IDD: A case-based model of learning in design using artificial neural network-based approach

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Summary
This research aims at integrating Artificial Intelligence, Human Factors and Design Methodology to search for an ideal case-based design decision model of walking aids used by the handicapped people. The research adopts design information system, artificial neural network-based approach and product design morphology to build up a cased-based intelligent design decision (abbreviated as IDD) model.

Key words:
Artificial Intelligence, Human Factors, Design Methodology, Design Decision Model. Human Computer Interaction

Introduction

Design is an intelligent human information-processing activity requiring many skills and much knowledge. Many scholars indicated that Design is an ill-structured activity requiring intelligence, and that provides a lot of opportunities for us to develop totally new tools and new models to support design activities[1-3]. Some researchers are also concerned with what needs to be represented to support the intelligent design systems, and with what progress has been made in intelligent design systems over the last ten years**.** Now, design has become an important area to study by using many artificial intelligent techniques with a rapid growing literature[4-7]. Intelligent design systems can range from autonomous design tools, that when given requirements will produce designs, to design aids that interact with a human designer (or designers) to support their designs[8]. Accordingly, this study is focused on the application of artificial neural network-based approach to develop a new cased-

based model of learning to support the decision of walking aid design. The decision process of walking aid design is a very complex and poorly understood area for designers because of involving lots of knowledge of human factors and rehabilitation medical science as well as design science.

The year 1981 had been issued to be the international handicapped year. That means the handicapped problems had been commonly concerned by all worldwide nations. Until 1992, the congress of U.N. had past a special issue and announced that the third of December was international handicapped day. According to the statistical data surveyed by social bureau of the ministry of interior affairs in R.O.C.[9-10], there have been 221,144 persons received handicapped identity pamphlet, among them 118,258 persons, about 53%, are limb-handicapped people. All these data indicate that walking aids design for handicapped people has been increasingly important in the future.

Walking aids, including wheelchair, crutch, cane and other walking-aided apparatus, play an important role not only in the process of rehabilitation to recover health to some temporary handicapped people but also to be the walking-aided support in the whole life to other permanent handicapped people[11]. Designing walking aids should consider many factors such as the various individual physiological situations, different human operation patterns, manufacturing process and so on. Among all these factors, perhaps the man-machine interface directly dominates the success of walking aids design from the viewpoint of human factors and rehabilitated medical science [12]. According to the statistical data issued by U.S. Consumer Product Safety Commission（1987）, there were 20,245 accidents suffered by using walking aids. Therefore, from the viewpoint of the product evaluation, to integrate artificial intelligence and human factors into rehabilitated medical knowledge and build up better-humanized design criteria for the walking aids

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designers are increasingly essential and helpful to the contributions of our social welfare as a whole.
Based on the above studies, this paper attempts to search for the possible optimal Intelligent design decision (abbreviated as IDD) model from the man-machine interface viewpoint by introducing the knowledge of artificial neural network-based approach, biomechanics, gait analysis and physiological response of operating walking aids by handicapped people. The new IDD model is supposed to synthesize design parameters and morphological characteristic analysis to formulate a basic systematic framework of computerized design decision support model

2. Fundamental Theory of IDD Model

The basic theory of IDD model is virtually derived from the concept of the author's integrated design decision-making procedure (abbreviated as IDP) model which was presented in 1991（Lai, 1991;1992）. Theoretically, the framework of IDP model explains the concrete structure of a design problem in the form of dynamic system and uses strategic system control as its means to search for the solution of design problem. This means-end relation is proved to be the optimal theory of action, as well as the important basis for rationalization and systemization of design by the most famous design scholars and experts[13-14]. Basically, the IDP model consists of three main parts: (1) Analysis of systematic praxiology: this emphasizes design perception as the precondition for problem-solving and explains the entity or phenomenon of the problem's attributes by means of systematic praxiology. (2) Analysis of strategic feedback control: this analysis uses the dynamic optimization of multiple objects to solve the consequential decision-making problems. (3) Integrated decision-making procedure: this studies the approaches, which use integrated procedure to search for design value.

The new IDD model is aimed at introducing the effective factors of physiological aspects in the process of walk-learning development to meet the design requirements of operating walking aids. Owing to the complex and interactive factors produced by the interface of man-machine (in this situation this means the handicapped person and his using of walking aid), it is necessary to apply artificial neural network for processing parallel-distributed design information. The new model pinpoints different design problems and design factors, by using backward transforming network, to obtain better learning capacity. In this research, the fundamental operating concept of IDD model is attempted to adopt back propagation neural network to integrate the locomotion and coordination design of man-machine interface for the reference of objective walking aids designers' decision-making.

