

Dynamic Textures Synthesis Based on Motion Distribution Statistics

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Dynamic textures



Suggested Motion-Based Approach

The proposed method:

- may be exploited for recreating perceptually irrelevant parts of the scene, such as highly textured regions
- relaxes the common constraint of pixel fidelity
- allows omitting motion vector coding and encoding of prediction residuals
- employs dense optical flow for modeling random motion of dynamic textures

Definitions

Suggested Motion-Based Approach - Definitions

sGOP - a group of pictures considered for synthesis.

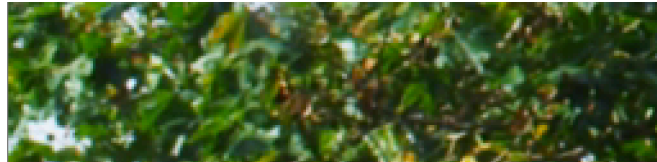
Motion Vector Frame ($MV^{t_{i,j}}$) - dense optical flow (**OF**) computed between two adjacent frames I_t and I_{t-1} , describes at which position in I_{t-1} we get prediction for position (i, j) in frame I_t .

Motion Co-occurrence Matrix (MCM, M) - a tabulation of how often different combinations of 4 motion vectors ($\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3, \mathbf{v}_4$) occur, such that $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3$ - associated with $MV^{t-1}_{i,j}, MV^{t-1}_{i-1,j}, MV^{t-1}_{i,j-1}$ respectively and \mathbf{v}_4 - associated with $MV^{t_{i,j}}$.

[2] Rahman, Ashfaur, and Manzur Murshed. "Dynamic texture synthesis using motion distribution statistics." Journal of Research and Practice in Information Technology 40.2 (2008): 129.

Suggested Motion-Based Approach - Motion Vector Frame

I_{t-1}



I_t



Estimate
dense OF

Motion Vector Frame

$MV^{t_{i,j}}$

↖	↖	↑	↗	→	↑	...	↑
↖	↑	↗	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

Suggested Motion-Based Approach - Motion Vector Frame

I_t



I_{t+1}



Estimate
dense OF

Motion Vector Frame

$MV^{t+1}_{i,j}$

→	↑	↗	→	↑	↗	...	↗
↘	↗	→	↘	↗	→	...	→
↑	↗	↘	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↘
→	↗	↘	↗	→	↘	...	↘
→	↘	↑	←	↘	↗	...	↘
...
↗	↓	↗	↓	↘	↗	↘	↘

Suggested Motion-Based Approach - Motion Co-occurrence Matrix

Motion Vector Frame

$$MV^{t_{i,j}}$$

↖	↖	↑	↗	→	↑	...	↑
↖	↑	↗	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

Motion Vector Frame

$$MV^{t+1_{i,j}}$$

→	↑	↗	→	↑	↗	...	↗
↘	↗	→	↘	↗	→	...	→
↑	↗	↖	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↖
→	↗	↖	↗	→	↖	...	↖
→	↘	↑	←	↘	↗	...	↖
...
↗	↓	↗	↓	↖	↗	↖	↖

Suggested Motion-Based Approach - Motion Co-occurrence Matrix

Motion Vector Frame
 $MV^{t_{i,j}}$

↖	v_3^t	↑	↗	→	↑	...	↑
v_2^t	v_1^t	↗	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

Motion Vector Frame
 $MV^{t+1_{i,j}}$

→	↑	↗	→	↑	↗	...	↗
↘	v_4^{t+1}	→	↘	↗	→	...	→
↑	↗	↖	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↖
→	↗	↖	↗	→	↖	...	↖
→	↘	↑	←	↘	↗	...	↖
...
↗	↓	↗	↓	↖	↗	↖	↖

$$(\mathbf{v}_1^t, \mathbf{v}_2^t, \mathbf{v}_3^t, \mathbf{v}_4^{t+1})_k \longrightarrow \mathbf{M}, t=1, \dots, T; k=1, 2, \dots, N \times N$$

Suggested Motion-Based Approach - Motion Co-occurrence Matrix

Motion Vector Frame
 $MV^{t_{i,j}}$

↖	↑	v^t_3	↗	→	↑	...	↑
↗	v^t_2	v^t_1	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

