Computer Vision II - Lecture 1

Introduction

15.04.2014

Bastian Leibe
RWTH Aachen
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Organization

- Lecturer
  - Prof. Bastian Leibe (leibe@vision.rwth-aachen.de)
- Teaching Assistants
  - Stefan Breuers (breuers@vision.rwth-aachen.de)
  - Umer Rafi (rafi@vision.rwth-aachen.de)
- Course webpage
  - http://www.vision.rwth-aachen.de/teaching/
    → Computer Vision2
  - Slides will be made available on the webpage
  - There is also an L2P electronic repository
- Please subscribe to the lecture on the Campus system!
  - Important to get email announcements and L2P access!

Language

- Official course language will be English
  - If at least one English-speaking student is present.
  - If not… you can choose.
- However…
  - Please tell me when I'm talking too fast or when I should repeat something in German for better understanding!
  - You may at any time ask questions in German!
  - You may turn in your exercises in German.
  - You may answer exam questions in German.

Organization

- Structure: 3V (lecture) + 1Ü (exercises)
  - 6 EECS credits
  - Part of the area "Applied Computer Science"
- Place & Time
  - Lecture: Tue 14:15 - 15:45 UMIC 025
  - Lecture/Exercises: Thu 14:15 - 15:45 UMIC 025
- Exam
  - Planned as oral exam
  - We'll propose a list of dates towards the end of the semester

Course Webpage

Tentative Schedule

Date	Topic	Content	Slides	Related Material
08.04.14	*no class (Introduction week)*	-		
10.04.14	*no class (Introduction week)*	-		
15.04.14	Introduction	What is Tracking?	pdf, fullpage	
17.04.14	*Exercise 0*	*Intro Matlab*		Matlab resources Presentation Exercise Content
22.04.14	Background Modeling	MoG Background Model, Online Adaptation, Non-parametric Models		
24.04.14	Template based Tracking	LK Tracking, fast template matching, Affine LK, Line Tracking, Model based Tracking		
29.04.14	Color based Tracking			
01.05.14	*no class (May 1st)*	-		

Thursday: Matlab tutorial

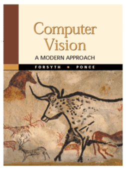
http://www.vision.rwth-aachen.de/teaching/

Exercises and Demos

- Exercises
  - Typically 1 exercise sheet every 2 weeks (Matlab based)
  - Hands-on experience with the algorithms from the lecture.
  - Send in your solutions the night before the exercise class.
- Teams are encouraged!
  - You can form teams of up to 3 people for the exercises.
  - Each team should only turn in one solution.
  - But list the names of all team members in the submission.

Textbooks

- No single textbook for the class.
- Some basic material is covered in the following book:



D. Forsyth, J. Ponce
Computer Vision - A Modern Approach
Prentice Hall, 2002

(available in the library's "Handapparat")

- We will mostly give out research papers
  - Tutorials for basic techniques
  - State-of-the-art research papers for current developments

Computer Vision II

- We will build upon the basics from previous lectures
  - Computer Vision I
  - Machine Learning
- However,
  - If you haven't heard those lectures yet, you may still attend and benefit from this lecture.
  - But please look at the available online material from those lectures to get additional background on the basic techniques.
  - I will regularly point out what background to repeat.

How to Find Us

- Office:
  - UMIC Research Centre
  - Mies-van-der-Rohe-Strasse 15, room 124

- Office hours
  - If you have questions to the lecture, come to Stefan/Umer or me.
  - My regular office hours will be announced (additional slots are available upon request)
  - Send us an email before to confirm a time slot.

Questions are welcome!

Why Computer Vision?

Slide credit: Kristen Grauman

Images and Video Are Everywhere...

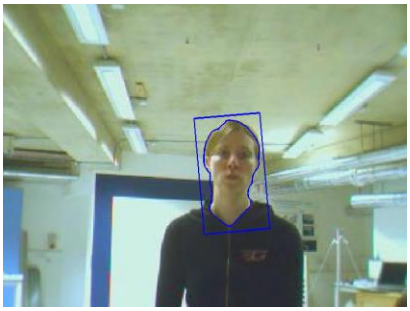
Slide adapted from Svetlana Lazebnik

Computer Vision I Covered the Basics...

