

Einführung in die Erweiterte Realität

- 9. Tracker -

Gudrun Klinker

Jan 13, 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.

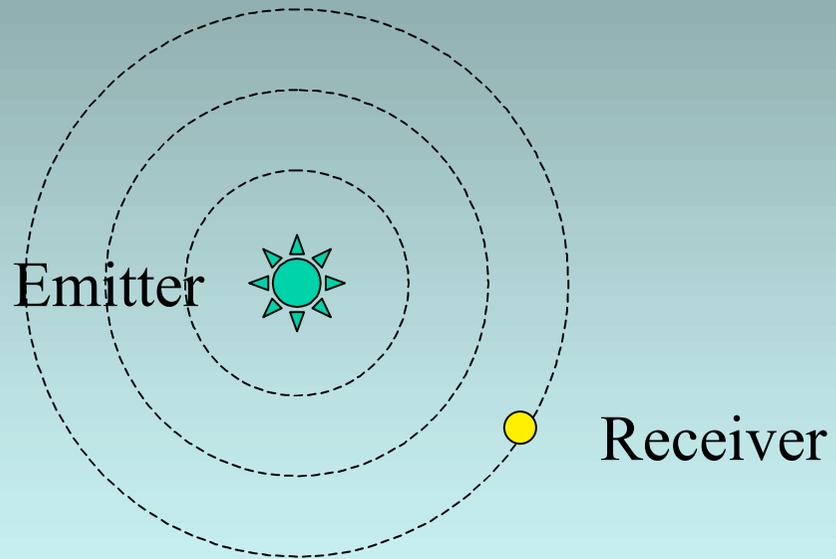
Agenda

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

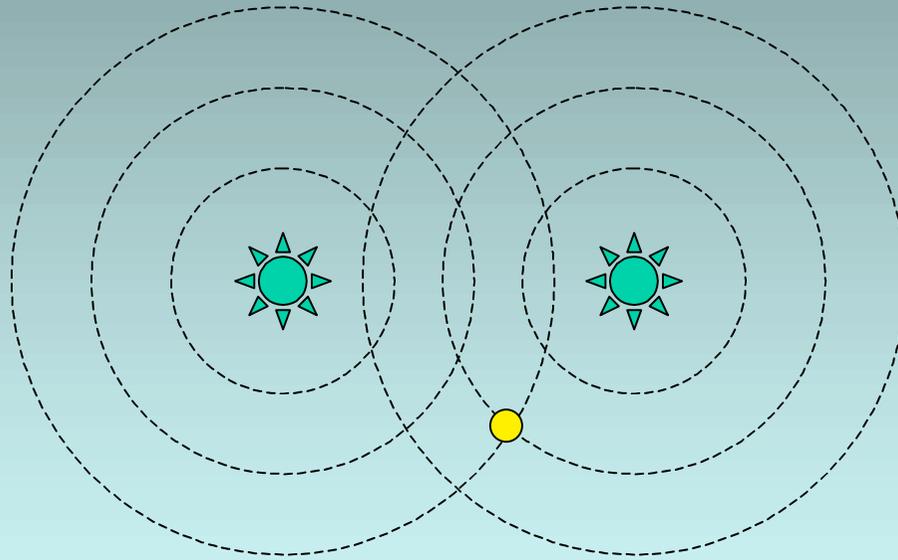
1. Time-Frequency Measurements (Time of Flight: TOF)

