VIRTUAL VISION
IMAGE
PATTERN

Weekly Seminar :: INAPR :: January 28th 2022
Indonesian Association for Pattern Recognition

Document Image Processing for Balinese Palm Leaf Manuscripts

Protocol, Scheme, and Challenges

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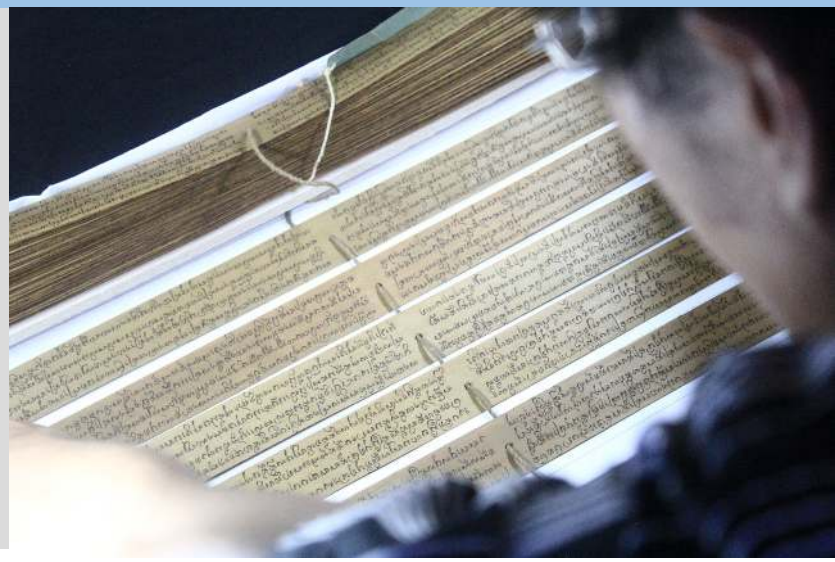

Outline

- Research Contexts :
  - ❑ Projects
  - ❑ Motivations
  - ❑ Objectives
- Research Problematics
  - ✓ Challenges
  - ✓ Protocol
  - ✓ Scheme

Research Contexts

Heritage Documents

Palm Leaf Manuscripts

AMADI Project (multidisciplinary)

Limited Access

Socio Cultural

Valuable Contents

Linguistic Difficulties

Philological and Linguistic

Preservation Projects

Physical Condition

Information Technology

Digitization

Content Exploration

Document Image Analysis (DIA)

Project :: *from AMADI Project to EpsiLont Project*

2014 – 2018

AMADI Project

Ancient MAnuscripts Digitization and Indexation

STIC Asia Program - French Ministry of Foreign Affairs and International Development (MAEDI).

Partners: France, Indonesia and Cambodia

- Laboratory Informatique Image et Interaction (L3i) of ULR, France
- Laboratory Cultural Informatics (LCI) of UNDIKSHA, Bali, Indonesia
- Laboratory RAID and Center for Sundanese Culture Studies of UNPAD, Bandung, Indonesia
- Laboratory GIC of ITC, Phnom Penh, Cambodia

2019-2021-??

EpsiLont Project

Electronic Pattern Analysis for Lontar

- PDUPT Ristekbrin 2019-2021
- Penelitian Terapan DIPA Undiksha 2020

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VIRTUAL VISION
IMAGE
PATTERN

Balinese L O N T A R

Collections

Museum Gedong Kertya and Bali

± 6,000 collections

Private Family

± 50,000 collections

religion, holy formulae, rituals, family genealogies, law codes, treaties on medicine (usadha), arts and architecture, calendar, prose, poem and even magic

Writing and Materials

Palm tree

small pen-knife *pengerupak*

scratching palm leaves

rubbed with natural black dye

cleaned up with cotton

Transliteration Books (in Indonesian language : `Alih Aksara`)

- hard to associate the collection
- belongs to a collection which is not stored in the Museum

Catalog (example): Lontar Collection Museum Bali, Denpasar

Rak I.1

BABAD

1. Babad Brahma Siwa - 07.252/6103
2. Prasasti Ngurah Sidemen - 07.262/5353
3. Mpu Kuturan - 07.256/6162
4. Babad Sukawati - 07.266/6291
5. Babad Bali Pulina - 07.270/6149
6. Babad Brahmana Manuaba - 07.251/6150
7. Prasasti Buleleng - 07.164/6153
8. Usana Bali - 07.269/6289
9. Brahmangsa - 07.158/6152
10. Babad Mayadanawa - 07.257/5381
11. Babad Ularan - 07.267/6363/N
12. Pamancangah Dalem - 07.259/5165/IV.a
13. Babad Mangwi - 07.258/6366
14. Prasasti Pande Capung - 07.260/6361
15. Babad Danghyang Nirarta - 07.255/5971
16. Babad Pasek - 07.268/5951
17. Babad Calonarang - 07.203/6596/N
18. Pamancangah Badung - 07.209/5290
19. Prasasti Dukuh Kedangan - 07.24/01/MB
20. Babad Brahma Cute - 07.250/6362
21. Babad Bandesa Sakti Beng - 07.248/6364
22. Babad Sangging - 07.264/6367

Rak I.2

GAGURITAN

1. Peparikan Lawe - 07.308/6151
2. Peparikan Tantri - 07.278/5164.3
3. Gaguritan Jayaprana - 07.282/6105/N
4. Gaguritan Aji Tatwa Mimit - 07.284/5275
5. Gaguritan Gunawati - 07.280/6108
6. Gaguritan Sasak - 07.283/5284
7. Gaguritan Dewa Manggis - 07.281/5310
8. Gaguritan Sampik - 07.213/3813.3

Rak II.2

MANTRA ASTAWA

1. Utama Japa - 07.158/6470
2. Puja Srawa - 07.145/05/MB
3. Panyapa Brahma Wisnu - 07.131/5958
4. Kusuma Dewa - 07.33/5102
5. Tata Kramaning Pabaktian - 07.299/6467
6. Ludra Pinggala - 07.148/5956
7. Puja Serawa - 07.144/6072
8. Banyu Awang - 07.107/6589
9. Puja Soha - 07.129/6587
10. Pangaskara Wong Mati - 07.128/5278/I.c
11. Pangembak Mantra - 07.146/5687

Rak I.3

KAKAWIN

1. Kakawin Bharatyuddha - 07.17/6058
2. Bharatyuddha Grantang Basa - 07.19/5862
3. Kakawin Bharatyuddha - 07.16/5635.3
4. Bharatyuddha Kreta Basa - 07.18/5832
5. Kakawin Arjuna Sastrabahu - 07.6/6165
6. Kakawin Harisraya - 07.29/5157.3
7. kakawin Kangsa - 07.32/5830
8. Kakawin Bhomantaka - 07.249/5859
9. Kakawin Sutasoma - 07.48/5858
10. Arjunawiwaha Grantang Basa - 07.7/6030

Rak I.6

KIDUNG

12. Kidung Tantri Kamandaka - 07.276/5699
13. Kidung Lawe - 07.60/5052
14. Kidung Pararaton - 07.62/5053
15. Kidung Tantri Kamandaka - 07.275/5545
16. Kidung Prembon Edan Wirangrong - 07.64/5035
17. Kidung Suphala Sidanta - 07.67/6679
18. Kidung Dhamar Wulan - 07.274/5160

Rak I.4

KAKAWIN

11. Arjuna Wiwaha - 07.8/5621
12. Arjuna Wiwaha - 07.9/5944
13. Kakawin Bharatayuddha - 07.34.A/5099
14. Kakawin Ariwangsa - 07.5/5547
15. Bharatayuddha Grantang Basa - 07.34/3781
16. Arjuna Wiwaha Grantang Basa - 07.10/5863
17. Kakawin Ramayana - 07.40/5634.3
18. Kakawin Ramayana - 07.41/5634.3
19. Bharatayuddha Grantang Basa - 07.20/5941
20. Arjuna Wiwaha - 07.11/5864
21. Kakawin Ramayana - 07.42

