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Infotech Enterprises Ltd

High Resolution DEM'S from Satellite Imagery – An Industry Perspective

January 31, 2013

We deliver Global Engineering Solutions. Efficiently.

Introduction

- Digital Elevation Model – A brief outline
- Producing DEM from remotely sensed imagery is important for a variety of mapping applications which include: Ortho photo generation, terrain modeling, volumetric analysis, mine modeling, city modeling and creation of perspective views, etc.
- Latest sensors from DigitalGlobe WorldView1 (WV1) and WorldView2 (WV2) stereo imagery is found to be an excellent source for generating high resolution DEMs which would support the needs of various industries such as Mining, Oil & Gas and Natural Resources industries

Introduction (Cont.)

- This paper sheds light on:
  - ✓ The methods and data sources, used for generating DEM, and calculation of land surface parameters that have changed over a period of time
  - ✓ Highlights examples of high resolution DEMs that were generated under typical topographic locations using SocetSet's Next Generation Automatic Terrain Extraction (NGATE) software module
  - ✓ The factor of speed constitutes an important element while generating the DEM

Digital Elevation Model (DEM)

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What ?

A Digital Elevation Model (DEM) is a representation of the terrain elevation values (Bare Earth) over a specified area, by a regular array of z-values, referenced to a specific horizontal projection system and vertical datum

Why ?

- Flood mapping
- Land use studies
- Geological applications
- Ortho rectification
- City modeling, 3D perspectives generation
- Line of sight analysis
- Surface analysis

Digital Terrain Model (DTM)

- Topographic features that represent terrain surface can generally be divided into two categories.
  - ✓ Mass points / Elevation Points – collected at a defined grid or random
  - ✓ Breaklines - linear features collected to represent the abrupt change in elevation

Together, mass points and breaklines are considered as a digital terrain model (DTM).

Digital Terrain Model (DTM)

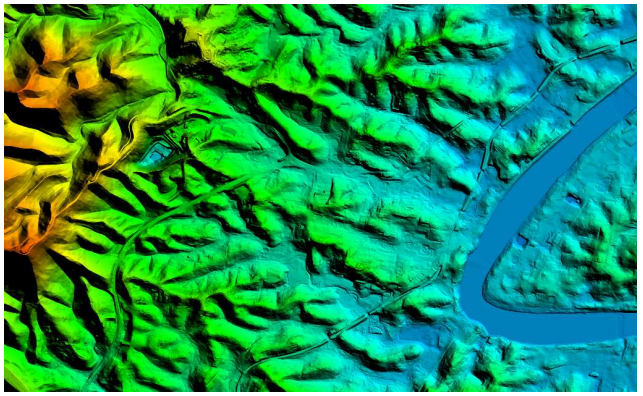
- Mass points collected at an evenly spaced grid (e.g. 2 m). This type of elevation model is considered a Digital Elevation Model (DEM)

- DTM is often imported into software to generate an interpolated data Triangulated Irregular Network (TIN) model. A TIN may be also referred as a surface model

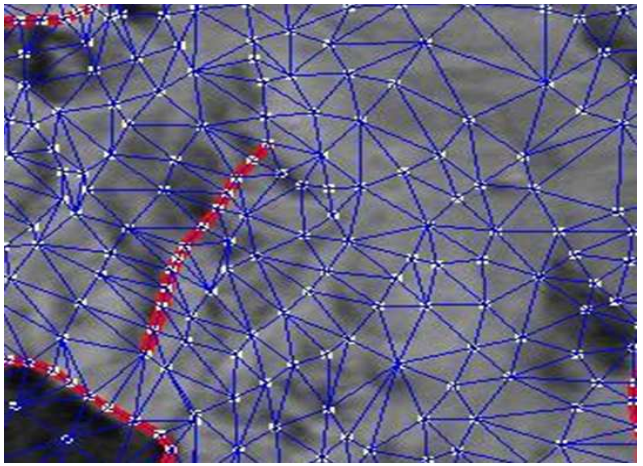
- A TIN model can be processed through software to generate contour lines (lines of equal elevation). TIN models can also be used to layout and produce cross-section data across an area of interest (i.e., stream crossings for hydraulic analysis)

DEM Types

- **Grid :** Raster DEM represent a surface as a regular grid consisting of a rectangular array of uniformly spaced cells with z-values

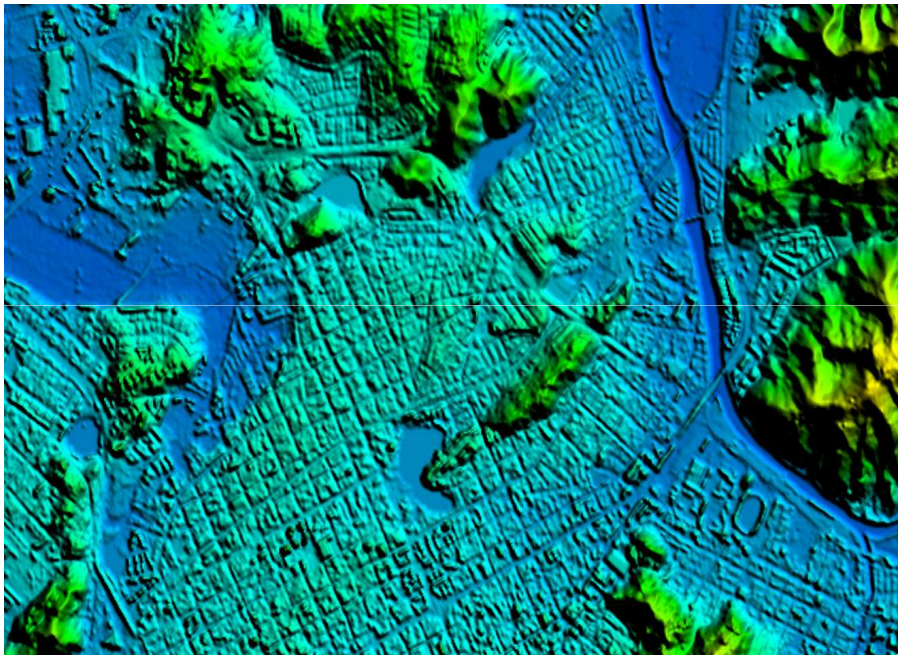


- **TIN:** Triangulated Irregular Network represent a surface as a set of irregularly located points linked to form a network of triangles with z-values stored at the nodes



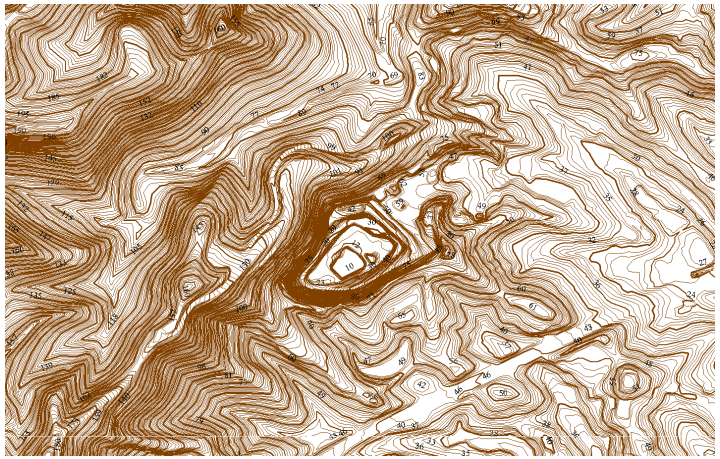
Digital Surface Model (DSM)

- DSM: A digital surface model (DSM) is the representation of terrain elevation features, by a regular array of z-values, including buildings, vegetation, and roads, as well as natural terrain features

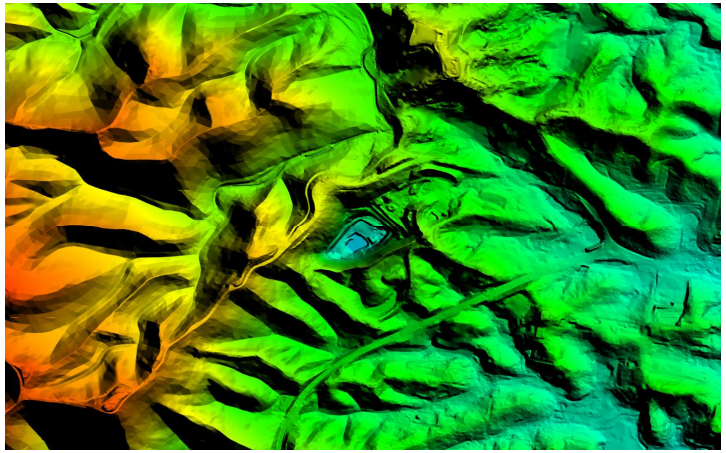


DEM Representation

- Contour: Contours are lines that represent equal height.



- Sources of DEM:
  - ✓ Topographic maps
  - ✓ Surveying
  - ✓ Aerial photogrammetry
  - ✓ Satellite photogrammetry
  - ✓ Radar data
  - ✓ LIDAR



Remote Sensing Imagery and Stereo Capabilities

- Stereo View Capable
  - ✓ DigitalGlobe - Worldview-1, Worldview-2,
  - ✓ GeoEye - GeoEye-1, IKONOS
  - ✓ Astrium - SPOT-5
  - ✓ ISRO - CARTOSAT1

Satellite	Sensor	Resolution(m)	Capability	Bands	Swath
Worldview-2	PAN	0.5	Stereo	PAN	16.4 km
	MSS	2	8 band	CB,B,G,Y,R,RE,NIR1,NIR 2	
Worldview-1	PAN	0.5	Stereo	PAN	17.6 km
Geoeye-1	PAN	0.4	Stereo	PAN	15.2 km
	MSS	1.6	4band	B,G,R,NIR	
IKONOS	PAN	1	Steteo	PAN	11 km
	MSS	4	4band	B,G,R,NIR	
CARTOSAT-1	PAN	2.5	Stereo	PAN	
SPOT-5	PAN	2.5	Stereo	PAN	
	MSS	10	4 band	G,R,NIR,SWIR	60 km

Basic Accuracy of Satellite Imagery

Worldview-2 Accuracy

Image Accuracy Specification (Basic and Ortho Ready Stereo)		
Horizontal	5.0 m CE90 at <30º off nadir	Typical performance in the range of 3.0 - 4.0 m CE90 at nadir
Vertical	5.0 m LE90 at <30º off nadir	Typical performance in the range of 3.0 - 4.0 m LE90 at nadir
A - Accuracy specifications exclude terrain induced displacement and is applied to products with an off nadir of less than 30 degrees		

