Master in Computer Vision Barcelona

Project Module 6 Coordination

Video Surveillance for Road Traffic Monitoring

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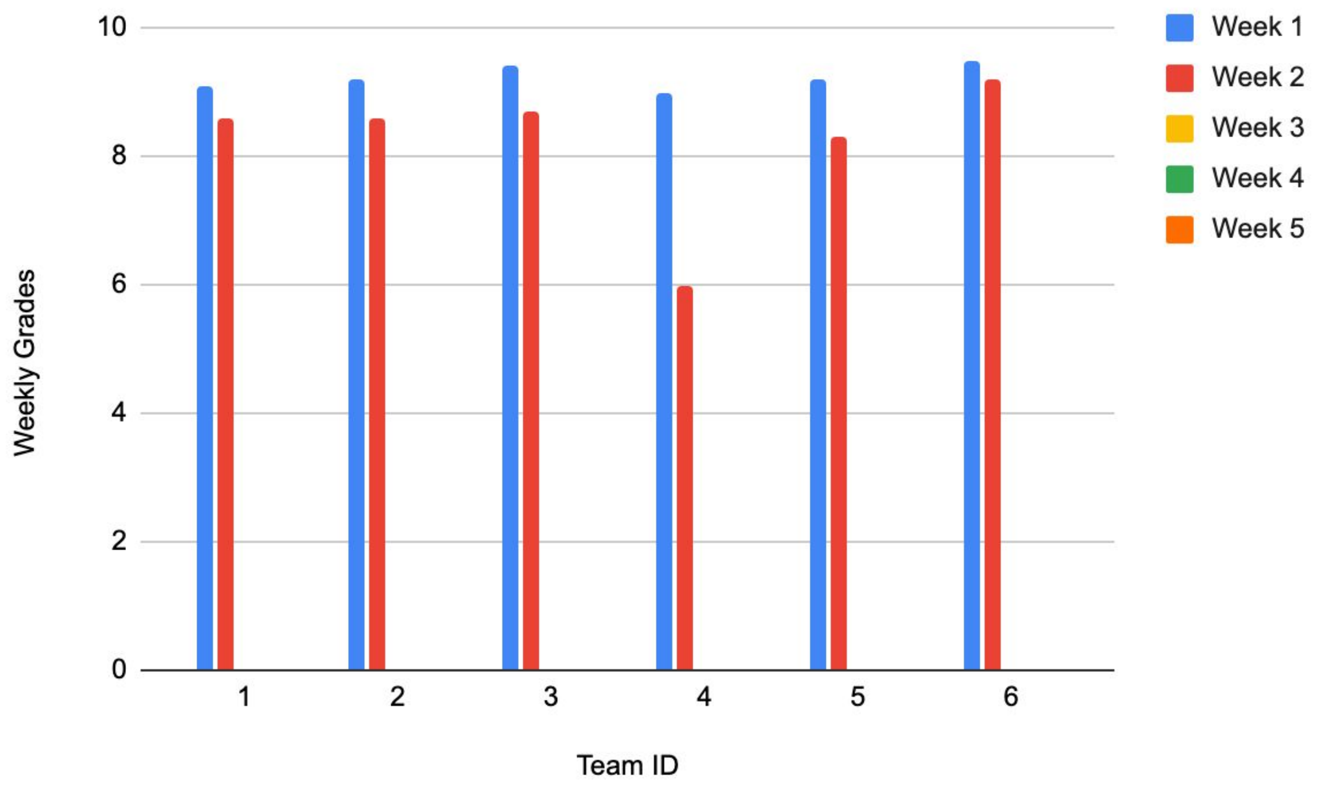
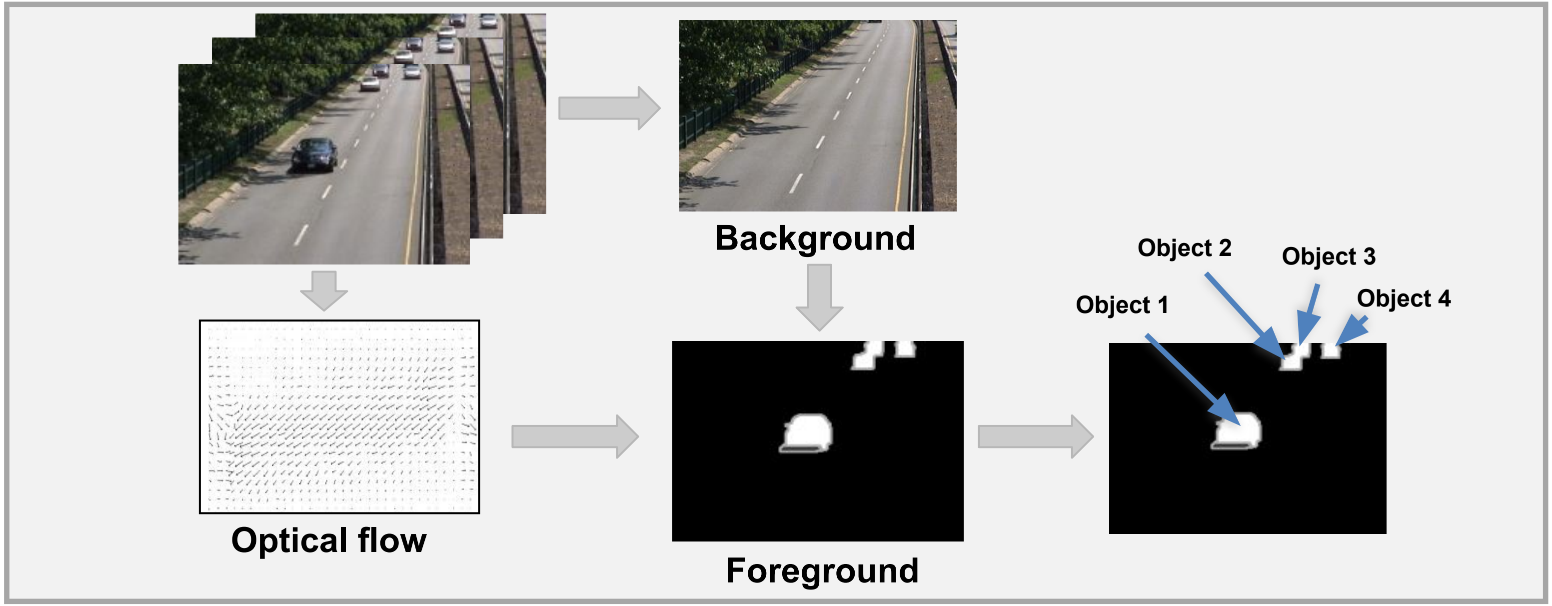
Week 4: Instructions

