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An Instrument Mounted Mini-Display for Intraoperative Guidance in Hip Surgery

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Abstract

A new mini-display has been developed which is directly mounted to navigated surgical instruments. It receives signals from the navigation system and visualizes information how to guide to the instrument in order to reach the pre-planned target pose. Thus the surgeon does not need to change his eye-focus between the operating area and the computer screen of the navigation system.

1 INTRODUCTION

Total hip replacement in Germany has been performed in 227293 cases in 2015 (DRG 2015) and tendency is increasing. Although it is a standard intervention, freehand positioning of cup protheses has frequently poor accuracy (Saxler, 2004), (Bosker, 2007). Image-based and image-free navigation systems improve the accuracy but most of them provide target positions as alphanumeric values on large-size screens above the patient site (Renkawitz, 2011). In this case the surgeon always has to move his head frequently to change his eye-focus between incision and display to capture the target values. Already published studies using e.g. IPod-based displays (Koenen, 2016) or LED ring displays (Herrlich, 2015) show the chance for improvement by alternative approaches. Therefore, we propose a novel solution for an instrument-mounted small display in order to visualize intuitive instructions for instrument guidance directly in the viewing area of the surgeon.

2 Materials and Methods

We have used an optical tracking system composed of an Axios CamBar B2 stereo camera and our custom-designed navigation software to track surgical instruments equipped with reference bodies.

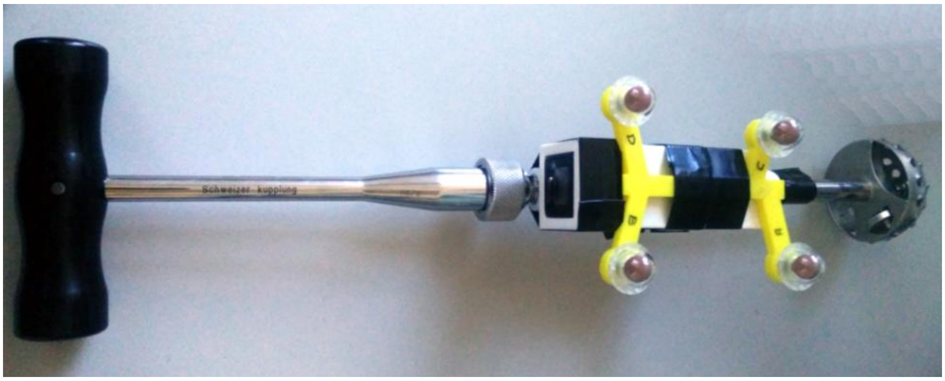

Figure 1: Display (white) and reference body (yellow) for navigation mounted to a reamer tool

The navigation software of our system provides the pose information of the tracked instrument. Having this and a desired target pose for the instrument it can be guided from the actual pose to the target pose.

In contrast to the above-mentioned large-screen solutions the guiding information should be displayed as intuitive as possible and directly in the surgeons field of view. For this purpose a mini-display solution consisting of a MicroView OLED display with integrated Arduino microcontroller, equipped with a Bluetooth interface as well as a battery has been developed and mounted to the instrument (Figure 1). The display size is 2,7 by 2,7 centimeters with 64 times 48 pixels. Encased in a housing containing all the components the overall measurements of the device are 3,5 cm x 3,5 cm x 9 cm.

The first implementation of the mini-display is adapted to total hip replacement and focuses on assistance while reaming the acetabulum to prepare hip shell implantations. In this case the reamer has to be centered to the middle point of the acetabular rim circle and its rotation axis must be aligned to the acetabular center axis (Hakki, 2010). By means of these references, the deviations between the current reamer pose and the target pose at the acetabulum can be determined. The actual deviations are indicated separately for position and orientation. Position deviations are given along x and y axes in the entrance plane of the acetabulum. The depth deviation is given by the distance of the reamer tip to the entrance plane along the reamer rotation axis. Additionally, the angular deviation between this axis and the acetabular center axis is determined. Finally, the rotation angles are calculated by which the tool has to be rotated around the x- and y axis in order to align it to the acetabular center axis. A third angle is not needed because of rotational symmetry of the reamer.

