



PA198 Augmented Reality Interfaces

Lecture 4
Augmented Reality Tracking

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26th October 2015



What is Tracking?

- Tracking works out where we are standing and looking
 - So that graphics can be drawn in the right place



- Continually locating the users viewpoint
 - Position (x, y, z)
 - Orientation (yaw, pitch, roll)



Ideal Tracking

- Not easy
- Ideal scenario:
 - Accuracy
 - Precision
 - Low-latency
 - Agile
 - Robust

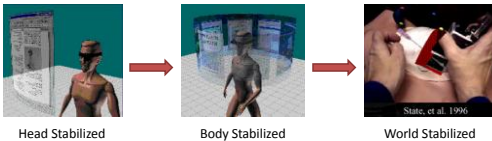


Tracking for AR

- More difficult than VR
- Tracking systems used for AR environments must satisfy three basic requirements:
 - The tracker must provide high accuracy when calculating the pose
 - The latency between the graphics system and the tracker must be very low
 - The tracker's range of operation must be wide enough to cover the needs of the application



Tracking Requirements



- Augmented Reality Information Display
 - World Stabilized
 - Body Stabilized
 - Head Stabilized



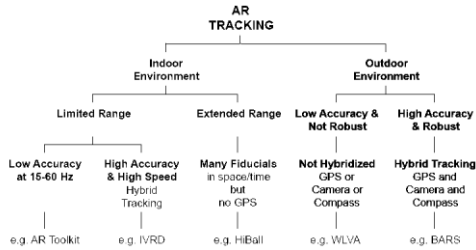
Tracking Technologies

- Active
 - Mechanical, Magnetic, Ultrasonic
 - GPS, Wifi, cell location
- Passive
 - Inertial sensors (compass, accelerometer, gyro)
 - Computer Vision
 - Marker based, natural feature tracking
- Hybrid Tracking
 - Combined sensors (i.e. vision + inertial)





AR Tracking Taxonomy



Billingshurst, M., Clark, A. Lee, G. A Survey of Augmented Reality, Foundations and Trends in Human-Computer Interaction, Vol. 8, No. 2-3 2014



Tracking Categories



- Three types of tracking:
 - Sensors
 - Visual
 - Hybrid



Sensor Tracking



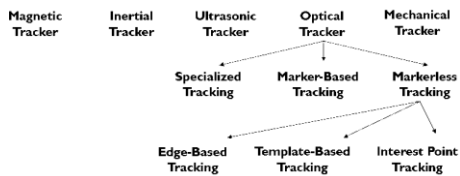
Tracking Principles



- The six main principles of tracking operation include:
 - Time of flight (TOF)
 - Spatial scan
 - Mechanical linkages
 - Inertial sensing
 - Phase difference sensing
 - Direct-field sensing



Tracking Types



Billingshurst, M., Clark, A. Lee, G. A Survey of Augmented Reality, Foundations and Trends in Human-Computer Interaction, Vol. 8, No. 2-3 2014



Mechanical Trackers



- Mechanical tracking devices are widely used nowadays due to the low cost of production
- The lack of certain hardware devices (i.e. transmitter/receiver) makes mechanical trackers much less sensitive to their immediate environment than other types of trackers
 - i.e. Electromagnetic trackers
- Two different types of mechanical devices are currently used in the industry/research including
 - The arm
 - Force sensing ball



Mechanical Trackers .

- Idea: mechanical arms with joint sensors
 - Advantages: high accuracy, haptic feedback
 - Disadvantages: cumbersome, expensive



Billingshurst, M. COSC 426: Augmented Reality, July 26th 2013.



Mechanical Trackers ..

- The 'arm' or 'boom' sensing device takes measurements in rotation using either a potentiometer or optical encoders
- The device measures the forces exerted and it is therefore applied in force-sensing joysticks



Mechanical Trackers ...



BOOM 3C



BOOM HF

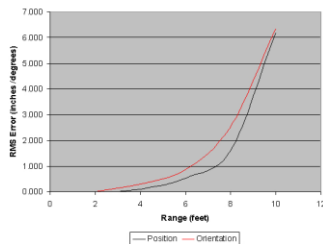


Electromagnetic Trackers

- Electromagnetic trackers are comprised of two simple electronic systems:
 - A transmitter
 - A receiver
- Usually, their main function is to detect the generated variations of the received signal
- In other words, the position and orientation of the transmitters can be calculated



Tracking Error



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Electromagnetic Trackers .



Polhemus FASTRACK electromagnetic tracker





Optical Trackers

- Optical trackers have the ability to operate over large areas in indoor or outdoor environments
- However, the implementations of optical tracking systems are diverse using
 - Infra-red LEDs, photodiodes, lasers, video cameras, web-cameras
 - Combinations of these



Optical Trackers .

