# Toward to Real-Time Optical IGRT

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# Disclosure

- No founding from any vendor
- Co-developed a 3D Optical Surface-guided RT System with NIH SBIR Phase I Grants
- Supported by a Pilot Grant and a NIH Sponsor Breast Cancer Project at Johns Hopkins Cancer Center
- Received a small Faculty Senator Seed Fund at Temple University

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# List of Topics

1. ***History of OG in Radiotherapy***
2. ***Principles of 3D Optical Imaging***
3. ***Clinical Aspects of 3D Video Systems.***
4. ***Initial Experiences of Surface-guided Radiotherapy***

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# 1. History of OG in RT

- In early 1990s, U. of Florida (led by Bova FJ) had introduced infrared marker-based stereotactic radiotherapy (Bova, et al, IJROBP. 1997, 38:875-82)
- In 1995s, U. of Chicago (led by Chen G) had initiated orthogonal 2D video-based patient position system (Jakson LS, et al. IJROBP. 1999, 45:205-13, Milliken BD, et al. IJROBP. 1997, 38:855-66 ).
- In 2000, Johns Hopkins University (led by Li S) had initiated 3D OG SRT/IMRT (Li S, et al, Med. Phys. 2006, 33, 492-503, Li S, et al, TCRT. 2010 9603-17).
- Q1: Is it the time for real-time OG RT?

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## 2. Optical 3D/4D Imaging Principles

A. Marker-based 3D optical system
   a). Passive Marker Tracking System
   b). Active Marker Tracking System
B. Time-of-Flight (TOF) Method
C. Laser Scanner
D. Triangulation-based 3D camera
   a). Passive stereovision
   b). Structured light 3D camera

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## A. Infrared 3D Marker Tracking Systems

OPTOTRAK certus

Tracking rate 60 fps


Polaris Spectra has bump detection and laser positioning used by Elekta iGUIDE and Resonant US Image system

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## Active (left) and passive (right) markers Courtesy to NDI company's permision

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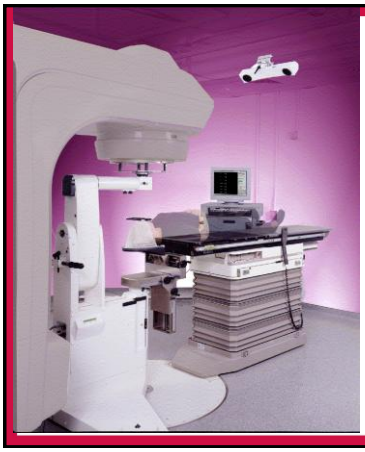

An optic-guided SRT system established at Iowa University Initiated at Florida U.

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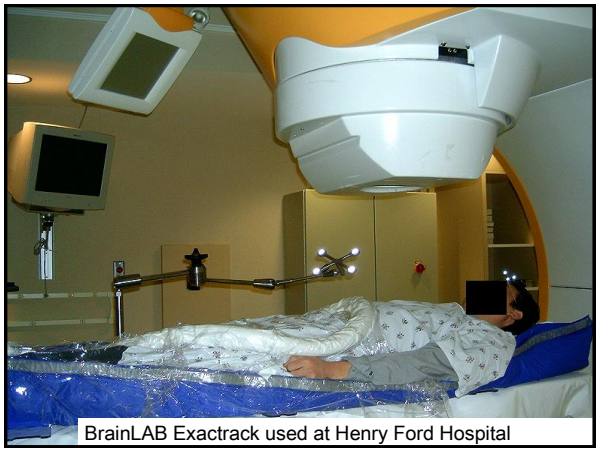

BrainLAB Exactrack used at Henry Ford Hospital

## Cyberknife Optotracking System

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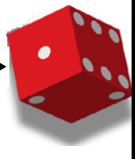
## B. Time-of-Flight (TOF) Method

- 2D image data are provided by 2D camera
- The third dimension and time can be given by using TOF

sending light pulses $t_i$

receiving reflected pulses $t_i + \tau_i$



$$R(t_i) = \tau_i \bullet c_{air} / 2$$

- Presently, TOF has difficulty in achieving the sub-millimeter accuracy.

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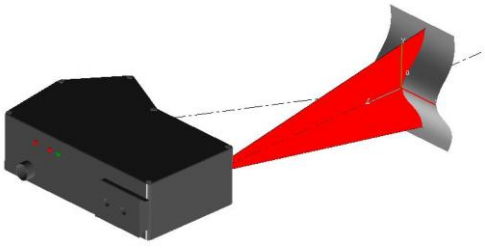
## C. 3D Laser scanners



- Swapping laser line and using triangulation

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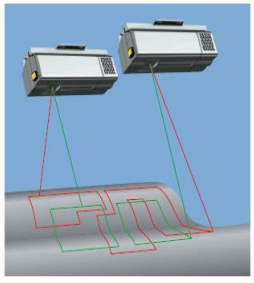
## Laser scanner examples


C-RAD, Uppsala, Sweden



LAP, Luneburg, Germany;

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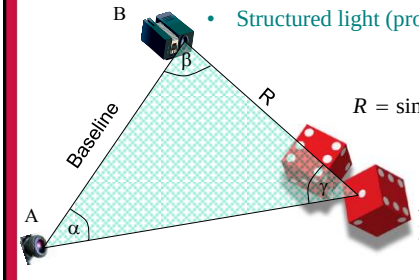
## D. Triangulation-based 3D camera

- Passive stereovision (2 cameras)
- Structured light (projector + camera)




$$R = \sin(\alpha)\frac{Baseline}{\sin(\alpha+\beta)}$$

Q2: How to identify the corresponding point?

