# Revision Report

**Feedback comment:** add addition KA overlap: Software Engineering; Algorithms

And less so with Hardware/Operaing Systems (if a module goes into the details of bandwidth issues, pipelines)

**How incorporated:** added Architecture and Organization and Software Engineering so that the revised the sentence is:

There is considerable overlap with other computer science knowledge areas: Algorithmic Foundations, Architecture and Organization, Artificial Intelligence; Human Computer Interaction; Parallel and Distributed Computing; Specialized Platform Development; Software Engineering, and Society, Ethics and Professionalism.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** implementation specific.

Not sure why this term is used here. Not implementation specific.

I would say that the requirements are complicated, depending on perception, cognition, but also the role of the images in a HCI context (thus a module might have a very different positioning. E.G. 2D graphics as an adjunct to a HCI/UI course, versus 3D graphics for games programmers)

**How incorporated:** removed implementation specific.

Added the following sentence:

Unlike other knowledge areas, knowledge units or topics within Graphics and Interactive Techniques may be included in a variety of elective courses ranging from a traditional Interactive Computer Graphics course to Gaming or Animation. Alternatively, graphics topics may be introduced in an applied project in HCI, Embedded Systems, Web Development, etc.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** I don't think it is the embedding of sensors that is important, it is the proliferation of interfaces driven by deployment of sensors and thus the controls that they use.

**How incorporated:**

Revised sentence to read:

Machine learning, computer vision, data science, artificial intelligence, and interfaces driven by embedded sensors in everything from cars to coffee makers utilize graphics and interactive techniques.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** smartphone is probably better as cellphone conjures images of dumb phones

**How incorporated:** changed cell phone to smartphone

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** I wouldn't put this here without defining it perhaps "the interactive techniques to manipulate them"

**How incorporated:** used "the interactive techniques to manipulate them"

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** Which data?

**How incorporated:** "data" is now qualified as "stored digital data"

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** Two different references needed?

**How incorporated:** Moved the reference to the appropriate sentence.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** deep-space rather than deep fakes

**How incorporated:** changed sentence to

Today's news unfortunately provides  examples of inequity and wrong-doing in autonomous navigation, deepfakes, computational photography, and facial recognition.


**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** 1) Seems to be missing something on displays? Hinted at with frame-rate, tristimulus, but possibility needs fleshing out). 2) can't discuss framerate or tone mapping without introducing output devices

**How incorporated:**

Added section on graphic output before human vision system

Graphic output

      a.  display (LCD)
      b.  printer
      c.  resolution
          i.  pixels for visual display
         ii.  dots for laser printers
      d.  aspect ratio
      e.  frame rate


**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** re tone mapping, "If this is about HVS, then the topic here is brightness adaptation, NOT tone-mapping"

**How incorporated:**

added dynamic range to clarify

      a.   non-linear response (dynamic range, tone mapping)

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** re sampling and quantization, "Tricky before media formats. Typically only done for rasters."

**How incorporated:**

Moved "media formats" to precede "digitization"

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** re Standard media formats, "image?"

**How incorporated:**

Changed standard media formats to Standard image formats

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** IP is perhaps more important - copyright, digitisation, remixing, etc.

**How incorporated:**

    revised order of SEP issues so IP is first
    "intellectual property, deep fakes, facial recognition, privacy"

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** This one not covered well

    Construct a simple user interface using a standard API.

**How incorporated:**

**Why not incorporated:**

API intentionally not specified because there is not one standard graphics API, but revised to say graphical user interface.

**Date considered:** 06-23-2023

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**Feedback comment:** If I would doing this, I would want to include analogue displays (film) as well)

**How incorporated:** added "analog film" to graphic output

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** Re Math, "Probability, esp. for image processing. Perhaps even required for that?"

**How incorporated:**

Added probability in desired math.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** In Tangible computing: WHat about processes, paper prototypes, user feedback, etc.?

**How incorporated:**

**Why not incorporated:** While critical to the success projects with users, this is covered in HCI and SE

**Date considered:** 06-23-2023

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**Feedback comment:** I think a modern course should not put accessibility under gestural. It is a major topic in its own right.

**How incorporated:** Accessibility already is a topic in interaction, but putting this example under gestural detracted from the standalone topic. Removed from gestural and added to accessibility.

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** "Interrupt event processing" This is a bit esoteric these days isn't it?

**How incorporated:**

Removed "Interrupt event processing"

**Why not incorporated:**

**Date considered:** 06-23-2023

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**Feedback comment:** Digitization is "Tricky before media formats. Typically only done for rasters."