- Ultrasound
- GPS

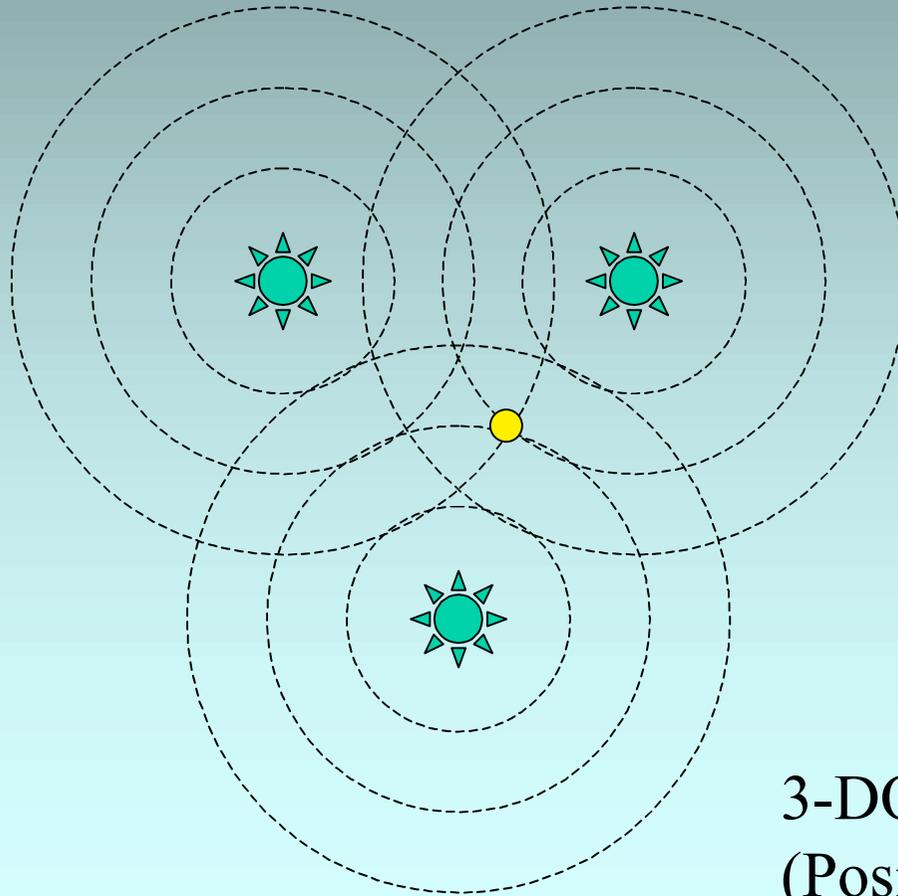
1.1 Ultrasound



1.1 Ultrasound

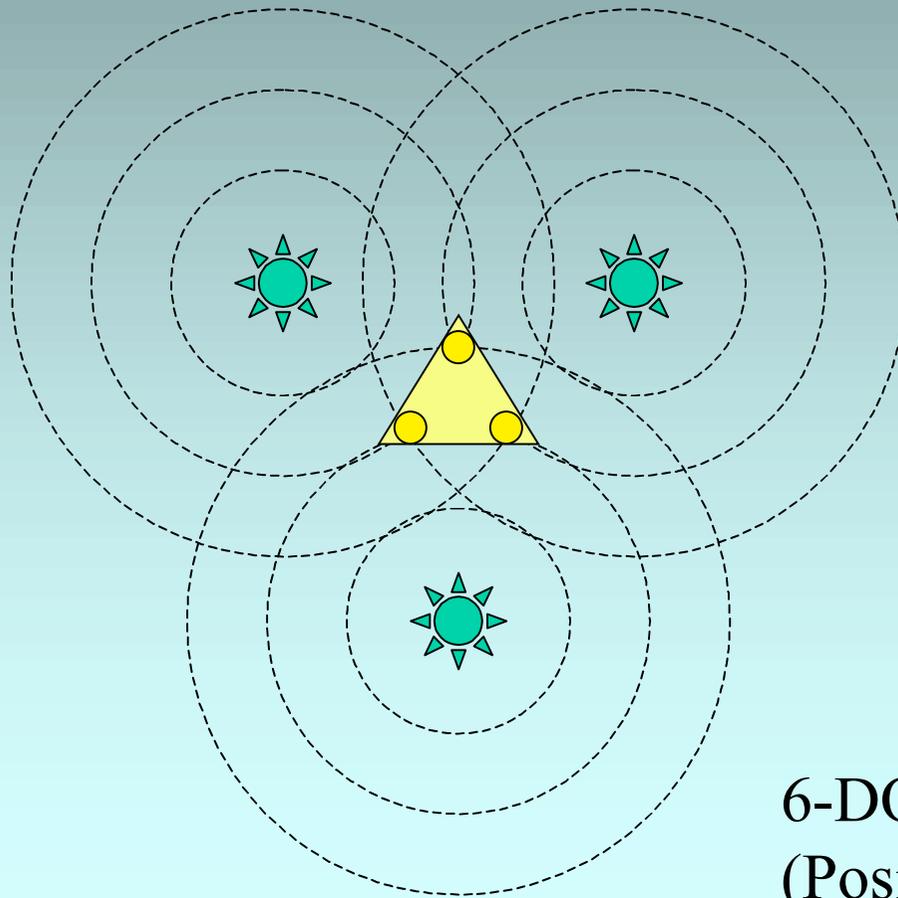


1.1 Ultrasound



3-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

Introduction

