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Traffic and Space
Preliminary Communication
Accepted: Sep. 22, 2006
Approved: Mar. 1, 2007

VIRTUAL REALITY AND ITS IMPLEMENTATION IN TRANSPORT ERGONOMICS

ABSTRACT

The experience of our environment is based on the information that reach us by means of our sensory organs, and which are subsequently processed in our brains. Digital interpretation implemented to mathematical models of the studied subjects brings us to the so-called virtual reality that allows us to replace some natural human senses, in this case the visual ones, by computer-generated information. The procedure is expanded to three-dimensional (3D) scanning i. e. searching of the special form of the observed subject/object, then digital recording of the space point cloud (pixels) which correspond to the item, then vectorisation of the form, rendering and finally animation. In this way, by watching the display, the impression of the virtual environment can be generated in the human perception. Moreover, in this way the human model can be realized in a characteristic way in such a virtual space. The implementation of this virtual reality, in accordance with the possibilities that it provides, has been the subject of very intensive research in the world, and in Croatia as well. The work presents some possibilities of applying virtual reality in the field of ergonomic analysis of the collision process of two vehicles.

KEY WORDS

dynamic moments of inertia, virtual models, virtual reality, crash analysis

INTRODUCTION

In numerous examples of analysing the collision processes, there is often the need to observe the vehicles as solids. Apart from translation movement, in such examples one should also consider the rotation movements of the vehicles. As an illustrative example the so-called plane example of a collision of two vehicles is considered, as presented on models in Figure 1. In such a selected example one should know the dynamic inertia moments around the presented axes z of each vehicle. On the other hand, the vehicle manufacturers provide data on magnitudes of central dynamic inertia moments for different types of vehicles by means of inertia radii, which, according to the data from literature range in values from 2500 to 3000 kgm^2. The values refer to the central axes of inertia of empty vehicles. In other words, this means that the intention is to define the central dynamic moments of inertia of the driver and the passengers in the foreseen seating position depending on the suitable anthropometric characteristics of our population. Then these need to be assigned to the main central axes of the vehicle inertia by using the so-called Steiner rules or as also called by means of the theorem about the parallel axis shift.

This work aims to define the field of values of the dynamic moments of inertia of the distances of local axes of passenger and luggage inertia from the central vehicle axes from the analysis of the influence of the passenger positions and their masses, as well as the assumed luggage mass. This measurement task had been estimated in the past practice, since actual measurement is almost impossible.

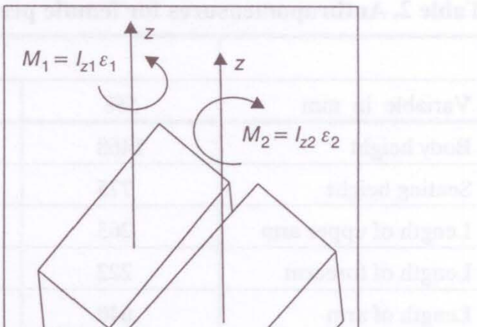

Figure 1 - General collision model of two bodies in a plane

This has been solved by developing the so-called virtual model of people and vehicles which can accommodate, as necessary, one or several persons, and then the desired distance of the inertia axis of each subject in relation to the central vehicle axis can be determined directly in the model.

METHODS AND SUBJECTS

The basic data to determine the dynamic anthropo-characteristics in the people of Croatian population are based on the linear anthropo-measures that have been developed by Rudan. These data can be found for the adult persons of Croatian population in Tables 1 and 2.

Table 1 - Anthropomeasures for male persons (157 subjects), Rudan

	Percentiles				
Variable in mm	5%	25%	50%	70%	95%
Body height	1592	1620	1648	1724	1801
Seating height	820	848	882	908	941
Length of upper arm	288	303	316	326	341
Length of forearm	241	260	270	278	298
Length of arm	708	743	759	784	821
Length of upper leg	474	502	523	540	570
Length of lower leg	333	362	376	390	414
Length of leg	881	935	965	996	1045
Bichromial range	358	377	393	404	432
Pelvis width	269	283	293	302	318
Body mass in kg	56,5	64,9	71,5	80,2	95

