Acta Tecnología - International Scientific Journal about Technologies
Volume: 6 2020 Issue: 4 Pages: 105-110 ISSN 2453-675X

doi:10.22306/atec.v6i4.88 *Received: 18 June 2020; Revised: 12 Oct. 2020; Accepted: 23 Nov. 2020*

HAND 3D SCANNING POSSIBILITIES

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Keywords: 3D scanning, hand, forearm, grip, grasping
Abstract: 3D scanning as an innovative method of obtaining specific substrates for the design of prosthetic-orthotic devices is now becoming increasingly popular. The advantages of this technology over the classic way of taking the dimensional and shape characteristics of parts of the human body are its non-invasiveness, speed, archiving and, more recently, the possibility of using a low-cost 3D scanner, thus reducing economic demands and making the technology available to most orthopaedic technicians. The article offers a comprehensive overview of the correct positioning of the hand and fingers for selected types of gripping as well as possible complications in their scanning, for the achievement of correct digital models applicable to the design of personalized orthotic devices.

1 Introduction

Today, technological developments offer several possibilities for obtaining detailed information about the internal structure of objects. Digitising the outer shape of real objects becomes a standard tool in various sectors e.g., engineering, quality management, forensic sciences, archaeology and medicine, especially in the field of prosthetics and orthotics. For these purposes, 3D scanners, devices that convert a real object into a digital form, capture information about the shape, dimensions and texture of real objects, and then transform them into a digital form for further computer processing [1].

2 Hand and its basic functions

In the process of human development, the hand played one of the key tasks. The interaction of the hand as an organ that enables work, and work as an activity that forms and improves the hand, has a decisive impact on the development of the relevant areas of the brain, thereby on the development of man as an animal species with an exceptional position in nature. The human hand is distinguished from other animals by creating the ability of the thumb opposition, i.e., converting the hand from the movement organ (used in walking) to the gripping organ. The main function of the hand is to grasp the object and press it with such force that the hand can move the object.

The hand with the wrist, as its functional part, consists of 27 bones, has over 20 joints and 33 different muscles and nerves participating in controlling its movement. The human hand is a highly mobile organ that allows combination of several movements [1].

The bones of the hand are arranged into three arches, which are reinforced by the inner muscles of the hand. Those are two transverse arches and one longitude arch.

Most of the activities are done between the thumb and forefinger or middle finger, the remaining two ring fingers and the little finger serve as auxiliary fingers.

The grip can be generally defined as active handling of an object with a purpose of holding it and using it for an activity. For an optimally performed grip not only hand and the entire upper limb must take the right position, but also the body and its individual functional segments. From the typology point of view, grasping can be divided into 2 main groups, on precise (fine) grasping and power (force) grasping [1][2].

For precise grasping, the object is located between the tips of the fingers and thumb, while the thumb is in the abduction. These grips provide precise and gentle movement with objects that are small and fragile, and can be divided into lateral, terminal and opposition grips [3]. The power grasping is used when the object needs to be held by force. Fingers tend to bend in one direction and the thumb embraces the object. Power grasping is further divided into cylindrical, spherical, hook and directional grip.

3 Hand 3D scanning

Before the scanning of upper extremities, it is advisable to know the purpose for which the digitization of the segment is carried out. If the model of the limb is to serve as a blueprint for designing of an orthopaedic device, it is necessary to consider the functional purpose of the device. Should the function be dynamic or static? If the segment needs to be fixed, it is advisable to perform a scan in the position in which the segment should be fixed. The scanning position also depends on the quality of priority areas [3].

When digitising the entire upper limb, it is optimal to capture the subject in a sitting position with the upper limb abducted (120° to 160°), ensuring an appropriate scanning distance and relatively free access from all sides. In this position, however, it is necessary to know that the subject may not maintain a sufficiently static position, and in the distal part of the limb, movement may occur, which may not be compensated when processing the digital model. This creates a risk of reduced accuracy of the resulting model, its morphological deformation as well as the formation of artefacts and bifurcated scans due to the impossibility of correct alignment (Figure 1).

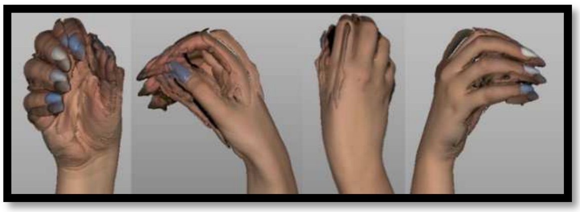

Figure 1 Example of a bifurcated model

When scanning the area of the hand and forearm, it is advisable to stabilize the elbow joint by resting it against the mat, thus significantly facilitating the ability to keep the distal segment in a stabile position. The position of the thumb and fingers must be chosen according to the purpose to which the model will serve. The thumb may be positioned in opposition if the resulting position of the model of the hand is to be rested or active, or in a reposition if the aim is to focus on the entire palm area. Fingers can be digitized in mutual adduction or abduction.

