Module IN 2018

Introduction to Augmented Reality

Prof. Gudrun Klinker

Tracking Devices

SS 2018

Literature

- J.P. Rolland, L.D. Davis and Y. Baillot: *A Survey of Tracking Technology for Virtual Environments*,, in Fundamentals of Wearable Computers and Augmented Reality (chap. 3), 2001, pp.67-112.
- Greg Welch, Eric Foxlin: *Motion Tracking: No Silver Bullet, but a Respectable Arsenal*. IEEE Computer Graphics and Applications 22(6): 24-38 (2002)

Agenda

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

1. Placement Strategies

Sensors

- Mobile:
  - Wide range
  - Dynamic motion
- Stationary:
  - Precalibrated (precise)
  - Limited range

Targets

- Mobile
  - Many
  - Cheap
  - Natural???
- Stationary
  - Must be set up (ugly?)

Sensors \ Targets	Mobile	Stationary
Mobile	Inside-In	Inside-Out
Stationary	Outside-In	Outside-Out

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1. Placement strategies
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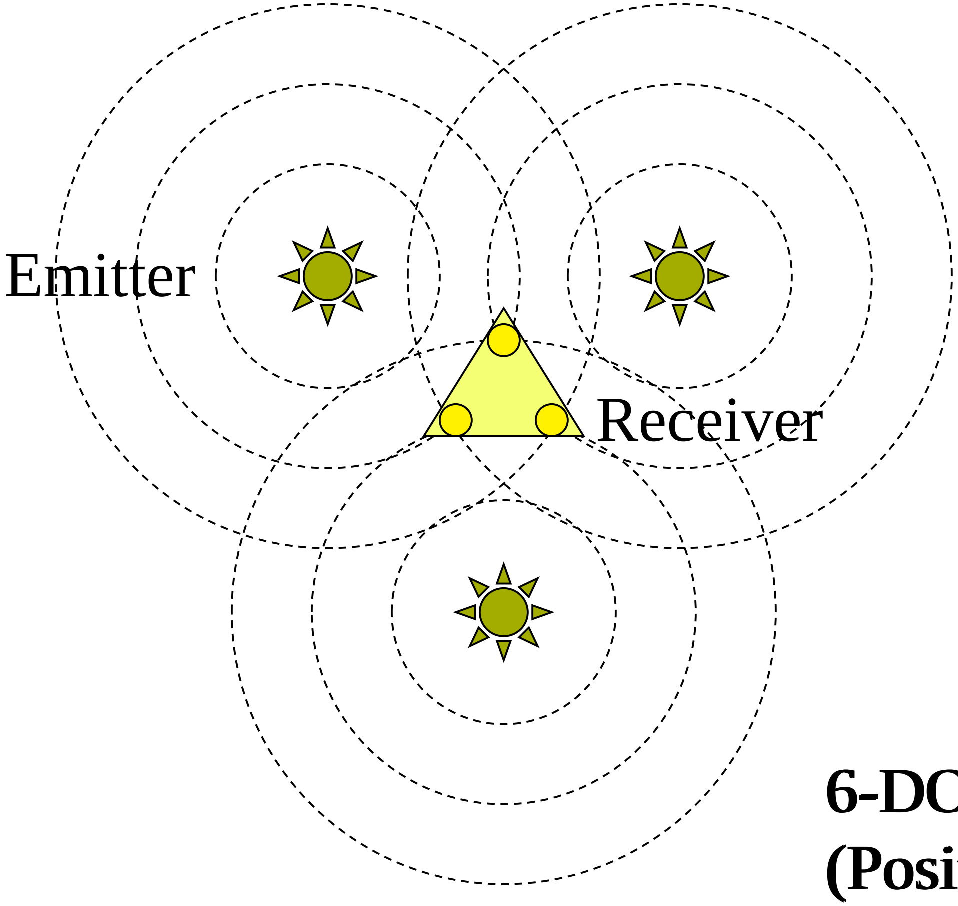
2. Time-Frequency Measurements

→ 2.1 Ultrasound

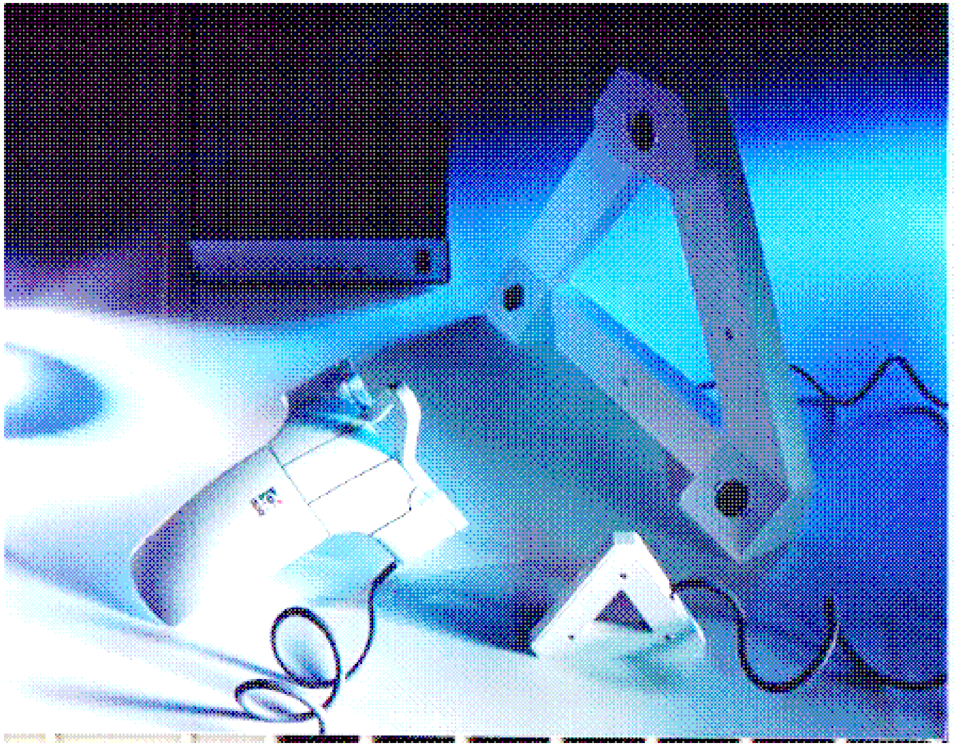
2.2 GPS

2.1 Ultrasound



6-DOF Tracker
(Position)and Orientation)

2.1 Ultrasound



Logitech

Intersense

2.1 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 (?)

