

1.	<p>Augmented Reality</p> <p>(a) What's Augmented Reality (AR) and Mixed Reality (MR)?</p> <p>(b) Design an AR application. Please describe in detail about the motivation, hardware/software system, and operating scenario of your design.</p>
	<p>(a) Augmented reality (AR) is a direct or indirect live view of a physical, real-world environment whose elements are "augmented" by computer-generated perceptual information, ideally across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Mixed reality (MR), sometimes referred to as hybrid reality, is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Mixed reality takes place not only in the physical world or the virtual world, but is a mix of reality and virtual reality, encompassing both augmented reality and augmented virtuality via immersive technology.</p> <p>(b) The AR application I designed is an AR glasses. When the user wears the device, it will display the estimated value of the items he sees in the real life.</p>
2.	<p>Term project</p> <p>What is the term project you want to do for this semester? What kind of technical problems will you encounter and have to be solved?</p>
6.	<p>Force-feedback devices</p> <p>Agent Mulder build his 3D sculpting system with a force-feedback device.</p> <p>The pseudo code of his main algorithm is following:</p> <pre> while(sculpting) {     Do the "collusion detection" with current sculptor position     Calculate the "feedback force" and set it to force-feedback device     Modify the 3D scene     Render the 3D scene } </pre> <p>(a) What are the parameters that the force feedback device needs to send them back to the computer to simulate the force system? Can you write down and explain the formula for simulating the force feedback system with previous parameters?</p> <p>(b) Let's simulate a "rock" wall (hard surface) using such a spring system using a large spring constant <math>K = 1000000 \text{ NT/m}</math>. Do you think it is a good system design? What are the potential problems?</p> <p>(c) For the problem in (b), can you think of ways to actually simulate a hard surface in virtual reality?</p> <p>(d) Assuming the joystick stiffness = 0, mass = 0.5 KG, and viscosity = 4 NT-Sec/Meter, While human operator (arm and wrist) stiffness = 400 NT/m, viscosity = 3 NT-Sec/Meter, and mass = 3 kg. Let's simulate a spring (with spring constant <math>K = 100</math>) with a length of 50 cm, while at both ends are "rock" walls (hard surface) using such a spring system using a large spring constant <math>K = 1000000 \text{ NT/m}</math>. Your joystick is at the middle of the spring, say at 25 cm. Please write down your simulation equations.</p>

7.	<p>In terms of graphics acceleration, there are at least two approaches been proposed, namely</p> <p>(1) parallel processing or SIMD, such as in the NVIDIA GeForce4 chip set, and</p> <p>(2) binary machines such as the Pixel Planes chip set.</p> <p>(a) Can you describe the basic idea of how these two approaches can accelerate graphics and the major difference between them.</p> <p>(b) There is a function <code>fast_calculate (A, B, C, x, y)</code> which can be evaluated in parallel, where <code>fast_calculate()</code> can calculate <math>A*x + B*y + C</math> for each pixel position <math>(x, y)</math>. For a triangle defined by vertices <math>(0, 6, 0)</math>, <math>(0, 0, 0)</math> and <math>(8, 0, 0)</math>, please write a parallel procedure using <code>fast_calculate()</code> to draw all the pixels inside this triangle by Phong shading (vertex normal interpolation) with the shading function (surface normal) <code>dot_product (light_direction)</code>. The surface normal at <math>(0, 6, 0)</math> is <math>(1, 0, 0)</math>, at <math>(0, 0, 0)</math> is <math>(0.6, 0.8, 0)</math>, and at <math>(8, 0, 0)</math> is <math>(0, 1, 0)</math>, and the light is at <math>(0, 0, 15)</math>. We view this triangle from Z axis above.</p>															
8.	<p>In order for objects in virtual environment to move realistically, the response time of the system must be very short. However, in practice, there is always system lag (latency). To solve the problem, many different methods have been proposed to "predict" the future movement upon the past motion path. One method is the simple extrapolation:</p> <table><tr><td>Time(ms)</td><td>t - 200</td><td>t - 100</td><td>t</td><td>t + 100</td></tr><tr><td>Input</td><td>X(n - 2)</td><td>X(n - 1)</td><td>X(n)</td><td>X(n + 1)</td></tr><tr><td>Value</td><td>1.2</td><td>1.3</td><td>1.5</td><td></td></tr></table> <p>(a) By first order linear interpolation, <math>X(n + 1) = ?</math></p> <p>(b) By second order extrapolation, <math>X(n + 1) = ?</math> How to formulate your equation?</p> <p>(c) Suppose the moving object has a mass M, will this fact help the prediction?</p> <p>(d) Do you think more data in the past will help? Why? Is there an upper bound (number of past data) for the past data? If so, what are the factors that will limit the past length?</p> <p>(Hint: second order prediction: a curve passing through <math>X(n)</math>, <math>X(n - 1)</math>, <math>(n - 2)</math>)</p>	Time(ms)	t - 200	t - 100	t	t + 100	Input	X(n - 2)	X(n - 1)	X(n)	X(n + 1)	Value	1.2	1.3	1.5	
Time(ms)	t - 200	t - 100	t	t + 100												
Input	X(n - 2)	X(n - 1)	X(n)	X(n + 1)												
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2.	<p>(a) Please give an example application of Augmented Reality on smartphones.</p> <p>(b) Microsoft Kinect camera can estimate the depth information of the scene in real-time. Can you give an example of research topics which could be solved or improved by using Kinect?</p>
4.	<p>(a) Is a typical RPG (role playing game) game considered VR technology? Why and why not?</p> <p>(b) What is motion parallax? How to estimate the thickness of a brick if front of us, if we have only one good eye and the other eye is blind?</p> <p>(c) Please describe three cases where it is easy to cause "motion sickness", why?</p>
	<p>(a) Yes</p> <p>(b) ...</p> <p>(c) 1. In boat rides: While you're in boat rides, the VR-device will be continually shaking, thus it'll cause motion sickness.</p>

