TSBB15
Computer Vision

Lecture 7
Object Tracking Project

CE1

Not everyone finished CE1 yesterday.

Opportunity to show the completed lab to TAs:

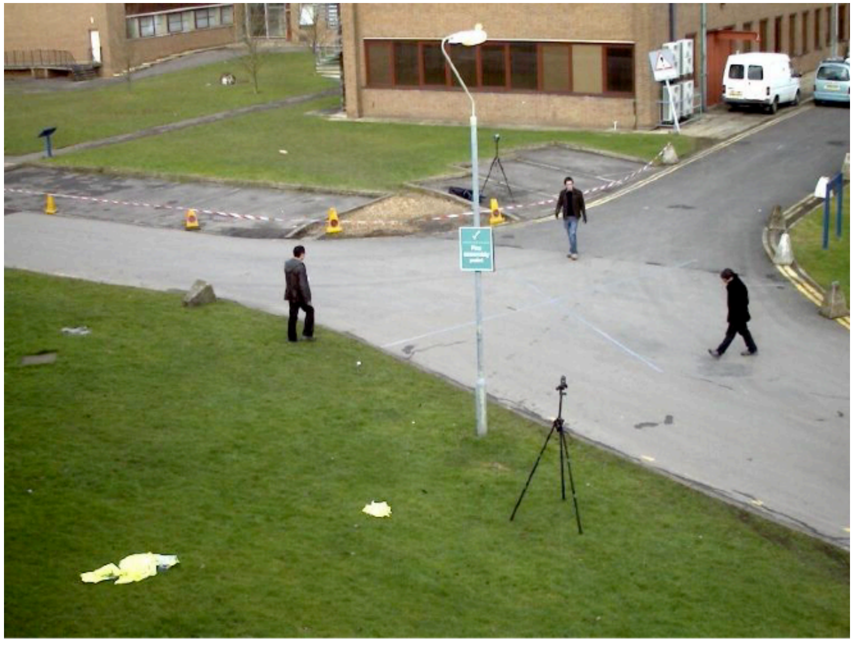
Feb 10: 13.00 in Asgård
(just before CE2)

Project goals

Technical goals of this project

Given an image sequence,
detect and **track** all moving objects

Indicate objects with
boxes + identity numbers



PETS09-S2L1

Assumptions

Static camera

Static background

Humans or cars are moving on a flat ground plane

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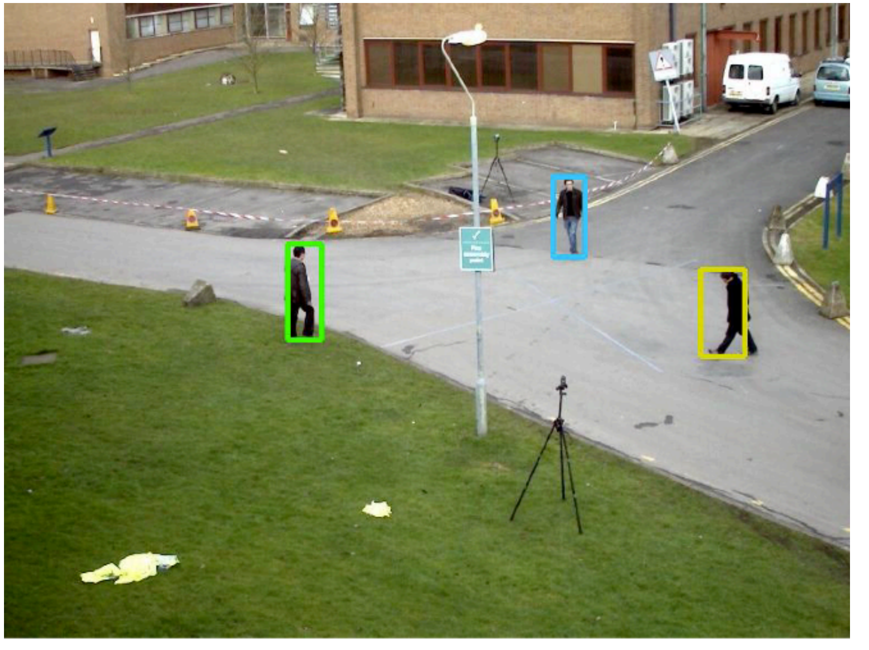