2.1 Ultrasound

Evaluation and Summary

	Speed	Precision	Robustness	Range	Tethered?	Comment
Ultrasound	++	-	++	+	y / n	echoes

Evaluation Criteria:
- Speed: Rate, Lag
- Precision (Repeatability, low Variance), Accuracy (small Discrepancy)
- Robustness w.r.t. fast Motions
- Range
- Tethered

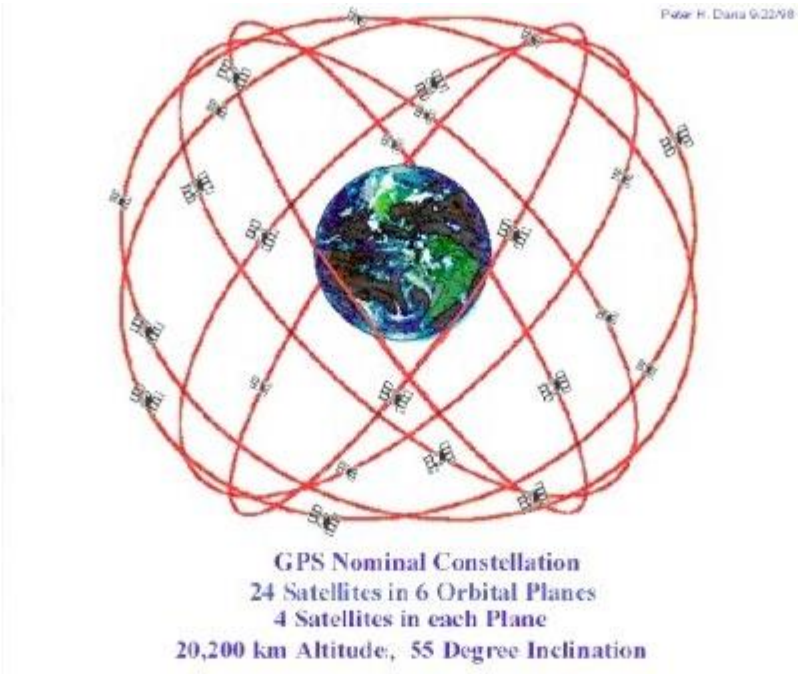
2. Time-frequency Measurements

2.1 Ultrasound

→ 2.2 GPS

2.2 GPS

- Time and position-encoded signal (radio waves) from satellites with atomic clocks
- 24 satellites in 6 different orbits (4 per orbit) (not geostationary, but semi-synchronous 12h)

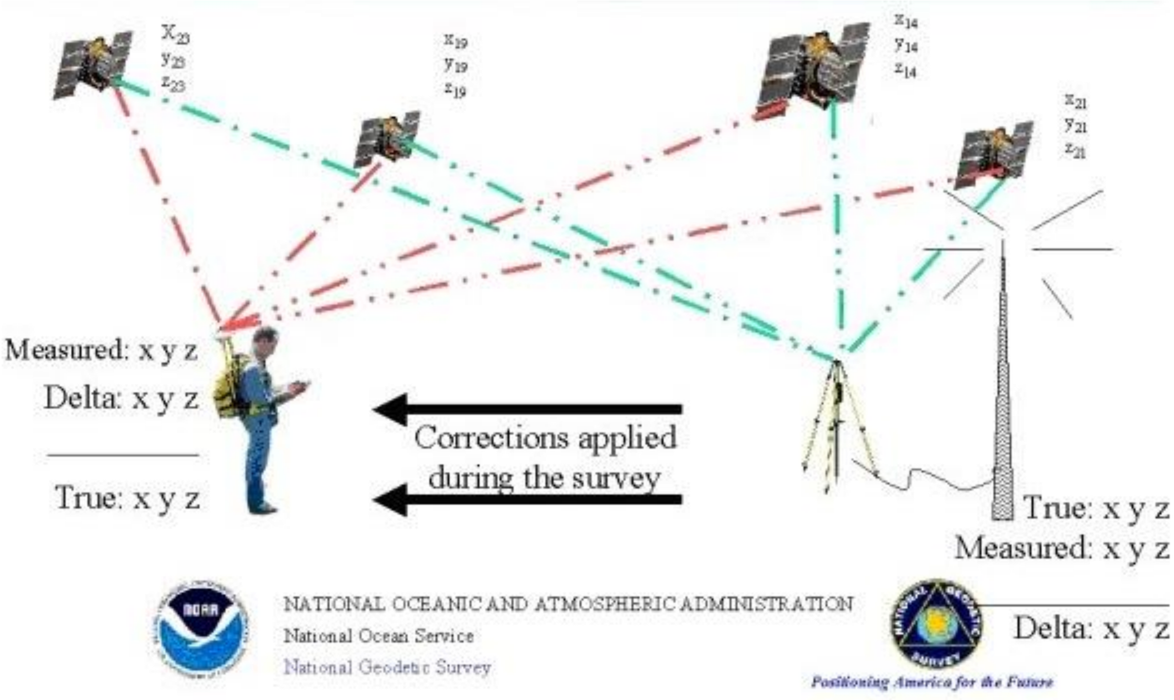


Source: www.noaa.gov/CORS

2.2 GPS

At least 4 satellites needed to pinpoint

- Precise positioning system (PPS)
- Differential GPS



Source: www.noaa.gov/CORS

2.2 GPS

Garmin
5 m accuracy (GPS)
1 m accuracy (DGPS)

