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A million pixels, a million polygons: which is heavier?

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A million pixels, a million polygons.
Which is heavier?

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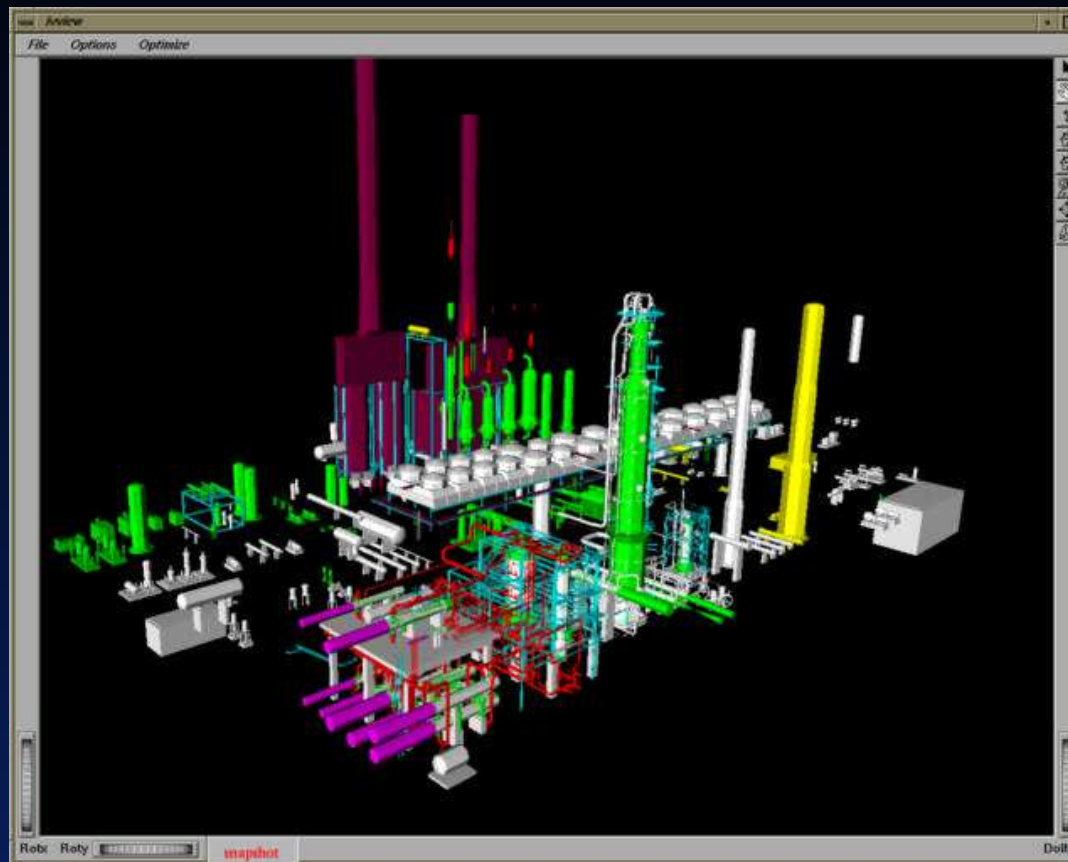
*A joint research project of CNRS, INRIA, INPG and UJF

iMAGIS

Why this question?

- ✓ Evolution of processing power and architectures
- ✓ New applications, demands and markets
 - Giant databases (digital mock up)
 - virtual reality, games...
- ✓ Image-based graphics:
 - current state and trends
 - potentialities

A million polygons



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Who needs a million polygons?

- ✓ Assemblies of CAD models
- ✓ Integrated design/manufacturing
- ✓ Digital mock-ups

A million pixels



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Rendering in Computer Graphics

- ✓ Models for 3D geometry, light reflection
- ✓ Global illumination simulation
- ✓ Real-time rendering

All of these requirements
present difficult challenges !

Subtle illumination effects



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Real-time rendering for dynamic scenes



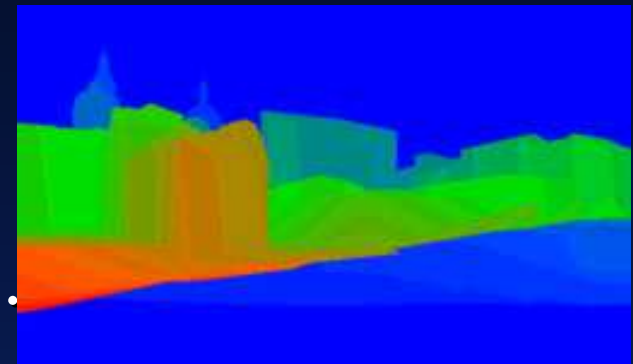
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Image-based rendering (IBR)

- ✓ Avoid expensive/difficult 3D model
- ✓ Start from a set of images
- ✓ Manipulate pixels to create new image
- ✓ With real images, elaborate lighting effects are “free”
- ✓ QuicktimeVR [Chen95], [Laveau], [McMillan95,97],...

