4D IMADAS 2020 – 3D Forest Cadastre

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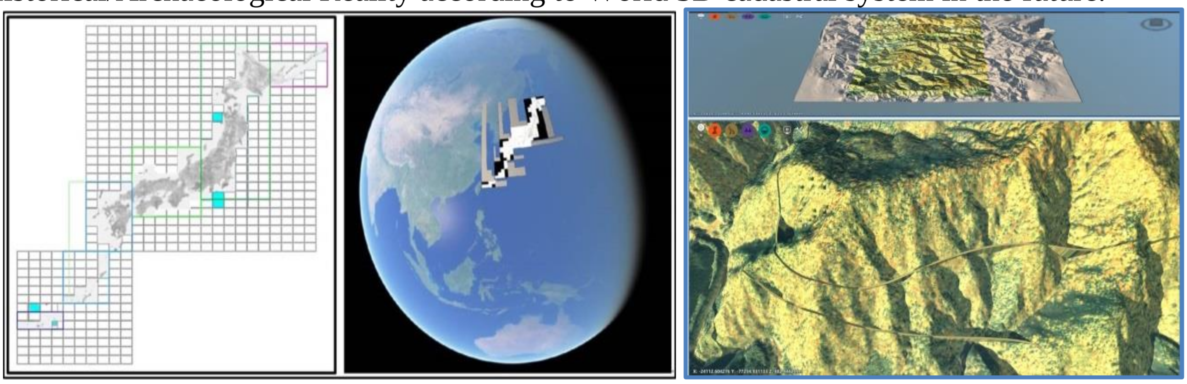
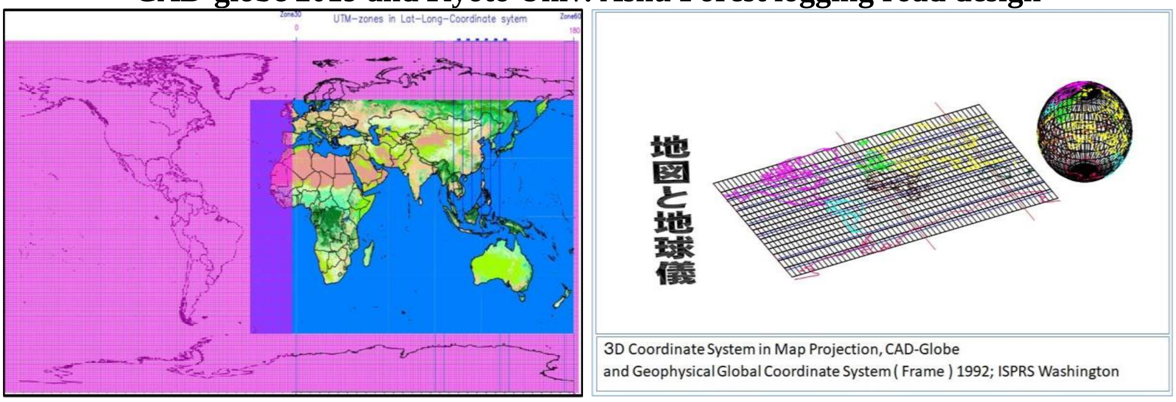
Key words: 4D- Image Map Archives, Helicopter photogrammetry, logging road design on 3D - diorama, 3D precise Forest-cadastre, World 3D cadastral system

SUMMARY

Based on 4D-Image Map Archive of forest area, which is 70% of the land in Japan, we could establish 3D diorama for 3D cadaster from maps, photogrammetric models and DEM data on CAD globe. Also we have created 3D-diorama of Kyoto city in 1946 aerial photos, and proceed to generate 1cm accuracy photogrammetric model from Helicopter photogrammetry. For logging road design and construction, we could use 3D diorama model on CAD globe as 3D forest-cadastre map. 3D mapper could be photogrammetric model, RTK rover and Terrain Laser Scanner mounted on Wheeled Harvester, which is the most powerful forestry machine. 4D-Image Map Archive Designed Aerial Survey (4D-IMADAS) system realizes old cadastral inventory and 3D cadastral survey from Heian capital (794) in Japan as Historical/Archaeological Reality according to World 3D cadastral system in the future.



CAD-globe 2019 and Kyoto Univ. Ashu Forest logging road design



4D-IMADAS 2013 Kyoto Univ. ASAFAS : Map and CAD globe;1992

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1. 3D FOREST CADASTER MAPPING AS GISE BASE MAP

3D forest cadaster mapping is to produce 3D forest base map, which is used for not only 3D precise cadastral map but also 3D surface modeling to construct logging road and erosion control dam. As Ground Control Points are derived from geocentric coordinate system with GNSS geodetic networking, the accuracy is the level of a few cm over the area to be mapped. Accuracy standard for forest cadaster survey could be as precise as the level of urban ground control points. 3D photogrammetric models could be also almost the same level of GCPs, if tree canopies do not disturb terrain surface measurement. To augment airborne laser scanning and photogrammetric surface measurement, we could apply RTK – GNSS satellite surveying in direct positioning and terrain-laser-scanning (TLS) for tree-terrain-surface point cloud measurement. As a platform of RTK and TLS instruments, wheeled harvester could be used with its cutting device replaced and manipulated by driver-cabin tablet-PC. As a final product, we could generate 3D vector line features as existing logging roads and terrain spot heights. In 3D CAD system, terrain random 3D points and 3D lines are to be created as Triangulated Irregular Network (TIN) to represent terrain surface as a whole. For further applications, Digital Elevation Model in Digital Surface Model and Digital Terrain Model could be utilized in design and landscape analysis. Adding Ortho-Mosaic image from photogrammetric stereo matching and airborne laser scanning on to Digital Elevation Model, we could have 3D mapping platform: 3D-diorama in 3D CAD environment. Mapping features are to be selected by forestry administrations and researchers as the basic components of Geo Informations Systeme(GISe) and ALKIS (German Cadastral Standard) of 3D cadastral system.
German cadastral system : GeoInfoDok-ALKIS evolves to 3D- GIS cadastral system, and has many practical land registration software based on AutoCAD based surveying systems.
Japanese cadastral system could be modernized from 3D forest cadastral survey as an authentic land administration basis, corresponding with MLIT’s i-Construction initiative.

