

Transforming Segment Moment of Inertia

Let the inertia tensor of Segment (foot or shank) in it's own local coordinate system (l) be given:

$$I_{lcs} = \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}$$

Note: These are the values stored in Visual3D and viewable in the segment properties.

Find the value of this inertia tensor in any other reference frame (for example, ground) using the following equation:

$$I_{\text{ground}} = R_{\text{lcs_to_ground}} * I_{lcs} * R_{\text{ground_to_lcs}}$$

Where $R_{\text{lcs_to_ground}}$ is the rotation matrix that transforms a vector from it's own coordinate system (lcs) to the ground coordinate system

and $R_{\text{ground_to_lcs}}$ is its transpose.

The above expression does not include the terms due to the parallel axis theorem (I_{mass}) which are:

$$I_{\text{mass}} = \begin{bmatrix} s_2^2 + s_3^2 & -s_1 s_2 & -s_1 s_3 \\ -s_2 s_1 & s_1^2 + s_3^2 & -s_2 s_3 \\ -s_3 s_1 & -s_3 s_2 & s_1^2 + s_2^2 \end{bmatrix}$$

where the vector s defines the location of hte segment's center of mass relative to ground.

The total Inerties I_{segment} for the segment is:

$$I_{\text{segment}} = I_{\text{ground}} + I_{\text{mass}}$$

To find the total moment of inertia of all segments relative to ground you add the individual segment inertias:

$$I_{\text{total}} = \sum I_{\text{segment}}$$

This entire procedure is outlined nicely by Fred Yeadon in the following series of articles.

Yeadon, M.R. (1993). The biomechanics of twisting somersaults. Part I: Rigid body motions. Journal of Sports Sciences 11, 187-198.

Yeadon, M.R. (1993). The biomechanics of twisting somersaults. Part II: Contact twist. Journal of

Sports Sciences 11, 199-208.

Yeadon, M.R. (1993). The biomechanics of twisting somersaults. Part III: Aerial twist. Journal of Sports Sciences 11, 209-218.

Yeadon, M.R. (1993). The biomechanics of twisting somersaults. Part IV: Partitioning performance using the tilt angle. Journal of Sports Sciences 11, 219-225.

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