Average grades per team



Project Schedule



Week 1
- Introduction
- DB
- Evaluation metrics

Week 2
- Background estimation
- Stauffer & Grimson

Week 3
- Object Detection
- Tracking

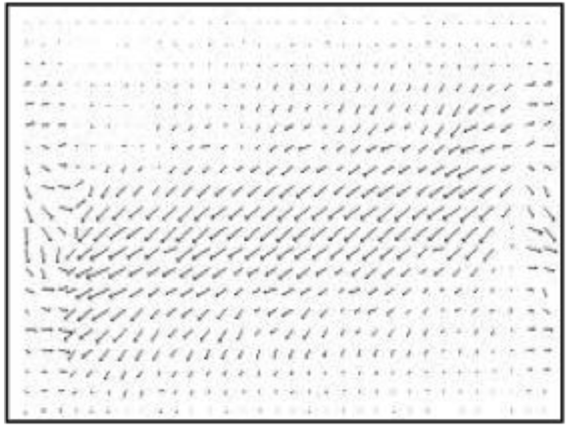
Week 4
- Optical flow
- Tracking (single camera)

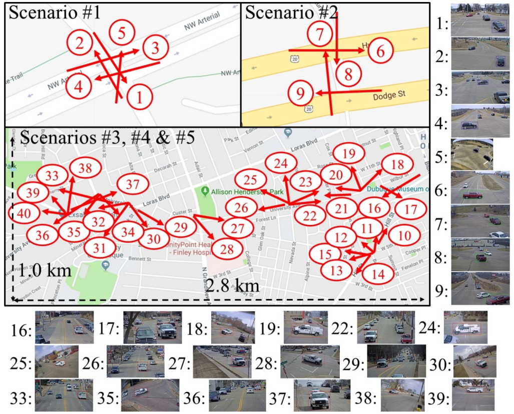
Week 5
- Tracking (multiple cameras)

Week 6
- Presentation workshop

Goals Week 4

- Estimate the optical flow of a video sequence.
- Estimate the optical flow and try to improve an object tracking algorithm.
- Provide results on data from the CVPR AI City Challenge.



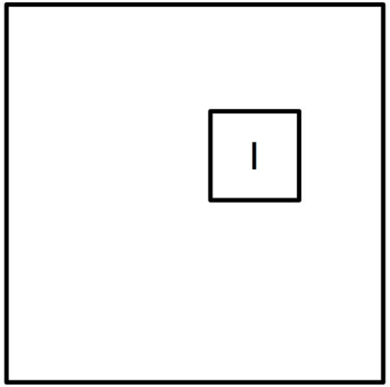


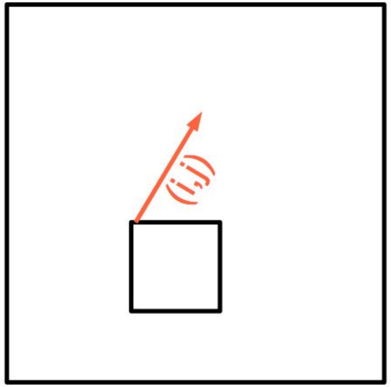
Week 4: Tasks

- **Task 1: Optical flow**
  - **Task 1.1: Optical flow estimation with block matching**
  - **Task 1.2: Optical flow estimation with off-the-shelf method**
  - **Task 1.3: Improve tracking with optical flow**
- Task 2: Multi-Target Single-Camera tracking
- Task 3 (optional): Extend test sequences

Task 1.1: Optical flow with Block Matching

- Implement a block matching solution for optical flow estimation.
- Configurations and parameters to explore:
  - Area of Search.
  - Size of the blocks.
  - Error function.
  - etc.

