Orderless Tracking through Model-Averaged Posterior Estimation

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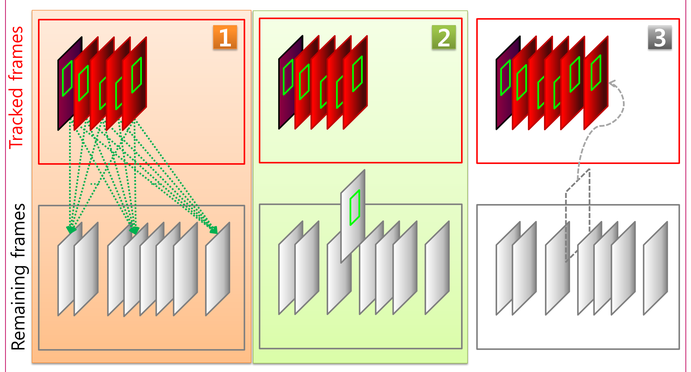
Problem

- ***Objective:*** tracking easy-to-track frames first by searching a suitable order of the frames.
- ***Our approach:*** *iteratively* tracking and searching subsequent frames to track *offline*.
- ***Main framework***

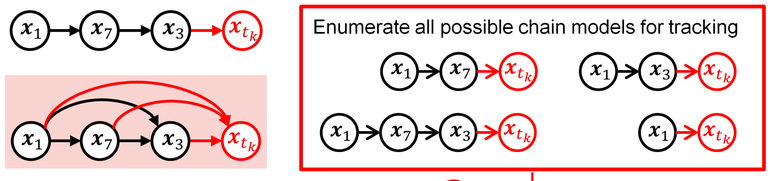


- Iteratively perform the following procedure :

1. Estimating the posteriors of remaining frames given tracked frames
2. Selecting the next frame with the most reliable posterior
3. Adding the selected frame to the set of tracked frames

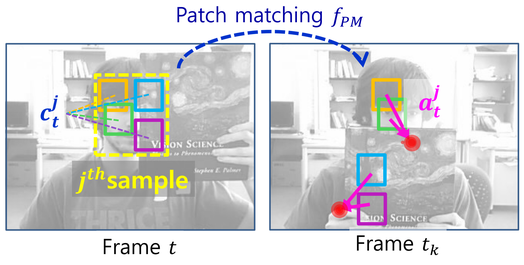
1 Model-Averaged Posterior Estimation

- Aggregation of the propagated posteriors by ***Bayesian Model Averaging***



$$\tilde{P}(x_{t_k}) \propto \frac{1}{k-1} \sum_{t \in \mathcal{T}_{k-1}} p(Z_{t_k}|x_{t_k}) \int p(x_{t_k}|x_t)\tilde{P}(x_t)dx_t$$

- ***Posterior propagation for a single chain model***
  - Transition and measurement model simulated by ***Patch matching and voting process***



$$\approx \sum_{x_t^i \in \mathbb{S}_t} p(Z_{t_k}|x_{t_k}) p(x_{t_k}|x_t^i)$$

$$\approx \sum_{x_t^i \in \mathbb{S}_t} \sum_j \mathcal{N}(x_{t_k}|f_{PM}(c_t^j) - a_t^j, \Sigma)$$

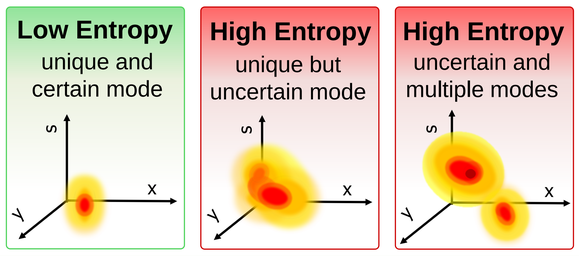
2 Identifying Subsequent Frame

- Given posteriors of remaining frames, **select the frame with minimum entropy as next frame to track**

