Apollo3D Team Description Paper

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Abstract. Apollo3D is a team in RoboCup soccer simulation 3D league. We mainly aim at building a systematical architecture of intelligent and skillful robots. During the past year we achieved to create the new cooperation tactics to handle the current vision. The 9vs9 version requires a more and better complicated tactic to avoid robots's being in a disorder. And given to the noise added to the server, Apollo3D Soccer Simulation Team adopts another new method of localization, WorldModel construction and OppModel construction. Based on the solution of inverse kinematics of a leg by combining analysis method with numerical method, trajectory planning method is used to implement the humanoid robot walking skill in the 3D simulation environment, and also Omni-directional walk under certain conditions is achieved.

1 Introduction

Apollo Simulation 3D Team was established in 2006, and successfully attended several competitions. We have won the 1st place in Robocup 2010 and the 3rd place in Robocup 2011 recently. The Nao robot is much like the real robot. This creature attracts a large amount of students to devote to the research field. Thanks to the devotion and cooperation of these students, several achievements had been achieved in the past year. In the following section2, the new method of localization is presented.

Biped walking pattern is one of the most difficult problems in the humanoid robot area, and there exists no ideal algorithm for a generalized walking scenario. The method for planning walking patterns is presented in section 3. The new tacitic will be shown in section4. It is followed by conclusion and future work in section 5.

2 Localization

We have the same vision mode with last year's. According the feature of the vision mode, we gain the equation as follow:

$$(x-x_1)^2+(y-y_1)^2+(z-z_1)^2=r_1^2 \tag{1}$$

where x, y and z that are describe as (x, y, z) is the position of the center of the robot, and x_1,y_1,z_1 that describe as (x_1, y_1, z_1) is the position of the flag namely of the field in the Fig.1. And r_1, r_2, r_3 that describe as (r_1, r_2, r_3) is the distance between the center of robot and the flag of the field. So we gain one equations set including eight equations.

Thanks to the same height for z direction of all the flags of the field, we can solve the x or y easily form of two equations of the equations set that have the same y or x. For example choosing two equations formed from flag F_L_1 and flag F_L_2, we can calculate the y directly. To improve the accuracy, we select the equations with the same x coordinates to calculate the y coordinates, and then take average. The final result will be the y coordinates of the center of the robot. As the same way, we can also gain the x coordinates of the centered.