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

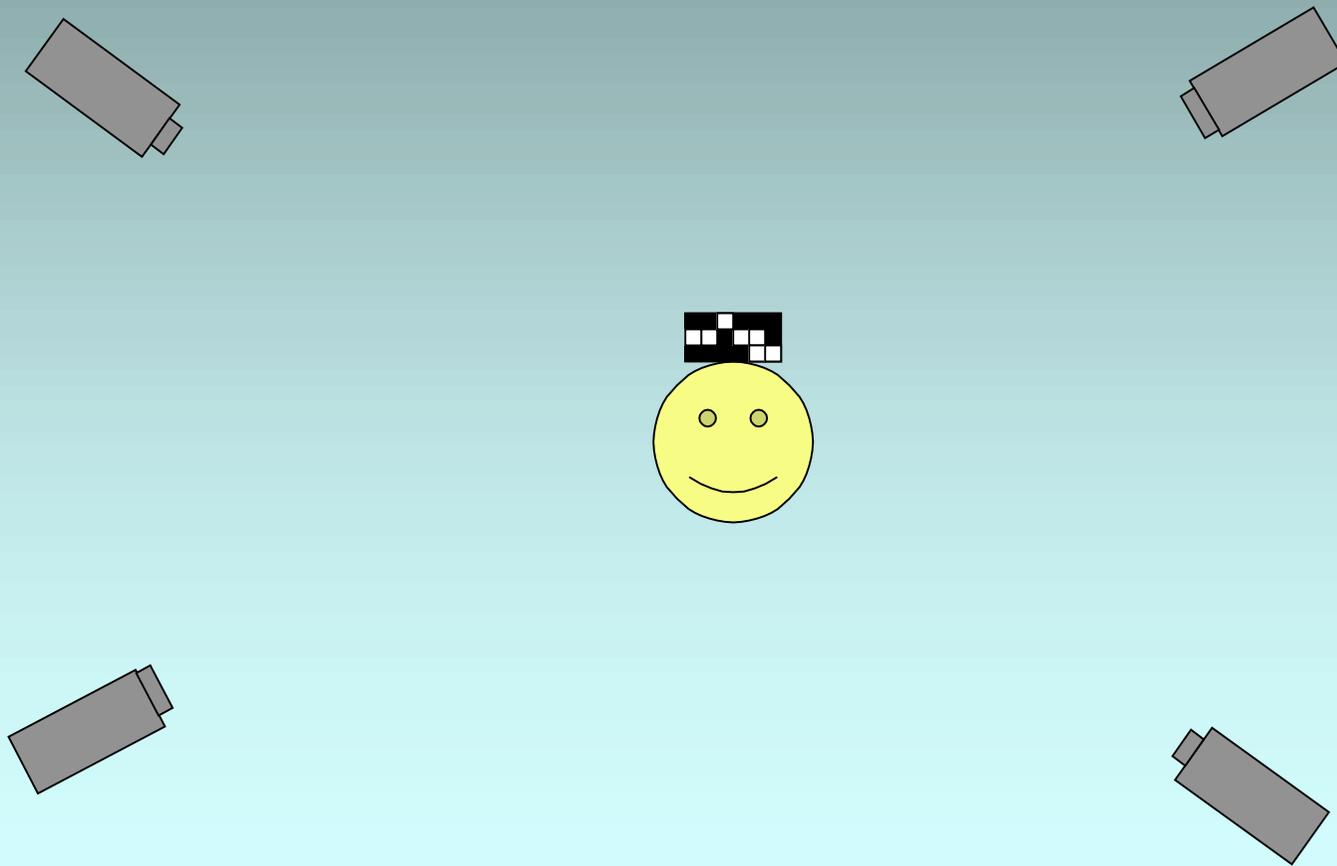
- Evaluation and summary

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

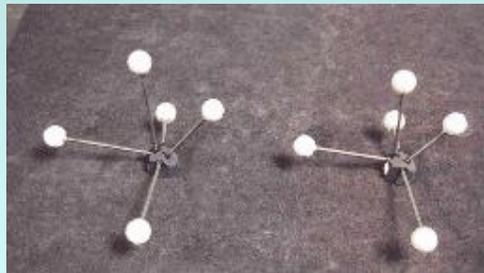
2. Spatial Scan

- Outside-In
- Inside-Out

