

CMU
Image Understanding
Program

September 11, 1990

Takeo Kanade

CMU
Image Understanding
Program

Takeo Kanade

Physics-Based Vision

Sensor Development

Very Fast Range Finder

Photo Sampler

**Vision for Object Recognition and
Manipulation**

Vision for Navigation

Parallel Vision

Physics-Based Vision I

Color and Reflection

- Color understanding
- Shape from interreflection
- Unified reflection model

Physics-Based Vision II

Shape, Motion and Texture

- Factorization method for shape and motion from image stream
- Adaptive window for stereo matching
- Texture analysis by image spectrogram

Physics-Based Vision III

Calibrated Imaging Lab

- Renovation and new equipment
- Camera control for high quality imaging

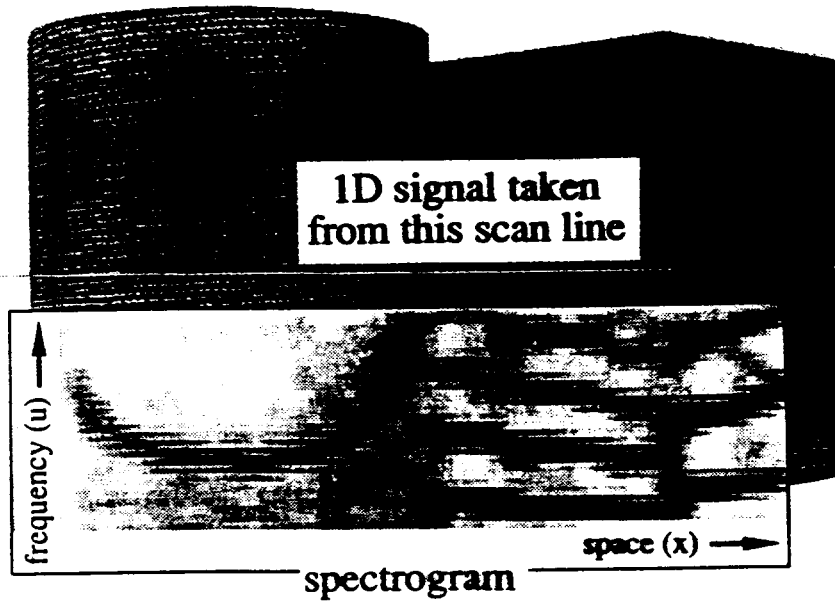
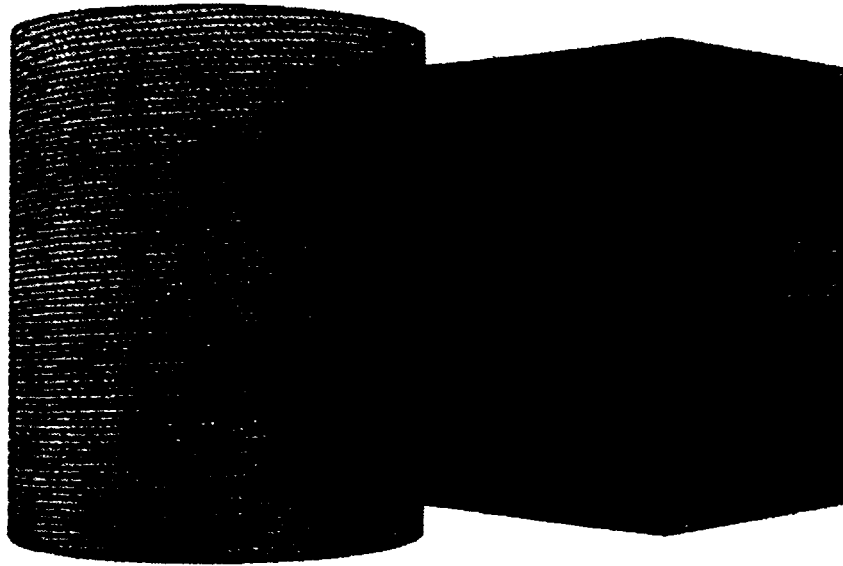
Object Recognition and Manipulation III

