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QUANTIFICATION OF BALANCE IN SINGLE LIMB STANCE USING KINECT

[1]Kingshuk Chakravarty, [1]Suraj Suman, [1]Brojeshwar Bhowmick, [1]Aniruddha Sinha, [2]Dr. Abhijit Das

[1]Innovation Labs, Tata Consultancy Services Ltd. [2]Institute of Neurosciences, Kolkata

Motivation

- Poor postural balance control causes injury or falls in huge population.
- Single Limb Stance (SLS) [1] is a good option for assessing postural steadiness in a static position.
- SLS training for patients reduces chances of injury or fall risk
- SLS provides a quick, reliable and easy way to screen their patients for fall risks [2].

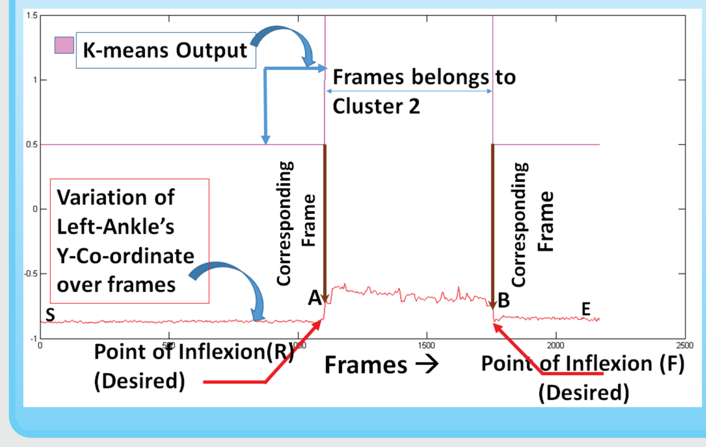
Our contributions

- A Kinect based unobtrusive system is proposed to measure SLS duration, human body balance and vibration-jitter analysis.

Noise removal

- The noisy skeleton data is filtered using method similar to [3].

SLS Duration Measurement



- Compute covariance matrix $\dot{X}\dot{X}^T$(X= data points in the arc S to A)
- Perform Eigen value decomposition on $\dot{X}\dot{X}^T$
- The curvature points R and F are obtained through minimum ptojection error of the eigen vector corresponding to smallest eigen-value

$$argmin_r [\dot{P}_r - (\dot{P}_r . \dot{u})\dot{u}]$$

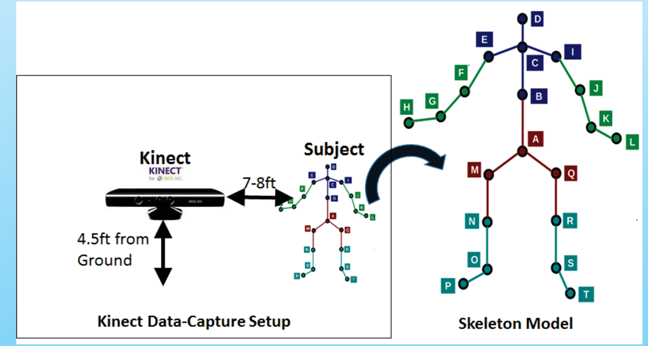
$\dot{P}_r$ is the original signal value at frame r and $\dot{u}$ is the unit vector along $\dot{E}_{min}$

How SLS balance assessment is performed?

- Balance in SLS is assessed in terms SLS duration and center of pressure (COP) movements. It does not consider the sway/movement associated with different body parts.
- Marker based motion analysis system like VICON is expensive and complex.
- Fall risk questionnaire is used to assess fall risk.

