



Introduction to Computer Graphics

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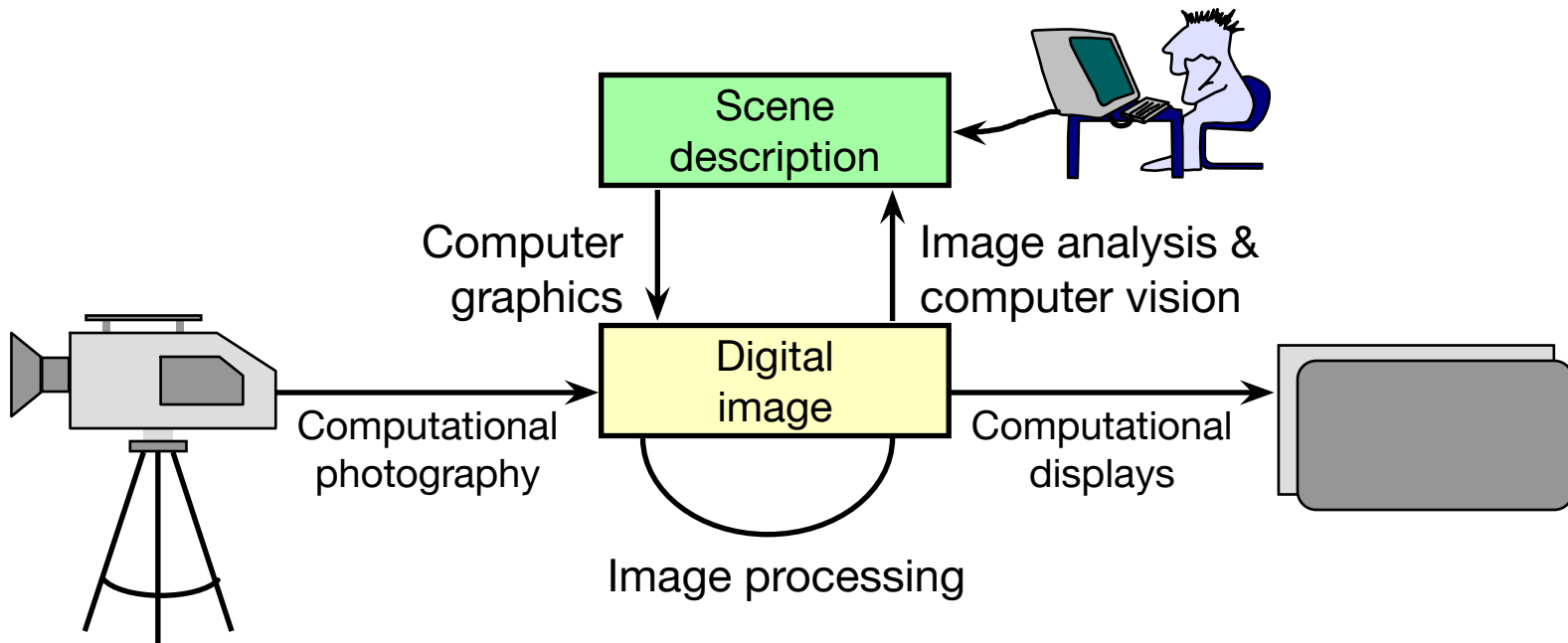
Eight lectures & two practical tasks (one optional)

Part IA CST

Two supervisions suggested

Two exam questions on Paper 3

What are Computer Graphics & Visual Computing?



