Comparative Tracking Error analysis of five different Optical tracking systems

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Outline

- Intro to PAKCoR Project
- Background
- Introduction to Optical Tracking System
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- Possible Future Step

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PAKCoR Project

Precise Automated Kinematic Calibration of RCM Robots

Main Goal: Quantify the error of RCM and develop more accurate RCM

Important Steps:

- Calibrating the accuracy of Polaris Optical Tracking System
- Quantify the error of RCM
- Develop a new and more accurate RCM

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Background

Comparative Tracking Error Analysis of Five Different Optical Tracking Systems

Rasool Khadem, Ph.D., Clement C. Yeh, M.S., Mohammad Sadeghi-Tehrani, M.S., Michael R. Bax, M.S., Jeremy A. Johnson, M.S., Jacqueline Nerney Welch, M.S., Eric P. Wilkinson, B.S.E., and Ramin Shahidi, Ph.D.
Image Guidance Laboratories, Stanford University School of Medicine, Stanford, California

- Precision Analysis using Jitter* measurement
- 5 different Optical Tracking Systems
- Tested in X-Y-Z axis
- Tested in all range of Digitizing Volume*

*Digitizing volume: a range of position inside of which the tracking apparatus is completely visible to the camera

*jitter: the undesired deviation from true periodicity of an assumed periodic data(wikipedia)

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Introduction

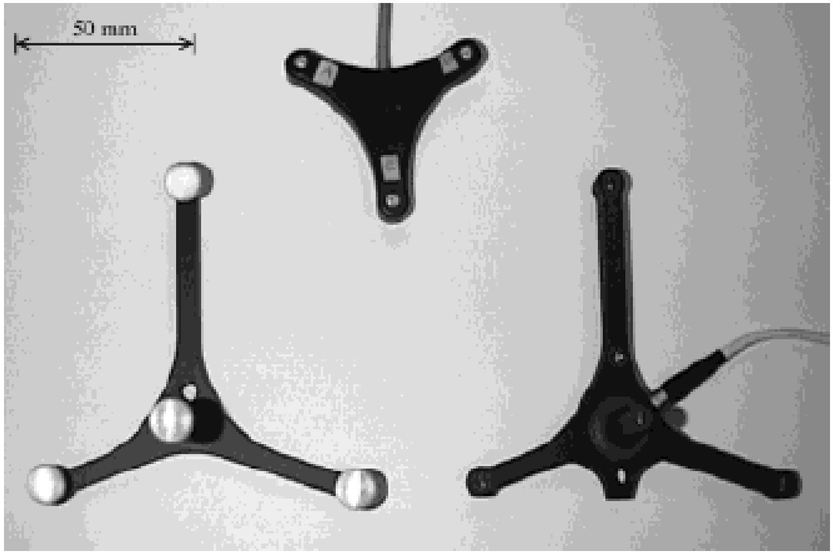
- Optical Tracking Systems (OTS)

Consist of 1D or 2D image sensors and emitters

- 5 OTSs tested in this paper

System	Manufacturer
300 mm FlashPoint	Image Guided Technology Inc. (IGT)
580 mm FlashPoint	Image Guided Technology Inc.
1 m FlashPoint	Image Guided Technology Inc.
Polaris	Northern Digital Inc. (NDI)
Polaris(passive)	Northern Digital Inc.

Introduction



DRF:

Dynamic Reference Frame

- Active Configuration

Emitters are mounted on the DRF

- Passive Configuration

Camera emits the Infrared light and DRF reflects the light

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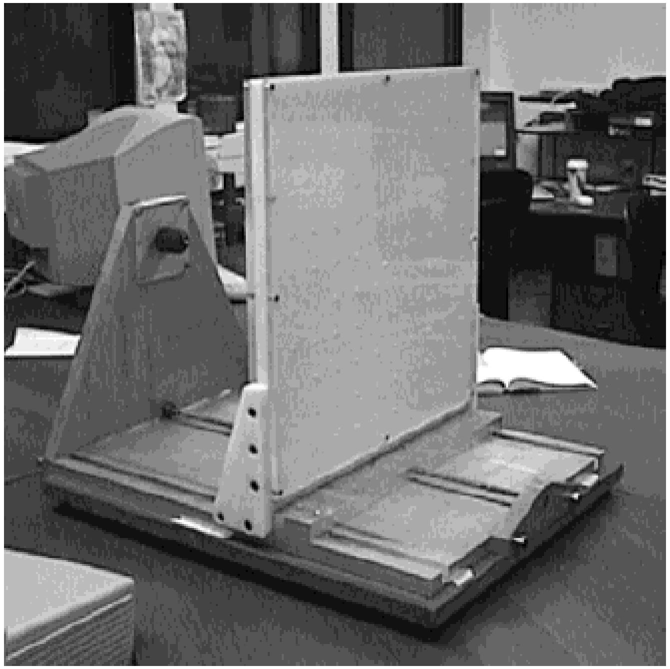
Introduction

DRF used

System	DRF
300 mm FlashPoint	3 LED 50 mm ACTIVE
580 mm FlashPoint	3 LED 50 mm ACTIVE
1 m FlashPoint	3 LED 50 mm ACTIVE
Polaris	4 LED Active TRAXTAL
Polaris(passive)	4 LED Passive TRAXTAL

Methods

LTA (Linear testing apparatus)



- Precision-machined
- 500 mm^2 plate with 10x10 grid of holes (X-Y axis)
- 700 mm linear track with 10mm shift (Z-axis)

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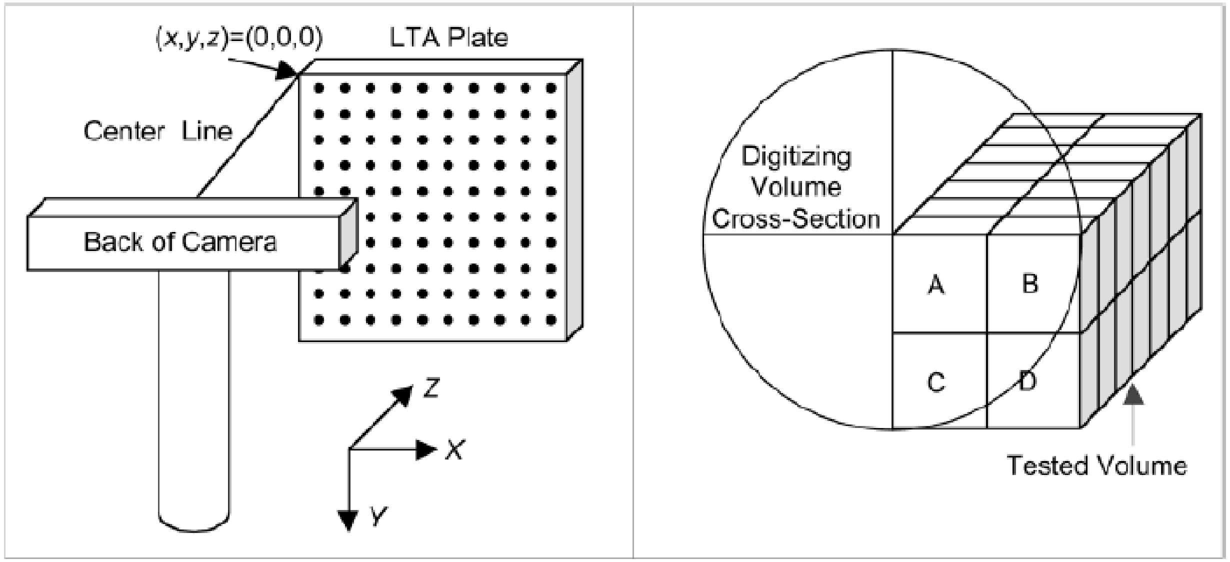
Methods

Digitizing Volume (Spec & Tested)

