Parameters Affecting the Accuracy of A UAV Photogrammetry Project

Maples and the bodyguard together

By

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Contents

UAV photogrammetry: Definition

- An Unmanned Aerial Vehicle (UAV) on which a camera is mounted
- The camera is controlled to take photos for mapping purposes

Unmanned Aerial Vehicle (UAV): Components

- Vehicle
- Camera

Components of a UAV: Vehicle

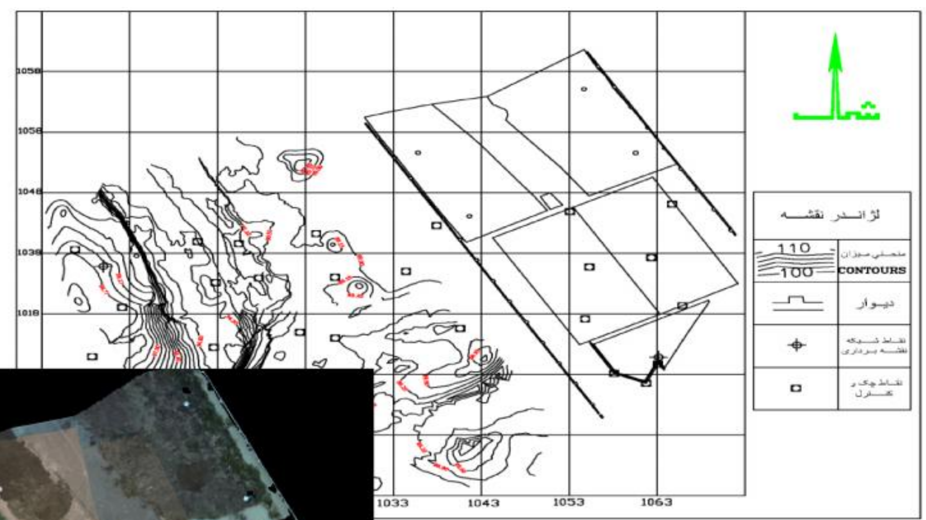
- Body
  - Aircraft
  - Multi-Rotor
  - VTOL
- Control and navigation (Autopilot and GPS/INS)
- Gimbal

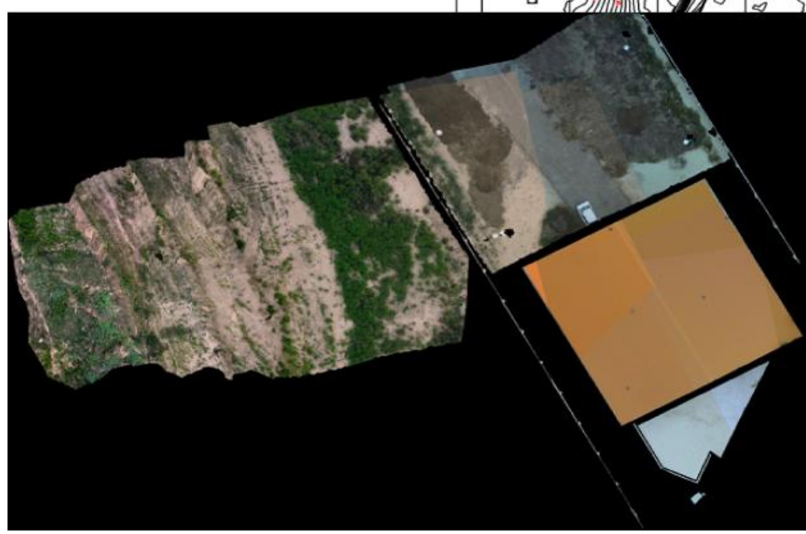
Components of a UAV: Camera

- Usually use of small format non-metric cameras
- More expensive systems employ metric medium format cameras

UAV photogrammetry: Products

- Dense cloud
- Digital terrain (or surface) models
- 3D realistic model
- Topographic map
- Orthophoto





UAV photogrammetry: Applications

- Topographic mapping
- Archaeological studies
- Flood and coastline and Modelling
- Oil and Gas Exploration
- Minerals (Volumetric calculations)
- Urban and pollution Planning
- Cellular Network Planning
- …

A Big Question

With UAV&non-metric-camera technology,

why

use traditional expensive aerial photography

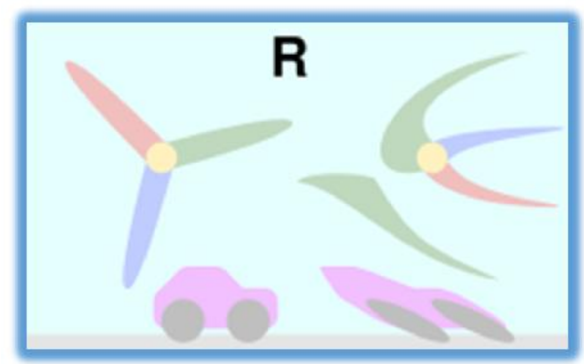
Accuracy Issues

- Camera related issues
- Vehicle related issues

Accuracy Issues: Camera

- Sensor type
  - CCD Vs CMOS
    - CCD: more expensive, less noise, larger dynamic range
    - CMOS: cheaper, faster, lighter→ used in most off-the-shelf cameras

      More noise, smaller dynamic range, weaker radiometric quality
- Sensor size
  - Large Vs Small sensor size: the smaller the sensor size, the larger the noise
  - Medium/Large Vs Small format frame: smaller frame→ many more images needed
- Lens distortions (geometric and radiometric)
  - Accurate, small and stable Vs inaccurate, large and unstable
- Shutter type
  - Global Vs rolling shutter
    - Rolling shutter effect mainly due to vehicle's speed



Accuracy Issues: Vehicle

- Vibrations: leads to image random blurring
  - Mostly in Multi-rotors due to motor vibrations
- Motion: leads to directional blurring
  - Mainly in airplanes due to high flight speeds

Camera Issues: Some Solutions

Problem	Solution	Notes
CMOS sensor	• Increase CMOS quality • Decrease CCD manufacturing price	-
Small camera frame	• Use multi-camera configurations • Fly higher	• Calibration and stability issues • Introduces more radiometric noise into the images → Need more sophisticated calibration
Small sensor size	Improve manufacturing technology	
Lens distortions	• Improve manufacturing technology at lower costs • Develop more sophisticated calibration techniques • Use more control points/overlaps	• More computation and image capture costs
Rolling shutter effect	Increase readout speed Develop appropriate algorithms	Increases cost May affect model stereo quality

