

Truck Instep Evaluation Using a Sample of Manikins

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ABSTRACT

Digital Human Models enable to evaluate very early a design architecture as they can interact with a digital environment. However, the question of which and how many manikins should be used to evaluate an architecture remains open. Most frequently, only a few manikins, representing the 5th, the 50th and the 95th percentile are used. Evaluations, based on so few manikins, give only rough ideas of how well the design fits a population of users. This paper proposes to use a sample population of manikins, randomly generated and representative in terms of anthropometric dimensions of the target population of users.

The application case evaluates a truck instep and handle geometric configuration. The simulated posture is the one of the manikin reaching the handles with the hands and the first step with the left foot, the right foot remaining on the ground. For such a task, the possible collision between the left knee and the second step has to be evaluated and avoided.

At first, the two conclusions of both approaches are compared for a specific truck instep. The questions which can be answered by the simulation of a large number of manikins are highlighted. In a second stage, the influences of two parameters (the handles height and the first step height) are evaluated in order to give some guidelines to the designers. Finally, this paper discusses about the anthropometric and biomechanics data that would help to have a more complete evaluation of such a task such as joint limits or joint torques.

INTRODUCTION

In order to reduce cost developments and time to market, the number of digital evaluations of future products has recently increased. As for the evaluation of the accommodation of a product to its target population of users, Digital Human Models (DHM) appear to be the right tools to be used as the interactions between the future users and product can be assessed very early in the design process. However, the use of DHMs remains complex and errors can be made if they are not used correctly. The main reason is the large variability in human beings in terms of anthropometry, functional capacity as well as behavior.

This paper deals with the problematic of anthropometry. Most frequently, industrials assess their future products using very few manikins: a short female, a medium male and a tall male (see Stephens et al. 2006 for example). Using these three manikins only, the multivariate properties of anthropometric dimensions are not taken into account at all: a short female will be thin and with short torso and hands whereas a tall male will be large and with long torso and hands. This is important as the same three manikins are most frequently used to assess every task a user can realize; whereas for some tasks, it might be more relevant to evaluate the influence of some specific anthropometric dimensions. For example, in a reaching task, it seems that the sitting height and the arm length are more important than the stature. In order to evaluate the task of inserting a key to start a car engine, the right anthropometric dimensions are the one of the hand (length and width).

An alternative, which is often proposed in the literature, to percentile models is to define boundary manikins. Such a method enables to take into account a few anthropometric dimensions (two in Kouchi et al. 2005 and three in Johnson et al. 2006). The idea is to define a set of extreme manikins (long torso and long legs, long torso and short legs...) and assume that these extreme cases are accommodated, then all the other

less extreme manikins will also be. The main drawback of this approach is that, when one manikin is not accommodated, then the percentage of accommodated user is not known although this is the designers' key question. In addition, only a low number of anthropometric dimensions can be taken into account.

Recently, Wirsching and Premkumar (2007) proposed to define, for a given task, optimal test samples of manikins from population data. However, the number of manikins remains low and the percentage of accommodated users remains unknown. Sarath and Dibakar (2007) proposed to use a high number of manikins in order to evaluate a reaching task. They have shown that, to give accurate results, the anthropometric dimensions have to be defined upon other anthropometric dimensions (eg. the mean and standard deviation of the lower arm length as a function of the upper arm length). Thanks to the high number of tested manikins, the percentage of accommodated users can be evaluated. However, the method is difficult to generalize to multiple body segments.

This paper therefore proposes a method that enables to evaluate the percentage of accommodated users to a complex task where several anthropometric dimensions have to be taken into account.

TASK DEFINITION

The task is the one of a truck driver getting in the truck cabin. In order to simplify this very complex task, only one posture is evaluated here: the one of the driver reaching the handles, the left foot on the first step and the right foot on the ground. In such a posture, a collision can occur with the second step and has to be avoided in order to simulate a realistic posture (see Figure 1).

These constraints were defined using RPx, a motion and posture simulation tool (Monnier 2008). The simulation algorithm is based on:

1. A comfortable referential posture obtained experimentally during a motion capture session
2. A constraint definition. For this task, the hands are free to glide along the handles, the left foot on the step and the right foot on the ground. A collision detection algorithm enables to drive back the left shin in the case it collides with the second step
3. A definition of the degrees of freedom fulfilling the constraints; here one whole body chain including the legs, spine and arms. The degrees of freedom of the spine were coordinated (Monnier 2007) so that all the spine segments cannot align themselves.

The resulting posture is the one that fulfills the constraints and is the closer to the referential posture. The calculation time for this posture is between 2s for a tall male with no collision problem and 60s for a short female which could hardly reach the handles, not to mention the collision problem, on an up-to-date laptop.

This posture is not frequently used by all truck drivers who need to get into the cabin very quickly and therefore reach for the left handle later on, while the right foot is not on the ground anymore. This is particularly true for trucks dedicated to frequent deliver where truck drivers are in hurry. Nevertheless, the possibility to reach both handles while the right foot is still on the ground is one of the key features that a truck instep designer has to evaluate.

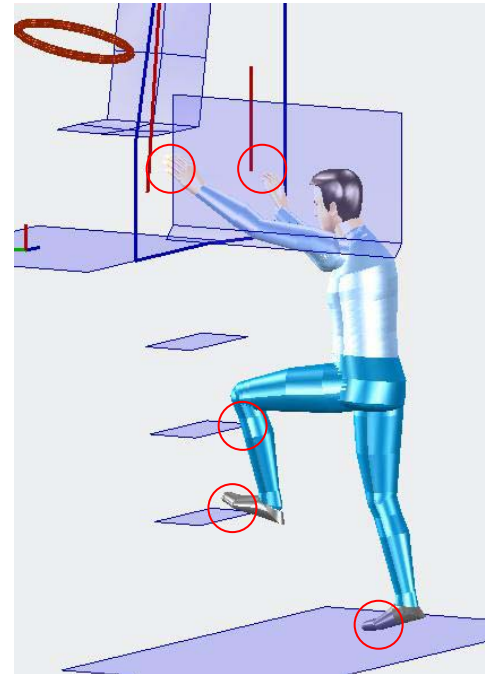


Figure 1. Five constraints defined on both feet, both hands and the left shin.

MANIKINS DEFINITION

For this task, most of the anthropometric lengths are important and will affect the posture. Here, the body height, the sitting height, the lower leg length, the upper arm length and the lower arm length were selected. The weight was added to this list. As for the upper leg length, it was not integrated into this list as the body height, the sitting height and the lower leg length already impose this dimension.

For each of these six anthropometric variables, the mean and standard deviations were defined in accordance with Volvo and their target population of users. The correlations between these variables were taken from the US Army Natic database.

Based on these input data (mean value, standard deviations and correlations), a 100 male and a 100 female manikins were randomly generated. For each population (male and female), the distribution of each anthropometric variable is close to a normal distribution (see Figure 2) were mean and standard deviations meet the input data. In addition, the correlations between the variables also meet the input data (see Figure 3). The dimensions of 200 manikins were therefore generated.