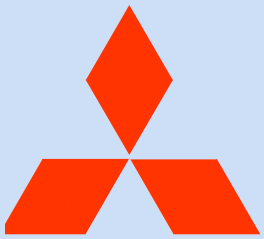
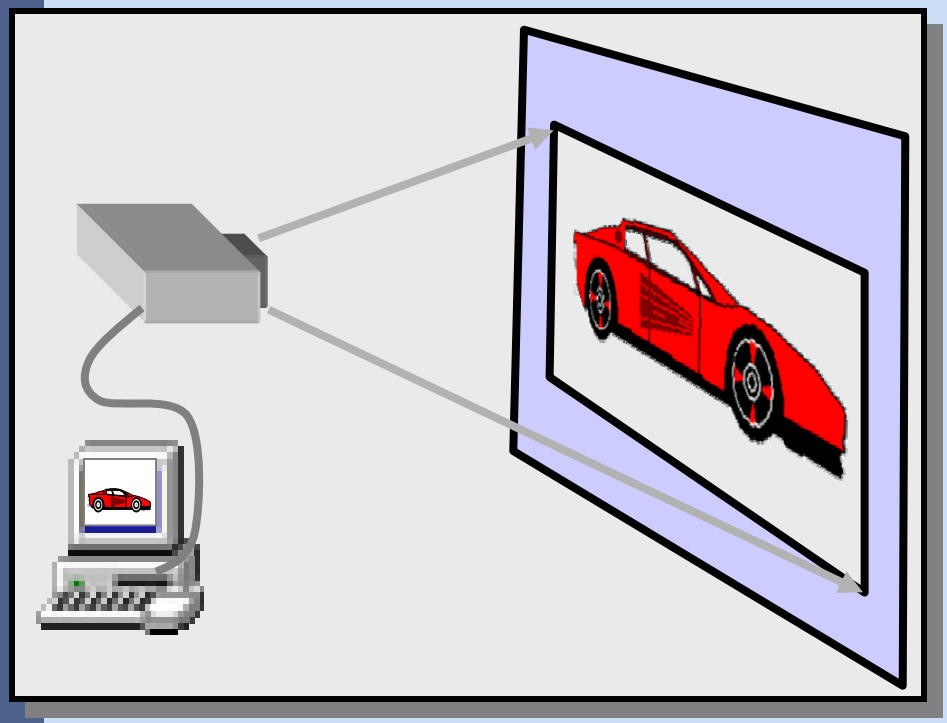
The Large Display Dilemma

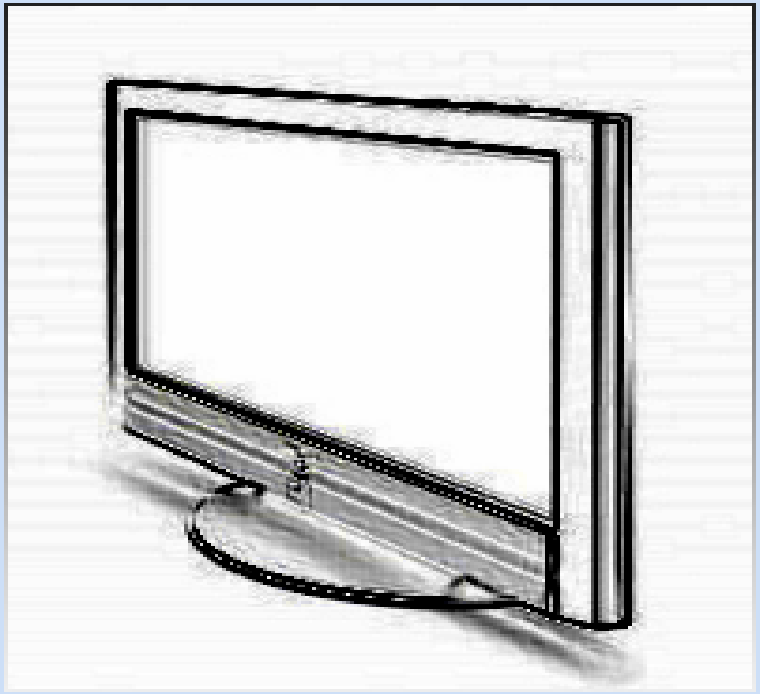


Ramesh Raskar

Mitsubishi Electric Research Labs,
Cambridge, MA USA

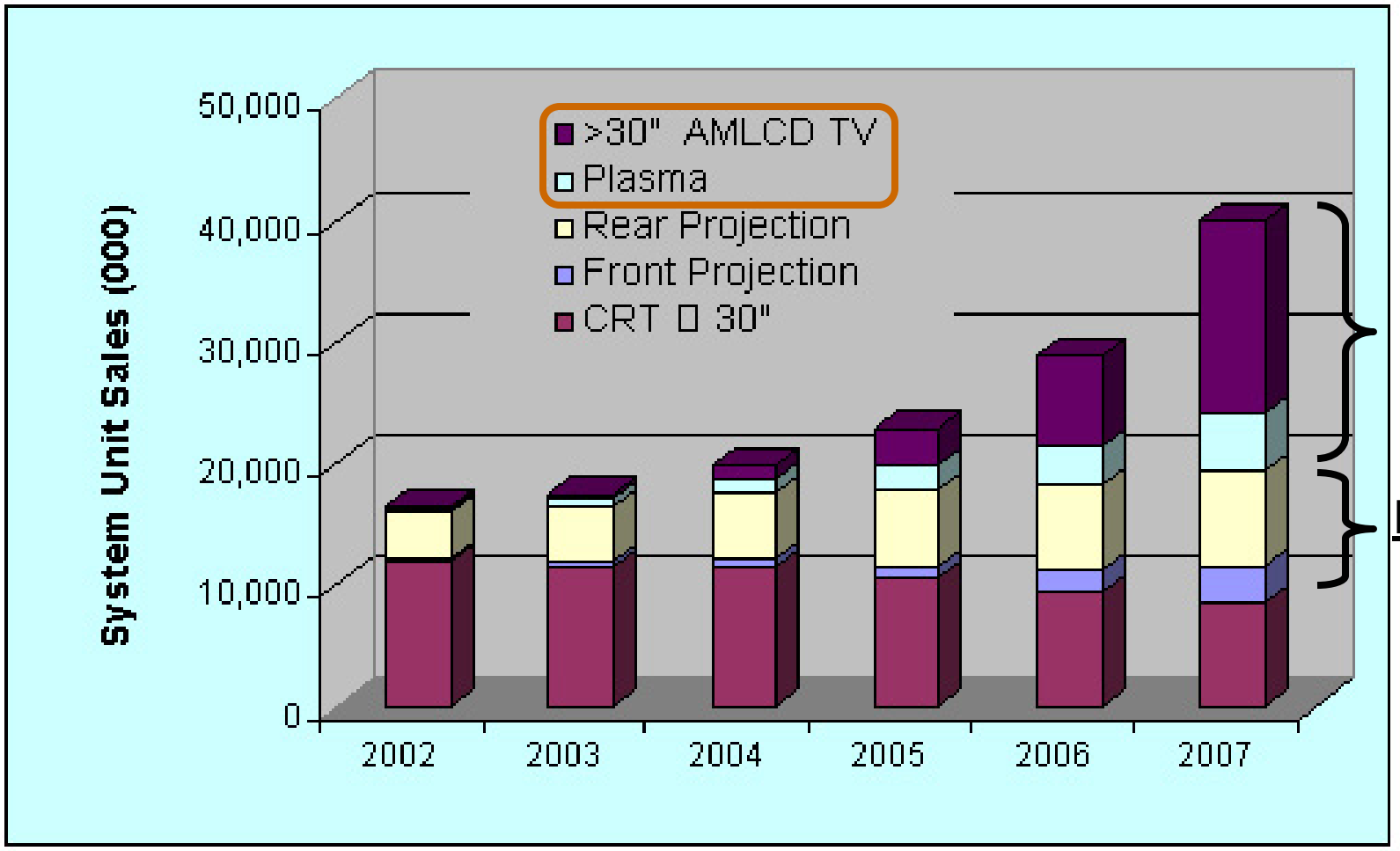
The Large Display Dilemma





Projector **or** **Flat panel display ?**

Flat panel displays are outselling Projectors



Insight Media and McLaughin Consulting Group, Microdisplay Forecast Report, 2003

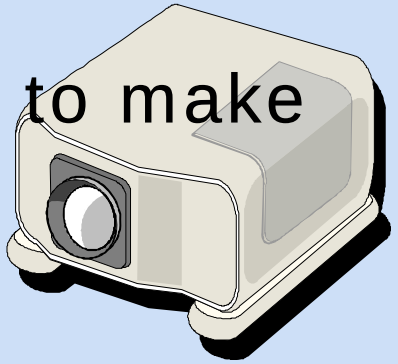
The Numbers
Should we believe them ?

		2003	2007
Units	Proj	3M	6M
	FPD	1M	20M
Revenue	Proj	$5B	$6B
	FPD	$3B	$50B

Insight Media and McLaughin Consulting Group,
Microdisplay Forecast Report, 2003

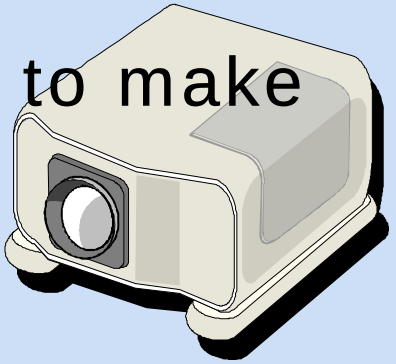
Growth Expectations

- Our reasons
  - Projectors are cheaper and easy to make
  - Portable, aim anywhere
  - Tile-able to expand



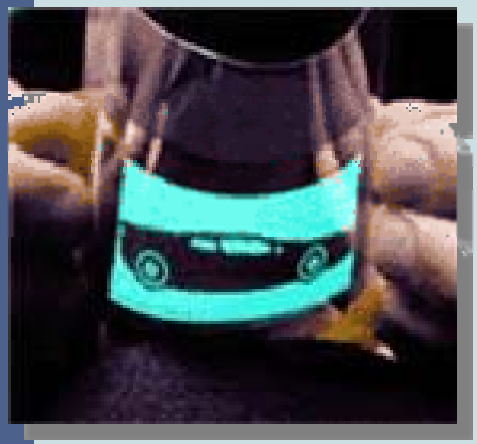
Display Choices

- Our reasons
  - Projectors are cheaper and easy to make
  - Portable, aim anywhere
  - Tile-able to expand



- 'Their' reasons
  - FDP Expensive but beats ambient light, screen reflectance
  - No shadows, focus, FOV issues
  - Maybe large does not need portable

Foldable Displays



Organic LED

Light Emitting Polymer

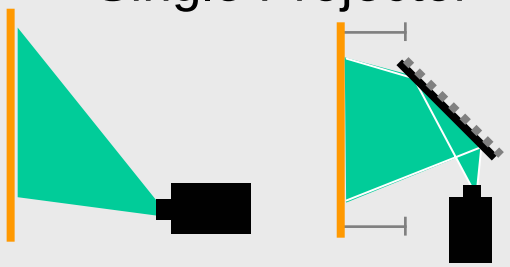
Emissive substrates

E-Ink

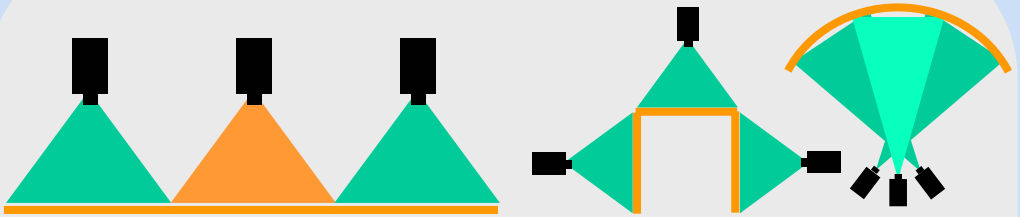
Reflective substrates

Traditional Data Projector Markets

Single Projector



Multi Projector



Main Markets

Biz Presentations, home theater, ImmWorkbench

Trend

FPTV, RPTV → FPD

Bulky → Thin

Main Markets

Control rooms, Advertising, Visualization

Trend

Still cumbersome

Tiling with substrates easy

Will FPD kill Projectors !