Products and Accuracy - High Accuracy Digital Elevation Data

- Highly accurate Digital Surface Models and Digital Terrain Models can be produced from various stereo satellite sensors such as Worldview- 1 and /or 2
- Highly accurate DEM and DSM serve as key building blocks for
  - ✓ Exploration
  - ✓ Engineering,
  - ✓ Land Management
  - ✓ Simulation
- Numerous product configuration options for accuracy, resolution, type, and format are possible from which users can select the product specifications that best fit their project's elevation demand

Specifications			
Product Accuracy	Mapping	Precision	Very High Precision
Resolution	8 m	4 m	2 m
Relative Vertical (LE90)	5 m	2 m	1 m
Absolute Vertical (LE90)	8 m	4 m	2 m
Relative Horizontal (CE90)	8 m	4 m	2 m
Absolute Horizontal (CE90)	10 m	5 m	3 m

DEM - Products

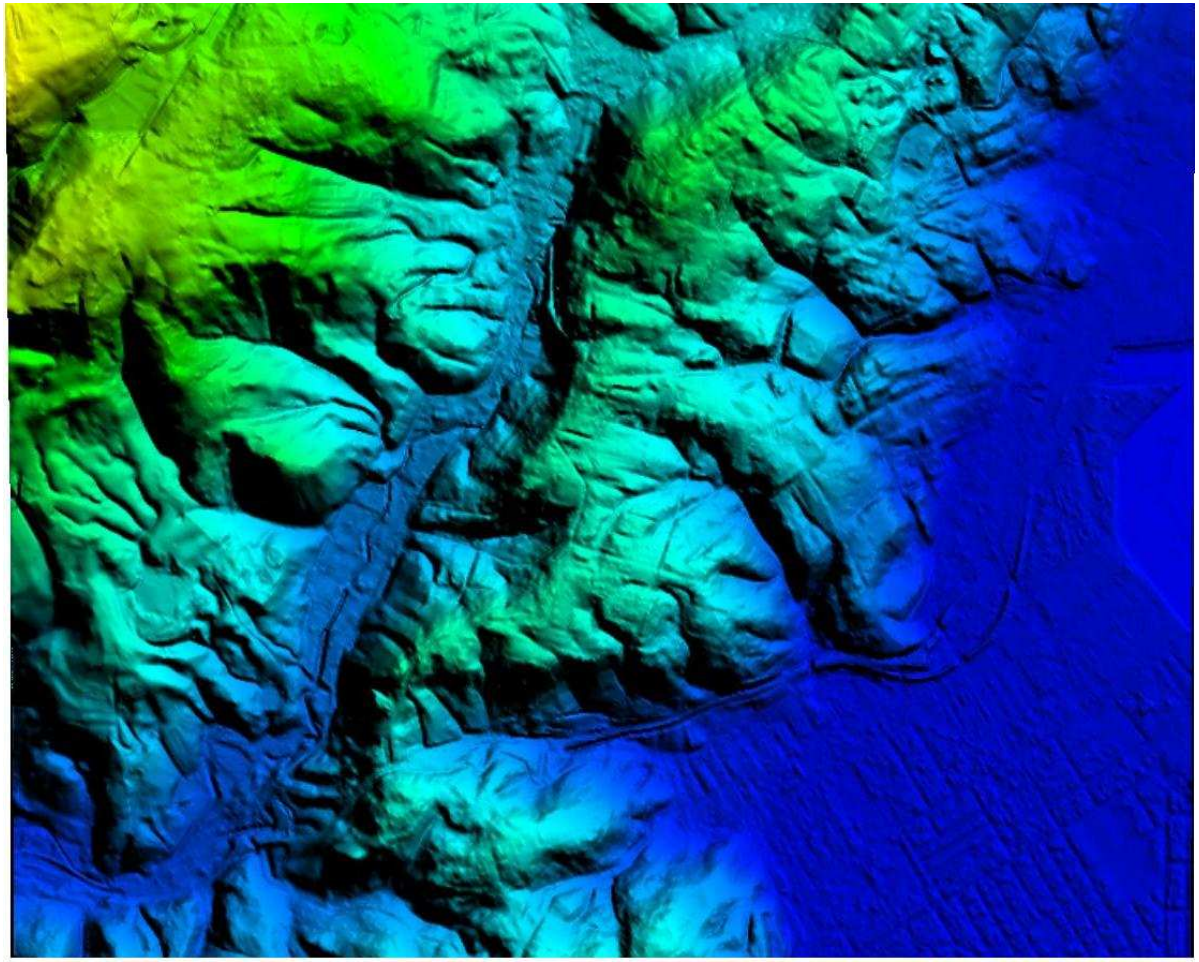
- **Mapping Level Elevation Products:** Native accuracies of Worldview-1 & Worldview-2 satellites supports the accuracy for the product

- **Precision Level Elevation Products:** Native accuracies supported by Worldview-1 and Worldvie-2 are enhanced with Ground Control Points (GCP's) to achieve the desired product level accuracy. These products have 4m post spacing

- **Very High Precision Level Elevation Products:** Native accuracies supported by Worldview-1 and Worldvie-2 satellites are enhanced with Ground Control Points (GCP's) to achieve the desired product level accuracy. These products have 2m post spacing

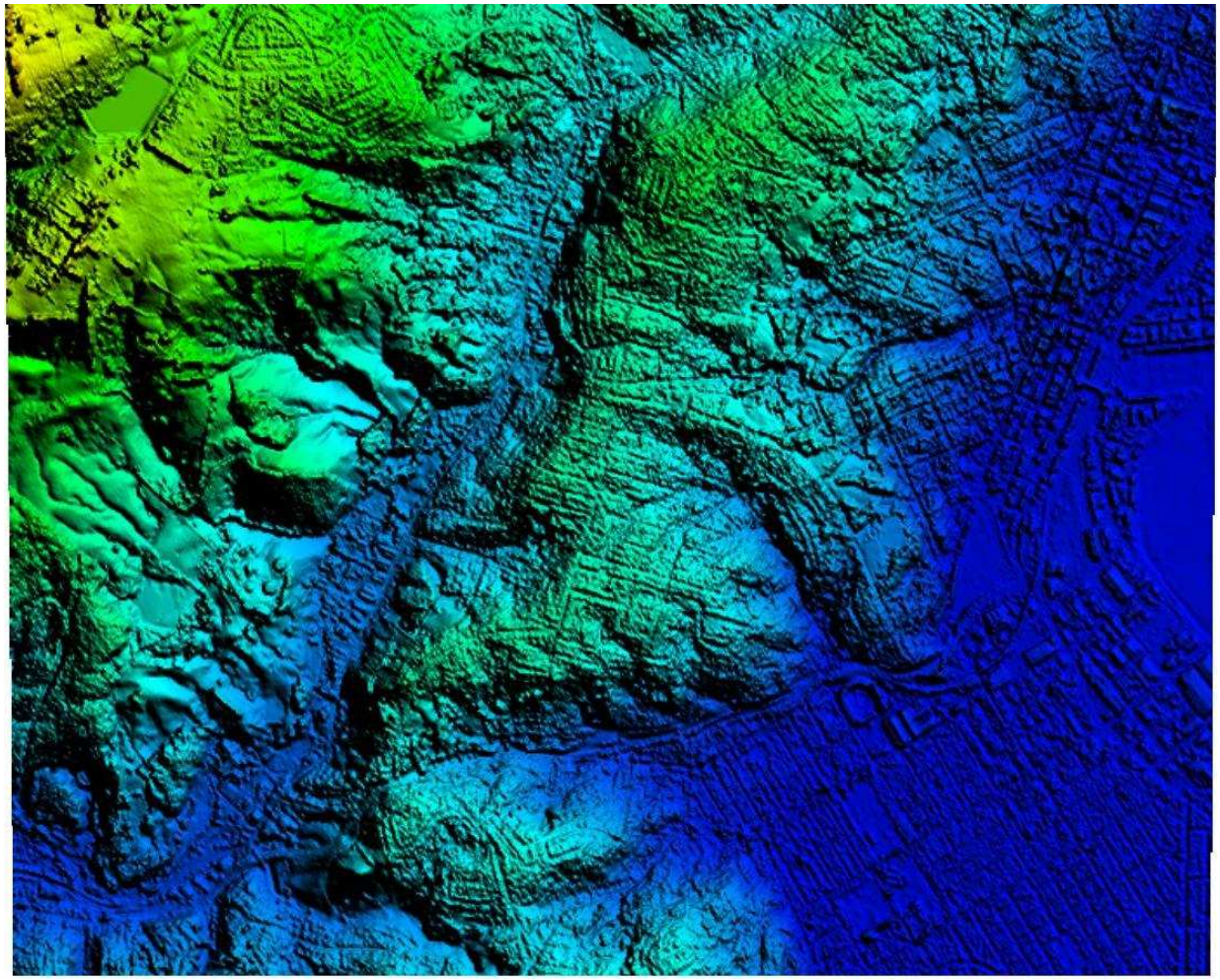
Mapping Level Elevation Product: 8 Meter DTM

- Remove spikes, wells and blunders
- Flatten Coastal areas
- Flatten Roads
- Use third party source such as SRTM for null / cloud areas to fill the voids