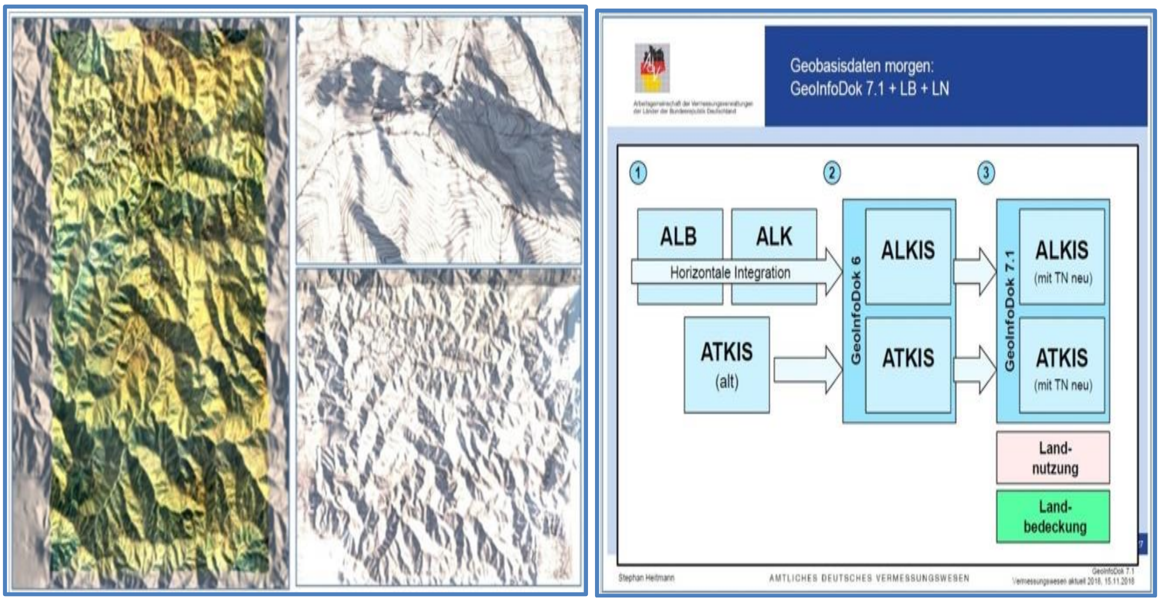


Fig. 1 : 3D forest map - 3D diorama : GeoInfoDok 7_1

2. PHOTOGRAMMETRIC MODELS

Photogrammetry generates 3D image models, as stereo viewing models on digital stereo plotter, from overlapped photos, via bundle triangulation. With 3D image models, stereo matching digital elevation modeling, ortho-mosaic image generation could be processed and finally 3D stereo model measurement could be combined with 3D-CAD for 3D forest cadastral mapping. Extended application of this process is 3D diorama mapping on CAD-globe, like Google Earth. Logging roads and erosion control dams are major 3D object features in 3D forest cadastral mapping on photogrammetric models.

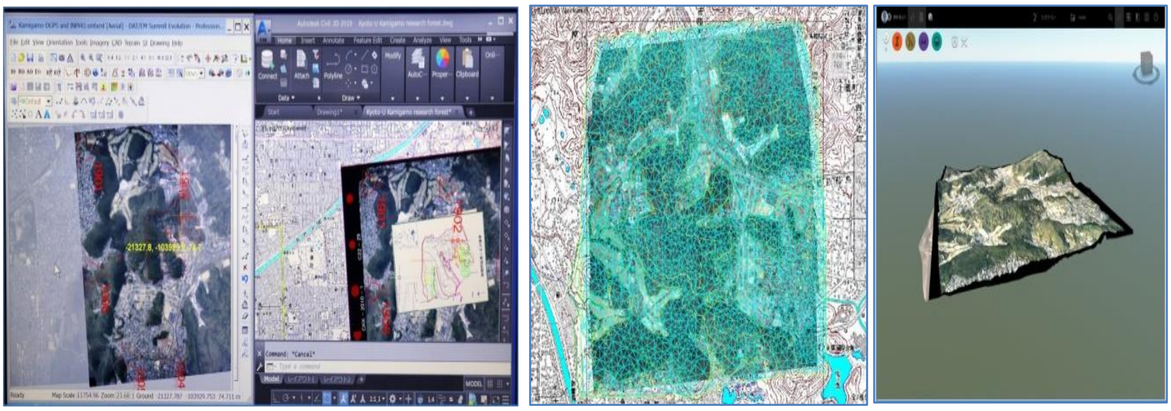


Fig.2 : Stereo model (AutoCAD 3D drawing) : TIN-DEM : 3D-diorama

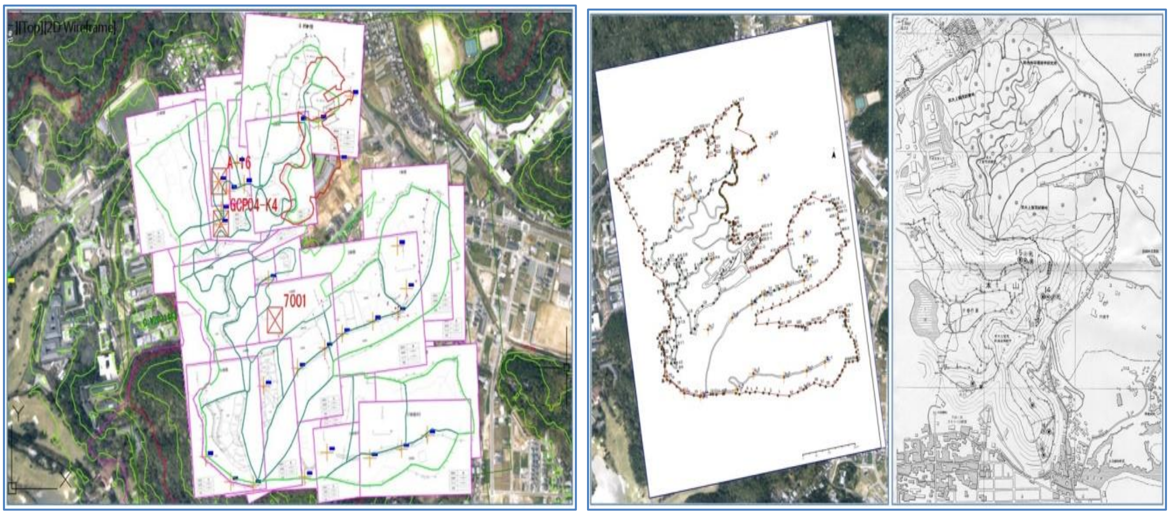


Fig.3 : Kyoto Univ. Kamigamo forest plan maps - GCPs - Forestry Agency base map

2.1 Aerial photogrammetry

Aerial photogrammetry has been widely used in basic mapping since 1900s. Old existing aerial photos, as paper prints or roll films, are the source of 3D image models, as historical reality, different from virtual and augment reality. 4D Image Map Archive is based on not only original photos but 3D image models, with exterior orientation parameters and digital image data file.