- Image Processing Basics
- Segmentation
- Local Features & Matching
- Object Recognition and Categorization
- 3D Reconstruction



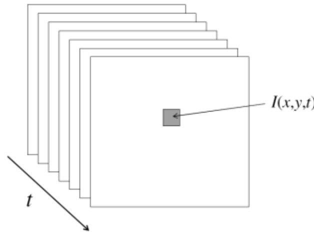
Computer Vision II is all about Motion



How can we track an object's motion over time?

Motion Requires Video

- A video is a sequence of frames captured over time
- Our image data is a function of space (x, y) and time (t)



What Is Tracking?

- Goal
  - *Estimate the **number** and state of objects in a region of interest*
- Number
  - 1: Single-target tracking
  - 0 or 1: Detection and tracking
  - N: Multi-target detection and tracking

What Is Tracking?

- Goal
  - *Estimate the number and **state** of objects in a region of interest*
- State
  - We are using the term state to describe a vector of quantities that characterize the object being tracked.

E.g.	$[x, y]$	(location)
	$[x, y, dx, dy]$	(location + velocity)
	$[x, y, appearance\text{-}params]$	(location + appearance)

  - Because our observations will be noisy, estimating the state vector will be a statistical estimation problem.

What Is Tracking?

- Goal
  - *Estimate the number and state of **objects** in a region of interest*
- Objects
  - We will look at a large variety of objects to track.
  - They can be given by a user or detected automatically.
  - Most interesting are people.

Image sources: Kristen Grauman, Michael Breitenstein, Vittorio Ferrari

What Is Tracking?

- Goal
  - ***Estimate** the number and state of objects in a region of interest*
- What distinguishes tracking from "typical" statistical estimation (or machine learning) problems?
  - Typically a strong temporal component is involved.
  - Estimating quantities that are expected to change over time (thus, expectations of the dynamics play a role).
  - Interested in current state S_t for a given time step t.
  - Usually assume that we can only compute information seen at previous time steps $1, 2, \ldots, t\text{-}1$. (*Can't look into the future!*)
  - Usually we want to be as efficient as possible, even "real-time".

⇒ These concerns lead naturally to recursive estimators.

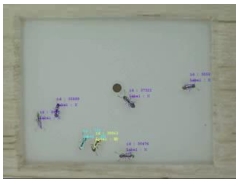
Types of Tracking

- **Single-object tracking** focuses on tracking a single target in isolation.

[Z. Kalal, K. Mikolajczyk, J. Matas, PAMI'10]

Types of Tracking

- **Multi-object tracking** tries to follow the motion of multiple objects simultaneously.



Ant behavior, courtesy of Georgia Tech biotracking

"Objects" can be corners, and tracking gives us optical flow.

Types of Tracking

- **Articulated tracking** tries to estimate the motion of objects with multiple, coordinated parts

[I. Matthews, S. Baker, IJCV'04]

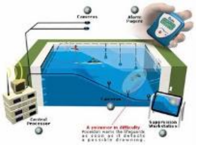
Types of Tracking

- **Active tracking** involves moving the sensor in response to motion of the target. Needs to be real-time!

Applications: Safety & Security

Autonomous robots

Driver assistance



Monitoring pools
(Poseidon)

Pedestrian detection
[MERL, Viola et al.]

Surveillance

Applications: Vision-based Interfaces

Games
(Microsoft Kinect)

Assistive technology systems
Camera Mouse
Boston College

Applications: Visual Special Effects

The Matrix

MoCap for *Pirates of the Carribean*, Industrial Light and Magic
(Source: S. Seitz)

Why Are There So Many Papers on Tracking?

- Because what kind of tracking "works" depends on problem-specific factors...

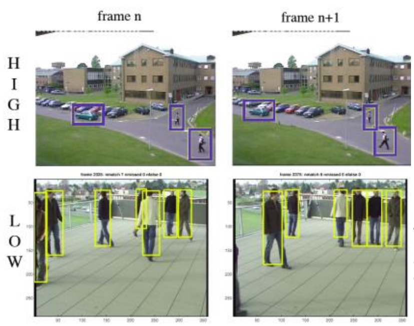
Factors: Discriminability

- How easy is it to discriminate one object from another?