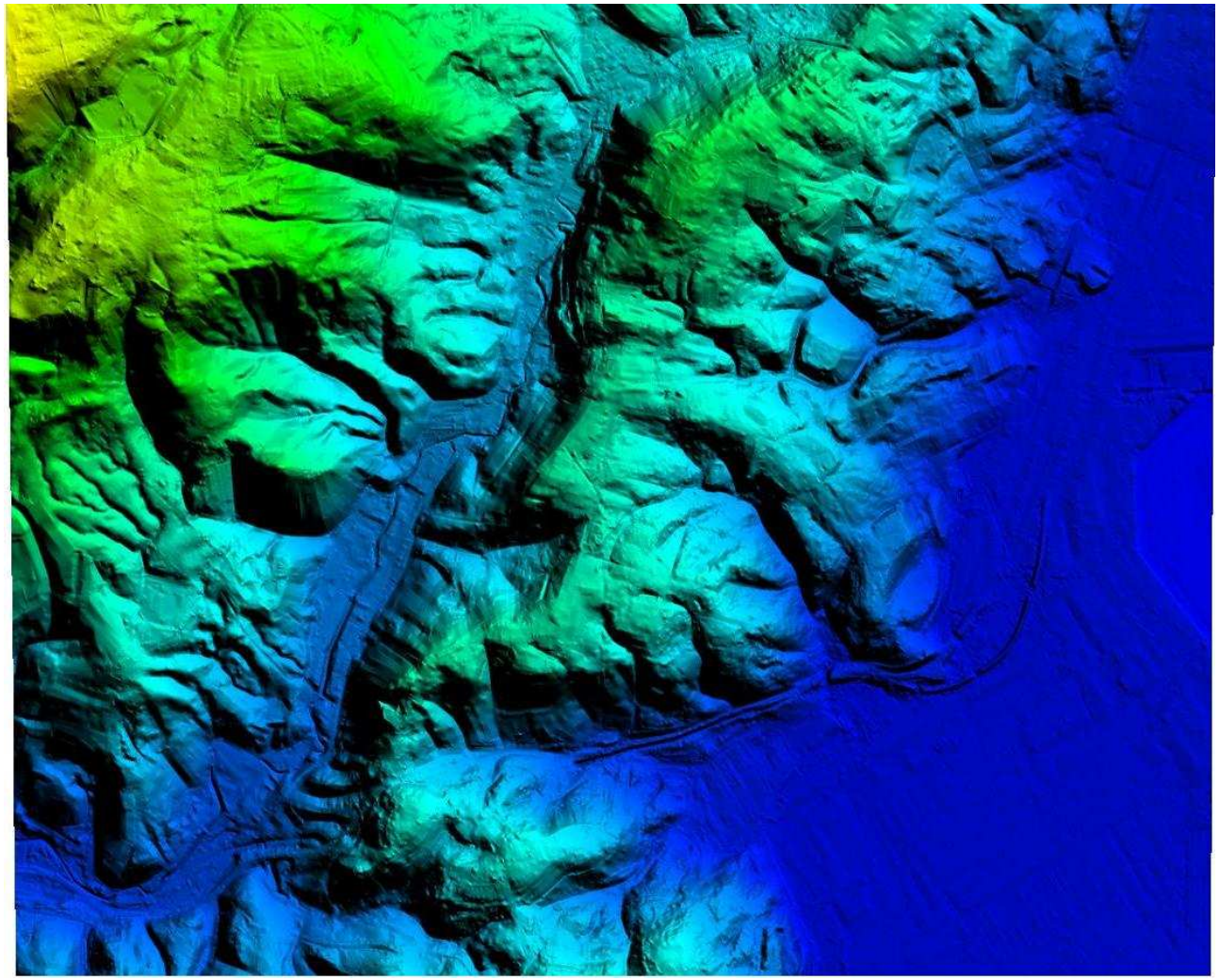
Mapping Level Elevation Product: 8 Meter DSM

- Remove spikes, wells and blunders
- Flatten Coastal areas
- Use third party source such as SRTM for null / cloud areas to fill the voids



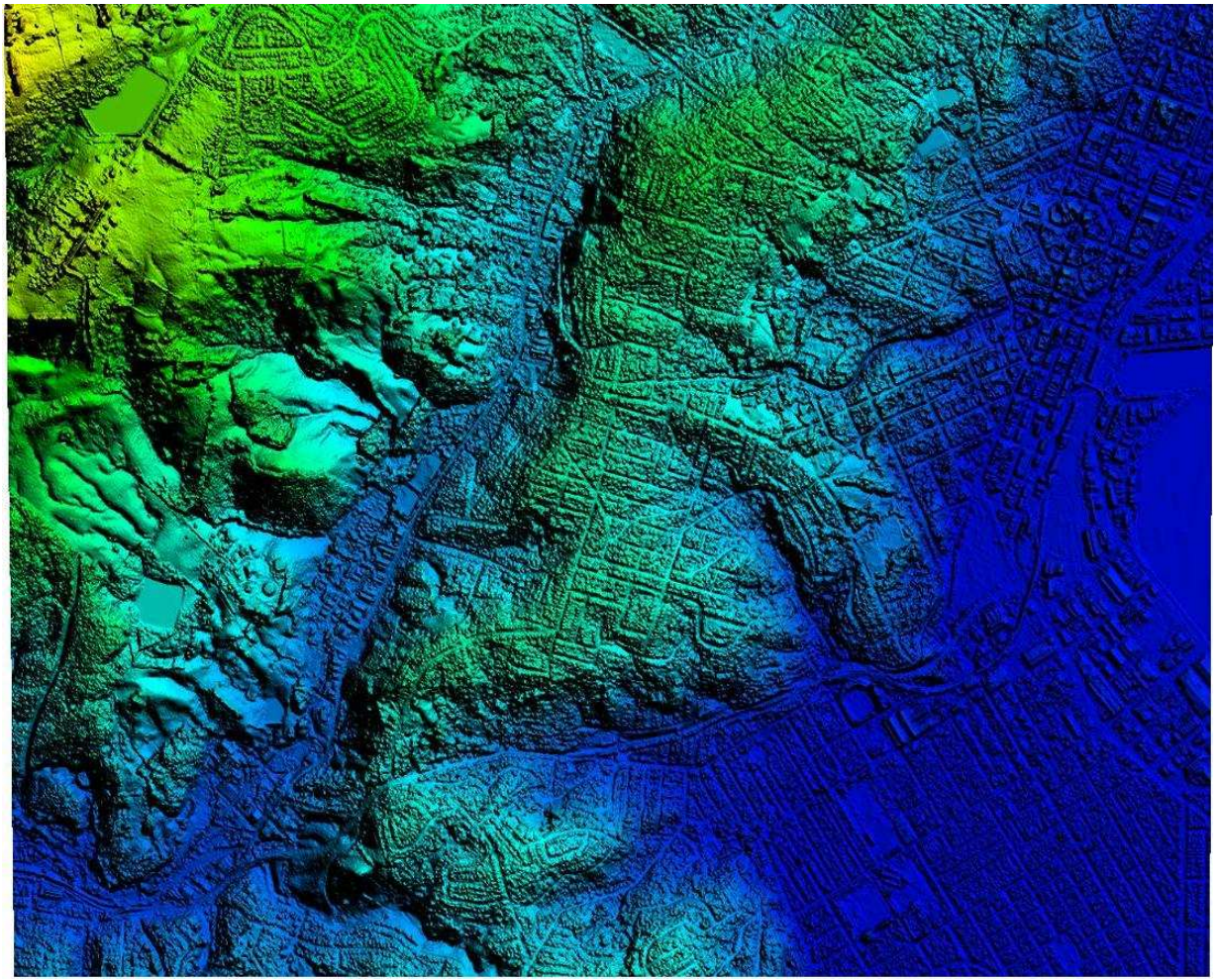
Precision Level Elevation Product: 4 Meter DTM

- Remove spikes, wells and blunders
- Flatten Coastal areas
- Hydro Enforcement
- Flatten Roads
- Use third party source such as SRTM for null / cloud areas to fill the voids



Precision Level Elevation Product: 4 Meter DSM

- Remove spikes, wells and blunders
- Flatten Coastal areas
- Hydro enforcement
- Use third party source such as SRTM for null / cloud areas to fill the voids