- The creation and maintenance of a corresponding virtual line of sight is essential for the operation of any optical tracking system
- They function by placing the light sources or fiducials on the object to be tracked and then determine the position of the object using light detectors



Cheap Optical Trackers



Optical Tracker

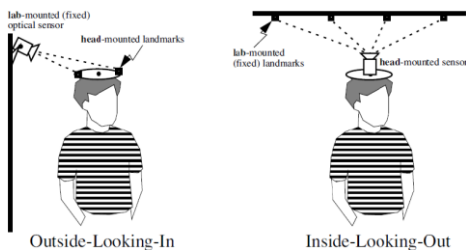
- Idea
 - Image Processing and Computer Vision
- Specialized
 - Infrared, Retro-Reflective, Stereoscopic
- Monocular Based Vision Tracking



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Outside-In v.s. Inside-Out Tracking



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Optical Tracking Technologies

- Scalable active trackers
 - InterSense IS-900, 3rd Tech HiBall
- Passive optical computer vision
 - Line of sight, may require landmarks
 - Can be brittle
- Computer vision is computationally-intensive



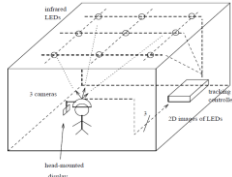
3rd Tech, Inc.

Billingshurst, M. COSC 426: Augmented Reality, July 26th 2013.



HiBall Tracking System (3rd Tech)

- Inside-Out Tracker
 - \$50K USD
- Scalable over large area
 - Fast update (2000Hz)
 - Latency Less than 1 ms
- Accurate
 - Position 0.4mm RMS
 - Orientation 0.02° RMS

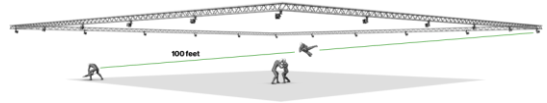


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Motion Tracking

- Very popular for games
- Need markers
- Can track whole body
- Expensive solution
- Visit HCI Lab!!



VRECKO

- Modular framework for experiments in VR

Polygonal mesh editing



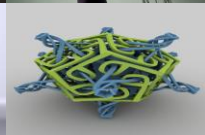
Motion Capture



Physical simulations



Geometrical sculpture

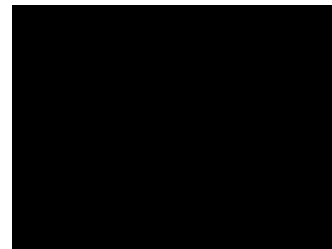


<http://vrecko.cz/>

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VRECKO Video



<http://vrecko.cz/research/yakya/freehand-painting/>

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Acoustic Trackers

- Acoustic tracking systems make use of ultrasonic signals to avoid interference with the detectable spectrum of human users
 - Based on TOF measurement
- This method measures the time needed for the sound to reach the receivers and then the distance is calculated based on the speed of sound in the air, producing absolute position and orientation values



Acoustic Trackers .

- Since TOF can only measure distance, to achieve 3D tracking a combination of transmitter and receiver is required
 - For 3 DOF one transmitter and one receiver is required
- For 6 DOF tracking 3 transmitters and 3 receivers are necessary



Acoustic Magic



Acoustic Trackers Pros and Cons



- Pros: Small, Cheap
- Cons: 3DOF, Line of Sight, Low resolution, Affected Environment Condition (pressure, temperature)



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Inertial Trackers



- Inertial trackers measure changes in rotation regarding one, two or even three axes by using a device called a gyroscope
- Gyroscopes can maintain spinning on a particular axis while in motion based on the laws of conservation of angular momentum
 - When an external force is applied the reaction is a motion perpendicular to the axis of rotation
- Common applications for gyroscopes include
 - Direction measurements for submarines, ships and pedestrian navigation



Inertial Trackers .



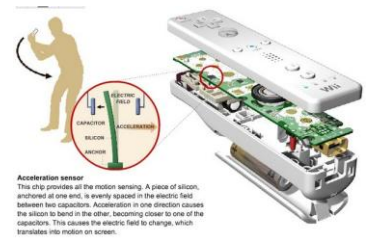
- Their main advantage is that they do not use receivers or transmitters avoiding communication errors
- The main disadvantage is that they provide only rotational information (3 DOF)
 - Therefore it is more difficult for them to interface when compared to other tracking systems (6 DOF)



Inertial Trackers ..



Inertia Cube from InterSense



Wii Remote



GPS Trackers



- GPS is a technology widely used for outdoor tracking
- The most important categories include
 - Standard GPS
 - Differential GPS
 - Real-time kinematic GPS



GPS Trackers .

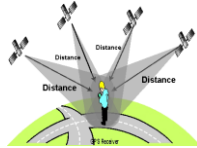


- Standard GPS is a satellite based positioning system that utilizes a total of 29 satellites
 - This will change with Galileo!
- The position of the user is determined by processing radio signals from the satellites
- In theory, GPS systems can estimate the user's position, by calculating the arrival time of at least three satellite signals



GPS Trackers .

