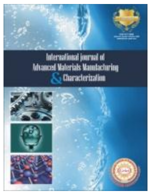

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Biped Robot

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ABSTRACT

This paper represents the important features of biped robot in step wise manner. Initially Development design in which lightweight aluminum sheet are used so that it can act as that of human. Walking and kicking behavior is performed by using controller using EyeBot that produces intelligent commands. Dynamic walking control and Stability on orientation motion of biped robot aiming at target object which can be done by visual tracking feedback control walk and that will lead to decision making walk by the use of CCD camera mounted on the head which follows the target. Vision sensors mounted on the robot is used to detect Zero moment point (ZMP), whenever appropriate flexibility around ankle joints are given. It is difficult to generate stable and natural walking motion in various environments

Introduction

There are many applications where mobile biped robot is used including area which is hazardous for humans. Biped possess human like mobility such that it allow it to maneuvers in areas containing obstacle such as climbing ladder, stairs and uneven surfaces [1]. Similarly legged robot is having advantage over wheeled one when dealt with terrain, climbing stairs. Multilink provides a compelling advantage in climbing stairs. Hardest challenge is in constructing and developing it. Factors affecting these are, balancing of weight of the robot during walking, running, kicking and other similar activities. Current scenario is not to walk but also to react in real time to external forces and stimuli. Robot are naturally unstable so large effort is needed to ensure that control system are efficient enough. Safety is also one of the biggest concerns when robot is occupying human space. Important parameter to be met in building a walking robot is balance of mass with respect to centre of gravity. Component for walking is initiated by activating joints which lie below the hip, and above structure are considered as a payload for a simple walking robot [2].

Initially Bipedal locomotion in artificial systems was engineered using trajectory of leg joints but there adaptivity is highly restricted because that requires a precise environment model and demanding computational duty for calculating the trajectories, For solving this researchers came up with passive dynamic walking [PDW], based on biomechanical model .This is so called “compass gait model” or“ ballistic walking model”. Inspired band the muscle activities it has been developed and demonstrated natural walking behaviour .By implementing actuators with PDWs ,dynamic walking can be achieved with high energy efficiently and little control on the level ground [3].

Biped walk cannot be traced based on the camera image mounted on the walking robot and visual servoing by the posture change for the purpose of the target image tracking in the camera frame. There are few difficulties in tracking biped walk which are: (1) the biped motion is generally cyclic motion without permanent contact with ground, so that there will be disturbance generated on camera periodically. (2) Robot structure has physical restriction due to hardware. (3) Large time delay has been incurred when there is slight modification in walking condition like slide width, direction and the posture because biped walking plan is well prepared before the actual motion. Here first consideration given to stabilization of visual walking robot when the red target surrounded by four vertices in the image plane. Secondly CPU computational time for the feature value calculation is taken in to account and the time delay is compensated [4].

In mobile robot system visual data is used for various purposes such as environment recognition, 3D mapping, and ego motion estimation and so on. Visual based control is one of the important key technologies for sophisticated mobility under human living environment. For dynamic balance gait, the zero point moment is most popular indicator of dynamic equation of robot motion.in many cases ZMP Is detected by force or pressure sensors as COP. If minute mechanical flexibility is detected

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around foot sole then its mechanical deformation is saved to the ZMP deviation, at that time the deformation can be detected from the movement of visual target in the field, it means that ZMP can be detected by only vision sensor under some assumption if the stiffness coefficient is previously known. Usually position based servo control (PBVS) and image based one (IBVS) are the major way to design the visual feedback controller[5].In future humanoid robots are one of the burning topics of robotics research and assumed to have high future application. At present humanoid robots have a substantial lack of mobility. The humanoid biped ends up with relatively high center of mass (COM) while standing upright, as a result the stance of a humanoid robot become little unstable. Gait planning for humanoid robots is basically different from for simple robotic arms robots centre of mass is in motion all the time and in unilateral way feet will be interacting with the ground, it means that there will be only repulsive and no attractive force between ground and feet. Therefore the movement of the centre of mass cannot be controlled directly, but is governed by eventual contact forces arising from ground interaction and momentum for postural stability [6].

Motion of biped robot are achieved by the phased movement of legs such that legs must alternate between support that is on the ground, and transfer phase that's in air, in order to propel the robot forward.3D walking is divided into two planes, one is sagittal plane where the plane is vertical to the floor including the walking direction and second one is motion in the lateral plane where plane is vertical to the walking direction. Here only sagittal plane motion is discussed [1].