Vehicle Issues: Some Solutions

Problem	Solution	Notes
• Vehicle Vibration	• Use advanced gimbals, motors, autopilots	• Cost issues
Vehicle directional movement	• Reduce flight speed • Use more sensitive ISO	• More flight time • More noise

An alternative solution

Develop algorithms/procedures to cope with errors/issues

and

improve quality of the results

Recent research

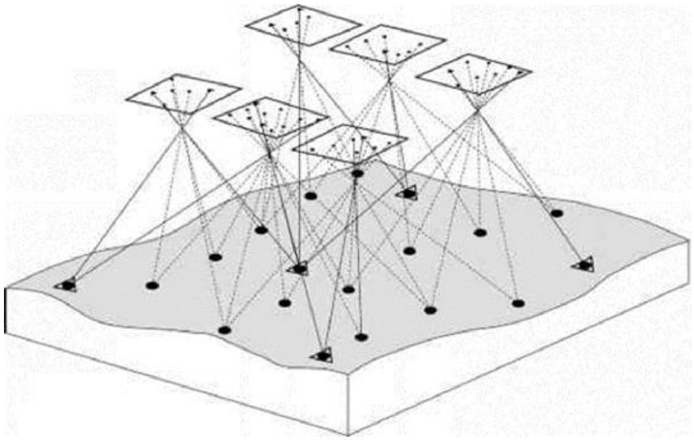
- Aim: development of algorithms/procedures to reduce the effect of weakening parameters

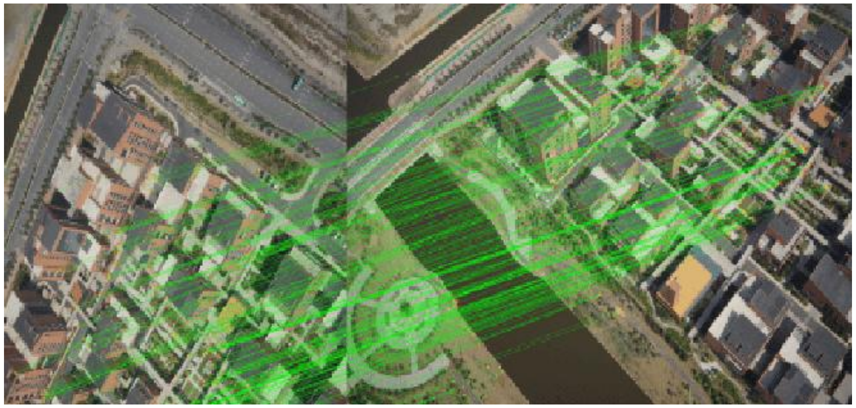
1. Keypoint filtering using multi-criteria decision making algorithms

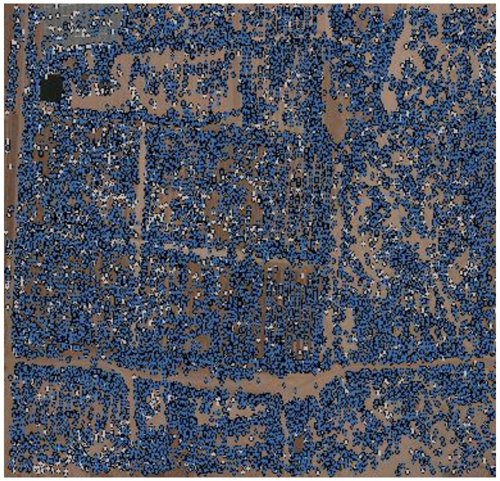
2. Automatic selection of control points using clustering techniques