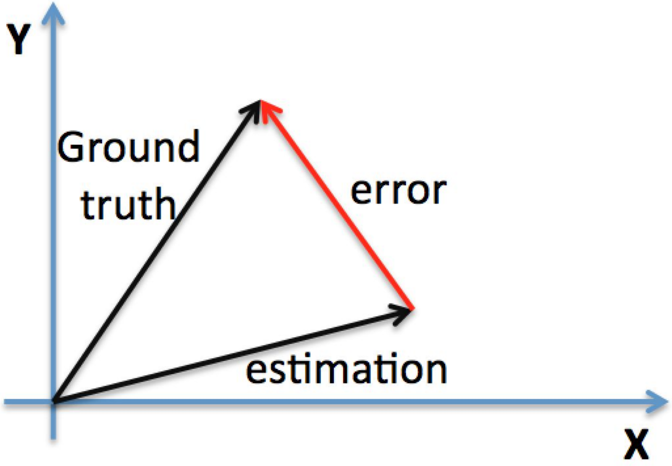




Task 1.1: Optical flow with Block Matching

Same as Week 1

- Quantitative results
  - **MSEN:** Mean Square Error in Non-occluded areas
  - **PEPN:** Percentage of Erroneous Pixels in Non-occluded areas
  - **Runtime**
- Dataset: Sequences 45 (image_0) from KITTI.



http://www.cvlibs.net/datasets/kitti/
(Flow 2012 > Stereo / Optical flow dataset)

Task 1.1: Optical flow with Block Matching

	Report all explored values (use **bold** to indicate the best configuration)					Best configuration	
	Area of Search	Size of Blocks	Step size	Error function	Others	Avg. PEPN	Avg. MSEN
Team 1							
Team 2							
Team 3							
Team 4							
Team 5							
Team 6							

* Images: 000045_{10, 11}.png

Task 1.1: Optical flow with Block Matching

Team 1 (class 2021)

Exhaustive Search

block_size=16, search_area=8, step_size=1
(fixed 256 iterations/block)

Three Step Search (Logarithmic)

block_size=16, step_size=8,
(4 iterations (max. possible = 28 iterations))

template object
search region
sliding window

Exhaustive search calculates the cost function at each possible location in the search window.

- \+ best possible match
- \+ highest PSNR for motion compensated image
- \- very computationally expensive and ineffecient

Three Step Search can sometimes lead to a **local minima**. This is a trade-off
we pay between accuracy and speed. This will also happen when using exhaustive search with steps > 1.

Three Step Search recursively finds and reduces the most probable neighbourhood in a given search area by selecting the one that is most similar to the template object

- \+ much faster than exhaustive search
- \- converges to local minima

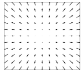
Task 1.1: Optical flow with Block Matching

Team 5 (class 2021)

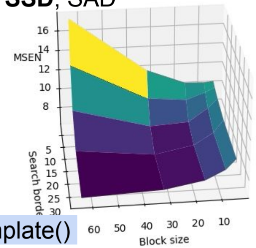
Exhaustive search

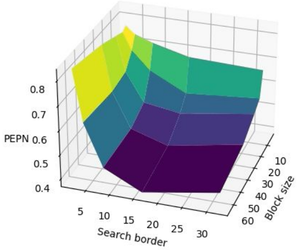
We have tested:

- Estimation direction: forward and **backward**
- Block size: 4, 8, 16, **32**, 64
- Search area: 2, 4, 8, **16**, **32**
- Distances: **SSD**, SAD



Exhaustive search experiments results with backward and SSD



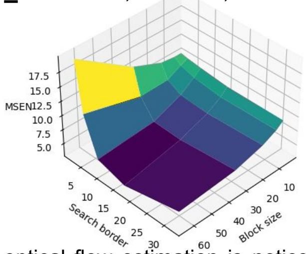


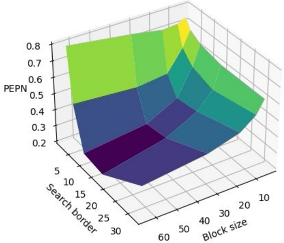
OpenCV: matchTemplate()

We have tested:

- Estimation direction: forward and **backward**
- Block size: 4, 8, 16, **32**, 64
- Search area: 2, 4, 8, 16, **32**
- Distances: CCOEFF, **CCOEFF_NORMED**, CCORR, **CCORR_NORMED**, SQDIFF, SQDIFF_NORMED

Exhaustive search experiments results with backward and CCOEFF_NORMED

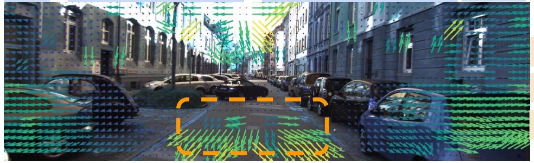




It can be seen the optical flow estimation is noticeably **better and faster** using template methods, which find the best similarity using specific distance metrics. Notice that the best results are obtained using **backward** estimation direction and with **big block sizes and search areas**

Here we show the best 2 results with SSD (minimum PEPN or MSEN): in the first one, the error is concentrated in the road; in the second, the error is more distributed