PETS09-S2L1-GT

Assumptions

Static camera

Static background

Humans or cars are moving
on a flat ground plane

Object tracking

Application areas

surveillance, traffic analysis, animal behaviour, sports, …

Commercial systems

Axis, Chyron Hego (Tracab), Irisity, Viscando

Research projects

iPatch (pirate detection at sea)

VOT (visual object tracking challenge)

PETS (annual workshop)

Student projects in TSBB11

Project web page

Full specification of the project on webpage:

www.cvl.isy.liu.se/education/undergraduate/tsbb15/object-tracking-project

Requirements

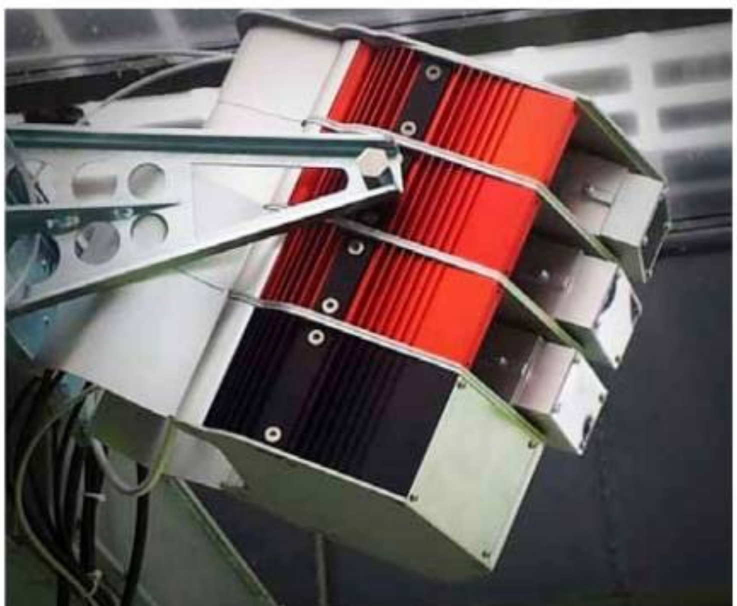
Datasets

References

…

Sports Analysis

Example:
Tracab system (from company ChyronHego) for automatic tracking of football players.



3D tracking in real time using a pack of stereo rigs.

Project Challenges

- Shadows / reflections from moving objects
  - Create “ghost” objects
- Uneven illumination of the scene
  - Visual appearance of an object changes
  - Variation both in space and in time
- 3D rotations, articulation
  - Object appearance changes
- Occlusion
  - Ambiguities in object identity

Toolbox of methods

As we assume a static camera & background:

- Use *background modeling* to detect motion

To robustly maintain object identity:

- KL-tracking, Foreground Model, Motion Prediction,
- Ground plane mapping + 3D tracking

Shadows/reflections can be managed by:

- Colour modeling

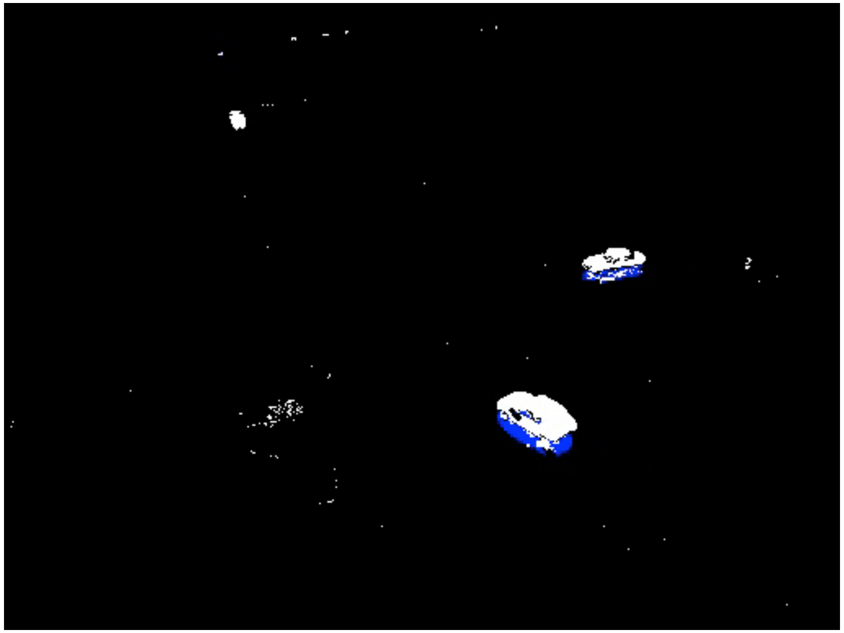
Background modeling

A popular application of *mixture models* [LE6]

- A background model is a set of mixture models; one for each pixel in the image
  - 1 component is sometimes sufficient
  - 2 or more components to handle more general scenes
- Pixel values far from the mixture model are seen as foreground pixels = moving objects
- Popular way to track e.g. people and cars in stationary surveillance cameras
- Fast compared to dense motion estimation

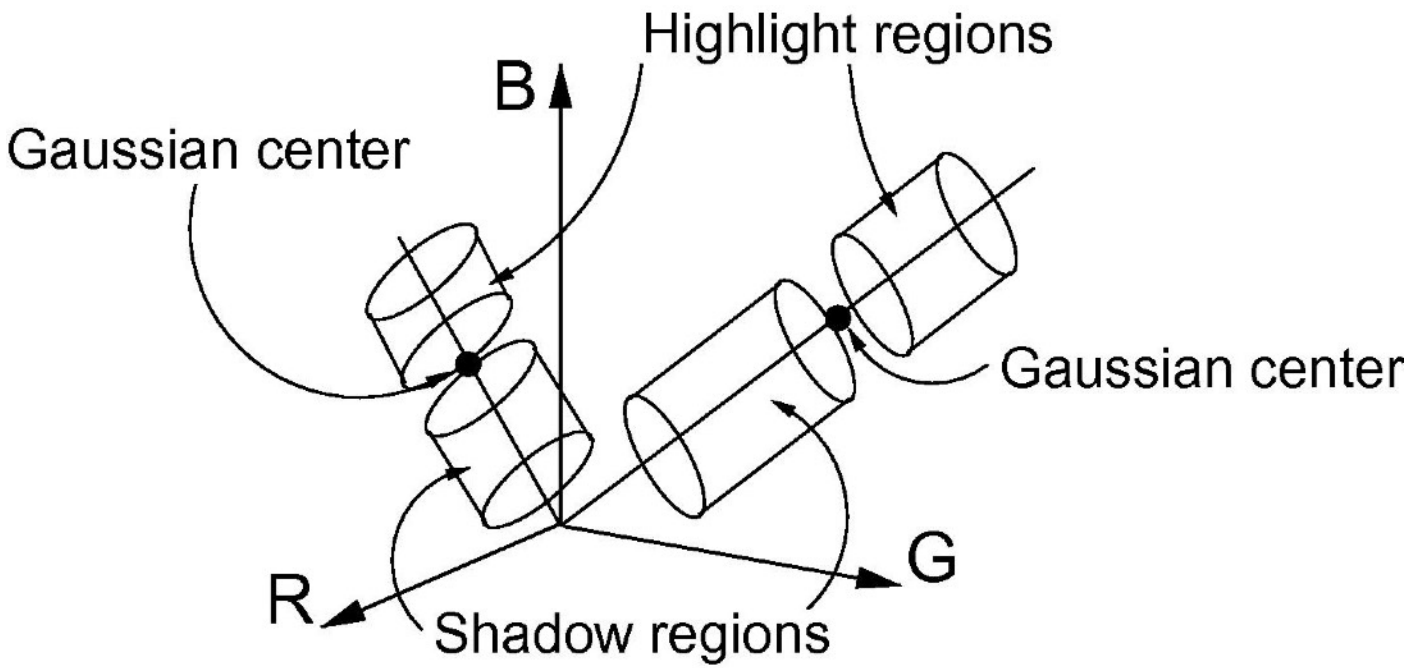
Background modeling

- Master thesis project at CVL, LiU, by John Wood
- Background modeling + shadow detection