Motion Vector Frame
 $MV^{t+1_{i,j}}$

→	↑	↗	→	↑	↗	...	↗
↘	↗	v^{t+1}_4	↘	↗	→	...	→
↑	↗	↖	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↖
→	↗	↖	↗	→	↖	...	↘
→	↘	↑	←	↘	↗	...	↖
...
↗	↓	↗	↓	↖	↗	↖	↖

$$(v^t_1, v^t_2, v^t_3, v^{t+1}_4)_k \longrightarrow M, t=1, \dots, T; k=1, 2, \dots, N*N$$

Suggested Motion-Based Approach - Motion Co-occurrence Matrix

Motion Vector Frame
 $MV^{t_{i,j}}$

↖	↑	→	v^t_3	→	↑	...	↑
↗	↗	v^t_2	v^t_1	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

Motion Vector Frame
 $MV^{t+1_{i,j}}$

→	↑	↗	→	↑	↗	...	↗
↘	↗	→	v^{t+1}_4	↗	→	...	→
↑	↗	↖	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↖
→	↗	↖	↗	→	↖	...	↘
→	↘	↑	←	↘	↗	...	↖
...
↗	↓	↗	↓	↖	↗	↖	↖

$$(v^t_1, v^t_2, v^t_3, v^{t+1}_4)_k \longrightarrow M, t=1, \dots, T; k=1, 2, \dots, N \times N$$

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t-1}_1 , \mathbf{v}^{t-1}_2 and \mathbf{v}^{t-1}_3 are available (e.g. estimated using dense OF method)

$MV^{t-1}_{i,j}$

↖	\mathbf{v}^{t-1}_3	↑	↗	→	↑	...	↑
\mathbf{v}^{t-1}_2	\mathbf{v}^{t-1}_1	↗	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

$MV'^t_{i,j}$

?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t-1}_4 is chosen from \mathbf{M} , based on information about \mathbf{v}^{t-1}_1 , \mathbf{v}^{t-1}_2 and \mathbf{v}^{t-1}_3 .

$MV^{t-1}_{i,j}$

↖	\mathbf{v}^{t-1}_3	↑	↗	→	↑	...	↑
\mathbf{v}^{t-1}_2	\mathbf{v}^{t-1}_1	↗	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

$MV^{t-1}_{i,j}$

?	?	?	?	?	?	...	?
?	\mathbf{v}^{t-1}_4	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t_4} is chosen from \mathbf{M} , based on information about \mathbf{v}^{t-1}_1 , \mathbf{v}^{t-1}_2 and \mathbf{v}^{t-1}_3 .

$MV^{t-1}_{i,j}$

↖	↑	\mathbf{v}^{t-1}_3	↗	→	↑	...	↑
↗	\mathbf{v}^{t-1}_2	\mathbf{v}^{t-1}_1	→	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

$MV^{t_4}_{i,j}$

?	?	?	?	?	?	...	?
?	↗	\mathbf{v}^{t_4}	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t_4} is chosen from \mathbf{M} , based on information about \mathbf{v}^{t-1}_1 , \mathbf{v}^{t-1}_2 and \mathbf{v}^{t-1}_3 .

$MV^{t-1}_{i,j}$

↖	↑	↑	\mathbf{v}^{t-1}_3	→	↑	...	↑
↗	↑	\mathbf{v}^{t-1}_2	\mathbf{v}^{t-1}_1	↘	↗	...	↗
←	←	↗	→	↘	↗	...	↗
↖	↖	↑	↗	→	↗	...	↗
↖	↑	↗	→	↘	→	...	→
←	←	↗	→	↘	→	...	→
...
↖	↑	↖	↑	↗	→	↘	↗

$MV^{t_4}_{i,j}$

?	?	?	?	?	?	...	?
?	↗	→	\mathbf{v}^{t_4}	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t+1}_4 is chosen from \mathbf{M} , based on information about $\mathbf{v}^{t_1}_1$, $\mathbf{v}^{t_2}_2$ and $\mathbf{v}^{t_3}_3$.

