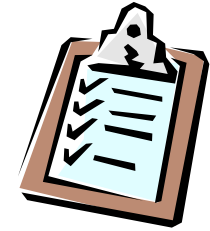# 1.4 Computer visualization

Ir Dr. Sam C. M. Hui
Department of Mechanical Engineering
The University of Hong Kong
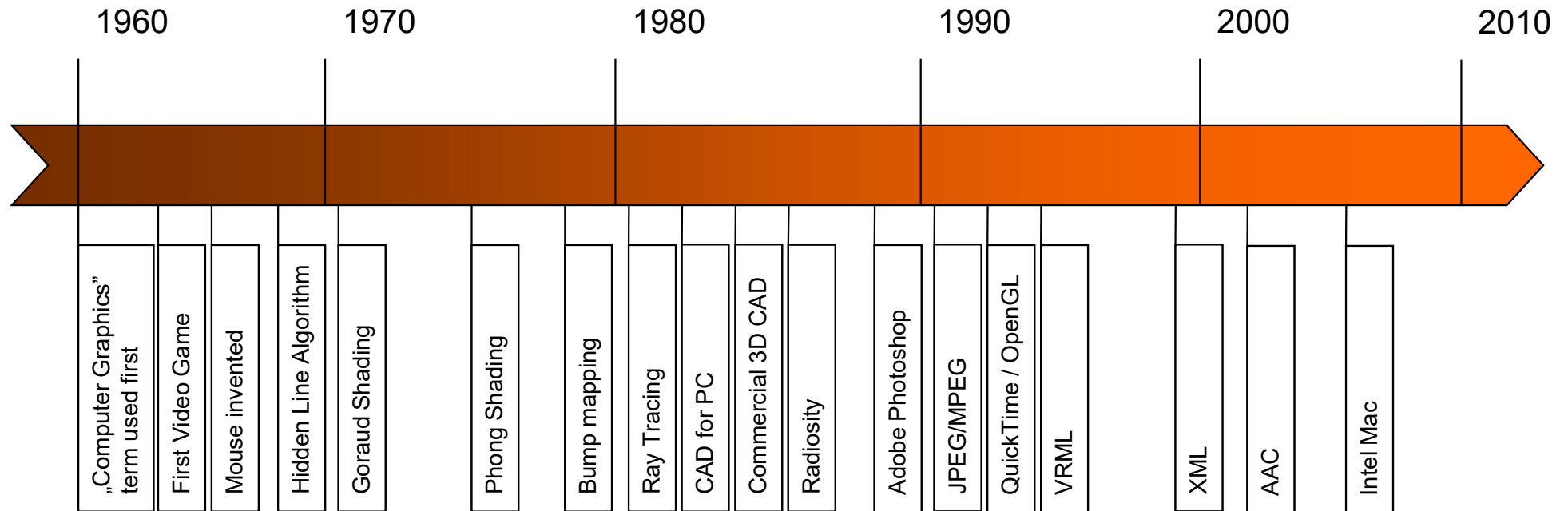E-mail: cmhui@hku.hk

Jun 2025

Contents

- History
- Computer visualization methods
- Visualization workflow
- Technology background
- BIM visualization
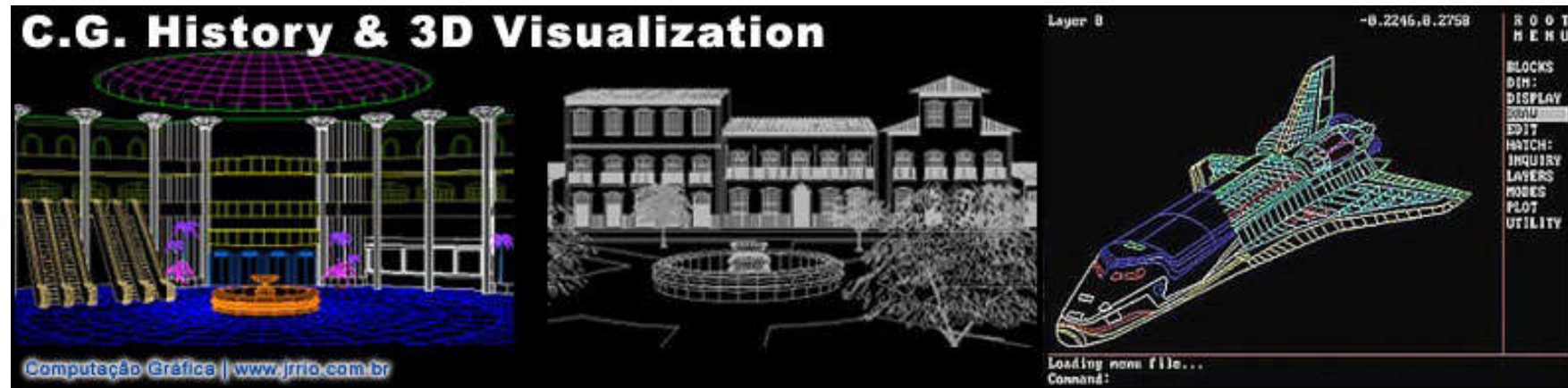- Virtual reality systems
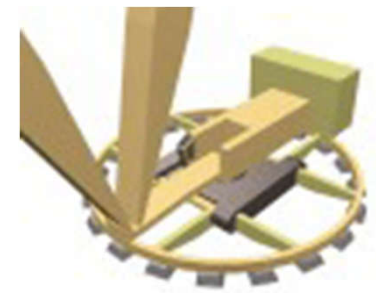- Future trends

Technology Timeline

1960	1970	1980	1990	2000	2010

- „Computer Graphics" term used first
- First Video Game
- Mouse invented
- Hidden Line Algorithm
- Goraud Shading
- Phong Shading
- Bump mapping
- Ray Tracing
- CAD for PC
- Commercial 3D CAD
- Radiosity
- Adobe Photoshop
- JPEG/MPEG
- QuickTime / OpenGL
- VRML
- XML
- AAC
- Intel Mac

http://accad.osu.edu/~waynec/history/timeline.html

C. G. = Computer Graphics

(Source: History of Computer Graphics and 3D Visualization http://www.jrrio.com/en-hist.html)
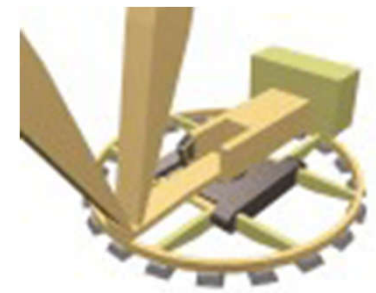
History

- History of computer graphics (CG) and 3D visualization
  - 1945 Whirlwing computer at MIT that operated in real time using video displays for output
  - 1982 AutoCAD software running on IBM PC
  - 1990~now: 3D Studio and 3ds Max
    - Use of micro-computers - Personal Computer (PC)
    - Computer Graphics (CG) and animation
    - 3D model and rendering, photorealistic rendering
    - 3D visualization, wire frame, virtual reality (VR)

(Source: History of Computer Graphics and 3D Visualization http://www.jrrio.com/en-hist.html)
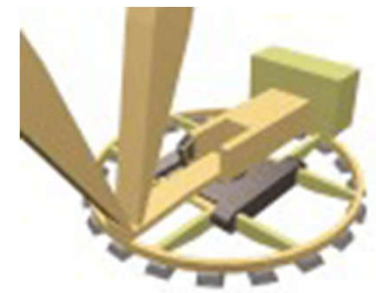
History