$$t_k = arg\min_r \mathcal{H}(x_r), \quad r \in \mathcal{R}_{k-1}$$

- Locate a target in selected frame by MAP estimate

$$X_{t_k}^* = arg\max_{x_{t_k}} p(x_{t_k})$$



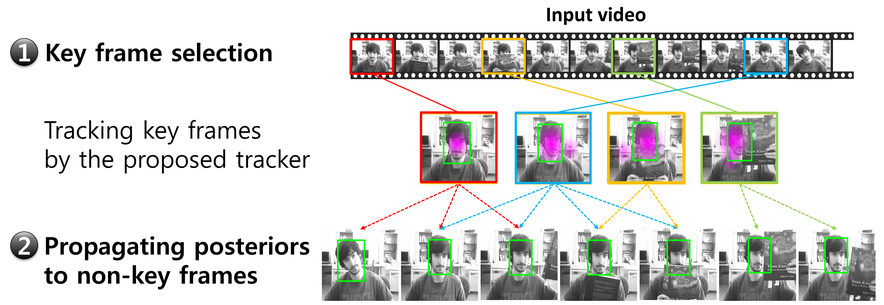
3 Updating Lists

- Updating the lists of tracked and remaining frames

$$\mathcal{T}_k = \mathcal{T}_{k-1} \cup \{t_k\}$$
$$\mathcal{R}_k = \mathcal{R}_{k-1} \backslash \{t_k\}$$

Efficient Hierarchical Approach

- **Track key frames first, and propagate posteriors to non-key frames.**



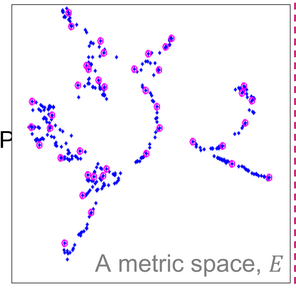
1 Key frame selection

- Computing distance between all pairs of frames

$$D(I_1, I_2) = \frac{1}{n_1}\sum_{P \in I_1} \min_{Q \in I_2} d(P,Q) + \frac{1}{n_2}\sum_{Q \in I_2} \min_{P \in I_1} d(P,Q)$$

- Embedding frames into a metric space by ISOMAP
- Selecting k most representative frames by solving k-center problem in metric space E

$$\mathcal{K}^* = \arg\min_{\mathcal{K} \subseteq \mathcal{F}} \max_{v \in \mathcal{F}} \min_{u \in \mathcal{K}} d_E(u,v)$$

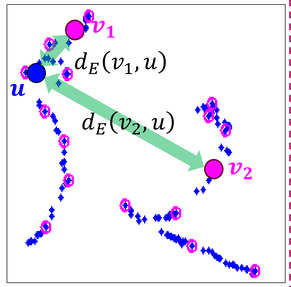


2 Density propagation to non-key frames

$$\tilde{P}(x_u) = \sum_{v \in \mathcal{K}} P(x_u|Z_{\mathcal{K}}, p_{v \to u}) P(p_{v \to u})$$

Density propagation through the single hop $p_{v \to u}$ by patch matching and voting

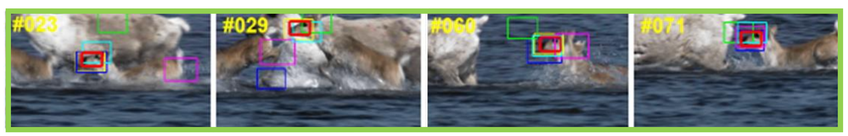
Weight for the single hop $\frac{\exp(-d_E(u,v))}{\sum_w \exp(-d_E(u,w))}$



