

# Estimation of the Temporomandibular Joint Position\*

Vladimír Smutný, Jan Čech, Radim Šára, Tatjana Dostálová†

Czech Technical University, Center for Machine Perception, †Charles University, Prague  
e-mail: smutny@cmp.felk.cvut.cz

*Abstract. In dentistry there is a problem of measuring temporomandibular joint head (condyle) trajectory relative to the skull. In this paper we propose a noninvasive photogrammetric method for this measurement. A camera is aimed at two known targets, the first is attached to the upper teeth (that is on the skull), the second is mounted on the lower teeth (on the jawbone). The relative position of the targets is estimated by a camera autocalibration procedure using known points on the targets. The position and trajectory of the condyle, which is not directly measured, is calculated from the sequence of images.*

## 1 Medical Motivation

Dental prosthetics is widely practiced and almost everybody will sooner or later be treated. Prosthetics requires modelling of the matching between the inserted prosthesis and the opposing teeth on the other arch. This matching is performed using a special apparatus called the articulator (see Fig. 1, left). The articulator models the position and the motion of the mandible relative to the skull. Contemporary articulators have several adjustable parameters which model the differences between individual patients.

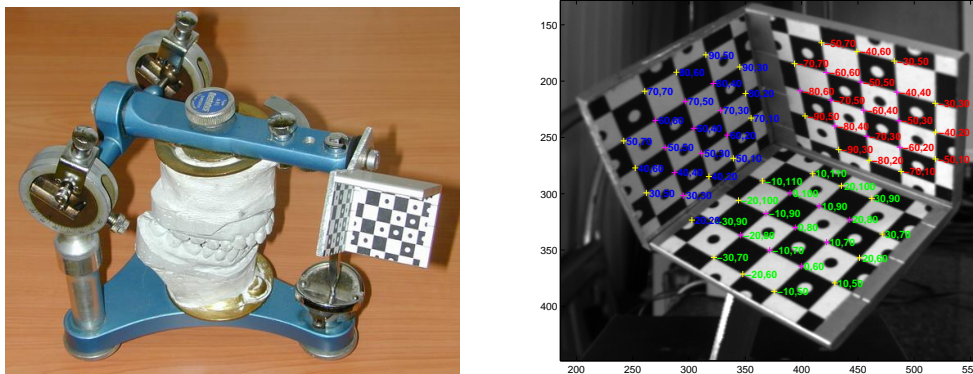


Figure 1: The articulator (left). The image of the target with detected landmarks (right).

The actual shape of the condyle and mandibular joint socket define the allowed motions. The first approximation of the individual condyle motion is rotation around the axis passing

\*The 1st author was supported by the European Union under project IST-2001-33266 and by the Czech Ministry of Education under projects MSM 210000012, MSMT Kontakt ME412 and by the Grant Agency of the Czech Republic under projects GACR 102/01/0971, GACR 102/01/1371 and by the Czech Ministry of Health under project NN6333-3/2000. The 3rd author was supported by the Czech Ministry of Education under project LN00B096 and by the Czech Ministry of Health under project NN6333-3/2000.

through the centers of both condyles (abduction) and its gliding along the joint socket either synchronously (propulsion) or individually (lateropulsion).

Among the most important parameters which shall be adjusted to individuals are two angles, reflecting the orientation of the mandibular joint relative to the skull. The first angle is the angle between an approximation of the joint trajectory shape by the straight line and the plane defined by the upper dental arch (occlusal plane). The second angle is between the sagittal plane and the trajectory curve.

## 2 Proposed Method

The basic principle of the proposed method is the estimation of the moving target position from its image. For estimating the camera's external and internal parameters only one image of the calibration target is required if the target is three-dimensional [4]. In our case the target takes the shape of a convex or concave corner (Fig. 1, right). The corner is covered by the self identifying pattern [1]. The main design feature of the pattern is that position of the vertices of the chessboard-like pattern (landmarks) can be measured with high accuracy.

**Principle** The targets are mounted on both the mandible and maxilla (Fig. 2). The landmarks are easily identified in the captured image, their positions in the target coordinate system are known from separate calibration. This data is sufficient to estimate camera orientation (and position)  $A$  relative to the target (by the so called camera calibration procedure). If two targets are present in the scene, one obtains two matrices  $A_1$  and  $A_2$ , and the relative position of the targets is computed as  $A_1 A_2^{-1}$ . The patient's motion is eliminated.

Another procedure is used to establish the relative position of the condyle and the upper target. Finally the position of the condyle is known in the coordinate system defined by the occlusal plane and the line passing through both condyles.

For more details see [3].