Keypoint filtering using multi-criteria decision making algorithms

UAV Photogrammetry Computations

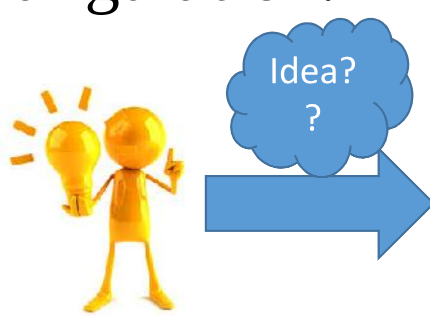






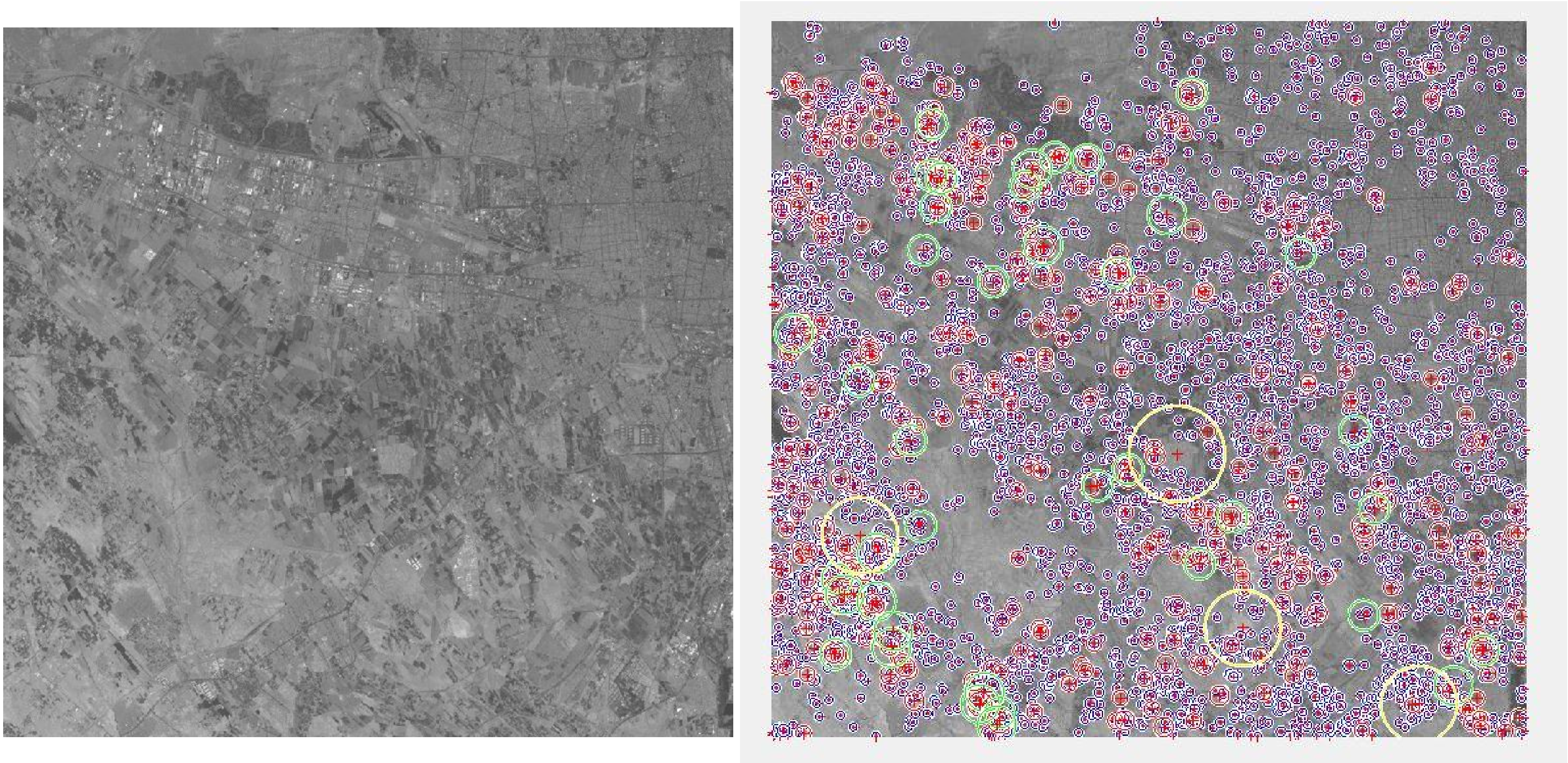
Shortcomings of Current Solutions

- Usually huge number of image correspondences are generated
- Tie points are usually uniformly computed in the images.
- All the extracted tie points are not qualified enough to participate in Arial triangulation.



Finding a solution to refine and optimize the keypoints before aerial triangulation

An Example of Keypoints Detected Using SIFT



Filtering Methodology

- 9 criteria are selected for weighting keypoints
- All keypoints are evaluated by MCDM methods(TOPSIS) using these criteria.

1. Robustness
2. Principal curvature
3. Gradient
4. Entropy
5. Saliency
6. Texture Coefficient
7. Scale
8. Confusion Risk
9. Distance

Stability

Information Content of features

Size

Texture repeatability

Uniform Distribution

Weighting Parameters

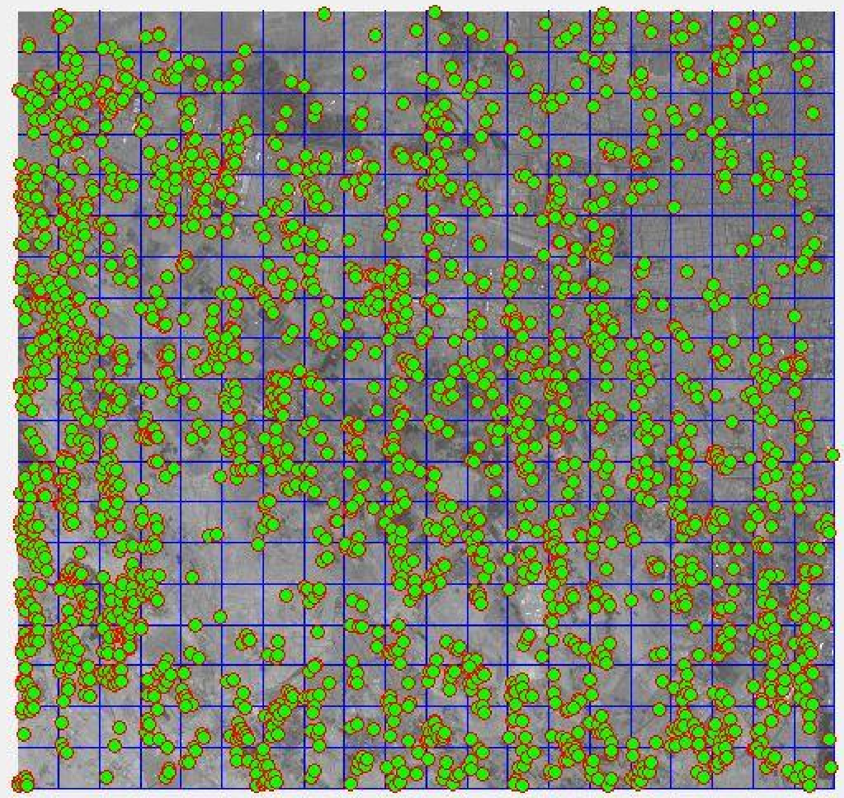
- **Robustness (same as Sift)**
  - Indicates keypoint stability against geometric and radiometric distortions.
- **Principal curvature (same as sift)**
  - Computed using a 2x2 Hessian matrix, A poorly defined peak in the difference-of-Gaussian function will have a large principal curvature and thus is not a stable feature.
- **Gradient distribution:**
  - greater gradient change (around a keypoint) indicates a higher level of information content
- **Entropy & Spatial Saliency (**uniqueness of the keypoint)
  - Entropy: the frequency of a gray level appearing in an image ; bigger frequency lower entropy
  - Saliency: defines non homogeneity of an image
- **Texture Coefficient**
  - To evaluate the quality of the surrounding texture
  - Computed using DNs with respect to average pixel gray level

Weighting Parameters (cont.)

- **Scale**
- The size of the extracted keypoint according to the observation of pyramid level of source image
- **Confusion Risk**
  - Weighting based on repeatability of the feature in the area of interest
  - similar patterns repeated regularly in the scene tends the matching step to be troublesome. This measure discarding local descriptors based on their probability of confusion during the matching stage.
- **Distance to other keypoints**
  - To distribute keypoints evenly across the image
  - Uses Average minimum distance to neighbour points