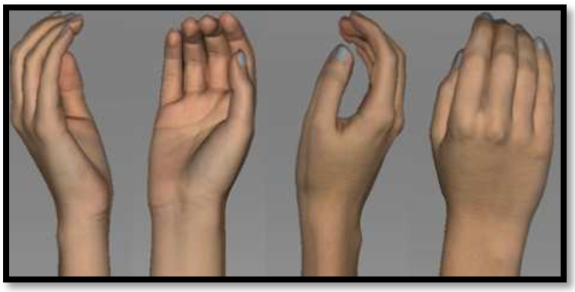

Figure 2 Scan of the hand area with the fingers in a mutual adduction

When scanning with the fingers in adduction, it is not possible to capture the gap between the fingers, so it is necessary to count on the fact that the second to the fifth finger will be captured as a single unit (Figure 2). However, digitisation itself is simple and there is no need to focus on scanning the lateral aspects of individual fingers.

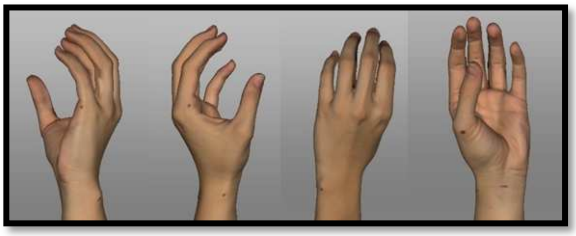

Figure 3 Scan of the hand area with the fingers in a mutual abduction

When digitising the hand with abducted fingers, it is essential to adjust the gap between each finger, so that it can capture their lateral aspects well (Figure 3). If the gaps are too wide, the natural position of the hand is lost and passes into the form of a spherical grip, if the gaps are too narrow, it is difficult to obtain a model with separate fingers without deformations and artefacts.

When digitizing the fingers, it is necessary to pay attention to the area of distal digits and scan the entire area of the edge of the nail, especially from the palmar side. The area of distal digits is critical in the formation of the model in terms of the risk of deformities and artefacts (Figure 4).

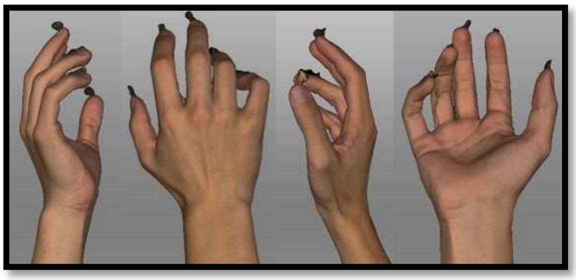

Figure 4 Artefacts on the distal finger digits

3.1 Grasp scanning

The following four grips - spherical, cylindrical, lateral and opposition grip - are selected to showcase the options within the grasp scanning.

3.1.1 Spherical grip

The distal (DIP) and proximal interphalangeal (PIP) joints are approximately in 30-degree flexion and the thumb is abducted relative to the metacarpophalangeal (MCP) joint. Forces are formed between the fingers and the palm.

Figure 5 Scan and photography of a spherical grip

The spherical grip is relatively simple from a scanning perspective (Figure 5). Since the fingers are in mutual abduction, it is possible to take a good scan of their lateral aspects. If the wrist is positioned between 45° palmar to 60° dorsal flexion, the dorsal aspect of the hand is very well digitized. It is necessary to focus on the distal parts of the fingers and when scanning with a holding object on the transition between the object and fingers, where the transition between the texture of the object and the hand doesn't have to be clearly defined (Figure 6).

Figure 6 Scan and photography of a spherical grip with an object

A well-captured texture of both the hand and the held object – the apple (Figure 7) is visible on the scan. The fingers are clearly separated, also the aspect of the palm is taken. Distal digits that are free of artefacts are also digitised.

