Bio Robotics project

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Gait analysis in single support phase of 2D bipedal robot

The position of each characteristic points can be found as follow: Mathematically we use the following equation in all cases to find the position of vector in relative to the reference point.

$$ {}^{org}_{p_3}r = {}^{org}_{p_2}r + R_T * {}^{p_2}_{p_3}r $$

${}^{org}_{p_3}r$=is the vector position from the point org (reference) to the desired point (p_3).

${}^{org}_{p_2}r$=is the vector position of point p_2 in relative to the origin.

To describe the position of the p3 in relative to p2 we have to underestimate the rotation of the frames in relative to each other.

I. Heel of left foot:

Considering the reference point in the left heel point, we can find the position of the other characteristic points.

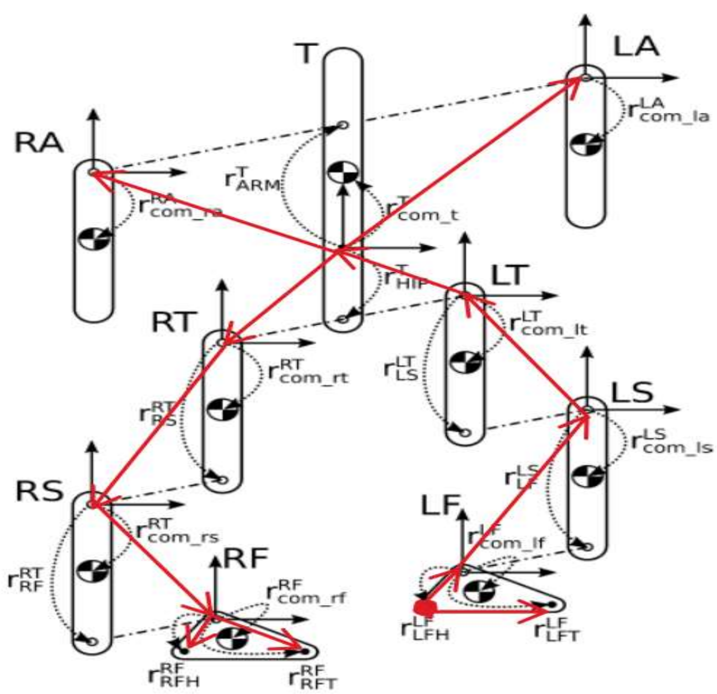

Figure 1: Direction the vectors for position of points from LFH

II. Heel of right foot:

To find the position of each point in relative to the reference of the heel right foot (RFH). we use the direction of green colored position described in the below kinematic description.