Computing without graphics

```
PS C:\> Get-Childitem 'MediaCenter\Music' -rec |
>> where < -not & { $_.Extension -and & { $_.Extension -match '.*mp3' } } |
Measure-Object -property length -sum -min -max -ave

Count       : 1307
Average     : 1491276.09563887
Sum         : 21770979857
Maximum     : 229085457
Minimum     : 3235
Property    : length

PS C:\> Get-WmiObject CIM_BIOSElement | select bios*, man*, ser* | Format-List

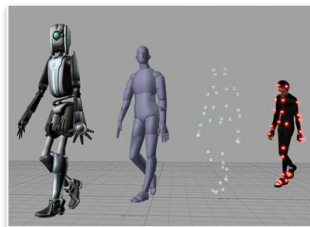
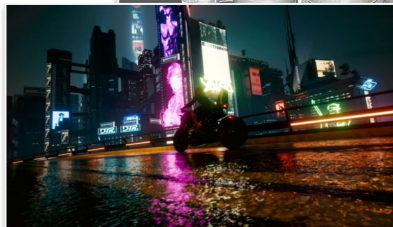
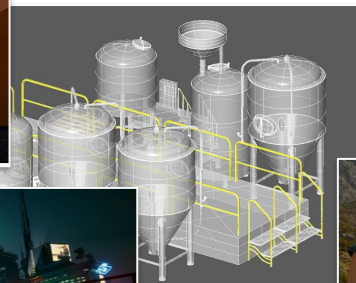
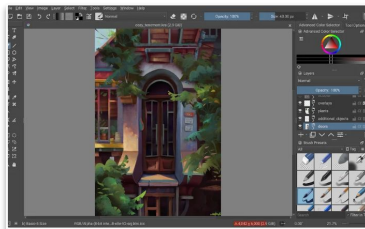
BIOSVersion : <IOSCPL - 6040000, Ver 1.00PARTIDB>
Manufacturer : 105101M
SerialNumber : R02111608

PS C:\> ([wmiSearcher]@
>> SELECT * FROM CIM_Job
>> WHERE Priority > 1
>> 'E'.get() | Format-Custom

Class ManagementObjectRoot\Cim2\Win32_PrintJob
Document - Monad Manifesto - Public
JobId = 6
JobStatus =
Owner = User
Priority = 62
Size = 1027088
Name = Epson Stylus COLOR 740 ESC/P 2, 6

PS C:\> $resUrl = 'http://blogs.msdn.com/powershell/rss.aspx'
PS C:\> $blog = [xml](New-Object System.Net.WebClient).DownloadString($resUrl)
PS C:\> $blog.rss.channel.item | select title -first 3

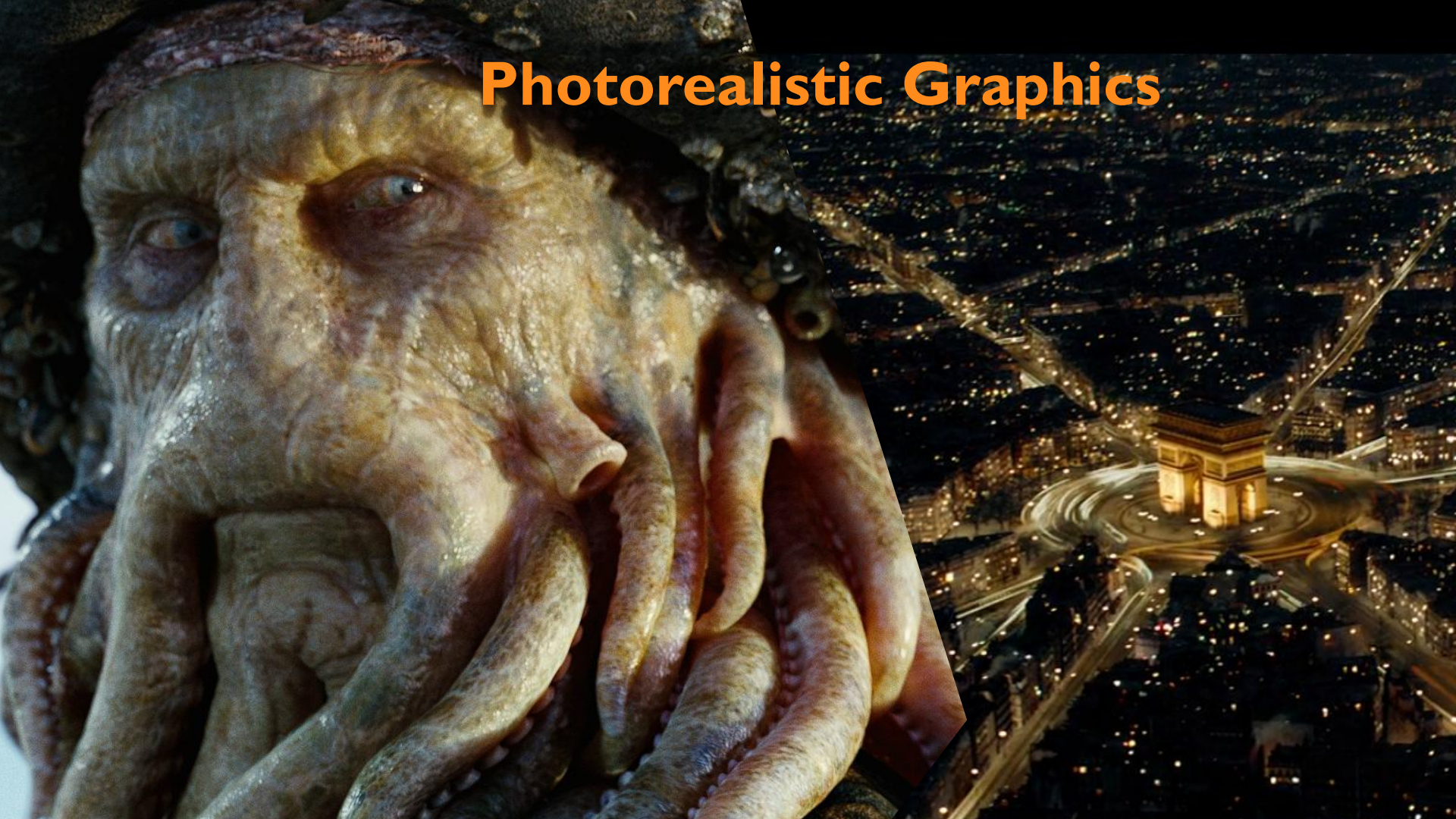
title
RSS: What's Coming In PowerShell V2
PowerShell Presence at PMS
PMS Talks: System Center Foundation Technologies
[root@localhost ~]# ping -q fa.wikipedia.org
PS C:\> [root@localhost ~]# ping -q fa.wikipedia.org (208.80.152.2) 56(84) bytes of data.
PS C:\>
PS C:\> -- text.pmtpa.wiki.media.org ping statistics --
packets transmitted, 1 received, 0% packet loss, time 8ms