$MV^{t_{i,j}}$

→	$\mathbf{v}^{t_3}_3$	↗	→	↑	↗	...	↗
$\mathbf{v}^{t_2}_2$	$\mathbf{v}^{t_1}_1$	→	↘	↗	→	...	→
↑	↗	↘	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↘
→	↗	↘	↗	→	↘	...	↘
→	↘	↑	←	↘	↗	...	↘
...
↗	↓	↗	↓	↘	↗	↘	↘

$MV^{t+1}_{i,j}$

?	?	?	?	?	?	...	?
?	\mathbf{v}^{t+1}_4	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t+1}_4 is chosen from \mathbf{M} , based on information about $\mathbf{v}^{t_1}_1$, $\mathbf{v}^{t_2}_2$ and $\mathbf{v}^{t_3}_3$.

$MV^{t_{i,j}}$

→	↑	$\mathbf{v}^{t_3}_3$	→	↑	↗	...	↗
↘	$\mathbf{v}^{t_2}_2$	$\mathbf{v}^{t_1}_1$	↘	↗	→	...	→
↑	↗	↘	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↘
→	↗	↘	↗	→	↘	...	↘
→	↘	↑	←	↘	↗	...	↘
...
↗	↓	↗	↓	↘	↗	↘	↘

$MV^{t+1}_{i,j}$

?	?	?	?	?	?	...	?
?	↗	\mathbf{v}^{t+1}_4	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Suggested Motion-Based Approach - Predicting Motion Vectors

\mathbf{v}^{t+1}_4 is chosen from \mathbf{M} , based on information about \mathbf{v}^{t_1} , \mathbf{v}^{t_2} and \mathbf{v}^{t_3} .

$MV^{t_{i,j}}$

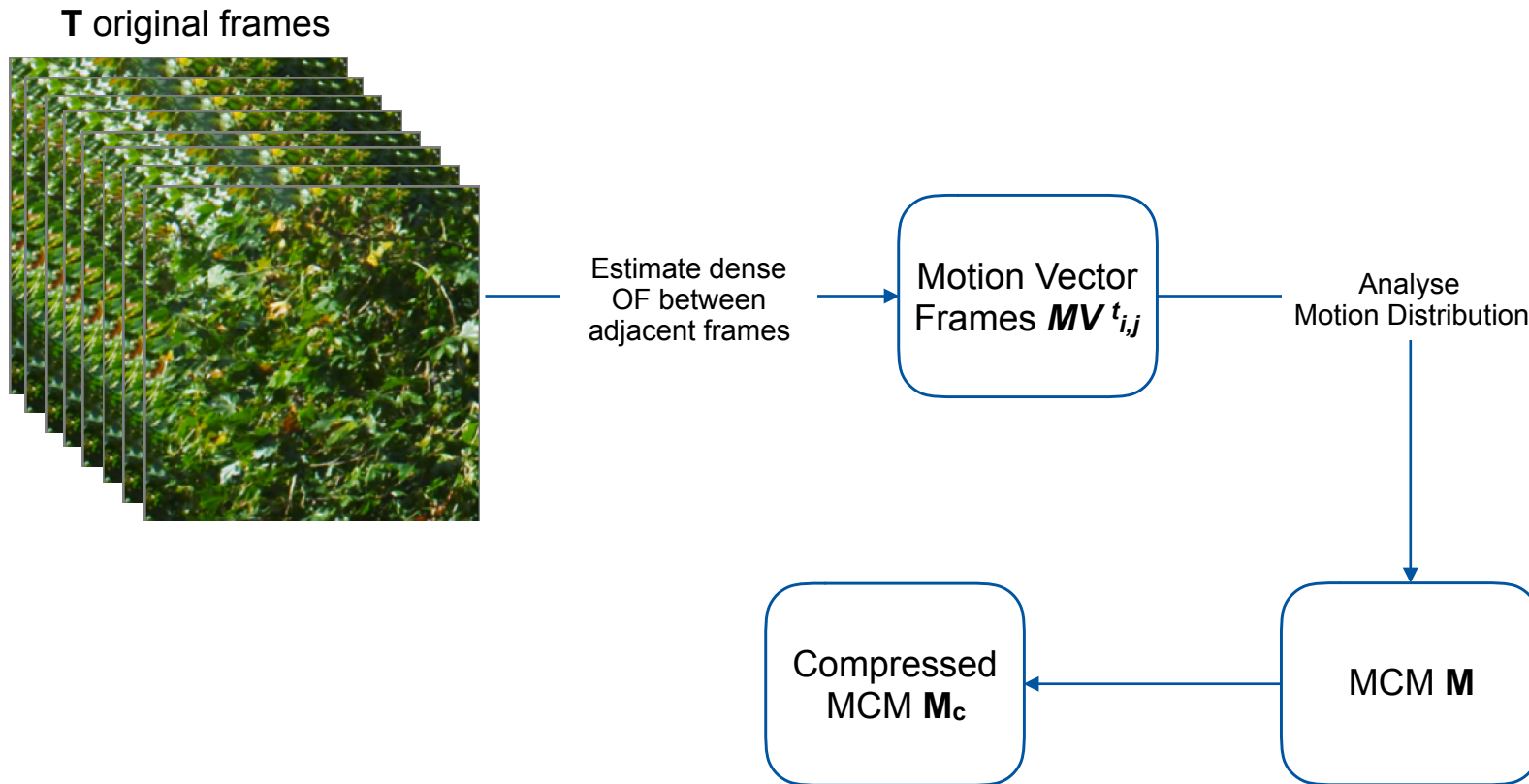
→	↑	↗	\mathbf{v}^{t_3}	↑	↗	...	↗
↘	↗	\mathbf{v}^{t_2}	\mathbf{v}^{t_1}	↗	→	...	→
↑	↗	↘	←	←	↑	...	→
←	←	→	↘	↗	↑	...	↘
→	↗	↘	↗	→	↘	...	↘
→	↘	↑	←	↘	↗	...	↘
...
↗	↓	↗	↓	↘	↗	↘	↘