**How incorporated:** Moved digitization section to precede media formats and removed reference to vectors in that section

**Why not incorporated:**

**Date considered:** 07-06-2023

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**Feedback comment:** standard media formats… "For images?"

**How incorporated:** standard media formats now reads standard *image* formats

**Why not incorporated:**

**Date considered:** 07-06-2023

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**Feedback comment:** Quite a complex phrasing. (referring to

**How incorporated:**

Describe the tradeoffs between storing information vs. storing enough information to reproduce the information, as in the difference between vector and raster formats.

to

Tradeoffs between storing image data and re-computing image data. (Example: raster and vector representations of image formats)

**Why not incorporated:**

**Date considered:** 07-06-2023

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**Feedback comment:** If I would doing this, I would want to include analogue displays (film) as well

**How incorporated:**

Added the first bullet point below

- Compare and contrast digital video to analog video.
- Describe the basic process of producing continuous motion from a sequence of discrete frames (sometimes called "flicker fusion").

**Why not incorporated:**

**Date considered:** 07-06-2023

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**Feedback comment:**

Missing cameras and projection.

**How incorporated:**

Added Synthetic Camera Model (camera, image plane, and projection)

**Why not incorporated:**

**Date considered:** 07-06-2023

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**Feedback comment:** Not everyone starts with a "pipeline". E.G you can just start with ray-tracing and then implement as a pipeline as an optimisation.

Pipeline doesn't work well when you come back to high-quality techniques such as path-tracing.

**How incorporated:**

**Why not incorporated:** Regardless of whether everyone starts with a pipeline, graphics students should know what a graphics pipeline is.

**Date considered:** 07-06-2023

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**Feedback comment:** Quite a broad set of terms (radiometry, similar triangles, and projection model) that are perhaps here because of a specific need for an algorithm rather than being general.

**How incorporated:**

Basic radiometry, similar triangles, and projection model.
to
Basic radiosity.

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:**  wouldn't teach raytracing as a solution to visibility and occlusion

**How incorporated:** while this is a good point, the topic of raytracing precedes this bullet point, thus how raytracing uses "backwards" rays to handle occlusion would have already been covered.

**Why not incorporated:**


**Date considered:** 07-07-2023

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**Feedback comment:** Re "Simple triangle rasterization", If someone teaches this, they probably teach line rasterisation too

**How incorporated:**

Simple triangle rasterization.

to

Simple line and triangle rasterization.

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** re "Application of spatial data structures to rendering." Generally this is speed-up techniques, such as culling, sorting, etc.

**How incorporated:**

Application of spatial data structures to rendering

to

Spatial data structures: object centric (bounding volumes), space subdivision (octrees, BSP trees).

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** re "Scene graphs", There is a general topic which is scene representations.

**How incorporated:** "Scene graphs" to "Scene representations and scene graphs"

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** This section (Illustrative learning outcomes)  hasn't really addressed APIs

**How incorporated:**

**Why not incorporated:** We believe it has

**Date considered:** 07-07-2023

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**Feedback comment:** do the following belong in rendering

- Compute space requirements based on resolution and color coding.
- Compute time requirements based on refresh rates and rasterization techniques.

**How incorporated:** moved to fundamentals

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** Probability, esp. for image processing. Perhaps even required for that?

**How incorporated:** added probability to desired math

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** What about processes, paper prototypes, user feedback, etc.?

**How incorporated:**

**Why not incorporated:** This is covered in HCI so to avoid overlap, not here

**Date considered:** 07-07-2023

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**Feedback comment:** Why AI?

There is nothing particularly immersive about brainwave (EEG) - there is lots of work on BCIs that is not "immersive". This might be confused here with "head-worn".

**How incorporated:** changed to

1. Head-worn Interfaces
    a. brainwave (EEG type electrodes)
    b. headsets with embedded eye tracking
    c. AR glasses
2. Natural Language Interfaces

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** I think a modern course should not put this [accessibility] under gestural. It is a major topic in its own right; What about game controllers, touch screens?

**How incorporated:**

1. Gestural Interfaces
    a. Touch screens
    b. Game controllers

Added section on Accessibility

**Why not incorporated:**

**Date considered:** 07-07-2023

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**Feedback comment:** I don't teach this area [Interaction], but this looks quite "old school", not user-centred, process-driven, etc. Very nuts and bolts.

