RAČUNALNA 3D ANALIZA OPASNOSTI POGREŠNE PROJEKTNE UGRADNJE KROVNOG KOSOG PROZORA
COMPUTER 3D ANALYSIS OF DANGERS OF INCORRECT PROJECT INSTALLATION OF A PITCHED ROOF WINDOW

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Sažetak: *Poznavanjem antropometrijskih mjera i zona dosega dijelova tijela moguće je računalnim 3D znanstvenim metodama u ergonomskom i sigurnosnom smislu provesti virtualno konstruiranje i oblikovanje okolišnih sustava s kojima čovjek dolazi u djelatnu interakciju. Uvođenjem računala i računalnih 3D programskih rješenja dobiva se virtualni okoliš i pripadni 3D humanoidni modeli, na kojima je moguće interaktivno provesti sva potrebna oblikovanja i izmjene u realnom vremenu. Time se mogu ustanoviti točni položaji korisnika unutar zahvatnog prostora povećane opasnosti glede izvedenog stanja pogrešne projektne ugradnje krovnog kosog prozora.*

Ključne riječi: *znanstvena vizualizacija, računalna 3D analiza, virtualni modeli*

Abstract: *By knowing the anthropometric measurements and the extent of the body's reach is possible by computer 3D scientific methods in ergonomic and safety sense to carry out the virtual design and shaping of environmental systems with which man comes into active interaction. By introducing computers and computer 3D software solutions, we obtain a virtual environment and associated 3D humanoid models, on which it is possible to interactively perform all the necessary real-time shaping and modification. This can be used to establish the exact position of the user within the access area of the increased danger regarding the incorrect project installation of a pitched roof window.*

Keywords: *scientific visualization, computer 3D analysis, virtual models*

1. INTRODUCTION

Computer Aided Ergonomy Analyses (*CAEA*) of designing active environmental systems can be described as spatial shaping in the scientific domain; anthropometric, ergonomic and biomechanical research, resulting in the adaptation of the working environment and the active elements to the anthropometric measurements of people. Comfort of the working environment to man is achieved by the psychological shaping of working environmental systems, eco - design of work places, based on the acceptance of the world's environmental guidelines and standards in adjusting the observed environment to people, physiological shaping of active environmental systems adjusts the methods of action to physical measurements of users, visually design of the working environments in order to enable timely observation of the relevant information during the course of the analyzed process, the organizational design of the active environmental systems, while respecting the laws of physiological needs of man during his work, determines not only time norms and dangers, but also the procedures for performing some of the interventions, Figure 1 [1]. In addition to the above mentioned factors of ergonomic design of work environment systems, the respect and the requirements of physical protection and protection at work prescribed by law and regulations are of utmost importance [2].

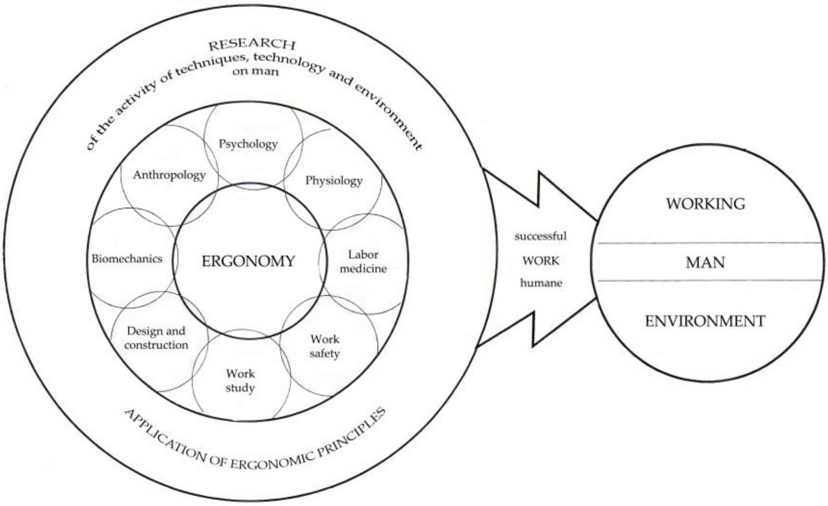

Fig. 1. *Man, working activity, active environmental system*

By introducing computers and computer 3D software solutions, it is possible to incorporate individual virtual humanoid models into different digitally generated virtual environments, where it is possible to interactively perform all the necessary designs and changes in real time, which further results in ergonomic, biomechanical and significant safety improvements in work and life environment systems based on digital measurements of people. By making these three-dimensional models, the necessary corrections of the size of the physical segments are also possible, allowing the individualization of the subject being analyzed, which is not possible as in the existing data on anthropomeasures [3].

