Application of Waves displacement algorithms for the generation of gaits in an all terrain hexapod

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Abstract

Gait generation for legged robots has been studied since decades. Different ways of generating them for rough terrain have been proposed with more or less success. Here we propose a method for gait generation based on triple periodic functions, which parameters are automatically altered to ensure a smooth walking over rough terrain.

Keywords: gaits, hexapod, rough terrain.

1 Introduction

Since decades legged vehicles have been identified as the way of overcoming obstacles [1], [2], [3], [4] instead of other ways like using wheels or treads. Although many studies have been published about the gait generation for legged robots in rough terrain, the problem of making robots walk smoothly over any kind of terrain is still under consideration. In this work we will explain a gait generation method applied to an hexapod that will give to it the capability of walking over rough terrain, adapting the gait to the surface while the body of the robot continue moving with no alteration on its linear speed, direction and elevation.

This method has been applied to the robot Melanie-III [5] developed by the author, demonstrating its practical results.

The gait explained in this document is in base a periodic gait, that is altered in order to adapt it to the obstacles [6]. Therefore we get a sort of free gait [7] while walking over rough terrain, that becomes periodic when the robot walks on flat terrain.

2 The periodic gait generation algorithm

The algorithm is based on the determination of the point *(x,y,z)* in the space of the extreme of each leg (see **Fig. 1.**).

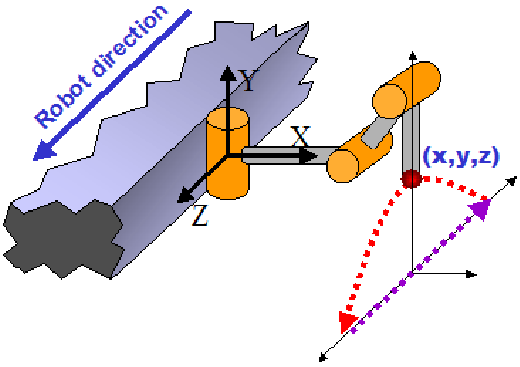

Fig. 1. Leg movement

The generation of such points is based on the displacement of three functions in time. Each function is defined as *f1(t)*, *f2(t)* and *f3(t)* that determines the value of each of the coordinates *x*, *y* and *z*.

The functions are all of periodic sort and may be altered in phase, amplitude and wave length.

Therefore the equation (1) of movement could be defined as the matrix:

$$f(t) = (f1(t), f2(t), f3(t)) \qquad (1)$$

Such function gives the position *(x,y,z)* in the space of the extreme of each leg.

As it was our intention to implement a system as simple as possible, we decided to use a function that simply moves each leg backwards in parallel to the body when the leg is touching the floor and then trace an arc with the leg to the front (see **Fig. 1.**)

One of the function that makes this movement possible is one were:

- The *x* component is always constant in order to make the extreme of the leg move always parallel to the body (see **Fig. 2.**),
- The *y* component is a half sinusoidal wave, so it traces an arc when going to the front, while maintaining the position when moving backwards (see **Fig. 2.**) and

- The *z* component is a sinusoidal wave that makes the leg move from back to front and front to back (see **Fig. 2.**).

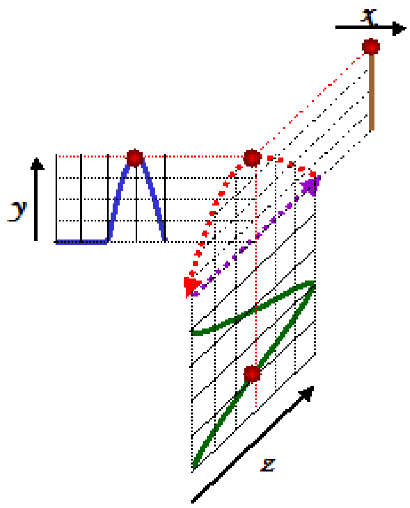

Fig. 2. Function of movement

At each moment *t* in time it is calculated the result of the three functions, obtaining the coordinates of the extreme of the leg. Then inverse kinematics algorithms are applied [8] in order to move the three motors of each leg to the correct angle.

Modifying the phase out between legs, and therefore between their functions, and changing the shape of the wave it is possible to get different gaits for the robot to walk. Again, as we are looking for the simplest way of implementing and demonstrating the method, we have used the tripod gait, which is obtained just ensuring a phase out of 180º in three legs in respect to the other three (see **Fig. 3.**).

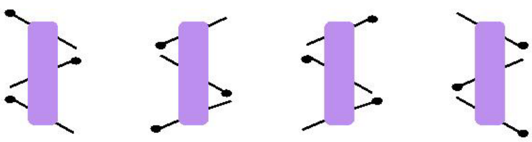

Fig. 3. Steps using tripod Gait

Up to now this method allow us to make the robot walk in flat terrain with a tripod gait, although we have the possibility to change the parameter to walk with different gaits. In next section we will explain how to use this method also to walk on rough terrain.

3 Rough terrain gait algorithm

As explained in the previous section, the coordinates of the legs are obtained from three functions (see **Fig. 4.**).

