Dense-SIFT Foreground-Background Tracker

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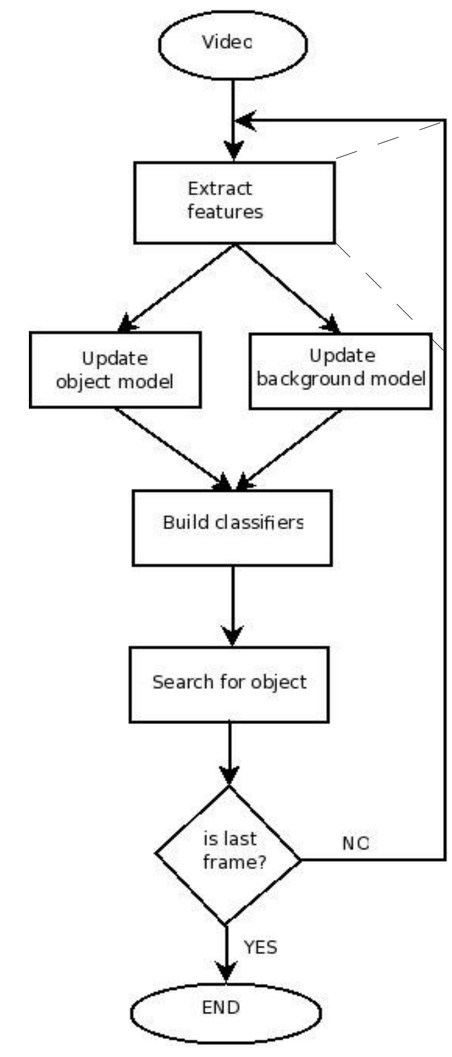
Problem Statement

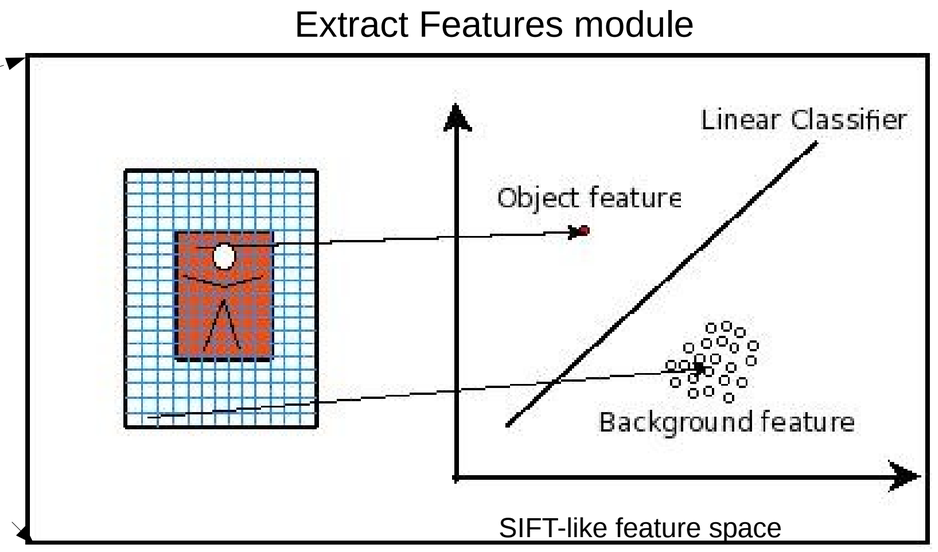
Foreground background tracking framework enables tracking objects with complicated motion as long as there is clear discrimination between object and background. However the original framework is vulnerable to cluttered background and when there are similar patterns occurring in both object and background. We would like to address the following problem: how to improve the foreground-background tracking framework?

Approach

- Combine the foreground-background tracking framework with advanced features. We use three features, namely: intensity-SIFT, Opponent-SIFT and RGB-SIFT
- Use SIFT-like features with dense sampling instead of interest points in the original SIFT
- Use a fast implementation of SIFT to speed up the tracker

The Proposed Tracker





Object model update:

$$f_i^{o(t)} = (1-\gamma) f_i^{o(t-1)} + \gamma f(p_i;\theta)$$

Background model update: very simple and efficient due to using the linear classifier; do not need to keep background features, only need to keep their mean and covariance matrix

$$\bar{f}^{b(t)} = (1-\gamma)\bar{f}^{b(t-1)} + \gamma \bar{f}^{b}{}_{new}$$

$$B^{(t)} = (1-\gamma)B^{(t-1)} + (1-\gamma)\bar{f}^{b(t-1)}\bar{f}^{b(t-1)T} - \bar{f}^{b(t)}\bar{f}^{b(t)T} + \frac{\gamma}{m}\sum_{j=M+1}^{M+m} f_j^b f_j^{bT}$$

