Visualization Pipeline

A. Explain the visualization pipeline. What are the four stages?
   Data acquisition => Filtering /Enhancement => Visualization mapping => Rendering [01, p. 74]
B. Explain the data acquisition stage. What are three general cases?
   Simulation, Data bases, Sensors [01, p. 74]
C. Explain the filtering/enhancement stage. Give at least two examples.
   Modify the data to obtain useful information. Resampling to grid, interpolation, data reduction [01, p. 76]
D. Explain the visualization mapping stage. Give at least two examples.
   Transform the derived data into graphical primitives. Vector field to vectors, Tensor field to glyphs. [01, p. 77]
E. In which stage of the visualization pipeline happens resampling to a regular grid?
   filtering/enhancement stage [01, p. 76]
F. In which stage of the visualization pipeline are the viewpoint and lighting parameters specified?
   Rendering [01, p. 78]
G. In which stage of the visualization pipeline happen lighting and shading?
   Rendering [01, p. 78]
H. In which stage of the visualization pipeline are colors assigned to every voxel?
   Visualization Mapping [01, p. 77]

Data Representation

A. Discuss independent vs. dependent variables in data. Give at least two examples each.
   Independent variables - dimensions of domain + time, dependent - types, physical quantities (velocity etc), dimensions to be visualized(?)(usually stuff computed or inferred from dependent values) [02, p. 2-4]
B. What are the independent and dependent variables in a 3D spatial curve $\varphi : R \rightarrow R$ 3
   Independent - parametric 1D value along the line, dependent - 3D coordinate of the point on the line
C. What are the independent and dependent variables in a 3D vector field?
   Independent - 3D coordinate of points in the domain, dependant - components of 3D vector field
D. Draw an illustration of a Cartesian grid. Describe how such a grid is different from a regular grid? Which information needs to be specified explicitly for such a grid?
   regular grid = orthogonal, equidistant grid, but dx != dy. dx, dy step size.
E. What is a curvilinear grid? How is it characterized? How is it different from an unstructured grid? Which information needs to be specified explicitly for such a grid?
   Curvilinear grid - non-orthogonal grid with explicitly specified coordinates of its points; neighbourhood is implicit, all cells are quadrilaterals
   Unstructured grid - both points and neighbours are specified explicitly (1st difference); cell could be triangle, tetrahedral and hexahedra in 3d (2nd difference) [03, p. 8-9]

Data Interpolation

A. a) For the triangulation shown below, proof or disproof that this triangulation is a Delaunay triangulation. Your proof should be geometrically, meaning that you either illustrate the Delaunay property in the figure or illustrate that this property is violated.

   Draw circles that touches the 3 vertex of each triangle, but how to calculate the center of the circle? If you want to find them exact, e.g. during the exam, draw any two perpendicular bisectors for the triangle, i.e. find middles for two sides of the triangle and draw perpendiculars inside the triangle until the intersection and it will be the centre

B. b) For the tetrahedron with vertices A = (0,0,0), B = (1,0,0), C = (0,1,0), D = (0,0,1) and the corresponding scalar values f A , f B , f C , f D , the linear interpolation function $f(x, y, z) = 1 - x + 2 \cdot y - 2 \cdot z$ is given. Compute the concrete scalar values at the four vertices.
   Just plug in the values. f(A) = 1, f(B) = 0, f (C) = 3 f(D) = -1

C. c) For the tetrahedron given in the previous assignment, assume that the scalar values inside the tetrahedron are interpolated via barycentric interpolation. Compute the gradient of the interpolated scalar field at the points P = (0.5, 0.25, 0.5) and Q = (0, 0, 0).
   Gradient \nabla f = (-1,2,-2) is the same for any point Why this question even exist? We just take gradient of the initial function f(x,y,z) without any interpolation

