COMPUTER GRAPHICS, COMPUTER VISION AND IMAGE PROCESSING
INTERCONNECTS AND APPLICATIONS

Muhammad Mobeen Movania

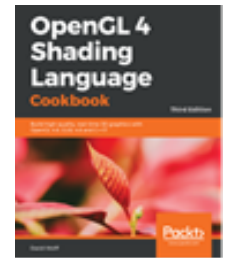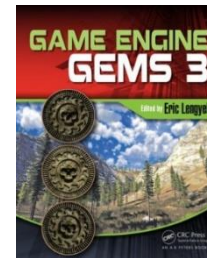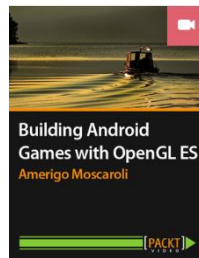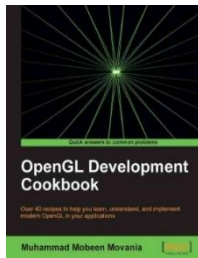Assistant Professor

Habib University

Outlines

- About the presenter
- What is Computer Graphics
- What is Computer Vision
- What is Digital Image Processing
- Interconnects between CG, CV and DIP
- Applications
- Resources to get started
- Useful libraries and tools
- Our research work in Computer Graphics
- Conclusion

About the Presenter

- PhD, Computer Graphics and Visualization, Nanyang Technological University Singapore, 2012
  - Post-Doc Research at Institute for Infocomm Research (I^{2}R), A-Star, Singapore (~1.5 years)

- Publications: 2 books, 3 book chapters, 9 Journals, 10 conferences
  - OpenGL 4 Shading Language Cookbook - Third Edition, 2018. (Reviewer)
  - OpenGL-Build high performance graphics, 2017. (Author)
  - Game Engine Gems 3, April 2016. (Contributor)
  - WebGL Insights, Aug 2015. (Contributor/Reviewer)
  - OpenGL 4 Shading Language Cookbook - Second Edition, 2014. (Reviewer)
  - Building Android Games with OpenGL ES online course, 2014. (Reviewer)
  - OpenGL Development Cookbook, 2013. (Author)
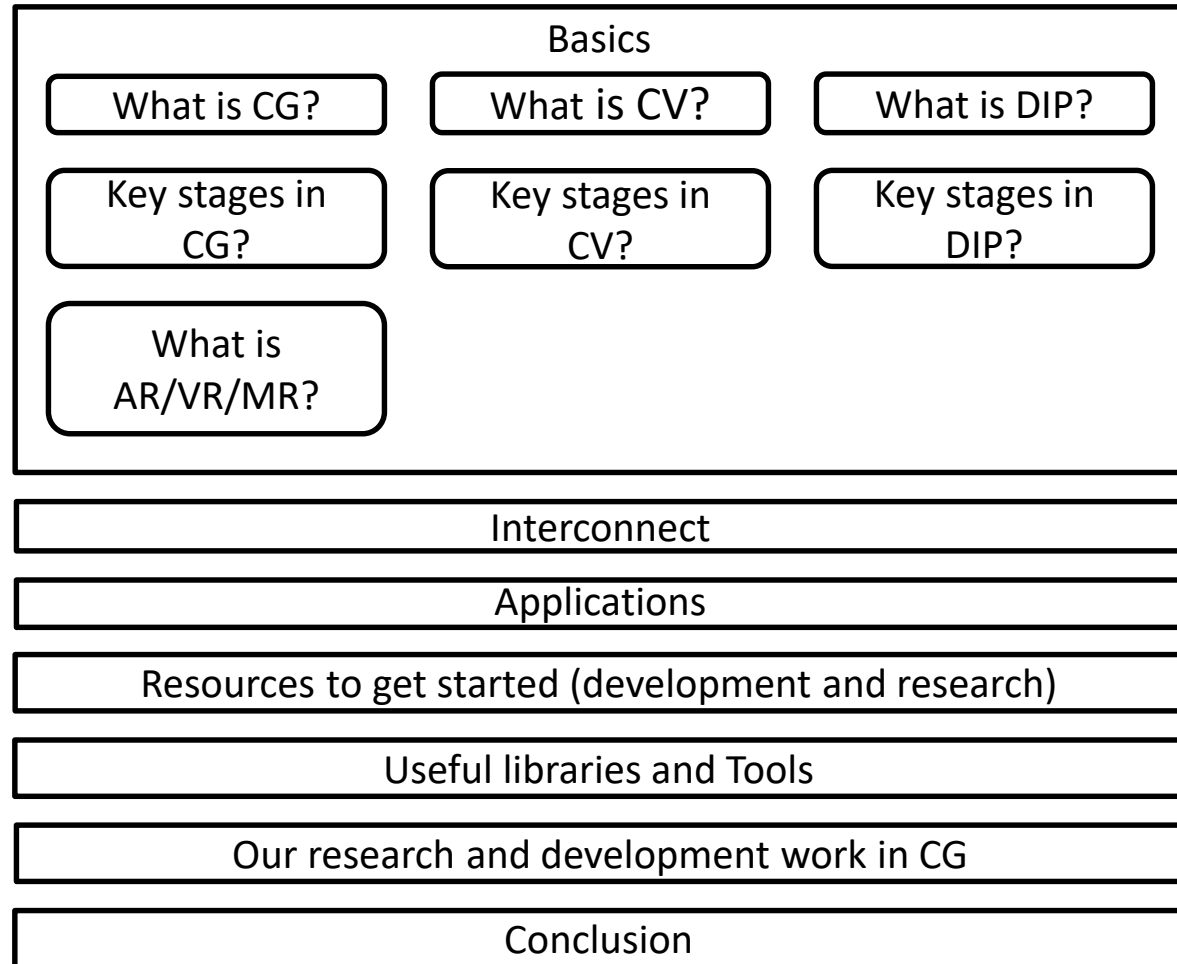 - OpenGL Insights, 2012. (Contributor/Reviewer)

Flow of this Talk

Slide 5

Progression of presentation

Basics

What is CG?	What is CV?	What is DIP?
Key stages in CG?	Key stages in CV?	Key stages in DIP?
What is AR/VR/MR?		

Interconnect

Applications

Resources to get started (development and research)

