

Einführung in die Erweiterte Realität

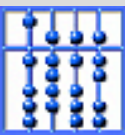
6. Trackers

Prof. Gudrun Klinker, Ph.D.

Institut für Informatik, Technische Universität München

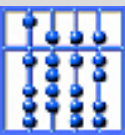
klinker@in.tum.de

Dec 7, 2004



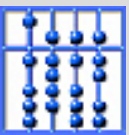
Reference

“A Survey of Tracking Technology for Virtual Environments”, J.P. Rolland, L.D. Davis and Y. Baillet, in Fundamentals of Wearable Computers and Augmented Reality (chap. 3), 2001, pp.67-112.



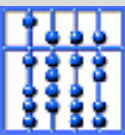
X

- X

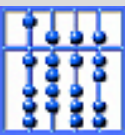


Agenda

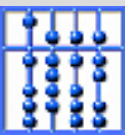
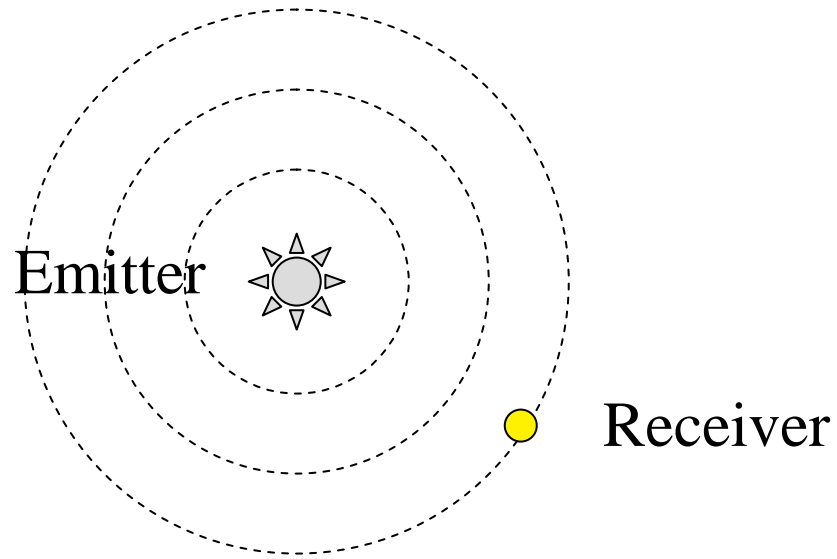
1. Time-frequency measurements
2. Spatial scan
3. Inertial sensing
4. Mechanical linkages
5. Direct-field sensing
6. Hybrid systems
7. Discussion



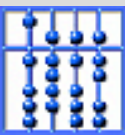
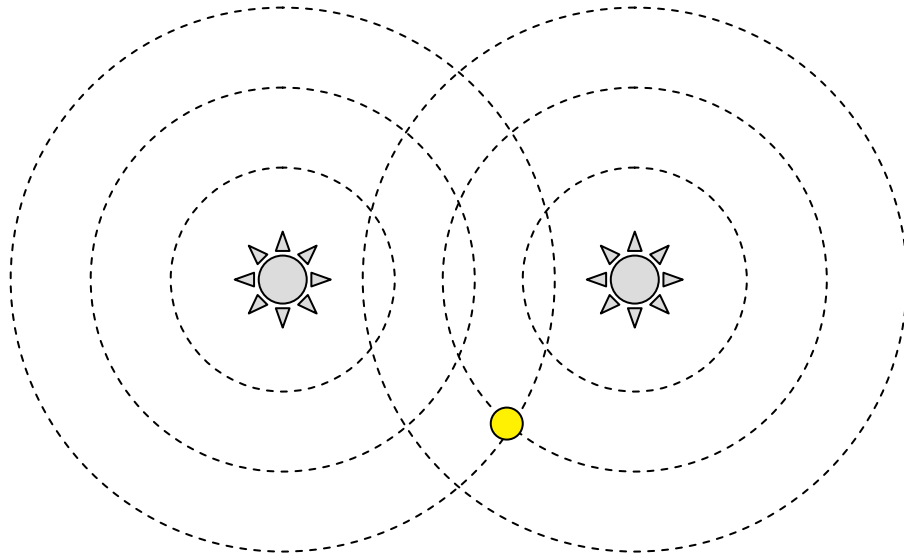
- Ultrasound
- GPS