Results

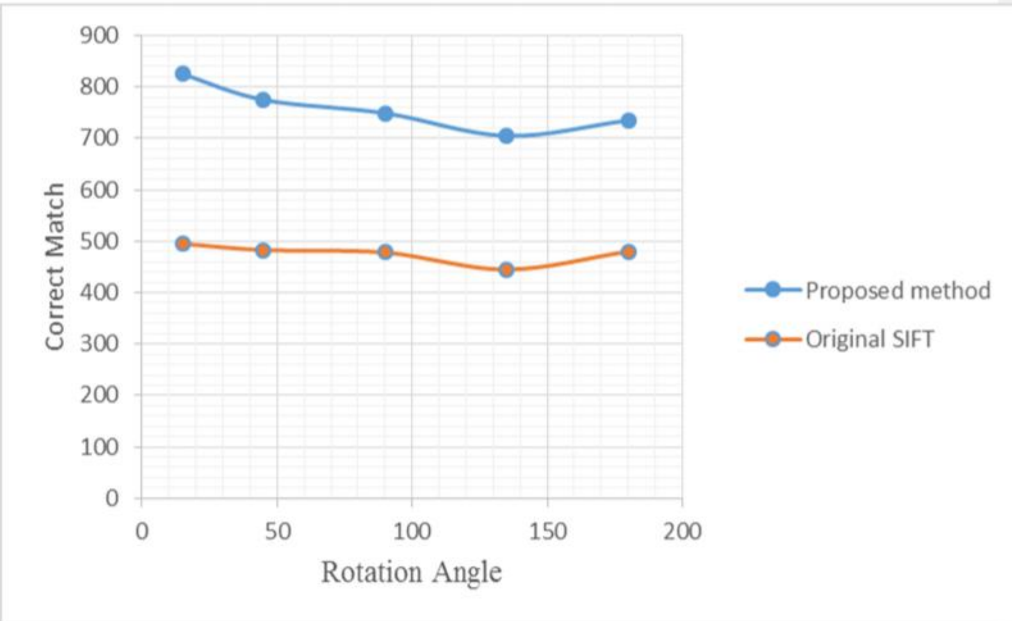
SIFT

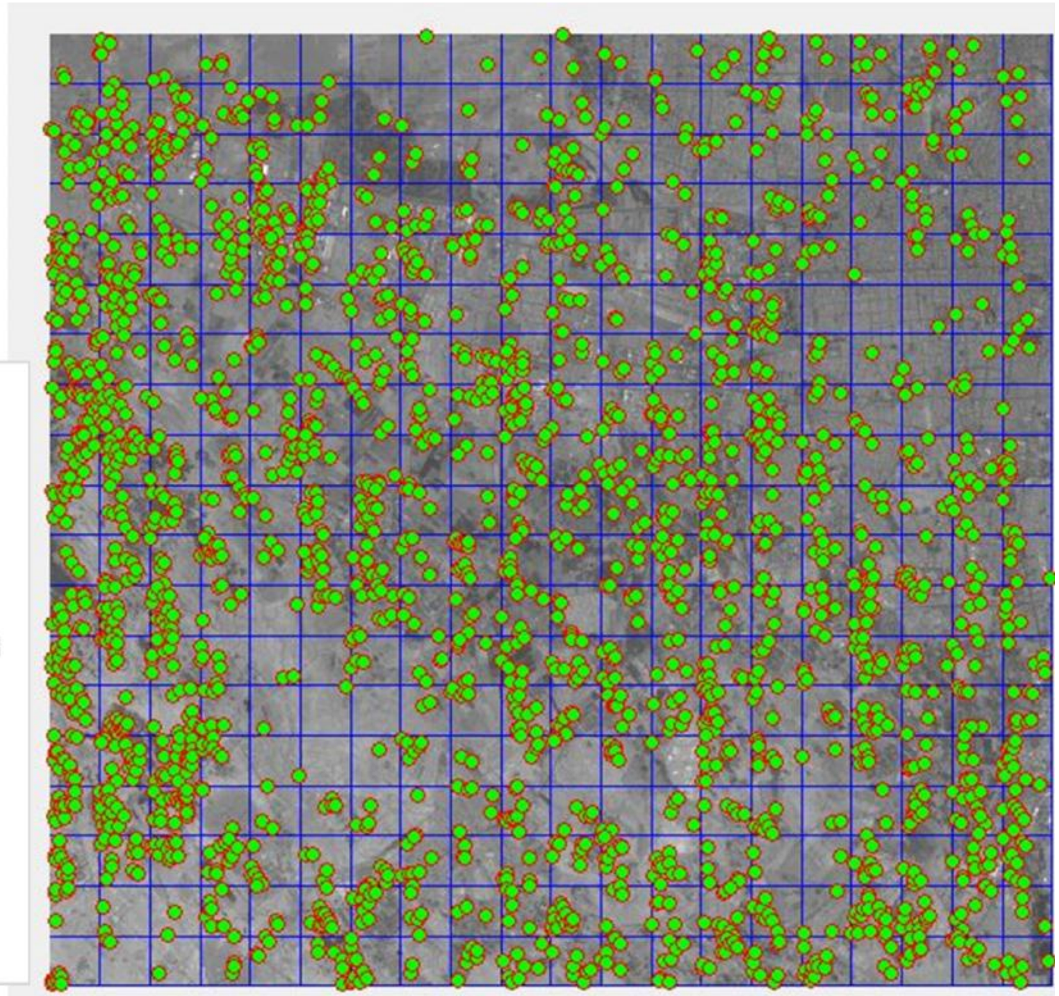


Proposed Method

Features refined by Proposed Method

- *Number of extracted features:2292*
- *Number of Matched features:*

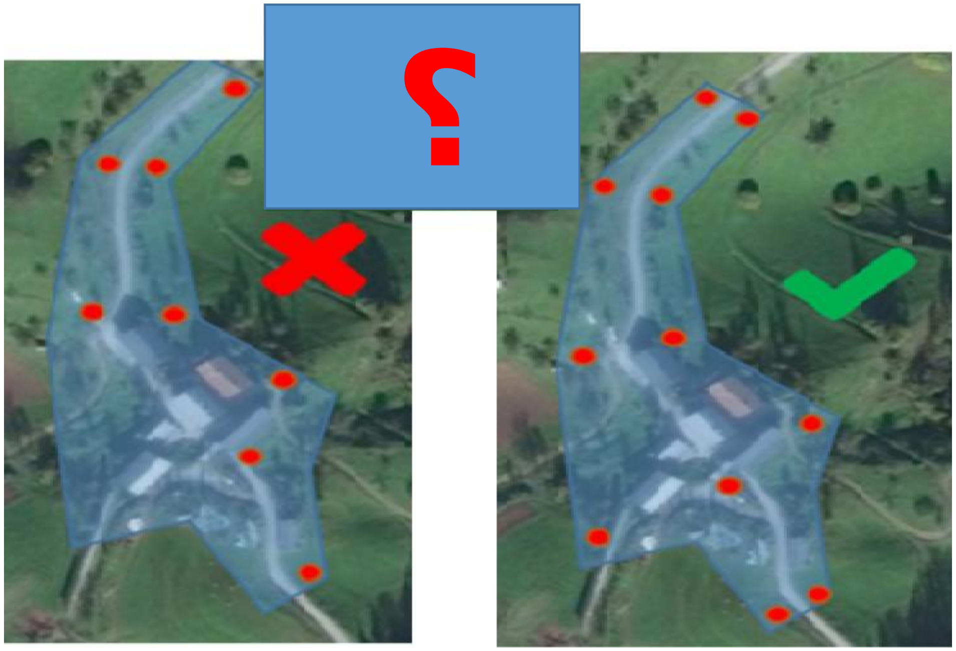




Automatic selection of control points using clustering techniques

Aim

- Automatically define ground control point locations

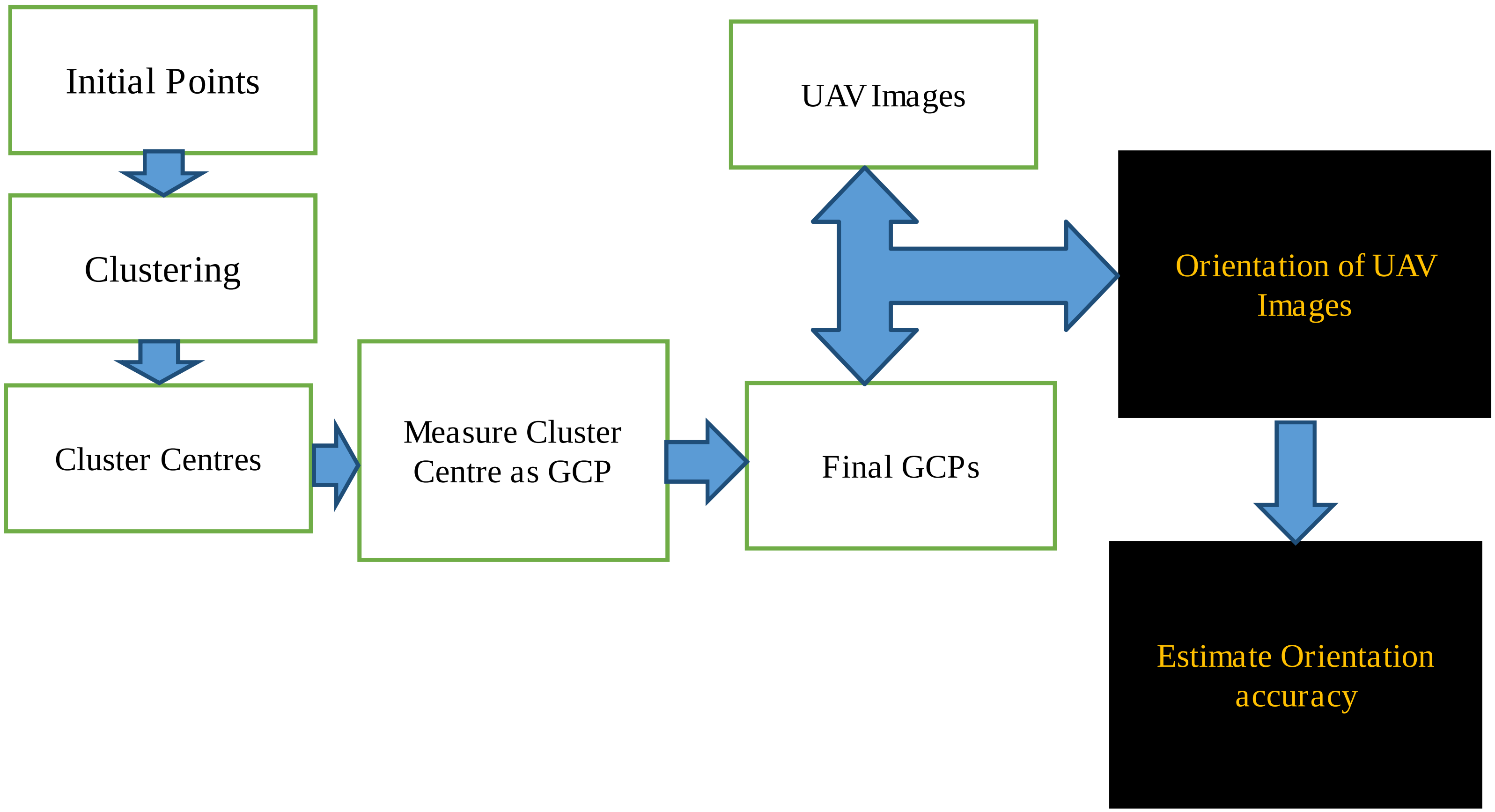


Methodology

- Define an and Image an area (400m*400m)
