



#### Editorial Special Issue "Novel Approaches and Applications in Ergonomic Design"

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#### 1. Introduction

Interactions between humans and systems need to be designed appropriately for safety, usability, productivity, health, and/or wellness. Emerging technologies such as affective artificial intelligence, cloud computing, Internet of Things, big data analytics, autonomous vehicle technology, robotics, and wireless technology in the fourth industrial revolution era have challenged ergonomists and human factors professionals to explore novel design methodologies and solutions of human–system interactions for the synergistic fusion of the physical, digital, and biological worlds. The objective of this Special Issue is to share novel approaches and applications produced by researchers in various fields so that their efforts can be more effectively spread and transmitted to the development of ergonomic designs for a better harmony between humans, systems, and environments. In the Special Issue, a total of 12 papers have been published out of 22 manuscripts submitted. The following sections provide a brief summary of each of the papers published.

## 2. Fusing Hand Postures and Speech Recognition for Tasks Performed by an Integrated Leg-Arm Hexapod Robot

As robots are used increasingly in our daily lives, natural interaction between humans and robots becomes a vital design issue so that humans, including non-experts, can interact with robots conveniently and efficiently. Qi et al. [1] developed a system to control the movement and manipulation of an integrated leg–arm hexapod robot by recognizing hand postures and speech instructions for surveillance and rescue tasks in a public security application. The robot control system developed in the study consists of seven modules (hand posture, speech, fusion, mechanical structure, control, path planning, and 3D simultaneous localization and mapping modules). Experiments of human–robot interaction using hand postures, speech instructions, and the combination of hand postures and speech instructions were conducted in the study to examine the performance of the robot control system.

# 3. Effects of Smartphone Size and Hand Size on Grip Posture in One-Handed Hard Key Operations

Information regarding user-preferred grip postures in the operation of hard keys on a hand-held device is needed to determine the optimal locations of the hard keys for better operational efficiency and comfort. Choi et al. [2] conducted an experiment to identify the preferred grip postures of 45 smartphone users with various hand sizes in one-handed hard key operations for major smartphone tasks with smartphones of various screen sizes (3.0 to 7.0 inches). Dominant grip postures preferred by the users were identified, and the effects of smartphone size and hand size on the frequency distribution of user-preferred grip postures were examined in the study. Future research is needed to determine the optimal locations of hard keys on hand-held devices using the information of dominant grip postures.



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### 4. Identifying the Risk Factors in the Context of Use of Electric Kick Scooters Based on a Latent Dirichlet Allocation

Although accidents related to electric kick scooters are increasing rapidly, most research concentrates on reporting accidents and injury patterns. Lee et al. [3] identified risk factors in the context of use of electric kick scooters using the latent Dirichlet allocation (LDA) topic modeling method. A total of 423 risk episodes of 23 electric kick scooter users were collected in the study by an online survey for two months. The collected risk episodes were classified into nine topics (e.g., felt danger from a car or a pedestrian appeared suddenly) using the LDA method. Then, four risk factors (moving entities–user, product–user, environment–user, and environment–product) were identified by analyzing the nine topics and the causes of risks in the contexts of use. The study is not just reporting accidents but rather organizing risk episodes systematically from users' perspectives and providing directions of design improvement to prevent accidents.

#### 5. Estimation of Finite Finger Joint Centers of Rotation Using 3D Hand Skeleton Motions Reconstructed from CT Scans

The accurate locations of joint centers of rotation (CoRs) of the fingers are important for a digital hand model to simulate postures of the hand interacting with an object with high accuracy. Yang et al. [4] developed a novel method to estimate the finger joint CoRs with high accuracy using 3D hand skeleton motions reconstructed from CT scans. A total of 10 hand postures, from a fully extended posture to a fist posture, with about  $10^{\circ}$  difference in flexion between the adjacent postures, were captured by a 256-slice CT scanner from 15 male participants. The finger joint CoR estimation method consists of four steps: (1) a hand skeleton is reconstructed from CT data for each of the ten postures, (2) the bone segments in the template posture are registered to respective bone segments in each of the nine remaining postures, (3) the proximal bone segment of a joint from each of the nine remaining postures is registered to that in the template posture, (4) the centerline of the distal bone segment of the joint from each of the ten postures is identified by the PCA method, and (5) the CoR of the joint between two different postures is estimated as the intersection point of the identified centerlines of the distal bone segments of the joint from the two postures. The study identified that the proposed CoR estimation method reduced the variability of finite joint CoRs by 16.0% to 67.0% among the finger joints compared with the existing methods.