What's an image?

- ✓ array of RGB (α) samples
- ✓ add depth sample
- ✓ add multiple depths, normals..
(Layered Depth Image, LDI)



Tour into the picture [Horry 97]



- ✓ Use a single image
- ✓ Manually define simple perspective
- ✓ Manually create layers with selected portions of the image

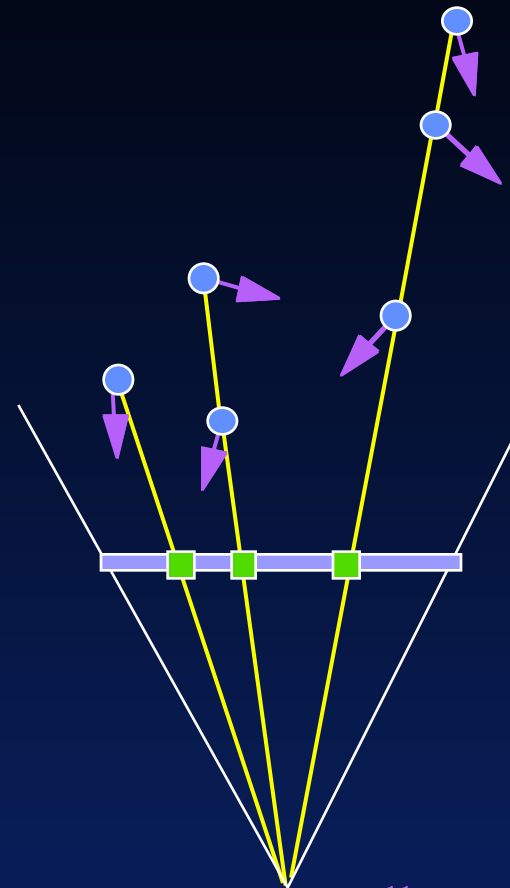
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See <http://www-syntim.inria.fr/~horry/images/s97slide.html>

Layered depth images [Gortler97]

See http://www.research.microsoft.com/research/graphics/cohen/SIG_97_IBR/index.htm

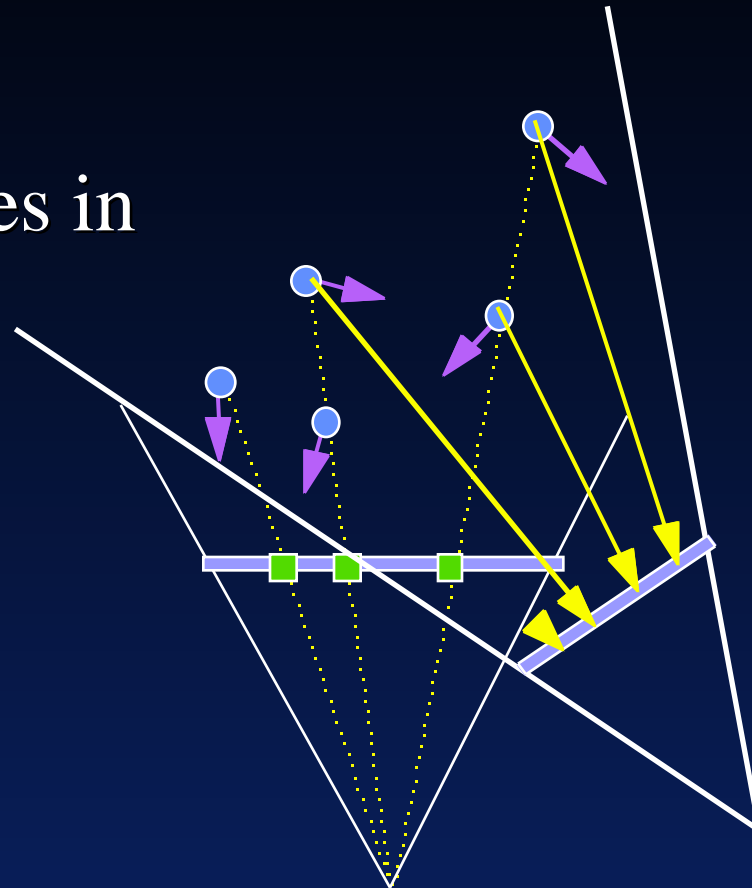
- ✓ Gather multiple depth samples for each pixel



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Layered depth images

- ✓ Reproject all samples in new image
 - no need for depth comparisons
 - splatting technique



Rendering from a million polygons?

- ✓ Transform 1-3M vertices 20 M flop
- ✓ Lighting 10 M flop
- ✓ Texturing 15 M flop
- ✓ Memory bandwidth 100 Mb
- ✓ Raster engine, z-buffering ?

Rendering from a million pixels?