rtt min/avg/max/mdev = 548.526/540.528/540.528/0.000 ms
[root@localhost ~]# pwd
root
[root@localhost ~]# cd /var
[root@localhost ~]# ls -la
total 72
drwxr-xr-x. 18 root root 4096 Jul 30 22:43 .
drwxr-xr-x. 23 root root 4096 Sep 14 20:42 ..
drwxr-xr-x. 2 root root 4096 May 14 09:16 account
drwxr-xr-x. 11 root root 4096 Jul 31 22:28 cache
drwxr-xr-x. 3 root root 4096 May 18 16:03 dh
drwxr-xr-x. 3 root root 4096 May 18 16:03 empty
drwxr-xr-x. 2 root root 4096 May 18 16:03 games
drwxr-xr-x. 2 root gdm 4096 Jun 2 18:08 gdm
drwxr-xr-x. 30 root root 4096 May 18 16:03 lib
drwxr-xr-x. 2 root root 4096 May 18 16:03 local
drwxr-xr-x. 1 root root 11 May 14 09:12 lock -> ../run/lock
drwxr-xr-x. 14 root root 4096 Sep 14 20:42 log
drwxr-xr-x. 1 root root 10 Jul 30 22:43 mail -> ../run/mail
drwxr-xr-x. 2 root root 4096 May 18 16:03 nls
drwxr-xr-x. 2 root root 4096 May 18 16:03 opt
drwxr-xr-x. 2 root root 4096 May 18 16:03 preserve
drwxr-xr-x. 2 root root 4096 Jul 1 12:21 report
drwxr-xr-x. 1 root root 6 May 14 09:12 run -> ../run
drwxr-xr-x. 14 root root 4096 May 18 16:03 spool
drwxr-xr-x. 4 root root 4096 Sep 12 23:50 systemd
drwxr-xr-x. 2 root root 4096 May 18 16:03 yp
[root@localhost ~]# yum search wiki
loaded plugins: langpacks, presto, refresh-packagekit, remove-with-leaves
repofusion-free-updates | 2.7 kB | 00:00
repofusion-free-updates/primary_db | 208 kB | 00:04
repofusion-nonfree-updates | 2.7 kB | 00:00
updates/metalink | 5.9 kB | 00:00
updates | 4.7 kB | 00:00
updates/primary_db | 73% [ ] 62 kB/s | 2.6 MB | 00:15 ETA
```



