Scientific Visualization (INMSV-08) Examination

The theoretical part of this course is evaluated by means of a multiple-choice exam. The 60 questions below cover the material mentioned during the course as being mandatory for the exam. The study material is given by the slides and the course textbook.

Each question has only one correct answer (study the formulation of the question carefully). Below are given several such questions, with a short explanation of the reasoning behind the (correct) answer. The questions are grouped with respect to the theoretical visualization aspects they address.

During the exam, students are allowed to browse the course textbook "Data Visualization – Principles and Practice", but not any other written or electronic material (e.g. paper notes).

For each question, mark the right answer, by filling in the rectangle next to that answer.

A. Aims and scope of visualization

1. Data-related questions can be answered using several complementary methods, such as data queries (DQ) or data visualization (DV) . Which is the key difference between DQ and DV?
   a. ▯ DQ can answer only quantitative questions, and DV can answer only qualitative questions.
   b. ▯ Both DQ and DV are fully interchangeable for all question types (qualitative and quantitative)
   c. ▯ DQ typically targets quantitative questions which have a simple answer (e.g. a single value) while DV best targets questions which have a complex answer (e.g. a distribution).

2. Which of the following is the best example of a *qualitative* question that visualization can answer:
   a. ▯ Given a scalar dataset, find and show the several local maxima of the scalar values.
   b. ▯ Given a vector dataset, find and show the low vorticity regions.
   c. ▯ Given a signal y = f(x), where x and y are real values, find and show the distribution of y values over the entire x range.
   d. ▯ Given a CT (computer tomography) volumetric dataset, find and show tumor regions.

3. Interaction is a fundamental ingredient of visualization applications. Interaction is needed in visualization applications because... (*select the right answer below*):
   a. ▯ We have time-dependent data which we cannot visualize otherwise.
   b. ▯ We have too much data, varying questions, and varying ways to map data to images which we want to try out.
   c. ▯ We need to modify (preprocess) the data prior to visualization.

4. One of the key use-cases for visualization is to gain "insight". Which of the following is the best description of the term "insight" as used in the above context: :
   a. ▯ Insight refers to learning techniques to process the data to generate the final desired visualizations.

b. ☐ Insight refers to understanding the underlying phenomena that have generated the visualized data, and also formulating new questions on that data.

c. ☐ Insight refers to a better understanding of the visual mapping process that transforms data to images.

B. Graphics and visualization

1. Computer graphics is different from data visualization because:
   a. ☐ It involves interactive techniques such as selection, zooming, and changing rendering parameters.
   b. ☐ It only processes two-dimensional datasets (images), while visualization processes n-dimensional datasets.
   c. ☐ It is the only part of the visualization pipeline which can be applied on the graphics card or graphics-processing unit (GPU).
   d. ☐ It is the last step of the visualization pipeline, where the earlier steps are specific to visualization only.

2. Gouraud shading is best described as:
   a. ☐ Bilinear color interpolation applied to colors computed using the Phong lighting model at the vertices of a polygon.
   b. ☐ The computation of colors at the vertices of a polygon given the polygon normal, view position, and light position.
   c. ☐ The computation of vertex normals from polygon, or face, normals.
   d. ☐ Any type of linear interpolation performed on quantities defined over a polygon.

3. Given a curved, orientable, and non-self-intersecting surface embedded in three dimensions (3D), which of the following statements is true in the continuous case:
   a. ☐ Such a surface can be always described as the graph of a function z = f(x,y)
   b. ☐ Such a surface can be always be described as the contour of a function f(x,y,z) = 0
   c. ☐ Such a surface cannot be described by the models listed above under (a) and (b)
   d. ☐ Such a surface can be described by both models listed above under (a) and (b)

