NOTE: no guarantee of correctness!

General

What kind of tracking technologies are there?

- Mechanical
- Magnetic
    - ac, dc, passive (compass)
- Optical
    - Markers: Fiducials, Infrared: Passive, Active Markers
    - Natural features, Gestures
    - Depth cameras
        - structured light (known light pattern -> observing distortion)
        - time of flight (time it takes infrared pulse to get to object and back)
        - light field camera (light field emanating from space -> using microlenses)
- Inertial
    - gravity, acceleration
- Time of Flight
    - Acoustic Tracking
    - GPS
    - Radio frequency
- Hybrid

Tracking

Optical Tracking with Fiducials

- pipeline
    - camera -> fiducials detection -> contours
    - rectangle fitting -> rectangle
    - pattern checking -> identified markers
    - lens distortion -> undistorted corners
    - pose estimation -> estimated poses

Optical Tracking with Infrared and Passive Markers (iotracker)

- pipeline
    1. calibration: how cameras are situated towards each other
    2. segmentation: find blobs
    3. feature correlation: find blobs in other images
    4. projective reconstruction: generate lines to blobs, generate 3d point cloud
    5. model fitting: find blob constellation in the point clouds
    6. output of position and orientation: compute position in space

Optical Tracking with Infrared and Passive Markers (lighthouse)

- inside out tracking system - hmd with camera
- 2 laser base stations with IR LED, 1 hmd, 2 controllers
- principle
    - laser goes in y direction -> flash -> then in x direction -> flash
    - flash means new iteration
    - time difference -> from flash to hit on hmd -> angle to base
- pro: very precise, robust
- cons: restricted tracking area, occlusion, needs to attach base stations at certain height

PTAM Tracking (Natural Feature Tracking)

- pipeline
    1. pose estimation (you know where the user was before -> try to guess where it is now)
    2. feature are projected into image
    3. quickly search through features (50)
    4. camera pose is updated based from the 50 features
    5. larger number of features are searched in image
    6. final estimate for the frame based of the matches

3D Graphics

Rasterization Algorithm

- projects each triangle to the screen
- rasterize the triangle
- solve visibility by z-buffer
- compute per pixel color
- pipeline
    - application (contains the scene)
    - vertex processing (shader - applying model-view-projection matrix)
    - clipping (discarding triangles outside the view)
    - rasterizer (scanning through objects and generating fragments)
    - fragment processing (shader - vertex data to fragments)
    - screen (forward screen buffer to output pixels)

Ray Tracing Algorithm

- generate ray of camera
- object intersection
- shading (checks light conditions)
- secondary rays (if refracted or reflected)
- recursion (if secondary rays creates more secondary rays)

Prüfung 2023-05-15

What is virtual Augmented Virtuality and where is it in the milgram diagram?

- Virtual world is enhanced by real objects or componentes, e.g a real person is projected in the virtual world
- The milgram diagram portrays the continuum of the whole mixed reality as a spectrum:
- real environment - augmented reality - augmented virtuality - virtual environment

What is Exposure Therapy and why use virtual reality?

- Exposure therapy is exposing the patient slowly to its to be cured condition, e.g. someone who has phobia of spiders
- slowly exposing it to spiders in a virtual world
- Virtual reality has the benefit of the possibility of controlling the environment, and the therapist can stop the process anytime
- It is important that the user feels immersed and that a therapist is present
- Also, it might be cheaper to stimulate this process in comparison to recreate the scenes in real life.

What is haptic, force feedback and where do we use it?

- haptic is the output as physical touch in virtual reality
- it is divided into touch feedback and force feedback
- Touch feedback is getting a sensation on the skin, while force feedback must actively resist the user's motion
- First is e.g. wearing a glove and getting an impulse when performing the wrong task
- while force feedback is e.g. the user pressing against a machine and it actively resist the force of the user "pressing against a wall".

How does the ray tracing algorithm work?

- ray tracing works by simulating a ray in a virtual scene
- 1. ray generation - shoot a ray in the 3d world
- 2. ray intersection - if the ray intersects with any objects
- 3. shading & lightning - calculating the lighting conditions
- 4. secondary rays - if the ray is reflected or refracted on the object
- 5. recursion - secondary rays can create even more secondary rays

What is WIM, world in miniature?

