PA198
Augmented Reality Interfaces

Lecture 6

Augmented Reality Tracking

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What is Tracking?

- Tracking works out where we are standing and looking
  - So that graphics can be draw 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

Head Stabilized

Body Stabilized

World Stabilized

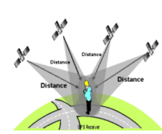
- Augmented Reality Information Display
  - World Stabilized
  - Body Stabilized
  - Head Stabilized

Increasing Tracking Requirements

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

Tracking Technologies

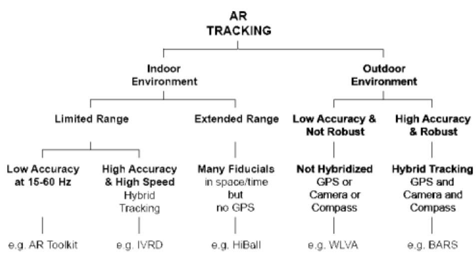
- Active
  - Mechanical, Magnetic, Ultrasonic
  - GPS, Wifi, cell location



- Passive
  - Inertial sensors (compass, accelerometer, gyro)
  - Computer Vision
  - Marker based, natural feature tracking
- Hybrid Tracking
  - Combined sensors (i.e. vision + inertial)

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

AR Tracking Taxonomy



Billinghurst, 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

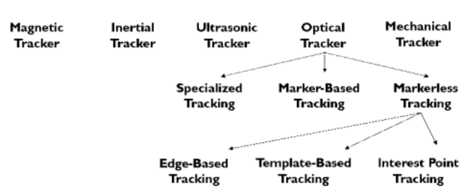
- Three types of tracking:
  - Sensors
  - Visual
  - Hybrid

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



Billinghurst, 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

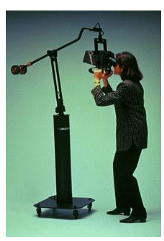
Billinghurst, M. COSC 426: Augmented Reality, July 26th 2013.

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

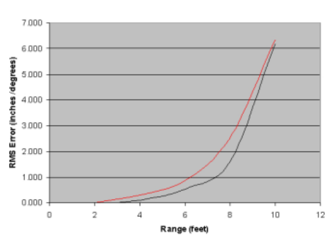


BOOM HF

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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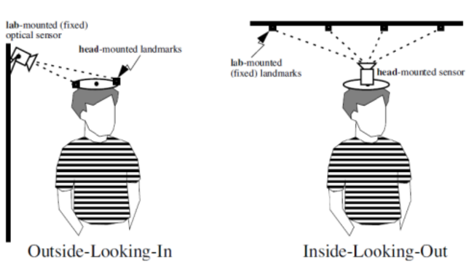
Outside-In v.s. Inside-Out Tracking



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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.

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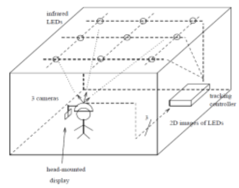
HiBall Tracking System (3rd Tech)

- 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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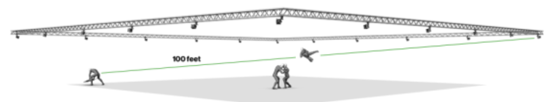
Motion Tracking

- 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

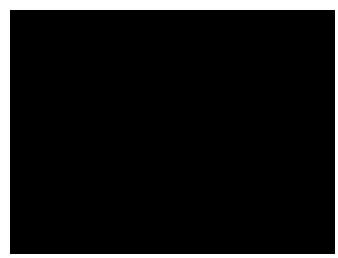
Physical simulations

Geometrical sculpture

http://vrecko.cz/

27

VRECKO Video



http://vrecko.cz/research/vekva/freehand-painting/

28

Valve's Lighthouse Tracking

- The main idea behind tracking is flooding a room with non-visible light, Lighthouse functions as a reference point for any positional tracking device (like a VR headset or a game controller) to figure out where it is in real 3D space

http://gizmodo.com/this-is-how-valve-s-amazing-lighthouse-tracking-technol-1705356768

Valve's Lighthouse Tracking .