4. Consider the surface described by the graph of the function z = -abs(x,y), where abs() denotes the absolute value, and x,y are real-valued numbers. When using the gradient of the function z(x,y) to compute the normal to this surface, which of the following is true:
   a. ☐ We can compute the normal at any desired point on the surface.
   b. ☐ We can compute the normal at all points on the surface where z(x,y) is differentiable.
   c. ☐ We can compute the normal at any desired point on the surface, but only with a certain approximation, given by the discretization (meshing) of the surface into a grid.
   d. ☐ The orientation of the normal computed with the gradient can be inconsistent (e.g., neighbor points have normals whose orientation is flipped by 180 degrees)

C. Data representation

1. In data visualization, we typically use discrete datasets represented as a finite collection of sample points, sample values, and cells. Which of the following describes the reason why we do not use continuous datasets for data representation:
   a. ▯ Continuous differentiation, such as computing gradients or principal components, is always more computationally expensive than discrete differentiation.
   b. ▯ Continuous representations do not allow mixing datasets of different dimensionalities (e.g. 2D and 3D) in the same dataset.
   c. ▯ Discrete representations take significantly less memory for storage, and thus are more efficient from an implementation perspective.
   d. ▯ We do not always have the data to visualize in a continuous form.

2. Sampling and reconstruction are operations which connect the continuous and discrete representations of a visualization dataset. Which of the following statements is true:
   a. ▯ The same basis, or interpolation, functions must be used when sampling the data as well as when reconstructing the data.
   b. ▯ The order of continuity of a reconstructed dataset is always lower than the order of continuity of the original data that we sampled from.
   c. ▯ The order of continuity of a reconstructed dataset is determined solely by the interpolation functions used during the reconstruction.
   d. ▯ The order of continuity of a reconstructed dataset depends on the interpolation functions but also dimensionality of the dataset (e.g. 1D, 2D, or 3D)

3. Data interpolation in visualization is typically done using a sum of interpolation functions weighted, at each sample point, by the sampled data values. For this method, which of the following statements is true:
   a. ▯ All used interpolation functions must have the same analytic expression for the reconstruction to work.
   b. ▯ All used interpolation functions do typically have the same analytic expression for simplicity and implementation efficiency.
   c. ▯ All interpolation functions must evaluate to 1 at all sample points.
   d. ▯ All interpolation functions must be polynomials.

4. During data reconstruction, basis functions are typically defined in a so-called *reference* coordinate system (thus, the name reference basis functions), after which they are transformed into the local coordinate systems of each dataset cell. Which is the main reason for using these reference basis functions?
   a. ▯ We can use the same (simple) analytic definition for all basis functions in the (single) reference coordinate system.
   b. ▯ Basis functions can only be defined in an axis-aligned coordinate system.
   c. ▯ We can use hardware acceleration to speed up the computation of the reference-to-local transformations, thus gain performance.
   d. ▯ Derivatives (e.g. gradients) can only be computed in a reference coordinate system.

5. Grid *cells* are, along with sample points, sample values, and interpolation functions, a fundamental ingredient of a discrete dataset representation. What is the fundamental reason why we use cells in this context?
   a. ▯ Without cells, we have no shapes which we can render to visualize our dataset.
   b. ▯ Cells map efficiently to graphics primitives (e.g. rectangles, quads, lines) and hence we gain computational efficiency.
   c. ▯ Cells partition the dataset's spatial domain into distinct regions of space over which we can conveniently evaluate our interpolation functions.
   d. ▯ Cells allow ordering the sample points in a unique way for consistent data storage and retrieval.

6. In data representation, we use cells of several dimensionalities, such as 1D (lines), 2D (quads), or 3D (tetrahedra). Which is the reason why we need cells of several dimensionalities?
   a. ▯ Datasets can have 1D, 2D, or 3D spatial domains, so to cover these, we need cells of the same dimensionality.
   b. ▯ Data attributes (sample values) can be 1D, 2D, or 3D, so to represent these, we need cells of the same dimensionality.
   c. ▯ We can develop more efficient algorithms if we split cells into several dimensionality grups.
   d. ▯ The cell dimensionalities are determined by the capabilities of (modern) graphics cards.