D. d) Given is the following quadrilateral cell with its four vertices v 1 , v 2 , v 3 , v 4 and the corresponding scalar values f 1 , f 2 , f 3 , f 4 . A grid is shown for orientation purpose, i.e., it does not affect the interpolation.
   Draw the iso-contour (bold) for the iso-value 0.4 into the same illustration, i.e., all points in the interior of the cell which have a value equal to 0.4. Bi-linear interpolation is assumed for interpolation.
   Using x and y as interpolation coordinates: f(x,y) = (1-x)*y*1.2 + x*(1-y)*0.5 then the isosurface is 0.4 = f(x,y)
   Plot:
   http://www.wolframalpha.com/input/?i=plot+(1-x)*y*1.2+%2B+x*(1-y)*0.5%3D0.4+from+x%3D0+to+x%3D1,+from+y%3D0+to+y%3D1

E. e) In the figure below, a quadrilateral cell is shown. Scalar values are given at the cell corners and bi-linear interpolation of these values is used to reconstruct scalar values across the cell. Is it possible that at the four edge points marked by dots the same scalar value is reconstructed? Explain your answer.
   NO! In the image there is no way to draw asymptotes such that the isolines joining pairs do not cross them. You can prove it by contradiction I would say it is possible if it is constant scalar field. >>If it is constant then the isosurface would be the whole square.

F. f) In the figure below, a 2D Cartesian grid is shown. It has a constant spacing of 1 between adjacent grid points along either axis. The origin of this grid is at (1, 1). A second grid is shown, which consists of one triangle with vertices at (2.5, 4.5), (3.5, 6.5), (4.5, 4.5) and one quadrilateral with vertices (2.5, 2.5), (2.5, 4.5), (4.5, 4.5), (4.5, 2.5). At the vertices of the second grid, scalar values are given. These values are equal to 1 at vertices marked with a filled circle and 0 at vertices marked with a non-filled circle.

Compute the barycentric coordinates of the points (3.5, 4.5) and (3.5, 2.5) with respect to the triangle.

[03, p. 71]

(3.5, 4.5) : a_1 = 1/2 , a_2 = 0 a_3 = ½

(3,5, 2.5) : a_1 = a_3 = 1 , a_2 = -1

For the quadrilateral, determine the coefficients a, b, c, d of the bi-linear interpolation function f(x, y) = a + b · x + c · y + d · x · y which interpolates the scalar values at the vertices of the quadrilateral.

f(a,b) = (1-a)(1-b)*f_ij + a(1-b)*f_i+1j + (1-a)b*f_ij+1 + ab*f_i+1j+1 = (1-a)(1-b)*1 + a(1-b)*1 + (1-a)b*1 + ab*0 = 1 - ab

b= (y-2.5)/(4.5-2.5) , a= (x-2.5)/2 => f(x,y) = 1 + x*⅝ + y*⅝ - xy*1/4

G. g) An interpolation function f(x) = ∑ Ni=1 w i φ(|| p i − x ||) is a weighted sum of N radial 2 functions φ(r) = e −r where || p i − x || is the distance between the points p i and x. Compute the weights w i such that the function f(p i) interpolates the data points p 1 = 1, 1 p 2 = 3, p 3 = 3.5 with corresponding scalar values f 1 = 1, f 2 = 0, f 3 = 4 . The table below shows approximate values for φ(r) with respect to different distances r.

~~[03, p. 28] w_1 = 1 w_2 = 5 w_3 = -15 / 4~~

w_1 = 1, w_2 = -5/9, w_3= 25/36 (Yehor) << I got this one / Jorge

I also got the same as yehor

H. h) Given the interpolation function f(x) from the previous assignment, compute the interpolated value at point x = 2.

~~-81 /40~~

1*⅖ -5/9*⅖ + 25/36*1/10=89/360 (Yehor)

I think the left hand side of the equation is right, but the final answer is wrong. 89/360 instead. (ShengHsuan) See

http://www.wolframalpha.com/input/?i=2%2F5+-+5%2F9*2%2F5%2B25%2F36%2F10

>>Ok i fixed it

Volume and Isosurface Rendering

A. a) Name an algorithm commonly used in indirect volume visualization. Why is it considered to be “indirect” compared to “direct” volume rendering?