- world in miniature is a manipulation technique

- the user has the environment as a miniature version in the hand “dollhouse”
- can manipulate this miniature version -> every change in miniature is applied to real world
- not efficient for big environment, does not fill all

Explain optical tracking and advantages, disadvantages

- optical tracking relies on visual cues to track the environment
- e.g. using markers
    - fiducials
        - pro: stable, fairy simple, open source
        - cons: optical noise, dependency of marker (too far away: can’t see, too close: doesn’t fit)
    - infrared light with active/ passive markers
        - pro: very accurate, supports tracking in large volume
        - cons: required markers, occlusion problem
- e.g. using natural features
    - pros: markers not needed, setup cleaners
    - cons: slower and more difficult than marker tracking, not very robust, initialization needed, suffers from light conditions, environmental changes, camera field of view
- e.g. depth cameras
    - structured light
    - time of flight
    - light field cameras
        - pro: gets additional depth info
        - cons: IR issues: too sunny outside

What is the z buffer and where do we use it?

- The z-buffer is used to store depth information about a pixel
    - if a pixel is rendered: checks if the screen is closer to the pixel or any pixel that has already been drawn -> if pixel is closer -> draw to screen -> if other pixel is closer -> this pixel is behind already drawn pixel
- is used in the rasterization process when rendering a scene

How would you illuminate a room of objects?

- would use infrared to get depth information
- so a depth camera -> structured light e.g.
- just like in the project with fire fighter, get whole overview of the scene

What is the main difference between LCD and DPL?

- both are types of projectors
- technology behind is different: LCD is the transmissive, DPL is reflective
    - LCD
        - using backlight and crystals to project

        - with LCD true black is not possible
    - DPL
        - no backlight, using rotating mirror to direct light

What is active stereo and how does it work?

- active stereo is seeing with 3d with active shutter glasses
- the display and glasses are synchronized with infrared light
    - the glasses shutter between left and right eye
    - the display shows then accordingly the image for left or right eye
- cons:
    - ghosting (black to white pixel cannot switch that fast -> you still see old image)
    - occlusion (can avoid IR contact between glasses and screen -> no shuttertin)

What is phantom rendering? (or phantom devices?)

- render something that is not there in real life
- objects that are not actually present in the scene
    - e.g. pokemon characters in augmented reality game pokemon go
- phantom device
    - a device which stimulates something that is not actually there, but in the virtual world
    - e.g. force feedback in a game

What is naturalism interactions approach and magic interaction approach in vr?

- naturalism interaction approach
    - depicts interactions like in real life
    - 1:1 depiction
    - pro: feels natural, easy to learn
    - cons: restrictive in movement
    - e.g. walking
- magic interaction approach
    - give the user magical abilities, which are not possible in rl
    - pro: might take some time to learn, unintuitive
    - cons: give the user more movement
    - e.g. teleportation

What is the relation of vr exposure duration and cybersickness?

- the longer an user is exposed to the virtual environment, the more sick the user gets
- linear relation

Prüfung 2021-02-18

Latency, Update Rate and Phase Lag

Please explain Latency, Update Rate and Phase Lag of a tracking system.

- Phase Lag = Latency + Update Rate
- Latency: the time between every acquisition of data (e.g. camera takes picture every 5ms -> 5ms latency)
- Update Rate: the time the processor needs to output position (e.g. time to process image & extract data)

What effects can it have on humans if tracking is slow or if phase lag is large?

- cyber sickness -> movement you feel vs you see is different
- user adapts to lag -> if hand is slower than real hand -> user will move hand accordingly

What are advantages and disadvantages of time-of-flight tracking?

- measure time of propagation of a signal
- measure frequency of waves to indirectly estimate time difference
- pro:
    - is independent from optical markers
    - can get additional depth information when you IR light
    - inexpensive, small and light targets
- cons:
    - is dependent from air
        - if air changes, propagation changes (humidity, temperature)
        - ultrasonic noise (reflection of signal)
    - is dependent from velocity of sound
    - line of sight issues

Infrared tracking

How does infrared optical marker tracking with passive markers work?

- emitter which sends infrared light to passive markers
- passive marker reflect light
- based on passive marker position can be calculated
- you need at least 2 cameras to 3d position

Which steps are needed from calibration to output of position and orientation of the target constellation? Briefly describe the 6 steps that are needed to track targets (as explained in the lecture for iotracker)

1. calibration: how cameras are situated towards each other
2. segmentation: find blobs
3. feature correlation: find blobs in other images
4. projective reconstruction: generate lines to blobs, generate 3d point cloud

5. model fitting: find blob constellation in the point clouds
6. output of position and orientation: compute position in space

Stereo

What is active and passive stereo? [1 p.]

- active stereo:
    - using shutter glasses (= actively shuttering)
    - screen and shutter glasses correlate
    - so screen shutter between image for left eye and right eye
    - glasses shutter as well
- passive stereo:
    - using glasses with polarization filter
    - using two projectors, showing two images at the same time
    - left eye has different filter to right eye
    - each eye sees correct image

Which types of polarization exist? Why is polarization used? [2 p.]