- ✓ Transform 1M points (coherence) 6 M flop
- ✓ No lighting
- ✓ No z-buffering
- ✓ Memory bandwidth (coherent access) 8 Mb

Rendering performance considerations

- ✓ 3D rendering reaches the consumer market
 - thousands of lit, textured polygons / second.
 - specialized boards require careful design for efficient integration.
- ✓ Image processing subsystems
 - video (analog/digital),
 - texture (games),
 - multimedia extensions

Generating and obtaining IBR models

- ✓ From synthetic images
 - Ray tracing
 - Range images, LDIs, Lumigraphs
- ✓ From real images
 - use panoramic views, vision techniques
 - feature matching (difficult)
 - Lumigraphs (no depth)

Link with vision

- ✓ Image based modeling (IBM...)
- ✓ Use images + parameters
 - avoid WYSIAYG
 - object class information
 - interactive modeling (facade)

IBR = sampling + reconstruction

- ✓ Operate without geometry
- ✓ More complete representations
(higher dimensionality)
- ✓ Simplified representations
(adding simplified 3D model)

Light field - Lumigraph

4D Light Field

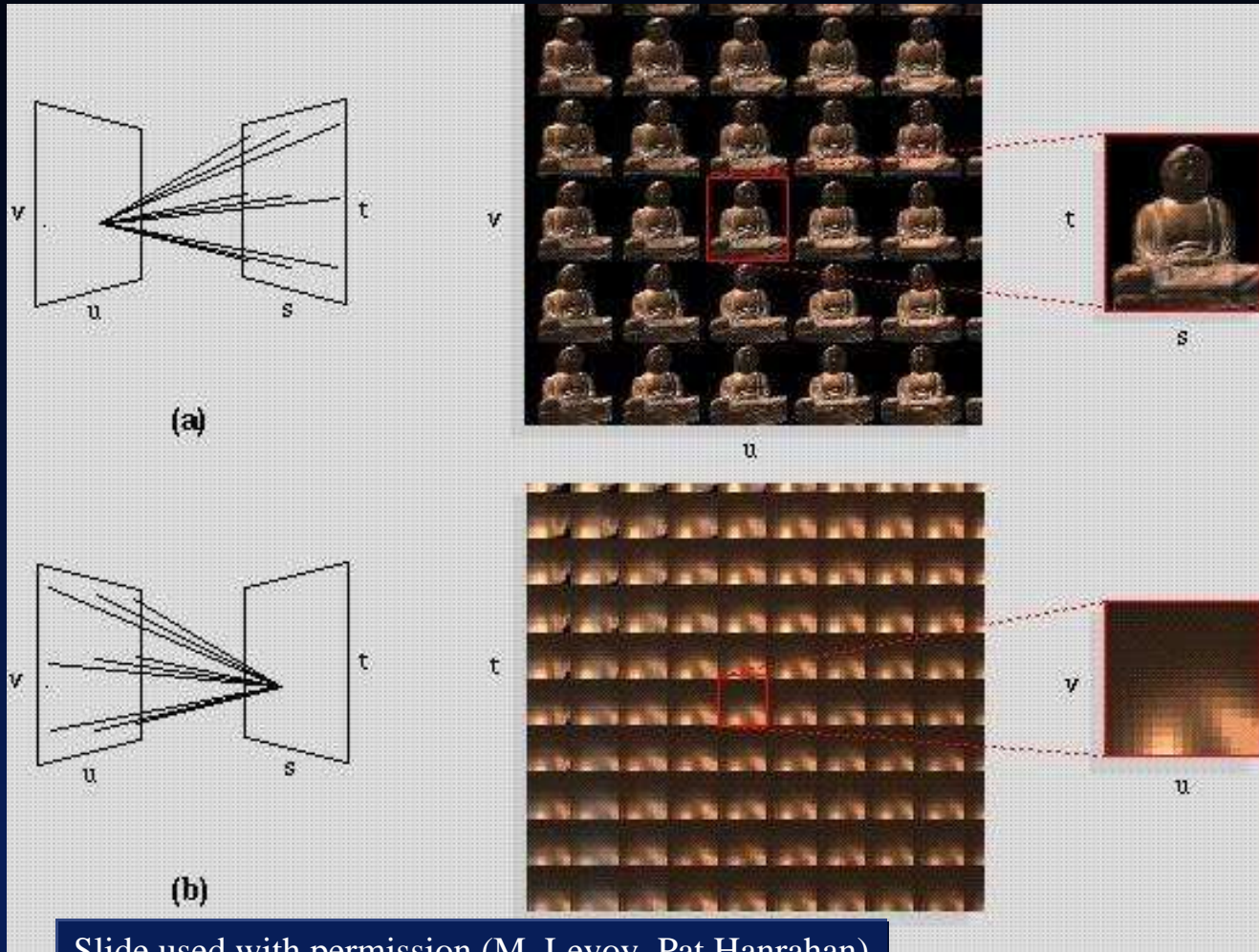


Levoy, Hanrahan 96
Gortler et al 96

Slide used with permission (M. Levoy, Pat Hanrahan)
See <http://www-graphics.stanford.edu/projects/lightfield>