~~slicing, Iso-surfacing~~ Marching cube algorithm . Indirect method reduce the volume data to intermediate representation, e.g. surface in 3d, while direct method consider the optic properties of the 3d material and try to represent the data directly. (slide 05, page 09)

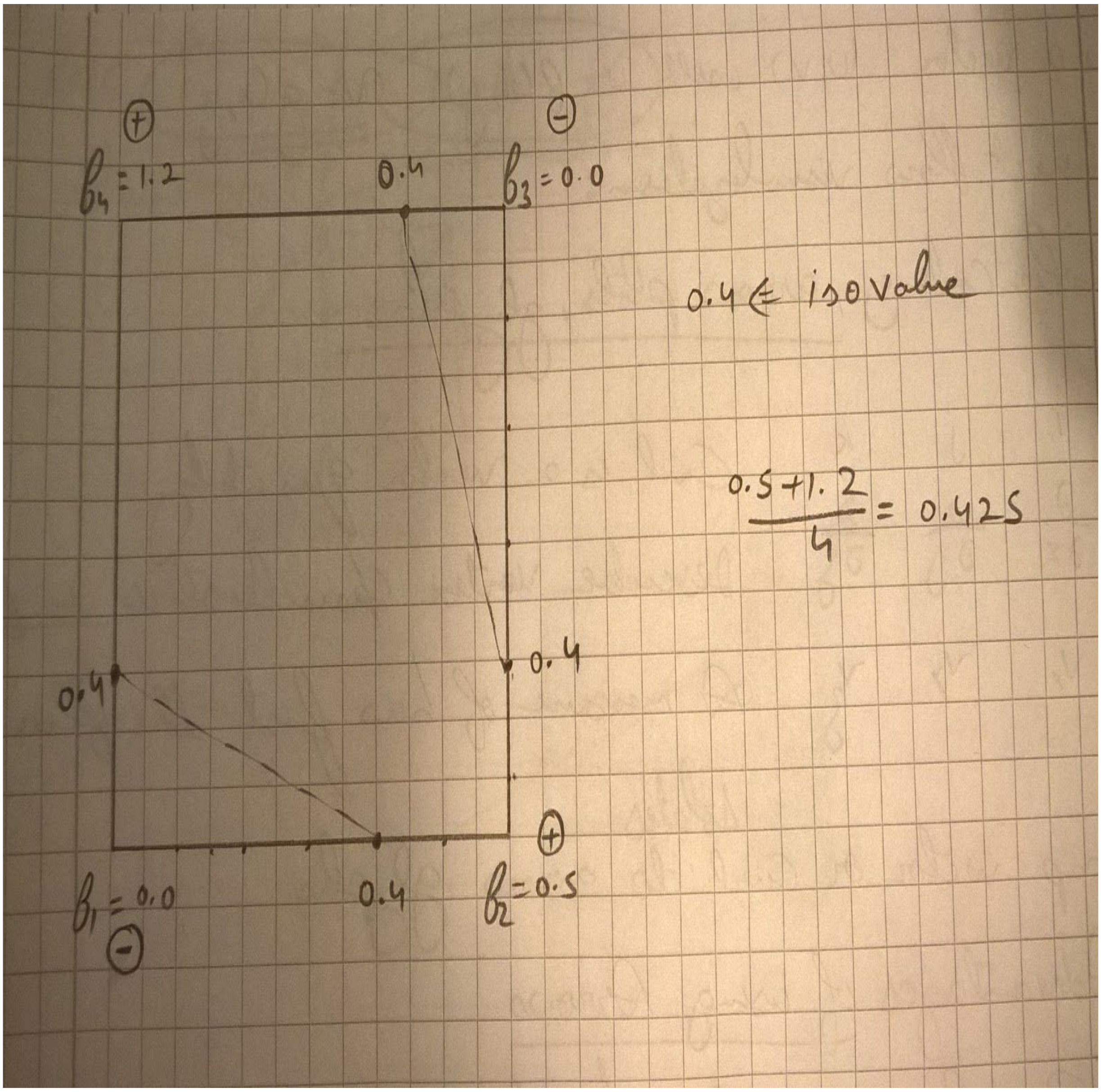
Read this for better understanding

https://graphics.ethz.ch/teaching/former/scivis_07/Notes/stuff/StuttgartCourse/VIS-Modules-05-Volume_Visualization.pdf