Rak II.1

KIDUNG

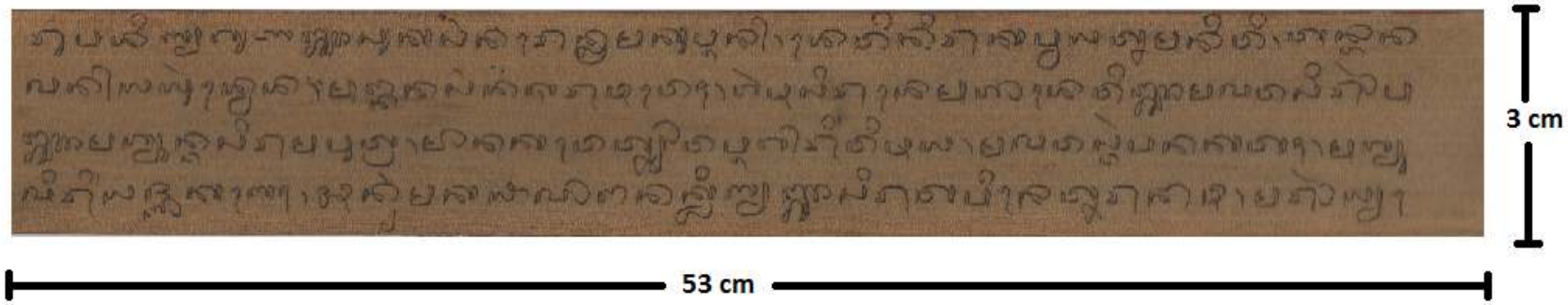
1. Kidung Rusak Sasak - 07.66/5056
2. Kidung Aji Pasurwan - 07.56/5054
3. Kidung Wijaya Krama - 07.69/5103
4. Kidung Widhari Smara - 07.51/5562
5. Kidung Bagus Umbara - 07.57/5351.2
6. Kidung Cupak - 07.58/5057
7. Kidung Tantri - 07.279/5062.3
8. Kidung Tantri - 07.247/6029
9. Kidung Amad Raden Saputra - 07.279/3814
10. Kidung Arsawijaya - 07.55/5058.3
11. Kidung Panji - 07.142/6062

Rak I.5

KAKAWIN

22. Kakawin Bharatayuddha - 07.15/5826
23. Kakawin Ramayana - 07.38/5059/IV/b
24. Kakawin Ramayana - 07.17/5970
25. Kakawin Bhuta Yadnya - 07.24/5822
26. Kakawin Sang Hyang Kala - 07.44/6598

Physical Dimension of Lontar



- Normally, in one leaf, there are 4 text lines

- Number of leaf for a collection, example :
  - ✓ For the collection of **Kakawin Ramayana - 07.41/5634.3** = 140 leafs
  - ✓ For the collection of **Kakawin Ramayana - 07.40/5634.3** = 155 leafs

Production Process of Lontar

✓ Sidemen Village, Region of Karangasem, Bali




Production Process of Lontar

Choose the leaves: a little old, wide enough, smooth and flat

Production Process of Lontar

Soak in cold water (for 10 days) - the leaves will become a bit soft

Production Process of Lontar

Boil for 4 hours + ingredients and spices e.g. tea and pepper to prevent bugs

Production Process of Lontar

Dry in the sun for 2/3 days

Production Process of Lontar

Define the size and cut

Make three hole markers

Tighten and press with wood

Production Process of Lontar

Smoothing the edges of the leaves

Production Process of Lontar

Create lines with carbon to guide the writing

Production Process of Lontar

Tighten and press with wood

Production Process of Lontar

Ready to write

Writing Process and the Script

Script

- The writings:
  - the ancient literary texts composed in the old Javanese of Kawi and Sanskrit;

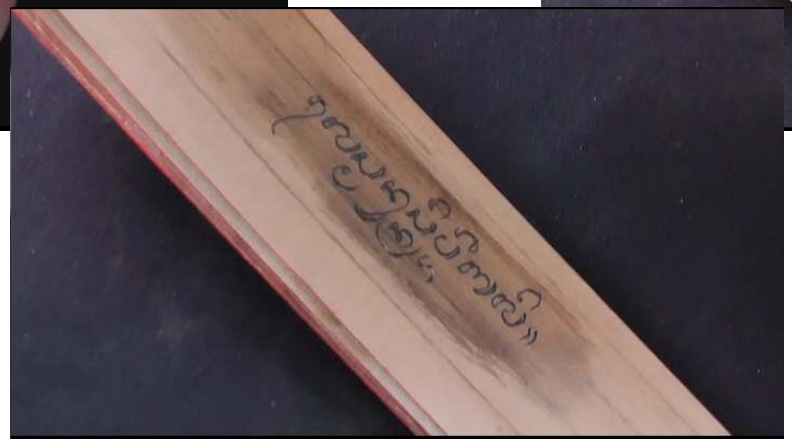
http://www.wonderfullbali.com

Lontar are inscribed with a special tool called a pengerupak. It is made up of iron, with its sharp tip in a triangular shape so it can make inscriptions thick and thin. There are two types of pengerupak, one for writing and one for drawing. The pengerupak for writing is about 15 in length and 1.5 cm wide, the pengerupak for drawing is the same length but is only 0.5 to 1 cm wide. There is also a third long type which is used for cutting rontar leaves.

Writing Process

Lontar are inscribed with a special tool called a pengerupak. It is made up of iron, with its sharp tip in a triangular shape so it can make inscriptions thick and thin.

The writings were incised on one (and or both) sides of the sheet with a sharp knife and the script is therefore blackened with soot



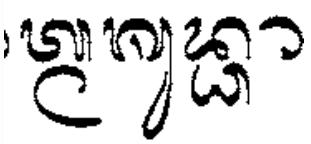
Ancient palm leaf manuscript is written on a dried palm leaf using a kind of small knife, which is then rubbed with natural dyes

The Unicode Standard, Version 7.0
Balinese, Range : 1B00 – 1B7F

Various signs

1B00	◌ᭀ	BALINESE SIGN ULU RICEM = ardhacandra
1B01	◌ᭁ	BALINESE SIGN ULU CANDRA = candrabindu
1B02	◌ᭂ	BALINESE SIGN CECEK = anusvara
1B03	◌ᭃ	BALINESE SIGN SURANG = repha
1B04	◌᭄	BALINESE SIGN BISAH = visarga

	1B0	1B1	1B2	1B3	1B4	1B5	1B6	1B7
0	◌ᭀ 1B00	᭐ 1B10	᭰ 1B20	◌᭰ 1B30	◌ᭀ 1B40	ᭀ 1B50	᭠ 1B60	◌ᭀ 1B70
1	◌ᭁ 1B01	᭑ 1B11	᭱ 1B21	◌᭱ 1B31	◌ᭁ 1B41	ᭁ 1B51	᭡ 1B61	◌ᭁ 1B71
2	◌ᭂ 1B02	᭒ 1B12	᭲ 1B22	◌᭲ 1B32	◌ᭂ 1B42	ᭂ 1B52	᭢ 1B62	◌ᭂ 1B72
3	◌ᭃ 1B03	᭓ 1B13	᭳ 1B23	◌᭳ 1B33	◌ᭃ 1B43	ᭃ 1B53	᭣ 1B63	◌ᭃ 1B73
4	◌᭄ 1B04	᭔ 1B14	᭴ 1B24	◌᭴ 1B34	◌᭄ 1B44	᭄ 1B54	᭤ 1B64	᭼ 1B74
5	ᭅ 1B05	᭕ 1B15	᭵ 1B25	◌᭵ 1B35	ᭅ 1B45	ᭅ 1B55	᭥ 1B65	◌᭽ 1B75
6	ᭆ 1B06	᭖ 1B16	᭶ 1B26	◌᭶ 1B36	ᭆ 1B46	ᭆ 1B56	᭦ 1B66	᭾ 1B76
7	ᭇ 1B07	᭗ 1B17	᭷ 1B27	◌᭷ 1B37	ᭇ 1B47	ᭇ 1B57	᭧ 1B67	᭿ 1B77
8	ᭈ 1B08	᭘ 1B18	᭸ 1B28	◌᭸ 1B38	ᭈ 1B48	ᭈ 1B58	᭨ 1B68	ᮀ 1B78
9	ᭉ 1B09	᭙ 1B19	᭹ 1B29	◌᭹ 1B39	ᭉ 1B49	ᭉ 1B59	᭩ 1B69	ᮁ 1B79
A	ᭊ 1B0A	᭚ 1B1A	᭺ 1B2A	◌᭺ 1B3A	ᭊ 1B4A	ᭊ 1B5A	᭪ 1B6A	ᮂ 1B7A
B	ᭋ 1B0B	᭛ 1B1B	᭻ 1B2B	◌᭻ 1B3B	ᭋ 1B4B	ᭋ 1B5B	᭫ 1B6B	ᮃ 1B7B



Motivations and Objectives

Motivations

- to bring added value to digitized palm leaf manuscripts
  - analyze
  - transliterate
  - index

more accessible, *readable* and *understandable*

... in working with the collections of palm leaf manuscripts

- preservation
  - physical condition of material
- access
  - very valuable cultural content
- sharing
  - open to community

Technical Objectives

to develop a DIA system for document images of palm leaf manuscripts

Research Problematics :: *Very Wide Range ! Pipeline!!*

- ✓ **Digitization**
- ✓ **Ground Truth Dataset Construction**
- ✓ Document Image Pre-processing
- ✓ **Binarization**
- ✓ **Segmentation/Localization/Detection**
  - ✓ Physical : **Text Area**, Paragraph, Figure/Diagram/Logo/Letterine/**Prasi Lontar**, **Textline**, Word, **Character/Glyph**, Tabel
  - ✓ Semantic : Header/Footer, Footnote, Formula/Equation, Title, Comic components
- ✓ **Recognition**
  - ✓ Text : **Textline**, **Word**, **Character/Glyph**, Formula/Equation
  - ✓ Image : Figure/Diagram/Logo/Letterine, Shape and Curve, **Prasi Lontar**
- ✓ Identification : Script, Writer
- ✓ **Transliteration + Post Transliteration Correction**
- ✓ **Word Spotting**
- ✓ **Document Indexation/Retrieval**