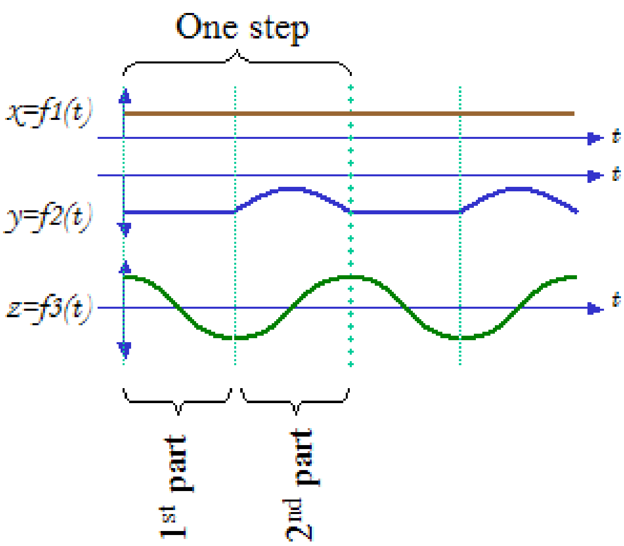

Fig. 4. Three coordinate generator functions

Varying the phase out between the waves of the different legs and the relation between the length from the first part and second part of the cycle of the wave different gaits are obtained.

The first part of the cycle corresponds to the moment at which the end of the leg is touching the ground and moving backwards (body advancing), whereas the second part of the cycle corresponds to the elevation and displacement ahead in arc of the leg (positioning for a new step). Thus for example in the previous figure, the first and second part of the cycle is of the same length (in time), so it will take the same time in moving backwards the leg than in positioning it again ahead.

The robot is prepared for the detection of obstacles on the ground and to adapt the gait to walk over these obstacles.

The way it is done is by measuring the pressure sensors values at the moment each leg is going down to put its end on the ground.

If the pressure measurement is over a given threshold, the leg stops a fraction of second, its position is obtained and the parameters of the functions are suitably altered to overcome the obstacle (see **Fig. 5.**).

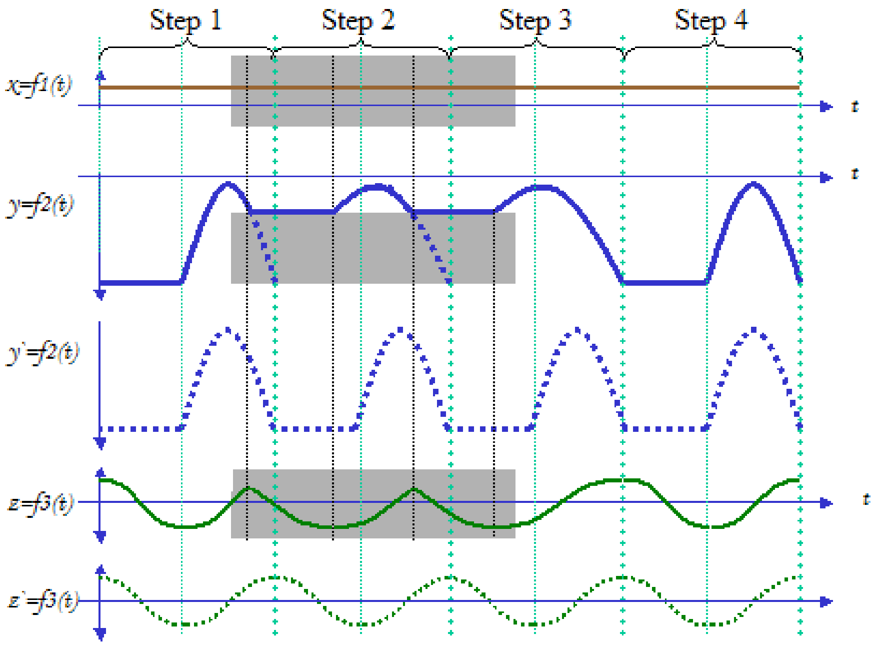

Fig. 5. Functions altered by an obstacle (grey area)

f1(t) is not altered and remain constant as in any case the leg will continue moving parallel to the body.

f2(t) and *f3(t)* are affected by the obstacle (grey area). The obstacle of the figure is long enough to affect to consecutive steps. As it could be seen, the obstacle is reached in the second part of the first step. This means, when the leg was moving forward in arc and going down. Therefore the evolution of the second part of the cycle could not continue and hence the leg start moving backwards over the obstacle (first part of the next cycle hence next step). The first part of a cycle is always of the same length because this ensure that all legs move at the same speed while they are on the ground, so the robot could continue moving smoothly with no slip of the legs. After the first part of the cycle is complete, the second part of the cycle starts, but this time the wave length is increased to make possible the leg to go to it's original position if no obstacle is detected. In the case shown in the figure, an obstacle is again detected by the leg, so the process is repeated. After the obstacle is overcome, the leg goes to the original position and the parameters of the functions are normalized, with no disruption in the continuity of the waves during the transition.

x, y, z show the functions affected by the obstacles while *x, y'* and *z'* show how would evolve the functions in time if no obstacle would have been detected, so it is possible to compare both cases in one graph.

The result is that applying this algorithm, the robot could walk over many kind of complex surface.

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