Camera	Max X spec [mm]	Max X tested [mm]	Max Y spec [mm]	Max Y tested [mm]	Min Z spec [mm]	Min Z tested [mm]	Max Z spec [mm]	Max Z tested [mm]
300 mm Flashpoint	150	300	150	400	600	600	900	900
580 mm Flashpoint	500	430	500	650	1000	1060	2000	2160
1 m Flashpoint	500	800	500	650	1000	1060	2000	2160
Polaris	500	410	500	620	1400	1400	2400	2400
Polaris (passive)	500	350	500	620	1400	1400	2400	2400

- Tested moving the LTA Volume Unit in 3 dimensions
- 30 degree was chosen for viewing angle

Methods



- DRF was Mounted on X-Y 100 holes and 10cm shift in Z
- Camera was mounted on a tripod
- Orientations of camera and LTA were Aligned
- Tested in all range of digitizing volume

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Methods

$$\boldsymbol{J_{xyz}} = \left\| [\boldsymbol{X_i}\ \boldsymbol{Y_i}\ \boldsymbol{Z_i}]^{\boldsymbol{T}} - [\boldsymbol{\mu_X}\ \boldsymbol{\mu_Y}\ \boldsymbol{\mu_Z}]^{\boldsymbol{T}} \right\|$$

- Sampled 100 times, ($X_i\ Y_i\ Z_i$) for $1 \leq i \leq 100$
- Jitter was calculated relative to the mean coordinates – ($\mu_X\ \mu_Y\ \mu_Z$)
- J_X , J_Y, J_Z are the normalized standard deviation of each x, y, z

- *jitter: the undesired deviation from true periodicity of an assumed periodic data(wikipedia)

