Ergonomic Analysis of Virtual Passenger in Airplane Environments

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Summary: In the paper are shown the statistical anthropometric analysis of the supposed Croatian population, furthermore it is shown a harmonic circle for so-called synthetic formation of the individual anthropomeasurements of the free chosen subjects of both genders. Also, were defined computer modeled, exact and reliable (CAEA) virtual human models that can be applied in the scientific visual methods of the ergonomic research. Concerning the human three dimensional body activity, the neutral spatial positions of the human body that are possible to acquire during the length of the plane flight, and as well as the reference deviation from the neutral positions, were determined. In the paper are also shown the spatial positioning of the virtual human models, as well as their belonging computer generated 3D visualizations inside the airplane. Computer supported three dimensional ergonomic analysis of modeling of the passenger seats and tuck space, the space that is occupied by the human body which is in the state of moving, static position or in the state of the inconsiderable movement is analyzed as well.

Key words: virtual character, digitalized environment, scientific visualization.

1. INTRODUCTION

Industrial and technical technological development have imposed the need to trace new constructional solutions of making and equipping the travel space inside the airplane, as well as adapting to certain ergonomic and biomechanical criteria that is connected to the passengers. The higher standard of living, new materials, technologies, ergonomic-biomechanical cognitions and the competition demand from constructors and manufacturers of airplanes higher requirements in the process of design, planning and formation of interior of the airplanes. With the optimal connection of the human body and single elements or group of elements of the interior, one can influence on the regular position of a man. In the ergonomic functional restudied and performed environment, the harmony of the static and impact loads of human body is achieved and fatigue which emerges because of the active work of muscle is diminished.

If the body movements, throughout travelings, are in the larger measure limited only on some constant movements, that is the respective group of muscles, as the consequence of static efforts of muscles, if body limbs are immobile, the fatigue occurs. Because of the long-lasting compulsory position of the upper part of body, extremities and head, and increased general muscular tone, very often muscular bone problems, as well as spine problems appear, although in principle, this sitting travel position, along the criterion of energy consumption can be classified as light.

Sitting position of a passenger, throughout the traveling, can completely change sagital twisting of the spine, which completely carries off on the lumbar lordosa. This depends on the way of sitting and construction of base where the workers sits. Pelvis position has the most important role, since appearance of lumbal spine depends on its slope. As for example, during upright sitting without back pelvis is leaned forward, similar as with standing and lordosa is expressed lumbally. Considerable muscle activity is necessary for keeping of such position and therefore fatigue occurs. During (comfortably) relaxed sitting with a back under various angles (90^o do 100^o), sagital and lumbal curve is completely levelled or even lumbal kifosis occurs.

It is important to mention that for normal sitting it is essential that both hips are movable, since only so flexion is possible necessary for parallel position of upper legs while pelvis in horizontal plane is parallel with the base. In such position normal flow of physiological sagital spine curves is possible and burdening if equally distribute on all of its composite parts. During sitting sagital curves of the spine could be changed and thus a man can sit correctly and incorrectly as well as comfortable or uncomfortable [1].

2. ERGONOMIC ANTHROPOMETRY

In the formation of the complete environmental space of travel part of an airplane, consistently with the total ergonomic-biomechanical postulates for the sitting position, it is necessary to be familiar with the anthropometric characteristics of the passengers body. Choice of ″ergonomic anthropometric measures″ varies depending on the whole line of factors, in the first line depending upon the shape, construction and the size of airplane. Furthermore, it is necessary to consider which parts of bodies of passengers will come in a direct contact with the environmental elements of the airplane interior, then to establish those parts of travel environment that are in the direct closeness of a man, or those that only periodically come in the contact with him. There are numerous and different sources of the anthropometric data, that is fundamentally divided in the static, kinematic and dynamic anthropomeasures [2,3].

Results of research of authors of characteristic sitting anthropometric measures for separated cases of the female passengers, height 152 cm, 162 cm and 172 cm, as well as the male passengers, height 182 cm, 192 cm and 202 cm are presented in the Table 1.

Table 1. Values of the characteristic ergonomic anthropomeasures for women and men.

