# 3차원 혼합현실 방송 컨텐츠 기술

연세대학교
전기전자공학과
손광훈

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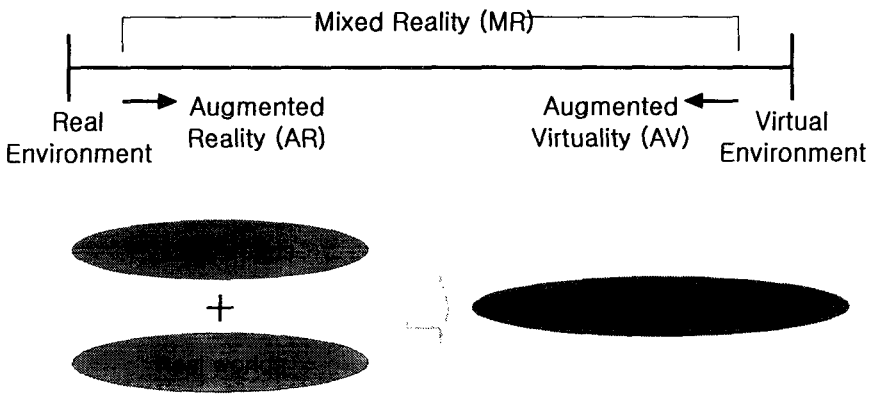
## Mixed Reality

❋Mixed Reality

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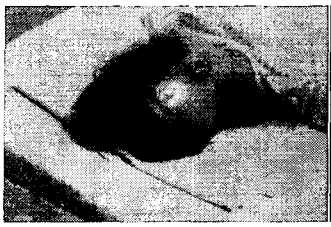
# Applications



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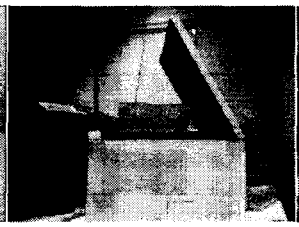
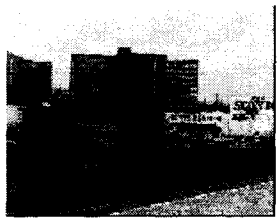


<Hand-free manual>

<simulated combat>

Model



<Construction plan>

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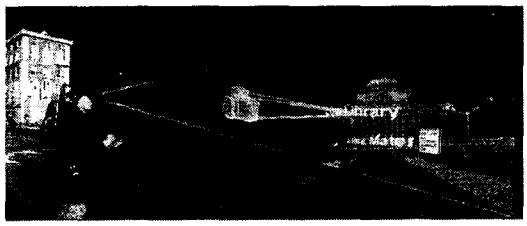
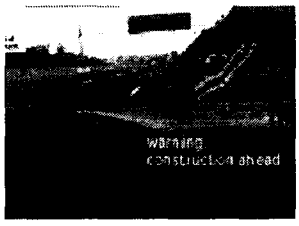
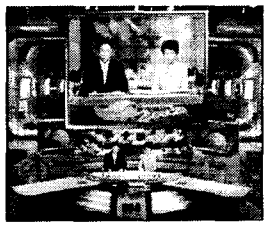
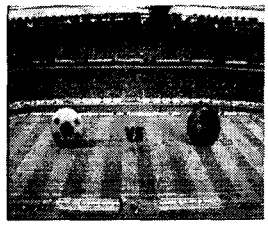
# Applications





<Public information>





<Broadcasting>

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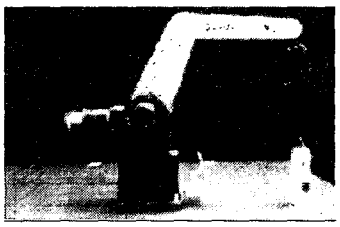
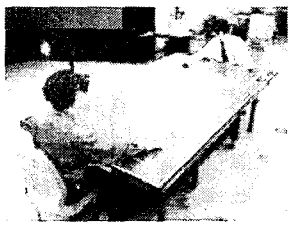
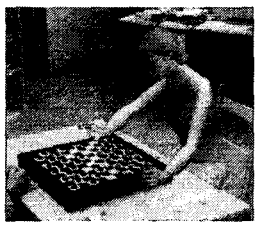
# Applications

