<u>Scientific Visualization: Homework: - 3</u>

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1) **Why is the Fourier transform used to analyze data sampling and reconstruction process? What is Nyquist Theorem?**
Ans: - The Fourier transform is a very powerful mathematical tool that is commonly in use in data sampling and in data reconstruction. The Fourier transform enables us to decompose a signal into its fundamental and individual spectral signals, to provide valuable insights into the information associated with the frequency. This helps in data sampling and evaluation since the spectral components will now be linked to the data.
Nyquist's theorem is a fundamental theorem in signal processing that states that the sampling rate of a periodic signal must be greater than twice that of the signal component with the highest frequency.

2) **When we use *multiplication* in Fourier domain, what is the corresponding operation in spatial domain?**
Ans: It basically states that the convolution of the two Fourier Transforms is the Fourier Transform of the product of two signals in time.

The Fourier Transform, as we all know, is an important image processing tool that is used to decompose an image into its sine and cosine components. The Fourier or frequency domain equivalent of the image is represented by the transformation's output, while the spatial domain equivalent is represented by the input image.

In addition, convolution in the time domain corresponds to ordinary multiplication in the frequency domain. For finite size arrays, multiplication in the frequency domain is equivalent to circular convolution in the time domain, not linear convolution.

3) **There are four filters which can be used in data sampling:**
linear, gaussian, cubic, box,
Please order them based on sampling accuracy starting from the lowest to the highest.

Ans: Box, linear, cubic, Gaussian

4) **What is the difference of volumetric data compared to surface data? What are the pros and cons of using volume and surface models in graphics?**

Ans: Surface data representations are adequate for objects with similar or homogeneous material distributions that are not transparent. Only when object boundaries are important are these representations useful. It would contain geometry, viewpoint, texture information, and so on, allowing you to create a visual representation of an object's exterior and contours, i.e., surface. It is more concerned with the outside of an object. Furniture, mechanical objects, and so on are examples. Examples of applications include video games, virtual reality, and computer-aided design.

However, surface graphics do not work well for clouds, fog, gas, water, smoke, and other amorphous phenomena. It also won't help users who want to investigate objects with extremely complex internal structures. So, for this volume graphics, a good technical solution to the shortcomings of surface graphics is provided. It provides a better understanding of different features within volume data by classifying the spatial information of volume data and projecting it onto the screen. Volume data thus includes volume modeling (representations) as well as volume rendering algorithms for displaying such representations. MRI and CT are two examples.

MODEL OF THE SURFACE:

PRONS: There is an explicit distinction between inside and outside surfaces, which makes rendering calculations simple and efficient; hardware implementations are inexpensive; and it can use realism-enhancing techniques such as texture mapping.

CONS: It only approximates reality and does not allow users to peer into or through objects.

MODEL OF VOLUME:

PROS: It maintains a representation that is close to the underlying fully-3D object (but discrete), it can achieve a level of realism that surface graphics cannot match, and it enables easy and natural exploration of volumetric datasets.

CONS: It is computationally expensive, hardware acceleration is very costly.

5) **What What are the iso-surfaces in volume rendering?**

Ans: - Iso surface volume rendering is a visualization technique that makes it possible to see surfaces in several dimensions at extremely fast frame rates—up to five images per second. As a result, the surface is known as iso surface and the speed at which the picture moves across the viewing frame is known as iso value.

6) **What is the Marching Cubes method? Explain the method's basic strategy**
Ans: ***<u>Marching Cubes method</u>***
In computer graphics <u>Marching Cubes method</u> is a graphics algorithm.
<u>History:</u> published in the 1987 SIGGRAPH proceedings by Lorenzen and Cline, for extracting a polygonal mesh of an isosurface from a three-dimensional discrete scalar field (the elements of which are sometimes called voxels). The applications of this algorithm are mainly concerned with medical visualizations such as CT and MRI scan data images, and special effects or 3-D modelling with what is usually called meatballs or other metal surfaces. The marching cubes algorithm is meant to be used for 3-D; the 2-D version of this algorithm is called the marching squares algorithm. The algorithm was developed by William E. Lorensen (1946-2019) and Harvey E. Cline because of their research for General Electric. At General Electric they worked on a way to efficiently visualize data from CT and MRI devices.

<u>The method's basic strategy</u>

The Marching Cubes algorithm solves five tasks to extract a surface from volume data:
1. Determination of the case index of each cell.
2. Determination of the intersected edges.
3. Computation of intersections by means of linear interpolation.
4. Triangulation of the intersections.
and the last one is
5. Computation of outward-pointing surface normal for illumination.

7) **What is its computational complexity of Marching Cubes considering the number of cells (N) in volume datasets? How can we increase the computational performance?**
Ans: While n is the total number of cells in the volume data, the construction requires O(nlogn) time and O(n) storage space.

When searching in the tree with an isovalue of "q," it will only move through the nodes that correspond to the volume data's active cells. Since there are p active cells, the query takes on + p) time.

By systematically triangulating the polygon in the cell interior, redefining the configurations, and using Edge transformations that will improve mesh quality, we may increase the computation performance of marching cubes.

8**) In raycasting method, how a ray is determined for perspective projection?**
Ans: To project particular rays into three dimensions, a specific set of rays must be chosen. And then there is a technique used to filter out rays that meet a criterion; these rays are grouped together based on specific geometric restrictions. After getting a ray from the camera's lens, it is computed based on the object.

The base for the projection is then created by filtering the nearest to the best projection ray. Therefore, the ray used for the perspective projection is determined via ray casting and ray tracing x.

9) **What are the differences of MIP and X-Ray ray casting?**
Ans: he MIP (Maximum intensity projection) can produce 3D to 2D projection from any mentioned viewpoint. It provides the special techniques of ray tracing which gives highest result as possible. It can be used to display the computer tomographic angiography data sets.

To calculate the maximum intensity projection, we can use the formula,

MIP = maximum (image, [], dimension)

And,

X-ray ray casting is a rendered technique which normally used in computer graphics and computational geometry. Generally, x-ray is the best method of detecting internal defects. so, in addition to this ray casting in X-ray can create a three-dimensional perspective in a 2D map.

So, in short this is the difference between MIP and X-ray ray casting.

10) **Ray casting can be time consuming? Explain the major reasons.**
Ans: As in ray casting computes the depth at each pixel it can take a lot of time analyze. Analytics solutions to different primitives can be difficult. For example, a sphere is easier to handle as it can analyze the upper and lower limit based on the distance from the center of the sphere. But for example, a cylinder whose axis are skewed it would take a lot of time to analyze and it would prove out to be time consuming.