Very High Precision Level Elevation Product: 2 Meter DTM

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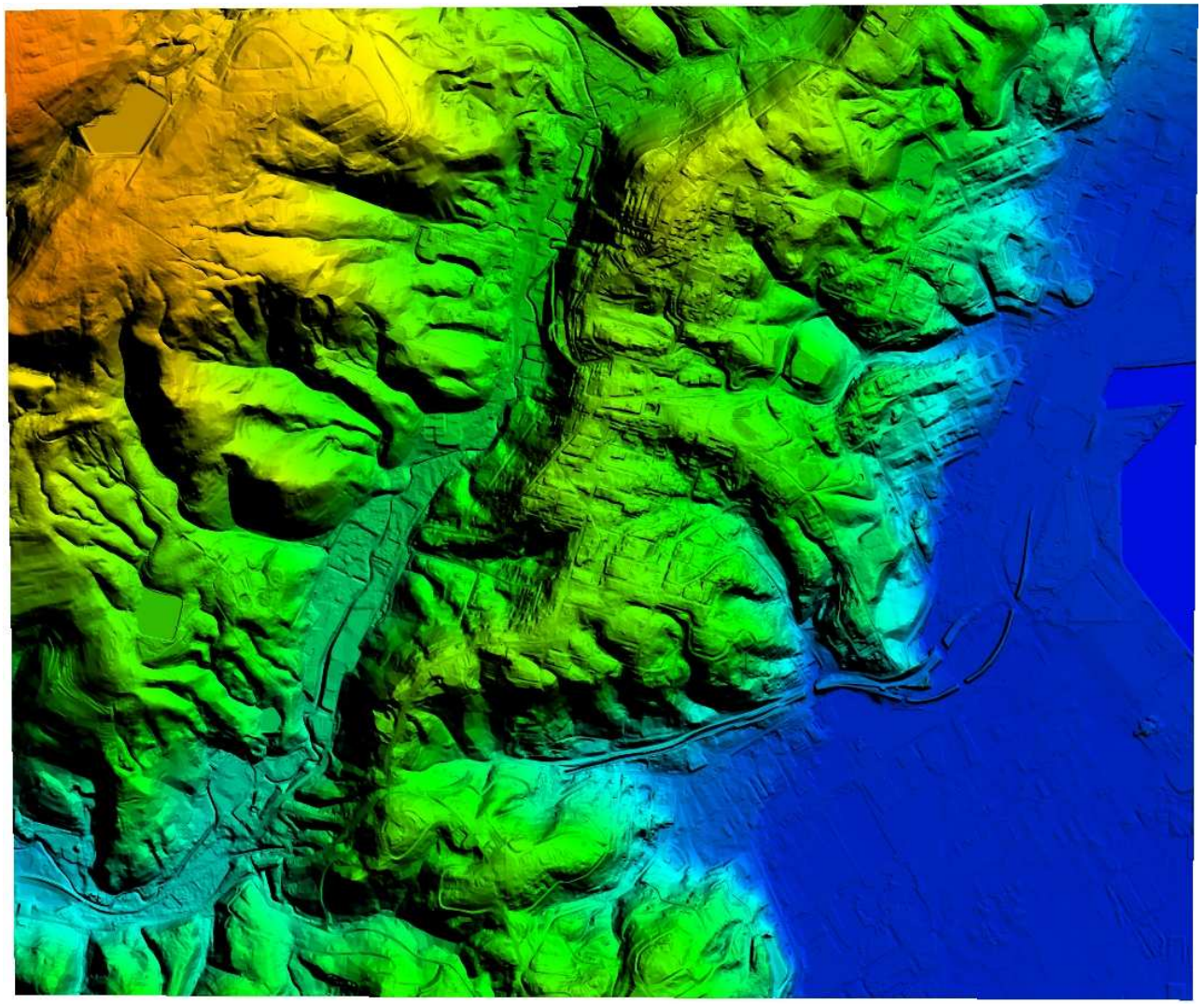
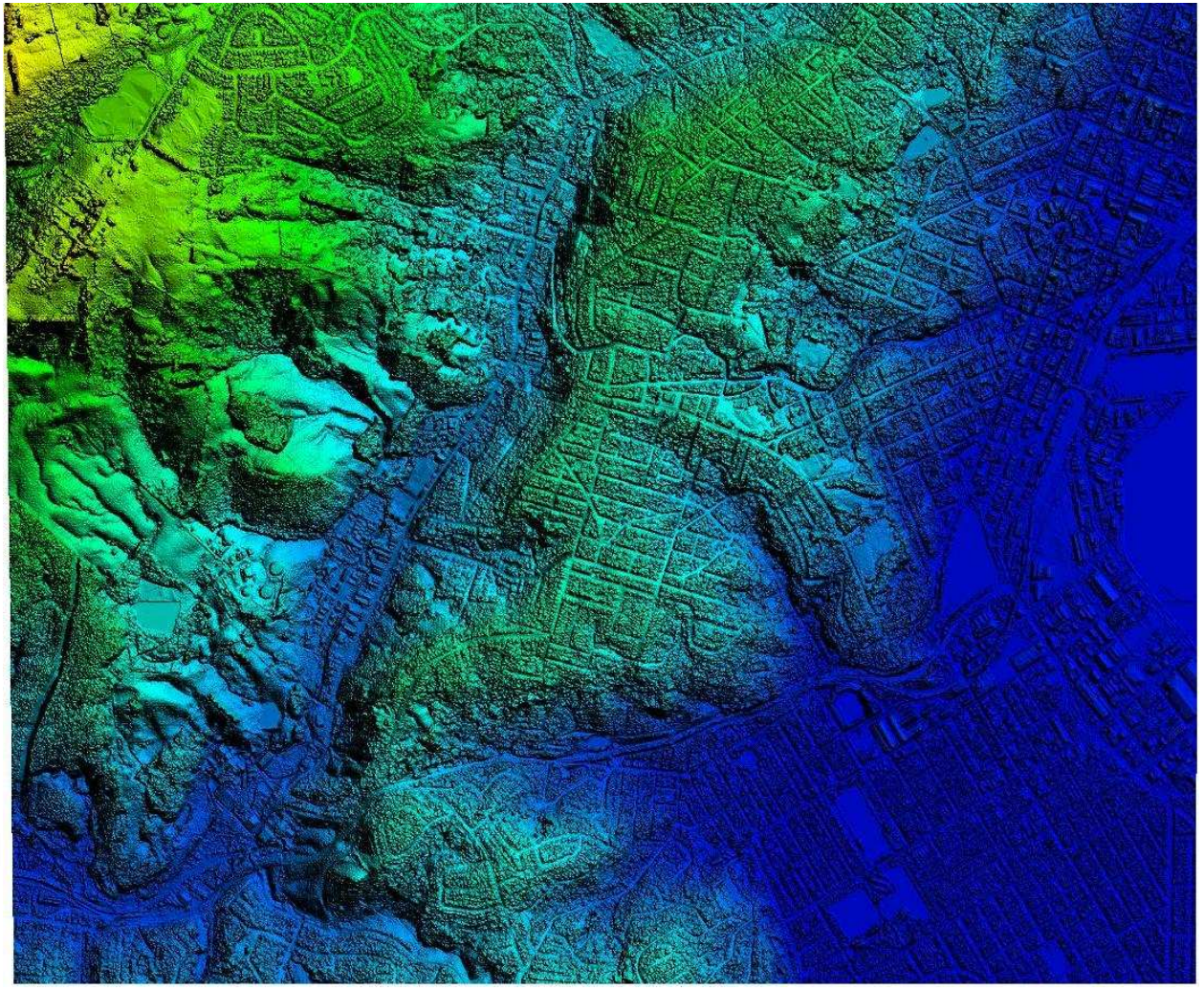
- Remove spikes, wells and blunders
- Flatten Coastal areas
- Hydro Enforcement
- Flatten Roads
- Use third party source such as SRTM for null / cloud areas to fill the voids

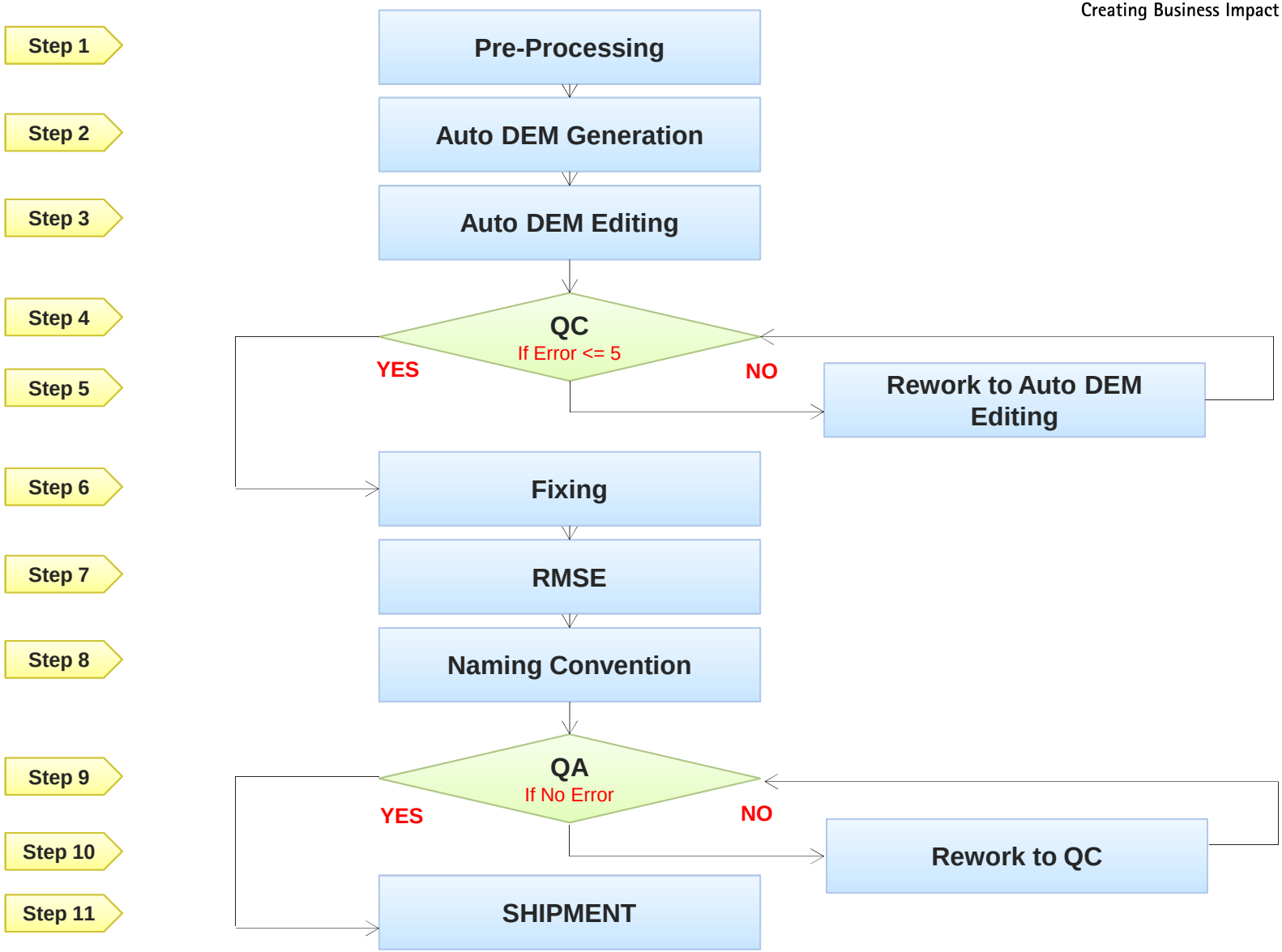


Very High Precision Level Elevation Product: 2 Meter DSM

- Remove spikes, wells and blunders
- Flatten Coastal areas
- Hydro Enforcement
- Flatten Roads
- Roof flattened
- Use third party source such as SRTM for null / cloud areas to fill the voids



DTM/DSM - Process flow chart



Next Generation Automatic Terrain Extraction (NGATE)

- NGATE: An automatic terrain generation module in SOCETSET software
- Advantages of NGATE over ATE: The DEM generated form NGATE is far more accurate than DEM from ATE process

Criterion	NGATE	ATE
Computation of image matching	Every pixel	Each post
Type of matching	Combines results optimally from area-matching and edge-matching	Uses only area-matching
Basis of accuracy and speed	RSET level at which to stop	Post spacing or number of posts
Back matching	On by default	User can turn on/off via GUI
Performance	Better with large-scale imagery in urban areas	
Editing time	Less, resulting from highly accurate DTMs	

Parameters & Strategies

- In DEM generation NGATE attempts to eliminate structures/trees above the ground from the smallest size to the largest size defined by two sets of parameters: the minimum height and maximum width

- There are several strategies available in SOCET SET or can be customized based on terrain type
  - ✓ Ngate_urban_strategy file can be used for general purpose.
  - ✓ ngate_urban_canyon.strategy - urban areas with tall buildings
  - ✓ ngate.strategy- rural and easy terrain
  - ✓ ngate_low_sp.strategy - For desert or images without much texture
  - ✓ Custom strategy

Interactive Editing

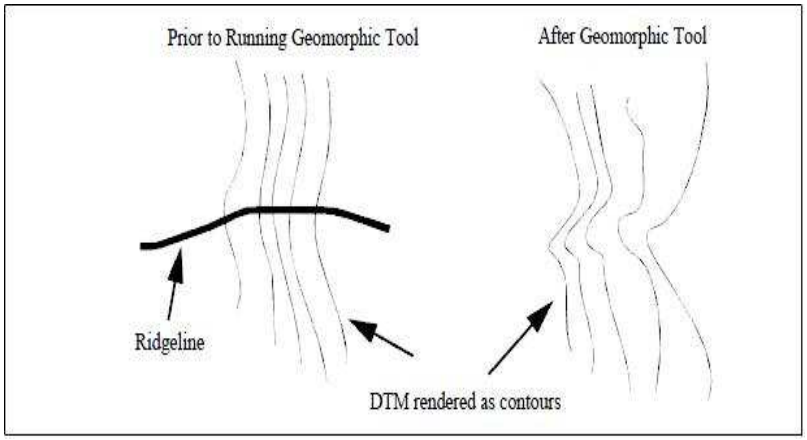
- Interactive Terrain Editing (ITE) module is best suitable for DEM/DSM manual editing process. There are many in built tools in ITE which increase the speed of DEM generation

