How do we plan movements?:A geometric answer

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***Abstract*— Human movement is essentially a complex phenomenon. When humans work closely with robots, understanding human motion using robot's sensors is a very challenging problem. This is partially due to the lack of proper consensus among researchers on which representation to use in such situations. This extended abstract presents a novel kinematic framework to study human intention using hybrid twists. This is important as the functional aspects of the human shoulder are evaluated using the information embedded in thoraco-humeral kinematics. We successfully demonstrate that our approach is singularity free. We also demonstrate that how the twist parameters vary according to the movement being performed.**

I. INTRODUCTION

As we progress towards robot-assisted neuro-rehabilitation, robots are expected to have automatic understanding of human intention. In the case of human upper limb, it is the fine motor skills that enable us to perform successful manipulation. The human shoulder acts as a base for the forearm and the hand in everyday manipulation tasks. But, we are presented with important challenges in attempting to paramatrise human shoulder motion; like its complex anatomy, its large range of motion capability, kinematic redundancy, and inherent motion variability.

Current approaches in modelling human shoulder kinematics is not suited for high-reliability applications like neuro-rehabilitaion [1]. Because, numerical instabilities in widely accepted shoulder kinematic representations introduces singularities, which in turn compromises the reliability. Therefore, we present a special class of spatial vectors that has the potential to be useful in such applications. Also, we demonstrate that our approach is singularity-free in Section III. The results discussed in this extended abstract is a subset of our work under review [4]. We present a brief overview of hybrid-twists in the next section.

II. HYBRID-TWISTS

For any generalized rigid body, the instantaneous velocity of a body-fixed point R is given in terms of the velocity $\mathbf{v_A}$ of the origin of body-fixed coordinate system A and angular velocity vector $\boldsymbol{\omega} \in \mathcal{R}^3$ expressed as

$$\mathbf{v_R} = \mathbf{v_A} + \boldsymbol{\omega} \times \mathbf{p_{AR}}. \tag{1}$$

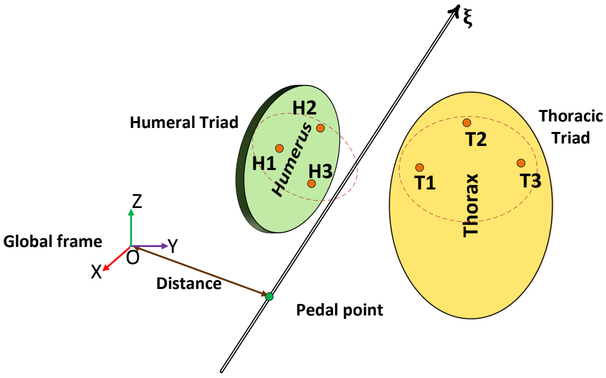

Fig. 1. Figure illustrates the concept of hybrid-twists in describing shoulder motion. The markers T1-T3 constitute the thoracic triad and H1-H3 forms the humeral triad.

Any generalised motion of a rigid body as in (1) can be parametrised using spatial vectors or twists [2]. A generalised hybrid-twist in terms of instantaneous velocities is defined as (2).

$$\boldsymbol{\xi} = \begin{bmatrix} \boldsymbol{\omega} \\ \mathbf{v_A} \end{bmatrix} \mathbf{D_A}. \tag{2}$$

The basis vector $\mathbf{D_A}$, that defines hybrid-twists belong to the Plücker basis. The axis defined by the hybrid-twists represent a line in 3D-space along which the rigid body velocities are of minimum magnitude. Hybrid-twists have several advantages like they are singularity-free and decoupling in segment kinematics. The concept of hybrid twists in parametrising human shoulder kinematics, is shown in Fig.1. In the next section we will describe our experiments and computation.

III. EXPERIMENTS AND COMPUTATION

We mounted passive markers on brace supports on a healthy male subject (aged 20 years, weight: 80 kg, dominant right hand). A total of six markers were mounted on the subject: T1-T3 on the thoracic segment and H1-H3 on the humeral segment. Using an Optotrak MOTIVE 17-camera system, the motion of the passive markers were captured at a rate of 120 fps. The volunteer was asked to perform three basic shoulder motions at a self-selected pace, namely: 1) *Flexion-Extension* in the sagittal plane, 2) *Abduction-Adduction* in the coronal plane and 3) *Elevation-Depression* which is generalised raising and lowering motion of the arm. From the marker data the rigid segment velocities were computed following the procedure in [3]. Each movement was repeated five times.

