A new registration method to robustly align a series of sparse 3D data

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To entirely measure the surface of a complex object an optical 3D sensor usually needs to acquire partial 3D views from different positions around the object. These views have to be aligned in order to gain one complete 3D model. The method presented in this paper is tailored for the automatic registration of sparse 3D views in which 3D data is only available along single lines.

1 Introduction

Optical measurement tasks often require an acquisition of several partial 3D views to collect complete 3D information of an object surface. We consider a sensor that acquires the surface information by taking a series of sparse partial 3D views while being freely moved around the object [1, 2]. Each partial view provides 3D data only along parallel lines. Fig. 1 illustrates this concept. In order to obtain a dense 3D model of the surface all partial views have to be aligned.

Existing methods for registration tasks usually detect common surface features and map them onto each other [3, 4, 5]. However, in case of sparse data these methods fail, because insufficient or no neighborhood surface information is available to find common features.

We propose a new method that is specifically tailored for the robust registration of sparse 3D data in real time and show measurement results.

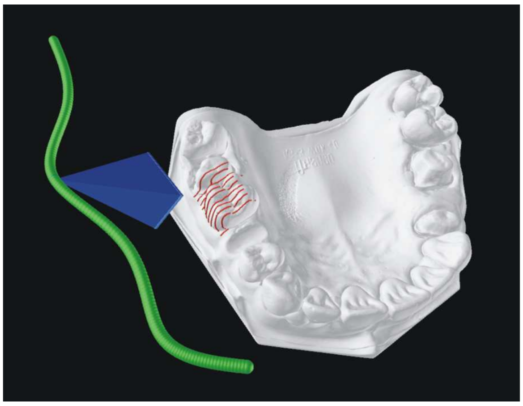

Fig. 1 *A sensor is freely moved around an object while acquiring a series of sparse 3D views.*

2 Coarse registration of sparse 3D views

In order to obtain a complete surface model the 3D views have to be aligned until all lie in a common coordinate system. This can be achieved by registering every two consecutive 3D views successively (Fig. 2). Since the views contain exclusively sparse data along separated lines, only marginal surface information is available. Hence, the alignement of two 3D views is based on detecting corresponding points instead of surface features.

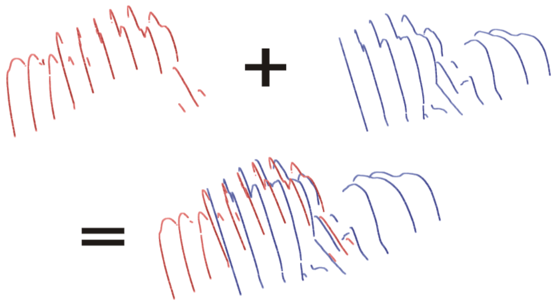

Fig. 2 *Alignment of two consecutive 3D views.*

The underlying idea of our registration algorithm can be illustrated as follows: One 3D view is represented by a table with N legs, the other 3D view by a rough surface with M heaps. Goal of the registration is to find the position where the distance (red arrow) of the legs to the heaps is minimal (Fig. 3).

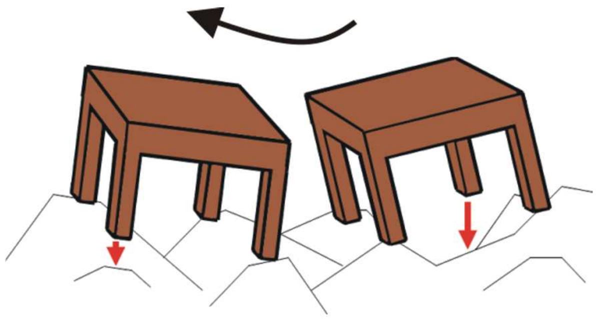

Fig. 3 *The task of aligning two 3D views is equivalent to the taks of positioning a table on a rough surface. The registration result is the position where the table is most stable.*

3 Reconstruction of sensor movement

The successive registration leads to an accumulation of the error along the series of views. Thus, we use outlier elimination and multi registration approaches to reconstruct the complete path along which the sensor was moved around the object more precisely. Simulations of a whole measurement show that the error is thereby reduced significantly. See Fig. 4 for an example.

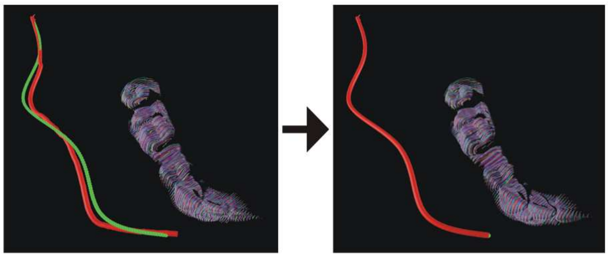

Fig. 4 Simulation results (object as in Fig. 1): Comparison between reconstructed (red) and actual sensor movement (green). Without outlier elimination and multi registration the movements differ clearly (left). Afterwards the reconstructed movement fits the actual movement almost perfectly (right).

4 Results

We developed methods for the automatic registration of a series of sparse 3D data sets. By applying outlier elimination and multi registration approaches the results have been improved considerably.
To demonstrate the registration performance our sensor was moved freely along a dental cast and acquired 500 images in 17 seconds. Fig. 5 shows several unregistered 3D views. The registration result of the whole measurement is presented in Fig. 6.

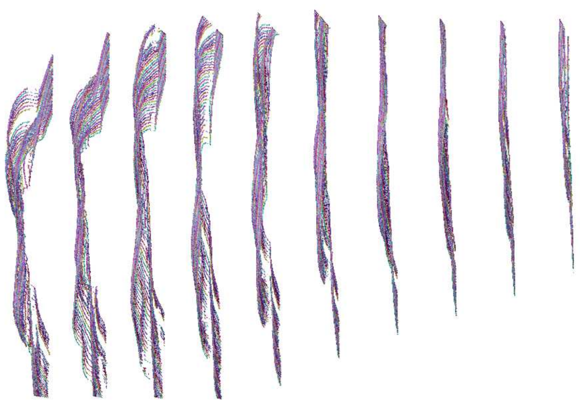

Fig. 5 Several unregistered 3D views in the sensor coordinate system.

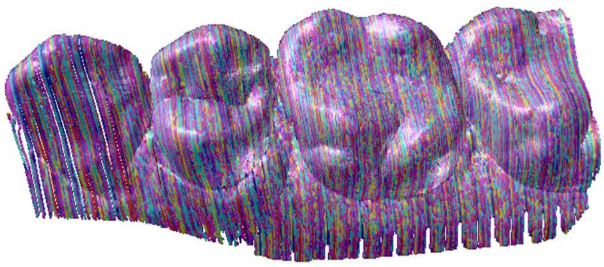

Fig. 6 Complete and dense 3D model obtained by registration and reconstruction of sensor movement.

As Tab. 1 shows the registration is able to perform in real time with up to 30 frames per second and thereby allows to provide the operator with real-time feedback during the measurement. An offline registration can be applied afterwards to further improve the accuracy.

Method	**Time per view**
Coarse Registration	10 ms
Multi registration	30 ms
Offline registration	0-500ms

Tab. 1 Average time consumptions per 3D view: Run-time performance allows registration in real time. Offline registration is used to improve the result afterwards. (Quadcore 2.83Ghz, 8GB RAM).

References

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