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Concept and Preliminary Experiments of Navigated Imaging with an Electromagnetic Position Measurement System

(Konzept und vorbereitende Experimente der navigierten Bildgebung mit einem elektromagnetischen Positionsmesssystem)

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Abstract

Purpose

In cardiology the angiography is a method to detect vascular stenosis by using X-ray radiation and contrast medium. There is special equipment, so called C-arms, to produce radioscopic images. An angiography system consists of an X-ray image intensifier (XRII), an X-ray source, and the mechanical structure to position the system around the patient.

In general, the measurement and 3-d-reconstruction of cardiovascular structures is limited and difficult to use. The usual diagnostic methods in angiography produce a high X-ray radiation exposure to patients and medical staff.

Preliminary work and valuable results described in [1] and [2] using optical measuring system. In [3] the catheter tip position was determined in a dynamic heart phantom with electromagnetic tracking. Similar to that the catheter tip was tracked in a static model with an electromagnetic measuring system in [4]. The feasibility of magnetic tracking devices for image-guided intervention was showed in [5] and [6].

In this work a concept and preliminary tests are presented, which combines the concept of measurement using navigated imaging with direct position measuring. The aim is the visualization of the position and movement of the catheter tip in digital X-ray images without constant fluoroscopy.

Material and Methods

To reach the specified goal the electromagnetic position measuring system Aurora (NDI, Ontario, Canada) is used with the angiography system Integris BH 5000 (Philips Medical, Best, The Netherlands).

Different useful positions of placing the field generator were determined (figure 1, 2). Three aspects were important to find the correct position:

1. Clinical application as position in sterile/ non-sterile area without disturbing the intervention process
2. Position has to allow typical rotational positions of the C-arm
3. Patient's heart must be inside the measurement volume of the position measuring system

Several metallic equipments disturbed the measurement results and capabilities, such as X-ray source, image-intensifier, patient table, C-arm, monitors, other medical equipment used in the catheter lab. Probably the main interfering part, the image-intensifier, could be tracked, too. For typical imaging positions of the C-arms special error-correction functions can be calculated.

After finding a feasible position, measurement with different positions of the C-arm were carried out to determine the influence of image-intensifier and C-arm on the measurement results. Similar to the planned clinical application the relative error is most important.

Therefore different positions of two probes were measured using a geometrically known phantom. One probe was fixed and the other turned to pre-defined positions to simulate motion during pulsation (figure 3). The distance of both probes was calculated and compared to their real distance to resolve a relative error. This experiment was carried out twice per C-arm position. After performing the experiment for the first time, the C-arm was rotated and put to the same position again.

Another test was carried out to determine the absolute position during C-arm movement. While rotating the C-arm in all possible directions the position of a probe and its distance to the measurement system was measured.

Results

The preliminary evaluation showed a mean relative error of 2.91 mm (std: 2.48 mm, N = 64) over all different distances. Subdivided into eight different distances the relative mean error grew from short to long distances. Integrating the effect, that large distances had large errors the relative mean error is 4.3 % (std: 2.8 %, N = 64). Figure 4 summarizes the relative error vectors for one experiment, to visualize the directions of errors.

The unique direction of the error vectors for one C-arm position results in the following functions for one setup carried out twice.

$$f(x, y) = \sqrt{(x+3.4)^2 + (y-0.05)^2}$$

$$f(x, y) = \sqrt{(x+4.05)^2 + (y-0.05)^2}$$

The next two functions describe the error compensation for the other experiment.

$$f(x, y) = \sqrt{(x-1.1)^2 + (y-3.05)^2}$$

$$f(x, y) = \sqrt{(x-1.2)^2 + (y-3.5)^2}$$

The measurement of absolute positions, as determined during C-arm movement, showed an distance range of 259.4 mm to 315.5 mm (N = 18) which implied a mean distance of 298.8 mm with a standard deviation of 13.2 mm. Figure 5 shows the influence of C-arm movement on measurement results.