Table 2. Anthropomeasures for female persons (155 subjects), Rudan

	Percentiles				
Variable in mm	5%	25%	50%	70%	95%
Body height	1468	1531	1572	1617	1684
Seating height	775	803	828	854	891
Length of upper arm	263	280	290	298	315
Length of forearm	222	231	242	252	267
Length of arm	640	676	692	712	745
Length of upper leg	450	478	491	508	534
Length of lower leg	311	334	348	362	388
Length of leg	830	870	896	925	973
Bichromial range	333	353	365	379	393
Pelvis width	264	283	298	306	324
Body mass in kg	52	57,1	62,2	70,2	83,5

Further step in determining the dynamic characteristics of our population was in the defining of the biomechanical model of the subjects in the assumed posture they occupy in the vehicle. Regarding the low influence exerted by the movements of arms and legs, the model has been assumed as a static model. Figure 2 represents a selected driver and passengers model.

According to the modelling method, regular geometric solids have been selected of the segmental parts of the body, such as e. g. cylinders, parallelepipeds and ellipsoids, for which it is possible to calculate simply the dynamic inertia moments with appropriate assumptions on the density, etc. and eventually, they can be reduced to an assumed central coordinate system. In this way it is possible to determine the dynamic inertia moments for the static subjects for the indicated axes x, y, z.

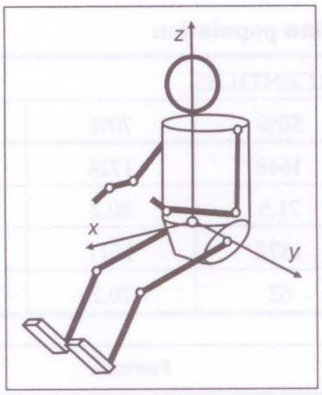

Figure 2 - Biomechanical model of driver with marked coordinate system axes

METHOD OF VIRTUAL ERGONOMIC ANTHROPOMETRY

The virtual reality techniques allow creation and application of new computer methods and systems that had not been possible before. The virtual reality techniques offer the possibility of creating "realistic" simulations that are useful e. g. in the analysis of the work of humans within a certain arbitrary environment. It is known that simulation techniques had been known before as well; however, virtual simulation techniques create the impression of our involvement in a non-existent world – in the virtual space. Such an impression can be realized by means of advanced computers and equipment for recording which realizes the human – computer connection.

3D VISUALISATION

The basic idea of virtual reality is based on the replacement of information received by our senses, by artificially organized "senses" in the computer. In such an example, it is actually possible to deceive human perception and to create an impression of another external world surrounding the human. In this way the objective reality that we are experiencing is replaced by virtual reality.

The development of three-dimensional modelling, design, animation and visualisation is performed on graphic working sites using several different 3D graphic-animation program packages. Based on the recorded vehicle, driver and passengers in it, a computer 3D model of the vehicle, driver and passengers in the vehicle is produced. The obtained computer 3D model is compared and adapted to the real model of the vehicle and passengers. According to the real data on the obtained 3D scene by methods of visualisation using the program package ERSABA 4.2 a virtual 3D biomechanical analysis of the passengers in the vehicle is made. The 3D model of the driver and the vehicle form the 3D scene which in computer graphics means the oriented part of the space with assigned coordinate system which is used to define the position and orientation of the subjects, objects or groups thereof. The geometric shape within the computer 3D graphical programs can be defined by:

a) a set of points,

b) a set of polygons,

c) a set of curves.

Using the program package "body SABA", photo-realistic presentations of the virtually defined vehicle and passengers in the vehicle have been obtained.

RESULTS

Based on the selected models that are presented in Figure 2, as well as with the values of static anthropomeasures from Tables 1 and 2, with suitable replacement by simple geometric solids, the dynamic moments of inertia have been calculated for a group of female and male persons divided into five statistically defined groups.

Table 3 - Segmental body masses with assigned dimensions

Part of body		Height as percentage of total height, %		Mass as percentage of total mass %
		Male	Female	
Foot		3.52	3.5	1.371
Upper leg		26.43	26.1	14.165
Lower leg		22.59	22	4.33
Hand		10.44	10.2	0.614
Upper arm		19.33	18.4	2.707
Forearm		16.48	15.58	1.615
Body	upper	31.5	32.5	15.956
	middle			16.327
	lower			11.174
Foot length		15.42	15.1	
Head with neck		15.9	15.9	6.94
Body width		19	20	

The observed example considers the task of distributing the dynamic moments of inertia of the vehicle with passengers and luggage. The input values of mass and height are for persons from five percentile statistical groups that have been calculated according to the anthropomeasures defined according to Rudan. Respective data are presented in Table 4.