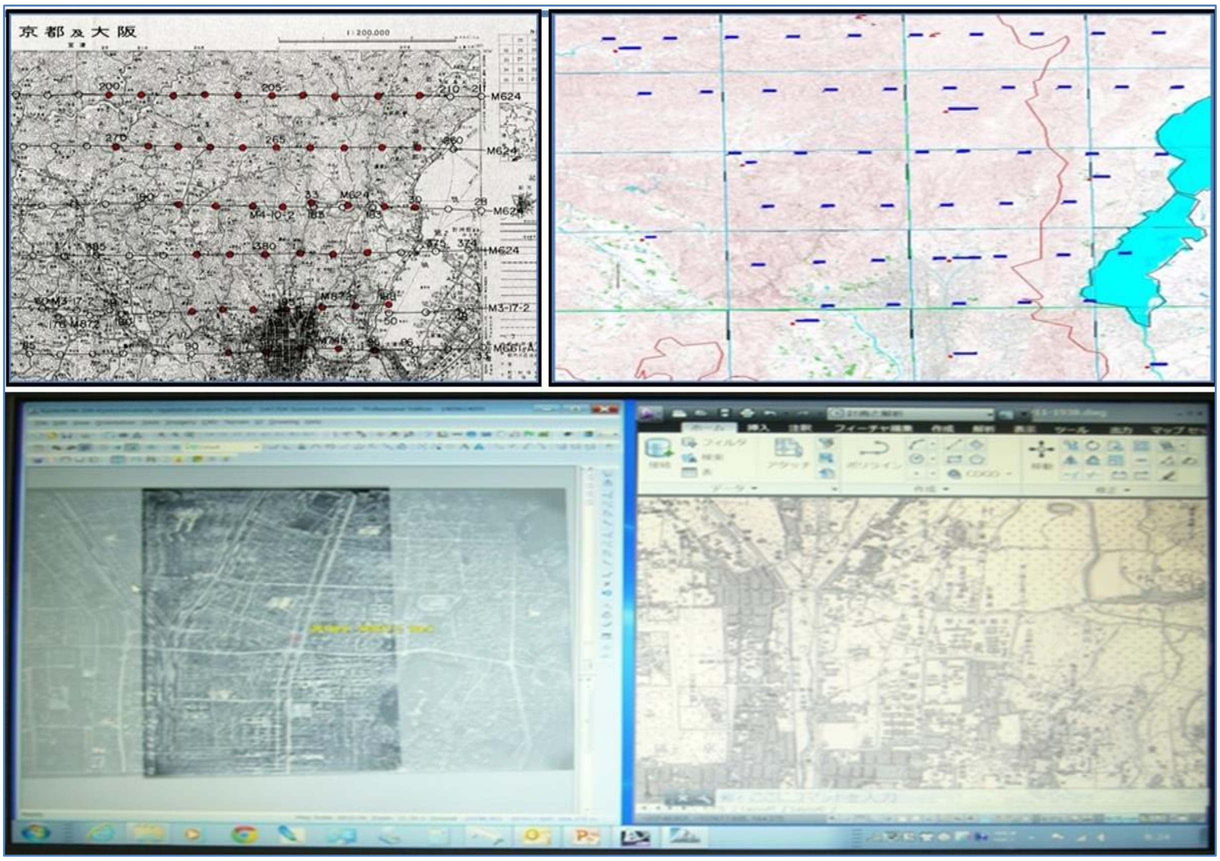


Fig.4 : Aerial photogrammetry (1946 photos): Summit Evolution (DATEM, USA)

2.1.1 Bundle triangulation

Bundle triangulation realizes the accuracy of 3D image models with highest angular resolution, through camera calibration and simultaneous exterior orientation, based on least square adjustment of explicit unknowns. Currently only old existing photos are used as historical reality, for time series analysis and registration work of forestry administration.

2.1.2 Stereo matching Digital Elevation Modeling

Photogrammetric stereo matching could acquire Digital Surface Model, like canopy surface, as grid wise heights of the 3D image stereo models. DSM could be compared with DTM, to compute volume of an area to be converted to average height of tree species.

2.1.3 Ortho-Mosaic Image generation

Overlapped image models are used for combined orthogonal image of the area, and overlaid with 3D vector feature lines as contents of 3D forest cadastral maps.

2.1.4 3D diorama on CAD-globe

3D diorama on CAD-globe is now produced on AutoCAD-Infraworks, which is the major product for BIM initiative of construction design and construction work. The idea and schematic representation of CAD-globe was presented to the public in1992 ISPRS Washington Congress by the author.

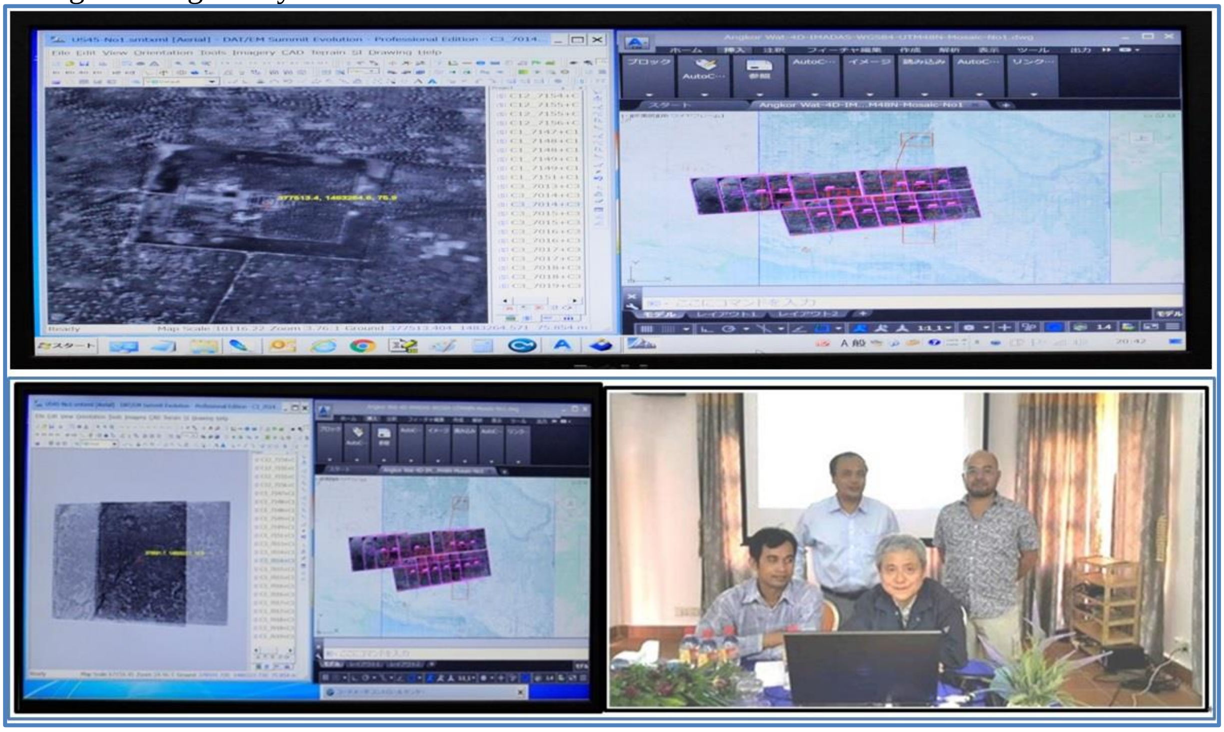


Fig.5 : Angkor Wat - bundle triangulation from 1945 aerial photos (2016)

2.1.5 3D diorama logging road design and landscape analysis

Logging road design and landscape analysis could be the major tasks of AutoCAD-Infraworks, combined with automatic manipulation of forestry machines.

2.1.6 Logging road construction by forestry machine's automatic control

For automatic control of forestry machines, we need now sustainable 3D map and concrete operational specifications towards construction works and archival registration.