**How incorporated:**

**Why not incorporated:** The HCI KA covers the necessary user-centered design aspects

**Date considered:** 07-08-2023

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**Feedback comment:** Interactive modeling not relevant to immersion

**How incorporated:** deleted

**Why not incorporated:**

**Date considered:** 07-08-2023

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**Feedback comment:** Visibility computation in immersive: Covered elsewhere

**How incorporated:**

**Why not incorporated:** deleted

**Date considered:** 07-08-2023

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**Feedback comment:** Light Field sort of stands out here as not quite the same as the others as it is primarily a reflection on the topic.

**How incorporated:**

moved light field from Shading to Rendering, which now reads

- Rendering in nature, e.g., the emission and scattering of light and its relation to numerical integration, and the light field

**Why not incorporated:**

**Date considered:** 07-08-2023

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**Feedback comment:** split out 360 video separately. Time-critical rendering is a topic, but it is just "standard" rendering tricks. There is a bit to say about stereo rendering/stereo cameras, overlays, etc

**How incorporated:**

Added

360 Video
Stereoscopic display
    a. Head-mounted displays
    b. Stereo glasses


and changed

Time-critical rendering, multiple levels of details (LOD) Image-based VR system
○ Motion to Photon latency


to

Time-critical rendering to achieve optimal motion to photon (MTP) latency
    a. Multiple levels of details (LOD)
    b. Image-based VR system
    c. Branching movies

**Why not incorporated:**

**Date considered:** 07-08-2023

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**Feedback comment:** Re transforms in animation, If anything is implied by order this should go higher up, before kinematics.

**How incorporated:** this is actually in the rendering / core graphic section and should not be repeated here. Expanded affine transformations in the rendering section to explicitly include translation, scale/shear, and rotation.

**Why not incorporated:**

**Date considered:** 07-23-2023

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**Feedback comment:** "Implement a non-trivial shading algorithm (e.g., toon shading, cascaded shadow maps) under a rasterization API." is awkward

**How incorporated:** Changed to

Implement a non-trivial shading algorithm (e.g., toon shading, cascaded shadow maps) using an API.

**Why not incorporated:**

**Date considered:** 07-08-2023

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**Feedback comment:** [Metaballs] isn't covered, and is a bit out of date now?

**How incorporated:**

Use common animation software to construct simple organic forms using metaball and skeleton

changed to

Use common animation software to construct, rig, and animate simple organic forms.

**Why not incorporated:**

**Date considered:** 07-23-2023

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**Feedback comment: [**in Animation] Once we've done this [mo-cap], what about blending, etc.

**How incorporated:** changed

Motion capture
o Set up and fundamentals
o Ethical considerations (e.g., accessibility and privacy)
       ▪ Avoidance of "default" captures - there is no typical human walk cycle.
to

Motion capture
-     ○   Set up and fundamentals
-     ○   Blending motion capture clips
-     ○   Blending motion capture and keyframe animation
-     ○   Ethical considerations (e.g., accessibility and privacy)
  -     ■   Avoidance of "default" captures - there is no typical human walk cycle.

**Why not incorporated:**

**Date considered:** 07-23-2023

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**Feedback comment:** in Animation Once we've done this [mo-cap], what about motion graphics, etc.

**How incorporated:** Added section on Types of Animation

Types of animation
       a. 2- and 3-dimensional animation
       b. motion graphics

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c.   motion capture
d.   motion graphics
e.   stop animation
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**Why not incorporated:** This is probably a more superficial coverage of motion graphics than what the reviewer wanted, but with the 10-hour cap of classroom coverage for non-core Knowledge Units, this was all we had room for.

**Date considered:** 07-23-2023

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**Feedback comment:** [Animation ] Need more outcomes?

**How incorporated:**

**Why not incorporated:** These are illustrative learning outcomes, not a comprehensive list of learning outcomes.

**Date considered:** 07-23-2023

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**Feedback comment:** [Immersion] Missing the whole area of 3D User Interfaces (selection, manipulation, etc.) Also interactive systems (e.g. physics, animation). Possibly avatars and self-representation. Perhaps theories of immersion and presence.

**How incorporated:** Added immersion and presence into the Immersion KU

**Why not incorporated:** We felt like while the others are linked to GIT related Immersion content, to avoid duplication we will put 3D User Interfaces as part of Interaction and HCI, avatars and self-representation with HCI & SEP, Interactive Systems with AI and Machine Learning.

**Date considered:** 07-23-2023

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**Feedback comment:** What about haptics and other modalities, physical computing, integration with sound? Images is a limited view of what a graphics course might include.