Task-Oriented Vision Paradigm

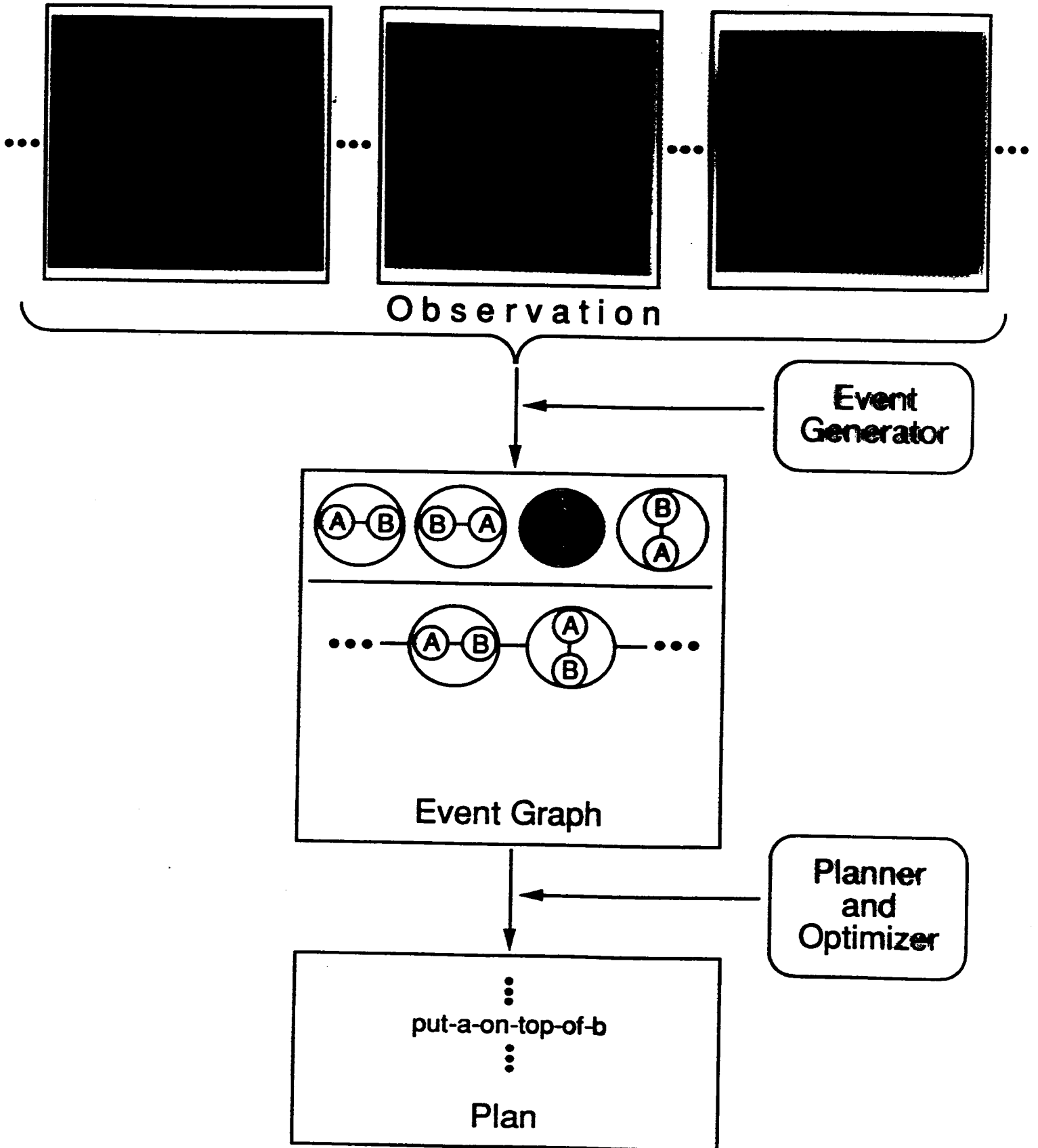
Navigation I

CMU Navlab

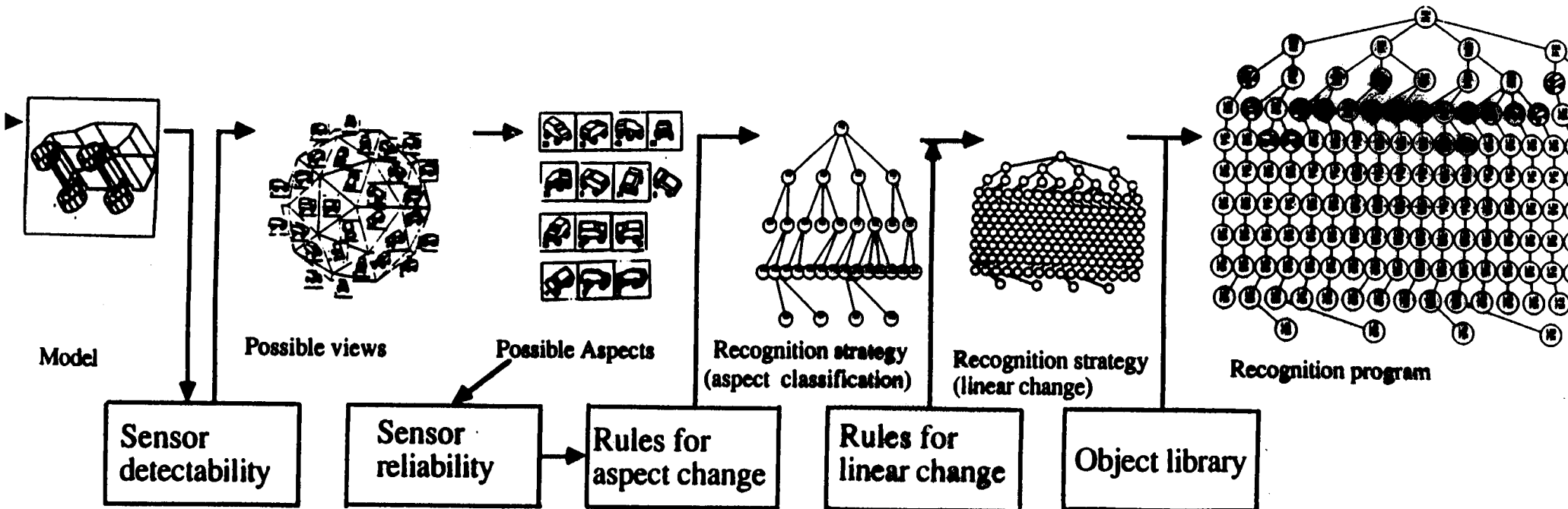
- Continued to advance components, capabilities, architecture, and system demonstration
- Color vision - SCARF, YARF
- Annotated map
- Map building by active sensor
- Mail (Coke, beer) delivery demonstration
- Architecture tool kit - EDDIE