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Light field - Lumigraph sampling



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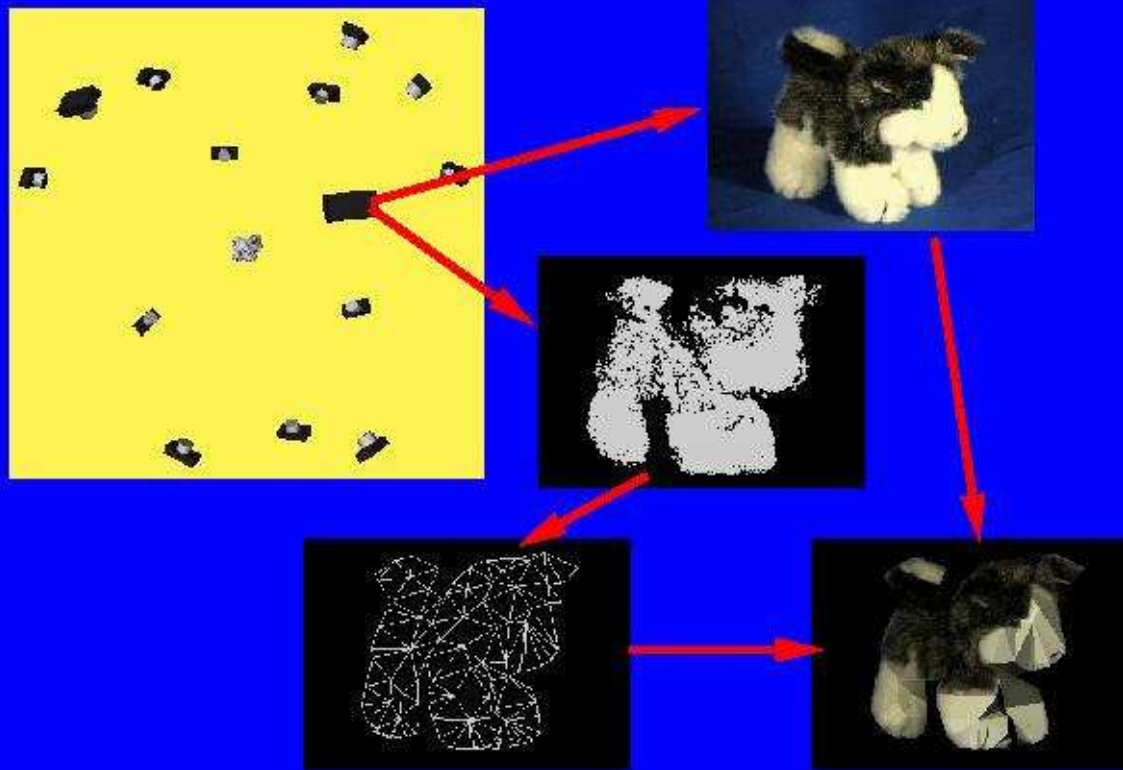
h, iMAGIS 1997

Impostors

- ✓ Create textured 3D model from images
 - *simplified* representation
 - rendered as 3D geometry
- ✓ Planar polygons [Maciel95, Schaufler96, Shade96]
- ✓ 3D meshes from range images
[Pulli 97, Darsa 97, Sillion 97]

Textured 3D mesh from a range image

View based models



Pulli 97

ion, iMAGIS 1997

Slide used with permission (K. Pulli et al.)

Blending required to combine views



without blending
(z-buffer)