Trimble
1-2 m accuracy

2.2 GPS

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

2.2 GPS

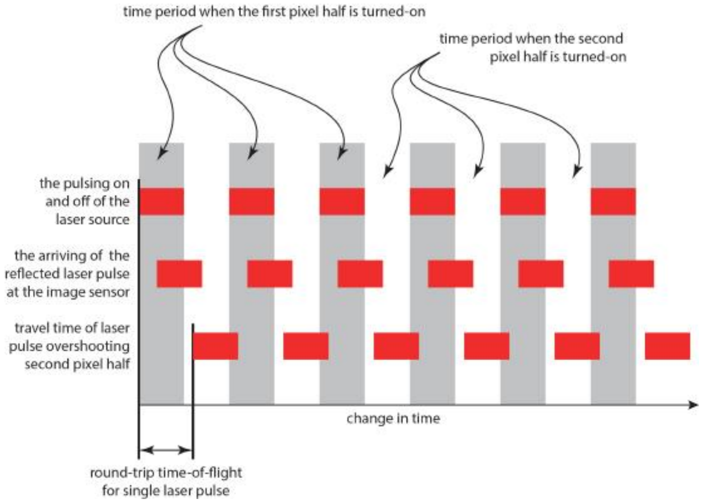
Evaluation and Summary

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

2.3 Kinect 2

Source: chip.de

- Range sensing („time of flight“)
  - IR projector
  - Very high speed „IR camera“



Source: x-tech.am

Source: Daniel Lau, Gamasutra, http://www.gamasutra.com/blogs/DanielLau/20131127/205820/The_Science_Behind_Kinects_or_Kinect_10_versus_20.php

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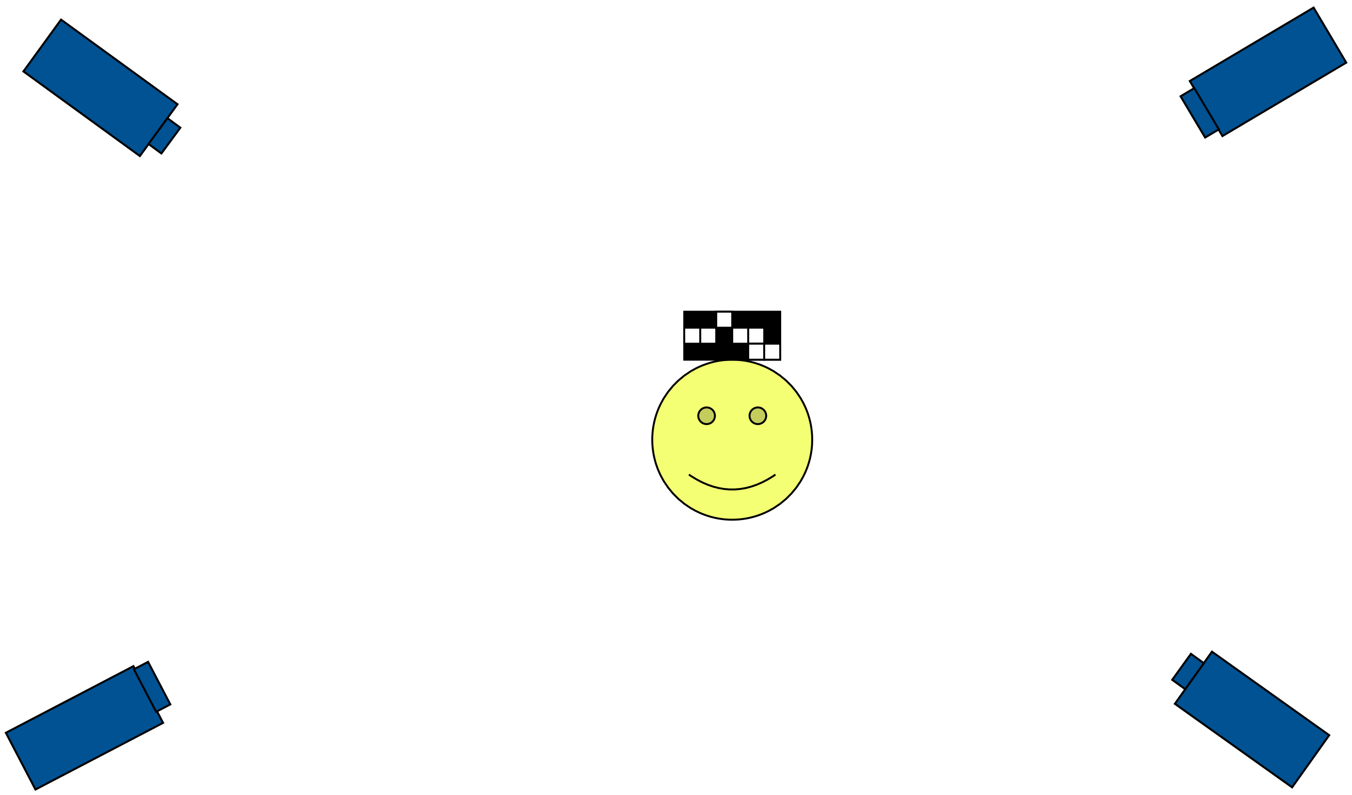
3. Spatial Scan