**How incorporated:** added:

Today's graphics courses increasingly include physical computing, animation, sound, and haptics.

**Why not incorporated:**

**Date considered:** 07-24-2023

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**Feedback comment:** Graphics textbooks have long had sections on interaction - the title to this section includes interaction. I've taught standard interaction techniques since the early 1990s.

**How incorporated:** added interaction into the list of traditional graphics topics

Traditionally, graphics at the undergraduate level focused on rendering, linear algebra, physics, the graphics pipeline, interaction, and phenomenological approaches.

**Why not incorporated:**

**Date considered:** 07-23-2023

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**Feedback comment:** I've never included all of these outside the formal graphics course. I don't see POV, Mach banding, tone mapping, stereo, strobing as something for all CS students.

**How incorporated:**

**Why not incorporated:** because all students use and generate graphics now, would like to see all students understand—at some level—these topics

**Date considered:** 07-23-2023

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**Feedback comment:** The applications (bullet point 1) and SEP issues (bullet point 8) are connected and probably should be at least listed together – the joint point being students should know how graphics is used and the risks/abuses.

**How incorporated:** combined these two sections ino "Uses and potential risks and abuses"

**Why not incorporated:**

**Date considered:** 07-23-2023

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**Feedback comment:** There's nothing in the topics on learning to program images and interfaces, but there's an outcome on programming an interface with an API. I would say every CS major should learn interactive interface programming, whether a Java API, mobile app creation, or whatever – and if you're going to have an outcome, include a topic.

**How incorporated:** Added interactive interface

**Why not incorporated:**

**Date considered:** 08-04-2023

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**Feedback comment:** Re "Describe the tradeoffs between storing information vs. storing enough information to reproduce the information, as in the difference between vector and raster formats." This is implying raster formats are lossy versions of vector data, which they can be but not always - why have this one when you have #8 on lossy vs lossless compression? The general idea that data representation or compression can be lossy or lossless should be combined.

**How incorporated:**

Deleted learning outcome #10.

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment:** I teach this (memory for video) in intro major and non major courses, but only after doing memory requirements for images at n by m resolution and b bit depth. This outcome sits weirdly alone.

**How incorporated:**

**Why not incorporated:** These learning outcomes are illustrative, and this one intentionally requires the student to understand memory requirements for images

**Date considered:** 08-09-2023

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**Feedback comment:** Re: Describe a possible visual mis-representation that could result from digitally sampling an analog world. This just the nyquist limit? I do teach that in intro courses.

**How incorporated:**

**Why not incorporated:** This is the visual artifact induced by aliasing. We did not think that every computer science student must know the Nyquist limit, but should recognise why the visual artifact exists.

**Date considered:** 08-09-2023

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**Feedback comment:** Data vs information visualization is a nuanced point - doesn't appear in the outcomes, and I'm not sure what outcome I'd have here.

**How incorporated:** Added the following ILO

Compare and contrast data visualization and information visualization

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment: Add:** *"Suggested reorganization: Object and scene modeling Object representations: polygonal, parametric, o…"*

**How incorporated:** excellent reorg suggestion, adopted as shown below

1. Object and scene modeling
   a. Object representations: polygonal, parametric, other
   b. Modeling transformations: affine and coordinate system transformations
   c. Scene representations: scene graphs
2. Camera and projection modeling
   a. Pinhole cameras, similar triangles and projection model
   b. Camera models
   c. Projective geometry
3. Radiometry and light models
   a. Radiometry
   b. Rendering equation
   c. Rendering in nature – emission and scattering, etc
4. Rendering
   a. Simple triangle rasterization
   b. Rendering with a shader-based API
   c. Visibility and occlusion, including solutions to this problem (e.g. depth buffering, Painter's algorithm, and ray tracing)
   d. Texture mapping, including minification and magnification (e.g., trilinear MIP-mapping).
   e. Application of spatial data structures to rendering.
   f. Ray tracing
   g. Sampling and anti-aliasing

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment:** Homogenous coordinates are here but not in the topics. Lots of math implied here if you do it right - are projective matrices, etc, all included?

**How incorporated:**

**Why not incorporated:** Yes, concatenation of matrices is included for both projections and model view.

**Date considered:** 08-09-2023

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**Feedback comment: Re** Implement simple procedures that perform transformation and clipping operations on simple 2-dimensional images. **Does this imply image resampling? Bilinear, etc?**

**How incorporated:** No it does not imply image resampling.

Changed image to shape (Implement simple procedures that perform transformation and clipping operations on simple 2-dimensional **shapes**.)