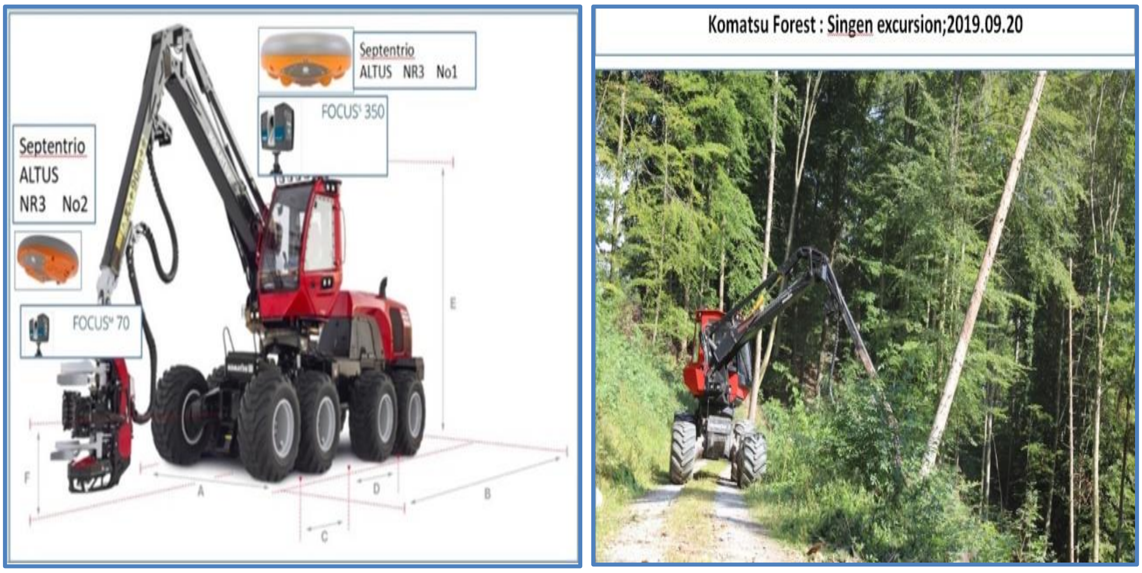


Fig.6 : Logging 3D mapper : Harvester cutting

2.2 Helicopter photogrammetry

Helicopter, as a platform of photogrammetry, has some advantages for large scale photogrammetry: close range photogrammetry. With slow velocity, forward motion blur could be cancelled, with even slow shutter speed of a camera. With small but high resolution camera, such as 50M pixel digital camera of huge number of image storage, we could get constantly overlapped images along long road lines and wide forest area. Key issues are flight planning and control related with exposure positioning devices, like GNSS and IMU devices, supported by tablet based monitoring screen PC.

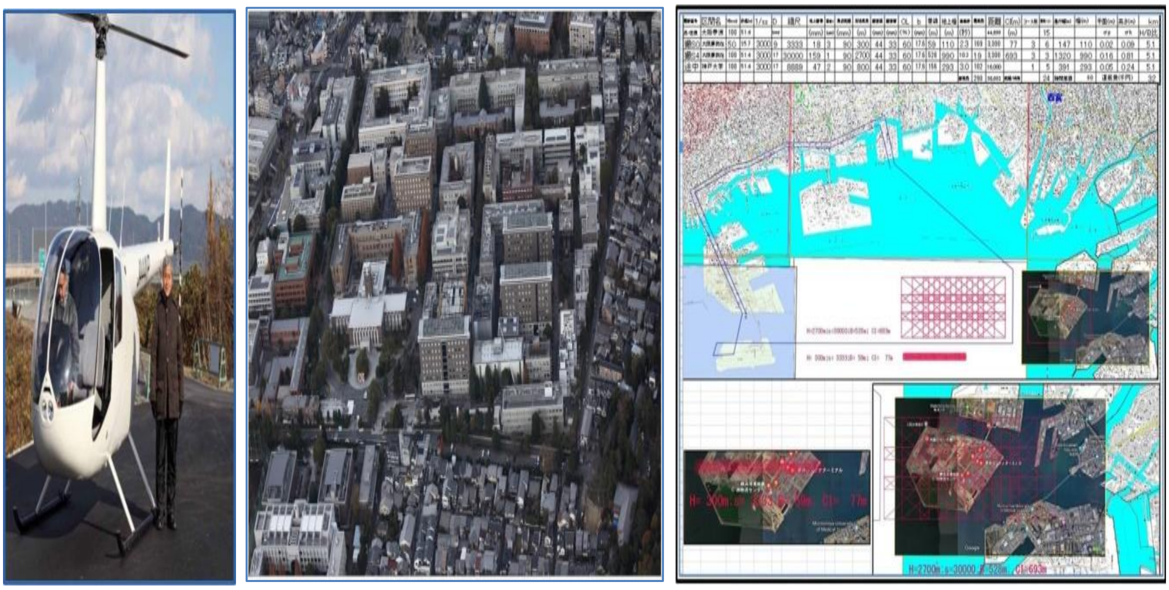


Fig.7 : Helicopter photogrammetry: Kyoto Univ. oblique image: Osaka EXPO2025 area

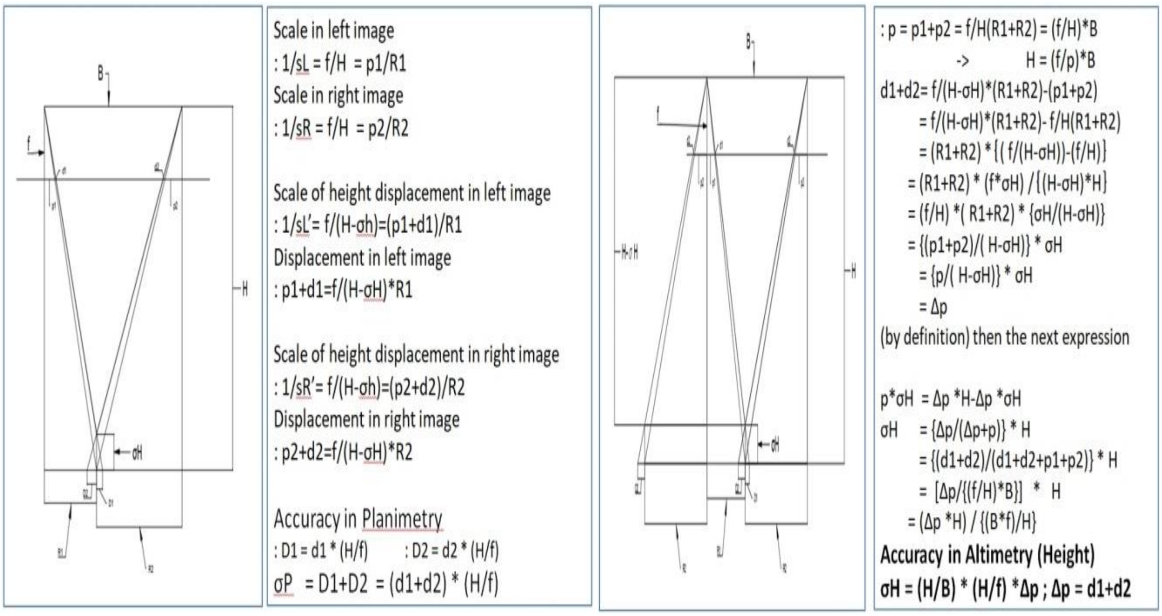


Fig.8 : Planimetric accuracy (σP) : Altimetric accuracy (σ H)