Useful libraries and Tools

Our research and development work in CG
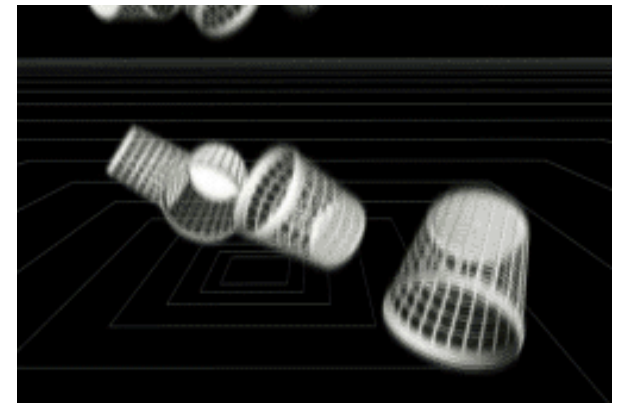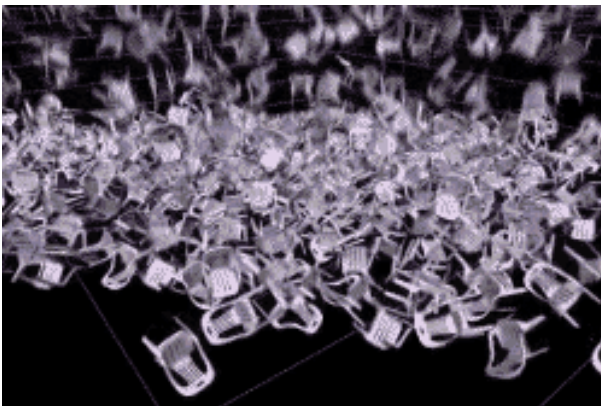
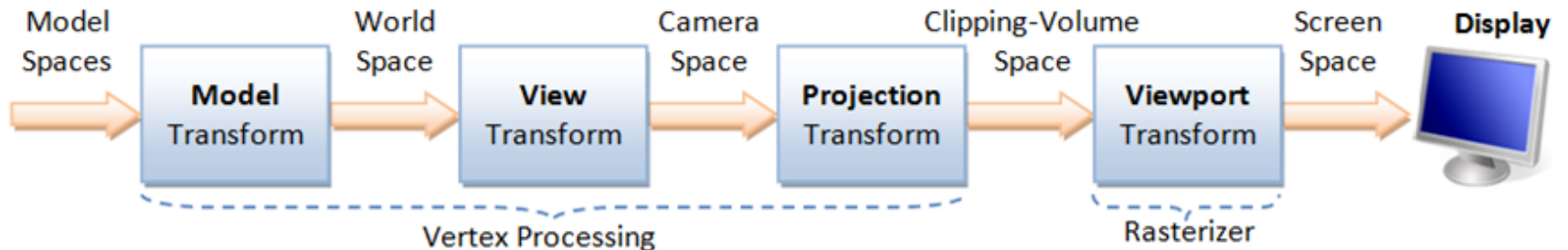Conclusion

Slide 57

Basics

What is Computer Graphics?

- Converting mathematics into pictures
- Everything that you see on computer screen is either text or graphics
- A powerful medium to communicate
  - A picture is worth a thousand words