Design aspects

The primary design focuses on biped walking movement using servos. Initially design were based on servos kept at parallel axis of rotation, but that led to serious problems due to the lack of lateral balance control. Then designs were mainly focused on making light weight robot and able to walk while keep the body stable or balanced. Finally came into existence with a biped robot having 2 legs with 3 servos on each leg , an EyeBot controller which is mounted on the hip. EyeBot is also known as house of controller and it is responsible for coordinating the motion of robot. Main structure of biped can be made up of aluminum of 2mm thickness in order to reduce the weight and provides enough strength and flexibility. For balanced motion one of the important key parameter is Centre of mass. COM is dependent on weight distribution, height of the robot and the distance between the legs. Another important parameter is angular motion to balance and counter-balance the walking and kicking motions. Biped consists of six servos having three degree of freedom per leg. The servos were placed on the hip, knee and ankle joints to meet the configuration of a human. Hip and knee servos have the same axis of rotation (perpendicular to the robot's side surface) while ankle joint servo moves the robot right and left. In order to balance the robot's centre of gravity from side to side ankle joint is used to rotate and to balance the robot about the forward and backward directions the hip and knee joints are used. 6 high-torque servos give quick reaction and fast motion but these servos draw more current from the battery resulting in reduction in battery life as well as dips in current while moving. To overcome this problem a set of normal servos are used. Each servo needed to be calibrated for angular movement [2].

Model of a biped robot

It is important to note that some of the aspects of human walking dynamics are not reproduced by the compass gait model; significant difference is noticed in the vertical movement of the body. The compass gait model shows the elliptic trajectory of the body movement around the foot ground contact during a stance phase, where as in the human body excursion at stance phase at the beginning vertical position of the body decreases, then it increases and decreases; toward the end of the stance phase, it starts increasing again. One of the main advantages of this movement is that it has less displacement of vertical oscillation of the body. Secondly, knee joint behaviour during stance phase is also different from compass gait model: At the beginning of stance phase, the knee angle first decreases before a large peak. A relevant advantage of the first decrease is that joint could absorb more impact force at touch down. Thirdly, the ankle joint shows significant dynamics compared to the compass gait model has no ankle joint; There is a small peak at the beginning, and it increases toward the end of stance phase. By understanding the underlying mechanisms, it is possible not only to obtain additional insights into the nature of human locomotion, but also design and build better legged robots [3].

Model of biped robot consists of seven body segments, hip joints is provided with two motors for position control, knee and ankle joints provided with four passive joints, and eight linear springs. These linear springs are used as alternative for muscle-tendon systems, which constrain the passive joints. A unique feature of these robot is that six of the springs are connected over two joints, referred to as bi-articular muscles in biological systems (i.e. two springs attached between the thigh and the heel, four are between the hip and the shank) The vertical ground reaction forces are approximated by nonlinear spring damper interaction, and the horizontal forces are calculated by a sliding and stiction model. It switches between sliding and stiction when the velocity of the foot becomes lower or higher than the specified limit [3].Atypical humanoid robot like LOLA weighs approximately55 kg and 180 cm tall. Its physical dimensions are based on anthropometric data. The significant characteristics of LOLA are the redundant kinematic structure with 7-DoF legs, Lola is an extremely lightweight design and using brushless motors they are having a modular joint design. The mass distribution of the leg is improved to achieve good dynamic performance [7].

Kinematic Structure

Heel lift-off during terminal stance which occurs shortly before the swing leg contacts the ground, is another measure to reduce joint loads. Heel rise in human gait contributes significantly to reducing the centre of mass (COM) vertical displacement. Due to the importance of stance leg Heel rise in human walking, the idea of implementing toe joints on a humanoid robot is not new. Yet, there are very few humanoid robots with actively driven toe. LOLA therefore has an additional, active toe joint which allows the swing leg to be in a more extended configuration. Area contact of the toe segment stabilizes .The sensor system supports the implementation of model based control algorithms and is optimized for signal quality and bandwidth. Absolute angular sensors on the output shafts of all joints compensate elasticity and nonlinearities in the drivetrains and enable the robot to (theoretically) start from arbitrary positions. Two custom-made six-axis force/torque sensors are tightly integrated into the foot structure. At a total weight of 395 g the sensor includes an overload protection and all necessary electronics. The inertial measurement unit (IMU) estimates the orientation and angular velocities of the upper body [7].

Design process

Thorough design of the mechatronic system is required for Fast locomotion of biped robots. It is an iterative and open-ended process of design and simulation. Inertia properties of the links and actuators are obtained from the 3D-CAD model after certain design milestones completion; these are used to estimate joint loads, workspaces and constraint forces using the dynamics simulation of the robot, which is the basis for the dimensioning of actuators and structural components .To balance structural stiffness and actuator performance with lightness of the mechanical components is the basic objective. To neglect a particular range of resonant frequencies, these considerations cannot be limited to the component-level. Moreover, the elastodynamic dimensioning of the robot structure must include the drivetrains and other components within the load path, such as bolted flange connections and link bearings unlike humans, the largest portion of a biped robot's weight resides in its legs, since motors and gears determine approximately a third of the overall weight. The COM height is therefore lower than in humans, typically at the height of the hip joint or below. At higher COM positions lateral swing decreases. Especially at higher walking speeds, the stability of the robot is increased if swing is small, because oscillations of the angular Momentum around the longitudinal axis are reduced. Shifting the total COM as close as possible to the hip joint is therefore a basic design requirement.