- Often the dense vegetation, Hydro features, urban areas, cloud cover and shadows are challenging and time taking in DEM production. Effective usage of ITE tools drastically reduces the time of manual process

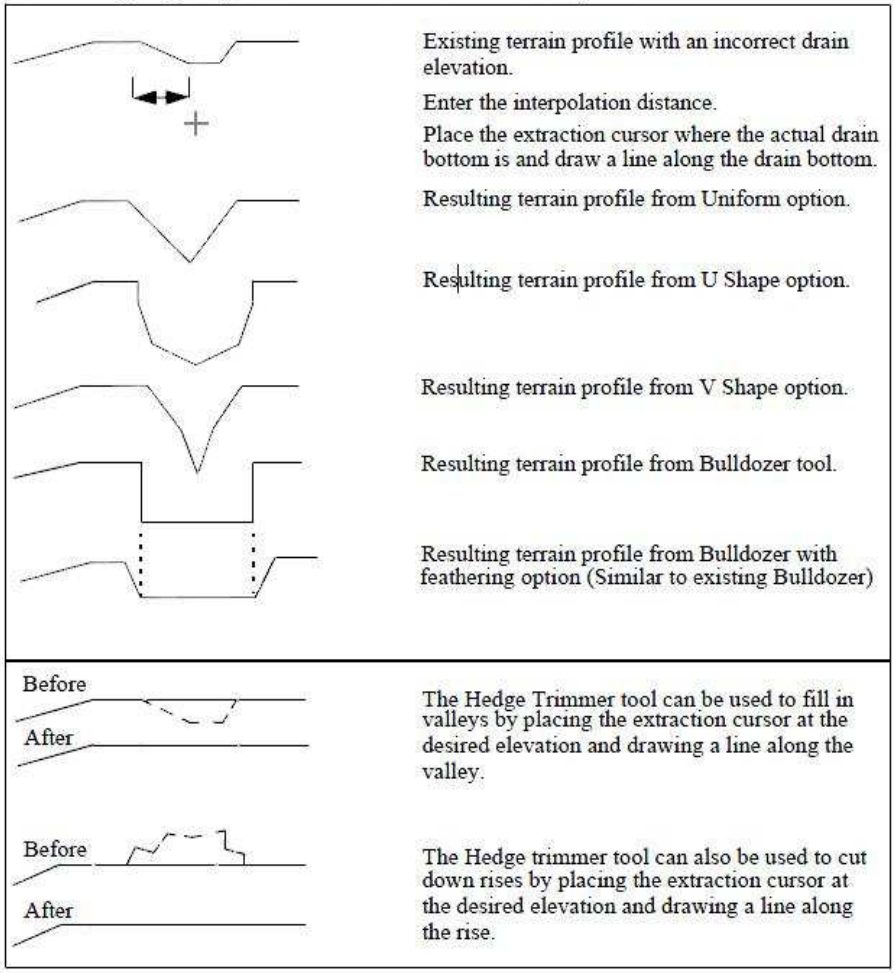
- Based on the development of elevation products in various terrains and related projects, IEL has developed several methodologies integrated with manual editing to automated algorithms and filters

Interactive Editing

Geomorphic editor window has number of tools viz. uniform slope, U Shaped slope, V shaped slope, bulldozer, bulldozer with feathering, and Hedge Trimmer etc.



The following diagram gives an elevation view of these tool options.



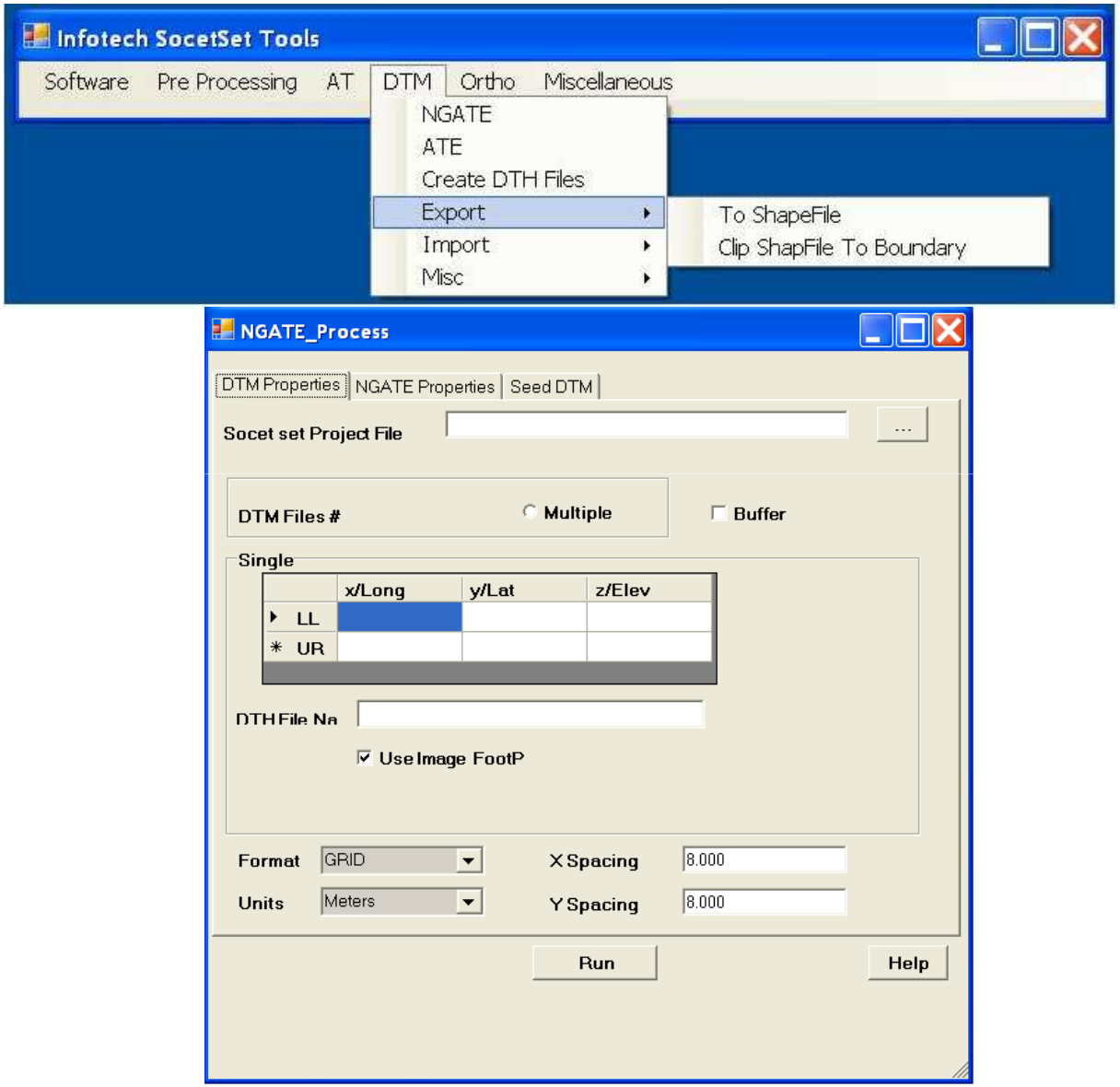
Terrain Editing – Customized Tools

- Productivity and Efficiency are the Key factors in production environment to produce DEM or DSM on large scale. There need to be ways to improve the productivity by optimizing the performance of processors

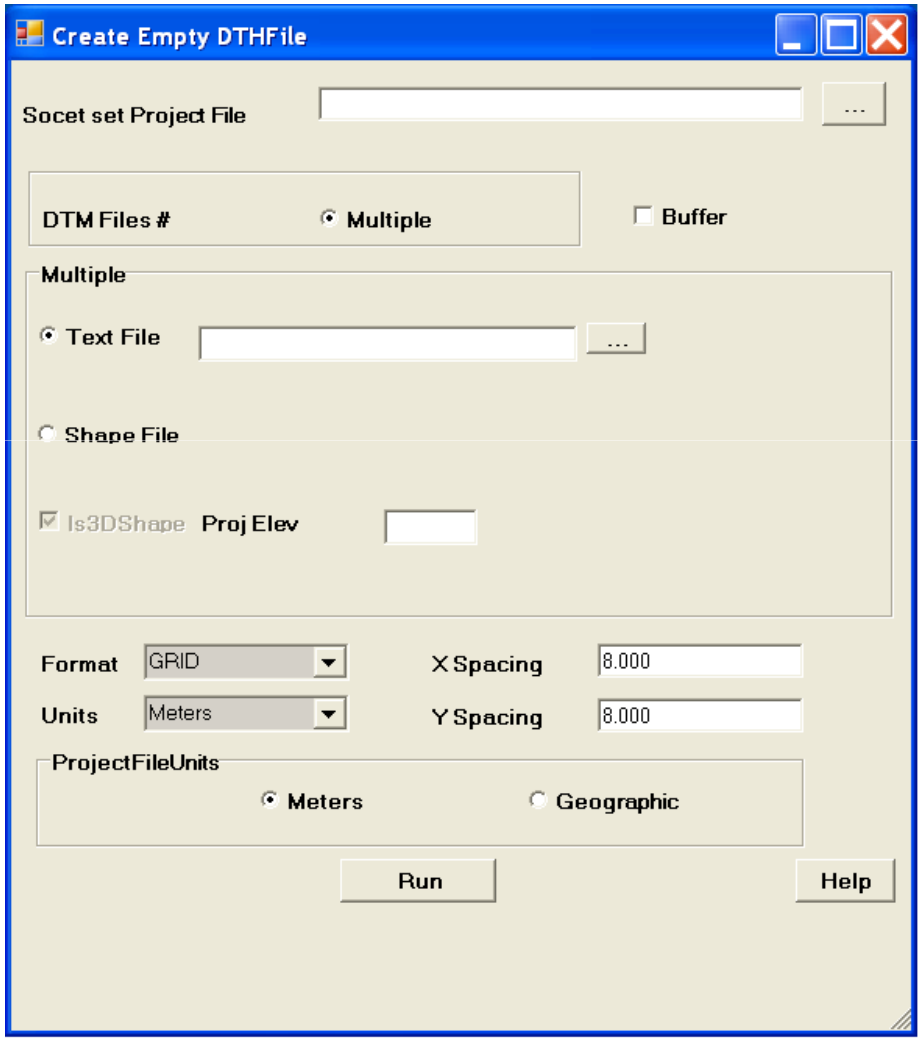
- Infotech has developed several tools to aid the increase in the productivity