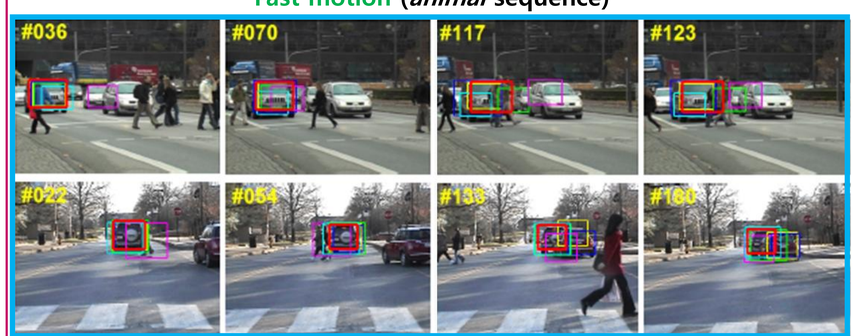
Experiments

- **Qualitative results**

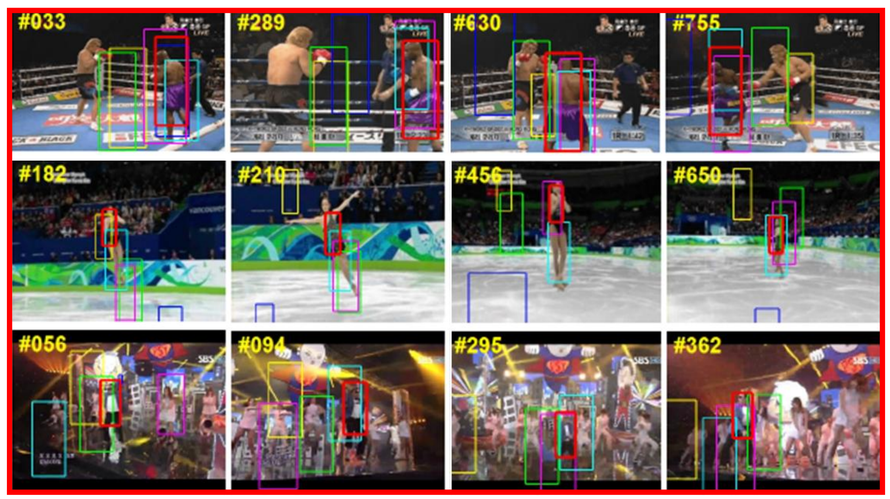
OMA (ours) WLMC OTLE FRAG SCM L1APG



Fast motion (*animal* sequence)



Occlusion (top : *TUD*, bottom : *campus* sequence)



Shot change (top : *boxing*, middle : *skating*, bottom : *psy* sequence)

- **Quantitative results**

Table 1. Average center location error (in pixels). Red: best, blue: second best.

	IVT	MIL	SCM	L1APG	MTT	ASLSA	L1	FRAG	WLMC	OTLE	OMA	SMA
animal	10.6	32.0	16.6	48.8	12.6	179.6	164.9	94.1	64.8	19.4	7.7	7.4
TUD	12.6	57.1	12.2	7.4	37.2	67.2	64.7	17.3	68.2	27.4	4.4	5.9
campus	38.7	37.1	12.2	16.1	6.0	12.2	68.4	3.3	13.5	5.8	3.2	7.0
accident	27.6	24.8	3.0	20.3	21.9	2.9	32.4	7.4	12.2	9.1	2.6	6.5
tennis	68.7	74.4	65.9	85.0	65.6	68.8	111.4	67.4	31.0	37.0	6.9	11.9
boxing	128.1	88.9	96.0	117.6	87.0	106.8	103.5	80.0	11.7	41.7	10.5	22.6
youngki	95.2	115.2	115	137.9	176.5	151.8	121.8	97.5	16.0	15.7	11.4	14.0
skating	77.8	15.0	49.4	143.9	100.4	22.8	72	35.4	14.7	18.3	8.0	10.8
psy	156.5	220.6	213.3	71.8	117.8	146.8	124.6	95.2	66.0	61.2	15.0	21.9
dance	283.9	169.4	208.0	113.9	133.4	118.1	143.1	132.4	39.7	118.8	15.1	19.7

Table 2. Average overlap ratio. Red: best, blue: second best.

	IVT	MIL	SCM	L1APG	MTT	ASLSA	L1	FRAG	WLMC	OTLE	OMA	SMA
animal	0.60	0.42	0.55	0.4	0.57	0.04	0.04	0.08	0.31	0.48	0.71	0.71
TUD	0.65	0.34	0.67	0.85	0.52	0.32	0.62	0.59	0.38	0.48	0.82	0.75
campus	0.56	0.45	0.62	0.52	0.76	0.63	0.01	0.77	0.52	0.72	0.78	0.67
accident	0.58	0.53	0.87	0.69	0.69	0.84	0.45	0.60	0.57	0.59	0.85	0.76
tennis	0.06	0.20	0.11	0.29	0.11	0.12	0.03	0.11	0.43	0.31	0.63	0.56
boxing	0.05	0.06	0.13	0.13	0.06	0.11	0.16	0.22	0.65	0.38	0.70	0.51
youngki	0.09	0.13	0.13	0.02	0.10	0.06	0.02	0.19	0.62	0.54	0.62	0.54
skating	0.01	0.41	0.20	0.02	0.03	0.29	0.06	0.25	0.46	0.41	0.42	0.37
psy	0.07	0.08	0.07	0.02	0.23	0.17	0.25	0.23	0.39	0.40	0.63	0.57
dance	0.03	0.07	0.07	0.10	0.10	0.11	0.11	0.14	0.45	0.30	0.52	0.50