Learning From Observation



Constructing Vision Algorithm Compiler for Bin-picking Tasks



Vision Algorithm Compiler

Vision Algorithm Compiler for object localization task

- top most object -- VANTAGE
- occluded object

Vision Algorithm Compiler for object recognition task

- air planes in SAR images -- MISTER
- cars in NAVLAB images

Vision Algorithm Compiler for object inspection task

- metal surface -- PHOTOSAMPLING

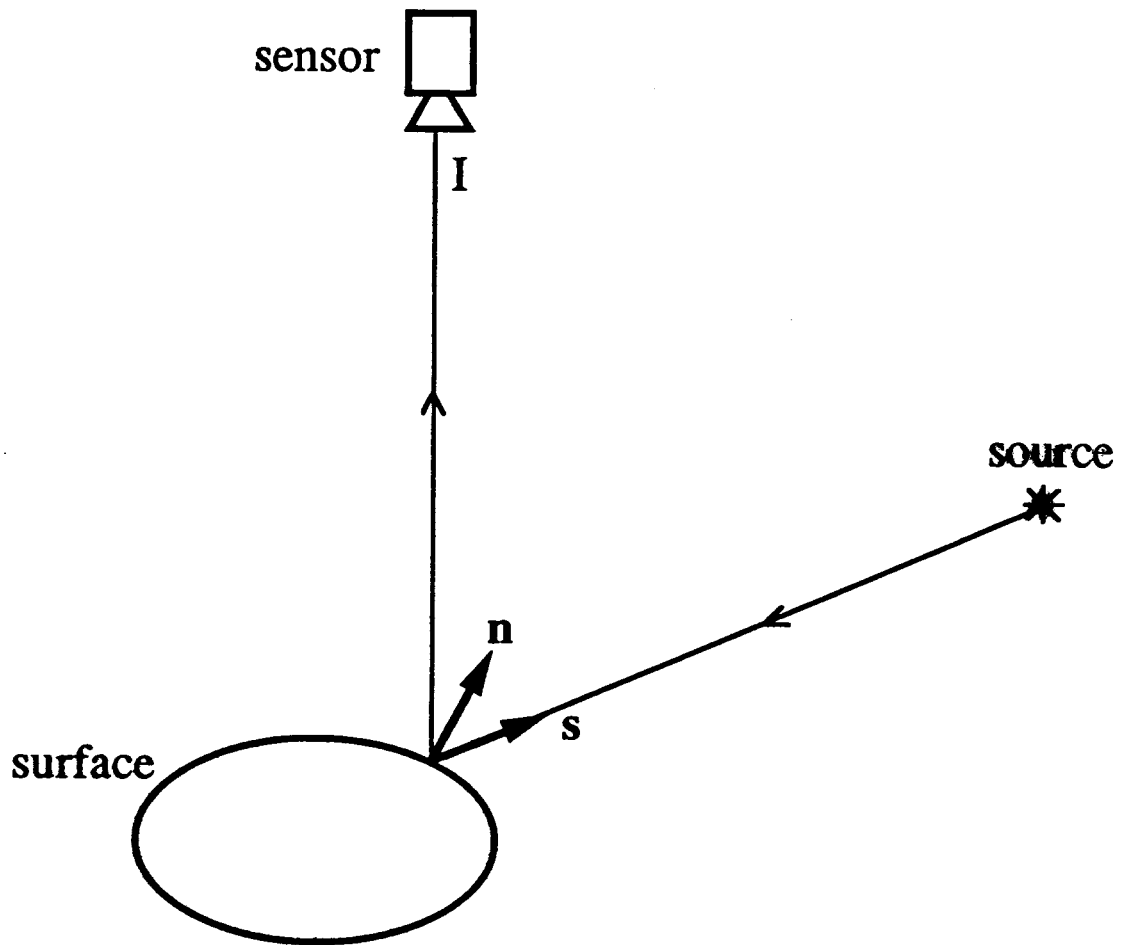
Vision Algorithm Compiler for hand-eye task

- assembly -- ROBOT WORLD

Vision Algorithm Compiler for navigation task

Vision Algorithm Compiler for

Shape from Intensity



• $\{ I, s \} \longrightarrow n$

• Existing Techniques:

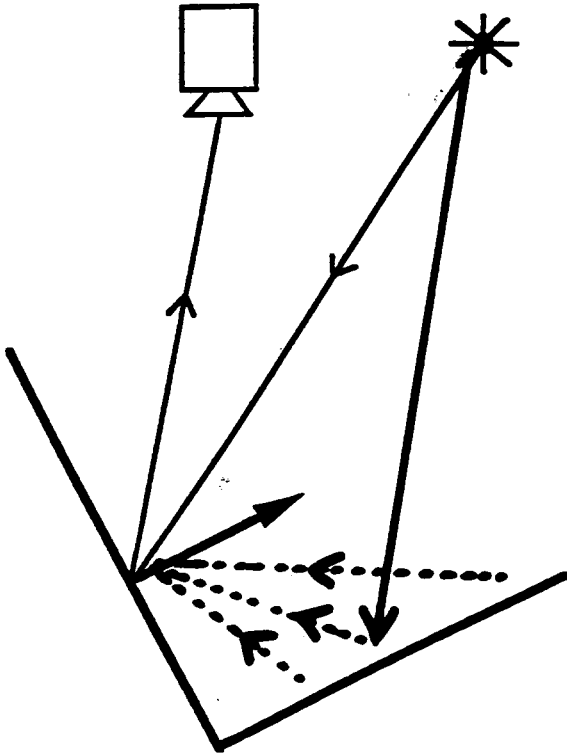
- Shape from ShadingHorn (1970)
- Photometric StereoWoodham (1978)
- Photometric SamplingNayar, Ikeuchi, Kanade (1989)

⋮

SINGLE CONVEX SURFACE ONLY !