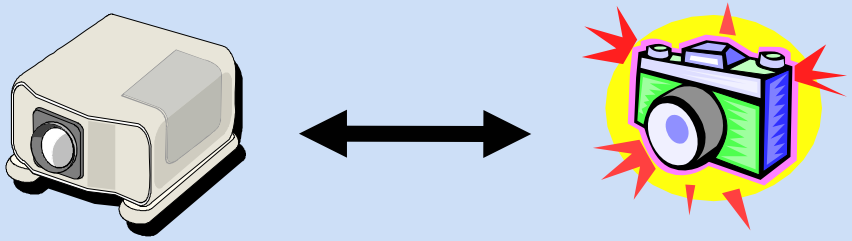
Projector Research

- But Plenty of Important Problems !
  - Hardware design
  - Geometric Alignment [Hereld, Fuchs, Wallace]
  - Photometric Correction [Majumder, Nayar, Ulichney]
  - Interaction [Pinhanez]
  - Stereo and 3D display
  - Super-resolution [Jaynes, Majumder]
  - Shadow Removal [Summet, Cham, Sukhthankar, Jaynes]

A short window of opportunity !

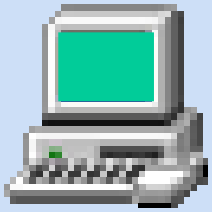
What is the Best App ?

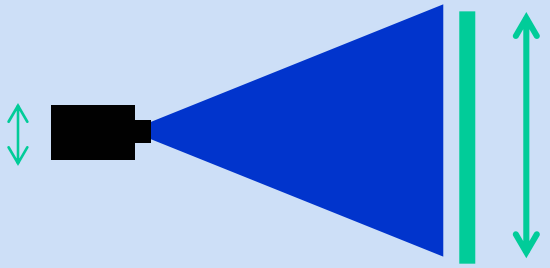
Advantages of Projector vs FPD



- Decoupled Device

  Image can be larger than device



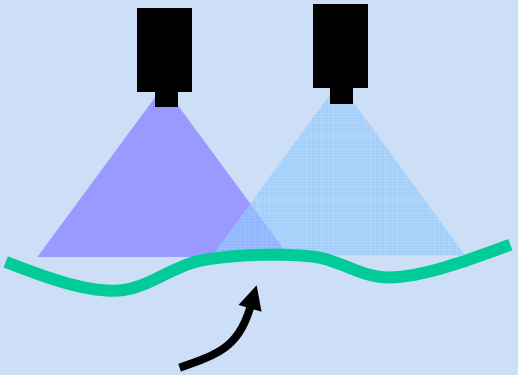


- Combination of images

  Images can be superimposed and added

- Shape of display surface

  Displayed images may be non-planar

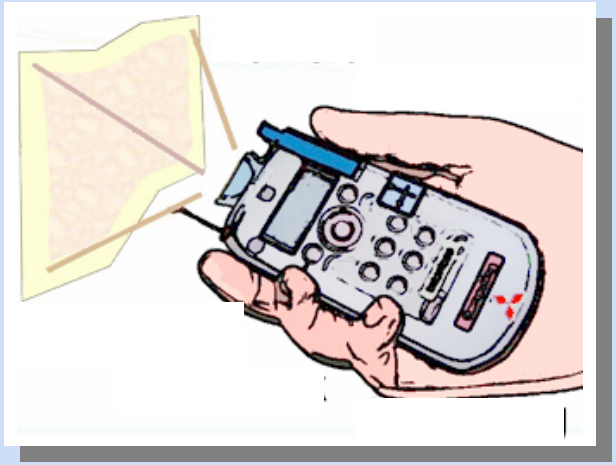


Outline

New Opportunities:
Exploit Proj-Cam Aspect

Outline
New Opportunities

- Aware Handy Projectors
  - Decoupled display size
  - Ability to combine



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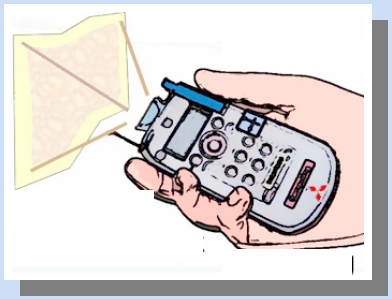
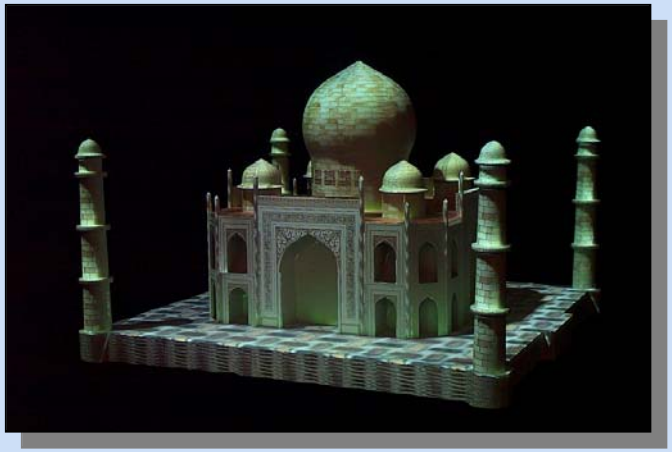


- Image Overlay on Real Objects
  - Decoupled device
  - Non-planar surfaces



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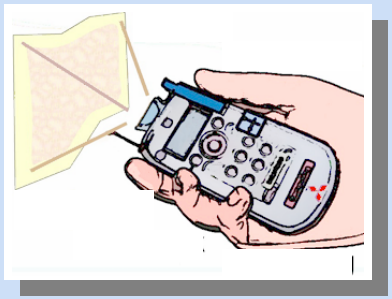

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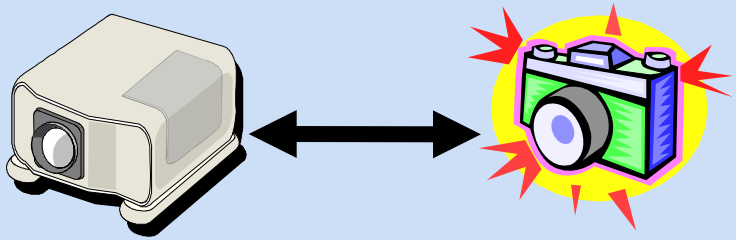
- Projectors in Machine Vision
  - Projector as dual of a camera



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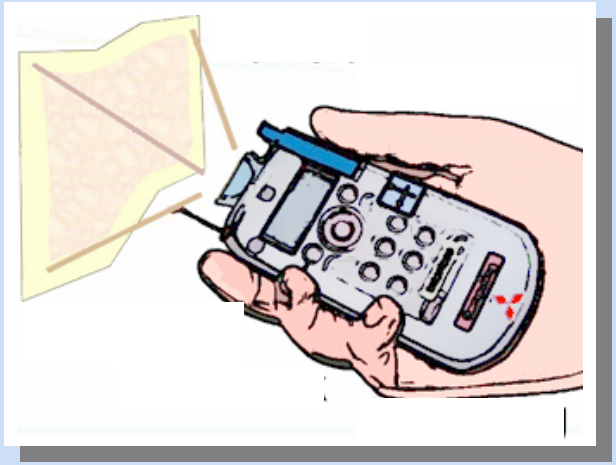
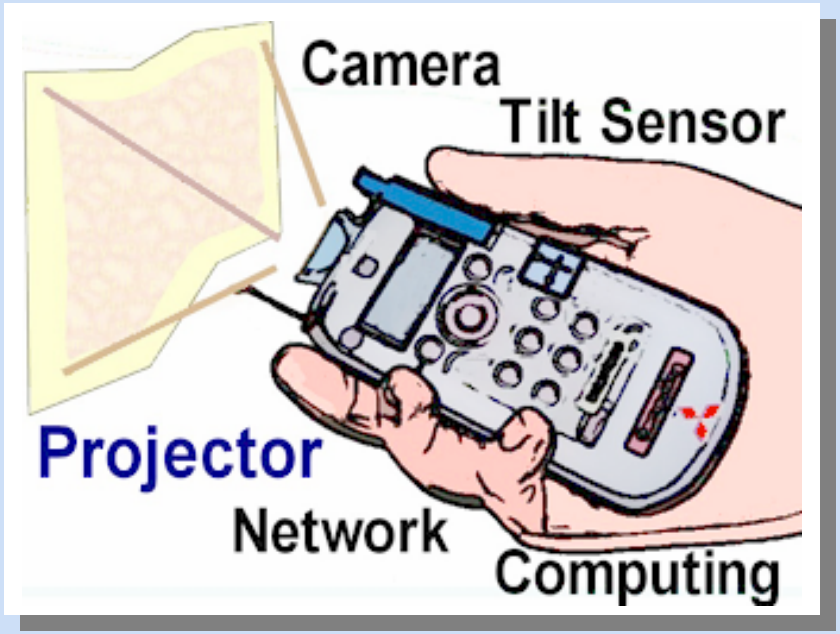
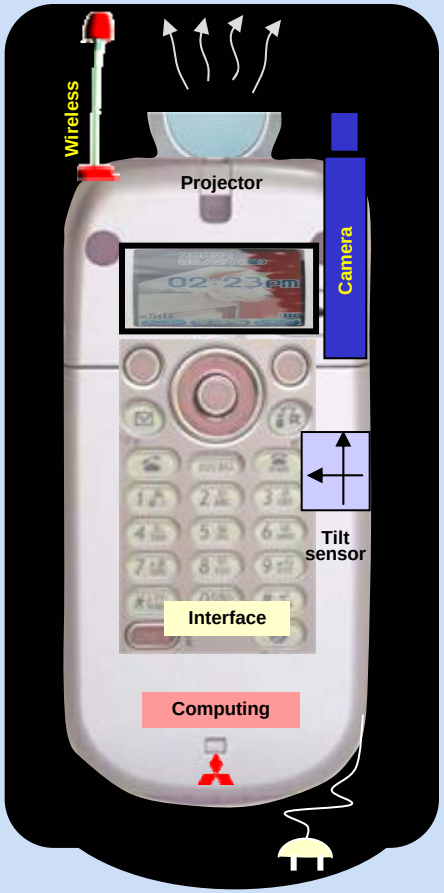


