UNIVERSITETET I OSLO

Det matematisk-naturvitenskapelige fakultet

Eksamen i	INF3320 — Metoder i grafisk databehandling og diskret geometri
Eksamensdag:	29. november 2011
Tid for eksamen:	14.30 – 18.30
Oppgavesettet er på 5 sider.	
Vedlegg:	Ingen
Tillatte hjelpemidler:	None

Kontroller at oppgavesettet er komplett før du begynner å besvare spørsmålene.

Hver oppgave teller like mye

Oppgave 1 Datagrafikk

Forklar følgende begreper innen datagrafikk:

1. Framebuffer.
2. Depth buffer.
3. Geometry shader.
4. BRDF.
5. GPGPU.

Løsning.

1. *Framebuffer - It is a buffer (continuous segment of memory) that typically resides on a graphics card and is used as a destination for the pixel color values produced by a graphics pipeline as a result of processing geometry. It is also late presented on the screen.*
2. *Depth buffer - It is a buffer (continuous segment of memory) that typically resides on a graphics card and is used as a destination for the pixel depth values produced by a graphics pipeline as a result of processing geometry. It is used to preform depth testing.*

(Fortsettes på side 2.)

3. *Geometry shader - Is a programable stage in the graphics pipeline that provides the capability to process whole primitives (as opposed to isolated vertices processed by the vertex shader). It typically also allows to output additional primitives or output no primitives at all effectively discarding the geometry.*

4. *BRDF - Bi-directional reflectance function. It is a function that describes a fraction of light incoming from a certain direction that is reflected into some other direction. As such it is a function of* 4 *arguments - a pair of angles that describe the incoming light direction and a second pair of angles that describes the outgoing directions. All the angles are typically measured from surface normal.*

5. *GPGPU - I a general term used for a wide range of techniques that utilize the graphics processing unit (GPU) for general purpose (GP) computations.*

Oppgave 2 Lyssetting

I denne oppgaven skal vi se på Phongs lyssettings modell (ikke Phong-shading) med en lyskilde med ikke-null intensitet.

1. Skriv ned modellen med half-vector. Forklar de enkelte leddene og illustrer med en figur.

2. I hvilke tilfeller blir diffuse komponenten null? I hvilke tilfeller blir specular komponenten null?

3. Forklar med et eksempel hvordan diffuse komponenten kan være null mens specular komponenten kan være positiv. Forklar hvorfor dette ikke kan skje i virkeligheten og hvordan man kan unngå problemet i praksis.

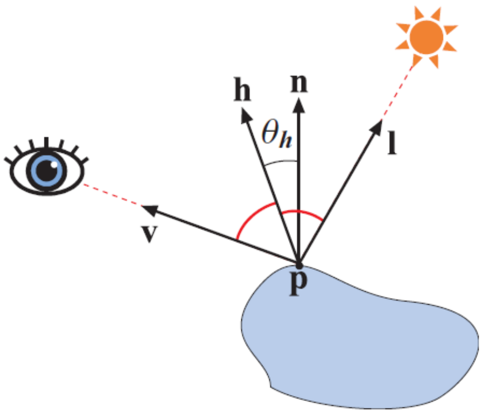
Løsning.

1. *Phong shading model:*
   $c = f(d)(I_d \cdot M_d \otimes L_d + [I_d > 0] \cdot I_s \cdot M_s \otimes L_s + M_a \otimes L_a)$ *where:*

   - M_d, M_s and M_a *denote the material diffuse, specular and ambient components*
   - L_d, L_s and L_a *denote the light diffuse, specular and ambient components*
   - $f(d) = 1/(ad^2 + bd + c)$ *denotes the attenuation function where* d *is the distance from the light and* a, b, c *are the light attenuation factors.*
   - $I_d = max(n \cdot l, 0)$ *is a diffuse contribution factor*
   - $I_s = max(n \cdot h, 0)^s$ *is a specular contribution factor, where* $h = (v + l)/\|v + l\|$ *is a half vector and* s *is a material shininess.*
   - n *is the normal vector*
   - l *is the light vector (points towards the light)*

(Fortsettes på side 3.)

