Automatic patient alignment in six degrees of freedom for particle beam treatment

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Automatic patient alignment

Outline

• MedCom
• Motivation
• Patient Position Verification System
• Automatic correction
  • Image Registration
  • Back-projection
• Results & Perspective
MedCom GmbH

Darmstadt, Germany
Overview

• Founded in 1997 as Spin-Off of Fraunhofer IGD
• Manufacturer of Medical Software Systems
  • Radiotherapy planning / treatment
  • Virtual Simulation, Virtual Navigation
  • 3D Ultrasound Acquisition
  • Ultrasound simulator for training & education
• OEM Partner for
  • ESAOTE, Nucletron, …, Varian Accel, … IBA-Worldwide, …
• Products
  • Prosoma (Virtual Simulation)
  • SWIFT (HDR)
  • VeriSuite (PPVS)
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Motivation

• Particle therapy becomes commercial
• Treatment times per patient need to be optimized
• High precision positioning of patient

Need for

• High accurate, fast, reliable, flexible PPVS
• Supervision by Therapist
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PPVS consists of

- **Hardware**
  - X-ray imaging hardware (generator, tubes, digital flat panel receptors)
  - High end PC workstation

- **Software**
  - 2 DRRs (high resolution CT image series of patient)
  - DICOM RT Ion Plan
  - Control of X-ray generator
  - Acquisition of 2 X-ray images
  - Mutual information based image registration
  - Calculation of correction vector (5 or 6 DoF)
  - Connectivity to environment (TCS, DICOM Archive, etc.)
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PPVS: 6 image treatment view
Automatic patient alignment

PPVS: Room view
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Correction calculation overview

Treatment position

Image Registration

Back-projection

Correction Vector & Quality Indicator

$\Delta X / \Delta Y / \Delta Z / \Delta rx / \Delta ry / \Delta rz$
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Input for calculation of correction vector
- Treatment position (from TCS / DICOM RT Ion Plan)
- 2 DRRs calculated on the fly from a CT image series
- 2 X-rays acquired in treatment position
- Calibrated system geometry

Calculation Steps
- 2D Image registration (DRR 1--X-ray 1, DRR 2--X-ray 21)
- Back-projection of shift & rotation to isocenter
- Iterative repetition
- 5/6 DoF
- Quality indicator calculation
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DRRs

- High resolution CT image series
- On the fly calculation during verification
- Perspective volume rendering, ray casting
- Regard of exact treatment (gantry-) system geometry
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System’s geometry
- Determined by a calibration with a phantom
- Position & orientation of DFPs
- Position of X-ray tubes
- SID, SAD
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2D Image registration
• Based on mutual information

\[ MI(A, B) = H(A) + H(B) - H(A, B) \]

\[ H = - \sum_{g=0}^{G} p_g \ln p_g \]

• „Image statistics“
• Histograms & joint histogram of X-ray n / DRR n
• Robust approach
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2D Image registration

- Minimisation of

\[ -Q = -\sum_{i=1}^{N} MI_i^2 \]

- Downhill Simplex parameter selection

Result

- 2D image shift X,Y
- Rotation \( r_z \)
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3D back-projection

Detector A

2D Image shift (right)

Q

Original position

Corrected position

Detector B

2D Image shift (left)

Correctional spatial shift

Source B

Patient support

Source A
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Iterative repetition

• Re-calculation of DRRs for corrected position
• 2D image registration
• Back-projection
• End if correction vector below $\varepsilon$
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Correction calculation overview

CT image series → DRR calculation 2
   Position

X-ray 1 → DRR 1 → 2D Registration 1 → Back-projection
   ∆x, ∆y, r_z

X-ray 2 → DRR 2 → 2D Registration 2
   ∆x, ∆y, r_z

Back-projection

Correction < ε
   Yes
   No
   finished
Automatic patient alignment I
Automatic patient alignment II
Automatic patient alignment III
Quality Indicator

- Probability for correctness of correction vector
- Weighted sum of
  - Difference image of DRR--X-ray image
  - Steepness of gradient of MI
  - Error in Backprojection
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Results & Perspective

• Fast automatic matching
• Supportive calculation of QI
• Accuracy 0,5-1mm
• Manual intervention possible

• Installed in RPTC, Munich
• Clinical experience
• More features, e.g. automatically detected fiducial markers
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Thank you for your attention.