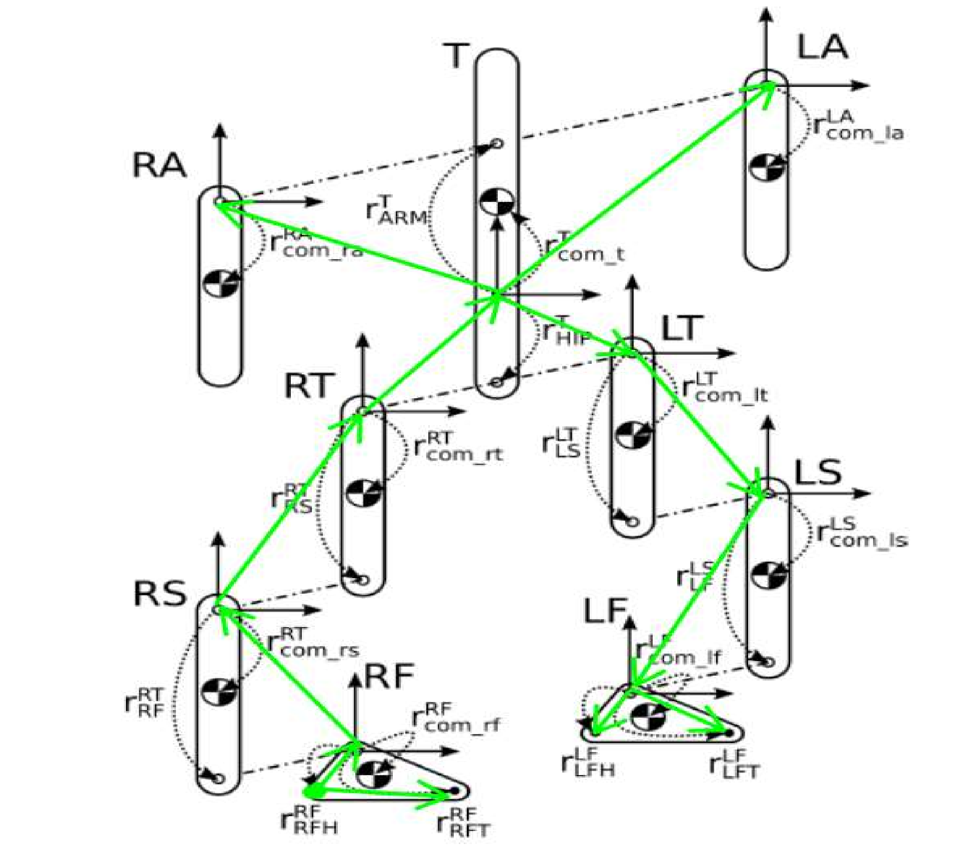

Figure 2: Direction the vectors for position of points from RFH

To determine the velocity and acceleration, we take the differences of the position at each time frames divided by frame rate .in our case which is 0.01. synonymously we have calculated the acceleration by taking the differences for the velocity. ('diff' function in MATLAB)

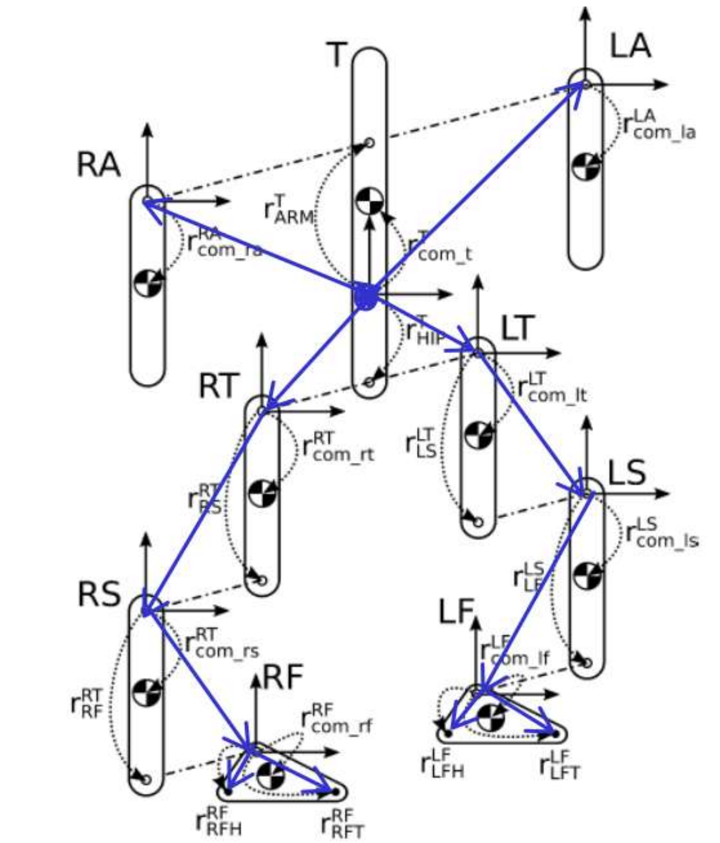

Figure 3: Direction the vectors for position of points from Trunk

Visualization of robot movements from MATLAB

The visualization of the robot in all three cases of references (LFH, RFH, T) for sample single frame is as following

