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A quadruped robot with parallel mechanism legs

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Abstract—**The design and control of quadruped robots has become a fascinating research field because they have better mobility on unstructured terrains. Until now, many kinds of quadruped robots were developed, such as JROB-1 [1], BISAM [2], BigDog [3], LittleDog [4], HyQ [5] and Cheetah cub [6]. They have shown significant walking performance. However, most of them use serial mechanism legs and have animal like structure: the thigh and the crus. To swing the crus in swing phase and support the body's weight in stance phase, a linear actuator is attached on the thigh [2, 3, 5, 6], or instead, a rotational actuator is installed on the knee joint [1, 4]. To make the robot more useful in the wild environment, e.g., the detection or manipulation tasks, the payload capability is very important. To carry the sensors or tools, heavy load legged robot is very necessary. Thus the knee actuator should be lightweight, powerful and easy to maintain. However, this can be very costly and hard to satisfy at the same time.**

This video introduces our lately developed quadruped robot. It is named as "Baby Elephant" because of the heavy load capability and the elephant like appearance. The leg is a serial-parallel hybrid mechanism that is one novelty of our robot. On the sagittal plane, it is a parallel mechanism consisting of two symmetrical crossed limbs. Each leg has three active DOFs, driven by three hydraulic actuators mounted on the hip. To guarantee the sufficient workspace of the leg (i.e., the spatial range that the foot tip can reach) during the walking, the leg structure parameters are optimized. Springs are attached to the legs to reduce the impact and save energy. Using the pressure sensors on hydraulic actuators, it is possible to estimate the ground forces without extra foot force sensors. Comparing with its serial mechanism counterpart, this leg has neither actuator nor sensor on the lower part of the leg. Thus the leg's inertia becomes lower. Moreover, it is easy to protect electronic devices when the robot is walking on marshy terrains. Two hip actuators on the sagittal plane support the body's weight together, and thus the load capability is also increased.

A type of hydraulic actuator named the "Hy-Mo" was developed that is another novelty of our robot. Its principle is that the hydraulic cylinder's motion is controlled by the motor while its power is supplied by hydraulic system. The servo motor controls the valve opening, which is proportional to the piston displacement via an inner mechanical feedback. The advantage is that it does not need servo valve, cooler, filter and accumulator. It will result in a more simplified structure, better heat dissipation, and lower leakage.

Currently, two control schemes are employed. When the robot is in a static walking gait, a ZMP-based online planning algorithm [7] is employed to generate the trajectory of the body's COG. The ZMP is guaranteed to be located inside the support polygon. The ground reaction force (GRF) is estimated from the driving force of the actuators using a force estimation model. The ZMP can be calculated from the GRFs. Meanwhile, an inverse kinetic solver coordinates each leg and controls the body's orientation. When the robot is in a trotting gait, the ZMP planning is no longer usable. We developed another trajectory planning algorithm to generate trajectories of the feet according to a gait pattern that has been verified in the simulation environment.

The trot experiments were carried out. The "Baby Elephant" was equipped with a Li-ion battery to supply the power. The self-weight of robot was about 130kg and the extra load was 30kg. The maximum speed is 1.8 km/h. The static gait experiment with the same load was also conducted, which shows that the Baby Elephant can walk on different kinds of terrains. The maximum load can be up to 100kg.

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