

RESEARCH ON COMPUTER-AIDED ERGONOMICS FOR INDUSTRIAL DESIGN

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Abstract: *The paper discusses some communication problems that occur under ergonomists, designers and design tools. A project of a platform of ergonomically knowledge is brought out. Present computer aided ergonomics concentrates on analysis and evaluation in the later design stage. The technology of computer aided ergonomics for the full life cycle of the industrial design is presented. Also, there are described the key technology at every stage in the design process. Finally, a prototype system and some examples of our research prove relevant scientific content of our research during a CNC SIS contract (type A): “Product and Production Systems Ergonomics Design for Increasing Their Safety and Quality During Their Whole Life Cycle”.*

Key words: *ergonomics, computer aided industrial design, ergonomics simulation, ergonomics evaluation, industrial design.*

1. INTRODUCTION

The term “ergonomics” as a combination of the Greek *ergon*, (was the former term for work) and *nomos* (order or fundamental science) translated freely, has something to do with the more bland *work science*. Ergonomics is a science which is expected to contribute to the design of user-friendly products and working conditions which are adequate for human beings. “Human Factors Engineering” (Anglo-American term) makes clear that fundamental knowledge about the functioning of the human body, is indispensable for activities in this field. In this context, the International Ergonomics Association (IEA) gives the most relevant definition of Ergonomics sciences. “Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance” (ww.iea.cc).

Nowadays the ergonomic design process is computer aided using different specialized software or even specialized modules attached to CAD or CAM products. The human interface design is developed using software like: Simuli 8, TOMAS, SAFE WORK, Delmia V5 or D5 (non CATIA), WITNESS or RAMSIS etc. [3, 4].

Traditional industrial design focused on the function implement and obtaining low costs of production. With the development of the society and improvement of technology, the consumption idea of the society have changed consequently. The product functions are not the most important factor that consumer decides to buy it or not. On the other sides, the ergonomic factors such as convenience, comfort, reliability, safety and efficiency are being paid more and more attention. Today, traditional ergonomics is used to analyse and evaluate product after manufacture, taking into consideration the product behaviour during the whole life cycle [2].

Since 1990s, with the development of information technology, computer aided ergonomics has already become the research focus of CAID (Computer Aided Industrial Design) field. Computer aided ergonomics can evaluate the design plan in the process of design. It can improve the success rate of product design, with a short development period.

At present, the research of computer aided ergonomics has centralised on two sides:

1. *Ergonomic consulting system for aiding ergonomics design.* CDEEP [2] adopts regular reasoning to deal with the ergonomic standard of design, and offers ergonomic advice to designer. ErgoCop [6] provides various kinds of ergonomic information of workplace design. ERGOEX [5] is an ergonomic expert system, which can aid workspace design. The PeopleSize system [3, 4] offers the human measurement data to designs.

2. *The analysis and evaluation system used for computer aided product design.* In this field, the famous research institutions are HMS research centre of University of Pennsylvania and the Ergonomics Centre of Michigan University. The former developed JACK [1], which could analyse and evaluate three-dimensional models of the automobile and aviation products from the ergonomics point of view. The latter has developed a serial of ergonomic analysis tools, such as 3DSSP, EEP. Nottingham University from Great Britain develop and commercialised the SAMMIE software, which could test the workplace range, check kinetics interference, measure the view come, and evaluate work posture and calculate the balance. An important IT German company has put out two software, Ramsis and EM-human, that could carry on the systemic ergonomic analysis for automobile cockpit [3, 4].

According to above information, computer aided ergonomics has developed greatly and can provide good support for industrial design. But some questions exist yet in the area of computer aided ergonomics as it is shown in Fig. 1 [5, 6].

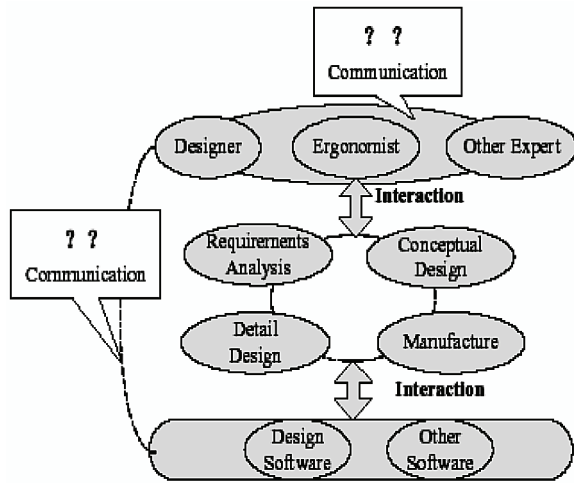


Fig. 1. Relations among design factors.