2.2.1 Camera calibration

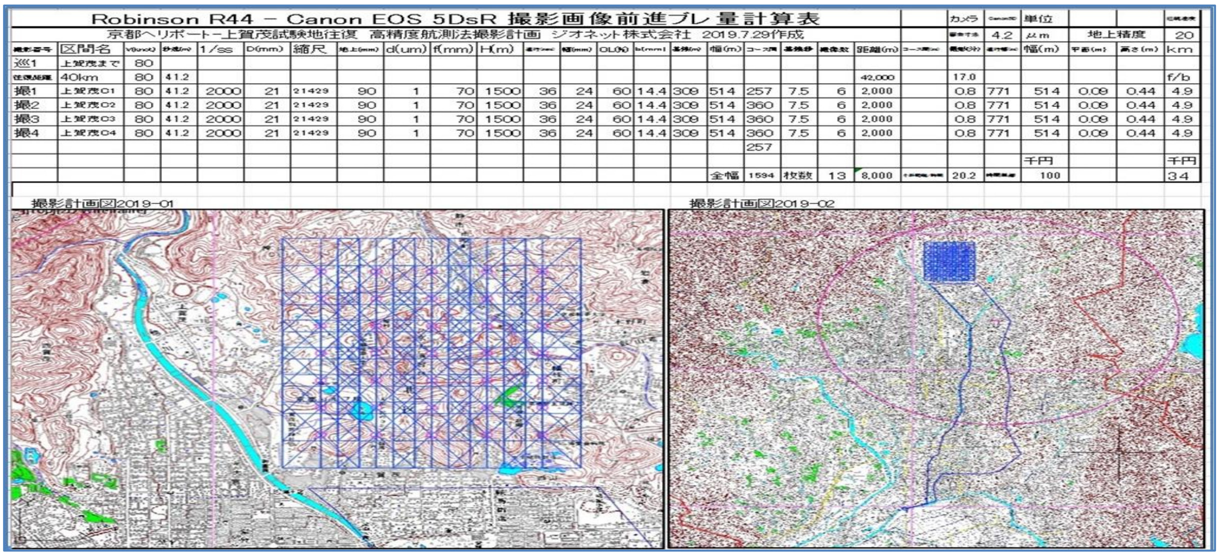
Authentic aerial camera ensured the interior orientation parameters and lens distortion values less than 10 um. Also for height accuracy, good B/H ratio was given with large size photo format. Digital camera has a flat image surface and dimension of image pixels.

2.2.2 Accuracy analysis

Photogrammetry ensures 3D image model accuracy in planimetry and altimetry, based on image pixel accuracy and sub-pixel 3D pointing on digital stereo plotter with 3D-CAD system. Terrain Laser Scanner generates 3D point cloud with pulse line interval and beam circle. Vertical exposures represent approximate accuracy in planimetry and altimetry as above;

2.2.3 Flight planning and control

Flight planning table is now organized, depending on major factors, as follows;



Robinson R44 － Canon EOS 5DsR 撮影画像前進ブレ量計算表

京都ヘリポートー上賀茂試験地往復　高精度航測法撮影計画　ジオネット株式会社　2019.7.29作成

カメラ	[illegible]	単位			[illegible]
[illegible]	4.2	μm	地上精度		20

[illegible]	区間名	V(knot)	秒速(m)	1/ss	D(mm)	縮尺	地上(mm)	d(um)	f(mm)	H(m)	[illegible]	幅(mm)	OL(%)	b(mm)	基線(m)	幅(m)	コース間	基線秒	撮像数	距離(m)	[illegible]	撮影(分)	[illegible]	幅(m)	平面(m)	高さ(m)	km
巡1	上賀茂まで	80																									
往復距離	40km	80	41.2																	42,000		17.0					f/b
撮1	上賀茂C1	80	41.2	2000	21	21429	90	1	70	1500	36	24	60	14.4	309	514	257	7.5	6	2,000		0.8	771	514	0.09	0.44	4.9
撮2	上賀茂C2	80	41.2	2000	21	21429	90	1	70	1500	36	24	60	14.4	309	514	360	7.5	6	2,000		0.8	771	514	0.09	0.44	4.9
撮3	上賀茂C3	80	41.2	2000	21	21429	90	1	70	1500	36	24	60	14.4	309	514	360	7.5	6	2,000		0.8	771	514	0.09	0.44	4.9
撮4	上賀茂C4	80	41.2	2000	21	21429	90	1	70	1500	36	24	60	14.4	309	514	360	7.5	6	2,000		0.8	771	514	0.09	0.44	4.9
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Fig.9 : Helicopter photogrammetry - flight plan 2019

Fig.10 : Flight lines and 1 sec DGPS positioning : Kyoto Univ. Kamigamo forest

2.2.4 Automatic bundle triangulation

Huge number of overlapped images is well arranged with automatic bundle triangulation, resulting final exterior orientation parameters and accuracy measures of the whole 3D models.

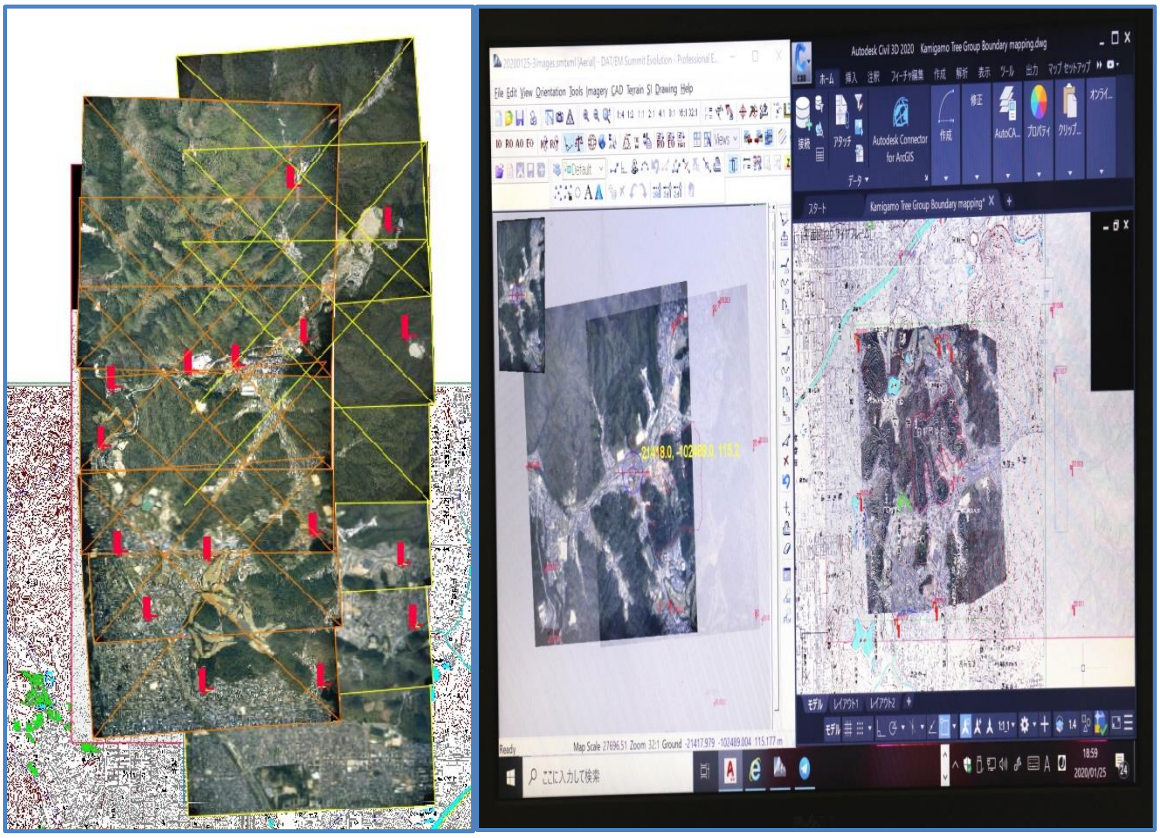

Fig. 11 : Automatic bundle triangulation and 3D-image model (Summit Evolution)

2.3 Satellite photogrammetry

Satellite stereo images, such as 3 line sensor images, give us ideal stereo models with large image scale and good B/H ratio in planimetry and altimetry. Based on pixel size and focal length of 3 line sensors, we could get ground accuracy of 30cm to 50cm, which is similar to ground resolution. From now on we could recommend 3 line sensor satellite images for 3D mapping of the earth. As alternative approaches, we could use DEM with single satellite image to view stereo images for 3D mapping with 3D CAD system.