<Wearable computer>







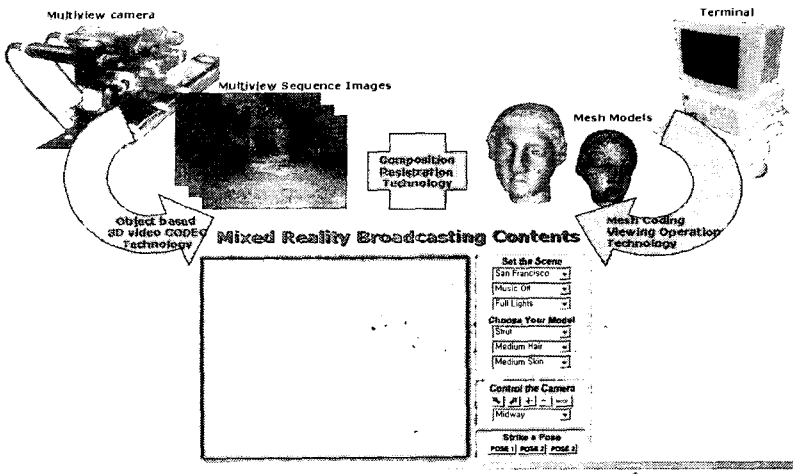
<Robot path planning>

<Entertainment>

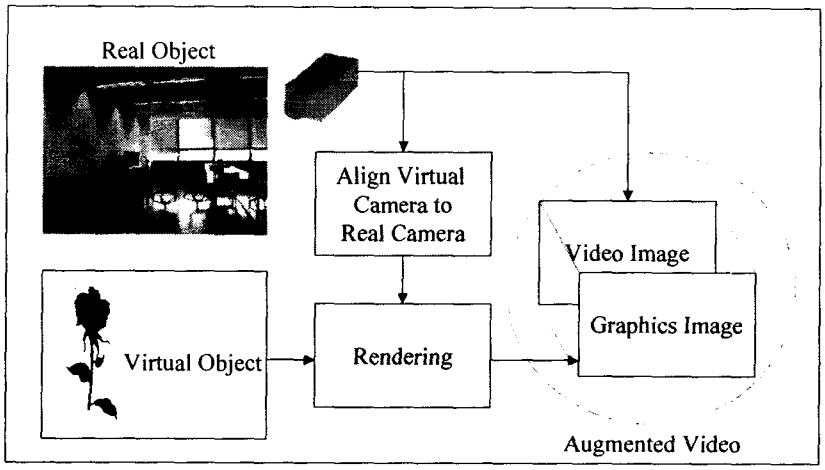


# Applications

## ❋Interactive MR broadcasting system



# Mixed Reality System

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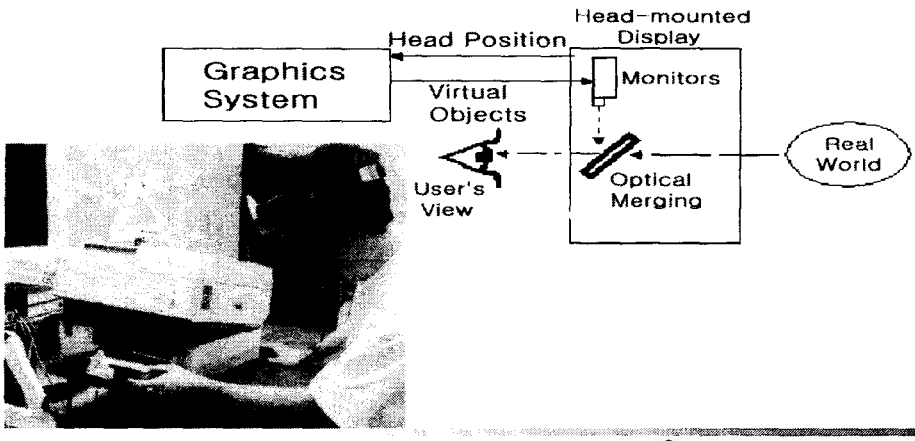
# MR System

- Display Device
  - **Optical see-through HMD**

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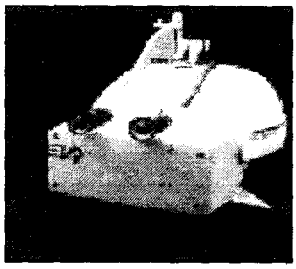
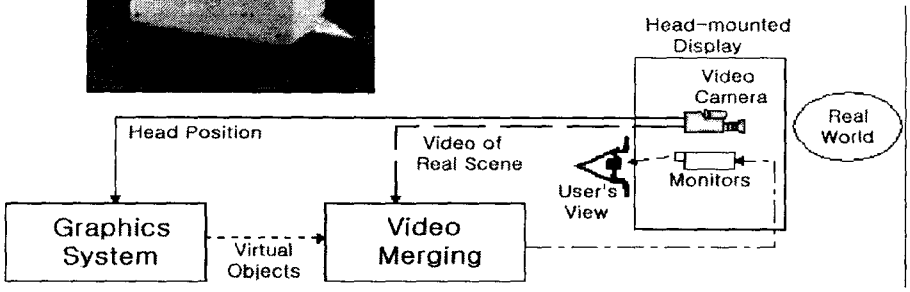
# MR System