Handy PDA+Phone+Projector

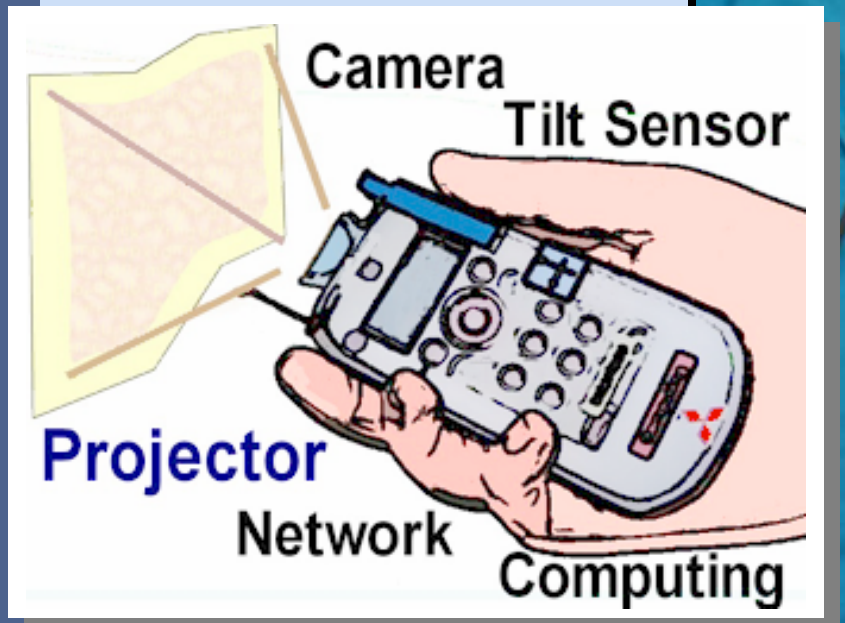


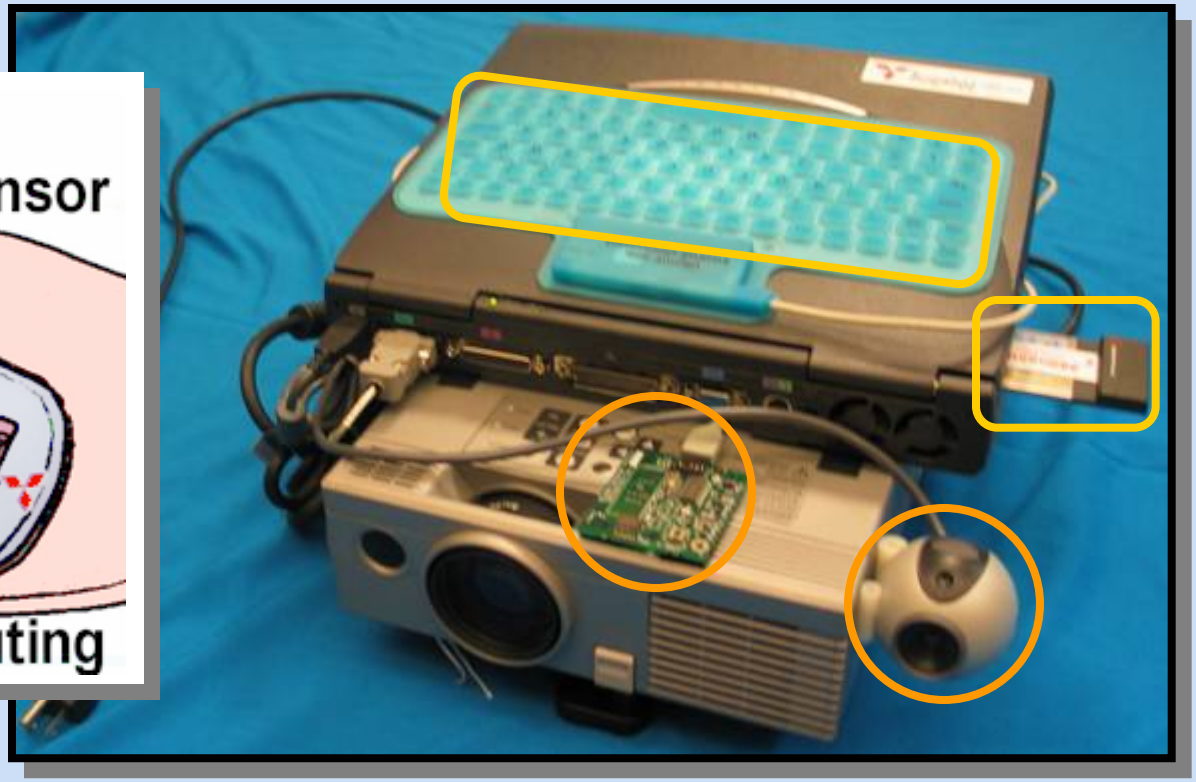


Self-contained Device

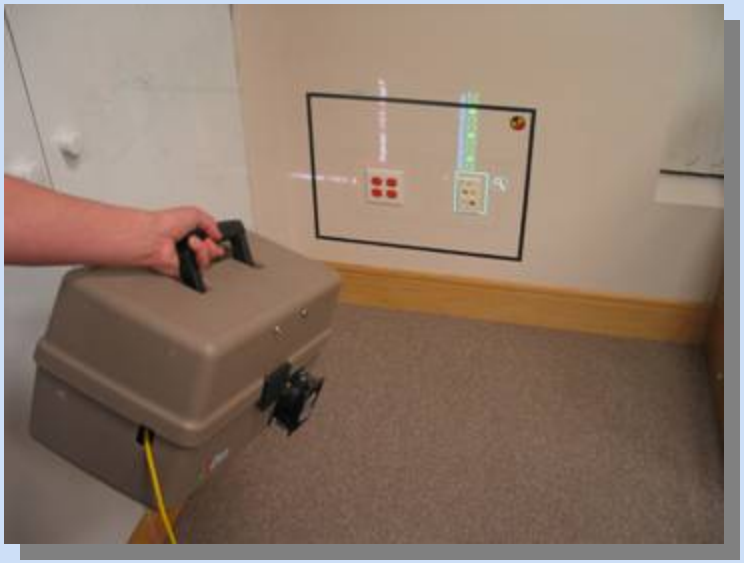
Future Projectors

- What are possible applications ?
- What are geometric problems ?
  - Sense: Aware of surroundings
  - Respond: Display accordingly
  - Communicate: Support ad-hoc clusters
- What components are necessary ?





Geometrically Aware Projector



Application of Handy Projector

Raskar, vanBaar, Beardsley et al, Siggraph 2003

Shape Adaptive Projection

Conformal mapping of image

Illuminate developable surface

Least sqr conformal mapping for non-developable surfaces

Raskar et al, Siggraph 2003

Handy Projectors

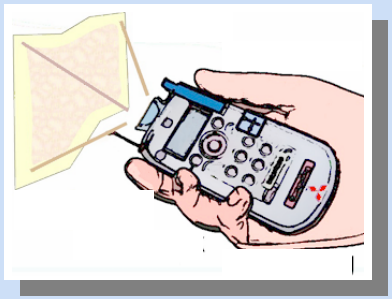
ool

Siemens Minibeamer

- LED based lamps
  - Less heat, simpler optics
  - Coherent colors
  - Long lamp life
- Laser projectors
  - Vector display
  - Large DOF
- Projected keyboards

Outline
New Opportunities

- Aware Handy Projectors
  - Decoupled display size
  - Ability to combine



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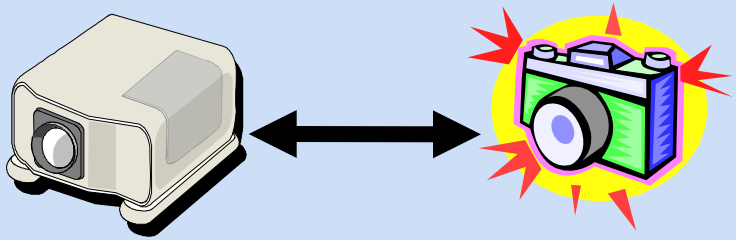


