CARS 2008 Computer Assisted Radiology and Surgery
22nd International Congress and Exhibition
June 25 - 28, 2008 Barcelona, Spain

Optical Marker Recognition and Pose Determination Using Neural Networks: Toward Development of A Dental Surgical Navigation System

Auranuch Lorsakul[1] , Chanjira Sinthanayothin[2], and Jackrit Suthakorn*[,1]

[1]Department of Biomedical Engineering, Center for Biomedical and Robotics Technology, Faculty of Engineering, Mahidol University, THAILAND.

[2]Advanced Dental Technology Center, National Science and Technology Development Agency, THAILAND.

*Corresponding Author: egjst@mahidol.ac.th

IINTRODUCTION

A new system of computer-assisted surgery for dental implant has been developed and introduced clinically. This navigation system combines preoperative surgery and intraoperative support offered to minimize potential risk of damage to critical anatomic structures of patients. A robust and high accuracy tracking system is a main parameter in navigation system. A set of infrared (IR) based surgical marker emitters are designed in different patterns for tracking the moving surgical instruments. The benefit of the infrared base is that the objects except the surgical markers in the operation room become invisible. IR surgical marker is introduced and developed following the procedures of image capture and processing.

Computer-assisted surgery has been introduced in many clinical aims, for example, in skull-base surgery. In 1990, Werner Krybus *et al.* employed a hand-guided electromechanical 3D-Coordinate digitizer to locate points of interest within the operative field for skull-based surgery. The coordinates measured this method are correlated with a voxel model of the object gained by a preceding CT examination. The accuracy of this way is less than ± 1 mm and this system has been successfully applied in ear-nose-throat (ENT) operations and neurosurgical procedures.

Furthermore, a new technique such a Fuzzy logic has been implemented in a current tracking system for navigation purpose. Fang-Chun Huang *et al.* develop an active vision based space-positioning robot (AVBSPR) by using a Fuzzy inference engine to construct the dynamic tracking the surgical marker movement. They used the fuzzy logic to track and determine the image capture orientation in realtime. The experimental results showed that the robot can track the surgical markers and the positioning error is around 5 mm within 2000 mm distance operating ranges.

Sigeru Omatu *et al.* proposed a rotation-invariant neural pattern recognition system to apply on a rotated coin recognition problem. They used neural network which consisted of a preprocessing network to detect the edge features of input patterns and a trainable multilayered network to recognize rotated patterns and estimate their rotation angles. The results had been proven well compared with the results based on mental rotation via theory of information types which is useful for elucidation of the human perceptual process.

This paper proposed surgical marker pattern recognition and rotation angle determination for surgical navigation application. The objective of this study is to implement a new version of tracking algorithm for marker recognition and orientation by using neural network architecture. A rotation-invariant neural pattern recognition system can recognize a rotated pattern and determine its rotation angle. Artificial neural networks have been focused to perform in many works effectively, such as in pattern recognition, optimization problems, control techniques and so forth for last decade. The tracking system consists of markers which are indifferent patterns. The rotation-invariant neural network algorithm has to be trained by a certain quantity of 2D-Image data in various angles of rotation. Then the system is able to recognize the specific marker patterns and provide information of their rotation angles.

METHOD

The system consists of Rotation Invariant Neural Network which includes input layer, hidden layer and output layer. The input layer has been fed by the training data in various angles in each pattern. Then the network has been trained to adjust weights which can be explained as follows.

Rotation-Invariant Neural Network

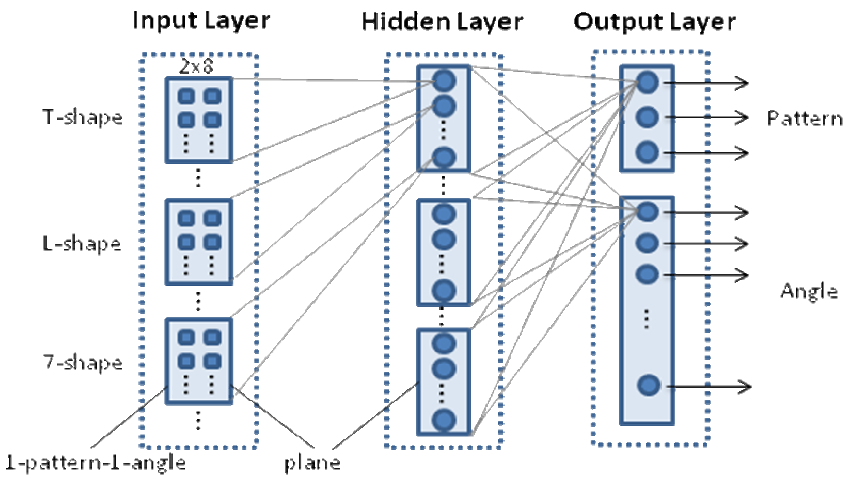

Figure 1 Rotation invariant neural network performs pattern recognition and rotation angle determination.

A rotation-invariant neural network is a multilayered network which is capable of recognizing a rotated pattern and determining its rotation angle as shown in Fig 1. It is a three-layered network, in which the input layer is a set of orientation specific cell pattern. A hidden layer is separated into two different parts, one part to activate pattern recognition and the other part to activate rotation angle determination. The network includes two different parts in its output layers. They are pattern recognition and rotation angle determination parts.