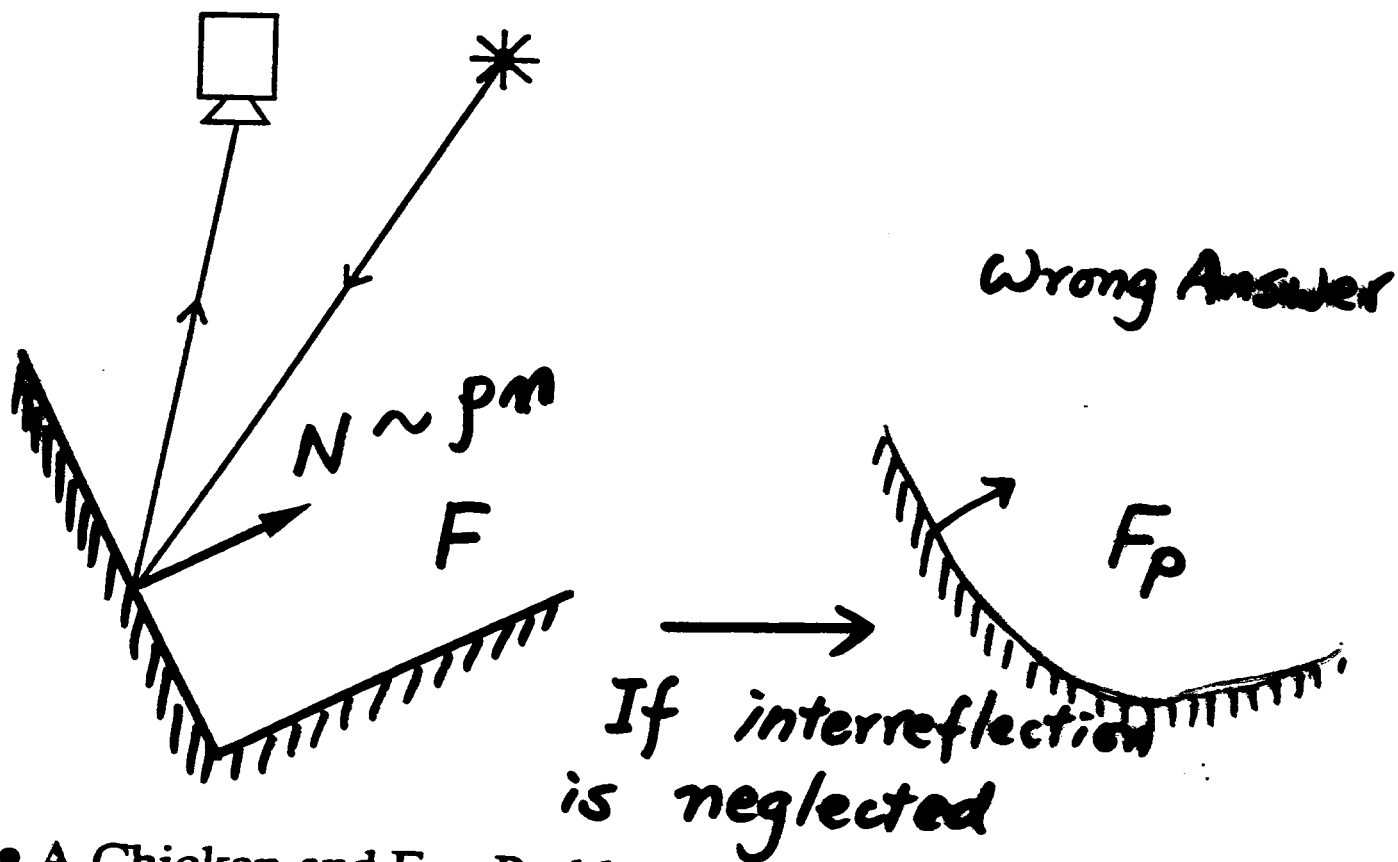
Interreflection Problem

- Problem with *all* Shape-from-Intensity Methods

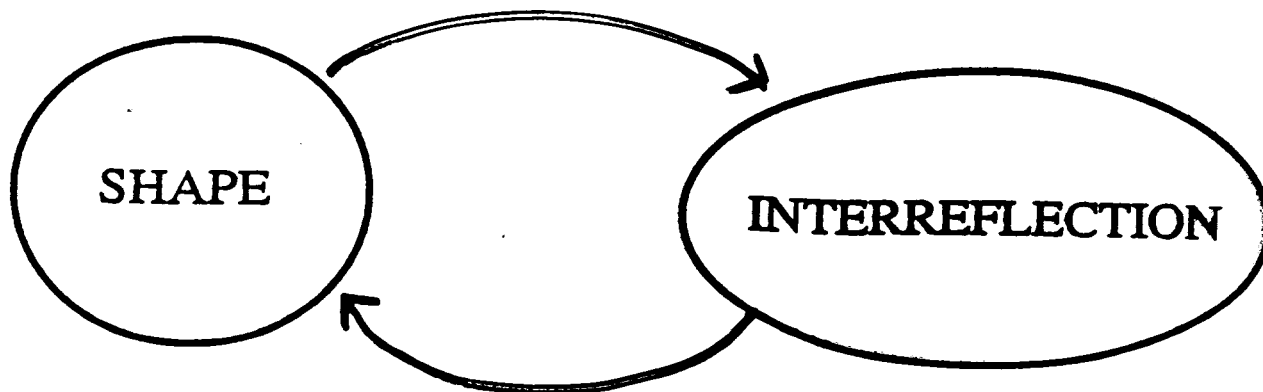


Interreflection Problem

- Problem with *all* Shape-from-Intensity Methods



- A Chicken and Egg Problem



- Graphics

$$L = (I - PK)^{-1} L_s$$

↑
|
^

Total Radiance shape Radiance due to S only

Reflectance

- F_p and F have the same relation!!