Regarding the acceptable formatting of the active intervention space and the acceptable and safe working methods within the human - machine - environment system, the whole system needs to be adapted to man, because he due to the anatomy of the body, the ability to perform movement and personal abilities (natural and acquired), makes and integral part of the system with the most variable variables [4, 5]. These data are contained in static and dynamic measurements of anthropometric sizes and are the basis of a suitable three-dimensional computer design; place of activity, active methods, construction of work elements, process design and active environment design. The safety factors of computer 3D analysis, with the knowledge of ergonomic anthropometric measurements of the user, vary greatly depending on the nature of the environment and its task. It is necessary to consider which parts of the human body will come into direct relationship with the product (by handling it, relying on it, etc.), then it is necessary to identify those parts that are in its immediate vicinity or who only occasionally come into touch with it [6, 7].

2. DIGITAL ERGONOMIC ANTROPOMETRY

In living beings, including humans, there is an apparent harmony of the dimensions of certain parts of the body in correlation with gender, age and race. In this way, by knowing the dimension of a body part with a relatively high accuracy, the dimensions of any other part of the body can be determined. The choice of ergonomic anthropometric measures depends on a whole set of factors - primarily about the shape, construction and size of the environmental system. There are numerous and diverse sources of anthropometric data, which are generally divided into static, kinematic and dynamic body anthropomeasures. From this fact, a number of attempts have been made to establish legitimacy among dimensional relationships, first among the linear sizes, and then on other types, for example physical features [6].

A large number of dimensional differences of individuals occur depending on gender distribution and then race, so it is not enough to construct a working environment or to design products according to the so called average person. Mean dimensions are simply statistical indicators that indicate that in a population of subjects whose body dimensions are registered, about 50 percent has the reference body size or smaller. It is necessary to know the dimensions of a man as the function of statistical distribution, because the mean value of an anthropomeasure is not a complete indicator of the relationship between a man and the active environmental system and therefore can not be the basis for construction and design at all. Anthropometric traits of 5th and 95th percentiles are often considered, within which is the data of 90% of a population or data of mean values with two standard deviations (± 2σ), wherein this includes data of 95.46% of some population [3].

With the use of the computer program "*Er*SABA" (*ERgonomy by SArajko BAksa*) relevant anthropometric measures of standing active positions were established for isolated cases of researched characteristic heights of women; 155,0 cm, 165,0 cm and 175,0 cm, and heights of men; 175,0 cm, 185,0 cm and 195,0 cm, as shown in Table 1.

Tab. 1. *Anthropometric measures of male and female in standing positions*

Marking and name of anthropometric measure		Anthropometric measures (cm)					
		Female			Male		
A	Standing tallness	155	165	175	175	185	195
B	Eyesight height (standing)	144,8	154,0	163,2	164,0	174,0	184,0
C	Shoulder height (standing)	125,7	134,0	142,3	144,0	152,3	160,7
D	Elbow distance from the floor	96,3	103,0	109,7	108,0	114,7	121,3
E	Knee height (standing)	46,5	49,0	52,3	51,0	53,5	56,0
F	Arm reaching range	155,0	165,0	175,0	186,0	196,0	206,0
H	Length of the arm from the elbow	40,5	43,0	45,5	48,0	50,5	53,0
I	Shoulder width	37,5	40,0	41,7	46,0	48,5	51,0
K	Body thickness (chest)	23,3	25,0	26,7	23,0	23,8	24,7
L	Hip width	32,3	34,0	36,5	32,0	33,7	35,3
V	Foot length	23,3	25,0	26,7	27,0	28,7	30,3
X	Foot width	8,6	9,0	9,4	10,0	10,4	10,8
Y	Hand length	16,3	17,5	18,3	19,0	20,7	22,3

3. FUNCTIONAL ZONES OF REACH

For physical measurements of the real studied model (S. Baksa) and the associated environmental system of computerized construction hazard analysis due to incorrect project installation of a pitched roof window for the needs of virtual design, modeling and visualization of the environment elements and the virtual 3D humanoid model, along with the use of the computer program "ErSABA", also used was the author's computer software program for spatial physical digital three-dimensional body scanning "*Body*SABA".

Figure 2 shows a photogrammetric sequence of the author's access zone, body height of 190 cm, with the central suspension type window, open to levels 210, 190 and 170 cm above the floor level.

Figure 2. *Access zones for a person with a window sloped to 210 cm (a, b, c), 190 cm (d, e, f) and 170 cm (g, h, i)*

4. SPATIAL 3D VIRTUALIZATION

In spatial computer 3D analysis of the dangers of incorrect project installation of a pitched roof window (central suspension), along with the detection of functional access zones of the real space, a scientific virtualization of the design of the overall environmental system was performed, Figure 3. In accordance with the knowledge of the anthropometric characteristics of the human body and the total ergonomic - biomechanical - safety postulates, the computational scientific analysis was carried out on derived 3D humanoid models and the associated virtual 3D space model to determine the minimum distribution levels of unobstructed and harmless approaches, Figure 4.