Computing with graphics



Photorealistic Graphics



A cinematic shot of two lion cubs, Simba and Nala, standing close together in a savanna landscape. They are both roaring with their mouths wide open, showing their teeth. The background features a vast, open plain with some distant animals and a dramatic, cloudy sky at sunset or sunrise.

Disney
MUFASA
THE LION KING

OFFICIAL TRAILER



**GEFORCE
RTX**

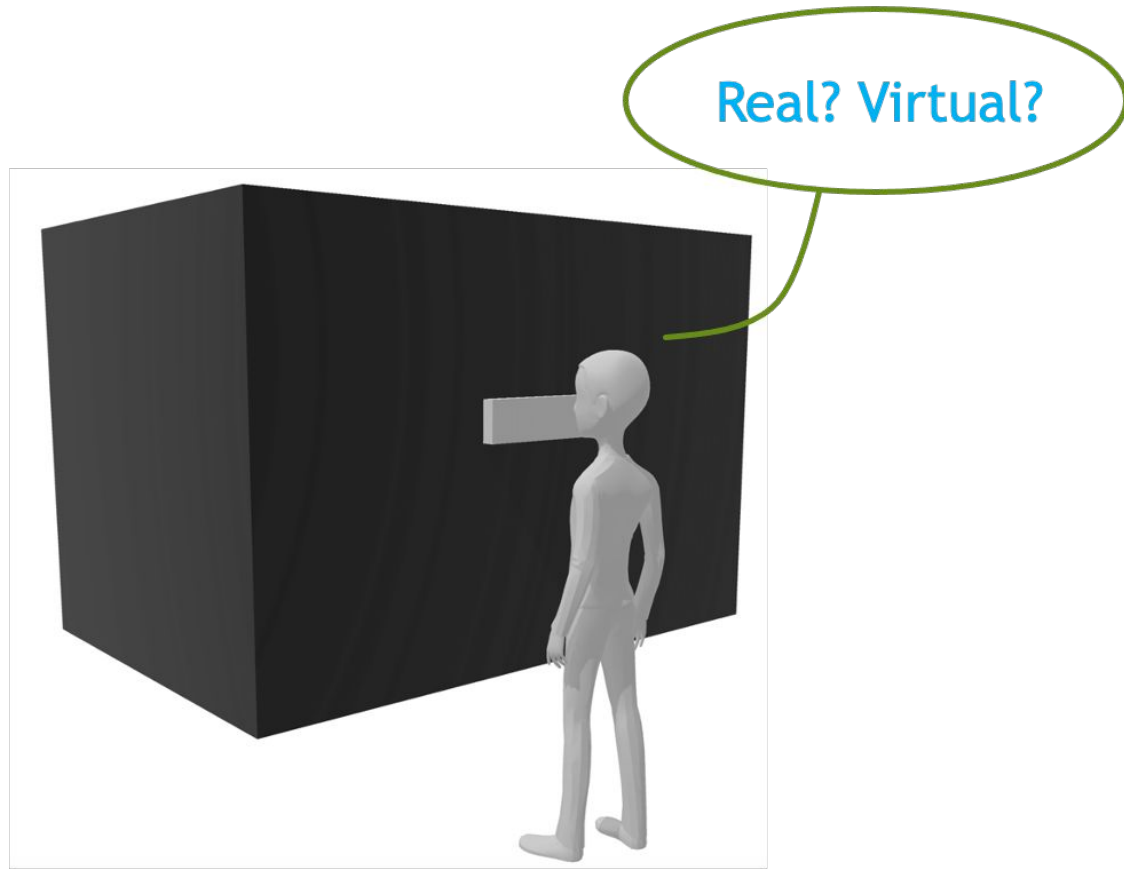
Powering Advanced AI

BLACK MYTH
WUKONG

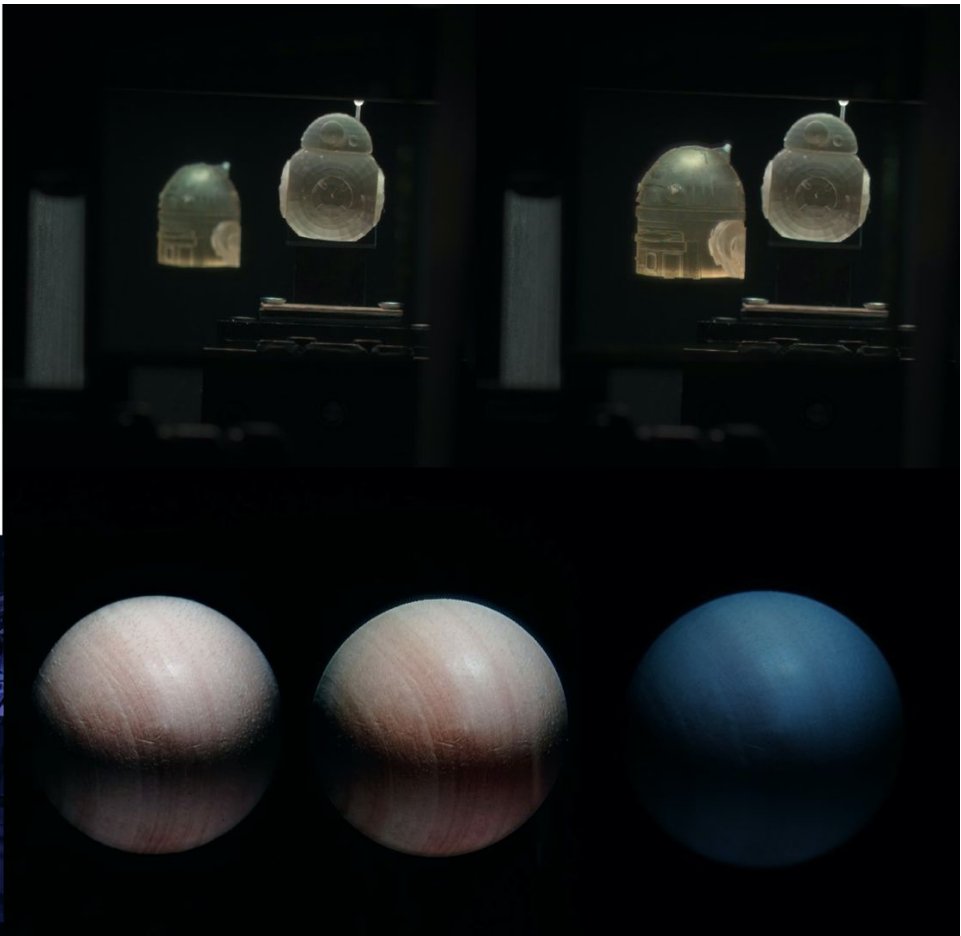
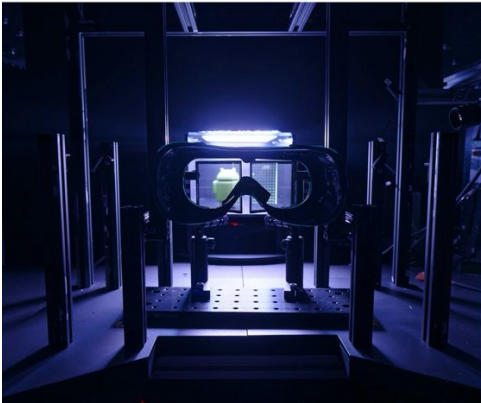