$$F_p = (I - PK)^{-1} F$$

Pseudo
Real

- Algorithm: for solving for F from F_p

$$F^{k+1} = [I - P(F^k) \cdot K(F^k)] F_p$$

where $F^0 = F_p$

Lambertian

Concave & Convex

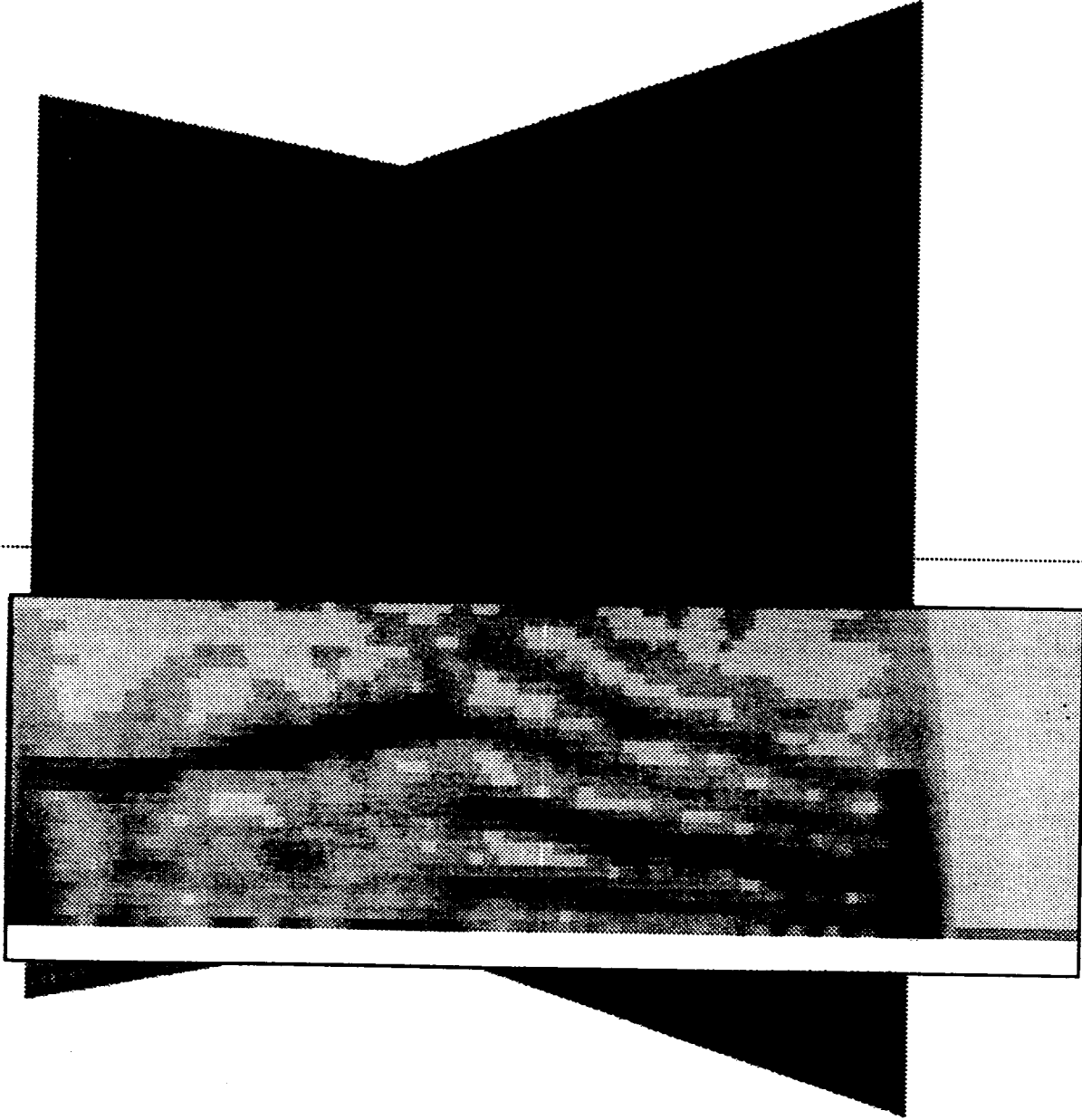
Arbitrary Unknown and
Varying Reflectivity

