Proposition and Implementation of Imaginary Membrane Locomotion: omni-directional crawling locomotion for shape changing robot

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I. INTRODUCTION

A versatile locomotive system for uncertain rough terrain is one major challenge of mobile robotics, and Shape changing locomotion by shape changing robots have recently been focused as one answer towards it.

The thee popular types of shape changing robots include Tensegrity, Side Actuating, and Spiny Multipedal (Fig. 1).

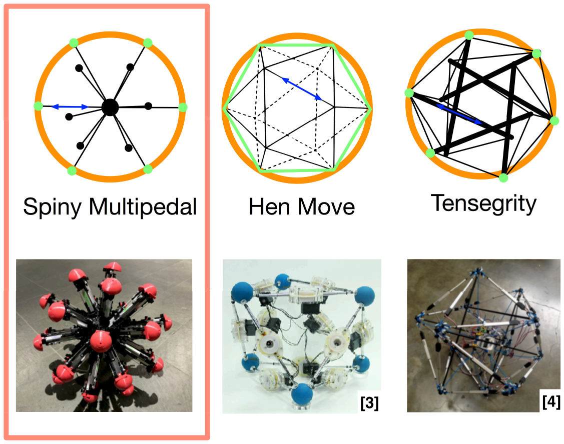

Fig. 1. 3 types of shape changing robots

The most popular locomotion method for these shape changing robots right now is rolling motion. This locomotion works as follows:

1. Robot will assign one of its surface of its "primitive" as contact surface (resting phase)
2. Robot will transform and move its center of mass out of boundaries of contact surface (transforming phase)
3. Robot will start rolling, and contact surface disappears (transition phase)
4. Robot will fall to another surface, making that surface the new contact surface (resting phase again)

Yet this method is very simple and straight forward, it constrains the locomotion and pass planning greatly through the primitive of the shape changing robot. Here, the primitive refers to the three dimensional shape polyhedron which are represented by connecting the contacting part of robot body. Our Spiny Multipedal robot's pedal tip will represent edge of rhombic triacontahedron, for example. Usually, primitive of a shape changing robot is regular or semi-regular polyhedron itself or its dual polyhedron.

II. IMAGINARY MEMBRANE LOCOMOTION

In this paper, we will introduce the new shape changing robot's locomotion method called Imaginary Membrane Locomotion (IML) which frees the locomotion from restriction of robot's primitive(Fig.2^a).

In prior to explain this method, we will introduce two new concepts to represent the state of the robot: Imaginary Membrane and Imaginary Contact Surface.

Imaginary Membrane (IM) can be defined as an smooth two dimensional surface that represents a desired contacting surface of any shape of the robot. In IML, robot will be controlled in a way that all its "contact points" will be placed on this membrane. These contact points will act as components of approximated IM, and increased number of contact points will result in higher resolution of approximation. The configuration of the robot which will accomplish this approximation will be decided uniquely based on the relative angle between IM and robot.

Imaginary Contact Surface (ICS) is a special type of IM which is assigned to contact with the ground for the purpose of IML. The characteristic of the ICS will be decided responsively with the condition of the terrain.

In the IML, robot will first expand its IM according to terrain creating ICS of appropriate area the it will update the relative angle between self and IM, resulting in update of its state to approximation of IM. As a result, friction between contact points that are located on ICS will push the whole body forward using IM like an omni-directional crawler.

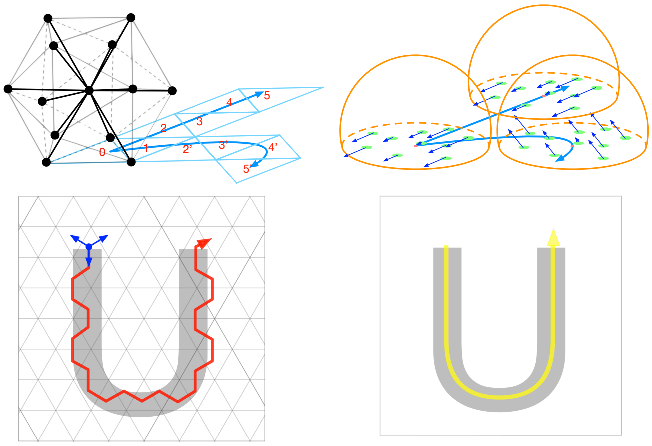

Fig. 2. Difference in motion and path

Through IML, we have managed to increase the degree of freedom in its path from one to two. In the former

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approach, the path of robot was constrained highly by shape of robot's primitive. Lets take the robot with primitive of regular icosahedron (Fig3 (a)) as an example. As it's surface is triangle, from the resting stopped position it can only move in 3 direction, and once its out of resting phase it can not change the direction until it reaches the next resting phase. Also, its whole path has to be defined by combination of such movement, resulting in low resolution path which can not even draw a straight line. In contrast, IML can move to any direction in any point of time. As it does not have transition phase, its movement is much smoother and free. The improvement of the locomotive freedom can be seen clearly from Fig. 3.

III. OUR CONTRIBUTION

In order to prove this concept, we have developed a Spiny Multipedal robot with primitive of rhombic triacontahedron (Fig. 1, (a)). Although IML is applicable to all three different shapes of shape changing robot, we chose the Spiny Multipedal as it required the minimum extension rate of an actuator. This robot consists of 32 legs with actuators, and all the actuation and power supply systems are self contained with a microcomputer which receives signal from outer simulator.