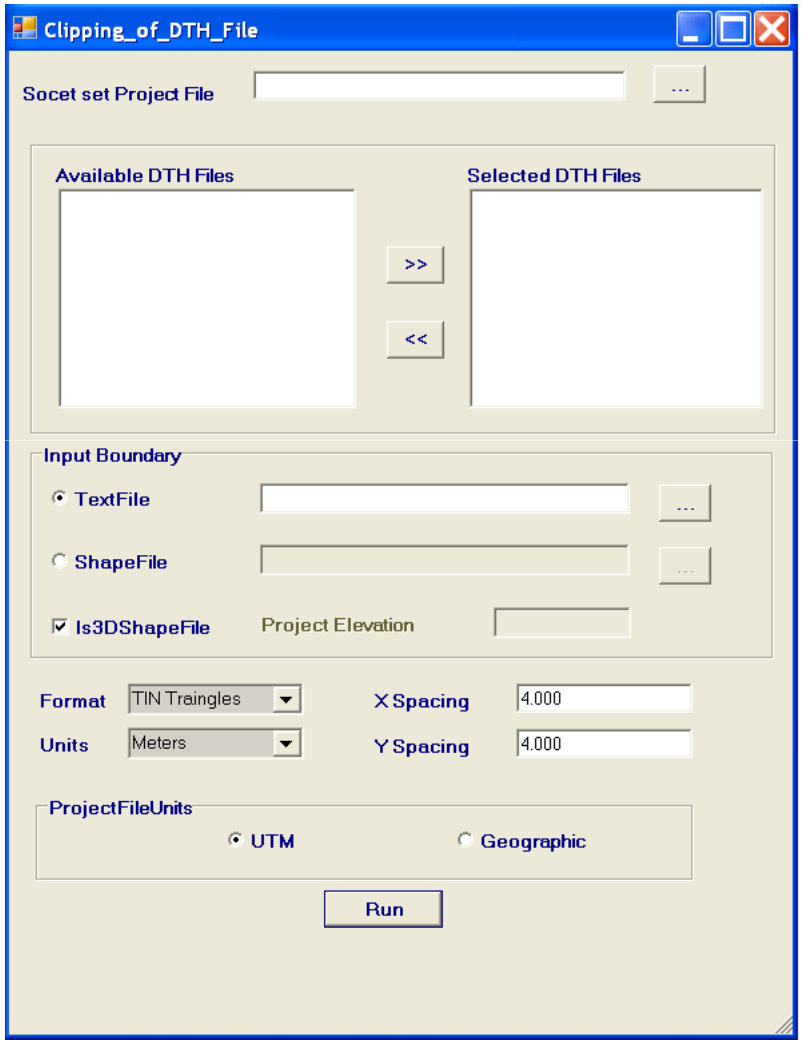
- The tools were organized in to different modules