- *v is the eye/viewer vector (points towards the viewer)*



2. *Diffuse component is zero if $n \cdot l \leq 0$ and specular component is zero if $n \cdot h \leq 0$.*

3. *Consider all the vectors n, l, v lying in the one plane. Furthermore consider the l vector such that it makes and angle $-120°$ degrees with n and the v vector that makes the angle $30°$ degrees with n. Then $n \cdot l < 0$, however h makes and angle of $-45°$ degrees with n and as such $h \cdot n > 0$. In real life this cannot happened because $n \cdot l \leq 0$ means that the light is hitting the surface from behind so both diffuse and specular contributions should be zero. In practice this can be avoided by testing for non zero diffuse contribution before computing the specular contribution.*

Oppgave 3 Subdivision kurver

I denne oppgaven skal vi se på kubisk uniform spline subdivision på et **åpent** kontrollpolygon $\mathbf{P}$ med kontroll-punkter $P_1, P_2, ..., P_n$ i $\mathbb{R}^2$.

1. Skriv ned de to stensilene for nye indre kontrollpunkter (ikke endepunkter).
2. Foreslå stensil for endepunkter slik at grense-kurven interpolerer endepunktene P_1 og P_n.
3. Illustrer med en figur ett steg og grensekurven for dette skjemaet.
4. Skriv ned et eksplisitt uttrykk for tangent-retningene til kontrollpolygonet $\mathbf{P}$ og for grense-kurven. Illustrer med en figur.

Løsning.

1. *$a^e = \{1/8, 6/8, 1/8\}$ and $a^o = \{1/2, 1/2\}$.*
2. *$a^e = \{1\}$.*

(Fortsettes på side 4.)

3. *An example consists of* $P_1 = (0,0)$, $P_2 = (0,1)$, $P_3 = (1,1)$ *and* $P_4 = (1,0)$. *After the subdivision new points are* $Q_1 = (0,0)$, $Q_2 = (0,1/2)$, $Q_3 = (1/8,7/8)$, $Q_4 = (1/2,1)$, $Q_5 = (7/8,7/8)$, $Q_6 = (1,1/2)$ *and* $Q_7 = (1,0)$.

4. *Tangent at the* P_0 *is equal to* $P_0 - P_1$ *and tangent at* P_n *is equal to* $P_n - P_{n-1}$. *[NO FIGURE HERE]*

Oppgave 4 Transformasjoner

VI skal se på en sylinder C med lengde 2 og radius 3, sentrert i origo i $\mathbb{R}^3$ og innrettet i y-retningen.

1. Skriv ned OpenGL kode som setter opp en view-transformasjon som plasserer kamera i et vilkårlig punkt $\mathbf{p}$ på en sirkel med radius 5 rundt origo i xz-planet. Kameraet skal peke mot origo og ha opp-vektor $(0,1,0)$. Illustrer med en figur. Avhenger kameraets bilde av sylinderen av valg av $\mathbf{p}$?

2. Skriv OpenGL kode som setter opp det minste view-frustumet som inneholder hele C. Illustrer med en figur. (Hint: $\tan\alpha = \sin\alpha/\sqrt{1-\sin^2\alpha}$).

Løsning.

1. *Assuming that* θ *is an counterclockwise angle that a vector from origin to the camera makes with the* x*-axis then the code is* `glLookAt(`$5\cos\theta, 0, 5\sin\theta, 0, 0, 0, 0, 1, 0$`)`. *[NO FIGURE HERE]*