B. b) What is a transfer function? Which visual/optical properties are assigned by it?

Function that maps data values to visual properties (colour and opacity) [05, p. 11-23]

C. c) Given is the following quadrilateral cell with its four vertices v 1 , v 2 , v 3 , v 4 and the corresponding scalar values f 1 , f 2 , f 3 , f 4 . A grid is shown for orientation purpose, i.e., it does not affect the interpolation. v 3 , f 3 = 1.2 v 1 , f 1 = 0.0 v 4 , f 4 = 0.0 v 2 , f 2 = 0.5 Draw the iso-line (dashed) for the iso-value 0.4 into the illustration using the marching squares algorithm. Use the mid-point decider for ambiguous cases. Draw the iso-contour (bold) for the iso-value 0.4 into the same illustration, i.e., all points in the interior of the cell which have a value equal to 0.4. Bi-linear interpolation is assumed for interpolation.



Comments on the image bitte...Did you guys also got the same?

>>Seems ok according to midpoint decider.

>>Just in case, you get a different result with asymptotic decider // J

I dont want to do it with asymptotic decider

Bilinear interpolation: f(x,y) = (1-x)(1-y)*0 + x(1-y)*0.5 + (1-x)y*1.2 + xy*0 =
= 0.5*x + 1.2*y - 0.7*xy

Midpoint decider = ¼(0+1.2+0+0.5) = 0.425 > 0.4

Asymptotic decider: f(a_0,b_0) =??? f(0.5*(2/3+4/5), 0.5*(⅓+⅕)) = f(22/30, 8/30) = 11/30+ 8/25 - 119/1125 ...

D. d) A scene consisting of 3 objects (vertical lines) with different intensities (I) and opacities () is shown. The -value (second component) represents the object's opacity, where 0 =´completely transparent´ and 1 =´completely opaque´. The 3 objects are ordered as shown. For the three rays starting at the viewpoint, determine the intensity that is seen along these rays using 1) front-to-back -compositing for the upper ray, 2) the compositing scheme Average for the middle ray, and 3) the compositing scheme Maximum for the lower ray. Specify exactly how the intensities are combined in either case. Iα = (0.5, 1) Iα = (1, 0.5) Iα = (0.75, 0.25)

(1) I = 0.75; (2) I= 9/12; (3) I = 1 [03 p.42,45] >> These are correct

a. compositing scheme I1 = 0+1*0.5 = 0.5 a1=0 + 1*0.5=0.5
I2= 0.5+0.5*0.5= 0.75 a2=0.5 +0.5=1
I3= 0.75

after 2nd material the value of alpha reaches 1 so after that C does not change

b. average = (1+0.5+0.75)/3

c. max(1,0.5,0.75) = 1

E. e) Name the three components of the Phong illumination model.

Ambient light, Diffuse reflector, Specular reflector [04 p 35].

F. f) How can a perfect mirror be simulated via the Phong illumination model?

Ambient light=0, Diffuse reflector = 0, Specular reflector k_s=1 O_d=1 n>>1 (n -> inf) (just a theory) Correct

http://140.129.20.249/~jmchen/cg/docs/rendering%20pipeline/rendering/light_specular.html

G. g) Let L be an incoming light ray and M a diffusely reflecting material. Complement the illustration on the right in the figure according to the illustration on the left. Hint: Take into account the direction and strength of the reflection.

Should be again reflected into the semicircle with const magnitude, but this time magnitude is smaller because I ~ (l*n)<1 now [04, p. 40]

H. h) Let L be an incoming light ray and M a specular reflecting material. The viewer is positioned at the light source and is looking along L. Complement the following figure according to the previous one.

Should be some kind of 'raindrop' with I ~ (r*v)^n [04, p.44-46]

>> I think the viewer should see nothing. since the angle is larger than 90. it make no sense for the cosine to be negative. Yeah, but we should still draw the raindrop anyway.