DTM Module

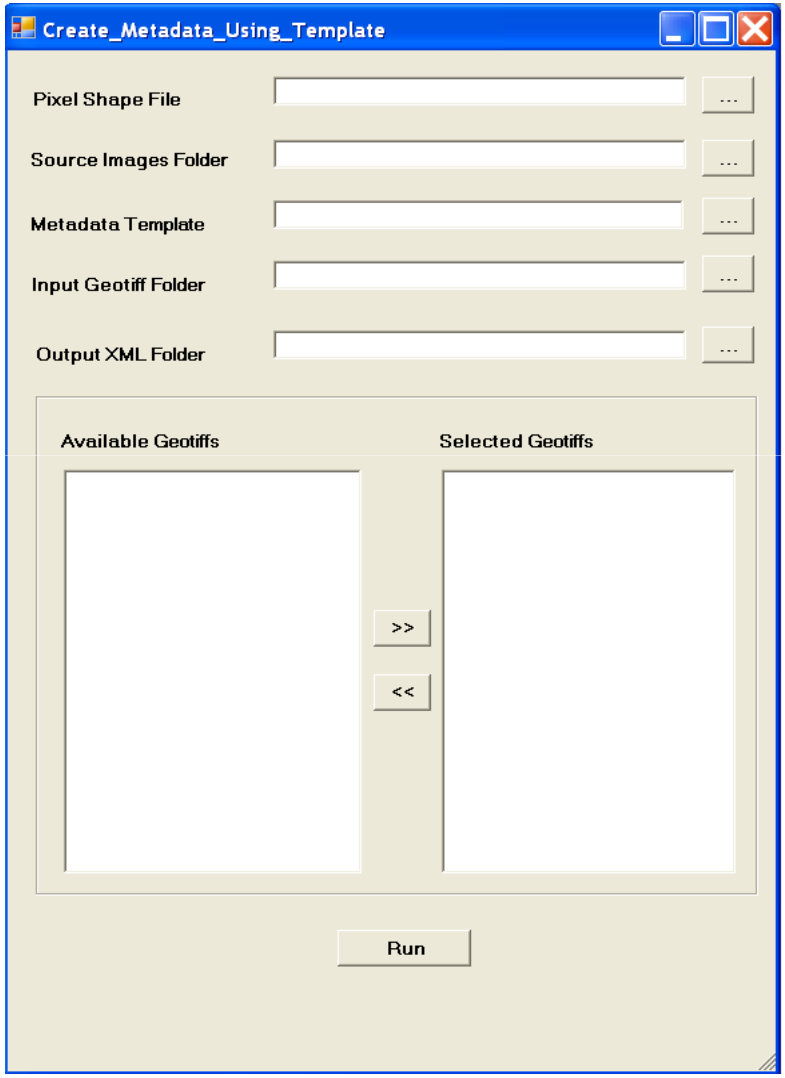


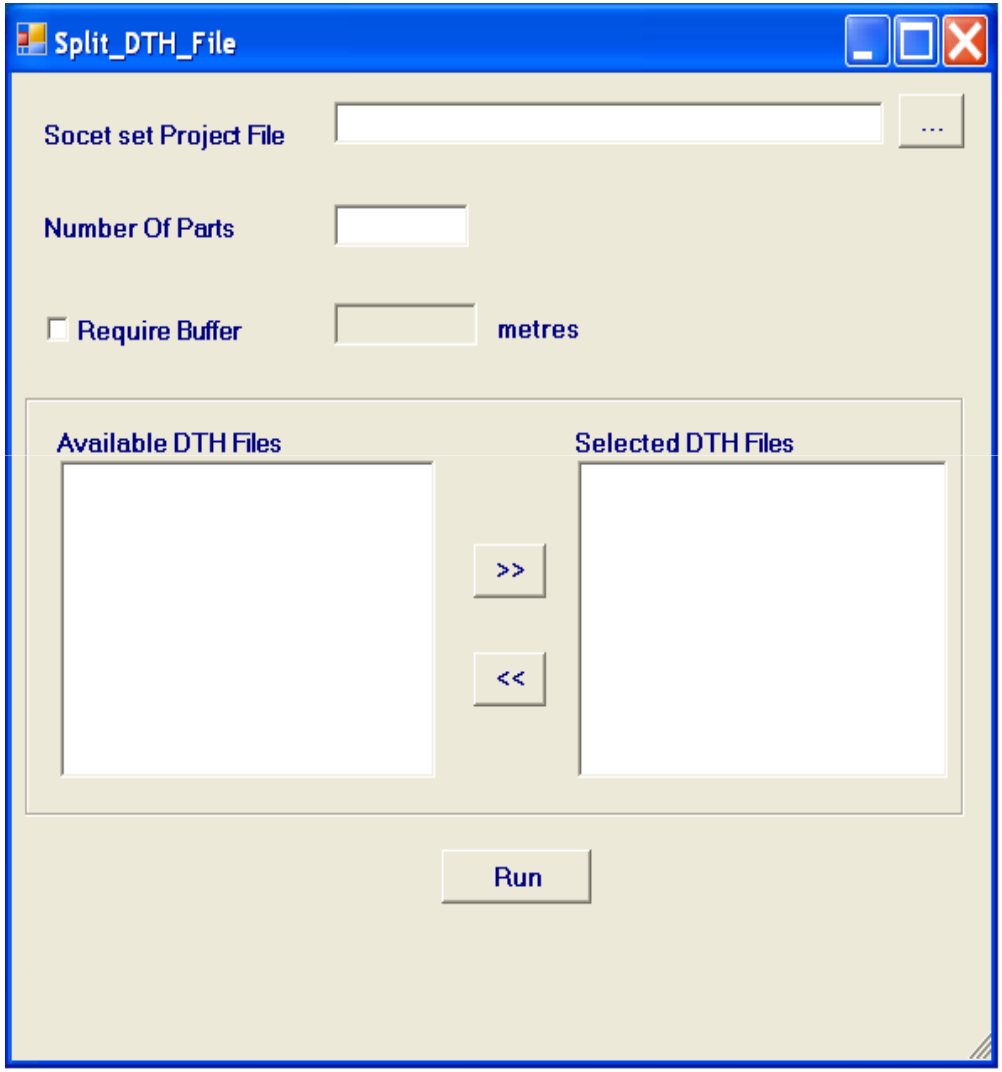
DTM Module





DTM Module





Results and Accuracy for 2Meter DEM

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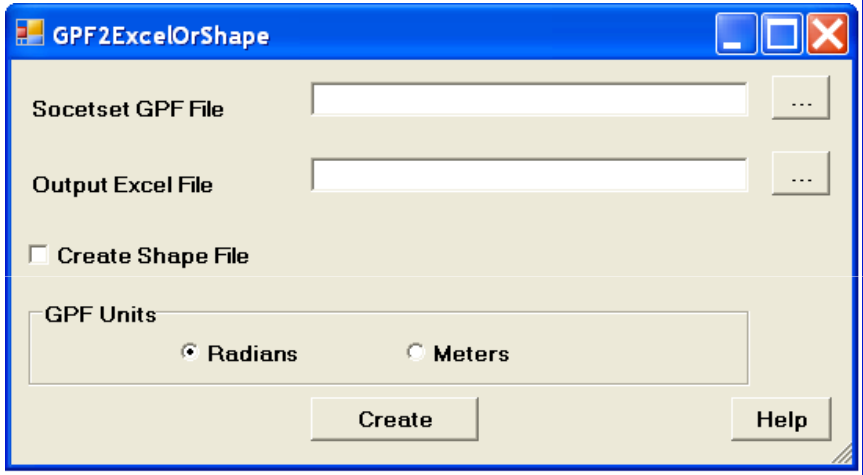
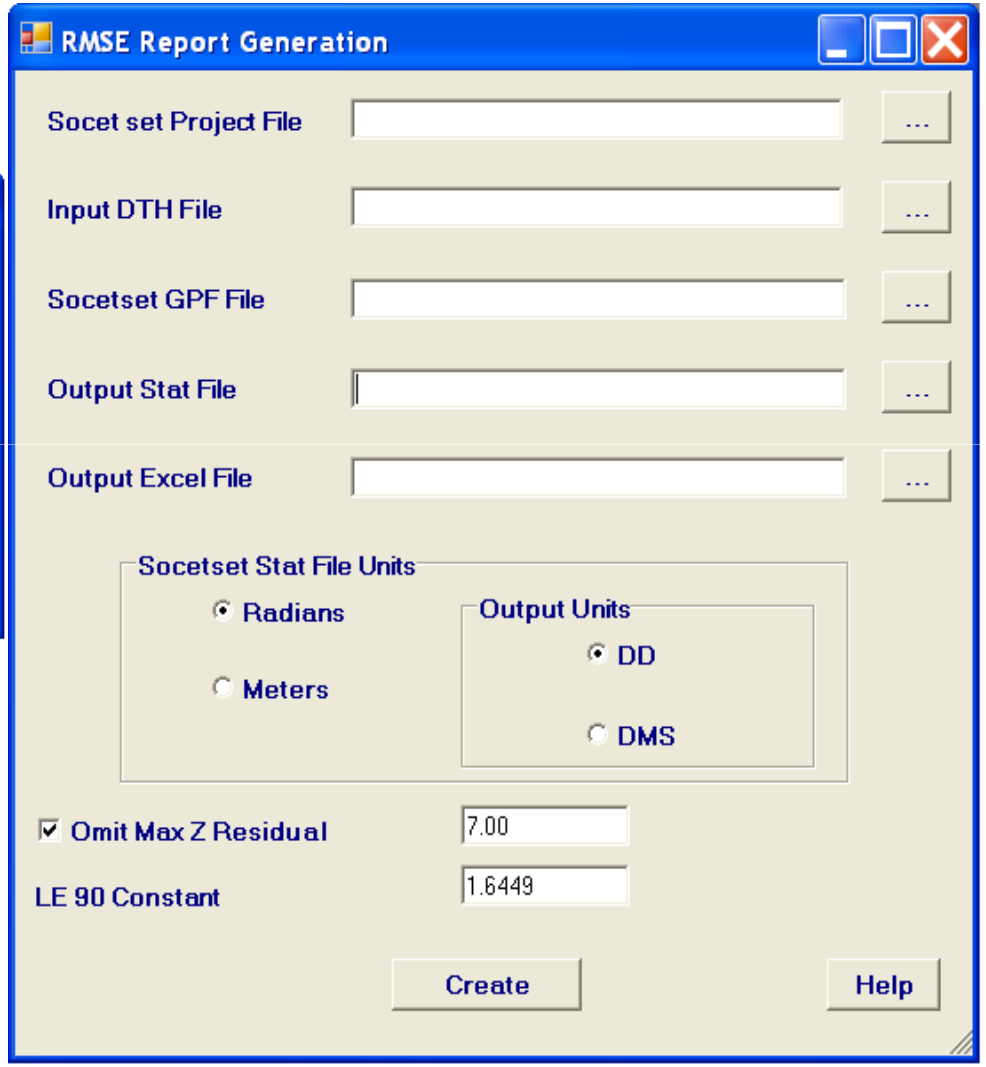
Infotech deploys rigorous quality control process to evaluate, correct, and verify the DEM data. The terrain is fixed with the necessary elevation controls, the rough contours and relief map will be generated for terrain matching and quality checking purpose

		Surveyed Ground Control Points			Stereo Measured Value									
		UTM 32 N - (Meter)			UTM 32 N - (Meter)			Residuals [Meter]			Residuals Squared			
ID	control_type	E	N	Elev	E	N	Elev	V(E)	V(N)	V(Elev)	V(E)*2	V(N)*2	V(Z)*2	Notes
DRF001	Full(XYZ)	593795.8558	5263192.904	857.71	593795.827	5263192.772	857.71	0.029	0.132	0.000	0.001	0.017	0.000	
DRF002	Full(XYZ)	593014.1951	5260766.291	903.769	593014.034	5260766.188	903.474	0.161	0.103	0.295	0.026	0.011	0.087	
DRF003	Full(XYZ)	593380.4496	5255897.869	896.442	593380.684	5255897.679	896.093	-0.234	0.190	0.349	0.055	0.036	0.122	
DRF004	Full(XYZ)	593601.881	5250853.678	964.144	593601.652	5250853.156	964.487	0.229	0.522	-0.343	0.052	0.272	0.118	
DRF005	Full(XYZ)	597491.3464	5263826.799	798.231	597491.842	5263826.462	798.375	-0.496	0.337	-0.144	0.246	0.113	0.021	
DRF006	Full(XYZ)	605872.7165	5263690.779	1213.971	605872.547	5263691.044	1214.057	0.169	-0.265	-0.086	0.029	0.070	0.007	
DRF007	Full(XYZ)	597700.6116	5256843.508	899.876	597700.72	5256843.484	900.132	-0.108	0.024	-0.256	0.012	0.001	0.066	
DRF008	Full(XYZ)	606289.7207	5258710.063	906.743	606288.767	5258710.386	906.743	0.954	-0.323	0.000	0.909	0.104	0.000	
DRF010	Full(XYZ)	596558.5458	5249679.821	861.506	596558.849	5249679.64	861.349	-0.303	0.181	0.157	0.092	0.033	0.025	
DRF011	Full(XYZ)	605471.9561	5253031.517	1198.674	605471.967	5253032.087	1198.362	-0.011	-0.570	0.312	0.000	0.325	0.097	
DRF012	Full(XYZ)	606213.968	5250919.677	1292.437	606213.531	5250919.773	1292.363	0.437	-0.096	0.074	0.191	0.009	0.005	
DRF110	Full(XYZ)	596667.1607	5249725.586	862.24	596667.246	5249725.453	862.021	-0.085	0.133	0.219	0.007	0.018	0.048	
									Number of samples:		12	12	12	
									Sum of Residuals squared:		1.620	1.009	0.596	
									RMSE of each coordinate:		0.367431	0.289985	0.22278	
	CE90 :	0.498814522												

