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X-ray Localization Technique for Total Hip Replacement Operation In Augmented Reality for Therapy (ART)

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Abstract – A novel approach for the localization of acetabular prosthesis cup placement, using X-ray images, in total hip replacement operation is described. A computational mathematical model is given and simulation results are presented. This information helps the orthopaedic surgeons to know the position of the hip in world coordinate system and direct him to the right position of implant insertion tool, viewing through a capture and display unit. X-ray localization can be used both preoperatively and intraoperatively. Ability to use X-ray intraoperatively is the major advantage of our proposed technique.

Keywords: Total hip replacement, X-ray localization

I.INTRODUCTION

The incidence of dislocation following primary total hip replacement (THR) surgery is between 2-6% and even higher following revisions [1][2]. The most common early post-operative complication following THR is dislocation of the femoral implant from the acetabulam, resulting in significant distress to the patient and surgeon, poor clinical follow-up, and associated additional treatment costs. A significant problem with THR is that surgeons do not know the right orientation of the hip-cup during the operation and they fix the implant based on their experience. For THR the adopted imaging technique to guide the operation is CT. These images are taken preoperatively and often at high cost [3]. Hence, X-ray localization is the dream for surgeons. From one or two X-ray images we can find the coordinates of points in 2D on the screen and can calculate 3D world coordinates of the hip using our mathematical model without making the complete image of cup, and hence the right path of the implant insertion tool.

II. METHOD

We can deduce 3-D points matrices from 2-D image(s). In general transformed image can be represented by

$$h[P^*] = [P][T_c] \qquad (1)$$

h is the normalization factor, $[P^*]$ is the transformed points matrix, [P] is the original points matrix and $[T_c]$ is the transformation matrix that may include perspective information. Since screen projection $[P^*]$ has only x and y components, the third column of $[T_c]$ must be zero, hence we have 12 unknowns in this matrix. Hence we need 6 points to develop the transformation. For this Eq. of the form [A][T]=[B] is formed with [A] is (11x11), [T] and [B] are of (11x1) with T_{44}=1(one of the component of $[T_c]$). After solving we get the transformation matrix $[T_c]$, and any point other than six points, 3D coordinates can be found easily. Through some image processing we can find the screen coordinates of the hip-cup periphery and hence the 3D location.

III. RELSULTS AND DISCUSSIONS

The proposed method is applied for finding 3D location of markers (using Optotrak, Northern Digital Inc, Waterloo Canada, or any other device for 3D position and tracking), and their corresponding image coordinates, we develop the transformation. After doing this, the coordinates of the periphery of hip cup is found and hence its 3D location. The simulation result is given in Fig.1.

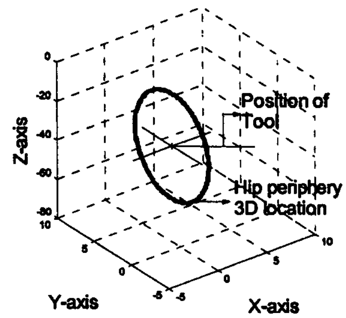

Fig 1. 3D location of hip and correct path of tool.

The oval represents 3D location of the hip and the line is showing the right path of the tool (45° of abduction and 15°-20° of anterversion) for implanting the acetabular component.

IV. CONCLUSIONS

An X-ray localization technique has been developed which gives the position of the hip in 3D,in particular the socket, without making the complete image. This technique can be used preoperatively and intraoperatively. It requires very low X-ray exposure and less time to localize. The system is therefore efficient and cheap.

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