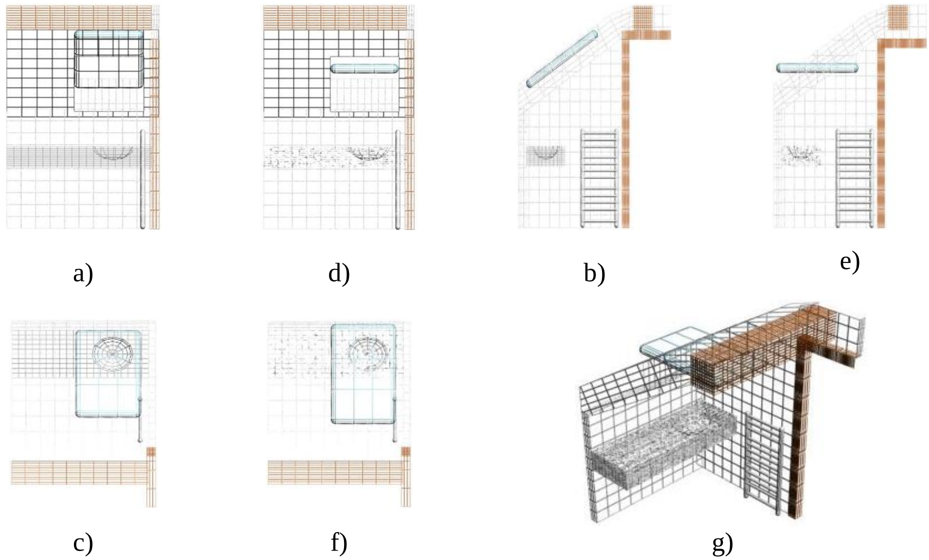

Figure 3. *Virtualization of the closed; front view (a), top view (c), side view (d) and open window; front view (d), top view (f), side view (e), with perspective view (g)*

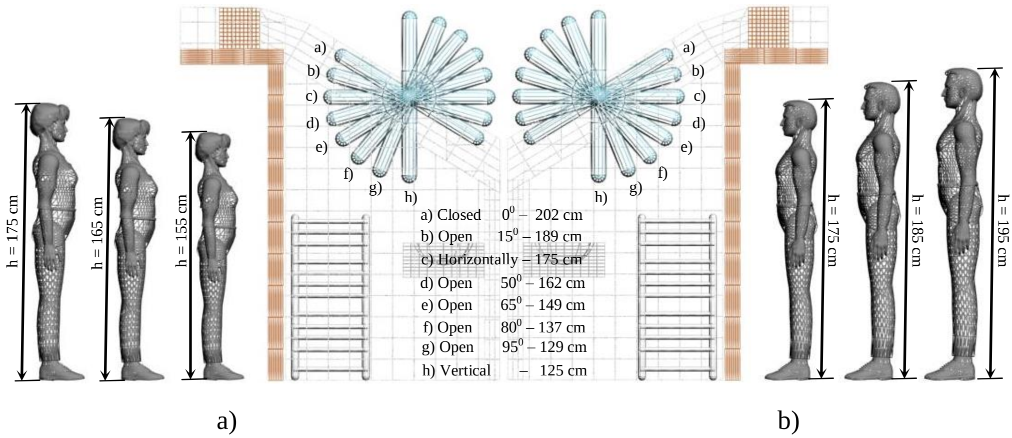

Figure 4. *Virtualization of the intervention zones of 3D female (a) and male (b) entity*

5. RESULTS AND CONCLUSION

Analysis of the dangers of incorrect installation of a pitched roof window (central pivot) was performed by methods of scientific spatial 3D visualization within the virtual space and correlation with the digitally generated computer 3D humanoid models, with the purpose of determining the minimum distribution levels of unobstructed and harmless user access as in the roof window with an additional handle in the lower part that opens around the central but also around the upper hinge, the so called double - hung windows.

For selected female entity attributes, it was determined that for the body height of 175 cm, conditionally acceptable horizontal opening is (*c*) and acceptable opening of 15^0 (*b*), for height of 165 cm, acceptable horizontal opening is (*c*), and for height of 155 cm, acceptable opening is 50^0 (d). In the analyzed male entities of the body height of 195 cm, the only acceptable option for a harmless user access is a closed window (*a*), thus proving the risk of incorrect installation of the pitched roof window. At a body height of 185 cm, acceptable openness is 15^0 (*b*), and conditional horizontal opening (*c*), and an acceptable opening of 15^0 (b), for a height of 175 cm.

By studying the movement and work activity of a person, just the results of static anthropology, and the static researches carried out within this work, are not enough for the design of active environmental systems. In fact, during work activities, the human body is moving and the relationship between the individual body segments are dynamically changing, so that the possibilities and the changes of motion are not a simple set of static measures, and they have to be supplemented with the data that comes with dynamic spatial anthropometry. Therefore, in order to make the results of the analysis relevant to the user's use of the analyzed spatial systems, in addition to the static dimensions of the body, as a basic information, information about the amplitude of movement in the joints and the field of reach are also necessary in relation to the dynamics of the different positions of the body. This information can also be accessed through laboratory and other research in specific activity situations, as well as scientific time and spatial computer analysis, so-called 4D analysis within the derived virtual systems, so the acceptability of horizontal openness (*c*) is only conditional.

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