Implementation of Customary Cadastre with Integrating BIM and GIS on SuperMap Software in Bali, Indonesia

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2021

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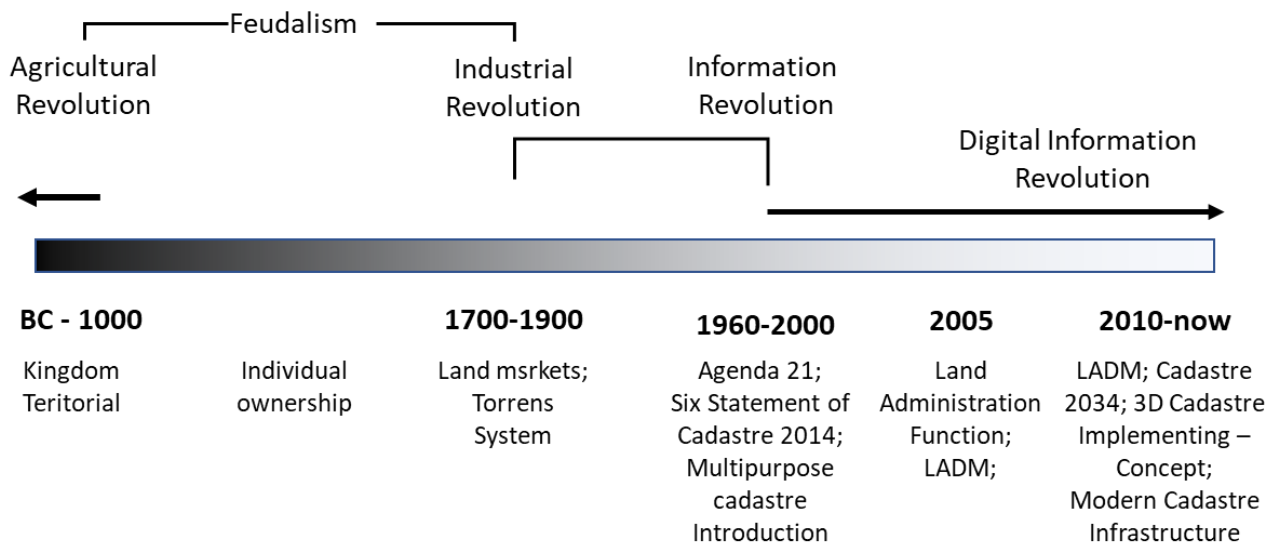
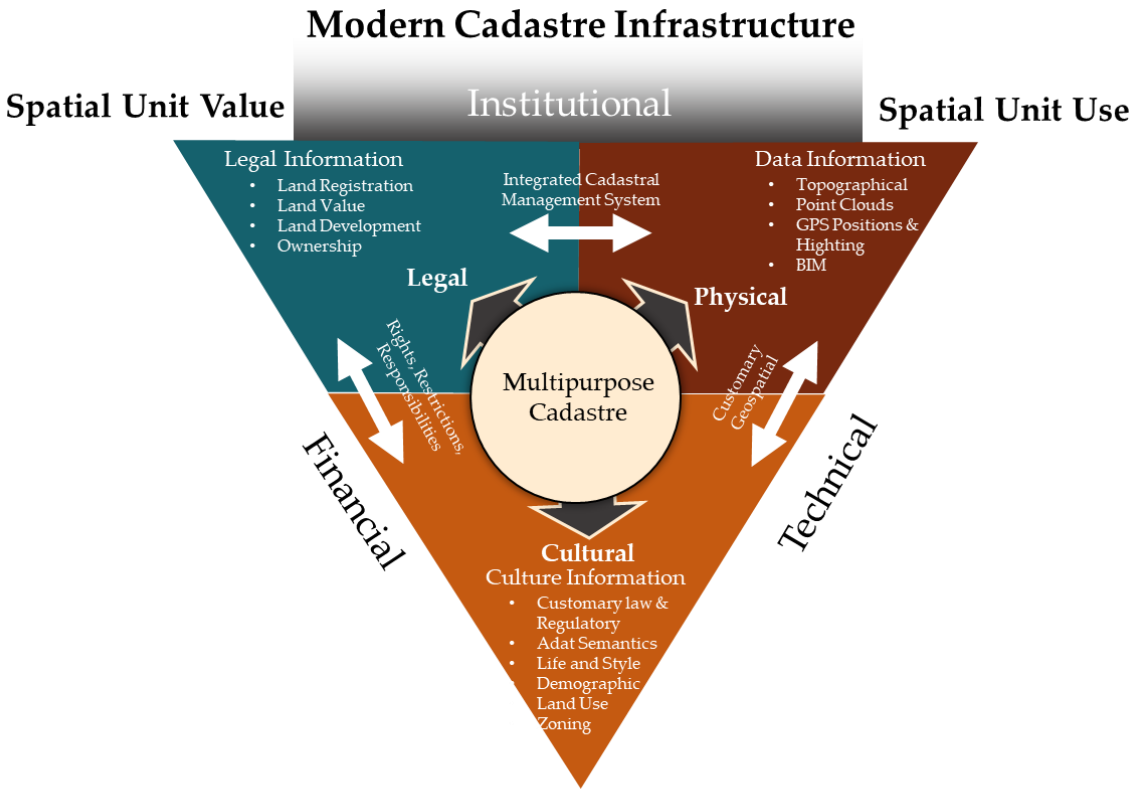


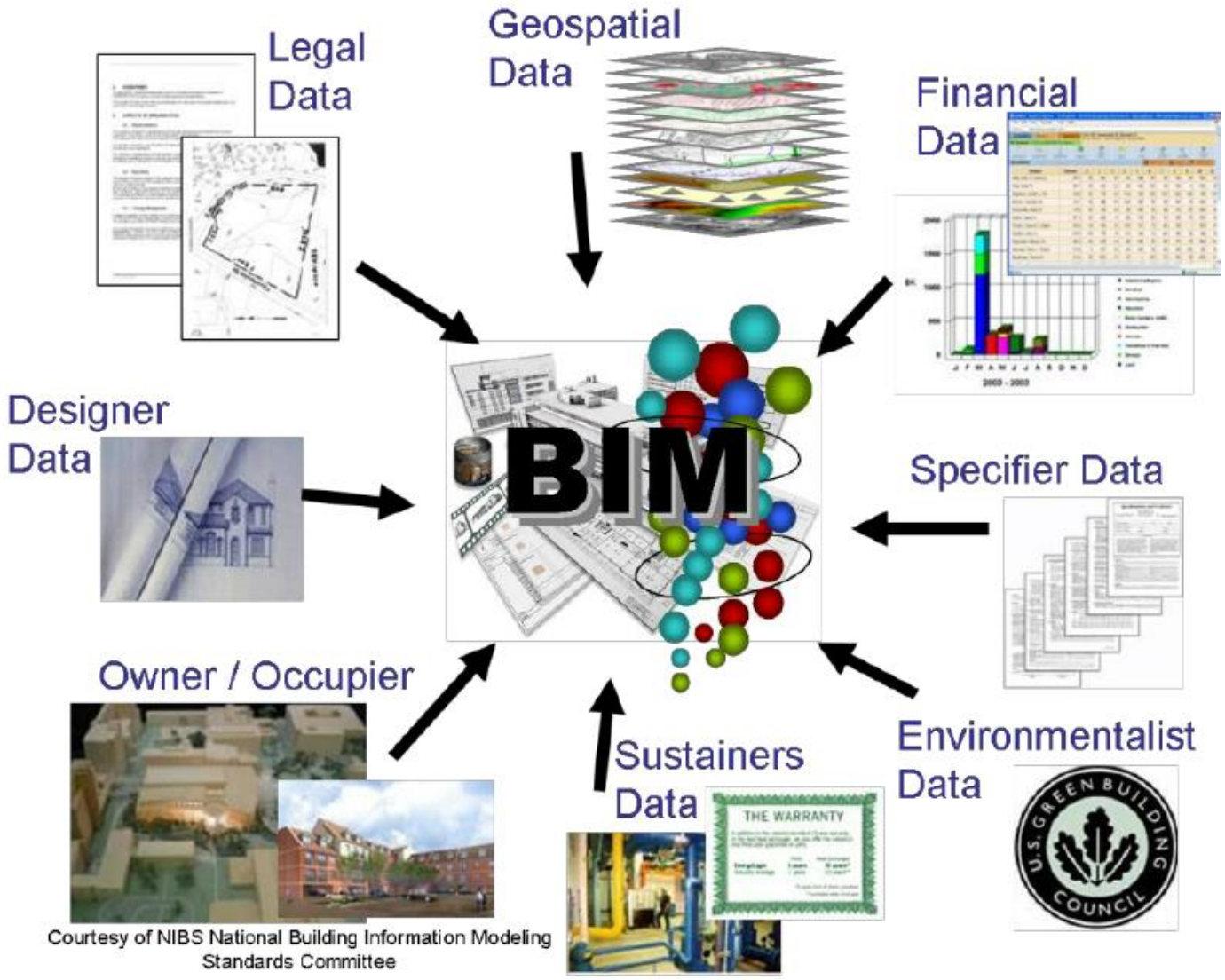
In essence, the cadastre is used as a record of land rights and part of the land administration function towards sustainable development.

Multipurpose cadastre is an integrated land information system containing legal (e.g. property ownership or cadastre), physical (e.g. topography, man-made features), and cultural (e.g. land use, demographics).

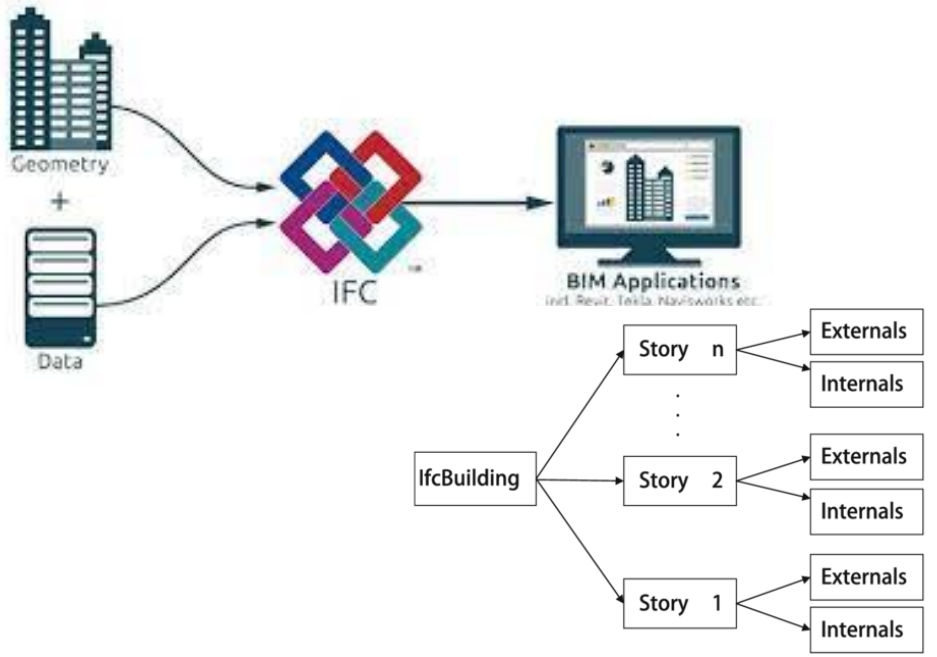
Currently, the application of a multipurpose cadastral system in 3D to support modern cadastre has many technologies. One of them uses BIM and GIS as the perfect approach in providing spatial information related to legal certainty, land assessment, and use of space.

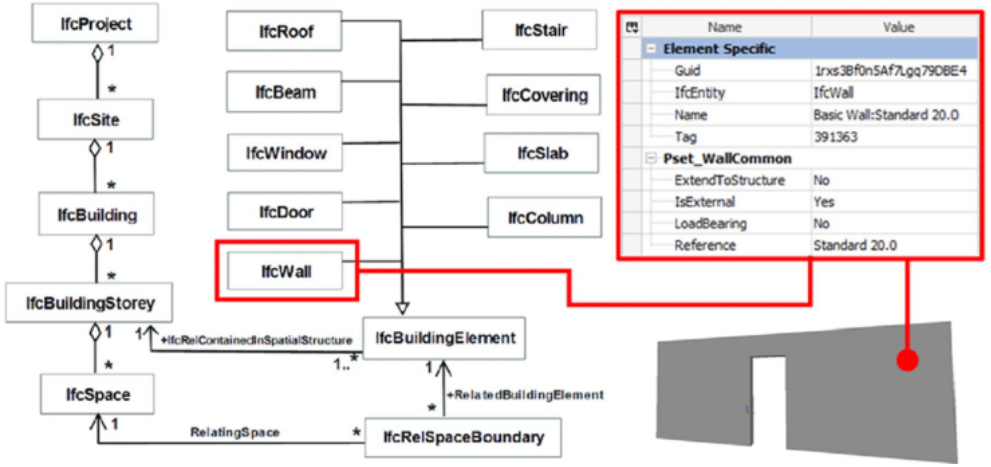


(Mahmood and Ahmad, 2015; Abdulharis, 2012, Intergrated and Modified by Author)

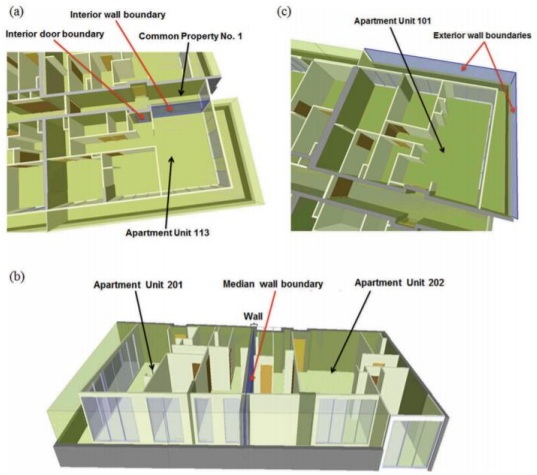


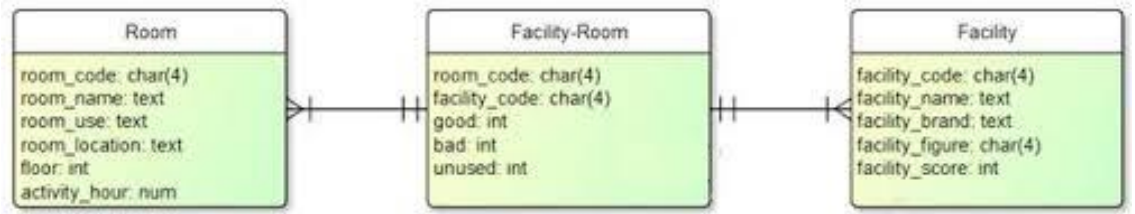
Courtesy of NIBS National Building Information Modeling Standards Committee



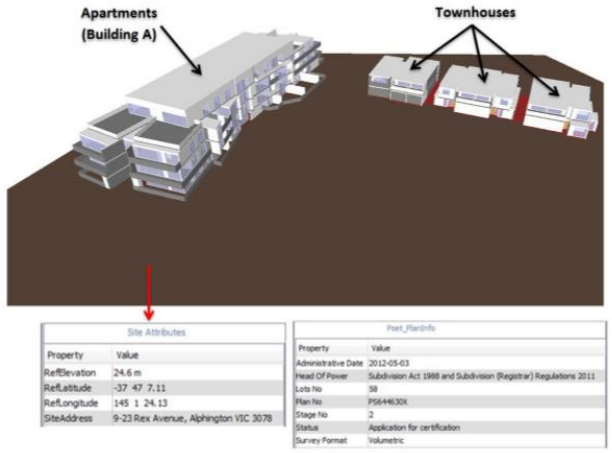


(Herley, 2020)

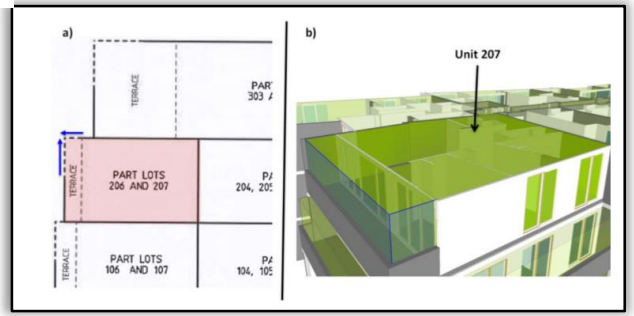


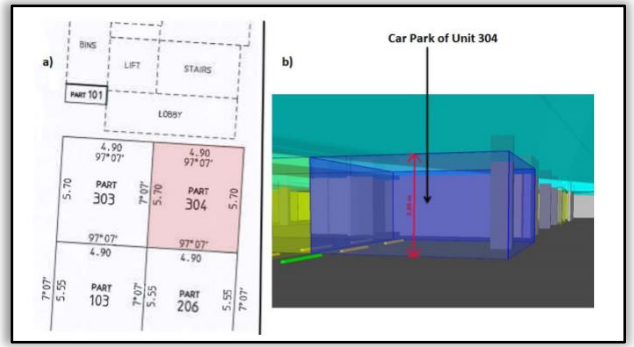


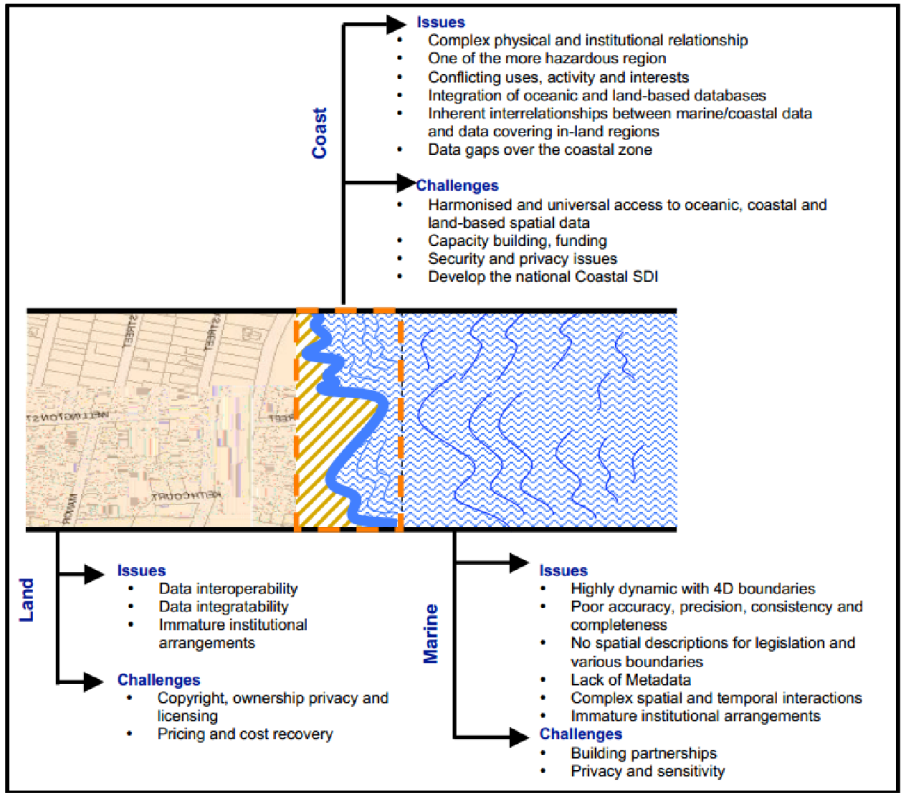
(alif et al., 2019)



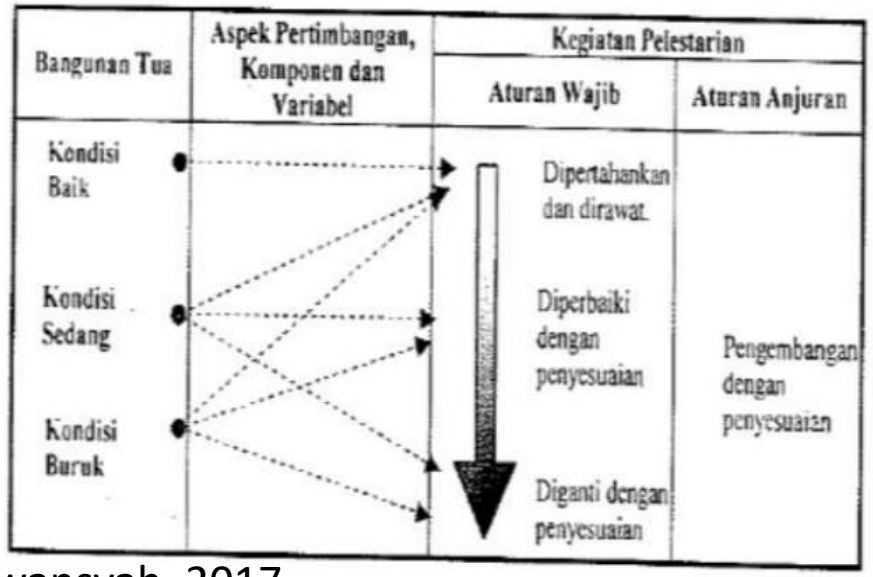
(Atazadeh, 2018)



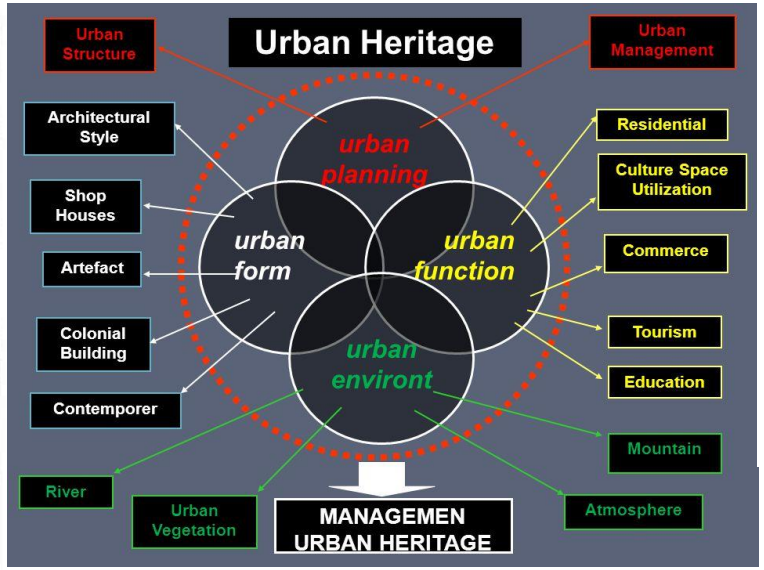




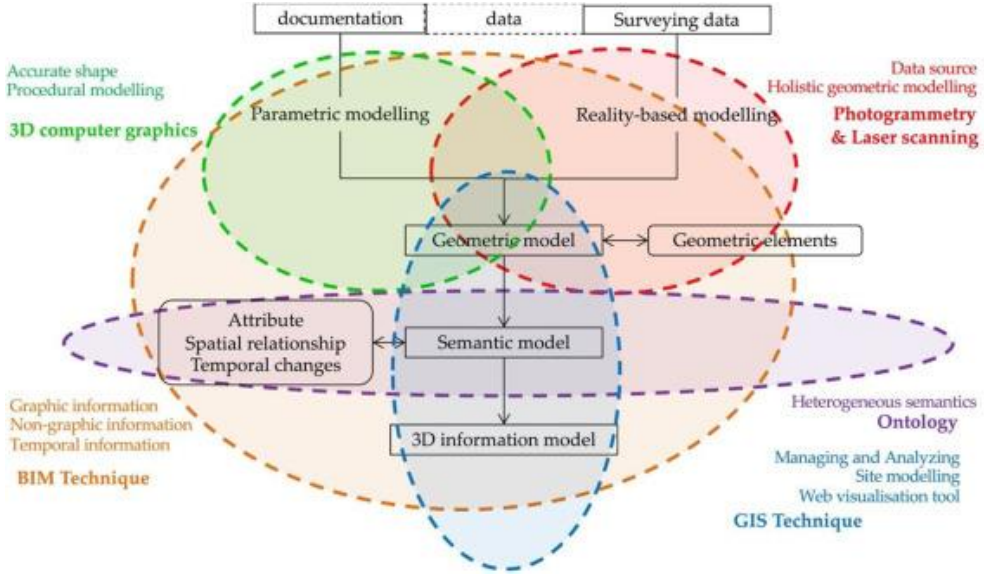
(Rajabifard, 2008)