Lack of the support to ergonomists. The research of the existing computer aided ergonomics software for the design process, the request of ergonomics is seldom considered. The information inter-communication among designers, ergonomists and design tool is also not unobstructed. On one hand, the ergonomists have done a large number of experiments and accumulated a lot of ergonomics data; on the other hand, due to various reasons, the data are very difficult to utilise directly by designers and incorporated in the plan of design.

Lack of support to design in the whole life cycle. The life cycle of industrial design is ordinarily divided into request analysis, conceptual design, detail design and manufacturing. Every design phase has different ergonomic demands that developed specific knowledge. The existing computer aided ergonomic tools only provide consultation tool and evaluation tool after the product design process, it is unable to be to support design in the full life cycle.

Computer aided ergonomics tool can't be combined with the design tool organically yet. There is no corresponding ergonomic module in the present popular industrial design software. And the present computer aided ergonomics tools requires more complicated operation, or strong professional knowledge, so they are very difficult to be really used by designers. Most designers are still relying on experience to carry out the design process based on the ergonomics principles.

The above questions make it necessary to think over computer aided ergonomics for industry design again. What ergonomic technology does designers need? What support should computer aided ergonomics offer to industry design? For these reasons, the paper has put forward the framework of computer aided ergonomics for industry design, and describes the key technology among them.

2. ERGONOMICS AIDED TECHNOLOGY FOR INDUSTRIAL DESIGN

Ergonomics technology for industrial design should coordinate the relationship among CAD software, ergonomists, and designers. Meanwhile, it should support full life cycle industrial design [2] process (Fig. 2).

Some details about the main principles of our scientific development are given in the following [5, 6].

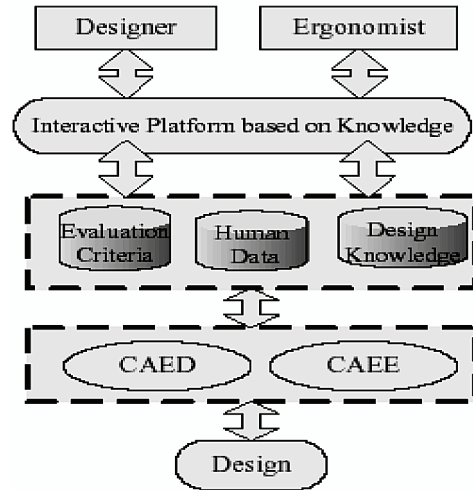


Fig. 2. Framework computer aided ergonomics.

2.1. Ergonomics Platform Based on Knowledge

Ergonomists would be granted to participate in design discussion on the ergonomics platform, give their opinions to design plan. So ergonomics systems supporting multiple man-machine interaction modes and spontaneously participation are strongly recommended. The knowledge can not be used in design field until design data and ergonomics data are unified. In the platform, knowledge acquisition, representation and utilisation are usually use for dealing with the data.

2.2. CAED-Computer Aided Ergonomics Design

In design phase, the most critical phase is distributing functions between human and product (Fig. 3). The whole relationship among human, product, and environment are considered. The roles of human in the systems are analysed [2, 4].

According to above request, the content of CAED in design phase include:

- The collection and transaction of multiple-format data have to be supported. Original ergonomics data may be characters, charts, or even pictures, videos and others. CAED should be able to translate these original materials to unifying knowledge and build a database.