- Computer 2D and 3D visualization
  - Architectural rendering and perspective
    - Exterior, interior, floor plans, sections, cutaway
    - Industrial equipment, plant rooms, machinery
    - Aerial views and site plan view
    - Photorealistic and non-photorealistic
    - Transformation (before & after renovation), e.g. http://www.jrrio.com/en-reforma.html
    - Examples: http://www.jrrio.com/en-lista.html, http://www.jrrio.com/en-lista3.html

History

- Architectural visualization
  - 3D renderings with true-to-life materials representation
  - 3D stylized renderings to evoke a mood, tell a story or elicit a response
  - 3D animations which add scenic motion such as flyovers or walk-through
  - Simulations of sun light or material properties
  - Panoramic views to create a stunning 360-degree experience of proposed property
  - 'Old-School' computer-generated pen-and-ink with watercolor rendering

Visualization Techniques

•Photorealistic images (rendering)
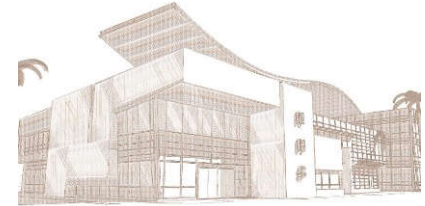
Artistic images
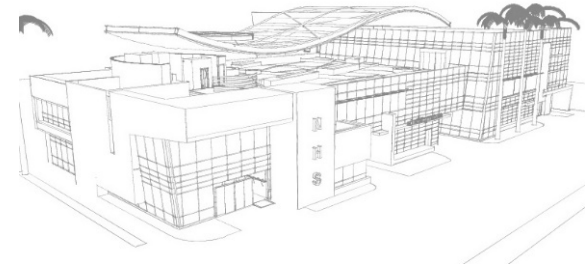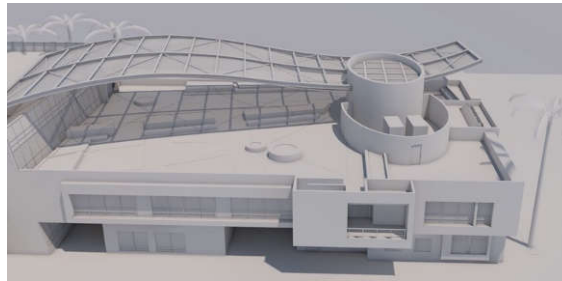
Interactive virtual models

Fly through animations

Sun studies

(38.9167, -77.0000) 2015Jul13 04:58:00

Integrated BIM Visualization Workflow
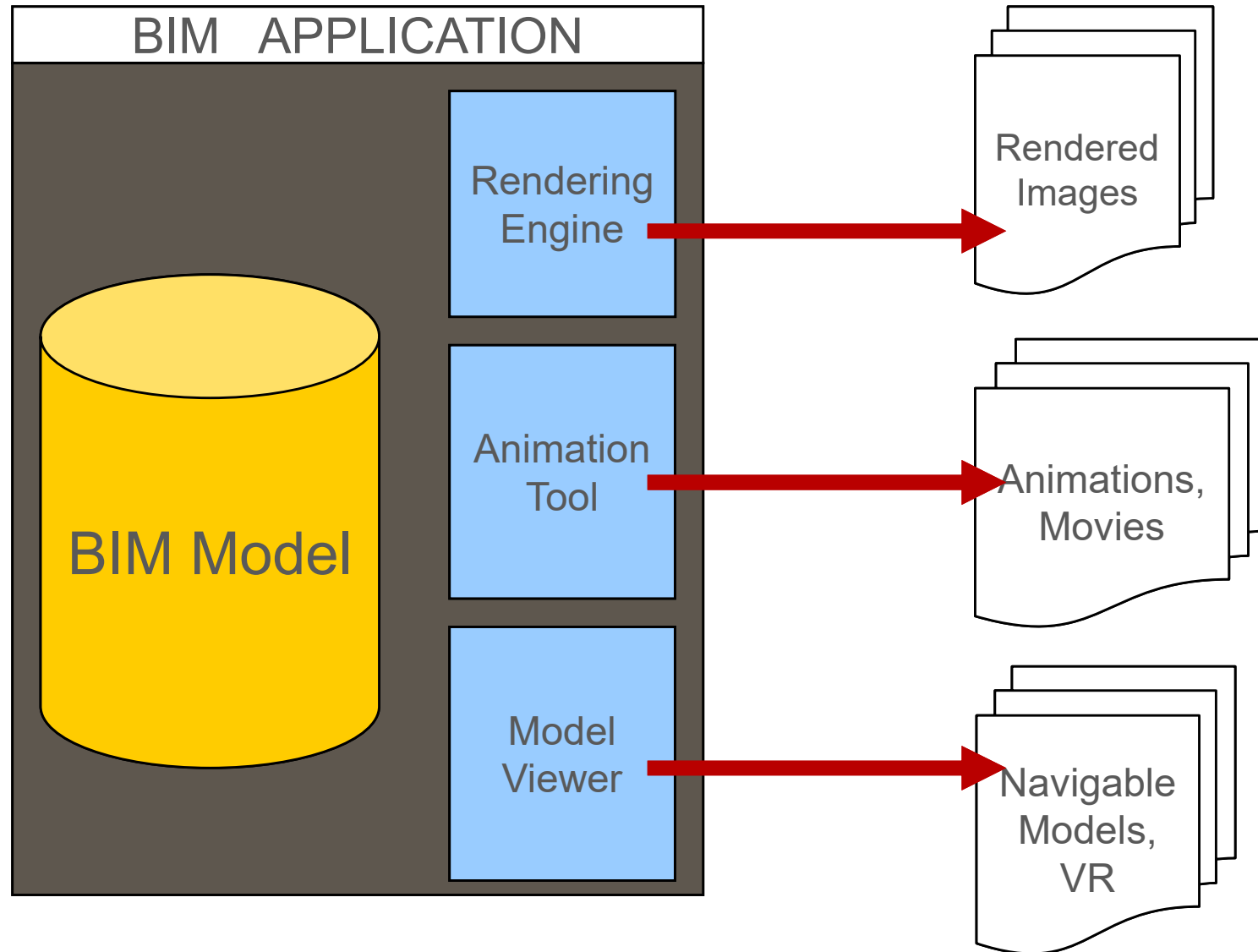
Complex Visualization Workflow
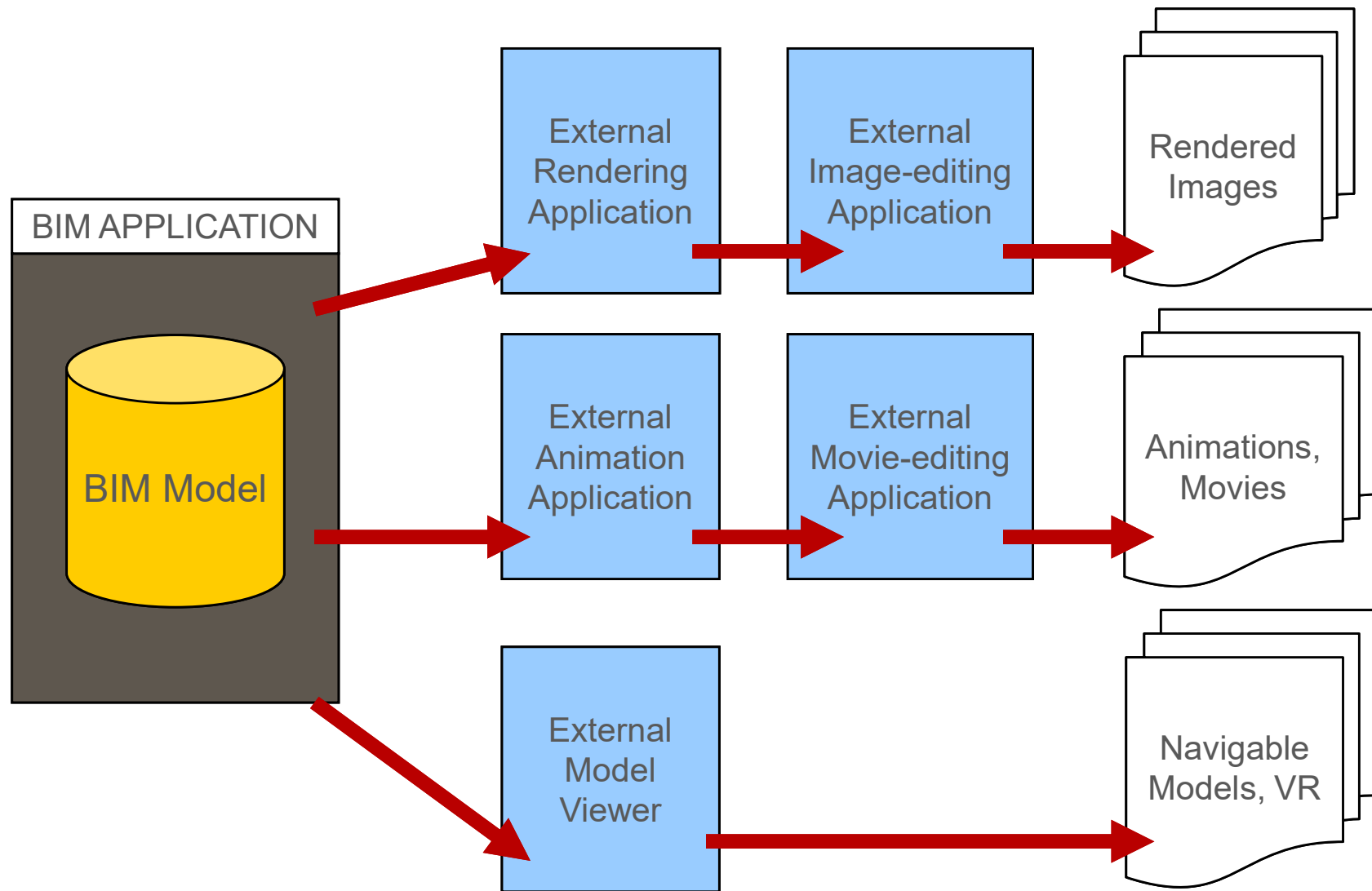
Photorendering