- Perform clustering
- Use cluster centres as candidate control points
- Measure the identified control points
- Evaluations:
  - Stability of clustering techniques
  - Absolute orientation accuracy,
  - GCP distribution

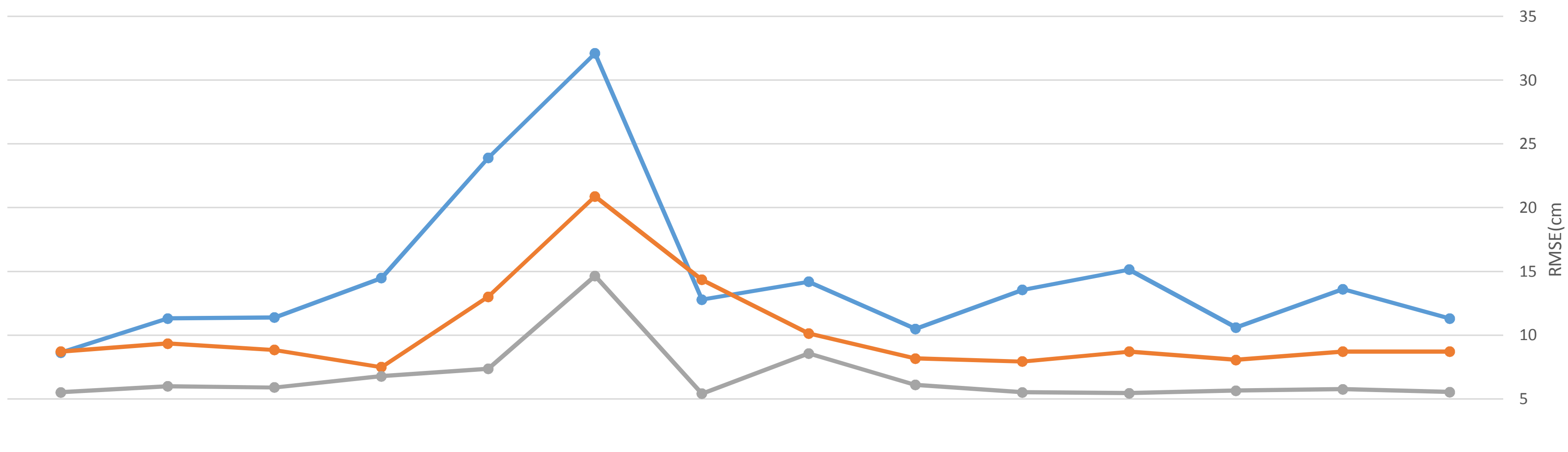
Clustering Method	Partitional	Hierarchical	Density	Model	Fuzzy	Graph	Modern
Clustering algorithms of each clustering method	K-means K-medoids	Single link Compelet link Average link	DBSCAN OPTIC Mean shift	SOM	FCM	Gclust	PSO GA

