism called a pantograph model based on the bi-articular muscle arrangement that is only present in animals for a quadruped robot. He successfully attempted to propose a robot leg system which is capable for jumping and during jumping the net resultant force passes through the centre of gravity of the system, which is one of the important condition for jumping easily without disturbing the balance. He investigated the motion characteristics of the pantograph model and analysed the change in motion when the ground reaction force is generated by extending the legs.Aim of this research study is development of leg mechanism that functions like that of an animal and that enables stable running with simple computational control. In this research the team analysed in detail motion mechanism of animal leg and they have tried to generate artificial system consist of three actuators and different linkages arranged in such a way that the system produce motion similar to the motion generated by legs of animal. System arrangement and simulation model is as shown in fig.4.

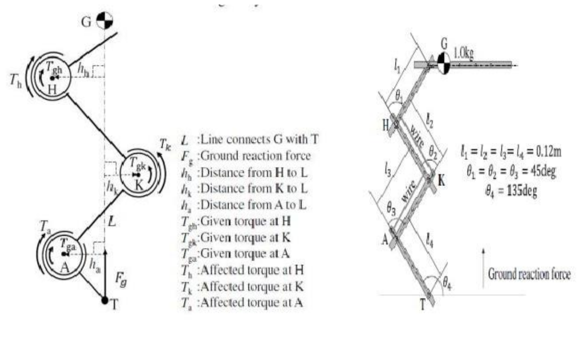

Fig.4 Series link mechanism and Simulation model equipped with Pantograph link Mechanism [1]

B. Jumping Mechanism Imitating Vertebrate by the Mechanical Function of Bi-articular Muscle.

In this research work an attempt of designing an efficient leg mechanism with jumping capability was done and for that three different mechanisms analysed in detail. The proposed three mechanisms are,

1. The mechanism in two actuators are arranged on the knee and ankle joint separately.
2. The mechanism in two actuators are arranged on the knee and ankle joint, and attached two joints by a wire.
3. The mechanism in which arranged one actuator only at knee joint, and connected two joints by a wire.

After analysis he find out that out of these three mechanisms the last one is more efficient and easy for control. He also stated that in many conventional robots, the number of actuators is the same as the number of degree of freedoms but in case of vertebrate, the number of actuators differs from the number of muscles. In this study, unique effectiveness of vertebrate skeletal arrangements including the bi-articular muscle is examined on jumping motion from the viewpoint of mechanical engineering.In this study it is proved that high-speed controller which detects the centre of gravity and adjusts the joint torque is required in the serious link mechanism and there is unique function which adjusts the torque automatically in the pantograph type link mechanism which does not need an actuator for actuating, which should just arrange a actuator equivalent to the mono-articular muscle on the knee (in the femur), and which should just connect the two joints with the wire equivalent to the bi-articular muscle.Study is concentrated on function of bi-articular muscle and shown that it is possible to control jumping motion if the complex mechanism used by using high speed controller but if pantograph link mechanism is used then it is possible to control by unique function of bi-articular function.

C. A Study on the Support Pattern of a Quadruped Walking Robot for Aperiodic Motion.

As legged robots have solid importance in robotics field but only the use of periodic motion mechanism does not satisfy the need especially in off roads and in arbitrary stepped path aperiodic motion mechanisms are required. In this paper aperiodic gait for straight motion and spinning motion was analysed and a schematic design of leg mechanism that is spatially decoupled by using a 2-dimensional pantograph mechanism and a vertical linear actuator was introduced.

The main goal of this paper is to derive the conditions of support pattern that enable to preserve the standard leg-lifting sequence in straight motion and in spinning motion and second goal is to introduce a 3-dimensional leg mechanism. The configuration diagram of quadruped robot is shown in fig.5.

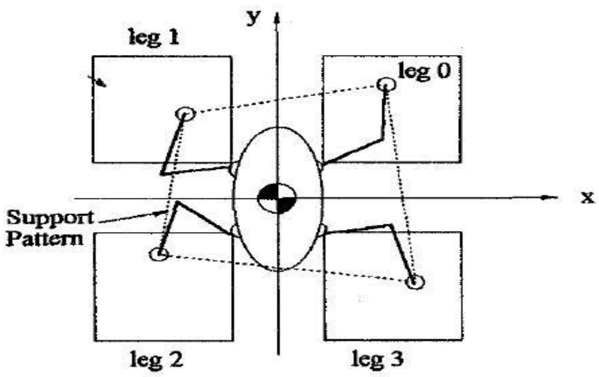

Fig.5 Configuration diagram of quadruped robot [3]

Detailed study of straight and spinning motion with different leg lifting sequences is done and based on that introduced pantograph type spatially decoupled orthogonal leg mechanism.