Key Stages in Computer Graphics

```
┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│  Modeling   │ ───▶ │  Animation  │ ───▶ │  Rendering  │
└─────────────┘      └─────────────┘      └─────────────┘
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Model Spaces → **Model** Transform → World Space → **View** Transform → Camera Space → **Projection** Transform → Clipping-Volume Space → **Viewport** Transform → Screen Space → **Display**

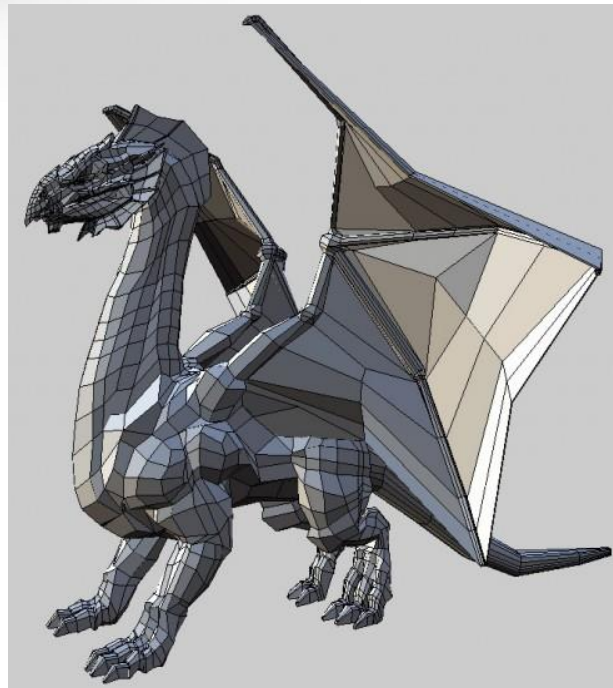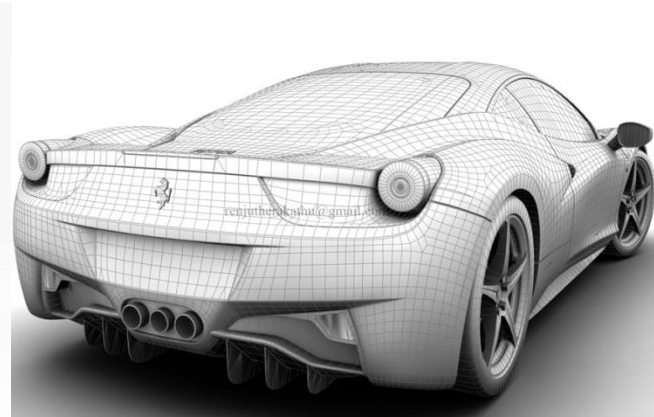Vertex Processing

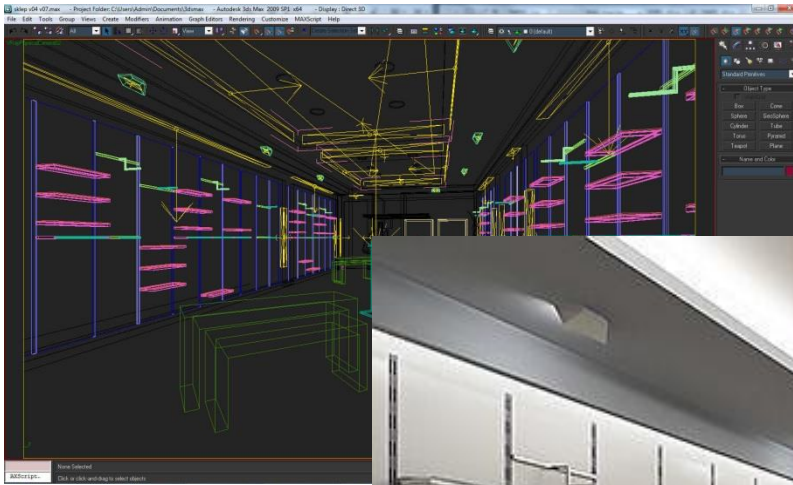Rasterizer

Components of Computer Graphics

- Three basic components
  - Modeling
  - Rendering
  - Animation
- Modeling
  - Developing a mathematical representation of any 3D *surface* of an object
- Rendering
  - Converting 2D/3D information into pixels
- Animation
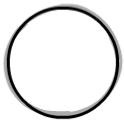 - Changing properties over time to give an illusion of motion

Modeling

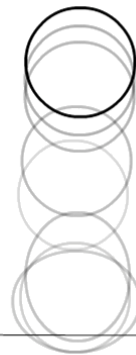# Rendering

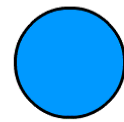# Animation

Frame 1   All Frames   Final Animation

What is Virtual Reality (VR)?

- Experience that **simulates immersive physical presence** in a **real or imagined** environment.

Virtual Reality - SteamVR featuring the HTC Vive
6,382,088 views • 5 Apr 2016

10 Virtual Reality Experiences That Are Too Realistic And Immersive
200,400 views • 7 Dec 2018

What is Augmented Reality (AR)?

- Experience that **supplements** the **view of a live, physical environment** with **digital** assets.

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What is Mixed Reality (MR)?

- Mixed reality is overlay of virtual content over the real world but **virtual content and the real-world content** are able to **react to one another** in **real time**.
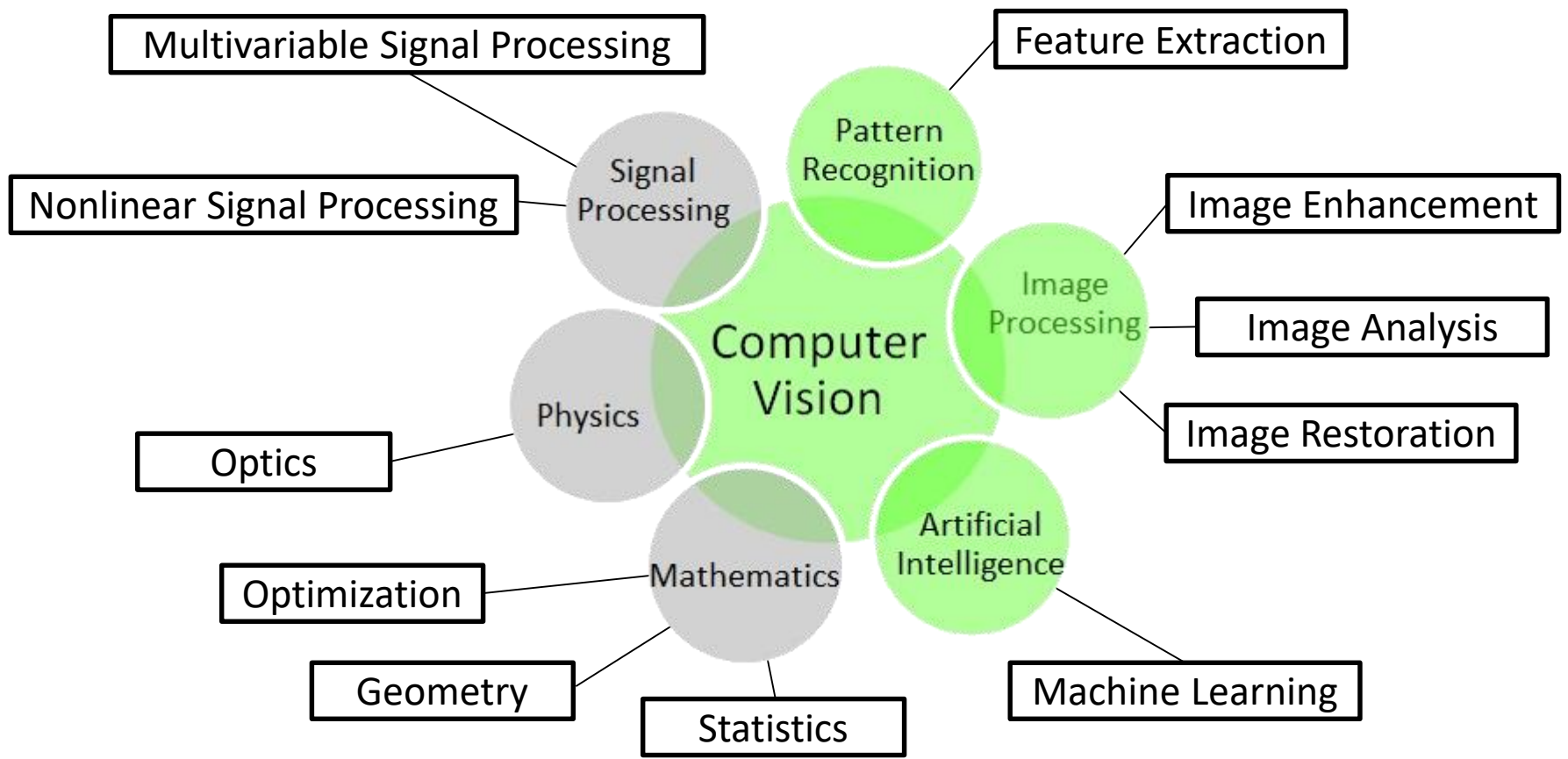
What is Computer Vision?

Deals with how computers can gain high-level understanding from digital images or videos

Key stages in Computer Vision

Multivariable Signal Processing

Nonlinear Signal Processing

Feature Extraction

Image Enhancement

Image Analysis

Image Restoration

Optics

Optimization

Geometry

Statistics

Machine Learning

Signal Processing

Pattern Recognition

Image Processing

Computer Vision

Physics

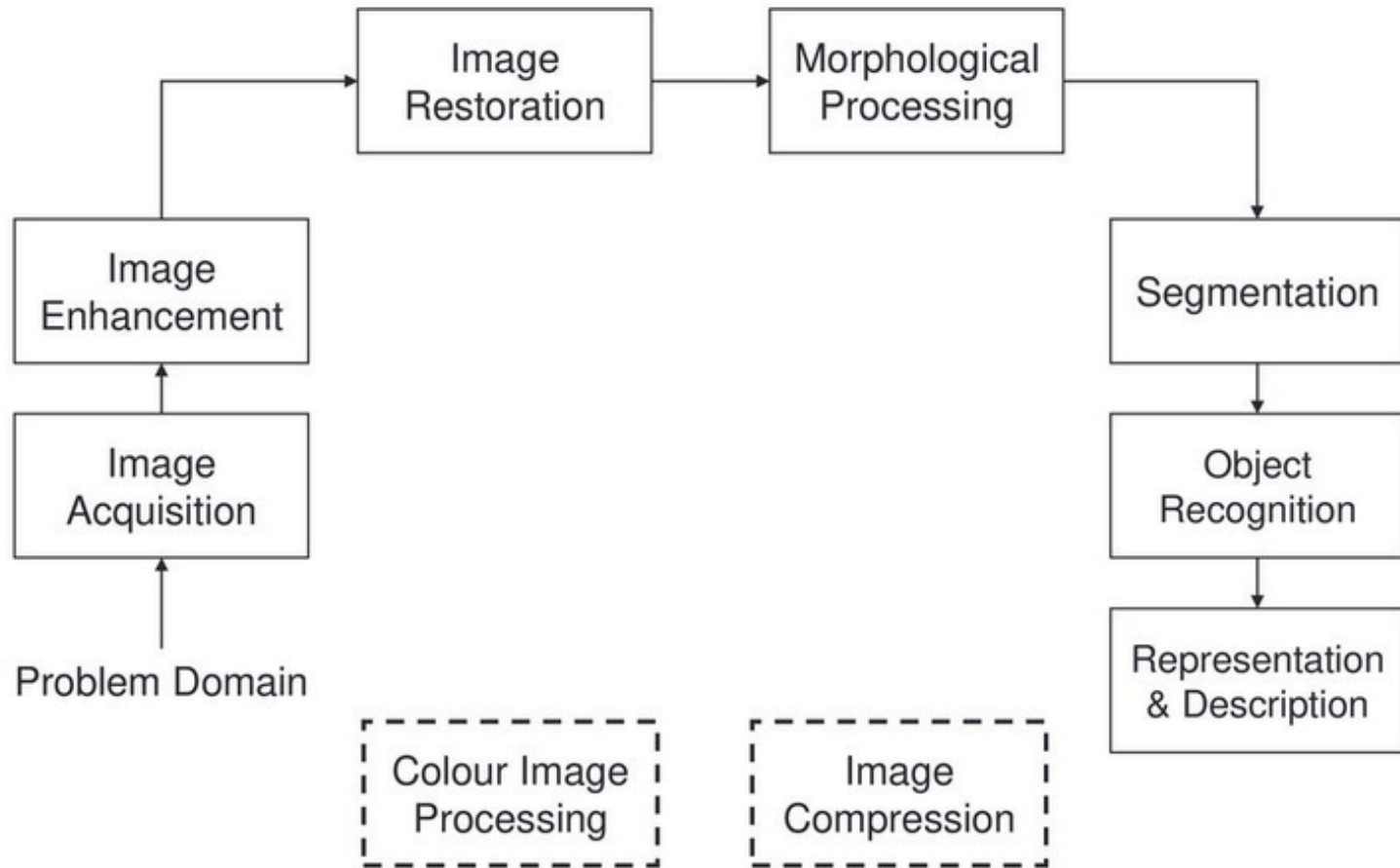Mathematics

Artificial Intelligence

