BlueSheep

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ABSTRACT

This paper presents the discussion of bio-inspired robots and the advantageous features of the blue sheep which has an excellent balance ability and special feet to help them inhabit on mountains and cliffs. Based on those features of the blue sheep, a rough idea of designing and developing a walking robot, called BlueSheep, inspired by blue sheep is provided.

Keywords: Bio-inspired robot, Walking machine, Blue sheep, BlueSheep

1. INTRODUCTION

1.1 Bio-inspired Robot

Human beings try to build machines that emulate features of animals around us for many years. That kind machines are also be known as bio-inspired robots. Different kinds of bio-inspired robots have already been designed and developed (see Fig. 1) such as flying robot called SmartBird inspired from the herring gull developed by FESTO [15], walking robot called BigDog inspired from mule developed by Boston Dynamics [3], and swimming robot called Airacuda inspired from fish developed by FESTO [16].

Figure 1. BigDog [Boston Dynamics], SmartBird and Airacuda [FESTO]

Bio-inspired walking robots are designed using concepts from nature and able to walk as nature. Since those walking robots using legs instead of wheels or tracks, they have more advantages during moving as follows [17]:

1. Legs can step over obstacles as well as up and down stairs.
2. Legged locomotion can carry a vehicle over wide chasms or extremely broken ground (consider the dynamics of kangaroos and mountain goats).
3. A legged walking machine can achieve a smooth ride on the rough ground by varying the effective length of its legs to match the undulations of the ground.
4. Legs do less damage to the ground than tracks and many wheels.

Base on the number of legs a walking machine has, it can be classified as biped robots, quadrupedal robots, hexapod robots walking on six legs inspired by insects like RHex [1], octopod robots which have ten legs inspired from spiders, as well as other more feet robot. Some biped robots have already built inspired from different 2 feet animals. PETMAN, which is able to balance itself and moves freely, walking bending and doing a variety of tasks, was designed and developed by Boston Dynamics [4]. ATRIAS, inspired from birds, was designed and built by Oregon State University Dynamic Robotics Laboratory [8]. BionicKangaroo which is able to realistically emulate the jumping behavior of real kangaroos was developed by Festo [10].

A range of quadruped robots have been built already or are being designed and developed. The BigDog and WildCat robots developed by Boston Dynamics [3] are well-known. They were designed as a rough-terrain robot or fast running robot. Similarly, the Sabertooth is designed as a high mobility quadruped robot platform capable of delivering a payload over terrain at a speed of 5 feet per second developed by Worcester Polytechnic Institute [5]. A pneumatic quadrupedal robot is presented in [18], which is a pneumatically servo actuated robot quadruped with three actuated joints in each leg. In [12], a bio-inspired knee joint mechanism for a small, light-weight and versatile hydraulic quadruped called MiniHyQ is presented. A cat-inspired robotic leg for fast running is presented in [14] and the single leg clamped to a vertically moving slider exhibits a step frequency of 4.45 Hz while supporting a 0.5 kg body

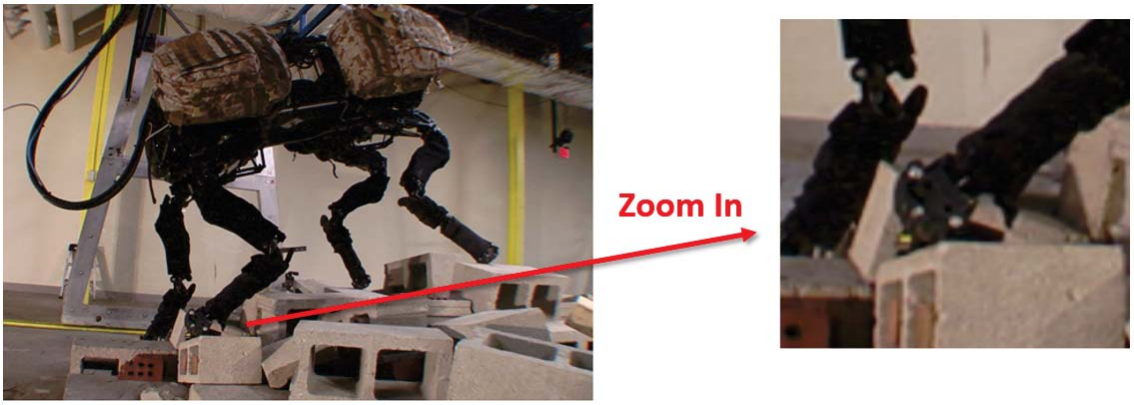

Figure 2. BigDog and the Zoom in of Its Foot [3]

