Chapter 14

3D Surface Reconstruction from Multiviews for Prosthetic Design

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ABSTRACT

Existing methods that use a fringe projection technique for prosthetic designs produce good results for the trunk and lower limbs; however, the devices used for this purpose are expensive. This chapter investigates the use of an inexpensive passive method involving 3D surface reconstruction from video images taken at multiple views. The design and evaluation methodology, consisting of a number of techniques suitable for prosthetic design, is developed. The method that focuses on fitting the reference model (3D model) of an object to the target data (3D data) is presented. The 3D model is obtained by a computer program while the 3D data uses the shape-from-silhouette technique in an approximately circular motion. The modification of existing model-based reconstruction – mainly on the deformation process of vertices – is discussed, and the results of different objects show a good possibility for using a passive method in prosthetic devices. The methodology developed is shown to be useful for prosthetic designers as an alternative to manual impression during the design.

INTRODUCTION

Three-dimensional (3D) digitalisation systems applied to the orthopaedic domain allow for the freeing from the necessity of making manual impressions of the socket during prosthetic design. The work carried out in these fields aims to find the best fitting of the socket into the portion of the arm or leg remaining after an amputation (residual limb or stump), during the prosthetic design by using a multiview method. A prosthetic device is an artificial substitute for a missing body part such as an arm, leg, hand or foot, and is used for functional or cosmetic reasons, or both. Most of the previous works on prosthetic design are based on manual design and use Computer-Aided Design (CAD).
systems (Lusardi and Nielson, 2007; Seymour (2002)). With a manual design, the most common way of defining the shape of a residual limb is to make a mould of the residual limb itself. A trained practitioner can then manipulate the mould in order to correctly spread out the pressure that the mould exerts on the patient. One of the advantages in CAD is the reduced need for cast modifications and is, thus, a time saver. However, computer-aided systems increase the initial cost and training that is needed to operate the system. This initial cost and training is decreased if there is a system that can capture the residual limb shapes and give the actual dimension of the limb for the design. This can be realized using a reconstructed image of the limb for orthotic and prosthetic design. The cost of training will be reduced as the image is analysed automatically. Using the reconstructed 3D image would also be more comfortable for the patient when compared to using a traditional fabrication, as the latter might cause more injury during the design. In this chapter, the shapes of objects which are similar to a limb are used as a starting point of this research. A cylinder, cone or a combination of these are suitably similar shapes to the limb. This chapter provides 3D reconstruction system that capable to produce the measurement of the limb as well as creating a model of the limb. The finding will help the practitioner or prosthetist in designing the prosthetic device.

ORTHOTIC AND PROSTHETIC

Orthotic and prosthetic devices have existed for many years. Originally, orthotic and prosthetic devices were simply replacements for missing limbs or used as supports for the human body, but now they enable people to have active lives. Prosthetics involves the design, fabrication and fitting of custom-made artificial limbs or other assistive devices for patients who have lost limbs as a result of traumatic injuries, vascular diseases, diabetes, cancer or congenital disorders. These devices will restore — as completely as possible — the function and appearance of a full or partially missing limb. Because of the vast differences in human anatomy, the fabrication of prostheses is an intricate, custom procedure requiring a high degree of skill combined with sophisticated technology. Orthotics involves the design, fabrication, fitting and supervised use of devices that provide external support or assist weak or abnormal joints and/or muscle groups. Musculoskeletal disorders, joint weakness, back problems, or the inability of any joint or muscle group to function correctly can detrimentally affect an individual’s quality of life and mobility. These problems can be caused by congenital factors, traumatic injury, chronic conditions, sports injuries, or degenerative disease.

Many improvements have been made possible because of new surgical techniques, the advancement of components for making prosthetics, and creative engineering ideas (Lusardi and Nielson, 2007). Improved materials and technologies are enabling many individuals with disabilities to return to activities they previously enjoyed. Custom fabricated and custom fitted prostheses and orthoses require high strength and low weight. Advancements in technology continue to improve patient care. Technological breakthroughs such as electronic knees and computer imaging are changing the way orthoses and prostheses enable patients to fulfil their potential.

Materials used in each device depend on the weight of the user, their desired activities and their personal preferences. Flexible polymers provide increased comfort for patients. Carbon fibre, Kevlar® and titanium are all used for reducing the weight and increasing the strength and durability of the device.

CAD/CAM technology is increasingly being used to help design and fabricate models from which orthoses and prosthetic sockets are produced. Measurements can be scanned by laser or by using a special hand-held wand. This information describing the size and shape of the limb allows the prosthetist and orthotist to design the device.