Background modeling

- Master thesis project at CVL, LiU, by John Wood
- Background modeling + shadow detection + highlights



Background modeling

Popular approaches:

- Gaussian Mixture Models [LE6]

  Pseudo-code for on-line updates in J. Wood's master thesis, section 4.3

- Median filtering

  Masters thesis of J. Wood, section 2.2

  PhD thesis of H. Ardö, section 3.2.2

  Simple and thus useful to start with.

- Sample based approaches

  O. Barnich, M. Droogenbroeck, *ViBe: A Universal Background Subtraction Algorithm for Video Sequences*, TIP 2011
  Check this out for tricks to improve your performance (They also work for Median and GMM)

Foreground segmentation

- Background modeling gives a **likelihood map** with $p(I(x,y)|\text{background})$ [See LE6]
- Use likelihood map to find **consistent regions**
  - cleanup alt1: Gaussian filtering and thresholding
  - cleanup alt2: thresholding + morphological shrink + expand
  - labeling: to get contiguous regions
- From these regions, extract **bounding boxes**
  - The smallest rectangle that includes the detected object

Maintaining object identity

Start by detecting moving objects in each frame

Next: determine which detection in frame t corresponds to which one in frame $t + 1$

Maintaining object identity

Start by detecting moving objects in each frame

Next: determine which detection in frame t corresponds to which one in frame $t + 1$

Simple approach:

Check how much all pairs of detections overlap

In general this leads to the ***assignment problem***

Find the optimal assignment of correspondence between detections in frame t, and t+1, given ***match scores***.
Solutions: Hungarian methods

In this project, **greedy approximations are acceptable**.

Maintaining object identity

Example: overlap scores

Frame t regions \ Frame t+1 regions:	0	1	2	3	4
0	0.6	0.0	0.0	0.0	0.0
1	0.0	0.5	0.55	0.0	0.0
2	0.0	0.0	0.0	0.87	0.0
3	0.0	0.0	0.0	0.0	0.62

Maintaining object identity

Example: overlap scores, assignment

Frame t regions \ Frame t+1 regions:	0	1	2	3	4
0	0.6	0.0	0.0	0.0	0.0
1	0.0	0.5	0.55	0.0	0.0
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3	0.0	0.0	0.0	0.0	0.62

Maintaining object identity

Some possible **match scores** for assignment:

- Overlap of bounding box
- Overlap of *predicted* bounding box
- Overlap of region mask
- Overlap of warped/predicted region mask
- Overlap + visual appearance score [see LE8]
- etc…

Temporal prediction

Prediction of bounding box/mask locations

From temporal filtering we can predict where the object will end up in the next frame
e.g. IIR, Kalman, KLT tracks, optical flow

Can help to maintain object identity in case of

occlusion

close objects, rapid motion

or noise in general

Ground plane modeling

Assumption:

objects are moving on a planar surface: the ground plane.

Mapping from image coordinates to ground plane is a homography, which can be estimated (TSBB06).

- "foot points" of object can be mapped to a position in the ground plane
- The ground plane position can be temporally filtered
- **Hand-over** to other views is possible

Datasets

The scientific community has produced a number of standard datasets for *multiple object tracking*:

- CAVIAR
- PETS and MOT (annual competitions)
- IVSS
- changedetection.net

They typically contain:

- Video sequences (MPEG + JPEG)
- Annotation (labelling of objects) in some datasets

Performance evaluation

Compare your boxes with *ground truth* (GT)

