Assisted Scanning Techniques Optimization with Application in Biomechanics

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Abstract— **The paper presents a software interface dedicated to indicate the proper method used for the scanning different complex models with application in Biomechanics, like orthopedic orthesis. There is described the way in which certain physical models with application in Biomechanics were scanned using two different methods. The results on the scanning precision were synthesized as statistics into a software application created by us for this reason. Finally a conclusion about the proper scanning method depending on Biomechanics application can be obtained and established for our further research.**

Keywords— **scanning, routine, accuracy, method, programming.**

I. INTRODUCTION

Due to the fact that nowadays the rapid prototyping in Biomechanics is more and more required, the scanning technology is a concept that concern the researches. The most suggestive examples refer to the prosthesis and orthesis prototyping. An efficient and proper prototyping requires previously a suitable scanning process to generate a CAD model faithful to biomechanical element for which the prosthesis or orthesis prototyping is realized.

II. THE RESEARCH OBJECT

Due to the fact that some important parameters, like walking or standing stability affect directly the life's quality, we have choose as study object the orthopedic orthosis.

Our research issue is to find a low cost and efficient method to prototype a family of plantar orthesis which role is to correct progressively any diseases for human subjects.

About foot sole scanning, different dedicated devices having their associated software environment are largely used. *Foto Scan 3D Handheld Scanner* or *Foto Scan 3D for custom insole* (United Kingdom) could be considered as representative examples. The information about plantar pressure can be registered and processed through their associated software systems. As a result, a decision on the plantar orthotic achievement items could be taken.

Until now, different types of plantar orthosis were developed, like: plantar supporters, foot inserts, calcaneal sights orthesis for correction of static foot etc. [1], [2].

Although the actual used methods for the corrective plantar orthosis obtaining are very efficient, their main disadvantage refers to the costs caused to the used complex equipment. For this reason, the main purpose of our studies is to establish an efficient, non expansive and accurate method for orthopedic orthesis prototyping. One of their functions could be to correct progressively the walking or stability parameters for persons having different diseases [1]. Another destination could be the stimulation of certain nervous centers in the plantar area for the persons presenting diseases of internal organs.

Our current researches aim is to develop an efficient method as to ensure a rapid and low cost prototyping process for some elements that could compose such a plantar orthosis.

Our actual research refers to the first stage on prototyping, namely the proper and efficient scanning process for the initial CAD models that will lead to the final design of the prototypes. For this reason, the aspect of interest referred to the scanning precision for some foot sole physical models obtained previously.

The models were provided from 5 persons aged between 25 and 40 years, without disabilities. For each human subject, two physical models were made.

For a more accurate statistical determination in terms of accuracy of scanning was necessary to achieve a larger number of physical models, each of which being scanned. Based on information obtained in this respect, our research found to be sufficient development of physical models for five subjects.

The procedure to obtain a physical model for a human foot sole was the following: the foot was introduced into a plaster mass, the model being obtained as a negative profile of the human foot.

III. THE SCANNING METHODS DESCRIPTION

The applied procedure to obtain the physical model was repeated for both foot of each of the five evaluated persons.

Once the physical models were obtained, we identified two different solutions for their scanning. Each of them relies on the two existing equipment as standard our research department.

The first scanning method invoked the using of the *DEA GLOBAL Performance 05 x 05 x 05* (Italy) series coordinate measuring machine permitting the scanning with contact. The main technical characteristics are presented below:

Table 1 The main technical specification of the used coordinate measuring machine [3]

Model	**05 x 05 x 05**
Measuring range along along the three axes of coordinate system [mm]	500 x 500 x 500
Measuring head ordering	automatic, by software
Software interface environment	PC-DMIS, 4.1.1
Measuring/scanning accuracy [mm]	0.001

The second method was based on the principle of non-contact scanning, for it using the *ExaScan 30144* portable scanner with laser beam, which technical characteristics are presented below:

Table 2 The technical characteristics for the used non contact principle portable scanner [4]

Model	*ExaScan 30144*
Measuring range [mm]	± 22.5
Measuring frequency [no of emission-reception cycles/s]	25000
Measuring resolution [mm]	0.05
Scanning distance [mm]	300

The aim of our research was know which method could be applied successfully for clinical investigations in human subjects for the purpose CAD modeling and orthotic plantar prototyping elements.

When applying the first method, we established the step scan of 3 mm. The reason for choosing this value is related to both the process and the quality of the surface point cloud formed after scanning. Thus, experimentally, after repeating the procedure with different values of step scan, it was observed that for this step value the machine precision scanning was not affected. Under these conditions the process of scanning a physical model lasted approximately 3 hours.