2.1 Outside-In Optical Trackers



2.1 Outside-In Optical Trackers

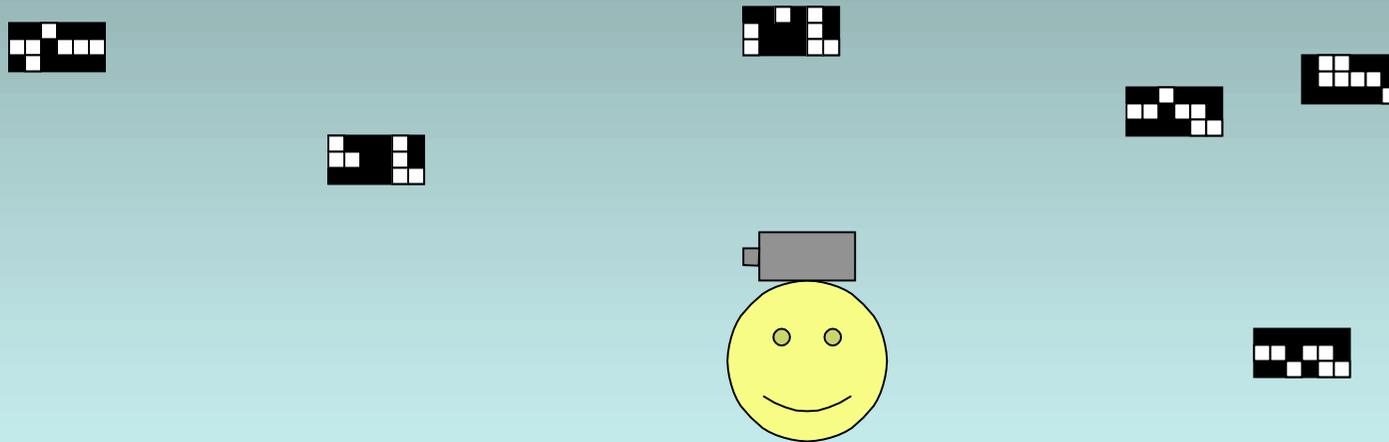


A.R.T. GmbH

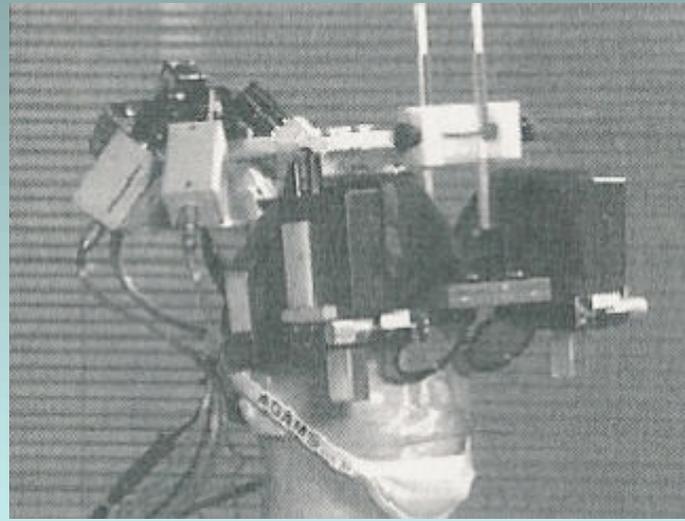
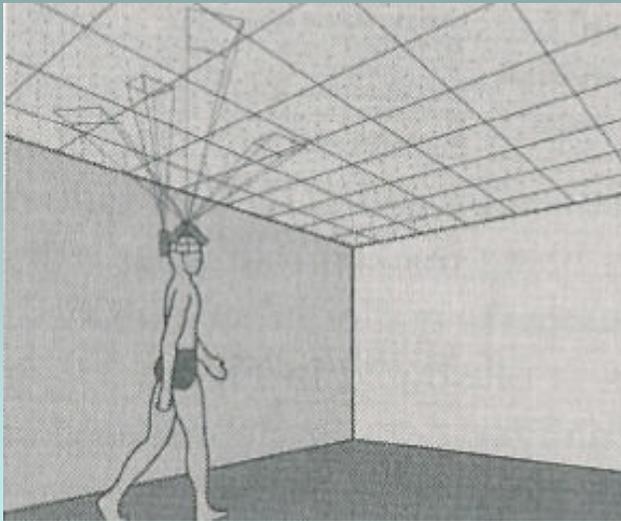
2.1 Outside-In Optical Trackers