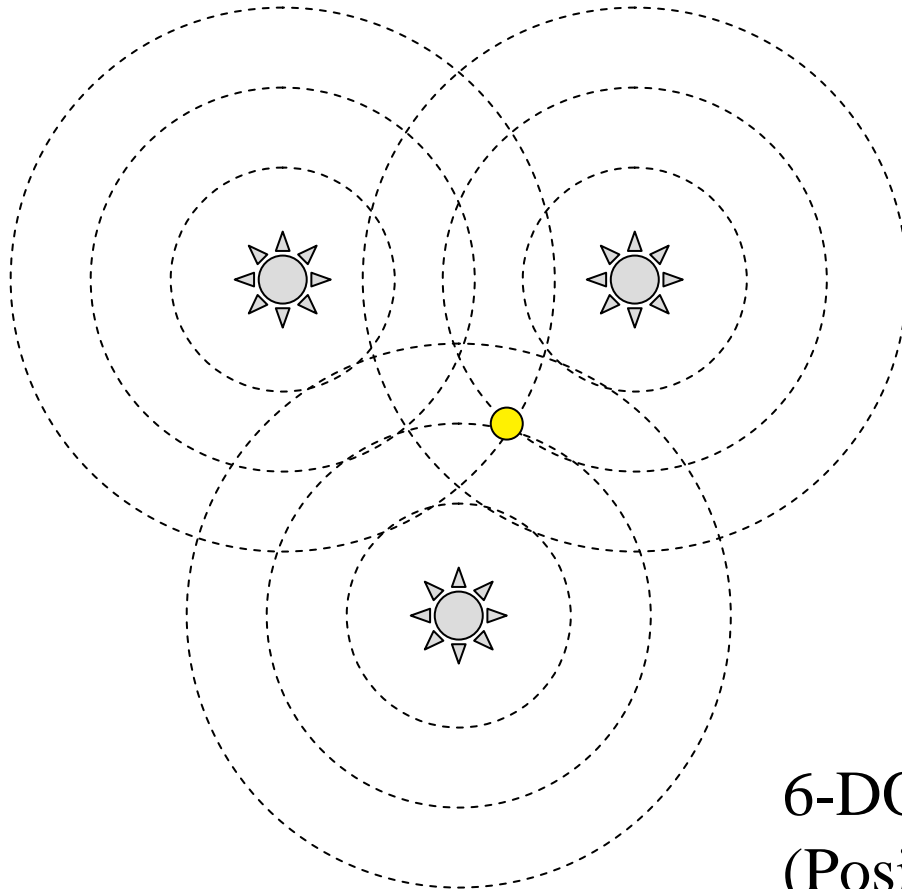
1.1 Ultrasound



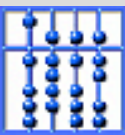
1.1 Ultrasound



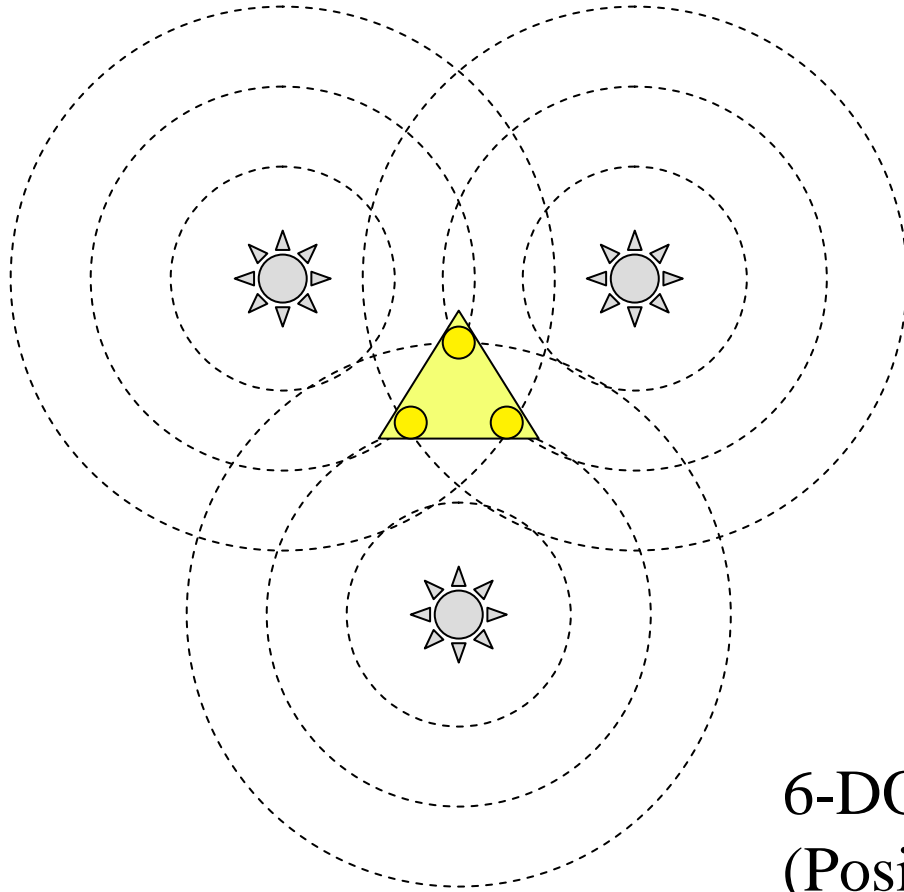
1.1 Ultrasound



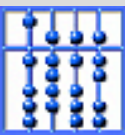
6-DOF Tracker
(Position)



1.1 Ultrasound



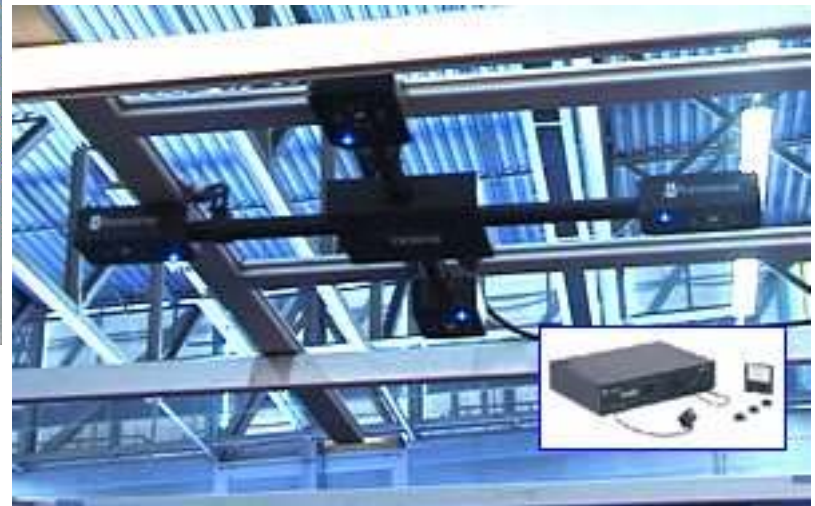
6-DOF Tracker
(Position and Orientation)



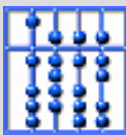
1.1 Ultrasound



Logitech

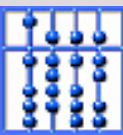


Intersense



1.1 Ultrasound

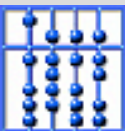
- Pros
 - Small and lightweight
 - Independent of the line of sight
- Cons
 - Speed of ultrasound varies with temperature, pressure, humidity, and turbulence
 - Fast signal attenuation
 - Ultrasonic ambient noise (e.g., echoes)
 - Tethered (?)