- Video see-through HMD



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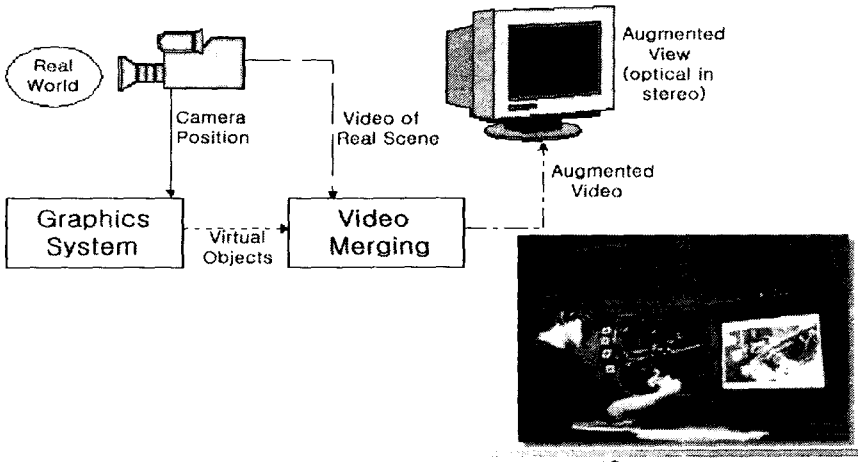
# MR System

- Stereo glasses-Monitor Based System

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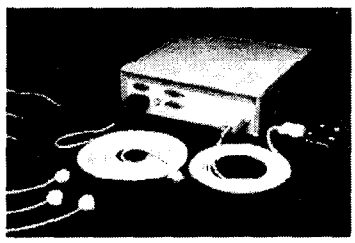
## MR System

❋ Haptic device

❋ Tracking Device



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## 3D Image Processing

❋ 3D?

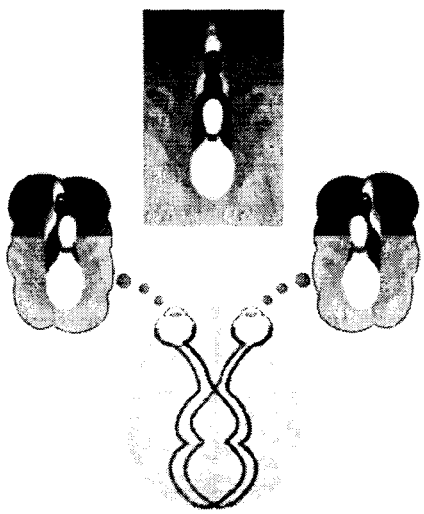
- 2D = width + height
- 3D = 2D + depth
  Increase reality

❋ Human perception

- Two eyes + Brain
  two 2D images  a 3D view

❋ 3D video sequence

- Left eye view sequence
  + Right eye view sequence



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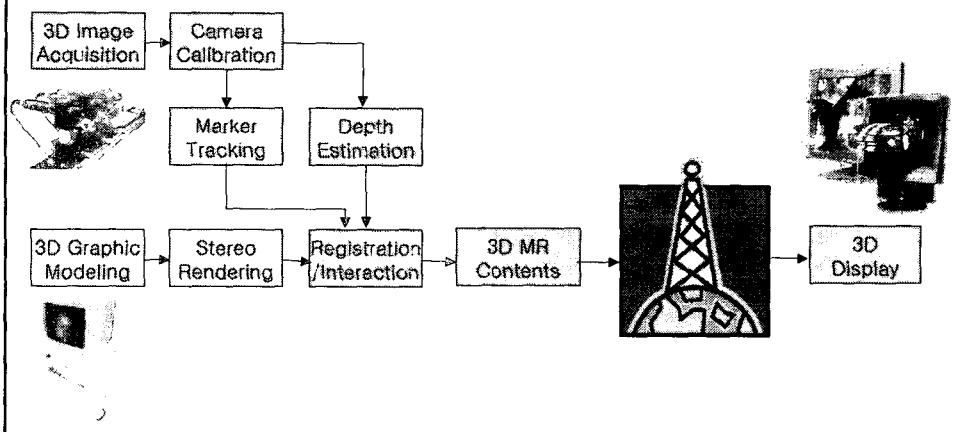
# 3D MR System