Method of evaluation



Estimating the ability of clustering methods to select control points

Accuracy of clustering methods and Grid method with <u>90% overalp</u>

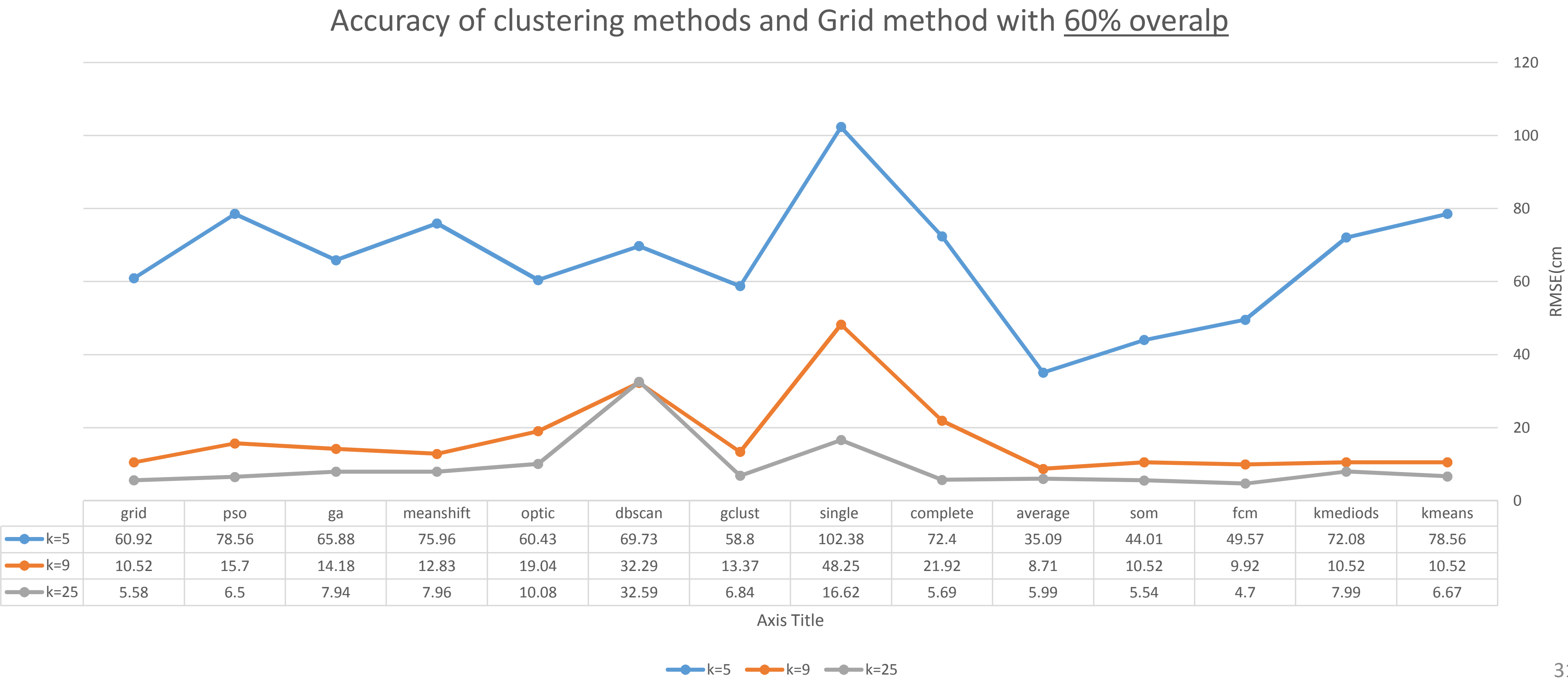


	grid	pso	ga	meanshift	optic	dbscan	gclust	single	complete	average	som	fcm	kmediods	kmeans
k=5	8.642	11.31	11.39	14.49	23.91	32.11	12.8	14.2	10.49	13.56	15.15	10.61	13.61	11.31
k=9	8.71	9.34	8.85	7.5	13.02	20.89	14.35	10.14	8.17	7.94	8.71	8.06	8.71	8.71
k=25	5.52	5.99	5.91	6.78	7.37	14.65	5.42	8.57	6.11	5.52	5.45	5.65	5.76	5.54

Axis Title

k=5 k=9 k=25

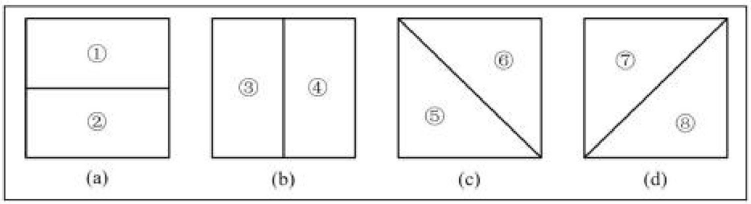
Estimating the ability of clustering methods to select control points



	grid	pso	ga	meanshift	optic	dbscan	gclust	single	complete	average	som	fcm	kmediods	kmeans
k=5	60.92	78.56	65.88	75.96	60.43	69.73	58.8	102.38	72.4	35.09	44.01	49.57	72.08	78.56
k=9	10.52	15.7	14.18	12.83	19.04	32.29	13.37	48.25	21.92	8.71	10.52	9.92	10.52	10.52
k=25	5.58	6.5	7.94	7.96	10.08	32.59	6.84	16.62	5.69	5.99	5.54	4.7	7.99	6.67

Investigating the distribution of produced ground control points (cluster centers)

