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Estimated anthropometry for male commercial pilots in Europe and an approach to its use in seat design

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ABSTRACT

This research provides an estimate of the anthropometry of the male commercial pilot population in Europe and details a new method for applying these data in multivariate design problems: the cockpit seat. For the safety and vigilance, the pilot must fit the seat. Although the anthropometric variability of pilot can be readily quantified, the magnitude of variability and the associated physical requirements are large in this complex posture. The research presented here demonstrates an approach that allows the designer to explore combinations of advices for the seat adjustments that will fit a chosen population (for example 90% of all the pilots). The data were generated after the evaluation of relevant data synthesis methods. To explore the huge design space, genetic algorithm are used on a 4 variables application case and the results are presented through a parallel graph. The results of the study is a tool taking in input the target of population (ex 95%) giving in results family of combinations of percentage of population on each parameters to see who in the population database will fit the pilot seat.

Relevance to industry: The domain of transportation, in which pilots or driver can stay a long time sitting in their vehicle is very challenging in finding an adaptable seat for every driver to be adjust.

1. Introduction

In ergonomics, work station and particularly cockpit have a rich history. The work position on a seat is fundamental to avoid physical troubles and default of concentration. There are a number of factors in seat performance including safety, comfort, and the position of the user within the seat and seated environment. One factor that influences each of these is the body size and shape of the target user population. This study considers the spatial requirements of European pilots in the design of aircraft cockpit seats. Determining the spatial requirements of a particular population is usually confounded by the lack of appropriate data. While a number of detailed databases of body size and shape exist, they represent only a few, specific populations (e.g., the U.S. military, young Japanese civilians, etc.) and not the target user population of the artifact to be designed. Consequently, methods for estimating anthropometric variability within a specific population are very important. For this paper, summary statistics for male European commercial air pilots were provided by an airline. Data synthesis techniques were used to obtain an estimate of the detailed anthropometry in this population. Several methods were compared and the method mostly likely to provide accurate estimates was utilized.

A second difficulty in cockpit design is the multivariate nature of the problem. Univariate approaches to multivariate design problems (Mehta et al., 2008; HFES 300 Committee, 2004) are known to provide inaccurate estimates of accommodation (Moroney and Smith, 1972; Gannon and Moroney, 1998; Haslegrave, 1986). There are typically a number of relevant anthropometric measures (e.g., seated hip breadth, sitting height, lower leg length, upper leg length, arm lengths, etc.). Since the lengths and widths within individuals are not perfectly correlated, they must be considered simultaneously. Although the application of boundary manikins can simplify this aspect of the problem (Bittner, 2000), their use is fraught with other difficulties (Garneau and Parkinson, 2009, 2010).

The research presented here demonstrates an approach that allows the designer to explore combinations of measures that will achieve a fixed accommodation level (e.g., 90%). This is an opportunity to exploit the multivariate nature of the problem and improve accommodation where it is most efficient (e.g., in terms of

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cost or spatial requirements). For large multivariate problems, an exhaustive study of every possible combination of factors can be mathematically impossible. The problem can be significantly reduced, however, by immediately discarding designs that are obviously intractable. For example, there is no need to consider a design that excludes 30% of the population on a single measure when the target accommodation level is 90% across all of them. The designer can also be aided through the use of optimization strategies that systematically evaluate candidate designs and consider multiple design priorities. The result is a tool that allows designers to explore the relationships between measures, trading them off to identify the specific configuration that best meets their design requirements.

2. Relevance to industry

With the evolution of population explaining the higher heterogeneity of people, the industries must take into account the anthropometry. In the field of furniture, tools, clothes (…) everything is dependent on human measurements. The workstation is a subject studied in all businesses. Its lack of ergonomics and comfort is often the cause of physical problems for the user. The domain of transportation, in which pilots or driver can stay a long time sitting in their vehicle is very challenging in finding an adaptable seat for every driver to be adjust.

More importantly, the bad position can imply a loss of vigilance, completely unthinkable for example for an aircraft pilot where an error can be vital. For the manufacturer, optimizing seat adjustments means reducing unnecessary variation ranges and therefore reducing the weight of the plane, constant objective. New proposals in aeronautics include removing the sleeping area of a pilot. The seat becomes either a cockpit but also a place of rest/sleep. That explains the growing interest of companies to improve the quality and adaptability of their seats.