Conclusion

The preliminary experiments show the feasibility of using electromagnetic position system in clinical application of angiography with sufficient correction of positions. The main influences on electromagnetic tracking are metallic equipment such as C-arms or image-intensifiers which are near the measurement volume. The relative distance measurement shows a continuous growing error, which will be described quadratic polynomial.

The absolute position measurement error increases while getting in contact with metallic equipment as mentioned in [7]. The shortest distances were measured while the image-intensifier is near to the Aurora field generator.

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References

1. Kirschstein U., Lenze C., Kronberg K., Hein A.: Measurement of cardiovascular structures in angiographic images with navigated imaging. Curac, München, Germany, Oct. 8-9, (2004). http://www.curac.org/curac04/download/abstract/081_f.pdf

2. Hein A., Kirschstein U.: Navigated Imaging for Angiography – Concept and Calibration. *IEEE Conference on Mechatronics and Robotics 2004*, Aachen, Germany, 13.-15. Sept. 2004, pp. 1409-1414.

3. Timinger H., Krueger S., Borgert J., Grewer R.: Motion compensation for interventional navigation on 3D static roadmaps based on an affine model and gating, Physics in Medicine and Biology, 49 (2004), p. 719-732

4. Sacolick L., Patel N., Tang J., Levy E., Cleary K.: Electromagnetically tracked placement of a peripherally inserted central catheter, Proc. of SPIE Medical Imaging, Denver, USA, 1.-6. Aug. 2004

5. Corral G., Cleary K., Tang J., Levy E., Glossop N.: Orientation Accuracy of a Magnetic Tracking device for Image-Guided Interventions, Proc. of CARS, London, United Kingdom, 25.-28. June, 2003

6. Tang J., Cleary K.: Breakdown of Tracking for Electromagnetically Guided Abdominal Interventions, Proc. of CARS, London, United Kingdom, 25.-28. June, 2003

7. Mucha D., Kosmecki B., Lueth T.: Applying electromagnetic position sensing for navigation in dental implantology – A first analysis, 2nd International Symposium CAS-H, Bern, 17.-19. Sept. 2004.

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Figure 1 and 2: Different positions of field generator in clinical application (Univ. of Oldenburg, 2005)

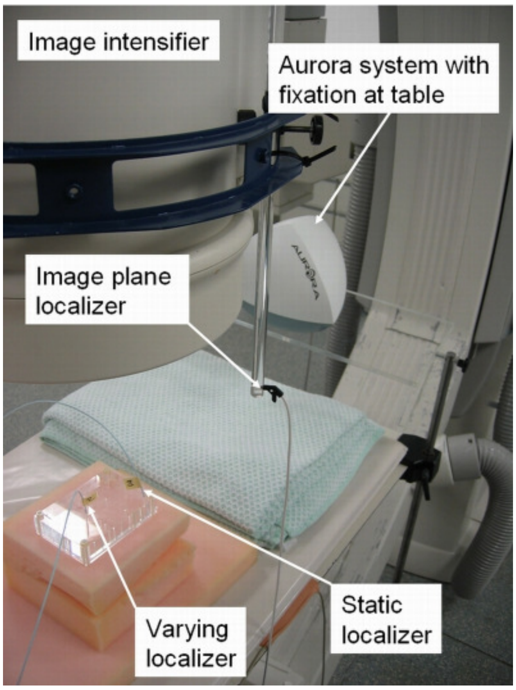

Figure 3: Carrying out the experiments using measurement phantom, electromagnetic position measuring system, and X-ray C-arm in clinical set-up (Univ. of Oldenburg, 2005)