The position deviation is displayed by a cross-hair indicator with a moving circle for current position. Angular deviations are shown in two bubble level bars displayed at the edge of the display. The depth is given by a square in square indicator (Figure 2). All display parts are furnished with an adaptive variable scale, which changes depending on the reamers proximity to the target pose. The largest scaling range shows -60 to 60 degrees for the angles and -14 to 14 millimeters for position. Highest possible resolution is 0,5 degrees angular and 1 millimeter for position for the smallest scale. Depth resolution is set to 2 mm, concerning that the depth control is supported by the touch sense of the operator as soon as the reamer has bone contact.

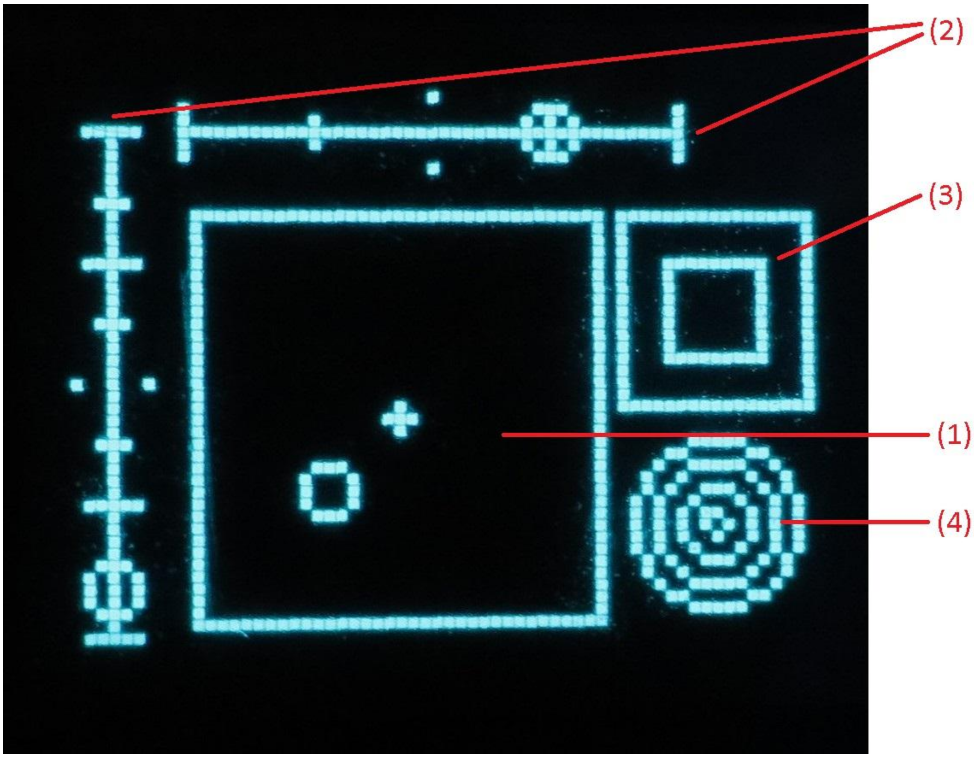

Figure 2: Indicators of the display: position(1), angles (2), depth (3) and tool visibility (4)

3 Results

The proposed instrument-mounted solution with compact dimensions offers a space-saving, wireless indication of all relevant positioning and guidance information. Despite the low display resolution, it allows a fast intuitive interpretation for the surgeon to guide the instrument to the target pose while being continuously focused on the display and the incision site. This has been confirmed by probands and cooperating physicians in first application tests.

Concerning tremor and possible slippage, precision of instrument guidance and hitting of the target pose is supposed to be higher if surgeons have steady eye contact to the navigation display. Currently detailed accuracy investigations are carried out whether the resolution offered by the stereo camera can be visualized adequately. First results confirm our assumption that the mini-display will support the surgeon to easier achieve accurate and reproducible results when using navigation systems.

4 Discussion

Compared to existing approaches for instrument-mounted displays (Herrlich, 2015), (Koenen, 2016) the small display of our solution offers high flexibility to adjust the mounting position such that it is best visible for the surgeon while not constraining instrument handling. Despite of the small size, the proposed visualization symbols provide all information for instrument positioning in an intuitive way.

5 Acknowledgement

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