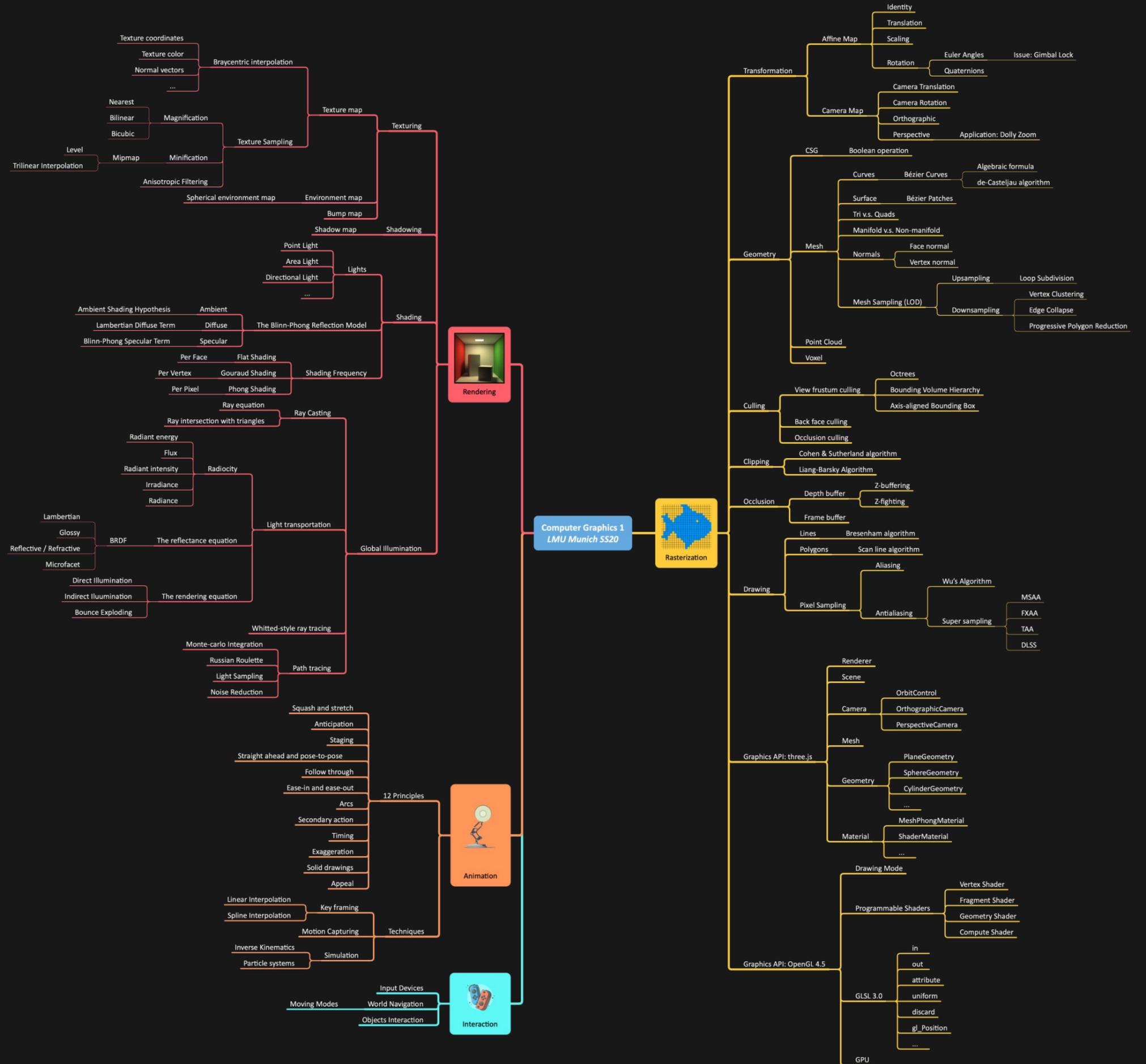**Tutorial 8**

Final Review

Computer Graphics

Summer Semester 2020

Ludwig-Maximilians-Universität München

A CG1 Mind Map

- The mind map may not be complete

- This is for your inspiration and we encourage you to do that too

Texture coordinates
Texture color
Normal vectors
... — Braycentric interpolation
Nearest
Bilinear — Magnification
Bicubic
Level — Texture Sampling
Trilinear Interpolation — Mipmap — Minification
Anisotropic Filtering
Spherical environment map — Environment map
Bump map
Texture map — Texturing
Shadow map — Shadowing