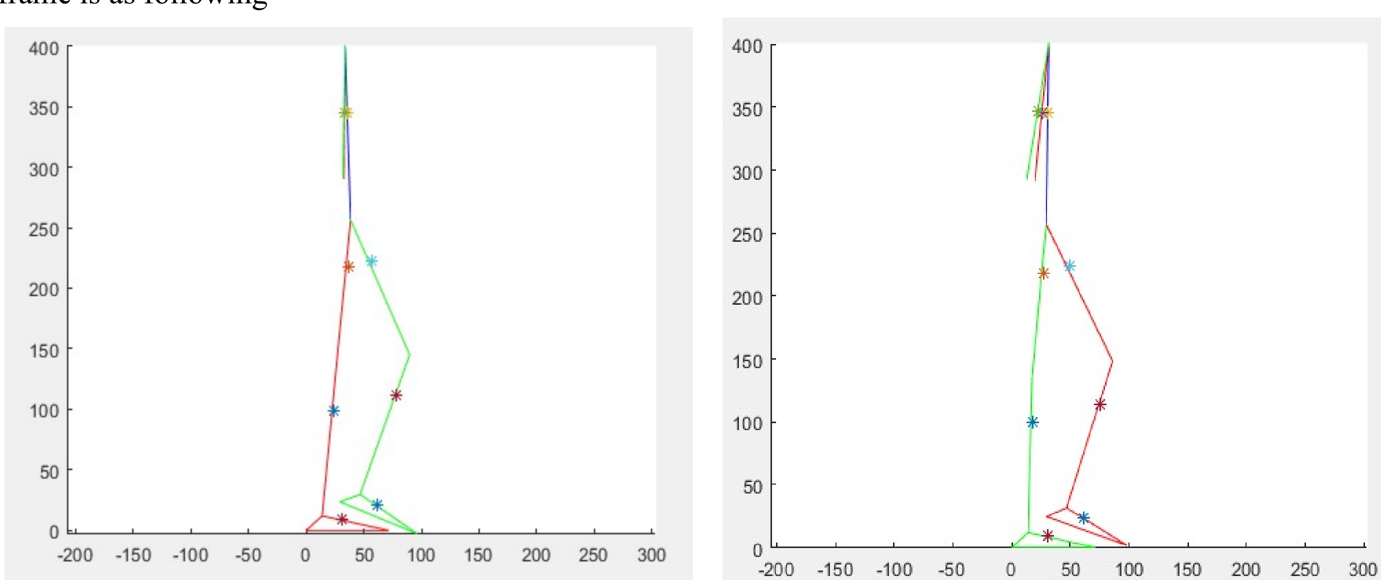

Figure 4 Single stick diagram for single time frame of for LFH and RFH cases

The stick diagram of single time frame for Trunk as reference will be:

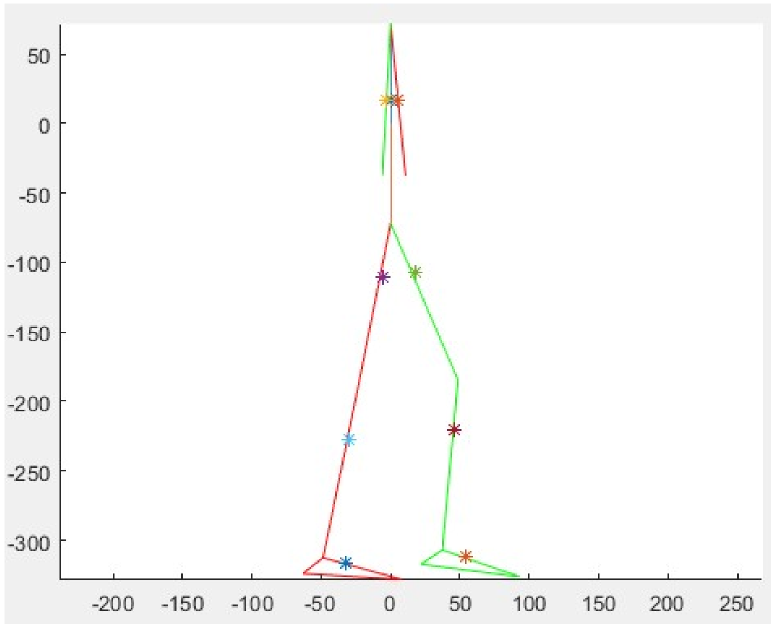

Figure 5 Stick diagram of single time frame in case of trunk reference

The output for visualization incases of all time frames is animated as following. The left part of the walking part is represented by 'red' color while the right part of is green and the trunk in blue.