- variance-to-mean ratio



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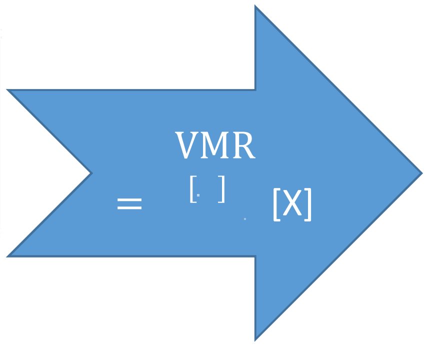
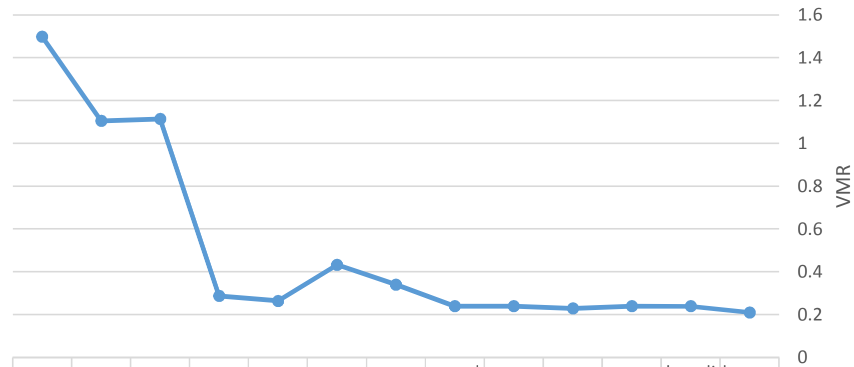
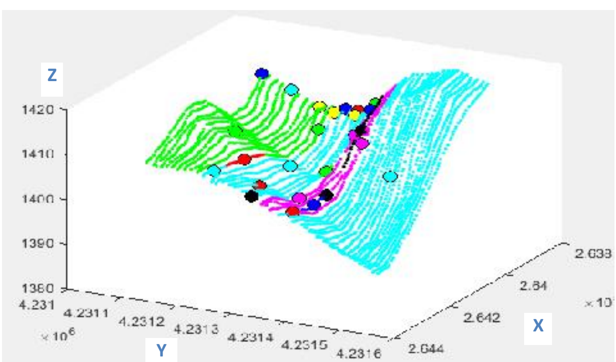


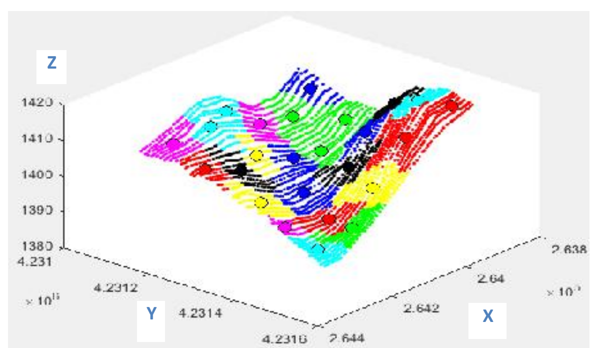


	single	optic	dbscan	pso	ga	meanshift	gclust	complete	average	som	fcm	kmedoids	kmeans
Series1	1.498	1.105	1.114	0.2874	0.264	0.433	0.34	0.239	0.239	0.229	0.239	0.239	0.21

clustering method



Single link VMR>1



Average link VMR<1

Study of the stability of cluster centers and its impact on the accuracy of the region model

Method clustering	Rmse.1 (cm) K=9	Rmse.2 (cm) K=9	Rmse.3 (cm) K=9	Rmse.4 (cm) K=9	Stability
K-means	8.71867	9.34419	8.71867	8.71867	0.62552
K-mediods	8.71867	8.59	9.1	9.34	0.62133
FCM	8.06367	8.71867	8.71867	8.71867	0.655
GA	8.85227	8.8668	8.192	10.1896	1.9976
PSO	9.34419	9.34419	9.34419	8.16549	1.1787
SOM	8.71867	8.71867	8.71867	8.71867	0
Average link	7.94921	7.94921	7.94921	7.94921	0
Complete link	8.17113	8.17113	8.17113	8.17113	0
Single link	10.1405	10.1405	10.1405	10.1405	0
Gclust	14.3556	14.3556	14.3556	14.3556	0
DBSCAN	20.8903	20.8903	20.8903	20.8903	0
OPTIC	13.0227	13.0227	13.0227	13.0227	0
Mean shift	7.50406	7.50406	7.50406	7.50406	0

The stability of clustering methods with coverage of 90% images

Method clustering	Rmse.1 (cm) K=9	Rmse.2 (cm) K=9	Rmse.3 (cm) K=9	Rmse.4 (cm) K=9	Stability
K-means	10.52	10.52	10.52	15.7	5.18
K-mediods	10.52	13.30	8.77	15.7	6.93
FCM	9.92	10.52	10.52	10.52	0.6
GA	14.18	13.20	16.40	22.84	9.64
PSO	15.7	15.7	15.7	11.44	4.26
SOM	10.52	10.52	10.52	10.52	0
Average link	8.71	8.71	8.71	8.71	0
Complete link	21.92	21.92	21.92	21.92	0
Single link	48.25	48.25	48.25	48.25	0
Gclust	13.37	13.37	13.37	13.37	0
DBSCAN	32.29	32.29	32.29	32.29	0
OPTIC	19.04	19.04	19.04	19.04	0
Mean shift	12.83	12.83	12.83	12.83	0

The stability of clustering methods with coverage of 60% images

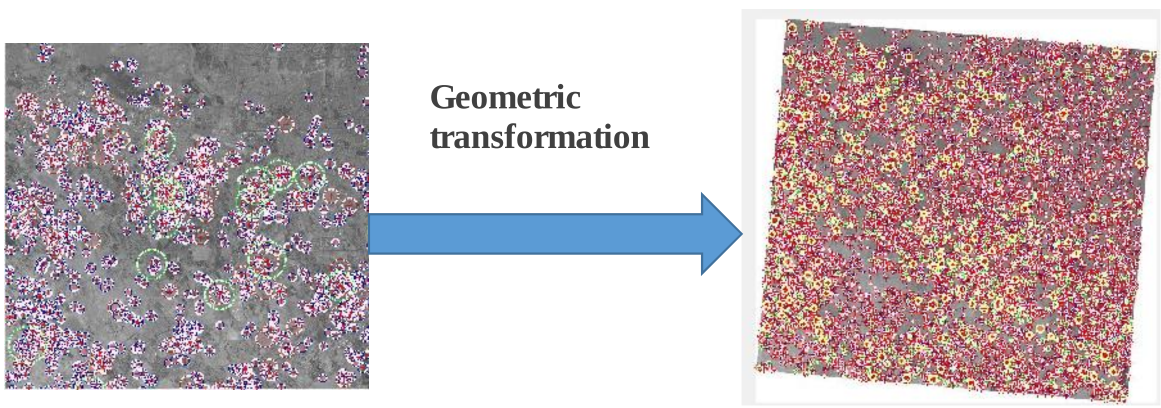
Accuracy & Distribution & Stability

clustering method	Accuracy	Distribution	stability
K-means	78.56	0.21	5.18
K-mediods	72.08	0.239	6.93
FCM	49.57	0.239	0.6
GA	65.88	0.264	9.64
PSO	78.56	0.287	4.26
SOM	44.01	0.229	0
Average link	35.09	0.239	0
Complete link	72.4	0.239	0
Single link	102.38	1.498	0
Gclust	58.8	0.34	0
DBSCAN	69.73	1.114	0
OPTIC	60.43	1.105	0
Mean shift	75.96	0.433	0