1.1 Ultrasound

- Evaluation and summary

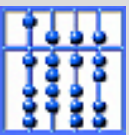
| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|----------|-------|-----------|------------|-------|------------|-----------------|
| Acoustic | + | - | + | - | n | multiple echoes |



1.2 GPS

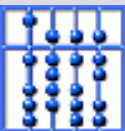
Good introduction at

http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html



1.2 GPS

- Time-encoded signal from satellites with atomic clocks
- At least 4 satellites needed to pinpoint
- 24 satellites in 6 different orbits (4 per orbit)
- Standard positioning system (SPS)
(no longer an issue)
- Precise positioning system (PPS)
- Differential GPS



1.2 GPS



Garmin

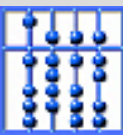
15 m accuracy (GPS)

3-5 m accuracy (DGPS)



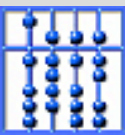
Trimble

2-5 m accuracy



1.2 GPS

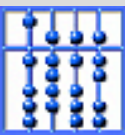
- Pros
 - Available world-wide
- Cons
 - Slow update rate
 - Imprecise
 - Depends on line of sight



1.2 GPS

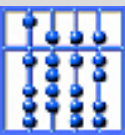
- Evaluation and summary

| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|--------|-------|-----------|------------|-------|------------|-----------------------------|
| (d)GPS | -- | -(-) | + | ++ | n | line of sight to satellites |

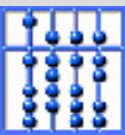
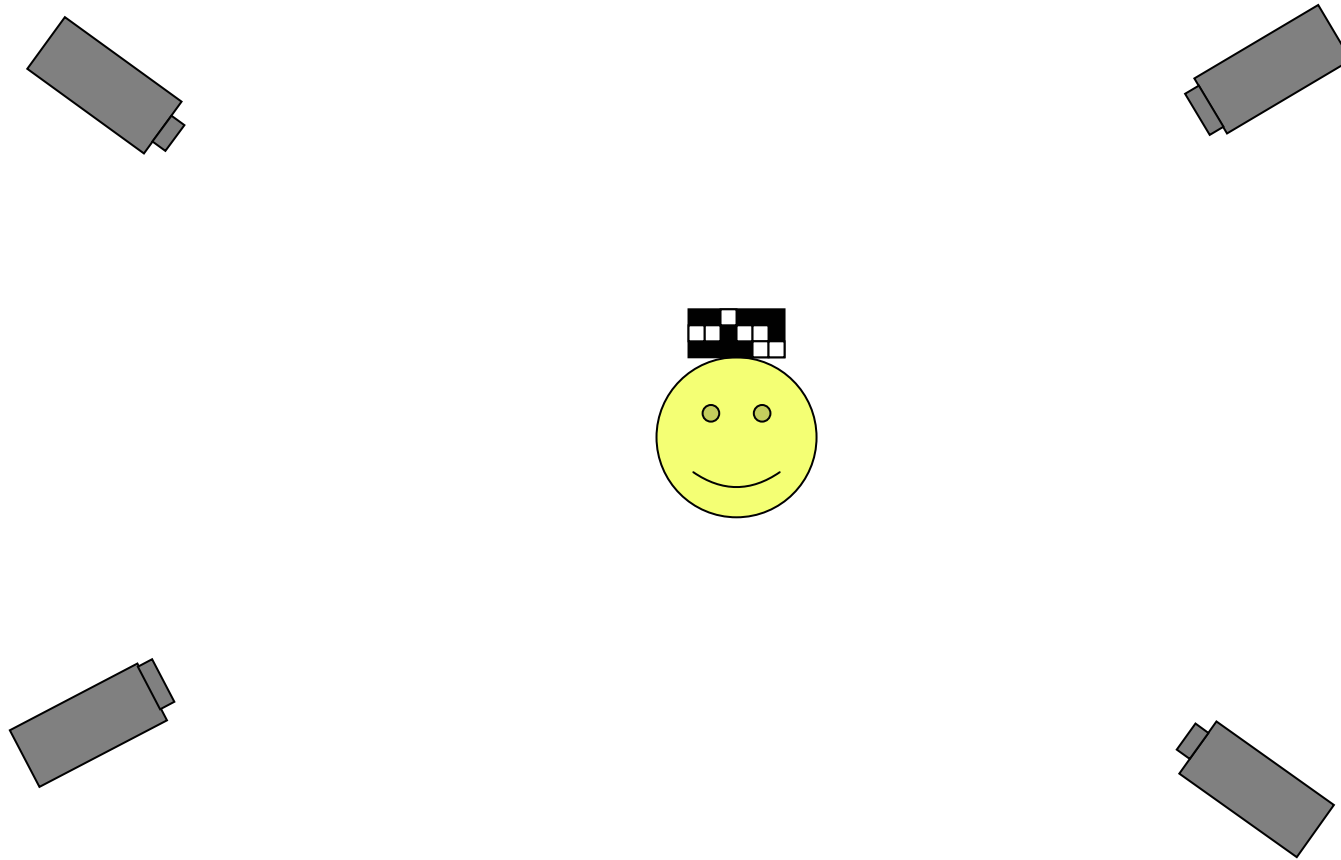


2. Spatial Scan

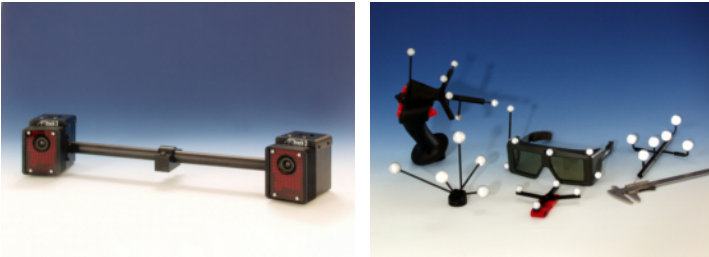
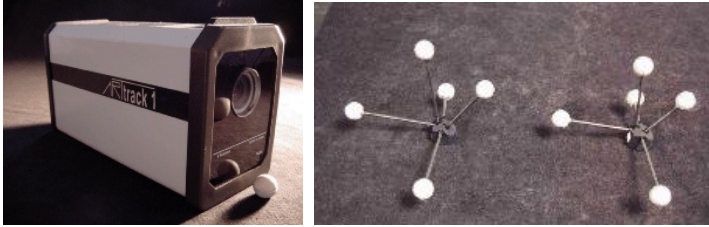
- Outside-In
- Inside-Out