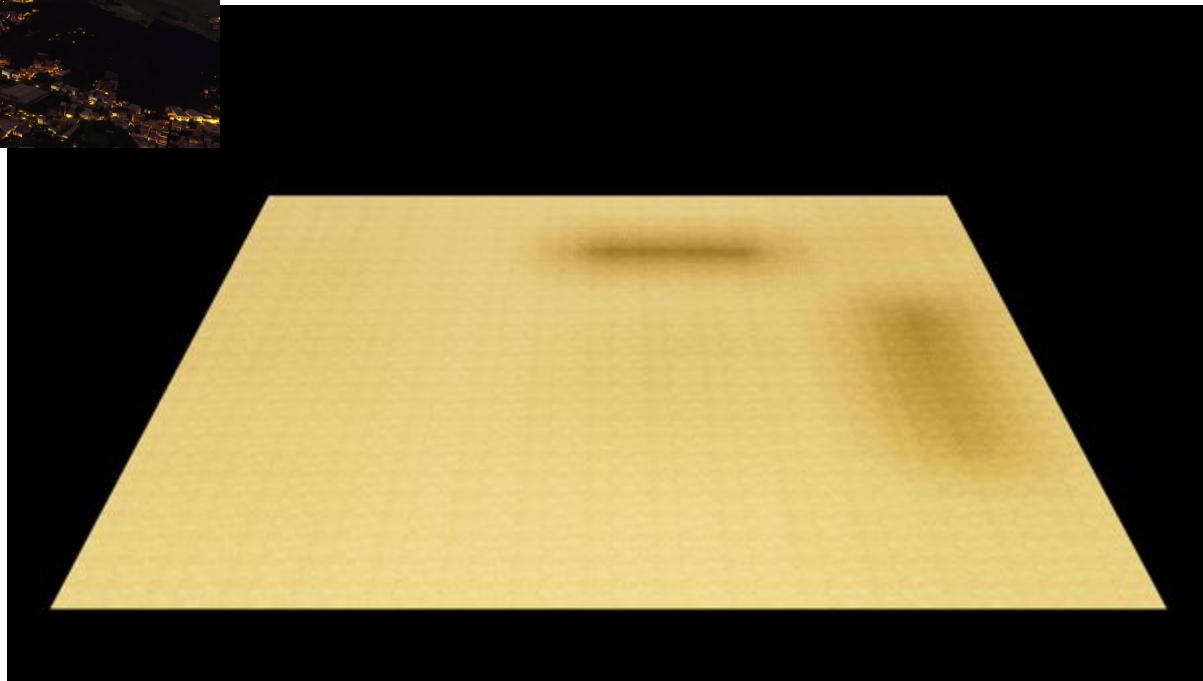
Perceptually Realistic Graphics



Visual Turing Test



World's first mixed-reality system that passed a visual Turing test at Cambridge





CARLA
Release 0.9.15

Course Structure

◆ Background

- ◆ What is an image? Resolution and quantisation. Storage of images in memory. [1 lecture]

◆ Rendering

- ◆ Perspective. Reflection of light from surfaces and shading. Geometric models. **Ray tracing**. [2 lectures]

◆ Graphics pipeline (real-time rendering pipeline)

- ◆ Polygonal mesh models. Transformations using matrices in 2D and 3D. Homogeneous coordinates. Projection: orthographic and perspective. **Rasterisation**. [2 lectures]

◆ Graphics hardware and OpenGL

- ◆ GPU APIs. Vertex processing. Fragment processing. Working with meshes and textures. [1 lectures]

◆ Human vision, colour and tone mapping

- ◆ Colour perception. Colour spaces. Tone mapping [2 lectures]

Course books

✦ ***Fundamentals of Computer Graphics***

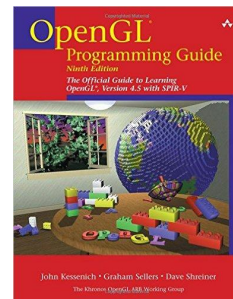
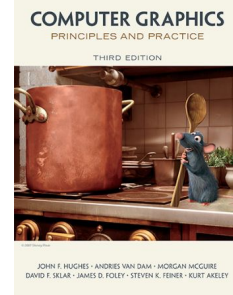
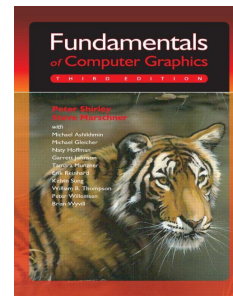
- ◆ Shirley & Marschner
CRC Press 2015 (4th or 5th edition)
- ◆ [FCG 8.1/9.1] – reference to section 3.1 in the 4th edition, 9.1 in the 5th edition

✦ ***Computer Graphics: Principles & Practice***

- ◆ Hughes, van Dam, McGuire, Sklar et al.
Addison-Wesley 2013 (3rd edition)

✦ ***OpenGL Programming Guide: The Official Guide to Learning OpenGL Version 4.5 with SPIR-V***