Processing Sequence

Challenges

Socio-cultural Challenges

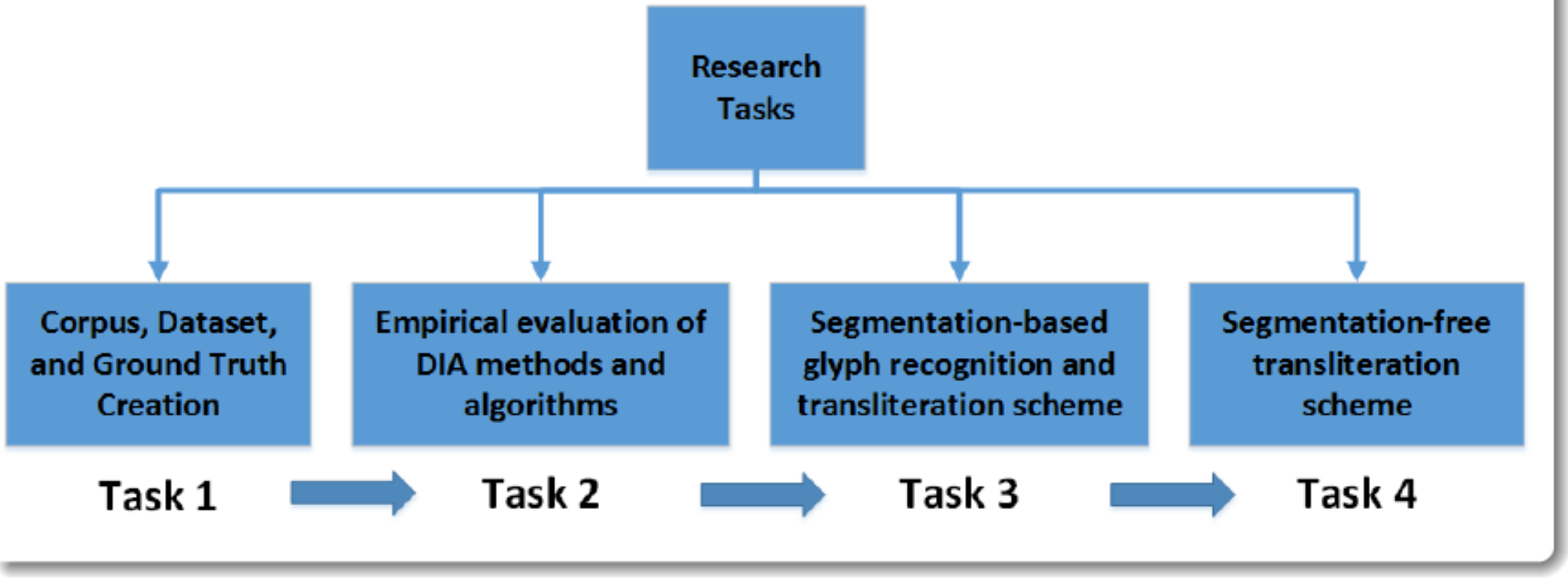
Difficulty in collecting samples

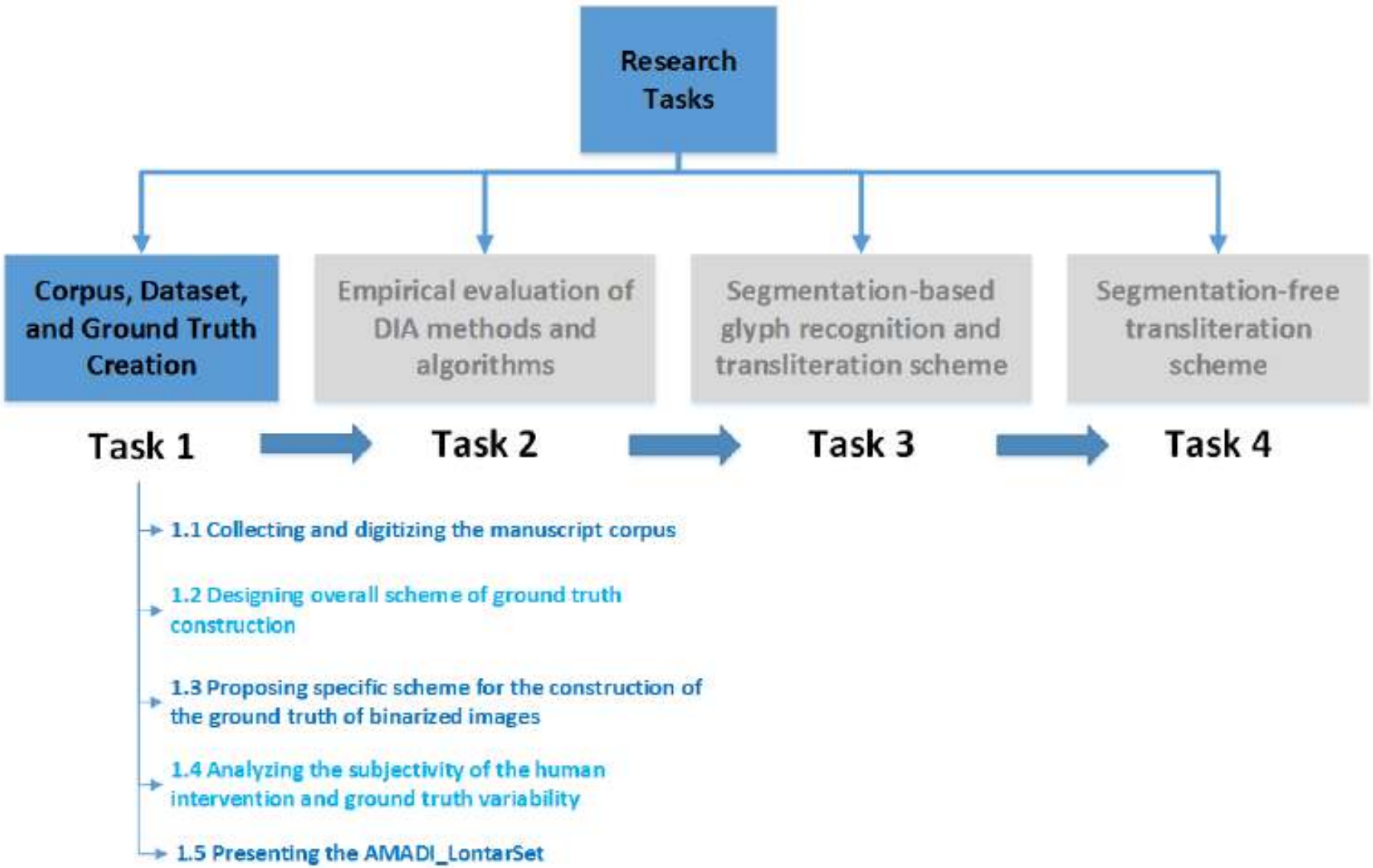
- cultural and religious conditions
- sacred collections
- permission
- rules
- families are very reluctant

Difficulty in finding the Balinese philologist

- not many Balinese can read
- not used everyday
- not popular
- retirement
- lack experience

Global Overview




Research Tasks
Corpus, Dataset, and Ground Truth Creation
Empirical evaluation of DIA methods and algorithms
Segmentation-based glyph recognition and transliteration scheme
Segmentation-free transliteration scheme
Task 1
Task 2
Task 3
Task 4
1.1 Collecting and digitizing the manuscript corpus
1.2 Designing overall scheme of ground truth construction
1.3 Proposing specific scheme for the construction of the ground truth of binarized images
1.4 Analyzing the subjectivity of the human intervention and ground truth variability
1.5 Presenting the AMADI_LontarSet

Challenges :: *Digitization*




- ✓ Size of Lontar
- ✓ Lontar pages packaging
- ✓ Fragility of Lontar material
- ✓ Sacred collection and location