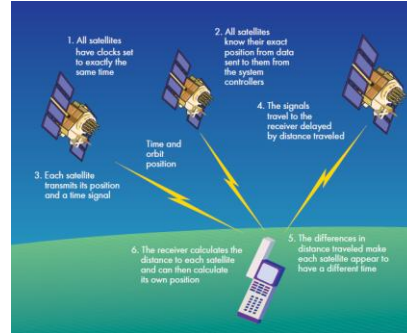
- Satellites send position + time
- GPS Receiver positioning
 - 4 satellites need to be visible
 - Differential time of arrival
 - Triangulation
- Accuracy
 - 5-30m+, blocked by weather, buildings etc



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GPS Trackers ..



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Problems with GPS

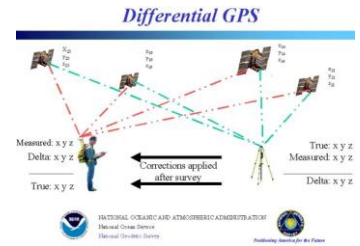
- Takes time to get satellite fix
 - Satellites moving around
- Earth's atmosphere affects signal
 - Assumes consistent speed (the speed of light)
 - Delay depends where you are on Earth
 - Weather effects
- Signal reflection
 - Multi-path reflection off buildings
 - Signal blocking
 - Trees, buildings, mountains
- Satellites send out bad data
 - Misreport their own position

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Differential GPS

- Uses emitting ground stations that refine the resolution
- Accurate to < 5cm close to base station
 - 22m/100 km
- Expensive
 - \$20-40,000 USD

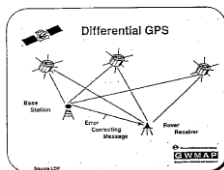


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Differential GPS .

- The mobile GPS receiver monitors signals from a fixed radio transmitter and another GPS receiver
- To refine the resolution the transmitter sends the corrected co-ordinates
 - Based on the difference between the known and the computed positions



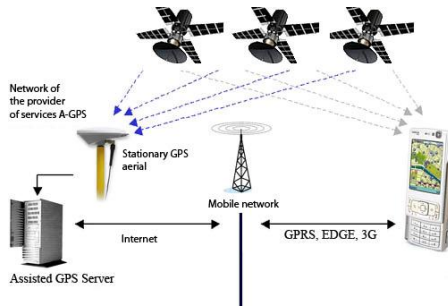
Assisted-GPS (A-GPS)

- Use external location server to send GPS signal
 - GPS receivers on cell towers, etc
 - Sends precise satellite position (Ephemeris)
- Speeds up GPS Tracking
 - Makes it faster to search for satellites
 - Provides navigation data (don't decode on phone)
- Other benefits
 - Provides support for indoor positioning
 - Can use cheaper GPS hardware
 - Uses less battery power on device

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Assisted-GPS (A-GPS)

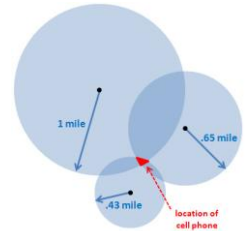
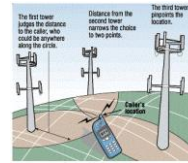


<http://gps-response.com/63-a-gps.html>



Cell Tower Triangulation

- Calculate phone position from signal strength
 - < 50 m in cities
 - > 1 km in rural



Triangulation - cell phone detected within a certain radius of each of 3 cell towers - the area where each cell tower overlaps the phone is where it is pinpointed.

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WiFi Positioning

- Estimate location based on WiFi access points
 - Use known locations of WiFi access points
- Triangulate through signal strength
 - i.e. PlaceEngine
- Accuracy
 - 5 to 100m
 - Depending on WiFi density



PlaceEngine

- Enables a device equipped with Wi-Fi such as a laptop PC or smart phone to determine its current location
 - Can be used in conjunction with web sites that provide local area information to gain easy access to nearby services
 - Client software for PC and mobiles
 - Free of charge

<http://www.placeengine.com/en>



Indoor WiFi Location Sensing

- Indoor Location
 - Asset is people tracking
- Aeroscout
 - <http://aeroscout.com/>
 - WiFi + RFID
- Ekahau
 - <http://www.ekahau.com/>
 - WiFi + LED tracking



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Integrated Systems

- Combine different systems
 - GPS, Cell tower, WiFi signals
- Database of known locations
 - 700 million Wi-Fi access points and cellular towers



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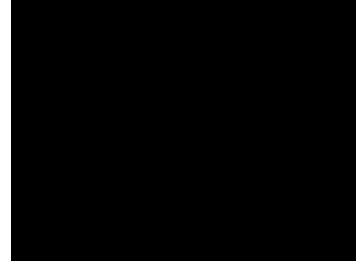
Skyhook



Skyhook Video



- Skyhook Context Accelerator's features and analytics allows you to create place-specific experiences
- Combines Wi-Fi with GPS, Cell Towers, IP address and device sensors to give you the fastest, most accurate positioning for any device on any OS



<http://www.skyhookwireless.com/>

<http://www.skyhookwireless.com/>



Comparative Accuracies



- Study testing iPhone 3GS cf. low cost GPS
- A-GPS
 - 8 m error
- WiFi
 - 74 m error
- Cell Tower Positioning
 - 600 m error

Visual Tracking

Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi, and Cellular Positioning, Transactions in GIS, Volume 13 Issue 1, 5 - 25



Visual Tracking



Visual Tracking .