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment: Re** Compute space requirements based on resolution and color coding. . **Belongs in core.**

**How incorporated:**

Moved to core

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment: Re** Basic geometric operations such as intersection calculation and proximity tests, Parametric models or mesh or solid geometry?

**How incorporated:**

Changed to "Basic geometric operations such as intersection calculation and proximity tests **on 2D primitives"**

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment: Re** Elastically deformation and freeform deformable models. Quasi-static methods, Bi-harmonic capture/deform.

Seems a different order of complexity and specificity than other topics.

**How incorporated:**

Good point, removed.

**Why not incorporated:**

**Date considered:** 08-09-2023

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**Feedback comment:** [multiresolution modeling] Implies LOD?

**How incorporated:**

**Why not incorporated:** yes it does

**Date considered:** 08-09-2023

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**Feedback comment:** This is 3D scanning, photogrammetry, etc? Reconstruction is pretty vague

**How incorporated:**

Added e.g., 3D scanning, photogrammetry, etc.

**Why not incorporated:**

**Date considered:** 08-10-2023

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**Feedback comment:** Ray tracing was a topic back in Basic Rendering and now it reappears here (and with Phongs BRDF approximation that's still basic rendering) - and it isn't mentioned as a topic in this section.

**How incorporated:**

**Why not incorporated:** Basic Rendering is a pre-req for this KA (Shading). Thus understanding the concept of ray tracing occurs in Basic Rendering. This KA extends on that, so Implementing a ray tracer is an illustrative learning outcome.

**Date considered:** 08-10-2023

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**Feedback comment:** many systems like these - why only these?

**How incorporated:**  e.g., L-Systems, Space-colonizing systems, Game of Life


**Why not incorporated:**

**Date considered:** 08-10-2023

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**Feedback comment:** Also risk of extremely personal data collection by HMD firms.

**How incorporated:** added

**Why not incorporated:**

**Date considered:** 08-10-2023

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**Feedback comment:** re Gestural interfaces, Gestures by touch screen, webcam, phone accelerometer, what?

**How incorporated:** added touch screens and hand and body gestures

**Why not incorporated:**

**Date considered:** 08-17-2023

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**Feedback comment:** Program a circuit to respond to a variable resistor sounds like arduino

**How incorporated:** moved to physical computing

**Why not incorporated:**

**Date considered:** 08-17-2023

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**Feedback comment:** re "Describe the ethical pitfalls of facial recognition. Can facial recognition be used ethically? If so, how?" Feels out of place with the topics here - the section seems out of Glassner's "Principles of Digital Image Synthesis", not computer vision

**How incorporated:** moved to SEP

**Why not incorporated:**

**Date considered:** 08-17-2023

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**Feedback comment:** In general terms explain what happens between the graphics API and the frame buffer. should be GPU rather than Frame Buffer

**How incorporated:** In general terms explain what happens between the graphics API and the GPU

**Why not incorporated:**

**Date considered:** 08-17-2023

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**Feedback comment:**  re "reaction diffusion model to produce stripes"—**discretized differential equation? Not in math.**

**How incorporated:** Added the following for desired math

4.  Numerical Methods
    a.  Simulation

**Why not incorporated:**

**Date considered:** 09-08-2023

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**Feedback comment:** Feels like lots of calc is missing: see previous discussion of integration. I use considerable differentiation, vector calc, tensors, diff. Geometry, in intro undergrad graphics.

**How incorporated:** Added to desirable math (calculus)

    b.  Differentiation
    c.  Vector calculus
    d.  Tensors
    e.  Differential geometry

**Why not incorporated:** In CS2023 we are justifying all math. Your point is a good one, and for colleges where calculus is a pre-req this is spot on, but for colleges without calc as a pre-req to graphics, is that a hard stop for the course?

**Date considered:** 09-08-2023

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**Feedback comment: Continuity I really only use in piecewise parametric curves**

**How incorporated:**

**Why not incorporated:** We left in continuity, it's critical for curves and patches so continuity seems fundamental although not enough to require calc as a pre-req.

**Date considered:** 09-08-2023

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**Feedback comment:** Re professional dispositions: Nothing here seems unique to graphics.

**How incorporated:** reduced the long list and added a sentence as to why each disposition is important in computer graphics

1. Self-directed: life-long learner, self-motivated. It is important for graphics developers to keep up with advances in the field.
2. Collaborative: team player: Graphics developers typically work in teams composed of people with differing specialties.
3. Effective communication is critical whether oral, written or through code.