Experimental Results

Dataset

1. Dudek video: short occlusion

2. Mouse pad video: rotation, different colors of the two sides

3. Trellis video: foliage illuminations

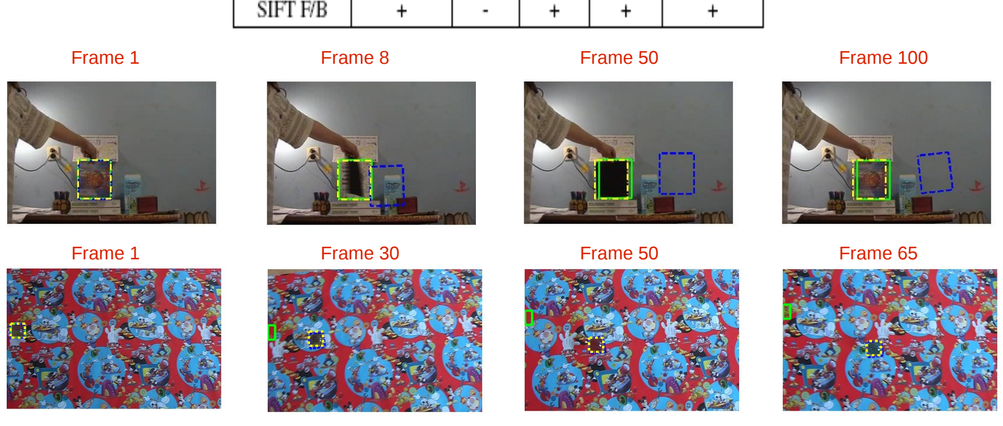
5. Transparent ball video: abrupt changes in object appearance, cluttered background

4. Cubic video: different appearance, cluttered background

Qualitative Comparison

We choose two state-of-the-art trackers in the region-based tracker category to compare with our proposed tracker: the original foreground-background tracker proposed in [Nguyen and Smeulders, IJCV 2006]; and the incremental learning visual tracker (IVT) proposed in [Ross *et al.* IJCV 2008]. In the table below, a minus sign means the corresponding tracker loses more than 50% of the object at some frame and can not recover after that. A plus sign means the tracker successfully follows the object.

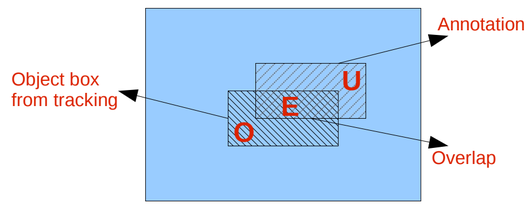
	Mousepad	Cubic	Trellis	Dudek	Trans.Ball
Original F/B	+	-	-	+	-
IVT	-	+	+	+	+
SIFT F/B	+	-	+	+	+



Quantitative Comparison

Error measures:

1. Tracking error: measure how precisely the tracker finds the object in each frame



$$e_1 = \frac{|O| + |U|}{|O| + |U| + 2|E|}$$

2. Underexplained error: measure how much portion of the object the tracker fails to cover

$$e_2 = \frac{|U|}{|U| + |E|}$$

3. Overexplained error: measure how much the tracker gets affected by the surrounding background of the object

$$e_3 = \frac{|O|}{|O| + |E|}$$

Tracking error (%)	Mousepad	Cubic	Trellis	Dudek	Trans. Ball
Original F/B	12.70	20.98	41.37	7.67	92.86
IVT	93.77	15.86	16.11	31.30	5.47
SIFT F/B	7.42	23.20	12.29	7.31	8.98

	$\bar{e}_1(\%)$	$\bar{e}_2(\%)$	$\bar{e}_3(\%)$
Original F/B	35.12	34.86	34.76
IVT	32.50	36.14	26.61
Intensity-SIFT F/B	11.84	29.59	10.84
Opponent-SIFT F/B	28.10	27.67	27.86
RGB-SIFT F/B	10.07	10.37	8.98

Conclusion and Future Work

- The poster shows advantages of combining advanced features into the foreground-background tracking framework. The framework enables the tracker to deal with abrupt changes in object appearance and motion. Furthermore, the invariant and highly discriminative properties of the chosen features make the tracker capable of following the object under different challenging environments: extreme lighting conditions, cluttered backgrounds, abrupt changes in object appearance
- Future work:
  - The experimental results suggest several ways of further improving the tracker. A mechanism to handle changes in object's size would reduce the underexplained error, and hence also reduce the tracking error.
  - Another possible way is to combine several SIFT-like features into a single system and then a feature selection technique will assist the tracker to choose the most suited one.

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