The joint actuators consumes around one third of the total weight, Development of compact and light-weight actuators crucial. Use of high-performance permanent magnet synchronous motors (PMSM) allow either increasing actuator performance without adding additional weight, or decreasing actuator mass without decreasing performance, and also because of their superior torque and speed capabilities.

There will be Increase in thigh moment of inertia due to Harmonic Drive-based actuator located in the knee joint axis which unacceptable, and a large output would be spent on accelerating the heavier thigh. By implementing a roller screw-based linear drive, sufficient mass distribution in the hip–thigh area is obtained. The thigh inertia can be reduced by 65% if the motor is located close to the hip joint axis and the mass of the actuator itself by more than 10%, without reducing performance.

Feet are the only parts of the robot which are subject to external loads during normal locomotion. These parts undergo the largest accelerations. The mechanical components must therefore be extremely lightweight, yet they must be able to withstand shock loads during initial contact. Most of the robotic feet consist of a monolithic baseplate covered with rubber or plastic to increase friction and use as shock absorbers. However, their stiffness is considerably lower than under pressure loading compared to shear loading, which can easily destabilize the robot during stance. The main requirements for foot are High grip on different surfaces, good damping, and rigid mechanical structure to transmit propulsive forces, Compensate smaller unevenness, and Minimal weight [7].

Visual walking Stability

As the feature value the median and area of target in the image plane is selected, only translation Motion is possible. To extract the rotation motion of the target, first the largest target in the image plane are extracted, and second vertexes of the square which surround this target in the image plane are calculated, and third, position information of the vertexes is used as feature value [4].

A gait posture is called statically balanced, if within the convex hull of the foot support area on the ground coincides with the projection of the robot's centre of mass. This kind of gait will have relatively low walking speeds. Natural human gaits typically consist of phases in which the projection of the COM leaves the support polygon therefore they are not statically stable. Gaits are called dynamically stable in which the dynamics and the momentum of the body are considered to keep the gait stable. The concept of the zero moment point (ZMP) is useful for understanding dynamic stability and also for monitoring and controlling a walking robot . The ZMP is the point on the ground where the tipping moment acting on the robot, due to gravity and inertia forces, equals zero. Component of the moment that is tangential to the supporting surface is called tipping moment. The component perpendicular moment to the ground may also cause the robot to rotate, to change the robot's direction without affecting its stability therefore ignored. For a stable posture, the ZMP has to be inside the support polygon [6].

Appropriate placement of the feet and a movement of the rest of the body are the general problem of walking. For resulting motion to be stable both of these must satisfy the condition. Desired walk is obtained by certain translational and rotational speed of the robot which might change over time, either smoothly or rapidly. This speed vector is the desired speed of the robot, which does not translate into its COM speed directly, for obvious stability reasons, but merely to its desired average. Thus at a particular point of time robot intends to follow certain path. To ensure the correct overall motion of the robot the feet of the robot have to be placed along this path. Dealing with uneven ground, the feet placement at safe positions must be prioritized, resulting in an irregular gait dictating different changes of speed within the foot space polygon Region for possible ZMP trajectories is defined as step patterns are set which leads to stable gaits [5].

Conclusion

A Humanoid robot are a new and promising application area for robotics In order to be useful and commercially successful, humanoids must have reliable biped locomotion capabilities, in this paper focuses is on the aspects of the mechatronic hardware design and real-time control system of our new biped robot LOLA [7]. Developmental design of a bipedal articulating robot is realized, Walking and kicking are the functions that the robot is able to perform while fully maintains its balance [2]. It is shown that biologically plausible walking dynamics can be achieved by using an extremely simple control. The approach utilizing compliant properties in the leg can be extended to running behavior. It would be particularly interesting to extend the same leg design for both walking and running behaviors [3]. The image-based approach to stabilizing the motion of biped walking robot. The visual feedback control becomes powerful functions of controlling the robot mobility according to environmental information in real-time .Here the direct control from camera image plane can be provided, and it contributes to visual navigation with considering the walking stability efficiently [4]. The description of the dynamic model of a 5-link biped robot, the planning of the trajectory and the software implementation of two control algorithms are discussed. Kinematic and dynamic models are presented. Then the computed torque method is used to control the biped robot [5]. The generation of walking patterns is described as a pipeline process transforming the desired translational and rotational speed into footsteps, ZMP trajectory, a COM trajectory relative to these footsteps, and finally into foot trajectories in a robot-relative coordinate frame. Special focus is given to the online calculation of the COM movement to achieve the desired ZMP trajectory [6].The future work will be focussed on implementing closed loop balancing system for the robot with inertial measurement devices: accelerometer and gyroscope [3], complementary utilization of the visual sensing with internal sensors will provides more reliable control structure of biped walking systems [4].

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