IDD characterizes a multiple feed-forward network, which possesses some particular learning abilities. Therefore, the new model is one kind of structured network, which includes input layer, hidden layer and output layer. The processing unit of input layer performs to input signals from external environment. The processing unit of output layer performs to transfer messages to external environment. The existing of hidden layer is to provide the interactions among the processing units. The basic relations of IDD model are shown in figure 1.

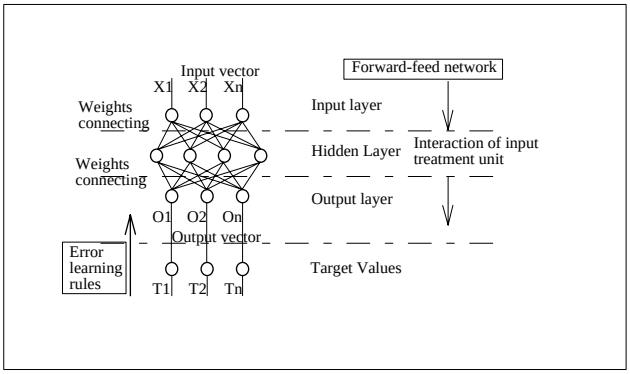

Fig. 1 The connecting concept of processing units in IDD model

In the learning process, IDD model adopts two steps learning network. The basic framework of IDD model in the first and second learning process is shown in Figure 2 and Figure 3, respectively. The input and output parameters in the first learning process are the physiological factors which affect walking development and the characteristics description of ill walking type. In the second learning process, these parameters are the characteristics description of ill walking type and functional

morphological characteristics of walking aids design. Similarly, in the recalling process, there are two choices of inputs, which are physiological factor values affecting walking development and characteristics description values of ill walking type. The final outputs of both choices are functional morphological characteristics of walking aids design to be provided for the reference of walking aids designers' decision-making. Figure 4 shows the basic framework of IDD model in the recalling process.

The algorithmic procedure in IDD model can be depicted in the following twelve steps:

(1) Determine network parameters, neuron numbers and learning speed （including input layer i, single hidden layer h, output layer j and target output layer T）.
(2) Set up the initial weight values and initial threshold values according to random numbers.
(3) Input training sample cases and target output values.
(4) Calculate the network output values.
(5) Calculate the differential quantities between output layer and hidden layer.
(6) Calculate the weight value revisions and threshold value revisions among all layers.
(7) Renew weight values and threshold values among all layers.
(8) Repeat from Step No.3 to Step No.7 until the network converged.
(9) Set up the final corrected network layers and the neuron numbers among all layers.
(10) Read well-trained network weight values and threshold values.
(11) Input one testing sample case.

Calculate the final inferential output values.