$MV^{t+1}_{i,j}$

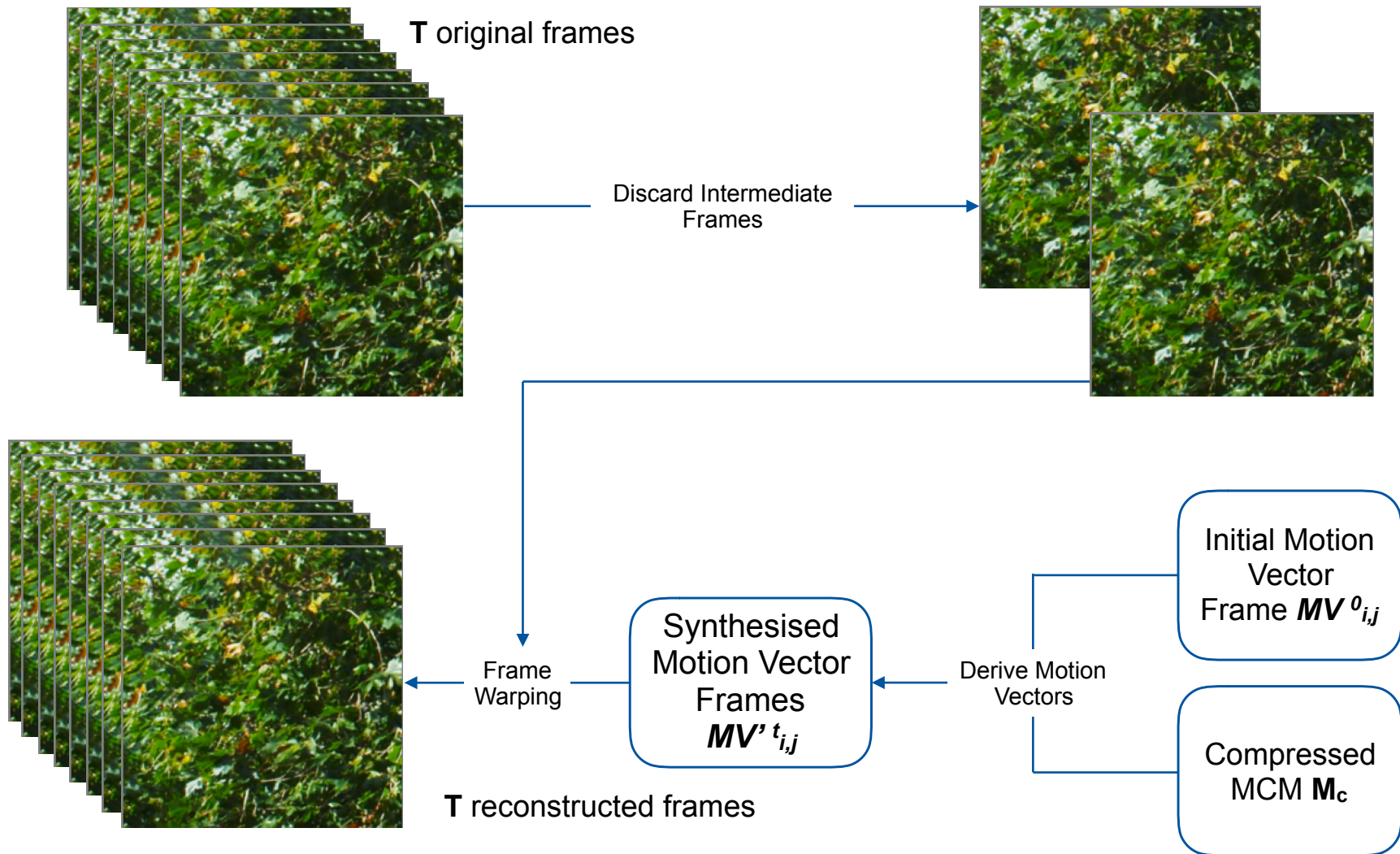
?	?	?	?	?	?	...	?
?	↗	→	\mathbf{v}^{t+1}_4	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
?	?	?	?	?	?	...	?
...
?	?	?	?	?	?	...	?

