로봇 수술을 위한 표면정합 시뮬레이션

Surface-Matching Simulation for Robot-Assisted Surgery

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1. INTRODUCTION

Registration is simply said to be a surface matching step that links the planning and execution phase for robot-assisted surgery applications. In this procedure, the geometric relationships between the patient's anatomy and the CAD models used for planning are estimated. One of the best known and widely used low level geometric matching algorithms is the iterative closest point (ICP) algorithm [3]-[5]. At each iteration, it first creates closest point correspondences between two sets of points (i.e., the patient's anatomy and the CAD models) and then minimizes the average distance between both sets by finding an optimal rigid body transformation.

Following Total Knee Arthroplasty DigiMatch [1], the considered registration is divided into two stages such as initial approximation and full registration. At first, the relationship between the patient and the robot is not known. So, we need initial registration to find an approximate relationship between a patient and a surgery robot. In this stage we can apply 8 points to ICP algorithm which are four anatomical landmarks (Distal, Anterior, Medial, Lateral) and Band four points (Medial, Medial anterior, Lateral, Anterior lateral). After that, full registration is performed with region points and cluster points to increase the accuracy.

When a patient is moved during surgery, 3 recovery marker points are used to determine the relationship between the patient and the robot. This allows to avoid repeating the complex and time consuming process. Final verification are required to assess if the registration process is good or not.

Sample data used in this paper was obtained from Hyundai Heavy Industry which have been developing a TKA surgery robot.

2. REALIZATION of an ICP ALGORITHM

The purpose of ICP is finding a 3 dimensional transformation for two point sets(D and M), we have to minimize distance measure between the two point sets. The performance index is expressed as

$$\min \frac{1}{N}\sum_{i=1}^{N} \| M_i - (RD_i + t) \|^2$$

where R is a 3 by 3 rotation matrix and t is a 3 by 1 translation vector. D is point set of patient anatomy data and M is a point set of its corresponding model and the subscript i refers to corresponding elements of the point sets M and D.

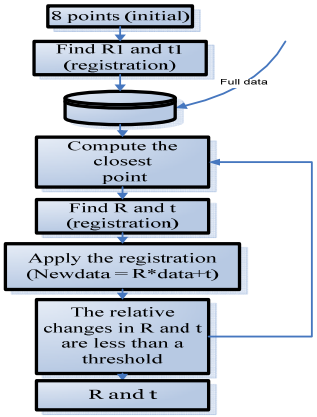

Fig.1: ICP algorithm

The basic idea behind the ICP algorithm is that, the point correspondence provided by sets of closest points is a reasonable approximation to the true point correspondence. Each step is performed following Fig.1.

In the initial (initial registration), eight sampling points were used. The corresponding point in the model and data is already known, so we can find the

initial rotation and translation for ICP algorithm.

3. 3D SURFACE MATCHING SIMULATOR

Based on the previous description, a 3D surface matching simulator is developed in VC++6.0. The main display of the simulator is shown in Fig. 2. where white points represent a CAD model, and red ones represent the measuring data after registration process completes. This simulator has following menus. 1)Digitizer: Microscribe GX2 digitizer is interfaced with this software so that it can directly obtain the measured data by the digitizer. 2) Load Data: the previously measured *.dat file could be used. 3) Step 1~3: Initial Registration(sampled data) and full registration(Region and cluster data) are performed sequentially. 4) Transformation: When the registration completes, the computed transformation matrix is shown(See Fig. 4).

The relative position between the measured point set and the CAD model point set is shown before/after the registration in Fig. 3. The computed

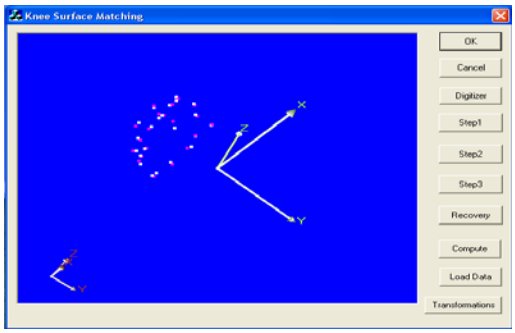

Fig. 2 Main display of the simulator

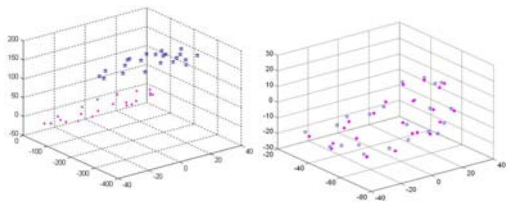

Fig. 3 Relative Position between the point sets before/after registration

transformation matrix between the point sets can be displayed as shown in Fig. 4.

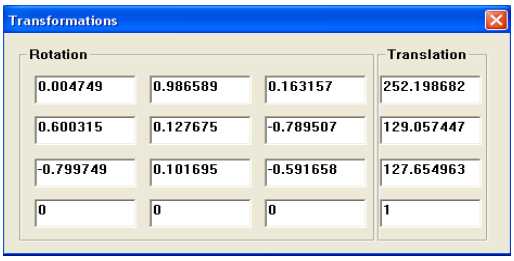

Fig. 4 The computed transformation matrix between the point sets

4. CONCLUSION

This paper shows the registration process required for Robot-Assisted surgery, based on the ICP(iterative Closest Point) algorithm. And it presents 3D surface matching simulator written in VC++6.0. This simulator is very helpful to check if the developed ICP based registration process could be acceptable or not for a certain robot-assisted surgery.

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