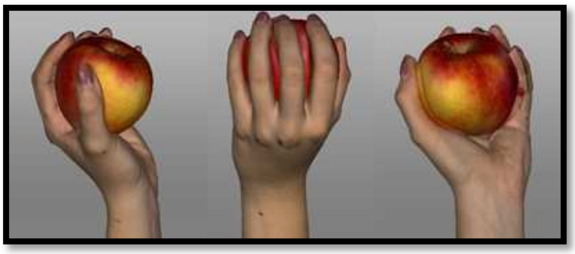

Figure 7 Example of a spherical grip with an object

3.1.2 Cylindrical grip

With the cylindrical grip, fingers and thumb are in flexion and the thumb embraces the object in the opposite direction to the fingers. Scanning the cylindrical grip without the object is quite difficult. This grip can be scanned with the second to the fifth finger with mutual abduction (Figure 8). In the first case, it is not possible to capture the gap between the fingers and therefore it is necessary to know that the fingers will be captured as a single unit. However, it is possible to modify and separate them. When scanning the cylindrical grip without the object, it is difficult to capture the ventral surfaces of the fingers, as they are strongly oriented towards the palm. It is therefore appropriate to be aware of reduced scan accuracy and possible occurrence of artefacts in this area and thus the need for a higher degree of additional modification and modification of the model.

Figure 8 Scan of a cylindrical grip without an object with adducted and abducted fingers

In the case of scanning the cylindrical grip with separate fingers, it is necessary to appropriately create a gap between each finger in order to maintain the grip, while at the same time make it possible to capture the lateral aspects of each finger with enough precision. In this case, it is often to redo the positioning and recapture the grip. Making a suitable scan of the cylindrical grip without the object requires experience in finger and hand positioning as well as in scanning.

While the most difficult part is to capture the palmar aspect of fingers, when grasping the object, this problem is eliminated. It is necessary to focus on setting the appropriate gaps between each finger (Figure 9).

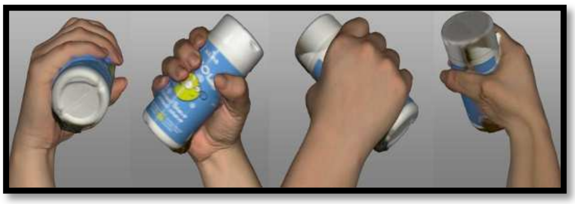

Figure 9 Cylindrical grip with an object

3.1.3 Opposition grip

It represents a press between the volar side of the pulp of the last digits of most of the first three fingers, i.e., three-point (but it can also be four points). It is mainly used when holding stationery.

Scanning an opposition grip without an object is relatively easy, but if a scan with a grasped object is required, the process is complicated. The quality of the resulting model depends heavily on the position of the fingers, which do not participate in the grasping. It is best if they are extended in MCP, proximal and distal interphalangeal joints in mild flexion, thus allowing for the scanning of the palmar area.

Figure 10 Opposition grip without an object

On the scan of the opposition grip without the object, the arches of the hand are clearly visible, as well as the articulated areas of the fingers, creases and palm drawing (Figure 10).

Figure 11 Opposition grip with an object - whiteboard marker

As can be seen in the images of the opposition grip with the object (whiteboard marker), the quality of the resulting scan is excellent, as the requirement for extension fourth and fifth finger in the MCP joint has been met and thus the digitization of the palm as well as the palm aspects of the fingers has been allowed (Figure 11).

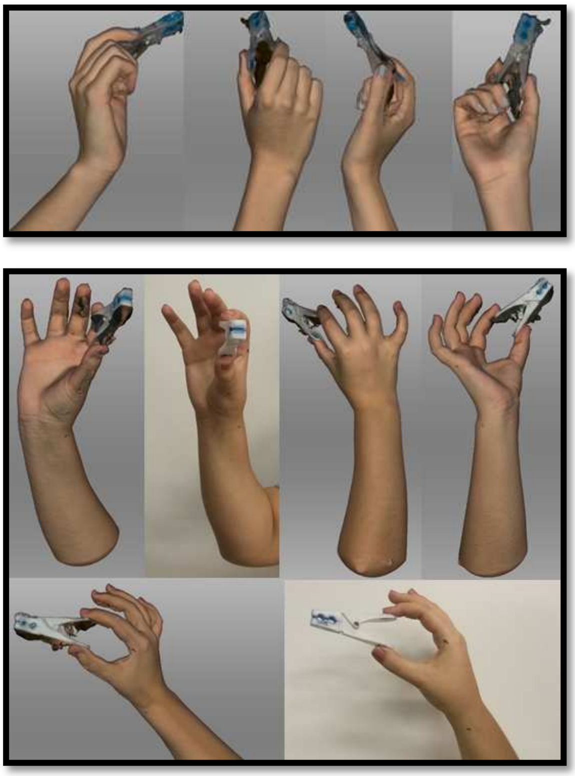

Figure 12 Opposition grasping with flexed and extended fingers

The figure shows an example of a scan with flexed fingers and the subsequent creation of artefacts in the area of the handled object, thumb and distal digit of the second finger (Figure 12). Represented below is a scan of the same subject with extended fingers and therefore enough space for data collection.

