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2020 IEEE/RSJ IROS Workshop on
Wearable SuperLimbs

Talk 1
Data-Driven System Design and Control:
A Methodology for SuperLimb Development

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Abstract

This talk at the 2020 IROS workshop on Wearable SuperLimbs will address a methodology for developing SuperLimbs based on data analysis of human movements. It is critically important in SuperLimbs design that we understand how the wearable robot works in concert with the human. Human movements, however, are complex. Instead of designing a system based on engineering intuition, here we propose to measure human movements and extract robot structure and control algorithm from the data.

This data-driven approach will be addressed for a new type of supernumerary robotic limbs (SuperLimb) consisting of joints powered by human body movements and ones by robot actuators. We aim to apply the new SuperLimb to assisting hemiplegic patients in performing a bi-manual task. This human-SuperLimb hybrid design reduces the number of actuators, so that the SuperLimb may be lighter and more compact and, thereby, becomes more wearable. The hybrid design also allows the wearer to directly communicate his/her intension to the robot through direct movements of the joints powered by the body motion. To fully exploit these features, a new data-driven method is presented and applied to assist hemiplegic patients in taking a meal with knife and folk. First, the motion of knife and folk recorded from demonstrations by healthy people is analyzed in order to extract useful information a) for designing the hybrid SuperLimb system, and b) for controlling the robotic hand in coordination with the healthy, unaffected hand. For a), Principal Component Analysis (PCA) is applied to the data of one hand, say the one holding a knife, which is to be replaced by a SuperLimb hybrid. PCA reveals that the knife motion, for example, can be represented with a fewer degrees of freedom (DOF) than 6, which allows for reducing the number of active joints. Those active DOF can be split between human DOF powered by human body and robot DOF powered by robot actuators. Those robot DOF must be controlled in coordination with human DOF and the unaffected hand. A predictor is formulated based on the demonstration data in order to predict desired movements for the robot DOF in correlation with the human movements. We propose to assign robot DOF to those principal components that are most predictable, and assign human DOF to least predictable ones. Interestingly, those least predictable components are least correlated with others. This implies that a patient wishes to control those DOF independently and spontaneously on his/her own. A prototype SuperLimb hybrid is designed and built, and the control algorithm is implemented and evaluated.

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