→ 3.1 Outside-In

3.2 Inside-Out

3.1 Outside-In



3.1 Outside-In

A.R.T. GmbH: ARTrack1, smARTrack1

Northern Digital (NDI): Polaris, Optotrak

3.1 Outside-In

- Pros
  - Rather precise
  - Fast
  - Robust everywhere within the given operating range
  - No tethering
- Cons
  - Rather small range
  - Expensive
  - Typically special, clumsy markers required
    (this may change: natural feature tracking)
  - Line of sight required

3.1 Outside-In

Evaluation and Summary

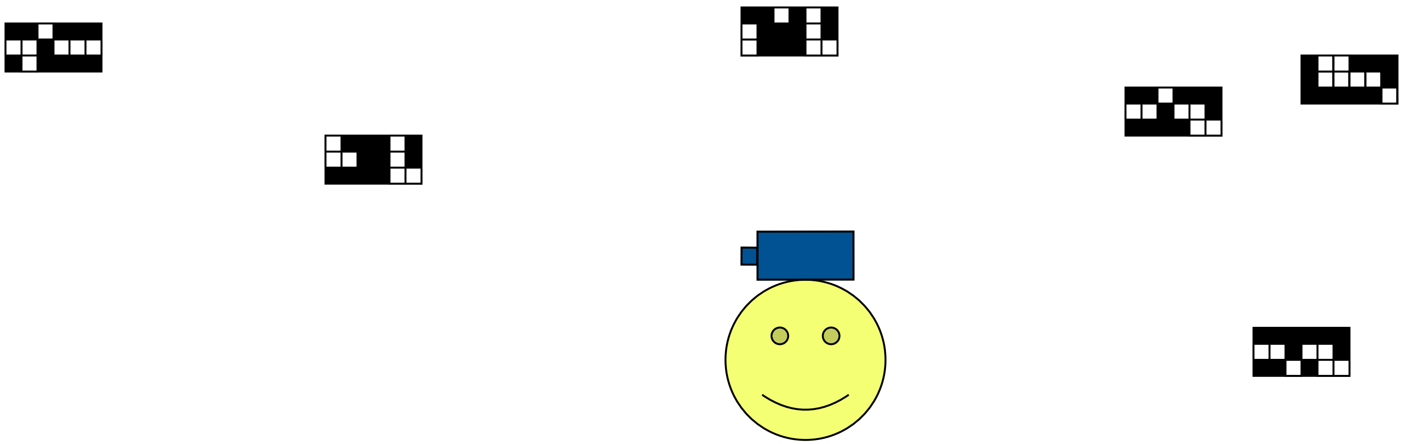
	Speed	Precision	Robustness	Range	Tethered?	Comment
Optical (o-i)	++	++	++	-	n	line of sight

