AN OPTIMIZATION PROCEDURE TO RECONSTRUCT THE AUTOMOBILE INGRESS MOVEMENT

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Abstract: To simulate the automobile ingress movement, joint angles are needed. The joint angles are computed from the experimental data issued from an optoelectronic motion capture system. As these systems are often corrupted by problems related either to the system or to the experimentation, the computed angles are biased. Lempereur et al. (2003) proposed an optimization procedure to remedy to this problem. However, their method gives good results only on the end effectors' trajectories, while the other bodies' trajectories are not considered by their method. That degrades the positions of these parts and causes their eventual collisions with the vehicle's parts. On the other hand the corrected angles present some vibrations causing unrealistic simulation. In this paper we present a multi objective optimization based procedure to correct the joint articulation angles in automobile ingress movement. Our method minimizes the distance between all reconstructed trajectories with the real ones at each step of time. Our method follows a compromise between all trajectories of the model. Our method gives better global results. Correction of the joint angles allows a realistic simulation.

1 INTRODUCTION

Automobile accessibility is a serious problem for elderly and/or disabled people that can lead them to stop driving definitely (Cappelaere et al., 1991). To avoid losing these customers, who are in a continuous increasing in the industrialized countries (Brutel, 2002), car manufactures show their interest in this population and in its behaviour during the accessibility movement. The new vehicles tend to be adapted so that to give less discomfort for drivers. However, vehicles can not be modified without considering the driver. Traditionally car manufactures use physical mock ups to test new vehicle prototypes. However, this procedure is very expensive and less reliable (Verriest, 2000). To remedy to its disadvantages, car manufactures had the recourse to the using of numerical simulation (Porter et al., 1993), (Tessier, 2000). HANDIMAN project goes in this direction and aims to integrate the accessibility discomfort evaluation in the first stage of the new vehicle conception for elderly and/or disabled people (Ait El Menceur et al., 2007).

This evaluation is done on the basis of the accessibility movement simulation. Simulation requires modelling of the system to simulate. In our case the system is the human being.

Modelling requires knowledge of the system. The knowledge is acquired from the experimentation on the human being. In HANDIMAN project we used an optoelectronic motion capture system to capture the ingress/egress movements of elderly and/or disabled people (Ait El Menceur et al., 2007). Even though they are among the most reliable movement studying systems, the use of optoelectronic systems encounters some problems (Cappozzo et al., 1996). These problems are due either to the system itself or to the experimental protocol. One of the problems met in the reconstruction, and caused by the experimental protocol, is the computation of joint articulation angles from non rigid bodies (human body) and the integration of these angles in a rigid body structure (humanoid model). The resulted angles are biased and their using in the movement reconstruction induces false trajectories of the humanoid. These trajectories can provoke the humanoid's collision with the different vehicle's parts (collision of the head with the roof, knee with the steering wheel, penetration of the humanoid inside the seat…).

Lempereur et al. (2003) proposed an optimization based approach to remedy to this problem. This procedure minimizes at each step of time the distance between the measured trajectory (desired trajectory) of the end effector and the trajectory of the humanoid reconstructed from the computation of the joint angles. This procedure gives good results on the end effortor's trajectories. However, as it does not consider other body parts' trajectories (like knees, ankles) these lasts can have erroneous trajectories as they can enter in collision with the vehicle's parts.

In our study we propose an optimization method based on a multi objective function that considers the trajectories of many body parts. Our method aims to minimize at each step of time the distance between the measured trajectories and the trajectories of some body parts (feet, ankles, knees, hips, trunk, neck and head).

Our paper is organized as follows: Section 2 presents the method. Section 3 will detail our optimization procedure. The results will be shown in section 4. The paper is concluded in section 5.

2 METHOD

2.1 Experimentation

The experiments were conducted as part of the French HANDIMAN (RNTS 2004) project. This project aims at integrating the ingress/egress discomfort for elderly and/or disabled persons in first stages of new vehicle conception for these populations. This project considers several trials of ingress and egress movement of 41 test subjects on four vehicles representative of a large part of vehicles present in the trade (Ait El Menceur et al., 2007). In the present study only the ingress trial of one subject on one vehicle is considered, the other trials of other subjects are similar. The trial is performed on a minivan vehicle (see figure 1).

An optoelectronic motion capture system Vicon® 612 at sampling rate of 60 Hz is used. The system is equipped with 8 CCD cameras.

Fifty three anatomical markers are set on the different body segments of the subject to capture the movements during the different acquisitions (Ait El Menceur et al., 2007).

The joint angles are computed for each joint. The ISB recommendation is adopted (Wu et al., 2002).

