# 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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## Why this question?

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

## A million polygons


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## Who needs a million polygons?

$\checkmark$ Assemblies of CAD models
$\checkmark$ Integrated design/manufacturing
$\checkmark$ Digital mock-ups

## A million pixels


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## Rendering in Computer Graphics

$\checkmark$ Models for 3D geometry, light reflection
$\checkmark$ Global illumination simulation
$\checkmark$ 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)

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

## What's an image?

$\checkmark$ array of RGB $(\alpha)$ samples

$\checkmark$ add depth sample
$\checkmark$ add multiple depths, normals.
(Layered Depth Image, LDI)
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## Tour into the picture [Horry 97]


$\checkmark$ Use a single image
$\checkmark$ Manually define simple perspective
$\checkmark$ Manually create layers with selected portions of the image © François sillion, iMAGIS 1997
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


## Layered depth images

$\checkmark$ Reproject all samples in new image
-no need for depth comparisons
-splatting technique

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## Rendering from a million polygons?

$\checkmark$ Transform 1-3M 20 M flop vertices
$\checkmark$ Lighting
$\checkmark$ Texturing
$\checkmark$ Memory bandwidth
100 Mb
$\checkmark$ Raster engine,
?
z-buffering
10 M flop
15 M flop
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## Rendering from a million pixels?

$\checkmark$ Transform 1M
6 M flop points (coherence)
No lighting
$\checkmark$ No z-buffering
$\checkmark$ Memory bandwith
8 Mb (coherent access)

## Rendering performance considerations

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

- multimedia extensions


## Generating and obtaining IBR models

$\checkmark$ From synthetic images
-Ray tracing
-Range images, LDIs, Lumigraphs
$\checkmark$ From real images

- use panoramic views, vision techniques
-feature matching (difficult)
-Lumigraphs (no depth)


## Link with vision

$\checkmark$ Image based modeling (IBM...)
$\checkmark$ Use images + parameters

- avoid WYSIAYG
-object class information
-interactive modeling (facade)


## IBR = sampling + reconstruction

$\checkmark$ Operate without geometry
$\checkmark$ More complete representations (higher dimensionality)
$\checkmark$ Simplified representations (adding simplified 3D model)

## Light field - Lumigraph

## 4D Light Field



Levoy, Hanrahan 96
Gortler et al 96

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See http://www-graphics.stanford.edu/projects/lightfield

## Light field - Lumigraph sampling


(a)

(b)

u


u
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## Impostors

$\checkmark$ Create textured 3D model from images
-simplified representation
-rendered as 3D geometry
$\checkmark$ Planar polygons [Macie195, Schaufler96, Shade96]
$\checkmark$ 3D meshes from range images
[Pulli 97, Darsa 97, Sillion 97]

## Textured 3D mesh from a range image


ion, iMAGIS 1997

## Blending required to combine views


without blending (z-buffer)
with blending
[Pulli 97]

## Principles of our approach: example


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## Local model (3D objects)



## Distant model (3D objects)



## Impostor (Textured 3D mesh)



## Combined model (local+impostor)



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## Combined model (local+impostor)



## Deforming impostors

$\checkmark$ Talisman [Torborg 96]
-Render sprites
-Layered model
-Affine transforms
[Lengyel97]
$\checkmark$ 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

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

## Polygons Pixels

$\checkmark$ Continuous
$\checkmark$ Modeling
$\checkmark$ Animation
$\checkmark$ Level of detail
$\checkmark$ Discrete
$\checkmark$ Capture
$\checkmark$ Video streams
$\checkmark$ Filtering

## Pixels

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

## Polygons

$\checkmark$ Complete 3D model
-solid modeling
-global illumination
-path planning, assembly checking, collision detection
$\checkmark$ Common denominator for many modeling systems
$\checkmark$ Can be simplified but it's hard to keep the model consistent rançois sillion, iMAGIS $1997^{\text {i }}$

## Extended notion of image-based models

$\checkmark$ Use both images and 3D data
$\checkmark$ Combine a simplified model with images
$\checkmark$ model can be extracted from images or other information

## IBR and availability of 3D models

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

## Problems with current algorithms

$\checkmark$ Holes in reconstructed images
$\checkmark$ Image deformation (impostors)
$\checkmark$ Volume of data
$\checkmark$ Sampling/filtering artifacts

## Can we expect hardware advances?

$\checkmark$ view interpolator
$\checkmark$ soft z-buffering and blending
$\checkmark$ multiple or view-dependent textures
$\checkmark$ decompression
$\checkmark$ memory bandwith

## Limitations of IBR

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

## Marketability

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

## ...and now?

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

## Computer-augmented reality



## Conclusions

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

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