

# Fortschritt-Berichte VDI

Reihe 10

Informatik/  
Kommunikation

Dipl.-Ing. Holger Meuel,  
Hannover

Nr. 865

Analysis of Affine  
Motion-Compensated  
Prediction and its  
Application in  
Aerial Video Coding



Institut für Informationsverarbeitung  
[www.tnt.uni-hannover.de](http://www.tnt.uni-hannover.de)

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Motion-Compensated Prediction . . . . .	3
1.2	Challenges for Aerial Surveillance Video Coding . . . . .	6
1.2.1	Region of interest-based video coding . . . . .	6
1.3	Contributions . . . . .	8
1.4	Outline . . . . .	10
<b>2</b>	<b>Basics</b>	<b>11</b>
2.1	Scene Model . . . . .	11
2.2	Camera Model . . . . .	13
2.2.1	Perspective projection . . . . .	13
2.2.2	Lens model . . . . .	14
2.2.3	Sensor model . . . . .	15
2.2.4	Homogeneous coordinates . . . . .	17
2.2.5	World coordinates to camera coordinates . . . . .	18
2.3	Projective Transformation and Homography . . . . .	18
2.4	Motion Estimation from Image Sequences . . . . .	20
2.4.1	Feature detection . . . . .	21
2.4.2	Correspondence analysis by Kanade-Lucas-Tomasi feature tracking . . . . .	23
2.4.3	Outlier removal: random sample consensus (RANSAC) . . . . .	25
2.5	Mosaicking of Aerial Videos . . . . .	26
2.6	Hybrid Video Coding . . . . .	27
2.6.1	Motion-compensated prediction . . . . .	28
2.6.2	Global motion compensation . . . . .	29
2.7	Rate-Distortion Theory . . . . .	29
2.8	Region of Interest- (ROI-) based Video Coding . . . . .	33
2.8.1	ROI definition and detection . . . . .	33
2.8.2	ROI encoding . . . . .	35
<b>3</b>	<b>Rate-Distortion Theory for Affine Motion Compensation in Video Coding</b>	<b>37</b>
3.1	Efficiency Analysis of Fully Affine Motion Compensation . . . . .	38
3.1.1	Affine motion and error model . . . . .	40
3.1.2	Probability density function of the displacement estimation error . . . . .	41
3.1.3	Power spectral density of the signal . . . . .	44
3.1.4	Power spectral density of the displacement estimation error . . . . .	45
3.1.5	Rate-distortion function . . . . .	45
3.1.6	Rate-distortion analysis of affine global motion-compensated prediction . . . . .	46
3.1.7	Conclusions for the fully affine motion model for global motion compensation . . . . .	52

3.2	Efficiency Analysis of Simplified Affine Motion Compensation . . . . .	54
3.2.1	Derivation of the probability density function of the displacement estimation error for a simplified affine model . . . . .	55
3.2.2	Rate-distortion analysis of the simplified affine model . . . . .	58
3.3	Summary of Affine Motion-Compensated Prediction in Video Coding . . . . .	63
<b>4</b>	<b>ROI-based System for Low Bit Rate Coding of Aerial Videos</b>	<b>65</b>
4.1	ROI: New Areas (NAs) . . . . .	67
4.1.1	Calculation of the new areas . . . . .	67
4.1.2	Long-term mosaicking of aerial videos . . . . .	68
4.1.3	In-loop radial distortion compensation . . . . .	70
4.2	ROI: Moving Objects (MOs) . . . . .	75
4.2.1	Highly performant difference image-based moving object detection . . . . .	75
4.3	ROI Coding of Aerial Video Sequences . . . . .	79
4.3.1	Inherent noise removal of the proposed general ROI coding . . . . .	83
4.4	Mosaicking of ROI-Encoded Videos . . . . .	84
4.5	Video Reconstruction from ROI-Encoded Videos . . . . .	85
<b>5</b>	<b>Experiments</b>	<b>87</b>
5.1	Affine Motion Compensation in Video Coding. . . . .	87
5.1.1	Efficiency measurements for fully affine motion-compensated prediction in video coding. . . . .	88
5.1.2	Operational rate-distortion diagrams using JEM . . . . .	95
5.2	Evaluation of the ROI-based System for Low Bit Rate Aerial Video Coding. . . . .	99
5.2.1	Objective evaluation of the general ROI-coding system compared to a modified HEVC-encoder and common HEVC coding . . . . .	99
5.2.2	Subjective tests . . . . .	102
5.2.3	Long-term mosaicking . . . . .	113
<b>6</b>	<b>Summary and Conclusions</b>	<b>117</b>
<b>A</b>	<b>Appendix</b>	<b>123</b>
A.1	Displacement Estimation Error pdf Derivation (Fully Affine Model) . . . . .	123
A.2	Displacement Estimation Error pdf Derivation (Simplified Affine Model) . . . . .	127
A.3	Fourier Transform of Displacement Estimation Error (Fully Affine Model) . . . . .	129
A.4	Fourier Transform of Displacement Estimation Error (Simplified Affine Model) . . . . .	130
	<b>Bibliography</b>	<b>133</b>