Appearance models can do all the work

Constraints on geometry and motion become crucial

Factors: Frame Rate



Gradient ascent (e.g. mean-shift) works OK

Much harder search problem. Good data association becomes crucial.

Other Factors

- Single target *vs.* multiple targets
- Single camera *vs.* multiple cameras
- On-line *vs.* batch mode
- Do we have a good generic detector? (e.g., faces, pedestrians)
- Does the object have multiple parts?
- ...

Elements of Tracking

t=1 t=2 ... t=20 t=21

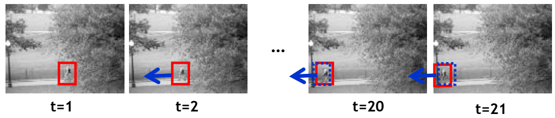
- Detection
  - Find the object(s) of interest in the image.

Elements of Tracking

- Detection
  - Find the object(s) of interest in the image.
- Association
  - Determine which observations come from the same object.

Image credit: Kristen Grauman

Elements of Tracking



- Detection
  - Find the object(s) of interest in the image.
- Association
  - Determine which observations come from the same object.
- Prediction
  - Predict future motion based on the observed motion pattern.
  - Use this prediction to improve detection and data association in later frames.

Image credit: Kristen Grauman

Outline of This Lecture

- Single-Object Tracking
  - Background modeling
  - Template based tracking
  - Color based tracking
  - Contour based tracking
  - Tracking by online classification
  - Tracking-by-detection
- Bayesian Filtering
- Multi-Object Tracking
- Articulated Tracking

Image sources: Kristen Grauman, Gary Bradsky, Esther Horbert, Helmut Grabner

Background Modeling

- Learning a statistical model of background appearance

A. Elgammal, D. Harwood, L.S. Davis, Non-parametric Model for Background Subtraction, ECCV 2000.

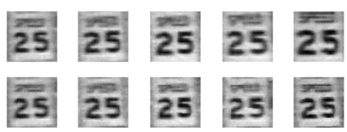
Applications: Visual Surveillance

Video by Daniel Roth, ETH Zurich

Template Tracking

- Lucas-Kanade registration applied to tracking ⇒ KLT

Video sequence



Tracked template

J. Shi and C. Tomasi. Good Features to Track. CVPR 1994.

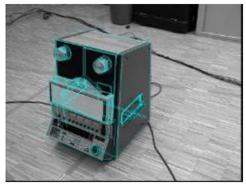
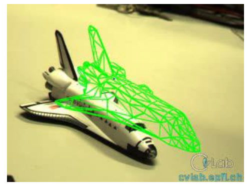
Color-based Tracking

- Mean-Shift Tracking


D. Comaniciu, V. Ramesh, P. Meer. Kernel-Based Object Tracking, PAMI, Vol. 25(5), pp. 564-575, 2003.

Model-based Tracking

- Tracking lines on the object given a 3D model

L. Vacchetti, V. Lepetit and P. Fua, Stable Real-Time 3D Tracking Using Online and Offline Information, PAMI, Vol. 26(10), pp. 1385-1391, 2004.

Applications: Tracking Faces for AR

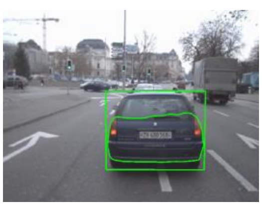
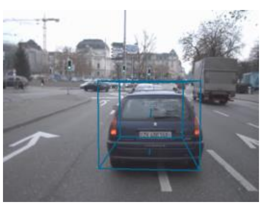
- Flexible models for an entire class of objects

