Balance Impairment Measurement using Margin of Stability

Gandhi Meet Bankim gandhi.meet@iitgn.ac.in

Dr. Vineet Vashista vineet.vashista@iitgn.ac.in

Indian Institute of Technology Gandhinagar, India

Objective

The goal of research was to determine and measure a gait parameter which can then be used to quantify Balance Disorder felt during gait of the subject wearing an ankle brace. Ankle Brace locks the ankle movement of the subject and hence is used for simulating below knee amputation in an able-bodied subject.

General Approach/ Methodology

1. Collect kinematic data of an able-bodied person and kinematic data of the same person after wearing ankl brace(for realizing Transtibial amputation) or wearing an iWalk(for realizing Transfemoral Amputation) using Vicon Motion Capture System.

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2. Create a Dynamic Model for human gait in Vicon Nexus Software so that it can recognize the subject under Motion Capture.

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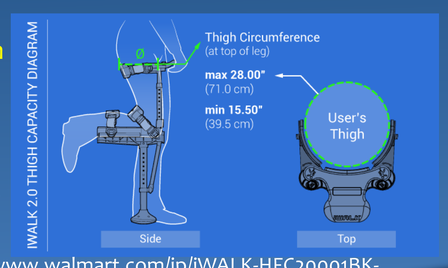
3. Analyze both the kinematic data collected using MATLAB and generate different gait parameters from that data. Choose from these derived parameters one which enables the formation of a feedback control loop.



https://www.walmart.com/ip/iWALK-HFC20001BK-Hands-Free-Crutch-Black/39241573

Introduction

By 2050, it is estimated that no. of population with lower limb prosthesis will increase. [3]

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Lower Limb amputees lack important senses of position and contact from prosthetic limb.
This loss of Proprioception leads to high metabolic costs in comparison to able-bodied person, chances of falling, asymmetry in walking and other pathological conditions like back pain.

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Much research is done in direction of Advanced Active prosthesis and other invasive methods, but drawback is that it is very expensive to manufacture and maintain for amputees living in developing countries like India.

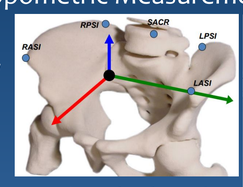
Experimental/Modeling Details

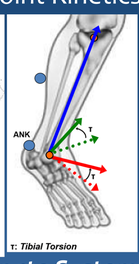
Plug-in Gait Model

Plug-in Gait (Marker trajectories, Center of Pressure, Ground Reaction force, Anthropometric Measurements) = Joint Kinetics and Kinematics.

Plug-in Gait Workflow

Hip Joint Center is calculated using [1].



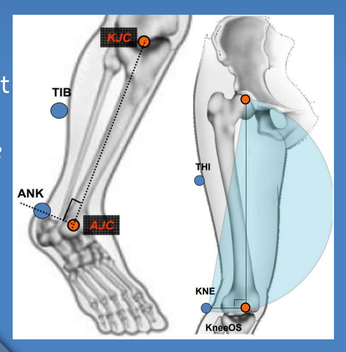


Knee and Ankle Joint Center is calculated using a CHORD function.

Pelvis, Knee and Ankle Coordinate System

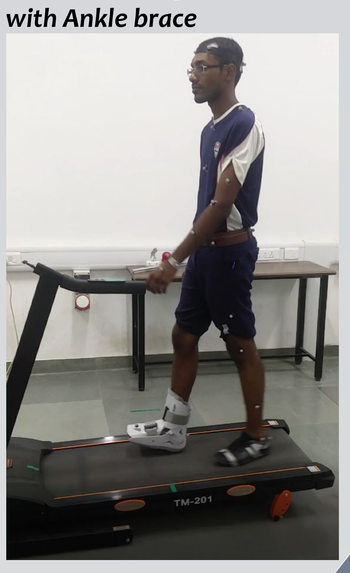
After determining local coordinate system for each segment, a Rotation Matrix corresponding to each joint can be constructed. Using these Rotation matrices, Plug-in Gait Model calculates the appropriate joint angles and hence calculates the trajectories of joints with respect to the global coordinate system.