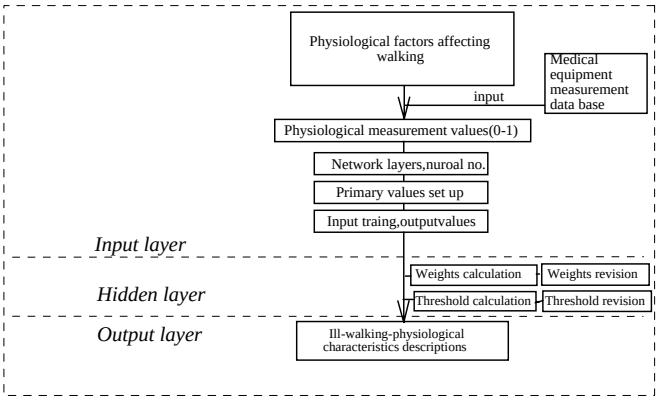

Fig. 2. The basic framework of IDD model in the first learning process

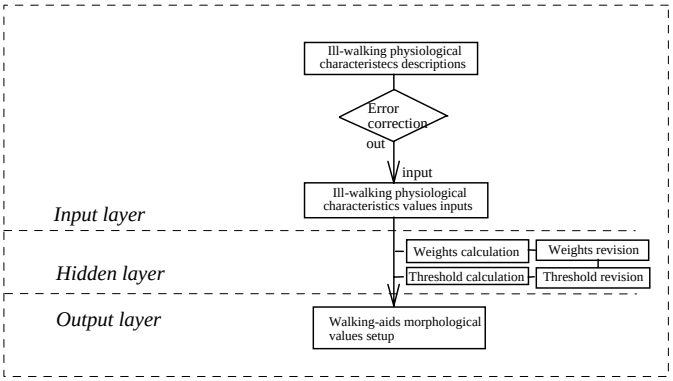

Fig. 3. The basic framework of IDD model in the second learning process

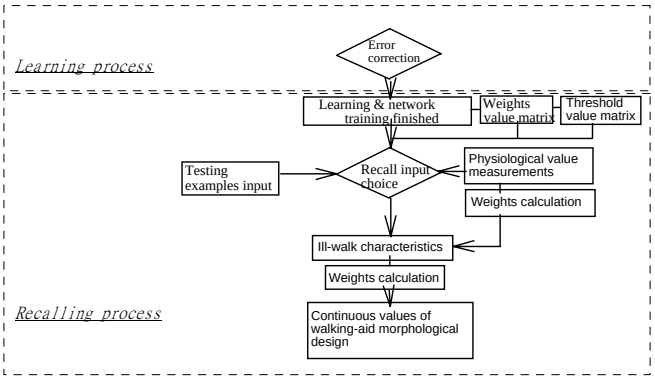

Fig. 4. The basic framework of IDD model in the recalling process

4. Simulation of IDD Model Operating

The operating simulation of IDD model employs the neural network software “Neural Works Professional Plus” to perform network learning and recall

operating simulation. The interface operation for walking aids designers' using IDD model employs a new designed window-dialogue software on computer program.

In the learning processing of IDD model, the input sample cases of 50-subject records are provided by the Rehabilitation Department of National Cheng Kung University Medical Centre. The input parameters include the measurements of muscle strength, the measurements of joint activity angles, the evaluation of gravity centre balance and the characteristics description of ill walking type. As for the output values of walking aids functional morphological characteristics are based on the previous studies of walking aids functional morphological factors and the suggestions to functional evaluation of existing walking aids.
The simulation of IDD model operating was demonstrated very well, network learning plan, reading input and output values as well as the network learning process in the first stage. The nature of learning process is actually a network convergent process. While the network reiterating the learning training, if the total error rate, which is equal to error numbers divided to total numbers of sample cases, is less than 0.1, then the convergence is considered as very good. In the IDD model simulation, the goodness of convergence adopts two judgements for evaluating errors, one is named as Test 1,which calculates the errors of each processing unit, and the other is Test 2, which calculates the total error rate of the network. The value of Test 2 is 0.022 for the first stage, and 0.097 for the second stage. Both values are less than 0.1, thus we can say the convergent situation is very good. In other words, these results demonstrate that the matrixes of weight values and the matrixes of threshold values are very reliable, and can provide for the application of recalling process. Therefore, the final output values are also very reliable.

5. Discussions

According to the above simulation results of IDD model operating, some benefits and disadvantages can be discussed as follows:

(1) The network connecting model of knowledge collection depends upon the framework of learning-recalling artificial neural network which can properly adjust network connecting values by itself and manage information with parallel distributed flow. The new IDD model possesses open-ended adapting performance through the learning training and will offer new walking aids design suggestions for the reference of designers' concept design process.

(2) The input and output values of IDD model in the procedure of knowledge analysis are defined as real numbers between 0 and 1. This represents two meanings: one is to reduce the unexplained values from the network calculation process, and the other is to show the effective degree of different factors. Through the response of strong and weak degree of output values, designers can synthesize the design requirements and design constraints to design better walking aids. The new design can meet the physiological load capacity and simultaneously avoid side-effect illness.

(3) Back propagation neural network used in IDD model usually needs plenty of input samples to increase the reliability of learning training, which is also mentioned in many neural network studies[15-18]. Therefore, the ideal objective of IDD model is attempted to employ neural network parallel treatment characteristics and learning judgment ability to integrate the expert knowledge of medical diagnosis into the design of walking aids. Through continuous self-adaptation and learning, the network model then can provide correct network for proper design decision-making of walking aids.

6. Conclusion

In this paper, we can find that every step in IDD model is very trivial and delicate. But triviality and delicacy are the requisite for accurate decision value. The new IDD model, which derived from the IDP model employing artificial neural network-based approach in walking aids design decision-making to assist design information system analysis, is possible to provide much better design criteria for walking aids designers. The new IDD model should be one kind of feasible design tools to reach the most reasonable walking aids design in this computer era. All in all, IDD model is not only an application of artificial intelligence, but also, in product design, an effective method for the study of man-machine system. It is the author’s sincere hope that the

outcome of this research can expedite the union of the experience of artificial intelligent experts, rehabilitation medical doctors, ergonomics engineers, and product designers to create higher-leveled products, so as to improve the life quality in our society.

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