7. Interpolation and cells share related aspects. Which of the following statements is true:
   a. ▯ The dimensionality of a cell (e.g., 1D, 2D, or 3D) determines the order of continuity of the basis functions that can be used on that cell, and thus the continuity of the reconstruction.
   b. ▯ When we perform data interpolation within a cell, we need to have also the information (sample points and sample values) of the neighboring cells.
   c. ▯ We always have to use the same interpolation expressions (functions) over all cells in a dataset.
   d. ▯ A cell gives only the spatial extent, and sample point values, with which interpolation has to work.

8. For data representation purposes, cells are assembled into grids. Which of the following statements is true:
   a. ▯ In a grid, we can only have cells of the same topology and dimensionality.
   b. ▯ The different grid types are cell-dimension-specific (e.g., we can only have unstructured grids with 2D cells, and uniform grids with 3D cells)
   c. ▯ Certain dataset domain shapes can only be covered by certain grid types.
   d. ▯ Grids describe only compact, connected, shapes.

9. Imagine a 2D square domain which has been sampled using a uniform grid of quad cells. Now, imagine that every grid point is slightly randomly jittered to a 2D position (in the same plane) close to its original position. The newly obtained grid can be

a. ▯ Still represented as a uniform grid, since the cells have not changed.
b. ▯ Only be represented by an unstructured grid, since each cell is different.
c. ▯ Be represented by a rectinilear grid, since the positions are confined to a 2D plane.
d. ▯ Be represented as a structured grid, since the cell descriptions remain the same.

10. Data attributes, in visualization, describe the sampled values stored, for instance, at cell vertices. Different types of attributes exist, e.g. scalar, vector, normal, and tensor. Usually, attributes are defined at *all* cell vertices within a dataset – there are no vertices without an assigned attribute value. The fundamental reason for this is that:

a. ▯ This considerably simplifies the implementation of the dataset.
b. ▯ This allows for more efficient computations, e.g. interpolation, to take place.
c. ▯ This reflects our intention to reconstruct the sampled quantity over the entire domain covered by the dataset.
d. ▯ We cannot render cells for which we have no defined attributes.

11. Both data attributes and vertex coordinates have a dimensionality, e.g., they can be 1D, 2D, or 3D quantities. Which is the relationship between these dimensionalities:

a. ▯ Data attributes and vertex coordinates must have the same dimensionality.
b. ▯ Data attributes can have a lower, or at most equal, dimensionality with respect to the vertex coordinates' dimensionality.
c. ▯ There is no relation between the two dimensionalities (one can be smaller, equal, or larger than the other)
d. ▯ Vertex coordinates can have a lower, or at most equal, dimensionality with respect to the data attributes' dimensionality.

12. Normal, color, and vector attributes are similar in the sense that they are triplets of scalar values. Which of the following statement is true:

a. ▯ Color attributes can be stored using less memory than normals and vectors.
b. ▯ Vector attributes are more general than normals and colors, so they take more storage space in general.
c. ▯ If we use the same precision, scalars, normals, and colors basically require the same storage space.
d. ▯ Normals are stored differently than vectors, since they always have unit length.

13. Tensor attributes are used in various data visualization applications, such as medical imaging, or 3D shape analysis. Which of the statements below is the correct and complete definition of a tensor:

a. ▯ A tensor is a set of three 3D vectors
b. ▯ A tensor is a set of three 3D vectors and three scalar values
c. ▯ A tensor gives the magnitude of a scalar quantity at a certain point in space and in a certain direction.
d. ▯ A tensor describes the minimal and maximal values of a scalar field.