- Valve's Lighthouse boxes don't have any cameras
- They just fire light out (sixty times every second) into the world to help ships (or VR headsets) navigate on their own
- That light comes from a whole bunch of stationary LEDs, plus a pair of active laser emitters that spin like crazy

http://gizmodo.com/this-is-how-valve-s-amazing-lighthouse-tracking-technol-1705356768

Valve's Lighthouse Tracking ..

- The receiver (VR headset or controller) is covered with little photosensors that detect the flashes and the laser beams
- When a flash occurs, the headset simply starts counting (like a stopwatch) until it "sees" which one of its photosensors gets hit by a laser beam
- It uses the relationship between where that photosensor exists on the headset, and when the beam hit the photosensor, to mathematically calculate its exact position relative to the base stations in the room

http://gizmodo.com/this-is-how-valve-s-amazing-lighthouse-tracking-technol-1705356768

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)

Ultrasonic Logitech

IS600

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Inertial Trackers

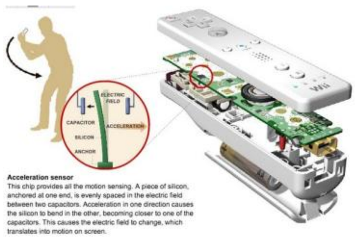
- Inertial trackers measure changes in rotation regarding one, two or even three axes by using a device called a gyroscope
- Gyroscopes can maintain spinning on a particular axis while in motion based on the laws of conservation of angular momentum
  - When an external force is applied the reaction is 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

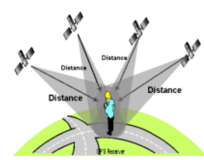
- GPS is a technology widely used for outdoor tracking
- The most important categories include
  - Standard GPS
  - Differential GPS
  - Real-time kinematic GPS

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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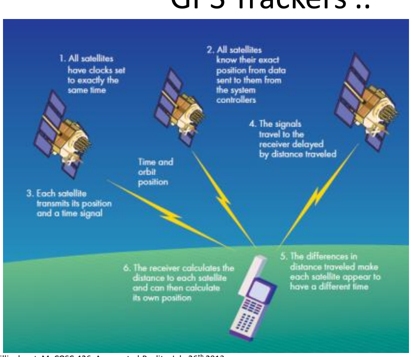
GPS Trackers ..



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Problems with GPS

- Takes time to get satellite fix
  - Satellites moving around
- Earths 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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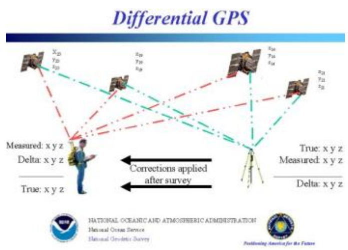
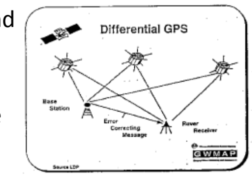
Differential GPS

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



Differential GPS .

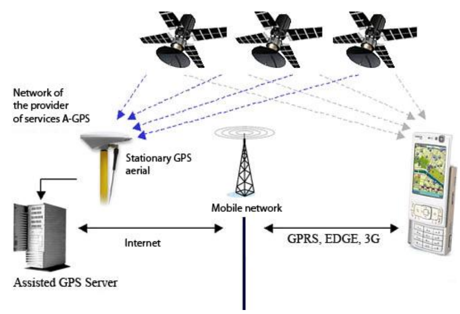
- The mobile GPS receiver monitors signals from a fixed radio transmitter and another GPS receiver
- To refine the resolution the transmitter sends the corrected co-ordinates
  - Based on the difference between the known and the computed positions



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

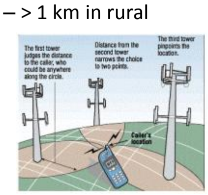
Assisted-GPS (A-GPS)

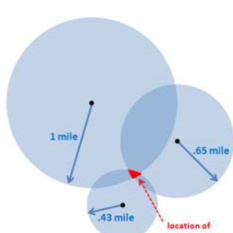


http://gps-response.com/61-a-gps.html

Cell Tower Triangulation

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

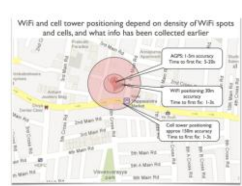




Triangulation - cell phone detected within a certain radius of each of 3 cell towers – the area where each cell tower overlaps the phone is where it is pinpointed.