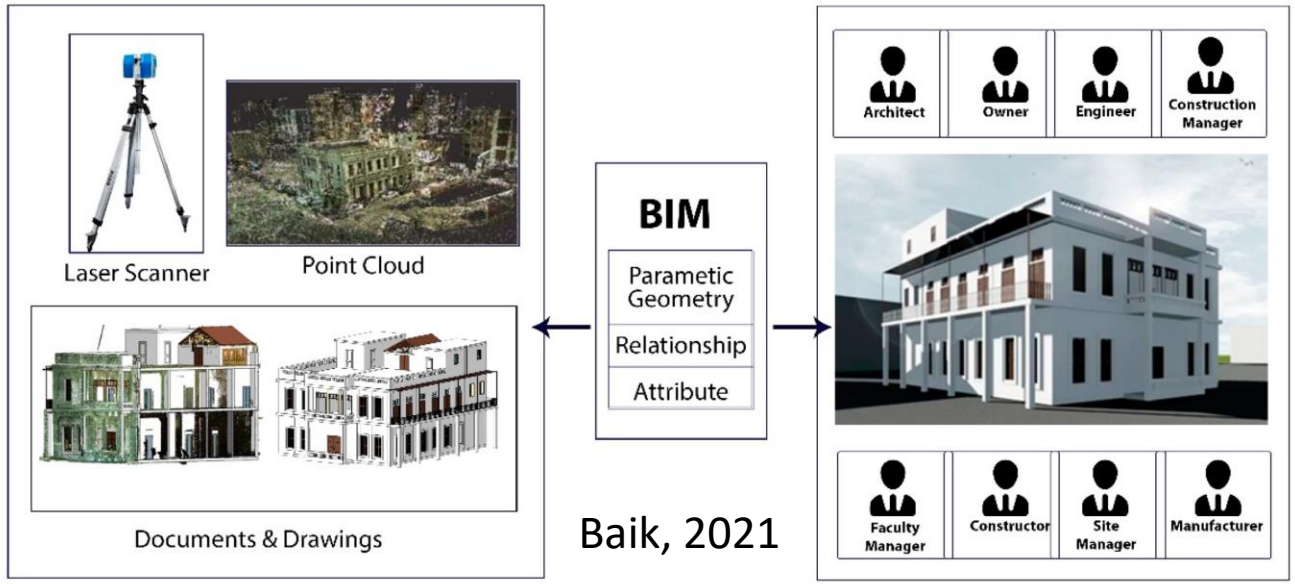


Irwansyah, 2017



Adhisakti, 2017

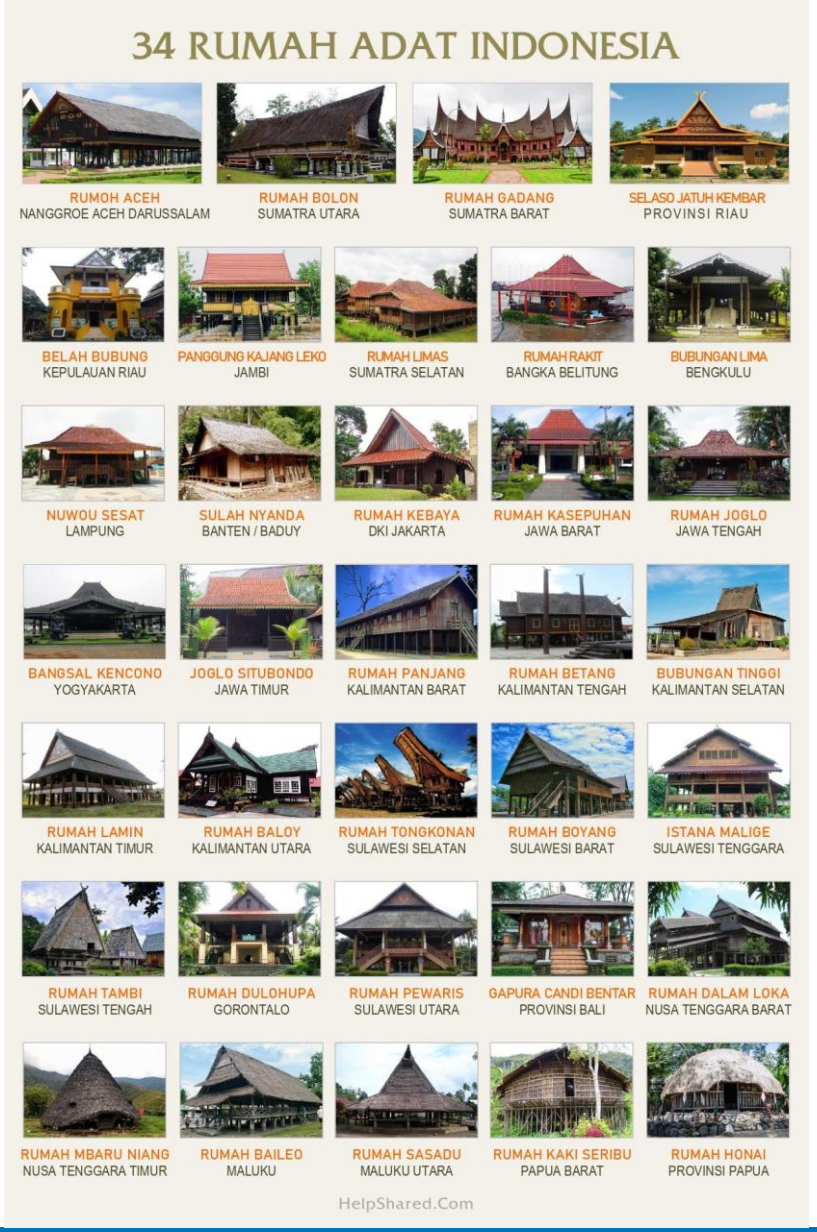




Baik, 2021

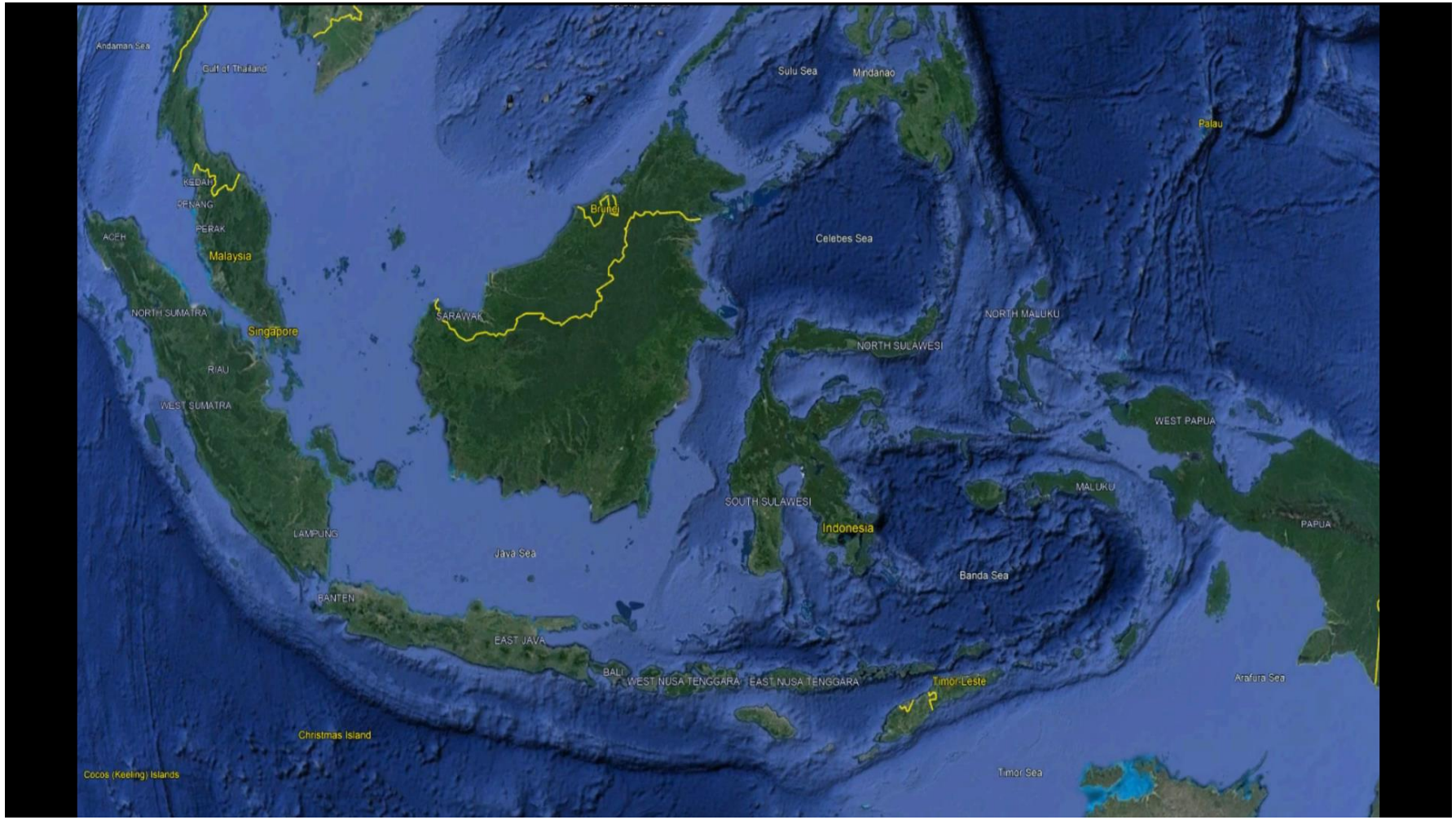
How to Implementation of 3D Cadastre in Indonesia?

More of ..
Local Languages?
Culture?
Different of Architecture?



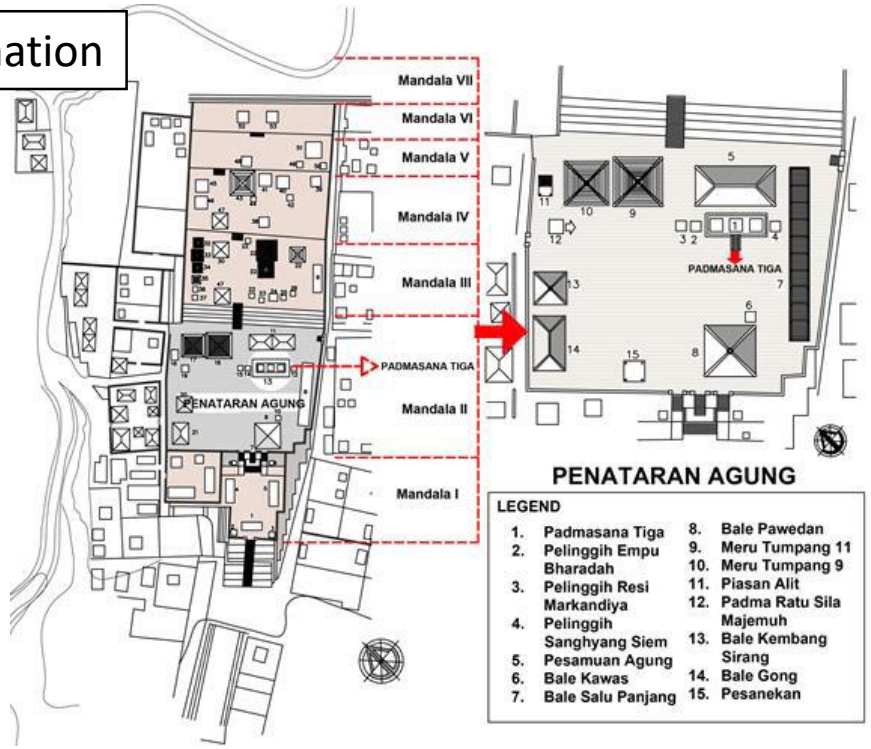
Do you have any knowledge of Bali Island?

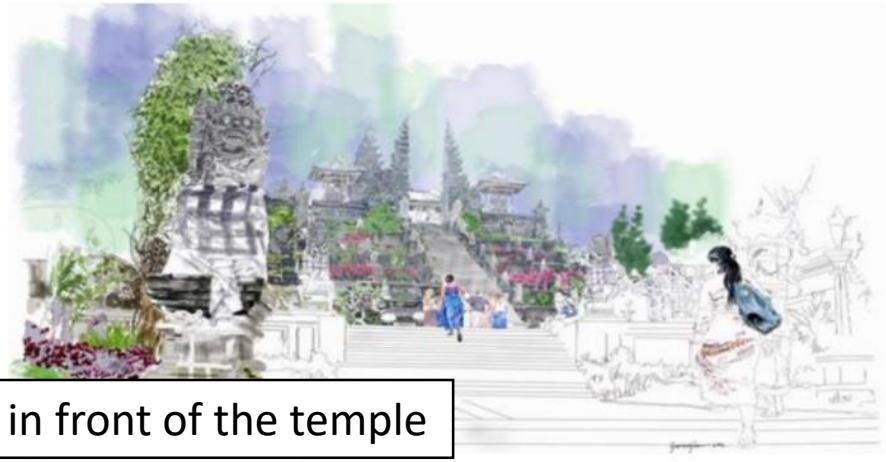
What makes Bali a unique location?



Implementing 3D Cadastre in Bali.

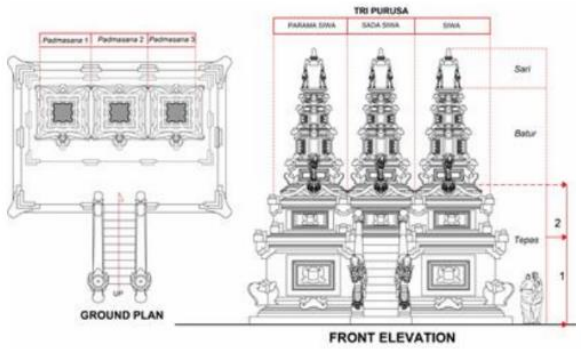
2D Information

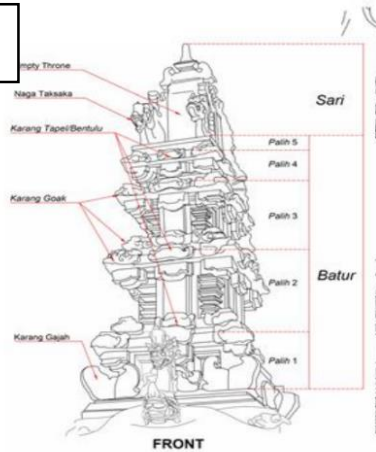


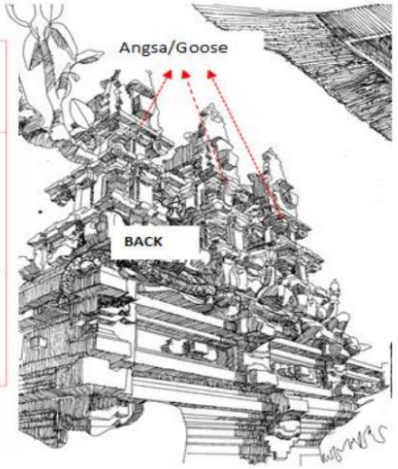


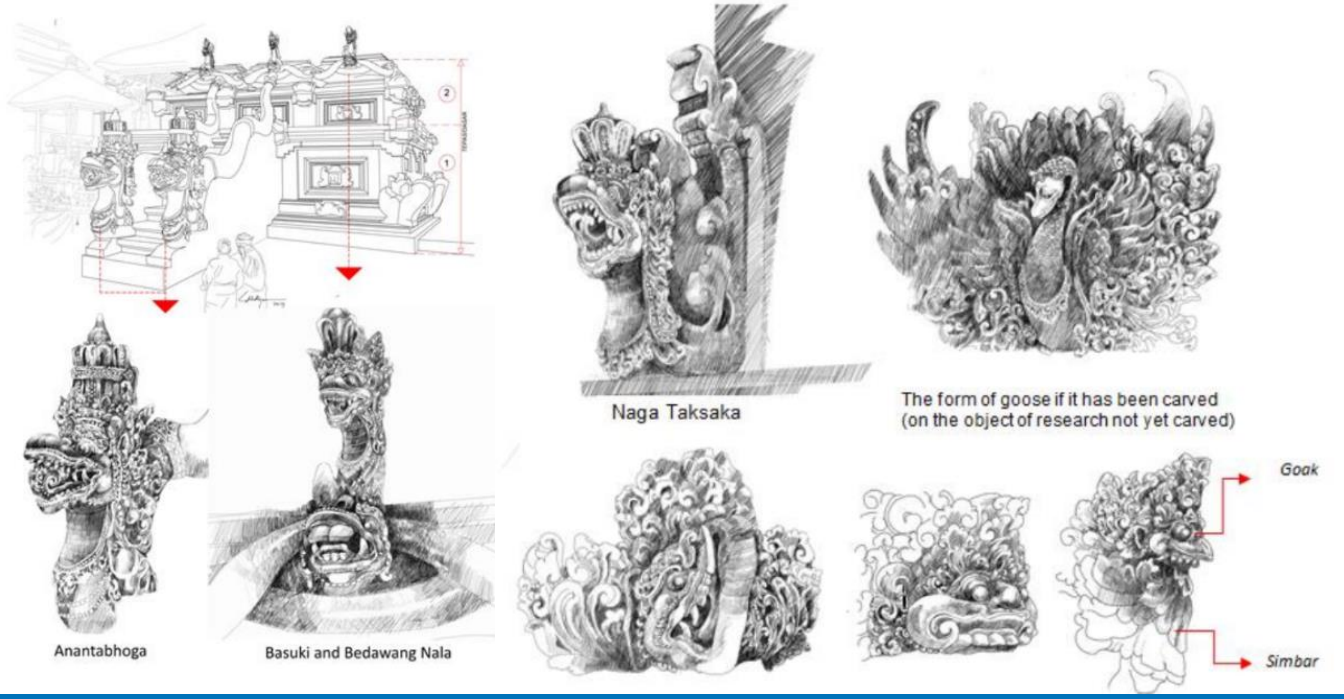
Picture in front of the temple

2,5D/3D Drawing Information









Why need implementing 3D Cadastre in Bali.

Complex Architectural Patterns and Adat Semantics.

Catusparta/Puri

Fig. 1. (a) The traditional gate in the Kesiman Palace, 2013; (b) The Majesty of Ubud Palace, Gianyar Regency, 2009; (c) the Besakih Temple, 2013; (d) the Water Palace Ujung Karangasem, 2013.

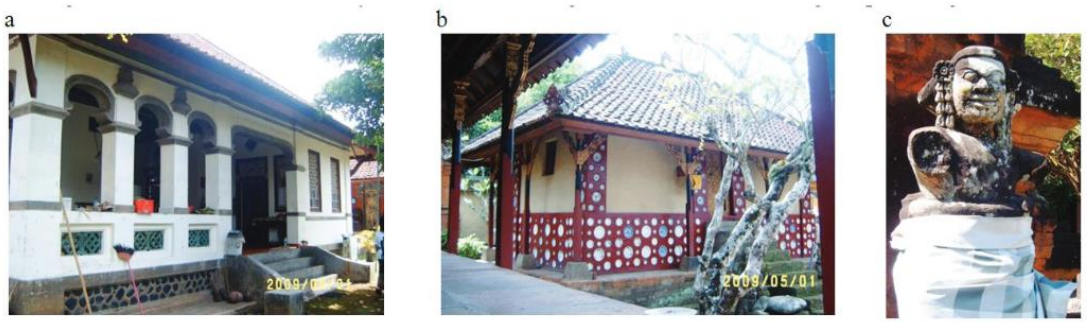


Fig. 7. (a) Colonial building style in Puri Agung Kerambitan, Tabanan Regency, 2009; (b) the using of Chinese plates decorates the traditional building in Puri Agung Kerambitan, Tabanan Regency, 2009; (c) Chinese statue as an evidence of Chinese's influence in Puri Sukawati, Gianyar Regency, 2009.

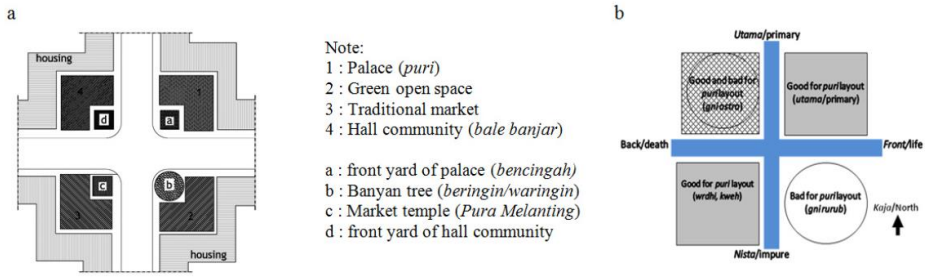


Fig. 2. (a) The palace (*puri*) in the *catuspatha* pattern (Source: Budiharjo, 1995); (b) Meaning of axis and *puri* layout alternative in the *catuspatha* pattern (Source: Putra, 2005).

(Yudantini, 2015)

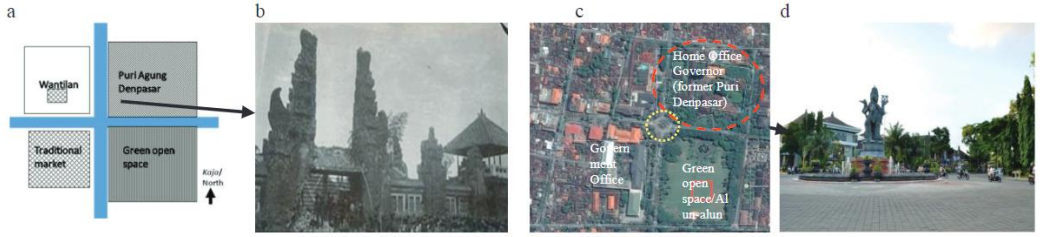


Fig. 5. (a) Cross-road of *catuspatha* pattern in Denpasar with Puri Agung Denpasar was placed in the Northeast direction (Source: Putra, 2005); (b) Puri Agung Denpasar during the Puputan Battle in 1908 (Source: KITLV); (c) the changes of Puri Agung Denpasar into government office in the *catuspatha* pattern (Source: Google Earth, 2014 and processed); (d) the *catuspatha* pattern in Denpasar City with *Caturmuka* (four faces) statue in the cross-road, 2013.

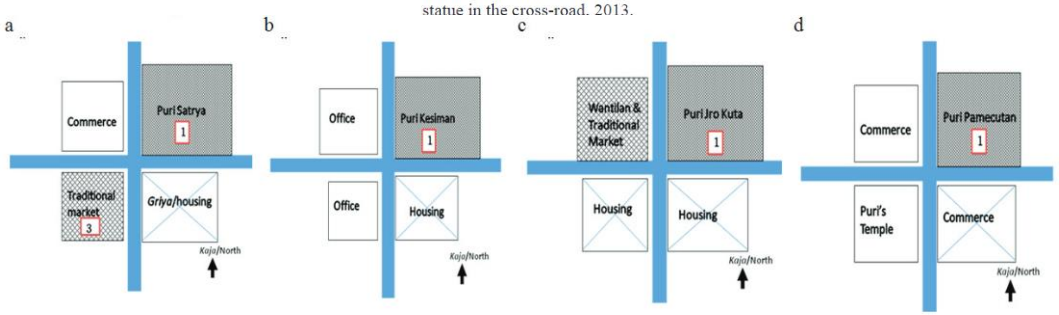


Fig. 6. (a), (b) , (c), and (d) the preservation of *puri* position in the northeast as the main value for palace and the changes it's surrounding, 2013.

Since the era of Indonesia's independence in 1945, royal power has diminished but Balinese people still maintain strong ties between aristocratic descendants and their regal associations.

To maintain a harmonious life, Bali establishes the concept of Tri Hita Karana.