14. Besides scalars, vectors, normals, colors, and tensors, one can define other dataset attributes. For example, consider a dataset where, at each sample point (cell vertex), a text value is stored. Can we construct a visualization of such a dataset? Which of the following is true?

    a. ☐ No, since there is no interpolation function that can handle text values.
    b. ☐ No, since text attributes are not numeric.
    c. ☐ Yes, but interpolation between cell vertices may prove very challenging.
    d. ☐ Yes, but only if we can first map the text values to numerical (scalar) values.

15. Data resampling is the process where we convert between two discrete datasets having different sample points. Which of the following is true:

    a. ☐ Data resampling can be only performed if we have vertex-based samples
    b. ☐ Data resampling can be only performed if we have cell-based samples
    c. ☐ Data resampling can be performed for both vertex-based and cell-based samples, but can only produce data of the same type (cell-based to cell-based and vertex-based to vertex-based)
    d. ☐ Data resampling can be performed for both vertex-based and cell-based samples, and we can create cell-based data from vertex-based data and conversely.

16. Consider the case where we have a 3D polygon mesh which we want to render using smooth shading and the Phong lighting model. Which case of resampling do we encounter here?

    a. ☐ We need to resample normals from cell-based to vertex-based to apply the Phong lighting at vertices, and next apply Gouraud shading to interpolate colors over the polygons.
    b. ☐ We first apply the Phong lighting model at the cell centers, then resample the color values at the vertices, then apply Gouraud shading to interpolate colors over the polygons.
    c. ☐ We first apply resampling to compute normals at the cell centers, then apply the Phong lighting model at the cell centers, then apply Gouraud shading colors over the polygons.
    d. ☐ We first apply the Phong lighting model at the cell vertices, then use resampling to compute the colors at the cell centers, then render the cells. No Gouraud shading or interpolation is needed.

17. Consider the case of a discrete dataset which we subsample by reducing the number of cell vertices (or sample points) to half. Which of the following statements is true?

    a. ☐ Subsampling will always decrease the accuracy by which the resulting dataset can approximate the original sampled signal.
    b. ☐ Subsampling will always keep the accuracy of the above-mentioned approximation constant, as this is described by the basis functions, not the sample points.
    c. ☐ Subsampling may keep the same accuracy or decrease it. We cannot make any further statement, since this depends on the combination of the original signal, position of sample points, and basis functions used.
    d. ☐ Subsampling will decrease the above-mentioned accuracy only if we convert data from vertex-based to cell-based data.

18. In data visualization, the RGB and HSV color systems are the most frequently used. Which of the following statement is true:

- **a.** ▯ **The RGB system is computationally more efficient than the HSV system.**
- **b.** ▯ **The HSV system can represent visible colors more accurately than the RGB system.**
- **c.** ▯ **The HSV system is more convenient for users than the RGB system.**
- **d.** ▯ **The RGB system can represent some colors that the HSV system cannot.**

D. The visualization pipeline

1. The visualization pipeline consists of several steps during which data is transformed to generate the final images. During these steps, the amount of data present in the processed dataset at a certain step in the pipeline:
   - a. ▯ always increases as we approach the end of the pipeline
   - b. ▯ always decreases as we approach the end of the pipeline
   - c. ▯ stays constant throughout the entire pipeline
   - d. ▯ can increase, stay constant, or decrease, depending on what the pipeline does

2. The purpose of splitting the visualization pipeline into a number of separate steps, or stages, is to
   - a. ▯ separate the logical operations for a better design, implementation, and modularity
   - b. ▯ increase the computational efficiency of the entire pipeline
   - c. ▯ allow for interactive data manipulation to take place
   - d. ▯ allow for the so-called 'inverse mapping' to take place

3. The last two steps of the visualization pipeline are the data mapping, and data rendering steps. Which is the key difference between these steps?
   - a. ▯ Data rendering is the step where user interaction takes place
   - b. ▯ Data mapping converts datasets to spatial shapes (e.g. polygons) prior to rendering
   - c. ▯ Data mapping resamples the data for the most efficient rendering to take place
   - d. ▯ There is no fundamental difference – once we have a dataset, we can render it right away