Motivation

View-dependent Appearance

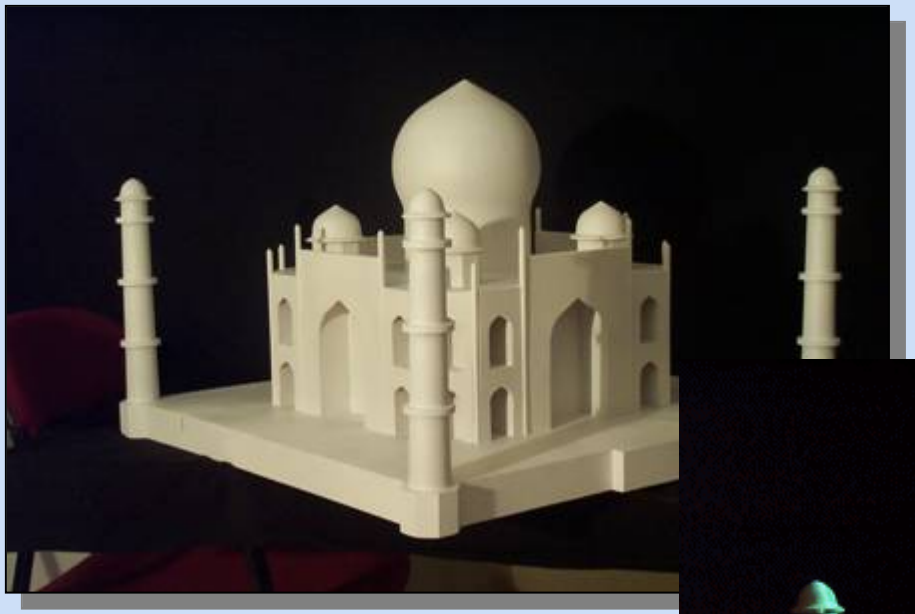
Changing Appearance

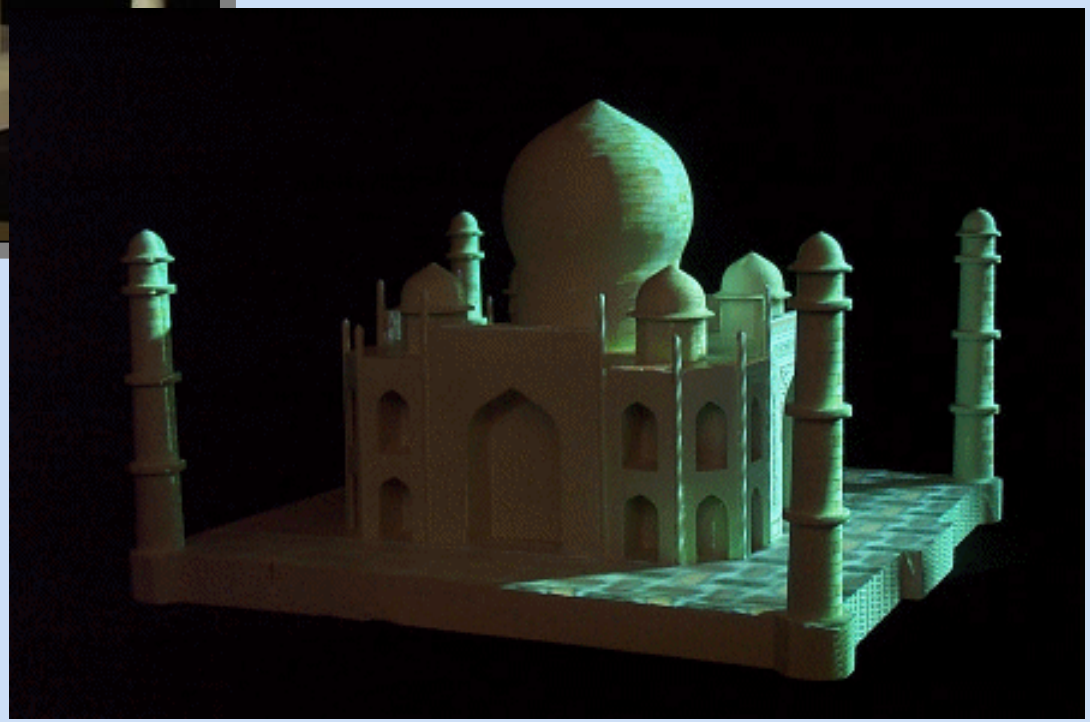
Virtual light source

Projector

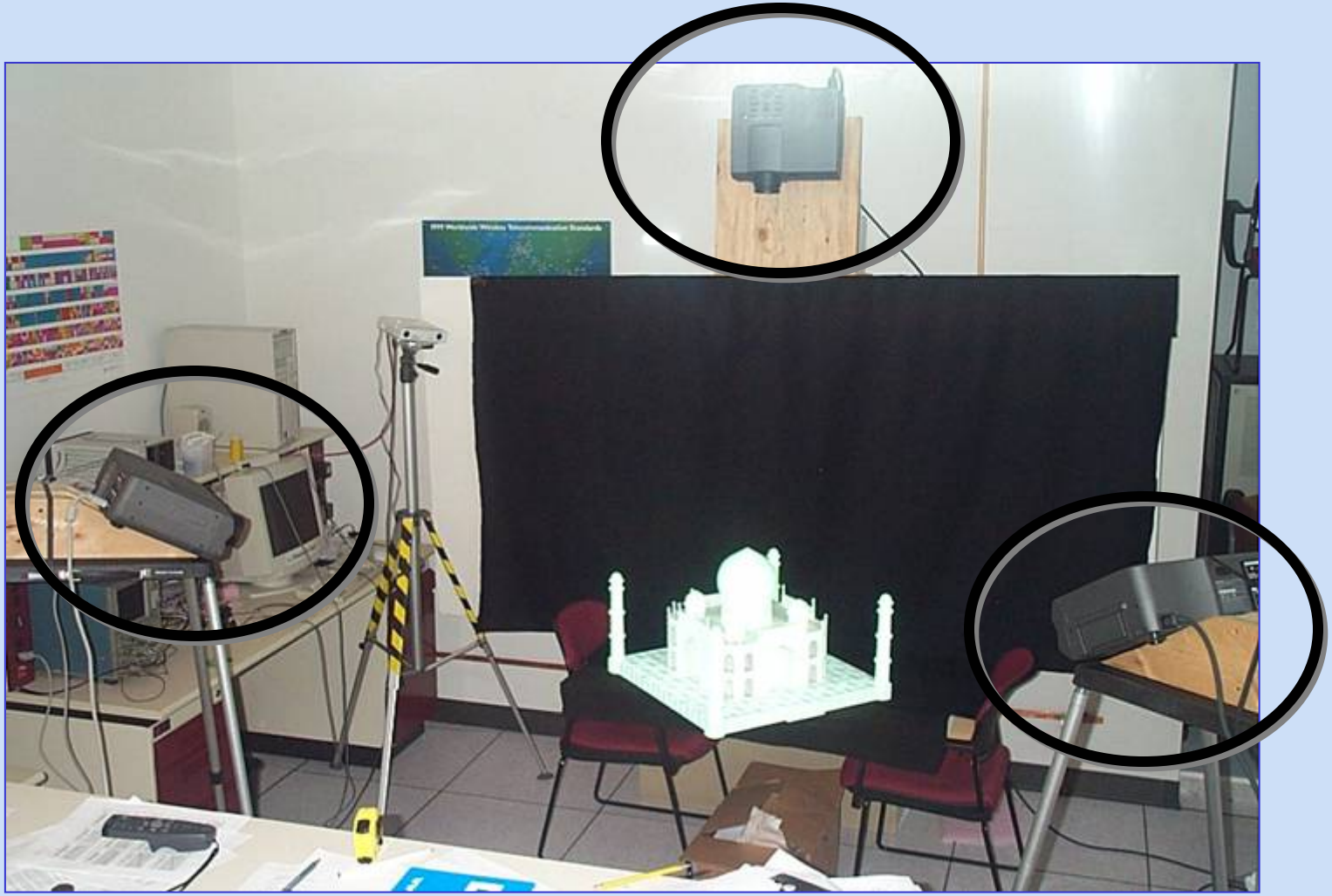
Projector

Changing Virtual Illumination

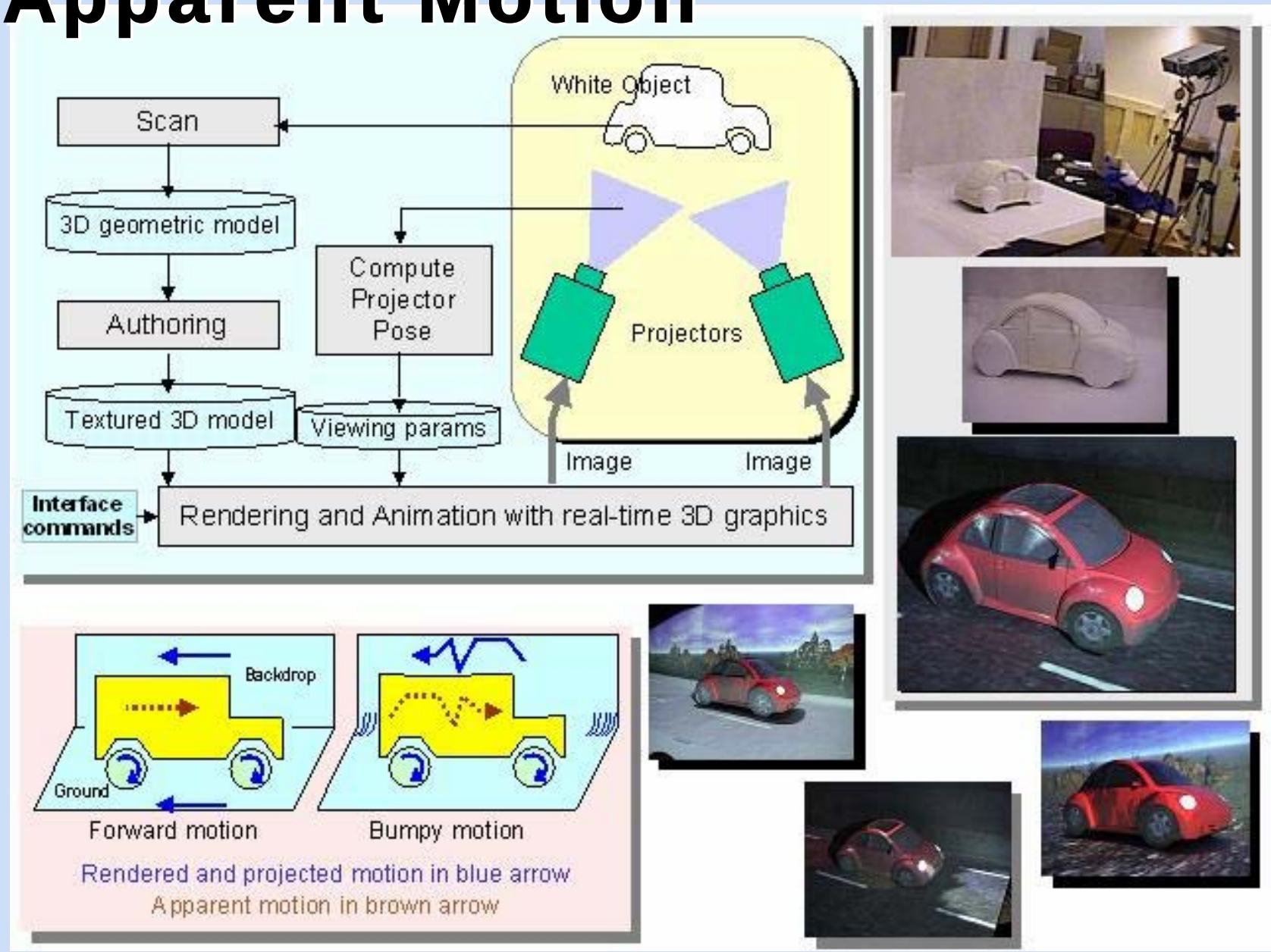




Raskar, Welch, Low, Bandyopadhyay,
"**Shader Lamps**" (2000)



Apparent Motion

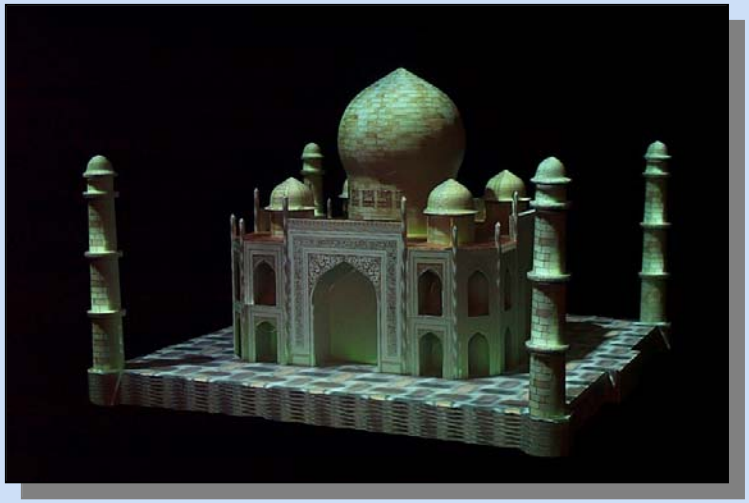


Raskar, Ziegler, Willwacher, “Cartoon Dioramas in Motion,” (NPAR 2002)