Solution :: *Digitization* :: *Corpus Collection*

23 different collections

- 5 different locations (regions):
  - 2 museums
  - 3 private families

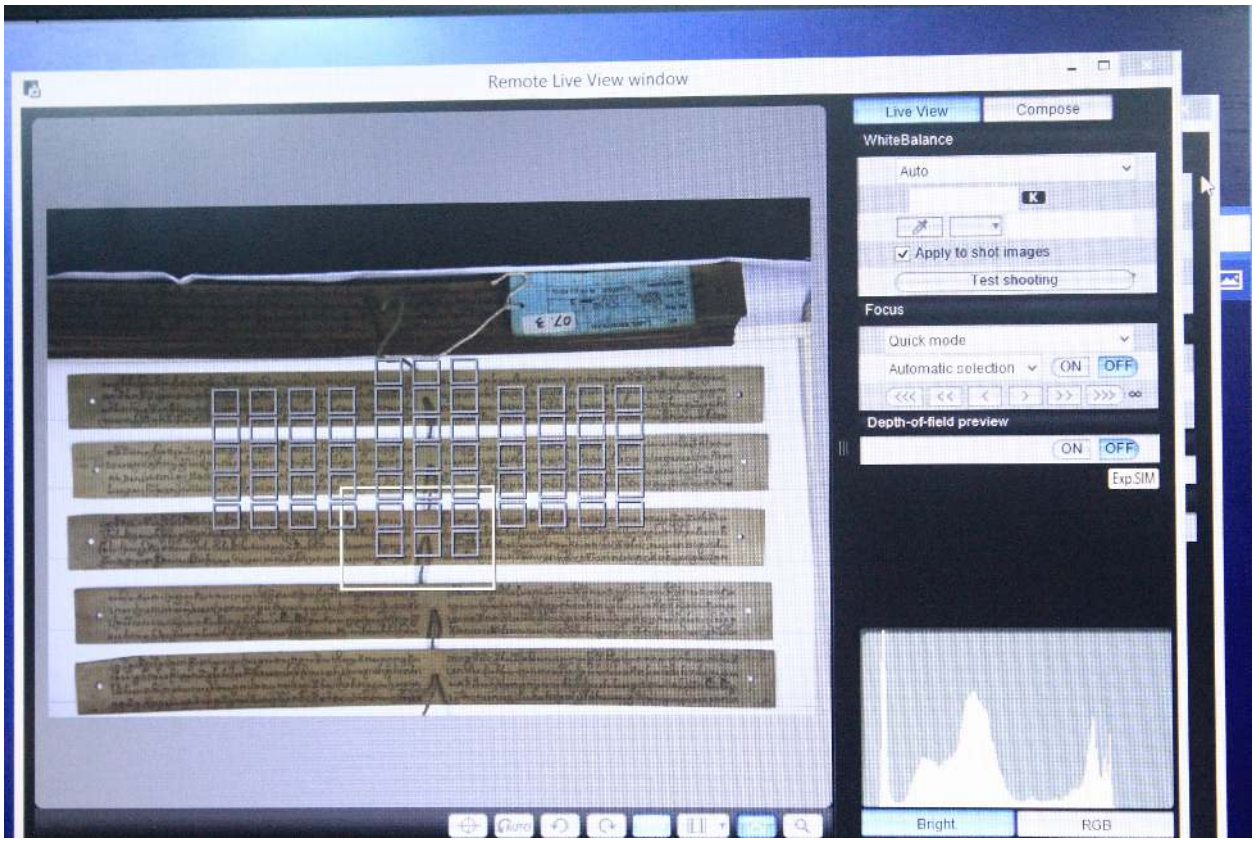
several restricted conditions

Camera Support

Digitization Process

Solution :: *Digitization Support*

Solution :: *Digitization* :: *Image Standardization*



Camera model : Canon EOS 5D Mark III
F-stop : f/22 (diafragma)
Exposure time : 1/50 sec
ISO speed : ISO-6400
Focal length : 70 mm
Flash : On - 1/64
Additional light : White Neon 50 cm 20 watt
Distance to object : 76 cm
Length object (manuscript) : +/- 50 cm
Focus : Quick mode - Auto selection On
Sensor size : 36x24 mm

Solution :: *Digitization Process*













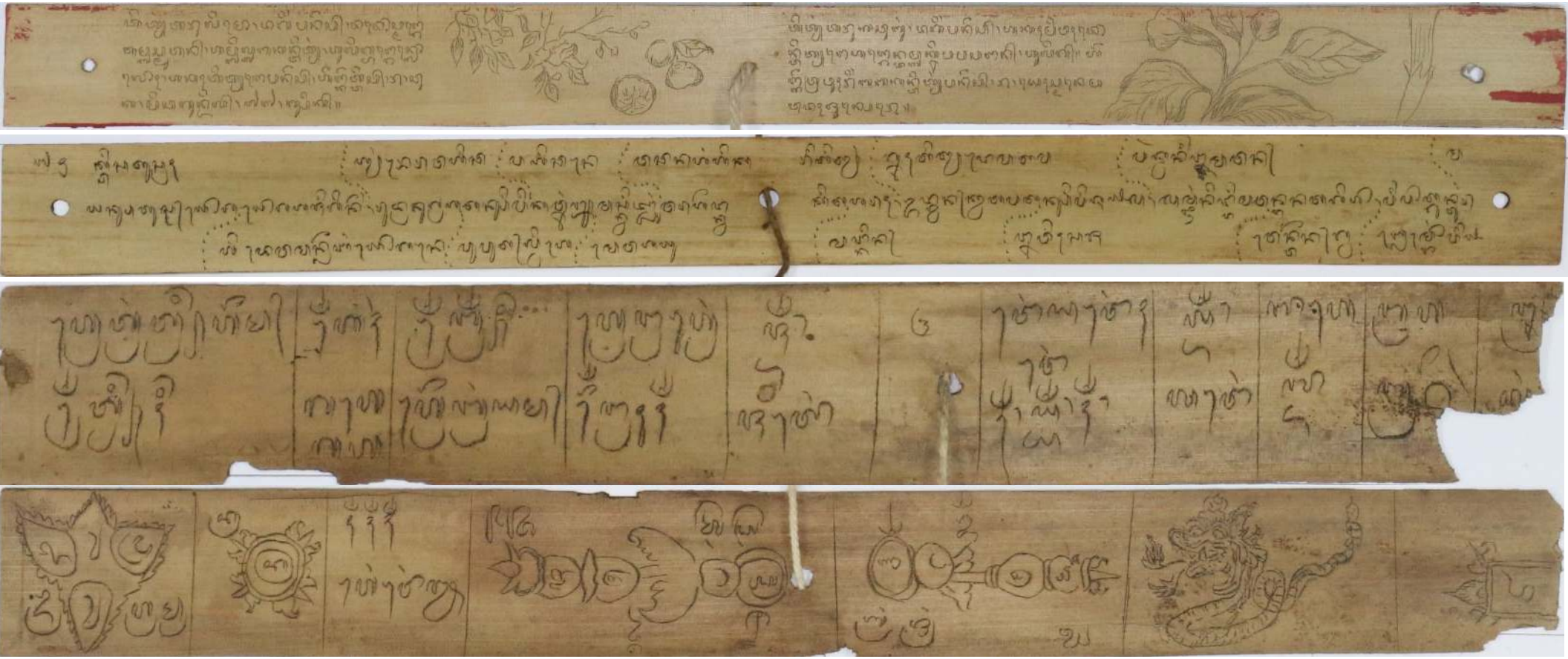




Solution :: *Digitization Process* :: *Image Samples*

Protocol 1 :
Sample Images of Manuscript from Museum Bali

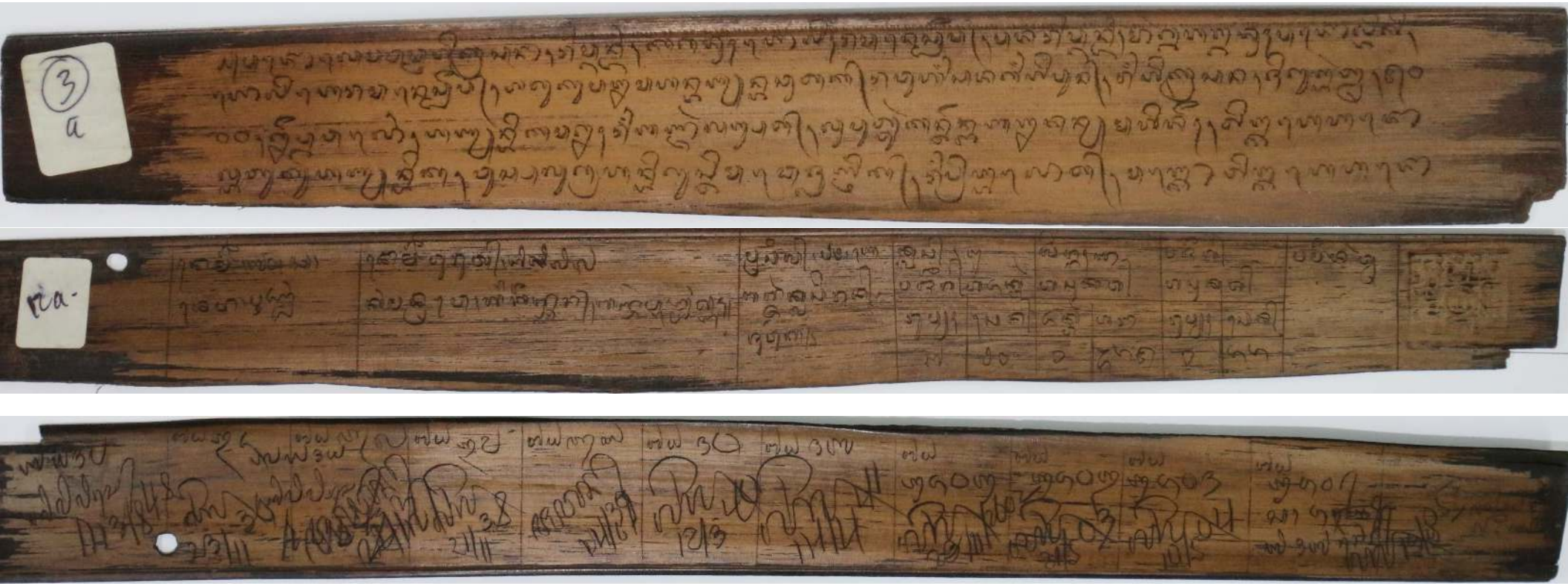
Protocol 1 :
Sample Images of Manuscript from Jagaraga