- Tracking in AR is usually performed using computer vision algorithms
 - Still experimental
 - Less expensive in terms of cost
 - More computing power is required
 - Works reasonably good for indoor environments
 - Problems with outdoor environments

- Establishes correspondences between the video feed and 3D positions in space

$$(u, v) \leftrightarrow (x, y, z)$$

- 6-DOF Position can be calculated from these correspondences



Visual Tracking ..



- Lots of tools:
 - Three-point-pose
 - RANSAC
 - N-point-pose
 - Iterative nonlinear optimisation
 - Robust M-estimation
 - etc

<http://www.raeng.org.uk/publications/other/georg-keirn-presentation-frontiers-of-engineering>



Approaches to Visual Tracking



- Use a marker
 - Corners of square give easy correspondences
- Use a known textured object
 - Coordinates of texture features are known
- Learn an unknown environment on-line
 - Coordinates of scene are computed on-the-fly

<http://www.raeng.org.uk/publications/other/georg-keirn-presentation-frontiers-of-engineering>



Marker-based Tracking



- Distinctive shapes which can be found using elementary image processing operations



ARToolkit (Kato & Billinghurst 1999)



Sony (Rekimoto et al)

<http://www.raeng.org.uk/publications/other/georg-keirn-presentation-frontiers-of-engineering>



Marker-based Tracking .



- Has been done for more than 10 years
- A square marker provides 4 corners
 - Enough for pose estimation!
- Several open source solutions exist
- Fairly simple to implement
 - Standard computer vision methods



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Marker-based Tracking ..



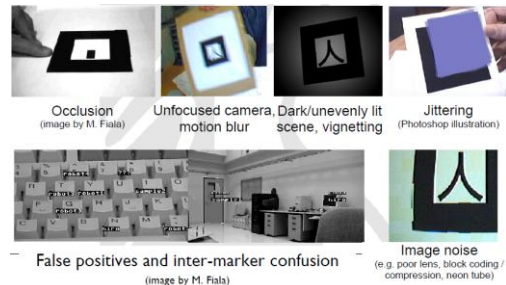
- Best suited for tangible manipulation of virtual elements and untrained users
- Unsuitable for uncontrolled environments



<http://www.raeng.org.uk/publications/other/georg-keirn-presentation-frontiers-of-engineering>



Tracking Challenges in ARToolKit



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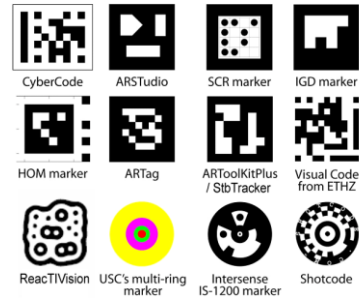
Limitations of ARToolKit

- Partial occlusions cause tracking failure
- Affected by lighting and shadows
- Tracking range depends on marker size
- Performance depends on number of markers
 - i.e. arTag, ARToolKitPlus
- Pose accuracy depends on distance to marker
- Pose accuracy depends on angle to marker

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Different Approaches



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Other Marker Tracking Libraries

- arTag
 - <http://www.artag.net/>
- ARToolKitPlus [Discontinued]
 - http://studierstube.icg.tu-graz.ac.at/handheld_ar/artoolkitplus.php
- stbTracker
 - http://studierstube.icg.tu-graz.ac.at/handheld_ar/stbtracker.php
- MXRToolKit
 - <http://sourceforge.net/projects/mxrtoolkit/>

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Known-Template Tracking

- Exploits advances in image processing
- Rapid feature extraction and invariant descriptor matching
- Distinctive points of a textured object are matched to the image
- Must be known in advance!

<http://www.raeng.org.uk/publications/other/zeora-4kin-presentation-frontiers-of-engineering>



Natural Feature Tracking

- Tracking from features of the surrounding environment
 - Corners, edges, blobs, ...
- Generally more difficult than marker tracking
 - Markers are designed for their purpose
 - The natural environment is not...
- Less well-established methods
- Usually much slower than marker tracking

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Natural Feature Tracking .