Sample CE90 - Report

Miscellaneous Tools





Results and Accuracy for 2Meter DEM

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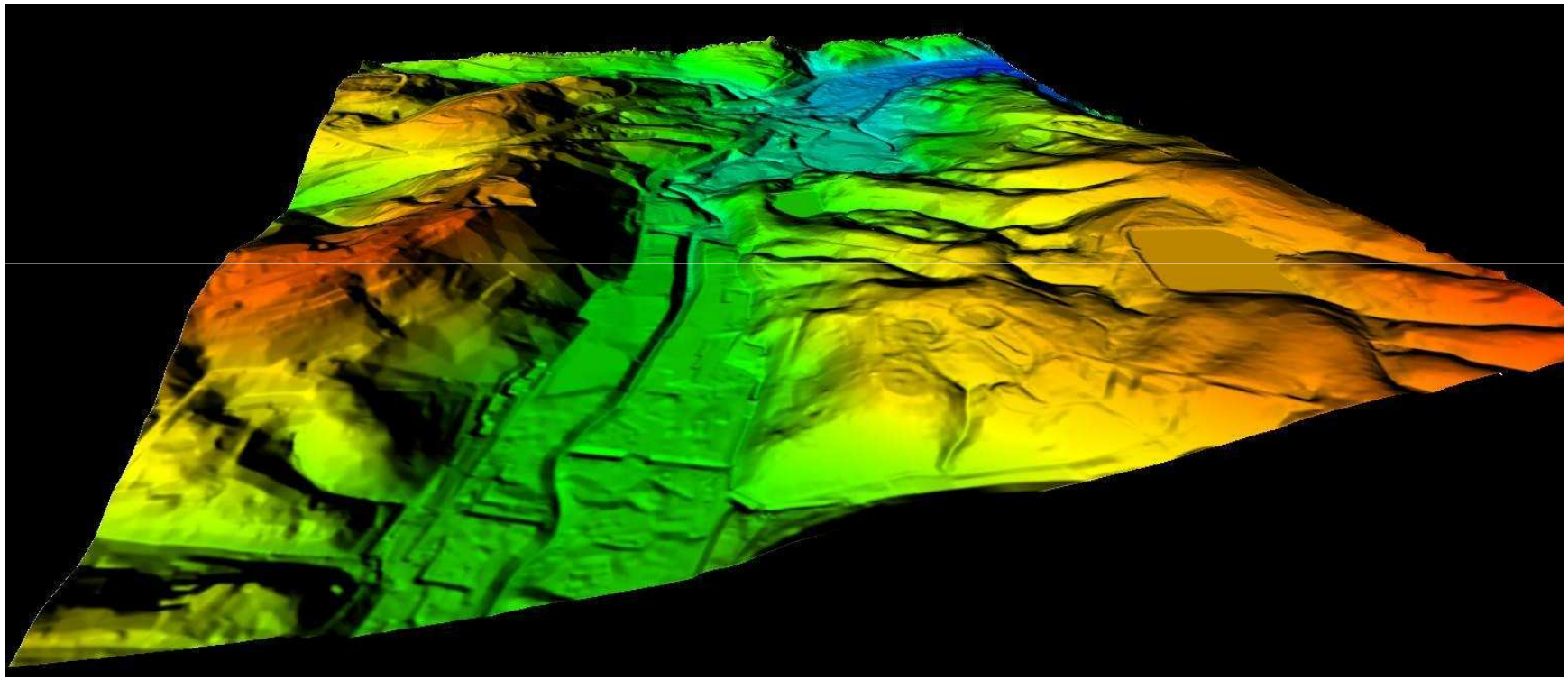
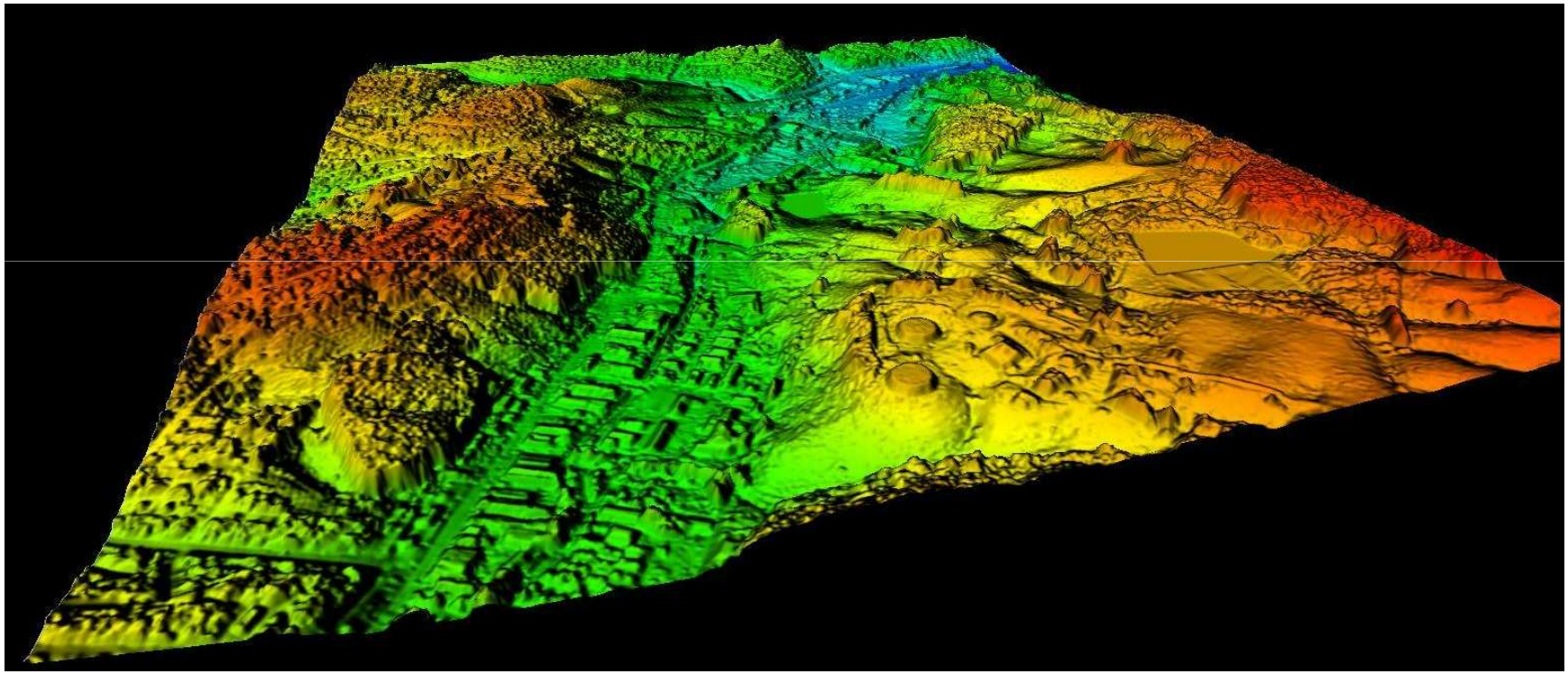
ID	control_type	AT Tie Computed Value& Stereo measured Check pts			Residuals [Meter]	Residuals Squared	Residuals Squared
		UTM 59S - (Meter)					
		E	N	Elev	V(Z diff)	V(Z)*2	Sqrt V(Z)*2
11AUG22103402-P1BS-052572390010_01_P002_3	TIE POINT	596113.352	5254197.811	822.799	-0.061	0.003721	0.061
11AUG22103402-P1BS-052572390010_01_P002_4	TIE POINT	597306.006	5253818.971	843.4932	-0.3677	0.13520329	0.3677
11AUG22103402-P1BS-052572390010_01_P002_5	TIE POINT	599310.36	5253783.528	1330.5449	0.5592	0.31270464	0.5592
11AUG22103402-P1BS-052572390010_01_P002_14	TIE POINT	596135.7	5253151.693	834.1862	-0.0172	0.00029584	0.0172
11AUG22103402-P1BS-052572390010_01_P002_15	TIE POINT	597297.294	5252912.873	880.2101	-0.6231	0.38825361	0.6231
11AUG22103402-P1BS-052572390010_01_P002_16	TIE POINT	599290.611	5252613.93	1907.4997	1.6398	2.68894404	1.6398
11AUG22103402-P1BS-052572390010_01_P002_25	TIE POINT	596114.649	5251680.529	851.1459	-0.246	0.060516	0.246
11AUG22103402-P1BS-052572390010_01_P002_26	TIE POINT	597702.469	5251607.533	993.4705	-0.4039	0.16313521	0.4039
11AUG22103402-P1BS-052572390010_01_P002_27	TIE POINT	599441.299	5251444.75	1333.2901	0.1333	0.01776889	0.1333
11AUG22103402-P1BS-052572390010_01_P002_36	TIE POINT	596031.862	5250571.888	850.8584	-0.1749	0.03059001	0.1749
11AUG22103402-P1BS-052572390010_01_P002_37	TIE POINT	597467.293	5250444.934	940.547	-0.3922	0.15382084	0.3922
Check-01	CHECK POINT	595461.943	5250435.556	845.1389	-0.3051	0.09308601	0.3051
Check-02	CHECK POINT	596010.805	5250450.638	850.9185	-0.7979	0.63664441	0.7979
Check-03	CHECK POINT	595952.804	5249774.689	856.8722	0.4118	0.16957924	0.4118
Check-04	CHECK POINT	596342.255	5249795.467	857.9501	0.093	0.008649	0.093
Check-05	CHECK POINT	596416.904	5250293.765	858.4926	-0.3848	0.14807104	0.3848
Check-06	CHECK POINT	596590.745	5250882.736	866.5587	0.1385	0.01918225	0.1385
Check-07	CHECK POINT	596953.54	5250417.123	943.8651	-0.3951	0.15610401	0.3951
Check-08	CHECK POINT	597011.884	5249815.861	915.3507	-0.3261	0.10634121	0.3261
Check-09	CHECK POINT	597338.293	5249817.503	945.1329	0.0211	0.00044521	0.0211
Check-10	CHECK POINT	597801.325	5249911.565	969.0372	-0.2054	0.04218916	0.2054
						Number of samples:	85
						Sum of Residuals squared:	28.429
						RMSE of each coordinate:	0.5783
LE90 -Relative	0.95128205						

Sample - LE90 Report

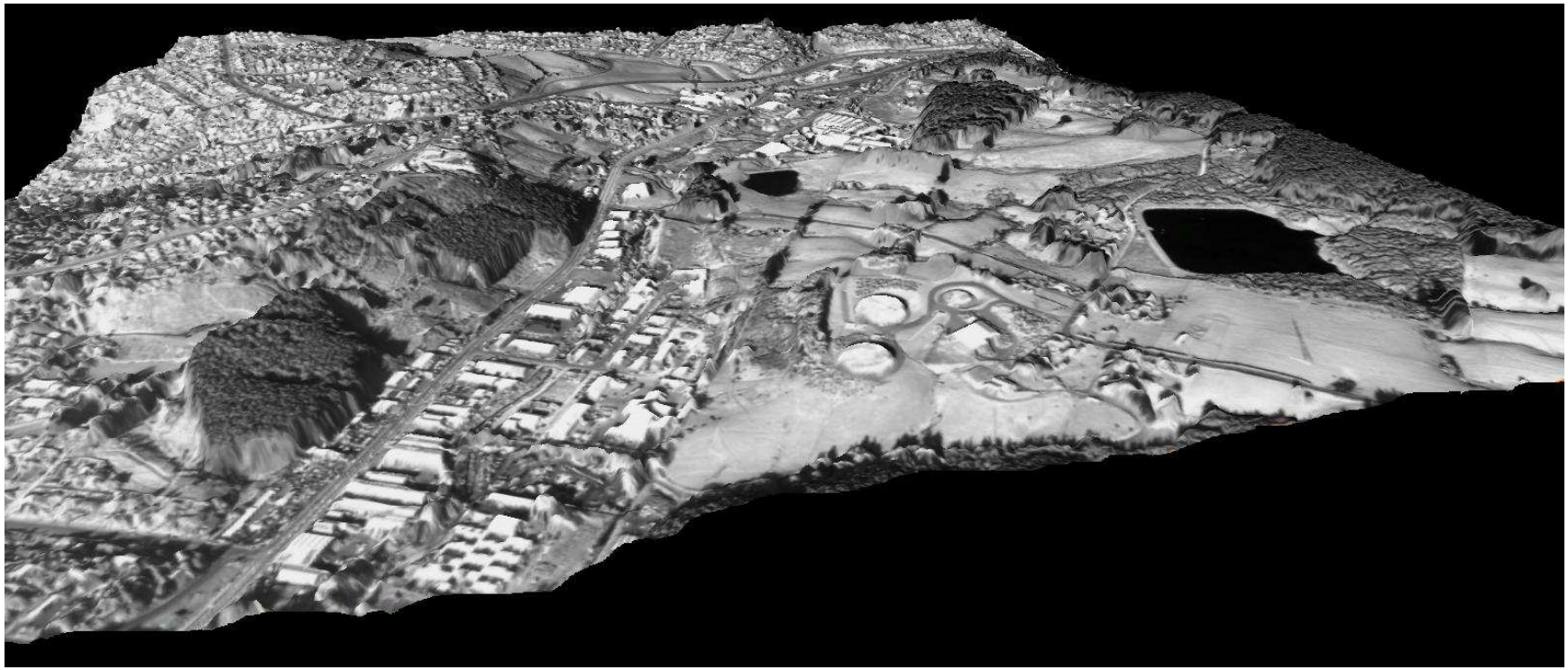
Worldview-2 DEM – 3D Perspective view



Worldview-2 DSM – 3D Perspective view



ORTHO – 3D Perspective view



Conclusions

- Through High Resolution Satellite imagery more accurate DEM can be produced in a cost effective manner

- The DEM accuracy of 2 meter can be achieved

- Based on the requirement of DEM, the user can choose the input from Worldview, GEOEYE, CARTOSAT-1 etc.

- DEM for large areas can be processed in short time

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