	<p>2. Driving in mountain roads: Same as above, the VR-device will be shaking.</p> <p>3. Simulator sickness (SS): It's a subset of motion sickness that is typically experienced by pilots who undergo training for extended periods of time in flight simulators. Due to the spatial limitations imposed on these simulators, perceived discrepancies between the motion of the simulator and that of the vehicle can occur and lead to simulator sickness.</p>
5.	In your opinion, what are the great technology breakthroughs of VR in the past fifteen years? Please list 5 such items in relative importance, and give very short explanations why it is important.
7.	<p>From one camera, you are looking at a triangle with known vertex positions, such as A(10, 30, 10), B(80, 30, 10), C(30, 10, 10).</p> <p>(a) How to determine the distance and orientation of the camera to the triangle?</p> <p>(b) In actual use, there are cases when one vertex of the triangle is blocked from the camera's view. What would be possible solutions to this problem? Please state your solution clearly and with explanation.</p>

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2.	<p>(a) Please design a method to achieve the goal "smell real" in a movie theater? Give at least one example.</p> <p>(b) In addition to "smell real", there is "feel real". In a fiction, there is a case showing that force feedback can be dangerous to human participants, even to the degree of being "murdered". How can this be done to a participant (user) in VR applications? Please explain.</p>
	<p>(a) Smell-O-Vision was a system that released odor during the projection of a film so that the viewer could "smell" what was happening in the movie. The technique was created by Hans Laube and made its only appearance in the 1960 film Scent of Mystery, produced by Mike Todd, Jr., son of film producer Mike Todd. The process injected 30 odors into a movie theater's seats when triggered by the film's soundtrack.</p> <p>(b)</p>
4.	<p>Rasterization is the popular rendering technique for producing real-time 3D computer-graphics. The algorithm takes 3D scene (described as polygons) to 2D surface (usually a computer monitor). At a very basic level, rasterizers simply take a stream of vertices, transform them into corresponding 2D points on the viewer's monitor and fill in the transformed 2D triangles as appropriate. If the 3D scene is very complicated, then the number of vertices may be very large. It will take a long time to do rasterization. Consider two ways for acceleration:</p> <p>(a) The first method is to dynamically decrease the number of triangles passing to the rasterizer. That is, reduced a model from 10 million triangles to 10000 triangles. Can you propose one idea to achieve this goal while maintain the rendering quality from our view points?</p> <p>Consider the hardware acceleration using Pixel Plane, knowing that it is capable of doing the calculation <math>Ax + By + C</math> in parallel:</p> <p>(b) For a triangle defined by vertices (0, 0), (2, 4) and (6, 2) with their colors on blue channel are 10, 50, 20, respectively. Please provide the precise A, B, C values such that the result of the formula</p>