Analysis and Synthesis

Suggested Motion-Based Approach - Analysis

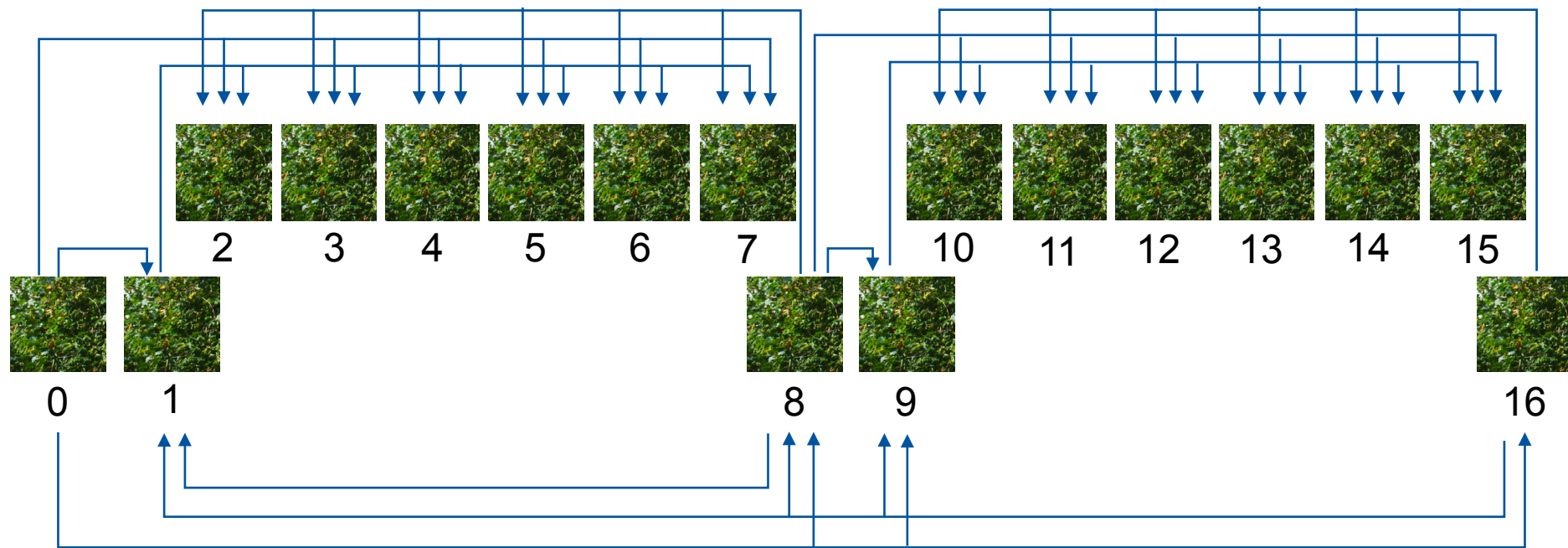


Suggested Motion-Based Approach - Synthesis



Suggested Motion-Based Approach - sGOP Structure

Example of the updated coding structure for sGOP size 8



Results

Suggested Motion-Based Approach - Experiments

Proposed method was tested on a set of 11 cropped sequences, containing water, leaves and smoke.