3. Spatial Scan

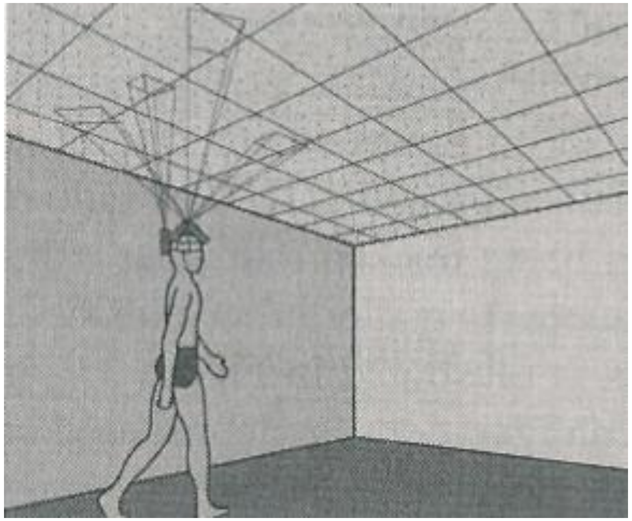
3.1 Outside-In

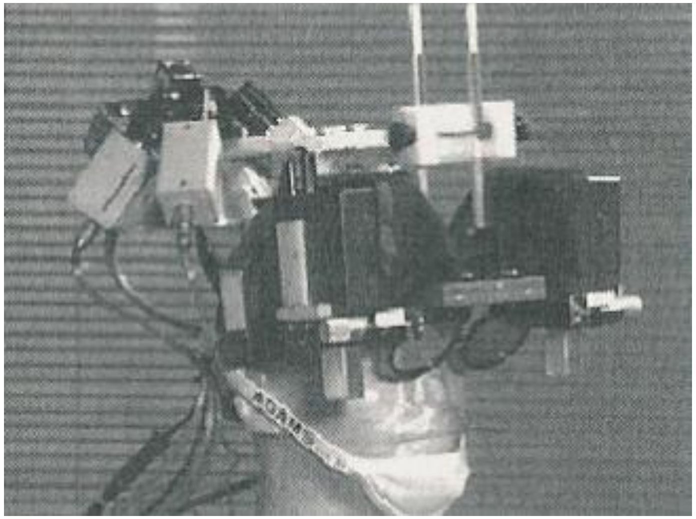
→ 3.2 Inside-Out

3.2 Inside-Out

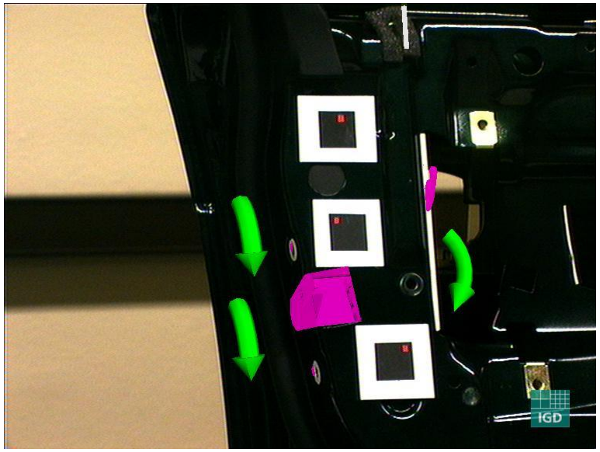


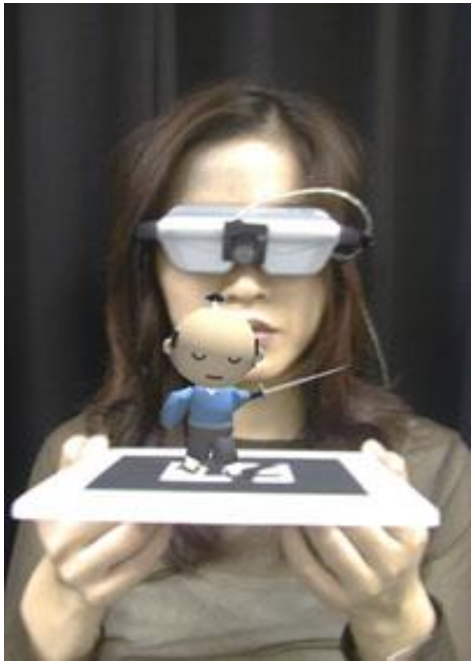
3.2 Inside-Out





3.2 Inside-Out





UNC, USC, IGD-FhG, ARVIKA, AR-Toolkit, metaio

3.2 Inside-Out

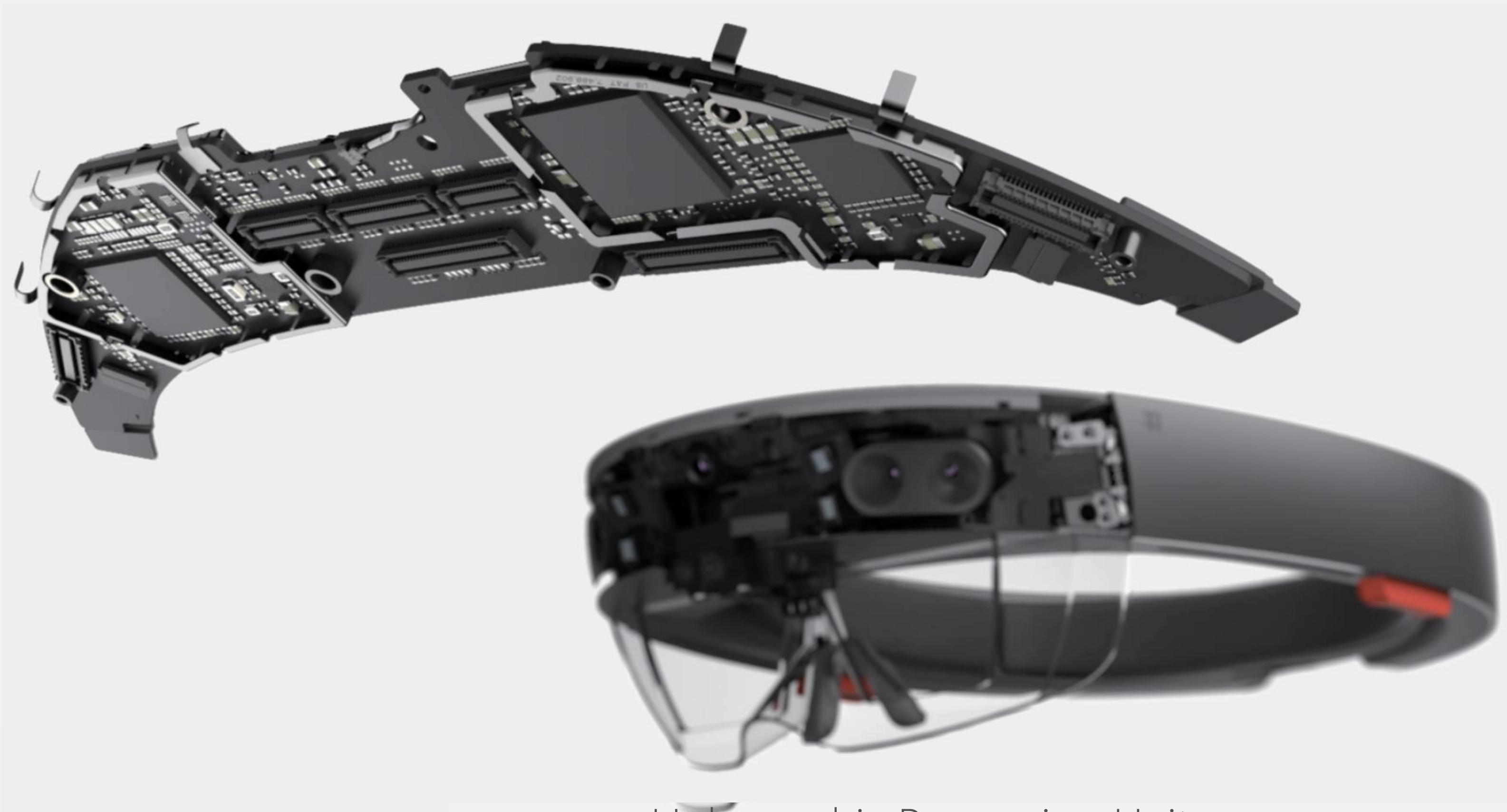
- Microsoft HoloLens

Advanced sensors

Microsoft HoloLens has advanced sensors to capture information about what you're doing and the environment you're in.

Transparent lenses

See-through holographic lenses use an advanced optical projection system, so you can see holograms in your world.



Holographic Processing Unit

The HPU is custom silicon that processes a large amount of data per second from the sensors, enabling Microsoft HoloLens to understand gestures, where you look, and map the world around you, all in real time.

