Optical 3-D scanning of extraoral defects using "kolibri-mobile"

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Introduction

Up to now to manufacture prostheses, respiratory masks and extraoral radiation applicators a mold of the part of the human body (in orthodontics and plastic surgery that means the face) have to be done using conventional molding materials such as silicones or alginates. Depending on the material, the molding method and the positioning of the patient, displacement of the soft tissues can thereby occur causing in a subsequent splitting of the edges (marginal gap) of the prostheses /1/. Furthermore, this procedure is really strenuous for the patient. Other technologies are oriented to CT or MRT data, whereby the patient undergoes considerable exposure to radiation. To overcome these problems an optical 3-D scanning technology was developed by the IOF to measure the face of the patient, generating a CAD-model and transfer the data to a rapid-prototyping system for the production of the facial prostheses (epithesis).

The 3-D scanning system – "kolibri-mobile"

For the use of 3-D scanning systems in medical applications like 3-D digitalization of a human face (or other parts of the human body) the scanning system has to fulfil some demands:

- the face have to be viewed from different directions simultaneously;
- the measurement have to be taken within some seconds;
- the system has to be mobile and simple in its use.

At the IOF a concept of 3-D measurement using structured-light illumination with a digital-light projection unit (DMD) has been developed in the years before having the ability to obtain a multi-view within a selfcalibrating measurement procedure, whereas the necessary merging of the single views takes place fully automatically /2/. In the basic measurement procedure the object have to be illuminated by two grating sequences rotated by 90° from different directions. The observing cameras capture these fringe pictures simultaneously resulting in at least 4 phase values for each pixel of the camera. Using these phase values, the 3-D coordinates as well as all of the orientation parameters are calculated. These measurement strategy was the basis of a family of 3-D measurement systems, named "kolibri", successfully applied in industry before /3/. As mentioned above, in some applications, such as human body surface measurement, data evaluation speed up to the whole 3-D image is the crucial point. To realize this we developed on the basis of the explained measurement strategy a mobile and high-speed measurement system, named "kolibri-mobile", see Fig. 1. Here the object is illuminated from different directions via a network of fixed mirrors and simultaneously observed from different directions. The switching of the projection direction is done by a central rotating mirror. The position and number of the mirrors and cameras can be chosen free, adapting the system to the application of interest. In the case to measure a human face an optimum number of cameras is 4 and the number of projection directions is 5, whereby the directions are more chosen from beneath to measure the chin, see Fig. 2.

The following parameters have been achieved with the system:

- measurement field: ∅ 400 mm
- data capturing time (with 4 cameras): < 20 s
- data evaluation time including self-calibration up to the complete 3-D image: < 20 s
- accuracy < 100 µm.

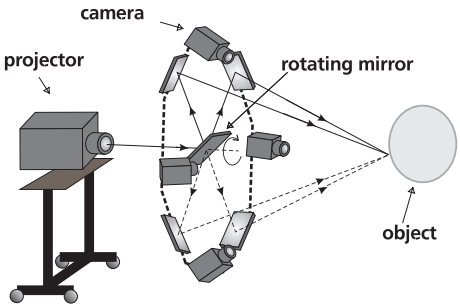

Fig.1:
Schematic sketch of the measurement set-up – "kolibri-mobile".

Fig. 2:
Photos of the self-calibrating measurement system – "kolibri-mobile".

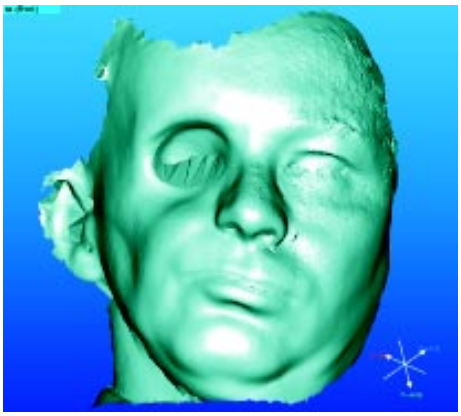

Fig. 4:
STL-file of the face of the patient.

The treatment of a patient – epithesis production

The treatment of a patient, start with the 3-D scanning of the face giving an extensive 3-D point cloud. On the basis of the point cloud an STL-model of the face is generated, see Fig. 4. For this a huge number of software-packages exists, like metris, geomagic, surfacer, to name a few. Here the SURFACER V 10.5 has been used. To obtain the volume data of the epithesis the healthy part of the face is mirrored to the ill part. The difference between both give the 3-D volume model of the necessary epithesis. On the basis of the obtained volume-model the rapid prototyping process for the production of the model of the epithesis is started. Here the model is generated by the 3-D printer "ThermoJet" (company 3-D systems, Darmstadt), whereby a polymer of the type ThermoJet 88 has been used. These model can then be tried at the patient. If it fit very well a prosthetic dentist or dental technician makes the final version out of the prosthetic material.

Summary

The use of optical 3-D scanning technique in combination with a rapid prototyping process in orthodontics and plastic surgery has several advantages. For example, displacement of the soft tissues caused by the mold as well as radiation exposure are avoided. The psychological stress caused by the previously techniques used is likewise eliminated. The new process also reduces manufacturing time. Furthermore, the new 3-D scanning system "kolibri-mobile" can by used in different fields of application, like 3-D inspection in the production line, for examples.

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