Table 4 - Anthropometric characteristics of the subjects of the Croatian population

		PERCENTILES				
		5%	25%	50%	70%	95%
Male	Body height (mm)	1592	1620	1648	1724	1801
	Body mass (kg)	56.5	64	71.5	80.2	95
Female	Body height (mm)	1468	1531	1572	1617	1684
	Body mass (kg)	52	57	62	70.2	83.5

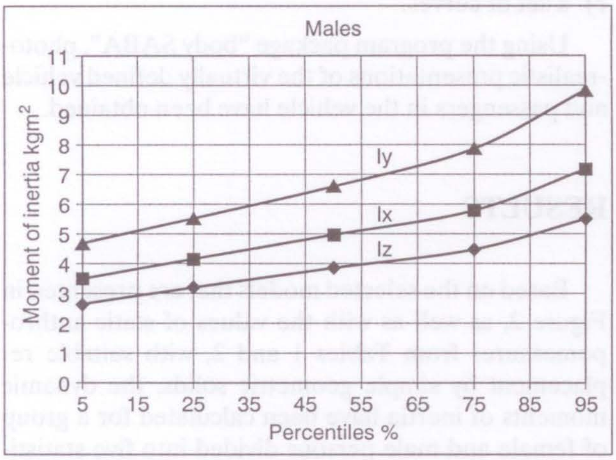

Figure 3 - Dynamic moments of inertia for male subjects depending on the statistical distribution

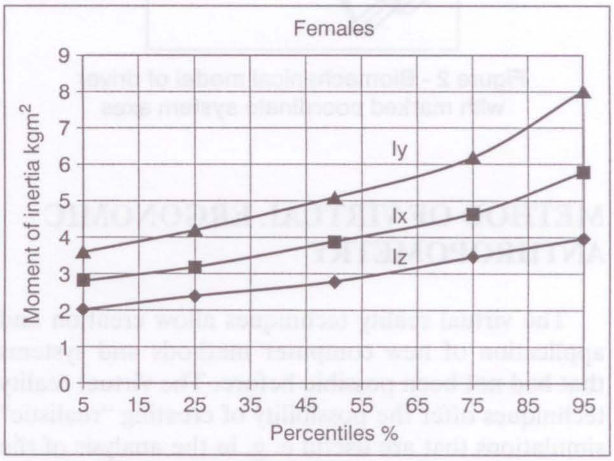

Figure 4 - Dynamic moments of inertia for female subjects depending on the statistical distribution

The dynamic inertia moments for the male and female population are presented in diagrams in Figures 3 and 4.

Four persons (driver and passengers with average standing height of 180 cm) have been set into a virtually defined vehicle represented in the form of a contour. Such a model can be oriented in space as necessary, and consequently the computer monitor displays images that are presented in Figures 5 to 8.

Figure 8 matches best our requirements, and it represents the layout with geometric relations that are needed to compute the dynamic inertia moment around axis z which is vertical to the drawing.

This is accompanied by a description of the presented points that represent the interesting positions of mass centres, both of the vehicle and of the passengers and cargo.

(TA) – vehicle centre of gravity

(TT) – cargo centre of gravity (positioned into the centre of the object that represents cargo)

Centre of gravity of the persons in the vehicle, (T1) – centre of gravity of the driver, (T2) – centre of gravity of the co-driver, (T3) – centre of gravity of the person behind the co-driver, and (T4) – centre of gravity of the person behind the driver.

The measured values of characteristic points from the virtual model of vehicle and passengers are presented in Table 5.

Table 5 - Tabular presentation of coordinate space positions of individual mass centres

Symbol	Coordinate axes		
	y (cm)	x (cm)	z (cm)
TA	0.0	0.0	0.0
T1	40.915	0.0	43.005
T2	-40.781	0.0	37.981
T3	40.781	-91.909	40.166
T4	-40.547	-91.909	40.166
TT	0.0	-184.865	46.522

Persons in the car are 180 cm tall, a Croatian average height for young male persons.