>> I think they mean just to draw nice arrows of how it is supposed to "work", nothing related to viewer, stop moving my text // for angle >90 just plain 0 intensity!

>> GOOD , Danke dir.

I. i) Below is an illustration of the Phong illumination model. All indicated vectors are normalized (i.e., their length is one). Answer whether the following statements are true or false:

a. The specular reflection is based on the scalar/dot product of n and v

False: is between r and v [04, p. 45]

b. The diffuse reflection is based on the scalar/dot product of n and l

True [04, p 38]

c. The ambient light is based on the scalar/dot product of l and r False, it is a background constant light.

d. The specular reflection is independent of the view vector v False, it depends.

J. j) Given is a surface point at position P = (3, 1, −2) T . The normal at that point is n⃗ = (0,1,0) T . The specular reflection coefficient of the surface is k s = 0.5. The specular exponent is n = 8. The position of a point light source is L pos = (1, 3, −1) T with RGB color C L = (0.8, 1, 0.5). The camera position is at E pos = (6, 5, −2) T . Compute the specular reflection at P using the Phong illumination model. Hint: You can compute the reflected light ray as⃗ r = 2(n⃗ · l)n⃗ − l , where n⃗ and l need to be normalized.

I got C = C_L * 0.5 * (14/15)^8 I also got this. >> I also got this

I've got 0.5*(2/3)^8 << You are wrong booooooooo.

K. k) In the four images below, a sphere is rendered using the Phong illumination model. Four different specular exponents (2, 4, 16, and 64) were used to create the specular reflection. Write the specular exponent that was used to create the rendering below each image.

The more the n, the less the radius of the spot. Makes 64-16-4-2 [04, p. 49]

L. l) Light/color has been emitted at a point along the viewing ray. How is it diminished (due to absorption) in a homogeneous, semi-transparent medium? Draw a typical curve.

I don't know what they mean exactly here. It is either the formula for C_out and alpha_out or the exponential decay

I think the answer is at [5 p 30] >> Agree, should be exponential decay in semi-transparent homogenous medium, the decay factor \alpha is constant since it is homogenous. so simply write something like $I = I_0 \times exp(-\alpha(x - x_0))$

M. m) How do you get values along the viewing ray (from volume data)?

I think the answer is at [5 p 32-33]

N. n) Which compositing schemes do you know (for combining values along the viewing ray)?

Ray casting (accumulate C and Alpha), could be backward and forward + Surface rendering(first hit), average, maximum [05, p.45]

Visualization Mapping

A. a) What's the difference between separable and integral visual channels?

Separable - visually different and can be proceed in parallel

Integral - have major interference [06. p.16]

B. b) Sort the following visual channels according to how accurately humans can compare them starting with the highest accuracy: 2D area – length – curvature – angle/slope

length - angle - area - curvature [06, p. 6]

C. c) What's the advantage/disadvantage of a pie chart?

+: Only for non-intersecting groups, hard to perceive small differences, if tilted perspective changes the real size