2.1 Outside-In Optical Trackers



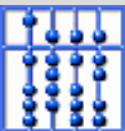
2.1 Outside-In Optical Trackers



A.R.T. GmbH: ARTrack1, smARTrack1

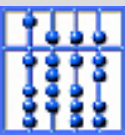


Northern Digital (NDI): Polaris, Optotrak

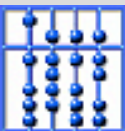
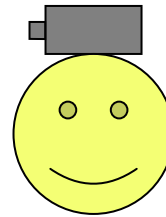
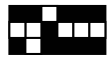


2.1 Outside-In Optical Trackers

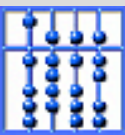
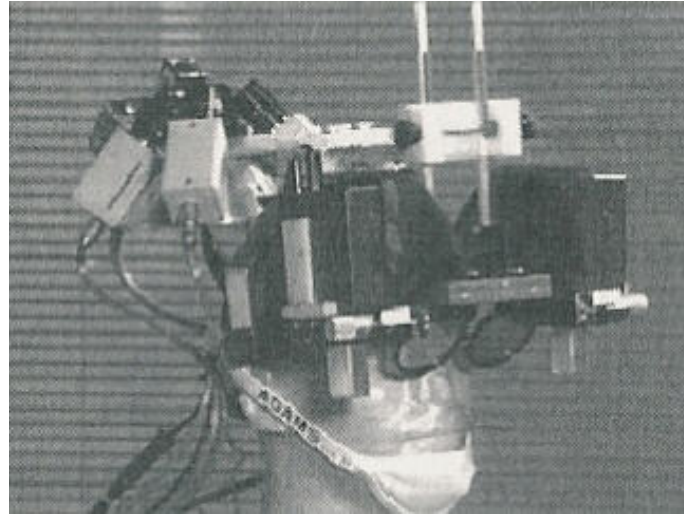
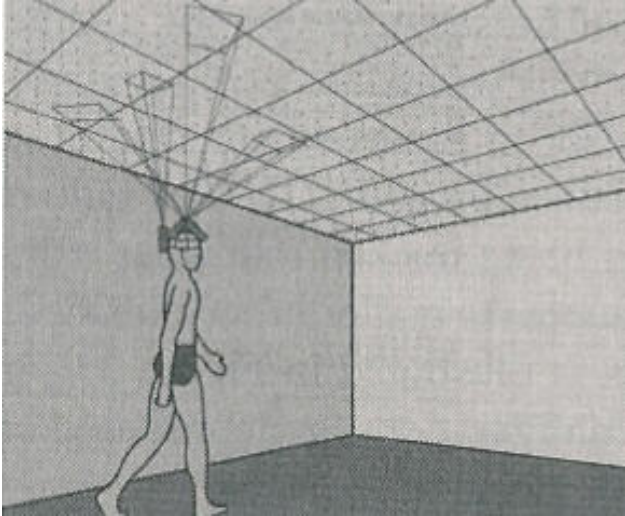
- Pros
- Cons



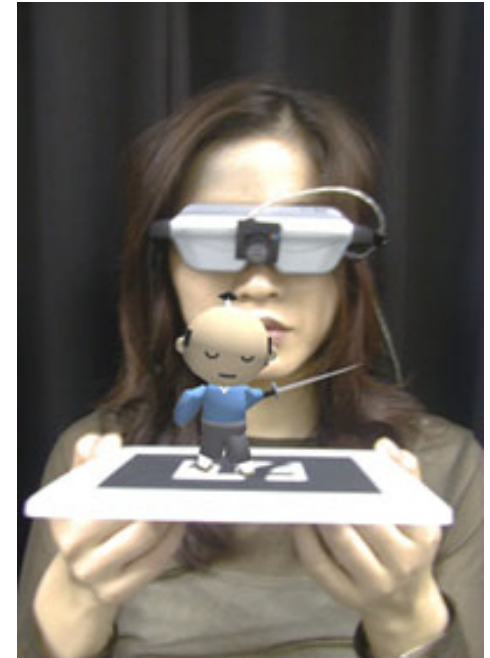
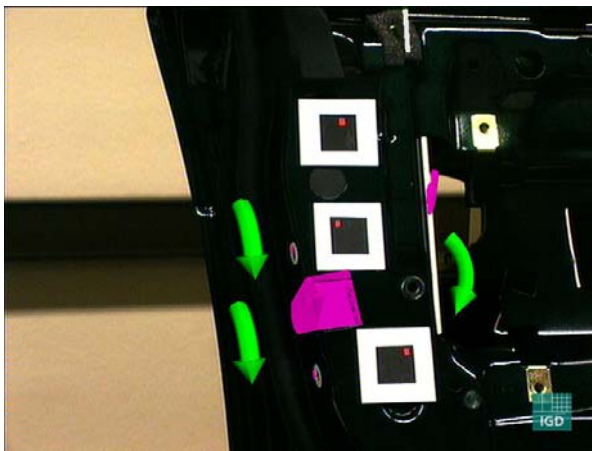
2.2 Inside-Out Optical Trackers



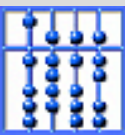
2.2 Inside-Out Optical Trackers



2.2 Inside-Out Optical Trackers

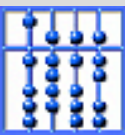


UNC, USC, IGD-FhG, ARVIKA, AR-Toolkit, Augmented Solutions



2.2 Inside-Out Optical Trackers

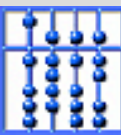
- Pros
- Cons



2.3 Optical Tracking

- Evaluation and summary

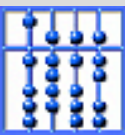
| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|---------|-------|-----------|------------|-------|------------|---------------|
| Optical | - | ++ | - | + | n | line of sight |



