STEELbot: Sprawling Type Energy Efficient Locomotion *A Quadruped Robot*

A Robot Modelling Project
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***Abstract*—A quadruped robot is a mechanical structure that walks on four legs. It can be of two types: (a) Mammal-type or (b) Sprawling-type. Mammal-type walking is like a cat or a dog walking whereas sprawling-type is inspired by the gait of a spider. This project presents an energy efficient walking design of a sprawling-type robot. The STEELbot is inspired by ETH Zurich's Titan-XIII & my previous REDIPS robot design. Unlike the mammal-type posture, the upper limbs in the sprawling-types are horizontal. Such four legged system differs from a typical three legged system in terms of dynamic walking. Unlike a tripod system, a quadruped can be dynamically stable (when at rest) if dynamic control system is applied. Using passive dynamic walking, maximum efficiency can be achieved as the robot uses its own momentum for the subsequent step. Sprawling type robots have generally lower center of gravity than the mammal type robots. This increases both stability and efficiency of the system. In this project, I aim to model a basic sprawling type quadruped robot and simulate a trot gait algorithm.**

I. Introduction

In order for a quadruped[1] to be stable, the walking algorithms needs to be precised. At any time (while walking), only three legs are on the ground to provide the stability[1] to the robot. These three legs should form a tripod configuration on the ground in order to have a dynamically stable quadruped robot [2]. For these three legs, the point on the ground (end effector of each leg) is the ground frame. In other words, a quadruped robot is a set of four robotic arms with no common fixed point in space *(Fig.1)*. In *Fig.2*, you can clearly see that each arm (or leg) possesses three revolute joints- hip, knee and foot. Technically, each leg is an RRR manipulator with a negligible shoulder offset[3]. This seems complex but the target is achievable.

II. Gait Algorithms

Stability is the most important criteria when it comes to a four legged robot. One of the basic alternating diagonal walk is known as the creep gait (also referred to as crawl; some call it the static stable gait). It is a bio-inspired algorithm from animals like deer and cat. In creep gait, the subject keep the body fully erect and lift each of the leg high in order to clear the objects. Now, for stability during walking, it is important to be in a tripod stability mode *i.e.* at moment, when one leg is in not in contact with ground, the center of gravity of the robot must lie inside the triangle formed by the other three end effector. Thus, the grounded legs are maintained in a geometry that keeps the center-of-mass of the body inside the triangle formed by the 3 points of the tripod at all times. As the suspended leg moves forward, the tripod legs shift the body forwards in synchrony, so that a new stable tripod can be formed when the suspended leg comes down[5].

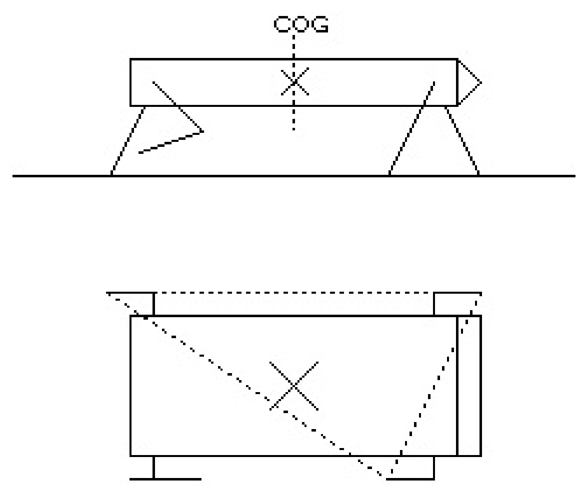

Fig. 1. Simple wire model of a four legged robot

A. The Timing Diagram

The creep gait works with 4-beat timing. One leg at a time, starting with the right-rear, picks up and moves forward and down during one beat, and then slowly moves backwards during the next 3 beats. During the second beat, the front leg on the same side goes through the same motion. During the 3rd beat, the rear leg on the opposite side does the same. Finally, the front leg on the opposite side does similar, during the fourth time beat[6]. The cycle repeats, and forward motion continues.