Objective:

Creating photorealistic images, based on the BIM model, using an internal or external rendering engine

Modelled with GRAPHISOFT ARCHICAD and rendered with built-in rendering engine: CineRender Engine.

Process:
1. Modeling
2. Scene layout setup
3. Rendering

NHS office complex by paastudio

Scene layout setup

Global Illumination
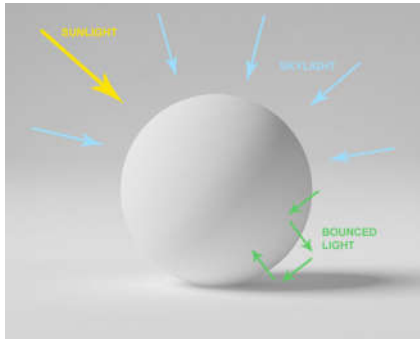
Surface Catalogs
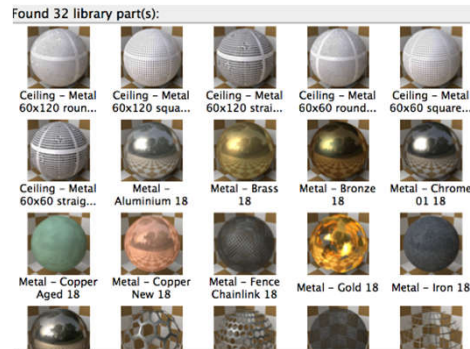
Physical Renderer

IES Lights
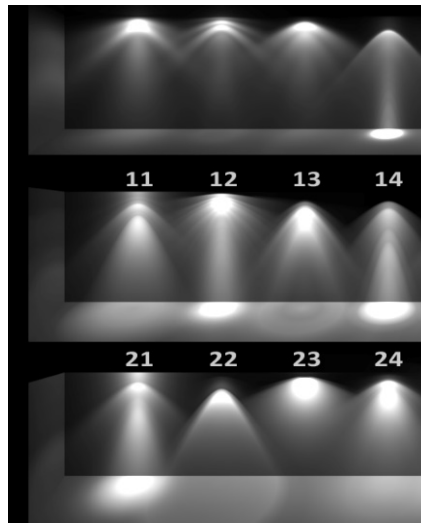
HDRI Sky

Physical Sky
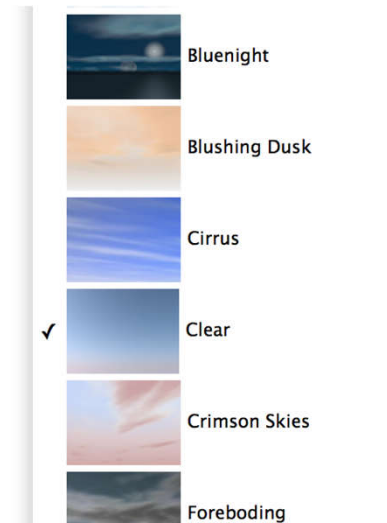
Visualization decisions

Abstract

- Faster computation
- Low hardware needs
- Strong artistic skills

Fender Katsalidis
Architects
Eureka Tower
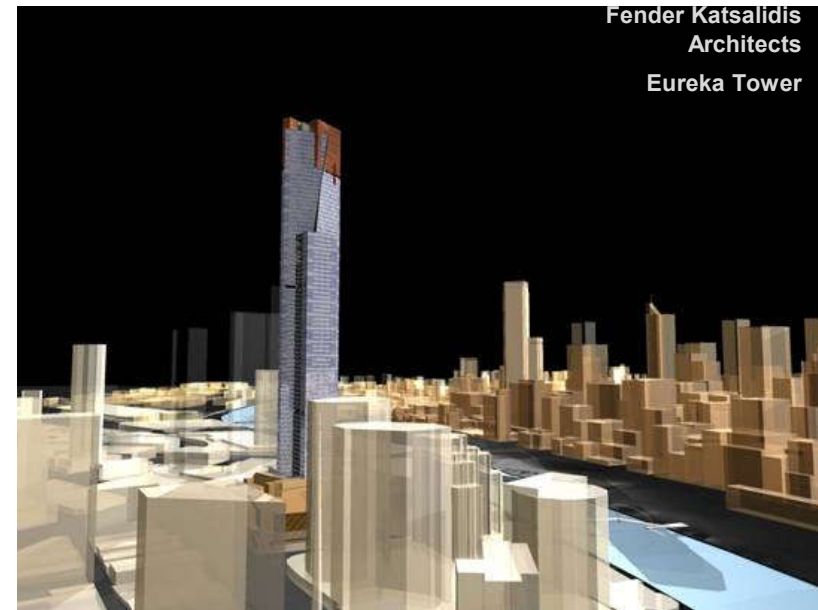
Realistic