3. Inertial Sensing

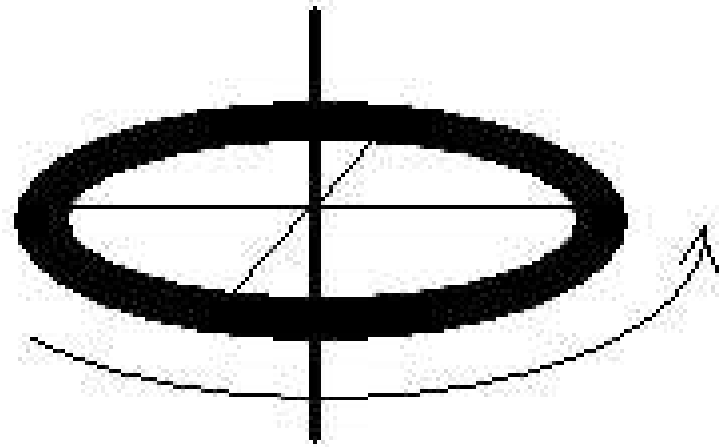
Inertia = resistance of matter to any change in the momentum of a body

- Gyroscopes
- Accelerometers



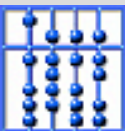
3.1 Gyroscopes

- Spinning wheel tries to conserve its angular momentum
- → Object-stabilized axis of rotation
- External rotational forces can be measured relative to the rotation axis

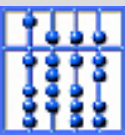


<http://www.howstuffworks.com/gyroscope.htm>

<http://www.accs.net/users/cefpearson/gyro.htm>

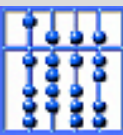


3.1 Gyroscopes



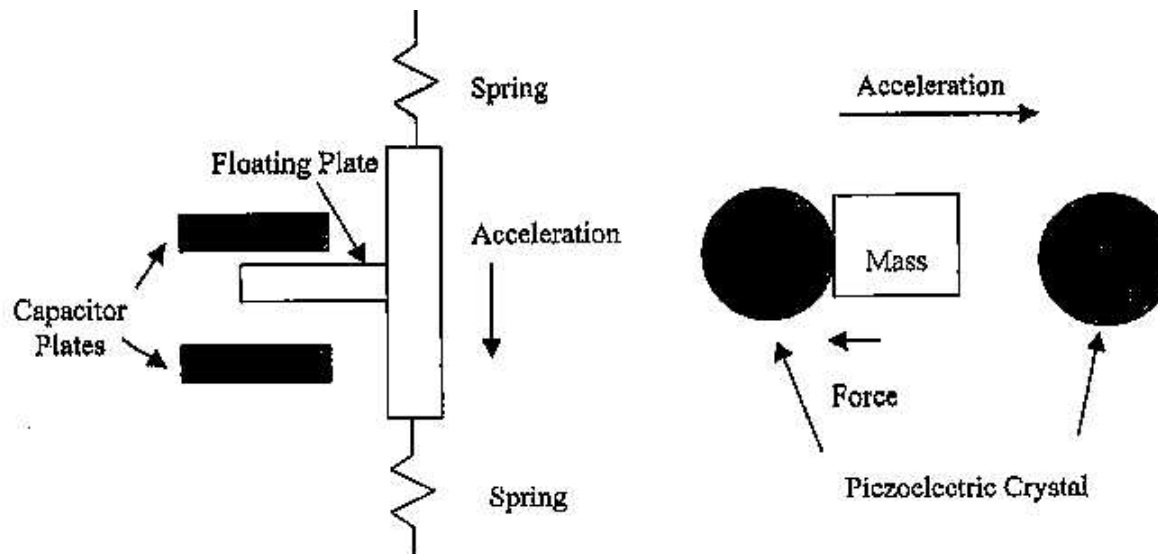
3.1 Gyroscopes

- Pros
 - Sourceless
 - Untethered
 - Wide range
 - Low latency
- Cons
 - Drift
 - Disturbed by gravity
 - Sensitive to vibration



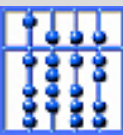
3.2 Accelerometers

- Mass tries to maintain its speed
- → Object-stabilized reference point
- External translations can be measured relative to the reference point (linear acceleration)



3.2 Accelerometers

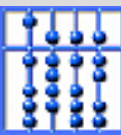
- Pros
 - Sourceless
 - Untethered
 - Wide range
 - Low latency
- Cons
 - Drift
 - Disturbed by gravity
 - Inaccurate for slow position changes



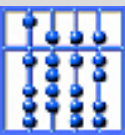
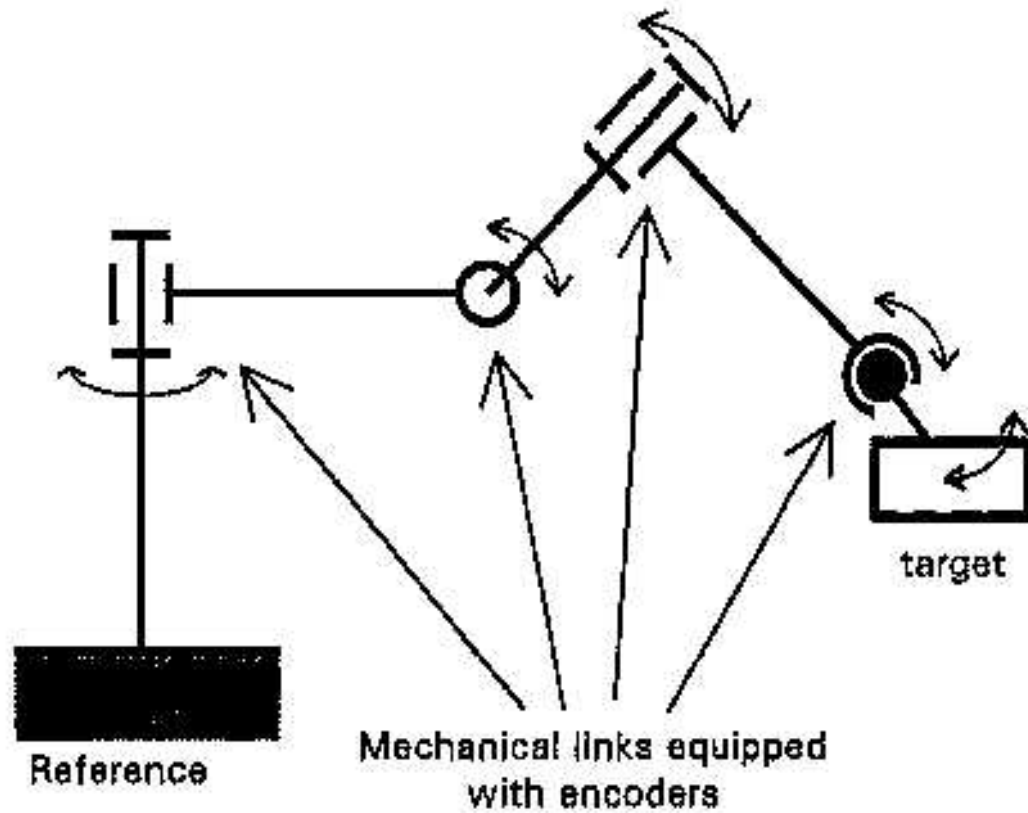
3.3 Inertial Tracking