Contour-based Tracking

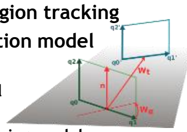
- Level Set Contour Tracking

C. Bibby, I. Reid, Robust Real-Time Visual Tracking using Pixel-Wise Posteriors, *ECCV'08*.

Geometrically Constrained Level-Set Tracking

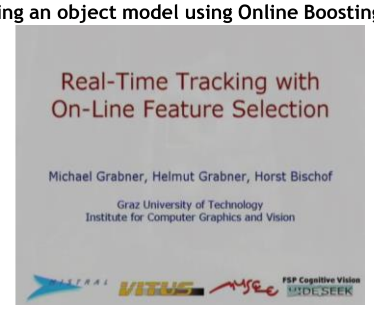
- Encode geometric constraints into region tracking
- Constrained homography transformation model
  - Translation on the ground plane
  - Rotation around the ground plane normal



⇒ Input for high-level tracker with car steering model.

Tracking by Online Classification

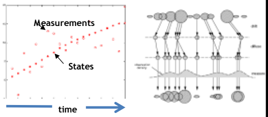
- Learning an object model using Online Boosting



H. Grabner, M. Grabner, H. Bischof. Real-time Tracking via On-line Boosting, BMVC'06.

Outline of This Lecture

- Single-Object Tracking
- Bayesian Filtering
  - Kalman Filters, EKF
  - Particle Filters
- Multi-Object Tracking
- Articulated Tracking



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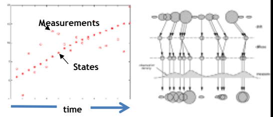
  - Particle Filters
- Multi-Object Tracking
  - Multi-hypothesis data association
  - MHT, JPDAF, MCMCDA
  - Network flow optimization
- Articulated Tracking



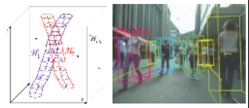


Image sources: Andreas Ess

Multi-Person Tracking

M. Breitenstein, F. Reichlin, B. Leibe, E. Koller-Meier, L. Van Gool. Online Multi-Person Tracking-by-Detection from a Single, Uncalibrated Camera, PAMI, Vol.33(9), pp. 1820-1833, 2011.

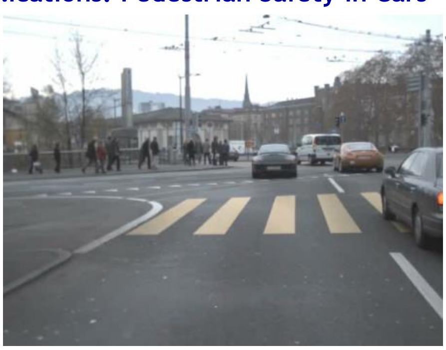
[Breitenstein, Reichlin, Leibe, Koller-Meier, Van Gool, ICCV'09; PAMI'10]

Applications: Tracking Sports Players

- Automatic player tracking for sports scene analysis
  - Several companies active in this area…

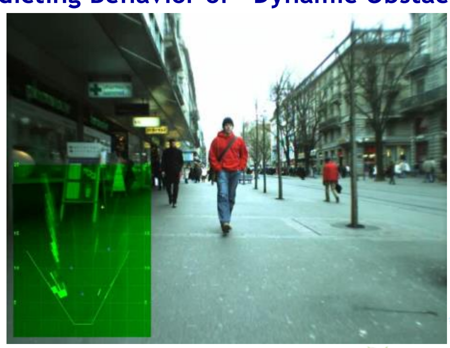
[Breitenstein, Reichlin, Leibe, Koller-Meier, Van Gool, ICCV'09; PAMI'10]

Applications: Pedestrian Safety in Cars



[Ess, Leibe, Schindler, Van Gool, PAMI'09]

Predicting Behavior of "Dynamic Obstacles"



[Ess, Leibe, Schindler, Van Gool, ICRA'09]

Applications: Mobile Robot Navigation

link to the video

Most Recent Version (Demo available)

- Kinect-based head-worn setup
  - Person detection + Tracking + Visual odometry + GP estimation
  - Result: 20-35 fps on single CPU core (no GPU involved!)
    15 fps with additional far-range detector (on the GPU)