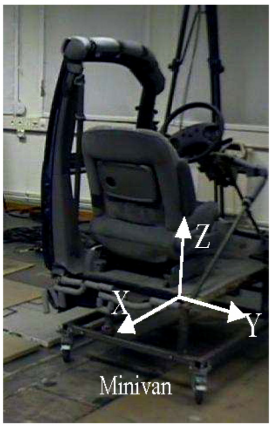

Figure 1: The stripped vehicle used in the study.

2.2 Humanoid Model

To reconstruct the ingress movement, we propose a three dimensional model of 20 DOF considering the two lower limbs and the trunk with the head.

The 20 DOF of the Humanoid model are partitioned as follows: 3 DOF for each hip, 3 DOF for the joint linking the two bodies of the trunk (T10 vertebra according to (Lempereur et al., 2005)), 3 DOF for the joint linking the head to the upper trunk, 2 DOF for each knee and ankle. The humanoid's articulations are rotoid. The convention of Denavit and Hartenberg (Denavit and Hartenberg, 1955) was adopted in the humanoid modeling process. The humanoid model is represented in figure 2.

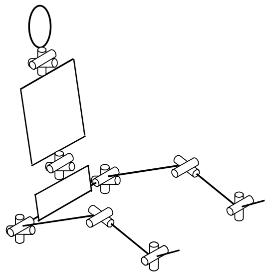

Figure 2: Humanoid model.

3 OPTIMIZATION PROCEDURE

Our method uses a multi objective optimization procedure. It minimizes the sum of the distances between all reconstructed trajectories of different body parts of our humanoid with the measured ones. The mathematical formulation of our optimization problem is given by the following expression.

$$\min \sum_{i=1}^{N} \| X_{di} - X_i \| = \min \sum_{i=1}^{N} \| X_{di} - f_i(q_j) \| \quad (1)$$

With N is the number of the body parts whose the positions are to be corrected. $\|.\|$: is the Euclidian distance (norm). q_j with j=1…7 (for the lower limbs chain) and j=1…6 (for the trunk chain) are the calculated joint angles. f_j are parts of the forward geometric function giving the positions of each body part.

The final expression of our optimization procedure is given as follows:

$$\begin{cases} \min \sum_{i=1}^{N} \| X_{di} - f_i(q_j) \| \\ \text{SC.} \quad q_{i\,min} < q_i < q_{i\,max} \\ \text{SC.} \quad |q_i - q_{ical}| < \varepsilon_i \\ \text{SC.} \quad |q_i - q_{i-1}| < V_i \end{cases} \quad (2)$$

The first constraint concerns the physiological angles limitation (Kapandji, 1974).

The second constraint imposes to the optimized angles to not diverge too much from the calculated angles. ε_i are found after several trial and error tests. For the lower limbs chains we kept same values of ε_i proposed by Lempereur et al. (2003). For the trunk chain we identified the corresponding ε_i :

Table 1: Values of ε_i for the trunk chain.

Joints	ε_i
Joint linking the two parts of the trunk	
- Flexion/Extension	19°
- Abduction/Adduction	17°
-Lateral/Medial rotation	13°
Joint linking the head to the upper trunk	
- Flexion/Extension	23°
- Abduction/Adduction	17°
-Lateral/Medial rotation	13°

The third constraint is the constraint of continuity. V_i is the maximum variation allowed between two successive optimized angles.

The maximum variations of the different joints depend on the movement and on the population.

Like in (Lempereur et al., 2003) our optimization procedure is achieved by using the Matlab® Optimization toolbox which uses the sequential quadratic program.

4 RESULTS

We have applied the method of Lempereur et al. (2003) and our method on different kinematic chains of our model. In general the method of Lempereur et al. (2003) gives good results on the end effectors trajectories. However it degrades the positions of other parts. On the other hand, the angles corrected by the method of Lempereur et al. (2003) show many vibrations and these lasts influence negatively on the reconstruction and rendering it “unrealistic”.

For an illustration purpose we present the optimization results of the method of Lempereur et al. (2003) and our method on a bit of the right ankle trajectory. Our method allows good correction of the right ankle trajectory. On the other hand this last is smoothed.

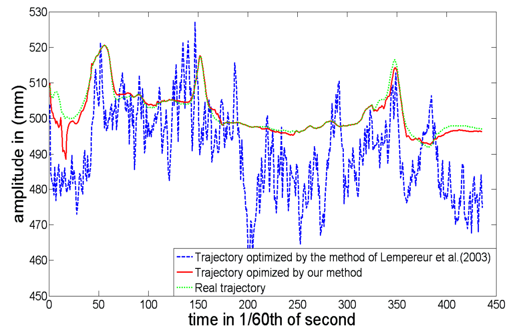

Figure 3: Right ankle different trajectories.