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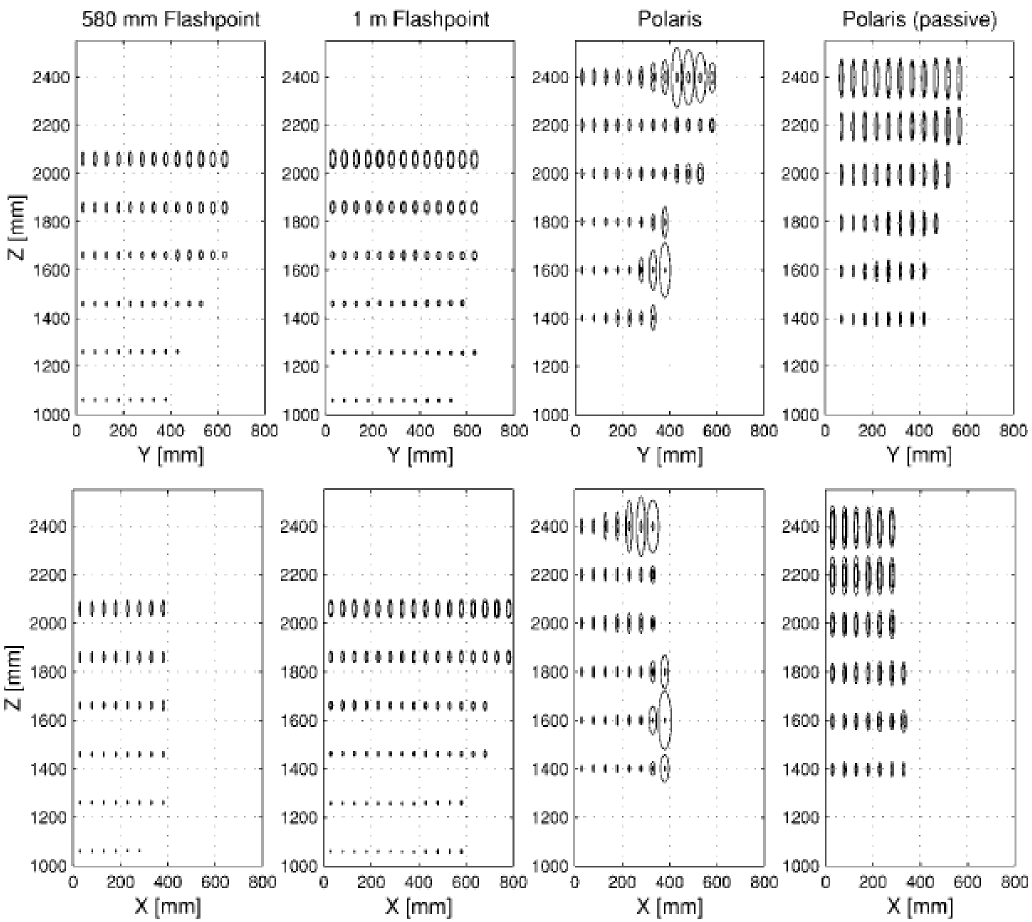
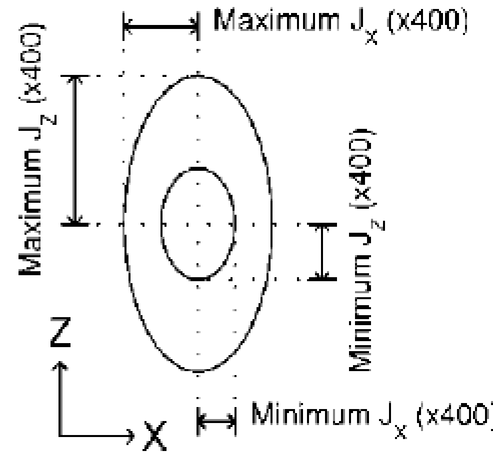
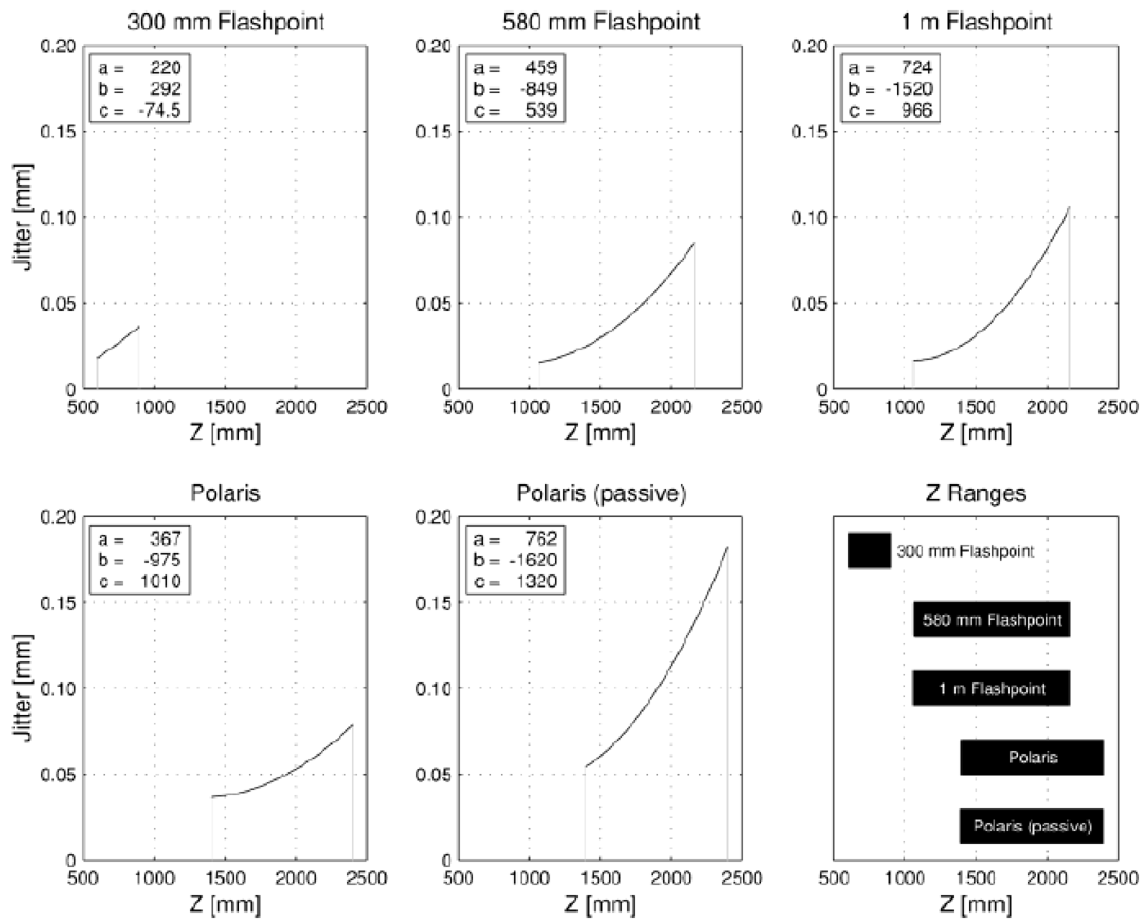
Results