Protocol 1 :
Sample Images of Manuscript from Jagaraga

Protocol 1 :
Sample Images of Manuscript from Bangli

Protocol 1 :
Sample Images of Manuscript from Rendang



Summary Corpus Collection

Location	NbCollection	Collection	NbPages
Collection Privee, Keluarga Bangli, Bangli	1	Bangli	82
Museum Gedong Kertya, Singaraja	10	IIA-10-1534	8
		IIA-5-789	8
		IIB-2-180	8
		IIIB-12-306	8
		IIIB-42-1526	8
		IIIB-45-2296	8
		IIIC-19-1293	8
		IIIC-20-1397	8
		IIIC-23-1506	8
		IIIC-24-1641	8
Collection Privee, Keluarga Jagaraga, Buleleng	7	JG-01	16
		JG-02	10
		JG-03	16
		JG-04	12
		JG-05	8
		JG-06	5
		JG-07	10
Museum Bali, Denpasar	4	MB-AdiParwa(Purana)-5338.2-IV.a	40
		MB-AjiGriguh-5783-107.2	20
		MB-ArjunaWiwaha-GrantangBasaII	30
		MB-TaruPramana	40
Collection Privee, Keluarga Rendang, Karangasem	1	WN	24
Total	23		393

Protocol 2 : Transliteration of Manuscripts

Bangli-P39

- Buik julang, ijo asuh, ta. Biing kuning rarajah soring tegil, ja, biing putih rarajah, ta. Biing kuning raraja
- H jarijinia, ja, nga, biing nyelem, ta. Biing jenar, ta. Biing jenar rarajah, ja, ijo jenar rarajah tuk muhmuh, tekaning putih
- Tulus, sabiru, wangkas biru, klau biru, ta. Biinga ijo, ja, putih tulus, putih siungan
- Ta. Biing bang karna, ja, buik kuning, ta. Biing gadang cucuk cemeng, ja, srawah putih, ta. Biing nyelem biing gadang

Protocol 2 : Transliteration of Manuscripts

IIIB-45-2296-P7

- Nto cai resepang apang pasti, di keneh yen suba anut ban cai ngonek sastra, pasang sutra keras ento masih tuptup, kalih munyining pidartane madan pidarta munyi. Sastra soroh matunggalan,
- Munyi tunggal mawa ada wuwuhin, nyan pidarta sangkan payu, dadi anto kaucap, di madune da dantia munyine patuh, ada len buin kaucap, sa dantia munyinya tunggil. Lan ta
- Lawia samurda, sok len sambat masih mamunyi tunggil, ta lati ta dantia patuh, masih teke talawia. Ada len to macelek suku kembung masih mawak talawia, tunggal munyinya wia
- Kti. Puh Durma. Ga gora ga dantia, mamunyi tunggal, na dantiane tekening ne madan na rambat, tunggal masih munyinya pe palane tunggal munyi teken pa dantia,

MB-TaruPramana-P4

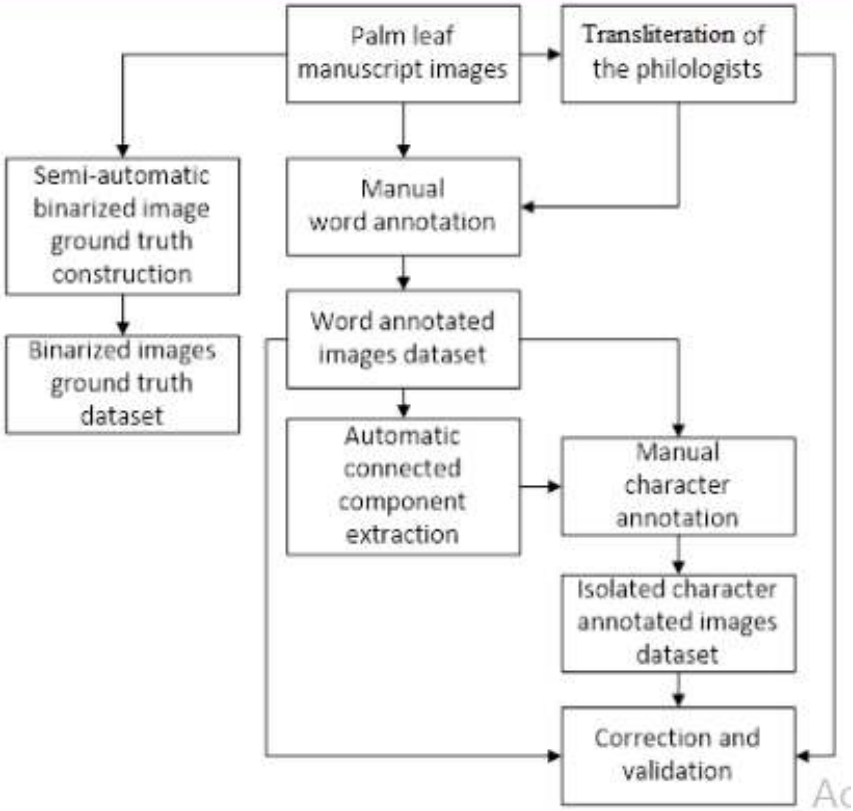
- Kadi titiang. Ngandika sang prabhu. Kene iba bingin, wireh awake dadi baleen, tan sida nyegerang jani,
- Makeneh nyekenang teken I kayu niri niri. Apa gunannyane, muang dadi anggon uba
- D apa. I taru bingin mapamit. Sang prabhu empu kuturan malih ngarad. Raris rauh wit kasela gui, sasampu
- Ne tinakenan annuli matur. Titiang mawasta kasela gui, daging titiange tis, dadong anggen tamba lolo

Scheme :: *Ground Truth Dataset Construction*

Approach

- man-hours
- expertized people
  - manual
  - semi automatic
- ground truther
  - Balinese philologist
  - students in Balinese literature
  - students in Informatics

Overall Scheme



Protocol :: *Ground Truth Dataset Construction*

Transliterated Text - Manual

IIIB-45-2296-P7
- Nto cai resepang apang pasti, di keneh yen suba anut ban cai ngonek sastra, pasang sut
- Munyi tunggal mawa ada wuwuhin, nyan pidarta sangkan payu, dadi anto kaucap, di ma
- Lawia samurda, sok len sambat masih mamunyi tunggil, ta lati ta dantia patuh, masih te
- Kti. Puh Durma. Ga gora ga dantia, mamunyi tunggal, na dantiane tekening ne madan n

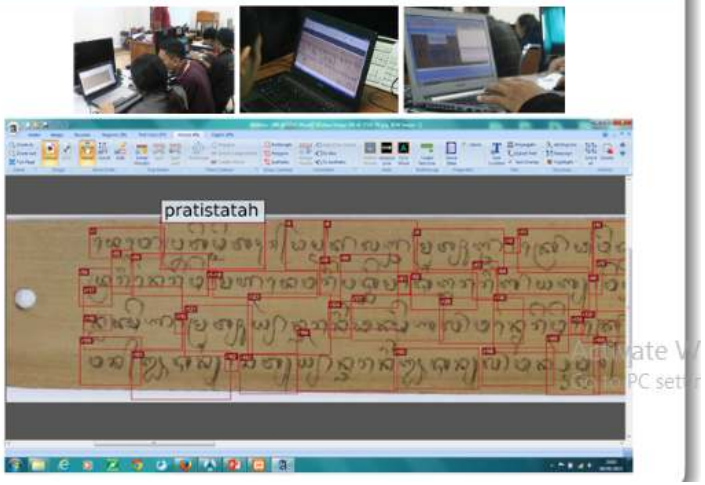
Text Line Segmented - Manual (from Binarized Image)

Binarized Image - Semi Auto

Proposed Binarization Scheme

Glyph Annotated - Semi Auto

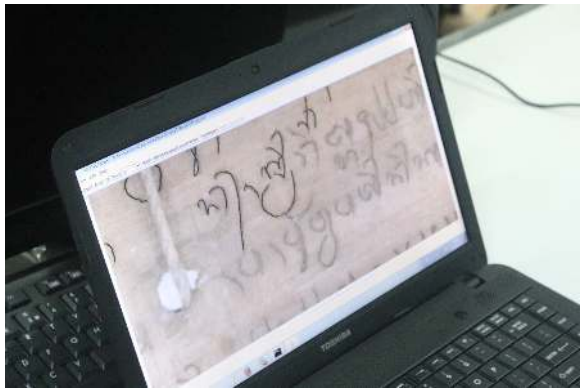
Word Annotated - Manual



Ground Truthers:
- ✓ 70 students of Informatics
- ✓ 10 students of Balinese Litterature
- ✓ 2 Balinese philologists