weight. Most of them were designed to emulate the walking skills , running skills climbing skills as well as jumping skills of tetrapods. However, only simple pads or balls are used as feet for those kind robots as Fig. 2 [3] shows.

1.2 BlueSheep

Figure 3. Blue Sheep [9]

Blue Sheep (see Fig. 3), also known as bharal, is a caprid found in the Himalayas of China, Nepal, India, Pakistan and Bhutan. The blue sheep is medium size and the length along the head-to-body is 115 to 165 *cm* long, with a 10 to 20 *cm* tail. They stand 60 to 91 *cm* high at the shoulder and the body mass of them can range from 35 to 75 *kg* [19]. They inhabit at a high mountain and Uncovered Rock zone around 2100 to 6300 meters high. It spends most of its time on the cliff or steep rock surfaces. It is the best climber of the cliff and mountains since it is able to climb any cliffs or mountains as long as there is enough space for its hoofs as Fig. 4 shows. It can also jump up or cross cliffs. It is able to jump around 2 to 3 meters high and it may not get hurt when they jump down from 10 meters high [2].

Figure 4. Blue Sheeps Stand on the Cliff [21]

The outstanding climbing ability of the blue sheep is not only derived from its almost perfect balance ability but also its special hooves (see Fig. 5) which are suitable for walking on cliffs. A hoof of the blue sheep has two cloven claws which can move independently of each other. The front tip and outer edge of the hooves are coated with a hard layer of hoof wall, however, the soft and flexible inner pads are as resilient as rubbers (see Fig. 6) and can feel any tiny convexity or concavity on the rocks to resist sliding as well as provide excellent traction in their precarious habitats. There is a space between two claws of the blue sheep's foot called interdigital cleft. The blue sheep can stand on an extremely narrow fulcrum with that special hooves. When the blue sheep walk or jump on the rock, the two cloven hooves are able to splay apart and clamp objects and rapidly like pliers. In addition, blue sheep also have *auxiliary feet* behind the main hooves to reduce impact when falling on the ground [19, 2, 7]. Based on those advantageous features

Figure 5. Blue Sheep's Feet [7]

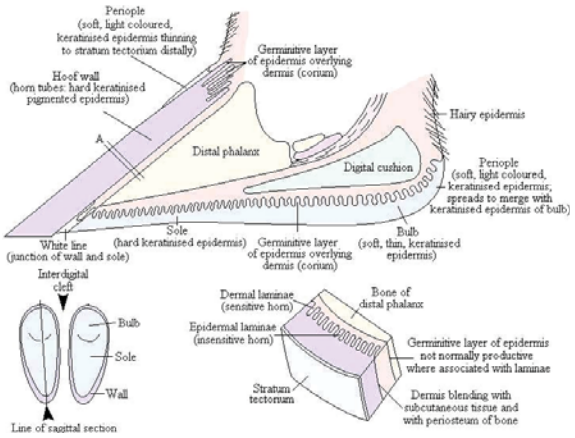

Figure 6. Anatomy of the Sheep's Foot [6]

of the blue sheep especially the feet of the blue sheep, a quadruped robot, which is able to walk, run, jump and climb as well as cross mountains, rocks and cliffs, inspired from the blue sheep is beneficial to design and develop for various application on civilian and military as well as space exploration.