BW | Block size: 32 | Search area: 32 | SSD

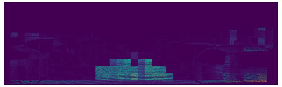


PEPN: **0.38**

MSEN: 7.23

Time: 29.991s

Dense plot



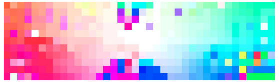
Error plot

BW | Block size: 32 | Search area: 16 | SSD

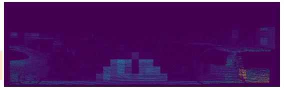
PEPN: 0.41

MSEN: **6.43**

Time: 7.729s

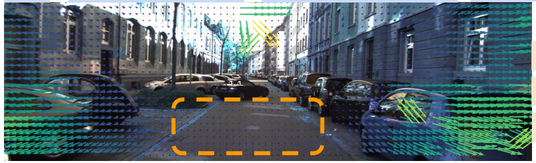


Dense plot



Error plot

BW | Block size: 32 | Search area: 32 | CCOEFF_NORMED



PEPN: **0.197**

MSEN: 3.05

Time: 0.232s

Dense plot

Error plot

BW | Block size: 32 | Search area: 32 | CCORR_NORMED

PEPN: 0.2

MSEN: **2.94**

Time: 0.216s

Dense plot

Error plot

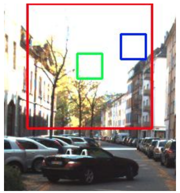
Task 1.1: Optical flow with Block Matching

Team 5 (class 2021)

When searching for the minimum distance using exhaustive search, **non-textured areas** (sky, road…) or **special surfaces** (windows, glass, water…) can produce errors in the **best match**, and that affects the optical flow.

EXAMPLES

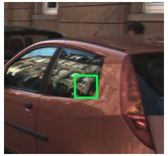
Two consecutive blocks in the sky produce opposite flow directions



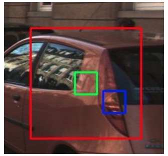
Past frame

Past frame

A mismatch due to a car window produces an erroneous flow direction



Future frame

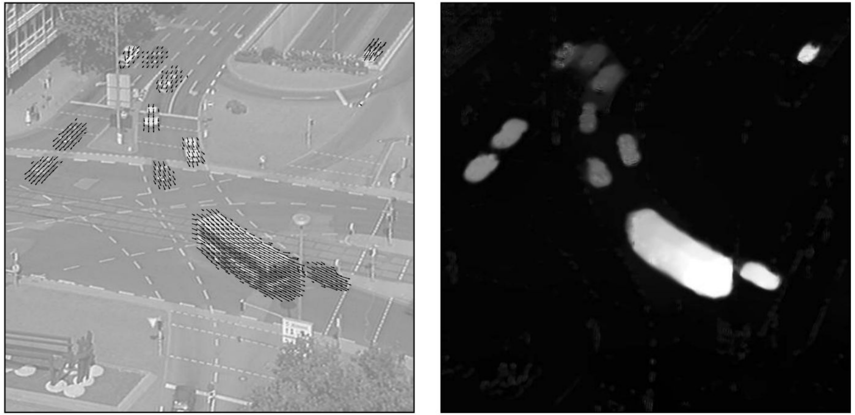


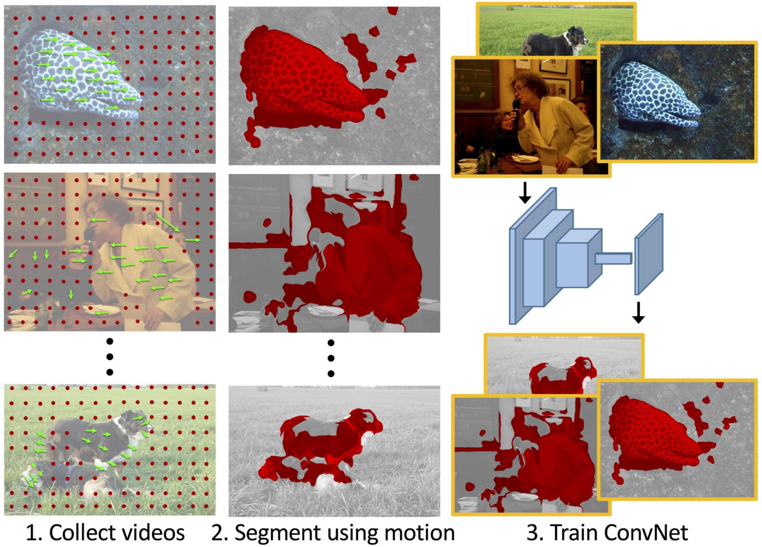
Past frame

Affectations in the optical flow

Task 1.2: Off-the-shelf Optical Flow

Compute and asses the optical flow provided in PyFlow.





#Coarse2Fine Brox, Thomas, Andrés Bruhn, Nils Papenberg, and Joachim Weickert. "High accuracy optical flow estimation based on a theory for warping." ECCV 2004.

