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**Title:** Using Video Equipment for Designing Ergonomic Workplaces.

**Abstract:**

This study shortly describes currently used methods of workplaces designing and presents a system for workplaces designing, based on CAD software and video equipment connected to the computer. The system has been worked out at Ergonomics Department, in Gdansk University of Technology (GUT), Faculty of Management and Economics. This system presents unique application in the domain of ergonomics. In the study results of a research concerning the system are presented.

## 1. Introduction

In designing of workplaces we can distinguish two approaches: topological and ergonomic.

In that first we tend to finding optimal, the most profitable value of so-called 'target function', that means the measure of covering the criteria assumed in advance. Such criterion could be for example, minimal value of total way of operator's hands to move during making the working task. The better a workplace covers assumed criteria, the more efficient it should be.

The second approach consists in such designing to mostly covering ergonomic criteria by designed workplace. That means, in restriction

## 2. Topological methods of workspace designing.

In topological approach space arrangement of a workplace is described by its mathematical model. The target function, mentioned in the introduction, is generally represented as follows:

$$Q=f(X)$$

where  $X$  means a set of parameters describing unambiguously solutions of problem of workplace elements location.

For optimal solution the target function reaches an extreme (minimum or maximum). [1]

Target function can be used both in location planning of single workplace elements and in designing of larger systems such: in small scale - workplaces groups, or in global scale - corporation divisions located in different places on the world.

Concerning single workplace, McCormick [2] and then Wierwille [3] suggested describing of elements location quality based on 1<sup>st</sup> order criteria associated with single elements, and 2<sup>nd</sup> order criteria associated with location of elements groups (panels).

Parameters for 1<sup>st</sup> order criteria are element importance and frequency of its use. For 2<sup>nd</sup> order criteria parameters are sequence of element use and element's functions.

If parameters of workplace mathematical model are frequency of elements ( $N_i$ ) and distance between the operator and the elements ( $D_{ij}$ ), then 1<sup>st</sup> order target function takes a form as follows:

$$Q^I = \sum_i N_i * D_i \tag{1}$$

Also, if the parameters are sequence of element use and distance between elements of similar functions, the 2<sup>nd</sup> order target function is:

$$Q^{II} = \sum_i \sum_{j>i} L_{ij} * D_{ij} \tag{2}$$

where  $L_{ij}$  means grade of association of  $i$ -th and  $j$ -th elements

$$\text{and } L_{ij} = \begin{cases} 1, & \text{where } i\text{-th and } j\text{-th} \\ & \text{elements are used} \\ & \text{one by one} \\ 0, & \text{in other cases} \end{cases}$$

$D_{ij}$  means the distance between  $i$ -th and  $j$ -th elements.

Mathematical workplace models are represented generally by formulas, so the modelling process is easy to automate. For example: computer programme LINKS [4] can count target functions of 1<sup>st</sup> and 2<sup>nd</sup> order, and also automatically locate elements parameters assumed in advance.

### 3. Ergonomic techniques of workspace designing

Generally we could distinguish ergonomic designing techniques as follows:

- 1) classic ('paper') techniques based on anthropometric data, where the designer uses boundary dimensions of human body:
  - anthropometric atlases (e.g. Batogowska, Słowikowski [5]);
  - so-called flat phantoms – paper models of human body (e.g. Batogowska, Słowikowski [6], Meyer [7]);
  - reach envelopes (e.g. Clark, Corlett [8]);
- 2) computer techniques, which are in fact 'electronic' version of classic ones:
  - computer atlases and data bases (e.g. PeopleSize [9]);
  - CAD class programmes using digital human models (3D phantoms); classic examples of this type could be Mannequin [10], APOLIN [11, 12] or ADAPS [13];
- 3) mock-up evaluation – testing a prototype or a mock-up of a workplace;
- 4) Hybrid methods combining the techniques mentioned above and special hardware, for example:
  - simulators using the VR (*Virtual Reality*) technology (e.g. Anthropos [14], Store Designer Pro [15];
  - CAD-based programmes using non-standard interfaces (Build-It [16]);and others.

Ergonomic methods allow considering in a project both: needs and physical properties of an operator. However these methods are either time-consuming (classic methods) or expensive (e.g. simulators).

#### **4. Using video equipment in designing process**

Independently from how advanced designing technologies are, evaluation of a design of a workplace in natural conditions is necessary. We could do this testing a mock-up or a prototype of the workplace. Then experts and/or end-users do or simulate doing actions suitable to this type of workplace. Changes suggested by them are implemented to the design by measuring element locations in the workplace, e.g. with a measuring tape or a ruler. Because measuring is time- and work consuming, to avoid this disadvantage there is a proposal of use video equipment connected to a computer to compare real view of workplace (or its mock-up or prototype) to its drawing. It should accelerate implementing changes to the design.

The method called CADMAN II, worked-out at Ergonomics Dept. of TUG, is a modification of mock-up evaluation consisting in using video equipment for observing and recording a workplace or its mock-up during test session [17, 18, 19]. Pictures from video cameras are compare to suitable drawing made with a CAD class programme.

