Optimization of sensor positions for a quasi-magnetostatic inverse problem

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I. INTRODUCTION

Inverse electromagnetic problems are in general difficult to solve. A successful example of the solution and applications of such a problem is magnetic tracking where the position and/or orientation of a transmitter is estimated from measurements of static or quasi-magnetostatic fields that it transmits. Magnetic tracking mainly finds its applications in situations where positioning is performed in or around the human body since human body tissue is transparent to low frequency magnetic fields. For example, magnetic tracking has been applied to real-time organ-positioning during radiotherapy of cancer tumors [1], and tracking of the pilot's head for helmet mounted sights in military aircraft [2].

The sensor positions of a magnetic tracking system substantially influence the system's performance. A bad design of the sensor array can render the inverse problem very difficult or even impossible to solve. Therefore, we propose a method for optimization of the sensor positions.

II. METHOD

We model the transmitter and a planar sensor array of a quasi-magnetostatic tracking system in free space with magnetic dipoles. Thereby, the derivatives of the measured signals with respect to the position and orientation of the transmitter can be expressed in closed form. With the aid of these derivatives, the Fisher information matrix is formulated. We exploit performance metrics based on the Fisher information matrix that consider average or worst-case performance in a measurement domain. A sensor selection approach with relaxed constraints [3] yields a convex optimization problem for the sensor positions that can be readily solved.

III. RESULTS

The proposed method is compared with a gradient-based multi-start global optimization method. The proposed method finds nearly optimal sensor positions in orders of magnitude shorter computation time. Figure 1 shows the sensor positions obtained with the global optimization method (crosses) and the proposed method (circles) for a specific measurement domain. Furthermore, we exploit the proposed method and investigate realistic measurement scenarios. In addition, we establish important characteristics of the measurement problem at hand.

IV. CONCLUSIONS

A method for sensor position optimization which yields a convex optimization problem is proposed and applied to a quasi-magnetostatic inverse problem. The proposed method yields nearly optimal results orders of magnitude quicker than a global optimization method. Optimized sensor positions for realistic measurement scenarios are computed and important characteristics of the measurement problem are identified.

REFERENCES

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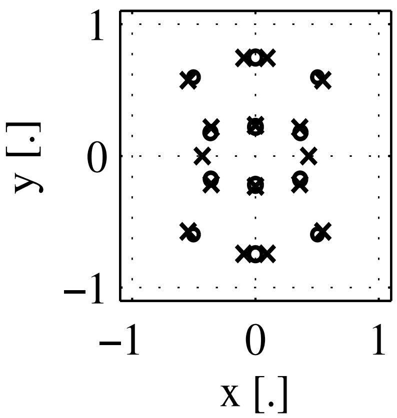

Figure 1: Optimized sensor positions obtained by the proposed method (circles) and a global optimization method (crosses).