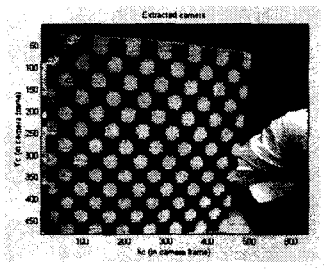



# Key Techniques

- ❋ Virtual Object Generation
  - 3D Modeling & Photorealistic Rendering
- ❋ Camera Calibration & Image analysis
  - Camera calibration
  - Feature extraction
  - Depth estimation
- ❋ Marker tracking & Registration
  - Realtime marker tracking
  - Object registration
- ❋ Synthesis & Interaction
  - Media Synchronization
  - HCI
  - Mutual interaction between real and virtual world

# Camera Calibration

- The extrinsic parameters
  - Translation matrix, T
  - Rotation matrix, R
- The intrinsic parameters
  - Focal length, f
  - The location, $(u_x , v_y)$
  - Effective pixel size $(s_x , s_y)$
  - The radial distortion coefficient, k(or θ)

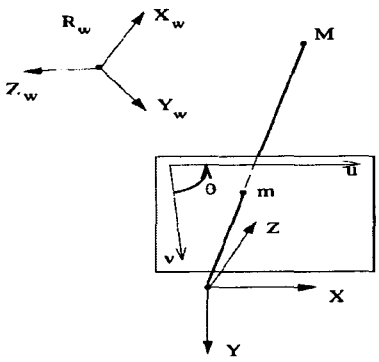





# Camera Calibration

- Camera model and stereo geometry
  - maps a 3D point to 2D image point

$$\begin{bmatrix} x \\ y \\ s \end{bmatrix} = \mathbf{A} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \mathbf{D} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} = \mathbf{P} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$




P : perspective projection matrix

S : scale parameter

A : intrinsic parameters matrix

D : extrinsic parameters matrix

# Camera Calibration

$$\mathbf{A} = \begin{bmatrix} f \cdot k_u & f \cdot k_u \cdot \cot\theta & u_0 \\ 0 & f\dfrac{v}{\sin\theta} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \mathbf{D} = \begin{bmatrix} \mathbf{R} & \mathbf{t} \\ \mathbf{0}_3^{\mathrm{T}} & 1 \end{bmatrix}$$

*where*:
- $f$ : focal length
- $k_u, k_v$ : scale factors
- $u_0, v_0$ : principal points
- $\theta$ : angle between retina axes

*where*:
- $\mathbf{R}$ : $3 \times 3$ rotation matrix
- $\mathbf{t}$ : $3 \times 1$ translation vector

=>If we know both the intrinsic and extrinsic parameters of the stereo system, we can reconstruct the 3D location of the point *M* from *m1* and *m2*

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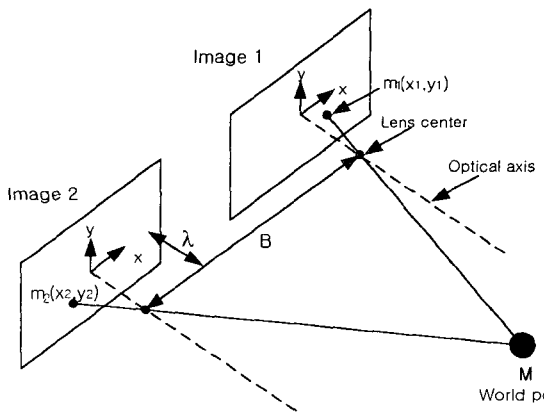
# Camera Calibration

❋Simple case of a parallel camera system




$$Z = \lambda - \frac{\lambda B}{x_2 - x_1}$$

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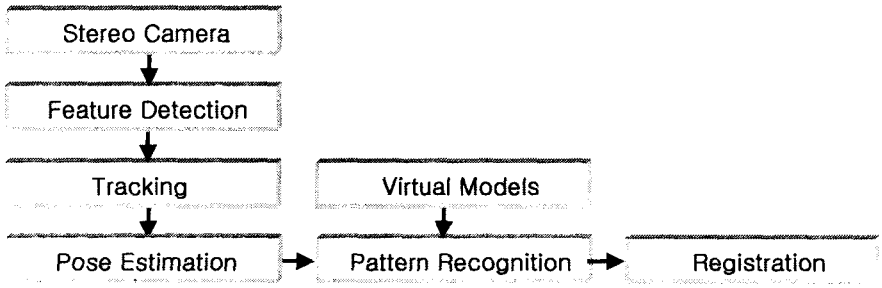
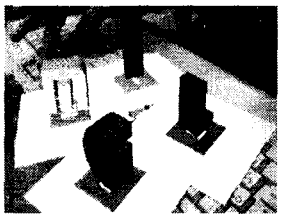
## Marker tracking & Registration