- Use Natural Cues of Real Elements
 - Curves
 - Edges
 - Lines
 - Surface Texture
 - Interest Points
- Model or Model-Free
- No visual pollution

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Curve Based Tracking



- Track curved features like the arches of the bridge
 - 1998



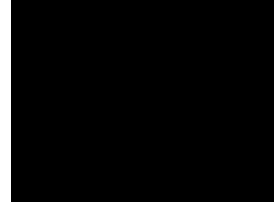
www.klna.fr/~netitia/papers/mva99.pdf



Edge Based Tracking



- RAPiD [Drummond et al. 02]
 - Initialization, Control Points, Pose Prediction (Global Method)



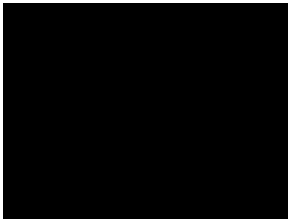
<https://ximec.com/91642721>



Line Based Tracking



- Visual Servoing [Comport et al. 2004]



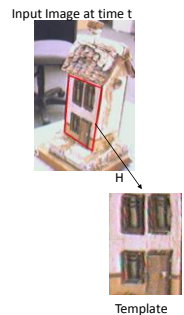
<https://www.youtube.com/watch?v=Dln237k25c>



Region-based Approach



- On initialization the user selects a plane of interest
- The rectifying Homography and rectified template image are retained



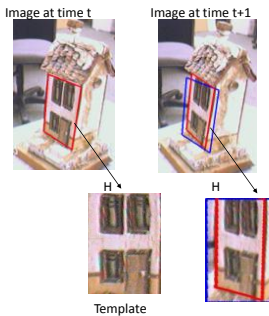
Birkbeck, N. Registration for Augmented Reality, 2006



Region-based Approach .



- When new image arrives, use image intensities to refine the Homography



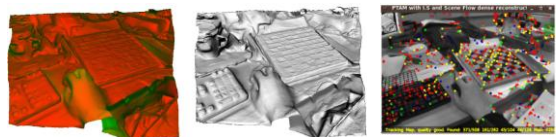
Birkbeck, N. Registration for Augmented Reality, 2006



Dense Reconstruction



- Allows occlusion and interaction between physical and real world
 - Newcombe & Davison 2010



<http://www.raeng.org.uk/publications/other/georg-keirn-presentation-frontiers-of-engineering>



Marker vs. Natural Feature Tracking

- Marker tracking
 - + Can require no image database to be stored
 - + Markers can be an eye-catcher
 - + Tracking is less demanding
 - - The environment must be instrumented with markers
 - - Markers usually work only when fully in view
- Natural feature tracking
 - - A database of keypoints must be stored/downloaded
 - + Natural feature targets might catch the attention less
 - + Natural feature targets are potentially everywhere
 - + Natural feature targets work also if partially in view

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Some Algorithms for Visual Tracking



Random Forest

- Multi-classifier based on Randomized Trees
- Firstly introduced in 1997 handwritten recognition (Amit, Y., German, D.)
- Developed by Leo Breiman (Medical Data Analysis)
- Applied to tracking by detection (LePetit06)

Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - Main Features

- Fast training step and execution
- Good precision
- Random selection of the independent variables
 - Known as features
- Random selection of examples
- Easy to implement and parallelizable

Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - Classifier Training

- N Binary-Trees are grown
- Pixel intensity tests are executed in any non-terminal node
- Pixels can be selected at random
- Posterior distributions are stored in leaf nodes



Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - Example Classification

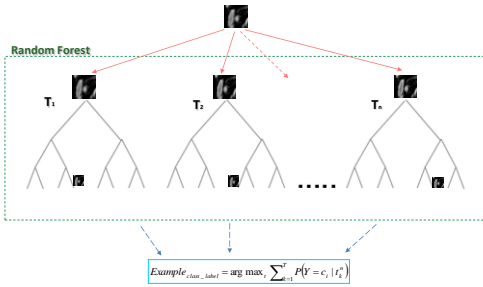
- Every example is dropped down the trees
- The example traverse the tree towards the leaf nodes



Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - Combine Results



Barandarian, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



FERNS

- Introduced in 2007 (Mustafa Özuysal)
- Multi-classifier
- Applied to 3D keypoint recognition
- Successfully applied to image recognition/retrieval (Zisserman07)

Barandarian, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Original FERNS

- A classic Naïve Bayesian framework provides a simple and fast method
- FERNS are non-hierarchical structures used to classify the patches
 - Each one consists of a small set of binary tests
 - Returns the probability that a patch belongs to any one of the classes that have been learned during training
- Combined in a Naive Bayesian way
- Using randomized trees the classifier is trained
 - By synthesizing many views of the keypoints extracted from a training image as they would appear under different perspective or scale

Özuysal, M., Fua, P., Lepetit, V. Fast Keypoint Recognition in Ten Lines of Code, Proc. CVPR, IEEE Computer Society, 2007. (DOI: 10.1109/CVPR.2007.383123)