- Pros
- Cons

2.2 Inside-Out Optical Trackers



2.2 Inside-Out Optical Trackers



2.2 Inside-Out Optical Trackers



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

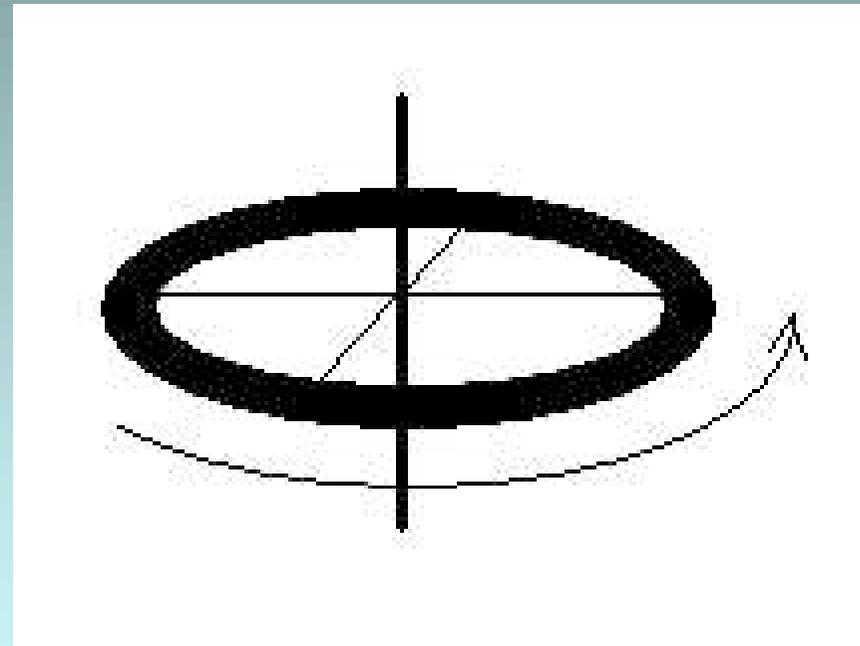
3. Inertial Sensing

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