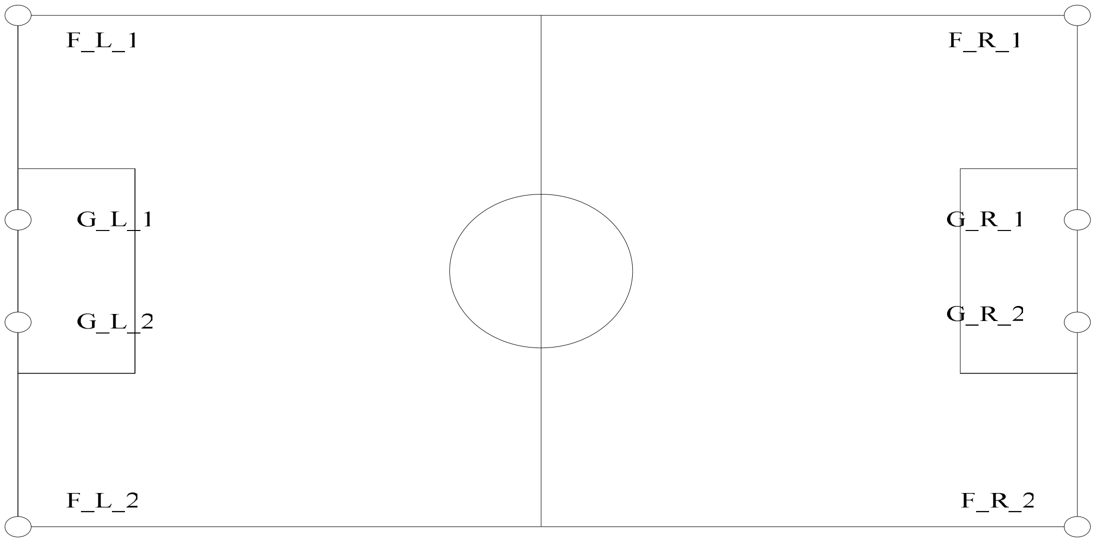

Fig.1 The sketch map of the field

3 Walking Trajectories

See Fig.2, each foot trajectory can be denoted by a vector $\mathbf{X}_a = [x_a(t), z_a(t), \theta_a(t)]^T$, and the hip trajectory can be denoted by a vector $\mathbf{X}_h = [x_h(t), z_h(t), \theta_h(t)]^T$.

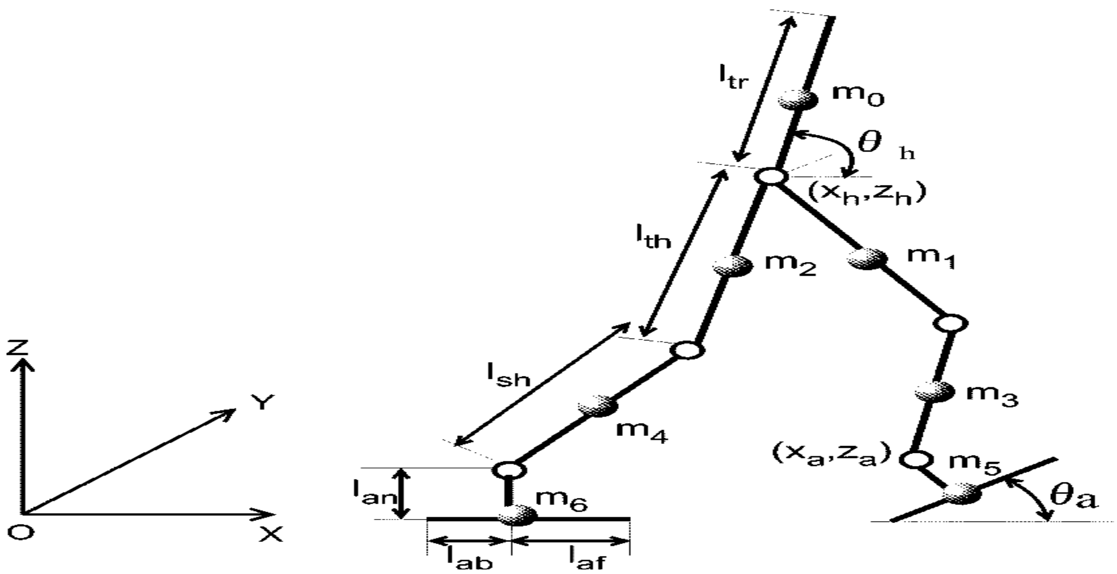

Fig.2 Model of the biped robot

3.1 Foot Trajectories

Assuming that the period necessary for one walking step is T_C, the time of the K_{th} is from kT_c to $(k+1)T_c$, $k=1,2,...,K$, K is the number of steps. To simplify our analysis, we define the K_{th} walking step to begin with the heel of the right foot leaving the ground at t=kT_c, and to end with the heel of the right foot making first contact with the ground at t=$(k+1)T_c$. In the following, we discuss only the generation of the right foot trajectory. The left foot trajectory is same as the right foot trajectory except for a T_C delay.