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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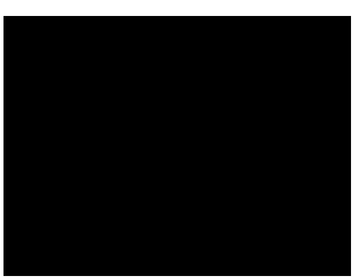
Skyhook

- Skyhook 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/

Skyhook Video



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

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

Visual Tracking .

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

(u, v) ↔ (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-klein-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-klein-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-klein-presentation-frontiers-of-engineering

Marker-based Tracking .

- Has been done for more than 15 years
- A square marker provides 4 corners
  - Enough for pose estimation!
- Several open source solutions exist
- Fairly simple to implement
  - Standard computer vision methods

Marker-based Tracking ..

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

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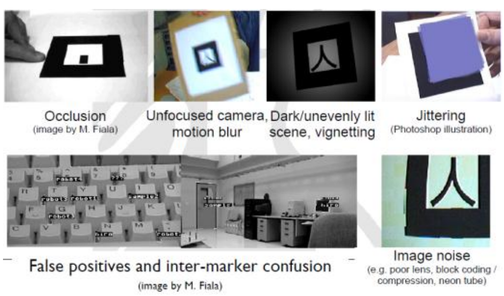
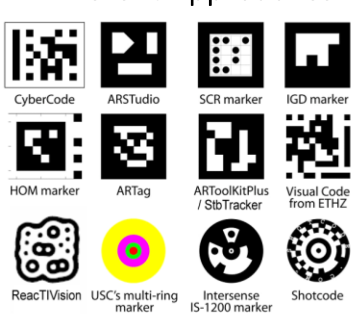
Tracking Challenges in ARToolKit



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. artTag, ARToolKitPlus
- Pose accuracy depends on distance to marker
- Pose accuracy depends on angle to marker

Different Approaches



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/

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/georg-klein-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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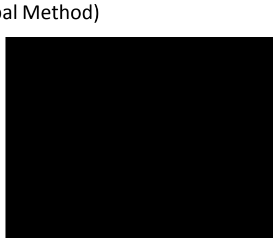
Curve Based Tracking

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

www.loria.fr/~petitjea/papers/mva99.pdf

Edge Based Tracking

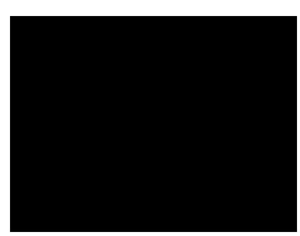
- RAPiD [Drummond et al. 02]
  – Initialization, Control Points, Pose Prediction (Global Method)



https://vimeo.com/91642721

Line Based Tracking

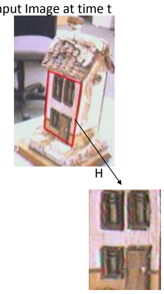
- Visual Servoing [Comport et al. 2004]



https://www.youtube.com/watch?v=_Dln257k2Sc

Region-based Approach

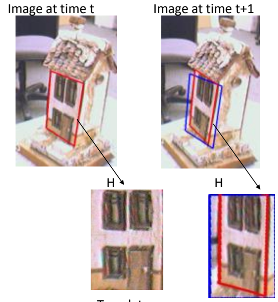
- On initialization the user selects a plane of interest
- The rectifying Homography and rectified template image are retained



Birkbeck, N. Registration for Augmented Reality, 2006

Region-based Approach .

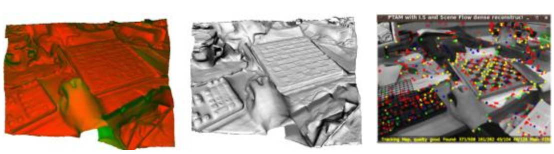
- When new image arrives, use image intensities to refine the Homography



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-klein-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 Analisys)
- Applied to tracking by detection (LePetit06)

Barandiaran, I., Cottez, 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., Cottez, 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 leave nodes