Left view

Right view

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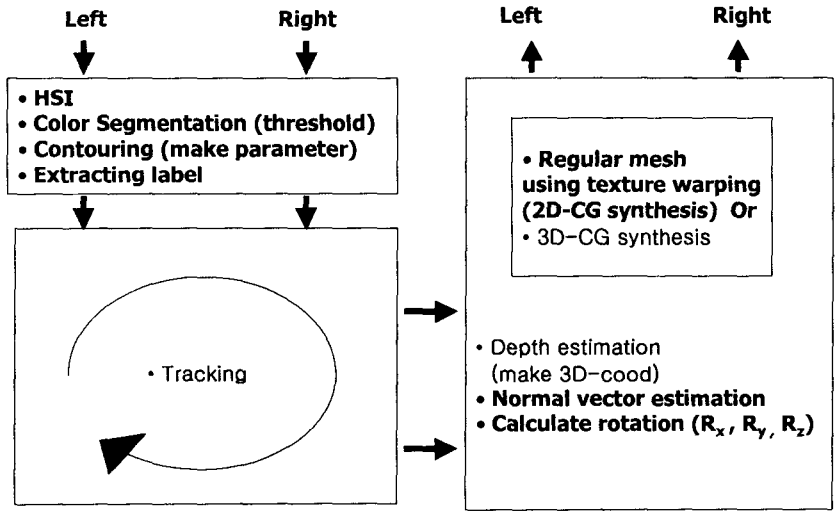
## Multimarker-based MR system

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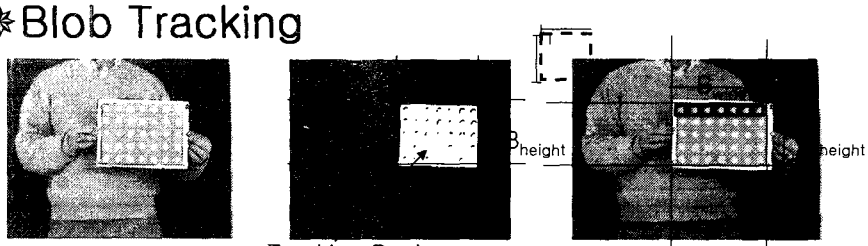
## DTM Multimarker-based MR system

❋HIS color enhancement

❋Blob Tracking




Tracking Region

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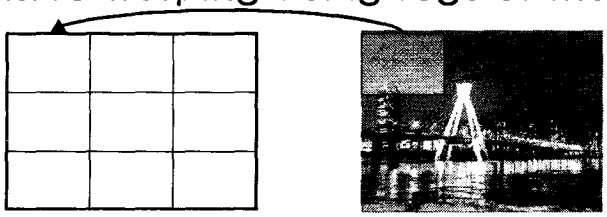
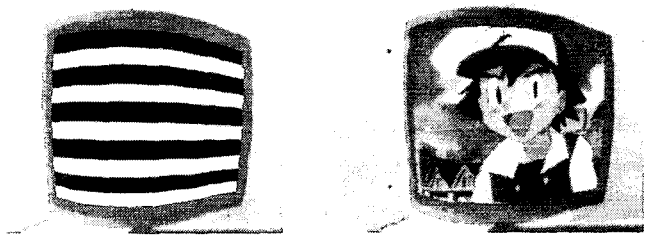
## DTM Multimarker-based MR system

❋Texture warping using regular mesh





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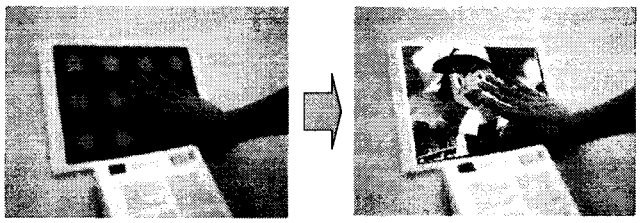
# Multimarker-based MR system

## ❋Lost Marker Estimation and Occlusion

- Lost blob position estimation from the rest of the blobs
- Synthesis using Depth data



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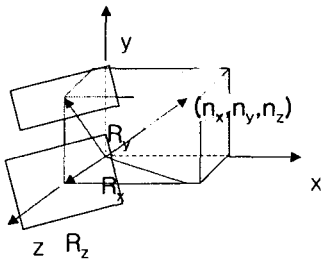
# Multimarker-based MR system