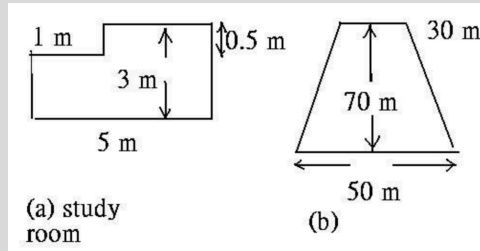
	<p><math>Ax + By + C</math> indicates the value of the pixel(x,y) on the blue channel using Gouraud shading (smooth shading, or called color interpolation shading).</p> <p>(c) Please calculate the values of the pixels (1, 1) and (3, 2) by adopting your formula in (c).</p>
	<p>(a) ...</p> <p>(b) <math>(x, y) = (0, 0) + s(2 - 0, 4 - 0) + t(6 - 0, 2 - 0)</math>  <math>(x, y) = s(2, 4) + t(6, 2)</math>  <math>x = 2s + 6t \rightarrow 2x = 4s + 12t</math>  <math>y = 4s + 2t \rightarrow 3y = 12s + 6t</math>  <math>x - 3y = -10s \rightarrow s = -1 / 10 * (x - 3y)</math>  <math>2x - y = 10t \rightarrow t = 1 / 10 * (2x - y)</math>  Color of pixel (x, y) = <math>10 + -1 / 10 * (x - 3y) * (50 - 10) + 1 / 10 * (2x - y) * (20 - 10)</math>  Color of pixel (x, y) = <math>10 - 4x + 12y + 2x - y</math>  Color of pixel (x, y) = <math>-2x + 11y + 10</math>  <math>A = -x, B = 11, C = 10</math></p> <p>(c) Value of (1, 1) = <math>-2 * 1 + 11 * 1 + 10 = 19</math>  Value of (3, 2) = <math>-2 * 3 + 11 * 2 + 10 = 26</math></p>
5.	<p>3D sound</p> <p>The goal of 3D sound is to simulate the direction and distance of a sound source in a real world.</p> <p>(a) The DVD standard uses the Dolby AC-3 as its sound output, where AC-3 uses 5 speakers plus one bass speaker, as shown in Figure (a). However, your PC has two speakers only. How would you design your PC to play a DVD movie with a sound similar to Dolby AC-3?</p> <p>(b) Noise cancellation application. The newest version of BOSE headphones has the feature that can reduce the engine noise while in the jet airplane. Can noise cancellation be done? How?</p>
6.	<p>Human Factors</p> <p>If you are required to design an IMAX movie theater which adopts an LED screen instead of a project screen. The screen size is 11m high and 20m wide. Given that the field of view of human eye is 90 degrees in the horizontal direction and 60 degrees in the vertical direction, can you define the appropriate distance between the first row seats and the screen? Please calculate the least number of LEDs that should be used in this screen.</p>
7.	<p>Force Display</p> <p>(a) Please design a system with a force feedback to simulate a case in stirring an oil tank with viscosity of 30 Newton-sec/meter, while using a Microsoft Future Force Feedback joystick with a mass of 0.3 Kg, stiffness of 0.01 Newton/meter, and viscosity of 1.17 Newton-sec/meter. Please write the necessary equations for the necessary force to be generated from the driving motors inside the joystick.</p> <p>(b) There exists one magic trick about the above system. When simulating a spring with stiffness of 1000 NT/m, you are holding the handle of a force feedback joystick. The harder you tense your forearm in holding the handle of the joystick, the stronger is the vibration in your hand. Can you explain this magic behavior? At what sampling frequency can this happen? (Hint: Human hand</p>

	has stiffness of 400 NT/m, viscosity 5 N-sec/m, and mass 2Kg, while the joystick has a viscosity of 1.5 N-sec/m).