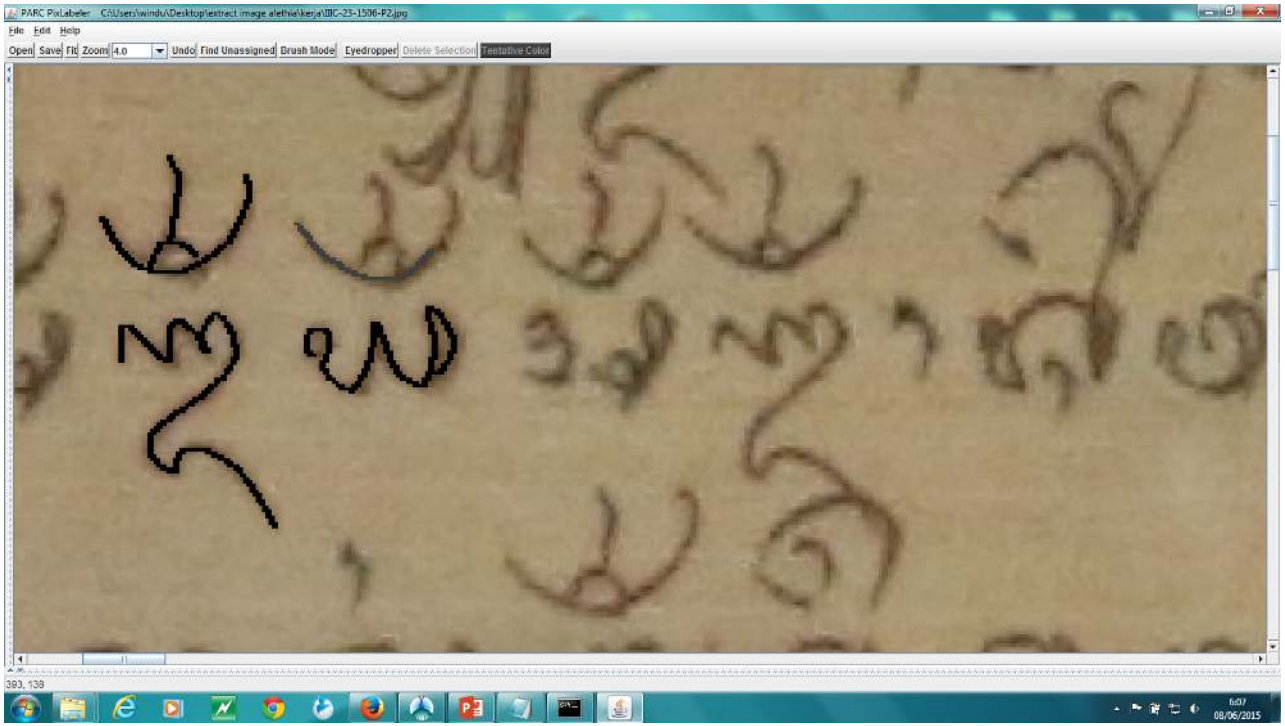
Tools:
- ✓ **PixLabeler** for Binarization
- ✓ **Aletheia** for Word Annotation
- ✓ Developed a **Web-based interface** for Glyph Annotation
- ✓ **Text Editor** for Text Transliteration

Process :: *Ground Truth Dataset Construction*





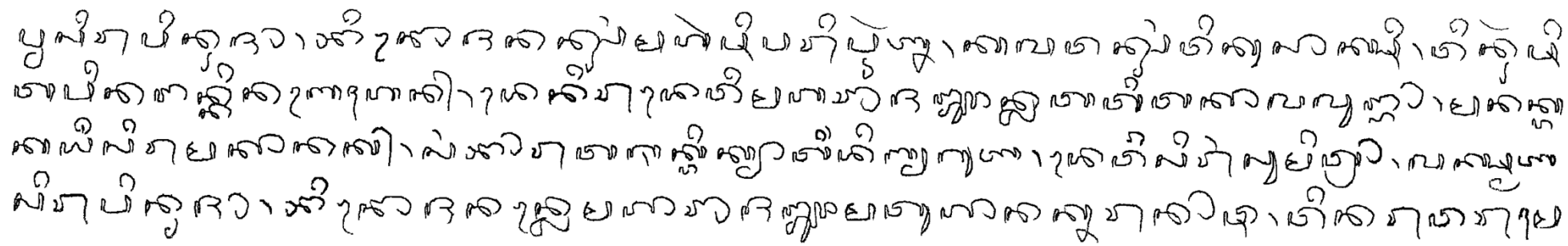

Protocol 3 : Ground Truth Creation
Binarized Image Dataset



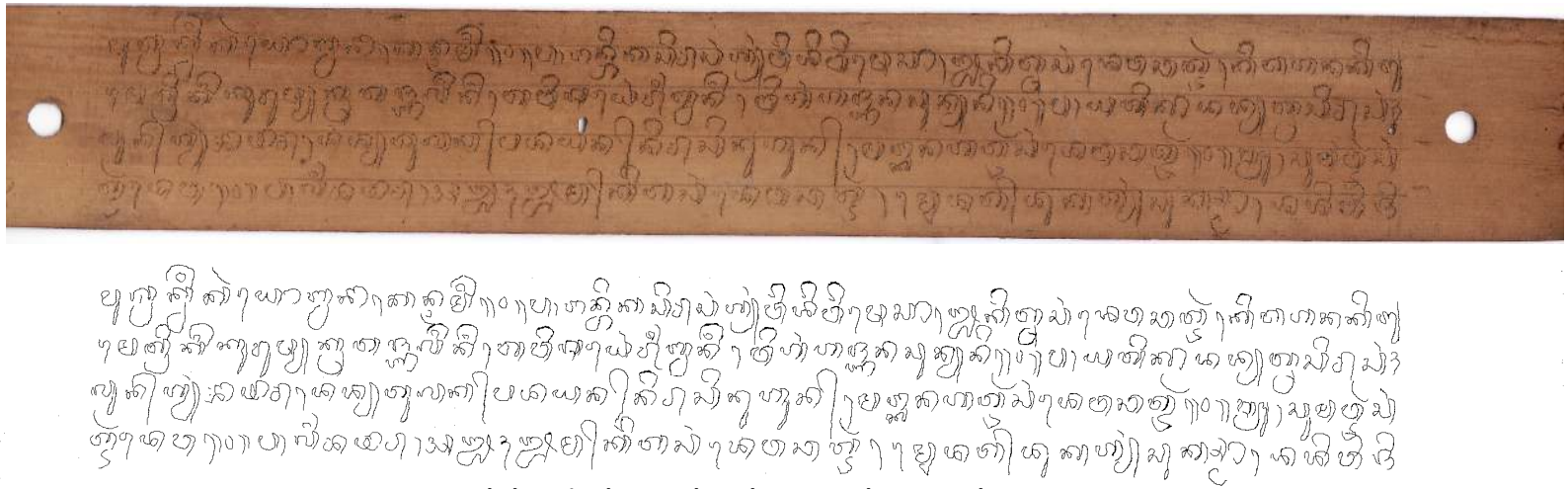
Tool : PixLabeler

[E. Saund, J. Lin, and P. Sarkar, “PixLabeler: User Interface for Pixel-Level Labeling of Elements in Document Images,” presented at the ICDAR ’09. 10th International Conference on Document Analysis and Recognition, 2009, pp. 646–650]

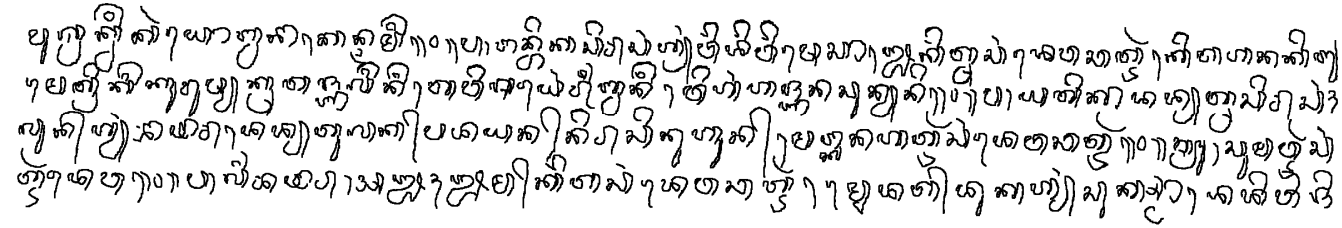
Result : Estimated Ground Truth of A Nondegraded Palm Leaf Manuscript Image