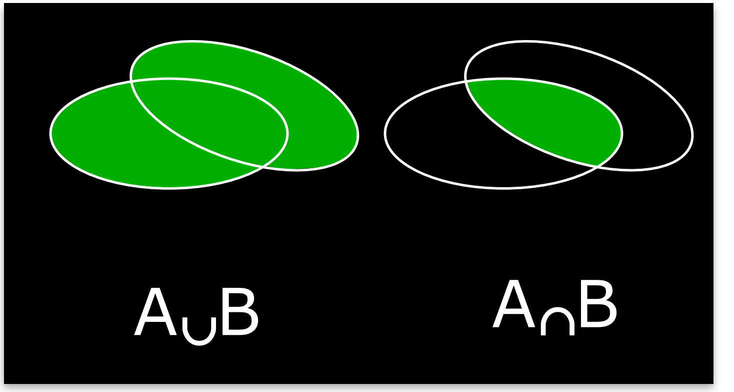
Possible performance measures:

- Average overlap error
- Number of identity switches for an object
- …
- [Details on project webpage]

Overlap

Intersection over union (IoU) aka. Jaccard index:

$$J(A,B) = \frac{\text{area}(A \cap B)}{\text{area}(A \cup B)}$$



Overlap error (aka. Jaccard distance):

$$\epsilon = 1 - \frac{\text{area}(A \cap B)}{\text{area}(A \cup B)}$$

Training set/test set

Parameter tuning

Many system parameters to tune

Define a training set/test bench for parameter tuning

Test on new sequences - with the same parameters!

See discussion in learning lecture [LE6]

Benchmark (test set) will be announced later

Last year we used three sequences from MOT15

Automated evaluation

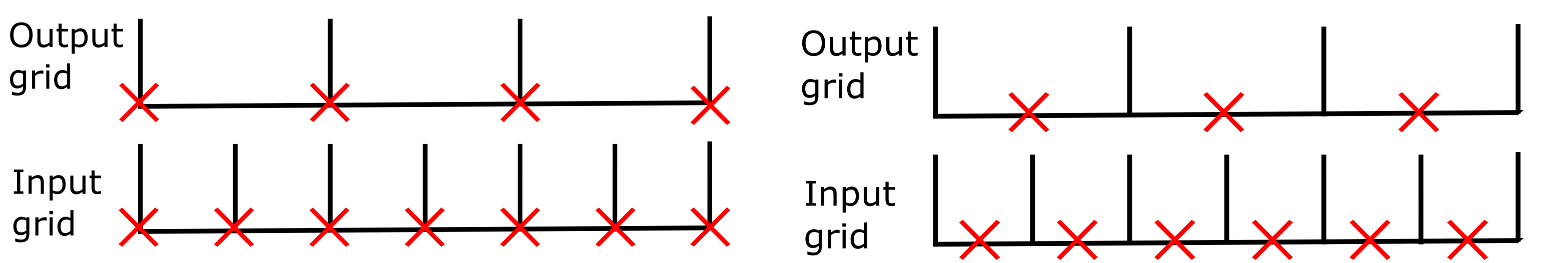
Your program should produce an output log

- A CSV-file with the tracking result
- Format is defined on the project webpage
- Ask your guide for details if needed
- Competition: logs are parsed to generate a summary table for all project groups

Results are to be produced for the input sequences. If you downsample the input you need to compensate your output!

Downsampling and coordinates

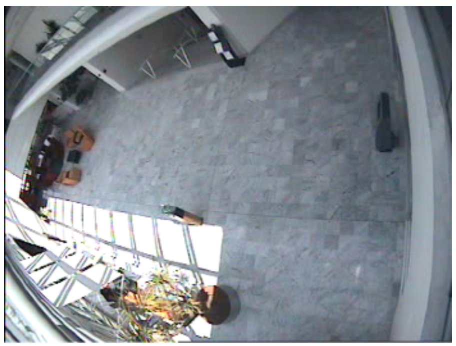
Results are to be produced for the input sequences. If you downsample the input you need to compensate your output!



There are several downsampling strategies. E.g. the two above. Check which one applies!