Jitter in Z increases with increasing distance Z.

Results



Quadratic Model of mean Jitter
using Least-squares fit

$$J(z) \approx \frac{az_m^2 + bz_m + c}{10000}$$

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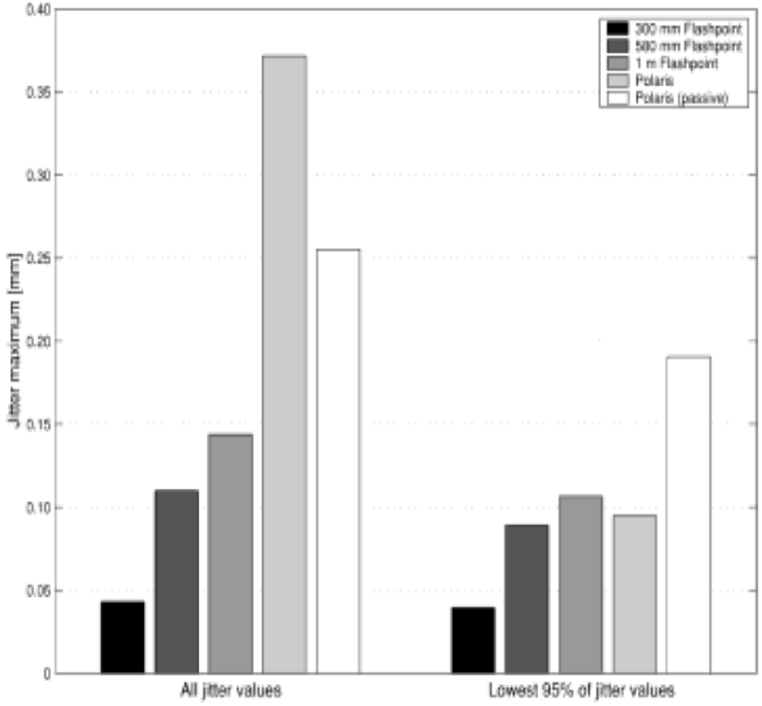
Results



- Maximum Jitter values

- For all,

NDI Polaris shows largest Jitter value.

- For Lowest 95%,

IGT OTSs and NDI OTSs are comparable

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Author's Conclusion

- Jitter result data is dominated in Z axis
- Suggestions
  - ✓OTS camera should be as close as possible
  - ✓Z axis of Camera should be in direction that is **least clinically significant**
- Among 5 OTSs, IGT active systems were more predictable than NDI

My Opinion

Positive

- Tried 5 different OTSs
- X-Y-Z analysis
- Jitter measurement
- The ellipses method
- Tested all range

Negative

- Hard to believe the orientations are perfectly aligned
- Author did not consider the other static errors
- Only dealt with precision
- The LTA did not reflect the typical clinical use
- Correction Algorithm

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Future Step

- Build the Accuracy Analysis methods
- Mathematic model and Correction algorithm
- Apparatus which can reflect the real use of tracking systems such as rotational or angular movements.

Reference

- Comparative Tracking Error Analysis of Five Different Optical Tracking Systems, Rassol Khadem,2000
- Accuracy assessment and interpretation for optical tracking systems ,Andrew D. Wiles 2004

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THANKS