Human arm impedance and EMG in 3D

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Abstract

This paper shows the relationship between EMG signals and human arm stiffness, measured in 3-D space. Preliminary results demonstrate the viability of this approach, which can then be used to measure human arm impedance from EMG only. Understanding human stiffness during interaction tasks will allow the development of an appropriate skill transfer exercise for Programming-by-Demonstration. Making the human aware of her own stiffness adaption gives a better understanding towards programming a robot impedance controller.

1. Introduction

The difference between the human skeletomuscular system and its robotic counterpart is clear from the way it interacts with its environment. Whereas a robotic system typically is a mechanically driven, stiff and highly deterministic system, its biological "ancestor" is governed by indeterminable, nonlinear elastic elements which do not only determine the position of each joint, but also its impedance.

Controlling the impedance is key for the interaction between man and his environment. Whereas fast interaction, in which much kinetic energy can be exchanged, requires a low impedance to absorb such energy, high-precision movements are better done with stiff limbs so as to improve positioning accuracy.

Even though such general rules are useful for simple tasks, knowing general rules for controlling human impedance is required to use such rules in the parametrisation of variable-impedance robotic systems, such as the DLR hand-arm system or even the DLR-KUKA light-weight arm.

In the literature, various approaches to the measurement of human arm impedance are in use. All scientifically accepted approaches, however, focus on the measurement of planar arm impedance done at test persons who move their arm in simple planar tasks, typically those of following a 2D trajectory or reaching a target in 2D while a disturbance field is being applied. While these experiments give very useful data, their 2D character cannot be extrapolated to movements in free space, i.e., 3D to 6D movements. Knowledge of limb impedance during movement in these spaces is essential to understand human motion control during various tasks such as peg-in-hole insertion, writing, ball throwing, etc.

2. Measuring human impedance

The measurement of human arm impedance was pioneered by Neville Hogan [1][2] at MIT. The test persons were instructed to hold a 2-joint scara manipulator while measuring arm EMG signals. More recently, Mitsuo Kawato at the ATR in Kyoto focused on this field of research [3][4]. Even though technical advances improved the measurements, these were still conducted only in the planar case.

Recently we have pioneered the measurement of human arm impedance for 3-dimensional movements. In this case, the wrist of the human hand was fixed to a DLR light-weight robot, which was controlled in impedance control so as to minimize the force felt by the test person (see Fig. 1).

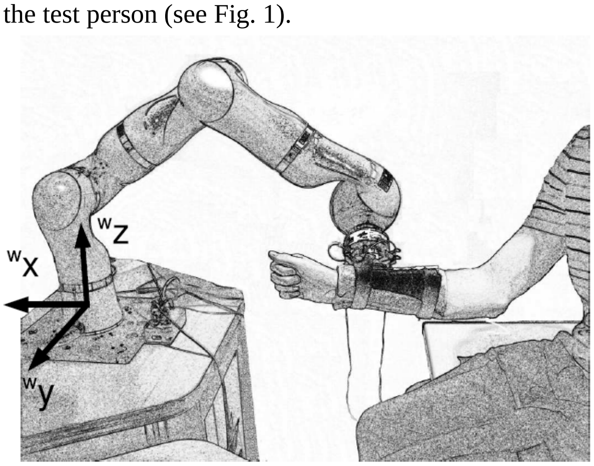

Fig. 1. DLR light-weight robot attached to a test person.

While performing predefined grasping tasks, the LWR was controlled to follow the arm in impedance control, but then "randomly" perturb the arm. In the meantime, EMG signals of the biceps, triceps, and pectoralis muscles were measured.

3. Results

Preliminary results show a very good correlation between the robot-measured impedance and the EMG-predicted impedance [5]. Fig. 2 demonstrates the results for measurement of 2-dimensional stiffness ellipses in the 3-dimensional space, plus the EMG-based prediction of these ellipses. Clearly, the stiffness signal can be well-predicted from the EMG signal alone.