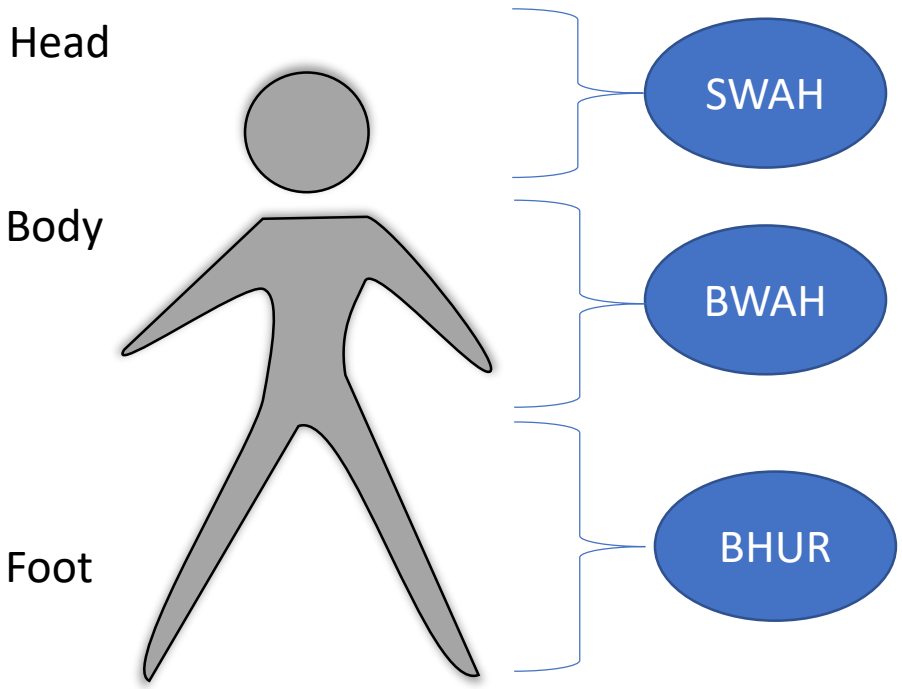
PARHYANGAN

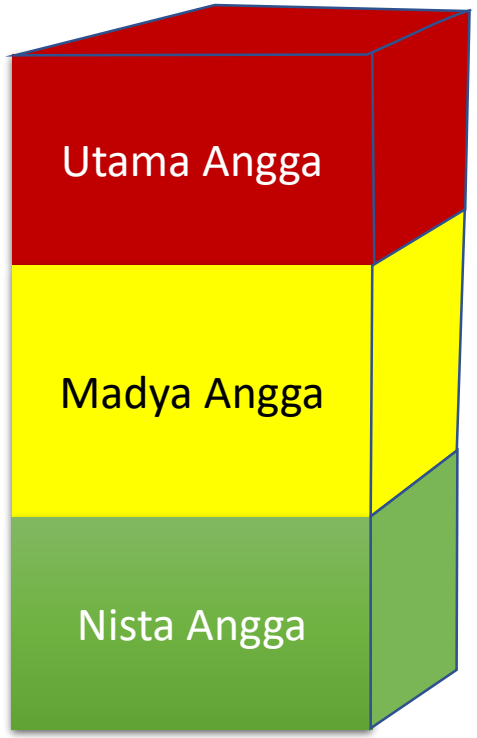
PAWONGAN

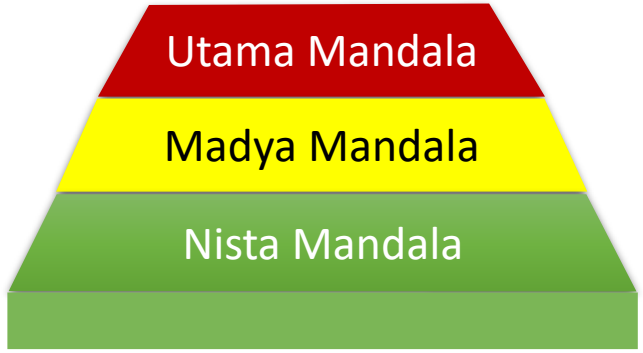
PALEMAHAN

Unsur	Atma (Jiwa)	Prana (Tenaga)	Angga (Fisik/jasmani)
Universe (Bhuana Agung)	Paramaatman (The One Almighty God)	The power that moves nature	The Five Elements of Mahabhuta
Village	Kahyangan tiga (Village Temple, Puseh, and Dalem)	Pawongan (Village people society)	Palemahan (Village territory)
Banjar	Parahyangan (Banjar temple)	Pawongan (Banjar people society)	Palemahan (Banjar territory)
House	Pamerajan/ Sanggah	Family members	Ownership boundaries
Human (Bhuana alit)	Atman (human soul)	Sabda Bayu Idep	Human body

Human — Relate — Tri Loka — Tri Angga (Vertical Zone) — Tri Mandala (Horizontal Zone)

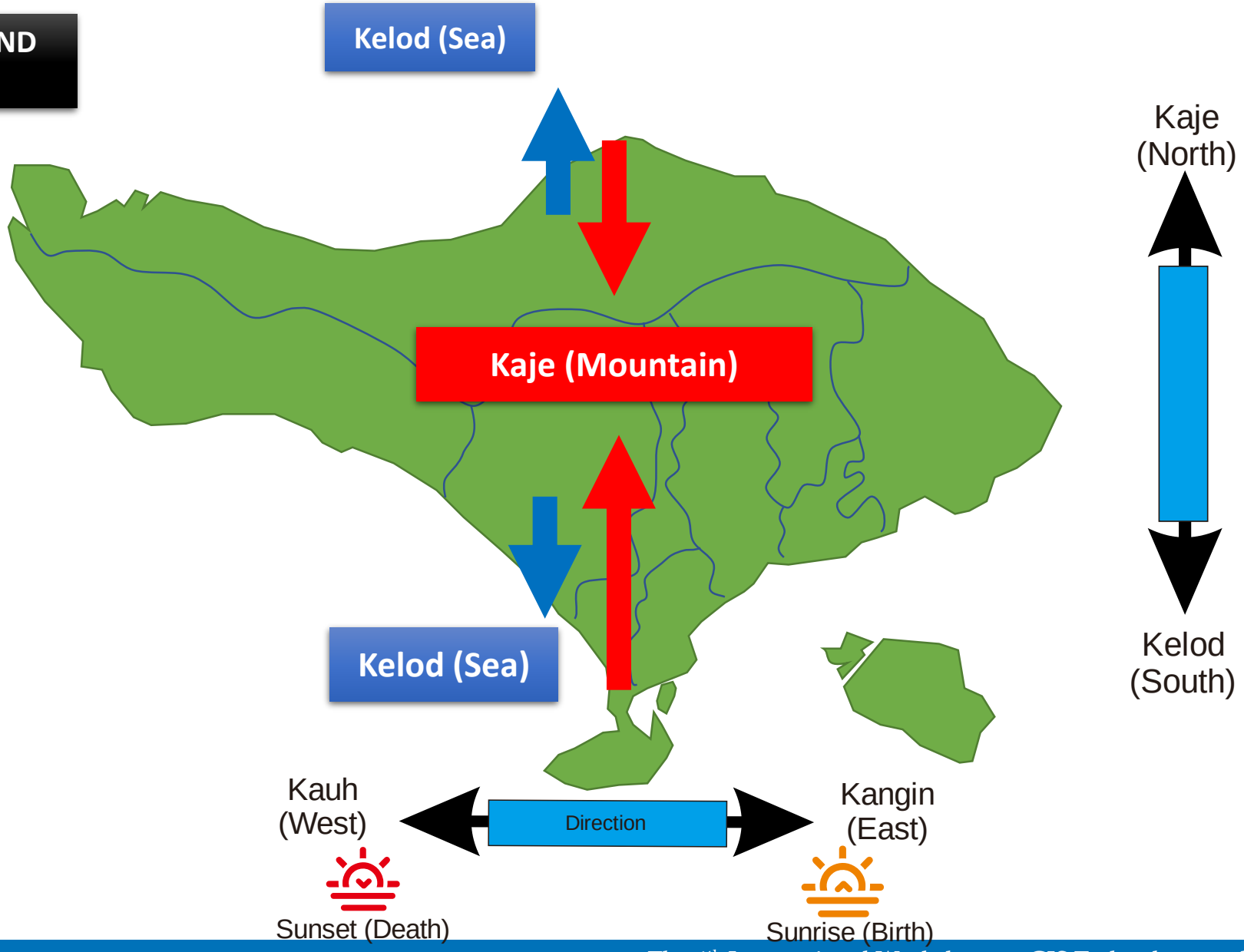




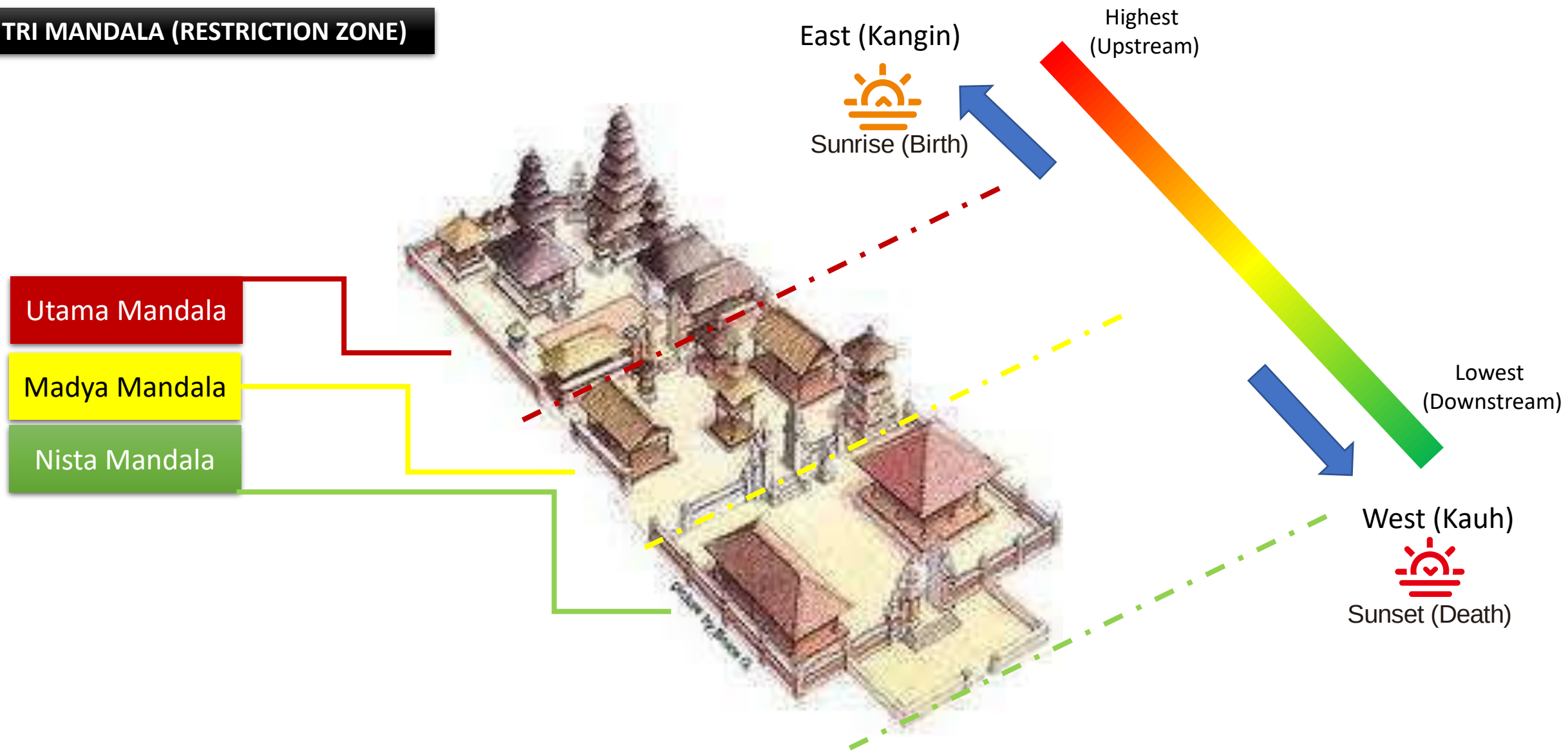


TRI MANDALA (ORIENTATION AND RESTRICTION ZONE)

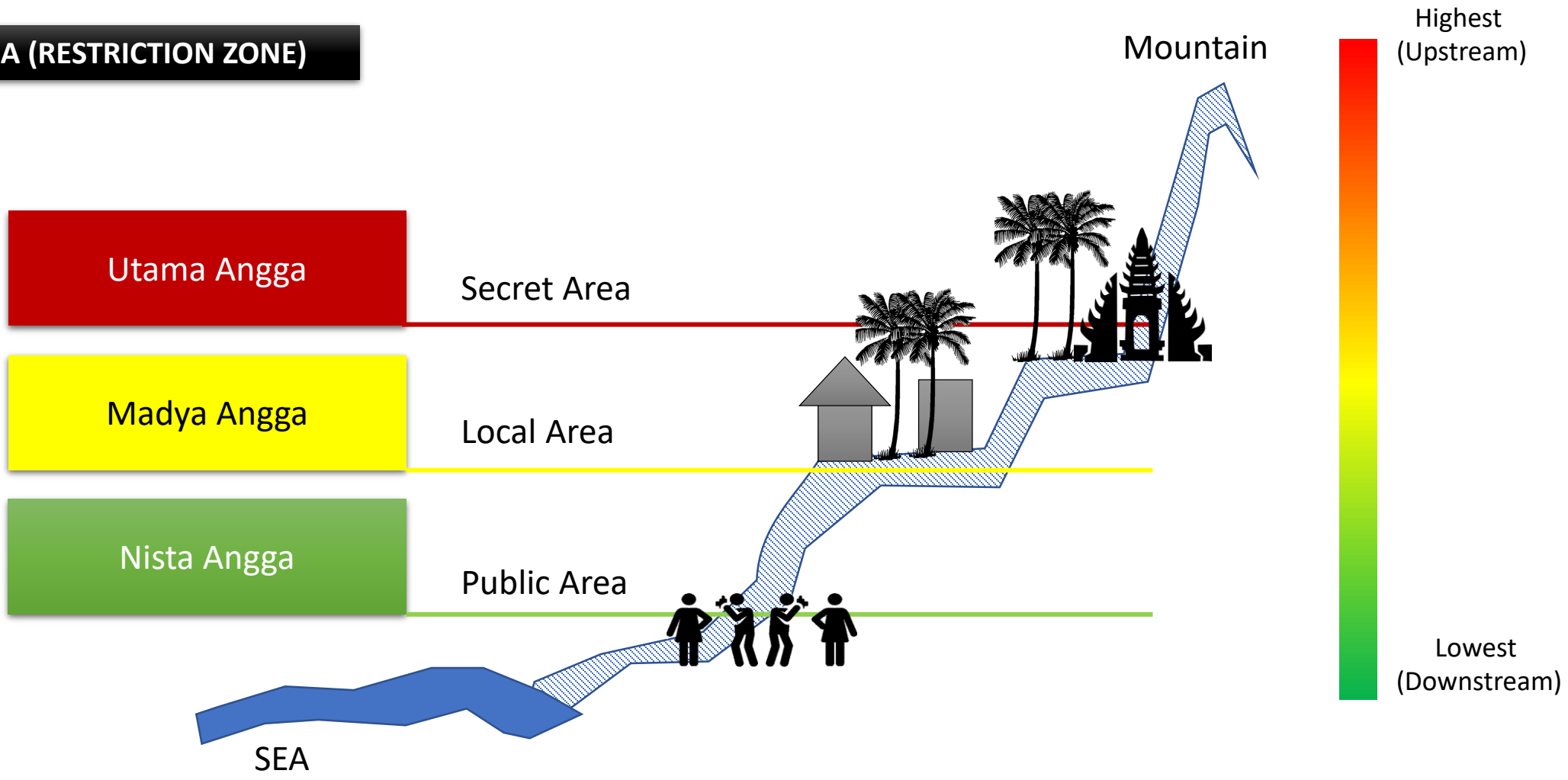
- Nista Mandala
- Madya Mandala
- Utama Mandala
- Madya Mandala
- Nista Mandala

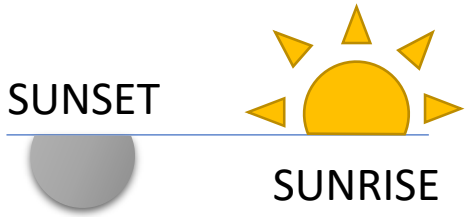


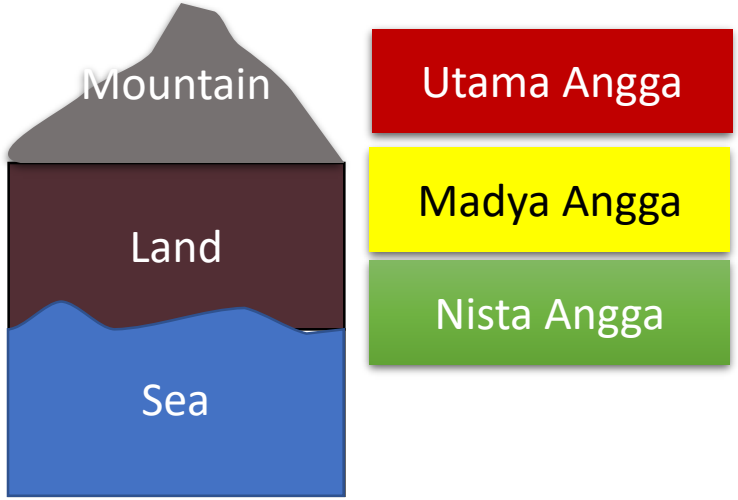
TRI MANDALA (RESTRICTION ZONE)



TRI ANGGA (RESTRICTION ZONE)

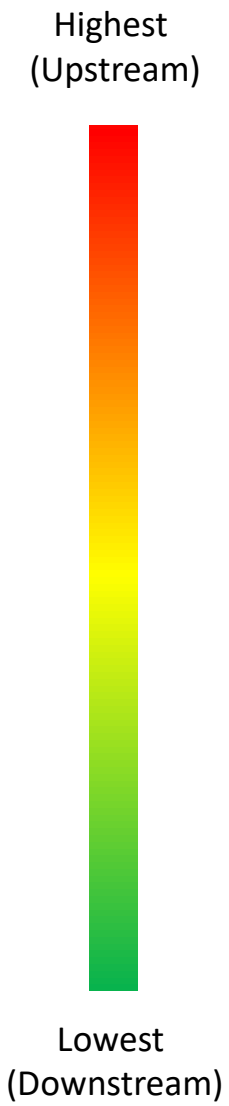






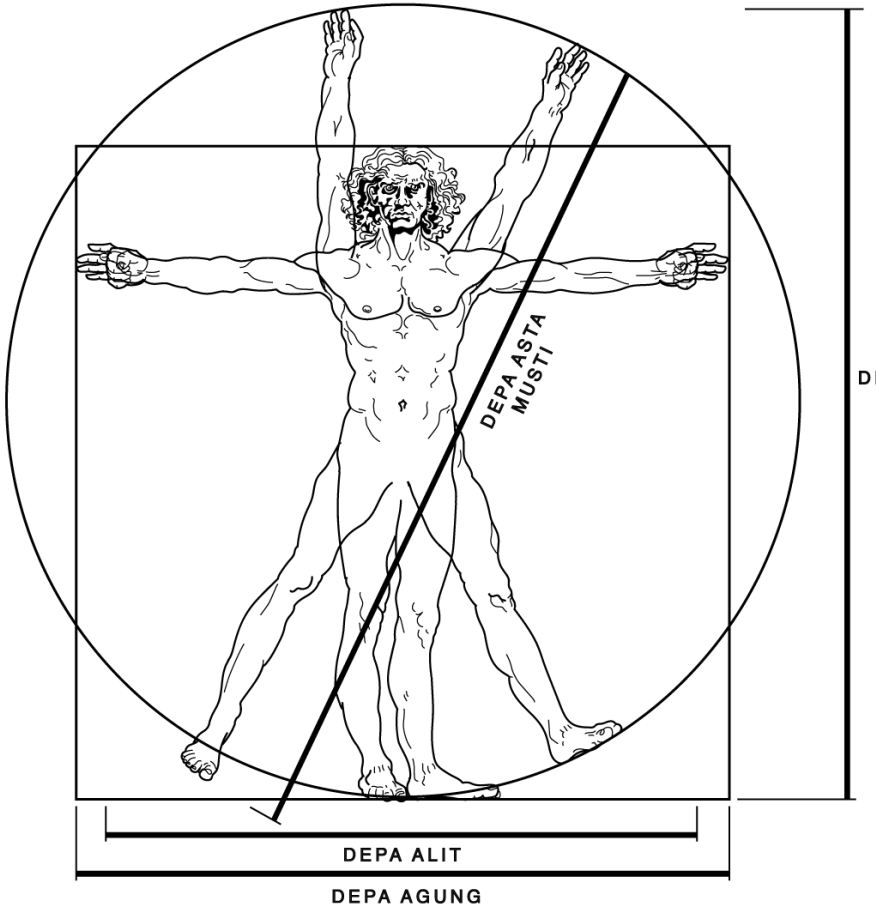
SANGGA DEWATA (RESTRICTION ZONE)

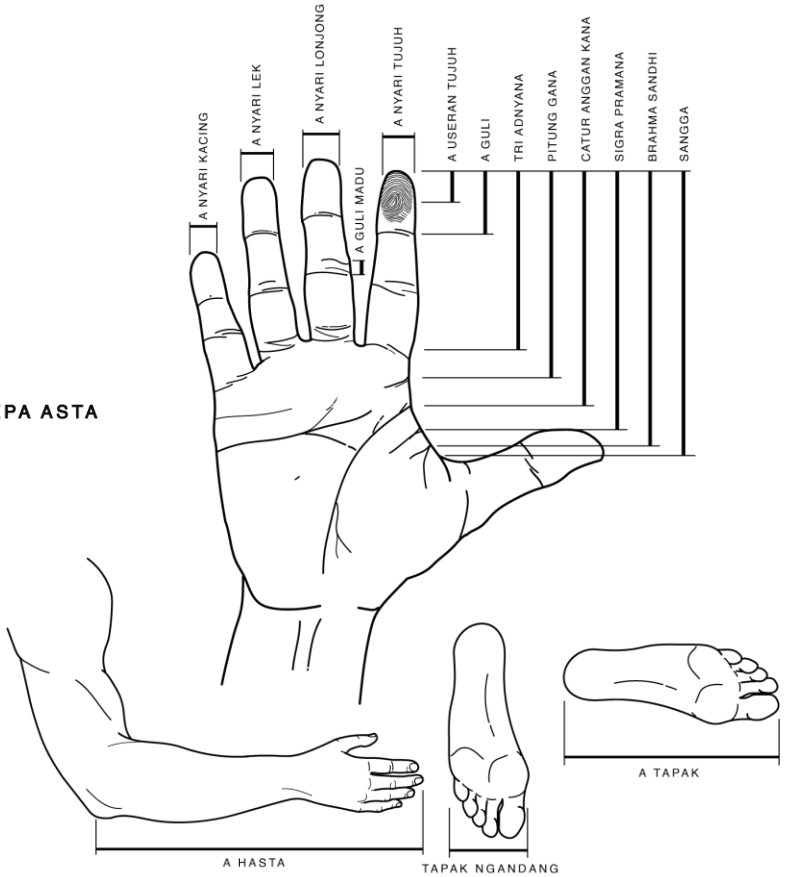
UTAMA NING NISTA	UTAMA NING MADYA	UTAMA NING UTAMA
MADYA NING NISTA	MADYA NING MADYA	UTAMA NING MADYA
NISTA NING NISTA	NISTA NING MADYA	UTAMA NING NISTA

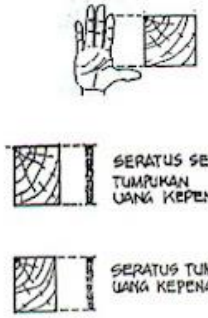


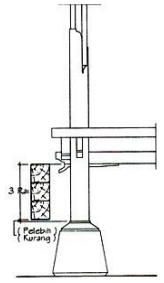
Conventional Measurement with Balinese Traditions.

The basic measurements used in traditional Balinese houses are using **Asta Kosala-Kosali and Asta Bumi lontar** instructions. The basic measurements used are based on the body size of the owner of the house, so that one Balinese house with another Balinese house has different sizes based on the elbow or the size of the owner of the house.