- type of polarization:
    - linear polarization
        - however when you tilt the head -> filter can be incorrect
        - little ghosting
    - circular polarization
        - prone against slight head movements
    - elliptical polarization
        - when phase difference is != 90 degrees
- why is polarization used:
    - can use cheap glasses
    - no need of correlation of glasses and screen (shutter glasses communicate with IR light)
    - IR independent -> in case of occlusion no shuttering

How does a passive stereo projection setup look like and what is the required hardware for projection (for example in a 3D cinema)? [2 p.]

- two projectors for each eye
- on each projector different filter
- glasses with filter
- screen with polarizing preserved coating
    - polarization needs to be preserved
    - special screen with holes to leave sound through
- projection technologies:
    - LCD projector: using crystals and backlight
    - DPL projector: using mirrors to reflect and direct light

Which auto-stereoscopic display technologies do you know? Describe them briefly. [2 p.]

- auto-stereoscopic: needs no glasses
- lenticular
    - many layers with images printed on special foil, depending on view sees different image
    - has a special lens on top: bend the light differently for each eye
- volumetric
    - stack of planes: switch through the planes to get 3d impression
    - or other example led installation in 3d
- holographic
    - light is refracted on a special holographic emulsion plate and an object
    - if plate is illuminated with light: shows hologram of object

Depth cameras, haptic devices

Explain the three different technologies that can be used to get a depth image with a single depth camera.

- Structured Light: based on distortion of known pattern calculate the depth
- Time of Flight: calculate the time it takes to send IR laser to pixel and back
- Light field cameras: get light field of a scene with capturing it with micro lenses

What is a haptic device? Give an example for a haptic device and describe one possible application for it

- output: haptic device is device which gives haptic feedback to the user
- touch feedback or force feedback
- simple haptic device: controller in vr sets -> let user know if a task has been done correctly -> gives him feedback
- application: a cue for users in games
- input: so the user can give input via haptics (touch, movements, force)
- pen attached to base: gives 1-point contract
- application: 3d-modeling, surgical simulation

Magnetic / Natural Feature Tracking

Explain the principle of magnetic tracking

- circulating electric current in coil -> magnetic field is generated
- using current of coils in target and tracker
- measure position based on current of the target
- ac:
    - transmitter: creates ac field
    - receiver: measure induced voltage

    - but imprecise
- dc:
    - 3 transmitter for each direction, 3 receiver
    - 4 phase measurement: for each direction, in 4th phase pause for earth magnetic field

What are the disadvantages of Natural Feature Tracking? When/why does it fail?

- initialization is troublesome
- fail when feature cannot be recognized
    - different light conditions
    - using camera with different fov
    - environment changes
    - large occlusions
    - blur in camera

Interaction

What are the universal interaction tasks? Briefly describe each.

- Selecting: picking up an object from a set
- Manipulating: modifying an object properties
- Navigation:
    - Travel: movement between 2 locations
    - Wayfinding: finding the way between 2 location
- System Control: changing system state
- Symbolic Input
- Modeling & Other Tasks

Which interaction techniques for Manipulation in 3D do you know? Give 3 examples for manipulation techniques. [3 p.]

- HOMER
    - when you select an object your hand gets attached to the object
    - can manipulate the object
    - after manipulation release object and returns to original position
- World in miniature
    - miniature of environment in your hand for manipulation
    - changes also applies to real world
- Voodoo
    - when you select an object a copy of the object is in your hand
    - every change applied on the copy gets applied to the real object

Immersion, Presence, Ray-Casting

What is Immersion? What is Presence? Explain both terms and give an example for a fully immersive environment. [3 p.]

- Immersion: convincing simulation of reality
- Presence: actually feel you are there
- not the same! immersion is caused by technology, presence is subjective
- example:
    - virtual reality game with headset and headphones

How does the Ray-Casting interaction technique work? What is the purpose of this technique and what are advantages and disadvantages? [2 p.]

- Selecting an object is like using a laser point to point at an object
- to extend physical boundaries -> can select objects further away with precision
- pros: extend boundaries, intuitive to use
- cons: hard to select for objects far away (hard to keep hand still)

Prüfung 2019-10-29

Was ist das Virtual Reality Continuum? Gib ein Beispiel samt Beschreibung wie VR in der Psychotherapie benutzt wird.

- spectrum of mixed reality
- real world - augmented reality - augmented virtuality - virtual world
- exposure therapy

Was braucht man um ein Cave mit polarisierter Projektion aufzubauen? Wieso wird Polarisierung bei der Projektion benutzt? Wie wird die Synchronisierung gewährleistet?