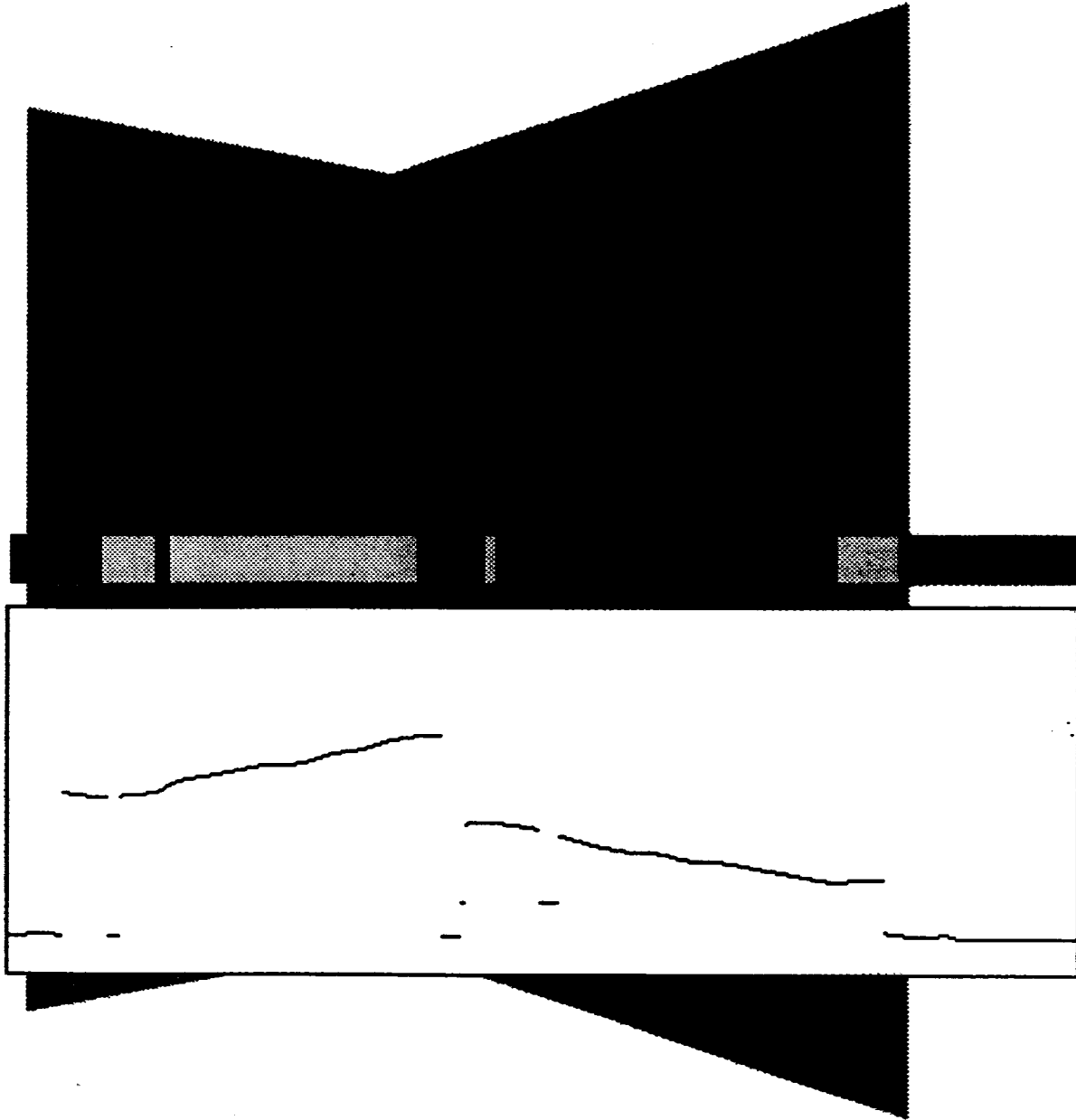
Adaptive Window

Intensity variation

Disparity variation

plates.tilt.texture.2.display.gif





Physics-Based Vision

Color and Reflection

Shape, Motion, and Texture

Sensor Development

Vision for Object Recognition and
Manipulation

Vision for Navigation

Parallel Vision

Physics-Based Vision

Sensor Development

**Vision for Object Recognition and
Manipulation**

Vision for Navigation

Navlab

Ambler

Underwater Vehicle

Parallel Vision

Physics-Based Vision

Sensor Development