What is (Digital) Image Processing?

Use of a digital computer to process digital images through an algorithm

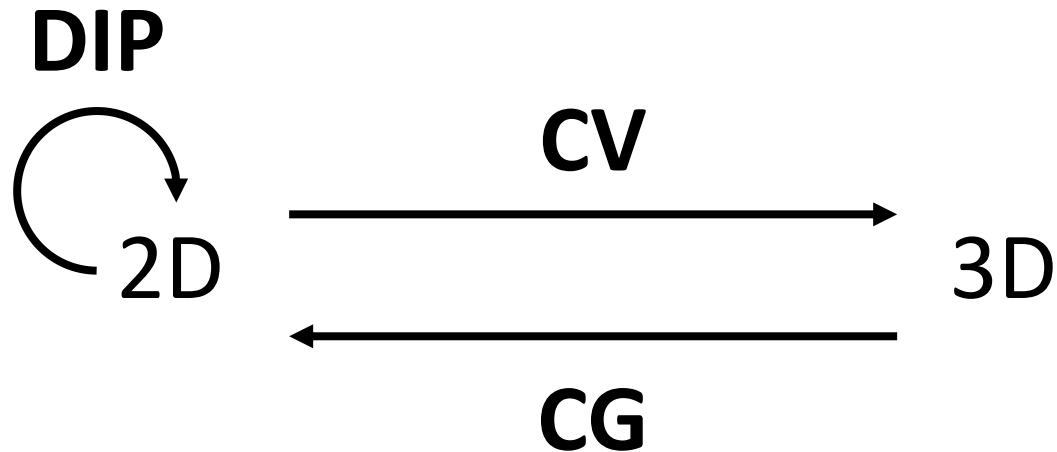# Key stages in Digital Image Processing

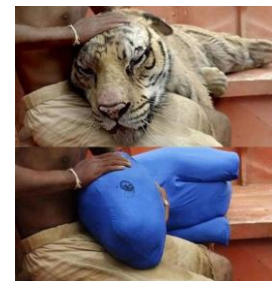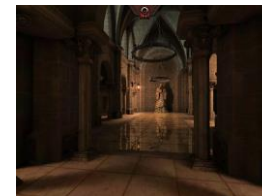# Interconnect - The Crux

DIP

CV

2D → 3D

CG

Computer Graphics (CG)
Computer Vision (CV)
Digital Image Processing (DIP)

Applications

Applications of Computer Graphics

- Applications
  - Scientific visualization
  - Games
  - Movie special effects
  - Tactical trainers and simulators
  - Virtual depiction of real world
  - Archiving digital heritage
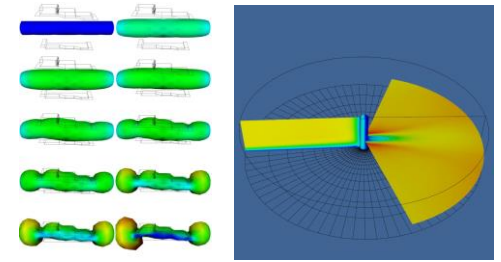
Applications of Computer Vision

Navigation: Self driving cars and drones.

Visual surveillance.
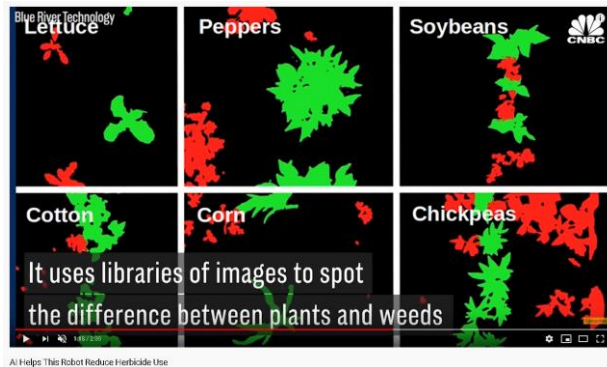
Automatic Crop Identification
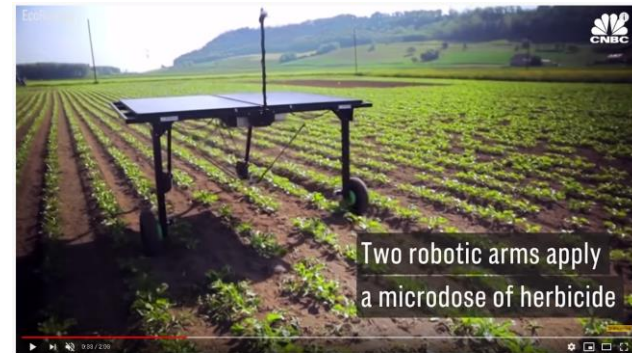
Smart Agriculture, disease identification, grading fruit/vegetables,

Applications of
Digital Image Processing
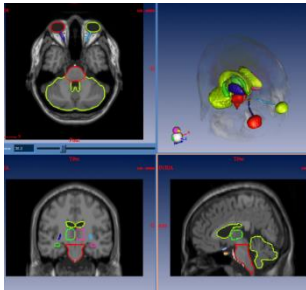
Medical image analysis

Image restoration
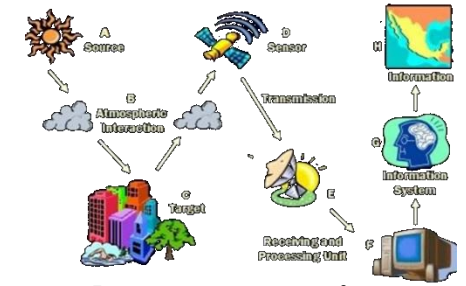
Remote sensing

Machine/Robot vision
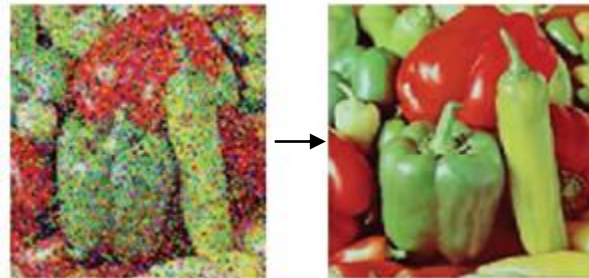
Color image processing
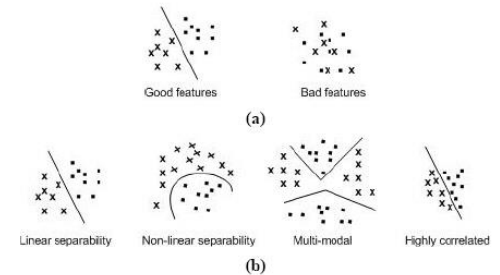
Pattern recognition
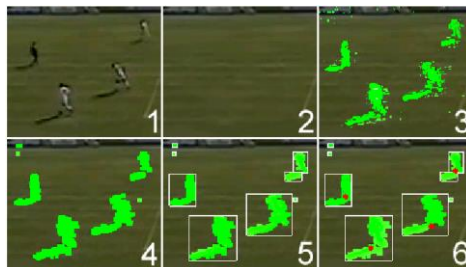
Video processing
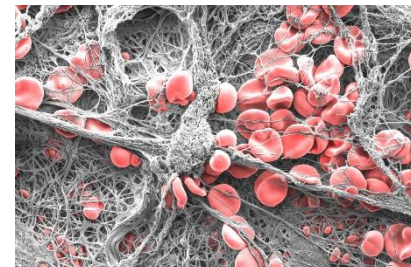
Microscopic imaging

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How to get started?

Prerequisites

- Know how to program in C/C++, Python, Matlab
- Strong in data structures and algorithms
- Have a solid understanding of vector mathematics and calculus
- Key courses
  - Calculus and Analytical Geometry
  - Multivariate Calculus
  - Linear Algebra
  - Differential Equations
  - Numerical Computing

Resources for Computer Graphics

Developing graphics applications

- For 2D graphics
  - Three options
    - Make your own engine (software)
    - Use existing game engines (GoDot, Unity, UE4, Cocos2D, etc.)
    - Hardware
      - Platform dependent (using Win32 GDI, GDI+ or Direct2D)
      - Platform independent (using OpenGL,Vulkan)
- For 3D graphics
  - Three options
    - Make your own engine in software
    - Make your own engine using API (DirectX,OpenGL,Vulkan)
    - Use existing engine/framework (Unity, UE4, TwinMotion, Stingray, Lumberyard, OGRE, Irrlicht, CryEngine, Cocos etc.)