2.3.1 Stereo model with Rational Parameter Coefficients and AutoCAD-Civil3D

Using World View 2 stereo images with Rational Parameter Coefficients, we could successfully an accurate stereo model on Summit Evolution (DATEM, USA) with AutoCAD-Civil3D in 2016.

2.3.2 Ortho-Mosaic image generation

Stereo image model could be used for ortho-mosaic image generation for further 3D forest cadastral mapping, augmented with 3D stereo image model on Summit Evolution.

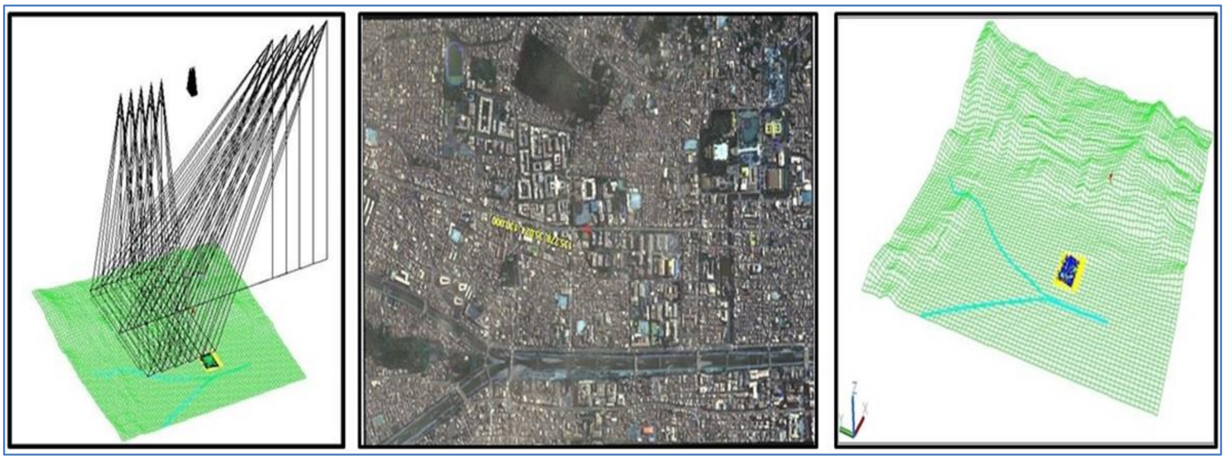

Fig.12 : Satellite photogrammetry 2016 (World View2, Kyoto Univ. campus area; 2015)
On Summit Evolution (DATEM, USA) with AutoCAD-Civil3D

3. 3D FOREST CADASTRAL SURVEY WITH TERRAIN SURFACE MAP

Japan has 70% of land area as forests, which locates mostly mountainous area. Mountainous forests need 3D mapping, even for cadastral survey. GNSS satellite geodetic networking supports 3D forest cadastral survey with precise 3D coordinates. 3D terrain surfaces and boundary lines of ownership are now to be prepared.

3.1 Airborne laser profiling and photogrammetric Digital Surface Modeling

From Japan GSI-5m-DEM of airborne laser profiling and 25k topographic maps, 3D diorama = 3D base map is generated on AutoCAD Infraworks as designing object. Ortho/Mosaic image and/or forest plan maps are draped on DEM surface in Infraworks. Contour lines are generated from TIN surface automatically, and forest inventory could be configured for lumber volume calculation and tree growth analysis.

Fig.13 : Airborne laser profiling and 25K topographic map

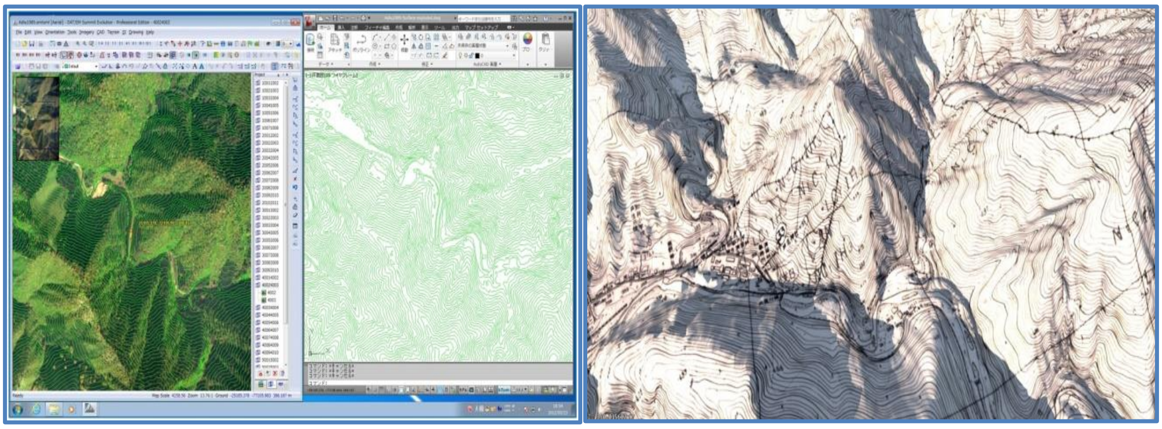

Fig.14 : Contour generation : 3D forest plan map (Kyoto Univ. Ashu Forest; 1989)

3.2 GNSS Direct terrain 3D measuring : Differential GPS / Real Time Kinematic
DGPS-Mapping : 3D topographic mapping was conducted as Tak Tak DGPS-mapping in Angkor Wat,Cambodia (2016) and showed sufficient accuracy of σ : 1-2m for 1/5,000 maps.