**Vision for Object Recognition and
Manipulation**

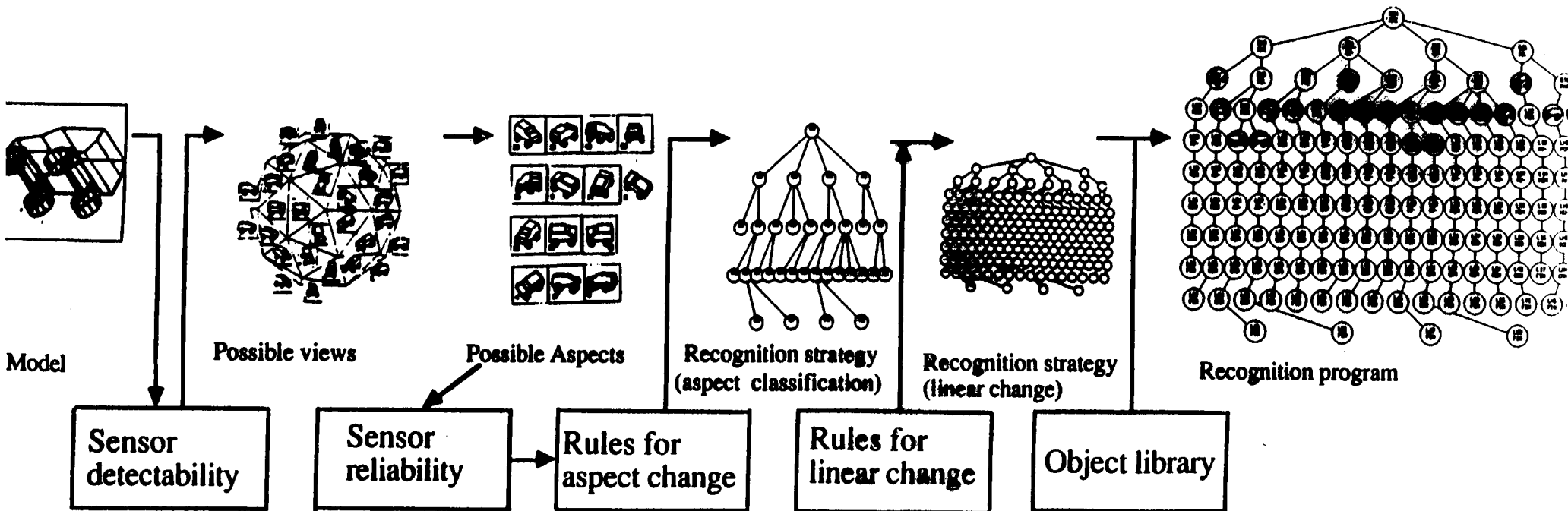
Vision Algorithm Compiler

Rock Sampling

Vision for Navigation

Parallel Vision

Constructing Vision Algorithm Compiler for Bin-picking Tasks



Experiments: 2-D

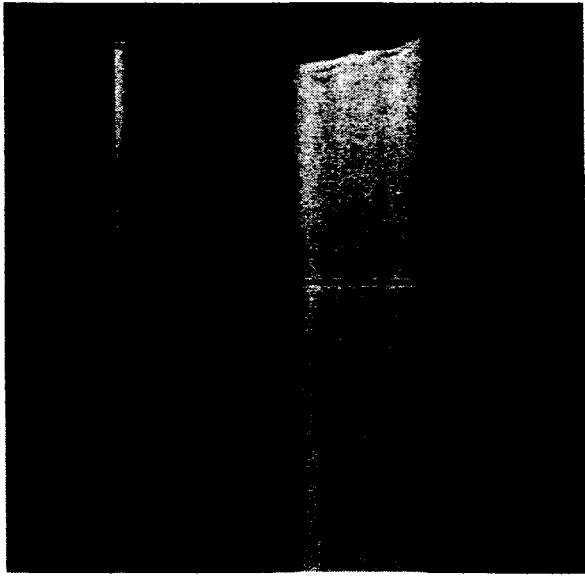


Photo of Object

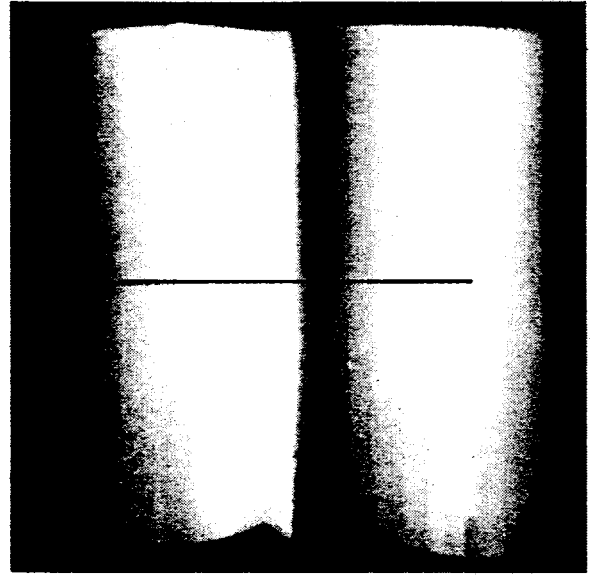
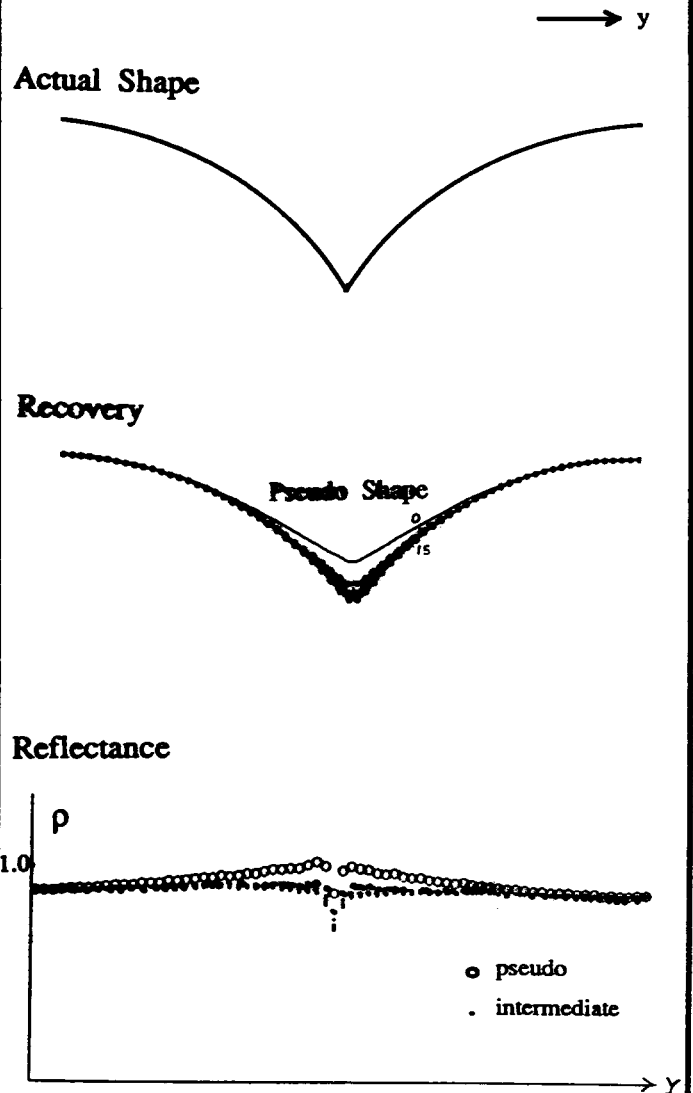
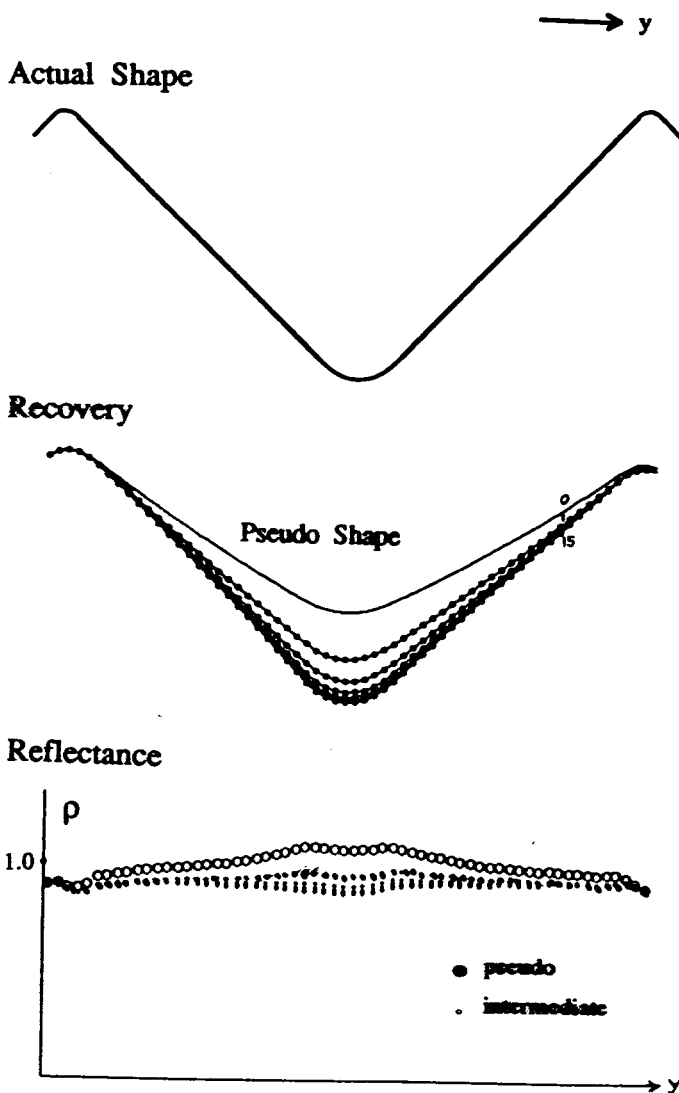
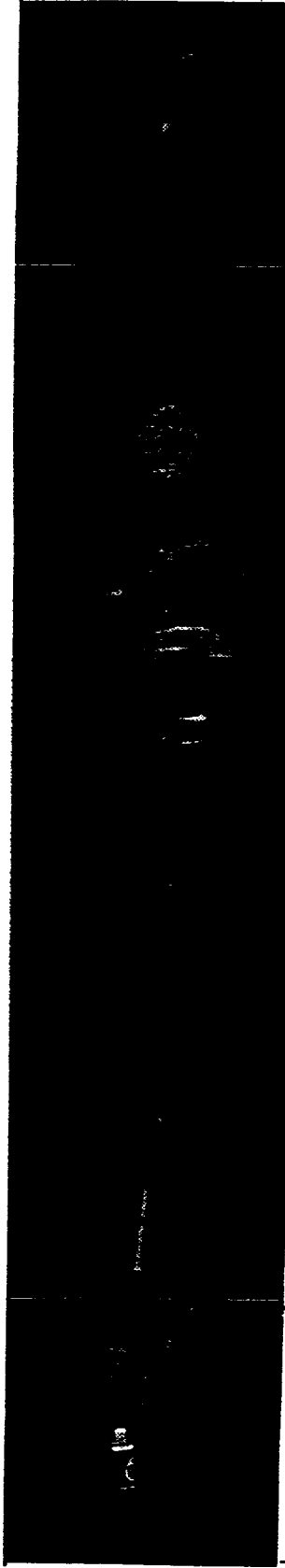
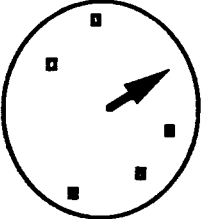
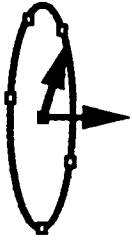