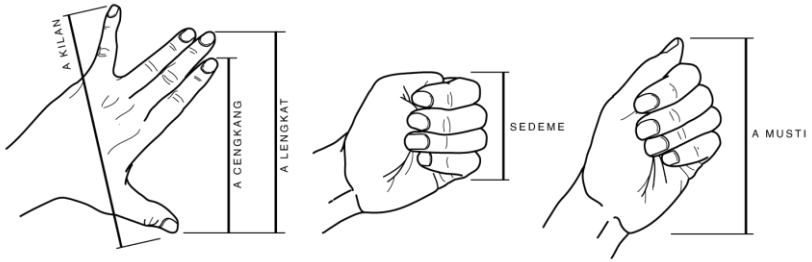


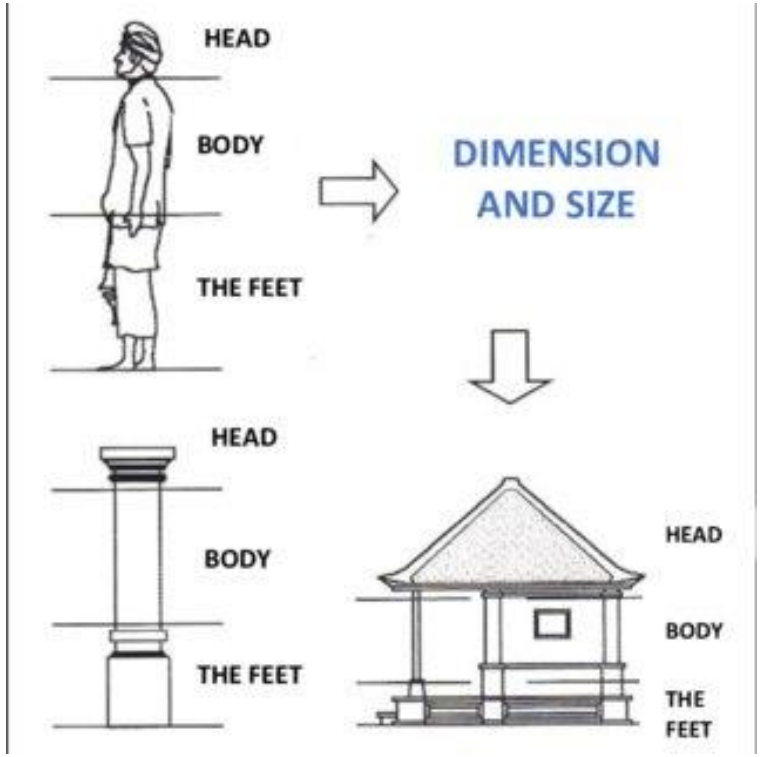


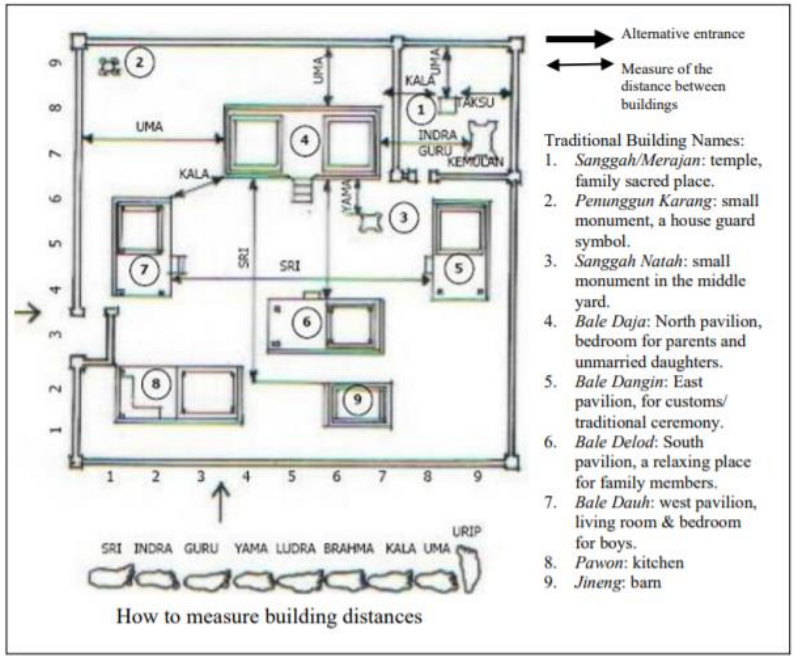
4	Rumah		Asangga Sikut satus solas Sikut satus	Utama Madya Nista



Dimensi Kaki Tiang
Sumber : Putra, I Gst Made. 2014

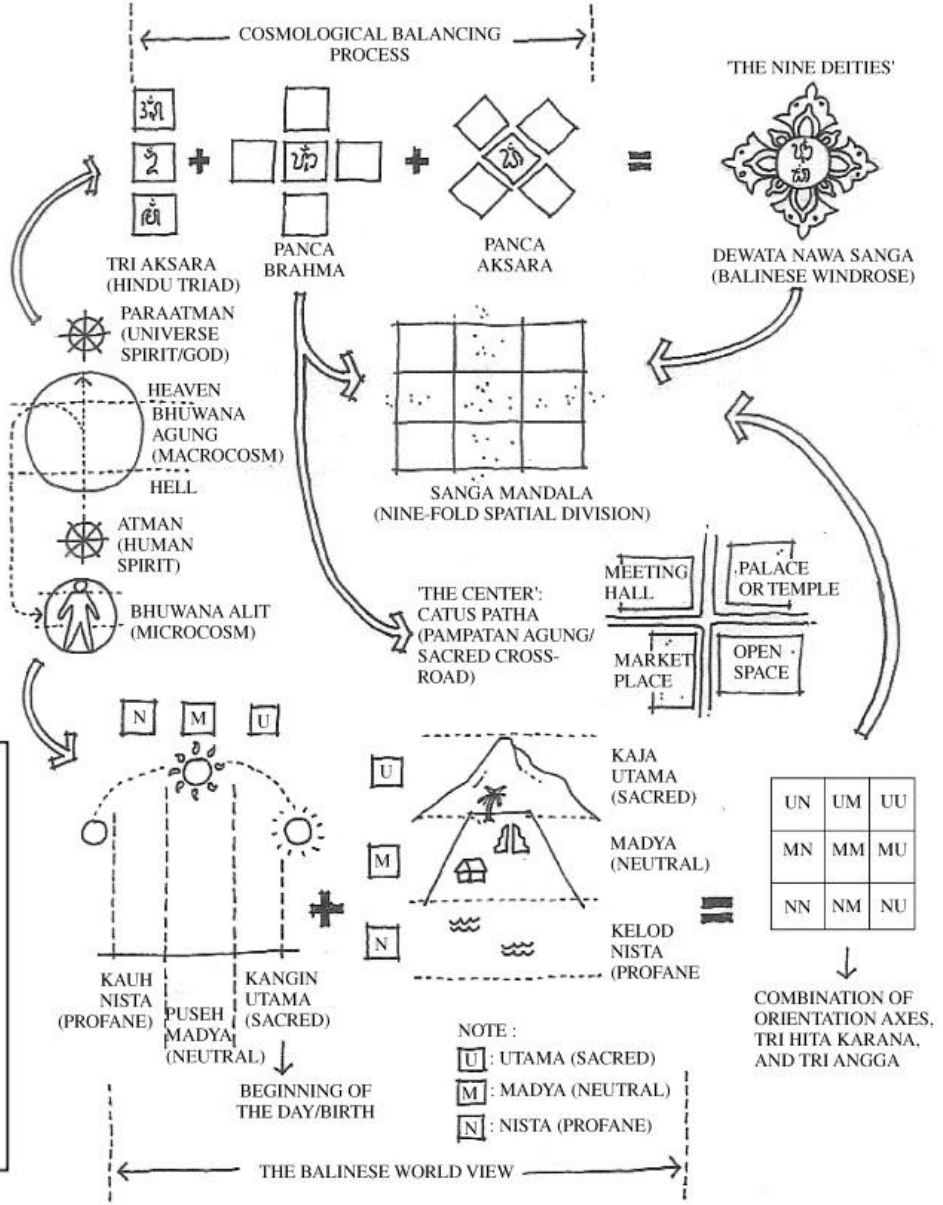


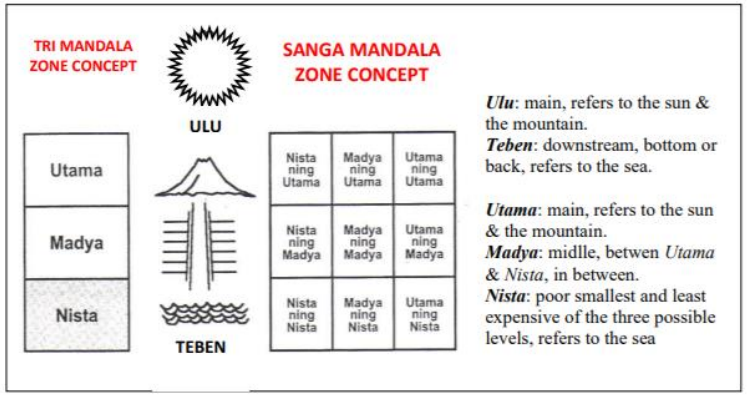




Traditional Building Names:

1. *Sanggah/Merajan*: temple, family sacred place.
2. *Penunggun Karang*: small monument, a house guard symbol.
3. *Sanggah Natah*: small monument in the middle yard.
4. *Bale Daja*: North pavilion, bedroom for parents and unmarried daughters.
5. *Bale Dangin*: East pavilion, for customs/ traditional ceremony.
6. *Bale Delod*: South pavilion, a relaxing place for family members.
7. *Bale Dauh*: west pavilion, living room & bedroom for boys.
8. *Pawon*: kitchen
9. *Jineng*: barn

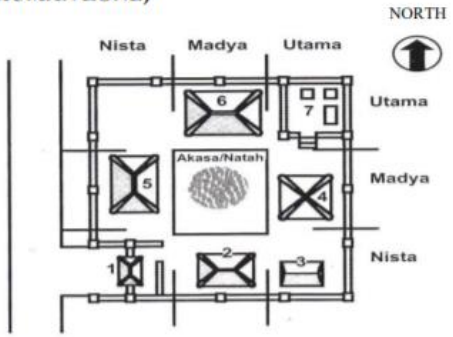




Ulu: main, refers to the sun & the mountain.
Teben: downstream, bottom or back, refers to the sea.

Utama: main, refers to the sun & the mountain.
Madya: midlle, betwen *Utama* & *Nista*, in between.
Nista: poor smallest and least expensive of the three possible levels, refers to the sea

ZONA PAWONGAN
(HUMAN ZONE)



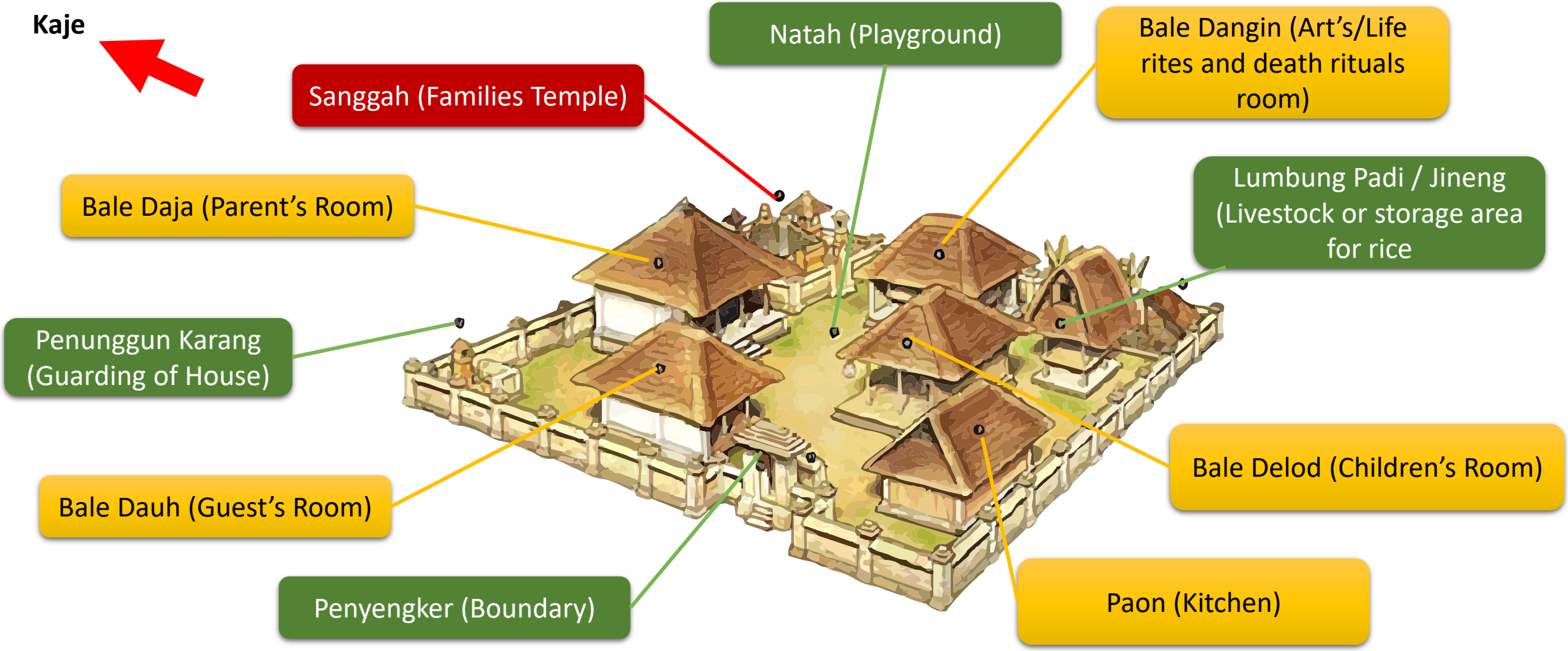
1. *Angkul-angkul*: gate
2. *Pawon*: Kitchen
3. *Lumbung*: barn
4. *Bale Gede*: pavilion for cuctoms/ traditional ceremony
5. *Bale Dauh:* west pavilion
6. *Bale* Meten: pavilion for sleep
7. Sanggah: family temple

Utama: main.
Madya: middle, in between.
Nista: poor smallest and least expensive of the three possible levels

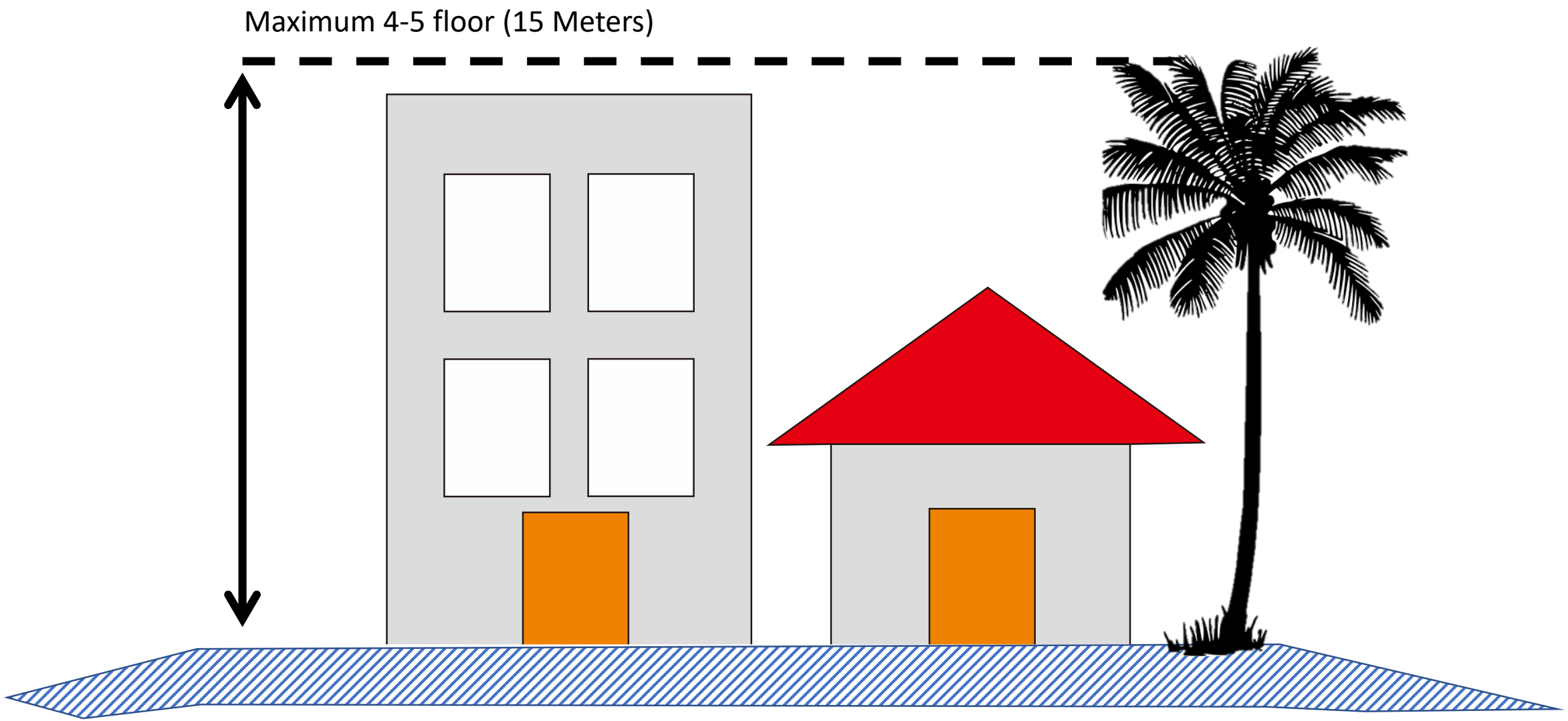
Aksara/Natah: emptyness

SANGGA DEWATA (RESTRICTION ZONE)

Utama Mandala | Madya Mandala | Nista Mandala

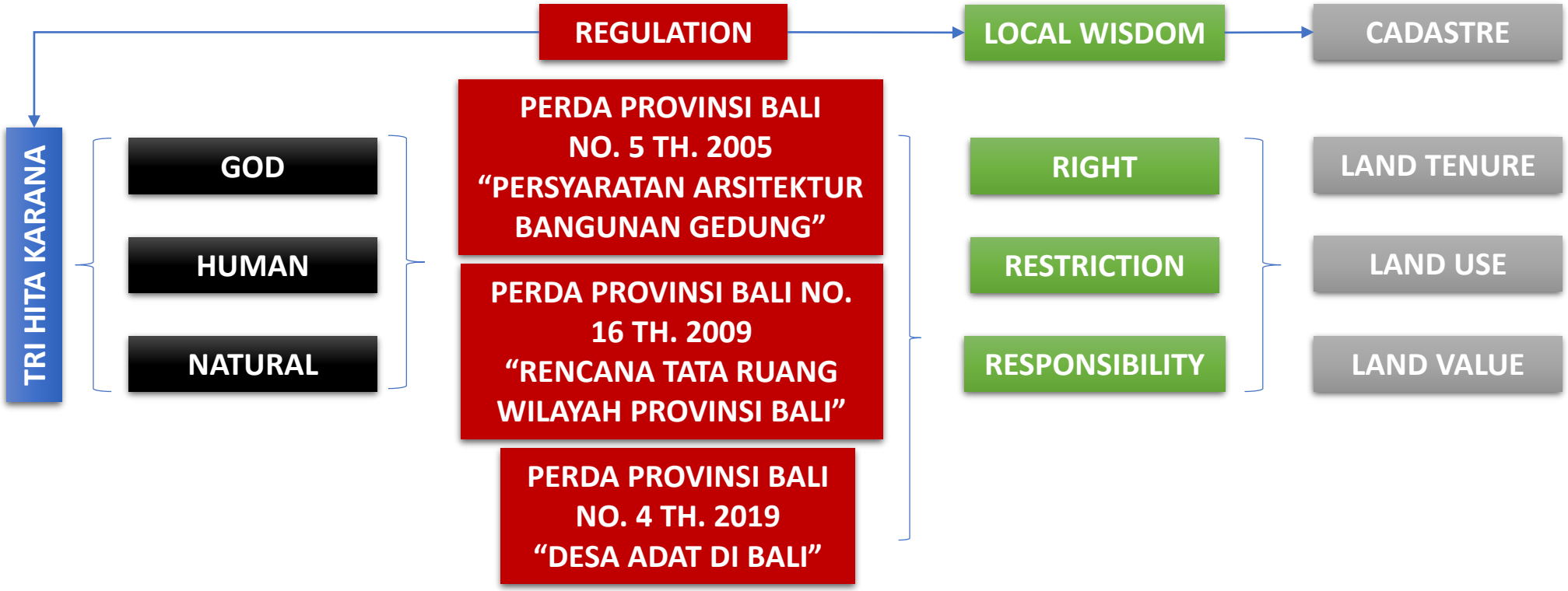


BUILDING HEIGHT (RESTRICTION ZONE)



"The Province of Bali regional regulation number 16 of 2009"

TRI HITA KARANA CONCEPT IN 3D CADASTRE



The Architecture Bali → **REGULATION** → **PERDA PROVINSI BALI NO. 5 TH. 2005 "PERSYARATAN ARSITEKTUR BANGUNAN GEDUNG"**

TRI HITA KARANA

- Bale Kaja
- Bale Kelod
- Bale Kangin
- Paon
- Bale Kauh
- Lumbung
- Sanggah
- Penunggun Karang
- Angkul-Angkul

Bale Kaja

Bale Kelod

Bale Kangin

Bale Kauh

Paon

Lumbung

Sanggah

Penunggun Karang

Angkul-Angkul

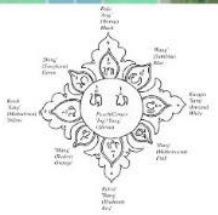
Homogeneous spatial pattern.

ASTA KOSALA KOSALI

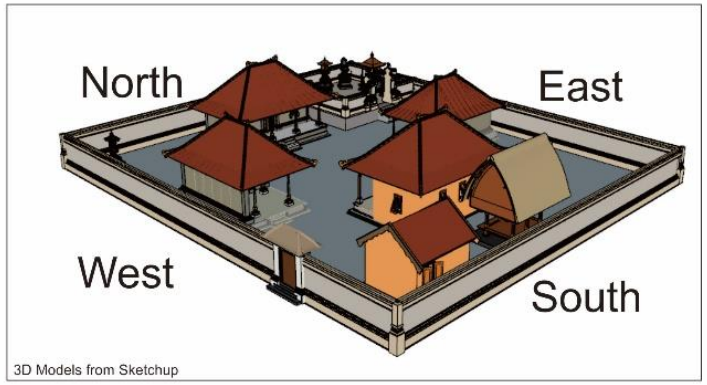
TRADISIONAL LAND USE

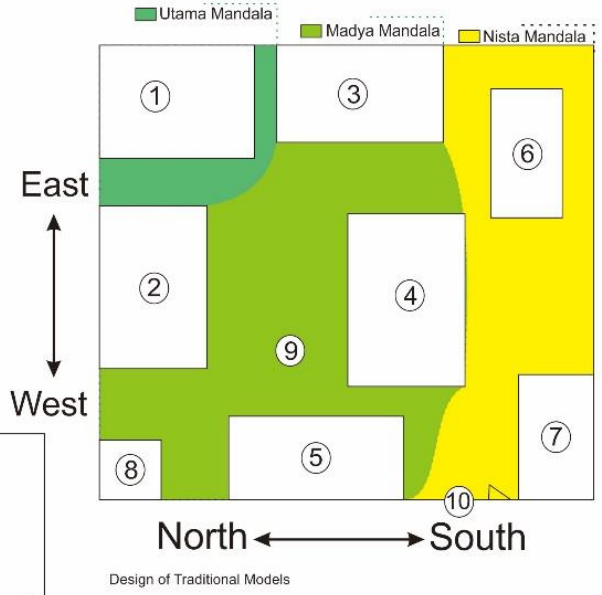
Orthophoto in Siangan Village, Gianyar, Bali
Land Use Concept of Tri Hita Karana

1. Sanggah (Temple Families)
2. Bale Kaja
3. Bale Kangin
4. Bale Kelod
5. Bale Kauh
6. Lumbung
7. Paon (Kitchen)
8. Padmasana (God)
9. Natah
10. Penyengker (Boundary)



