OPTIMIZATION OF TIEPOINT EXTRACTION FOR RAPID UAV IMAGE MOSAICKING

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Abstract: The use of UAVs (Unmanned Aerial Vehicles) is increasing in various fields with the rapid development of technology. Along with this increase, UAV image mosaicking became essential to many remote sensing application areas such as time series monitoring. One of the biggest challenges of the mosaicking is the significant time consumption of the process. In particular, tiepoint extraction is the most time-consuming part of the whole UAV image mosaic process. It includes feature keypoint extraction, feature matching, and outlier removal algorithms. This paper focuses on optimization of tiepoint extraction time for fast UAV image mosaicking.

Image downsampling reduces the image size proportional to the square of the scale factor. Consequently, it reduces the calculation process and operating time. On the other hand, excessive downsampling causes data loss and tiepoints with poor quality. The adjustment of feature keypoint quantity shows an analogous pattern to the above. Feature keypoint quantity refers to the maximum number of points to be extracted from each image. We extract feature keypoints for the entire images within the dataset and feed them to feature matching process. Feature extraction operation is reduced in the case of smaller feature keypoints quantity. It also affects the feature matching process afterward. Thus, reducing feature keypoints is effective for reducing overall operation time. Contrarily, an excessively low number of keypoints leads to tiepoints with poor quality or feature matching failure. In this respect, we analyzed proper image downsampling rates and feature keypoint quantity that reduces time to a minimum but maintains the quality of mosaic images.

For experiments, we used four datasets. All datasets were taken from agricultural areas in Korea consisting of from 130 to 220 images. Dataset 1 to 3(Chogye, Anbandegi, Myosan) images were taken by eBee (fixed wing) and Dataset 4(Gimje) images were taken by DJI Phantom 4 (rotary wing). We used the SURF (Speeded-Up Robust Features) algorithm to extract feature points and the linear interpolation for image downsampling. To evaluate the performance, we used the total number of extracted feature points, match points, the number of bundle adjustment successes, processing times, and mosaic images. The number of extracted features and matched points shows the amount of calculation in quantity, and the bundle adjustment success shows the quality of tiepoints.

Table 1 shows that low-quality of tiepoints were obtained with tiepoint extracted from the original images due to image blurring. However, increasing the downsampling rates up to 1/2 shows improved quality in tiepoints and mosaic images. When it exceeded 1/3 rates of downsampling, it showed declines in mosaic image qualities. Thus, we determined the optimal downsampling rates at

1/2 and experimented further with 8 different keypoint quantities. In the case of feature keypoint quantity, the quality of mosaic was maintained up to 50% of the maximum number (65535) applied to the original image. We reduced tiepoint processing time with image downsampling rate of 1/2 by 18% in dataset 1, 6% in dataset 2, 15% in dataset 3, and 6% in dataset 4. Similarly, we reduced tiepoint processing time with keypoints reduced by 50% by 10% in dataset 1, 18% in dataset 2, 11% in dataset 3, and 23% in dataset 4 as compared to maximum keypoints. In conclusion, by adjusting the number of feature keypoints and downsampling images by half, we reduced tiepoint extraction time by an average of 26% while maintaining mosaic quality.