Point Light
Area Light
Directional Light
... — Lights

Ambient Shading Hypothesis — Ambient
Lambertian Diffuse Term — Diffuse — The Blinn-Phong Reflection Model
Blinn-Phong Specular Term — Specular — Shading
Per Face — Flat Shading
Per Vertex — Gouraud Shading — Shading Frequency
Per Pixel — Phong Shading

Ray equation
Ray intersection with triangles — Ray Casting

Radiant energy
Flux
Radiant intensity — Radiocity
Irradiance
Radiance
Light transportation

Lambertian
Glossy
Reflective / Refractive — BRDF — The reflectance equation
Microfacet
Global Illumination

Direct Illumination
Indirect Illumination — The rendering equation
Bounce Exploding

Whitted-style ray tracing
Monte-carlo Integration
Russian Roulette
Light Sampling — Path tracing
Noise Reduction

Rendering

Squash and stretch
Anticipation
Staging
Straight ahead and pose-to-pose
Follow through
Ease-in and ease-out
Arcs — 12 Principles
Secondary action
Timing
Exaggeration
Solid drawings
Appeal

Linear Interpolation
Spline Interpolation — Key framing
Motion Capturing — Techniques
Inverse Kinematics — Simulation
Particle systems

Animation

Input Devices
Moving Modes — World Navigation
Objects Interaction

Interaction

Computer Graphics 1
LMU Munich SS20

Identity
Translation
Affine Map — Scaling
Rotation — Euler Angles — Issue: Gimbal Lock
Quaternions — Transformation
Camera Translation
Camera Rotation
Camera Map — Orthographic
Perspective — Application: Dolly Zoom

CSG — Boolean operation
Curves — Bézier Curves — Algebraic formula
de-Casteljau algorithm
Surface — Bézier Patches
Tri v.s. Quads
Manifold v.s. Non-manifold
Mesh — Normals — Face normal
Vertex normal
Geometry
Upsampling — Loop Subdivision
Vertex Clustering
Mesh Sampling (LOD) — Downsampling — Edge Collapse
Progressive Polygon Reduction
Point Cloud
Voxel

View frustum culling — Octrees
Bounding Volume Hierarchy
Culling — Axis-aligned Bounding Box
Back face culling
Occlusion culling

Clipping — Cohen & Sutherland algorithm
Liang-Barsky Algorithm

Occlusion — Depth buffer — Z-buffering
Z-fighting
Frame buffer

Lines — Bresenham algorithm
Drawing — Polygons — Scan line algorithm
Aliasing
Pixel Sampling — Wu's Algorithm
Antialiasing — MSAA
Super sampling — FXAA
TAA
DLSS

Rasterization

Renderer
Scene
Camera — OrbitControl
OrthographicCamera
PerspectiveCamera
Mesh
Graphics API: three.js — Geometry — PlaneGeometry
SphereGeometry
CylinderGeometry
...
Material — MeshPhongMaterial
ShaderMaterial
...

Drawing Mode
Vertex Shader
Programmable Shaders — Fragment Shader
Geometry Shader
Compute Shader
Graphics API: OpenGL 4.5
in
out
attribute
GLSL 3.0 — uniform
discard
gl_Position
...
GPU

A question list for you to prepare the exam

Topic 1: Transformations (1)

- What are the differences between point and vector?
- How to compute the vector norm?
- How to perform a vector dot/cross product?
- What is the geometric meaning of the cross product? Give an example
- How to perform matrix multiplication?
- How to express cross product using matrix notation?
- What is the geometric sense of span and basis? Give an example
- What are the span and basis?
- What is the geometric meaning of span and basis? Give an example
- What is an orthonormal basis, and why do we need it?
- How to compute an orthonormal basis?
- What is a determinant?
- How to calculate 2x2, 3x3, and 4x4 determinants?
- What is the geometric meaning of a determinant? Give an example
- Name differences of left-handed coordinate frame and right-handed coordinate reference frame
- How to express coordinates in a spherical coordinate reference frame?