Dataset Creation

- **Participants**: Thirty eight healthy volunteers (age: 21-65 years, weight: 45kg-120kg & height: 4ft6inch-6ft5inch



Body Vibration Analysis

- **Velocity for each joint is modeled as :** $V^j(t+\Delta t) = [v_x^j, v_y^j, v_z^j] = \dfrac{[x^j,(t+\Delta t), y^j,(t+\Delta t), z^j,(t+\Delta t)] - [x^j,(t), y^j,(t), z^j,(t)]}{\Delta t}$ the velocity profile of three segments during SLS exercise are analyzed separately, $V_k^j(\omega) = \sum_{n=0}^{N-1} v_k^j[n] e^{-i\omega n}, i^2 = -1$ $\quad f_k^j \leftrightarrow A_k^j$, Corresponding to maximum amplitude $f_m^j = \dfrac{\sum f_k^j A_k^j}{\sum A_k^j}$ **Vibration jitter** = $J_{1,2,3} = (f_m^j - f_{Vk}^j)|_{1,2,3}, f_m^j|_{S\text{-to-}R}, f_m^j|_{R\text{-to-}F}, f_m^j|_{F\text{-to-}E}$

Dominant comnonent of velocity $= V_k^j[n] = A_k^j \cos(2\pi f_k^j n)$, **force per unit mass (FPUM) for each joint =** $FPUM = \dfrac{\text{force } (F)}{\text{mass } (m)}$ **= acceleration** (a)

Fig: Bland-Altman plot. (a) Proposed with GT, (b) [4] vs. GT

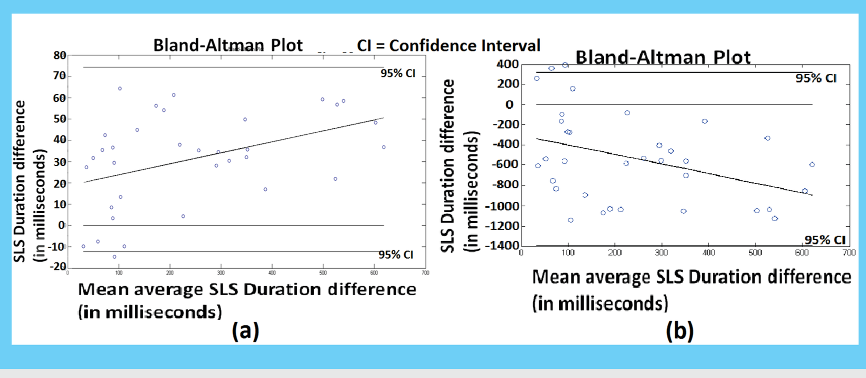
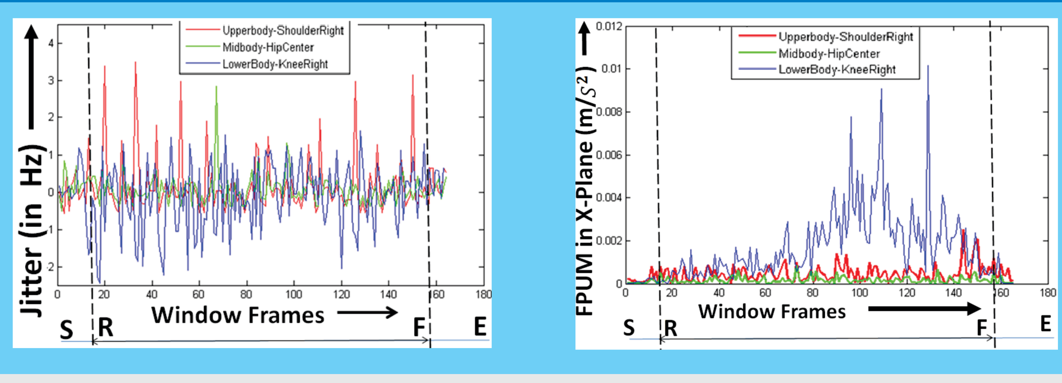