Developing Games

- Please don't start creating your own game engine
  - use an existing game engine otherwise, you will not be able to make a game
- For 2D games
  - Unity,Cocos2D,App Game Kit,Godot,Libgdx, Construct 2,Gamemaker: Studio,Stencyl,Starling
- For 3D games
  - Unity,UE4, TwinMotion, Stingray, CryEngine, Lumberyard

Graphics Frameworks and Libraries

- Graphics API
  - OpenGL/DirectX/Vulkan (for desktop development)
  - OpenGL ES (for mobile/tablets)
  - WebGL (for web browser on desktop/mobile/tablets)
- Shader languages
  - GLSL (OpenGL/OpenGL ES/WebGL)
  - HLSL (DirectX)
  - Cg (wrapper around GLSL for OpenGL applications and HLSL for DirectX applications)
  - Brook (a kernel based GPGPU emulation using shaders)
- Compute
  - CUDA (NVIDIA only)
  - OpenCL (general)
  - WebCL (browser based compute)
  - Direct Compute Shader (special shader type in DirectX 10 and above)
  - OpenGL Compute Shader (special shader type in OpenGL v 4.3 and above)
  - Vulkan Compute Shader

Graphics/Game content creation

- 2D Images
  - Photoshop/GIMP/Illustrator
- 3D models
  - 3dsmax/Maya/Blender/Wings3D
- Sound
  - Audacity
- Several online websites having free content
  - https://opengameart.org/
  - http://kenney.nl/assets
  - https://craftpix.net
  - https://v-play.net/game-resources/16-sites-featuring-free-game-sounds
  - https://en.wikipedia.org/wiki/Comparison_of_free_software_for_audio

Computer Graphics Books

- Introductory graphics
    - [Real-time Rendering 3rd Edition](#) by Tomas Akenine-Möller, Eric Haines, and Naty Hoffman
    - [Fundamentals of Computer Graphics 3rd Edition](#) by Peter Shirley and Steve Marschner
    - [Foundations of 3D Computer Graphics](#) by Steven J. Gortler
    - [Computer Graphics-Principles and Practice 3rd Edition](#) by John F. Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, Kurt Akeley
    - [Introduction to 3D Game Programming with DirectX 11](#) by Frank Luna

- Advanced graphics
    - [OpenGL Superbible 6th Edition](#) by Graham Sellers, Richard S Wright and Nicholas Haemel
    - [OpenGL 4 Shading Language Cookbook Volume 1](#) and [Volume 2](#) by David Wolff.
    - [OpenGL Development Cookbook](#) by Muhammad Mobeen Movania.
    - [OpenGL Insights](#) by Patrick Cozzi and Christophe Riccio
    - [GPU Pro Series](#) by Wolfgang Engel