When the positions of the mass centres of vehicles and subjects are determined, then the reduction of inertia moments on the central inertia coordinate system is defined by a theorem on parallel axes in the following way:

$$I_{Sz} = I_{Sz\,vozila} + \sum_{i=1}^{4} I_{izS} + d_i^2 m_i +$$
$$+ I_{z\,tereta} + d_{tereta}^2 m_{tereta}$$

I_{Sz} – total central inertia moment of vehicle and passengers;

$I_{Sz\,vozila}$ – central inertia moment of the vehicle;

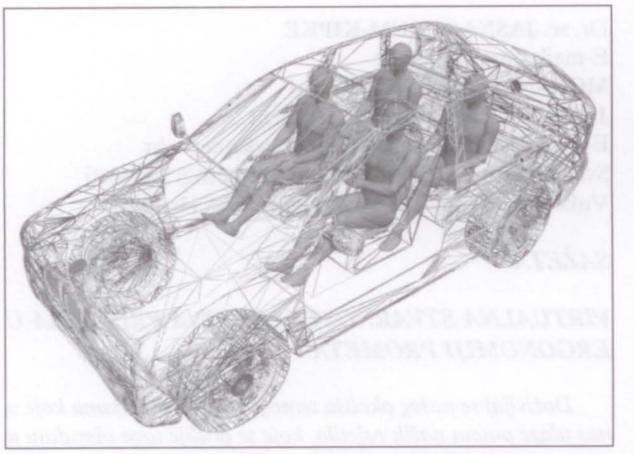

Figure 5 - Axonometric virtual view of the vehicle with four subjects

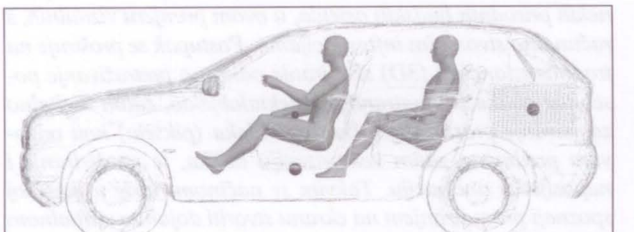

Figure 6 - Side view of the virtual model with respective subject models

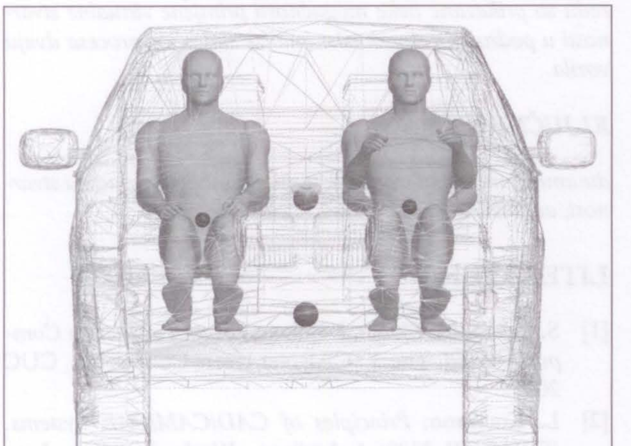

Figure 7 - Front view of the virtual image with respective subject models

I_{izS} – central inertia moment of the crew;

$I_{z\,tereta}$ – inertia moment of the cargo;

d_i – distance of the subject's centre of gravity to the vehicle's centre of gravity

d – distance of the centre of gravity of the cargo and centre of gravity of the vehicle;

m_i – mass of individual subjects;

m_{tereta} – cargo mass.

If it is assumed that the luggage is in the form of a parallelepiped with sides 0.5 × 0.5 × 1.2 metres and a mass of 100 kg, and a measured distance of the mass centre in relation to the vehicle centre of gravity of 1.85 metres, then its influence on the central dynamic inertia moment is about 341.75 kgm^2. Further, if the driver is selected as a subject belonging to the percentile group of 5%, then with the distance of the driver's centre of gravity to the vehicle centre of gravity with a value of 0.409 metres and individual main inertia moment $I_z = 2.8$ kgm^2, and the respective mass of 56.5kg, then its influence on the overall dynamic inertia moment by applying Steiner rules is 12.25 kgm^2. In order to determine the maximal influence of the driver and three more passengers, the subjects have been selected from the group of 95%, with personal mass of 95 kg, and personal dynamic inertia moments $I_z = 5.7$ kgm^2, and their distance from the centre of gravity for the first pair in the front is 0.409 metres, and for the second pair on the back seats of 1 metre, then their overall influence on the main dynamic moment of inertia is 237.78 kgm2.