Marking and name of anthropometric measure		Anthropometric measures (cm)					
		Female			Male		
A	Standing tallness	152	162	172	182	192	202
G	Arm length from the back contour	65,6	69,8	73,9	89,5	94,5	99,5
H	Length of the arm from the elbow	39,8	42,3	44,8	49,8	52,3	54,8
I	Shoulder width	36,8	39,3	41,2	47,8	50,3	52,8
K	Body thickness (chest)	22,8	24,5	26,2	23,6	24,4	25,3
L	Hip width	31,8	33,5	35,8	33,2	34,8	36,5
M	Sitting height	77,5	82,5	87,5	92,9	97,1	101,3
N	Eyesight height (sitting)	67,6	71,8	75,9	81,9	86,1	90,3
O	Shoulder height (sitting)	49,7	53,0	56,3	61,8	64,3	66,8
P	Elbow height (sitting)	19,9	21,1	22,4	23,6	24,4	25,3
R	Distance from knee to back (sitt.)	51,7	55,0	58,3	63,3	66,7	70,0
S	Hip length (sitting)	42,8	45,3	47,8	49,8	52,3	54,8
T	Sitting height (to the floor)	39,8	42,3	44,8	47,3	50,7	54,0
U	Hip height (sitting)	12,9	13,8	14,6	13,6	14,4	15,3
V	Foot length	22,8	24,5	26,2	28,2	29,8	31,5
X	Foot width	8,5	8,9	9,3	10,3	10,7	11,1
Y	Hand length	15,9	17,1	18,1	20,2	21,8	23,5

2.1. Harmonic anthropometrical analysis

Based on general results of harmonic analysis which are implemented on man and which have been shown as functions of anthropometrical magnitudes in relation with man's standing hight, Muftić's contemplation showed out that for defining ratio of body parts lenght so called harmonic circle is used. For the mentioned anthropometrical analysis greek canon of eight head lenghts is being used, which points that total human body hight shown equals sum of his eight head lenghts.

In case that this canon is joined to haromonic circle the grid construction is possible which shows contour limits of man, as shown on figure 1. With that, canon of eight head hights is joined with Zederbauers harmonic circle.

Considering this values, as well as the assesment of position of joints of knee, hip, shoulders and elbows, it was possible to draw into in the figure 1 grid, characteristic points A, B, C, ... By doing so, drawing into linking lenghts, auxiliary skeleton of a man has been drawn, so called stick model, as shown within the figure 2 [4].

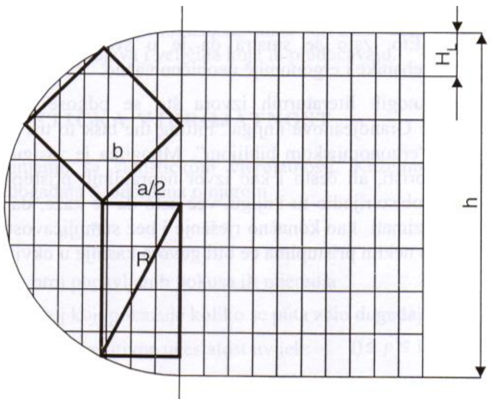


Fig. 1. *Harmonic circle with associated grid of eight head hights canon*

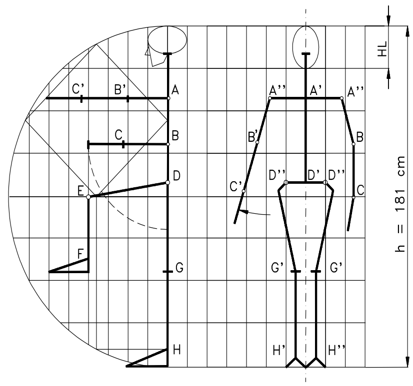


Fig. 2. *Harmonic circle with plane model of geometrical human skeleton*

2.2. The digital body anthropometry

Determining of anthropometric measures for the every individual especially, with the conventional way has been assembled and lengthily. Introducing the new computer methods it is possible to determine, fast and correctly, all important body sizes, in order to synchronize dimensions and shapes of the environmental system with the anthropometric measures of a man. In regard to this, S. Baksa has developed the computer program "*Er*SABA" (*ERgonomy SArajko BAksa*), which with the input data of body height, weight and gender of a person, as well as the necessary accuracies of work and positions when working, determines twenty-two characteristic anthropometric measures for sitting and standing work positions of the male and female examinees. Measuring data is momentary accessible to individuals who are approaching surveying and after computer processing, anthropometric data is automatically stored in the so-called anthropometric database, in order to be available in the later ″offline″ analysis.