Pathak, Deepak, Ross Girshick, Piotr Dollár, Trevor Darrell, and Bharath Hariharan. "Learning features by watching objects move." CVPR 2017

Task 1.2: Off-the-shelf Optical Flow

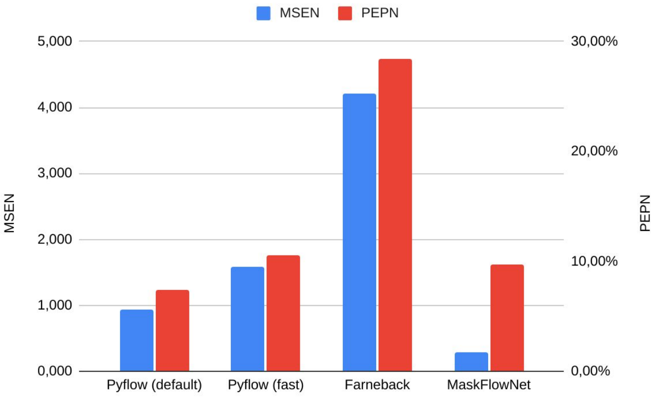
- Search and asses another optical flow implementation.
- For each referred technique, specify:
  - Citation to the related paper.
  - Link to an external implementation or specify if you wrote your own one.

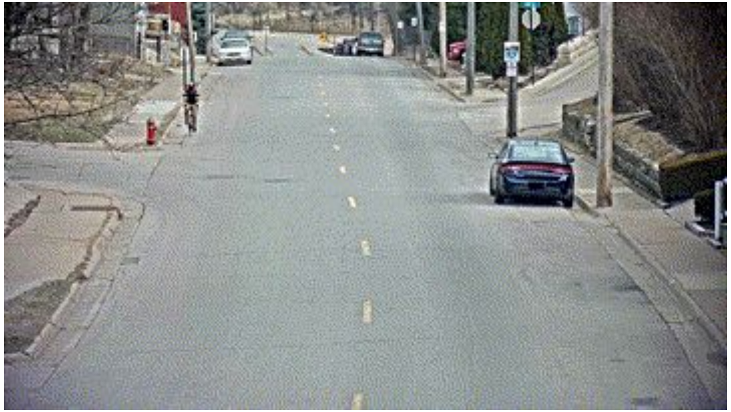
Some pointers that may be useful

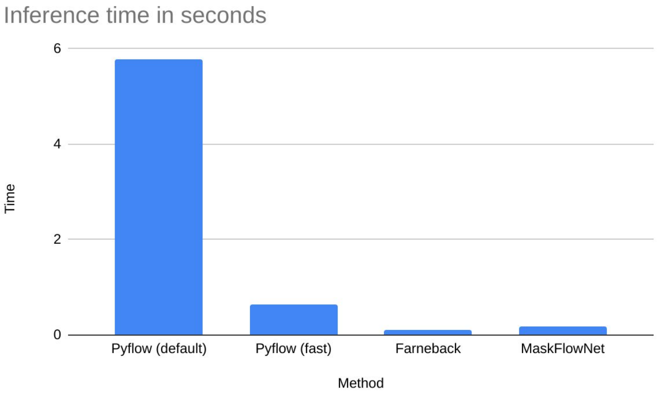
- Paperwithcode: Optical Flow Estimation
- Perceiver IO (ICLR 2022)
- RAFT (2020)
- MaskFlowNet (CVPR 2020)
- FlowNet2 (CVPR 2017)
- … check others ! Newer learning based methods will be better graded.

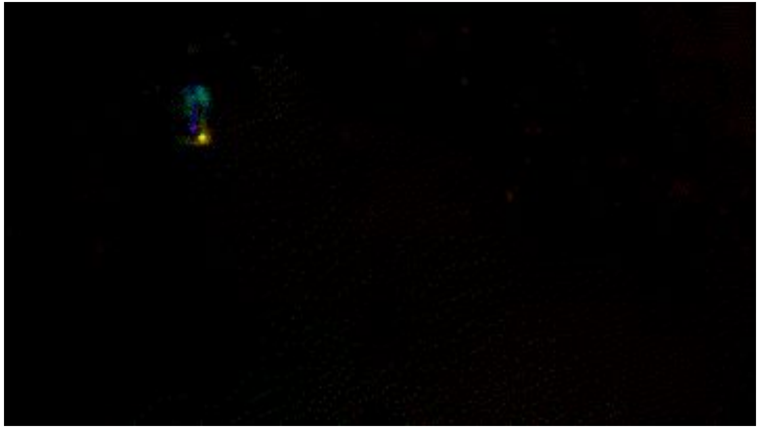
Task 1.2: Off-the-shelf Optical Flow

Team 5 (class 2021)