Fig: Body vibration analysis for a particular subject (a) Jitter (b) FPUM



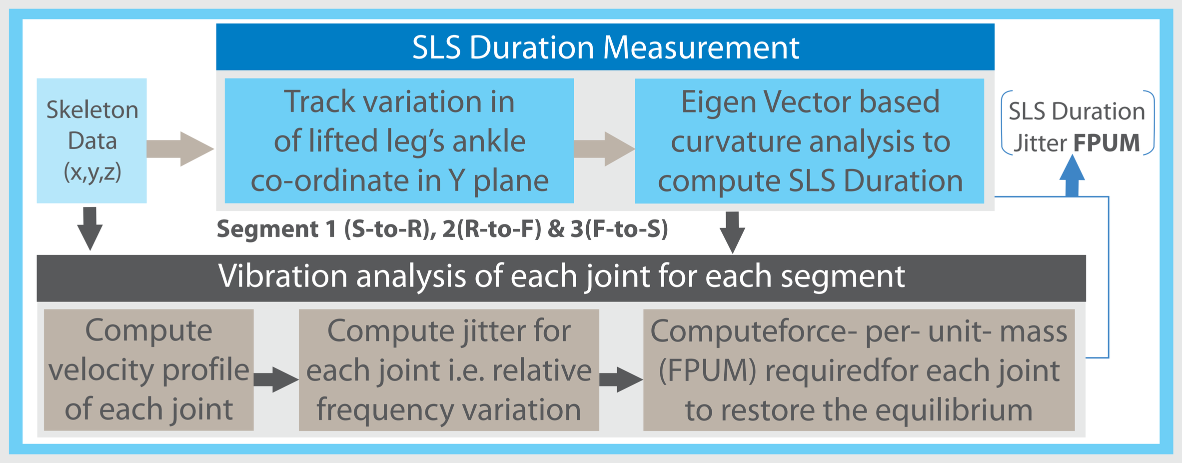


Table 1: FPUM comparison for 4 subjects for three joints. (A,B = sportspersons, but C,D don't practice any kind of exercises)

Subjects	Fitness	Segment-1(S-to-R)			Segment-2(R-to-F)			Segment-3(F-to-E)		
		KneeRight	HipCenter	ShoulderRight	KneeRight	HipCenter	ShoulderRight	KneeRight	HipCenter	ShoulderRight
A	10	5.01e-5±2.62e-5	1.53e-6±6.03e-6	9.56e-6±6.03e-6	0.0017±0.0017	2.03e-5±1.89e-5	5.34e-5±4.78e-5	2.26e-4±5.24e-4	7.51e-4±0.0020	0.0012±0.0030
B	9	2.11e-5±9.04e-6	1.59e-5±3.08e-5	1.05e-5±1.21e-5	1.83e-4±1.78e-4	4.21e-5±6.71e-5	1.08e-4±1.65e-4	5.59e-5±1.13e-4	1.32e-4±3.51e-4	2.93e-4±7.52e-4
C	1	2.09e-4±1.25e-4	1.73e-6±1.88e-6	1.36e-5±1.28e-5	7.68e-4±6.00e-4	9.93e-5±1.12e-4	9.38e-4±0.0018	4.19e-4±5.10e-4	1.89e-5±3.13e-5	3.96e-4±5.41e-1
D	2	7.08e-6±4.33e-6	2.80e-6±2.74e-6	6.38e-6±6.21e-6	3.36e-4±4.53e-4	1.18e-4±1.77e-4	0.0016±0.0022	1.53e-5±7.76e-6	2.76e-6±2.65e-6	5.53e-5±5.48e-5

[1] Richard W Bohannon, "Single limb stance times: A descriptive meta-analysis of data from individuals at least 60 years of age," Topics in Geriatric Rehabilitation, vol. 22, no. 1, pp. 70–77, 2006.

[2] JV Jacobs, FB Horak, VK Tran, and JG Nutt, "Multiple balance tests improve the assessment of postural stability in subjects with parkinsons disease," Journal of Neurology, Neurosurgery & Psychiatry, vol. 77,

[3] Aniruddha Sinha and Kingshuk Chakravarty, "Pose based person identification using kinect," in Systems, Man, and Cybernetics (SMC), 2013 IEEE International Conference on. IEEE, 2013, pp. 497–503.