Documentation

„Method for the computer-aided process of merging multiple independent 3D-data sets into one joint 3D-data set."

1. Introduction

When having a system for the topographical recording of object surfaces (using a 3D-camera for 3D-measurments resulting in respective 3D-data sets) where the measuring field and the measuring volume respectively is smaller that the dimension of the object's surface, it is necessary to scan the object using more than one single scan (one scan results in 3D-measurement): the 3D-camera is moved with respect to the object and 3D-scans are taken at different relative orientations.

The 3D-scans then have to be transformed into a joint reference coordinate system; in the following this process is called "merging". There is no a-priori knowledge about the needed coordinate transformations.

This document is about the optimization of merging the single 3D-scans into one joint 3D-data set.

2. State of the art

Various solutions for combining single 3D-scans F_1 to F_n (n scans) into one joint coordinate system are known (see e.g. literature on ICP algorithms).

3. Description of a problem

When 3D-scans are merged into one coordinate system typically corresponding points or areas respectively are used in order to define the transformation matrices that lead to the mathematical description of the surfaces in one joint coordinate system.

The prerequisite of those approaches to yield good results is that the surface contour of the object that is scanned does not change from F_1 to F_n. When this prerequisite is not valid, an systematic error is induced into the merging process that limits the achievable accuracy.

This is illustrated in figure 1 for the case of an oral cavity. When performing intraoral 3D-measurements certain surface areas as e.g. the gum-areas, the tongue or the lips can change their surface contours and their relative positions inside the oral cavity (Type A surfaces). These changes are induced e.g. by the use of the 3D-camera itself.

In contrast surfaces like e.g. the tooth, the tooth preparations or implants and parts of implants respectively do not change their surface or their relative positions inside the oral cavity.

When the known procedures for merging the single 3D-scans into a joint coordinate system are used type A surfaces induce an additional error in the result and limit the achievable accuracy.

Thus for an optimal result only type B surfaces should be taken into account during the merging process.

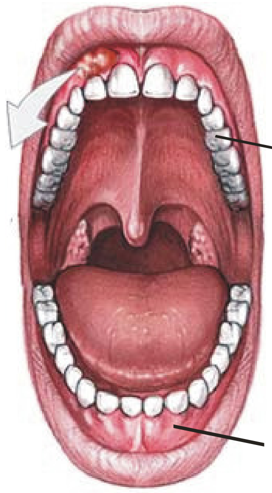


Figure 1: Surface type definition (see text for details).

4. Solution

The solution described in the previous section is to separate type A and type B surfaces by additional means prior to the merging process and to use only type B surface areas in the merging process or, alternatively, to use additional type B bodies in the measuring field and use the information on those bodies obtained in the 3D-scans during the merging process.

This can be done by e.g. the following ways:

- Alternative 1: (direct surface analysis)

  Analysis of the surface type by using the colour of the measured objects. When a 3D-scan is performed the colour of the surface area scanned is measured as well (see e.g. Cadent Patent EP1607064B1). In intraoral applications typically only two coarse colour-bands need to be distinguished. Reddish for type A surfaces and whitish/yellowish for type B surfaces.

- Alternative 2: (indirect surface analysis)

  When the object colour does not directly provide the information about the surface type (This is e.g. in an introral measurement the case, when the objects to be scanned are covered with a contrast agent / powder prior to the scanning process and all surfaces appear as white.) additional landmarks need to be defined that are identified in the single 3D-Scans and that are used for the merging process. Indirect surface analysis can be separated in two methods:

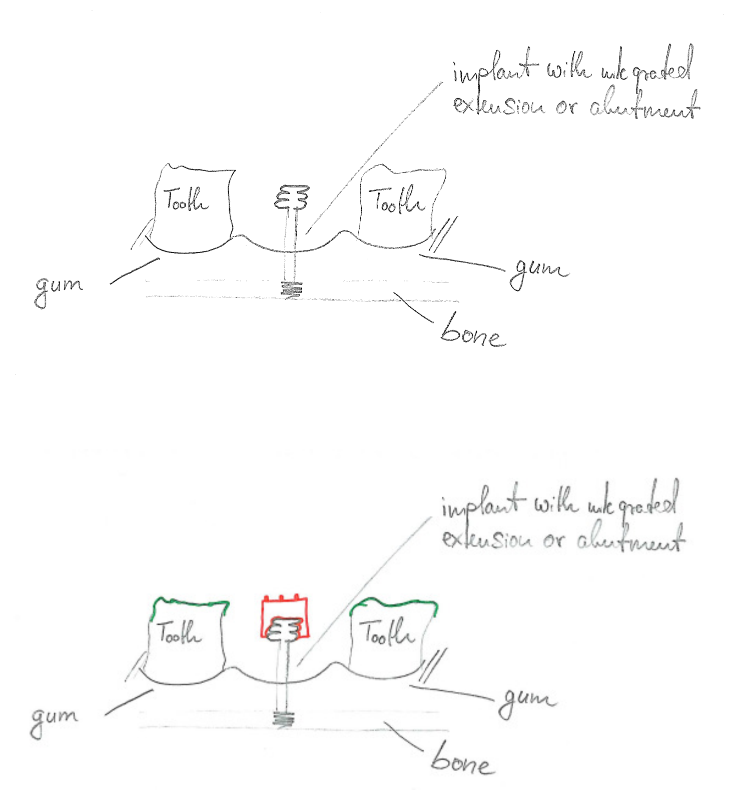
  (a) Alternative 2a: (indirect surface analysis with no additional bodies)

  Type B surface areas are marked prior to the scan. When marking the surface area the shape of the surface is not changed. This can be done e.g. by manually adding a feature with a certain colour on type B surfaces in order to mark those areas and the colour is determined as described for alternative A. In an intraoral application, where the contrast agent is needed, this can be done for example by additionally putting a contrast agent that has a colour that is separable from white in the type B areas.

(b) <u>Alternative 2b: </u>(indirect surface analysis with additional bodies)

Additional bodies that are easily detectable (the relevant feature can e.g. be the colour or the geometry) are attached to type B surfaces of the area to be scanned in a way that those additional bodies are of type B (fixed relative orientation of the additional body to the type B surface that it is attached to). In the merging process only the 3D-information of the additional bodies is used. When the merging process is complete the information on the alternative bodies is removed from the full 3D-data set. This is possible, because the additional bodies are clearly separable from the surface to be scanned and have a well known geometry.

In Figure 2 a descriptive example of the type separation is depicted. Figure 2a shows a sketch of the the case of an introral situation of two teeth next to an implant situation (one tooth is missing). In this situation it can occur that alternative 1 of the type separation can not be used because e.g. the teeth and/or the implant need coating with a contrast agent prior to the 3D-measurement. In the case that the complete scene is coated with a contrast agent alternative 2a can e.g. used for the teeth (green colour in figure 2b) and alternative 2b can be used for the implant and the abutment respective (red colour in figure 2b; note that in the depicted case the geometry of the additional body needs to be known precisely, because this information is to be removed from the merged 3D-data set.).



(a)

(b)

Figure 2: Illustration of the type separation (see text for details).