References

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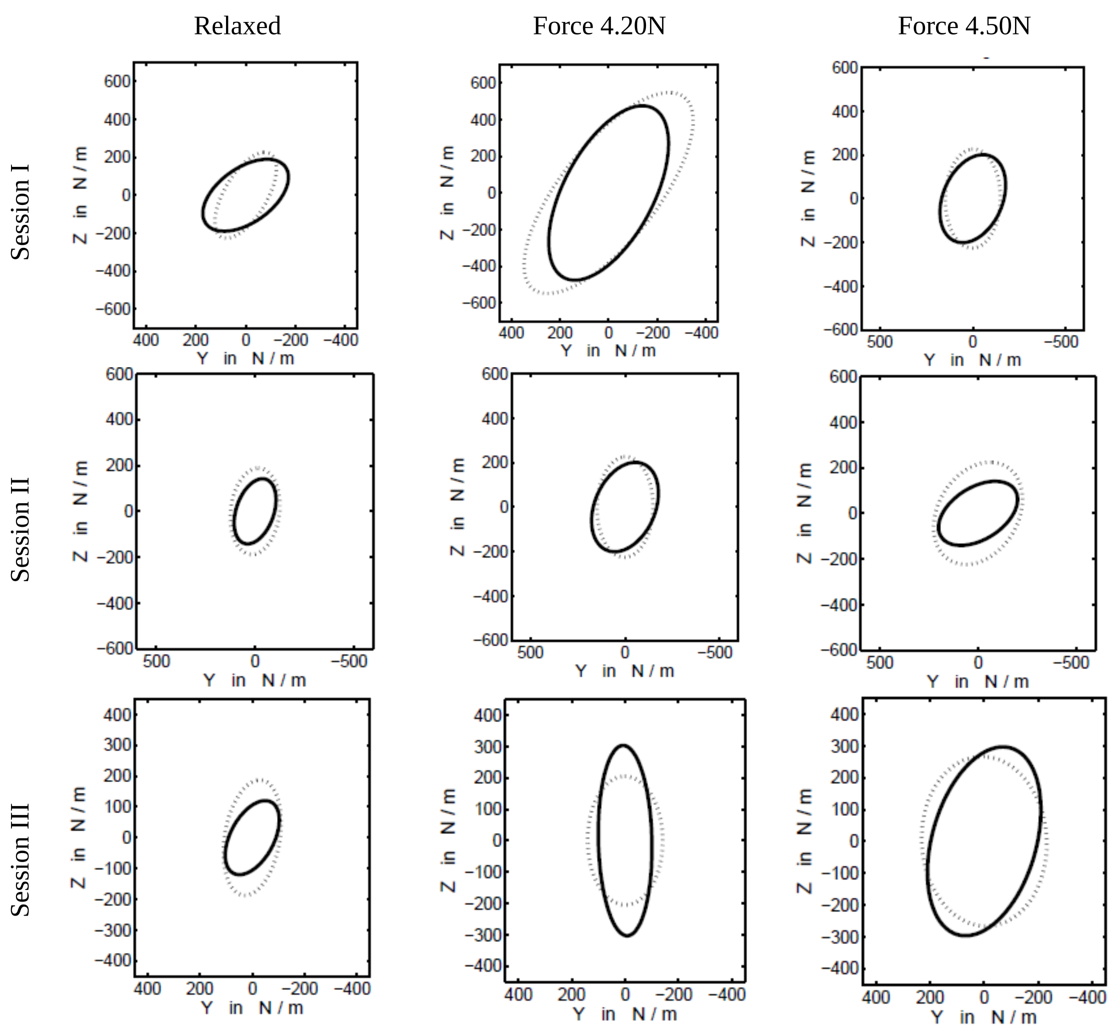

Fig. 2. Impedance measured by the robot (solid line) and through the EMG signal (dotted line) for different exerted forces and in different sessions. The stiffness ellipses are measured in a 2-dimensional plane while the movement is done in 3D; the resulting stiffness ellipse is then transferred to 2D for display purposes.