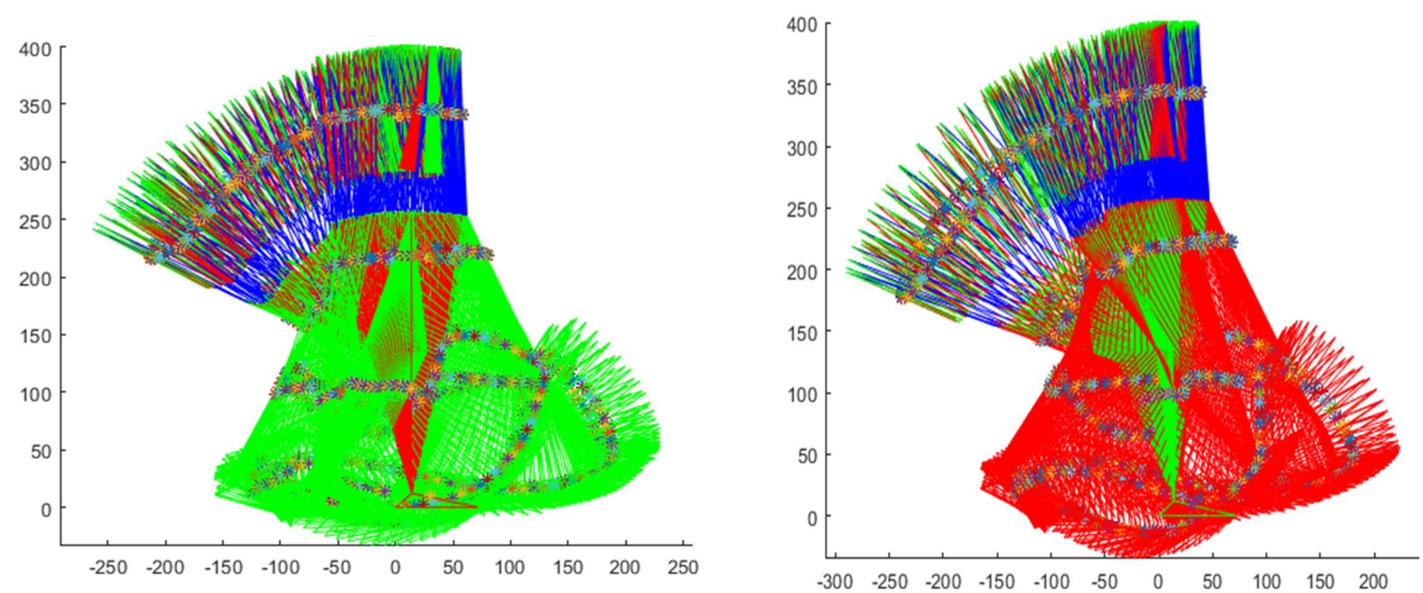

Figure 6 Animation for all time frames in LFH and RFH

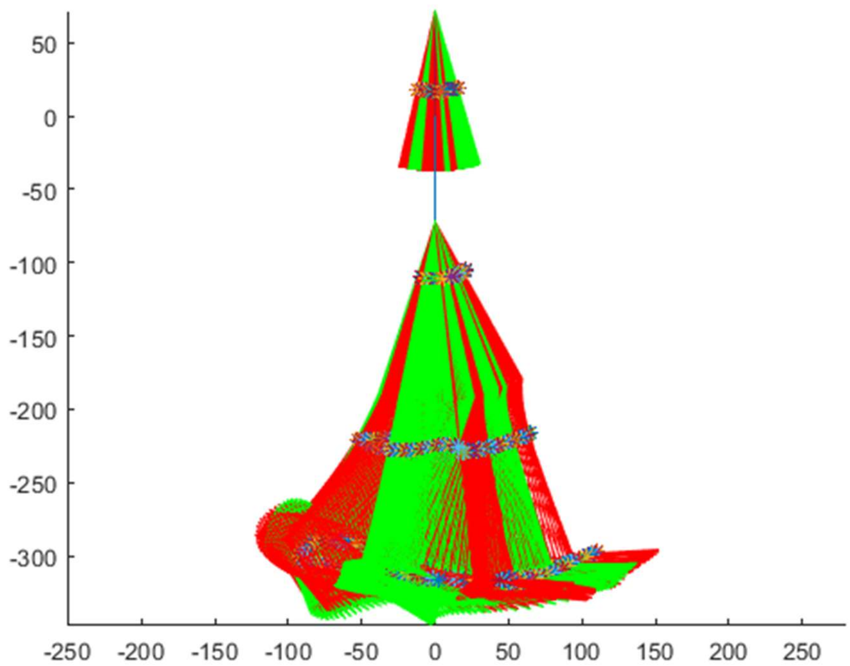

Figure 7 The animation for all time frame in case of Trunk origin

Single phase and double phase determination

To determine the single support phase and double support phase of the walking robot, the angle of knee for both left and right leg is necessary to know.