Two video cameras are mounted so, that both can 'observe' whole just-tested part of a workplace. We could use a construction like frame made from metal pipes to install – except the cameras – elements of a mock-up (see Fig.1)

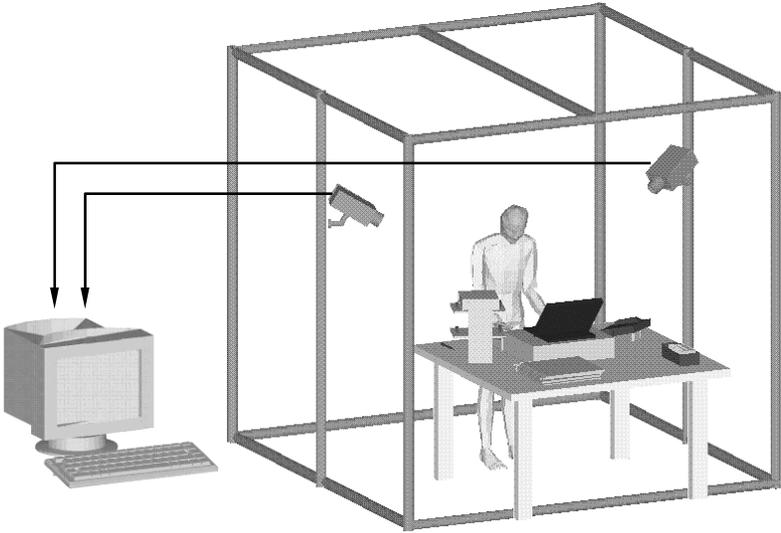


Fig.1. Workplace mock-up and a frame with video cameras mounted on

A drawing of the workplace should be made with a CAD class programme (e.g. AutoCAD) that enables inserting raster pictures (bitmaps) to a drawing. The programme should also enable working with many viewports at a time and creating perspective views in any viewport.

Pictures from the cameras are sent to a computer and inserted into the drawing as canvas each for one viewport. The drawing in a viewport is put onto the raster picture so, that the viewpoint in perspective view is suitable to the viewpoint of the camera (see Fig.2).

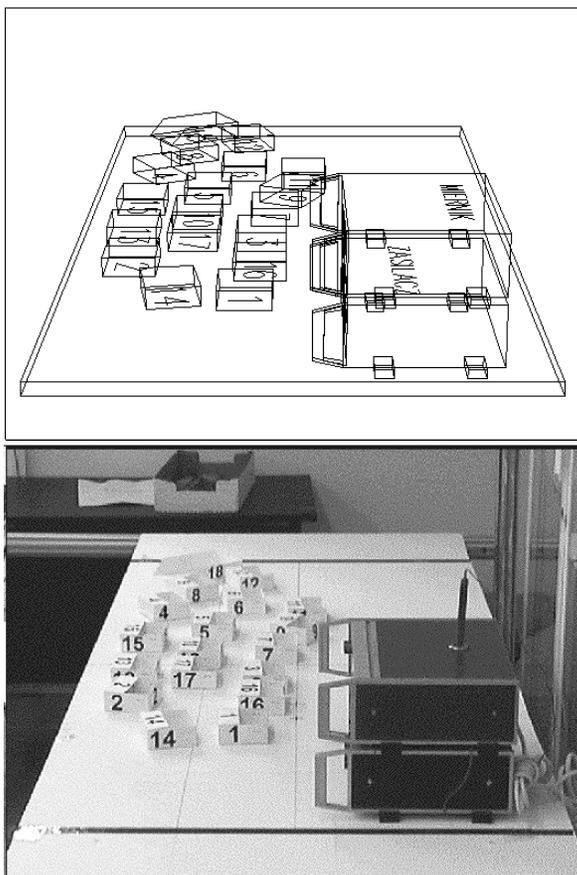


Fig.2. Comparison workplace's drawing to a picture from video camera

Thanks that, while location of any mock-up element is being changed, the designer can immediately correct the location of the element's image in the drawing to fit the drawing to the picture.

The changes can be made in any viewport. However for the designer most convenient for doing it is a non-perspective viewport

parallel to the plane of changes. Changes made in one of the viewports are visible in the others. The figure 3 presents an example of viewports arrangement on a computer screen.

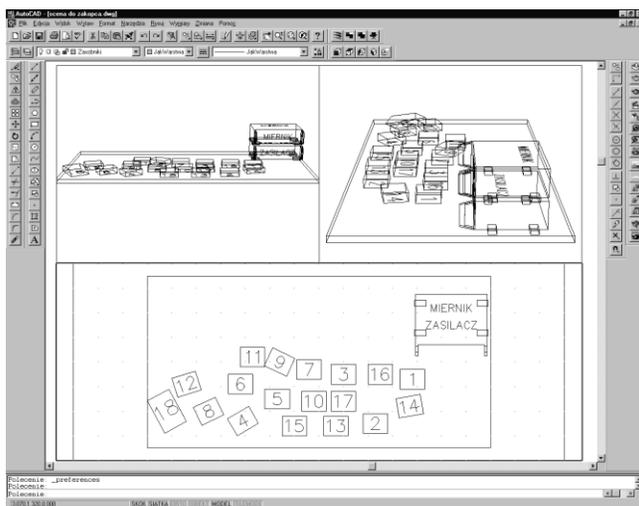


Fig.3. An example of viewports arrangement on a computer screen

In the example top viewports are used to compare a drawing to a picture from video cameras, and the bottom one – to make changes in the project.