- Slower computation
- Strong (infinitely)
  hardware required

copyright rice daubney (c) 2007

Modelling

- Low poly
  - Abstract geometry
  - Details by textures
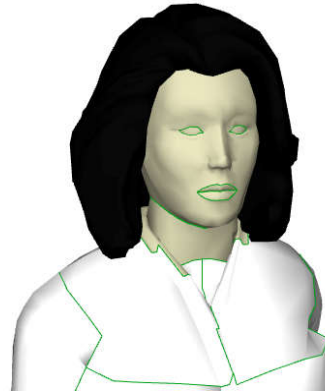
- High poly
  - Details modeled
  - Enables using realistic material
  - Particles, fur, grass

Elizabeth Tower
Andreea Horvath, Kiss Iosif-Andrei

(c) copyright Blender Foundation | durian.blender.org

Textures and Materials

Shading model
- Flat, Gouraud, Phong
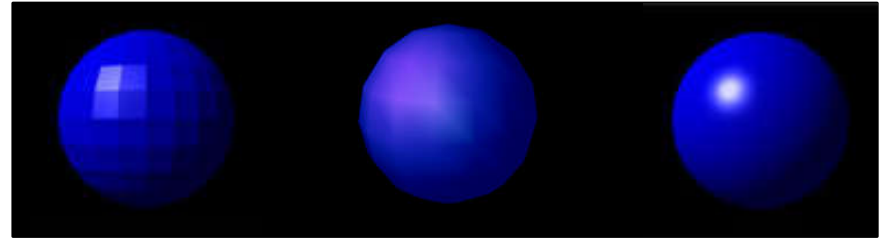
Simple textures
- Only colors

Complex textures
- Multi-layered colors
- Bump (normal) mapping
- Displace
- Reflecting and refracting

Light Settings

- **Simple lighting**
  - Based on light direction
  - Ambient for shadows
  - Diffuse for direct lights
  - Specular for glossiness

- **Complex lighting**
  - Traces photons
  - Indirect illuminations
  - Caustics for glossiness
  - Volume effects
  - Sub surface scattering

Luxrender
David Bucciarelli
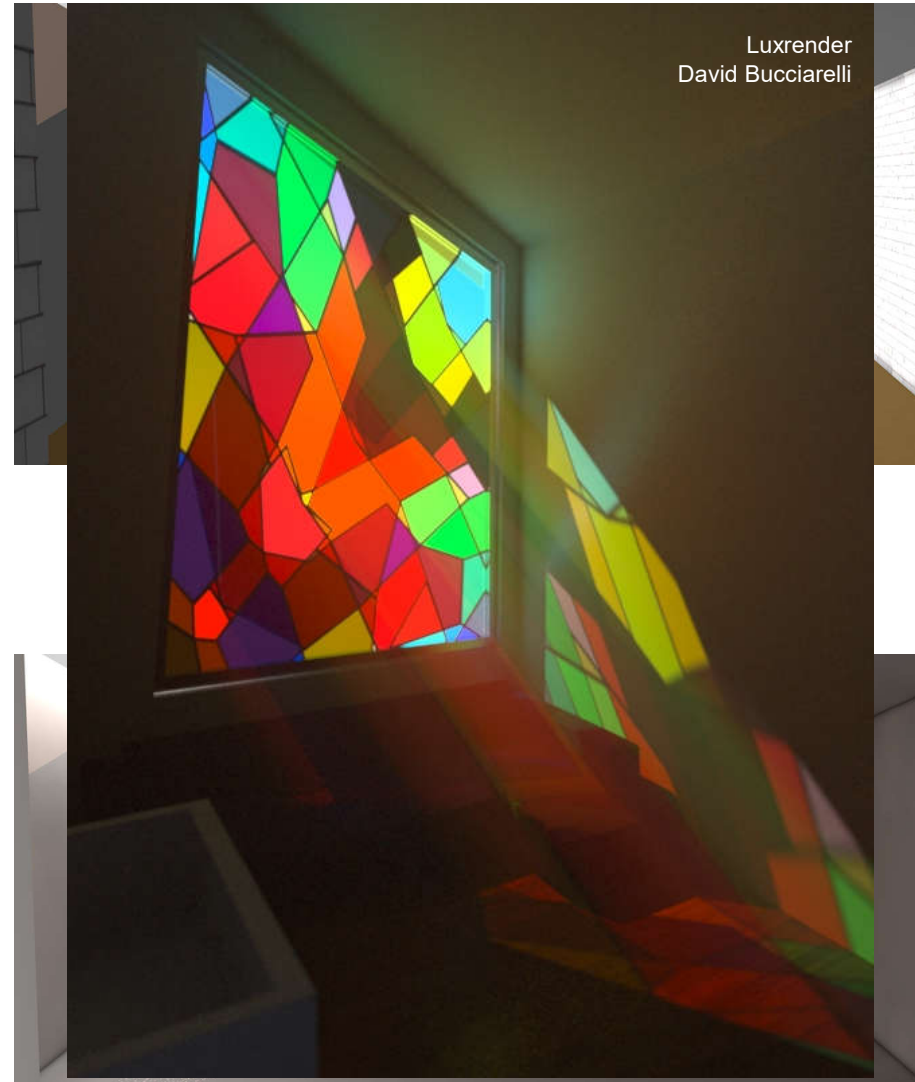
Lighting simulation using Radiance (real vs. simulated)

Virtual Reality?

Figure I-1. Real vs. Radiance simulations of conference room and bathroom.

(Source: http://radsite.lbl.gov/radiance/refer/)

Shadows

- Mapped
  - Blurry
  - Point or parallel lights
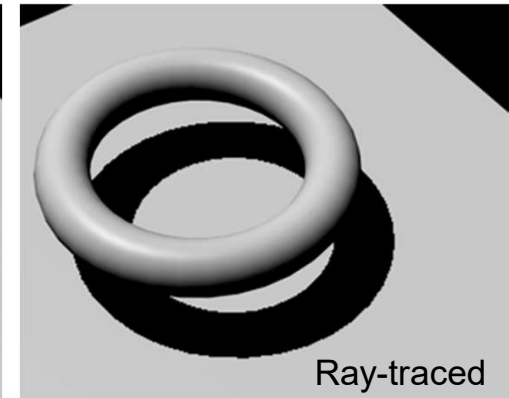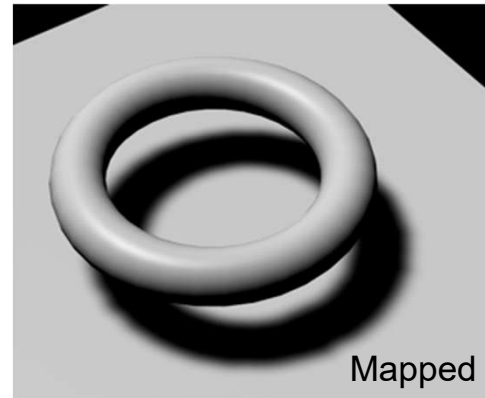
- Ray-traced
  - Accurate shadows
  - Special lighting shapes