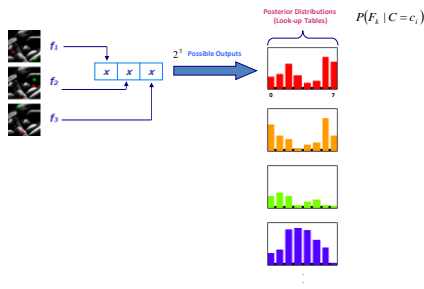
FERNS - Main Features

- Non hierarchical structure
- Semi Naive-Bayes Combination Strategy
- Random selection of the independent variables
 - Known as features
- Random selection of examples
- Easy to implement and parallelizable

Barandarian, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



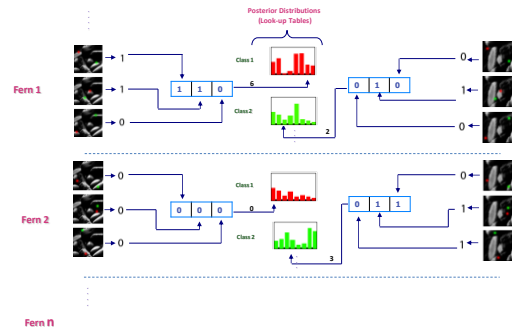
FERNS Classifier Training



Barandarian, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



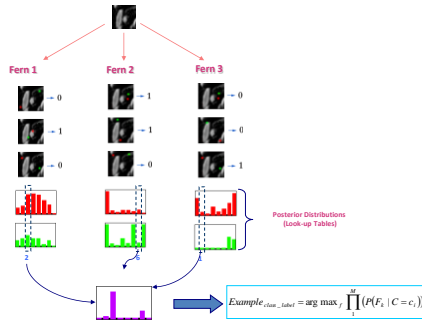
FERNS Classifier Training .



Barandarian, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Example Classification

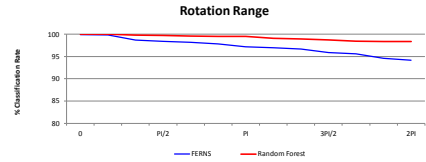


Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest vs FERNs

- Rotation Range
 - 20 Trees, 15 depth
 - 225 different classes
 - 400 images per class

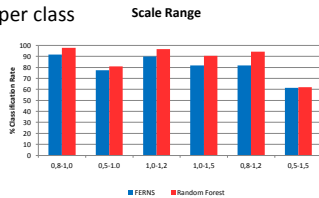


Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest vs FERNs .

- Scale Range
 - 20 trees, 15 depth
 - 225 different classes
 - 400 images per class

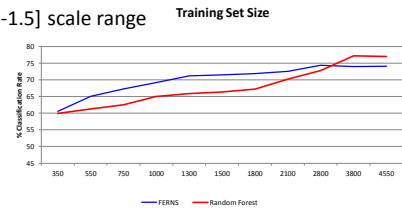


Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest vs FERNs ..

- Size of the training set
 - 20 trees, 15 depth
 - 225 different classes
 - [0.5-1.5] scale range

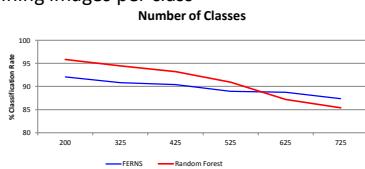


Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest vs FERNs ...

- Number of different classes
 - 20 trees, 15 depth
 - [0.8-1.2] scale range
 - 1500 Training images per class

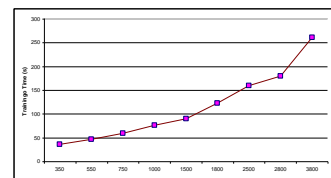


Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest vs FERNs

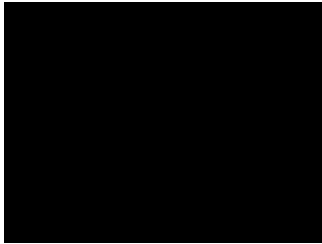
- Training time
 - 20 trees, 15 depth
 - 225 different classes
 - [0.5-1.5] scale range



Barandiaran, I., Cottet, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



FERNS Video



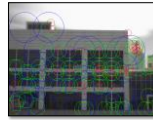
<http://www.youtube.com/watch?v=Cv8BDXWw0A>



Random Forest - FERNS



- Tracking of Planar Surfaces
- The Classifiers are applied for interest point (feature) matching
- Matched Points are used during camera pose estimation Process



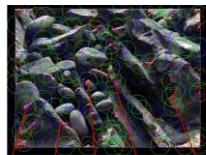
Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - FERNS .



- Building the training set
 - Frontal view of the object to be detected
 - Feature Point extraction FAST (Rosten06) and YAPE (CvLab)
 - Sub-images (patches) are generated for each class



Classes to be recognized by the Classifier →

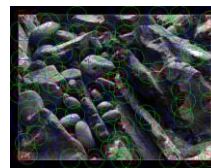
Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Random Forest - FERNS ..



