

Diploma thesis kick-off presentation

**Fast and efficient error correction
of electromagnetic tracking
and its application in prostate cancer treatment**

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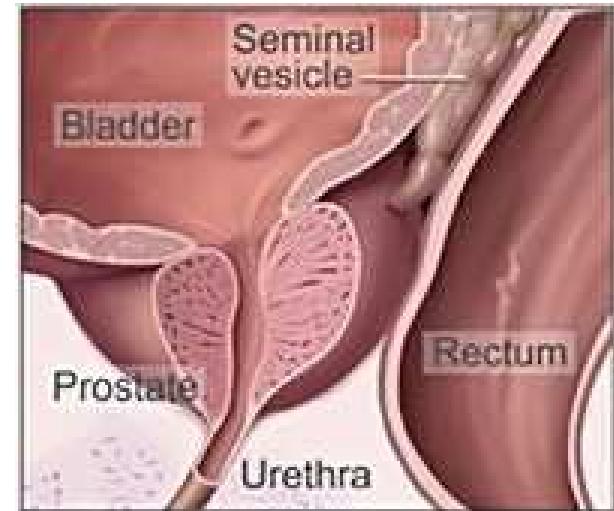
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Outline

1. Medical application: prostate cancer treatment
2. Error correction
3. Aim of this diploma thesis
4. Proposed method
 - Step 1: Device calibration
 - Step 2: Creating the Lookup-table
 - Step 3: Online error correction
5. Summary and vision for the future

1. Medical application: prostate cancer treatment

- prostate located in front of the rectum, under the bladder, encloses the urethra
- ∅: male patients and older than 50 years



source of the picture: http://en.wikipedia.org/wiki/Prostate_cancer

1.1 Medical procedure of treatment: Status Quo

- A balloon catheter is inserted into the rectum.
- The balloon is inflated to adjust the prostate in its position.
- A CT of the patient is done.
- The area of radiation is calculated (software).
- radiation of the calculated area every weekday with X-rays

1.2 Limitations of this treatment

- Rectum and urethra should not be radiated, but both are close to the prostate.
- The prostate always moves inside the body, even if it is fixed with the balloon.
- medical status quo:
The area of radiation has to be enlarged a little bit to ensure the radiation of the whole cancer.

⇒ A more precise knowledge of the location of the prostate is needed.

1.3 Remedy

- tracking inside the human body
⇒ electromagnetic tracking system used
- magnetic sensor attached to the balloon catheter
⇒ magnetic sensor visible on the CT
- optical tracking system used for the computation of the error function

2. Error correction^{1, 2}

- error correction needed for the electromagnetic tracking system
reason: gantry and metal always present in the radiation room
- optical tracking system used as ground truth values
- work based on the master thesis of Suhkbansbir Kaur:
 - analysis of error correction methods
 - the measurement error could be corrected very well
 - her method not suitable for prostate cancer scenario



¹ „A survey of electromagnetic position tracker calibration techniques“ by Volodymyr V. Kindratenko

² „Error Correction for ElectroMagnetic Tracking“, Master thesis by Suhkbansbir Kaur, handed in 2006/04/28

3. Aim of this diploma thesis

- improved error correction
(more precise)
- improved useability
(now: time-consuming and inconvenient)
- navigation interface
 - no complicated 3D-GUI is needed
 - simple output of „table coordinates“
(how the doctor has to move the table where the patient is laying)

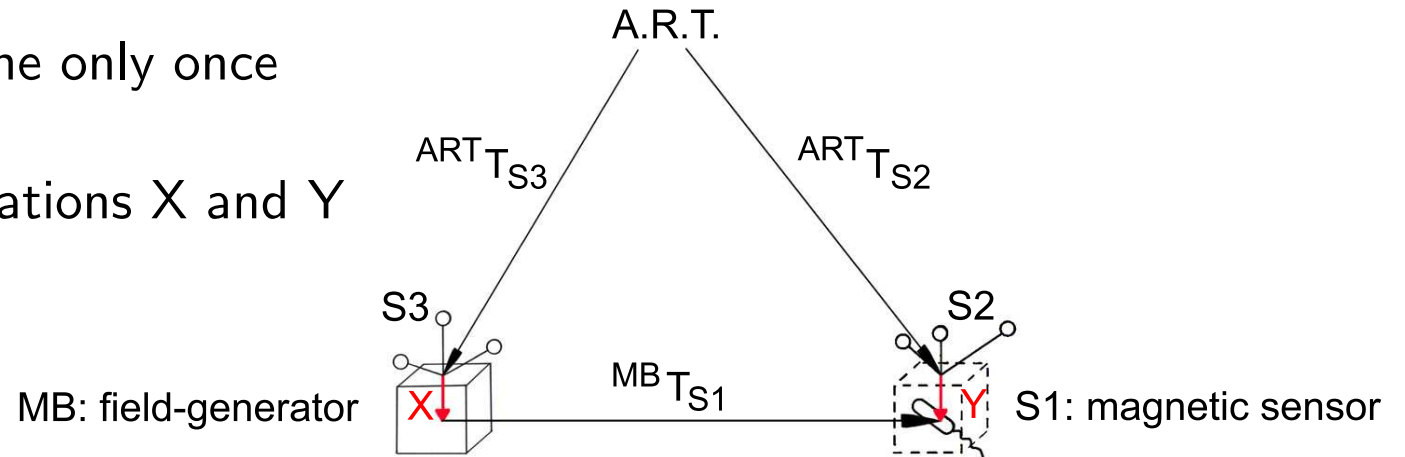
4. Proposed method

Method consists of three steps:

1. Device calibration
2. Creating the lookup-table
3. Online error correction

Step 1: Device Calibration^{3, 4}

- device calibration done only once
- for getting the translations X and Y
- equation:



$$ART_{T_{S3}} \cdot X \cdot MB_{T_{S1}} = ART_{T_{S2}} \cdot Y$$

³ „Tracking Systems in Surgical Navigation“ by Wolfgang Birkfellner, Chapter 5

⁴ „Aligning Optical and Electromagnetic Tracking Systems“, Diploma thesis by Sintje Göritz, handed in 2005/08/15

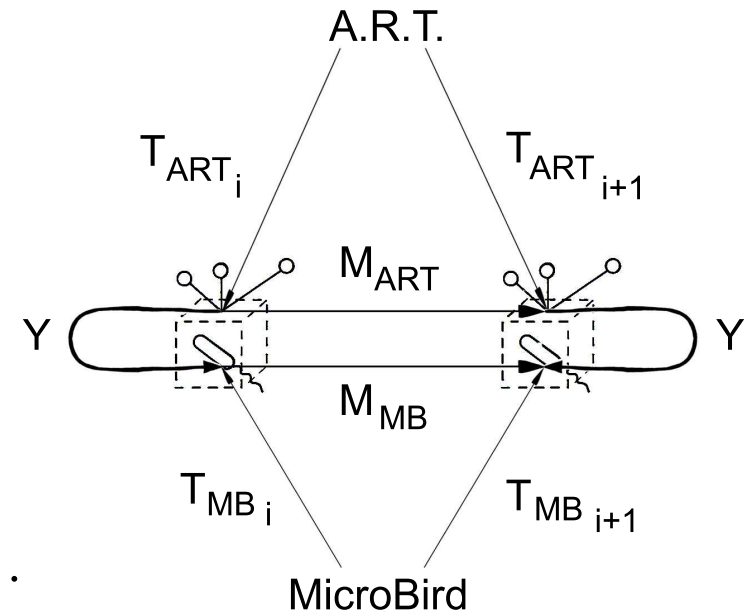
Explanation of the picture

- A.R.T. = optical tracking system,
Microbird = electromagnetic tracking system (abbreviated „MB“)
- on the left: magnetic field-generator with rigidly attached optical markers (S3)
- on the right: „combined target“ = magnetic sensor (S1) with rigidly attached optical markers (S2)

- X = transformation between the coordinate system of the field-generator and the optical tracking system
- Y = transformation between the coordinate system of the magnetic sensor and the optical tracking system

Step 1a: HandEyeCalibration to get Y

- combined target is moved around
- must be done in a non-distorted setting
- measurement data collected at several locations at several times $i, i + 1, \dots$
- measured data used to set up equations and to calculate Y



Step 1b: Reorganizing the equation to get X

$${}^{ART}T_{S3} \cdot X \cdot {}^{MB}T_{S1} = {}^{ART}T_{S2} \cdot Y$$

$$X = ({}^{ART}T_{S3})^{-1} \cdot {}^{ART}T_{S2} \cdot Y \cdot ({}^{MB}T_{S1})^{-1}$$

What's new

Suhkbansbir's method:

- no marker on the field-generator
 - therefore device calibration was done during online error correction
 - HandEyeCalibration had to be done more than once
 - HandEyeCalibration did work well in non-distorted settings, but HandEyeCalibration did not work in distorted settings
- ⇒ but: The prostate cancer setting is always distorted because of gantry and metal present in the radiation room.

Proposed method:

- additional optical marker attached to the field-generator
- therefore device calibration can be done in the beginning
- device calibration needs to be done only once

Step 2: Creating the Lookup-table (LUT)

- need to be done whenever the setting changes (metal)
- mapping function (incorrect values \rightarrow corrected values) implemented as LUT
- two entries per line:
 - measurement data of the electromagnetic tracking system
 - corresponding transformed measurement data of the optical tracking system
- optical data needs to be transformed into the magnetic coordinate system:

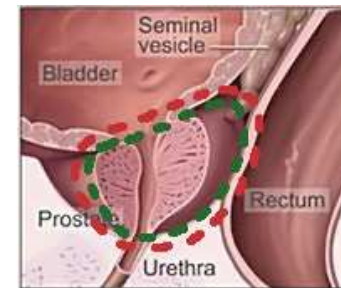
$$\underbrace{MBT_{S1}}_{\text{measurement data}} = \underbrace{X^{-1} \cdot (ART_{S3})^{-1} ART_{S2} \cdot Y}_{\text{ground truth values}}$$

Step 3: Online error correction

- based on the entries of the LUT
- optical tracking system not needed for this step
- algorithm for the online error correction:
 - If the actual position of the sensor is available in the LUT:
 - ⇒ use the corrected value from the LUT
 - If the actual position is not available in the LUT
 - ⇒ perform interpolation (trilinear / Hardy's Multi-Quadric)

5. Summary and vision for the future

- carry on the work of Suhkbansbir Kaur
- improve the error correction for magnetic tracking
(with the help of an optical tracking system used for the ground truth values)
- make the steps more useable for the clinical workflow
- medical aim:
⇒ enable more precise radiation of the prostate cancer



Status Quo
Vision

Further information

For more information about my thesis, please visit

<http://campar.in.tum.de/Students/DaProstate>