Mapped | Ray-traced | Point light | Area light
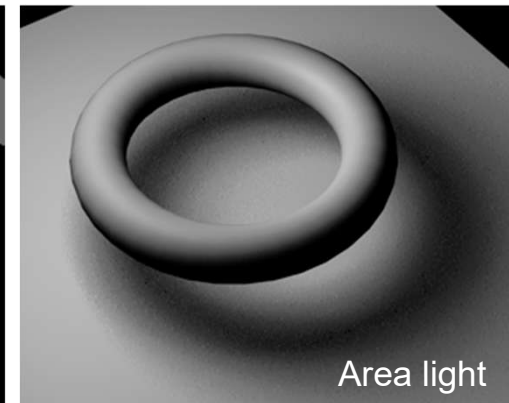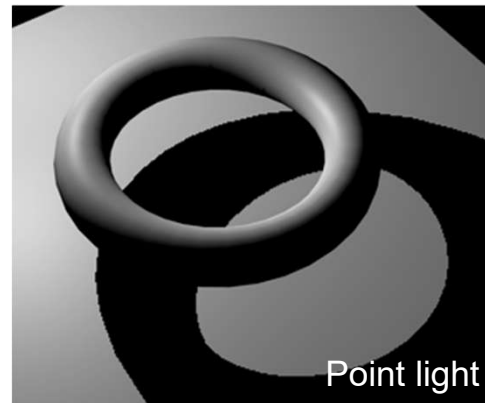
Camera Settings

- Projections
  - Axonometric
  - Perspective
  - Distorted (Fish eye)

- Anti-aliasing
  - Smoothing
  - Outline edges

- Lens effects
  - Depth of field
  - Motion blur
  - Glare
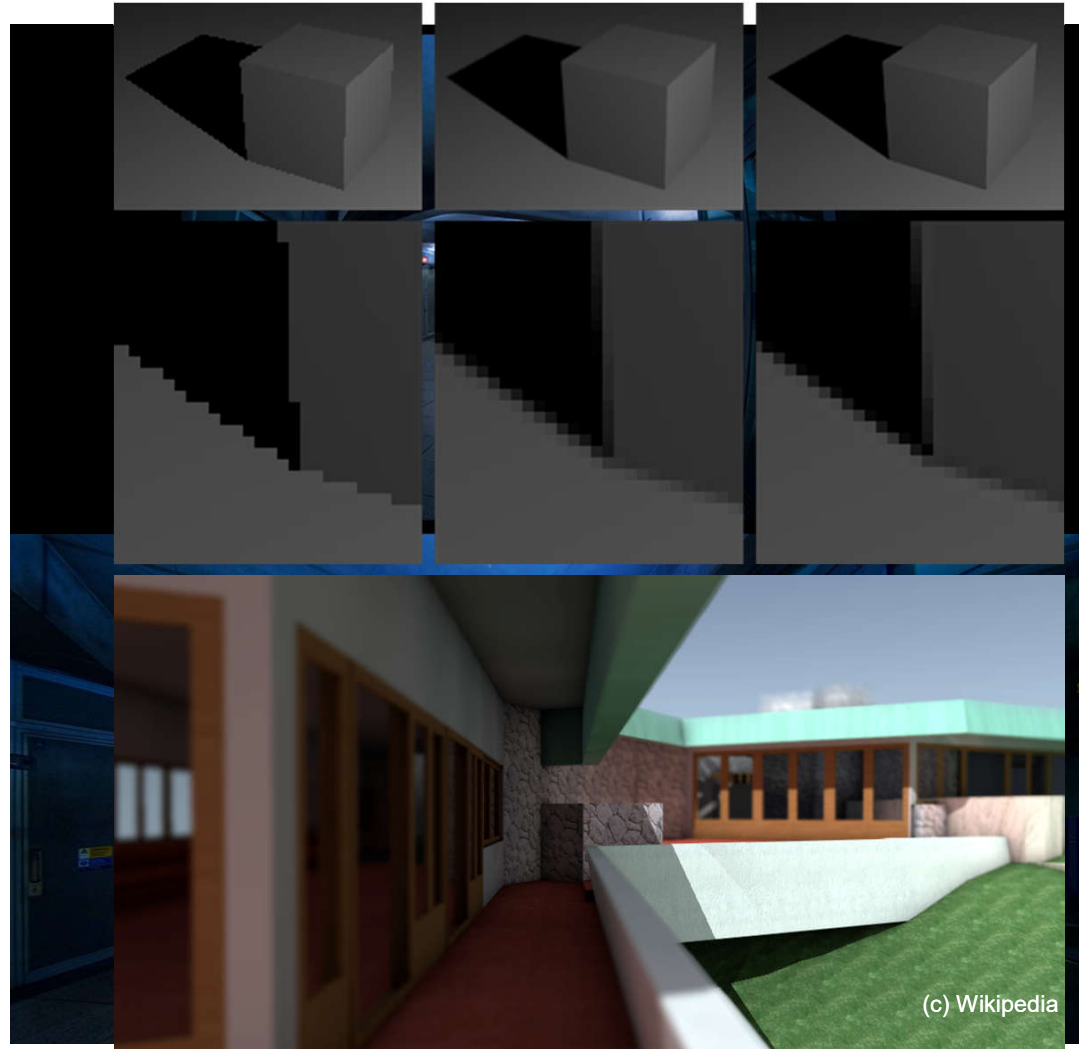
(c) Wikipedia

Non-photorealistic renderings

Creating **artistic style images** based on the BIM model using special rendering engine and/or photo editing software

Process A:

1. Modelling
2. Scene layout setup
3. Non-Photorealistic Rendering
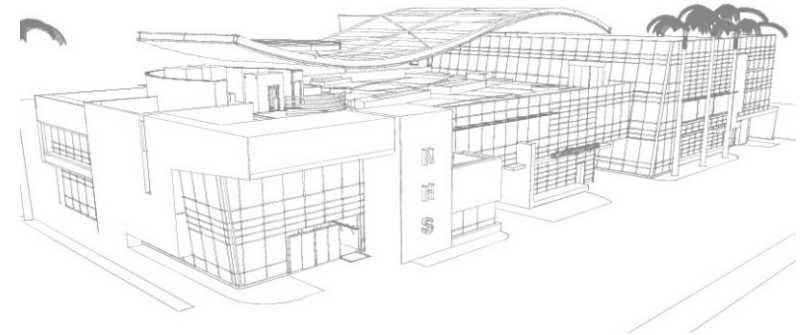
Process B:

1. Modelling
2. Scene layout setup
3. Photorealistic Rendering
4. Modifying the image in a photo-editing software
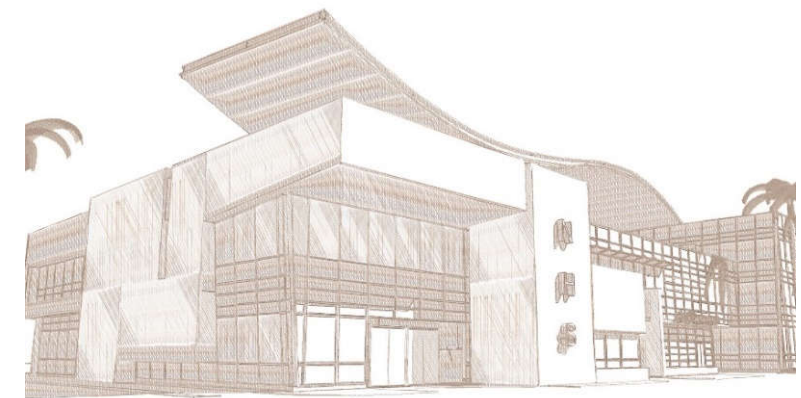
NHS office complex by paastudio

Non-photorealistic renderings

Artistic rendering applications support various painting styles:

- Pencil

- Ink

- Ball-Pen

- Water-colour

- Oil-colours
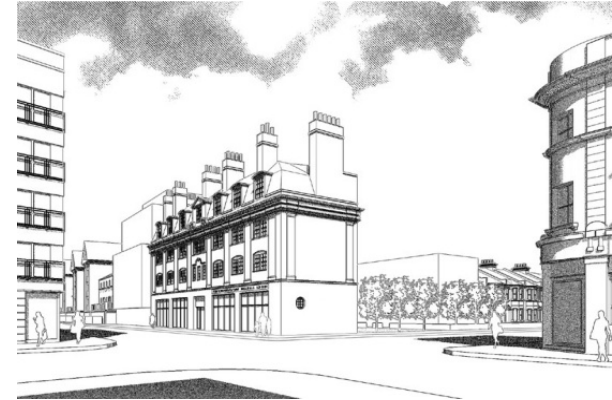
Images were made with Piranesi software from Informatix

Software for sketch and drawing (apps, online and computer-based):
Autodesk SketchBook https://www.sketchbook.com/
Tayasui Memopad https://itunes.apple.com/us/app/tayasui-memopad-draw-share-its-done/id968417727?mt=8

Fly Through Animations

Creating **movies** of the building along
a predefined camera path, based on
the BIM model, using internal or
external animation tools.

Workflow:

1. Modelling
2. Scene layout setup
3. Defining camera path
4. Movie calculation

Examples:
Enscape: a Revit plugin that creates a VR walkthrough https://enscape3d.com/
Exterior 3D Fly-through Animation Sample (4:13) https://youtu.be/APmx5Nm2oyw
3d Architecture walkthrough flythrough animation Service Singapore building Interior Exterior (2:09)
https://youtu.be/fC1OtZ4kAJs
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Animation Basics

- **Animation** is the optical illusion of a motion, created by the consecutive display of images of static elements.

- In computer animations each frame of the movie is produced individually by a computer software.

- When the frames are strung together there is an illusion of continuous movement.

- Typical Frame rate is 12-25 frames per second.

Sun studies

•**Sun study** is a special type of computer animation. The objective of making sun studies is to visualize the natural lighting conditions on a given location of the building at a particular day of the year. Unlike in fly through animations the camera position remain stable.

•Workflow:

1.Modeling
2.Scene layout setup
3.Day settings
4.Sun study calculation

(38.9167, -77.0000) 2015Jul13 04:58:00

Example: Revit Tutorial - True Solar/Shadow Studies (5:59) https://youtu.be/HwcYAE7OyJE

Virtual Reality (VR) 虛擬現實

- Virtual Reality (VR) is an environment that is simulated by a computer

- Most virtual reality environments are primarily for visual purposes

- VR-s provide more freedom for the users in exploring the building then pre-recorded animations

- Workflow
  - 1. Modelling
  - 2. Scene layout setup
  - 3. VR camera settings
  - 4. VR calculation

Model Viewers

- **Model Viewers** provide a navigable environment to explore 3D Models without the need of the authoring software they were created in.

- Most model viewers are for coordination or visual purpose and usually able to provide BIM information in some extent.

- Model Viewers provide more freedom for the users in exploring the building then pre-recorded animations.

SketchUp Mobile Viewer

BIM visualization

- Typical applications:
  - Architectural design, building system design, space planning, interior design
  - Business and management graphics (for decision-making, graphic data displays)
  - Education, learning & training (for developing visual thinking skills and creative abilities)
  - Human factors and user interfaces
  - Mapping (2D/3D), industrial design, analyses

Examples of visualization and analysis tasks in BIM

Key Term	Definition
Rendering	The process of creating realistic images of a model by replacing the shaded appearances of materials assigned to the visible elements with images of actual materials.
Cloud Rendering	A cloud based service that creates high quality renderings from a BIM model.
Interactive Panorama	Panoramas provide views of your project from multiple directions from a fixed camera point in the model.
Solar Studies	Are a means for simulating the course of the sun's movements in context of the building design to study the implications of shading at various times of day and year that may impact thermal comfort inside the building.
Illuminance Studies	Illuminance is a measure of how much light falls on a surface. It is useful for determining whether or not there is enough light to perform different activities (like reading, office work, or drafting). Illuminance is measured in lux or foot-candles.

Examples of visualization and analysis tasks in BIM

Rendering and interactive panorama

Solar studies
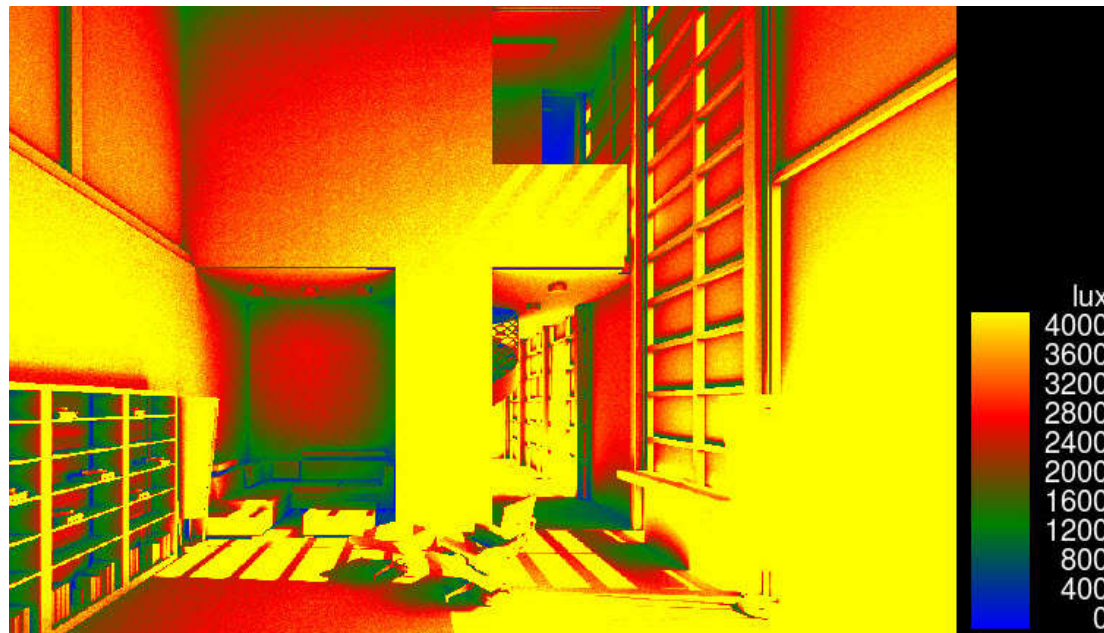
Illuminance studies

BIM visualization

- Computer visualization + 3D BIM technology
  = True power of visual technology
  - 3D design collaboration
    - Enhance systems coordination among disciplines & facilitate interactive 3D analysis (e.g. solar shading)
  - 3D architectural & interior design modelling
    - Creative 3D modelling that combines science, technology & artistic insight; immersive environment
  - 3D technical design & analysis
    - For MEP fabrication & installation, operation & maintenance

3D design collaboration: Examination of BIM model and information

Experience your design before it is ever built

BIM visualization

- The power of visual technology: Demonstrations
  - Create immersive architectural visualizations with Autodesk Revit Live (2:02)
    https://youtu.be/TnNjdWDn8SY
  - Explore your BIM model with Revit Live (2:14)
    https://youtu.be/LzSM1KqcYPk
  - Using BIM to reimagine the Palais Brongniart (2:37)
    https://youtu.be/kkwcCzZIyIE
  - BIM實例介紹－永吉住宅地下一層　龍泉電機 (1:08)
    https://youtu.be/7sYHYBTZSGo
  - Building roaming for metro station in Fuzor! (1:45)
    https://youtu.be/pPRLHatdc60