D. Passive compliant quadruped robot using central pattern generators for locomotion control.

In this research work author proposed a design of new quadruped robot having legs in three segment pantographic form with virtually powered knee joints and hip joint is actuated by real actuator. Central pattern generator is used to generate different giant patterns. Objective of this mechanism design is minimising inertia and possibly enabling different dynamic giants effectively.In this design three segment leg is chosen because it has several advantages over the more and fever segments like easy control and less power consumption for actuation etc. also a CPG (Central Pattern Generator) control is developed by inspiring from biological CPGs found in animals.CPM has capabilities to generate different giants by simply varying some parameters and simultaneously in CPG it is possible to control independently amplitude of trajectories and duration for ascending and descending of legs.Stated walking provides two actively actuated DOFs per leg - the hip joint and a passively compliant knee joint, which can be actively actuated through a proximally mounted actuator.

E. Improving the energy efficiency and speed of walking robots.

By using Decoupling concept author presented a design of 3 DOF leg which works such that because of gravitational decoupled actuation it requires very less energy for its actuation. In this design robot obtains a straight line velocity on plane surface by using three constant speed motors. Author studied the concept of PDW (passive dynamic walker) and compared efficiency of proposed design with PDW. He has calculated efficiency by using given term proposed by Gabrielli and von Karman.In this study author says that why GD (Gravitationally Decoupled) legs have improved performance than GC (Gravitationally Coupled) legs because in GD robots moving actuators do not bear the weight, and theoretically, no power is expected during the stance phase of GD legs due to the robot weight. Since the support phase is the part of the walking cycle demanding a higher energy consumption, GD legs success in improving the efficiency and autonomy if the system cannot regenerate negative power, i.e. if the system cannot transform the kinetic energy into electrical one. Hence in terms of efficiency, the GD configurations give rise to unimproved performance in comparison to GC ones.Another issue that determines the robot characteristics is the orientation in which the leg is connected to the hip. This way the leg can be laterally connected (LC), as in reptiles or crabs, or vertically connected (VC), as in mammals. The first type of legs in this figure shown, GC-VC legs, is the preferred one in day today modern robots, since this type of mimic robots the mammal configuration. The pantographic solutions were very good and popular in past years since these legs can easily be controlled in an easier and faster computational way. This paper presents a comparison in terms of consumed energy and speed between GC legs and GD legs.

Fig.6 Proposed Leg (GD-VC) [5]

Lastly he proposed an efficient GD-VC type leg as shown in fig.6 and two hybrid robots have been modelled and simulated: one including mammal-like (GC-VC) leg; and the other including the proposed (GD-VC) leg. Simulations show a reasonably more efficient performance of the hybrid robot with the proposed decoupled leg. Furthermore, there is a limitation in the speed of hybrid robot consisting of GC-VC legs that is not present in the proposed configuration.

F. Planning walking pattern for biped robot

To walk efficiently and stably robot leg mechanisms have to adapt to the ground conditions that are accompanied with a foot motion, and maintain its stability and orientation with a torso like motion. Robot should have always flexible for walking i.e. it must require less torque for its actuation and able to actuate at lower velocity for that leg must have to follow efficient walking pattern. For designing walking pattern all above criterions must have to full fill. In this study author has firstly formulated all constrains required by varying the values of the constraint parameters, we can produce different types of foot motion to adapt to ground conditions. From this study he has proposed a motion pattern which satisfies all desired conditions. Also the relation between the actuator specifications and the desired walking patterns is described by using simulation studies and plotting methods, and the effectiveness of the proposed way is validated by simulation examples and experimental analysis.

G. Work Analysis of complaint Leg Mechanisms for bipedal walking robots

In this research work detailed analysis of wok for robots has been done by author for that a model of biped robot has been developed for mathematical modelling. Compiled feet is considered for modelling this biped robot.To find the work basic work principle is used according to reaction which calculates the force. The usefulness of work is demonstrated by using simulation technique that are carried out and results are presented in the study. For modelling following basic biped model structure is used for analysis shown in fig.7.