Examples from CAVIAR

Camera 1: Wide field of view in a large room



Camera 2: Surveillance in a shopping mall

Guidance

Each project group will have a guide

- a PhD student that gives guidance
- approx. 1h/per week
- meetings at times agreed upon by both parties

Guidance implies

- Give advice
- Give references to literature, code, and data

GitLab @ LiU

More details: https://gitlab.liu.se

NOT GitHub!

GitLab is administered using LIU-ID

- Individual check-in, changes tracked with LIU-ID

Use the repository to store:

- all external code used in the project
- all code produced in the project
- all documents produced in the project

Data storage

Each project group can get write access to a section of the project disk: /courses/TSBB15/temp/G1 etc.

- ~10 GB size /group
- Deleted after project is finished
- If needed: ask your project guide

Cooperation and plagiarism

Discussions are allowed

- Both between students and between project groups

Declare code

- Declare which code/text has been produced by the group and which is external
- Put ”own” and ”external” code in different folders
- Material declared as “own” must not be plagiarized from external sources

Get external material approved

- External material (e.g. code) must be approved
- Allowed code packages are listed on web page
- **Ask the examiner before using other packages**

Design plan

Each group should produce a design plan:

- Describe the important functionalities (blocks)
- Describe data flow between the blocks
- Describe interfaces
- Describe methods of implementations
- To be approved by your guide

The plan should also assign responsibility:

- Each student must be responsible for the design of at least one major block
- Should be able to answer questions on that block during the final seminar

Project management

Use reasonable level of **project management**

1. make a design plan together
2. discuss it with your guide
3. update to get it approved
4. divide work among project members

Each member must have an **assigned task**

1. Responsibility for a part of the technical work (but also cooperate)
2. Present that part at the seminar
3. Answer questions by the examiner and audience on that part

Project context

Produce test cases

- Should be simple, easy to find expected result
- Continuous Integration (CI) can be used at gitlab.liu.se.
  (automated testing at commit)

Deliverables (examined individually and as a group)

- A good presentation
- A good report

Test, test, test!

Testing is one of the most important parts of the project

Divide your system into parts that can be easily tested

You should test using ***test data***

- Produces obvious or specified behavior
- Usually not the same data as the final system should operate on
- Can be synthetic data generated to produce well-known output from your system

Test all parts individually before integrating them

Do not integrate parts into a larger system before they are properly tested

Deliverables

A good presentation

- Including examination of each project member

A written project report

- Which problem is solved?
- How is it solved?
- What is the result? Performance evaluation!
- Why did you get this result?
- References
- Targeted to your fellow students, not doing this project (explain what you are doing!)

Active seminar participation

You will get to read another group's report and prepare questions.

Time table project 1, 2022

Feb 4 (today): formation of project groups

- Problem analysis
- Specification of required functionalities
- Selection of methods
- Who does what
- First contact with project guide

Feb 11: approval of design plan

March 25: hand in report, *approved* by guide

March 29: presentation of project results

Each student contributes ~80h (3hp) of work/project

Implementation

The project can be implemented in:

- Python and/or C/C++ (hint: pybind11 for Python & C++)
  close to real-time should be possible (not a requirement)
  use pycharm IDE (installed in computer labs)

Several code packages exist:

e.g. OpenCV for C/C++/Python

See list on web page

External software for background modeling is not allowed

OpenCV

- Version 3.4.3 for C++ (3.2.0 for Python)
  - Installed in ISY computer labs
- Contains many useful functions:
  - Image / video / camera input
  - Image display
  - KLT-tracker
  - Harris-operator
  - Morphology, statistics
- Requires C/C++/Python skills
  - See “OpenCV pitfalls” on course web page
  - Odd behaviour of some functions - always test external code!

Required functionalities

For all groups:

1. Tracking of objects in a simple sequence
2. Management of object identity
3. Evaluation of results using ground truth (includes logging)

Optional functionality:

1. Management of shadows and reflections
2. Management of spurious background motions (multi-modality)
3. Occlusion management
   e.g., prediction or ground plane modeling (camera hand over), foreground modelling, and KLT/optical flow

Groups of 5 students: 3 optional functions

Groups of 4 students: 2 optional functions

Group assignment

Not here: luddi824, alfsu259, albho866