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Then, the relative kinematics between the thoracic and humeral segments were computed using steps in [2]. We then calculate the pitch (h) of the screw given by the following

$$h = \frac{\boldsymbol{\omega} \cdot \mathbf{v_A}}{\boldsymbol{\omega} \cdot \boldsymbol{\omega}} = \pm \frac{\|\mathbf{v}_{\text{lin}}\|}{\|\boldsymbol{\omega}\|}. \tag{3}$$

The value of h describes the instantaneous relationship between the angular velocity and translational velocity: zero represents pure rotation, a positive value represents a right-handed screw, and a negative value represents a left-handed screw. The results have been shown in the next section.

IV. RESULTS AND DISCUSSION

The figures Fig.2-Fig.4 presents the pitch values for the subject during three basic shoulder movements. As can be seen in the results, the computed pitch curves have distinct features for each of these activities. For instance, during the elevation-depression task there is a positive pitch during elevation and corresponding negative pitch throughout the depression phase as can be seen in Fig.4. Similarly, individual pitch features can be seen in both flexion-extension (see Fig.2) and abduction-adduction (see Fig.3) movements.

As can be seen in our results, there are ringing features due to the wobbling effects of the segment soft tissue. We would like to propose pre-processing steps towards mitigating these; only then can we demonstrate the theoretically guaranteed high-reliability.

Despite our measurement limitations, it is evident that we are able to extract movement-related invariant features consistently. Parametrising complex shoulder movements using hybrid-twists is an interesting problem we would like to explore further. In the future, we look forward to answering questions related to movement planning using hybrid-twists.

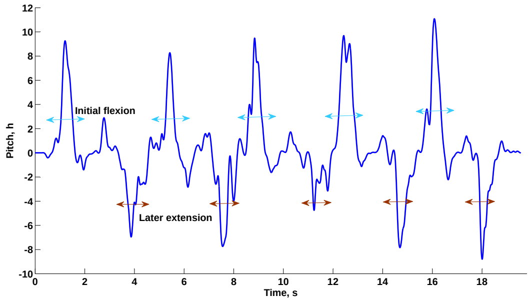

Fig. 2. Computed pitch values for flexion-extension task. Early flexion is marked by blue arrows and later extension is shown by brown arrows.

V. CONCLUSION

In short summary, we have proposed a well known kinematic parametrisation in robotics onto parametrising human movement. Despite our measurement limitations, we have shown that our approach can highlight movement-dependent kinematic features without being affected by numerical singularities. Thus, hybrid-twists do hold a potential towards successfully parametrising human shoulder kinematics.

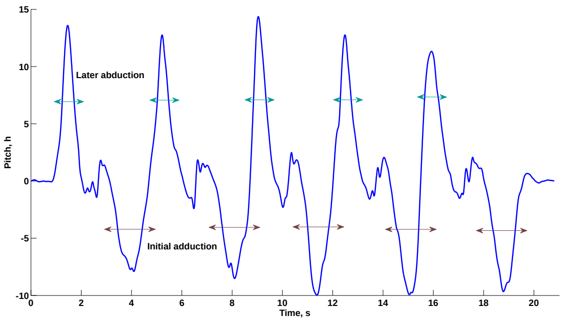

Fig. 3. Computed pitch values for abduction-adduction task. Later abduction phase is indicated by green arrows and early adduction by brown arrows.

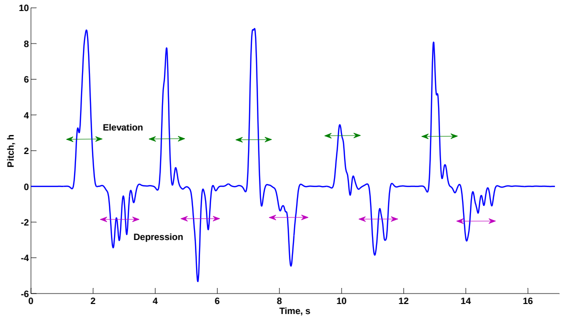

Fig. 4. Computed pitch values for elevation-depression task. Elevation phase is marked by green arrows and depression phase is marked by pink arrows.

VI. ACKNOWLEDGMENT

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