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Harmonizing Mechanical and Human Systems in Biomechatronics

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Abstract

In recent years, there has been a growing corpus of research on human-robot interactions, human-machine interfaces, and intelligent devices based on human applications; yet, these studies have mostly ignored how to harmonize interactions between mechatronic systems and humans in the loop. This is one of the most important aspects to consider when assessing the success of any mechatronic system on humans. The papers in this volume explore the cutting-edge of this field, examining how the efficacy of such bio mechatronic devices can be assessed and improved. There are 19 papers in total that look into Electromyography (EMG) and Electroencephalography (EEG), tactile feedback, external devices such as exoskeletons and prosthetic devices for assistance and rehabilitation, novel techniques such as machine learning and intelligent computation, and experimental evaluation or validation. The following paragraphs are intended to provide an overview of the contents of this eBook. These are divided into three distinct categories: (A) New exoskeletons for help and training, (B) Bio mechatronics advanced human-machine interfaces, and (C) Experimental results and validation.

Keywords: Electromyography; Electroencephalography; Bio Mechatronics

Humanitarian-Machine Interfaces in Biomechatronics

Many developed systems simply fail because they lack good interfaces for interpreting user motion intention/states and providing tactile feedback in the systems. Advanced Human-Machine Interfaces (HMIs) are the key to harmonizing mechatronic systems with human beings in the loop; many created systems simply fail due to a lack of suitable interfaces for interpreting user motion intentions/states and providing tactile feedback. Based on multichannel surface EMG signals, Liu et al. created a model for decoding multi-joint dynamic arm movements in a continuous and simultaneous manner [1]. This was used to Myoelectrically control exoskeletons for upper-limb rehabilitation, demonstrating the ability to manipulate damaged arms with ease.

Zhang et al. used sEMG signals for simultaneous and continuous estimation of shoulder and elbow kinematics using principal/independent component analysis and an artificial neural network for learning electromechanical association, using a similar approach. This was done in order to achieve natural and intuitive human-machine interaction, which is useful for exoskeletons, prostheses, and other arm rehabilitation procedures [2]. Wu et al. developed grip force and three-dimensional push-pull force estimation based on sEMG and a generalized regression neural network as an addition to the above approach. This study was presented to address the needs of the intelligent prosthetic hand's force control, which used EMG and grip force sensors to measure the human hand's output force [3].

Since EMG sensors were used in all of the previous studies, there must be a better approach to obtain steady signals. A Polypyrrole-coated nonwoven fabric sheet has been proposed by Jiang et al. for the design of EMG sensors [4]. The shape and size of the pattern can be adjusted, and it can be sewed into an elastic band for tight contact with the skin for practical control of the prosthetic hand. The sensors produced results that were comparable to those obtained with traditional Ag/AgCl electrodes often employed in EMG sensors. In contrast to EMG-based HMIs, which use muscle signals, EEG-based HMIs use brain signals, sometimes known as Brain-Machine Interfaces (BMIs). Previous non-invasive BMIs used Fourier-based time-frequency decomposition algorithms for EEG feature extraction [5].

This method, however, proved difficult to apply to multichannel EEG recordings. Wang and Veluvolu devised evolutionary algorithms for optimizing features to reduce overall dimensionality and maintain class-related information to improve the efficiency of multi-channel EEG classification [6]. Their findings demonstrate that the highest overall performance comes from combining a Fourier-based technique with a covariance matrix adaption evolution strategy. Invasive BMIs, as opposed to non-invasive BMIs based on scalp EEG, utilize high-quality brain signals, which are critical for advanced control of dexterous robotic arms or prosthetic hands. Using cortical neural spike recordings from monkeys, Ma et al. were able to decipher lower limb muscle activity and kinematics during stand/squat movements.

They provided through data analysis and fresh insights on invasive BMIs that could be used to regulate complicated bio mechatronic systems. A 3D computational model for estimating tactile nerve fiber excitability was developed to investigate the process of touch feeling under transcutaneous electrical nerve stimulation [7].

Investigated simultaneous adaptation of game difficulty and haptic assistance through psychophysiological signals (heart rate, skin conductance level, and skin conductance response frequency) and performance feedback in order to improve challenge/skill ratio in a multi-modal interface for human-robot interaction [8]. Unlike traditional diagnosis based on the patient's self-description, researchers have devised a pattern recognition method to classify pain intensity based on several physiological signs (blood volume pulse, electrocardiogram, and skin conductance level).

This has ramifications for individuals who are unable to explain their level of discomfort due to substantial cognitive and communication deficits. The method can provide objective and quantitative measurement of pain severity, according to the results of the experiments on healthy people.

Training and Assistance with Novel Exoskeletons

Since "soft robots" can give users with compliance with intrinsic safety features, there has been a rise of interest in putting them into every element of robotic support and training. The study discussed a soft robotic elbow sleeve with full design features and functionality employing elastomeric and fabric-based pneumatic actuators; however, the intent-based actuation control was more noteworthy [9]. Surface Electromyography (sEMG) was used to detect user intent in healthy people, and the results demonstrated that all users could control the elbow sleeve with EMG control.

Yap used soft robotic gloves with fabric-reinforced soft actuators to target hand function aid, which was an extension of the above notion by the same group. To increase the driving force for finger extension, they combined elastic fabric with soft actuators. With the help of the soft glove, stroke survivors improved their grasping performance in a pilot study. Oguntosin et al. took a somewhat different technique, demonstrating functional features of the exoskeleton actuated by soft modules. The exoskeleton is ultra-lightweight thanks to 3D printed pieces with passive joints and a gravity compensating technology. In neuro rehabilitation for those with specific motor deficits, the exoskeleton was proposed for precise reaching control [10]. The benefits of adopting soft modules for rehabilitation were underlined in these articles.

Huang et al. investigated a cable-based robot for assessing motor control during 3D movement tracking with position-varying gravity correction in a unique approach. They discovered a substantial difference in control techniques when gravity compensation was used versus when it wasn't, which could aid participants in completing optimal motions throughout rehabilitation. In the normal stride, people swing their arms synchronously with leg movement, as Fang et al. discovered. As a result, they created a rotational orthotics for gait training with arm swing to promote synchronized inter limb performance.

The gadget was examined for functional evaluation with normal people and was reported to produce a greater feeling of walking with arm swing than without, which could potentially improve gait rehabilitation outcomes for patients undergoing training.

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