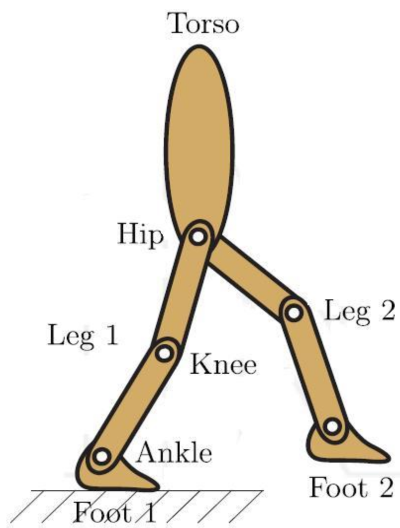

Fig. 7 Model of Biped Walking Robot [9]

It is shown that work analysis is used for evaluating fatigue of leg generated because of physical contact between supporting foot and contact surface. In this way so many important aspect about biped robots are described and accordingly results plotted which are very useful for designing efficient walking machine.

IV. APERIODIC MOTION

Aperiodic motion is a motion in which two succeeding cycles does not follow the same pattern of movement. Because they follow different patterns in each step this movement is useful in special conditions like in avoiding obstacles during walking, to avoid missing portions of road and so on. So because of that aperiodic motion generation in robots has its own importance.To build a robot which is expected to work in off road conditions like in international border area for surveillance it must have the ability to walk in a periodic way so in such cases aperiodic motion generating mechanisms are used for leg design.To generate such a complicated motion leg mechanisms should be able to generate the desired motion and simultaneously an active control is required. Active control helps to senses the condition of path through active sensors and according to that the motions are produced.

V. CONCLUSION

In this broad review all important aspects related to design of efficient walking leg mechanism are elaborated. Some design models are discussed so from that new robot designers will get idea of designing an efficient walking robot. Through different pantograph type leg models of robots it is shown that how effectively a pantograph mechanism can be used as a walking mechanism for humanoid robot.

REFRENCES

[1] Y. Washizuka, T. Oshima, K. Koyanagi and T. Motoyoshi, "The Development of a Mechanical Quadruped Robot with Animal-like Muscle Arrangement" 2012 IEEE/SICE International Symposium on System Integration (SII) Kyushu University, Fukuoka, Japan, December 16-18, 2012.

[2] Toru Oshima, Noboru Momose and Tomohiko Fujikawa "Jumping Mechanism Imitating Vertebrate by the Mechanical Function of Bi-articular Muscle" Proceedings of the 2007 IEEE, International Conference on Mechatronics and Automation, Harbin, China, August 5 - 8, 2007.

[3] Kyung-Min Jeong, Tae-Seok Yang and Jun-Ho Oh "A Study on the Support Pattern of a Quadruped Walking Robot for Aperiodic Motion" 0-8186-7108-4/95 1995 IEEE.

[4] Simon Rutishauser, Alexander Sprowitz, Ludovic Righetti and Auke Jan Ijspeert "Passive compliant quadruped robot using central pattern generators for locomotion control" Proceedings of the 2nd Biennial IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, Scottsdale, AZ, USA, Octobe19-22, 2008r.

[5] Angel Gaspar Gonzalez-Rodriguez, Antonio Gonzalez-Rodriguez, Fernando Castillo-Garcia "Improving the energy efficiency and speed of walking robots" 0957-4158 2014 Elsevier Ltd.

[6] Qiang Huang, Kazuhito Yokoi, Shuuji Kajita, Hirohiko Arai, Noriho Koyachi, and Kazuo Tanie "Planning Walking Patterns for a Biped Robot" IEEE transactions on robotics and automation, vol. 17, no. 3, june 2001.

[7] Raibert M, Chepponis M, Jr Brown H. "Running on four legs as though they were one". IEEE Journal of Robotics and Automation, 1986, 2, 70–82.

[8] M. G. Pandy, F. E. Zajac, E. U. Sim and W. S. Levine, An Optimal Control Model for Maximum-height Human Jumping, J. Biomechanics, Vol.23, No.12, pp. 1185-1198, 1990.

[9] Byoung-Ho Ki "Work analysis of compiled Mechanisms for Bipedal Walking Robots" International Journal of Advanced Robotic Systems Accepted 30 Jul 2013.

[10] G.V.Phani Babu and N.Amara Nageswara Rao "Design and Analysis of a Low Cost and Easy Operated Leg Mechanism for A Walking Robot" International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012.