- ◆ Kessenich, Sellers & Shreiner
Addison Wesley 2016 (7th edition and later)



Introduction to Computer Graphics

◆ **Background**

- ◆ What is an image?
- ◆ Resolution and quantisation
- ◆ Storage of images in memory

◆ **Rendering**

◆ **Graphics pipeline**

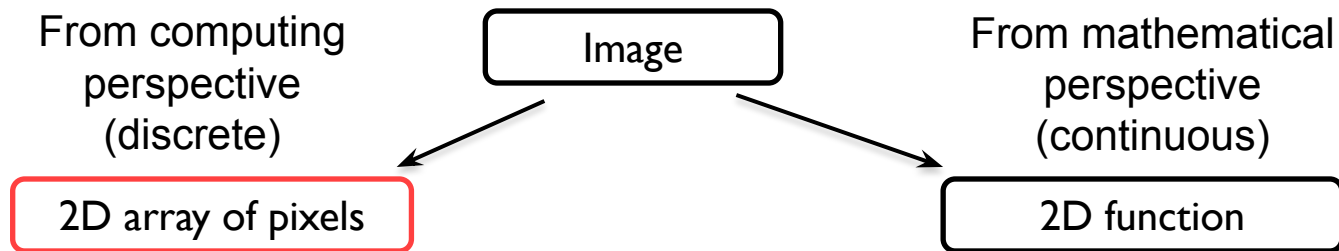
◆ **Rasterization**

◆ **Graphics hardware and OpenGL**

◆ **Human vision and colour & tone mapping**

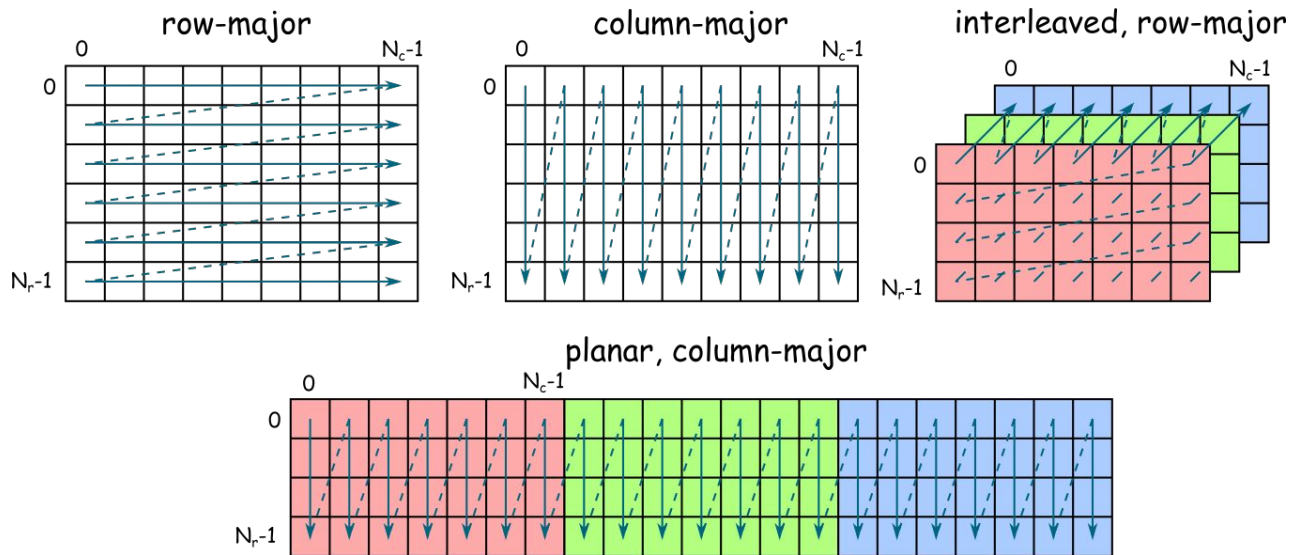
What is a (digital) image?

- ◆ A digital photograph? (“JPEG”)
- ◆ A snapshot of real-world lighting?



Image

- ◆ 2D array of pixels
- ◆ In most cases, each pixel takes 3 bytes: one for each red, green and blue
- ◆ But how to store a 2D array in memory?