3. Synthesizing a population of anthropometric data for commercial airline pilots

Databases of detailed anthropometric data are necessary for conducting multivariate design. Unfortunately, while there are an infinite number of distinct target user populations, the data in the public domain represent only a few of them. These include US military personnel (Gordon et al., 1989), Japanese civilians (of Human Engineering for Quality Life, 1994), and Chinese civilians (SAIGLOBAL, 1988). Summary statistics such as the means, standard deviations, and selected percentile values for a number of measures are available for many other populations including agricultural workers in India (Dewangan et al., 2008) and civilians in England (Barkla, 1961). When the detailed databases are available, they can be used directly in multivariate design. When only the summary statistics are available, the data for the underlying distributions must first be estimated (Pheasant, 1982). That is the situation in the present work, where only summary statistics were made available.

3.1. Simulating virtual populations

Although specific measures such as those required for cockpit packaging (e.g., buttock-popliteal length, seated hip breadth) are critical to design decision-making, they are not commonly available for the population of interest. While invaluable to proper design, correctly measuring anthropometric data can be an expensive and time-consuming process. Consequently, the designer is often left with only gross body dimensions such as stature and mass for the user population. As a result, numerous anthropometry-simulation techniques that use these measures (and BMI) to estimate the specific measures of interest have been developed.

Proportionality constants (Drillis and Contini, 1966) are used as a basis for a number of them, including some software tools, textbooks, and templates. While inherently simple, these methods have been shown to be inaccurate, particularly in estimating values in the tails of distributions where most design decisions occur (Moroney and Smith, 1972; Roebuck, 1995; Fromuth and Parkinson, 2008).

Another approach is to formulate linear regression models relating the required anthropometry to easily-obtainable predictors such as stature, mass, and BMI (body mass index, a normalized ratio of weight to stature) as in Ryu et al. (2004).

These models can be based on information from comprehensive databases such as ANSUR (a database of US Military in the 1980s, Gordon et al. (1989)) or CAESAR (a convenience sample of North American and European civilians, Blackwell et al. (2008)). Relationships in these data are used estimate the measures in the relevant target user population (Nadadur and Parkinson, 2008). The main drawbacks of this technique are: (1) inaccurate estimations of anthropometry at the tails of the distribution and (2) the necessity of a detailed database from which to obtain the regression equations. The accuracy of the regression methodology, particularly in the tails of the distribution, is increased considerably with the inclusion of residual variance as a stochastic component in the model (Parkinson and Reed, 2006; Garneau and Parkinson, 2009).

When this approach is used, some resulting distributions in the virtual populations are statistically equivalent, in terms of means and variances, to the actual anthropometry (Nadadur and Parkinson, 2009). Approaches using Principal Components Analysis (PCA) have been shown to further improve accuracy (Parkinson and Reed, 2009).

3.2. Comparing the methods

The ANSUR database was selected as the baseline database for this work since, of the available detailed data, the military personnel of the ANSUR population were thought to be closest (e.g., in terms of fitness, body shape, etc.) to the members of the male European commercial pilot population. To identify which of the methods outlined above would be most appropriate, a series of 28 design scenarios were considered. Each of seven synthesis methods was used to estimate the entire distribution of four relevant body dimensions. The dimensions were selected as those particularly relevant to the problem at hand: cockpit design. Successful seating positions support a number of specific activities. For example, a pilot must align to small beads to ensure a good view of the environment. They must also have their feet on the ground and shoulder blades resting on the seat. The seat pan must be wide enough to provide adequate support and pressure relief for long durations. The selected variables (Fig. 1) are: popliteal height (l_p), buttock-popliteal length (l_b), seated acromial height (l_a), and seated hip breadth (l_h).

The stature, mass, and BMI for the 1774 members of the male ANSUR population ($\mathbf{r}$) were used to estimate the four measures selected for the pilot (l_p, l_b, l_a, and l_h) using the synthesis methods outlined above.

Method 1: proportionality constant. The principle is to identify the different measures of the body by applying the average ratio of that measure to stature for a population. For each measure of interest x, the proportionality constant c_x is then:

$$c_x = \left(\sum_{j=1}^{n} \frac{r_{x,j}}{r_{s,j}} \right) \Big/ n \qquad (1)$$