In the figure 3 is given the screen display of site characteristic computer obtained anthropometric measures of man whose body height is 162 cm.

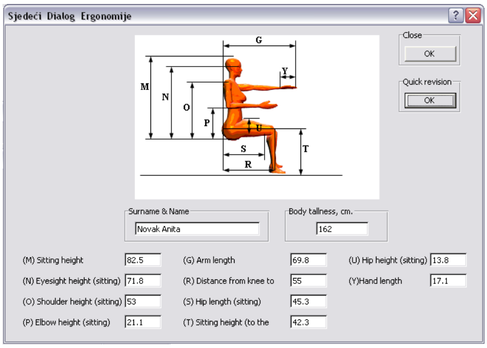


Fig. 3. *The screen display of screen dialogs of sitting characteristic anthropometric measures of computer program of static body anthropometry ″Er*SABA″

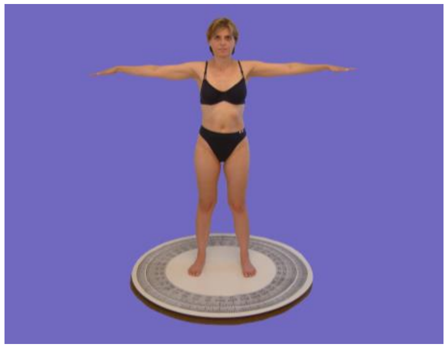


Fig. 4. *Body Capture and Measurement System* "*Body*SABA"

Most of the researches during construction of geometric model of human body, with the usage of reverse engineerings, focuses on the procedure of taking a row of surfaces that are limited, with coordinate points of the three-dimensional measuring cloud which was obtained by contemporary 3D scanners. Hereby, one obtains indicatively the same model of the body structure of individual which responds the specific dotted cloud and describes body measures of particular character.

Regarding the making of virtual models in real corresponding to their real sources, the system of spatial digital threedimensional body scanning "*Body*SABA" has been applied for the needs of this work. The figure 4 is showing Body Capture and Measurement System "*Body*SABA", during digitalisation of examined female model.

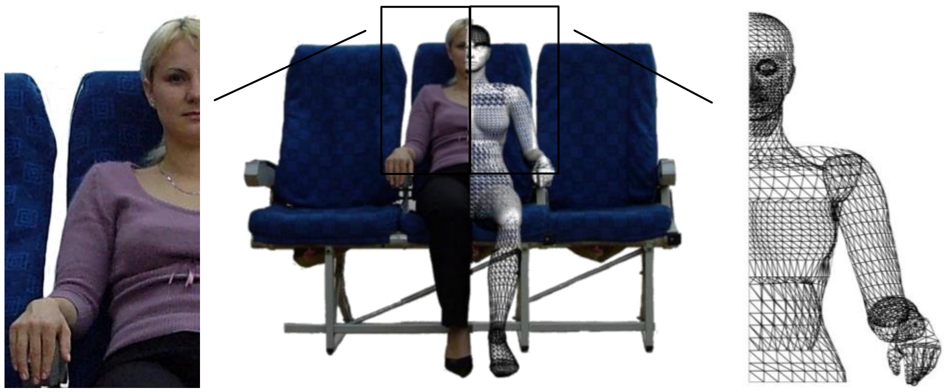
With computer approach of taking anthropometrical sizes of body measures it is possible to determine for each individual several thousands of coordinate measure points which describe spatial shape and body volumen of measured person. Three-dimensional digital body scanning with Body Measurement System "*Body*SABA" is designed for spatial 3D scanning of objects with the purpose of making virtual 3D models [5].