-: Easy to see part-to-whole ratio, describe several quantities using one object

D. d) How do Parallel sets work? What kind of data can be shown? wut
   Displays lines with width that represent a quantity of the intersection of two categories. Shows quantitative data under multiple categories.[06, p. 26]
E. e) How does the ThemeRiver/Horizon Graphs work? wut
   The ThemeRiver™ visualization helps users identify time-related patterns, trends, and relationships across a large collection of documents. The themes in the collection are represented by a "river" that flows left to right through time. The river widens or narrows to depict changes in the collective strength of selected themes in the underlying documents. Individual themes are represented as colored "currents" flowing within the river. The theme currents narrow or widen to indicate changes in individual theme strength at any point in time.
F. f) How does a scatterplot matrix work? How can you see correlations? wut
   Displays the data using the value of two variables as axis of the plot. This allows to see patterns in the data and indicates correlation.[06, p. 43]
G. g) Draw a visualization of the following data using parallel coordinates.
   [6 p 46]
H. h) What does it mean when the lines between two axes in a parallel coordinates plot meet in a point?
   It means negative correlation among neighbouring axis.
I. i) Name three examples for glyph-based visualization.
   stars, sticks, arrow, tensors-glyphs, Chernoff faces
J. j) How do stick figures encode information?
   Main attribute: length, other: thickness, angles, limbs properties
K. k) What is pre-attentive processing of visual information?
   Automatic and parallel detection of basic features in visual information (200-250 msec) [07, p. 34]
L. l) What are the advantages/disadvantages of a rainbow color ma
M. p?
   +: Familiarity, Attractive display, Reading data values using a color key.
   -:perceptually nonlinear, perceptually unordered, introduces artifacts, It obscures small details in the data.
   https://www.mathworks.com/tagteam/81137_92238v00_RainbowColorMap_57312.pdf
N. m) What does it mean, when a visual channel (e.g., color) is perceptually linear?
   change of the same amount in a color value should produce a change of about the same visual importance.
   https://en.wikipedia.org/wiki/List_of_color_spaces_and_their_uses
O. n) What are the characteristics of a diverging color map?
   meaningful central, and two different color on two different side, e.g. temperature red->white->blue

Vertical Field Visualization

A. a) Give two examples for direct flow visualization.
   tectonic plate motion, flow over an airfoil
   >> arrow , color coding
B. b) What challenges does arrow-based direct flow visualization have?

Could have spatial ambiguities when visualizing (e.g. In 3d, array pointing toward or away from you are the same.) and have poor results when flow changes abruptly

C. c) Give two examples for geometric (integration-based) flow visualization. How do these techniques relate to direct flow visualization?
Stream lines, Path lines, Streak lines ??? [08, p. 30]
>> they are lines that are constructed from the vectors in the direct flow visualization.

D. d) What is Runge-Kutta integration (2nd/4th order)? What's the advantage over Euler integration?
A method to approximate the solution of an ODE, is more precise and stable than euler.

E. e) Characteristic lines are tangential to the flow. What does that mean?
At each point its first derivative is same as vector field direction. That means that they are results of integral along directions i.e. solutions of and ODE+init.cond. [08, p. 44]

F. f) Calculate the Jacobi matrix J of the 2D vector field v(x, y) = (y^2 − 1, x − y) T .
J = (0, 2y ; 1 , -1)

G. g) Calculate the Jacobi matrix, divergence and curl of the 3D vector field v(x, y, z) = (cos(xy) , sin(x) , z) T .
// J(v) = (-y*sin xy, - x*sin xy, 0; cos x, 0, 0; 0, 0,1)
// curl(v) = (0; 0; cos x + x sin xy) ???
// div(v) = trace(J(v)) = 1 - y sin xy
>> (yeah but not so sure, given the fact that it is almost 3am now.)

H. h) A critical point in a 2D vector field v(x, y): R 2 → R 2 is a point (x, y) where v(x, y) = (0,0) T . How many critical points does the vector field v(x, y) = (y 2 − 1, x − y) T have, and where are these points located?
v(x,y)=0 => 2 points: A1=(1, 1), A2=(-1, -1)

I. i) Below are three examples of critical points together with the eigenvalues λ 1 , λ 2 of the respective Jacobi matrices. Classify each critical point according to the eigenvalues and sketch the typical flow around it.
1st: saddle; 2nd: circular sink; 3rd: noncircular source

J. j) Given the same 2D vector field v(x, y) = (y, − x2) T . Compute the next point x 1 of a stream line with seed point x 0 = (0, 2) T using the Midpoint integration method (also known as Runge-Kutta of 2 nd order) with a step size Δt = 1. Draw the resulting point and the used vector(s) in the illustration below (don't forget to annotate them). Specify exactly how the point and vectors are calculated.
x_temp = x_0 + v(x_0)*dt/2 = (0;2)+½(2;0)=(1;2)
v_mid = v(x_temp) = (2; -0.5)
x_1 = x_0 + v_mid*dt = (0;2)+(2;-0.5) = (2;1.5)

K. k) In Figure 6, a vector field at four different times is shown. The grid vertex marked by a dot is selected as initial position for particles that are seeded into the flow. Assume that a particle can only move diagonally, vertically, or horizontally (depending on the vector at the particles current position), and that it always moves from the current grid point to the next grid point in the respective direction. Figure 6 Illustrate in the grids given below a) the pathline of a particle released into the flow at the marked position at time t0, b) the streakline of particles released into the flow at the marked position at time t0, and c) the streamline of a particle released into the flow at the marked position in the fixed vector field at time t1.