## 5. Evaluation of the CADMAN II method

To evaluate the CADMAN II method there were made tests aiming at making a comparison of projects designed with two methods:

- Apolindex, a programme based on AutoCAD and using 3D phantoms;
- CADMAN II – the evaluated method.

The tests were made by two groups of students of Faculty of Management and Economics at TUG. Both of them had the same

design problem to solve, using two different methods. The task was to design a workplace for assembly of electronic circuits.

Group 'A' of 12 persons designed the project first with the programme Apolinex and then with the mock-up, which is a part of CADMAN II system. Inversely the second group 'B' of 15 persons used first the mock-up and then Apolinex.

To appreciate the quality of workplace elements location there were used the criteria of 1<sup>st</sup> and 2<sup>nd</sup> order suggested by McCormick and Wierwille. Target function of 1<sup>st</sup> order was counted by means of formula (1) from chapter 2, for all the projects made in both groups and with both methods. The results are shown at the chart below [20].

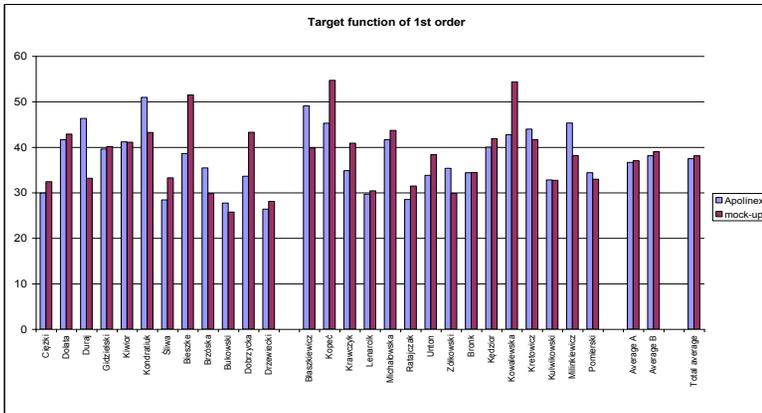


Fig.4. Comparison of values of 1<sup>st</sup> order target function for designs made with two methods: Apolinex and CADMAN II

In the similar way by means of formula (2) from chapter 2 there were counted values of 2<sup>nd</sup> order target function as shown below.



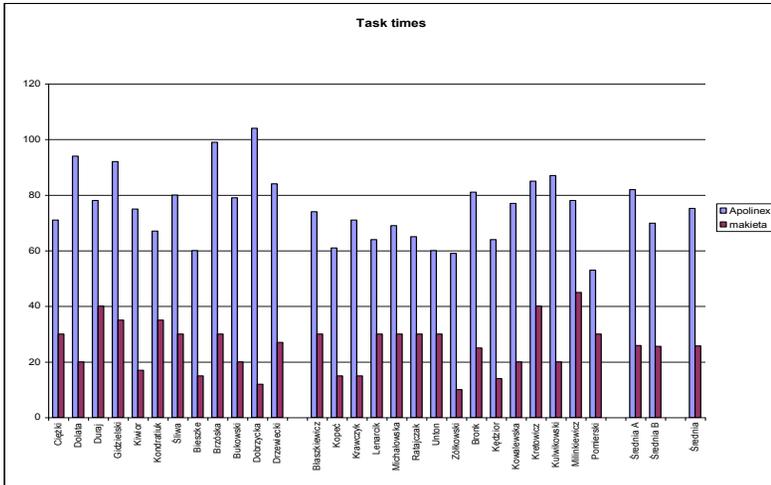


Fig.6. Comparison of task times for designs made with two methods: Apolinex and CADMAN II

Independently from order of use of designing methods, task time for CADMAN II was over two times shorter then for Apolinex.

It is necessary to mention that all testing persons knew Apolinex only from a course done before the tests and only one person knew AutoCAD before the course. However almost all the students learned AutoCAD during the course.

## 6. Summary

The CADMAN II method could be applied both in designing new workplaces (for testing new solutions not used yet) and in redesigning existing workplaces to adapt it for new needs (e.g. when the operator is a handicapped person).

Applying the method can be very useful especially in cases, where typical solutions can't be used or simply – such don't exist. For example when designed workplace is unique.

Contemporary means of communication enable sending recorded pictures or films for any distances (e.g. via the Internet),

therefore the project can be modified remotely and it is not necessary to build the mock-up close to design centre.

The CADMAN II method can be also used for testing prototypes of workplaces in its destination place (e.g. in a workshop).

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