Result : Estimated Ground Truth of A Degraded Palm Leaf Manuscript Image



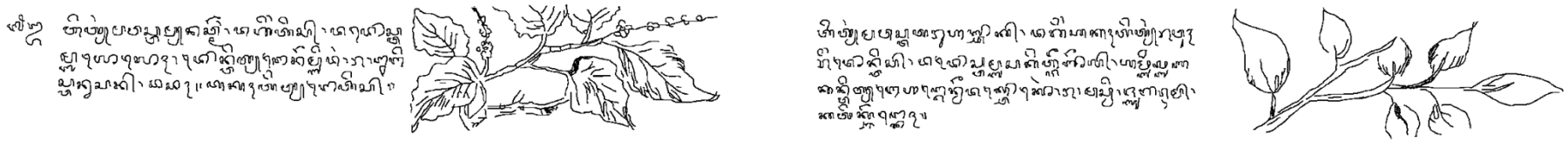
Skeletonized Ground Truth – Manual Corrected

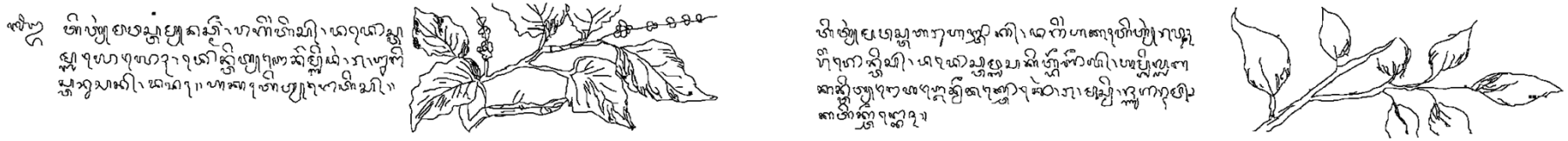


Ground truth image constructed without any constraint of initial binarized image

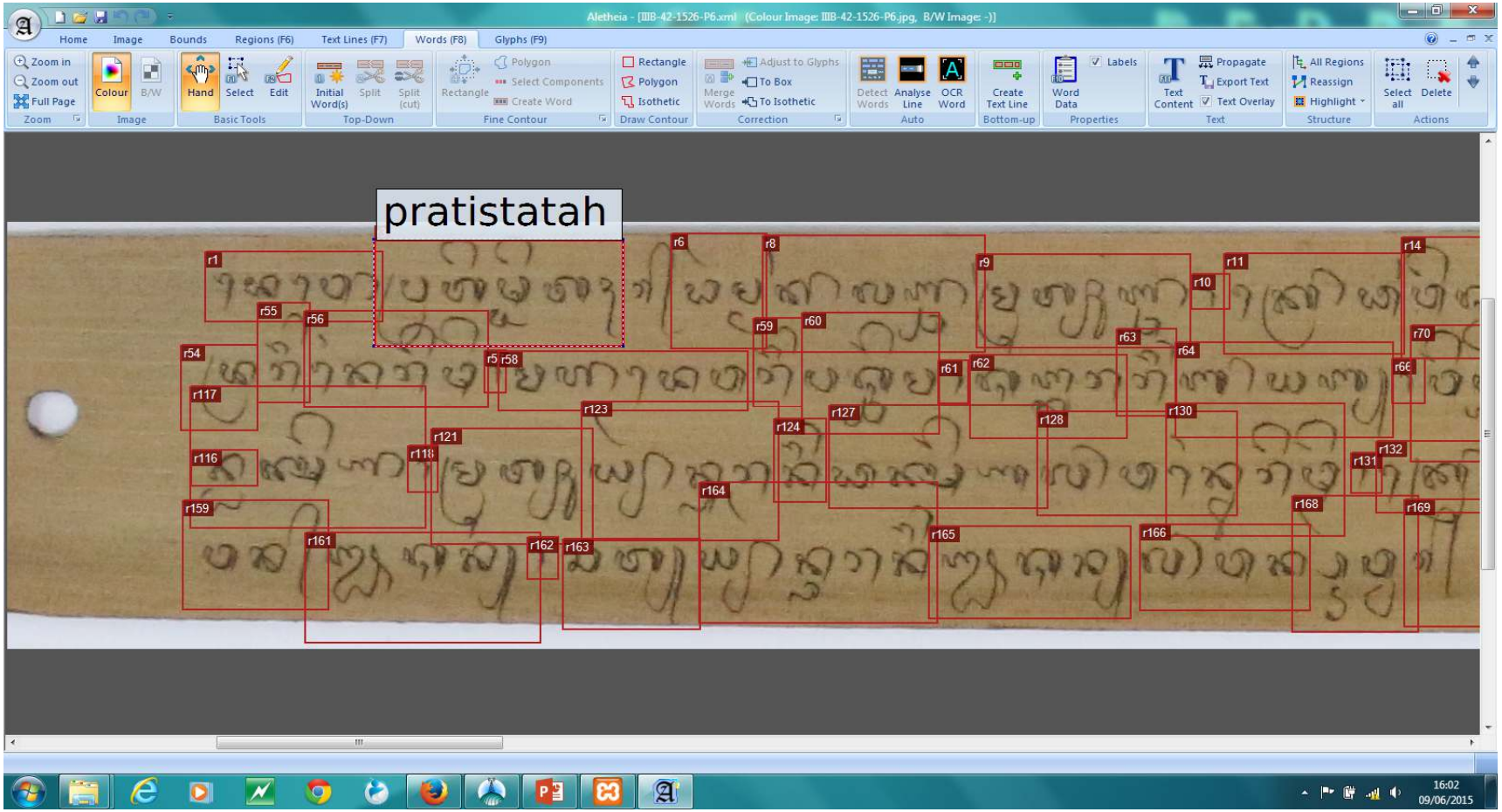
Result : Estimated Ground Truth of A Degraded Palm Leaf Manuscript Image

Ground Truth Binarized Image Variability

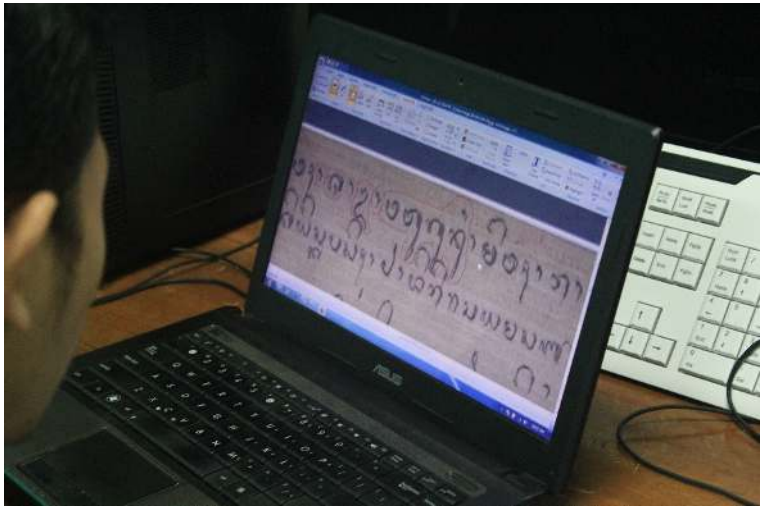




Protocol 4 : Ground Truth Creation
Word Annotated Image Dataset



Protocol 4: Ground Truth Creation Word Annotated Image Dataset



Data: Word Annotated Image Dataset

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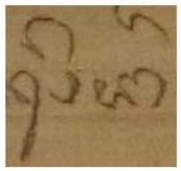

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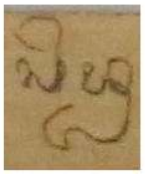