#### 6. The Impact of an Agent's Voice in Psychological Counseling: Session Evaluation and Counselor Rating

In recent years, there has been an increased interest in applying artificial intelligence (AI) technology to psychological counseling, as people show their emotions with less fear and pressure when communicating with an AI-based conversational agent (CA). The voice of an AI-based CA needs to be designed by considering social aspects and conversational contexts for a better outcome of psychological counseling. Kim et al. [5] examined the effects of a psychological CA with four voices of different genders and ages. The female-voiced agent showed a higher level of attractiveness than the male-voiced agent, regardless of the age of voice, and the older-voiced agent gave a higher perceived level of expertise than the younger-voiced agent regardless of the gender of the voice. Further research is needed to design an AI-based CA incorporating an optimal voice according to the purpose of use.

## 7. Quantitative Assessment Method of Force Tracking Capabilities for Detection of Motor Intentional Disorders

Quantitative assessment of dysfunction in the action–intention system of the brain is clinically important for the early detection of motor intentional disorders (MIDs) so that clinical interventions to MIDs can be administered at an early stage. Jung et al. [6] developed a quantitative assessment method of force control capabilities using a force tracking system (precision = 0.098 N, sampling rate = 32 Hz) that can record the forces exerted by the index finger while tracking 5 N, 10 N, 15 N, and 20 N of target forces, varying continuously over time. Quantifying force control capabilities were measured in terms of (1) initiation time, (2) development time, (3) maintenance error, (4) termination time, and (5) tracking error. The study then compared the force control capabilities of the normal group with those of two patient groups diagnosed with subcortical vascular mild cognitive impairment or subcortical vascular dementia. The clinical experiment found that the force tracking system discriminates the severity of the force control deficiencies more than the force control tests used in existing studies. Jung et al. discuss that the force tracking system can be used as a tool to enhance brain fitness and monitor the effectiveness of brain fitness exercises.

#### 8. A Boundary Zone Method for the Generation of Multivariate Representative Humanoids

A small group of digital humanoids that properly represent the target population are used in the ergonomic design and evaluation of products and workstations in a digital environment. Jung et al. [7] proposed a novel multivariate method that generates representative humanoids (RHs) at a boundary zone (BZ), employing cluster analysis and real anthropometric cases to overcome the limitations of existing multivariate methods (factor analysis and principal component analysis), such as, the loss of anthropometric variability, the large estimation error of anthropometric dimensions (ADs), and a lack of body size diversity. The BZ method consists of three steps: (1) the formation of a BZ for a designated accommodation percentage of the target population, (2) the clustering of anthropometric clusters as RHs. The proposed BZ method was preferred to the existing multivariate methods. This was evaluated using 1988 U.S. Army anthropometric data and 10 ADs pertinent to computer workstation design in terms of the loss of anthropometric variability to determine the estimation error of ADs and the lack of body size diversity. Further research is needed to examine the effectiveness of the BZ method in solving various ergonomic design problems.

#### 9. Test-Retest Reliability of Sole Morphology Measurements Using a Novel Single-Image-Based Pin-Array Impression Reconstruction Method

Existing sole morphology assessment methods are limited to the two-dimensional or non-weight-bearing conditions of the foot. Chen et al. [8] evaluated the reliability of the novel Single-Image-Based Pin-Array Impression Reconstruction (SIBPAIR) method when implemented on a commercial foot assessment system. In the study, the SIBPAIR method was found to have high intra-rater, inter-rater, and inter-session reliabilities (ICC > 0.90) by analyzing repeated measurements of 3D morphological sole scans from 15 healthy young adults by two physical therapists. Accurate and reliable measurements of the sole morphology could be used for foot assessments and subsequent applications, such as designing and manufacturing customized shoes and orthoses.