- cave mit polarised projection
    - at least 3 walls, to 6 walls
    - two projector per wall
    - polarised glasses
    - a pc (cluster) with good graphics engine
- synchronization
    - genlock: every pixel is synchronized and drawn at the same time
    - framelock: every frame is synchronized and start is at the same time, however during frame is not controlled

Was ist Natural Feature Tracking? Nenne 2 Bsp. wann dieses Tracking nicht gelingt. Nenne und beschreibe einen Natural Feature Tracking Algorithmus. Was sind die Vorteile und Nachteile von Natural Feature Tracking?

- PTAM natural feature tracking algorithm:
    - pose estimation
    - feature projected into image

    - coarse feature search in the image
    - camera pose is updated from coarse matches
    - refined feature search in the image
    - final pose estimate

Wie ist der Aufbau/das Prinzip von HTC Vive Lighthouse? Was sind die Vorteile und Nachteile?

- inside out tracking system - hmd with camera
- 2 laser base stations with IR LED, 1 hmd, 2 controllers
- principle
    - laser goes in y direction -> flash -> then in x direction -> flash
    - flash means new iteration
    - time difference -> from flash to hit on hmd -> angle to base
- pro: very precise, robust
- cons: restricted tracking area, occlusion, needs to attach base stations at certain height

Vorteile und Nachteile von inertial Tracking?

- pro: less noise, very fast, robust
- cons: drift due to integration

Nenne und erkläre die 3 Depth Kameras.

- structured light
- time of flight
- light field cameras

4 Stages of Usability Engineering aufzählen und beschreiben.

1. user task analysis - design the product
2. expert guidelines based evaluation - first test with experts and then evaluate
3. formative usability evaluation - iterative test with representative users
4. summative evaluation - end of product cycle, compare with other products

VR/AR System Architektur und Framework beschreiben.

- application (GUI, 3D UI)
- MR framework - connected to network
- tracking middleware (openxr) + distribution framework + rendering engine + network management
- ..
- computing platform - connected to network
- input device & tracking + output device

Was ist Cybersickness? Gib 2 Bsp wie man Cybersickness mindern kann.

- using medicine against motion sickness

- adaption -> getting used to virtual reality by using it more
- better hardware -> less lag between user and vr

Was ist Ray casting und Cone casting? Wozu werden sie verwendet?

- selection methods
- ray casting = laserpointer
- cone casting = selecting everything in a cone

Was ist die Go-Go Technik.

- hand behaves normally
- until certain point -> stretches/ extends exponentially

Prüfung 2019-02-21

VR/AR

Virtual Reality Continuum erklären. Was ist Mixed Reality?

- spectrum of mixed reality (RE - AR - AV - VE)
- mixed reality is any combination of real and virtual world

Welche psychologischen Möglichkeiten zur Betreuung kennt man bei VR, und auf was muss man beim Prozess achten?

- controlled environment by the therapist
- presence of a therapist, slow/ gradual exposure, user has to be present

15x15m Funkauto tracken INDOOR. Welche Methode, warum, Vor+Nachteile, Technische Umsetzung

Welche Methode

- Acoustic Tracking with Ultrasound
    - 3 emitters, one receiver
    - measures time of propagation of signal via triangulation
    - each emitter send signal sequentially
    - receiver receive signal simultaneously
- pro
    - wide area possible
    - small and inexpensive targets
    - inexpensive
- cons
    - line of sight issues
    - speed of sounds varies due to environment (humidity, etc)
    - ultrasonic noise

Andere Methode für selbes

- Radio Frequency (WLAN)
- triangulation similar to acoustic tracking
    - measure phase difference time of flight
    - comparison of phase shift
- pro
    - wide area also possible
    - high data rates possible
- cons
    - again depends on environment (temperature, etc)
    - reflection in the environment

Andere Methode für 50x50m Formel1 OUTDOOR

- also Radio Frequency but LPM Local Positioning Measurement (similar to radio frequency)
- or using DGPS

Prüfung 2018-02-22

Augmented Reality

Definition after Azuma

- combines real and virtual world
- interactive
- registered in 3D - objects are in 3 relation to each other

Definition of Presence

- when the user actually feels he/ she is in the environment
- presence is a state of consciousness where the user has a sense of being in the location specified by the displays

Accuracy

Static Accuracy

- Maximum deviation from fixed tracker position to fixed reference value
- influenced by
    - Receiver sensitivity
    - Environmental effects
    - Algorithmic errors
    - Installation errors

Dynamic Accuracy

- Accuracy as sensor is moved
- Dependent on static accuracy

- influenced by
    - Processor type
    - System architecture

Outdoor Tracking

- DGPS
    - additional fixed ground station to refine resolution
    - send correction vector
    - accuracy: theoretically 0.1m, practically 3-5m
- LPM
    - time of flight tracking with radio frequency
    - 500x500m
    - accuracy: +- 5cm