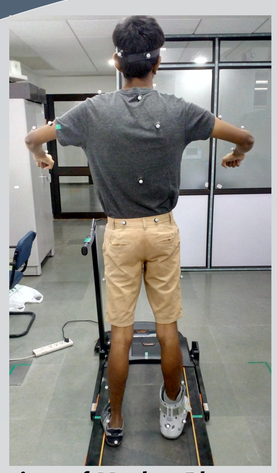
These joint trajectories can be used to get joint kinematics, thereafter using Inverse dynamics and GRF as well as CoP Data, Plug-in gait calculates joint kinetics.



Ankle and Knee Joint Centers

Subject walking on treadmill with Ankle brace



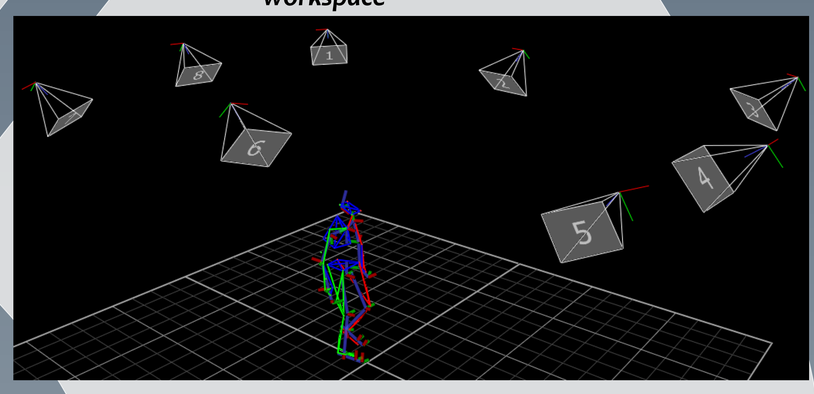


Back view of Marker Placement on subject for undergoing Plug-in Gait model based Motion Capture in Vicon Nexus

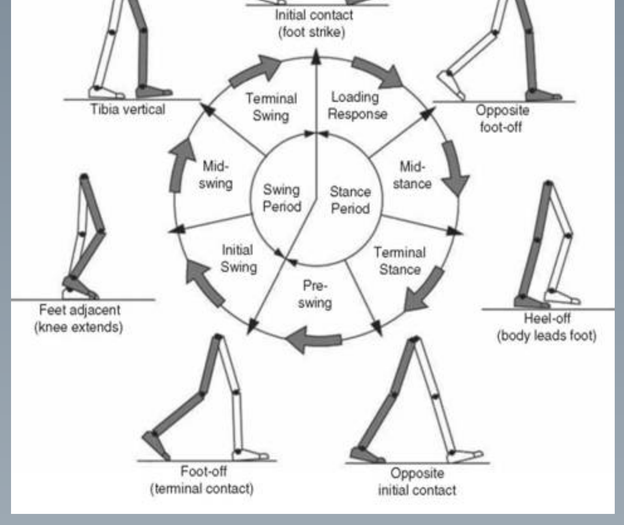
Vicon Vero Motion Capture System in Rehabilitation Robotics Lab, IITGN

Static Trial

Vicon Nexus Software showing Vicon Vero Motion Capture Camera Calibration wrt Subject and associated workspace