Traditional House Concept in Bali





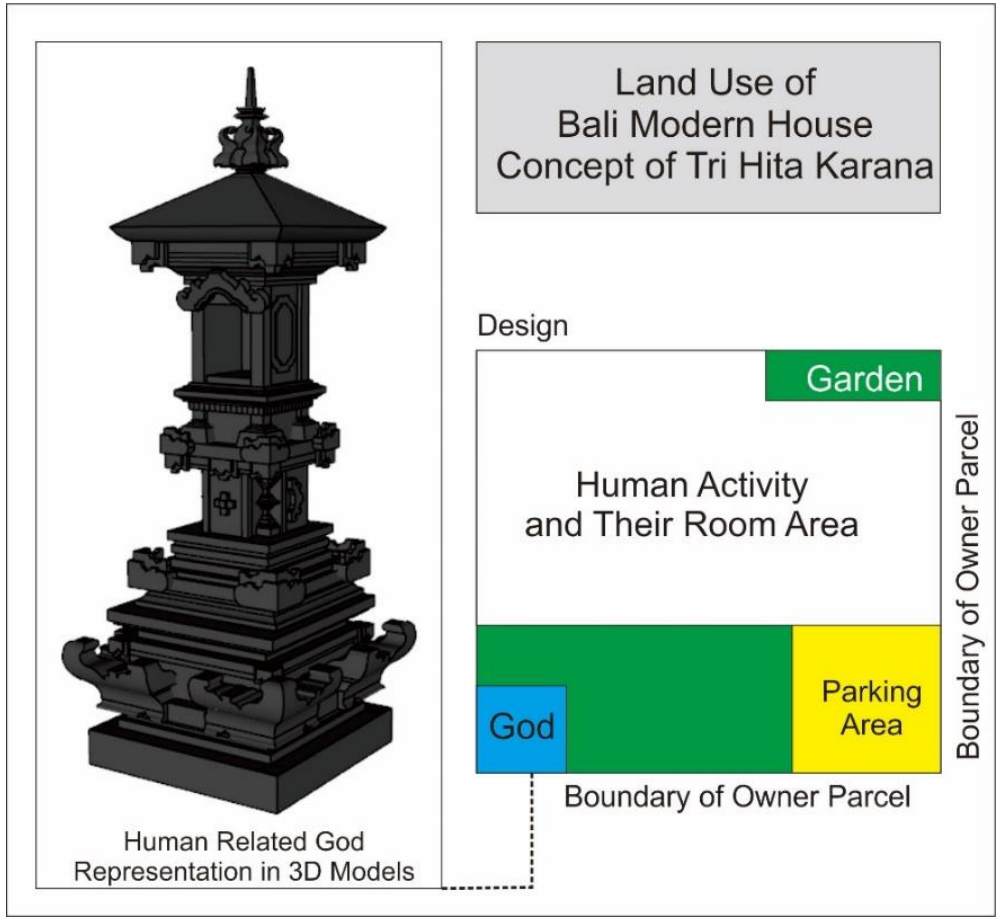
1. Sanggah (Temple Families)
2. Bale Kaja
3. Bale Kangin
4. Bale Kelod
5. Bale Kauh
6. Lumbung
7. Paon (Kitchen)
8. Padmasana (God)
9. Natah
10. Penyengker (Boundary)

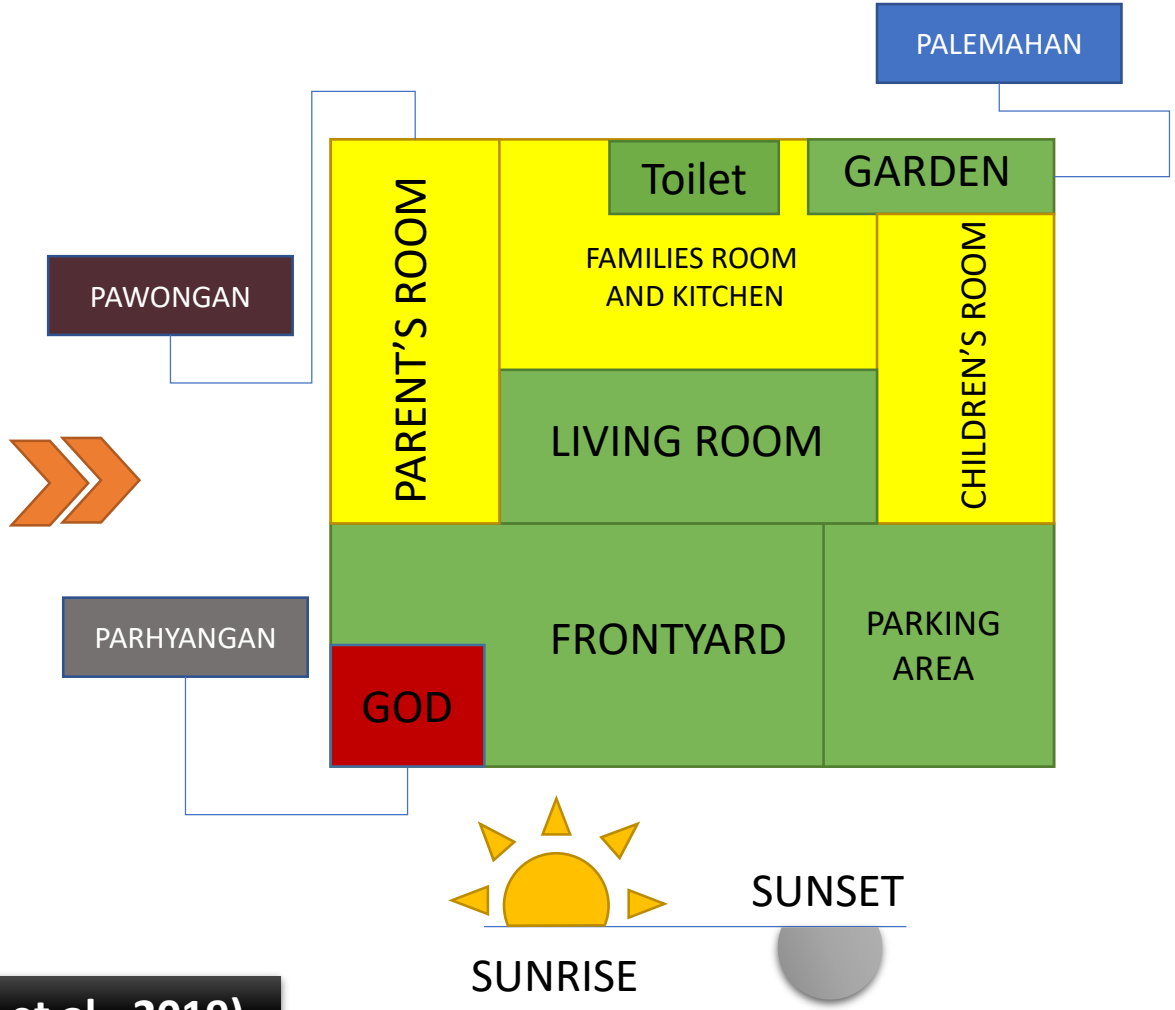
(Suhari et al., 2019)

Homogeneous spatial pattern.

MODERN MINIMALIST HOUSE LAND USE

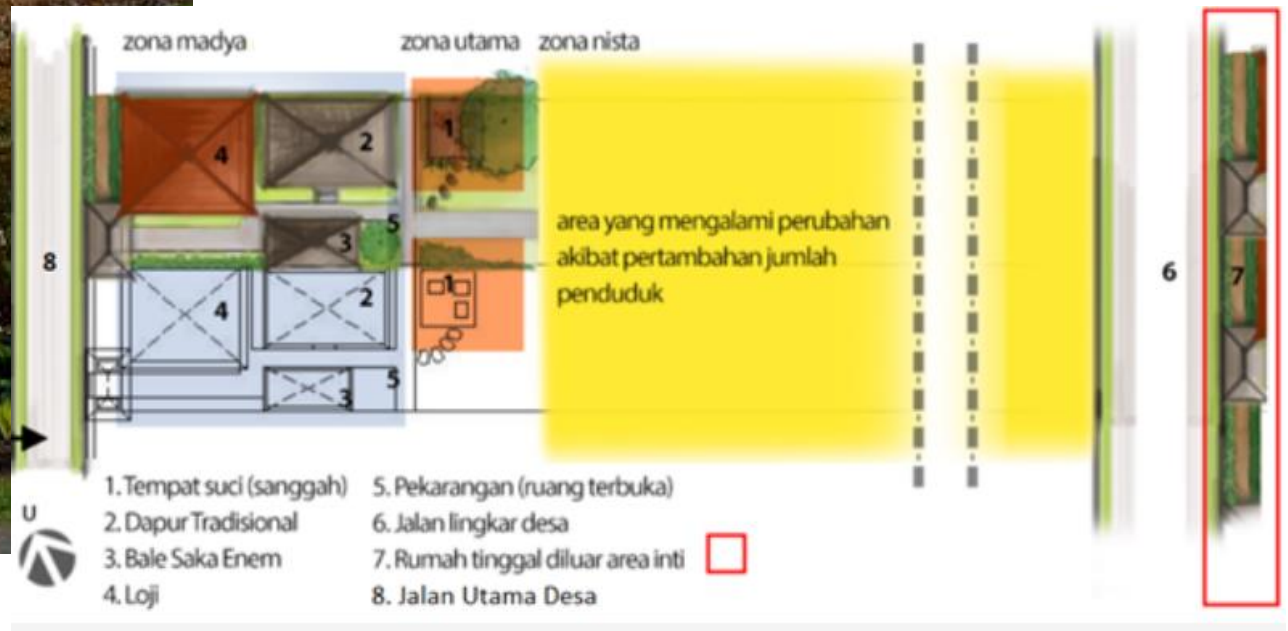
Utama Mandala | Madya Mandala | Nista Mandala



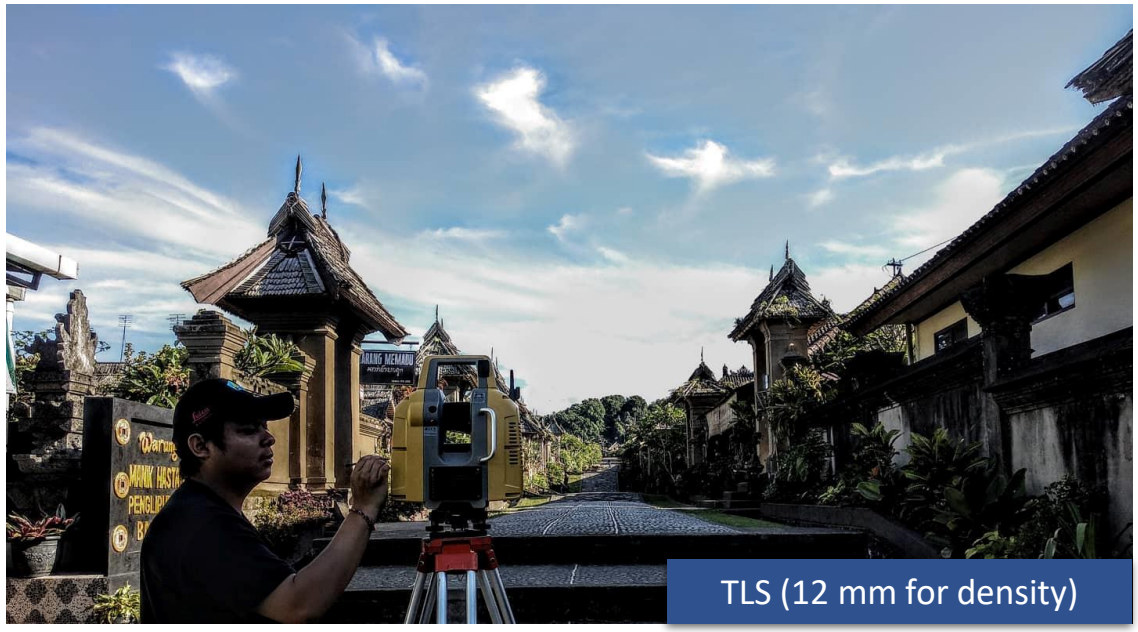


(Suhari et al., 2019)

The traditional Penglipuran village with its distinctive Penglipuran traditional Balinese spatial layout and building architecture has become a unique tourist destination and has been designated as a tourist village by the Bali Regional Government since 1992 (Astuti, 2002 in the writing of Kasuma and Suprijanto, 2012)



High Definition Surveying



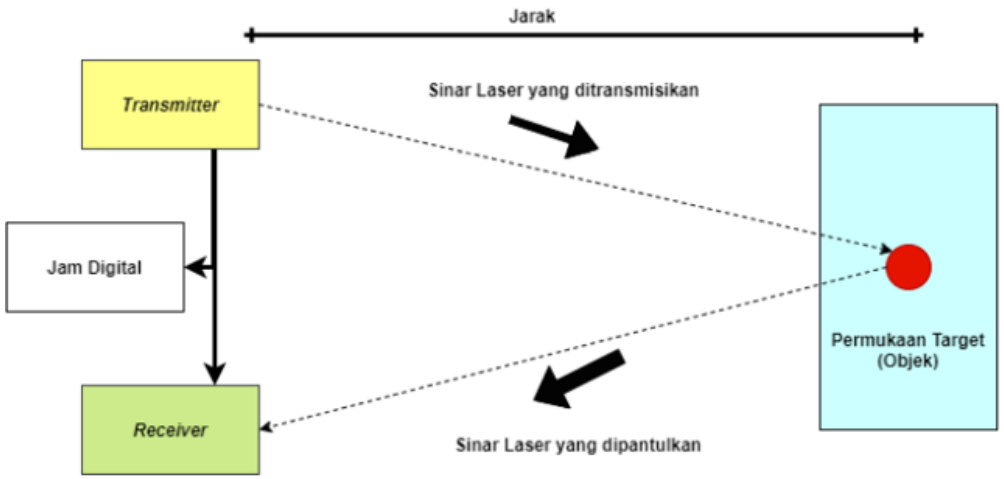
TLS (12 mm for density)

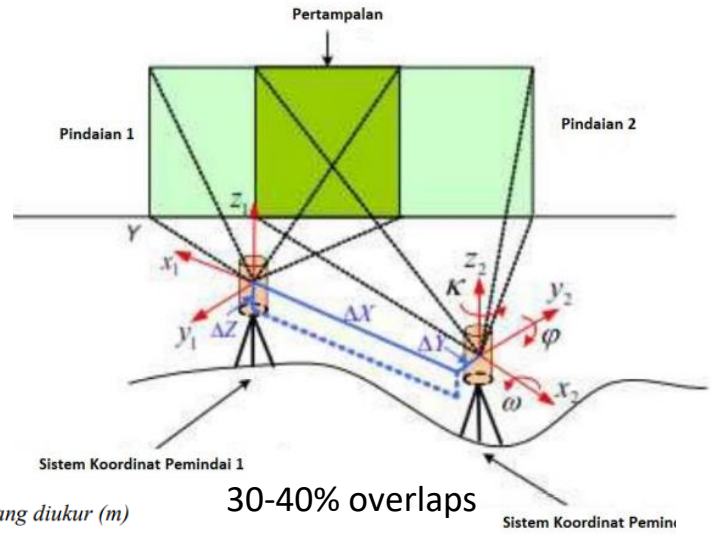
Gnss Observations (3 hours) – (E=0,3mm, N=0,3mm, H=1mm)

HLS for detail

Photogrammetry (3D Acquisition) H=70m, FO=75%, SO=65%, RMSE = 0.196 R=1,89cm/px

Integration of point clouds from TLS and Orthophoto
RMSE = 0.003m or 3 mm





30-40% overlaps

Nilai toleransi kesalahan $= 1{,}96\sigma$

σ = *single point positional accuracy*

(Soeta'at, 2003)

$$RMSE = \sqrt{\frac{\sum(R - R_1)^2}{n}}$$

(Wibowo, 2013)

RMSE = *Root Mean Square Error*

R = *Nilai yang dianggap benar*

R_1 = *Nilai hasil ukuran*

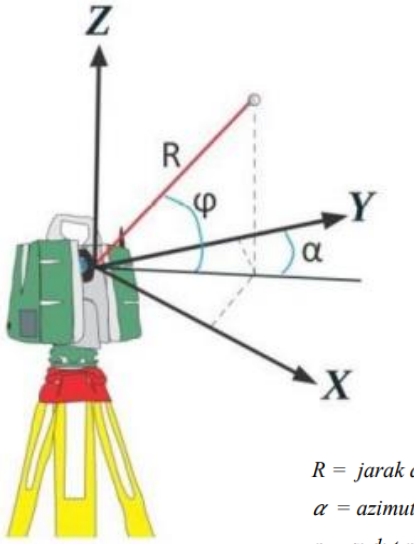
n = *Banyak ukuran yang digunakan*

$$R = \frac{C \times T}{2}$$

R = Jarak antara sensor dengan setiap objek titik yang diukur (m)

C = Konstanta kecepatan cahaya (299.792.458 m/s)

T = Selang waktu tempuh laser (nanosekon)



$$X = R.\cos(\varphi).\cos(\alpha)$$

$$Y = R.\cos(\varphi).\sin(\alpha)$$

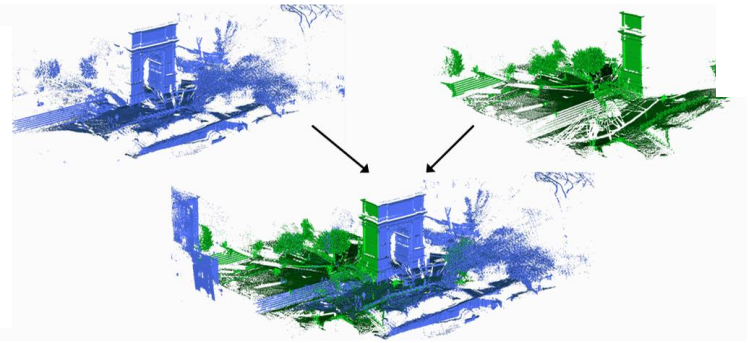
$$Z = R.\sin(\alpha)$$

R = jarak dari alat ke titik target (m),

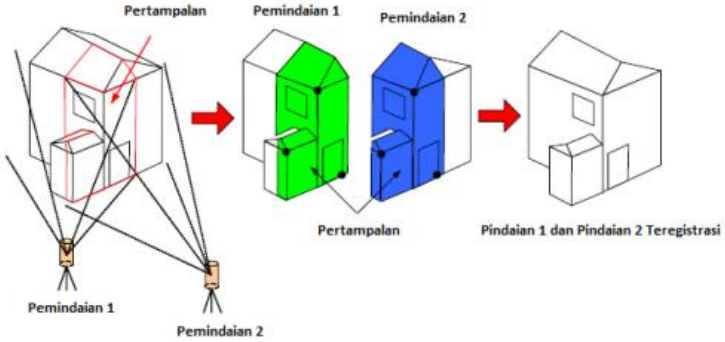
α = azimuth dari alat ke titik target : sumbu Y mengarah ke utara ,

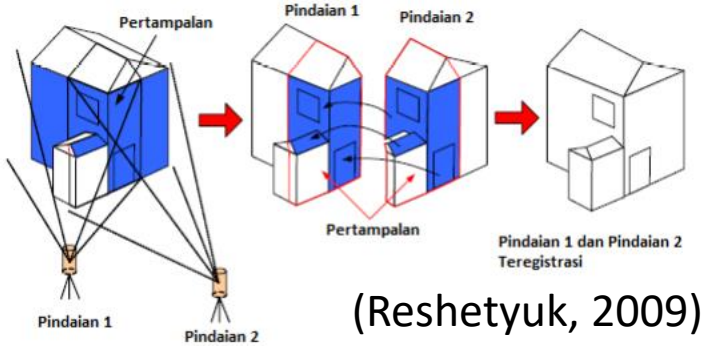
φ = sudut miring yang dibentuk oleh bidang horizontal alat dengan titik target.

Registration of Point Cloud

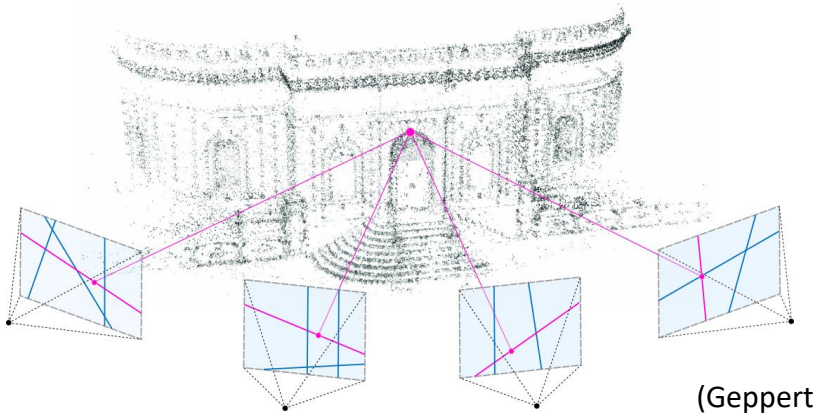


(Theiler, 2012)

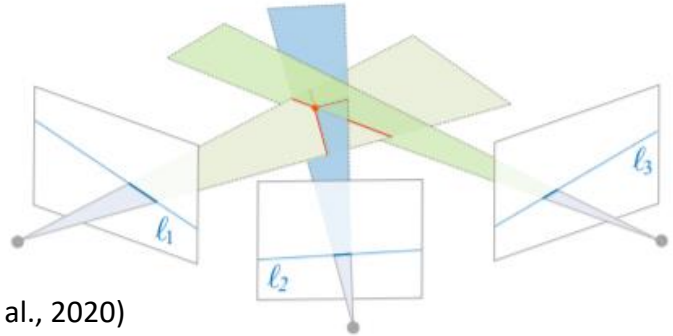




(Reshetyuk, 2009)



Triangulation



(Geppert et al., 2020)

Bundle Adjustment:

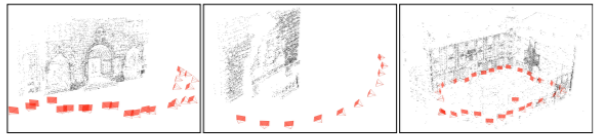
$$r_{ij}^2 = \frac{\left(\boldsymbol{n}^T \pi(R_i \boldsymbol{X}_j + t_i) + \alpha\right)^2}{\boldsymbol{n}^T \boldsymbol{n}} \quad \text{where} \quad \boldsymbol{\ell}_{ij} = (\boldsymbol{n}, \alpha)^T$$

Minimum Error:

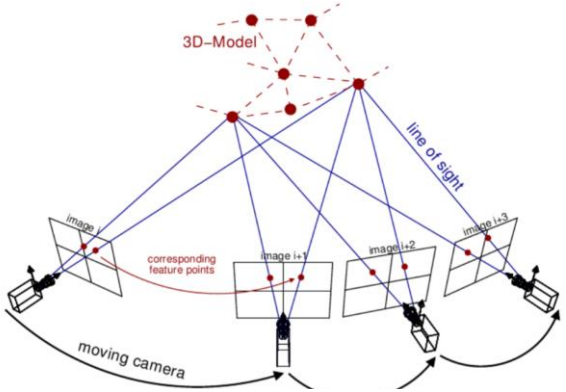
$$\min_{\{R_i,t_i\},\{X_j\}} \sum_{i,j} r_{ij}^2 \ .$$

Table 1: Evaluation of camera pose accuracy on the Strecha benchmark [44].