**Why not incorporated:**

**Date considered:** 09-08-2023

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**Feedback comment:** Leading with ML is an odd choice to me since it is the least obvious application. In truth, I'm not even sure *what* application is being implied here as ML is not itself an application area, so this seems similar to claiming that the applications include algorithms.

**How incorporated:** revised

Its applications include machine learning; medical imaging; engineering; scientific, information, and knowledge visualization; user interfaces; cartoons; special effects; artwork; simulators; and video games.
to

Its application domains include art and animation; engineering; machine learning; medical imaging; scientific, information, and knowledge visualization; simulators; special effects; user interfaces; and video games.

The list is now alphabetical and qualified as "application domains"

**Why not incorporated:**

**Date considered:** 09-08-2023

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**Feedback comment:** [GIT] ends up being a somewhat unfortunate acronym, as it is either a popular version control system or an "unpleasant person" (or rather both, since that is the origin of the VCS name, demonstrating that we geeks should be allowed to name things).

**How incorporated:**

**Why not incorporated:** While GIT is an unfortunate acronym, Graphics and Interactive Techniques is the  common description and accurately describes the content of the premier graphics conferences.

**Date considered:** 09-08-2023

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**Feedback comment:** Does computational photography want to be in this list? Image processing? I didn't add them in directly, because they aren't really "applications" in the way "medical imaging" is, though computational photography may be borderline.

**How incorporated:**

**Why not incorporated:** The list is not meant to be all-inclusive, but a sample. Trying to create an exhaustive list of all applications and domains would invariably miss something.

**Date considered:** 09-08-2023

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**Feedback comment:** Replace *Where provided,"* with *"Any"*

**How incorporated:** done

**Why not incorporated:**

**Date considered:** 09-08-2023

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**Feedback comment:** re "Machine learning, computer vision, data science, AI, and the inclusion of embedded sensors in everything from cars to coffee makers utilize graphics and interactive techniques"

Computer vision plays a big role in many of the ethical considerations. However, Computer vision is not one of the core topics. I agree that vision belongs in IS, not graphics. So I would remove it from places where it is mentioned. I would also contemplate if it is appropriate to include the social issues related to it (e.g. face tracking). On the one hand, students should see these issues in multiple places and contexts, but I think the connection is a little tenuous here.

**How incorporated:**

**Why not incorporated:** We're not saying that CV is a graphics KA, but that CV, AI, etc… *utilize* graphics and interactive techniques. Since SEP is now infused across the curriculum, social issues that arise within graphics and interactive techniques are critical to include.

**Date considered:** 09-08-2023

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**Feedback comment:** …less about graphics becoming more pervasive and more about how they are produced is changing.

With that in mind, this is the piece that I am missing from this "what has changed" section — a description of ways that the technologies for *producing* graphics has changed. This paragraph basically says graphics is more important than it was ten years ago, which is somewhat debatable since we are basically just seeing the continuation of the trends that were visible then — the iPhone was already 6 years old then.

**How incorporated:** While we still contend that graphics are more pervasive in 2023, the reviewer makes a very valid point that we did not focus enough on how improvements in graphics hardware are not stressed and new generative tools for producing graphics are not mentioned. Both are now with an illustriative comparison of graphics card specs and inclusion of generative graphics.

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** remove deep space imaging from wrong doing section

**How incorporated:** done

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** how are autonomous navigation and ml connected to graphics?

**How incorporated:**

**Why not incorporated:** image processing is foundational to autonomous navigation and ml

**Date considered:** 09-12-2023

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**Feedback comment:** Is there a reason that the CS core is totaled, but the KA core is not?

**How incorporated:**

**Why not incorporated:** KAs for computer graphics are all elective, so giving a subtotal artificially inflates the number of hours in CS2023

**Date considered:** 09-12-2023

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**Feedback comment:** This [Human Vision System] seems very detailed for fundamentals suggested for all computer scientists. RGB and accessibility I would agree with, but with only four hours I would not spend them on these other aspects.

**How incorporated:**

**Why not incorporated:** These can be covered superficially and as the reviewer suggests will need to be, but provide a context for how graphics formats take advantage of the physiology of the human eye.

**Date considered:** 09-12-2023

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**Feedback comment:** Add *Spatialization: coordinate systems, absolute and relative positioning.* I used to just assume that students would understand spatial relationships from math classes and existing in a physical world, but I continue to be surprised when students really struggle with basic spatial concepts. I think spatial understanding has long been missing as a core competency and without it graphics and visualization are extremely difficult.