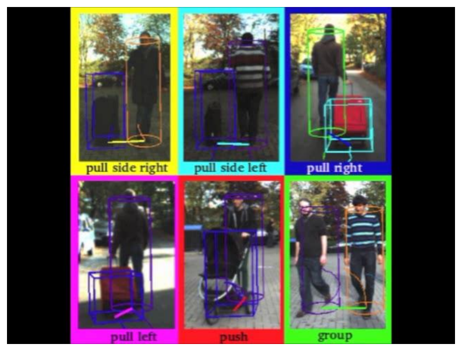
[O. Hosseini Jafari, D. Mitzel, B. Leibe, ICRA'14]

Mobile Tracking in Densely Populated Settings

(Tracking based on stereo depth only, no detector verification)

[D. Mitzel, B. Leibe, ECCV'12]

Analyzing Person-Object Interactions



[T. Baumgartner, D. Mitzel, B. Leibe, CVPR'13]

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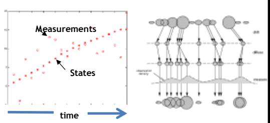
  - Kalman Filters, EKF
  - Particle Filters
- Multi-Object Tracking
  - Multi-hypothesis data association
  - MHT, JPDAF, MCMCDA
  - Network flow optimization
- Articulated Tracking
  - GP body pose estimation
  - Model-based tracking, AAMs
  - Pictorial Structures



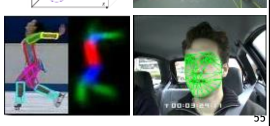


Image sources: Andreas Ess, Deva Ramanan, Ian Matthews

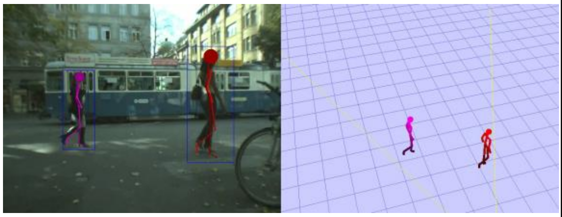
Articulated Person Tracking

- Tracking and interpreting detailed body motion.

D. Ramanan, D.A. Forsyth, A. Zisserman. Tracking People by Learning their Appearance, PAMI 2007.

[D. Ramanan, D. Forsyth, PAMI'07]

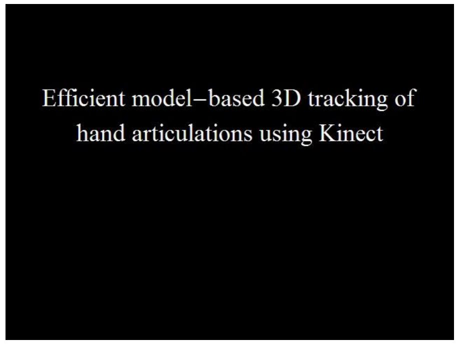
Combination: Articulated Multi-Person Tracking



- Multi-Person tracking
  - Recovers trajectories and solves data association
- Articulated Tracking
  - Estimates detailed body pose for each tracked person

[Gammeter, Ess, Jaeggli, Schindler, Leibe, Van Gool, ECCV'08]

Articulated Hand Tracking



[J. Oikonomidis, A. Argyros, BMVC'11]

Applications: Facial Animation Transfer

Face/Off: Live Facial Puppetry

PaperID 102

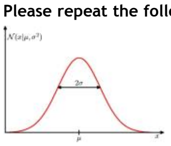
T. Weise, S. Bouaziz, H. Li, M. Pauly: Realtime Performance-based Facial Animation. SIGGRAPH 2011

Applications: Facial Animation Transfer

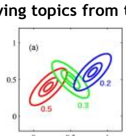
Commercialized by faceshift
https://www.youtube.com/watch?v=b5m40eF3C9E

Wrap-Up

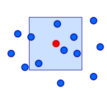
- You've seen many exciting applications
  - In this lecture, we'll look at how all of this works.
  - We will build upon basics from the CV I and ML lectures.
  - *You can attend the class without having heard those, but please use the available online material for self-study.*
- Next lecture: Background modeling
  - Please repeat the following topics from the ML lecture:



Gaussians & ML estimation



Mixtures of Gaussians & EM



Kernel density estimation

Questions?