Topic 1: Transformations (2)

- What are homogeneous coordinates, and why do we need it?
- Why (x, y, z, 1) and (wx, wy, wz, w) are equivalent?
- What is a linear transformation, and how to verify a transformation is linear?
- How to express scale, rotation, shear, reflection, translation, as affine transformation?
- What are the properties of linear/affine/isometric transformation?
- What are the Euler angles?
- What are the types of Euler angles?
- How to express 3D rotations with Euler angles?
- What is a quaternion?
- How to represent 3D rotations with quaternions?
- What is a gimbal lock? Explain how it occurs
- How does using quaternions solve the gimbal lock issue?
- What is a scene graph, and how to compute a model (object) transformation?

Topic 2: Geometry (1)

- What is CSG? Why and why not use it?
- What are the boolean operations? How to construct a geometry with CSG?
- What are the geometric primitives?
- Give an object example that can be constructed using extrusion
- Which geometric primitive is used in your case?
- What is a voxel, and when are they useful?
- What so special with point-based representation?
- What is interpolation?
- What is the Perlin noise, and how it works?
- How to draw a Bézier curve?
- What is the de Casteljau algorithm, and how it works?
- How to express a Bézier curve using Bernstein basis?
- What are the properties of Bézier curves?
- What is the piecewise Bézier curve, and why do we need it?
- What is a Bézier surface?

Topic 2: Geometry (2)

- Which data structure can be used to store a mesh?
- How to determine the front side of a polygon?
- Why triangles and why quads?
- Distinguish non-manifold from manifold surfaces
- What is the face normal and the vertex normal?
- What is mesh simplification?
- What is vertex clustering, and how it works?
- What are the drawbacks of vertex clustering?
- What is Melax's progressive polygon reduction, and how it works?
- What is mesh subdivision?
- What is the loop subdivision, and how it works?
- Name a subdivision approach for quad-meshes
- Why do we need mesh simplification and subdivision?
- What are mesh downsampling and upsampling?
- What is mesh aliasing?
- What is LOD, and why do we need it?

Topic 3: Camera

- What is the motivation for camera view transformation?
- What is the orthographic projection?
- What are the advantages and disadvantages of orthographic projection?
- What are the parameters we need to define the view frustum in orthographic projection?
- What is perspective projection?
- What are the advantages and disadvantages of perspective projection?
- What is a vanishing point, and what is the maximum vanishing points in perspective projection?
- What are the parameters we need to define the view frustum in perspective projection?
- What are the differences between orthographic and perspective projection?
- How to derive the perspective projection matrix?
- What are MVP matrices?
- What is viewport transformation and how to compute it?
- What is Dolly Zoom, and how can it be implemented?
- Why is Dolly Zoom not always perfect?
- Describe the transformation pipeline from a 3D geometry to a 2D viewport

Topic 4: Rasterization

- What is the Painter's algorithm, and what are the drawbacks?
- What is the depth buffer, and how it works?
- What problem can occur with depth buffer in perspective projection and how to solve it?
- What is frame buffer, and why do we need it?
- What are the types of culling, and what are their differences?
- What is BVH, and why is it better than Octrees in culling?
- What is AABB, and why is it more useful than the other types of bounding boxes?
- What is clipping, and what are the differences compare with culling?
- What are the purposes of clipping, and how is it involved in the transformation pipeline?
- What is Cohen & Sutherland algorithm, and how it works?
- What is the Liang-Barsky algorithm, and how it works?
- What is Bresenham's algorithm, and how it works?
- What is the Scan-Line algorithm, and how it works for triangles?
- What is point aliasing, and how to deal with it?
- What is supersampling?
- Explain how MSAA works, and what is the cost of it?

Topic 5: Material

- What is a texture map?
- What is the barycentric interpolation, and why do we need it?
- How to compute barycentric coordinates given a triangle?
- How to interpolate colors using barycentric coordinates?
- How to interpolate texture coordinates?
- What is magnification/minification? Give three examples of different types of methods for it.
- What is mipmap, and why do we need it?
- What is the storage overhead of mipmap?
- How to select an appropriate level in a mipmap?
- What is the environment map, and what is the application of it?
- What is the bump map? Give an example and how it is applied then explain the limitation of it.
- What is the shadow map, and how to create it?
- What are the types of shadow maps, and what are the limitations of them?
- What is BRDF, and how it relates to materials? What are the inputs and outputs of it?
- Draw a picture that demonstrates light reflection behavior regarding specular, glossy, diffuse surface
- How to calculate and measure a BRDF?