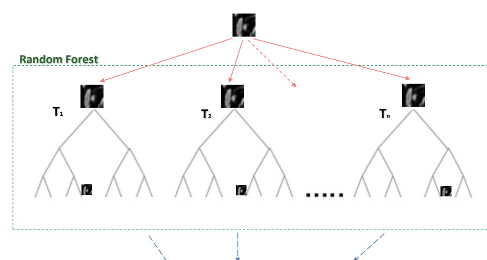
Barandiaran, I., Cottez, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008

Random Forest - Example Classification

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

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

Random Forest - Combine Results



$$Example_{class\_label} = \arg\max_t \sum_{k=1}^{T} P\left(Y = c_i \mid t_k^n\right)$$

Barandiaran, I., Cottez, 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)

Barandiaran, I., Cottez, 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

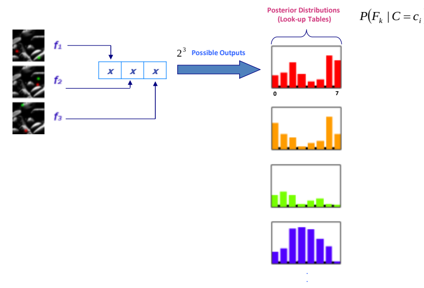
Ozuysal, M., Fua, P., Lepetit, V. Fast Keypoint Recognition in Ten Lines of Code, Proc. CVPR, IEEE Computer Society, 2007. (DOI: 10.1109/CVPR.2007.383123)

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

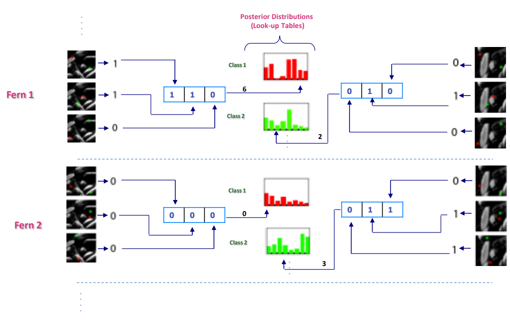
Barandiaran, I., Cottez, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008

FERNS Classifier Training



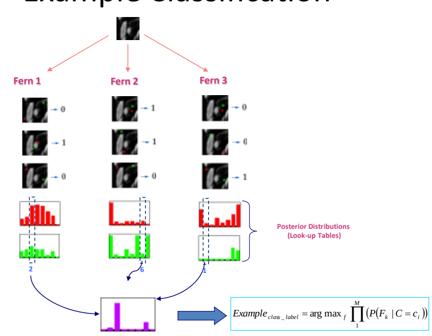
Barandiaran, I., Cottez, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008

FERNS Classifier Training .



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

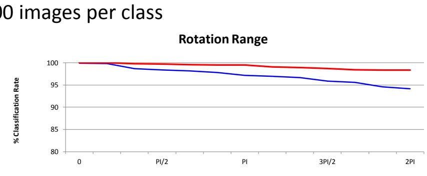
Example Classification



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

Random Forest vs FERNS

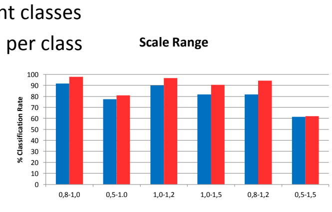
- Rotation Range
  - 20 Trees, 15 depth
  - 225 different classes
  - 400 images per class



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

Random Forest vs FERNS .

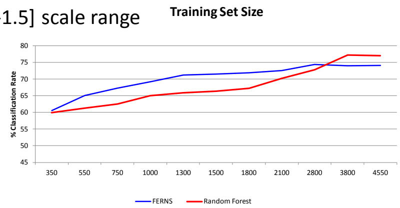
- Scale Range
  - 20 trees, 15 depth
  - 225 different classes
  - 400 images per class



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

Random Forest vs FERNS ..