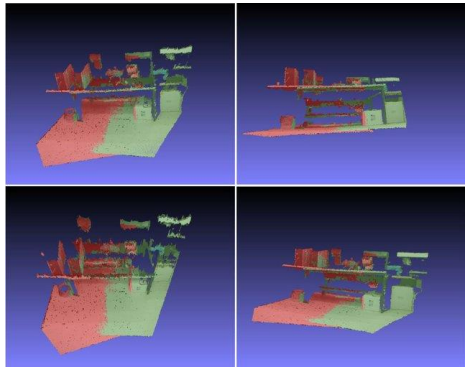
Scene	#Images Total	#Images Reg.	#Points 3D	#Points 2D	Track Length	Rotation (deg) Mean	Rotation (deg) Std.	Position (cm) Mean	Position (cm) Std.
castle-P19	19	15	4.3k	24.2k	5.7	0.29	0.20	10.80	17.47
castle-P30	30	30	11.5k	78.7k	6.8	0.08	0.03	4.00	2.73
entry-P10	10	10	4.0k	24.5k	6.1	0.05	0.01	0.71	0.26
fountain-P11	11	11	7.9k	46.2k	5.8	0.03	0.01	0.30	0.14
Herz-Jesu-P8	8	8	3.4k	17.6k	5.2	0.21	0.03	0.53	0.30
Herz-Jesu-P25	25	25	11.1k	86.8k	7.8	0.04	0.02	0.58	0.23



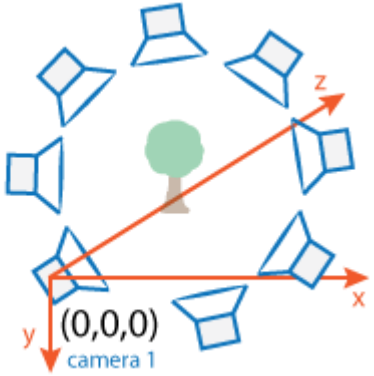
Herzjesu Fountain Castle

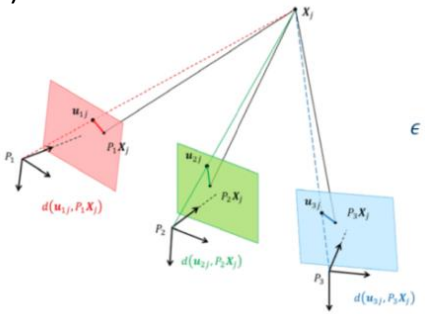


(Yilmaz, 2013)



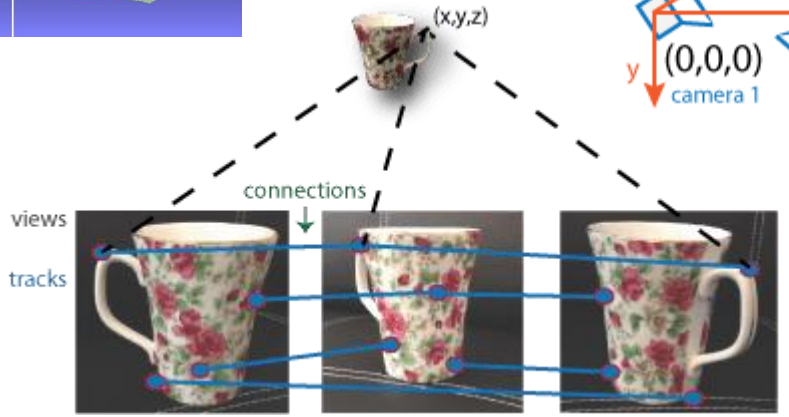
(Yilmaz, 2013)

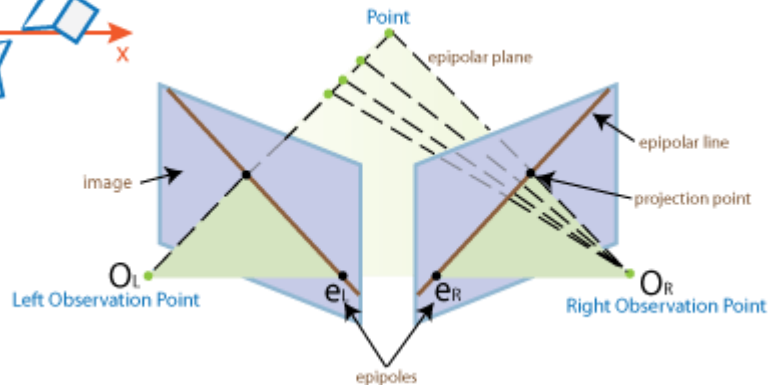




$$\epsilon = \sum_{i=1}^{m} \sum_{j=1}^{n} d(\tilde{\boldsymbol{u}}_{ij}, P_i \tilde{\boldsymbol{X}}_j)^2$$

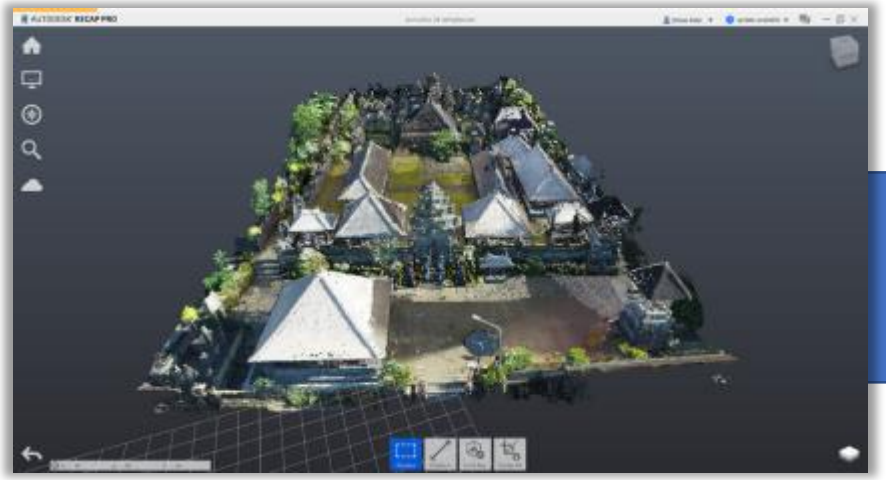
(https://ai-mrkogao.github.io/vision/structurefrommotion/)



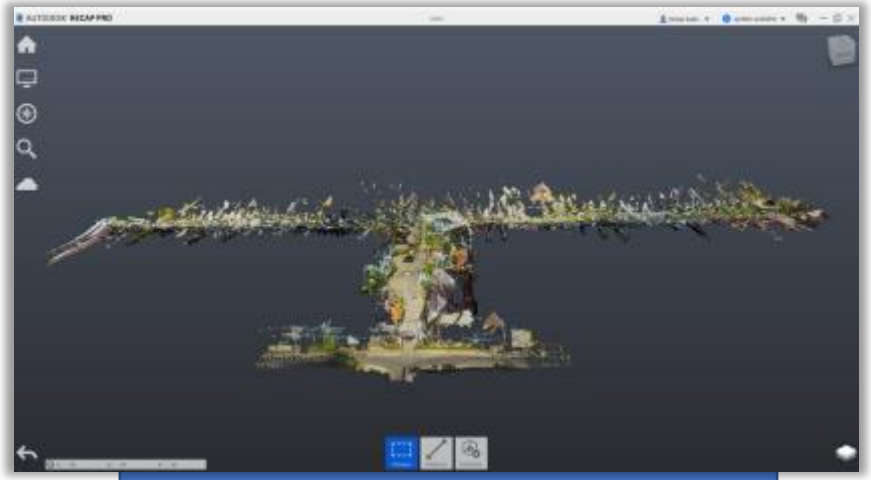


(https://se.mathworks.com/help/vision/ug/structure-from-motion.html)

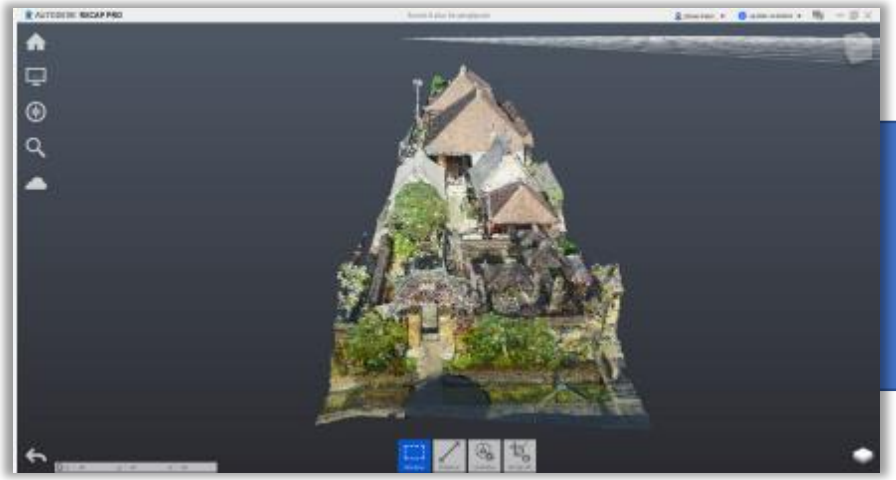
REGISTER POINT CLOUDS INTEGRATION



The Penglipuran Temple segment has an average RMSE of 0.004 m

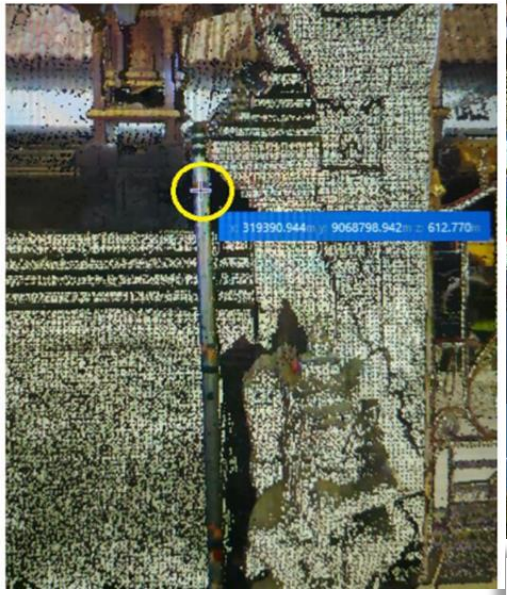


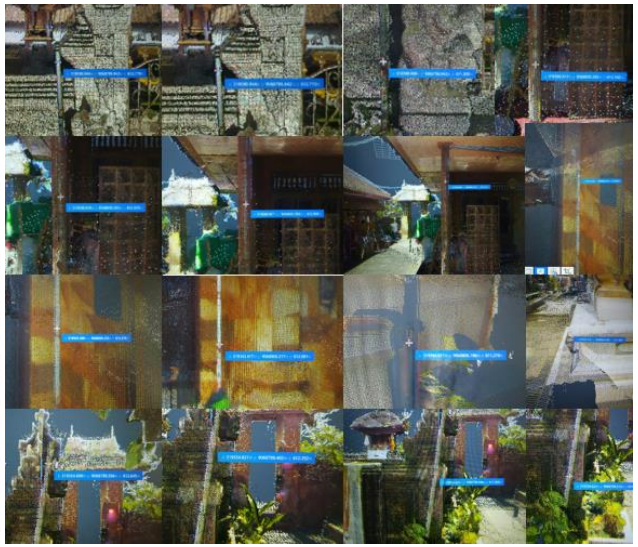
Penglipuran Village road segment with an average RMSE of 0.006 m



Traditional House segment no. 8 Average RMSE 0.003 m

VALIDATION OF POINT CLOUDS RESULTS





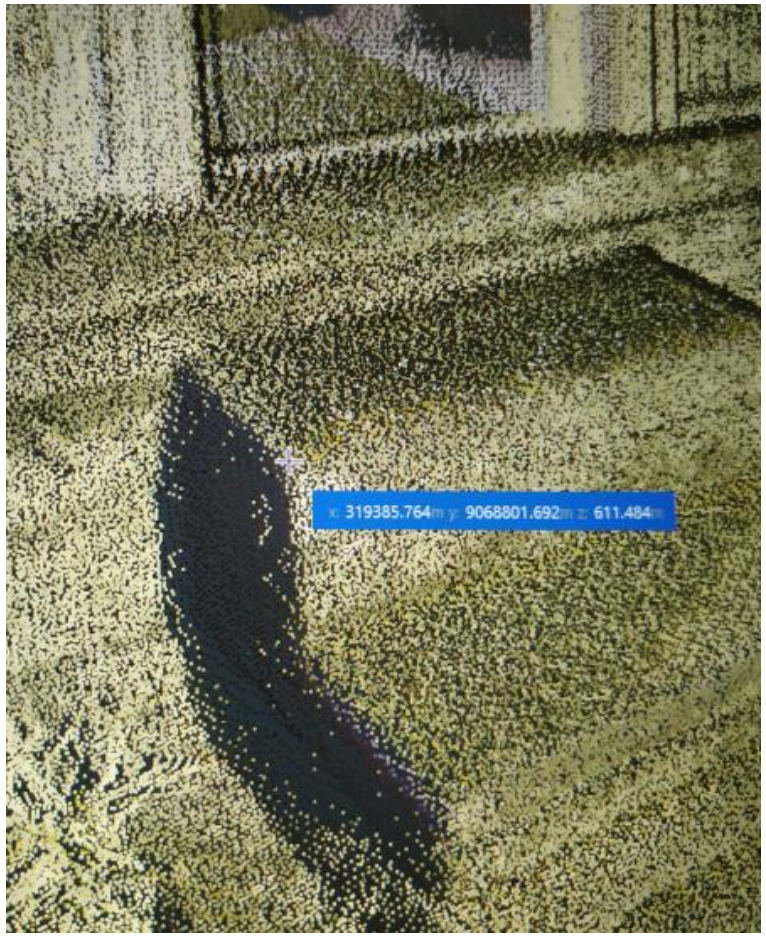
The difference between the coordinates of the point clouds and the coordinates of the ETS measurement results.

The difference in model validation results is below 0-2 mm

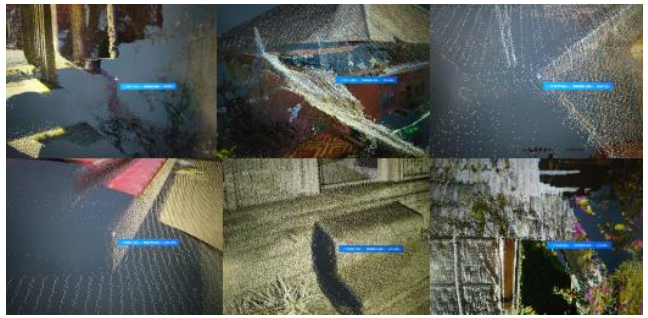
Titik	Koordinat pada *Point Clouds*			Koordinat Hasil Pengukuran ETS			Selisih (Δ Ukuran ETS - *Point Clouds*)		
	X (m)	*Y* (m)	*Z* (m)	*X* (m)	*Y* (m)	*Z* (m)	*X* (m)	*Y* (m)	*Z* (m)
VGPS3-1	319390,94	9068798,94	612,77	319390,95	9068798,939	612,768	0,002	-0,003	-0,002
VGPS3-2	319390,91	9068798,94	612,326	319390,91	9068798,938	612,32	0,002	0,002	-0,006
VGPS3-3	319390,87	9068798,94	611,835	319390,87	9068798,941	611,831	0	-0,001	-0,004
VGPS3-4	319380,92	9068800,39	612,142	319380,92	9068800,397	612,135	0,007	0,012	-0,007
VGPS3-5	319380,91	9068800,4	612,57	319380,92	9068800,402	612,569	0,007	0,007	-0,001
VGPS3-6	319380,91	9068800,4	612,969	319380,91	9068800,397	612,963	0,005	0,002	-0,006
VGPS3-7	319380,89	9068800,39	613,275	319380,91	9068800,393	613,27	0,02	0	-0,005
VTLS84-1	319343,39	9068806,24	613,023	319343,39	9068806,243	613,024	0	-0,001	0,001
VTLS84-2	319343,4	9068806,24	612,579	319343,4	9068806,231	612,575	0,001	-0,004	-0,004
VTLS84-3	319343,42	9068806,22	612,081	319343,41	9068806,213	612,085	-0,005	-0,004	0,004
VTLS84-4	319344,92	9068806,2	611,279	319344,92	9068806,192	611,277	-0,002	-0,004	-0,002
VTLS84-5	319343,42	9068802,46	611,284	319343,42	9068802,461	611,282	-0,003	0,003	-0,002
VTLS84-6	319354,61	9068799,36	612,645	319354,61	9068799,355	612,651	-0,003	-0,001	0,006
VTLS84-7	319354,62	9068799,4	612,352	319354,61	9068799,393	612,347	-0,011	-0,009	-0,005
VTLS84-8	319354,62	9068799,44	611,956	319354,62	9068799,433	611,956	-0,005	-0,011	0
VTLS84-9	319354,62	9068799,51	611,533	319354,62	9068799,509	611,527	-0,004	-0,004	-0,006
					Rata-rata Selisih		0,0007	-0,001	-0,002

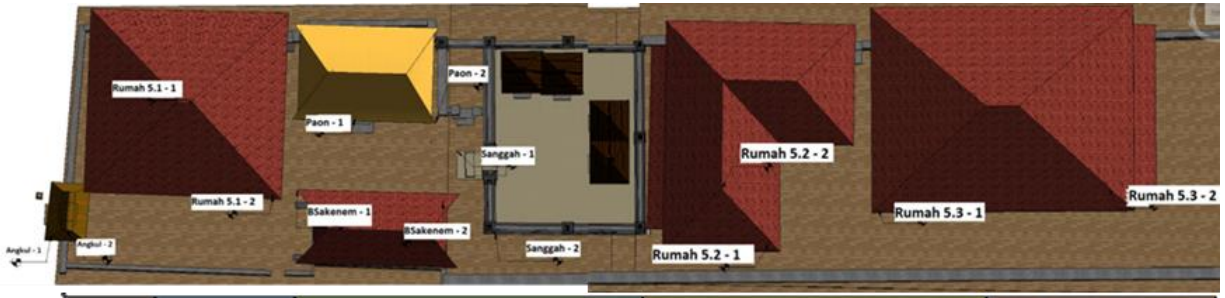
Verification of Modeling Results

Calculating the difference between the coordinate values of the points on the model and the point coordinates of the point clouds



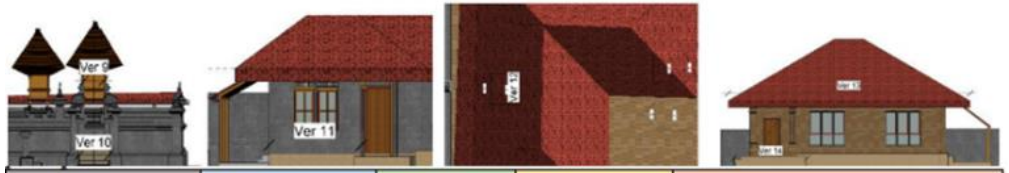
MODEL VERIFICATION





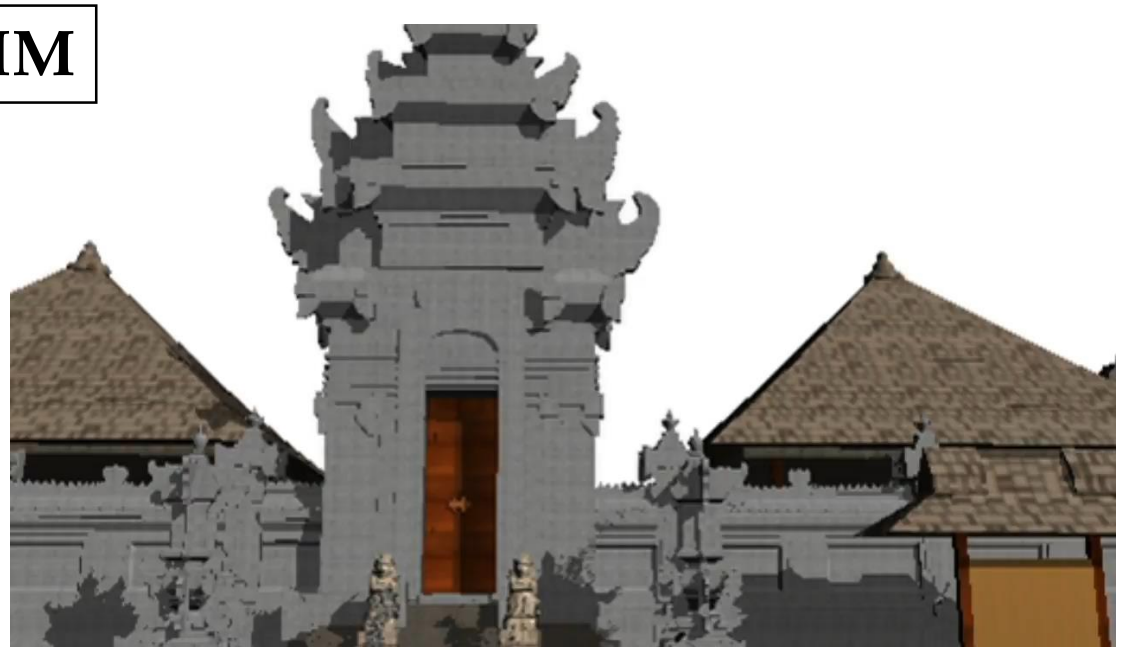
Objek	Titik	Koordinat pada Model			Koordinat pada *Point Clouds*			Selisih (Δ) = Koord. *Point Clouds* - Koord. Model		
		X (m)	*Y* (m)	*h* (m)	*X* (m)	*Y* (m)	*h* (m)	*ΔX* (m)	*ΔY* (m)	*Δh* (m)
Angkul-angkul	Angkul-1	319371,337	9068800,686	611,007	319371,467	9068800,486	610,991	0,130	-0,200	-0,016
	Angkul-2	319371,990	9068800,505	614,577	319371,989	9068800,345	614,586	-0,001	-0,160	0,009
Rumah 5.1	Rumah 5.1-1	319379,033	9068804,203	616,736	319378,965	9068804,290	616,712	-0,068	0,087	-0,024
	Rumah 5.1-2	319381,286	9068799,469	611,223	319381,323	9068799,487	611,179	0,037	0,018	-0,044
Paon	Paon-1	319385,763	9068801,702	611,484	319385,764	9068801,692	611,484	0,001	-0,010	0,000
	Paon-2	319389,084	9068800,368	612,850	319388,826	9068800,600	612,804	-0,258	0,232	-0,046
Bale Sakenem	BSakenem-1	319382,324	9068799,300	613,214	319382,444	9068799,044	613,153	0,120	-0,256	-0,061
	BSakenem-2	319388,378	9068796,956	611,663	319388,416	9068796,784	611,690	0,038	-0,172	0,027
Sanggah	Sanggah-1	319389,634	9068798,963	611,130	319389,673	9068798,971	611,120	0,039	0,008	-0,010
	Sanggah-2	319390,140	9068794,866	612,901	319390,206	9068794,884	612,908	0,066	0,018	0,007
Rumah 5.2	Rumah 5.2-1	319402,379	9068790,568	611,462	319402,487	9068790,775	611,458	0,108	0,207	-0,004
	Rumah 5.2-2	319400,856	9068793,462	616,142	319400,946	9068793,609	616,158	0,090	0,147	0,016
Rumah 5.3	Rumah 5.3-1	319407,880	9068790,468	611,699	319407,999	9068790,688	611,523	0,119	0,220	-0,176
	Rumah 5.3-2	319418,882	9068788,141	612,061	319418,990	9068788,488	611,891	0,108	0,347	-0,170
						RMSE		0,106	0,181	0,071

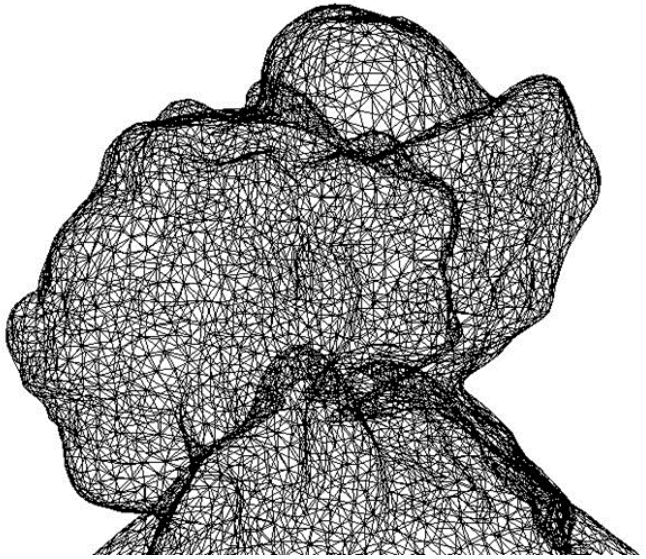
Dimensions



Objek	Nama Pengukuran	Model (m)	Point Cloud (m)	Selisih (Δ) = *Point Clouds* - Model (m)
Angkul-angkul	Ver1	2,648	2,646	-0,002
	Ver2	2,289	2,271	-0,018
Rumah 5.1	Ver3	8,449	8,390	-0,059
	Ver4	1,976	1,972	-0,004
Paon	Ver5	5,296	5,310	0,014
	Ver6	0,976	0,971	-0,005
Bale Sakenem	Ver7	4,464	4,471	0,007
	Ver8	5,453	5,445	-0,008
Sanggah	Ver9	0,686	0,687	0,001
	Ver10	1,040	1,028	-0,012
Rumah 5.2	Ver11	2,718	2,716	-0,002
	Ver12	5,008	5,031	0,023
Rumah 5.3	Ver13	12,700	12,705	0,005
	Ver14	3,826	3,808	-0,018
			RMSE	0,019

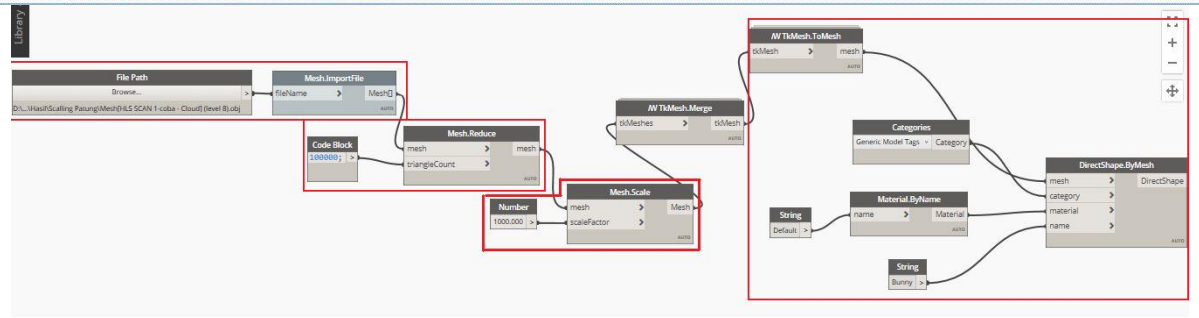
Results

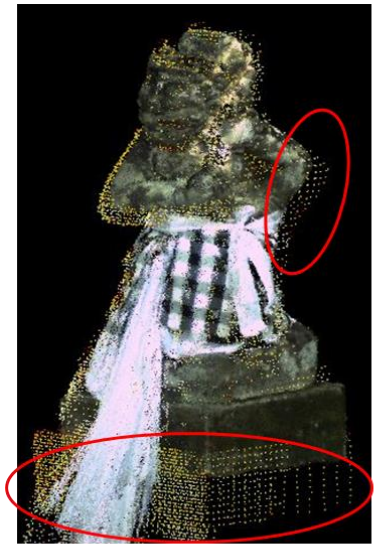




Type Parameters

Parameter	Value
Text	
ID	TGG1
Nama	Dwarapala
Makna	Sebagai Pelinggih/Setana dari Tuhan Yang Maha Esa dalam manifestasi-Nya. Bentuk menyerupai monster melambangkan sosok yang gagah
Fungsi	Sebagai "Apit Lawang" atau Penjaga Lawang. Selain itu, dwarapala juga berfungsi untuk menyeleksi orang yang masuk ke dalam Pura. Orang yang berniat buruk akan mendapatkan keburukan jika memasuki Pura





