

# Chapter 27

## Neural Networks for Modeling the Contact Foot–Shoe Upper

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### ABSTRACT

*Recently, important advances in virtual reality have made possible real improvements in computer aided design, CAD. These advances are being applied to all the fields and they have reached to the footwear design. The majority of the interaction foot-shoe simulation processes have been focused on the interaction between the foot and the sole. However, few efforts have been made in order to simulate the interaction between the shoe upper and the foot surface. To simulate this interaction, flexibility tests (characterization of the relationship between exerted force and displacement) are carried out to evaluate the materials used for the shoe upper. This chapter shows a procedure based on artificial neural networks (ANNs) to reduce the number of flexibility tests that are needed for a comfortable shoe design. Using the elastic parameters of the material as inputs to the ANN, it is possible to find a neural model that provides a unique equation for the relationship between force and displacement instead of a different characteristic curve for each material. Achieved results show the suitability of the proposed approach.*

### INTRODUCTION

Consumers are demanding higher levels of footwear comfort and functionality and the footwear designers are aware of these aspects when a new collection is designed. Two tests are currently used to assess the footwear comfort and functionality: Subjective tests based on user perceptions with feet standard

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Figure 1. SIMUCAL, Footwear Virtual Simulator



in size and form and objective tests based on the measure of biomechanical variables during the use of footwear in both real and simulated conditions. The use of the virtual reality and simulation techniques provide a viable alternative to these procedures which are costly and time consuming (Figure 1).

Comfort is very important in footwear manufacture, because the foot is one of the structures of the human body that supports most weight in gait. It is also the principal shock absorber of the impact against the ground. Most of the biomechanical research related to the foot has been focused on measuring the plantar pressure distribution, since the presence of high pressures at this zone is one of the major causes of diabetic ulcerations of the foot and pain in the soft tissues (Holewski et al., 1989; Onwuanyi, 2000). However, the shoe uppers also take part in comfort (Jordan & Bartlett, 1995) and their deformation can be the cause of pain and injury on the foot surface.

The deformation in the shoe upper material is due mainly to the contact with the foot surface. In order to model this contact, a whole study about the elasticity of the shoe upper material must be performed. Several tests must be done to determine the elastic parameters that characterize it. In this chapter, a model to characterize shoe upper materials is proposed. The model is aimed at reducing the quantity of elasticity tests necessary to determine the behavior of the materials subjected to this kind of contact.

As the foot surface has little soft tissue, foot surface behavior can be assumed to be completely determined by the behavior of the bones that form it, and in this sense, a set of tests called *flexibility tests* were designed for the Institute of Biomechanics of Valencia. These tests consist of applying a controlled force by means of a sphere that simulates a bone, on a sample of material fixed to a gag so that the slide was avoided (Figure 2a). The result of these tests is the measure of the force that the sphere exerts on the sample versus the displacement of the central point of the material shell (Figure 2b).

Three materials that are commonly used in the footwear manufacture were subjected to these tests in order to simulate how the material was deformed by pressure of the bones. With the results of these tests that provide the curves of the force exerted versus the displacement of the central point of the material shell, it is possible to draw an expression that characterizes the material. Different materials are usually separately modeled. However, there are several approaches within Machine Learning (ML) that allow obtaining a unique equation for all the materials. In this chapter, we show how a Multilayer Perceptron (MLP) is able to characterize all three materials with a unique equation that has the following inputs: the elastic parameters of the corresponding material (Young modulus and Poisson coefficient), the thickness

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