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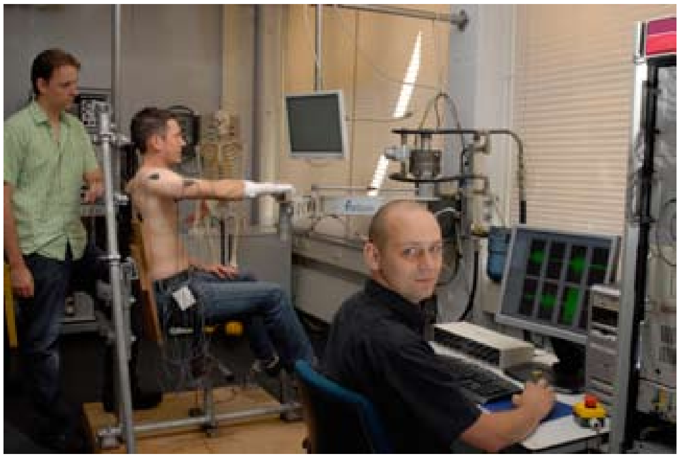
Delft Laboratory for NeuroMuscular Control

The Delft Laboratory for NeuroMuscular Control (NMC Lab) is part of the Biomechanical Engineering department of the Delft University of Technology in the Netherlands. A major thrust in the NMC Lab is to investigate the contribution of intrinsic muscular and reflexive control of human joints using system identification techniques and haptic robots. The NMC Lab co-operates with academic hospitals to apply their techniques to patients suffering from movement disorders, as e.g. in stroke, cerebral palsy and complex regional pain syndrome. Recent advances have been made by identification of multi-joint reflexes of the arm during natural posture tasks.

The NMC lab is equipped with two Bagnoli™ Desktop EMG systems – a 16 channel and a 4 channel system used for electromechanical correlation studies. In 2004 Professor Dr. F.C.T van der Helm, a member of the NMC team, was the recipient of the 2004 Delsys Prize (http://www.delsys.com/DelsysPrize/Prize_Winners.html).

Research

Quantification of proprioceptive feedback



Armanda, the unique force-controlled 2-DOF robotic manipulator to investigate human arm movements.

The NMC Lab investigates the functioning of proprioceptive feedback at spinal level during passive and active motor tasks of single and multiple joints. Proprioceptive feedback comprises neural feedback of muscle length and muscle force to the muscle itself (homonymous feedback) and to other muscles (heteronymous feedback). The proprioceptive feedback signal originates from the muscle spindles and the Golgi tendon organs, i.e. the Ia, Ib and II afferent pathways. Due to feedback, the causal relationship between muscle force and muscle length is not unambiguous. Closed loop identification techniques are used to deal with identification of feedback systems. Basically, for the quantification of afferent feedback gains the position of the hand (or foot) must be perturbed from its resting postural position or resting movement trajectory. For this purpose, an independent external force disturbance signal is used. The resulting resistant forces are described in terms of joint visco-elasticity with respect to the reference angle. The visco-elasticity is separated into muscular and reflexive components to obtain the desired reflexive feedback strengths. To improve the estimation of the reflexive feedback, EMG recordings are used as an additional signal inside the closed loop. The NMC Lab is equipped with several unique robotic manipulators for this purpose, for one Degree-of-Freedom (1DOF) and 2DOF identification. The manipulators are force-controlled allowing for interactive movements that facilitate a natural task perception: the subject has to actively control limb movement and preserve limb stability. Furthermore, the lab utilizes a 6 camera motion capture system.

System identification using surface EMG recordings

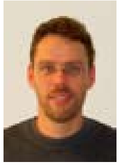
Clinical Applications

Normally, reflexive feedback adapt with different types of motor tasks and different types of loading conditions. The NMC Lab has broad experience in the research of reflex adaptations to changing mechanical loading conditions, as mimicked by the haptic manipulators. While normal reflex adaptation has been shown in healthy subjects, hampered reflex adaptation has been measured in patients having motor deficiencies.

Our identification and parameterization techniques are applied to patients suffering from stroke and complex regional pain syndrome. As reflexive feedback strength is estimated during natural tasks, the results can be related directly to performance and hence are valuable to assess motor functioning. Current outcomes are valuable to clinicians as they improve insight in the etiology of motor disorders such as spasticity and may help to adjust rehabilitation programs.

External force disturbance signals are optimized for the purpose of identification. These signals are continuous and constructed as a sum of sinusoids with random phases. By selective application of energy at specific frequencies, the signal-to-noise ratio between the external force disturbance and the other signals (angle, reaction force, EMG) can be increased. Furthermore, by increasing the compactness of the disturbance signal (cresting), the signal power can be raised, so that the signal-to-noise ratio can be increased even further. EMG signals of different muscles have been used to compose a lumped bidirectional antagonistic activation signal, i.e. as if the joint is actuated by one push-pull muscle. As our techniques are based on small signal analysis, such a linear lumped representation is warranted and verified by high coherence values over a wide range of frequencies, typically higher than 0.8 in the range from 0.5 to 20 Hz. By conversion the EMG signal into Newton unity, we succeed in creation of a virtual signal analogous to muscle force that otherwise is almost impossible to measure in vivo.

Dr Alfred C. Schouten received his PhD (2004) and MSc (1999) from the Delft University of Technology, the Netherlands. He is currently an Assistant Professor in the Department of Biomechanical Engineering at the Delft University of Technology. His research focuses on the control of human limbs, specifically the functional contribution of afferent feedback to human movement and the task-specific modulation of afferent feedback. He developed models to analyse the theoretical optimal contribution of afferent feedback for the prediction the task-dependent modulation. His research focuses on both able-bodied individuals and individuals with movement disorders.



Erwin de Vlugt (PhD, MSc Mech. Eng.) has his main interest in spinal reflex identification. Experimental paradigms have been developed that enable precise quantitative measures of muscle spindle and Golgi tendon organ feedback gains during natural positioning tasks. The method is based on a small signal analysis using linear models of the sensor dynamics, muscle activation proces and intrinsic muscle visco-elasticity. Extensions of these models are currently developed to cope with larger joint excursions entering nonlinear behavior. Applications are in to fields of rehabilitation medicine and neurophysiology.

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