    - [GPU Gems Series](#) (Volume 1 to Volume 3)

Computer Graphics Books

- Mathematics and Physics
  - [Physics based Animation](#) by Kenny Erleben et al.
  - [Game Physics 2nd Edition](#) by David H. Eberly.
  - [Geometric Tools for Computer Graphics (The Morgan Kaufmann Series in Computer Graphics)](#) by Philip Schneider, David H. Eberly
  - [Game Physics Pearls](#) by Gino van den Bergen and Dirk Gregorius.
  - [Mathematics for 3D Game Programming and Computer Graphics 3rd edition](#) by Eric Lengyel.
  - [3D Math Primer for Graphics and Games 2nd edition](#) by Fletcher Dunn and Ian Parberry
  - [Real-time collision detection](#) by Christer Ericson

Computer Graphics Books

- Raytracing/PBR/Rendering
  - [Physically based Rendering from theory to implementation 3rd Volume](#) by Matt Phar and Greg Humphreys
  - [Ray tracing from the ground up by Kevin Suffern Volume 1](#) and [Volume 2](#) by Kevin Suffern
  - [Raytracing in one weekend series](#) by Peter Shirley
  - [Realistic Ray Tracing 1](#) by Peter Shirley and R. Keith Morley
  - [Realistic Ray Tracing 2](#) by Peter Shirley and R. Keith Morley
  - [Realistic Image Synthesis using Photon Mapping](#) by Henrik Wann Jensen
  - [Principles of Digital Image Synthesis Volume I and Volume II](#) by Andrew Glassner
  - [Geometric Tools for Computer Graphics (The Morgan Kaufmann Series in Computer Graphics)](#) by Philip Schneider, David H. Eberly
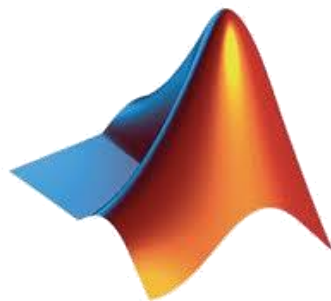
Resources for Computer Vision and Image Processing

Computer Vision Libraries/Tools

- OpenCV
- Matlab
- ITK
- Aforge.net
- Tensorflow
- SimpleCV
- ImageJ
- scikit-image

Computer Vision/Image Processing Books

- ## Computer Vision
  - Computer Vision: Algorithms and Applications by Richard Szeliski, 2010.
  - Computer Vision: Models, Learning, and Inference by Simon Prince, 2012.
  - Computer Vision: A Modern Approach by David Forsyth and Jean Ponce, 2002.
  - Introductory Techniques for 3-D Computer Vision by Emanuele Trucco and Alessandro Verri, 1998.
  - Multiple View Geometry in Computer Vision by Richard Hartley and Andrew Zisserman, 2004.

- ## Image Processing
  - Digital Image Processing by Rafael C Gonzalez and Richard E Woods
  - Image Processing, Analysis and Machine Vision by Milan Sonka and Vaclav Hlavac and Roger Boyle
  - Fundamentals of Digital Image Processing by Anil K Jain