Projector-based Augmentation

Reflectance

Illumination



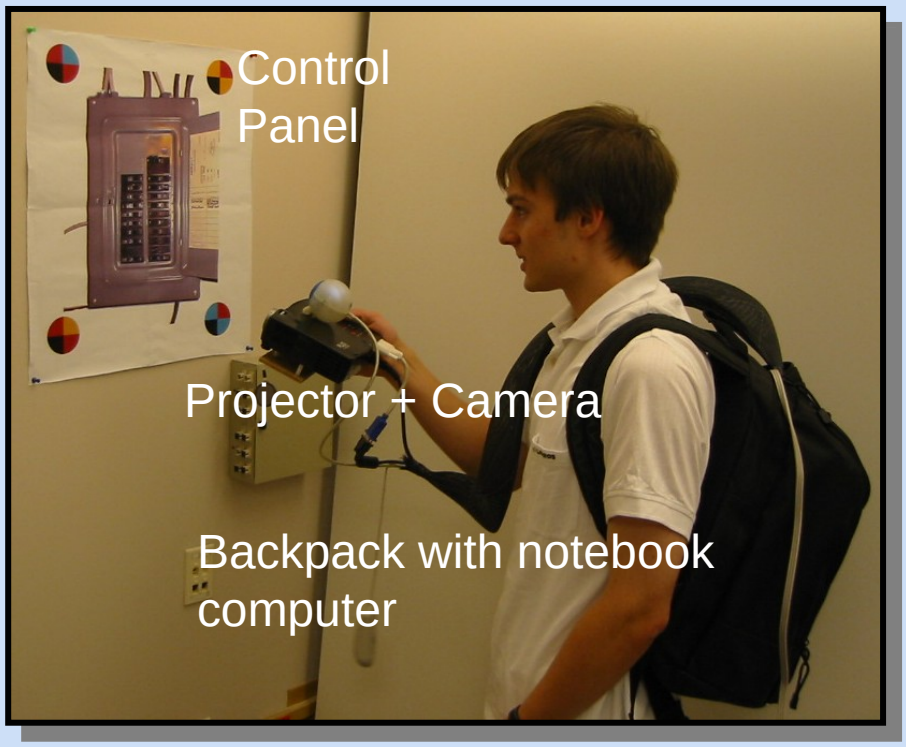
Motion

Interaction

www.ShaderLamps.com

Training and Maintenance
(Projector-based Augmented Reality)
Raskar, Beardsley, Forlines, 2002

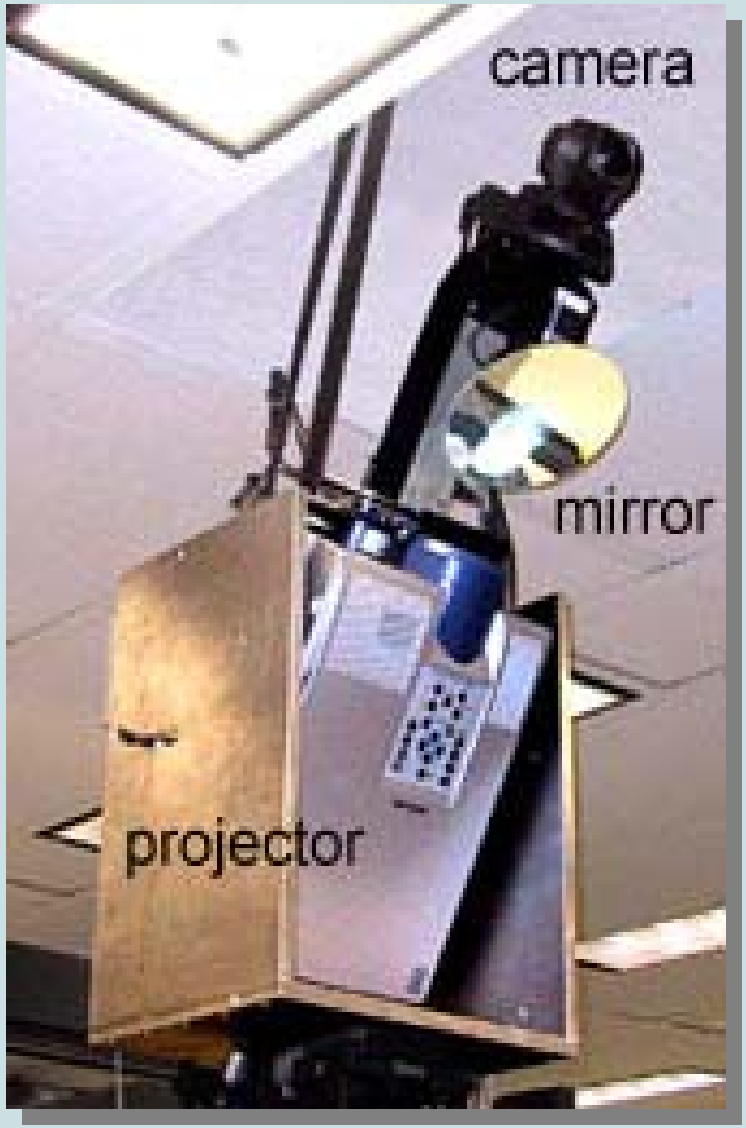
- Training images and videos
- Instruction manuals

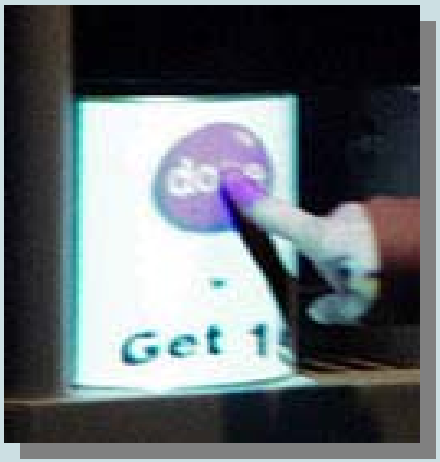


Dr. Shiotani, Mitsubishi Electric, Japan

Benefits vs
- HMD: tracking issues
- PDA: ‘Last foot’ problem

Spatial Projection Displays

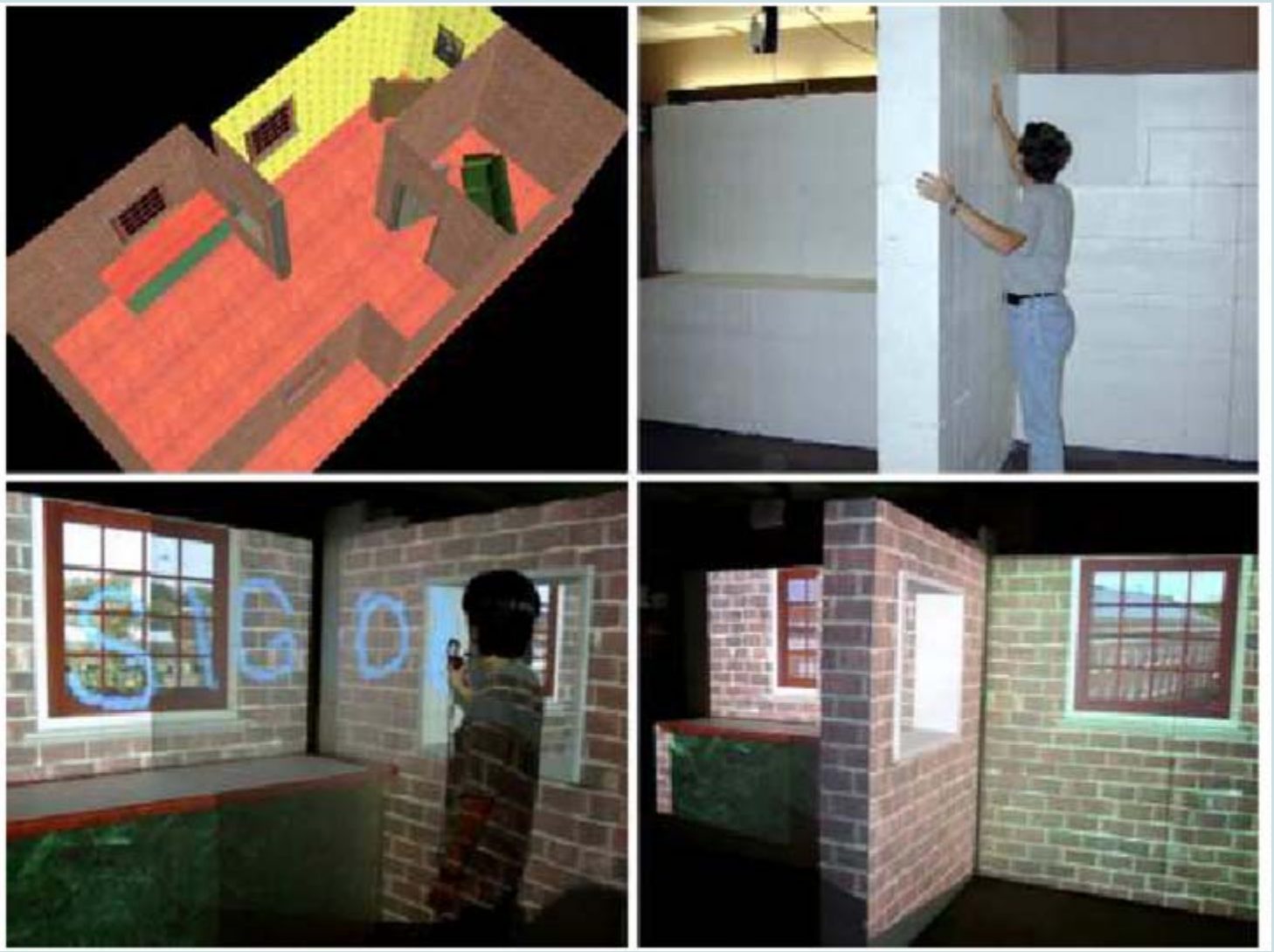




Pinhanez, C.
The Everywhere Displays Projector, 2001

Steerable Mirrors

Spatial Projection Displays
‘Being There



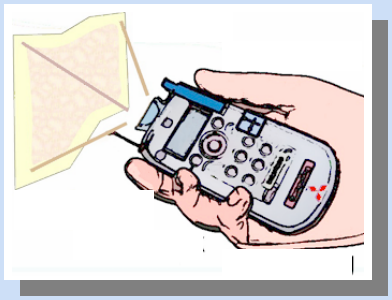
Low, K., Welch, G., Lastra, A., and Fuchs, H. UNC Chapel Hill 2001.