L. l) (2 points) Which characteristic line approaches do you know for unsteady/time-varying flow? What happens if you apply them to steady flows?
Streak lines and path lines. If it is steady flow they both are identical to stream lines

M. Answer whether the following statements are true or false.
The Jacobi matrix at a point in a constant 3D vector field has non-zero elements on the main diagonal. False, compute d/dx,d/dy
If the Jacobi matrix at every point in a 3D vector field is the identity matrix, then the vector field is divergence free. false: div=trace(J) => div = 3
The divergence at every point in a 3D vector field is a scalar value. true: div:R^3->R^1
Streamlines in a steady 3D vector field never cross. true, BUT crosses for sinks/sources >>THEORETICALLY, they never cross bc for sinks and sources, t goes to +/-infty >>> Semi-true They cross in the rendering if there is no detection for fast changes in z [08, p. 80]
LIC is a local method for visualizing a vector fields. false, global
The larger the extent of the convolution kernel used in LIC, the lower is the correlation between adjacent intensity values along a stream line.
>>False, higher the correlation (ShengHsuan), I would think in the following way. While the kernel has a larger extent, the values between adjacent intensity values will change more smoothly. In other words the value is closer to each other, hence more correlated.
LIC images show high correlation between the intensity values at adjacent streamlines. false, low correlation among neighbours
LIC is restricted to 2D vector fields. false, it can be used for 3d as well
The convolution kernel used in LIC has to be symmetric. false, it can be asymmetric and then it gives Oriented LIC

Formula need to know:

Linear Interpolation

2d points embedded as 3d plane : f(x,y) = a + bx + cy
3d points embedded as 4d plane : f(x,y,z) = a + bx +cy +dz
This is equivalent to Barycentric interpolation.

Barycentric interpolation:

the coefficient \alpha_i is proportional to the areas

$$X = \sum_i \alpha_i x_i, \quad where \sum_i \alpha_i = 1, \quad \text{then } f(X) = \sum_i \alpha_i f_i$$

Bilinear Interpolation

$$f(\alpha,\beta) = (1-\alpha)(1-\beta)f_{i,j} + \alpha(1-\beta)f_{i+1,j} + (1-\alpha)\beta f_{i,\,j+1} + \alpha\beta f_{i+1,\,j+1}$$

where

$$\alpha = \frac{x - x_i}{x_{i+1} - x_i}, \qquad \beta = \frac{y - y_i}{y_{i+1} - y_i}$$

The asymptotes

$$f(\alpha,\beta) = \gamma(\alpha - \alpha_0)(\beta - \beta_0) + \delta$$

These are valid for alpha and beta as proportions in the square. To get the real coordinates (in the cartesian plane), make the transformations:

>> alpha = (x-x0)/deltaX

>> beta = (y-y0)/deltaY

where deltaX is length of square in x axis and deltaY in the y axis, and x0 and y0 are the smaller x and y coordinates of the square (Gracias hermano)

Phong's illumination model:

Ambient (Background) Light: $C = k_\alpha C_\alpha O_d$

Diffuse reflection (rough surfaces,): $C = k_d C_p O_d \times (\vec{n} \cdot \vec{l})$

Scatters light equally in all directions

Specular reflection (mirror, view dependent): $C = k_s C_p O_d \times (\vec{r} \cdot \vec{v})^n$

n	normal vector
l	light vector
r	reflect vector
v	view vector

Ray casting:

Compositing of semi-transparent voxels

$c^{out} = c^{in} + (1 - \alpha^{in})\alpha C \quad \alpha^{out} = \alpha^{in} + (1 - \alpha^{in})\alpha$

RK2

RK4 formula