2. *Since cylinder is centered at the origin and of height* 2 *the bottom extent of the frustum is equal to* -1 *and the top extent is equal to* 1. *Also since the cylinder radius is equal to* 3 *the near plane of the frustum is* 2 *and the far plane of the frustum is* 8. *To compute the left and right extents we assume that* α *is an angle the right extent plane manes with the camera view vector. Then* $\sin\alpha = (\textit{radius})/(\textit{distance to cylinder center}) = 3/5$. *Then from the formula in the hint we knot that* $\tan\alpha = 3/4$. *On the other hand* $\tan\alpha = (\textit{right extent})/(\textit{near plane distance}) = x/2$. *Solving for* x *we obtain* $x = 1.5$. *Since the cylinder is symmetrical with the respect to the viewing axis the left extent is* -1.5. *The final code is* `glFrustum(-1.5, 1.5, -1, 1, 2, 8)`. *[NO FIGURE HERE]*

Oppgave 5 Trianguleringer

1. Hvilke egenskaper karakteriserer en gyldig triangulering i $\mathbb{R}^2$?

2. Hva er en edge-flip og hva brukes den typisk til? Illustrer med et eksempel en slik operasjon som leder til en ugyldig triangulering i $\mathbb{R}^2$.

(Fortsettes på side 5.)

3. Hva er en halfedge-collapse og hva brukes denne typisk til? Illustrer med et eksempel en slik operasjon som leder til en ugyldig triangulering i $\mathbb{R}^2$.

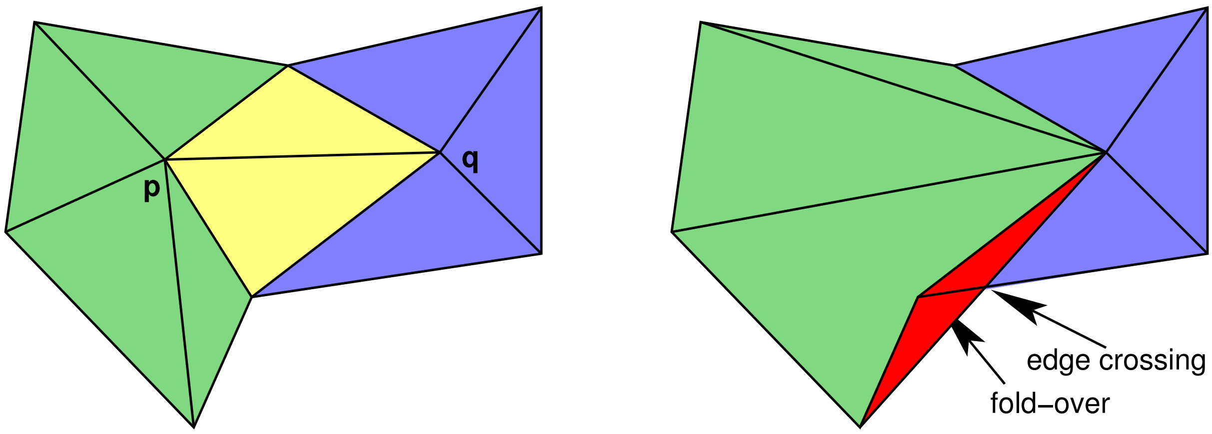
4. Hvordan kan man definere genus? Gi et eksempel på et lukket mesh med genus 0.

Løsning.

1. *A valid triangulation in $\mathbb{R}^2$ is a set of triangles such that the intersection between any pair of triangles is either empty, an vertex or a common edge. Furthermore they must be such that faces incident on a vertex form a triangle fan (either closed or open).*

2. *An edge flip is an operation that involves two triangles sharing an edge. To performing an edge flip means to discard an edge shared by the two triangles and replace it with an edge joining the vertices that did not belong to the removed edge. It is typically used for mesh optimization. [NO FIGURE HERE]*

3. *An half-edge collapse is an edge collapse that collapses one of the end points of an edge onto the other (which one is determined by the half-edge direction). It is typically used for mesh simplification. Example follows:*



4. *There are a few ways to define a genus. One of them is to say that the genus is the number of handles (i.e. the torus handles). The other way to say it is a maximum number of cuttings along the closes simple curves without disconnecting the surface. A final definition can be given by an equation $\chi = 2 - 2g$ where g is the genus and χ is the Euler characteristic. Examples of meshes with genus zero is a tetrahedron, sphere, cube - to name a few.*