There are a lot of 3D anthropometric techniques, such as contact measurement (template method; multiple probe method; casting method; anthropostereometry) and non-contact measurement (stereophotogrammetry; Moire contourgraphy; monophotometry/contour projector; computer vision techniques, triangulation-based spot sensing; light strip sensing; time-of-light-based ultrasonic range finder; laser range finder). Since the introduction of these 3D anthropometric techniques, engineers and ergonomists have sought to exploit the potential of this exciting technology [6].

3. VIRTUAL 3D BIOMECHANICAL MODELS

Increasing number of worlds development companies, throughout conception planning of ergonomic design of motor vehicles for various purposes, airplanes, working engines, cabins of drivers and control elements, uses various CAD-based 3D models of people and environmental systems [5].

On the figure 5 the visualization of the virtual 3D biomechanical model of female of height 152 cm and weight 47.5 kg, during the sitting on the travel seat and throughout traveling by airplane has been presented.



a b c

Fig. 5. *Visualization of real model of passenger (a), virtual 3D personalized model (c) and combined real and 3D layout (b)*

Structural scheeme of human skeleton has very large number of degrees of motion freedom. Regarding that human skeleton consists of 95 joints with one degree of motion freedom, 80 joints with two degrees of motion freedom and 75 joints with three degrees of motion freedom, which is in total 250 degrees of motion freedom, all complexity of kinematic and dynamic study of human skeleton can be understood. Some authors quote different degree numbers of motion freedom of normal skeleton, from 240 to 300. This is significant because mobility of computer 3D model depends on number of degrees of motion freedom of his constructive elements. [4].

On the basis of the stated statical and dynamic properties of human body biomechanical model of human body is made. Simulation of human body by means of biomechanic model is carried out so that first statical model of human body is established and then necessary dynamic properties are attached.

On the basis of inner kinematics model of human body computer kinematic model is made which serves as initiating basis for construction and character animation of virtual 3D character. Number of basic building elements of kinematic chain in e.g. virtual human can range from ten, in more rough analysis, several hundreds in finer up to several hundred thousands in very demanding characteristic scientific visualisations [1].

4. COMPUTER 3D VISUALIZATION

Making of three-dimensional modeling, design, animation and scientific visualization is performed on graphic workstations with the use of the preponderance 3D graphic-animation program packages. Based on shot man and insides of airplane environment, computer generated 3D model of the passenger, the gripping elements and interior, is made. The obtained computer 3D model has been compared and synchronized with real models of passengers of Croatian population and interiors of airplanes.

On obtained virtual 3D models of man and interior of travel space of airplane, with computer scientific visualization, biomechanical analysis of movements have been executed, based on the real correlation in the space, inter operating the passengers and associated gripping environmental systems. Using parameters of biomechanical analysis, dynamic anthropomeasures are calculated, which serve as a fundamental data for the stimulatory character animation. With implementation of 3D character inside the gripping space of virtual 3D model of interior of airplane travel environment, it is possible to conduct all necessary ergonomic and biomechanic formations and exchanges, with the possibility to analise the correlation of a man and elements or group of elements inside virtually performed model of airplane.

Contemporary computer 3D visualization is based on the use of the sophisticated interactive digital environmental systems with the response in the real-time. Scientific analysis of the virtual humanoid models within such digitalized realistic-time surroundings are possible with the use of so-called ″Avatar″ biomechanical models of simulated people.

On the figure 6 the structural display of concept of interactive virtual environmental systems with virtually generated humanoid models - Avatars is given. The concept is comprised from four characteristic entirety; The ability to growth, Database, Temporality and Particle space that interactively interweave within schematic central positioned entirety of Digitalized space, within computer 3D interactive visualization proceed [7]. And next to the basic conception of interactive computer 3D visualization, depending on the incoming data and their quality, in other words, scientific credibility, visualization can be categorized as fun, educational or scientific.