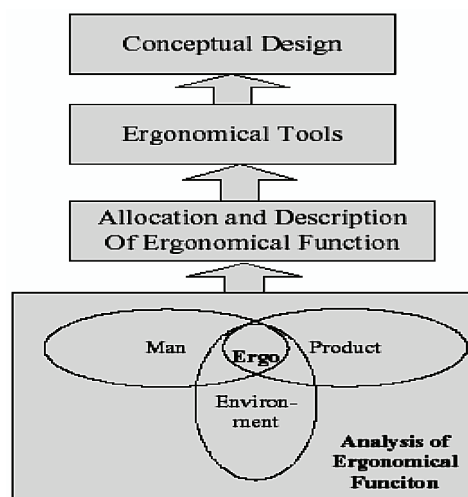


Fig. 3. Information Flow in the CAED module.

- In the design phase, consulting system based on expert knowledge and information system based on human database are needed.
- In the design phase, simple draft of conceptual design should be evaluated in the CAED system.

2.3. CAEE-Computer Aided Ergonomics Evaluation

In the detailed design phase, the main ergonomics tasks are as following:

- Product shape should be considered according to human physiological and psychological characteristics.
- The dimension of product components should be considered according to human size and capability.
- Operation convenience should be considered according to operator’s height and its movement zones.
- The product model can be evaluated by CAEE system as soon as it is built. After building the man-machine environment, each operation on the product can be simulated. Human factors can be quantitatively analysed and evaluated according to ergonomics algorithms (Fig. 4). Meanwhile, the result can be feedback to the designer in order to support product innovation.

As it is shown in Fig. 4, the key techniques are:

- *3D human model*: Parametric human model including dynamics and kinematics model are built based on human database.
- *Ergonomics evaluation algorithms*: It includes comfort assessment, low back analysis, static strength prediction, metabolic energy expenditure, fatigue recover, posture analysis, NIOSH lifting analysis, RULA pose analysis, OWAS, reach zones and view cones etc.
- *Ergonomics simulation*: The man-machine interaction process is simulated including operating process and special movement simulation [3, 4].

3. RESEARCH VALIDATION

For above analysis, we developed a prototype system to support ergonomics analysis and evaluation during conceptual design phase, and the detail design.

We will use some examples of our research to make further explanations for the developed systems.

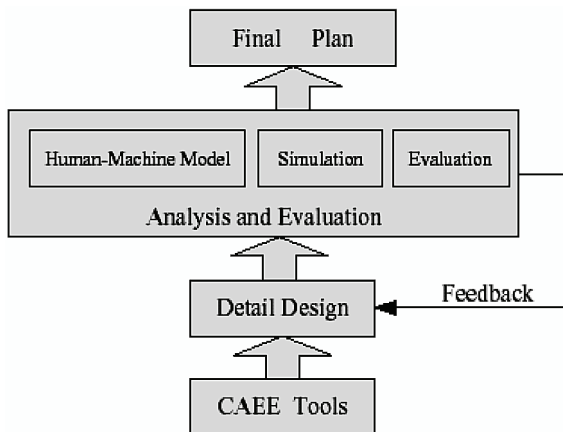


Fig. 4. Information Flow in the CAEE module.

3.1. Ergonomics Design and Evaluation of a Desk Office in the Conceptual Design Phase

- *Taking Human Factors as Layout Design Constrains.* In desk office design, the conceptual design phase is one of the most important product design phases. In this phase, designer must consider various layout design factors such as array, position, dimension etc. So it is also the critical phase in product innovation. Ergonomics design and evaluation regards human factors as specific layout constrains and takes human position as reference co-ordination. It brought out a new layout design model based on constrains. This model divides constrains into space constrains and ergonomics constrains between layout units. So the ergonomics aspects can be considered in the layout design. The desk office concept design model is depicted in Fig. 5 together with the abstract of the human interface model.
- *Ergonomics Analysis and Evaluation.* First, ergonomists design a human model attaching to the desk office using abstract, static, seated, side faced 3D model. Then, according to the basic human parameters and parameters provide for the desk office by the ergonomics design and evaluation system, it is build a 3D ergonomics evaluation system. So, there can be basically verify the usability and reasonability and of key design parameters. Finally, according to the features of the human model, there can be done ergonomics analysis of the posture and joints comfort assessment. The assessments include the comfort of the arms given by their position on working on a computer and the analysis of the visual ergonomics design. The model and evaluation results are presented in Figs. 6 and 7.