4. Key to the effectiveness of a visualization pipeline is the possibility to 'invert' the mapping that the pipeline performs – that is, go from the final rendered image to dataset-related features. Which of the following statements is true concerning this inverse mapping?
   - a. ▯ The inverse mapping can always be automated, just as the direct mapping
   - b. ▯ The inverse mapping is performed by the user mentally, not the visualization tool
   - c. ▯ The inverse mapping can be only performed when the input dataset contains sufficient information
   - d. ▯ The inverse mapping means that the final image stores as much information as the input dataset

E. Scalar visualization

1. Color mapping is one of the widest used, and simplest, scalar visualization techniques. Which of the following statements is true:
   a. ▯ Color mapping first applies the Phong lighting model, then maps the resulting color through a color map to obtain the final color
   b. ▯ Color mapping can be only applied if we have an invertible color map
   c. ▯ Color mapping can be only applied if we have two-dimensional datasets
   d. ▯ Color mapping can use color maps defined both in the RGB and HSV spaces

2. What is the difference between a color map and a color legend?
   a. ▯ A color map is a function that translates from scalars to colors, while a color legend is a graphical depiction of this function.
   b. ▯ A color map is always continuous, while a color legend is a discretized version of a color map
   c. ▯ A color legend is always continuous, while a color map is a discretized version of a color legend
   d. ▯ There is no difference – these are just two terms for the same concept

3. Different color maps are used for different application. Consider for instance the grayscale and rainbow color maps. Which of the following is true?
   a. ▯ The rainbow color map can be applied on any scalar range, while for the grayscale (black-to-white) color map we first need to normalize the scalars between 0 and 1
   b. ▯ The rainbow color map requires color attributes to be present in the dataset, while such attributes are not required by the grayscale color map
   c. ▯ The rainbow and grayscale color maps are, technically, freely interchangeable. The choice is determined by the actual application and use-case.
   d. ▯ The rainbow colormap is more suitable for highlighting data maxima than the grayscale colormap

4. Consider an application where we are interested to emphasize the variation of the data (first derivative) rather than its absolute value. Which colormap is best for this?
   a. ▯ A rainbow colormap
   b. ▯ A grayscale colormap
   c. ▯ A colormap containing sharp color transitions, such as a zebra colormap
   d. ▯ All colormaps are equally suited for this task

5. Consider a 2D scalar signal with minimum value m and maximum value M. Assume we visualize this signal using color mapping. However, the 'interesting' variations of the signal are confined in a small range of the interval $[m, M]$. What can we best do to make these variations more visible for the end user in the final visualization?
   a. ▯ Supersample the dataset which encodes the signal to create more grid points
   b. ▯ Increase the number of colors in the color map
   c. ▯ Apply a (possibly nonlinear) transformation to the scalar values
   d. ▯ Decrease the number of colors in the color map

6. What is the difference between vertex-based color mapping (VB) and texture-based color mapping (TB)?
   a. ▯ VB can only be done if we have vertex-based data attributes, while TB can handle both vertex-based and cell-based data attributes
   b. ▯ VB can generate 'false colors' (which do not even exist in the color map), while TB never has this issue
   c. ▯ Both VB and TB can generate 'false colors' as mentioned above, but TB does this less often
   d. ▯ VB requires vertex normals to be present, while TB does not
7. A simple, though not perfect, way to create contours is to use a so-called 'delta' colormap. Given a scalar contour value, or isovalue *a*, and a dataset with the scalar range [*m*, *M*], such a colormap maps all scalar values in the ranges [*m*, *a-d*] and [*a+d*, *M*] to one color, and the values in the range [*a-d*, *a+d*] to another color. However, this technique has some drawbacks as compared to the standard contouring technique (as implemented, for example, by marching squares). Which if the following statements is true:
   a. ▯ Delta colormapping cannot generate as many contours as marching squares
   b. ▯ Delta colormapping is more computationally intensive than marching squares
   c. ▯ Delta colormapping may generate disconnected contour fragments, while marching squares always generates connected contour fragments
   d. ▯ Delta colormapping generates piecewise-constant contour approximations, while marching squares generates piecewise-linear contour fragments