- Evaluation and summary

| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|----------|-------|-----------|------------|-------|------------|---------|
| Inertial | ++ | - | ++ | ++ | n | drift |

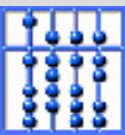


4. Mechanical Trackers



4. Mechanical Trackers

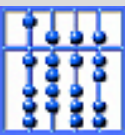
- Pros
- Cons



4. Mechanical Trackers

- Evaluation and summary

| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|------------|-------|-----------|------------|-------|------------|--------------------|
| Mechanical | + | ++ | ++ | -- | y | restricted motions |

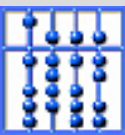


5. Direct Field Sensing

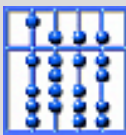
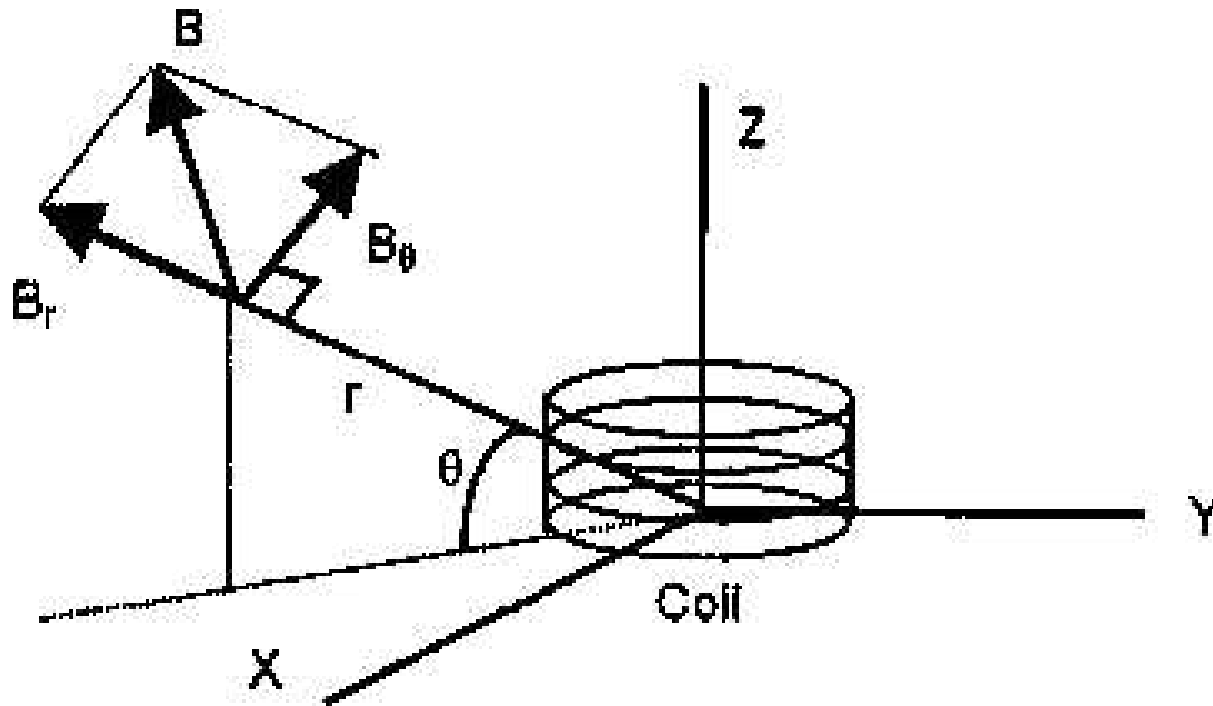
- Magnetic Field Sensing

<http://www.uni-weimar.de/architektur/InfAR/lehre/Course01/track4.html>

- Sinusoidal Alternating Current (AC)
- Pulsed Direct Current (DC)
- Compass
- Inclinometers (Gravitation)