**Measured Parameters** In order to fulfill dentist's requirements one has to measure the following parameters: (1) the orientation of the occlusal plane in the coordinate system of target  $H$  (Fig. 2), (2) the position of the axis connecting the condyles in the coordinate system of the target  $D$ , (3) the natural (resting) position of the axis connecting the condyles in the coordinate system of the target  $H$  and (4) the propulsion and the lateropulsion trajectories of the condyles.

First, the occlusal plane is found by placing a plate with attached target  $P$  to it, Fig. 2, right. As the plate's plane is known in the coordinate system of the target  $P$ , one calculates the orientation of the plane  $P$  in the coordinate system of the target  $H$  by capturing the image of the upper target  $H$  and the target  $P$ . Hence, the occlusal plane orientation in the target  $H$  coordinate system is established.

Second, the patient is asked to make an abduction. This is necessary to find the position of the left  $x^l$  and right  $x^r$  condyle in the lower target  $D$  coordinate system. Direct measurement is difficult, so we propose an automatic method which estimates first the joint axis  $j$  from opening the mouth, Fig. 2. When a patient slowly opens his or her mouth, we assume that the mandible's motion can be approximated by a pure rotation around the fixed axis  $j$  connecting the condyles. This motion is more complicated, but the approximation is acceptable for small angles of the mouth opening.

Third, the patient is asked to make a propulsion and a lateropulsion. The sequence of images is captured and processed. As the relative position of the condyles to the targets was established

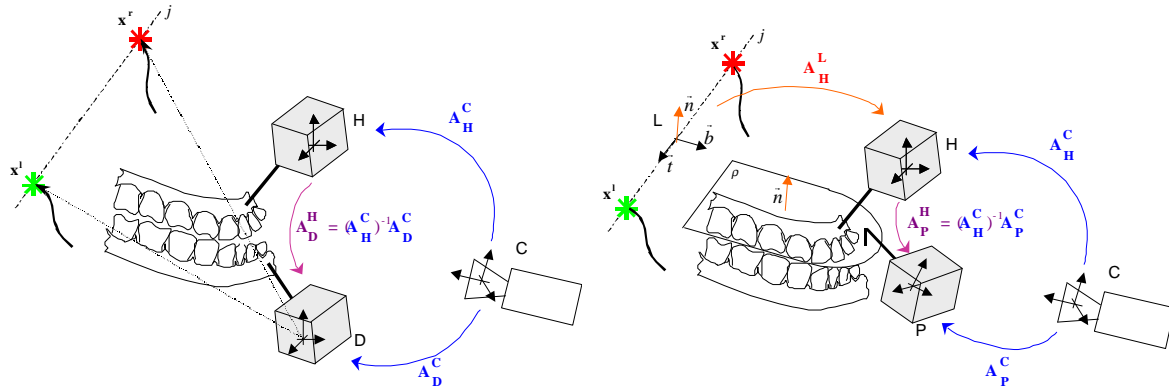


Figure 2: The connection of the targets to the coordinate systems. There are three targets used,  $H$ ,  $P$ , and  $D$ . The  $H$  target is mounted to the upper dental arch. Its coordinate system is connected to the skull coordinate system. The  $P$  target is mounted to the plate which is placed to the occlusal plane. The target  $D$  is mounted to the lower dental arch and its coordinate system is thus related to the condyle. The condyles, marked by stars, gliding along the “S” trajectories shown.

in the previous steps, it is easy to calculate the trajectory. The trajectories are later approximated by a straight line and the required parameters are determined.

### 3 Experimental Results and Discussion

The experiments till now were performed with the targets mounted on the computer controlled turn and translation table and with the targets mounted on the articulator. The measured results show that the position of the condyle is known with the accuracy in the range of 0.1 mm. These results give us motivation for further experiments in vivo. At the time we are preparing experiments with volunteers.

### References

- [1] P-J. Farrugia and R. Šára. Detection of lens calibration targets in noisy and distorted images. Research Report CTU-CMP-1999-8, Center for Machine Perception, Czech Technical University, Prague, Czech Republic, August 1999.
- [2] R. Hartley and A. Zisserman. *Multiple View Geometry in Computer Vision*. Cambridge University Press, Cambridge, 2000.
- [3] V. Smutný, J. Čech, R. Šára, and T. Dostálová. Estimation of the temporomandibular joint position. In H. Wildenauer, editor, *Proc. Computer Vision Winter Workshop*, page to appear, Wien, Austria, February 2002. PRIP.
- [4] M. Šonka, V. Hlaváč, and R. D. Boyle. *Image Processing, Analysis and Machine Vision*. PWS, Boston, USA, second edition, 1998.