8. Consider the comparison between delta color mapping and marching squares described above. If we want to increase the quality of the delta color mapping results, so they approach the results generated by marching squares, the best solution is to:
   a. ▯ Add more colors to the colormap
   b. ▯ Supersample the grid used to represent the dataset
   c. ▯ Make the width *a* of the color pulse narrower
   d. ▯ Do both (b) and (c)

9. Technically speaking, we can apply color mapping by (a) applying a scalar-to-color analytic function to every scalar value in our dataset; or (b) pre-sample this function in a so-called color table with N entries, and next index the table with the scalar values normalized in the range [1,N]. Which are the advantages of using a color table?

   a. ▯ We can in this way generate more visible colors in the final visualization
   b. ▯ We can limit the drawbacks described earlier at question 7.
   c. ▯ We can more easily design and interchange color maps
   d. ▯ We gain accuracy in the scalar-to-color mapping computations

10. Contouring, such as implemented by marching squares or marching cubes, generates approximations to 2D isolines and 3D isosurfaces respectively. What can be said about the accuracy of the resulting isolines and isosurfaces?

a. ▯ The accuracy depends on the number of contour values (isovalues) used: less values implies more accurate results
b. ▯ The accuracy depends on the actual isovalue(s) used: for certain isovalue(s), the results will be numerically more accurate than for others
c. ▯ The accuracy depends only on the sampling resolution of the input dataset
d. ▯ The accuracy depends on the cell types used

11. Consider a 2D dataset with vertex-based scalars where, for a range of neighboring cells, the data values are constant and equal to *v*. Consider now that we apply the marching squares algorithm. What will this algorithm produce for these cells?
    a. ▯ Nothing, since the algorithm produces line segments only for cells which have at least a vertex value below *v* and a vertex value larger than *v*.
    b. ▯ The full cells will be colored, since all their vertex values are equal to *v*.
    c. ▯ The edges of these cells will be all included into the produced isolines
    d. ▯ The lines connecting the centers of these cells will be all included in the produced isolines

12. Consider the rendering of a 3D isosurface produced with marching cubes from some 3D dataset. For optimal viewing results, we would like to smoothly shade such a surface. For this, in turn, we need to have vertex normals at all vertices of the polygonal isosurface. How can we compute such vertex normals?
    a. ▯ We cannot solve the problem in the general case, since the isosurface may have self-intersections, and these are singularities where the normal is not well-defined
    b. ▯ We can only compute the vertex normals by averaging the normals of the isosurface polygons that share a vertex
    c. ▯ We can only compute the vertex normals from the gradient of the 3D scalar data
    d. ▯ Both options (b) and (c) are possible, but (c) is more efficient than (b)

13. Consider a 2D function with non-constant first derivatives (such as, for example, a sine or exponential function). Consider now that we draw N isolines of this function, equally spaced in the function range (i.e., for equally spaced isovalues). What can we say about the spatial density of the resulting isolines?
    a. ▯ We have more isolines where the function varies quicker
    b. ▯ The spatial density of isolines is constant
    c. ▯ We have less isolines where the function varies quicker
    d. ▯ The spatial density of isolines depends on the grid sampling of the dataset

F. Vector visualization

1. Vector visualization is considered a more challenging problem than scalar visualization, because
    a. ▯ A vector field encodes more variation than a scalar field in general
    b. ▯ The dimensionality of the domains for vector fields is higher than for scalar fields
    c. ▯ The dimensionality of vector attributes is higher than that of scalar attributes

d. ▯ Vector visualization algorithms involve as a rule more numerically sensitive computations than scalar visualization algorithms