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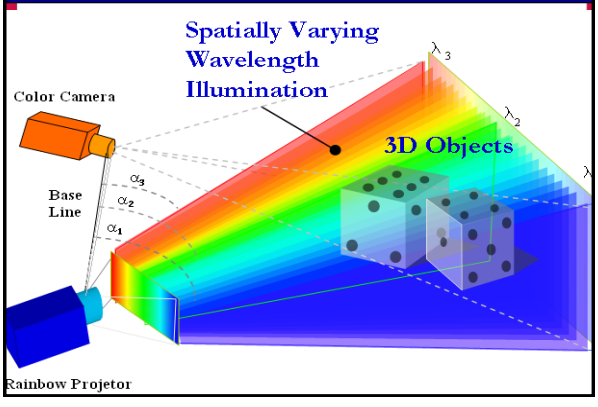
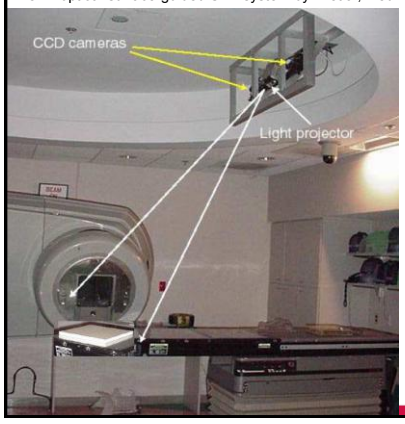
**Rainbow Camera** (Geng, Opt. Eng, 1996, Li, et al, Med. Phys. 2006) use color coding in projector and decoding in a color camera to determine angles

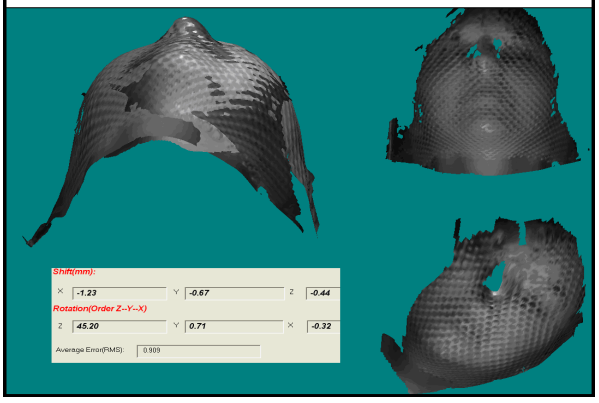


The 1st optical-surface-guided SRT system by Li et al, Med. Phys. 27:1433, 2000

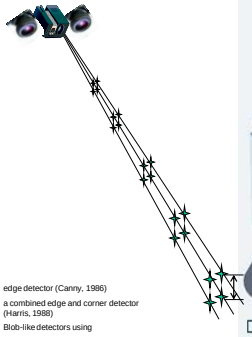


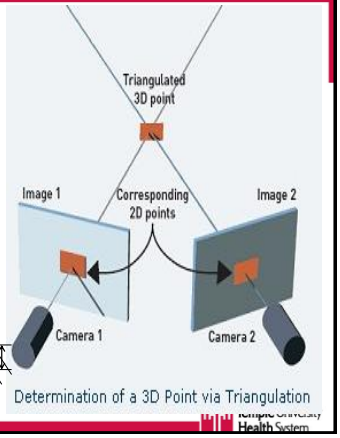

- Pixel-based 3D surface: resolution 0.5 – 1-mm at 2-m focus distance
- Less room light & skin tone effects
- Adjustable power of projector

Target refixation for none-coplanar beams/arcs




Feature-based triangulation






edge detector (Canny, 1986)

a combined edge and corner detector (Harris, 1988)

Blob-like detectors using

# The Laplacian of Gaussian

- An projection image $I(x,y)$, is convolved by a Gaussian kernel

$$g(x,y,\tau) = \frac{1}{2\pi\tau}\exp\{-(x^2+y^2)/2\tau\}$$

- Apply Laplace operator onto the function

$$\nabla^2 L = \left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)L = \left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\{I \otimes g\}$$

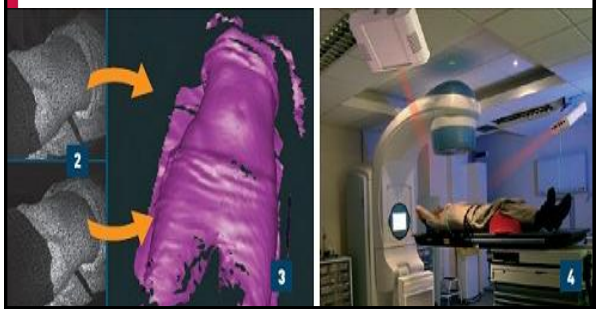
→large positive values for dark blobs

→ large negative values for bright blobs

- Accuracy and resolution depend on the blob size and the scale parameter $\tau$

**AlignRT (VisionRT Ltd, London, United Kingdom)**
**Bert et al. Med. Phys. 2005, Schöffel et al. Physics in Med. and Biol. 2007**

- Two cameras increase the view of patient's body
- Rapid imaging up to 7 fps
- Resolution and accuracy depend on speckle size




## Microsoft KINECT gets official on 11/4/2010


- Although the 30 fps imaging speed allows us to track body movements, 3D surface accuracy is not quit enough for optical-guided RT.

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We now need an in-depth review of structured light imaging techniques by Dr. J. Geng, an expert in optical imaging

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