3.2 Inside-Out

Marker-based

- Pros
  - Unrestricted range
  - Cheap
  - No tethering
  - Fast
  - Precise
- Cons
  - Line of sight to markers
  - Ugly markers

Marker-less (nat. Features)

- Pros
  - Unrestricted range
  - Cheap
  - No tethering
  - Very flexible (adaptive)
  - Unobtrusive
- Cons
  - Might slow down
  - Might drift

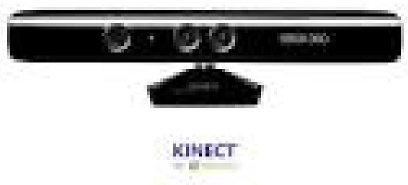
3.2 Inside-Out

Evaluation and Summary

	Speed	Precision	Robustness	Range	Tethered?	Comment
Optical (i-o)	+	+ / ++	+ / ++	+	n	line of sight

3.3 Kinect 1

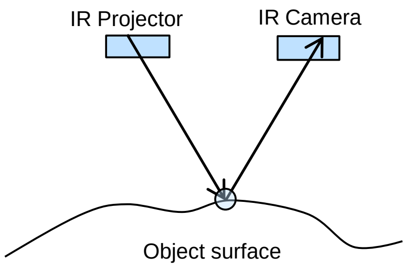
- Range sensing („structured light“)
  - IR projector, invisible light patterns
  - IR camera
  - Specially designed illumination pattern („random dots“)

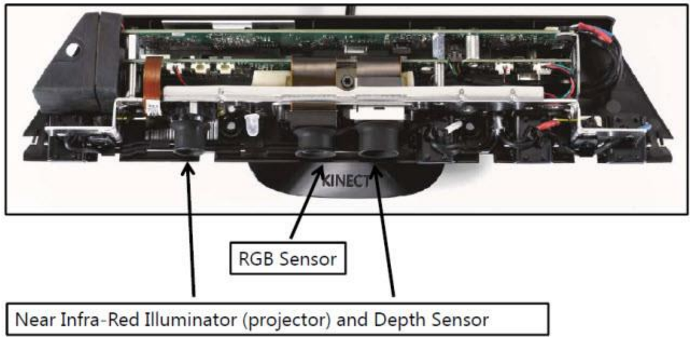


Source: gamesindustry.biz

Source: zdnet.de

Source: playnation.de





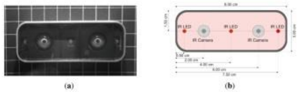
Source: venturebeat.com

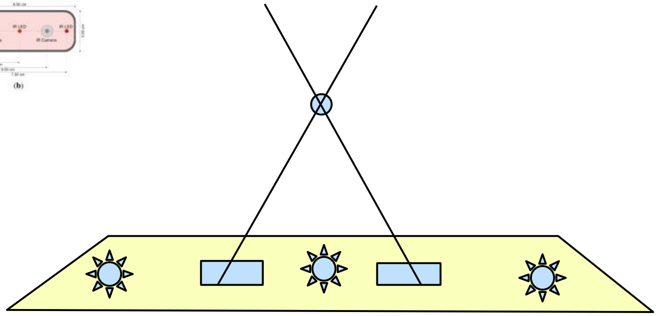
- RGB sensor

3.4 Leap Motion

Leap motion sensor (July 2013)
https://www.youtube.com/watch?v=uF0NSUmxFYA

- 2 IR cameras + 3 IR LEDs
  - LEDs: 3D illumination pattern
    https://www.youtube.com/watch?v=UI5EBzU_QqM
    Highspeed cameras (~300 fps)
  - Stereo computer vision





- To be placed on a desktop, facing upward
- Connected via USB
- Range: 20 cm - 1 meter
  https://www.youtube.com/watch?v=GUaTPhdjCcE

Source: Engadget.com

Source: Gizmag.com

Weichert et al: “Analysis of the Accuracy and Robustness of the Leap Motion Controller”, Sensors (Basel), May 2013 13(5): 6380-6393, 2013.

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4. Inertial Sensing

→ 4.1 Accelerometers

4.2 Gyroscopes

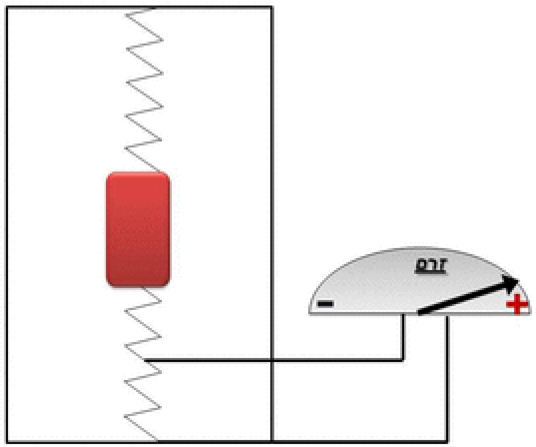
Inertia = resistance of matter to any change in the momentum of a body