Sequences:

- 256x256 pixels in width and height
- 250 frames
- frame-rate 60 fps
- encoded with HEVC Test Model (HM-16.6) with modified RA configuration, QP=22
- sGOP size considered - 8

Results

Sequence	HEVC Rate at QP22 (CTC RA), [kbps]	Synth. Rate (Modif. RA, QP22), [kbps] KeyFrames+ SynthPar	Rate Reduction, %	Corresponding HEVC QP / Rate [kbps] (CTC RA)
BallUnderWater	50.1	19.5 + 0.226	-60.67	29 / 21.1
BricksBushesStatic- Bushes1	1744.5	766.1 + 5.7	-55.75	28 / 765.1
BricksBushesStatic- Bushes2	1579.1	717.3 + 2.9	-54.39	28 / 706.0
LampLeaves-bushes1	1578.9	728.3 + 11.9	-53.11	28 / 706.0
LampLeaves-bushes2	1146.4	507.4 + 54.1	-51.02	27 / 582.5
LampLeaves-bushes3	1294.6	545.8 + 135.5	-47.37	27 / 661.2
LampLeaves- bushesBackground	552.4	281.2 + 7.5	-47.75	27 / 272.5
Petibato-cropped	735.1	391.5 + 153.3	-25.87	23 / 570.2
SmokeClear-middle	97.3	40.2 + 0.226	-58.46	28 / 40.1
SmokeClear-side	145.0	62.0 + 0.226	-57.08	27 / 58.4
TreeWills-cropped	970.6	584.3+ 0.44	-39.76	26 / 540.7
Average rate reduction			-50.11	

Results

PetiBato, HEVC (CTC RA, QP=23)



PetiBato, synthesis



Results

BricksBushes1, HEVC (CTC RA, QP=28)



BricksBushes1, synthesis



Results

BricksBushes2, HEVC (CTC RA, QP=28)

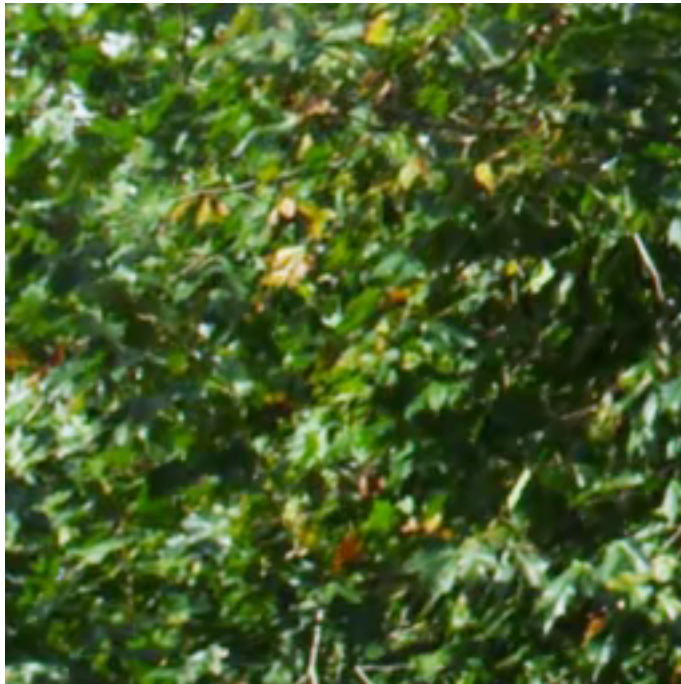


BricksBushes2, synthesis



Results

TreeWills, HEVC (CTC RA, QP=26)



TreeWills, synthesis



Conclusions

Approach to synthesis-based coding of dynamic textures

- Subjective results in conjunction with bitrate savings appear promising
→ potential topic in future standardization?
- Could be applied for content which has high rate demand in conventional coding
- So far only investigated with homogeneous dynamic texture, but should be applicable for local areas as well
- Integration into complete coding scheme to be done
- Determination of required normative elements
→ Representation of MCM, could be kind of SEI message
→ Synthesis does not need to be normative, unless a minimum decoded quality would be mandatory