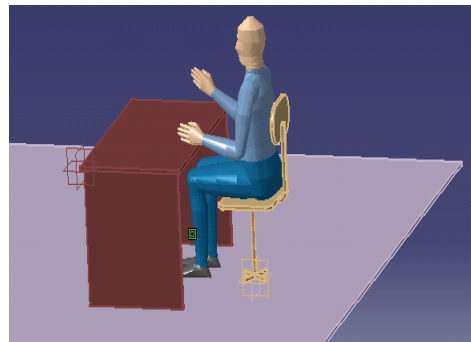


Fig. 5. The human-desk office model.

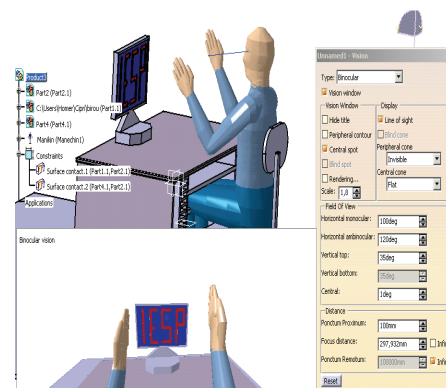


Fig. 6. The human’s vision or visual ergonomics design.

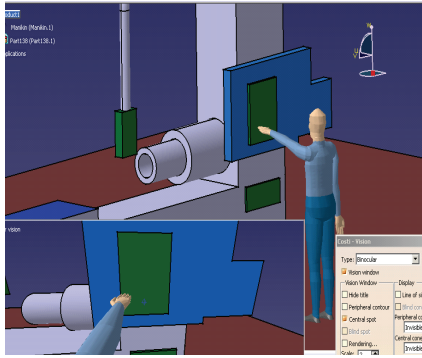


Fig. 7. Aspects of the human posture and activity analysis simulations (establishment of the lateral commands position).

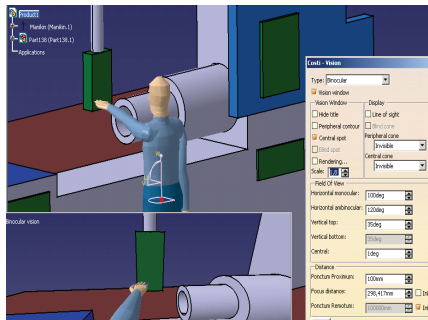


Fig. 8. Comfort assessment (simulations of the human posture when the buttons of the command panels are pressed).

3.2. Ergonomics Design and Evaluate in Final Design Phase

In the CAEE system, a 3D human model can be built base on importing product model. Ergonomics simulation can be carried through motion capture. Then dynamic ergonomics analysis and evaluation can be implemented. A case is given from a research for user-friendly workplace design by using the postural analysis and the human activity analysis in the case of machine-tool design process (complex research project for the user-interface study for the machine-tools made in Romania).

- Human model was chosen as a male adult (that corresponds to the 75% of the users' population) of 1.75 m, 65 kg [3].
- Ergonomics simulation is shown in the following figures. It depicts the action of the human operator upon the buttons of the machine tools command panel. Furthermore, it can simulate special movement through micro-control. The results of the ergonomics simulation process were taking into consideration for defining the product (machine-tools) final shape (an example is shown in Fig. 7) [3].
- Ergonomics evaluation (comfort assessment): Joint's dynamic assessment is carried through comfort analysis of the joint angle (Fig. 8). Analysing the assessment result, we can find that the left humerus and right elbow are not comfortable [3].

Reach zones and posture prediction can be calculated by through driving joint chain. Thus, we can distinguish whether a space point is reachable. Under the condition,

we can predict the adopted human posture. From the above analysis and evaluation, we can conclude that: the adult, when operating the machine tool's commands buttons, will get discomfort especially in the humerus and elbow joint because of the too big strength on his elbow. The optimisation solutions are to establish a lower position for the upper command panel and to adjust the spring force action for all the commands' buttons.

4. CONCLUSION

The computer-aided ergonomics has already got faster development, but it has some limit for supporting industrial design. The paper has put forward the framework of computer-aided ergonomics and described a model for industrial design. The ergonomics platform based on knowledge can co-ordinate the relationship among designers, ergonomists and CAD software engineers. The computer-aided ergonomics oriented full life cycle has brought out, it can help to solve ergonomics problem at each design stages [7].

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