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3.	<p>In terms of graphics acceleration, there are at least two approaches been proposed, namely</p> <p>(1) parallel processing or SIMD, such as in the NVIDIA GeForce4 chip set, and</p> <p>(2) binary machines such as the PixelPlanes chip set.</p> <p>(a) There is a function <code>fast_calculate (A, B, C, x, y)</code> which can be evaluated in parallel, where <code>fast_calculate()</code> can calculate <math>A*x + B*y + C</math> for each pixel position <math>(x, y)</math> in PixelPlanes. For a triangle defined by vertices <math>(5, 9)</math>, <math>(3, 2)</math> and <math>(10, 3)</math>, please write a parallel procedure using <code>fast_calculate()</code> to draw all the pixels <math>(x1, y1)</math> inside this triangle. (Hint: you have to determine whether <math>(x1, y1)</math> is inside of the triangle first, and for this case, what are the value of A, B, and C for this particular triangle. In general, what is the distance from <math>(x1, y1)</math> to the triangle edge?)</p> <p>(b) For 3D triangle vertices <math>A(5, 9, 0)</math>, <math>B(3, 2, 0)</math> and <math>C(10, 3, 0)</math>, how to use Z-buffer algorithm in Pixel Planes for visibility testing? Hint: Z-buffer algorithm:</p> <p>(a) Initialize <code>frame_buffer [1000, 1000]</code> to be all very big numbers (far from view point). For a pixel <math>(x, y)</math> located inside a triangle,</p> <p>(b) If it is closer (its Z value) to the view point (human eye), then paint this pixel with its color. At the same time, set <code>frame_buffer (x, y) = Z value</code>.</p> <p>(c) Otherwise, don't paint this pixel.</p>
4.	<p>Assume that a Google glass VERSION G has</p> <p>(i) camera</p> <p>(ii) lens on the right eye, that can reflect images from a Android phone, through a prism, for head-up display</p> <p>(iii) a Microsoft Kinect depth camera.</p> <p>(iv) Blue-tooth for near field communication</p> <p>(v) a GPS sensor.</p> <p>Hint: how to make the images from Android phone to be projected to your right eye through a prism?</p> <p>(a) Although the exact configuration is not yet disclosed, please draw a design (sketch diagram) so that every module is connected, and in its correct positions.</p> <p>(b) Please give one example of its possible cool usage, especially those that are not yet mentioned in the Internet introduction.</p>
7.	<p>The goal of 3D sound is to simulate the direction and distance of a sound source in a real world.</p> <p>(a) Please explain how to reduce the (big) engine noise in an airplane for the pilot wearing a headphone, while listening to music.</p> <p>(b) The following is the shape of your study room, and you want to hear the music (without wearing a headphone) exactly as it was generated in the opera house in Paris, France. Can it be done? How?</p>

Hint: use head related transfer functions (HRTF) and its measurements, then write down each steps to achieve this goal.



Pans opera house: A

Your study room: B

If we can send people to measure A, then

$$X_1 * L * F_L * M_L \text{ (left ear)}$$

$$X_1 * L * F_R * M_R \text{ (right ear)}$$

where  $M_L = M_R$  (Microphone transfer function), L: loud speaker.

Similarly, in your study room, measure

$$X_2 * L_S * F_{SL} * M_S \text{ (left ear)}$$

$$X_2 * L_S * F_{SR} * M_S \text{ (right ear)}$$

Where  $M_S$ : Microphone,  $L_S$ : loudspeaker.

Therefore, for the right ear signal:

$$X_2 = (X_1 * L * F_R * M_R) / (L_S * F_{SR} * M_S)$$

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1. The da Vinci System is designed to facilitate complex surgery using a minimally invasive approach. It consists of a surgeon's console that is typically in the same room as the patient, and a patient-side cart with four interactive robotic arms controlled from the console. Please answer the following questions:
  - (a) What technologies related to Virtual Reality are involved in this system? Please list 3 items and give a brief explanation.
  - (b) How can the surgeon know that the robotic arms had touched the patient? What good things will you design to inform the surgeon about the above situation?

3. In terms of graphics acceleration, there are at least two approaches been proposed, namely (1) parallel processing or SIMD, such as in the NVIDIA GeForce chip set, and (2) binary machines such as the PixelPlanes chip set.
  - (a) There is a function `fast_calculate(A, B, C, x, y)` which can be evaluated in parallel, where `fast_calculate()` can calculate  $Ax + By + C$  for each pixel position  $(x, y)$  in PixelPlanes. For a triangle defined by vertices  $(1, 2)$ ,  $(4, 4)$  and  $(7, 0)$ , please write a parallel procedure using `fast_calculate()` to draw all the pixels inside this triangle.
  - (b) For the triangle defined by vertices  $(1, 2)$ ,  $(4, 4)$  and  $(7, 0)$  with their colors on blue channel are 17, 31, 21, respectively. Please provide the precise A, B, C values such that the result of the formula  $Ax + By + C$  indicates the value of the pixel  $(x, y)$  on the blue channel using Gouraud shading (smooth shading, or called color interpolation shading).