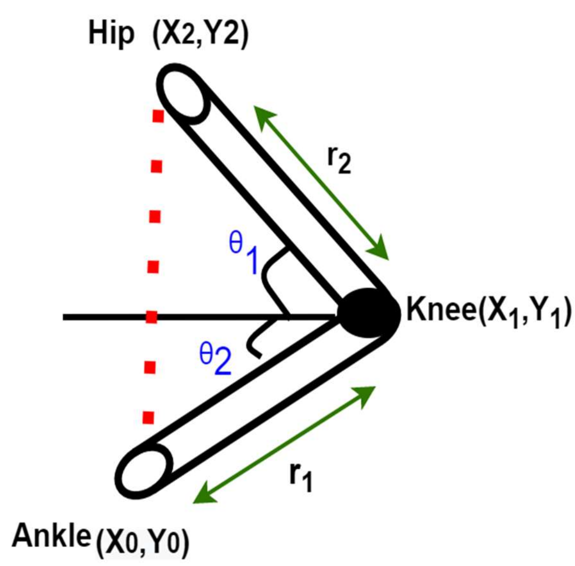

Figure 8 angle of knee

We can find the ankle knee from the above geometric figure. The magnitude vector of r_1 and r_2 are calculated as follow

$$r_1 = (x_2 - x_1, y_2 - y_1)$$

$$r_2 = (x_2 - x_1, y_2 - y_1)$$

Then

$$\theta_2 = Arctan(\frac{y_2 - y_1}{x_2 - x_1})$$

Same method for angle θ_1

$$\theta_2 = Arctan(\frac{y_1 - y_0}{x_1 - x_0})$$

Then finally, the ankle knee will be the sum $\boldsymbol{\theta_2}$+$\boldsymbol{\theta_2}$. Be having this we can have the angle knee difference between left and right legs for determining the single support phase and double support phase of the walking robot. For double support phase we will have small difference angle knees whereas for single support phase have large difference in the angle knees. After plotting and observation we start with initial conditions where we could see clearly in the graph, we had big differences in the knee angel. After observing the visualization of the robot at certain frame we changed our condition in each iteration until we reach the exact limit where the single phase started. For left foot base lower than -12 and bigger than 3. For the right foot base lower than -16 and

bigger than 3 and lower than -18 and bigger than 3 for the trunk.

