Abstract of dissertation

Thesis title:

ForceArm: a wearable pneumatic gel muscle (PGM)-based assistive suit for the upper limb
(ForceArm：ウェアラブル空気圧ゲル人工筋（PGM）を用いた上肢支援スーツ)

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This work is an attempt to design and evaluate a wearable robotic assist cum rehabilitation solution for the upper limb. We developed an upper limb wearable assistive suit called ForceArm that supports wrist flexion-extension, forearm pronation-supination, elbow flexion, and shoulder flexion. The ForceArm suit was evaluated to verify the effects of muscle unloading in elderly subjects for the degrees of freedom (DOFs) of the forearm. The other two DOFs, elbow and shoulder flexion, were evaluated to identify muscle unloading effects in young subjects. Also, a gaming scenario was set up to test the prototype's effectiveness in motor rehabilitation for the elderly with respect to time. ForceArm is comprised of low-pressure type pneumatic actuators called pneumatic gel muscles (PGMs). The PGMs have more potential than conventional pneumatic actuators due to their lower air pressure requirement. These muscles are capable of producing larger forces at lower air pressure as compared to commercially available low-pressure pneumatic actuators. This quality makes the system usable as a standalone, without the need for a heavyweight air compressor for extended time-periods. It was proved that at a lower operating air pressure, ForceArm could achieve equivalent force density, when compared to the other prototypes using pneumatic actuation technologies. Besides, only soft components were used to build the wearable part of the prototype. The qualifications which were prioritized during the design and are vital to fulfilling the aspirations of patients, medical and technical communities include:

- Minimum restriction of natural movements
- Easy donning and doffing
- Wearable to the most extent
- Lightweight: ForceArm weighs 2100g, and the only 214g is worn on the arm
- Relatively low complexity with low engineering and manufacturing cost
- Flexible
- Low/no maintenance after acquiring the product
- Low/no adverse effects by environmental factors such as dust, moisture, and water.
- Standalone: the use of low-pressure type muscles enables the system to be used with canisters for longer hours
- Associates to a higher number of DOFs of the upper limb: ForceArm associates to four DOFs of the arm

Interesting applications were tested for feasibility with this wearable prototype such as motor learning, rehabilitation, assistance in elderly, navigation assistance and virtual reality (VR) feedback. Qualities of wearability, portability and lightweightedness made it easier for human users to accept the augmentation and thus also making it a feasible solution for daily life usage.