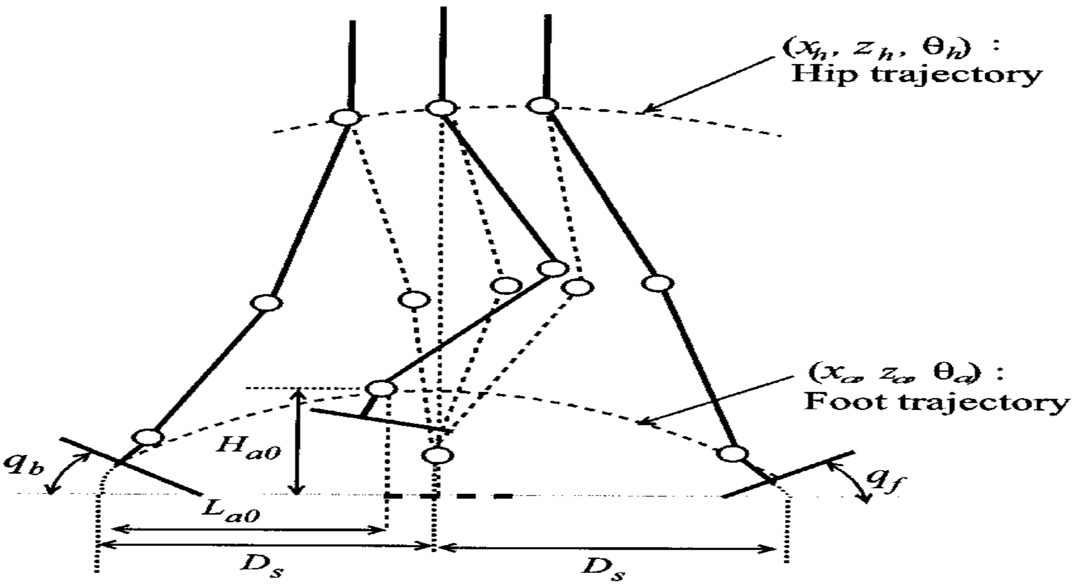

Fig.3 Walking parameters

See Fig.3, letting q_b and q_f be the designated angles of the right foot as it leaves and lands on the ground respectively. Assuming that the entire sole surface of the right foot is in contact with the ground at t=kT_c and $t=(k+1)T_c+T_d$, we get the following constraints:

$$\theta_a(t)=\begin{cases} q_{gs}(k), & t=kT_c \\ q_b, & t=kT_c+T_d \\ -q_f, & t=(k+1)T_c \\ -q_{ge}(k), & t=(k+1)T_c+T_d \end{cases} \quad (2)$$

Where T_d is the interval of the double-support phase, q_{ge} and q_{gs} are the angles of the ground surface under the support foot, particularly $q_{ge}=q_{gs}$=0 on level ground. The following constraints must be satisfied.

$$x_a(t)=\begin{cases} kD_s, & t=kT_c \\ kD_s+l_{an}\sin q_b+l_{af}(1-\cos q_b), & t=kT_c+T_d \\ kD_s+L_{ao}, & t=kT_c+T_m \\ (k+2)D_s-l_{an}\sin q_f-l_{ab}(1-\cos q_f), & t=(k+1)T_c \\ (k+2)D_s, & t=(k+1)T_c+T_d \end{cases} \quad (3)$$

$$z_a(t)=\begin{cases} h_{gs}(k)+l_{an}, & t=kT_c \\ h_{gs}(k)+l_{af}\sin q_b+l_{an}\cos q_b, & t=kT_c+T_d \\ H_{ao}, & t=kT_c+T_m \\ h_{ge}(k)+l_{ab}\sin q_f+l_{an}\cos q_f, & t=(k+1)T_c \\ h_{ge}(k)+l_{an}, & t=(k+1)T_c+T_d \end{cases} \quad (4)$$

Where D_s is the length of one step, kT_c+T_m is the time when the right foot is at its highest point, l_{an} is the height of the foot, l_{af} is the length from the ankle joint to the toe, l_{ab} is the length from the ankle joint to the heel, $h_{ge}(k)$ and $h_{gs}(k)$ are the heights of the ground surface which is under the support foot, particularly $h_{ge}(k)=h_{gs}(k)$ =0 on level ground.