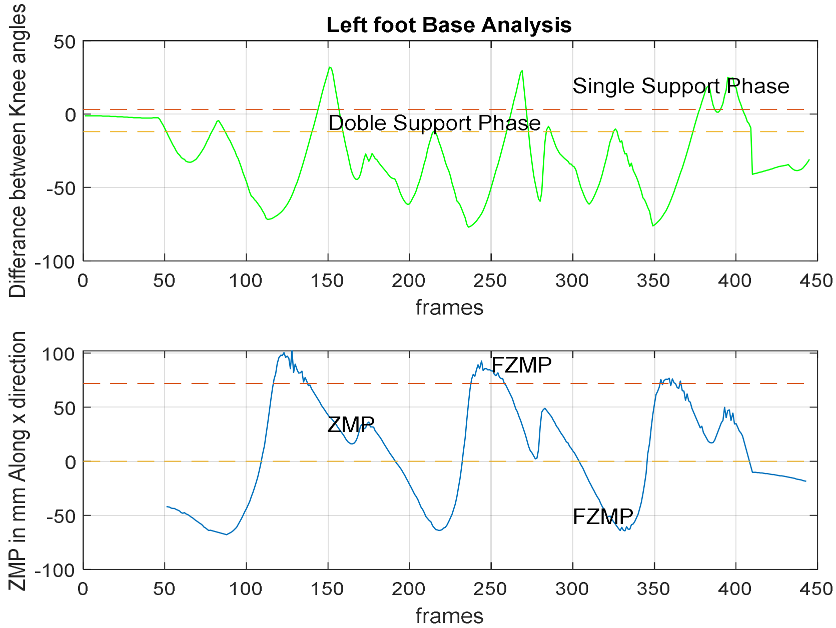

Figure 9 SSP, DSP, ZMP and FZMP in reference to left foot heel

On top of that, we can find also the ZMP and FZMP regions also from the walking robot in all cases. Then, first we have to determine is the region the polygon support in which the ZMP can exist only on this support. Points out of this area are considered to be as FZMP (fictious zero moment point).

The polygon support for single support phase is the area of the foot. Which is in our case it will be the difference between the toe and heel, from 0 to 72 mm in the x direction. For all cases considering references frame of left foot heel, right foot heel and trunk. we have put the results in plot from the MATLAB in figure 8,9 and 10.

To find the ZMP we use the following equation.

$$P_x = \frac{\sum_{i=1}^{n} m_i(\ddot{y}_i + g)x_i - \sum_{i=1}^{n} m_i \ddot{y}_i x_i}{\sum_{i=1}^{n} (\ddot{y}_i + g)m_i}$$