Image Overlay Applications

- Training and maintenance
  - Instructional text, images and procedures
- Entertainment
  - Live shows, exhibits, demonstrations
- Design and Prototype
  - Virtual material and lighting changes
- Scaled model visualization
  - Augment walk-around scaled model of buildings
  - Project and ‘paint’ surface colors, textures
  - Lighting, sunlight, seasons
  - Internal structure, pipes, wiring
- Advertising

Outline
New Opportunities

- Aware Handy Projectors
  - Decoupled display size
  - Ability to combine



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  - Non-planar surfaces

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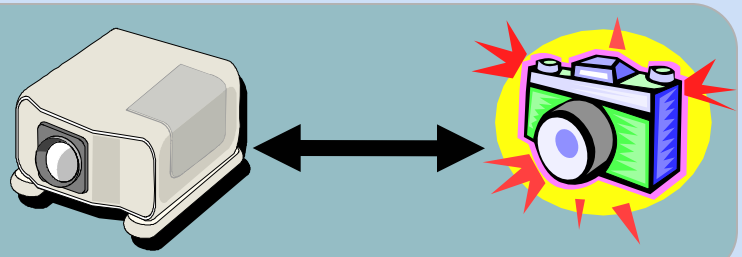
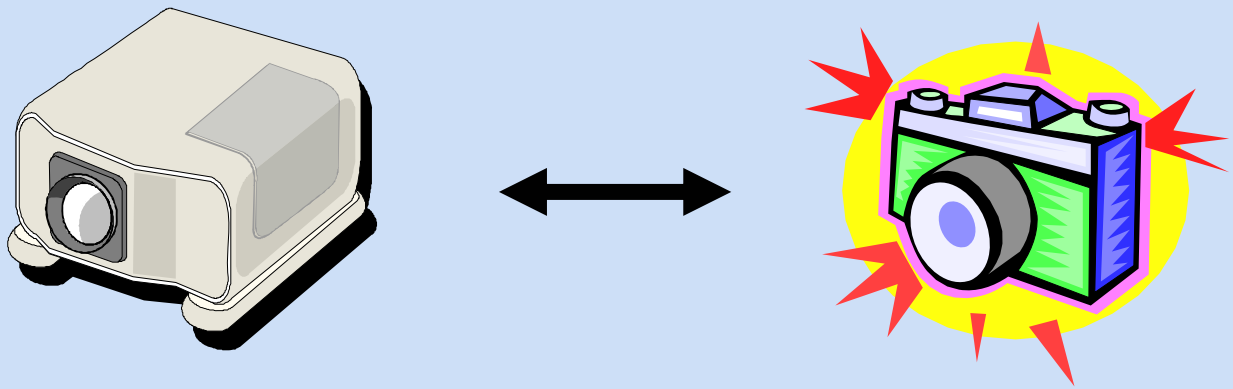
  - Projector as dual of a camera



Machine ‘Projection’

- Image Projection vs Machine Projection
- Machine Vision with projectors
  - Project images to assist machine computation



VitaPhone
('Don Juan' 1926)

Soundtrack recorded on film

EXTRA! Vitaphone! "Don Juan" EXTRA!

VARIETY

"DON JUAN" LOS ANGELES, CALIF., WEDNESDAY, OCTOBER 27, 1926 VITAPHONE

VITAPHONE THRILLS L. A.

REMARKABLE FIRST NIGHT CROWD ACCLAIMS VITAPHONE

Critical Audience of Celebrities and General Public Thrills at Introduction of New Instrument—Vitaphone Called "Great Invention"

NEW ERA IN PICTURES, SAYS HAYS OF THE VITAPHONE

M. P. Czar First Man to Address Public Through New Device—Welcomes Synchronized Music as Big Advance in Industry—Sees Great Possibilities

IT REPLACES PROLOGUE

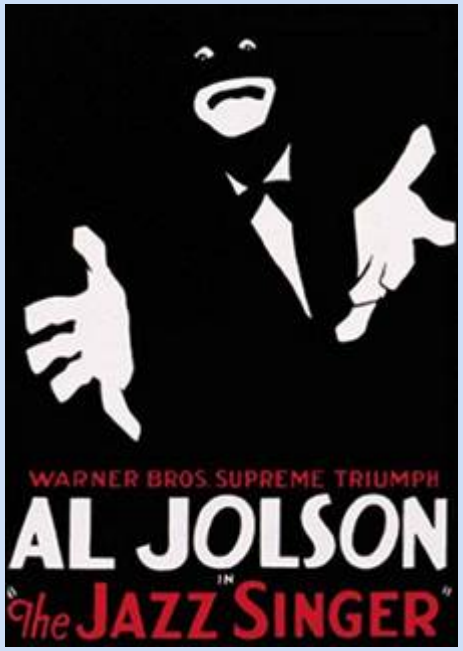
By ARTHUR UNGAR

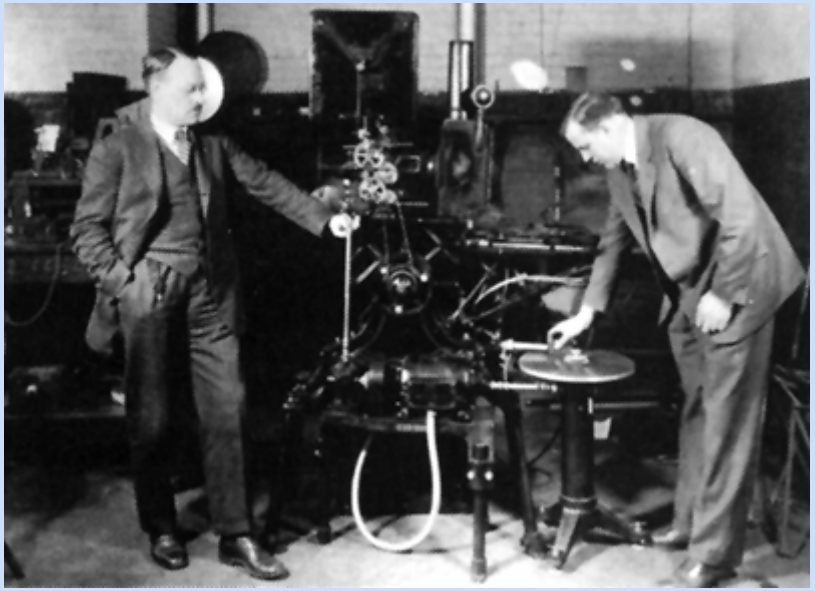
WARNER BROS. ROAD SHOWS AS UNITS

"Don Juan" First to Go Out with Vitaphone Presentation

SELL OUT FOR OPENING OF VITAPHONE

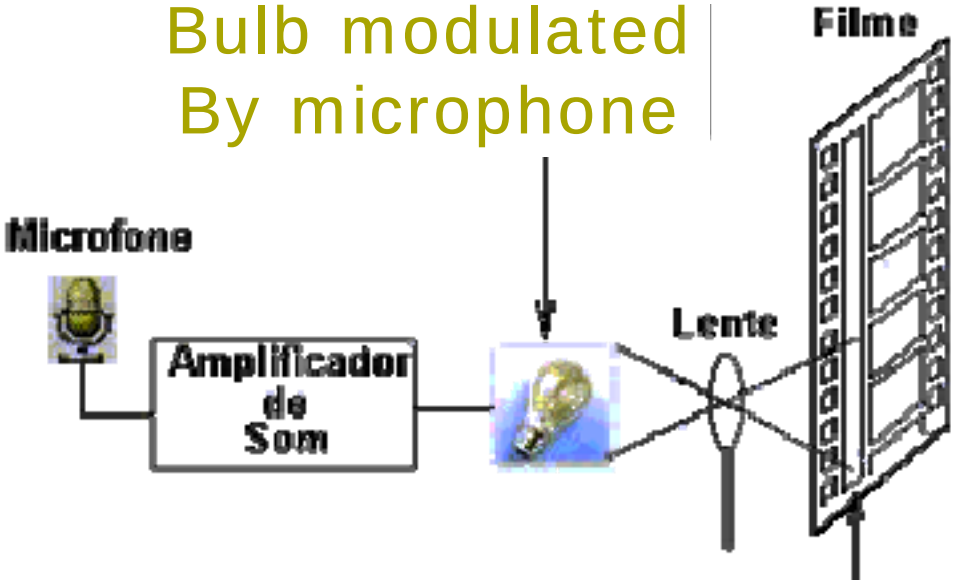
Music Lovers Crowd Grauman's Egyptian to Hear First Performance