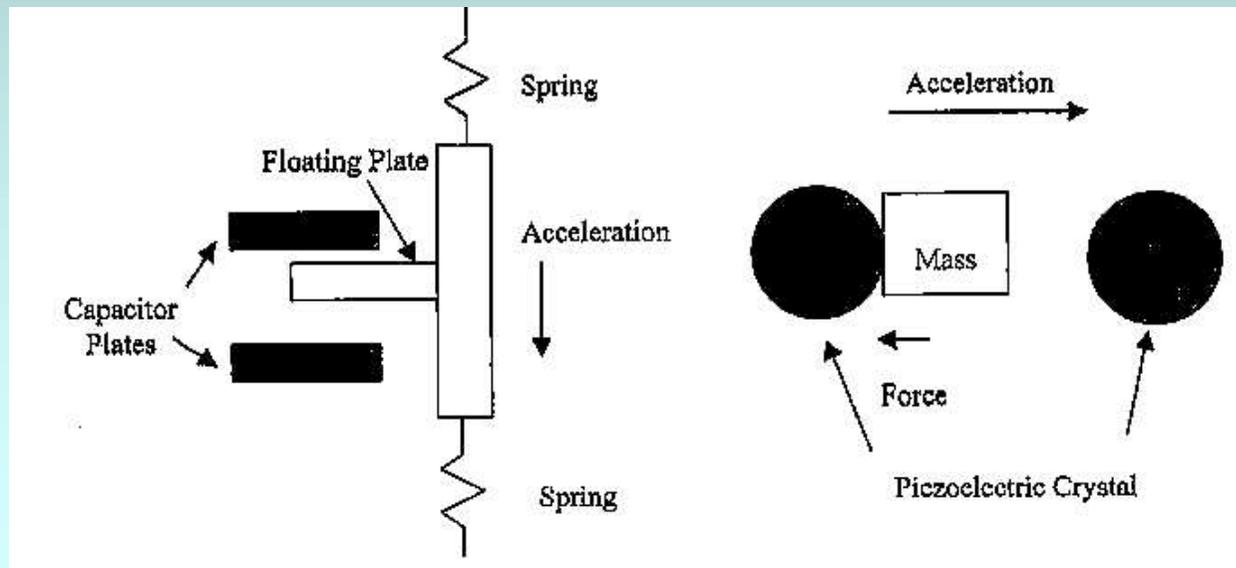


3.1 Gyroscopes

- 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

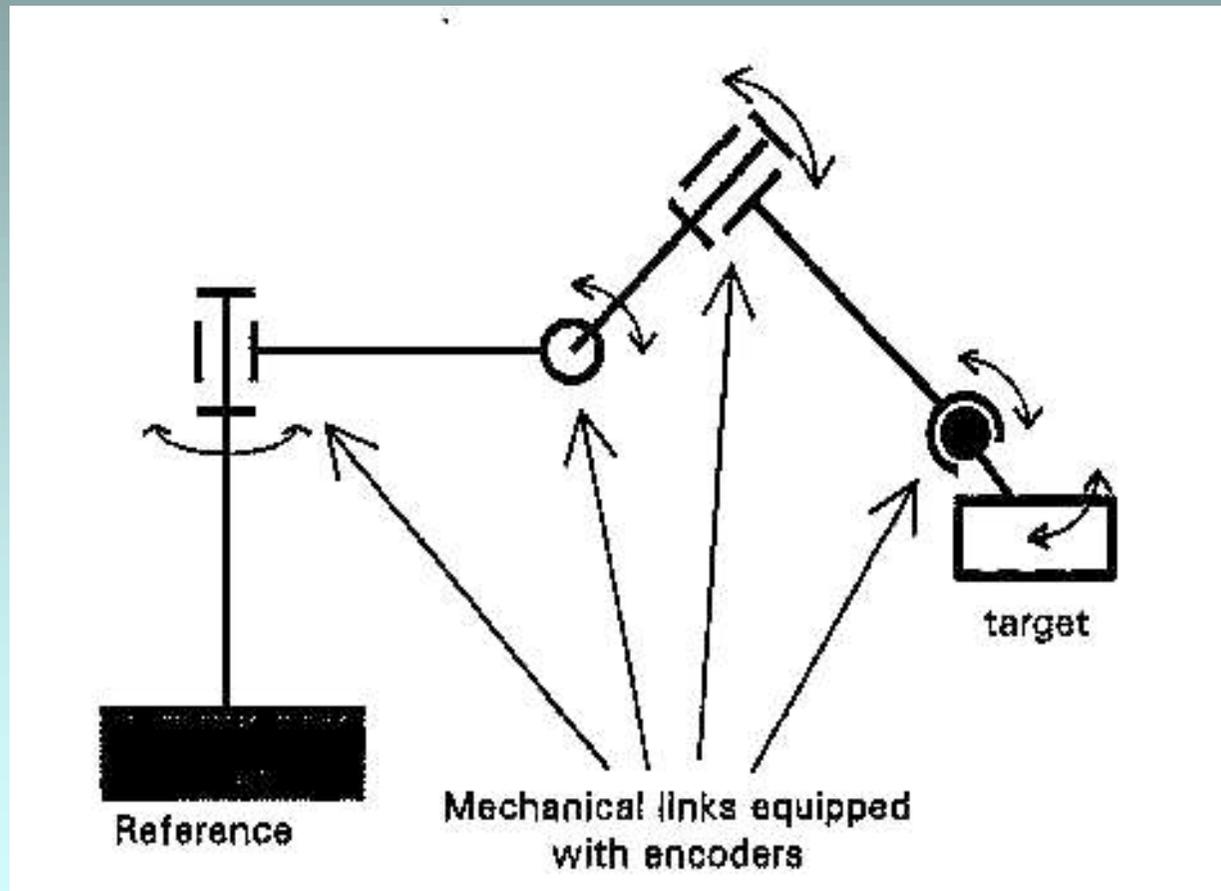
- Pros
 - Sourceless
 - Untethered
 - Wide range
 - Low latency
- Cons
 - Drift
 - Disturbed by gravity
 - Inaccurate for slow position changes