2. Divergence is used to reduce a vector field to a scalar field, for visualization purposes. Consider now the gradient **g** of some two-dimensional function z = f(x,y). Since **g** is a vector field, we can compute its divergence *d*. What is the relation between the extrema (minima, maxima) of f and those of *d*?
   a. ▯ The minima of *d* are the maxima of f
   b. ▯ The maxima of *d* are the minima of f
   c. ▯ Both (a) and (b) are true
   d. ▯ None of the above are true

3. Consider a two-dimensional function z=f(x,y) and its gradient field **g**. Which of the following is true?
   a. ▯ The curl of **g** is overall zero
   b. ▯ The streamlines of **g** meet only and precisely at the minima and maxima of f
   c. ▯ Both (a) and (b)
   d. ▯ None of the above

4. Vector glyphs are one of the simplest techniques to visualize the direction, magnitude, and orientation of vector fields. However, careless use thereof can lead to clutter. Which of the following is in general the best way to avoid such clutter, if we have a very large dataset?
   a. ▯ Subsample the grid on which the vector field is defined, but draw one glyph per dataset point
   b. ▯ Use a grayvalue color map for the vector glyphs
   c. ▯ Subsample the 'probe set' where vector glyphs are drawn (draw less glyphs)
   d. ▯ Reduce the scale factor used to scale the glyphs with the vector field magnitude, but draw one glyph per dataset point

5. Given no prior information about the variation encoded in a vector field, random positioning of the vector glyphs is often used to
   a. ▯ Reduce aliasing artifacts which can cause misleading visual patterns
   b. ▯ Enhance the robustness of the glyph computation
   c. ▯ Reduce the errors in the orientation of the glyphs
   d. ▯ Reduce the number of glyphs used to visualize the vector field

6. Transparency and color coding are complementary techniques used for glyph visualizations: Transparency reduces occlusion problem, while color coding shows the vector field magnitude or an additional scalar attribute. However, this combination can generate one of the following problems:
   a. ▯ Can create false colors not present in the color map used
   b. ▯ Can distort the directional information present in the glyphs
   c. ▯ Can reduce the numerical accuracy used in the glyph positioning algorithm

d. ▯ Requires more user interaction for glyph probe positioning

7. Consider a 3D vector field for which we know that it always has unit magnitude. Now, consider two points a and b in the domain of the field, and the corresponding vector values **v**(a) and **v**(b). We now want to interpolate **v** at the average location c=(a+b)/2, i.e., estimate **v**(c). Which is the best interpolation strategy we can use?
    a. ▯ As always, use linear interpolation of the components v_x, v_y, v_z of **v**(a) and **v**(b)
    b. ▯ As above, but normalize the average v(c) = (v(a)+v(b))/2 so it has length 1
    c. ▯ Compute the average direction between v(a) and **v**(b), i.e., the bisector line, and construct v(c) as a unit-length vector along this line.
    d. ▯ Options (b) and (c) are identical in terms of interpolation quality

8. Vector color coding is used as an alternative technique to vector glyphs for visualizing vector fields. Which is the main advantage of vector color coding as opposed to glyphs?
    a. ▯ Color coding produces a dense visualization and no clutter or occlusion
    b. ▯ Color coding is computationally cheaper
    c. ▯ Color coding can use color mapping to show additional data, whereas glyphs cannot
    d. ▯ Color coding can accommodate a higher attribute range than glyphs can

9. Displacement plots are an alternative for glyphs and color coding for vector field visualization. What is the main drawback of displacement plots?
    a. ▯ They cannot handle 3D datasets
    b. ▯ They cannot handle time-dependent datasets
    c. ▯ They can only work for uniform grids with cubic cells
    d. ▯ They require user interaction for probe placement

10. Displacement plots can create confusing self-intersections of the probe shape which is warped (deformed) by the vector field to visualize. Which of the following is best describing the strategy to reduce such self-intersections?
    a. ▯ Reduce the warping factor (distance along which the probe points are warped)
    b. ▯ Use a probe that has less sample points
    c. ▯ Reverse the warping direction
    d. ▯ Use an unstructured grid for the warping probe