Experiencing BIM in virtual reality for architectural visualization
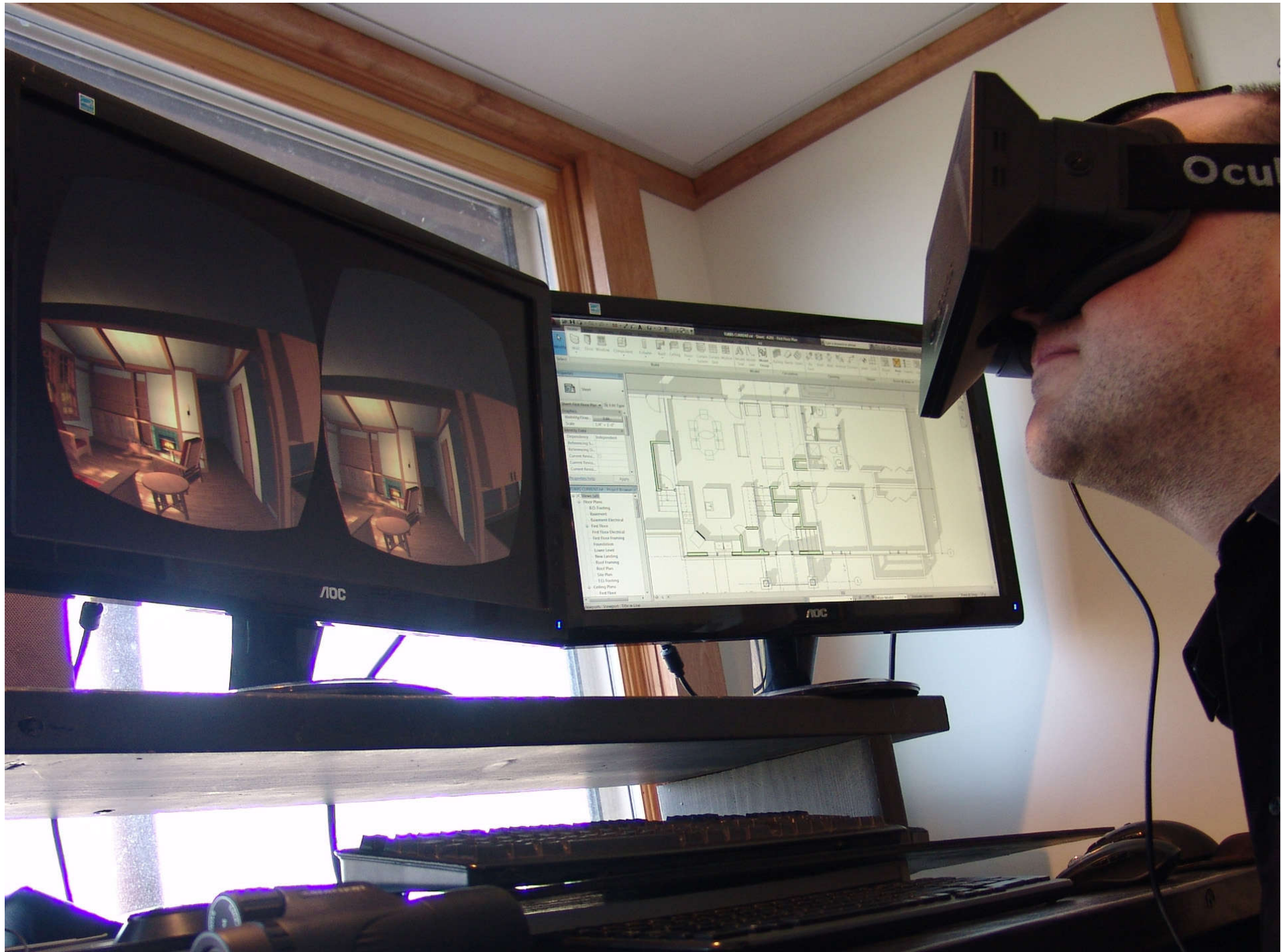
BIM visualization with virtual reality (VR) headsets

Video examples:
- HTC VIVE LIVE Architectural Visualisation (0:51) https://youtu.be/MW7V0a55FN4
- High-End Virtual Reality for Real Estate - Full (4:11) https://youtu.be/8l9qRDMVNRY

Virtual reality systems

- Types of virtual reality (VR) systems:
    - 1. <u>Non-immersive (desktop) systems</u>
        - Using a display monitor or TV/projector screen
    - 2. <u>Semi-immersive projection systems</u>
        - Learn from the flight simulation field; using a wide field of view; greater image resolution than HMD
    - 3. <u>Fully immersive systems</u>
        - With head-mounted display (HMD)
            - Such as HTC Vive or Oculus Rift
        - Software: Fuzor and Revit Live

3D Immersive   3D non-immersive

(Source: Types of VR system http://www.agocg.ac.uk/reports/virtual/37/chapter2.htm)

Use modelling & simulation (M&S) to explore many aspects of a system or an enterprise before it's actually built, which helps us understand what is possible and identify possible issues and risks

Why Visualization is Essential for BIM and Architectural Design?

REVIT

ENSCAPE

(Source: Why Real-Time Visualization is Essential for BIM and Architectural Design https://blog.enscape3d.com/real-time-visualization-bim)

Virtual reality systems

- CAVE: immersive virtual environment

  - Computer-Aided Virtual Environment or Cave Automatic Virtual Environment 洞穴狀自動虛擬系統

    - A virtual reality (VR) environment consisting of a cube-shaped VR room in which the walls, floors and ceilings are projection screens

    - The user typically wears a VR headset or head-up display and interacts through input devices such as wands, joysticks or data gloves

    - The person is fully immersed within it; 3-D images within the cave appear to float in mid-air

CAVE (Computer-Aided Virtual Environment) with 3D glasses

BIM CAVE (Computer-Aided Virtual Environment) at Texas A&M's Department of Construction Science

https://vimeo.com/32474275

BIM visualization

Virtual Reality (VR) headsets

Immersive projection system

Interactive projection

Virtual reality systems

- Augmented Reality (AR) 增強現實/擴增實境
  - It is a live, direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data
  - It is an overlay of content on the real world, but that content is not anchored to or part of it. The real-world content and the CG content are not able to respond to each other

(Source: VR? AR? MR? Sorry, I'm confused. https://www.foundry.com/industries/virtual-reality/vr-mr-ar-confused)

Virtual reality systems

- ## Mixed Reality (MR) 混合現實/混合實境

  - Sometimes refer to as hybrid reality

  - It is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time

  - It is an overlay of synthetic content on the real world that is anchored to and interacts with the real world. the synthetic content and real-world content are able to react to each other in real time

Integrating BIM and augmented reality (AR)

Augmented Reality (AR) and Mixed Reality (MR)
Bringing BIM models and information to the building site

Future trends

- Future trends in mixed reality technology:
  - Such as Microsoft HoloLens
    https://www.microsoft.com/en-us/hololens
  - Integrate BIM with holographic computing
    - Do you remember "the Iron Man" movie?
- Examples of MR for BIM:
  - Using HoloLens with voice command
    - First Look Fuzor for HoloLens (9:57)
      https://youtu.be/mcxMQ6k2caM
  - 3D holographic map/city viewer