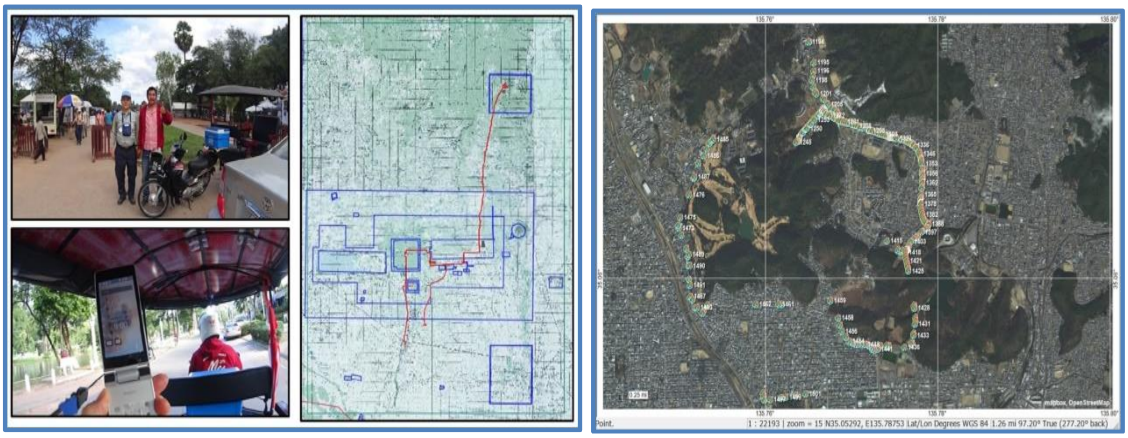

Fig.15 : TakTak mapping (AngkorWat) : TekTek DGPS mapping (Kamigamo Forest)

For GNSS Direct terrain 3D measuring, FKP(Flaechen Korrektor Parameter) - Real Time Adjustment has been used for 1cm accuracy real time 3D mapping in dense canopy woods.

Fig.16 : Shinshu Univ. test (2010) and Kyoto Univ. GCP - FKP test (2018)

3.3 Ground Control Points from National Electronic Control Point

For 3D forest cadastral survey, we have already applied parameter estimation approach of satellite geodesy, using GEONAP and GN-SMART software, to obtain the accuracy of a few cm on the ground, even under dense canopy and tall building area. Since 1999, we have been using Parameter Estimation Gnss Assisted SUrveying System(PEGASUS for short) to check ECP networks nationwide and utilized PEGASUS-Net to forest boundary control points, now we proceed to precise RTK surveying with multiple positioning satellite constellation.

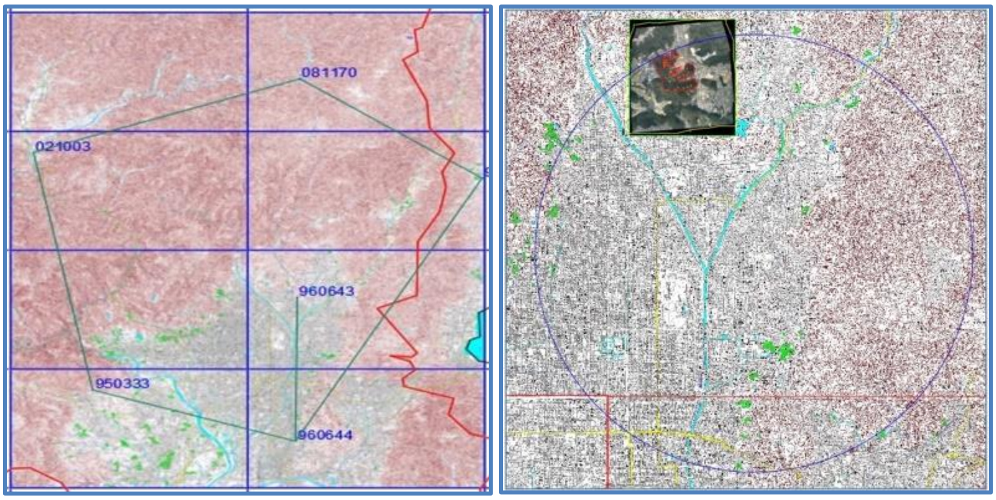

Fig.17 : Penta ECPs network- Kamigamo Forest : RTK-plan from Kyoto Univ. Campus

3.4 GNSS / Terrain Laser Scanner 3D dome traversing on Harvester Machine

Komatsu harvester cuts a standing tree in 5-10 seconds, along logging road, or on the slope surface. We have a plan to put GNSS antenna / Terrain Laser Scanner at the edge of stretching arm of harvester-forestry machine with wheels as 3D forest mapper.
3D terrain laser scanner point cloud is well organized with Ground Control Points and connecting spherical targets as traversing point cloud in geocentric system. Trees are well configured in 3D CAD with color information for inventory registration purposes.

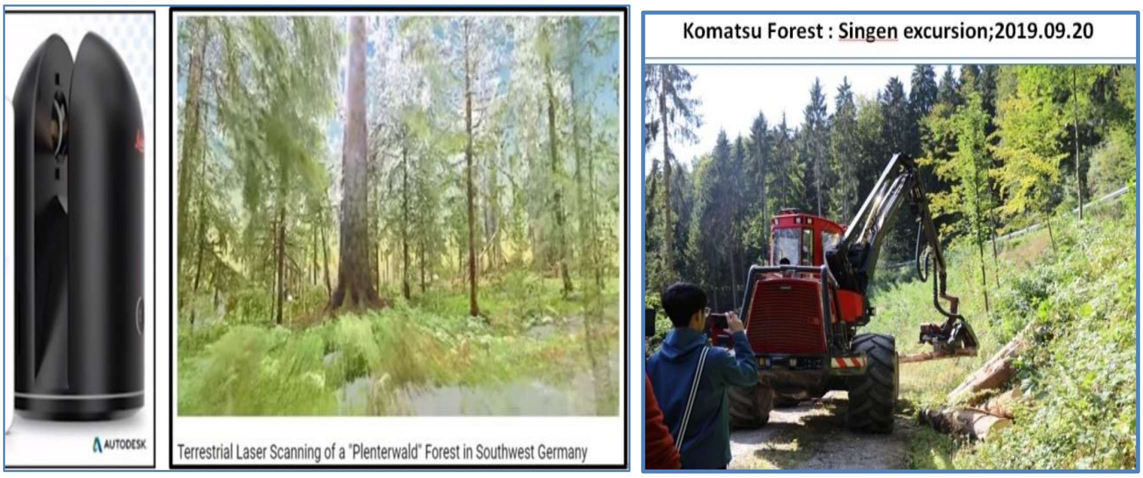

Fig.18 : Leica TLS -AutoCAD ReCap - point cloud : Harvester setting

As for Point cloud as 3D model object and photogrammetric 3D model object, 3D model objects are derived from point clouds of terrain laser scanner and photogrammetric 3D models. We need to know the accuracy characteristics for both sources.
As angular resolutions among Total station, laser point clouds and photogrammetric model are decisive for point accuracy measure, we could compare angular resolution among total station, laser point cloud and photogrammetric model.
For 3D CAD combination of point clouds and photogrammetric model, AutoCAD-Civil3D could combine point clouds from airborne and terrain scanner, and also photogrammetric model points and polylines, to be created 3D terrain surface model as TIN surface.
Using 3D vectorization and registration on 3D forest cadastral map, as the final product of 3D forest cadastral map, we could designate AutoCAD 3D drawing file. As an extension, 3D-diorama in AutoCAD- Infraworks could be the augment product.
Total station traversing and Terrain laser scanner traversing could be reconfigured by harvester driven 3D mapping system, considering the terrain slope inclination. For 3D forest cadaster mapping, Harvester driver is regarded as 3D mapper in itself, keeping copy right.
For forestry administration, inventory registration could be corresponded with individual trees of relevant area, even in case of steep slope inclination. 3D forest cadastral map would be combined with nice viewing system with stereoscopic display for public use.