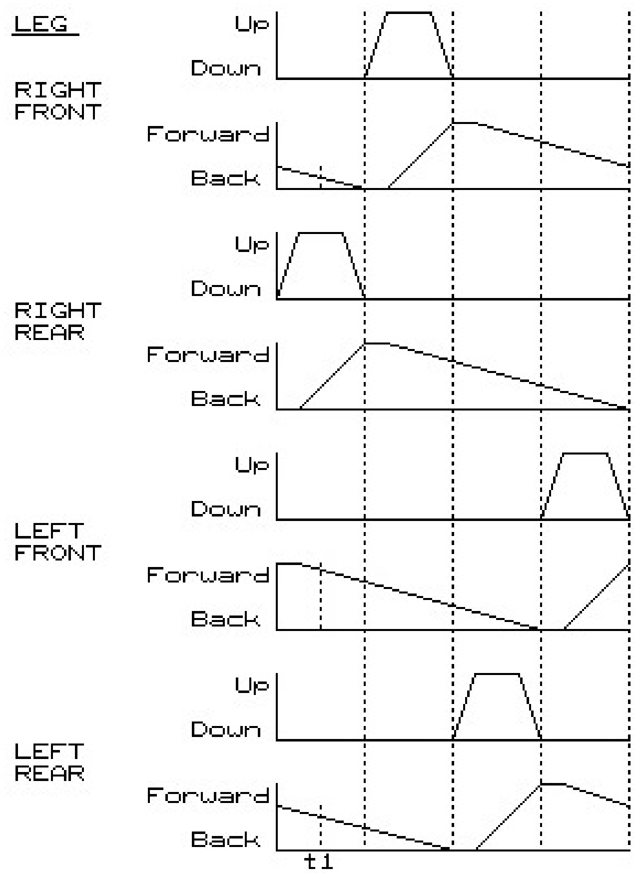

Fig. 2. Creep Gait Timing Diagram

B. Stability Criteria

The creep gait algorithm is stable "enough" for the locomotion in four leg robot since three legs form a stable support tripod whenever one of the leg is suspended. Deers do not face much problem with creep stability as they have very long legs as compared to their body dimensions. Thus, keeping the center of gravity within the triangle of stability formed by the 'on-ground' three legs is easy. Therefore, longer the legs are, easier it is to keep the robot stable.

III. Implementation

A quadruped was first designed on a CAD software: Autodesk Inventor 2017 and then imported using Matlab Simulink plugin for Inventor. The .xml was extracted in matlab and the 3D model was thus constructed. Each leg of the quadruped has 3 degrees of freedom, making it total to 12 degrees of freedom.

Using SimMechanics, I tried to simulate according to the timing diagram as shown in Fig. 2. Simulation files and video of the simulation are attached in the zip file.