**How incorporated:**  Added

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** The illustriative learning outcome of creating a user interface for a person with color impairment seems like a stretch since creating user interfaces is not part of this knowledge unit.

**How incorporated:**

**Why not incorporated:** Neither a KA or a KU corresponds to a course, and thus the GIT content will be incorporated into existing classes. This ILO is illustrative for a course that includes user interface design—which is actually a typical course in which graphics fundamentals are introduced.

**Date considered:** 09-12-2023

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**Feedback comment:** These are not graphics file formats. Yes, they were present in the 2013 recommendations, and they should have been then either. For that matter, the original outcome was more about lossy vs lossless storage, with the file formats as examples. It wasn't a great question to begin with it wasn't really comparing lossy and lossless formats, but even that seems to have been lost here. As this one is framed one would expect somewhat deep knowledge about the difference between the compression techniques, which seems ambitions for this knowledge level.

**How incorporated:** removed "graphics" and replaced with "common". A computer science student should know when to use each of these types of files. A short 15 minute lecture could cover the necessary material.

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** I'm not a huge fan of this [Compute the memory requirements for an *n* second movie based on *f* frames per second and *r* resolution], though I see where it was coming from. Without "lossless" and "silent" included, this isn't really answerable.

**How incorporated:**

**Why not incorporated:** A student could say it wasn't answerable because of temporal and other compression, or could do a direct calculation—both answers show comprehension of the huge amounts of data in video.

**Date considered:** 09-12-2023

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**Feedback comment:** What distinction are we making between "data" and "information" here? I usually use "data" and "information" synonymously, and use "scientific" if I want to talk about visualization of physical phenomena

**Answer:** Data are measured, information finds and conveys meaning to the collected data.

**Date considered:** 09-12-2023

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**Feedback comment:** This is a curious list to me…

**How incorporated:**

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** Add *"GeoJSON, shape files,"* to viz data formats

**How incorporated:** done

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** Replace**:** *"ASCII to parse"* with *"JSON,"* and Add**:** *"plain text"*

**How incorporated:**

**Why not incorporated:**

**Date considered:** 09-12-2023

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**Feedback comment:** These [Avoid misleading visualizations  (exaggeration, hole filling, smoothing, data cleanup); Even correct data can be misleading -– e.g., aliasing, incorrectly moving or stopped fan blades.] are both good points, but it seems like a list of topics slipped into lecture notes at this point.

**How incorporated:** while these bullet points need to remain, they were revised to

    a. Ethically responsible visualization
       i.   Misleading visualizations (e.g., exaggeration, hole filling, smoothing, data cleanup)
      ii.   Correct data may be misleading (e.g., aliasing, incorrectly moving or stopped fan blades)

**Why not incorporated:**

**Date considered:** 09-13-2023

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**Feedback comment:** Re [Evaluate the tradeoffs of visualization algorithms in terms of accuracy and performance.] it isn't clear what the goal is here. Are we talking about the *algorithm*, in which case I would interpret this as how well the visualization was created and how quickly, or are we talking about the *type*, in which case we are talking about how easy it is to read information back out of the visualization.

**How incorporated:**

**Why not incorporated:** While both an evaluation of the algorithm how easy it is to read information from the visualization are important, this question as stated is about the underlying algorithm, #'s 5 and 6 address the information gleaned from the visualization.

**Date considered:** 09-29-2023

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**Feedback comment:** Re ILO in Shading, What is meant here by "simple algorithm"?

**How incorporated:** clarified by revising "simple algorithm" to "simple shading algorithm"

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** Why [in Simulation] is this "topics by subject" and not just "Topics" like the rest?

**How incorporated:**

**Why not incorporated:**  This albeit unique organization most clearly communicated the appropriate topics for simulation.

**Date considered:** 09-29-2023

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**Feedback comment:** Re Simulation's Data Structures: I note that this differs from the other units by including the pre-requisite data structures and goals sections. I am not entirely sure what is being conveyed in these sections either. These are not pre-requisites for all of the topics, I am also not sure where the expectation is that these will be taught, since these are not common data structures. Why aren't these just topics here?

**How incorporated:** Removed data structures from Simulation for consistency

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** Is "particle system" a goal? It shows up as a "topic" under the next "goal". Is this prescribing how to teach these topics? While that would be useful, this doesn't seem like the place for it.

**How incorporated:**

**Why not incorporated:** Yes, these are teaching goals and the suggested topics that should be taught to achieve the goals. This is not a prescriptive list.