5.1 Magnetic Field Sensing

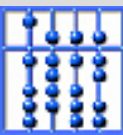


5.1 Magnetic Tracking

AC-Current



Ascension: Flock of Birds



5.1 Magnetic Tracking

DC-Current



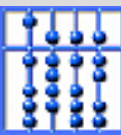
Polhemus: FASTRAK



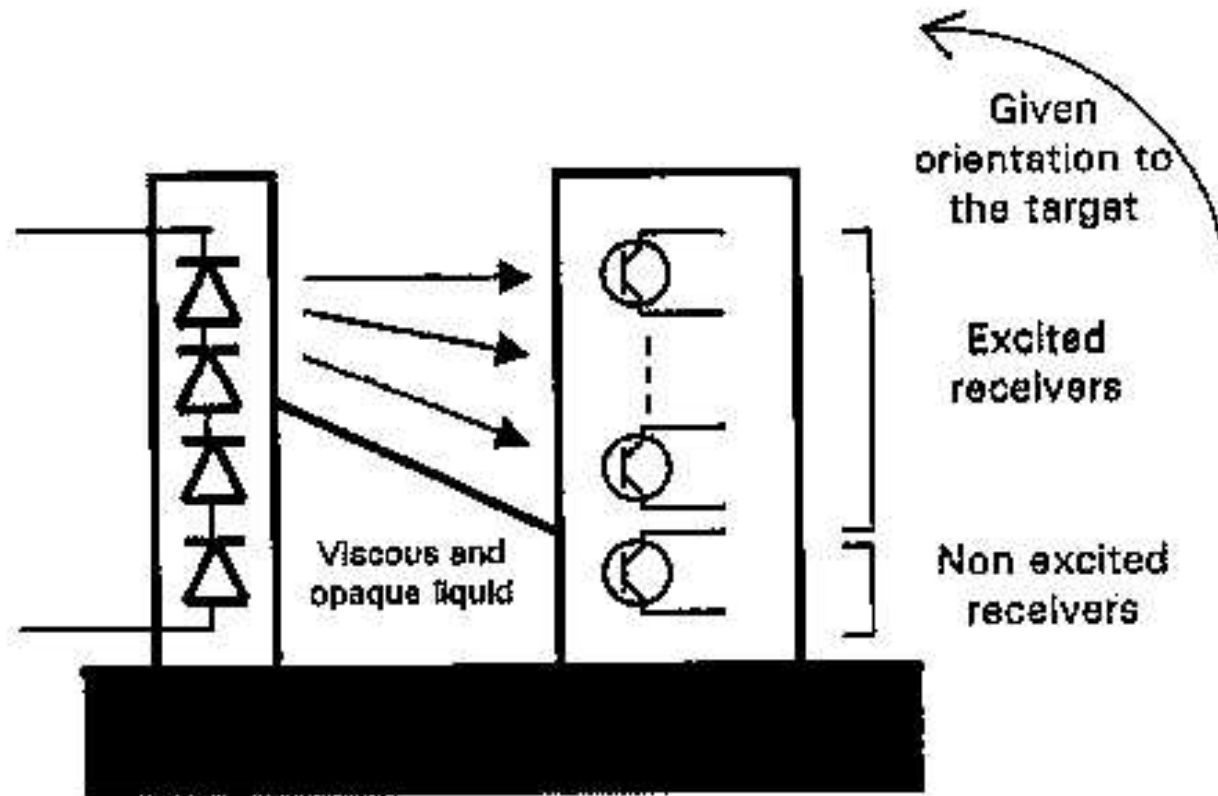
5.1 Magnetic Tracking

- Evaluation and summary

| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|----------|-------|-----------|------------|-------|------------|-----------|
| Magnetic | + | - | ++ | -- | y | no metals |



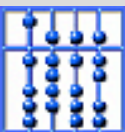
5.2 Inclinometer (Gravity)



5.3 Inclinometer + Compass

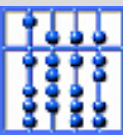
- Evaluation and summary

| | Speed | Precision | Robustness | Range | Teathered? | Comment |
|------------------------|-------|-----------|------------|-------|------------|----------------------------|
| Compass + Inclinometer | - | -- | + | ++ | n | no metals, earth magnetism |



6. Hybrid Systems

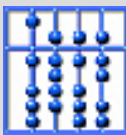
- GPS + Compass + Inclinometer
- Magnetic + Inertial
- Ultrasound + Inertial



6. Hybrid Systems

- Inside-Out / Inertial -

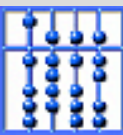
| | Inside-Out | Inertial | Hybrid |
|------------------------------|--|---|--------------------------------------|
| Characteristics / Advantages | Measures orientation and position, accurate | Compact, no occlusion problems, stable solution for pose position, small lag (Kalman) | Compact, accurate, small lag, stable |
| Limitations | Unstable, resolution degrading with distance | Long term orientation drift | Occlusion sensitive |



6. Hybrid Systems

- Magnetic / Videometric -

| | Magnetic | Videometric | Hybrid |
|------------------------------|--|--|--|
| Characteristics / Advantages | Robust, no occlusion sensitivity, inexpensive, fast, orientation plus position | Accurate, insensitive to metals, orientation plus position | Accurate, robust, insensitive to environment and occlusions, orientation plus position |
| Limitations | Inaccurate, sensitive to electromagnetic noise and ferromagnetic objects | Unstable, sensitive to occlusions, lag due to processing | Lag due to processing of videometric data |



7. Discussion

- Accuracy
- Resolution
- Real-Time
- Scalability
- Generality

Vergleich von Trackingmodalitäten

| | G | P | R | W | K | Einschränkungen |
|-----------------|----|----|----|----|---|--------------------------|
| Optisch | - | ++ | -- | + | N | Sichtlinie |
| Magnetisch | + | - | ++ | -- | J | keine Metalle |
| Akustisch | + | - | + | - | N | mehrfaches Echo |
| Inertial | ++ | - | ++ | ++ | N | Drift |
| Kompass+Neigung | - | -- | + | ++ | N | keine Metalle, Erdmagn. |
| dGPS | -- | -- | + | ++ | N | Sichtlinie zu Satelliten |
| Mechanisch | + | ++ | ++ | -- | J | eingesch. Bewegungen |

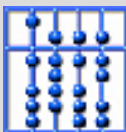
G = Geschwindigkeit, Verzögerung

P = Präzision, Wiederholbarkeit

R = Robustheit bei schnellen Bewegungen

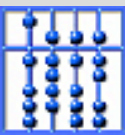
W = Weiträumigkeit

K = verkabelt?

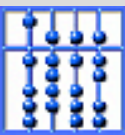


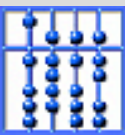
- Last slide -

Thank you!