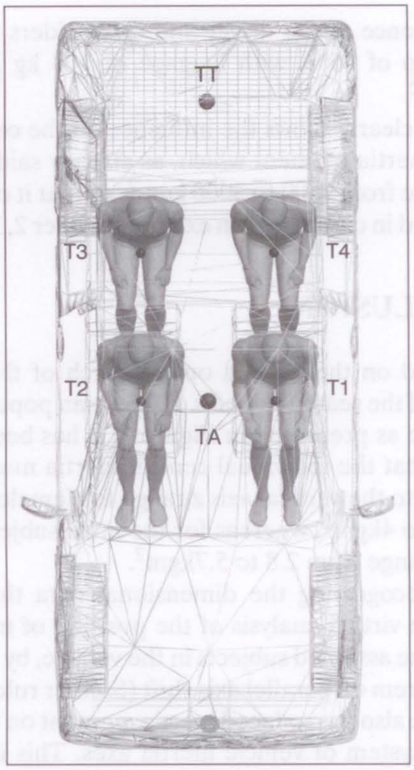

Figure 8 - Layout of the virtual model with respective subject models

In the above presented way we may describe the range of values of influence in the change of the dynamic central inertia moment..

1. Influence of the smallest driver on the vehicle without luggage is 12.25 kgm^2.
2. Influence of the smallest driver with assumed luggage of 100 kg is 354 kgm^2.
3. Influence of the driver and three passengers from the group of 95%, without luggage is 237.78 kgm^2.

4. Influence of the driver and three riders from the group of 95%, with luggage of 100 kg is 579.53 kgm^2.

This clearly shows the influence on the central dynamic inertia moment which, as already said fits into the range from 2500 to 3000 kgm^2, so that it cannot be neglected in calculation in examples under 2, 3 and 4.

CONCLUSION

Based on the carried out research of the virtual model of the seated subjects of Croatian population in a vehicle as presented in Figure 2, it has been determined that the individual central inertia moments in relation to the vertical axis z range for female subjects from 2 to 4kgm^2, whereas for the male subjects these values range from 2.8 to 5.7kgm^2.

By recognizing the dimensional data that result from the virtual analysis of the position of mass centres of the assumed subjects in the vehicle, by applying the theorem on parallel axis shift (Steiner rule) we can compute also the reduced inertia moment on the main central system of vehicle inertia axes. This influence has been analysed in the range from minimal percentile values to the maximum ones and ranges from 12.25 to 579.53 kgm^2, which in relation to the central dynamic vehicle inertia moments, as said in the introduction, range in values from 2500 to 3000 kgm^2; values that need to be recognized.

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SAŽETAK

VIRTUALNA STVARNOST I NJEZINA PRIMJENA U ERGONOMIJI PROMETA

Doživljaj se našeg okoliša temelji na informacijama koje u nas ulaze putem naših osjetila, koje se poslije toga obrađuju u našem mozgu. Digitalna interpretacija primijenjena na matematičke modele istraživanih subjekata dovodi nas do tzv. prividne ili virtualne stvarnost koja nam omogućava zamjenu nekih prirodnih ljudskih osjetila, u ovom primjeru vizualnih, s računalno stvorenim informacijama. Postupak se proširuje na trodimenzionalno (3D) skeniranje odnosno pretraživanje posebnog oblika promatranog subjekta/objekta, zatim digitalno zapisivanje prostornog točkastog oblaka (piksela) koji odgovara predmetu, zatim vektorizaciju oblika, te renderiranje i naposljetku animaciju. Takvim se načinom može u ljudskoj spoznaji promatranjem na ekranu stvoriti dojam o virtualnom okolišu. Štoviše moguće je i model čovjeka na svojstven način ostvariti u takvom virtualnom prostoru. Primjena je te virtualne stvarnosti, skladno s mogućnostima koje ona pruža, predmetom vrlo intenzivnih istraživanja u svijetu pa tako i u nas. U radu su prikazane neke mogućnosti primjene virtualne stvarnosti u području ergonomske analize sudarnog procesa dvaju vozila.

KLJUČNE RIJEČI

dinamički momenti tromosti, virtualni modeli, virtualna stvarnost, analiza sudara

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