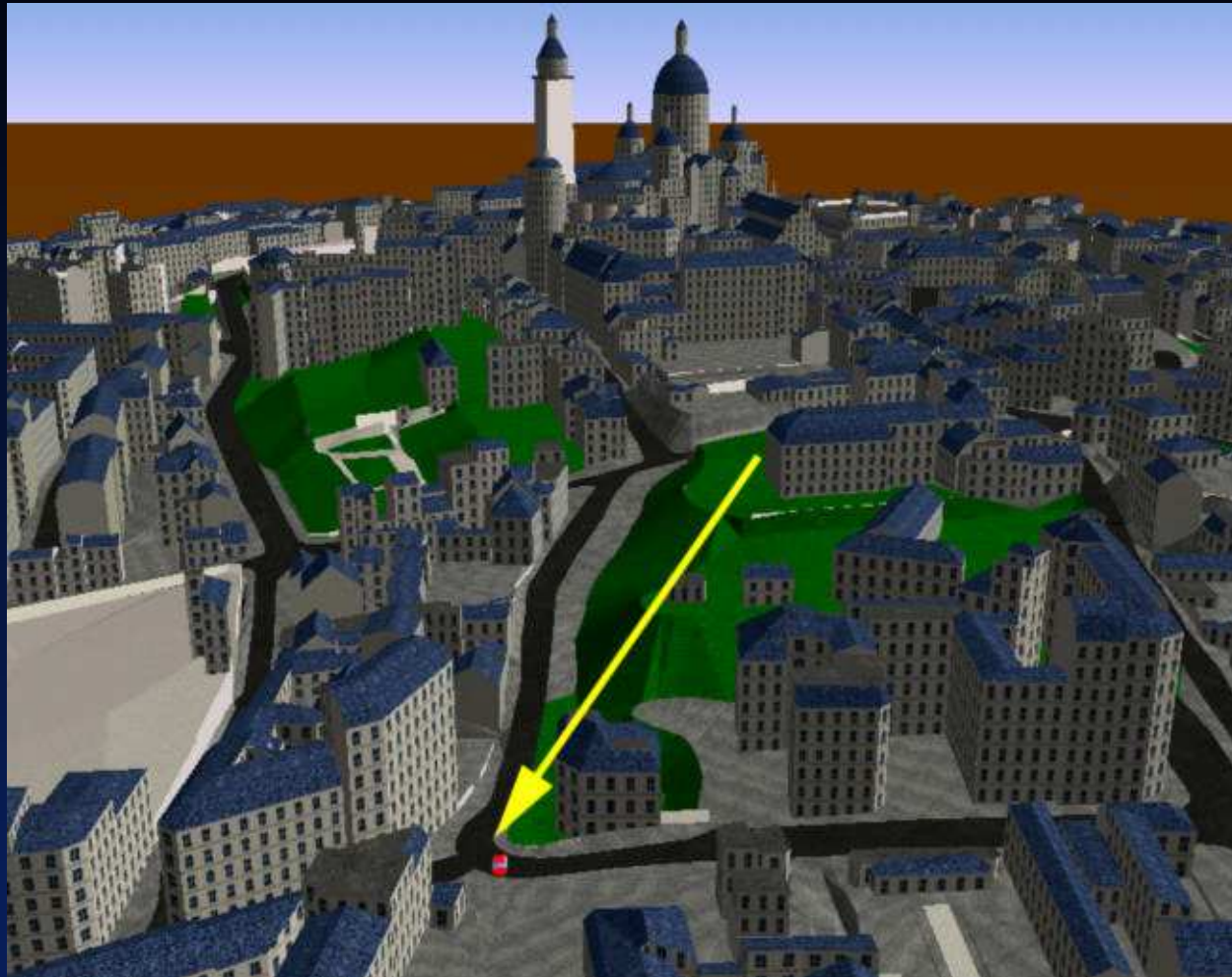


with blending
[Pulli 97]

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Images used with permission (K. Pulli et al.) See <http://www.cs.washington.edu/homes/kapu>

Principles of our approach: example



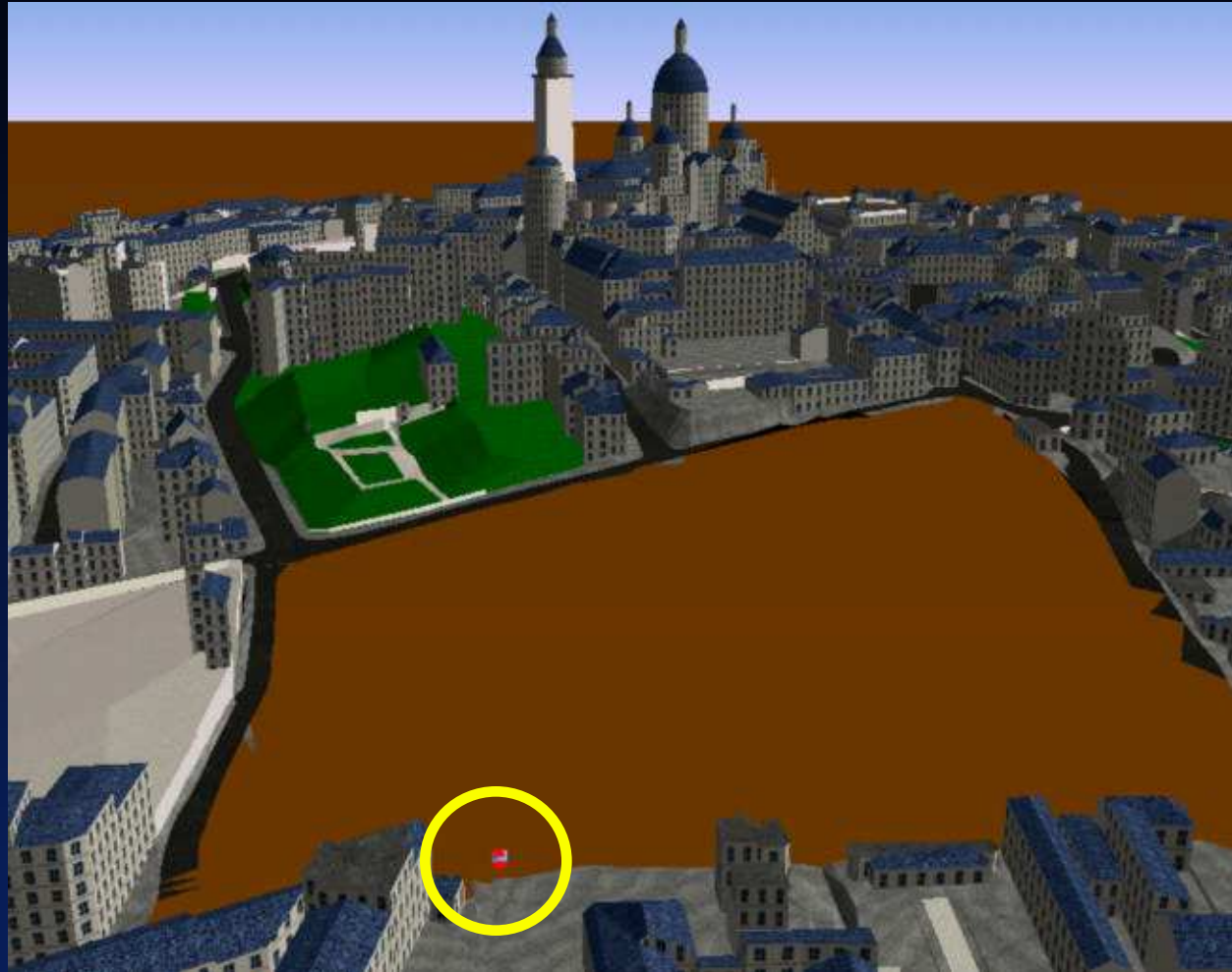
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Local model (3D objects)