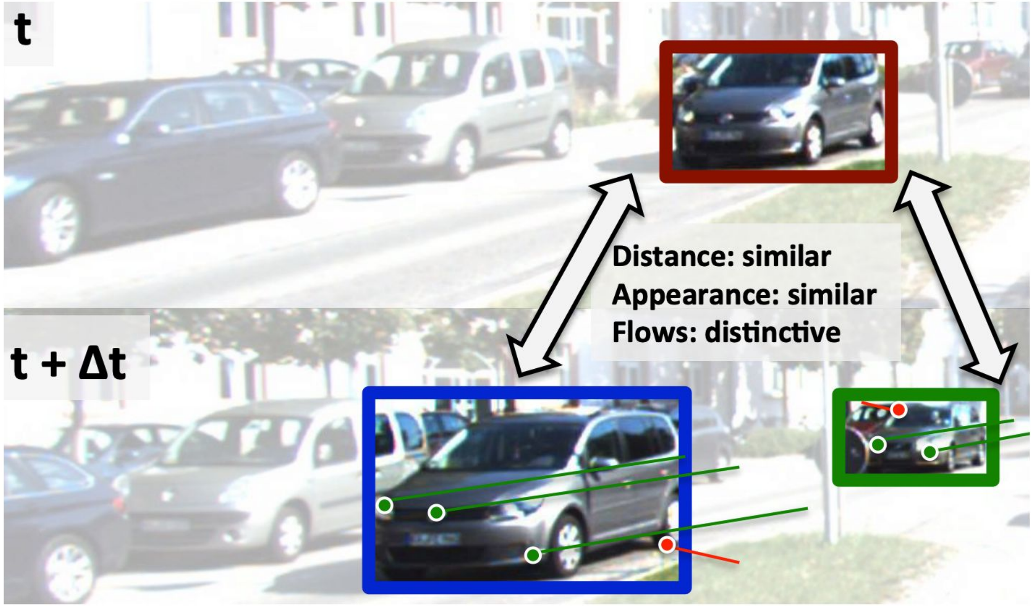
Task 1.2: Off-the-shelf Optical Flow

	MSEN		PEPN	
	PyFlow	Your other best	PyFlow	Your other best
Team 1				
Team 2				
Team 3				
Team 4				
Team 5				
Team 6				

* Images: 000045_{10, 11}.png

T1.3 Object Tracking with Optical Flow

Explore whether optical flow improves your results on object tracking from Week 3.



Choi, Wongun. ["Near-online multi-target tracking with aggregated local flow descriptor."]() ICCV 2015.

T1.3 Object Tracking with Optical Flow (Team X)

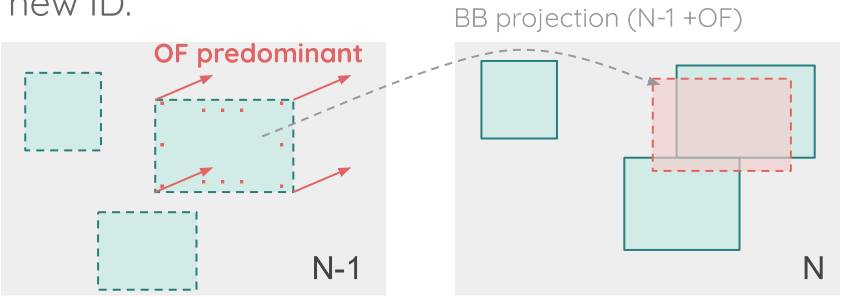
		IDF1/HOTA	
Team ID	**Your best algorithm (brief description)**	**Without optical flow**	**Using optical flow**
[Team 1]			
[Team 2]			
[Team 3]			
[Team 4]			
[Team 5]			
[Team 6]			

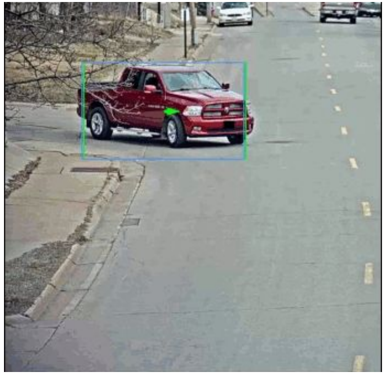
T1.3 Object Tracking with Optical Flow

Team 3 (class 2021)

Tracking + OF Algorithm:

1. **Initialization**: assign a unique ID to each detected object in the first frame.
2. **Optical Flow computation**: predict the position of the bbox in the next frame.
   a. The OF is computed using any proposed method.
   b. All the pixels in the window will be assigned the predominant OF.
3. Assign (in N) the same ID to the detection with the highest IoU in N-1 + OF. **Consider IoUs > 0.5**.
4. If no match, look backwards **up to N-5** for a match with IoU>0.5.
   a. If match, assign the corresponding ID and **interpolate detections between the intermediated frames**.
   b. Else, assign a new ID.
5. Return to 2.





T1.3 Object Tracking with Optical Flow

Team 4 (class 2021)

As in the previous method we are applying the same optical flow shifting to the four coordinates of the detected bonding box, we should decide how this overall optical flow is computed. We have implemented 5 different options, and computed the IDF1 (%) and runtime (mm:ss) for each of them:

Option 1

Compute the optical flow using Lucas Kanade for all the pixels inside the detected regions (bounding boxes). Compute the mean of all these optical flow vectors and use the result as the shifting optical flow.

Option 2

Obtain good features to track from the detected regions using goodFeaturesToTrack function from OpenCV. Compute the optical flow for all these points and compute the mean of the optical flow vectors of these points. Using this method we can have a case where any good feature to track is found, and in this case we compute the mean of the optical flow computed for all the pixels inside the detection region as we do on Option 1.
This method is faster than the Option 1 as for most of the detected regions there are good features to track and then less optical flow vectors are computed.