Hasil Overlay Metode *Helmert*

Hasil Overlay Metode *Affine*

bel 14. RMSE Hasil Transformasi Metode *Helmert*

Metode Transformasi *Helmert*	
RMSx (m)	0.04222755814
RMSy (m)	0.1575584548
RMSz (m)	0.04292241062
RMSe (m)	0.168671772

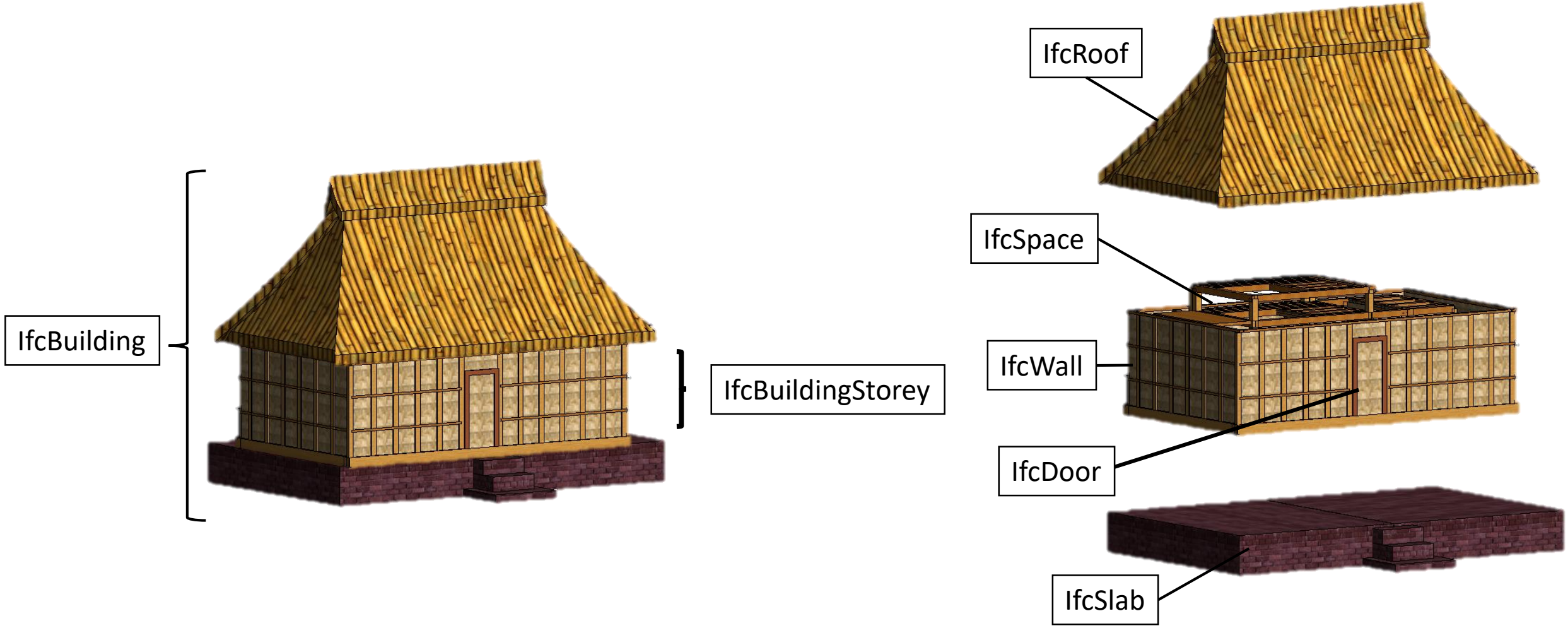
abel 15. RMSE Hasil Transformasi Metode *Affine*

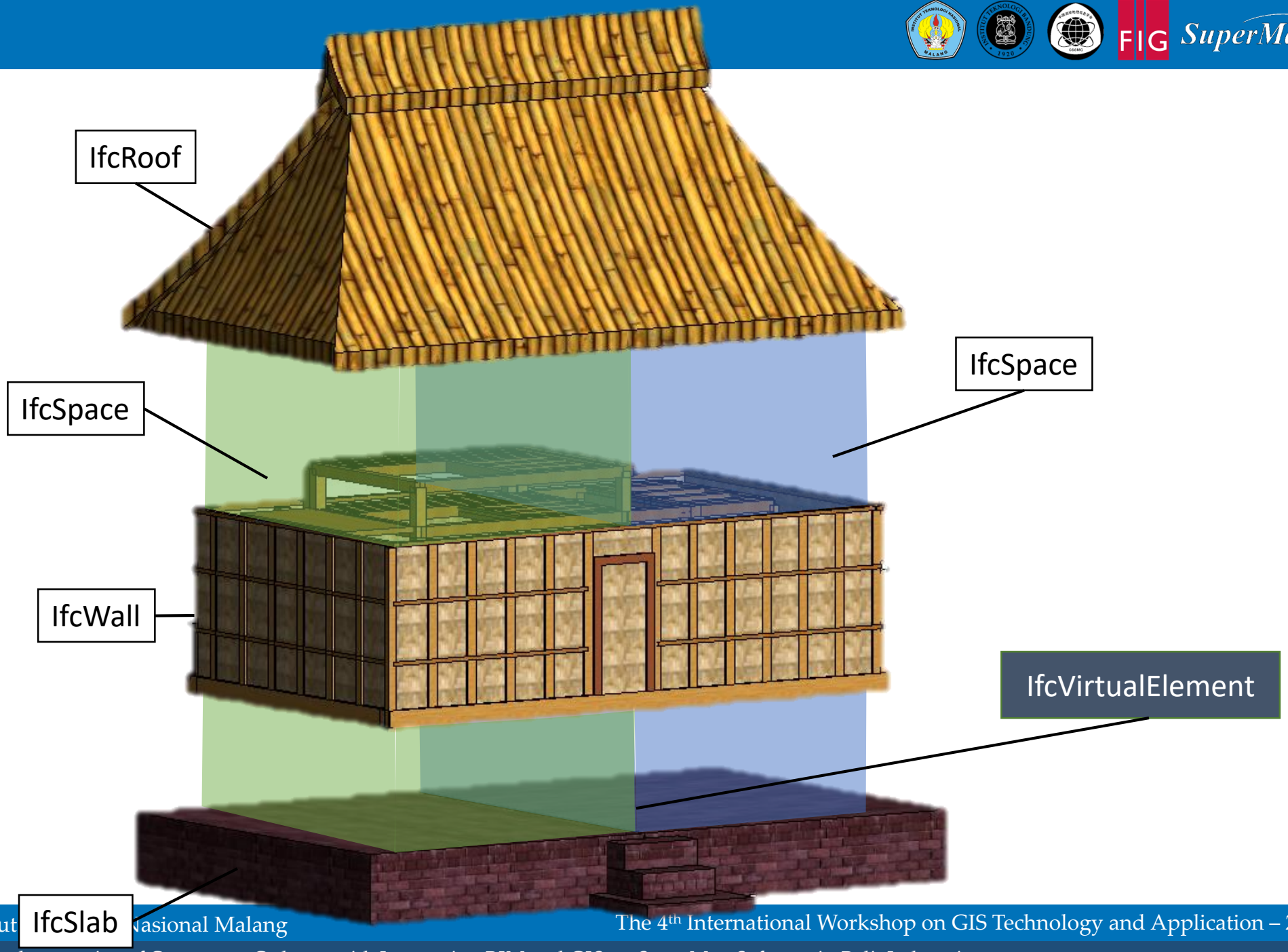
Metode Transformasi *Affine*	
RMSx (m)	0.003605551275
RMSy (m)	0.002516611478
RMSz (m)	0.002516611478
RMSe (m)	0.005066228051

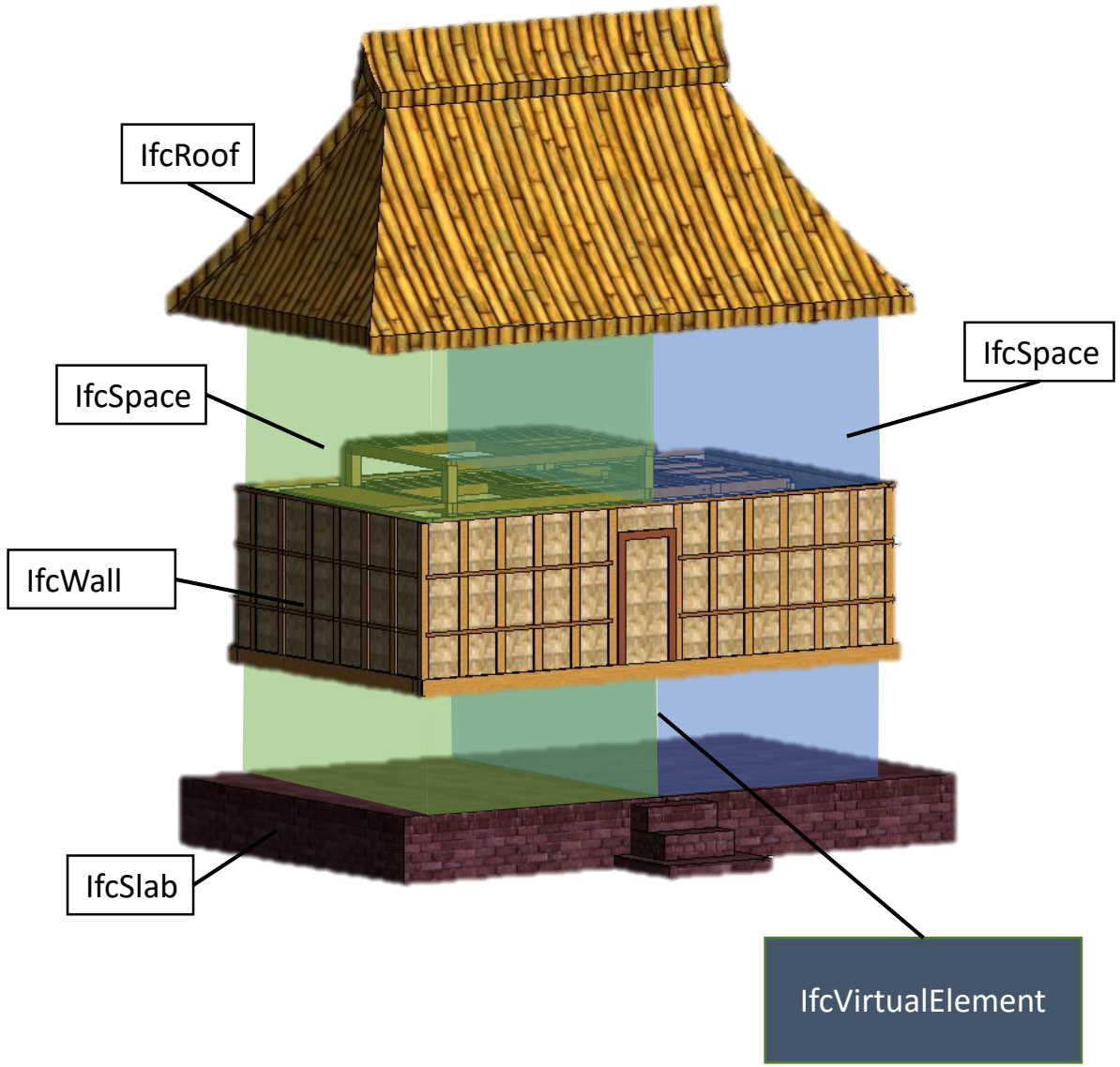
Hamdani, 2020

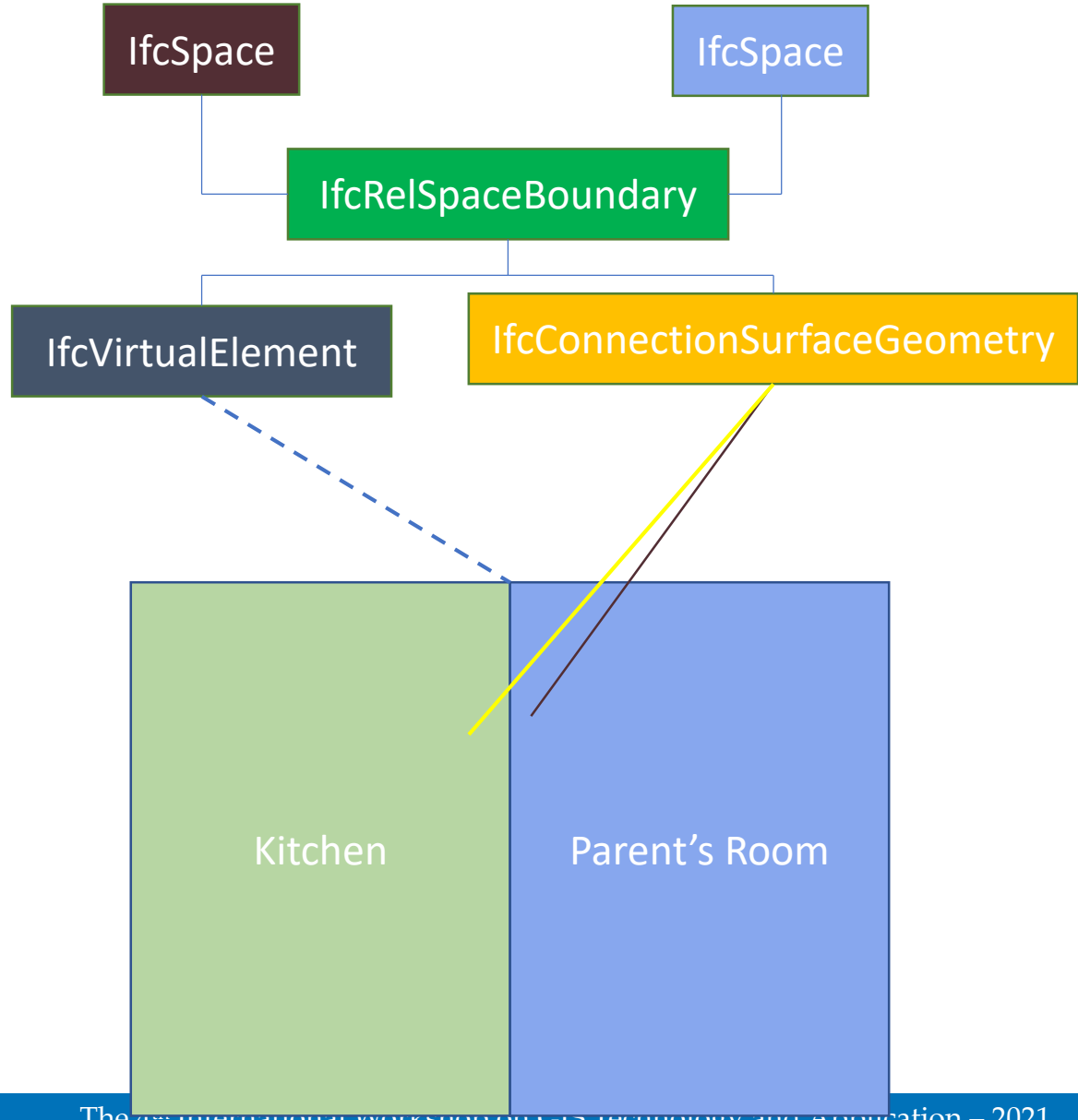
IfcBuilding

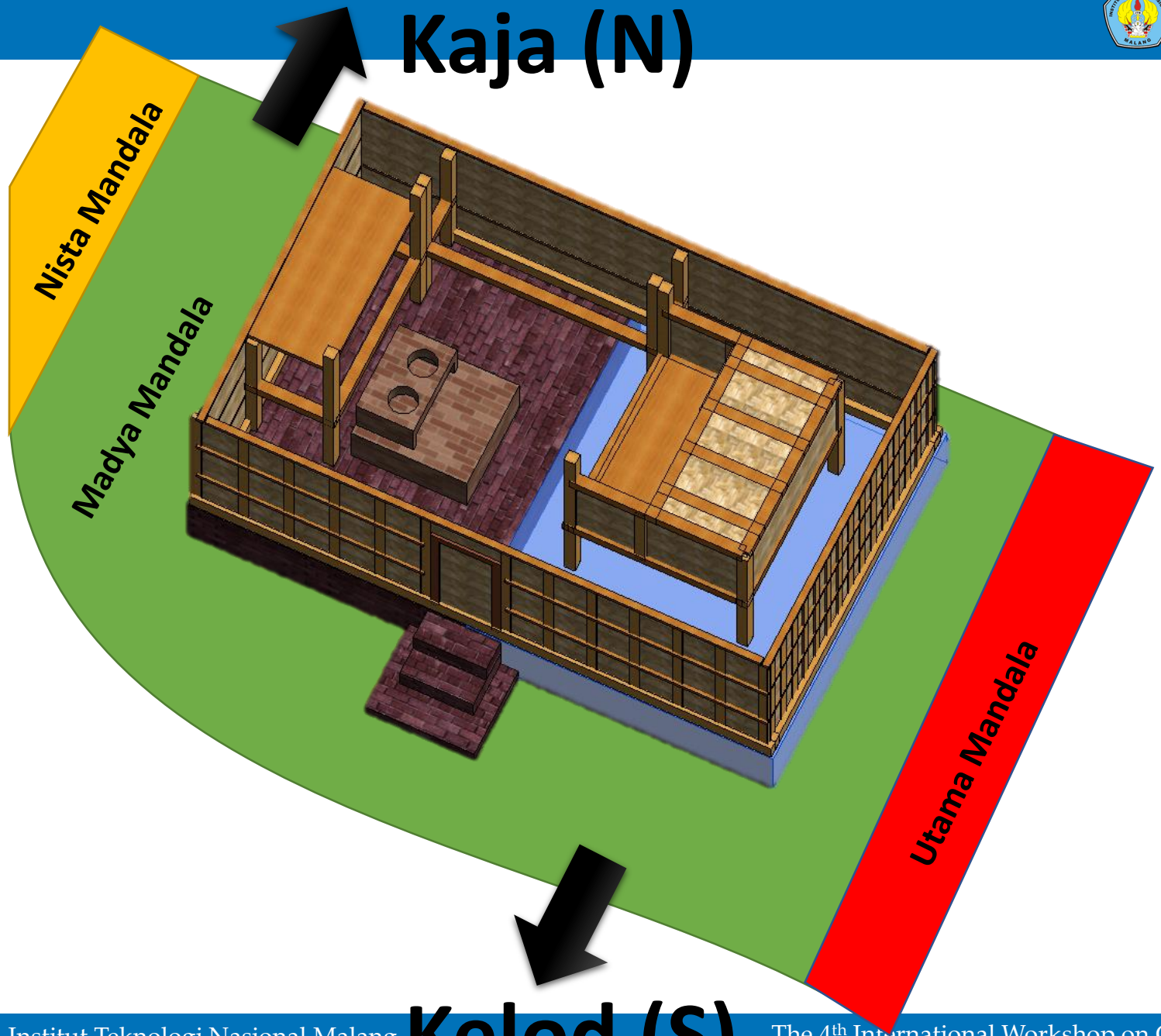
IfcBuildingStorey

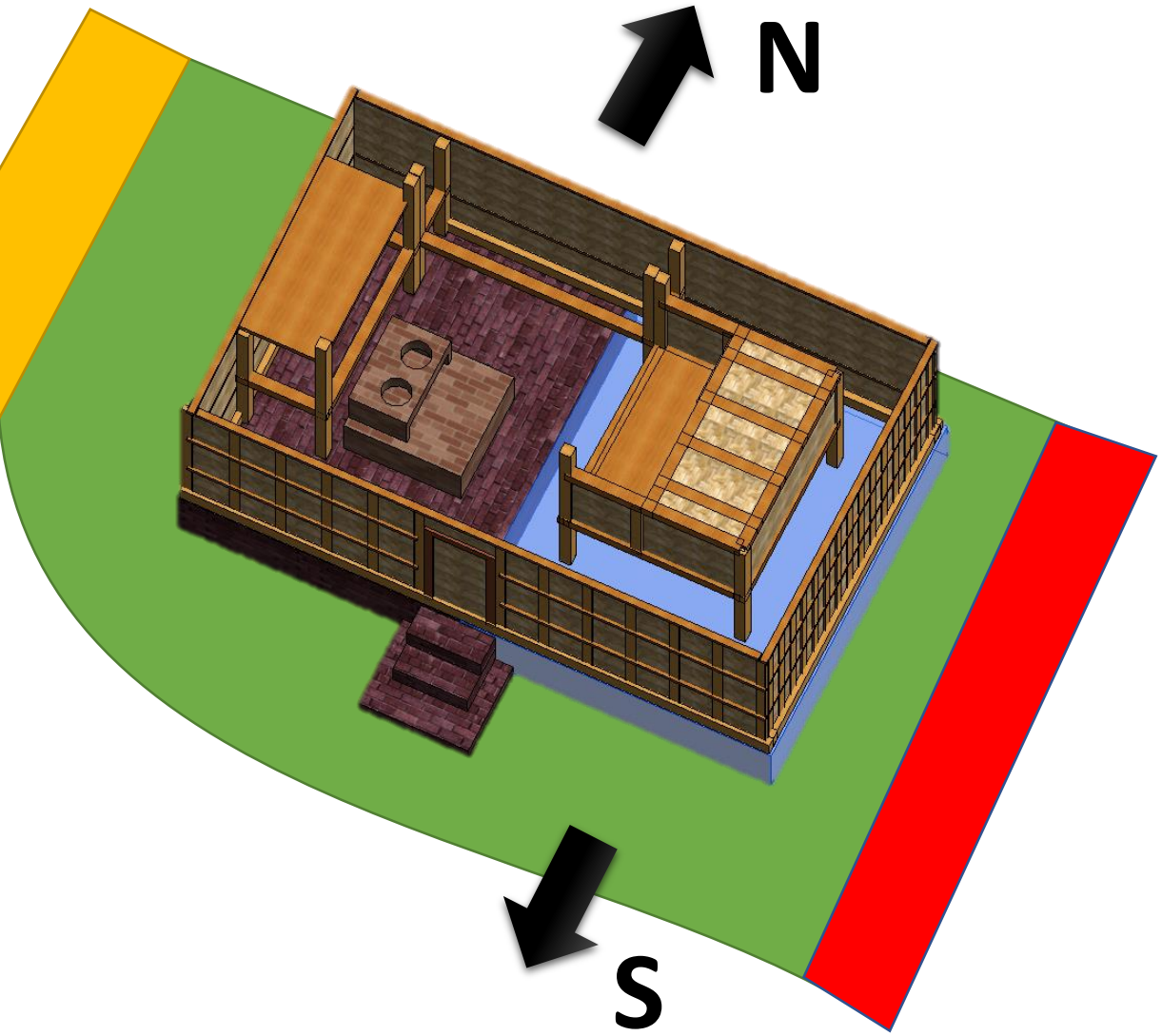

IfcBuilding
IfcBuildingStorey
IfcRoof
IfcSpace
IfcWall
IfcDoor
IfcSlab

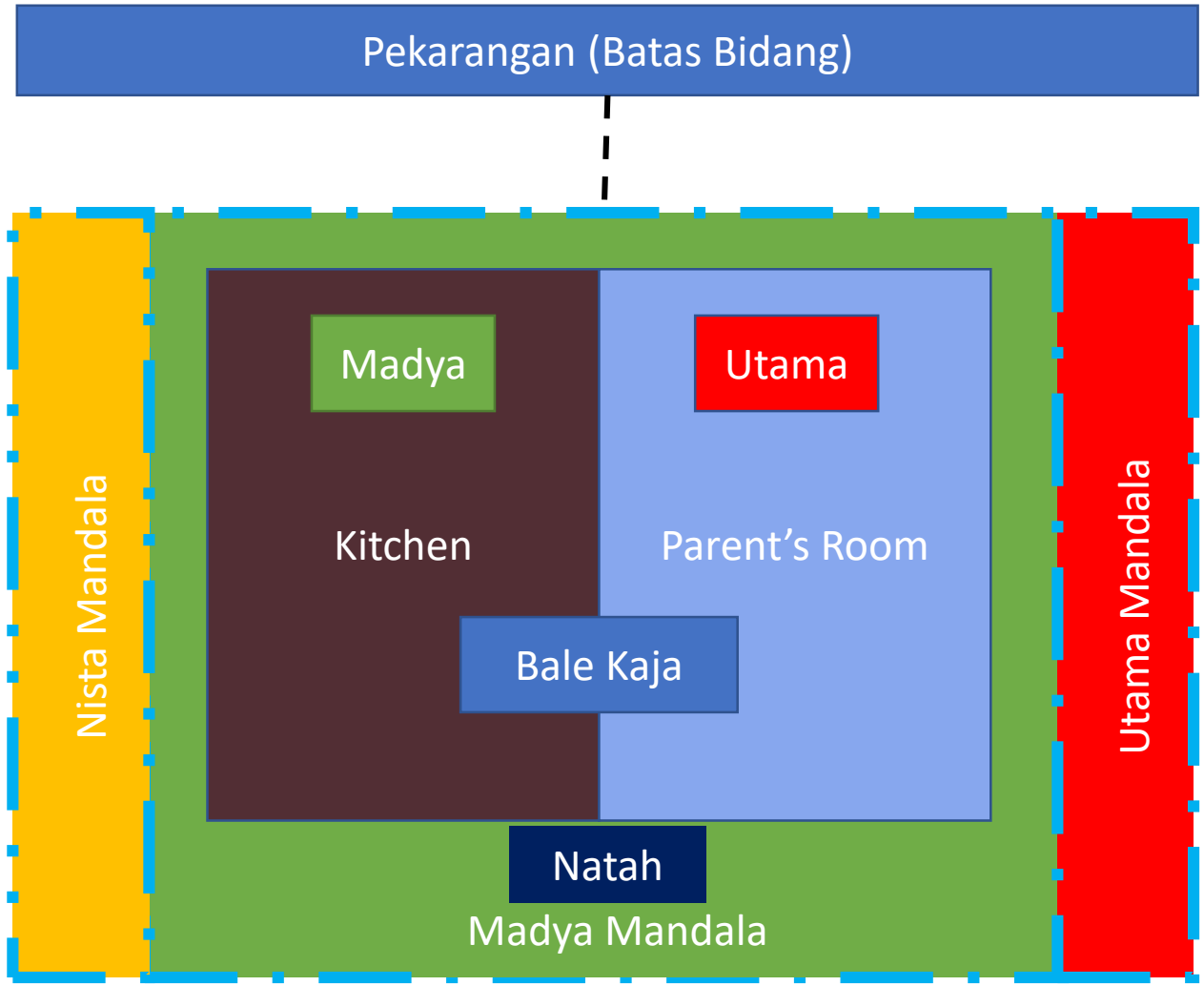

IfcRoof
IfcSpace
IfcSpace
IfcWall
IfcVirtualElement
IfcSlab


IfcRoof
IfcSpace
IfcSpace
IfcWall
IfcSlab
IfcVirtualElement


IfcSpace
IfcSpace
IfcRelSpaceBoundary
IfcVirtualElement
IfcConnectionSurfaceGeometry
Kitchen
Parent's Room