**Date considered:** 09-29-2023

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**Feedback comment:** *Define and distinguish"* with *"Immersion levels:"...*

**How incorporated:** Good point Define and distinguish is more of a task.

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** I was struck that the only implementation outcome was a single stereoscopic image and everything else was conceptual.

**How incorporated:** Added ILO

　　　Implement an application in AR or VR.

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** add the following to Immersion

**How incorporated:** Added:

*Presence and factors that impact level of immersion.*

*3D interaction.*

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** This may be considered too basic since it is typically a HS level course, but honestly geometry and trig comes up far more often that calculus in my classes.

**How incorporated:** Added trig to geometry

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** re shared concepts, I'm not sure why this section is included unless it is required. If required, then it should be fleshed out.

**How incorporated:** Revised to utilize standard format for all Knowledge Units

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** replace "*Graftals"* with *"L-Systems*

**How incorporated:** done!

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** Re cross-cutting themes, This is so abstract it doesn't feel particularly useful.

**How incorporated:**

**Why not incorporated:** a requirement at this time

**Date considered:** 09-29-2023

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**Feedback comment:** Re competency specifications: They all seem like reasonable tasks and I agree with the assessment of them. I just don't understand why these and not others. These don't seem to be different levels of competencies. Though they do seem to increase in complexity. Some explanation would be useful if this isn't part of some standard format for new curricular guidelines.

**How incorporated:** There will be a description of the competency model elsewhere in the docment.

**Why not incorporated:** These are illustrative and a requirement of the competency model adopted by the steering committee.

**Date considered:** 09-29-2023

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**Feedback comment:** re competency models, add core level

**How incorporated:** will do

**Why not incorporated:**

**Date considered:** 09-29-2023

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**Feedback comment:** Re the image showing prerequisites for KU's and some of the course packaging, … a curious collection of courses. The Tangible Computing course is the furthest from graphics I can imagine while still being under the GIT umbrella (though more HCI). On the other hand, there are no advanced graphics courses (courses that require Interactive Computer Graphics as a prerequisite), and other issues with other course packages

**How incorporated:** We thought the image showed the prerequisite KU hierarchy. Clearly it did not, so we changed the course packaging to show the requisite KU's.

**Why not incorporated:** We disadvantaged the reviewer by not clearly communicating that KU's are not courses. fundamentals + rendering + Interaction = the basis for the "standard" core computer graphics course which may be augmented with instructor-chosen content from other KU's. Interaction is a knowledge unit, not a class. Because the reader found the image confusing  rather than clarifying, we removed it. We thought the image showed the prerequisite KU hierarchy and it did not.

**Date considered:** 09-29-2023

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**Feedback comment:** re interactive computer graphics course packaging, If this is *Interactive* Computer Graphics, shouldn't it include some Interaction hours?

**How incorporated:** done!

**Why not incorporated:**

**Date considered:** 09-30-2023

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**Feedback comment:** re interactive computer graphics course packaging, 4 hours of ethics seems high for this class. I can buy 4 hours of social issues for the other courses in this list, but there are so many other things to cover in this course that 4 hours seems excessive since the ethical considerations are so distant from the actual material being covered.

**How incorporated:**

**Why not incorporated:** This packaging contains the content in a typical graphics course which for most students is the only graphics course they will take. Thus, it feels important to introduce the potentially harmful ways graphics can be utilized as well as intellectual property and copyright issues.

**Date considered:** 09-30-2023

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**Feedback comment:** re Tangible computing course packaging, This should include some HCI hours.

**How incorporated:** (previously added HCI User) and In response to this feedback, added an additional 3 hours of HCI: System

**Why not incorporated:**

**Date considered:** 09-30-2023

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**Feedback comment:** re Tangible computing course packaging, This is missing some low level things like interacting with sensors or networking, some mid-level concerns like event driven programming, and high-level concerns like why would you do this and design.

**How incorporated:** While we initially felt these the items you mentioned were implied within "learn to program a microcontroller", it is more complete to include them. The revised skill description is "A student who completes this course will be able to use human-centered design to build circuits and program a networked microcontroller. Additionally, they will learn to work with real time sensors and understand polarity, Ohm's law, and how to work with electronics safely."

**Why not incorporated:**

**Date considered:** 09-30-2023

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**Feedback comment:** re visualization course packaging, add *be able to read and evaluate existing visualizations"*

**How incorporated:** done!

**Why not incorporated:**

**Date considered:** 09-30-2023

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