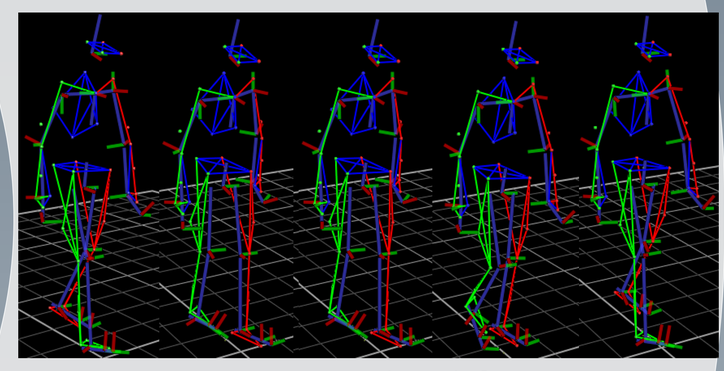


Vicon Vero Motion Capture System for Human Gait Data Collection

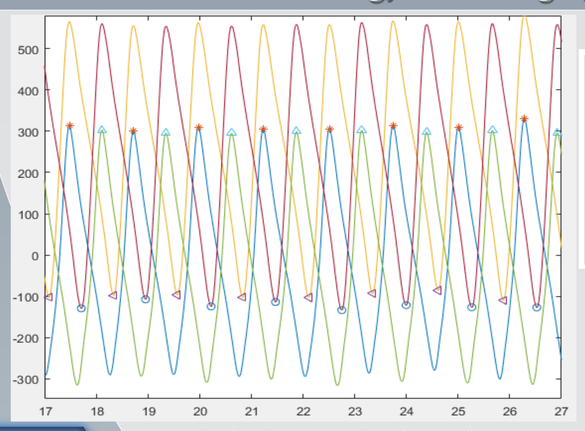


Gait Cycle for Right Leg

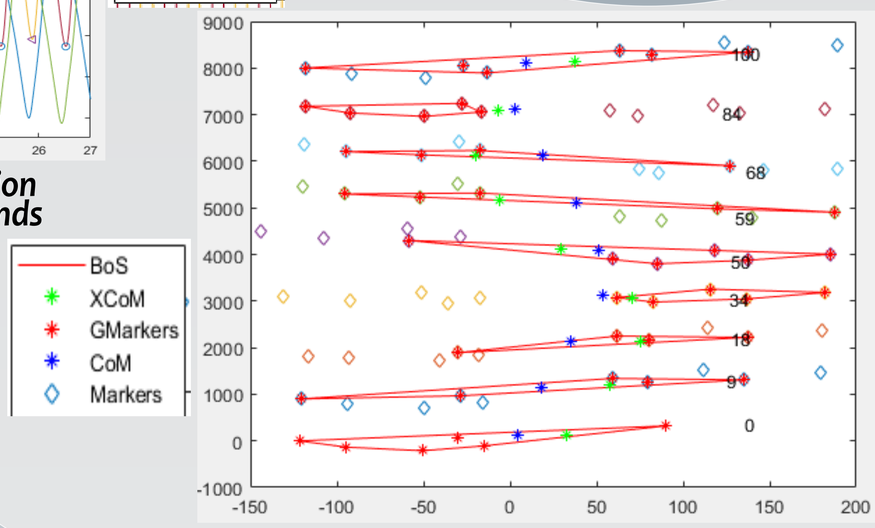
http://academlib.com/7410/health/



Dynamic Trial
Vicon Nexus Software + Plug-in Gait Model

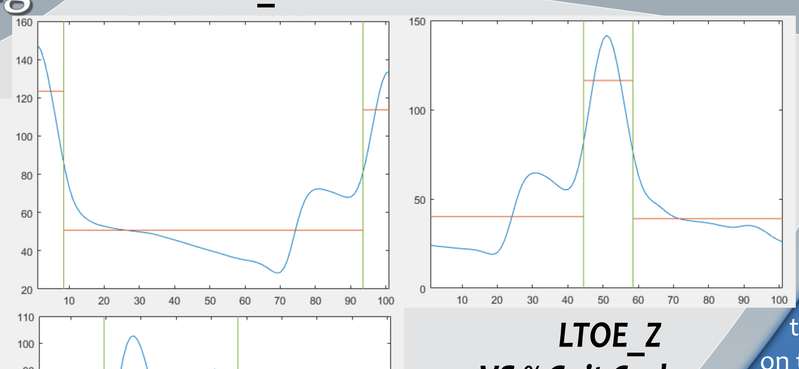


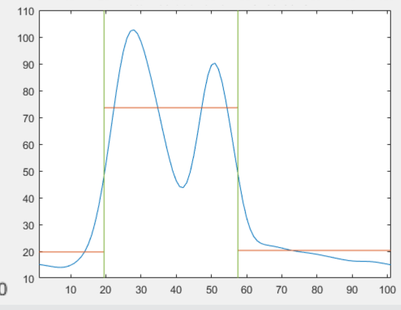
Gait Events Estimation centimeters VS seconds



