On 3-D Recovery of Scaler Stroke Posture

Megumu KUROIWA* Joo Kooi TAN** Hyoungseop KIM** and Seiji ISHIKAWA**

*Graduate School of Engineering, Kyushu Institute of Technology
**Department of Mechanical and Control Engineering, Kyushu Institute of Technology

Abstract: Periodontitis is a dental disease from which many people suffer. The most effective treatment with it is to remove dental plaque and scale periodically by a scaler. For this purpose, those who wish to be a dentist or a hygienist must take training of scaling and root planing using a jaw model and a scaler. It is, however, difficult to a trainer to evaluate the scaler stroke motion of a trainee, since the end of the scaler in a mouth cannot be observed directly. This paper proposes a method of visualizing the scaler stroke motion in the mouth three-dimensionally by the employment of a camera and a computer. The system is described and an experimental result is shown.

Keywords Dental training system, scaling, augmented reality, mobile cameras, computer vision.

1. Introduction

Periodontitis is a dental disease which many people suffer from. In order to treat the disease, a dentist or a hygienist remove dental plaque and scale of a patient periodically by use of a scaler. Those who wish to be a dentist or a hygienist must therefore take training of scaling and root planing using a jaw model and a scaler. Although a dental trainer is responsible for the training, it is actually difficult for him/her to evaluate each trainee if the trainee uses a scaler in an appropriate way. It is because the location and the motion of the end of a scaler in a mouth cannot be observed from the outside. Hence a system for visualizing the location and the motion of a scaler in a mouth is eagerly requested by the trainers.

This paper proposes a method of visualizing the scaler stroke motion in a mouth in a three-dimensional way by the employment of a camera and a computer. The idea is to capture the movement of the scaler a trainee uses by a mobile camera, and to recover its 3-D posture/motion using the markers attached to the scaler. The recovered scaler with its motion is superposed onto the training video image so that the trainer may observe the motion on a display. A similar system is already proposed and applied for a patent [1], but the proposed method has some advantages over [1], which will be discussed in the next section.

The idea of the proposed system is compared to related work and the entire system is explained.

2. Comparison with Related Work

Some different points between [1] and the proposed method is summerized in Table 1. The main superiority of the proposed method is that it employs a mobile camera which a trainer can move to the best location where it can observe the marker on the scaler well. Note that a polyhedral marker is attached to the top of a scaler as shown in Fig. 1 and five patterns are drawn on each of the five faces.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Camera</td>
<td>Two or more fixed cameras</td>
<td>A single mobile camera</td>
</tr>
<tr>
<td>Dead Angles</td>
<td>Many (because of fixed cameras)</td>
<td>A few (because of a mobile camera)</td>
</tr>
<tr>
<td>Posture of a scaler</td>
<td>Recover 3 points at absolute positions in the world coordinate system. Then compute the posture of a scaler.</td>
<td>Detect the points on a marker attached to a scaler. Then compute the posture of the scaler in the camera coordinate system.</td>
</tr>
<tr>
<td>Utility</td>
<td>Not very easy</td>
<td>Easy</td>
</tr>
<tr>
<td>Cost</td>
<td>Not very low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Fig. 1. A scaler with a polyhedral marker.
3. Overview of the Entire System

3.1 The entire system
As shown in Fig. 2, the entire system is composed of a jaw model fixed on a table, a scaler with a polyhedral marker, a mobile camera and a PC. The camera takes motion of the scaler operated by a trainee. The polyhedral marker attached to the scaler is not hidden by the trainee's hand, as the trainee holds the lower stick part of a scaler. The image of the marker is captured by the camera. By analyzing appearance of the star-shaped patterns drawn on the faces of the polyhedron, its posture recovers in a 3-D way.

3.2 Camera calibration and an undistorted camera
For the calibration of the camera shown in Fig. 2, a board with checker pattern is used. By finding correspondence of the points on the checker pattern whose 3-D coordinates are known with their projected points on a camera image, the camera inner parameter matrix $A'$ and the distortion coefficients $\kappa$ of the camera are calculated. Then an undistorted camera is defined: Its inner parameter matrix $A$ is calculated from $A'$ and $\kappa$.

3.3 Computational procedure and graphical display
Let us denote the inner camera parameter matrix by $A$ and the outer camera parameter matrix by $M$ which relates the camera coordinate system $(O_cX_cY_cZ_c)$ to the marker coordinate system. Matrix $M$ is further written as $M=\{R\ t\}$ where $R$ is a rotation matrix and $t$ is a parallel translation vector. Then the following holds:

$$A p_i = AMP_i = A(R\ t)P_i,$$

If the points $P_i$ (i=1,2,...,N) on the top face of the marker where $Z_m=0$ are chosen, we have

$$A p_i = A(r_1, r_2, \ t)P_i,$$

Since Eq.(2) shows the relation between the plane $Z_m=0$ and the image plane, it is described by homography $H$.

So we have

$$A(r_1, r_2, \ t) = H$$  \(3\)

The rotation matrix $R=\{r_1, r_2, r_3\}$ and the translation vector $t$ are then determined by

$$\begin{pmatrix} r_1 \\ r_2 \\ t \end{pmatrix} = A^{-1}H, \ r_3 = r_1 \times r_2$$  \(4\)

Matrix $R$ is further tuned using the singular value decomposition in order to satisfy $R^TR = RR^T = I$.

In this way, we obtain the matrix $M$. From $A$ and $M$, we get a projection matrix $M_p$ and a model view matrix $M_{mvi}$, respectively. These matrices are employed for displaying a virtual scaler on the original image so that it may be superposed on the real scaler.

4. Experimental Result
An experimental result is shown in Fig. 3. In Fig.3a, a real scaler with a polyhedral marker is placed in the mouth of a jaw model. In Fig. 3b, the 3-D location of the real scaler is computed and a virtual scaler is superposed onto it. The developed system currently follows the motion of the scaler used by a human well.

5. Conclusion
A method of visualizing a scaler's motion in the mouth was proposed to realize a dental training system. Unlike [2], we introduced an undistorted camera which corrects distortion of an image captured from a camera for better visibility of the images displayed in the system. Realizing a practical system based on the present system is the next issue to be investigated.

References

Fig. 3. Output image: (a) Original, (b) superposed.