Option 3

Compute the optical flow using Lucas Kanade for all the pixels inside the detected region as in Option 1 but using the median of all these optical flow vectors instead of the mean.

Option 4

In this option we are applying the same idea as the Option 2, but instead of using the mean using the median.

Option 5

For this last option, we are computing the optical flow using our Block Matching implementation on the detection region and computing the median of the optical flow result.

	IDF1 (%)	Runtime (mm:ss)
Without Optical Flow	**97.01**	**01:20**
Option 1	96.92	24:25
Option 2	97.01	13:13
Option 3	97.01	24:02
Option 4	97.01	12:10
Option 5	95.31	04:32

In quantitative terms, the addition of an optical flow compensation does not improve in any case. In some cases, such as option 5 (using block matching), the results are even worse, which might be due to the errors in the optical flow estimation in this case. Considering that the obtained results without optical flow were already really high, and that, as observed on the previous week, the tracking error was mainly introduced by the object detection algorithm, it is not a surprise that the optical flow doesn't help the system.

In terms of runtime, the computational cost added by the optical flow estimation slows down a lot the algorithm.

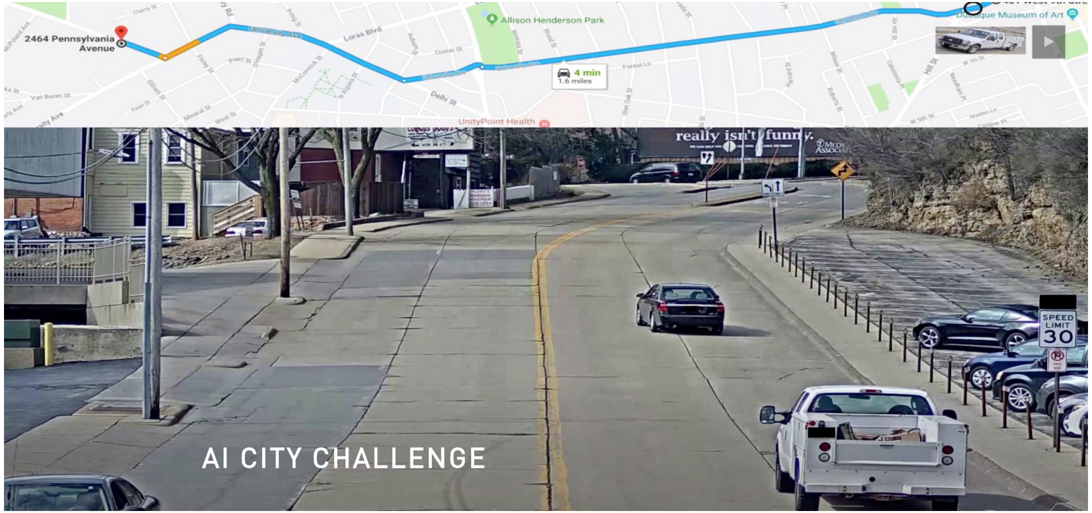
Week 4: Tasks

- Task 1: Optical flow
- **Task 2: Multi-Target Single-Camera tracking**
  - **Evaluate your best tracking algorithm in SEQ3 of AI City Challenge**
  - **Task 2.1: Report Quantitative metrics IDF1 / HOTA**
  - **Task 2.2: Discussion of results**
- Task 3 (optional): Extend test sequences

Task 2: Multi-target single-camera (MTSC) tracking

Assess the quality of your best solution on the [CVPR 2022 AI City Challenge]() (Track 1):

"Participating teams will track vehicles across multiple cameras both at a single intersection and across multiple intersections spread out across a city. This helps traffic engineers understand journey times along entire corridors. The team with the highest accuracy in tracking vehicles that appear in multiple cameras will be declared the winner of this track. In the event that multiple teams perform equally well in this track, the algorithm needing the least amount of manual supervision will be chosen as the winner."



Task 2.1: Multi-target single-camera (MTSC) tracking

Read the [Data & Evaluation] description for Track 1 (Multiple-camera tracking), but focus in the **single camera** set up.

- Data [3.3 GB]
  - Sequences S01, S03 and S04
    - Different cameras for each sequence.
  - Consider
    - Test sequence
      - Sequence S03
    - Train sequences (if needed)
      - S01 and S04

	Time (min.)	# cam.	# boxes	# IDs	Scene type	LOS
1	17.13	5	20,772	95	highway	A
2	13.52	4	20,956	145	highway	B
3	23.33	6	6,174	18	residential	A
4	17.97	25	17,302	71	residential	A
5	123.08	19	164,476	337	residential	B
total	195.03	40	229,680	666		

USAGE CONDITIONS

These data can only be used for the project in M6 in the Master in Computer Vision Barcelona 2021/2022.

You must delete these data once the module has finished.

Task 2.1: MTSC tracking - IDF1

Provide the results for your best technique

	IDF1 (SEQ 3)						
Camera	**c10**	**c11**	**c012**	**c013**	**c014**	**c015**	**Average**
Team 1							
Team 2							
Team 3							
Team 4							
Team 5							
Team 6							

Use implementation of IDF1/HOTA provided in TrackEval.