Research Information:
Top journals, conferences and research groups

Graphics Research

- Top journals
  - ACM TOG
  - IEEE TVCG
  - Comp. Graphics Forum
  - IEEE CGA
  - The Visual Computer (TVC)

- Notable books
  - GPU Gems 1,2,3
  - GPU Pro 1,2,3,4,5,6,7,8
  - Game Engine Gems 1,2,3
  - Graphics Gems 1,2,3,4,5,6,7,8
  - PBRT v3/v4 (pbrt.org)
  - http://www.realtimerendering.com/books.html

Top conferences
  - SIGGRAPH
  - SIGGRAPH Asia
  - Eurographics
  - IEEE Visualization
  - EuroVis
  - Pacific Graphics
  - HPG
  - I3D
  - WSCG

Computer Vision/Image Processing Research

- Top Journals
  - IEEE Trans. Pattern Analysis and Machine Intelligence (PAMI)
  - IEEE Trans. Image Processing (TIP)
  - IEEE Trans. Medical Imaging (TMI)
  - Pattern Recognition
  - Int. Journal of Comp. Vision
- Top Conferences
  - IEEE CVPR
  - IEEE ICCV
  - ECCV
  - IEEE ICIP
  - MICCAI
  - IROS
  - WACV

Some famous Graphics Researchers

- http://graphics.pixar.com/library/indexByTitle.html
- http://graphics.stanford.edu/people.html
- http://physbam.stanford.edu/~fedkiw/
- http://www.cs.cornell.edu/~djames/research/index.html
- http://www-bcf.usc.edu/~jbarbic/
- http://graphics.cs.cmu.edu/
- http://graphics.berkeley.edu/
- http://graphics.ethz.ch/
- http://www.cs.ubc.ca/~rbridson/
- http://www.matthiasmueller.info/
- https://cs.uwaterloo.ca/~c2batty/
- http://www.tessendorf.org/reports.html
- https://sites.google.com/site/takahiroharada/
- http://www.physicsbasedanimation.com/
- http://www.math.zju.edu.cn/ligangliu/CAGD/

Notable Local Research Groups[1]
(Computer Graphics/Computer Vision/Image Processing)

- Machine Vision and Learning Lab (SEECS)
- Vision and Image Processing (VIP) UMT
- Computer Vision and Machine Learning Lab (CVML) KICS UET Lahore
- Image and Video Processing Research Group (IVPRG) Comsats
- NEDUET, SmartCity Lab
- ReVeal (Recognition, Vision and Learning) Research Group (FAST NU Ismd)
- The Machine Intelligence Group (FAST NU Khi)

1. The list is non-exhaustive so it might not list all active local research groups

General Tools and Libraries

Some useful libraries/tools

- Processing (https://processing.org)
  - A very simple API written on top of java to create RAD graphics, computer vision and image processing applications
  - Supports both 2D and 3D graphics through OpenGL
  - Highly recommended for beginners