Pixel (PIcture ELe ment)

- ◆ Each pixel (usually) consist of three values describing the colour

(red, green, blue)

- ◆ For example
 - ◆ (255, 255, 255) for white
 - ◆ (0, 0, 0) for black
 - ◆ (255, 0, 0) for red

Color banding

- ◆ If there are not enough bits to represent color
- ◆ Dithering (added noise) can reduce banding



8-bit gradient



8-bit gradient,
dithered



24-bit gradient

What is a (computer) image?

- ◆ A digital photograph? (“JPEG”)
- ◆ A snapshot of real-world lighting?

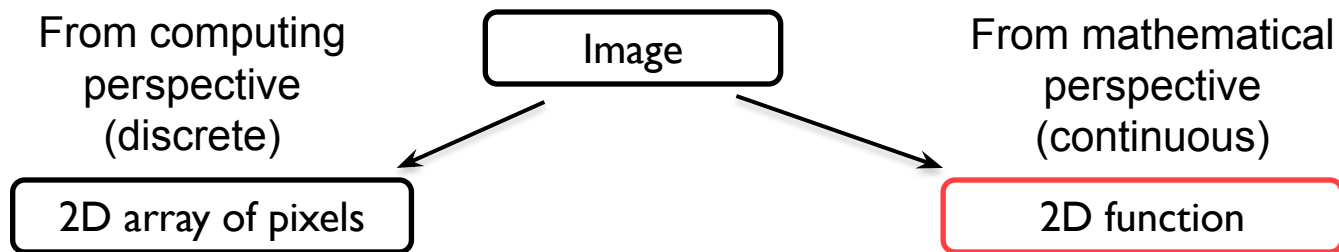


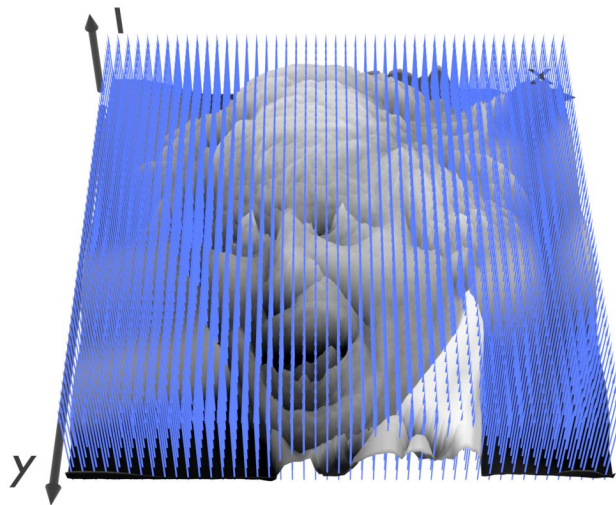
Image – 2D function

- Image can be seen as a function $I(x,y)$, that gives intensity value for any given coordinate (x,y)



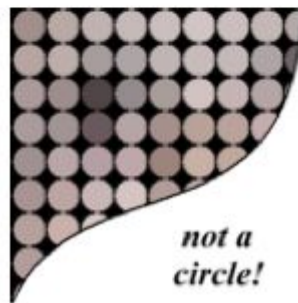
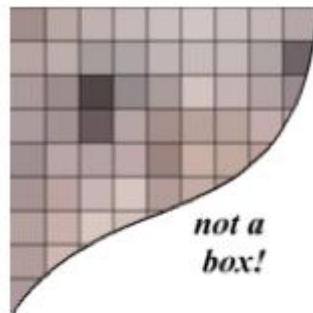
Sampling an image

- ◆ The image can be sampled on a rectangular sampling grid to yield a set of samples. These samples are pixels.



What is a pixel? (math)

- ◆ A pixel is not
 - ◆ a box
 - ◆ a disk
 - ◆ a teeny light
- ◆ A pixel is a point
 - ◆ it has no dimension
 - ◆ it occupies no area
 - ◆ it cannot be seen
 - ◆ it has coordinates
- ◆ A pixel is a **sample**



Sampling and quantization

- ◆ Physical world is described in terms of continuous quantities
- ◆ But computers work only with discrete numbers
- ◆ Sampling – process of mapping continuous function to a discrete one
- ◆ Quantization – process of mapping continuous variable to a discrete one