		1.Chogye Region (175 images)				2.Anbandegi Region (218 images)			
		Feature	Matched	Bundle	Processing	Feature	Matched	Bundle	Processing
	1	Points	Points	Adjustment	Time (s)	Points	Points	Adjustment	Time (s)
Down sampling Rates	1	11,272,020	161,275	21	246	14,286,630	675,716	25	314
	1/2	7,608,424	438,691	170	200	10,800,588	1,395,063	156	293
	1/3	3,788,657	204,365	170	168	10,284,416	611,472	84	217
	1/4	1,980,938	126,791	68	157	2,952,146	370,569	85	193
	1/5	1,292,022	71,277	60	152	2,034,745	201,146	63	184
Keypoint Reduce Rates	1	7,608,424	438,691	170	200	10,800,588	1,395,063	156	293
	7/8	7,597,479	437,666	170	202	10,746,256	1,390,920	155	300
	6/8	7,430,483	417,895	170	198	10,284,416	1,329,213	155	287
	5/8	6,785,676	368,378	167	195	8,905,496	1,137,890	146	257
	4/8	5,616,683	306,333	170	180	7,143,206	935,654	147	240
	3/8	4,227,072	229,434	170	178	5,357,568	659,165	84	226
	2/8	2,818,048	142,696	67	65	3,571,712	426,679	70	209
	1/8	1,409,024	43,430	8	157	1,785,856	184,891	9	192
		3.Myosan Region (139 images)				4.Gimje Region (175 images)			
		3.	Myosan R	egion (139 i	mages)	4. G	imje Regio	on (175 imag	ges)
		3. Feature Points	Myosan R Matched Points	egion (139 i Bundle Adjustment	mages) Processing Time (s)	4.G Feature Points	imje Regio Matched Points	on (175 imag Bundle Adjustment	ges) Processing Time (s)
	1	3. Feature Points 9,109,365	Myosan R Matched Points 211,865	egion (139 i Bundle Adjustment 20	mages) Processing Time (s) 200	4.G Feature Points 11,468,450	Matched Points 794,396	n (175 imag Bundle Adjustment 160	ges) Processing Time (s) 291
Down	1 1/2	3. Feature Points 9,109,365 6,446,874	Myosan R Matched Points 211,865 284,242	egion (139 i Bundle Adjustment 20 116	mages) Processing Time (s) 200 170	4.G Feature Points 11,468,450 10,410,588	imje Regio Matched Points 794,396 1,166,341	on (175 imag Bundle Adjustment 160 160	ges) Processing Time (s) 291 271
Down sampling	1 1/2 1/3	3. Feature Points 9,109,365 6,446,874 3,256,569	Myosan R Matched Points 211,865 284,242 140,349	egion (139 i Bundle Adjustment 20 116 109	mages) Processing Time (s) 200 170 138	4.G Feature Points 11,468,450 10,410,588 7,497,416	imje Regio Matched Points 794,396 1,166,341 527,779	on (175 imag Bundle Adjustment 160 160 160	ges) Processing Time (s) 291 271 214
Down sampling Rates	1 1/2 1/3 1/4	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005	Myosan R Matched Points 211,865 284,242 140,349 88,803	egion (139 i Bundle Adjustment 20 116 109 98	mages) Processing Time (s) 200 170 138 125	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680	Imje Regio Matched Points 794,396 1,166,341 527,779 306,634	m (175 imag Bundle Adjustment 160 160 160 160	ges) Processing Time (s) 291 271 214 181
Down sampling Rates	1 1/2 1/3 1/4 1/5	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023	egion (139 i Bundle Adjustment 20 116 109 98 37	mages) Processing Time (s) 200 170 138 125 101	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670	m (175 imag Bundle Adjustment 160 160 160 160 159	ges) Processing Time (s) 291 271 214 181 172
Down sampling Rates	1 1/2 1/3 1/4 1/5 1	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242	egion (139 i Bundle Adjustment 20 116 109 98 37 116	mages) Processing Time (s) 200 170 138 125 101 170	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341	m (175 imag Bundle Adjustment 160 160 160 159 160	ges) Processing Time (s) 291 271 214 181 172 271
Down sampling Rates	1 1/2 1/3 1/4 1/5 1 7/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,191	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116	mages) Processing Time (s) 200 170 138 125 101 170 168	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850	m (175 imag Bundle Adjustment 160 160 160 159 160 160	ges) Processing Time (s) 291 271 214 181 172 271 256
Down sampling Rates	1 1/2 1/3 1/4 1/5 1 7/8 6/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590 6,274,856	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,242 284,191 280,663	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116 116 116	mages) Processing Time (s) 200 170 138 125 101 170 168 166	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428 8,449,025	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850 836,768	m (175 imag Bundle Adjustment 160 160 160 159 160 160 160 160	ges) Processing Time (s) 291 271 214 181 172 271 256 236
Down sampling Rates Keypoint	1 1/2 1/3 1/4 1/5 1 7/8 6/8 5/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590 6,274,856 5,590,929	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,191 280,663 246,817	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116 116 116 113	mages) Processing Time (s) 200 170 138 125 101 170 168 166 158	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428 8,449,025 7,138,118	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850 836,768 645,038	m (175 imag Bundle Adjustment 160 160 160 159 160 160 160 160 160	ges) Processing Time (s) 291 271 214 181 172 271 256 236 221
Down sampling Rates Keypoint Reduce Rates	1 1/2 1/3 1/4 1/5 1 7/8 6/8 5/8 4/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590 6,274,856 5,590,929 4,546,316	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,242 284,191 280,663 246,817 211,893	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116 116 113 112	mages) Processing Time (s) 200 170 138 125 101 170 168 166 158 150	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428 8,449,025 7,138,118 5,729,465	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850 836,768 645,038 457,429	m (175 imag Bundle Adjustment 160 160 160 159 160 160 160 160 160 160 159	ges) Processing Time (s) 291 271 214 181 172 271 256 236 221 208
Down sampling Rates Keypoint Reduce Rates	1 1/2 1/3 1/4 1/5 1 7/8 6/8 5/8 4/8 3/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590 6,274,856 5,590,929 4,546,316 3,416,064	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,242 284,242 284,191 280,663 246,817 211,893 152,056	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116 116 113 112 107	mages) Processing Time (s) 200 170 138 125 101 170 168 166 158 150 144	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428 8,449,025 7,138,118 5,729,465 4,300,800	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850 836,768 645,038 457,429 296,075	m (175 imag Bundle Adjustment 160 160 160 159 160 160 160 160 160 160 159 139	ges) Processing Time (s) 291 271 214 181 172 271 256 236 221 208 198
Down sampling Rates Keypoint Reduce Rates	1 1/2 1/3 1/4 1/5 1 7/8 6/8 5/8 4/8 3/8 2/8	3. Feature Points 9,109,365 6,446,874 3,256,569 1,836,005 1,239,119 6,446,874 6,436,590 6,274,856 5,590,929 4,546,316 3,416,064 2,277,376	Myosan R Matched Points 211,865 284,242 140,349 88,803 52,023 284,242 284,191 280,663 246,817 211,893 152,056 94,774	egion (139 i Bundle Adjustment 20 116 109 98 37 116 116 116 116 113 112 107 99	mages) Processing Time (s) 200 170 138 125 101 170 168 166 158 150 144 139	4.G Feature Points 11,468,450 10,410,588 7,497,416 2,728,680 1,922,318 10,410,588 9,550,428 8,449,025 7,138,118 5,729,465 4,300,800 2,867,200	imje Regio Matched Points 794,396 1,166,341 527,779 306,634 162,670 1,166,341 1,010,850 836,768 645,038 457,429 296,075 179,723	m (175 imag Bundle Adjustment 160 160 160 159 160 160 160 160 160 160 159 139 77	ges) Processing Time (s) 291 271 214 181 172 271 256 236 221 208 198 189

Table 1. Tiepoint Extraction Results with 4 Datasets

Keyword: UAV image; Feature extraction; Feature matching; Mosaicking; Tiepoint;

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