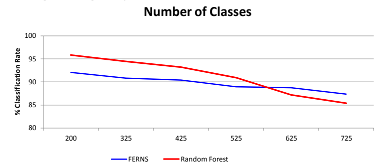
- Size of the training set
  - 20 trees, 15 depth
  - 225 different classes
  - [0.5-1.5] scale range



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

Random Forest vs FERNS …

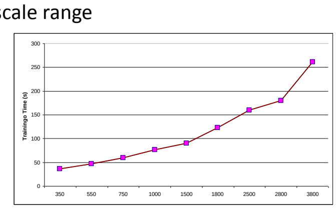
- Number of different classes
  - 20 trees, 15 depth
  - [0.8-1.2] scale range
  - 1500 Training images per class



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

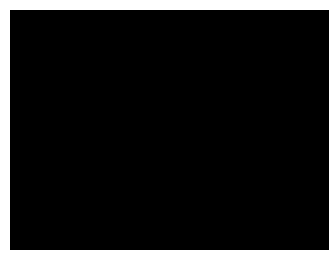
Random Forest vs FERNS ….

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



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

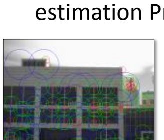
FERNS Video



https://www.youtube.com/watch?v=OxibDXlWIoA

Random Forest - FERNS

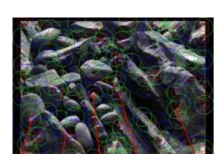
- Tracking of Planar Surfaces
- The Classifiers are applied for interest point (feature) matching
- Matched Points are used during camera pose estimation Process



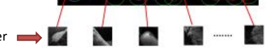
Barandiaran, I., Cottez, C., et al. Comparative Evaluation of Random Forest and Fern classifiers for Real-Time Feature Matching, VICOM Tech, 2008

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



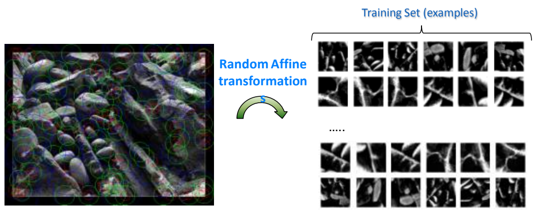
Classes to Be recognized by the Classifier



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

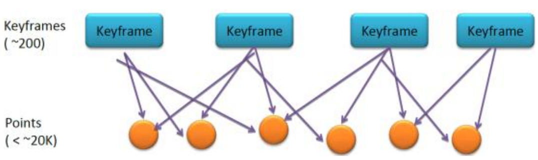
Unknown Environments

- 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.raeng.org.uk/publications/other/georg-klein-presentation-frontiers-of-engineering

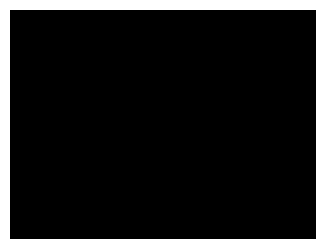
Parallel Tracking and Mapping (PTAM)

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



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

PTAM Video



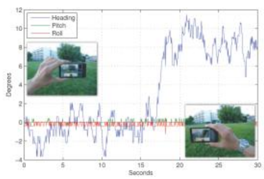
Hybrid Tracking

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

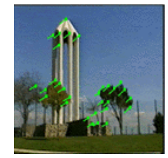
- Used by many “AR browsers”
- GPS, Compass, Accelerometer, Gyroscope
- Not sufficient alone (drift, interference)



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

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



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

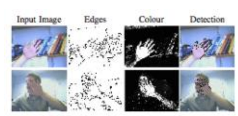
Combining Sensors and Vision

- 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)

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

Hand Tracking / Interaction

- Real-time unassisted monocular hand tracking is still unsolved



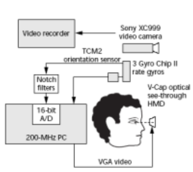
Stenger et al 2006

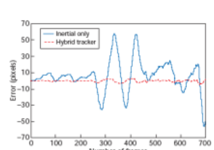
Wang and Popovic 2009

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

Outdoor AR Tracking System

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





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

Robust Outdoor Tracking

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

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

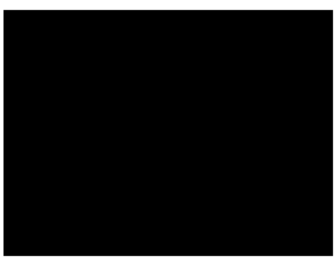
Handheld Display

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

Hybrid Tracking Indoors Video

https://www.youtube.com/watch?v=4H8JtLr0Mk8

Hybrid Tracking Outdoors Video



https://www.youtube.com/watch?v=GQ-Delh4DQA

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