The three dimensional RMS between, respectively, reconstructed trajectories, trajectories optimized by Lempereur et al. (2003) method, our method and the real trajectories are represented in table 2.

Table 2: RMS (in mm) between, respectively, reconstructed trajectories, trajectories optimized by Lempereur et al. (2003) method, our method and the real trajectories.

	Model	Method of Lempereur et al. (2003)	Our method
Right knee	19.0	19.4	18.5
Right ankle	19.3	6.4	3.7
Right foot	20.1	0.0	3.3
Left knee	23.5	32.6	25.4
Left ankle	23.3	13.0	5.6
Left foot	24.4	0.3	5.0
C7	4.3	56.8	34.6
Head	69.6	5.7	16.6

The method of Lempereur et al. (2003) gives good results on the end effectors' trajectories which can even lead to their superposition with the measured trajectories.

However we can see some degradations on other body parts trajectories (like knees and ankles) and that induces to eventual collisions of these parts with the vehicle's parts, like collision of the knee with the steering wheel or penetration of the legs inside the seat.

5 CONCLUSIONS

We have proposed another optimization method based on a multi objective function to correct the joint articulation angles in automobile ingress movement. Our method minimizes at each step of time the distances between all humanoid body parts' trajectories and their real trajectories. We kept same constraints defined by Lempereur et al. (2003) for the lower limbs.

Unlike the method of Lempereur et al. (2003), our method gives good global results on all trajectories. This is due to the fact that it follows a good compromise between all trajectories and at every step of time.

The correction of the joint angles will allow a realistic simulation.

Our method presents slight degradations of some body parts' trajectories. That can be enhanced by integrating some weighting factors on some trajectories.

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REFERENCES

Ait El Menceur, M-O., Pudlo, P., Découfour, N., Bassement, M., Gillet, C., Chateauroux, E., Gorce, P., Lepoutre, F-X., 2007. Towards dynamic studying of the car ingress/egress movement for elderly and disabled population. *in proceeding with IEEE HUMAN'07, Human Machine iNteraction Conference, Timimoun, Algeria, march 12-14th. pp. 350-355.*

Brutel C., 2002. La population de la France métropolitaine en 2050 : un vieillissement inéluctable. *Economie et Statistique*, N°355-356, pp 57-71.

Cappelaere, A., Thévenon, A., Delcambre, B., 1991. Polyarthrite rhumaoïde et conduite automobile. Essais contrôlés d'un véhicule de série. Ann. *Réadaptation Méd. Phys,* 34, pp 239-244.

Cappozzo, A., Catani, F., Leardini, A., Benedetti, M. G., Croce, U. D., 1996. Position and orientation in space of bones during movement : experimental artifacts, *Clinical Biomechanics*, Vol. 11, No. 2, pp. 90-100.

Denavit, J., and Hartenberg, R. S., 1955. A kinematic notation for lower pair mechanism based on matrices, *Journal of Applied Mechanics*, Vol. 22, pp. 215-221.

Kapandji, I. A., 1974. Physiologie articulaire, Fascicule II, Membre inférieur, *Librairie Maloine* S. A., Paris.

Lempereur, M., Pudlo, P., Gorce, P., Lepoutre, F-X., 2003b. Optimization approach for the simulation of car accessibility movement. *Proc. of the IEEE International Conference on Systems Man and Cybernetics, october 5-8, Washington DC, USA*, octobre, ISBN 0-7803-7953-5.

Lempereur, M., Pudlo, P., Gorce, P., Lepoutre, F-X., 2005. Mannequin virtuel adapté à la simulation du mouvement d'entrée-sortie au véhicule automobile. *Journal Européen des Systèmes Automatisés*, 38 (7-8), pp. 959-976.

Porter, J. M., Case, K., Freer, M.T., Bonney, M., 1993.Computer-Aided Ergonomics Design of Automobiles. *In Automotive Ergonomics, Eds. Peacock and Karwonski, Taylor & Francis*, 43- 78. ISBN: 0748400052, 1993.

Tessier, Y., 2000. Vers des mannequins numériques integrés dans la conception de produits . *Les modèles numériques de l'homme pour la conception de produits*, Lyon-Bron.

Verriest, J. P., 2000. Les mannequins numériques dans la conception de produits. *Les modèles numériques de l'homme pour la conception de produits* , Mars 2000, Institut National de Recherche sur les Transports et leur Sécurité.

Wu G., Siegler S., Allard P., Kirtley C., Leardini A., Rosenbaum D., Whittle M., D'Lima D. D.,

Cristofolini L., Witte H., 2002. ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion--part I: ankle, hip, and spine. Journal of Biomechanics, 35(4), 543-54.