- Building the training set
 - Generate random affine transformations
 - Generate new examples of each class



Barandiaran, I., Cotter, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008



Unknown Environments



- SLAM: Simultaneous Localization and Mapping
 - Introduced to computer vision by Davison et al 2003
- Structure of world computed from image
- (x,y) observed directly – z computed from parallax



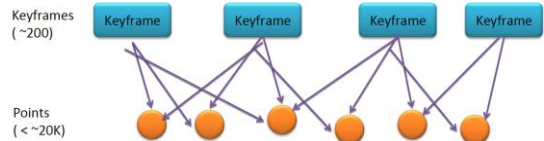
<http://www.rdg.ac.uk/publications/other/georg-keini-presentation-frontiers-of-engineering>



Parallel Tracking and Mapping (PTAM)



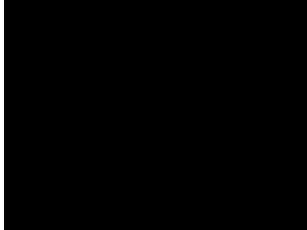
- Splits tracking and mapping into separate tasks
 - Map built in background from keyframes
- Draws from photogrammetry
 - Bundle adjustment and epipolar geometry



<http://www.rdg.ac.uk/publications/other/georg-keini-presentation-frontiers-of-engineering>



PTAM Video



Hybrid Tracking



Hybrid AR Systems



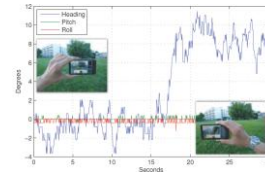
- Currently, there is no perfect tracking technology and the existing ones have some advantages as well as limitations
- To overcome the limitations of each tracking technology hybrid systems can be employed for combining hardware devices to achieve better results that otherwise could not be handled
- Hybrid systems can be successfully combine vision techniques with haptic devices to improve the overall tracking efficiency as well as increasing the capabilities of the system



Sensor Tracking



- Used by many “AR browsers”
- GPS, Compass, Accelerometer, Gyroscope
- Not sufficient alone (drift, interference)



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Outdoor Hybrid Tracking



- Combines
 - computer vision
 - Natural feature tracking
 - Inertial gyroscope sensors
- Both correct for each other
 - Inertial gyro - provides frame to frame prediction of camera orientation
 - Computer vision - correct for gyro drift



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Combining Sensors and Vision



- Sensors
 - Produce noisy output (= jittering augmentations)
 - Are not sufficiently accurate (= wrongly placed augmentations)
 - Gives us first information on where we are in the world, and what we are looking at
- Vision
 - Is more accurate (= stable and correct augmentations)
 - Requires choosing the correct keypoint database to track from
 - Requires registering our local coordinate frame (online generated model) to the global one (world)

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Hand Tracking / Interaction



- Real-time unassisted monocular hand tracking is still unsolved



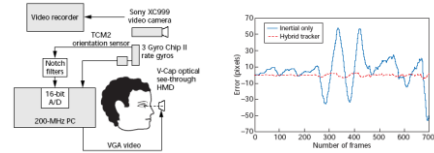
<http://www.crea.crg.uk/publications/other/georg-stein-presentation-frontiers-of-engineering>



Outdoor AR Tracking System



- You, Neumann, Azuma outdoor AR system (1999)



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Robust Outdoor Tracking



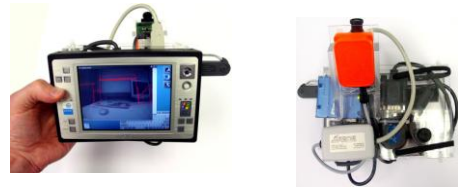
- Hybrid Tracking
 - Computer Vision, GPS, inertial
- Outdoors
 - Reitmayer & Drummond (Univ. Cambridge)



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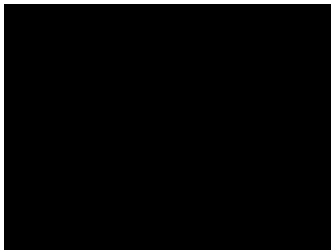
Handheld Display



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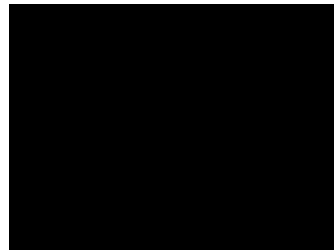
Hybrid Tracking Indoors Video



<https://www.youtube.com/watch?v=4HBJLLOM8>



Hybrid Tracking Outdoors Video



<https://www.youtube.com/watch?v=GG-DelH4DQA>



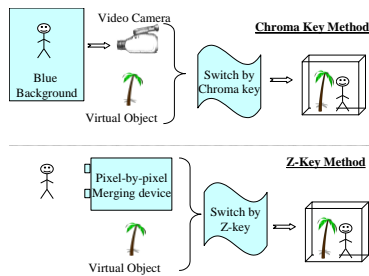
AR Registration

What is Registration?