4. 4D- IMAGE MAP ARCHIVE DESIGNED AERIAL SURVEY : IMADAS

4D- Image Map Archive Designed Aerial Survey : IMADAS started with “KYOTO HEIAN CAPITAL 4D IMADAS 2015 for 3D CITY MODELING” of ACRS 2015, Manila, Philippines. Based on historical reality of old maps and photogrammetric 3D models, 3D diorama of Heian- Kyoto capital is now reconstructed as basic 3D map of Kyoto city.

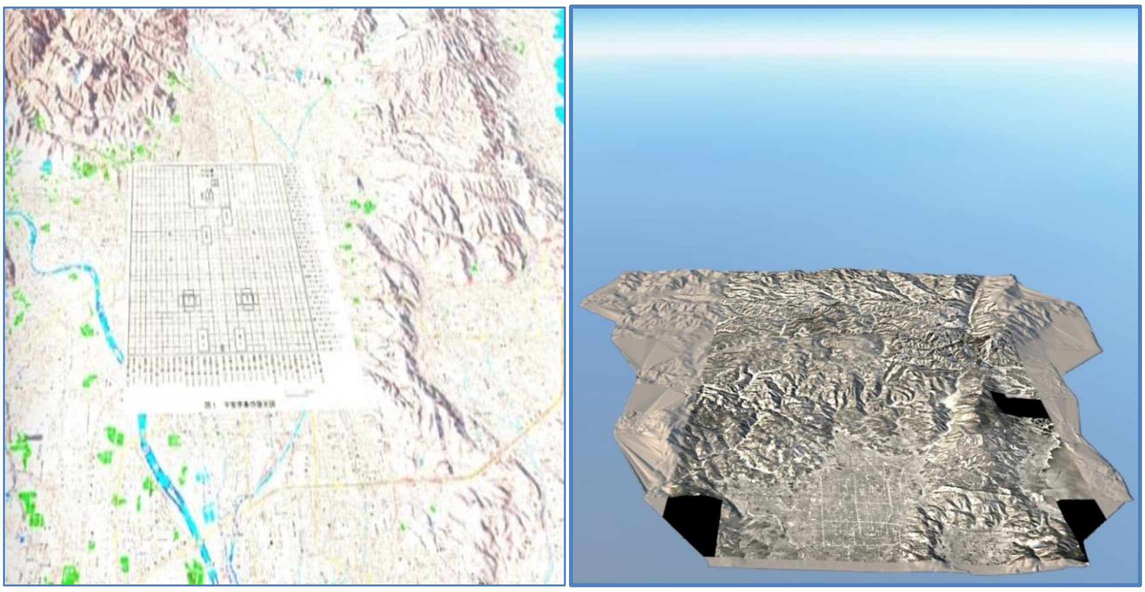

Fig.19 : Heian-Capital plan on 25K map-3D diorama and Kyoto photo-3D diorama1946

4.1 Historical Reality of old maps and photogrammetric 3D models

Having configured in WGS84 coordinate system and map projections, old maps since 1890 and aerial photos in 1946 are generated as 3D diorama map as historical reality.

4.2 CAD-GLOBE AND MAP PROJECTIONS ON 3D CAD

CAD-globe was conceptualized and represented on AutoCAD in 1992 by the author. In 3D CAD we could realize the relationship between earth-globe and map projection. We could define the location of the ground points according to geocentric coordinate system and projected map coordinate system consistently. Nowadays global sea level rise indicates the importance of equipotential surface: geoidal model worldwide. This aspect would be considered with ITRF definition, based on International GNSS service(IGS).

4.3 Map projection and Global rectangular coordinate system

Coordinate transformation and map projection could be consistently applied on 3D CAD system, utilizing 3D rectangular coordinate system and spatial similarity transformation, commonly used in Geodesy and Photogrammetry.

4.4 4D- Image Map Archive on World Geodetic System with Datum transformation

4D- Image Map Archive on World Geodetic System with Datum transformation is already realized with old maps from 1820s, in Japan, Myanmar, Bhutan, Cambodia, Indonesia and Tanzania, using AutoCAD-Infra works and old image maps.
In a similar way, we could organize Forest 4D Image Map Archive for tree growth analysis.

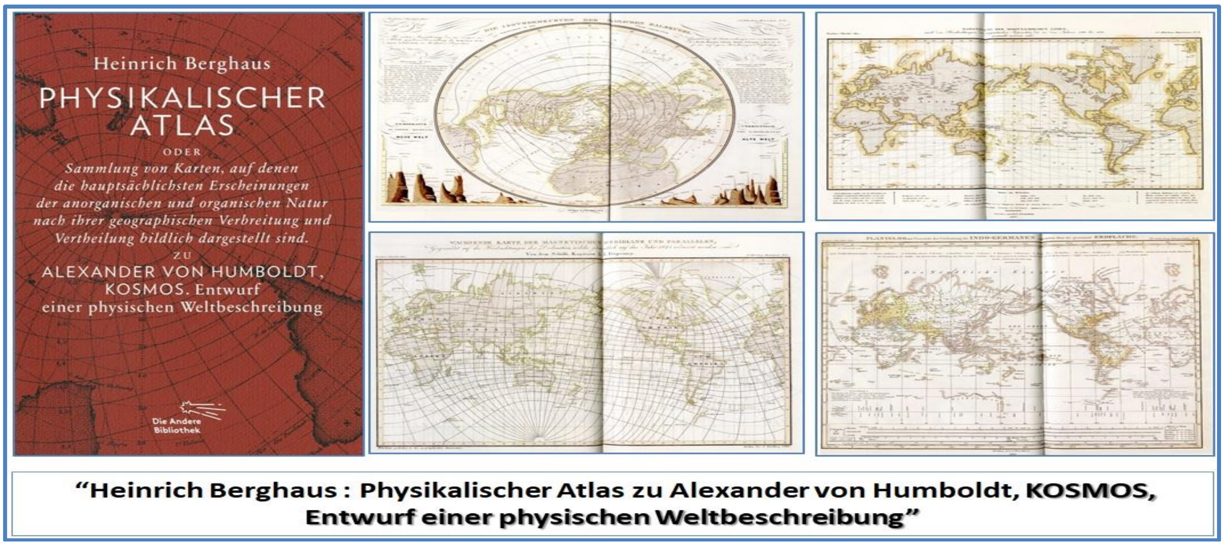

Fig.20 : Physikalischer Atlas zu Alexander von Humboldt,
KOSMOS, Entwurf einer physischen Weltbeschreibung

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BIOGRAPHICAL NOTES

Hiroyuki Hasegawa obtained a BA in Human Geography in 1971 from Kyoto University, Japan. In 1976 he was graduated from ITC, The Netherlands as Photogrammetric Technologist. From 1971 until 1999 he worked at PASCO Corporation in Tokyo, Japan. From 1999 until now he is working in GeoNet, Inc. in Osaka, Japan.
From 2013 he was the researcher of Graduate School of Asian and African Area Studies Kyoto University, Japan. From 2013 until now he is the researcher of Japan Federation of Land and House Investigators' Associations.
From 2014 to 2015 he was the representative of common research project of CSEAS (Center for Southeast Asian Studies Kyoto University): "4D IMADAS for Williams Hunt Collection".

In FIG Working Week 2019 Hanoi, 4D-IMADAS with 3D mapping of Kyoto(Heian) – Angkor(Khmer) capitals was presented. In South East Asia Survey Congress 2019 Darwin, 4D-IMADAS 2019 - 3D cadastral mapping was presented.

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