- dlib (http://dlib.net/)
  - A modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to solve real world problems

Some useful libraries/tools

- VTK (https://vtk.org/)
    - a powerful modular open source framework for 3D computer graphics, modeling, image processing, volume rendering, scientific visualization, and 2D plotting
    - allows fast integration and testing of new algorithms and development of robust applications

- ITK (https://itk.org)
    - a powerful modular open source image processing, image segmentation and image registration library

Some useful libraries/tools

- MeVis Lab (http://www.mevislab.de/)
  - a powerful modular framework for image processing research and development with a special focus on medical imaging
  - allows fast integration and testing of new algorithms and the development of clinical application prototypes

- Cinder (http://libcinder.org)
  - Cinder is a free and open source library for professional-quality creative coding in C++
  - Similar to processing but for C++

Some useful libraries/tools

- Paraview (http://www.paraview.org/)
  - a powerful open-source, multi-platform data analysis and visualization application
  - allows users to quickly build visualizations to analyze data

- Meshlab (https://www.meshlab.net/)
  - open source system for processing and editing 3D triangular meshes
  - provides a set of tools for editing, cleaning, healing, inspecting, rendering, texturing and converting meshes.
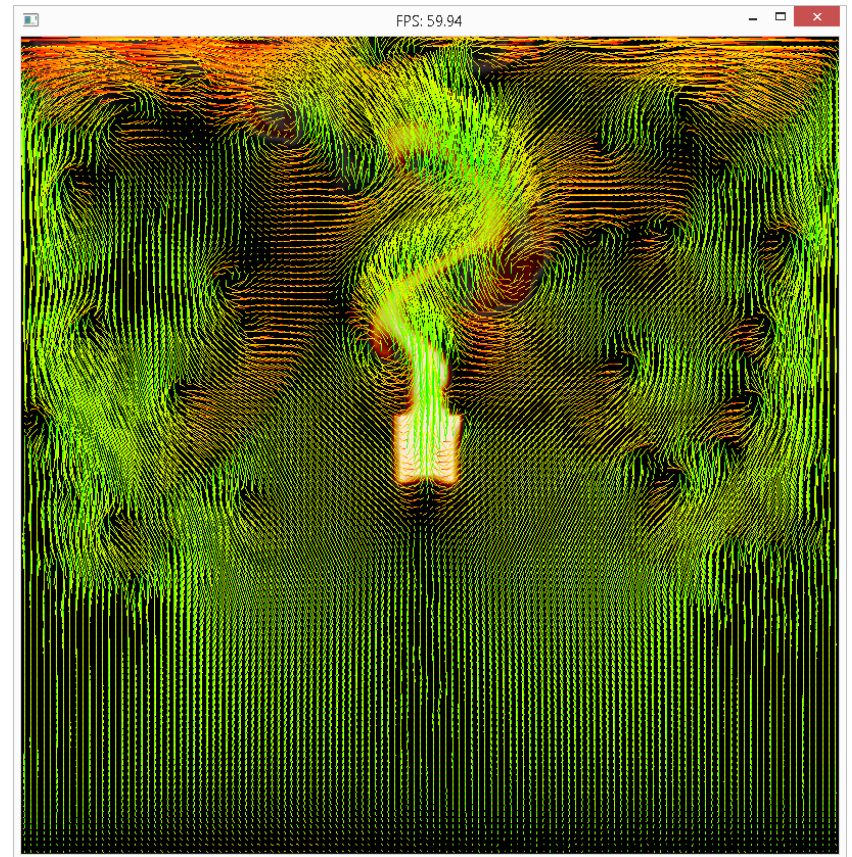
Our Research and Development Work in Computer Graphics
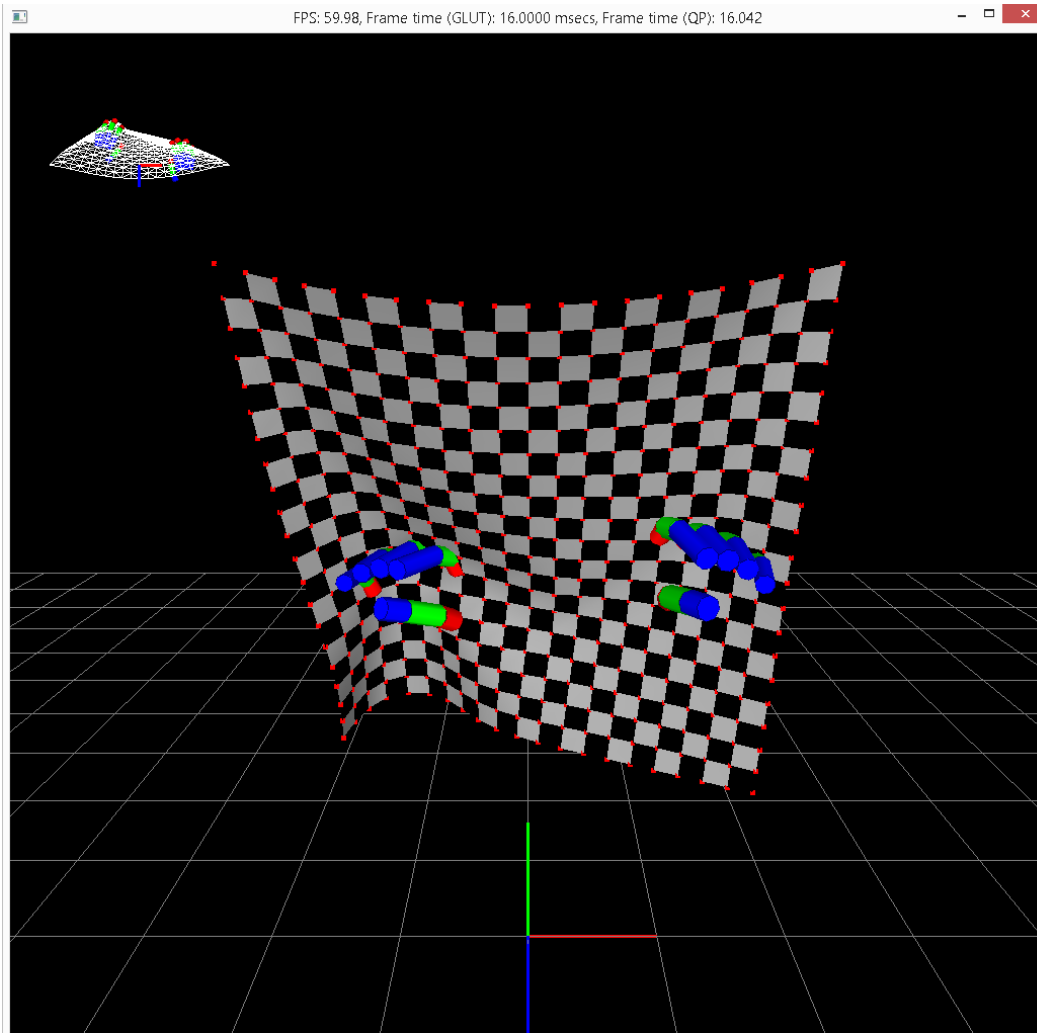
Photorealistic 3D environments

Physics Simulation

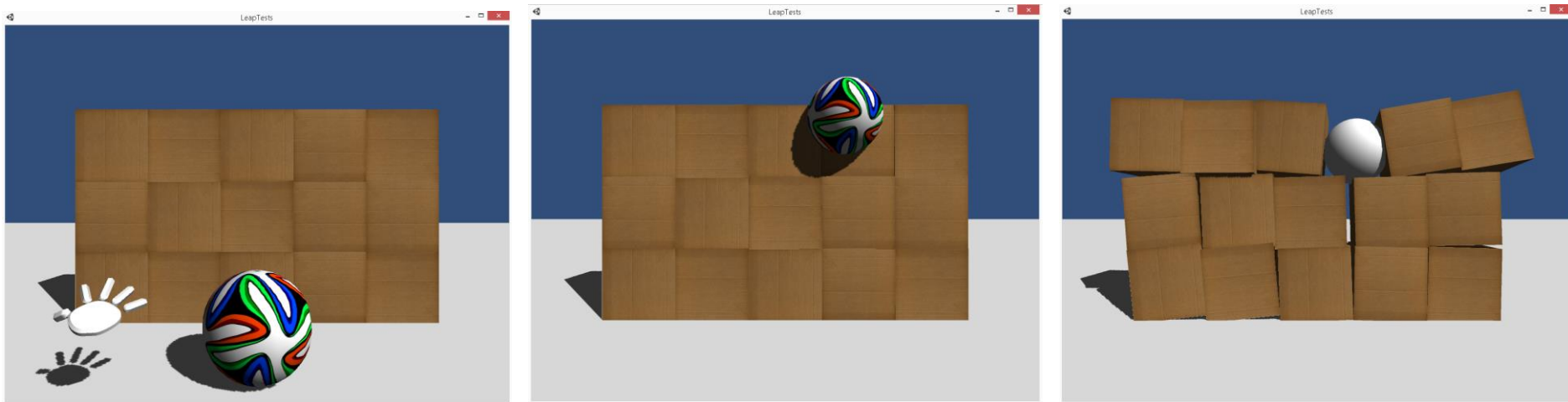

Fire Simulation Demo

Physics Simulation

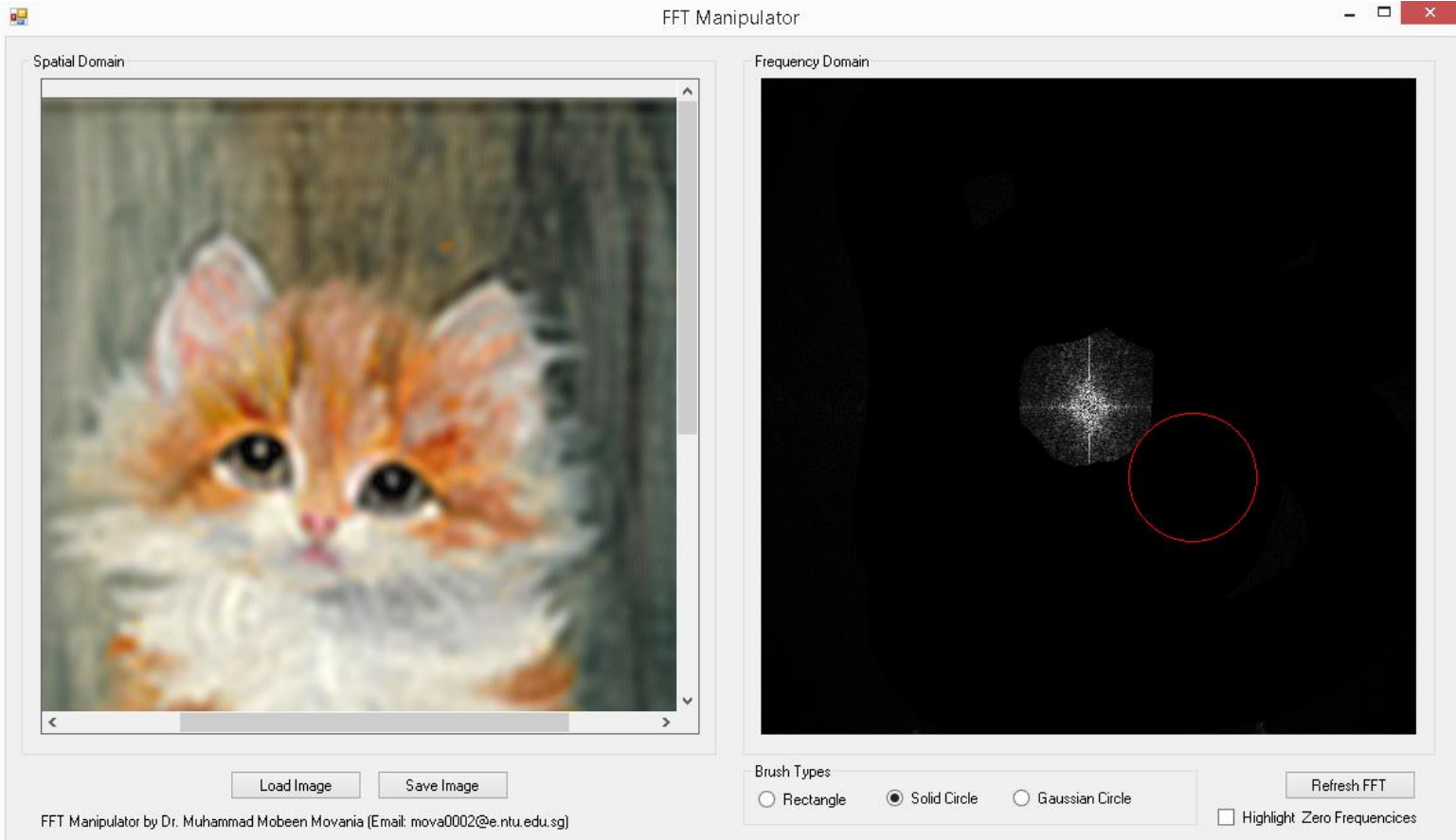Interactive Cloth Simulation with Leap Motion

Physics Simulation

Grab and Throw - Leap Motion Demo

FFT Manipulator

FFT Manipulator Demo
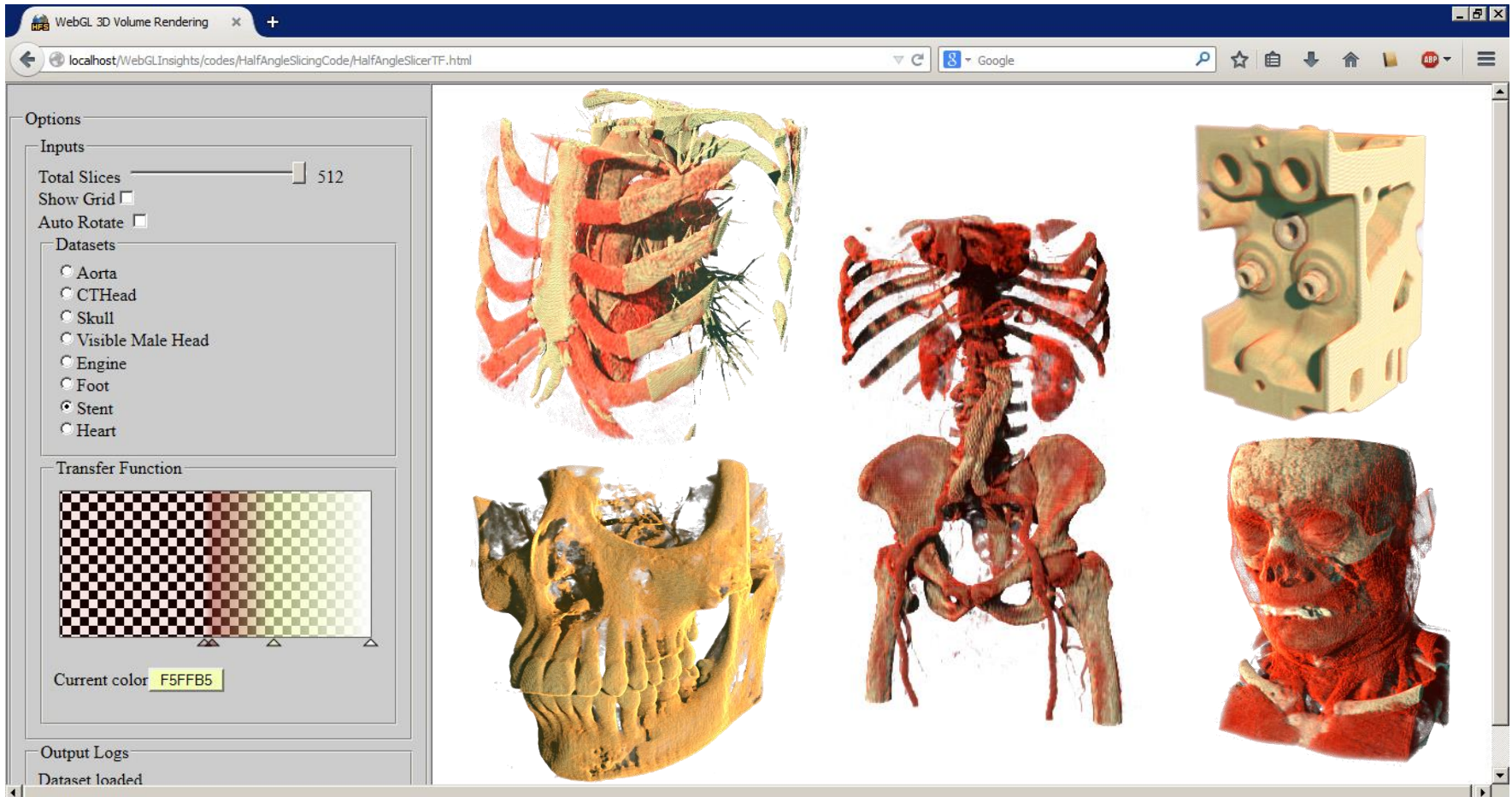
Fracture simulation
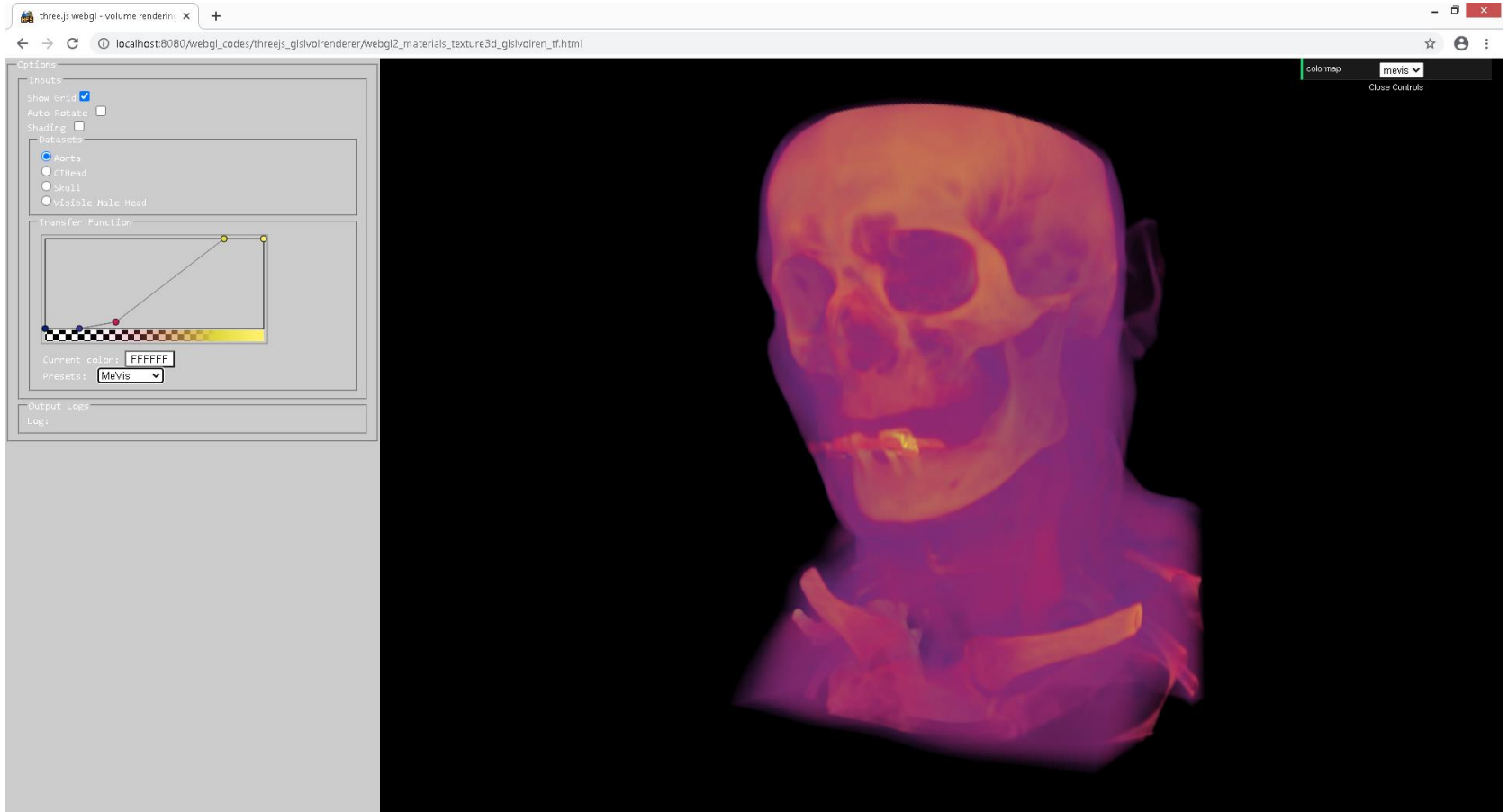

Vase Smasher Demo

Translucent material rendering

Translucency Demo

WebGL Volume Rendering

Browser based Volume Rendering

Browser based Volume Rendering Demo

Thanks

Any questions?

Please feel free to get in touch should you need any more information

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mova0002@e.ntu.edu.sg