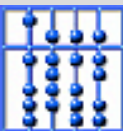
Additional information (not covered in class)





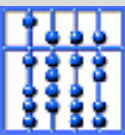
Summary: Ultrasound

| | |
|--------------------------|--|
| Physical phenomenon | Acoustic pulse propagation |
| Measured variable | Time of flight |
| DOF | 2, 3, 6 |
| Accuracy | 0.5 - 6 mm / 0.1 - 0.6 degree |
| Resolution | 0.1 - 0.5 mm / 0.02 - 0.5 degree |
| Update rate | 25 - 200 Hz |
| Range / Orientation span | 250 - 4500 mm / 45 degrees |
| Advantages | Small, light, no distortion |
| Limitations | Sensitive to temperature, pressure, humidity, occlusion and ultrasonic noise. Low update rate. |



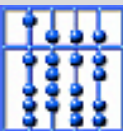
Summary: GPS

| | |
|--------------------------|--|
| Physical phenomenon | Line-of-sight radio signal |
| Measured variable | Time of arrival ranging |
| DOF | 2 |
| Accuracy | ~100 m hor, 156 m vert (SPS), 10 times better for PPS much smaller for differential GPS |
| Resolution | 25.46 m (SPS), 8.51 m (PPS) |
| Update rate | < 1000 Hz |
| Range / Orientation span | Global |
| Advantages | Worldwide availability, uniform accuracy |
| Limitations | Sensitive to occlusion, currently suited to large scale tracking |



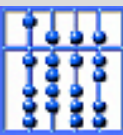
Summary: Outside-In Optical Trackers

| | |
|--------------------------|--|
| Physical phenomenon | Projection of an optical pattern |
| Measured variable | Shape of target features in a video image |
| DOF | 3, 6 |
| Accuracy | 0.1 - 0.45 mm / 1/2800 of camera's field of view / 2 - 15 mrad |
| Resolution | 1/1000 to 1/65536 of camera's field of view / 0.01 - 0.1 mm |
| Update rate | 50 - 400 Hz |
| Range / Orientation span | Up to 6000 mm / 8.8 - 27 degrees |
| Advantages | Good update rate |
| Limitations | Sensitive to optical noise, spurious light, ambiguity of surface and occlusion |



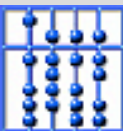
Summary: Inside-Out Optical Trackers

| | |
|--------------------------|--|
| Physical phenomenon | Spatial scan |
| Measured variable | Beam position of sweep detection |
| DOF | 3, 6 |
| Accuracy | 2 - 25 mrad |
| Resolution | Diminishes with range of operation |
| Update rate | Up to 1500 Hz |
| Range / Orientation span | In principle, scalability is unlimited (UNC tracker) |
| Advantages | Better resolution than outside-in systems, scalability |
| Limitations | Sensitive to occlusion. |



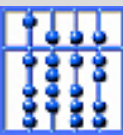
Summary: Gyroscopes

| | |
|--------------------------|--|
| Physical phenomenon | Inertia |
| Measured variable | Orientation between the axis of rotation of the wheel and an axis attached to the object |
| DOF | 1 - 3 |
| Accuracy | 0.2 degrees, static drift 0.01 deg/s, dynamic drift 0.25 deg/s |
| Resolution | 0.032 degree |
| Update rate | 50 Hz |
| Range / Orientation span | 132 degrees in yaw, 360 degrees in roll |
| Advantages | No reference model needed |
| Limitations | Error increases with time since measurements are relative to previous ones --- "drift" |



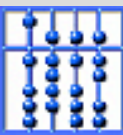
Summary: Accelerometers

| | |
|--------------------------|---------------------------------------|
| Physical phenomenon | Mass inertia |
| Measured variable | Depends on implementation |
| DOF | 1 |
| Accuracy | 0.0075 g |
| Resolution | 0.0001 g |
| Update rate | Up to 1500 Hz |
| Range / Orientation span | Unlimited |
| Advantages | No reference needed; light |
| Limitations | Errors in position due to integration |



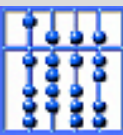
Summary: Mechanical Trackers

| | |
|--------------------------|---|
| Physical phenomenon | Mechanical linkages |
| Measured variable | Angle measured by rotating encoder(s) |
| DOF | 1 - 6 |
| Accuracy | 0.1 - 2.5 mm |
| Resolution | 0.05 - 1.5 mm / 0.15 - 1 degree |
| Update rate | Depends on data acquisition capabilities (~ 300 Hz) |
| Range / Orientation span | 1.8 m / 40 degrees; limited by the weight and deformation of the mechanical structure with distance from reference. |
| Advantages | Good accuracy, precision, update rate, and lag. No environmental linked error. |
| Limitations | Encoder resolution, limitation of motion. |



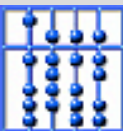
Summary: Magnetic Trackers

| | |
|--------------------------|---|
| Physical phenomenon | Magnetic coupling of two coils, one of which is fed with sinusoidal alternating current |
| Measured variable | Amplitude at the output of the receiving cell |
| DOF | 6 |
| Accuracy | 0.8 mm - 25 mm (75 mm - 5 m) / 0.15 - 3 degrees |
| Resolution | 0.04 mm - 0.8 mm / 0.025 - 0.1 degree |
| Update rate Lag | 15 - 120 Hz divided by number of emitters 4- 20 ms |
| Range / Orientation span | Up to 5000 mm / 360 degrees |
| Advantages | No occlusion problem, high update rate, low lag, inexpensive, small |
| Limitations | Small working volume, distortion of accuracy with distance, sensitive to electromagnetic noise and metallic objects, eddy currents by induction in metal sheets |



Summary: Compasses

| | |
|--------------------------|---------------------------|
| Physical phenomenon | Magnetic field sensing |
| Measured variable | Depends on implementation |
| DOF | 1 |
| Accuracy | Up to 1 degree |
| Resolution | 5 nT (nano-Teslas) |
| Update rate | 300 Hz |
| Range / Orientation span | |
| Advantages | No reference needed |
| Limitations | Unknown |



Summary: Inclinometers

| | |
|--------------------------|---|
| Physical phenomenon | Gravitational field sensing |
| Measured variable | Relative heights; capacitance |
| DOF | 1 |
| Accuracy | Up to 0.1 degrees |
| Resolution | Up to 0.03 degrees |
| Update rate | Up to 40 Hz |
| Range / Orientation span | |
| Advantages | No reference needed |
| Limitations | Reaction time degraded by viscosity of liquid |