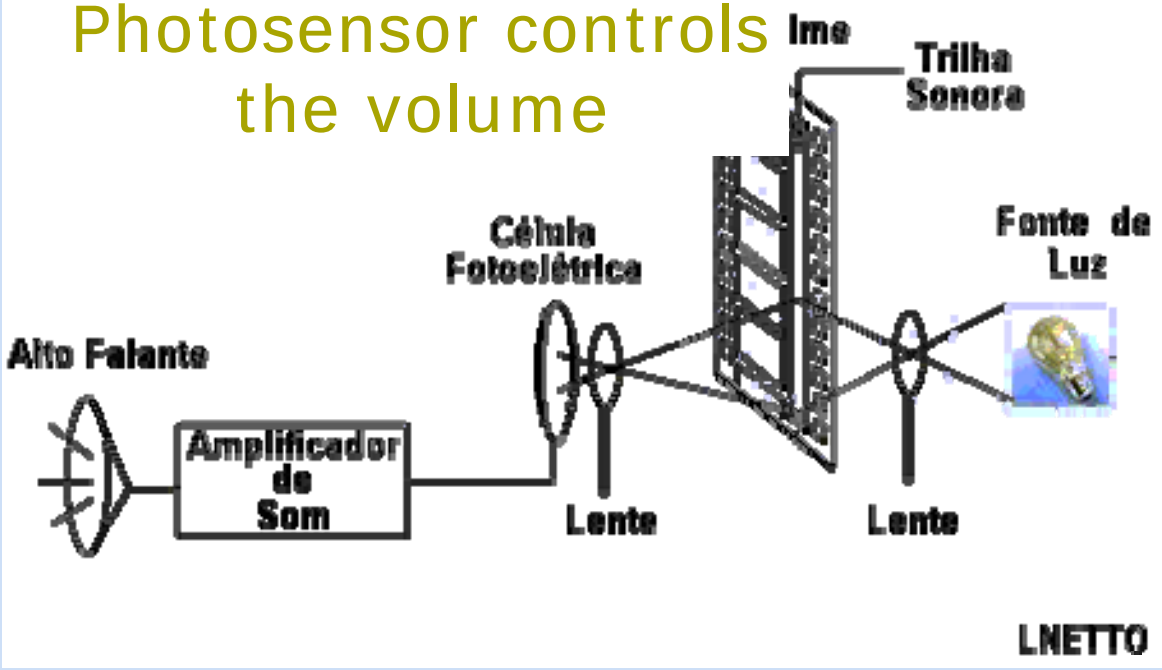
Recording

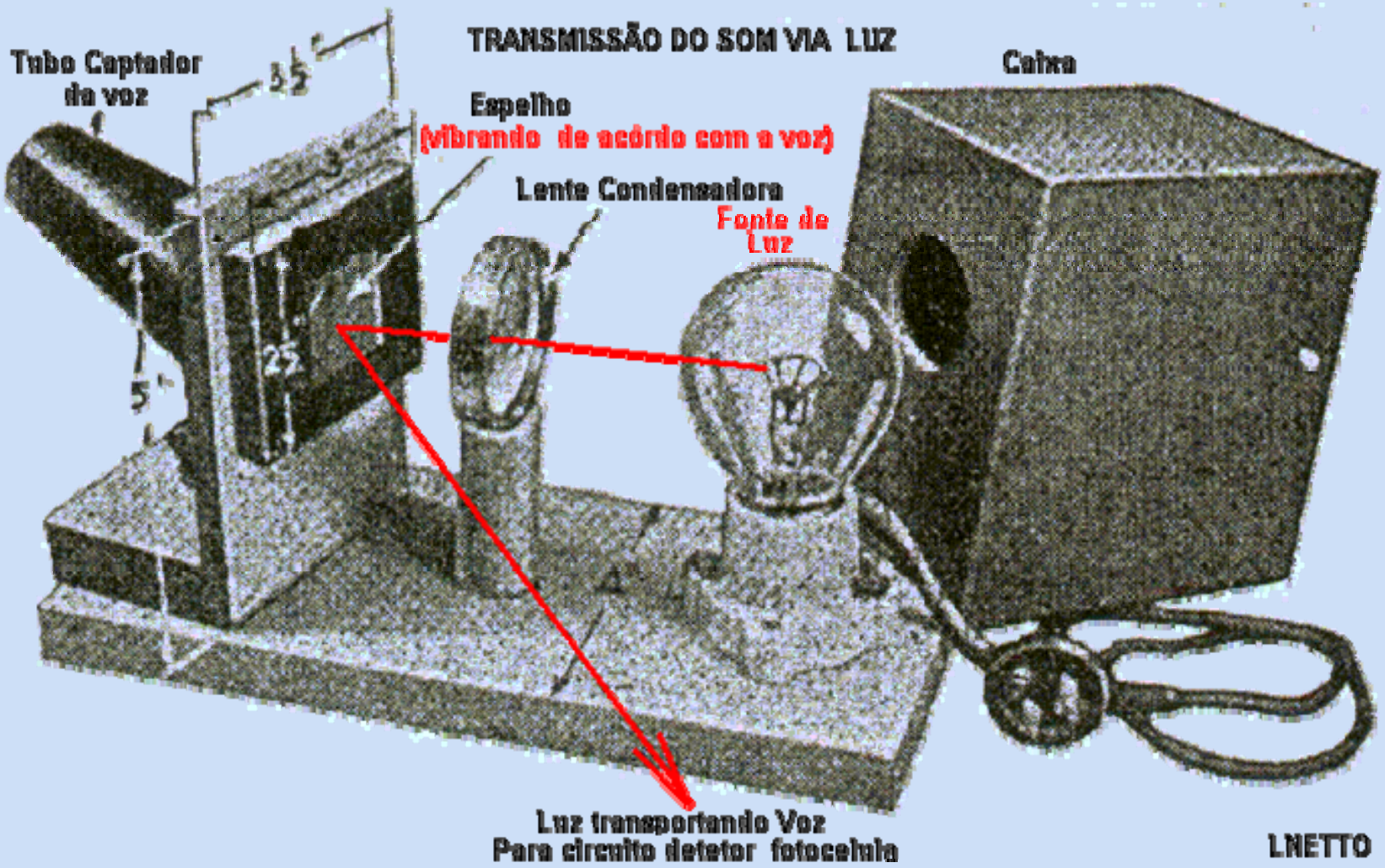
Bulb modulated
By microphone

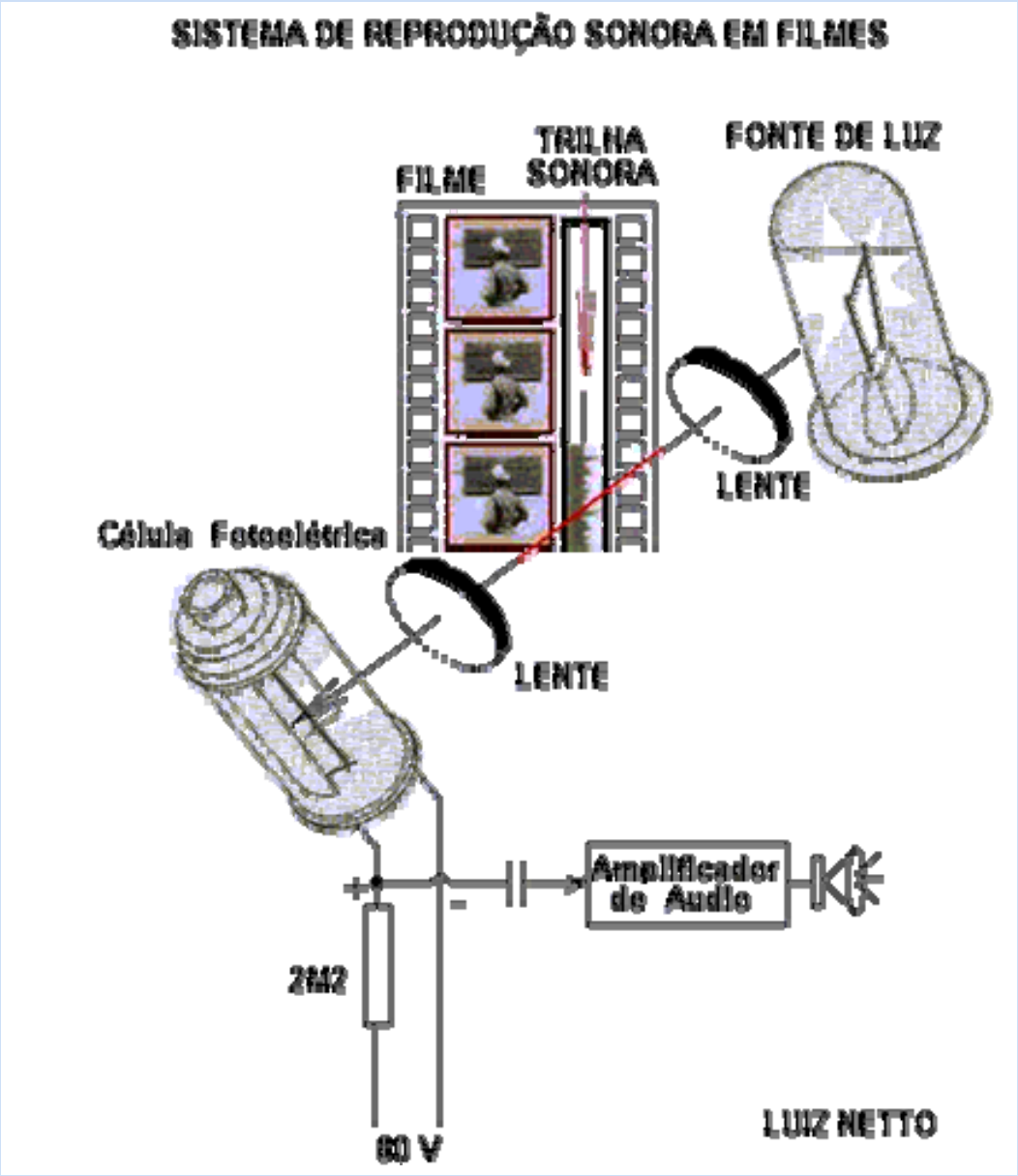


Reproduction

Photosensor controls
the volume

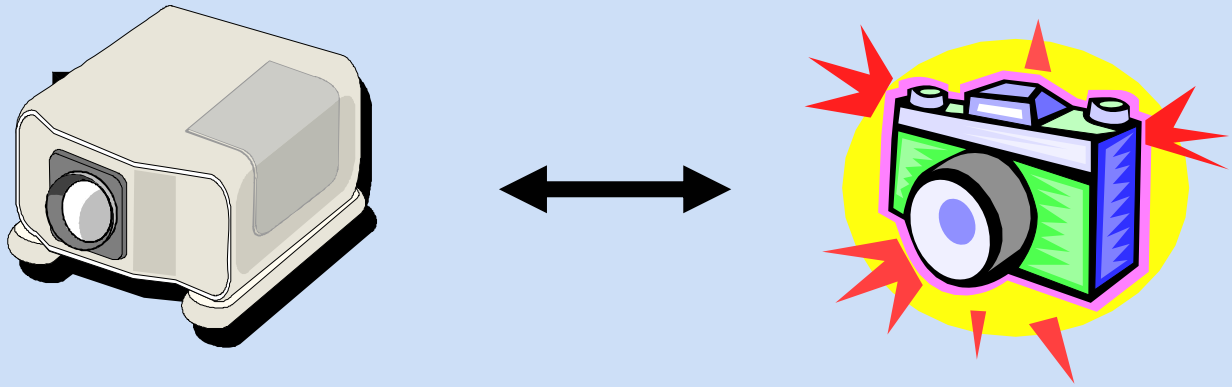



TRANSMISSÃO DO SOM VIA LUZ
Tubo Captador da voz
Espelho
(vibrando de acôrdo com a voz)
Lente Condensadora
Fonte de Luz
Caixa
Luz transportando Voz
Para circuito detetor fotocelula
LNETTO

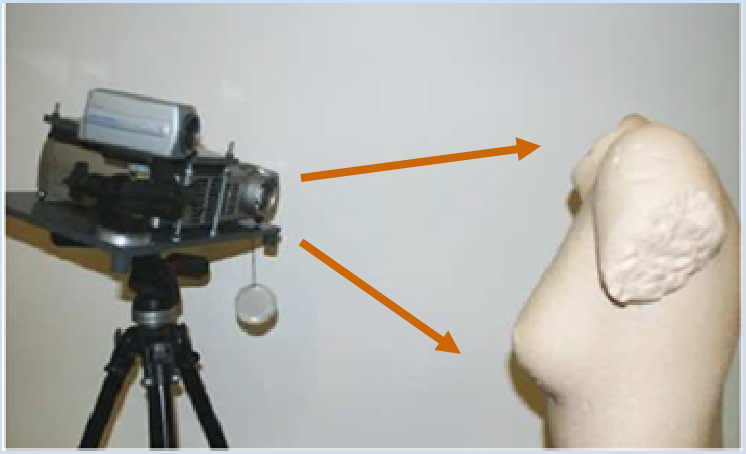

SISTEMA DE REPRODUÇÃO SONORA EM FILMES
TRILHA SONORA
FONTE DE LUZ
FILME
LENTE
Célula Fotoelétrica
LENTE
Amplificador de Audio
2M2
90 V
LUIZ NETTO

Machine ‘Projection’

- Machine Vision with projectors
  - Project images to assist computation
- Projector - a 3D projection device
  - Projector is a dual of a camera
  - Modulation and direction control