Through the first method, the scanned surfaces were imported as CAD models, in .IGS or .STL format, as cloud of points. For a complete and correct scanning procedure we proceeded to the finite scanning portions, allowing their perfect alignment and CAD model 3D reconstruction [5]. The way to apply the contact scanning is presented in the figure 1.

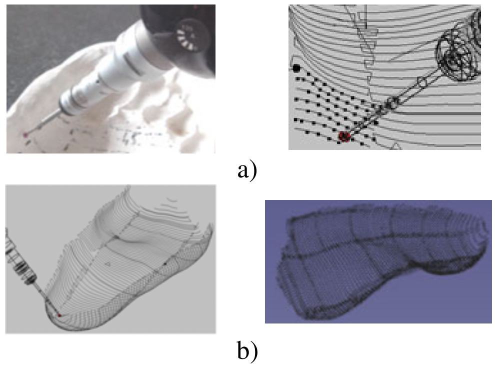


Fig. 1 The contact scanning procedure: a) the scanning process; b) the CAD model obtaining [4]

For the non contact principle scanning method, the scanning parameters on distance and laser beam intensity were established directly by software, using the option adjust automatically. For a better scanning process being used some marks placed at irregular distances [3]. The scanning duration for one model was about 20 minutes. The scanning procedure without contact is illustrated in the figure 2. The 3D CAD model was exported as .STL file, as shape surface. It will be used for further processing to generate its reference surface against which it can be constructed and modeled some orthotic plantar elements.

Once established the best method from the point of view of scanning speed, our research was concentrated on the scanning accuracy.

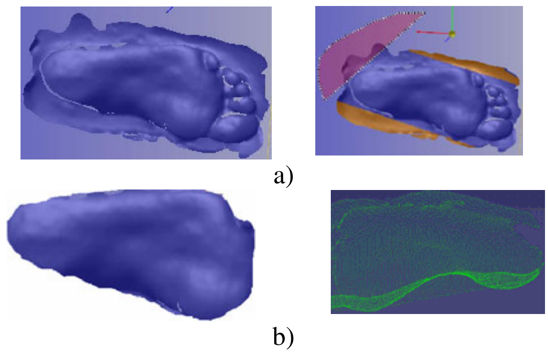


Fig. 2 The scanning procedure without contact: a) the scanning process including the adjusting; b) the CAD model obtaining [6]

The reason that research focused on assessing the two methods is that each of them may involve lower costs because there are not necessary complex equipment for human foot scanning foot.

Furthermore, our research aimed at identifying the scanning applications in Biomechanics, using portable scanner, its principle of operation being close to that used for specific scanning equipment, mentioned in section II.

Specifically, it aims to determine the precision of scanning for applying the principle of non-contact method, to know if this method can be successfully applied in clinical investigations, respectively for the orthotic items inspection.

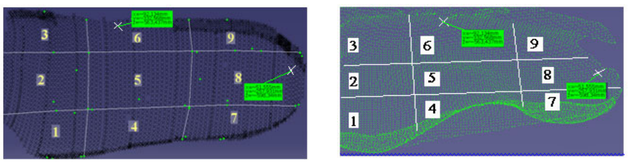
IV. Scanning accuracy evaluation using PC

To establish which scanning method is better, our research was especially focused on scanning precision. For this reason, we have developed a software interface that allows the automatic determination of the results on the scanning precision for each one of both used methods [7].

To evaluate the best possible the precision in scanning as there it was taken as an example the physical model, that was scanned through the both presented methods. There were taken into account the following aspects:

- the differences between the measured global dimensions on the CAD models (the CAD obtained as cloud of points due to the contact principle scanning and the CAD model obtained as .STL file, due to the non contact scanning principle); the second CAD model was generated as continuous surface, but it could be viewed also as cloud of points;

- the differences regarding the coordinates of some representative points measured on the cloud of points surface reported to the same representative points coordinates measured on the second CAD surface (due to the non contact scanning principle) (figure 3).



a) b)

Fig. 3 The measured coordinates of the same representative points on the CAD models: a) for the CAD model obtained due to the contact scanning method; b) for the CAD model obtained due to the non-contact scanning method

For this assessment to be made quickly and accurately, from our study on the interpretation of CAD models, it was established that the most effective method is to divide them into 9 areas of evaluation (figure 3). The division on the 9 areas was done as follows: 3 for the metatarsals, 3 for the arch and other 3 for the heel area.

For each area, as points of evaluation, there were taken the points of minimum and maximum share reported to the OZ axis. The differences between OZ coordinates of the same measured points for both CAD models have provided information on the differences between the two scans.

The points coordinates were measured directly on the CAD models and further the information was used for the statistical determination of the scanning deviation.

The entire procedure about the scanning process using both methods, followed by the CAD models evaluation was applied for each set of physical models providing from each of the 5 human subjects. This procedure was necessary for a more precise assessment of the accuracy of scanning physical models (see section II).

