

Tracking and Registration in Augmented Reality

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Outline

- What is an AR System
- Sensing modalities
- Scenarios
 - Indoor, controlled
 - Indoor, medical
 - Outdoor
- Registration errors
- Final thoughts
- References (partial)

What is an AR System

- A system that (Azuma et al., 2001)
 - Combines real and virtual objects in real environment
 - Runs interactively in real time
 - Registers (aligns) real and virtual objects with each other



AR display, courtesy Jannick Rolland



<http://www.crystalinks.com/ar.html>

Multiple Sensory modalities, merged together

- Real
 - Audio, visual, tactile, smell, temperature, temporal, etc.
- Virtual
 - Visual, visual, audio, tactile, temperature, etc.
 - Some more Visual

Visual

- Visual is the most important sense
- Visual capture (Welch, 1978)
 - Brain tends to believe what it sees
- Tracking, registration and other techniques for different AR scenarios
 - Indoor, controlled environment
 - Indoor, medical
 - Outdoor



Indoor, controlled environment

- Scenario:
 - Modification of environment
 - Rigid objects
 - Trade accuracy/speed for automatic control

Indoor, controlled environment

Tracking techniques:

- Those used in head-tracking (mechanical, electromagnetic, inertial, etc.)
- WiFi
- Marker tracking
- General template-based marker tracking
- Visual tracking





<http://www.hitl.washington.edu/artoolkit/>

Indoor, controlled, environment

Marker tracking:

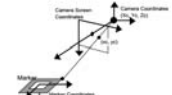
- Initially dots
- 2D code
 - Detect lines, then quadrilateral, then read the marker
 - Object identification
 - Relationship between the marker and the camera
- LED marker, etc.



Rekimoto, 1998

$$\begin{bmatrix} X_c & Y_c & Z_c & 0 & 0 & 0 \\ X_w & Y_w & Z_w & 0 & 0 & 0 \\ X_m & Y_m & Z_m & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

H. Kato et al., 1999



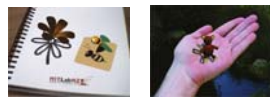
H. Kato et al., 1999

Marker toolkits

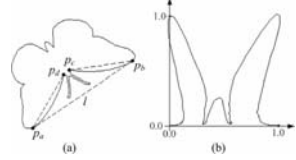
- ARToolkit, H. Kato et al. (UW, since 1999)
 - <http://www.hitl.washington.edu/artoolkit/>
- ARTag, M. Fiala et al. (Columbia, since 2004)
 - <http://www.artag.net/>
- Studierstube Tracker, D. Schmalstieg et al. (Graz, since 2007)
 - http://studierstube.icg.tugraz.at/handheld_ar/stbtracker.php
- Chillitags, Q. Bonnard et al. (EPFL, since 2013)
 - <http://chili.epfl.ch/software>

Indoor, controlled environment

- General template-based marker tracking
- Shapes are more natural (N. Hagbi et al., ISMAR 2009)
- Concavity invariance as feature



3 images from N. Hagbi et al., 2009



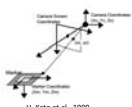
Indoor, controlled environment

- Visual tracking
 - Detection + smoothing
 - Mean-shift, etc.

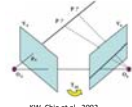
Indoor, controlled environment

Registration techniques:

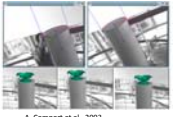
- Inertial sensor integral (accumulated error)
- Solve projection matrix
- Solve fundamental matrix (given reference frames)
- Hybrid



H. Kato et al., 1999



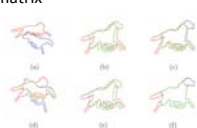
KW. Chiu et al., 2002



A. Comport et al., 2003

Indoor, controlled environment


- Visual tracking, how to find feature correspondences
 - Feature descriptor + RANSAC
 - Iterative Closest Points
 - Find closest reference point for source point
 - Estimate transformation matrix
 - Map source points using the above matrix
 - Iterate
 - Point-to-point / point-to-plane



S. Du et al., Robust iterative closest point algorithm for registration of point sets with outliers, 2011

Indoor, medical


- Scenario:
 - Deformable objects (organs, skin, bones)
 - High intensity interaction (Inevitable obstruction)
 - Speed and accuracy requirement



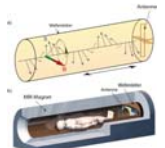
S. Nicolau et al., 2011

Indoor, medical

- Tracking techniques:
 - Ultrasonic probing
 - X-ray CT
 - Magnetic resonance imaging
 - Endoscope
 - Many other medical imaging



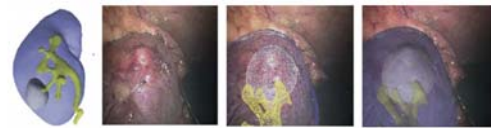
http://www.utwantenesthesia.com/regional/page_id=57



http://www.nature.com/nature/journal/v457/n7232/full/nature07752.html

Indoor, medical

- Registration techniques:
 - Interactive (manual) registration
 - Intra-operative imaging + structure extraction
 - Imposing pre-operative structure onto intra-operative information



S. Nicolau et al., 2011

Outdoor


- Challenge:
 - Cannot instrument the environment
- Tracking techniques:
 - Magnetic (compass)
 - GPS/DGPS
 - Barometer
 - Cell phone station
 - Gyro/accelerometer/inclinometer
 - Vision tracking

Outdoor

- Registration techniques:
 - GPS + magnetometer + inclinometer
 - Inertial + vision
 - GPS + compass + video + reference frame



S. You et al., 1999



V. Vlahakis et al., 2002



S. Feiner et al., 1997

Outdoor

- Registration techniques:
 - GPS + magnetometer + inertial + vision + Kalman filter
 - Other combinations

Overview of tracking techniques

Technology	Range (m)	Setup (hour)	Resolution (nm)	Time (seconds) (in which useful tracking occurs, i.e., before drift)	Environment
Magnetic	1	1	1	∞	In/Out
Ultrasound	10	1	10	∞	In
Inertial	1	0	1	10	In/Out
Accelerometer	1000	0	100	1000	In/Out
UWB	100	10	500	∞	In
Optical: outside-in	10	10	10	∞	In
Optical: marker-based	10	0	10	∞	In/Out
Optical: markerless	50	0-1	10	∞	In/Out
Hybrid	10	10	1	∞	In
GPS	∞	0	1000	∞	Out
Wi-Fi	100	10	1000	∞	In/Out

Table 1. Comparison of tracking technologies (adapted from DiVerdi and Höllerer³⁵)

Registration errors

- Static
 - Optical distortion
 - Errors in tracking system
 - Mechanical misalignments
 - Incorrect viewing Parameters
- Dynamic
 - Lag
 - Make components faster
 - Delay video
 - Predict



Partial references

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- R. Azuma et al., Recent Advances in Augmented Reality, 2001
- J. Carmignani et al., Augmented reality technologies, systems and applications, 2010
- T. Langlotz et al., Robust detection and tracking of annotations for outdoor augmented reality browsing, 2011
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- J. Rekimoto, Matrix: A Realtime Object Identification and Registration Method for Augmented Reality, 1998
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- S. Feiner et al., A Touring Machine: Prototyping 3D Hobbit Augmented Reality Systems for Exploring the Urban Environment, 1997
- V. Vlahakis et al., Archeoguide: an Augmented Reality Guide for Archaeological sites, 2002