mm (Y) VS mm (X)
Ground Projected Gait Parameters

RTOE_Z





LTOE_Z mm VS % Gait Cycle

LMT_Z

Inverted Pendulum Model

Extrapolated CoM is the projection of CoM on the ground in addition to CoM velocity multiplied by a constant factor depending on the height of CoM from ankle joint.

Margin of Stability here is the shortest distance between Extrapolated CoM and one of the boundaries of Base of Support area.

Base of Support here is the area enclosed by HEEL, TOE and ANKLE markers of both feet during double support phase of gait and respective markers of the foot in contact with the ground during single support phase of gait.

Conclusions &Future Work

Margin of Stability is gait parameter which can be used for designing an appropriate feedback control loop model; eg. Vibrotactile, Audio or Video based.

Validate if incorporated feedback control loop is beneficial to Passive Lower Limb Transfemoral amputee by verifying if the amputee is able to adapt to the prosthesis well and reduce metabolic costs, asymmetricity and the chances of falling.

Getting hold of 1. Electromyography sensor to record electrical activity of muscles and 2. Force Plate to record Ground Reaction forces.

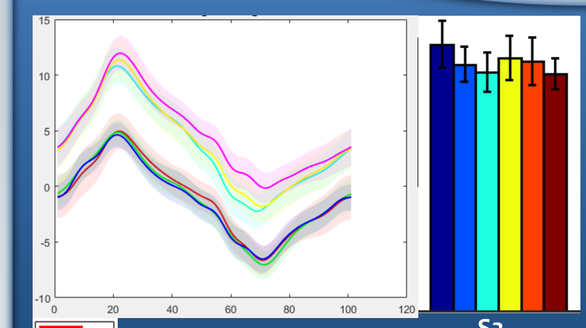
Using all the above data we would be able to simulate a well defined model using OpenSim, a simulation toolkit designed by Stanford University.

A musculoskeletal model in OpenSim

http://sciencebusiness.technewslit.com/?p=6709

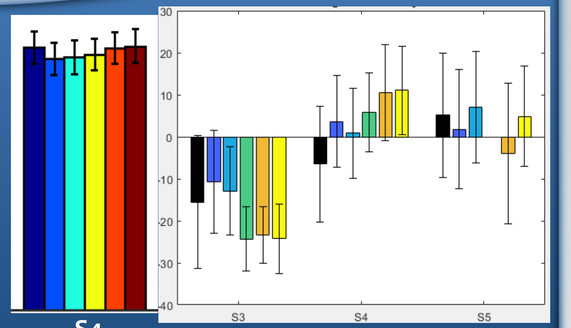
Gait Analysis and Rehabilitation

Results



Pelvic Euler Angle in Sagittal Plane

Medial Lateral Margin of Stability at Left Heel Strike



Margin of Stability at Right Toe Off

References

[1] Roy B. Davis, Sylvia Õunpuu, Dennis Tyburski, James R. Gage, A gait analysis data collection and reduction technique, Human Movement Science, Volume 10, Issue 5, 1991, Pages 575-587, ISSN 0167-9457, http://dx.doi.org/10.1016/0167-9457(91)90046-Z.

[2] Vicon_Plug in Gait WebEx Training Session 3 Module titled "Interpreting PiG results: PiG biomechanical modeling" by Gabriele Paolini: http://www.analisedemarcha.com/papers/manutencao/manuais/Vicon_Plug%20in%20Gait%20WebEx%20Training%20-%20Session3.pdf

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