Due to our researches on the contact scanning principle leaded to the conclusion that this method could be considered as reference solution on the scanning precision. This conclusion was drawn after the scanning accuracy analyzing for one surface of a parallel-gauge - the measured deviation was about 4 um. Based on this finding it could be evaluated a deviation of about 10 μm in case irregular convex surfaces scanning.

For this reason, our research was focused to calculate the scanning deviation in case of non contact method applying reported to the with contact scanning method.

To obtain a statistical result as accurate and faster as possible, this algorithm has been implemented into a software application created in the *Lab VIEW 7.1* virtual environment. The reason to choose LabVIEW as programming environment was that it is efficient and proper for all statistic determination [8].

The purpose of the application is to determine an overall average deviation for the principle of non-contact scanning in relation to the case of scanning by contact.

For this, in the application software there it were placed the information on the evaluation of each CAD part model. There it was taken into account the scanning and evaluation of all physical models providing from the 5 subjects.To develop the application, a sequential programming structure was used, for each sequence a calculus algorithm being defined. The calculus algorithm is similar for each sequence. For this reason, each sequence includes a programming sequential structure with 2 steps (figure 4).

A program routine of the calculus algorithm is illustrated in the figure 5.

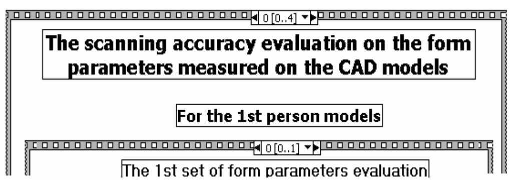


Fig. 4 Sequential structure programming for the data processing providing from the CAD models evaluation

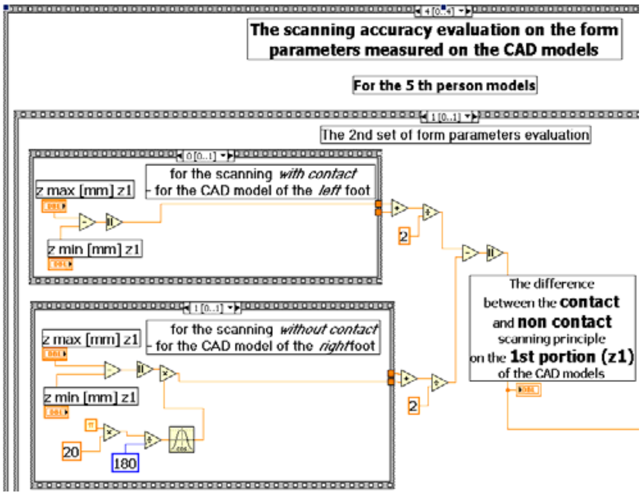


Fig. 5 Programming routine for the calculus algorithm for the scanning accuracy statistic determination on the models form parameters

In figure 5 there is presented a programming routine to calculate the difference between the measured values using both scanning methods, on the 1st portion of the CAD models (figure 3). Similar calculus algorithms were used for all form parameters (both sets). As a result, for the models associated to each tested subjects, the information on the scanning precision when using the portable scanner, non contact principle was synthesized (figure 6).

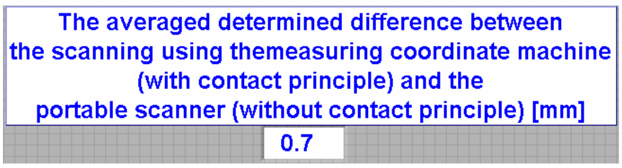


Fig. 6 The information on the scanning precision when applying the non contact scanning method

Taking also into account the determined difference on the scanning accuracy between the two used methods, we found that the scanning accuracy by non contact scanning is between ***0.65 mm and 0.75 mm***.

V. Conclusions

Based on the accuracy of the scan results, it could be concluded that non-contact scanning method using the portable scanner *ExaScan 30144* could be successfully applied to obtain the CAD reference model of the foot sole. It will be used for the some subsequent orthotic elements construction and CAD modeling. Furthermore, this method can be used even for direct scanning of the foot of the subject, if the foot remains fixed while scanning.

The other method being more accurate it could be used for the dimensional inspection and scanning of certain plantar orthotic elements for their design and form adjustment when prototyping.

If the orthotic items should be obtained from deformable material (silicone, shape memory material etc.), if they intended to correct some foot malformations (such as flat feet), could be recommended for non-contact scanning method. In case of progressive prototyping of some elements for the correction of certain deficiencies more difficult to be observed, we propose that for our next research, the non-contact scanning method to be matched by using the *Foot Scan* method. This refers to the subject's plantar pressures determination when walking and standing on a special plate [9]. The plate contains many pressure sensors, piezoelectric principle for a proper plantar pressure variation measuring along the foot sole.

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