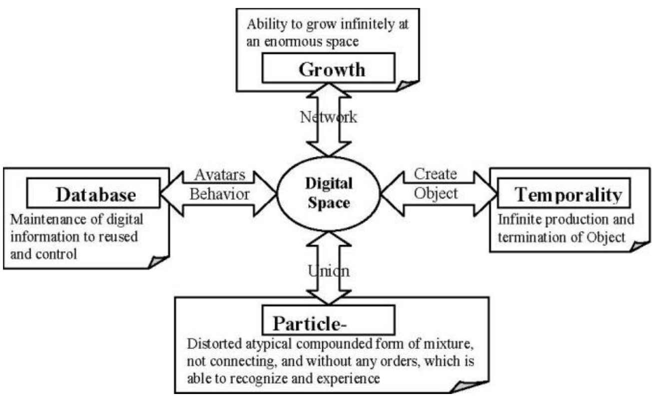


Fig. 6. *Concept of virtual interactive environmental systems with humanoid models*

5. RESULTS

For the analysis of correlation of human body of passenger and dimensions and shapes of the elements of airplane interior within this work 3D characters of different body heights and weights, as well as 3D model of the airplane travel space and the sitting space, have been made. Within the executed computer visualization, with real and digitally generated virtual models, characteristic frame, with whom positions of passengers with different body heights and gender during the airplane flight are defined. On the figure 7 male examine of body weight 202 cm (a), virtually generated 3D model of a passenger of height 177 cm (b) and female examine of body height 152 cm (c) has been presented.

a b c

Fig. 7. *Word picture of traveling positions inside the airplane of passenger of height of a) 202 cm, b) 177 cm and c) 152 cm*

On the basis of the defined travel attitude of bodies of real people during the airplane flight, with the help of computer visualization that has been executed on the preponderance of the virtual passenger of different body heights and proportions of male and female gender, their gripping positions have been studied and the judgment about the 3D execution of ergonomic formations of the airplane interior travel space in respect to differences to body proportions of passengers, their understanding of comfort of travel positions and on single ergonomic formation of airplane interior, has been established.

Considering that the airplane seats are mutually minimally spaced out (in the sitting position that distance brings out only 28 cm), in the table 2 is given the display of one of, for the travel comfort, the characteristic anthropometric sizes: distances of knees from the back and sufficiencies of vacancy to the sequent travel seat (+), that is the lack of space (-), for the final max. and min. heights of interrogated subjects, 202 cm for male gender and 152 cm for passengers of female gender.

Table 2. Display of values of the ergonomic non/sufficiency of airplane interior

Marking and name of anthropometric measure		Anthropometric measures / Distance to the neighboring seat (cm)					
		Female			Male		
A	Standing tallness	152	162	172	182	192	202
R	Distance from knee to back (sitt.)	51,7	55,0	58,3	63,3	66,7	70,0
Non/sufficiency to the neighboring seat		+ 16,3	+ 13,0	+ 9,7	+ 4,7	+ 1,3	- 2,0

6. DISCUSSION AND CONCLUSION

Respecting the conceives of the anthropometric researches of ergonomic formations of the airplane interior travel space, and with the use of computer equipment and computer 3D graphic programs, the harmony of optimal dimensions of a travel space and human body, as well as the regulate body position during the travel that enables the minimal fatigue and the maximal comfort of the flight, can be established and determined swiftly and efficiently.

Determining of anthropometric measures, especially for every person, with the conventional way, is complicated and lengthly. With introduction of the new computer methods, and based on height, weight masses distribution inside single body segments and persons gender, as well as the position and dynamism of movements when flying, it is possible, from the viewpoint of ergonomy and biomechanics to determine, swiftly and precisely, dimensions of the ideal shaped environmental system for the every person especially.

Position of sitting, throughout traveling, should be leisurely, and the airplane seat as well as the distances among them should be measured by body proportions of a man, that is, dimensions of environmental airplane interior should be adjusted with anthropometric measures of passengers.

Digitalized results of virtual surveyings show that the distances between seats and the alone floor pan are ergonomically performed and placed so that the comfortable travel position can take only passengers to the 196 cm of body height. Passengers of the higher body height lack the free anthropometric gripping space in the area of lower extremities.

7. REFERENCES

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