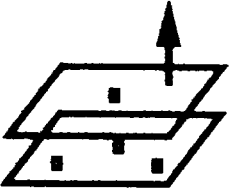
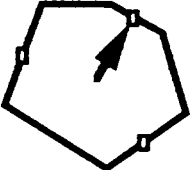
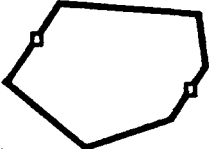


Photo of Object



grasping type	required functional capabilities	representation
	 <p>~ <i>center</i> ~ <i>radius</i></p>	superquadrics
	 <p>~ <i>center</i> ~ <i>radius</i> ~ <i>axis direction</i></p>	generalized cylinder
	 <p>~ <i>center</i> ~ <i>radius</i> ~ <i>axis direction</i> ~ <i>pulling direction</i></p>	superquadrics plus pulling direction
	 <p>orientation position of two planes width</p>	two parallel planes
	 <p>center radius</p>	cross-sectional shape
	 <p>position of points orientation</p>	two contact positions

Object Recognition and Manipulation II

Sampling of Rocks

- Natural object (rocks, pebbles) localization and manipulation

Object Recognition and Manipulation III

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Sensor Development

>100 Frames/sec Range Finder by Analog VLSI

Photometric Sampler (3D)

Object Recognition and Manipulation I

Vision Algorithm Compiler

- Automatic generation of object recognition program from object and sensor models
- Minimum cost recognition strategy
- Complex Extended Gaussian Image (CEGI)

Navigation II

Ambler

- Six-legged walker for autonomous planetary exploration

FAU / CMU Underwater Vehicle

Navigation I

CMU Navlab

- Continued to advance components, capabilities, architecture, and system demonstration
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Parallel Vision

Application of Warp, i-Warp, and Nectar

Architecture-Independent Programming Method

- Apply
- Adapt