Since the entire sole surface of the right foot is in contact with the ground at $t=kT_c$ and $(k+1)T_c+T_d$, the following derivative constraints must be satisfied:

$$\begin{cases} \dot{\theta}_a(kT_c)=0 \\ \dot{\theta}_a((k+1)T_c+T_d)=0 \end{cases} \quad (5)$$

$$\begin{cases} \dot{x}_a(kT_c)=0 \\ \dot{x}_a((k+1)T_c+T_d)=0 \end{cases} \quad (6)$$

$$\begin{cases} \dot{z}_a(kT_c)=0 \\ \dot{z}_a((k+1)T_c+T_d)=0 \end{cases} \quad (7)$$

To generate a smooth trajectory, it is necessary that the first derivative (velocity) terms $\dot{x}_a(t)$ and $\dot{z}_a(t)$ be differential, the second derivative (acceleration) terms $\ddot{x}_a(t)$, $\ddot{z}_a(t)$ and $\ddot{\theta}_a(t)$ must be be continuous at all t.

3.2 Hip Trajectories

From the viewpoint of stability, it is desirable that hip motion parameter $\theta_h(t)$ is constant when there is no waist joint; in particular, $\theta_h(t) = 0.5\pi$ rad on level ground. Hip motion $z_h(t)$ hardly affects the position of the ZMP. We can specify $z_h(t)$ to be constant, or to vary within a fixed range. Assuming that the hip is at its highest position $H_{h\max}$ at the middle of the single-support phase, and at its lowest position $H_{h\min}$ at the middle of the double-support phase during one walking step, $z_h(t)$ has the following constraints:

$$z_h(t) = \begin{cases} H_{h\min}, t = kT_c + 0.5T_d \\ H_{h\max}, t = kT_c + 0.5(T_c - T_d) \\ H_{h\min}, t = (k+1)T_c + 0.5T_d \end{cases} \tag{8}$$

The trajectory of $z_h(t)$ that satisfies (8) and the second derivative continuity condition also can be obtained by third spline interpolation. The change of $x_h(t)$ is the main factor that affects the stability of a biped robot walking in a sagittal plane. The defects of these methods are that not all desired ZMP trajectories can be attained and the hip acceleration may need to be very large. To solve these problems, we propose a method consisting of the following steps: 1) generate a series of smooth $x_h(t)$; 2) determine the final $x_h(t)$ with a large stability margin.

A complete walking process is composed of three phases: a starting phase in which the walking speed varies from zero to a desired constant velocity, a steady phase with a desired constant velocity, and an ending phase in which the walking speed varies from a desired constant velocity to zero. First, the hip motion $x_h(t)$ of the steady phase is obtained with the following procedure.