4.1 Accelerometers

- Mass tries to maintain its speed

  ⟶ Object-stabilized reference point

- External translations can be measured relative to the reference point (linear acceleration)



https://commons.wikimedia.org/wiki/File:Accelerometer_Spring.gif

4.1 Accelerometers

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

4.1 Accelerometers

Evaluation and Summary

	Speed	Precision	Robustness	Range	Tethered?	Comment
Inertial	++	-	++	++	n	drift

4. Inertial Sensing

4.1 Accelerometers

→ 4.2 Gyroscopes

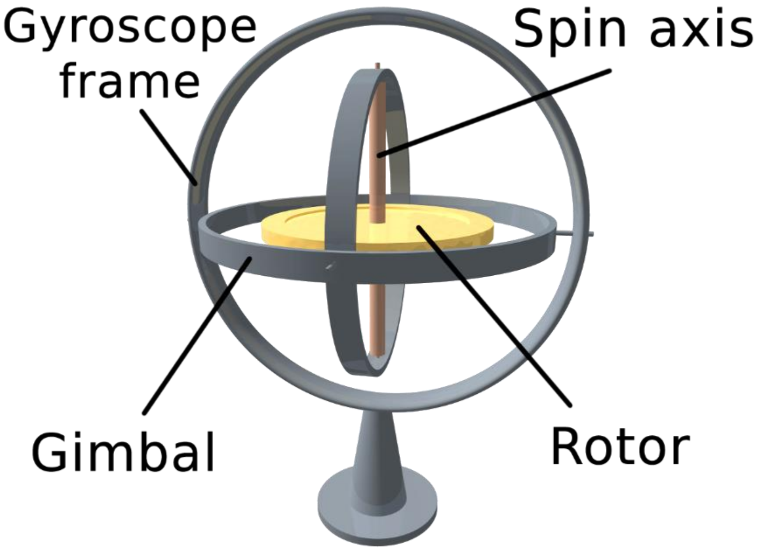
Inertia = resistance of matter to any change in the momentum of a body

4.2 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



https://simple.wikipedia.org/wiki/Gyroscope

4.2 Gyroscopes

4.2 Gyroscopes

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

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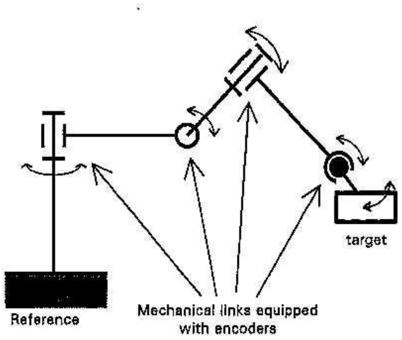
5. Mechanical Trackers

Source: https://commons.wikimedia.org/wiki/File:Onderzoekmetfaroarm.JPG



Source: faro.com

5. Mechanical Trackers

- Pros
  - Extremely precise (metrology)
  - Fast
- Cons
  - Limited range
  - Attached to the environment: restricted user motion

5. Mechanical Trackers

Evaluation and Summary

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

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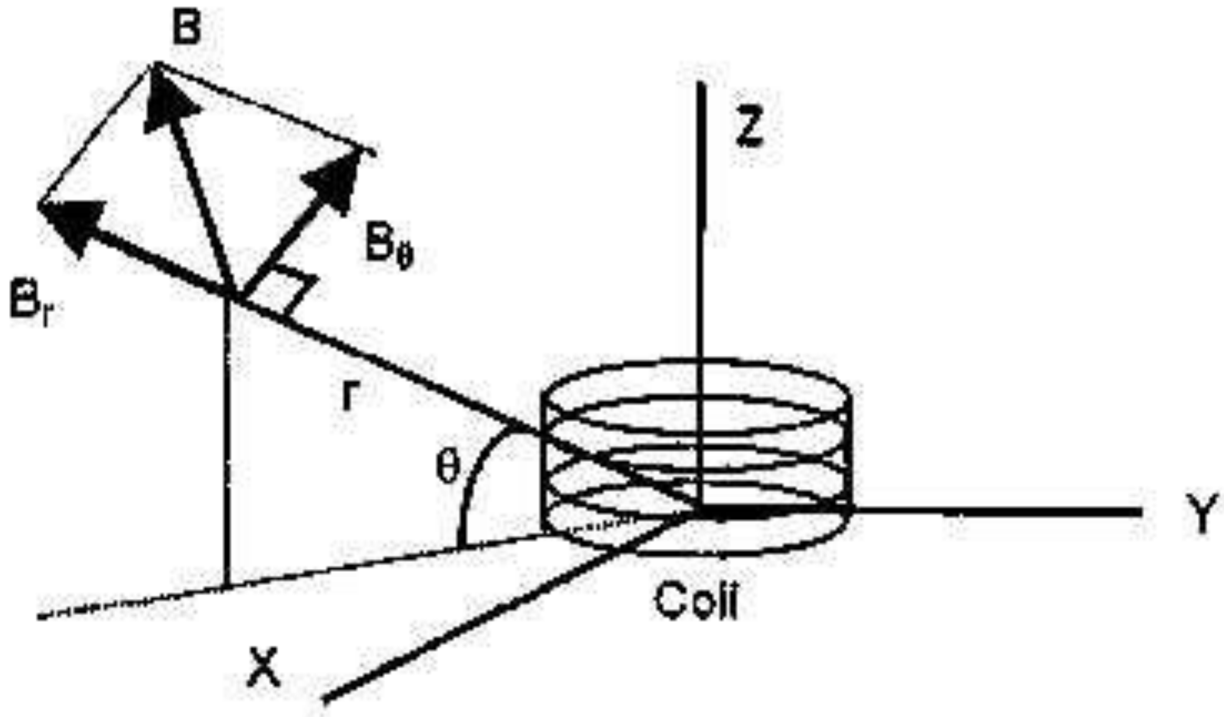
6. Direct-Field Sensing

→ 6.1 Electro-Magnetic Field Sensing
- Sinusoidal Alternating Current (AC)
- Pulsed Direct Current (DC)
- Compass