Input Layer

A pattern in input layer is partitioned to produce circular divisions. Each circular division has 4 to 15 different images in the same pattern and angle. The input angles are rotation about X-Axis (R_x), Y-Axis (R_y), and Z-Axis (R_z) as shown in Fig 2. The increment of angle in each division is set for every 1°. According to the physical of the rigid marker, a view display of markers in each rotation axis is limited in a certain number of orientation degrees. Therefore, the angles of training images for all marker patterns about X-Axis are between 0-360°. The angles of training data about Y-Axis and Z-Axis are between 0-180°. The number of training images is varied to 4, 8, 12, and 15 images per plane per pattern. Thus, the possible orientations of markers and number of training data that can be tracked by camera view are shown in table 1.

Hidden Layer

The hidden layer also includes of planes which consist of sigmoid neuron units as the number of the input planes. The neuron units in each plane have the same weights, and neuron units in another plane have different weights. Moreover, the neuron units on the hidden planes can receive inputs from every plane in the input layer.

Output Layer

In learning, the weights of all out units are updated to be the same. In pattern recognition part, the number of output units is the same as the number of marker pattern classes. In angle estimation part, the output units produce one's and zeros. This enables to estimate the rotation angle of input patterns.

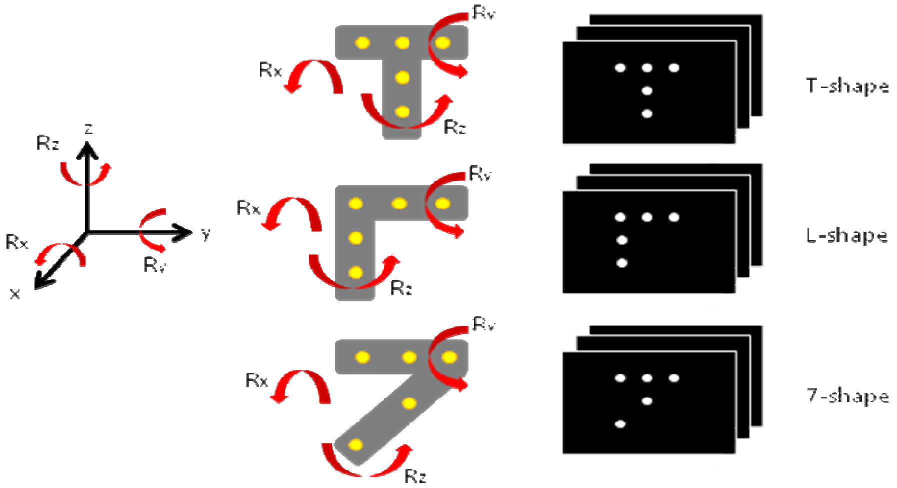

Figure 2 Training data in T-shaped, L-shaped, and Seven-shaped patterns rotate about X-Axis (R_x), Y-Axis (R_y), and Z-Axis (R_z) in every 1°.

Table 1: The possible orientation of markers and the total number of data images for training the network

	T-Shaped Pattern	7-Shaped Pattern	L-Shaped Pattern	1-image data/ plane	4-image data/ plane	8-image data/ plane	12-image data/ plane	15-image data/ plane
Rx	0-360°	0-360°	0-360°	1,080	4,320	8,640	12,960	16,200
Ry	0-180°	0-180°	0-180°	540	2,160	4,320	6,480	8,100
Rz	0-180°	0-180°	0-180°	540	2,160	4,320	6,480	8,100
Total				2,160	8,640	17,280	25,920	32,400

SIMULATION RESULTS

Computer simulations were carried out to show the effectiveness of the system. It is performed on MATLAB®. The training patterns used in the binary recognition. Accuracy of pattern recognition with varying numbers of hidden unites and varying numbers of training samples per pattern is evaluated. The number of training sample can be varied by numbers of images in the input plane to 4, 8, 12, and 15. The testing carried on with the starting hidden node number equals 5 units, and then increases until reaching 50 units. The results show that the accuracy increases with an increase in the number of hidden node units. Similarly, the accuracy also increases with the increasing number of training samples. For accuracy of rotation angle determination, the result is insensitive to change in the number of hidden planes. It is important for the network to give results in high accuracy for the angle estimation even in a small number of hidden planes.

CONCLUSION

This paper gives a tracking research on our ongoing project, the dental implant navigation system. In this work, it applies rotation-invariant neural network to employ in pattern recognition and angle determination of marker tracking system. The input images of marker patterns in possible various orientations about X, Y, and Z-Axis are fed into the designed network in order to update network weights in training procedure. The experiment shows the accuracy of the network by varying numbers of hidden node units, training samples, and hidden planes. The pattern recognition and angle determination accuracy increase with respect to the increasing number of hidden node units, training samples, and hidden planes.

Future work consists of experiment on Euler Angle of rotation about X, Y, and Z-Axis. There will be a combination of the rotation angles for training data. The optimization techniques will be performed for reducing such a huge number of training data to obtain to same accuracy results. Moreover, the development of computational performance will be proposed for the real time surgical navigation application.