Topic 6: Illumination (1)

- What are the differences between local illumination and global illumination?
- What is shading? What is the difference comparing to shadowing?
- What are ambient, diffuse, and specular?
- What is ambient shading, and what is the assumption of ambient shading?
- What is the influence of the ambient coefficient?
- What is Lambertian shading, and what is the assumption of Lambertian shading?
- What is the influence of the diffusion coefficient?
- What is the impact of the specular coefficient?
- What are Phong, Blinn-Phong shading, and what is the assumption in the Phong and Blinn-Phong shading term?
- What are the Phong and Blinn-Phong reflection model? Write the complete formula.
- What is the impact of the shininess factor?
- What are flat, Gouraud, and Phong shading, and what are their differences?
- What is the implied conclusion from shading frequency?
- What is point light, area light, directional light?

Topic 6: Illumination (2)

- What is the rendering equation? Draw a picture then mark the components and explain all symbols
- What makes computing the rendering equation so hard?
- What is ray tracing, and how is it different from rasterization?
- What Whitted-style ray tracing, and what is wrong with it?
- What is radiant energy, and what is intensity?
- What is irradiance, and what is radiance?
- What is the difference between radiance and irradiance?
- What is direct illumination, and what is indirect illumination?
- What is path tracing, and what is different from (Whitted-style) ray tracing?
- What is the distributed ray tracing?
- What is the expected value, variance, bias, PDF, and CDF?
- What is Monte Carlo Integration, and how to calculate it?
- How is the Monte Carlo method used to solve the rendering equation?
- What is Russian Roulette, and why do we need it?
- What are biased and unbiased estimators?
- What is noise reduction, and why do we need it?

Topic 7: Animation & Interaction

- What are the 12 principles in animation?
- Give an animation example then explain each principle
- What is the keyframing and how to interpolate between those keyframes?
- What are splines, and why is it useful in creating animations?
- What are the types of splines commonly used in computer graphics?
- Why are these splines popular? What properties make them most useful?
- Which physical law do we need for object acceleration simulation? Write the complete formula.
- What is motion capturing?
- What is the difference between forward and inverse kinematics?
- What is the particle system? Name three examples.
- What must be concerned to create an input device for 3D interaction?
- How to perform world navigation in a 3D world? Name an example.
- Name an input device and explain how it applies to object interaction in a 3D world?

Topic 8: Programming with JavaScript and Three.js

- When do we need to use const (const) other than variable (let)?
- What are the differences between a standard function and an arrow function?
- How to check the equality of two numbers in a flow control statement?
- What is the class, and what is the required method?
- What are the data types in JavaScript? Name two operations/methods for each of the data types
- How to handle errors in JS?
- What is Node.js, and why do we need it?
- What is npm, and why do we need it?
- What are the required steps to create a scene in three.js?
- Explain these concepts: Scene, Camera, Renderer, Geometry, Material, Mesh, Face, OrbitControl.
- How to express rotation in three.js?
- How to animate objects/camera in three.js?
- How to load a model in three.js?
- How to perform texture mapping in three.js?
- How to connect customized GLSL shaders in three.js?

Topic 9: Programming with OpenGL (4.5) and GLSL

- Why are GPUs considerably more suitable than CPUs in graphics processing?
- What are the drawbacks of using a graphics API?
- What is the relationship and differences between OpenGL and GLSL?
- What are the stages in the OpenGL graphics pipeline?
- What are the geometric primitives in OpenGL?
- What are the drawing modes in OpenGL?
- What is a shader, and where is it executed?
- What are the programmable shaders in OpenGL?
- What are the inputs and outputs of different shaders in OpenGL?
- How to write an OpenGL shader?
- What are in/out/attribute/uniform/discard?
- What are the required variables in every vertex/fragment shader?
- What is missing in WebGL 1.0 and 2.0 regarding the OpenGL graphics pipeline?

Final Notes

- You will pass the exam if:

  - you can answer 90% of questions that are listed here

  - you can solve all non-programming tasks in the assignments

  - you can solve 50% of the programming tasks in the assignments

- You will get an excellent grade if:

  - you can also complete all programming tasks individually without double checking the solution

Good Luck!