6.2 Inclinometers (Gravitation)

6.1 Electro-Magnetic Field Sensing



6.1 Electro-Magnetic Field Sensing

Ascension: Flock of Birds

Polhemus: FASTRAK

6.1 Electro-Magnetic Field Sensing

Evaluation and Summary

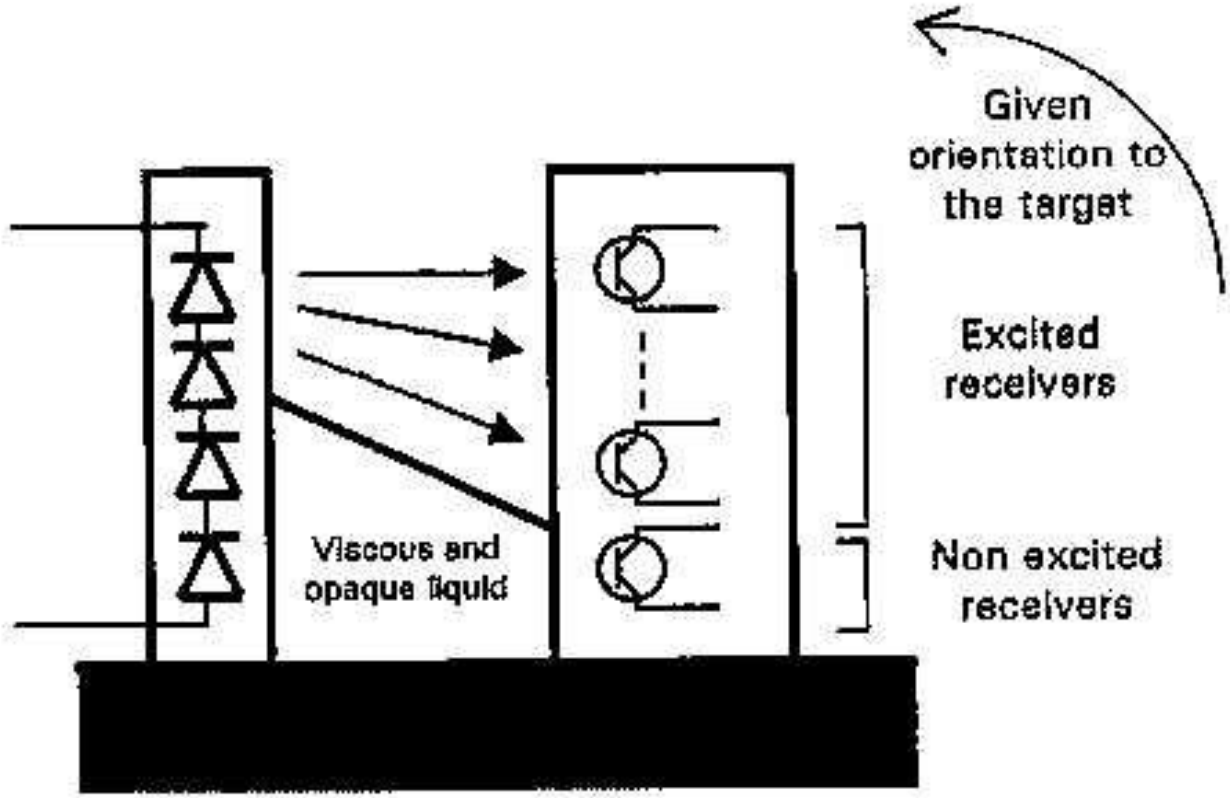
	Speed	Precision	Robustness	Range	Tethered?	Comment
Electro-Magnetic	++	-	++	-	y	no metals

6. Direct-Field Sensing

6.1 Electro-Magnetic Field Sensing

→ 6.2 Inclinometers (Gravitation)

6.2 Inclinometers (Gravitation)



6.2 Inclinometers (Gravitation)

Evaluation and Summary

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

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7. Hybrid Systems

7.1 Mobile: Optical IO / Inertial

	Optical Inside-Out	Inertial	Hybrid
Characteristics / Advantages	Measures orientation and position, accurate	Compact, no occlusion problems, stable solution for pose position, small lag	Compact, accurate, small lag, stable
Limitations	Unstable: occlusions and motion blurr, resolution degrading with distance, some lag	Long term drift	Might still drift, if optical occlusion or motion blur occur for an extended time

7.2 Stationary: Magnetic / Optical

	Magnetic	Optical	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, signal degrading with distance	Unstable: occlusion and motion blurr, resolution degrading with distance, some lag	Works only in rather small areas

7.3 Nintendo Wii

Source: player.de

Nintendo Wii

- Accelerometers
- IR camera + IR light bar (inside-out)
- Extra gadgets / regular controllers

Source: engadget.com

Source: nintendo.de

Source: asian-central.com

7.4 Classification of Hybrid Systems

Complementary

Only one option

- Functional
  - GPS + Compass + Inclinometer
  - WLAN + Gyroscope
- Temporal / Spatial
  - Optical + Optical (in spatially separate areas)

7.4 Classification of Hybrid Systems

Competitive

Several options

- Binary (take the best of several tracking signals)
  - Magnetic + Optical
  - Optical Inside-Out + Inertial
- Mixed (e.g., Kalman Filters)
  - Ultrasound + Inertial
  - Magnetic + Inertial

7.4 Classification of Hybrid Systems

Cooperative

No system can work alone

- Independent (consecutive)
  - Ultrasound + Inertial
- Dependent (initialization)
  - WLAN + Marker-less Optical

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8. Discussion

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

	Speed	Precision	Robustness	Range	Tethered?	Comment
Ultrasound	++	-	++	+	y / n	echoes
(d)GPS	--	- / --	+	++	n	line of sight to satellites
Optical (o-i)	++	++	++	-	n	line of sight
Optical (i-o)	+	+ / ++	+ / ++	+	n	line of sight
Inertial	++	-	++	++	n	drift
Mechanical	++	+++	++	--	y	restricted motions
Electro-Magnetic	++	-	++	-	y	no metals
Compass + Inclinometer	-	--	o	++	n	no metals, earth magnetism

Thank you!