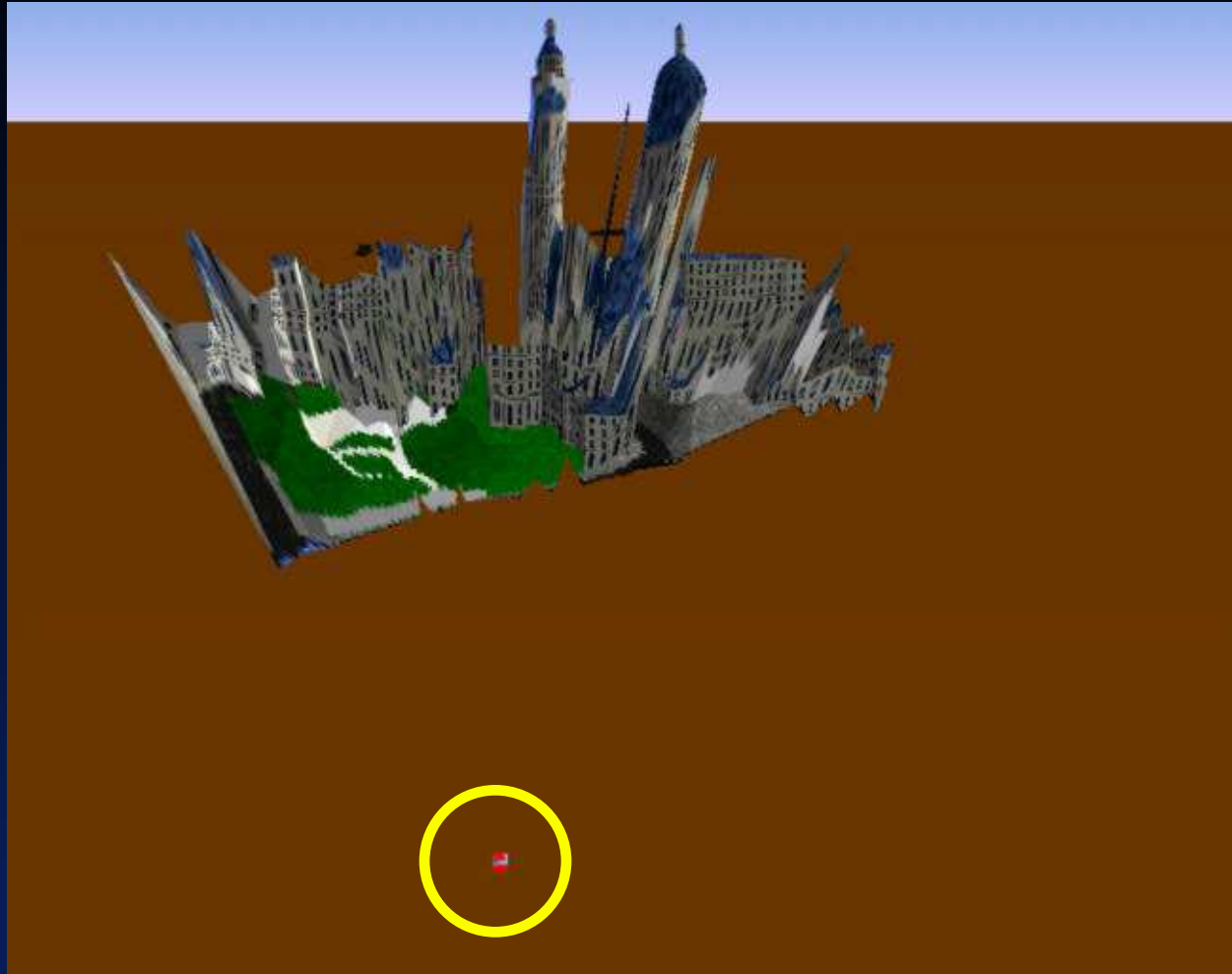
iMAGIS 1997

Distant model (3D objects)