- Registration is the accurate positioning of virtual information into the real environment
- Mis-registration:
 - Breaks the illusion that the two coexist
 - Prevents acceptance of many serious applications

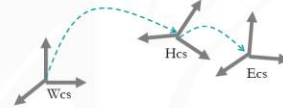


Chroma Key vs Z-Key



Spatial Registration

- Defining Relative Position of Each Elements of a Scene



- Elements are: User, User's eye, Environment (Table, Room, Building), Objects, etc.
- Coordinate Systems (Euclidian System)
- Initially: Calibration
- Temporally: 3D/6D **Tracking**

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Sources of Registration Errors

- Static errors
 - Optical distortions
 - Mechanical misalignments
 - Tracker errors
 - Incorrect viewing parameters
- Dynamic errors
 - System delays (largest source of error)
 - 1 ms delay = 1/3 mm registration error

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Reducing Static Errors

- Distortion compensation
- Manual adjustments
- View-based or direct measurements
- Camera calibration

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View Based Calibration (Azuma 94)

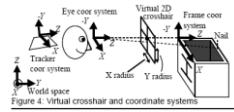


Figure 4. Virtual crosshair and coordinate systems



Figure 1. Wooden frame for calibration and registration

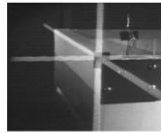
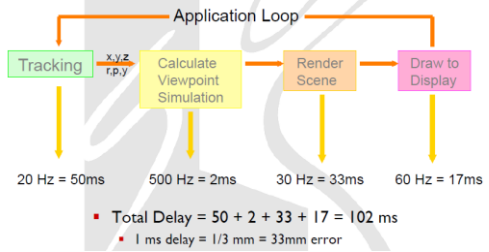


Figure 2. View seen in HMD, virtual axes on real frame

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Dynamic Errors



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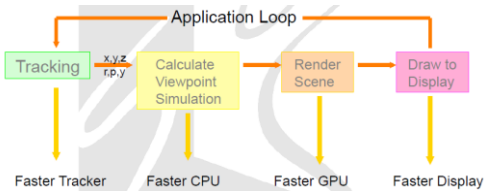
Reducing Dynamic Errors

- Reduce system lag
 - Faster components/system modules
- Reduce apparent lag
 - Image deflection
 - Image warping

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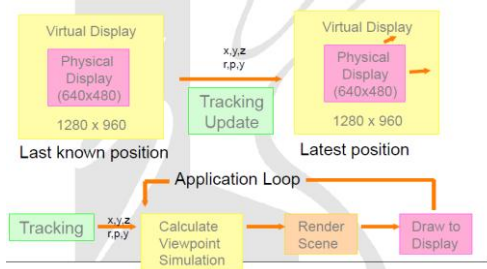
Reducing System Lag



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Reducing Apparent Lag

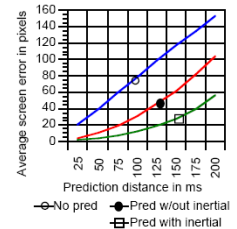


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More on Reducing Dynamic Errors

- Match input streams
 - Delay video of real world to match system lag
- Predictive Tracking
 - Inertial sensors helpful

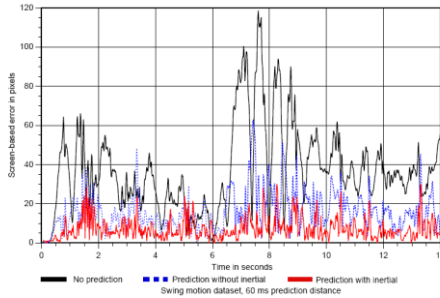


Azuma / Bishop 1994

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Predictive Tracking (Azuma 94)



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Conclusions

- Environment sensing
 - Effective AR needs:
 - User's position & orientation
 - Position of objects
 - Depth map
- Video tracking
 - Place markers in environment
 - Hybrid systems (video + magnetic sensors, video + accelerometer) have better performance

<http://www-inst.eecs.berkeley.edu/~ee225b/sp11/lectures/Recent%20Advances%20in%20Augmented%20Reality%20PPT.pdf>



Conclusions .

- Outdoor & mobile AR apps
 - Not practical to cover environment with markers
 - Compass/gyroscope tracker (orientation)
 - GPS (position)
- Unprepared environments
 - Rely on tracking visible natural features
 - Track horizon silhouette (given database of environment)



<http://www-inst.eecs.berkeley.edu/~ee225b/sp11/lectures/Recent%20Advances%20in%20Augmented%20Reality%20PPT.pdf>



Questions

