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Computer Aided Medical Procedures
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Augmented Reality, Spring 2022
Assignment 3
Due: Feb 23st (Wed) 2022, 8:30am

Assignment 3: Head Mounted Displays and Perception

1 (Written) Head Mounted Display Technologies [16 points]

1.1 Some users of Head Mounted Displays experience something called "Simulator sickness" or "Virtual reality sickness". Look it up, name and describe some of the causes (give two or more). (4 points)

1. The refresh rate of the system is lower than what the brain processes, that gap causes the sickness.

2. The resolution of the display animation is not high enough, so that the object that shown is different than what expected.

3. Virtual and vestibular stimuli/ feedback are out of sync.

1.2 What are the main differences between Video-See-Through Head Mounted Displays and Optical-See-Through Head Mounted Displays? Name and describe pros and cons of each technology (give two or more each). (4 points)

For OST HMD, there is a direct connection between the real environment and the user's eyes, while for VST, the user can only see the scenes through camera.

VST

Pros:

Can always augmented black into the system

Alignment won't be an issue if the camera is well calibrated

Cons:

Image quality and resolution are relatively low

Your sight may lose everything once if the system fails

OST

Pros:

Image quality and resolution are high because user can see real objects

You just see what you can see without the HMD, that's much safer

Cons:

Alignment will be an issue because one side is real and the other side is augmentation

Do not have pure black pixels

1.3 What is CAVE? What are its advantages and disadvantages when compared with HMD? (list 3 of them) (4 points)

CAVE is Cave Automatic Virtual Environment. It is an environment that is made of a cube-shaped VR room, whose walls are all projection screens.

Advantages:

Resolution is much higher than that of HMD

Can have multiple viewers having the same VR/MR experience

It requires lightweight glasses, and it's wireless

Disadvantages:

The cost is high

It's not completely immersive

The experience is shared and guided

1.4 Can we show all colors in an OST-HMD? Why? (2 points)

No, at least we can't see color black on the augmentation of an OST-HMD. Because an OST system uses additive display to show the augmentation, the brightness needs to be increased in order to see the object. However, for color black, we cannot do that.

1.5 Does HoloLens create Holograms? Why? (2 points)

No, it does not create a hologram. Because everything that it displayed is placed on a plane, but a hologram is a three-dimensional image.

2 (Written) + (Programming) Optical-See-Through Calibration [10 points + 10 points *(Bonus)*]

2.1 What is the goal of Optical-See-Through calibration? Why is it needed? What is the mathematical result of the calibration? How many degrees of freedom does it have? (4 points)

Goal: Put the virtual object correctly on the screen, so that the user can see it without any alignment or positioning issue.

Necessity: Because mixed reality has the need to visualize virtual object in real world, the correct position and alignment of the display are critical for the proper user experience.

Result: a 3×4 projection matrix P, which maps the 3D real world to the points in the image that users see.

DOF: 11

2.2 One common method for Optical-See-Through calibration is SPAAM (Single Point Active Alignment Method). Describe how it is performed. (2 points)

The user is required to align a cursor showing on the screen with a fixed point in the real world by moving round. The procedure is repeated until sufficient number of correspondences are collected for the calibration.

2.3 What is the main problem with methods similar to SPAAM? (2 points)

They are time-consuming since 10 or more alignments are needed for better results. However, there is not much improvement in the error after having collected around 20 points.

2.4 Can user interaction be excluded from Optical-See-Through calibration? Why/Why not? (2 points)

Users cannot be excluded. Because the calibration is to obtain the projection mapping from the 3D real world to the imaged points that users see. We do not have direct access to those images that users see, so they have to involve.

3 (Written) Medical Augmented Reality [10 points]

3.1 Give a general problem statement for medical augmented reality. (2 points)

Increase of imaging data makes it necessary to perform intelligent visualization of data and its proper integration into medical procedures, given that in most ORs 3d imaging data is currently displayed inappropriately.

3.2 Name three typical challenges in medical augmented reality. (3 points)

1. Motion tracking and deformable registration
2. Integration of medical AR into surgical workflow
3. Physicians need to get familiarization with the new technology, the change of culture is needed in teaching and training

3.3 Imagine we want to augment virtual organs on top of the camera's color stream. A prerequisite for this is to know the projection matrix P in order to map 3D points to the 2D image plane. What is the name of the process for obtaining P? Which algorithm can be used to realize it? (2 points) [Hint: recall what you have learned in the camera model and calibration lecture]

Camera/ Spatial calibration. Direct Linear Transformation (DLT).

3.4 Thanks to machine learning algorithms, we can retrieve the 3D position of human joints. Given d as the distance between a joint and the image plane at pixel coordinate (u,v), provide the formula to calculate the joint's position in 3D world space. (2 points)

3.5 For the visualization of organs, a virtual window to look "inside" the body is used, and organs can only be seen inside this window, as in Fig 1 (look into the TV). Why does this option have been chosen instead of simply overlaying all the organs on top of the user? (1 point)

In this way, user can have a better perception of depth, comparing with simply overlaying all the organs on top of the user. Thus the user experience gets enhanced.