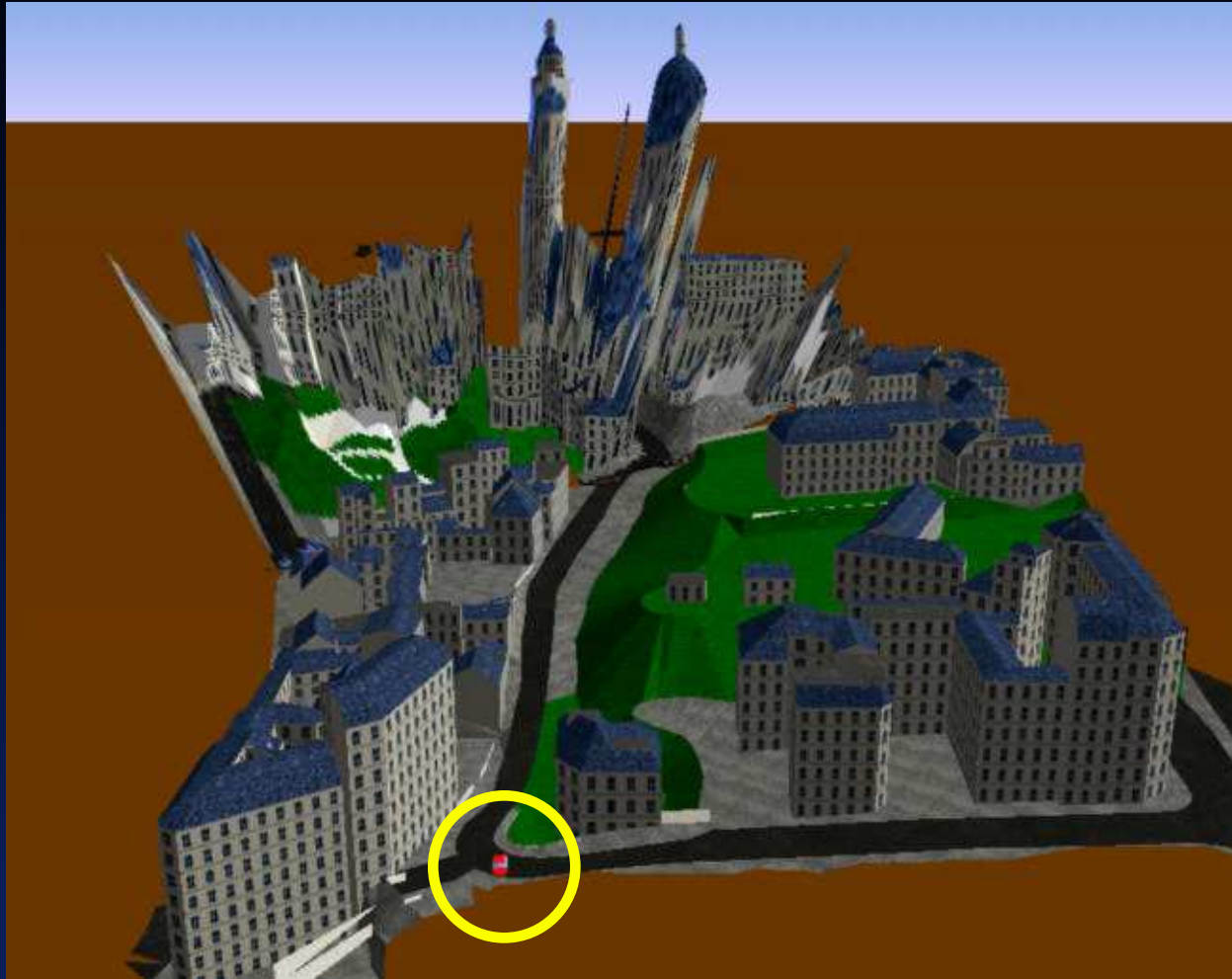
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Impostor (Textured 3D mesh)



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Combined model (local+impostor)