#### 10. Development of a Drawing Application for Communication Support during Endoscopic Surgery and Its Evaluation Using Steering Law

Computer-Supported Collaborative Work (CSCW) environments, using augmented reality (AR) technology, are expanding to various fields, including industry, education, and health sectors. Asao et al. [9] constructed a hands-free endoscopic surgical CSCW system that enables head movements to draw lines in space using AR technology and evaluated the applicability of the drawing motion using head movements to the steering law for its' potential use during endoscopic surgery. In the study, nine participants aged between 21 and 25 manipulated a cursor through a pathway using head movements. Data regarding the movement time (MT), the number of errors, and subjective evaluation of the difficulty of the task were collected in the study. A strong linear relationship ( $R^2 > 0.9$ ) between the index of difficulty (ID), MT, and higher performance was reported in the horizontal and vertical directions compared to that of the diagonal directions. Although the weight and biocompatibility of the AR glasses of Microsoft HoloLens need to be resolved for use in a

clinical setting, the study demonstrates the potential of an AR-based head-drawing system for endoscopic surgery in a CSCW environment.

## 11. Development of a Virtual Fit Analysis Method for an Ergonomic Design of Pilot Oxygen Mask

A virtual fit analysis is an effective method to examine the fit of a product design using the 3D scans of users before fabricating and testing physical prototypes. Lee et al. [10] developed a virtual fit analysis method to develop an ergonomic design of a pilot oxygen mask. Three types of information were considered in the virtual fit analysis for designing the shape and size of a mask: (1) 3D facial scan images and face measurements of the user population, (2) the boundary shape on which the mask contacts the face, and (3) the wearing positions of the mask on the face. An ergonomically optimized shape of the mask boundary for a designated user group was searched using an iterative design process and virtual fit analysis consisting of four steps: (1) the design of an initial shape for the mask boundary, (2) the calculation of horizontal distances between the mask boundary and 3D face surfaces, (3) the evaluation of the appropriateness of the mask boundary shape, (4) the adjustment of the mask boundary shape, and (5) the completion of a mask design based on the selected mask boundary shape. The oxygen mask design method based on the virtual fit analysis was applied to improve the existing design of MBU-20/P pilot oxygen masks for Korean fighter pilots. The study demonstrates the effectiveness of the virtual fit approach in developing an optimal design by the iterative process of adjusting a product design and checking its appropriateness to a large number of users using 3D body scans.

# 12. A Linkage Representation of the Human Hand Skeletal System Using CT Hand Scan Images

Although a linkage representation of the hand skeletal system is widely used in hand models by defining the segments and link lengths of the hand, an inappropriate linkage representation is commonly constructed based on bone length data or bony landmark locations. Cao et al. [11] proposed a novel method to estimate finger joint centers of rotation (CoRs) using 3D hand motions reconstructed from computed tomography (CT) scans and constructing participant-specific linkages from the derived hand joint CoRs. The study constructed regression equations to predict the locations of CoRs for the thumb CMC joint and the MCP joints of the other four fingers using the data of hand length and hand breadth. This method was also used to predict internal hand link lengths using hand length data for a linkage representation of the hand. Future research is needed to examine the applicability of the proposed CoR estimation method using various hand postures.

#### 13. The Variation in 3D Face Shapes of Dutch Children for Mask Design

Three-dimensional anthropometric head data are needed to develop head and face gear with a proper fit. Goto et al. [12] collected 3D head scans of 302 Dutch children (128 females, 174 males) aged from six months to seven years and conducted both measurement-based and shape-based principal component analyses (PCAs) for the design of a ventilation mask. The results of PCAs describe the morphological distribution of the children's faces. The mannequin tool on the DINED platform was developed during the study so that designers can examine body shape variations related to product design in an intuitive way.

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