4.	<p><b>Motion Capture</b></p> <p>Motion capture is the process of recording the movement of objects or people. Traditionally, the captured subject would wear several markers and the related motion would be recorded by several surrounding cameras. Nowadays, Kinect uses depth cameras to track human skeleton motion.</p> <p>Hint: Kinect's depth acquisition is enabled by "light coding" technology. The process codes the scene with near-IR light, light that returns distorted pattern depending upon where things are. The solution then uses a standard off-the-shelf CMOS image sensor to read the coded light back from the scene using various algorithms to triangulate and extract the 3D data.</p> <p>(a) Compare the traditional marker method and Kinect system. What are the pros and cons of each method?</p> <p>(b) Assume that you can capture human skeleton motion successfully. Please give one example of the possible cool usage, especially those that are not yet mentioned in the Internet introduction.</p>
6.	<p>In Windows 8, a multi-touch screen similar to Apple's iPhone is one unique way to provide new user interfaces. Assume that we have "two" cameras in each Notebook PC, located at the top right and left corner of the screen.</p> <p>(a) Can you describe a way to provide "multi-touch" user interfaces without even "touching" the screen?</p> <p>(b) Please describe your algorithm to solve the problem of determining finger positions (not just one, but perhaps two fingers).</p>

2.	<p><b>Head-Mounted Display</b></p> <p>Assume you are an engineer sitting in the office and you are anxious about the Google I/O in 2015 because you are in charge of designing Google Cardboard Part 2.</p> <p>(a) You start from hardware of Google Cardboard. Explain why you need two lens for your device. (Hint: What kind of lens will you need? What are the functions of the lens? )</p> <p>(b) After assembling all components, you start to design the software. You put figure 1 in your cellphone and start to watch it, but you found it to be blurry. What kind of adjustments for image will you need in your software? (Hint: What is the effect by lens and binocular vision?) (Figure 1: Same image in both left and right side)</p> <p>(c) You can see an image without blur but it is not with enough resolution. The length and width of your screen is 12 and 6 cm respectively and the distance between your eyes and screen is 6 cm. How many points will you need in your screen at least to achieve the best resolution? (Hint: Visual acuity: eye's ability to distinguish two points of light is limited to 2.0 mm at a distance of 10 meters.)</p>
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	<p>(d) Finally, you start to test your device. By using the gyroscope in the cellphone, you can pitch, roll and yaw. If you want to increase another inputs besides the gyroscope, please describe how to make the cardboard device obtain such information? Describe your methods in brief.</p> <p>(e) If you are about to publish Google Cardboard Part 2 next week. What kind of applications will you use?</p>
3.	<p>Augmented Reality and Virtual Reality (Figure 2: Oculus Rift(Left) and Microsoft HoloLens (Right))</p> <p>VR and AR are popular in recent years. Oculus Rift and Microsoft HoloLens are two such products which have high publicity.</p> <p>(a) What's the difference between Augmented Reality (AR) and Virtual Reality (VR)? Please classify the products (Oculus Rift and MSFT HoloLens) and explain it with your reasons.</p> <p>(b) One of core functions in Oculus is how to accurately determine the user's head movement. In order to improve user experience, Oculus uses a camera to assist it. Please explain why this camera can help Oculus to determine the user's head movement. Also, describe possible problems of this camera.</p> <p>(c) In HoloLens promotional video, there is a scenario that a woman is guiding by her father how to install the pipeline with some helpful virtual information such as installation path (Figure 3). Please analyze what kind of technology will be used in order to achieve the above result.</p>
6.	<p>Suppose we are going to use only two speakers to implement a 5-speaker Dolby AC-3 sound system in your study room. What will be the technical problems you have to solve instead of using headphones only? Give your formula or algorithms. Tell us what's missing (difficult to calculate) in your solution?</p>