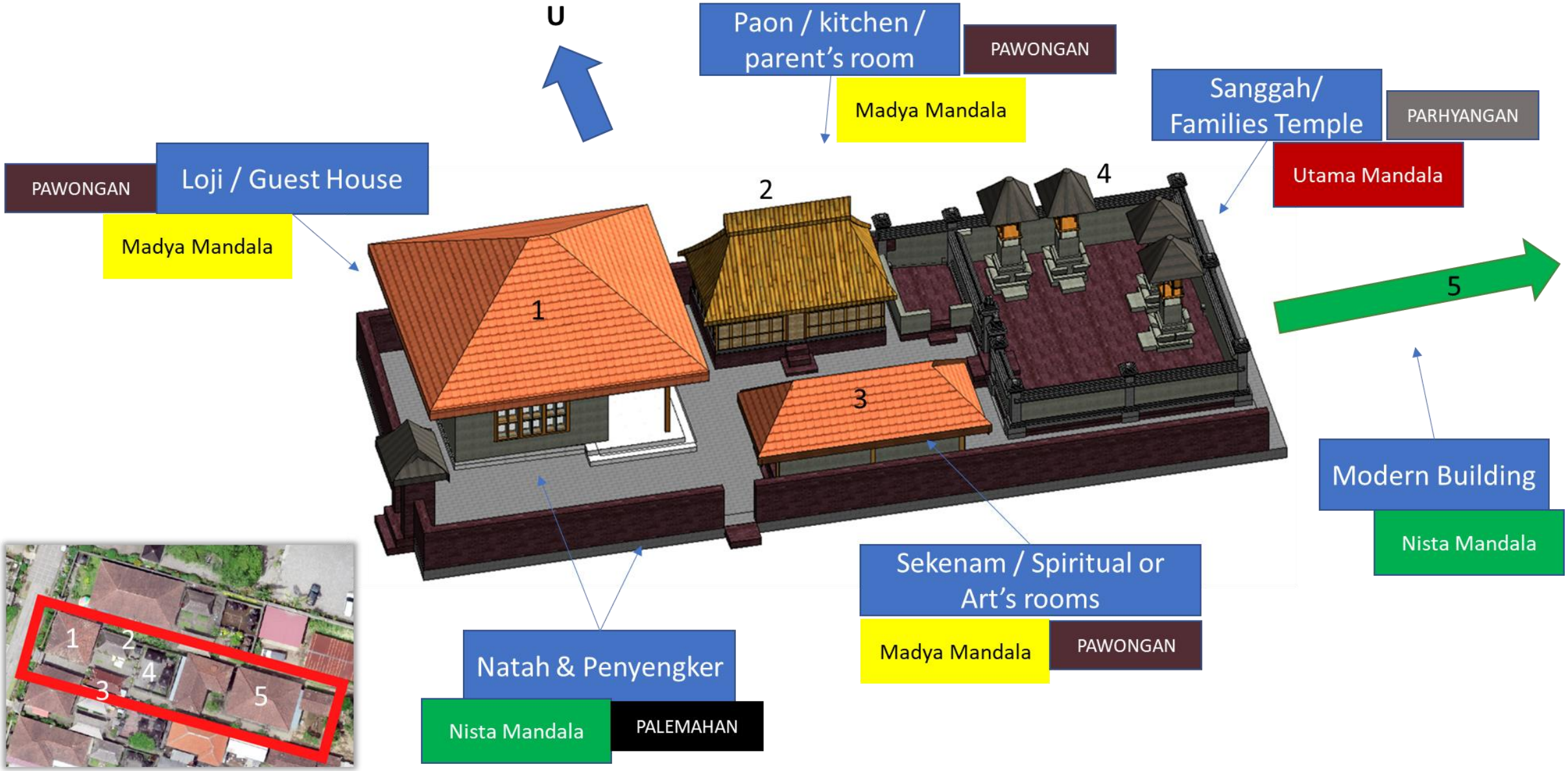

Kaja (N)
Nista Mandala
Madya Mandala
Utama Mandala
Kelod (S)


N
S

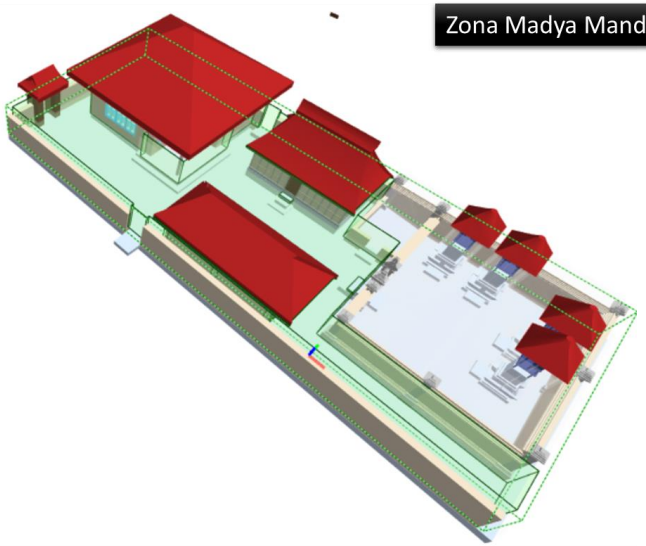

Pekarangan (Batas Bidang)
Nista Mandala
Madya
Utama
Kitchen
Parent's Room
Bale Kaja
Natah
Madya Mandala
Utama Mandala

Pekarangan 1
Jalan
Pekarangan 2
Nista Mandala
Madya
Utama
Kitchen
Parent's Room
Bale Kaja
Utama Mandala
Nista Mandala
Madya
Utama
Kitchen
Parent's Room
Bale Kaja
Utama Mandala
Nista Mandala
Natah
Madya Mandala
Natah
Madya Mandala
Pekarangan 3
Jalan
Pekarangan 4

Results


U
Paon / kitchen / parent's room
PAWONGAN
Madya Mandala
Sanggah/ Families Temple
PARHYANGAN
Utama Mandala
PAWONGAN
Loji / Guest House
Madya Mandala
1
2
3
4
5
Modern Building
Nista Mandala
Sekenam / Spiritual or Art's rooms
Madya Mandala
PAWONGAN
Natah & Penyengker
Nista Mandala
PALEMAHAN

Results

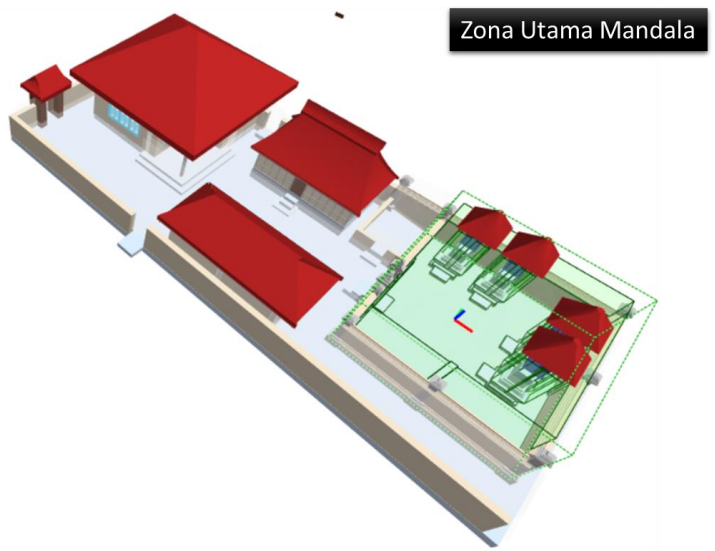


IFC Structure

Active	Type	Name	Description
✓	Space	2	Children's Room
✓	Space	3	Living Room
✓	Space	1	Utama
✓	Space	2	Madya
✓	Space	3	Madya
✓	Space	4	Nista
✓	Space	4	Parent's Room
✓	Space	5	Paon (Kitchen)
✓	Space	9	Ritual Room
✓	Space	10	Sanggah
✓	Space	11	Sanggah
✓	Space	12	Guest's Room
√ ✓	Space	13	Natah / Local Area
✓	Space	13	Madya

Properties | Location | Classification | Relations

Name	Value	Unit
Element Specific		
Legal Document		
Approved By	Kepala BPN Kab. Bangli	
Luas Bidang	119,917747	m2
Luas Volume	191,303782	m3
NIB	819	
Nilai Pajak	Rp. 0,-	
Pemilik	Desa Pakraman Penglipuran	
Register By	Ketut Tomy Suhari, ST	
Status	Approved	
Status Hak	Hak Milik	
Wilayah	Kelurahan Kubu, Kecamatan Bangli, Kabupaten Bangli, Provinsi Bali	
Tri Mandala Zona		
Zona	Madya	



IFC Structure

Active	Type	Name	Description
✓	Space	2	Children's Room
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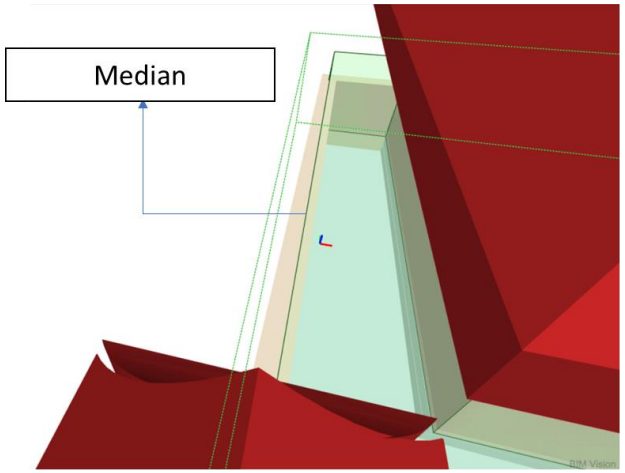
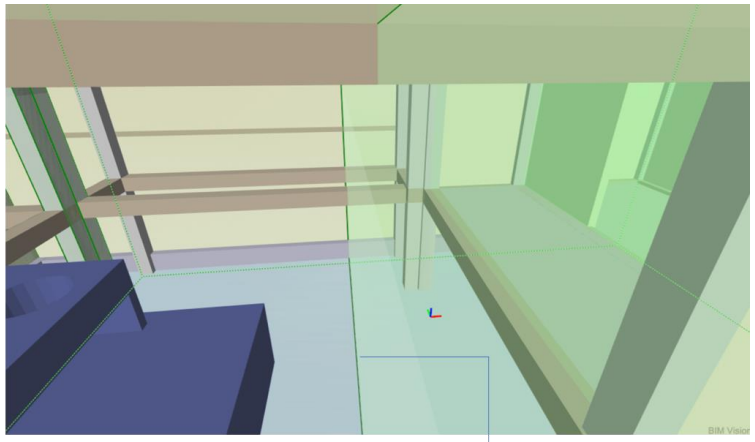
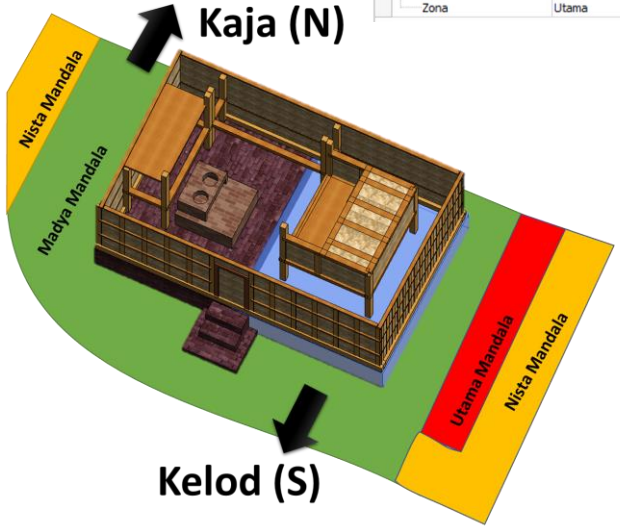
✓	Space	2	Madya
✓	Space	3	Madya
✓	Space	4	Nista
✓	Space	4	Parent's Room
✓	Space	5	Paon (Kitchen)
✓	Space	9	Ritual Room
√ ✓	Space	10	Sanggah
✓	Space	11	Sanggah
✓	Space	12	Guest's Room
✓	Space	13	Natah / Local Area
✓	Space	13	Madya

Properties | Location | Classification | Relations

Name	Value	Unit
Element Specific		
Legal Document		
Approved By	Kepala BPN Kab. Bangli	
Luas Bidang	52,850875	m2
Luas Volume	114,543494	m3
NIB	819	
Nilai Pajak	Rp. 0,-	
Pemilik	Desa Pakraman Penglipuran	
Register By	Ketut Tomy Suhari, ST	
Status	Approved	
Status Hak	Hak Milik	
Wilayah	Kelurahan Kubu, Kecamatan Bangli, Kabupaten Bangli, Provinsi Bali	
Tri Mandala Zona		
Zona	Utama	

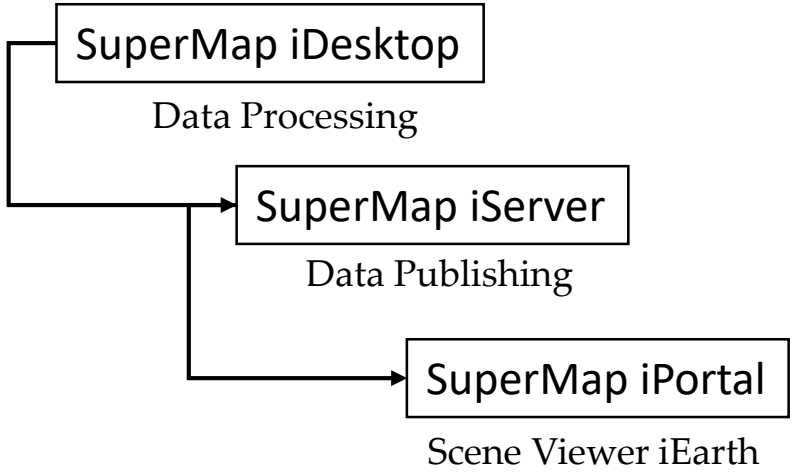




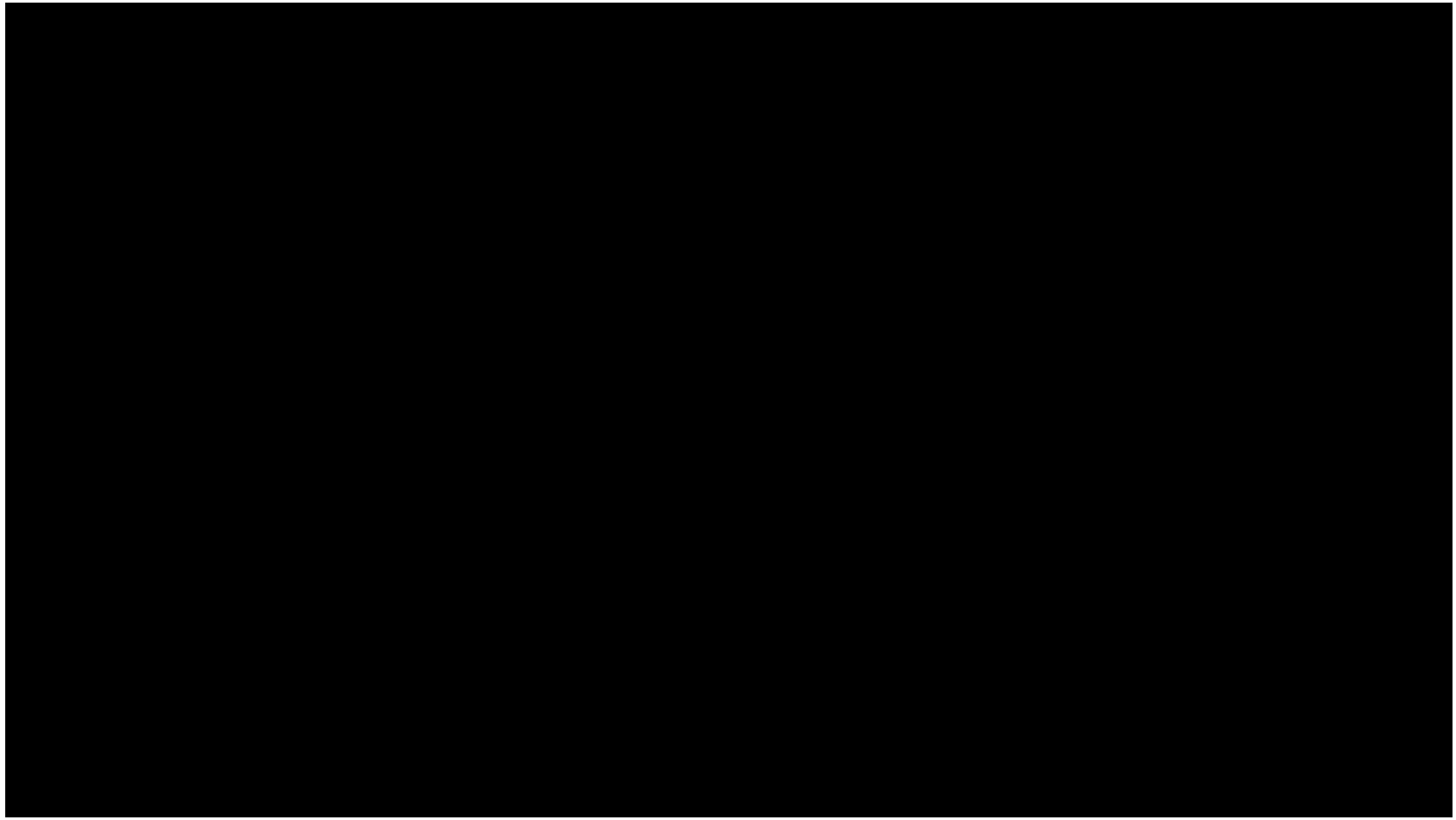


Implementing Customary Restrictions in Penglipuran Village In SuperMap Software

Method:

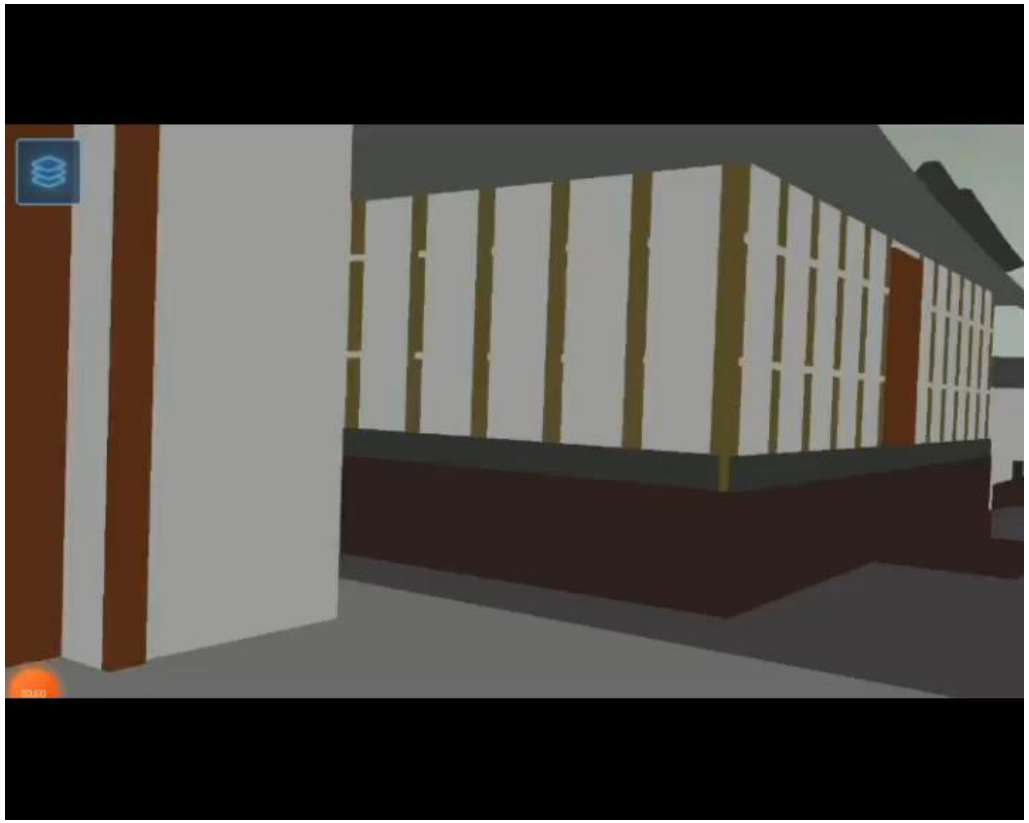


The integration of BIM and GIS can provide an overview of customary law and restrictions that apply in one customary village. This integration makes it easier for stakeholders to decide on modernization restrictions to maintain their traditional buildings.



Collaboration with Indonesian SuperMap Team

Conclusion



Customary/Adat Cadastre is important to be implemented in Indonesia. Because this activity will be socially related, considering that Indonesia has thousands of traditional villages scattered throughout Indonesia. A customary cadastre is not simply depicted in 2D; a registration system or recording in 3D is required. Thus, to identify customary adat (Right, Restriction, Responsibility) can use this 3D cadastre integration in various jobs (multipurpose cadastre) to support the function of the land registration.

Integrating BIM and GIS makes it possible to follow up on Bali regional regulations regulating building heights and modernization zones restrictions. It is an initial effort in the conservation of customary space in Bali. Likewise, that can apply in several other villages or even other countries that require the conservation of these customary spaces.

Thank You

Matur Suksma

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ksuhari@lecturer.itn.ac.id

or

Ketut Tomy Suhari