1.3 Related Work

Currently, there have been few studies on blue sheep. A dynamic analysis method on limbs of blue sheep is presented in [11] and a moving image process method of blue sheep based on Matlab is provided in [20]. A research on walking mechanisms inspired from goats is presented in [22], which provides a method to get the data of the motion of the goat using a high-speed camera and discuss the design and development of a bionic goat walking machine. A kinematics analysis of the blue sheep gait in Helan Mountain is provided in [13] and in [24], it provide design and kinematics analysis of a bionic mechanical goat hoof. A terrain adaptability mechanism of large ruminants' feet is presented on the kinematics view in [23].

A kind of bio-inspired blue sheep foot has already been designed and the prototype has been built by Beihang University as Fig 7 [7] shows. It is designed as a completely passive adaptation foot which means there is no actuator for it since the blue sheep's hoof has a small size and a drive system will make the mechanism too large or heavy. There are two symmetrical hooves with the central concave shape which is hard outside and soft inside. Additionally, the two cloven hooves have the same structure. The foot can

Figure 7. Prototype of the Bioinc Foot Inspired by Blue Sheep [7]

rotate and form a V-shape or an inverted V-shape with two symmetrical oblique hinges as ankle joints. The foot is able to form a V-shape (see Fig. 8 [7]) to increase resistance when moving downhill and form an inverted V-shape, as Fig. 9 [7] shows, to increase climbing force when moving uphill. [7]

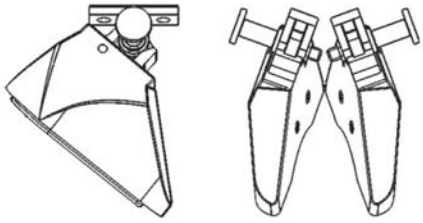

Figure 8. V-shape of the CAD Model of the Prototype [7]

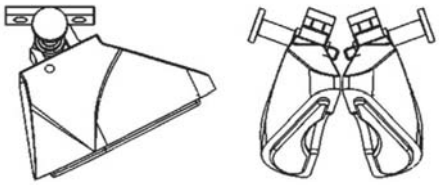

Figure 9. Inverted V-shape of the CAD Model of the Prototype [7]

2. PROPOSE ARCHITECTURE

There are lots of groups and labs designing and developing bio-inspired robots according to the animals' advantageous features, for example, bionic birds, bionic geckos, bionic cockroaches, etc. Based on the advantageous features of blue sheep discussed in last section, a concept of four legged robot inspired from Blue Sheep is proposed to be developed. The bio-inspired blue sheep robot (*BlueSheep*) should have most of the features of the real blue sheep, which means the BlueSheep should be able to walk and run on mountains and rough terrains as well as rock surfaces, jump, climb and cross mountains and cliffs.

In order to obtain those advantageous features, the BlueSheep should have an excellent balance ability as well as

legs and feet that able to "stand" on the rough terrain during walking, jumping and crossing the cliffs. A control system and suitable legs and feet design need to be developed to operate in the rough environment (i.e. mountain, cliff). A high-level controller is needed to analyze the surrounding data in order to control the legs mechanism; and several sub-control systems which include the control system of the legs and feet and other parts of the body. Various of sensors, such as distance sensors, orientation sensors, altimetric sensors, GPS, force sensors and so on, may be added for obtaining different kinds of data. The legs may have special structures which are able to generate enough force and specific locomotion of the real blue sheep. The feet may have those features of blue sheep already discussed in this paper and be able to be actuated to emulate the motions and abilities of the blue sheep.

3. FUTURE WORK

There is quite a lot work need to do for achieving the goal of building the BlueSheep. The first step is that design a leg with the foot for the BlueSheep including the structures and the control system of the leg. During that time, we may cooperate with the lab from BeiHang University to use and improve the feet they built. After that, four legs of the BlueSheep are able to design and build with simple modification. Then the whole body will be designed and built and the whole control system will be designed and developed.

4. SUMMARY

Bio-inspired robots especially the bio-inspired walking robots and the features of the blue sheep are discussed in this paper. Many work related to blue sheep is presented. A conceptual idea in developing a 4 legged robot inspired by blue sheep called BlueSheep and the plan of future work are presented in this paper.

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