## ❋3D Object Registration

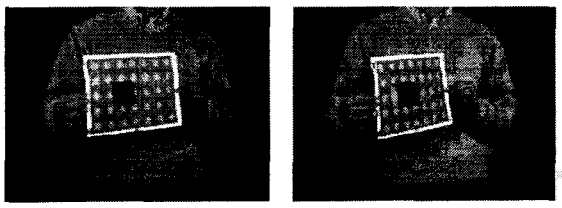
- Calculate the surface normal vector




$$R_x = a\cos(n_z / \sqrt{(n_y^2 + n_z^2)})$$

$$R_y = a\cos(n_z / \sqrt{(n_x^2 + n_z^2)})$$

$$R_z = a\cos(\sqrt{(y_2^2 - y_1^2)} / \sqrt{(x_2^2 - x_1^2)})$$



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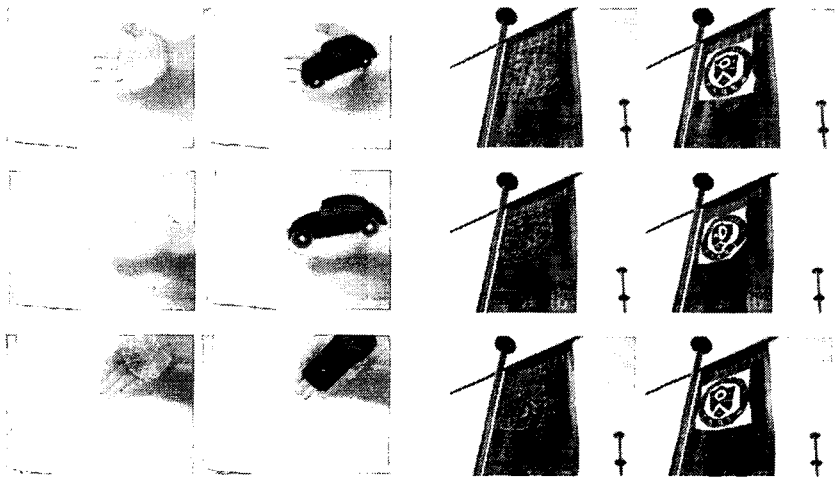
# Markerless MR system



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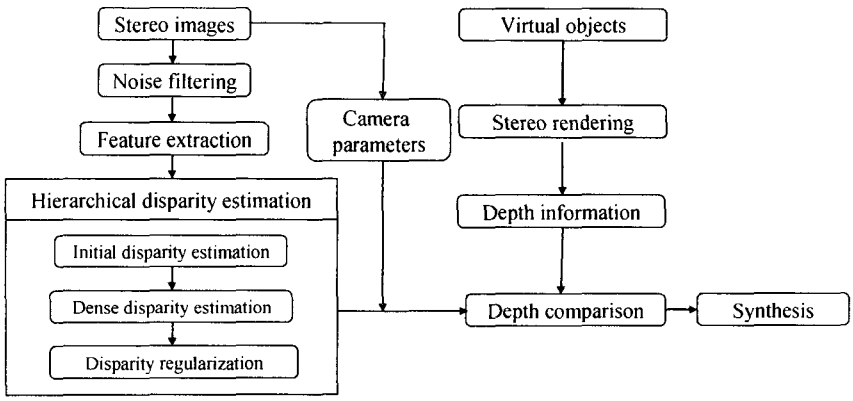
# Depth estimation & Synthesis

## ❋Block diagram

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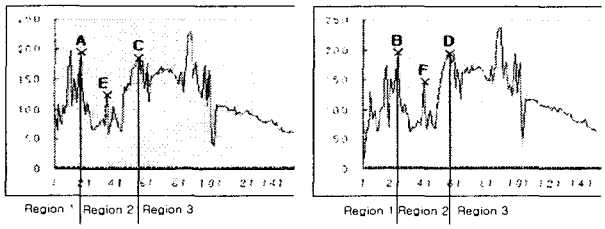
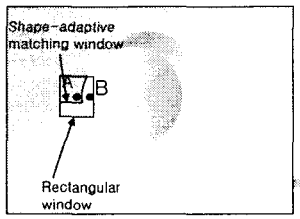
# Depth estimation

- Disparity estimation
  - Region-dividing technique




  - Shape-adaptive matching windows

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# Depth estimation

- Hierarchical disparity estimation
  - Initial Disparity Estimation
    - →Block-based disparity estimation in the subsampled images
    - →The region-dividing technique
  - Dense Disparity Estimation
    - →Pixel-based estimation in full resolution images
    - →The region-dividing technique and the shape-adaptive window technique

