Background subtraction and background generation

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August 2016

What is background subtraction in computer vision?

There are basically two "pure" approaches for motion analysis in a video sequence:

1. Motion analysis by *tracking* (= *motion estimation* based techniques):
    - detects some particular points (*features*) in a video frame.
    - find the corresponding points in the next frame.
    - based on a model, interpret the trajectories (called *tracks*) of the points (usually at the object level).
2. Motion analysis by *background subtraction*:
    - build a reference frame or model with no foreground in it.
    - compare a next frame to the reference.
    - extract foreground objects.

Number of papers on background subtraction

Searches in databases with the following keywords:

background subtraction video

Databases with pdf documents	2015	$\longrightarrow$ today
IEEE Explore	137	1,272
Springer Link	1,207	8,460
Elsevier (ScienceDirect)	774	7,169
google scholar	16,300	144,000

Motion analysis by background subtraction I

Original image

Segmentation map

- This is a classification problem (with two classes) that separates the *foreground* (pixels "in motion") from the *background* ("static" pixels).
- Evaluation via classification notions such as the *precision*, *recall*, *ROC space*, F_1 score, *error rate*, etc.

Steps in background subtraction

[Initialization] build a *reference frame* or a *statistical model* for the background.

[Subtraction or segmentation] *compare* the current frame to the reference frame or model, and "*subtract*" the frame to get a binary image indicating pixels who have changed.

[Updating] *update* the reference frame or model.

When developing a technique, we have to detail these three steps! This is why there are so many variants.

Rough typology of methods

1. Estimation of the probability distribution function (pdf) for each pixel location ($\Rightarrow$ statistical models)
   - Mixture of Gaussians MoG (parametric methods): estimate the mean + standard deviation
   - **Kernel Density Estimation KDE (non-parametric methods): estimate the pdf from past samples**
2. Techniques based on learning/dictionaries
   - Codebooks
   - Bag of words
3. Techniques based on data reduction
   - Robust PCA

Implementation issues

A video sequence is like a data *cube* whose dimension is only fixed in 2 (spatial) dimensions.

- Cube extends with time.
- Although the use of "memory" should be kept constant.

Challenges:

1. need to find a way to accumulate knowledge of increasing size inside of a constant-sized memory block.
2. this knowledge should be updated regularly to deal with changes (to understand the challenge, think of a camera operating day and night).

Background generation

Definition (Background generation)

Given a scene viewed from a fixed viewpoint, the problem of generating an image of the background is known as the *background generation problem*.

Figure: The generation of a stationary background image is a challenging task, especially when the background is never fully visible.

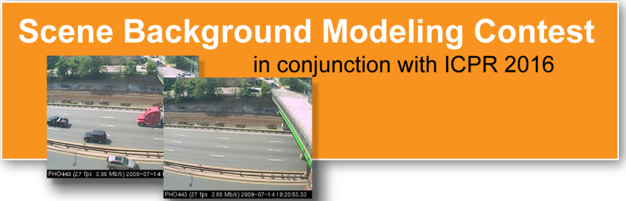
Comparison between background subtraction and background generation

background subtraction	**background generation**
infinite data volume	finite data volume
should be universal	scene specific
evaluation via classification metrics: *F_1 score* (↑)	evaluation via PSNR, error rate: *percentage of Error Pixels* (pEPs, ↓)

Background generation is closer to what we do in stellar imaging.

IEEE Scene Background Modeling Contest (July 2016)

http://pione.dinf.usherbrooke.ca/sbmc2016/ : 79 videos out of 8 categories



Results I

Method	Average ranking across categories	Average ranking
LaBGen [6]	4.25	3.33
LaBGen-P [7]	4.88	4.50
Temporal median filter [2]	5.13	6.67
SC-SOBS-C4 [9]	5.63	4.67
Bidirectional Analysis and Consensus Voting [12]	5.75	7.33
Bidirectional Analysis [28]	5.75	6.67
Wei-Liu-Aug-16-2 [11]	5.88	8.33

[6] LaBGen: A Method Based on Motion Detection for Generating the Background of a Scene, B. Laugraud, S. Piérard and M. Van Droogenbroeck, to appear in *Pattern Recognition Letters*, 2016.

Results II

LaBGen mechanisms

LaBGen uses:

1. a temporal median filter.
2. a pixel/patch based motion detection algorithm (via *background subtraction* techniques).
3. + other minor refinements.

Results III

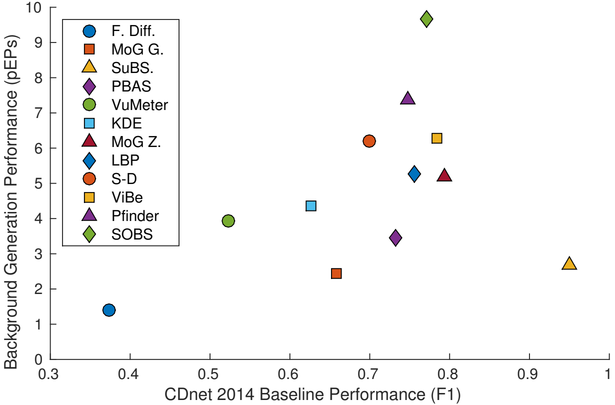


Figure: Comparison between the F_1 (↑) performance of a background subtraction algorithm on the baseline of the CDnet 2014 dataset and the pEPs score (↓).

Results IV

Conclusions

- The quality of *background generation* **is unrelated to** the *background subtraction* method: no (negative) correlation.
- The temporal median filter is within the top techniques (remember ADI/LOCI)

What's next? I

More machine learning (not yet for background generation?!)

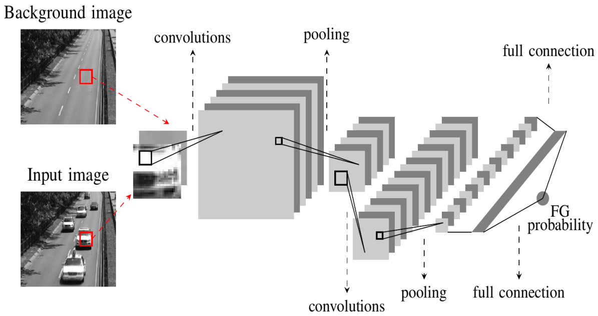


Figure: Deep learning for extracting the background in video scenes (M. Braham and M. Van Droogenbroeck. **Deep Background Subtraction with Scene-Specific Convolutional Neural Networks**. In *IEEE IWSSIP*, May 2016).

What's next? II

Method	$F_{overall}$	$F_{Baseline}$	F_{Jitter}	$F_{Shadows}$	$F_{LowFramerate}$
ConvNet-GT	**0.9046**	**0.9813**	**0.9020**	**0.9454**	**0.9612**
IUTIS-5	0.8093	0.9683	0.8022	0.8807	0.8515
SuBSENSE	0.8018	0.9603	0.7675	0.8732	0.8441
PAWCS	0.7984	0.9500	0.8473	0.8750	0.8988
PSP-MRF	0.7927	0.9566	0.7690	0.8735	0.8109
ConvNet-IUTIS	0.7897	0.9647	0.8013	0.8590	0.8273
EFIC	0.7883	0.9231	0.8050	0.8270	0.9336
Spectral-360	0.7867	0.9477	0.7511	0.7156	0.8797
SC_SOBS	0.7450	0.9491	0.7073	0.8602	0.7985
GMM	0.7444	0.9478	0.6103	0.8396	0.8182
GraphCut	0.7394	0.9304	0.5183	0.7543	0.8208

Table: Overall and per-category F scores for different methods.