3D holographic map/city viewer

(Videos: HoloLens - Networked Collaborative Environment (0:42) https://youtu.be/5mIGUj7yYM8,
Hololens - London City Skyline (1:34) https://youtu.be/KilkHpM_-b0)

(Source: HoloMaps https://taqtile.com/holomaps/)

Future trends

- Demonstrations of mixed reality (MR) + HoloLens
  - 小柳建設 - Microsoft HoloLens を活用した Holostruction (2:45) https://youtu.be/TmDHZ-NMQe0
  - Microsoft HoloLens: Puistovahti & Puistolinna, Oulu Finland (3:17) https://youtu.be/ry6SZgAReVA
  - ICONICS HoloLens (2:49) https://youtu.be/jADu589LtHc
  - The Modern Workplace with Hololens Mixed Reality (3:38) https://youtu.be/upWRwTbS6bw
  - Mechanical Room in HoloLens - HoloLive app (1:14) https://youtu.be/ERffDgckdSE
  - HoloLens XRay Vision for Building Maintenance (2:37) https://youtu.be/vGePnLQSFxg
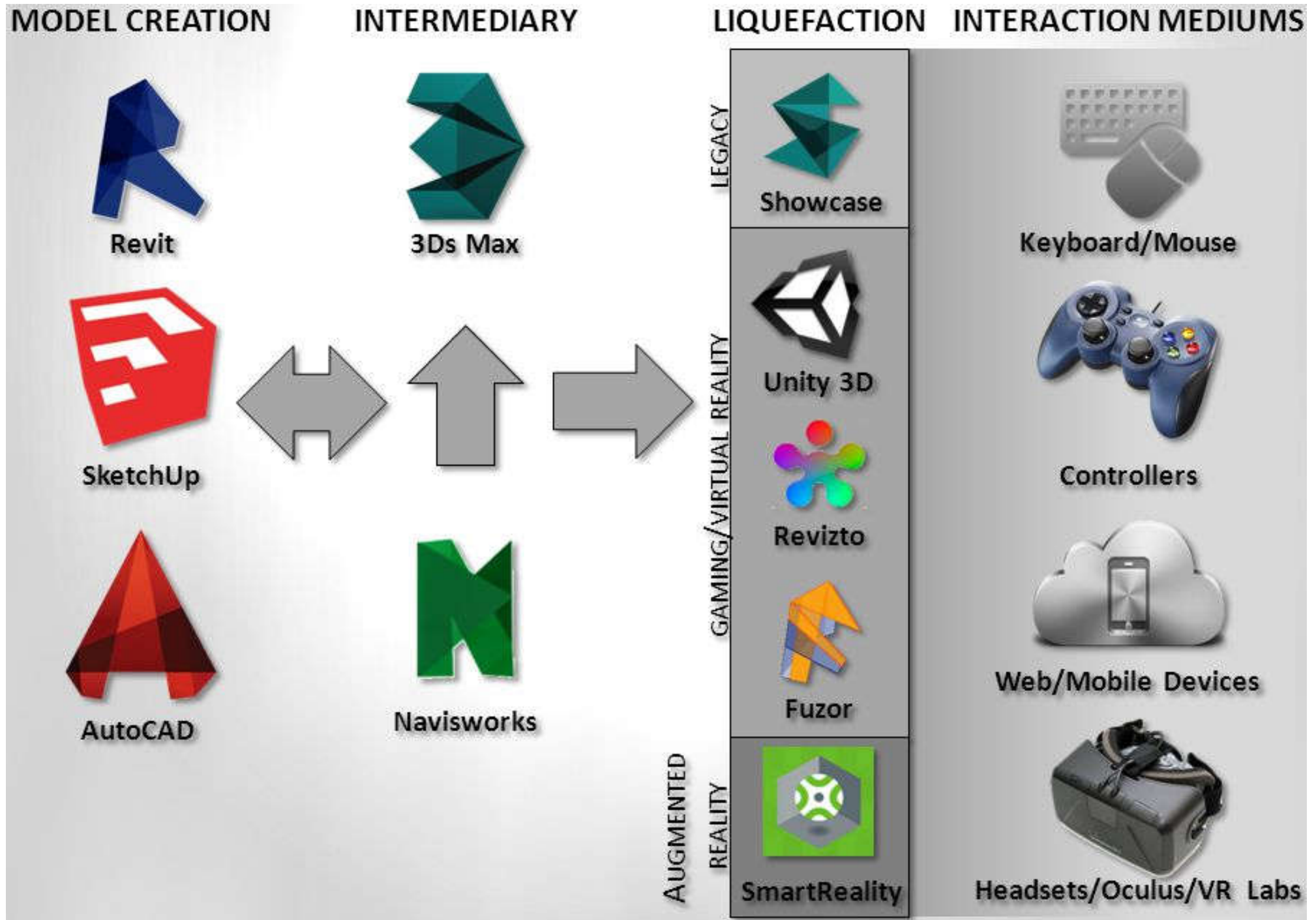
Future trends

- BIM visualization will look like "*Gaming*"

- Real-time rendering and visualization tool
  - Review design iterations
  - Designed for engineers, with Revit capabilities
  - Rendering and animation focused
  - Web viewing and sharing
  - Software tools, such as:
    - Showcase, Unity 3D, Revizto, Fuzor, SmartReality
    - *Unity 3D*: development platform for 3D and 2D games

Gaming engines for BIM: the next generation of project visualisation

MODEL CREATION | INTERMEDIARY | LIQUEFACTION | INTERACTION MEDIUMS

Revit
SketchUp
AutoCAD

3Ds Max
Navisworks

LEGACY — Showcase

GAMING/VIRTUAL REALITY — Unity 3D, Revizto, Fuzor

AUGMENTED REALITY — SmartReality

Keyboard/Mouse
Controllers
Web/Mobile Devices
Headsets/Oculus/VR Labs

Future trends

- Gaming/Virtual Reality: 3D engine and development platform
  - Customizable; Unity 3D object asset store
  - Full control over environment, lighting and materials
  - Multi-platform compatibility
  - Manual model export/import
  - Javascripting/coding required
  - Time/effort intensive

(Source: GAMING ENGINES for bim - The Next Generation of Project Visualization http://slideplayer.com/slide/3947416/)

Future trends

- Gaming/Virtual Reality: Converts design models into Unity 3D environments

    - Streamlines BIM to Unity 3D process

    - Multi-platform compatibility

    - Commercially available; fast and easy to use; viewer focused

    - Less control over environment, lighting and materials; baking

    - Purpose built; WYSIWYG (what you see is what you get)

Future trends

- Gaming/Virtual Reality: Connects design models and interactive environments

  - Bi-directional; such as Revit <=> Fuzor

  - View design iterations on the fly

  - Real-time physics, environment and lighting; no baking needed

  - Power user focused; 'platform' focused

  - Fuzor mobile viewer for client interaction

Future trends

- Augmented Reality: Brings virtual and augmented reality together

  - Apple and Android based apps

  - Cloud based; upload models and plans

  - Oculus AR integration

  - Service provider reliant

  - Pay per project

Future trends

- Collaborating in today's 'liquid' world
  - Laptop, projector and Xbox controller
  - Interactive, immersive client meetings
  - Web-based team collaboration
  - Digital designs in real-world context
- New service offerings and key differentiators
  - Virtual spec suites
  - Online user interaction - both project teams and public