Thank You

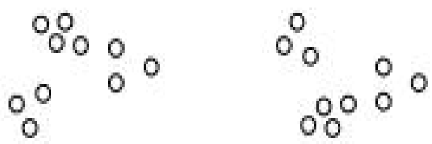
Performance evaluation criteria and implementation details

- The capability of the proposed method is evaluated by number of correct Matches.
- To evaluate the proposed method, 4 synthetic images are generated from the source image .
- The geometric relationship between each synthetic image and the source image is completely known and therefore the true positional accuracy of the matched keypoints can be easily computed.
- To distinguish correctly matched keypoints from falsely matched keypoints, a spatial threshold equal to 1.5 pixels is used.

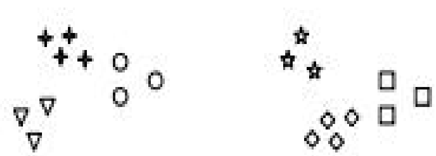


Clustering Method

- Clustering is a method for grouping unlabeled data. This grouping is based on the data attributes or relationships, so that the samples within each cluster have maximum similarity with each other and maximum difference with the samples of other groups.
- input to a clustering technique is a set of initial points that are grouped according to different mechanisms. The number of clusters can be defined either automatically or manually.



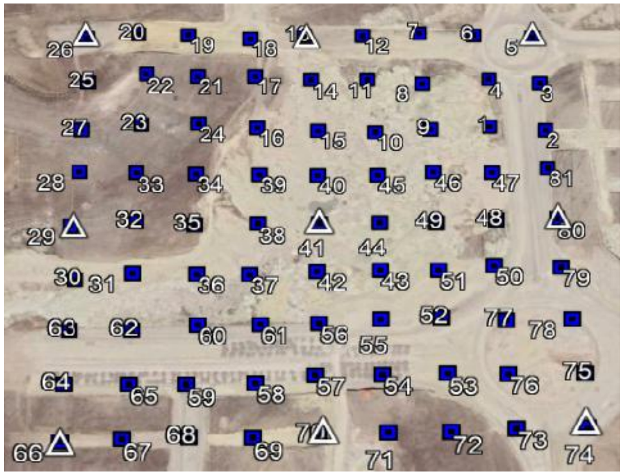
Initial points.



Six clusters

Obtaining UAV images and forming network control points

- a 400-by-400m area was considered somewhere close the city of Ardebil in the northwest of Iran.
- It was imaged using a Phantom 4 Pro drone.
- The flight height was 80 meters and the overlap between the images was 90 percent.
- The focal length of the camera is 8.8mm and the sensor is 1 inch.
- resolution of the images is 20 megapixels.
- In this area, 81 ground control points with a 50-meter interval were measured using GPS.
- 72 points were considered as the control point network and 9 points as check points

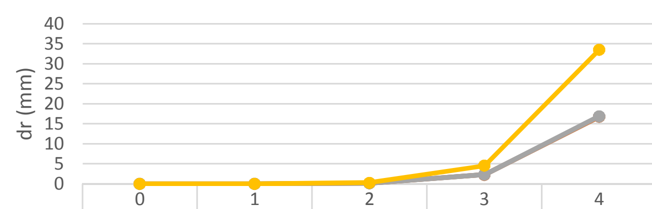


Position of ground control points (blue spots),

check points (triangles)

Examining internal network criteria by selecting ground control points by clustering method

Clustering Method	Point number	C(mm)	X_P(mm)	Y_P(mm)	K_1	K_2	K_3	P_1	P_2	Error Reprojection (pix)	Error Location (m) Camera
SOM	4	8.850	0.0680	0.0728	1.5e-4	5e-4	13e-4	1.5e-4	1.6e-5	0.306	18.751
	9	8.820	0.0695	0.0652	6.4e-5	31e-4	6.8e-4	7.9e-6	5.5e-6	0.306	19.143
	25	8.832	0.0038	0.0602	1.2e-5	5.1e-5	9.5e-5	2.6e-6	2.4e-6	0.308	18.211
FCM	5	8.834	0.0619	0.0472	1.1e-4	4.7e-4	1.2e-3	1.1e-4	9.9e-6	0.306	18.824
	9	8.817	0.0626	0.0641	6.8e-5	3.3e-4	7.5e-4	7.5e-5	6e-6	0.306	19.153
	25	8.844	-0.0052	0.05687	1.2e-5	5.1e-5	9.5e-5	2.6e-6	2.4e-6	0.307	17.867
Average link	5	8.834	0.0619	0.0472	1.1e-4	4.7e-4	1.2e-3	1.1e-4	9.9e-6	0.306	18.824
	9	8.791	0.0627	0.0686	8e-5	3.8e-4	9.2e-4	7.5e-5	6.2e-6	0.306	19.3065
	25	8.836	0.0013	0.0644	1.2e-5	5.1e-5	9.5e-5	2.6e-6	2.4e-6	0.308	18.4364
Grid	5	9.107	0.0969	0.1059	1.6e-4	7.8e-4	2.2e-3	3.5e-5	7.3e-6	0.306	17.256
	9	8.820	0.0695	0.06528	6.4e-5	3.1e-4	6.8e-4	7.9e-5	5.5e-6	0.306	19.143
	22	8.87	0.058	0.06	1.9e-5	9.7e-5	2e-4	2.4e-5	1.5e-6	0.306	18.489



	0	1	2	3	4
fcm	0	1.50E-03	1.42E-01	2.29E+00	1.68E+01
average	0	1.50E-03	1.42E-01	2.29E+00	1.68E+01
som	0	1.60E-03	1.45E-01	2.31E+00	1.69E+01
Grid	0	2.80E-03	2.79E-01	4.55E+00	3.35E+01

r(mm)

Radial error in clustering methods and grid method