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# Depth estimation

❋ Dense disparity with occlusion

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# Depth estimation

❋ Disparity regularization

★ The resultant disparity vector map should be smooth and detailed

→ continuous surfaces should produce smooth disparity map

→ preserves its discontinuities at the object boundaries

- Regularization of the vector fields

→ By minimizing the proposed energy functional

$$E(d(r)) = \int_{\Omega} (I_1(r) - I_2(r + d(r)))^2 dr + \lambda \int_{\Omega} \psi(\nabla d(r), \nabla I_1(r)) dr$$

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# Depth estimation

- $\psi(\nabla d, \nabla I_1)$ is a potential function whose gradient is given by :

$$\nabla(\psi(\nabla d, \nabla I_1)) = g(|\nabla I_1|^2)\nabla d$$

- Associated PDE (with the Neumann boundary conditions)

$$\frac{\partial d}{\partial t} = \lambda\, div(g(|\nabla I_1|^2)\nabla d) + (I_1(r) - I_2(r+d))\nabla I_2(r+d)$$

- Diffusion tensor

$$g(s^2) = \frac{1}{(1+s^2)^2}$$

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# Depth estimation

❋Numerical approximation

$$\frac{d^{k+1}(x,y) - d^k(x,y)}{\tau} = \lambda\left\{\frac{\partial}{\partial x}\left(g\left(\left|\frac{\partial I_1(x,y)}{\partial x}\right|\right)\times\frac{\partial d^k(x,y)}{\partial x}\right) + \frac{\partial}{\partial y}\left(g\left(\left|\frac{\partial I_1(x,y)}{\partial y}\right|\right)\times\frac{\partial d^k(x,y)}{\partial y}\right)\right\}$$
$$+\left(I_2(x+d^k(x,y),y) - I_1(x,y)\right)\times\frac{\partial I_2(x+d^k(x,y),y)}{\partial x}$$
$$+\left(d^k(x,y) - d^{k+1}(x,y)\right)\times\left(\frac{\partial I_2(x+d^k(x,y),y)}{\partial x}\right)^2$$

- Iterative solver

$$d^{k+1}(x,y) = d^k(x,y) + \frac{\tau}{1+\tau\left(\frac{\partial I_2(x+d^k(x,y),y)}{\partial x}\right)^2}$$
$$\times\left[\lambda\left\{\frac{\partial}{\partial x}\left(g\left(\left|\frac{\partial I_1(x,y)}{\partial x}\right|\right)\times\frac{\partial d^k(x,y)}{\partial x}\right) + \frac{\partial}{\partial y}\left(g\left(\left|\frac{\partial I_1(x,y)}{\partial y}\right|\right)\times\frac{\partial d^k(x,y)}{\partial y}\right)\right\}\right.$$
$$\left.+\left(I_2(x+d^k(x,y),y) - I_1(x,y)\right)\times\frac{\partial I_2(x+d^k(x,y),y)}{\partial x}\right]$$

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## Depth estimation

- Final disparity map

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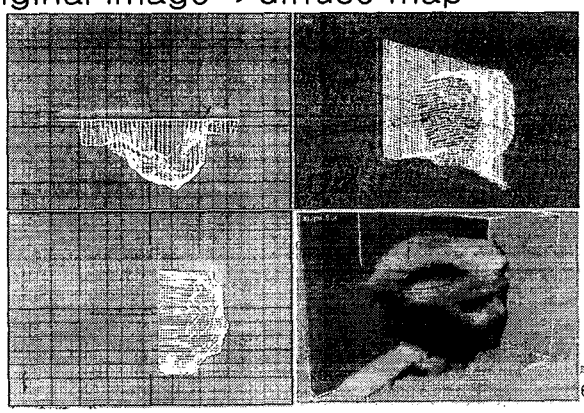
## 3D Reconstruction

- Reconstruct 3D model with 3D MAX
  - Estimated depth map=>displace map
  - Original image=>diffuse map



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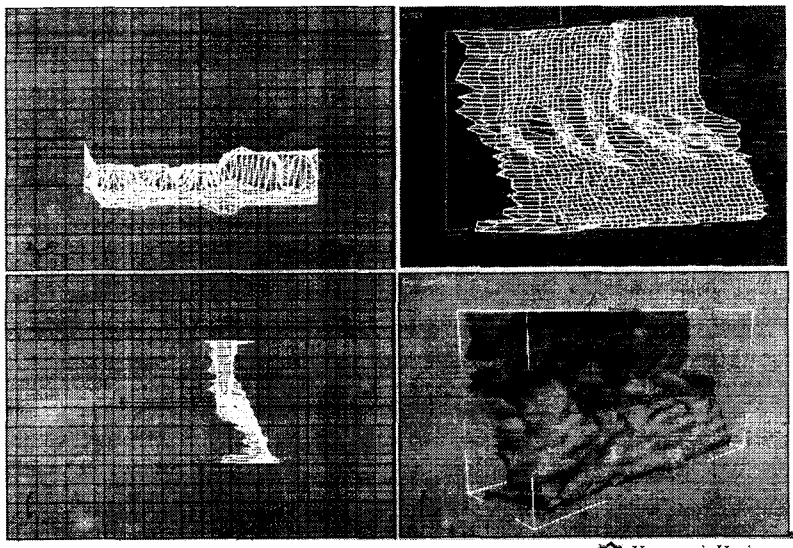
## 3D Reconstruction