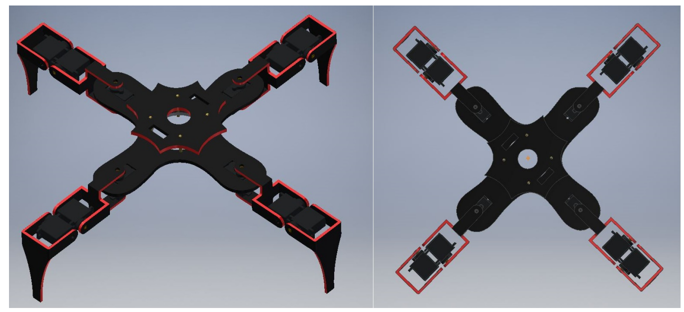

Fig. 3. Perspective and top view: Shaded with hidden edges

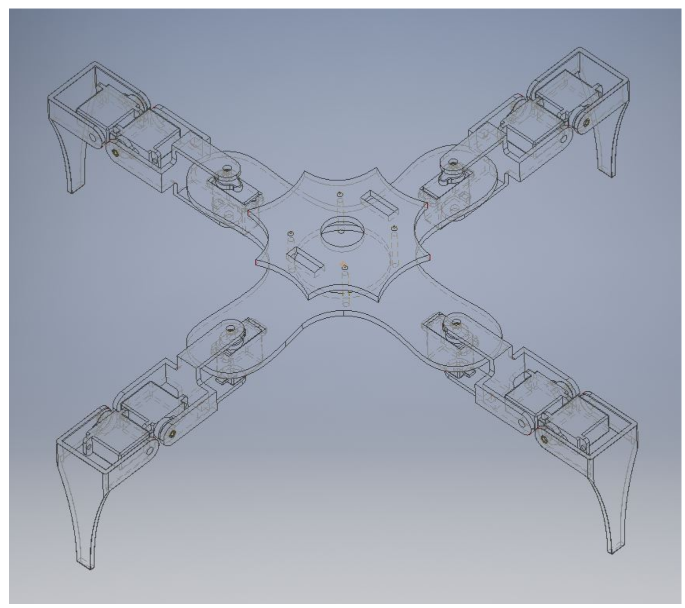

Fig. 4. Perspective view with Hidden Edges

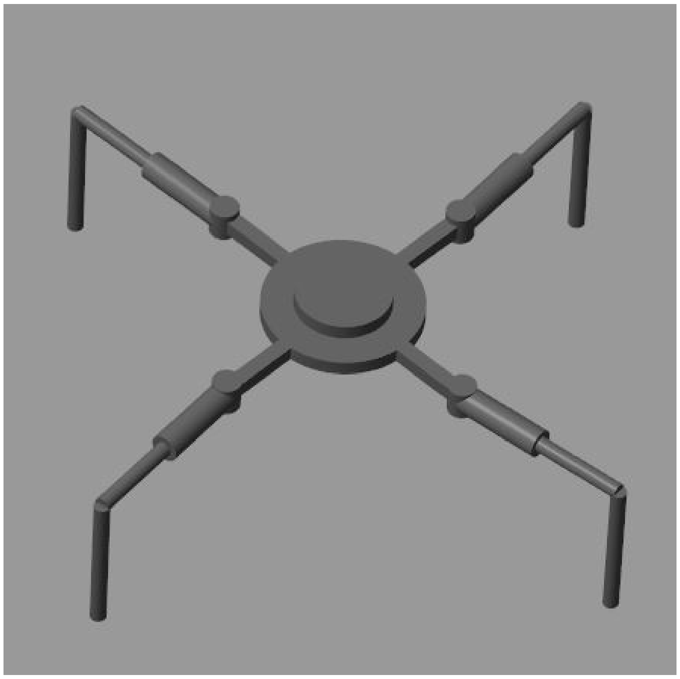

Fig. 5. Quadruped frame drawn using SimMechanics

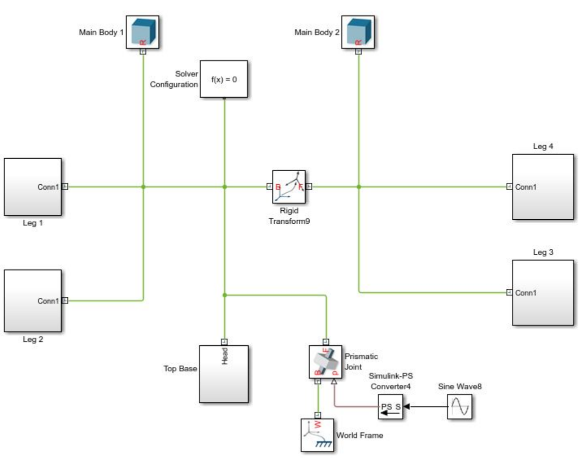

Fig. 6. Block Diagram of the system

CONCLUSION

STEELbot was successfully modelled using Inventor and SimMechanics.

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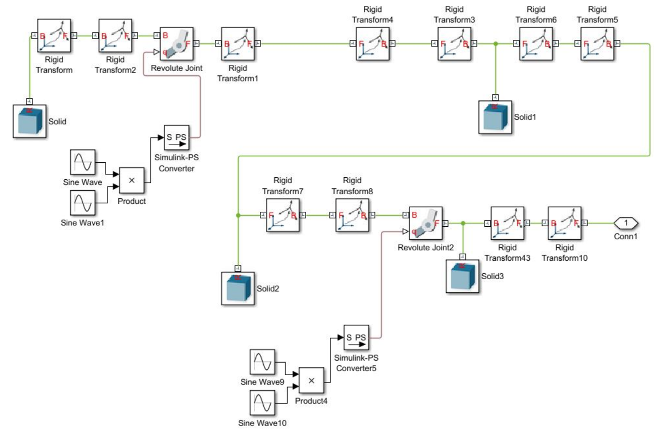

Fig. 7. Detailed block diagram of one single leg

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