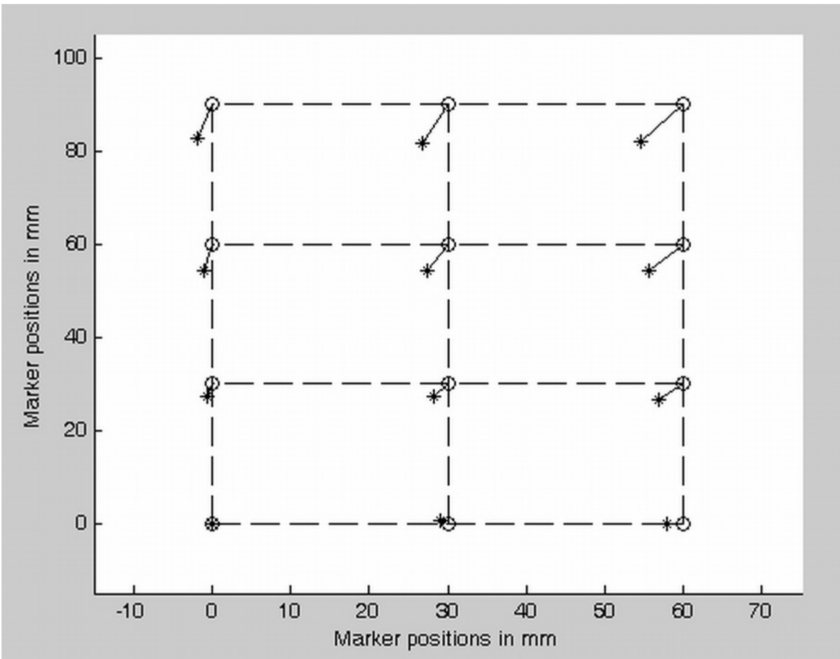

Figure 4: Position dependent error vectors showing consistent directions (Univ. of Oldenburg, 2005)

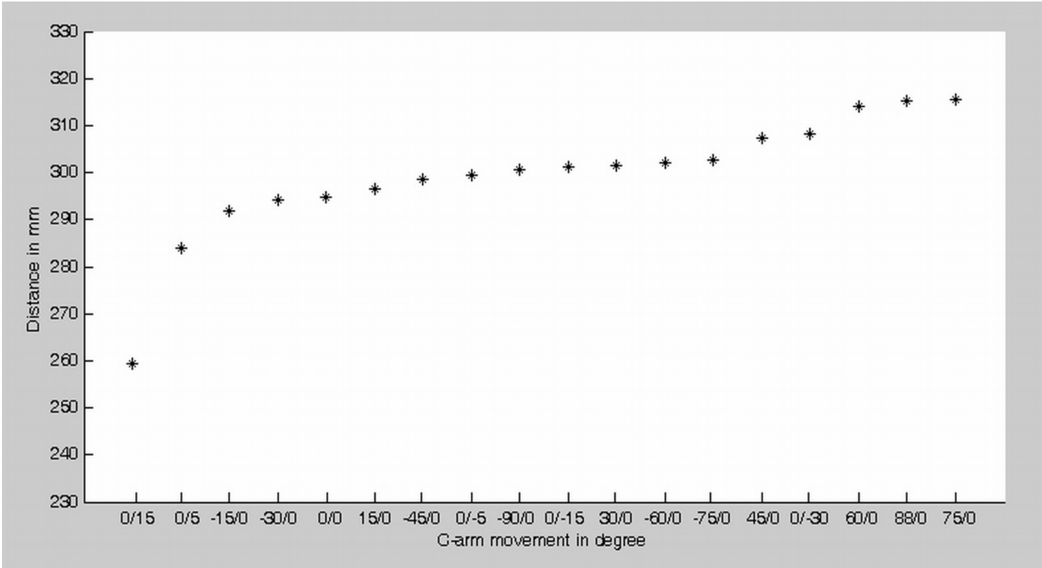

Figure 5: Changing measurement results depending on C-arm position; the results correspond to the distance from the field generator to image intensifier – position runs from close to far (Univ. of Oldenburg, 2005)