Structured Light for 3D Scanning



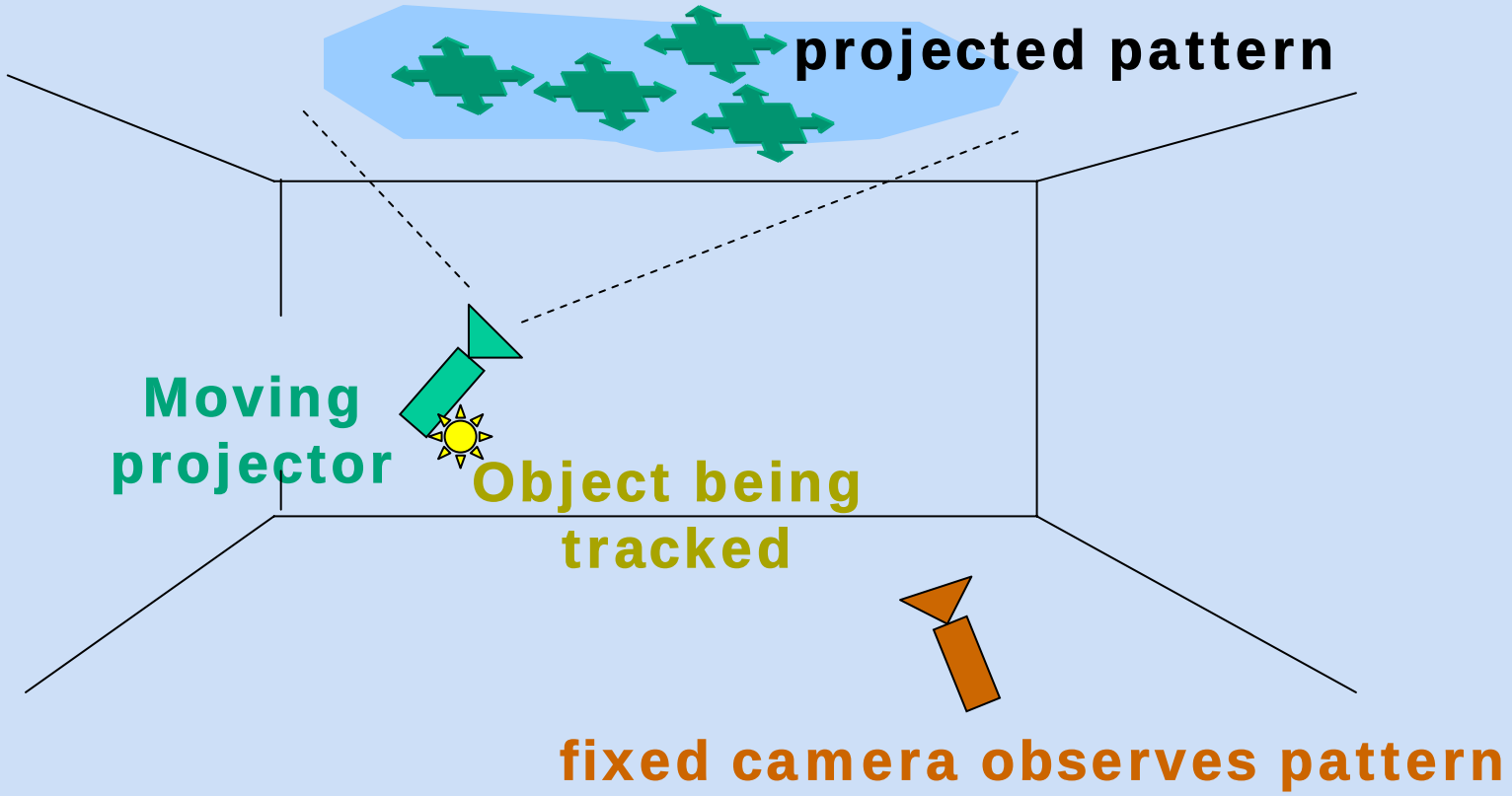
Need to be supported as a feature with each projector

[Jaeggly, Chang]

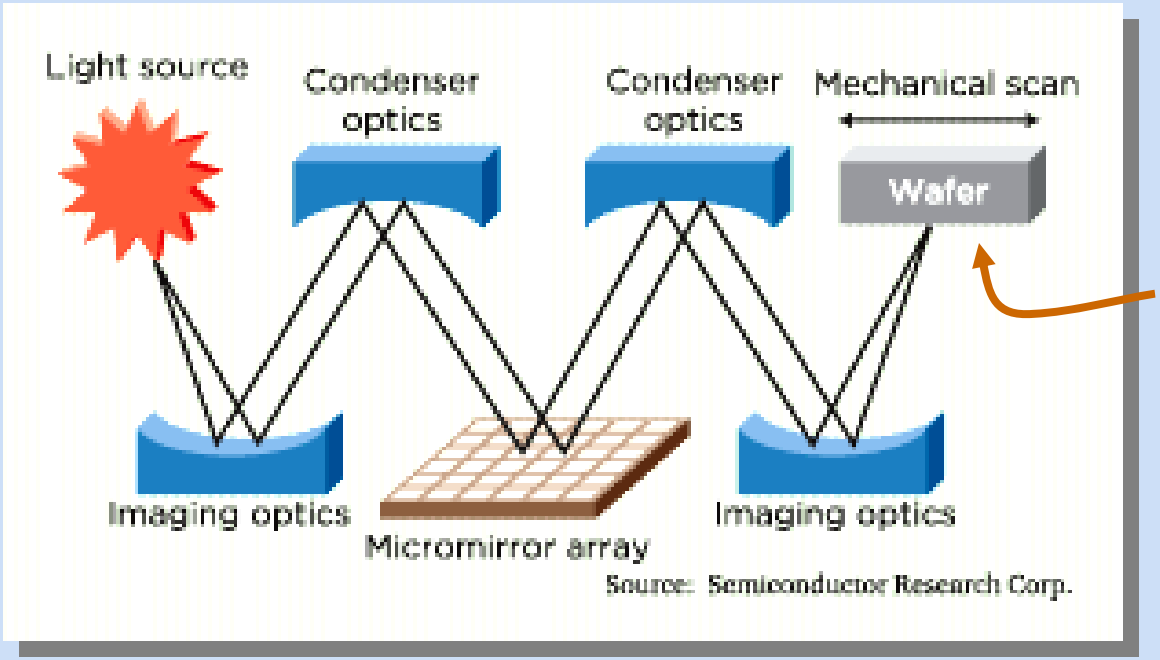
Striped Projection

Portable Tracking System

Beardsley, Raskar 2002

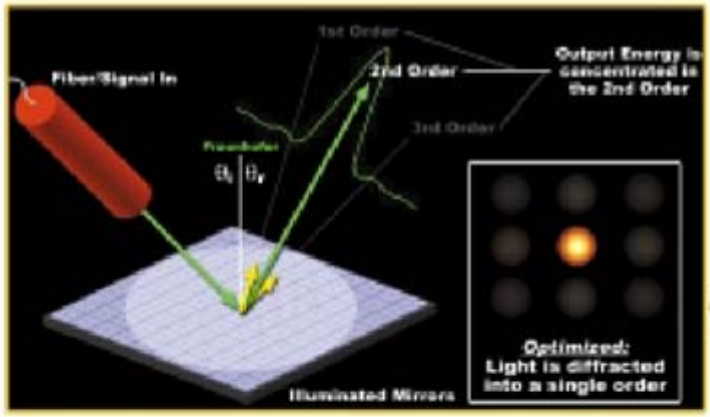


Maskless Lithography



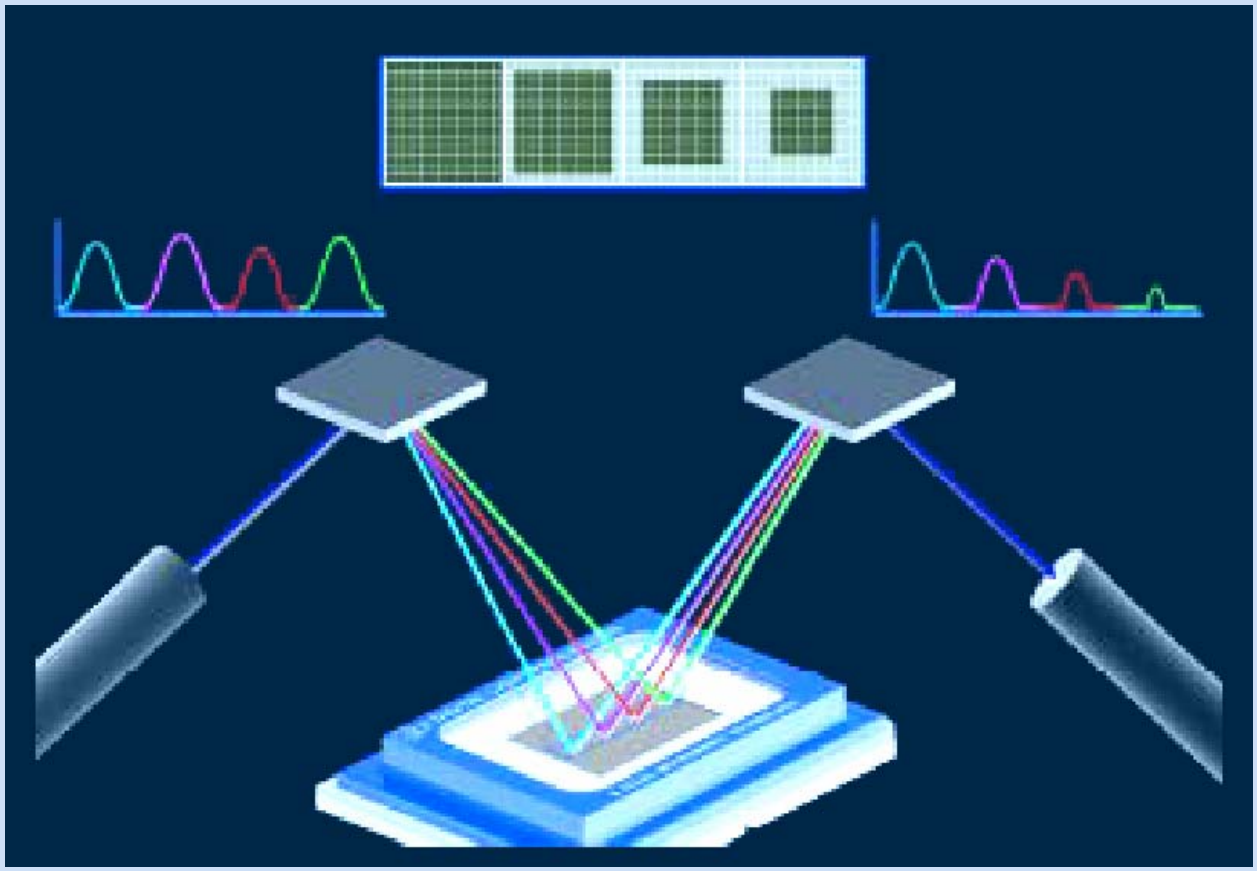
DLP Micro-mirror array
Fast parallel operation on optical resists

Optical Networking Gear



Parallel Switching and Routing at ~100KHz
Fixed diffraction grating + Optical switches

Optical Signal Processing



Multi-wavelength Operation (bandpass)
Encoding/decoding/transcoding

‘Machine Projection’ Applications

- Structured light for 3D scanning
- BRDF acquisition
- Tracking
- Etching, lithography
- Optical signal processing
- Optical networking gear

- How can we exploit image+machine projection ?

Discussion
Large Proj-Displays: Will they survive ?

- Controlled environments
  - Movie Theaters, IMAX, Planetariums
  - Digital Cinema, large visualizations
- Screen Technology
  - Active materials, Holo-screens
- Ad-hoc Tiling
  - Smart projector units instead of systems
- Displays tied to interaction
  - Multiuser touch sensitive, e.g. DiamondTouch
- Super cheap proj (maybe $200)
  - Completely new markets, casual use

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Display Dilemma

- Short opportunity to get back in the race
- Many interesting problems remain
- Lets exploit the 'proj-cam' aspect, new apps
  - Decoupled imagery: Aware handy projector
  - Overlay: Augment real world
  - Camera dual: Machine 'projection'
- *'Every mm at every ms'* - Henry Fuchs