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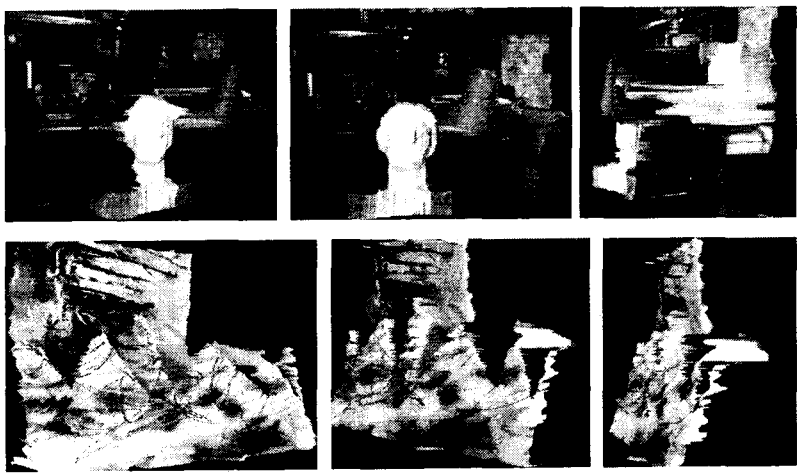
## 3D Reconstruction

- Rendered images



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# 3D Reconstruction

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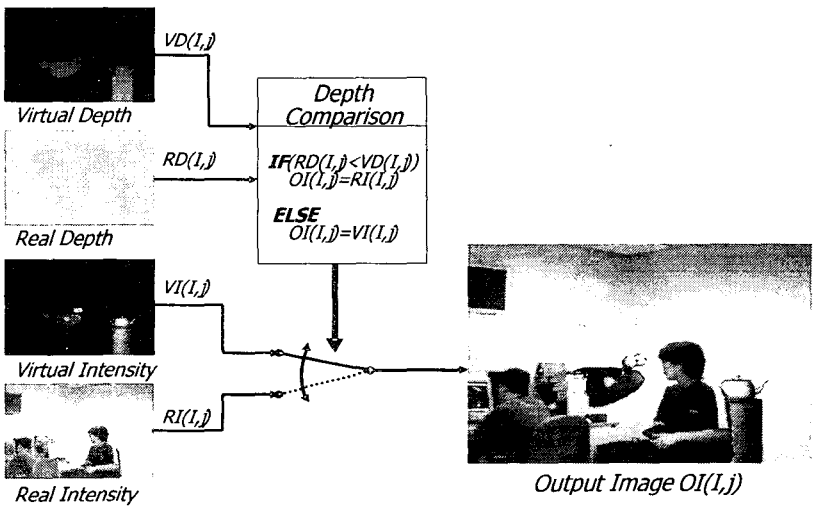
# Synthesis and Interaction

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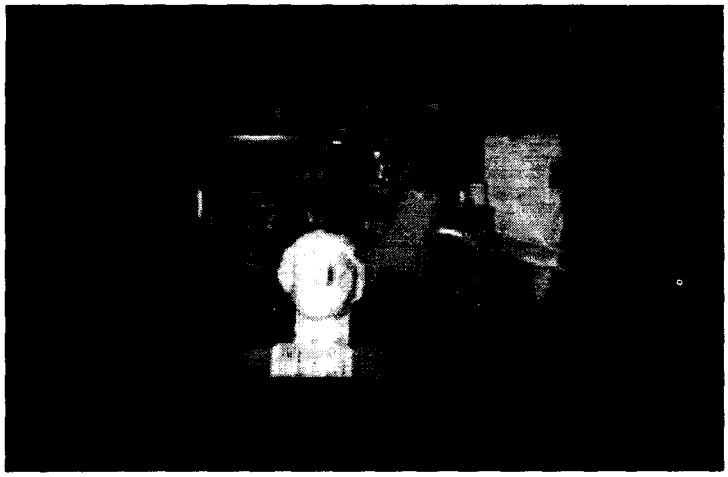
# DTM Synthesis and Interaction



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