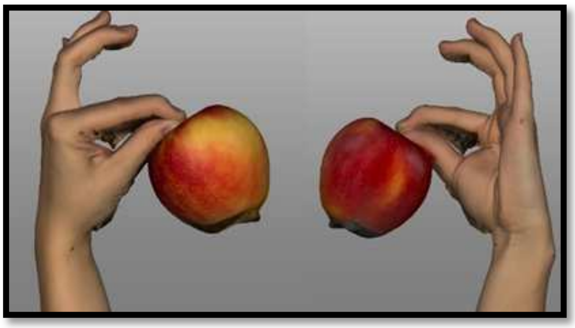

Figure 13 Artefacts between the second finger and the thumb

The picture below presents an insufficient scan of the palmar aspect of the thumb and the second finger, therefore, there is no clearly defined surface and gap between these aspects (Figure 13). The artefact is created when the model is processed and edited to fill in the missing data. It can be deleted by changing the crack fill setting or by modifying the created model.

Figure 14 Example of an unsuitable positioning during scanning

The figure shows an example of inappropriate positioning when scanning. The dorsal part of the hand and fingers as their distal aspect are very well accessible. However, the held object (an apple) prevents the capturing of the palmar aspect, where the non-compliant morphology and texture of the hand as well as the apple itself is subsequently created (Figure 14).

3.1.4 Lateral grip

With this grasp, considerable force can be exerted, and the tool coordinated. The thumb is in adduction on the radial aspect of the second fingers second digit. This grip is important for the coordinated handling of small objects.

Scanning the lateral grip, whether with or without the object, is quite easy. The resulting scans are of good quality, mostly without obvious deformations or artefacts. Second to fifth finger may be flexed in both MCP, PIP and DIP joints (in which case it is important to pay close attention when scanning the contact of distal digits and the palm) (Figure 15) or with flexed MCP and PIP joints and extended DIP joints (Figure 16).

Figure 15 Visible deformity of distal digits with flexed DIP joints

Figure 16 Satisfactory scan of the lateral grip without an object

Scanning of the lateral grasp with an object is not complicated, however, proper positioning is required, so that the object is accessible for scanning from all sides (Figure 18).

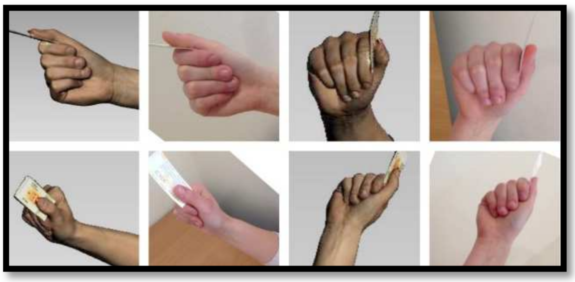

Figure 17 Lateral grip with an object

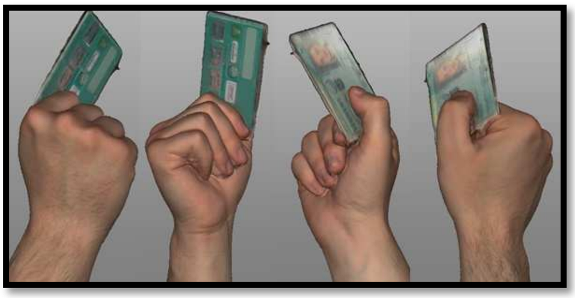

Figure 18 Example of a correct hand and object positioning during lateral grasping

4 Conclusions

3D scanners currently have a major impact on both medical research and practice, and their use for the purpose of obtaining the shape and dimensional parameters of the human body is very beneficial.

Digitising the hand in selected resting, functional, or gripping positions with a selected object or in its pathological position is currently advantageous in CAD designing of personalised orthotic devices in terms of their function as well as the offering of countless alternative options for model modifications.

Acknowledgement

The manuscript has been supported by research grants: Stimulus for Research and Development of Ministry of Education No. 1233/2018, Cultural and educational grant agency of the Ministry of Education, Science, Research and Sports of the Slovak Republic: KEGA 041TUKE-4/2019, KEGA 023TUKE-4/2020, Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences:VEGA 1/0316/18, VEGA 1/0179/19 and Research and Development Support Agency APVV-19-0290.

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Review process

Single-blind peer review process.