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

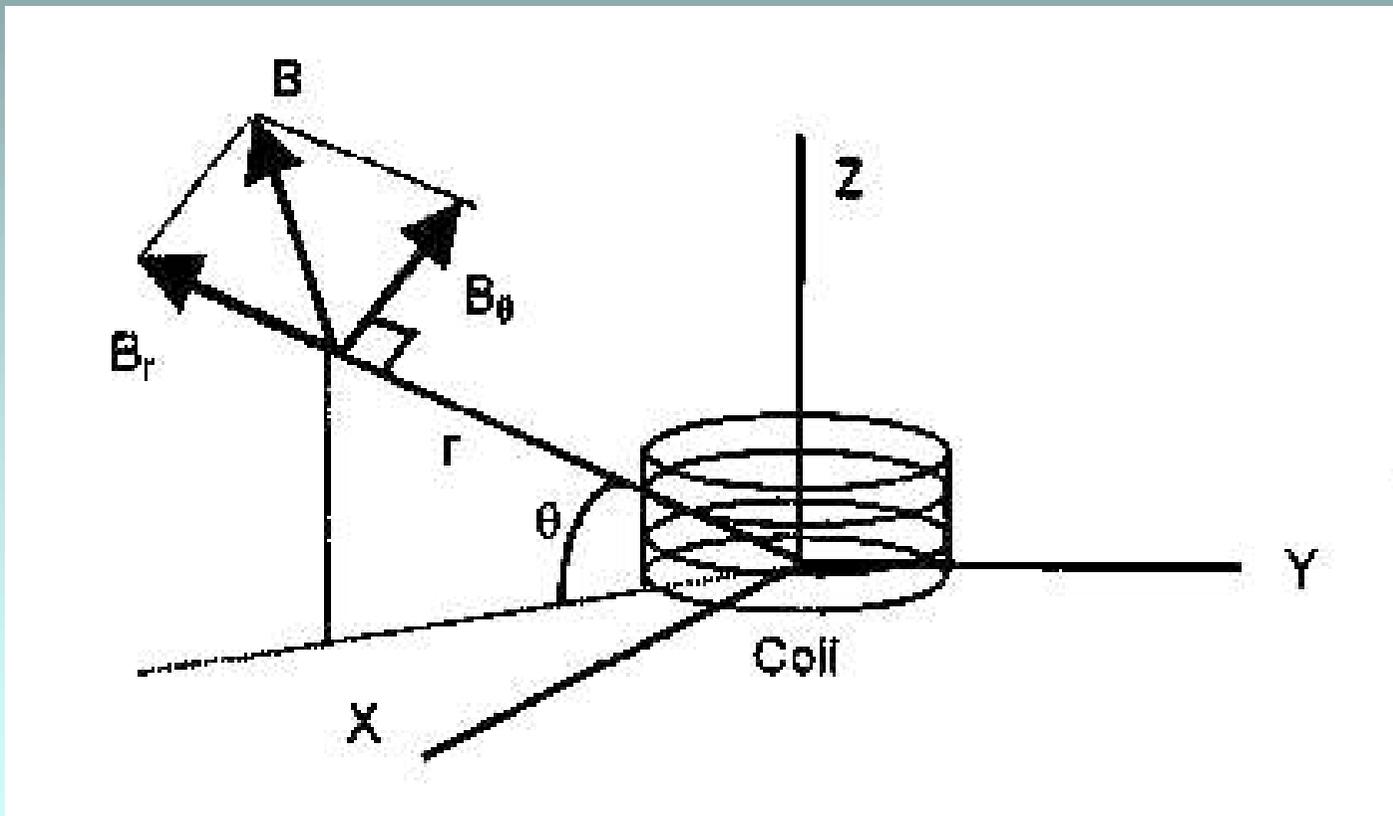
5. Direct-Field Sensing

- Magnetic Field Sensing

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

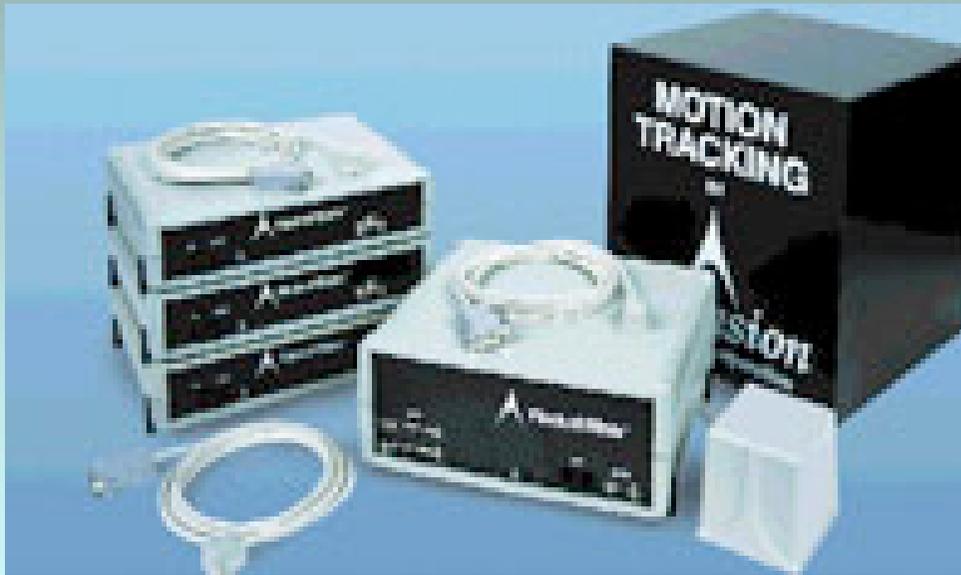
- Sinusoidal Alternating Current (AC)
 - Pulsed Direct Current (DC)
 - Compass
- Inclinometers (Gravitation)