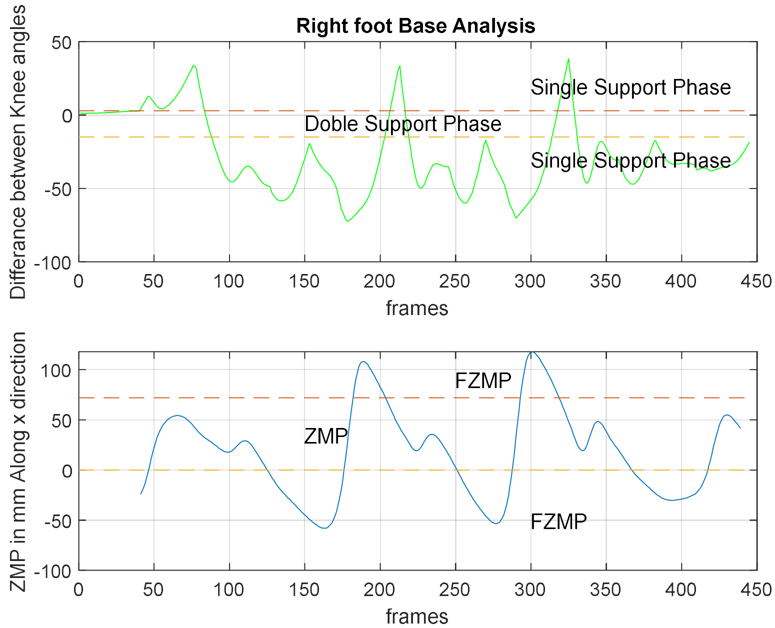

Figure 10 SSP, DSP, ZMP and FZMP in reference to right foot heel

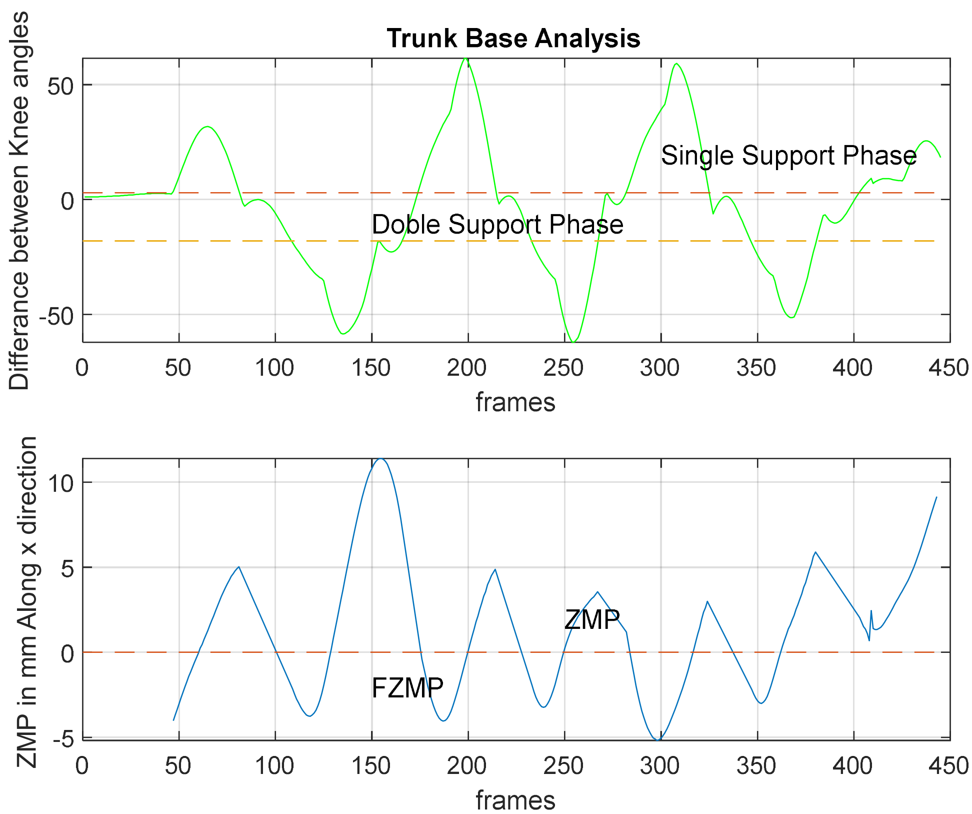

Figure 11 SSP, DSP, ZMP and FZMP in reference to Trunk

From the figure 11 we can see that the effect for the FZMP in the case of trunk reference frame is negligible almost comparing with the other cases.

We suggest as an improvement to the trajectory to make filtering the data for the positioning which will affect in the accuracy of the velocity, acceleration, and calculation of ZMP. we have used low pass Butterworth filter, we set the cut of frequency at 10 Hz.

After applying we can see from the last figure that there is improvement in ZMP which is much smoother than the previous output.

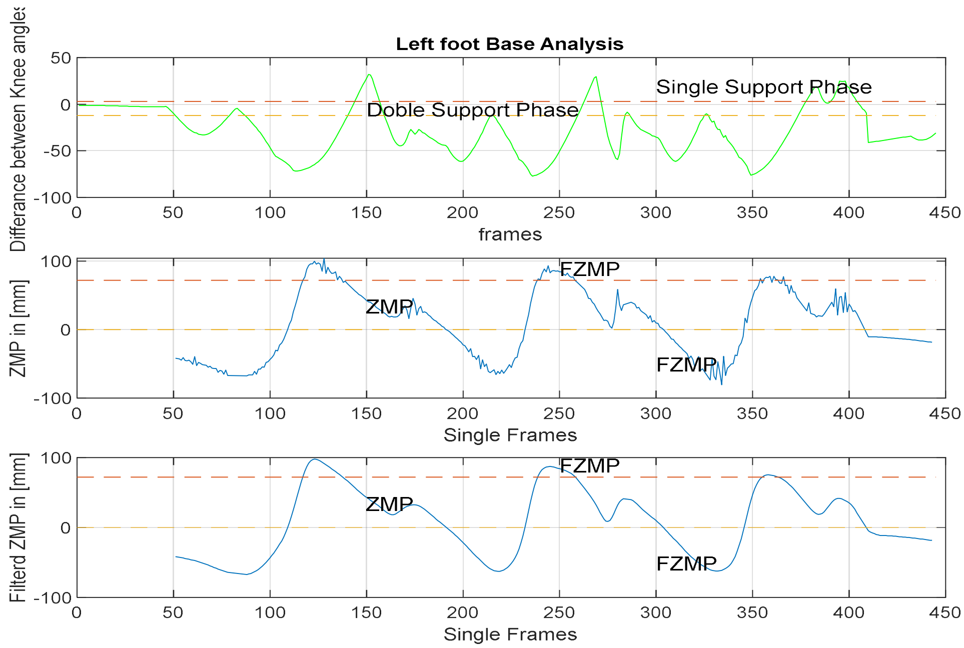

Figure 12 Improvement of the trajectory