Task 2.1: MTSC tracking - HOTA

Provide the results for your best technique

	HOTA (SEQ 3)						
Camera	**c10**	**c11**	**c012**	**c013**	**c014**	**c015**	**Average**
Team 1							
Team 2							
Team 3							
Team 4							
Team 5							
Team 6							

Use implementation of IDF1/HOTA provided in TrackEval.

Task 2.2: MTSC tracking - Discussion

Analyse IDF1/HOTA results in SEQ3 together with qualitative results.

(optional) Task 3: MTSC tracking - Other sequences

If computation capability allows it, provide test results for SEQ 1 & SEQ 4, considering the other two as training data.

	Time (min.)	# cam.	# boxes	# IDs	Scene type	LOS
1	17.13	5	20,772	95	highway	A
2	13.52	4	20,956	145	highway	B
3	23.33	6	6,174	18	residential	A
4	17.97	25	17,302	71	residential	A
5	123.08	19	164,476	337	residential	B
total	195.03	40	229,680	666		

	Time (min.)	# cam.	# boxes	# IDs	Scene type	LOS
1	17.13	5	20,772	95	highway	A
2	13.52	4	20,956	145	highway	B
3	23.33	6	6,174	18	residential	A
4	17.97	25	17,302	71	residential	A
5	123.08	19	164,476	337	residential	B
total	195.03	40	229,680	666		

(optional) Task 3.1: MTSC tracking - SEQ1

Provide the results for your best technique

	IDF1/HOTA (SEQ 1)						
Camera	c10	c11	c012	c013	c014	c015	Average
Team 1							
Team 2							
Team 3							
Team 4							
Team 5							
Team 6							

Use implementation of IDF1/HOTA provided in TrackEval.

(optional) Task 3.2: MTSC tracking - SEQ4

Provide the results for your best technique

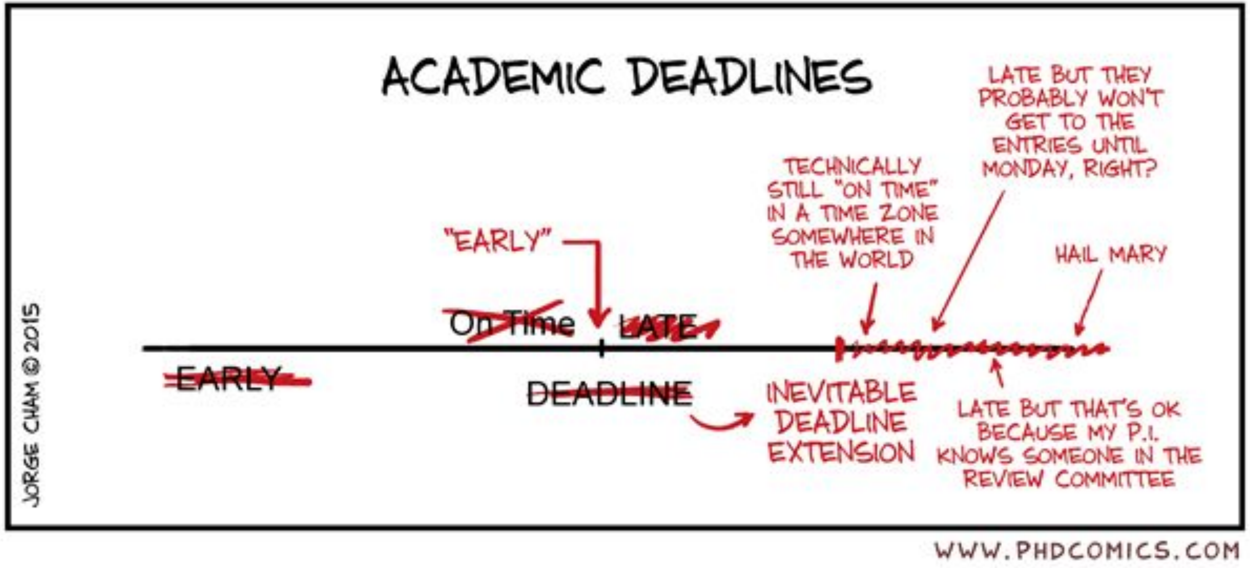
	IDF1/HOTA (SEQ 4)						
Camera	**c10**	**c11**	**c012**	**c013**	**c014**	**c015**	**Average**
Team 1							
Team 2							
Team 3							
Team 4							
Team 5							
Team 6							

Use implementation of IDF1/HOTA provided in TrackEval.

Scoring rubric

Task		Weight
T1	Optical Flow	
T1.1	Optical Flow with Block Matching	2
T1.2	Off-the-shelf Optical Flow	2
T1.3	Object Tracking with Optical Flow	3
T2	Multi-target single-camera (MTSC) tracking	
T2.1	SEQ 3 - IDF1 / HOTA	1
T2.2	Discussions	2
T3	SEQ1 + SEQ4 + Discussions	+1

Deliverables



- Deadline: **Wednesday April 12th at 3pm**
- Deliverables:
  - Submit your report by editing these slides: task1 and task2/3
  - Provide feedback regarding the teamwork (email)