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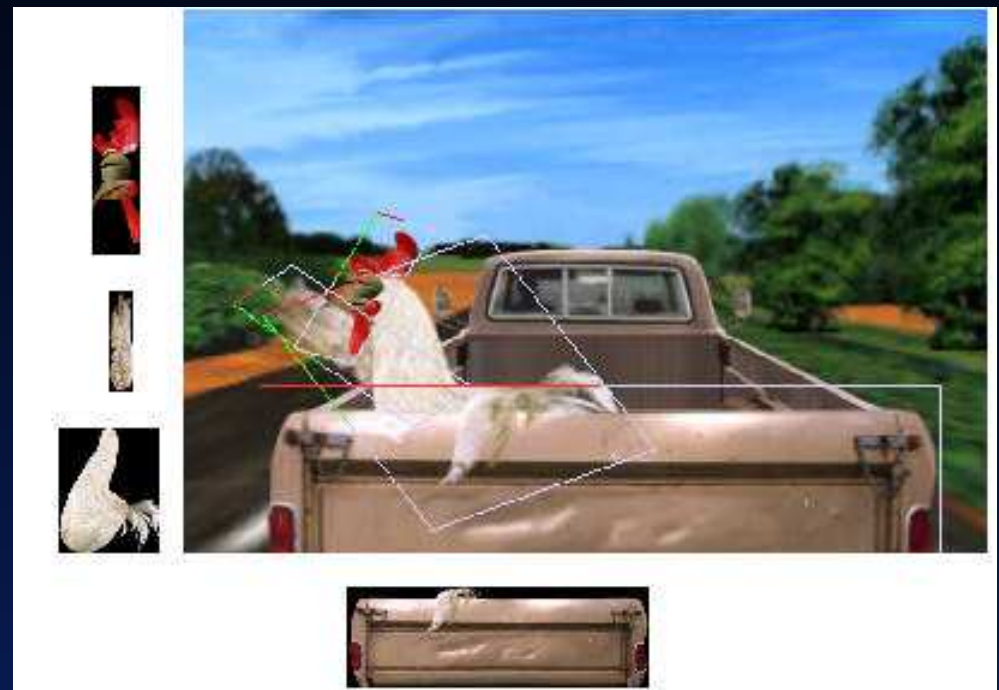
Combined model (local+impostor)



iMAGIS 1997

Deforming impostors

- ✓ Talisman [Torborg 96]
 - Render sprites
 - Layered model
 - Affine transforms [Lengyel97]
- ✓ Impostor transition



Slide used with permission (J. Lengyel et al, Microsoft research.)

See <http://research.microsoft.com/~jedl>

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Applications for IBR

- ✓ Walkthrough / view synthesis
- ✓ Stereo synthesis
- ✓ Interpolation/extrapolation
 - Latency compensation
 - Frame rate equalization
 - Network transmission
 - Leverage expensive rendering

Polygons

Pixels

- ✓ Continuous
- ✓ Modeling
- ✓ Animation
- ✓ Level of detail

- ✓ Discrete
- ✓ Capture
- ✓ Video streams
- ✓ Filtering

Pixels

- ✓ Discrete, regular nature
 - easy to filter: adaptation to user perceptual limitations
- ✓ Work with real images
 - Easy to capture
 - Let nature do the modeling/lighting
 - Work from existing images (historical, legal, forensic applications...)
- ✓ WYSIAYG

Polygons

- ✓ Complete 3D model
 - solid modeling
 - global illumination
 - path planning, assembly checking, collision detection
- ✓ Common denominator for many modeling systems
- ✓ Can be simplified but it's hard to keep the model consistent

Extended notion of image-based models

- ✓ Use *both* images and 3D data
- ✓ Combine a simplified model with images
- ✓ model can be extracted from images or other information

IBR and availability of 3D models

- ✓ Complete 3D model
 - IBR as graphics subsystem
- ✓ No 3D model
 - QTVR, plenoptic rendering
 - The model *is* the image(s)
- ✓ Range data available
 - Scanned data is huge: need to simplify

Problems with current algorithms

- ✓ Holes in reconstructed images
- ✓ Image deformation (impostors)
- ✓ Volume of data
- ✓ Sampling/filtering artifacts

Can we expect hardware advances?

- ✓ view interpolator
- ✓ soft z-buffering and blending
- ✓ multiple or view-dependent textures
- ✓ decompression
- ✓ memory bandwidth

Limitations of IBR

- ✓ Specularities
- ✓ Lighting/geometry/reflectance changes are hard
- ✓ Computer Vision issues: model building
- ✓ Images may not be available!

Marketability

- ✓ QTVR, panoramic images
- ✓ Image-based modeling
- ✓ Image-based rendering architectures
- ✓ Image caching, impostors
- ✓ Network applications (QoS)
- ✓ Light field

...and now?

- ✓ Simulation of global illumination
- ✓ Visibility calculations
- ✓ View-dependent texture mapping
 - disparity/depth
 - specularity/shading
 - re-lighting
- ✓ Compression of depth values

Computer-augmented reality



input panorama

Drettakis 97



computed solution **MAGIS 1997**

Conclusions

- ✓ IBR offers useful advances
 - leverage cost of high-quality rendering
 - fast extension via specialized subsystem
- ✓ Vision issues limit applicability of “pure” IBR for real images
- ✓ Use combined 3D models and images
- ✓ Polygons are still useful!

Acknowledgements

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