5.1 Magnetic Field Sensing



5.1 Magnetic Tracking

AC-Current



Ascension: Flock of Birds

5.1 Magnetic Tracking

DC-Current



Polhemus: FASTRAK

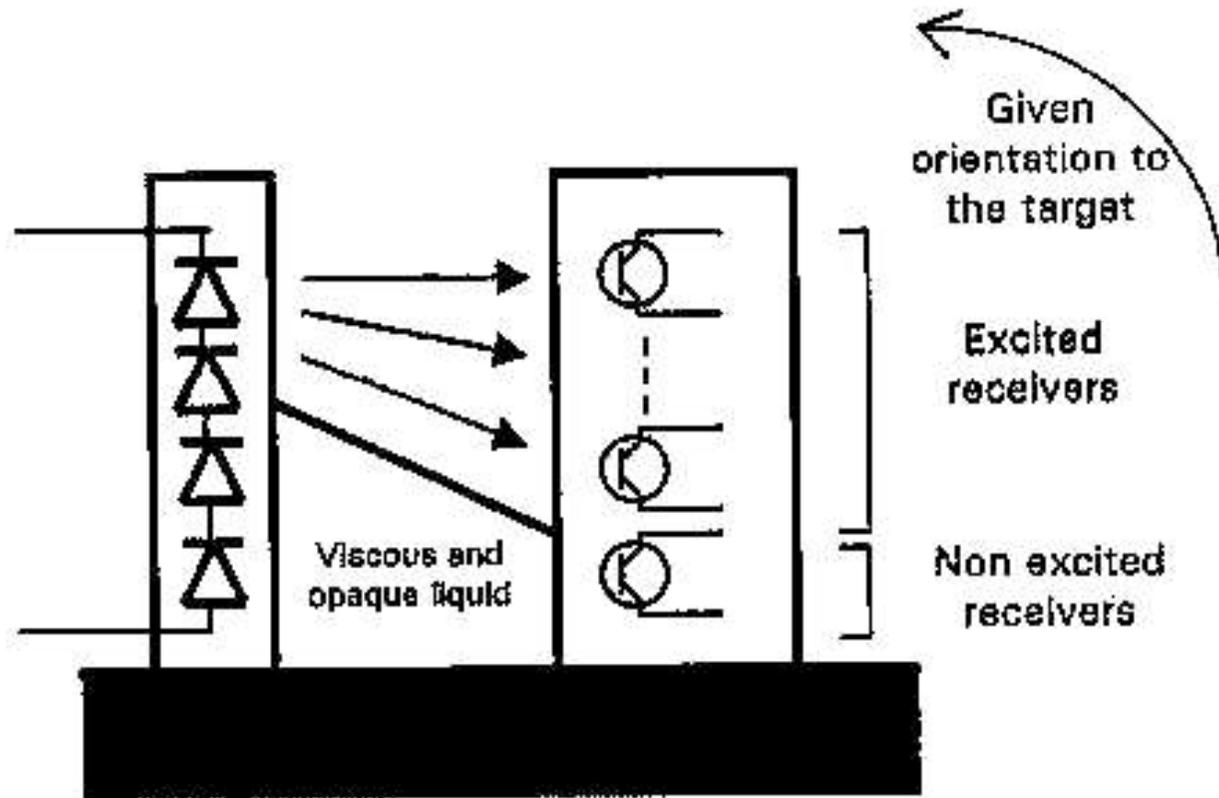


5.1 Magnetic Tracking

- Evaluation and summary

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

5.2 Inclinator (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

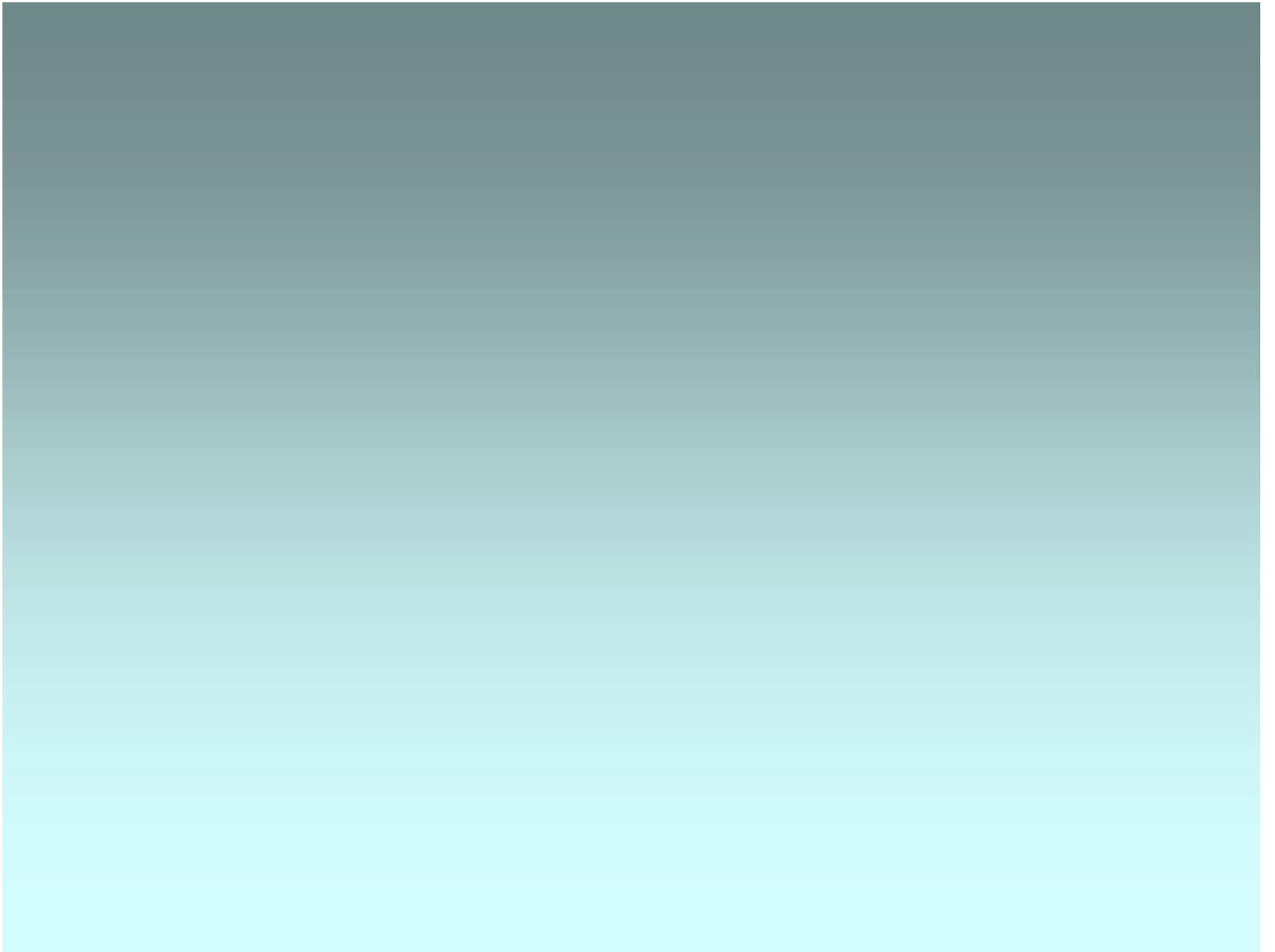
G = Geschwindigkeit, Verzögerung

P = Präzision, Wiederholbarkeit

R = Robustheit bei schnellen Bewegungen

W = Weitläufigkeit

K = verkabelt?



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	15 - 120 Hz divided by number of emitters
Lag	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