11. Streamlines are one of the most intuitive visualization techniques for vector fields. However, they are sensitive to various integration errors. To reduce such errors, the best strategy is to:
    a. ▯ Normalize the vector field and use a small integration time-step
    b. ▯ Use a small integration time-step but not normalize the vector field
    c. ▯ Normalize the vector field but use a large integration time-step
    d. ▯ Use an unstructured grid instead of a regular, uniform, or structured grid

12. Streamlines are tangent to the visualized vector field, by construction. Their construction implies the discretization of both space (field interpolation across cells) and time (integration). This may, or may not, lead to visualizations where streamlines intersect. Which of the following is true?

a. ▯ Streamlines cannot intersect in the continuous case, and the discretization issues mentioned above keep this non-intersection property in the discrete case too

b. ▯ Streamlines intersect in the discrete case only in locations where the curl of the vector field is identically zero

c. ▯ Streamlines intersect in the discrete case only in cells where the divergence of the vector field is non-zero

d. ▯ Streamlines can intersect in the continuous case too, so discretization is not an issue

13. Texture-based, or image-based, vector field visualization (IBFV) is an alternative to geometric methods such as streamlines, stream tubes, or vector glyphs. Which is the main advantage of IBFV with respect of geometric methods?

a. IBFV is faster to compute than geometric methods

b. IBFV has less numerical errors

c. IBFV produces dense visualizations where each pixel shows some information

d. ▯ IBFV can handle time-dependent vector fields

14. Besides the advantages of IBFV with respect to geometric methods mentioned above, IBFV has also some disadvantages. Which is one of these?

a. ▯ IBFV can only work in 2D, and thus cannot handle 3D vector fields

b. ▯ IBFV cannot use color-coding to show the vector field magnitude

c. ▯ IBFV shows only the direction (tangent) of the vector field, but not its orientation (e.g. left to right *vs* right to left)

d. ▯ IBFV cannot show the trajectory of a particle starting at a given point with the same precision as e.g. streamlines

15. IBFV uses, in its implementation, a random noise texture pattern which gets advected (transported) by the vector field. Imagine that the resolution of this pattern (number of pixels along x and/or y) is higher than the screen resolution for the final visualization. What do we obtain, as compared to a noise pattern of resolution equal to the screen resolution?

a. ▯ Nothing, we cannot display a texture with more detail than the number of screen pixels

b. ▯ We increase the internal accuracy of the advection step of the method

c. ▯ We decrease the internal accuracy of the advection step of the method

d. ▯ We can better handle time-dependent vector fields in this way

16. Consider the standard implementation of IBFV. Imagine, now, that we zoom in a certain portion of the visualization, by increasing the screen size of the dataset *cells* being displayed. What do we observe?

a. ▯ We obtain effectively a zoom-in in a portion of the dataset, and the size (granularity) of the animated patterns shown on the screen stays the same

b. ▯ The animated patterns shown on the screen become coarser, just as we obtain when magnifying a digital image

c. ▯ We cannot do this, for IBFV to work the dataset must be drawn at precisely the same resolution as the screen space

d. ▯ We notice a speed-up of the flow displayed on the screen

G. Tensor visualization

1. Principal component analysis (PCA) is used as a fundamental tool in various tensor visualization algorithms, such as oriented glyphs, hyperstreamlines, or anisotropy plots. What is the main purpose of this technique in the visualization context?
   a. ▯ Reduce the dimensionality of the data so that we can use existing scalar or vector algorithms to visualize it
   b. ▯ Make the tensor data independent on the coordinate system used
   c. ▯ Avoid the expensive computation of partial derivatives
   d. ▯ Reconstruct a continuous dataset from a discrete (sampled) one for visualization purposes