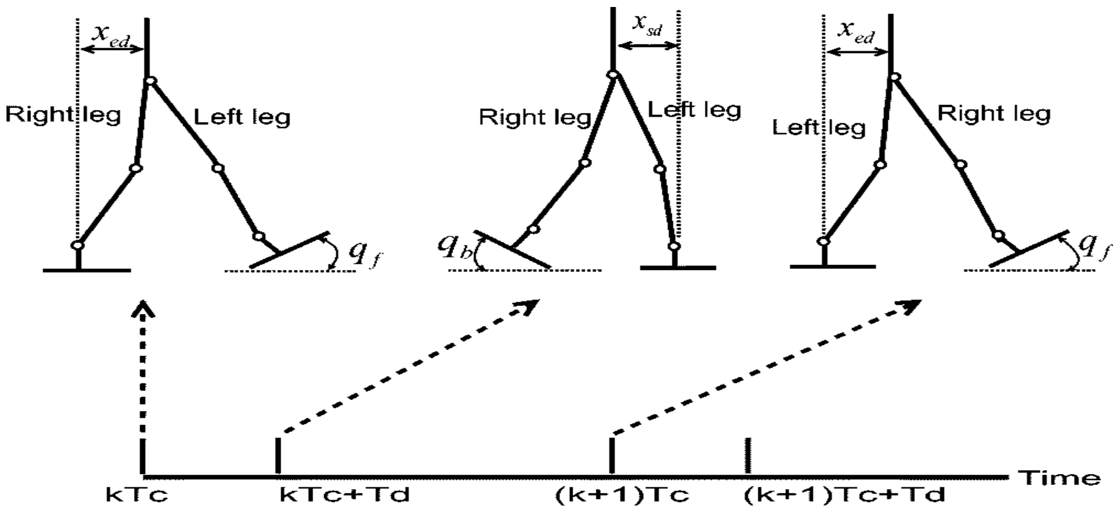

Fig.4 Walking cycle

During a one-step cycle, $x_h(t)$ can be described by two functions: one for the double-support phase and one for the singlesupport phase. Letting x_{sd} and x_{ed} denote distances along the x-axis from the hip to the ankle of the support foot at the start and end of the single-support phase, respectively (See Fig.4), we get the following equation:

$$\mathrm{x}_h(\mathrm{t}) = \begin{cases} kD_s + x_{ed}, t = kT_c \\ (k+1)D_s - x_{sd}, t = kT_c + T_d \\ (k+1)D_s + x_{ed}, t = (k+1)T_c \end{cases} \tag{9}$$

To obtain a smooth periodic $x_h(t)$ of the steady phase, the following derivative constraints must be satisfied:

$$\begin{cases} \dot{\mathrm{x}}_h(kT_c) = \dot{\mathrm{x}}_h(kT_c + T_c) \\ \ddot{\mathrm{x}}_h(kT_c) = \ddot{\mathrm{x}}_h(kT_c + T_c) \end{cases} \tag{10}$$

we obtain which satisfies constraints (9) and (10), and the second derivative continuity conditions is given in (11).

$$x_h(t) = \begin{cases} kD_s + \dfrac{D_s - x_{ed} - x_{sd}}{T_d^2(T_c - T_d)}[(T_d + kT_c - t)^3 - (t - kT_c)^3 \\ -T_d^2(T_d + kT_c - t) + T_d^2(t - kT_c)] + \dfrac{x_{ed}}{T_d}(T_d + kT_c - t) + \dfrac{D_s - x_{sd}}{T_d}(t - kT_c), t \in (kT_c, kT_c + T_d) \\ kDs + \dfrac{Ds - xed - xsd}{Td(Tc - Td)^2}[(t - kTc - Td)^3 - (Tc + kTc - t)^3 - (Tc - Td)^2(Tc + kTc - t) \\ -(Tc - Td)^2(t - kTc - Td)] + \dfrac{Ds - xsd}{Tc - Td}(Tc + kTc - t) + \dfrac{Ds + xed}{Tc - Td}(t - kTc - kTd), \\ \qquad t \in (kTc + Td, kTc + Tc) \end{cases} \tag{11}$$

By defining different values for x_{sd} and x_{ed}, we get a series of smooth $x_h(t)$ according to (11). We specify x_{sd} and x_{ed} to vary within a fixed range, in particular:

$$\begin{cases} 0.0 < x_{sd} < 0.5D_s \\ 0.0 < x_{ed} < 0.5D_s \end{cases} \tag{12}$$

4 More and better complicated tactics

Since the 9vs9 mode has been adopted, it is essential to figure out a systematic tactic instead of a looseness of tactic struct in order to consider more complicated environment. Attack Tactic and defence tactic are available respectively under certain circumstances. Especially defence tactic in our team's own field. Defenders are given different roles when they are in different positions. Robots may adopt different behaviour while opponents is close or far away from the goal. What's more, goalkeeper has been given a more important role with a much more effective block action.

5 Conclusion and Future Work

Humanoid robot research is a popular and trends in robot research, many researchers and engineers focus their research on this field. The planning method in this paper based on given parameters, it is not easy to implement this method to general robots. Our further work will focus on improving the current tactic and building a kind of walking control model of the robot.

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