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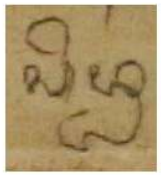
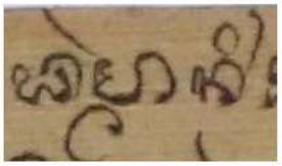
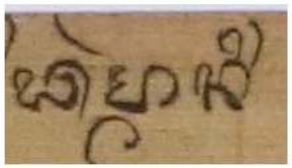
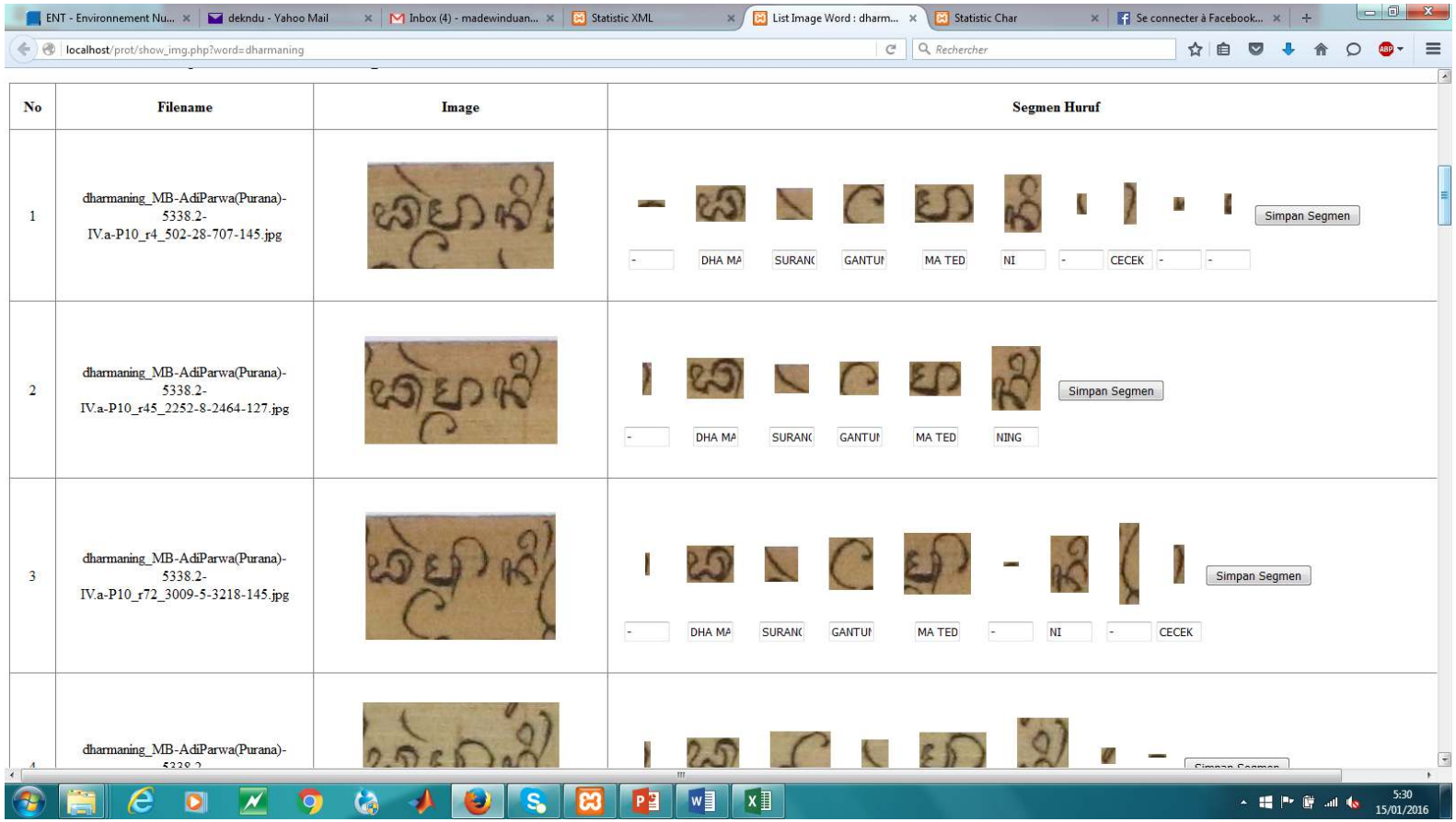


Protocol 5 : Ground Truth Creation
Character Annotated Image Dataset

1	dharmaning_MB-AdiParwa(Purana)-5338.2-IV.a-P10_r4_502-28-707-145.jpg		 - DHA MA SURAN(GANTUI MA TED NI - CECEK - - Simpan Segmen
2	dharmaning_MB-AdiParwa(Purana)-5338.2-IV.a-P10_r45_2252-8-2464-127.jpg		 - DHA MA SURAN(GANTUI MA TED NING Simpan Segmen

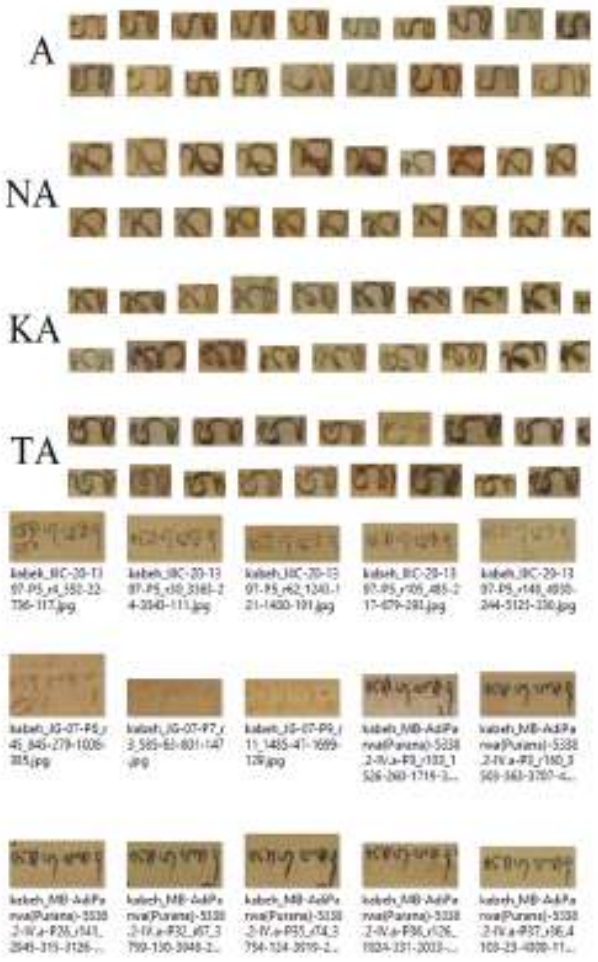
Web Dataset for Palm Leaf Manuscript Images



Contribution: The first handwritten Balinese palm leaf manuscript dataset [Kesiman et al., 2016a]

1. transliterated manuscript images (390 pages)
2. binarized images (100 pages, 200 ground truth images)
3. text line segmented images (96 pages, 363 text lines)
4. word annotated images (25,497 word images)
5. isolated glyph annotated images (19,383 glyph images)
6. page images with glyph segmentation and recognition (19 pages)

The dataset are already publicly available for scientific use



character and word annotated images

AMADI_LontarSet :
The first handwritten balinese Palm Leaf Manuscripts dataset

- **ICFHR 2016 Competition on the Analysis of Handwritten Text in Images of Balinese Palm Leaf Manuscripts**
- **ICFHR 2018 Competition On Document Image Analysis Tasks for Southeast Asian Palm Leaf Manuscripts**

Publicly available for scientific use on:

http://amadi.univ-lr.fr/ICFHR2016_Contest/

http://amadi.univ-lr.fr/ICDAR2017_Competition/

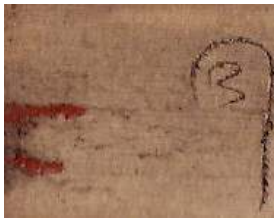
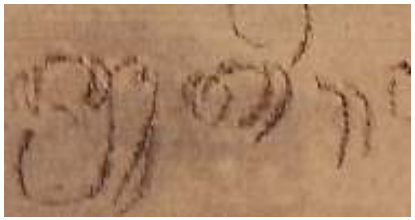
http://amadi.univ-lr.fr/ICFHR2018_Contest/

Made Windu Antara Kesiman, Jean-Christophe Burie, Jean-Marc Ogier, Gusti Ngurah Made Agus Wibawantara, I Made Gede Sunarya. **AMADI_LontarSet: The First Handwritten Balinese Palm Leaf Manuscripts Dataset** *15th International Conference on Frontiers in Handwriting Recognition 2016*, Oct 2016, Shenzhen, China, pp.168-172. <10.1109/ICFHR.2016.39>

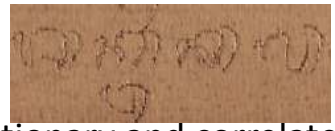
Problem Identification on Balinese Palm Leaf Manuscript Images

- artifacts due to aging, foxing, yellowing, marks of strain, local shading effects



- low intensity variations, low/poor contrast

- random noises, nonstationary and correlated noises




Problem Identification on Balinese Palm Leaf Manuscript Images (2)

- discoloured document, fading, variance of gray levels within object and the background

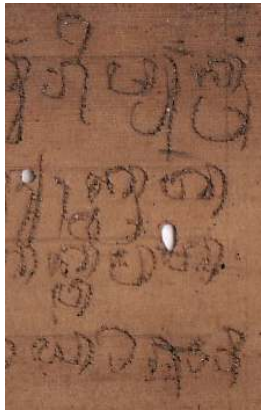
- the merges, fractures and other deformations in the character shapes

- use of non standard fonts

Problem Identification on Balinese Palm Leaf Manuscript Images (3)

- varying kerning (space between letters)

- varying leading (space between lines)



- Scanning errors and resolution, problems due to the conversion to digital image

Challenges :: *Technical Tasks*

Technical Challenges

Physical condition of the palm leaf

Low intensity variations, poor contrast

Artifacts due to aging, black nuances, foxing, and yellowing

Discoloured document, fading gray levels

Random noises

Challenging Tasks:

binarization | **text line segmentation** | **glyph segmentation**

Challenges :: *Binarization*

Binarization

- hard to separate the text from the background
- extract unrecognizable characters with noise

Method of Otsu, Niblack, Sauvola, Wolf, Rais

Challenges :: *Textline/Glyph Segmentation*

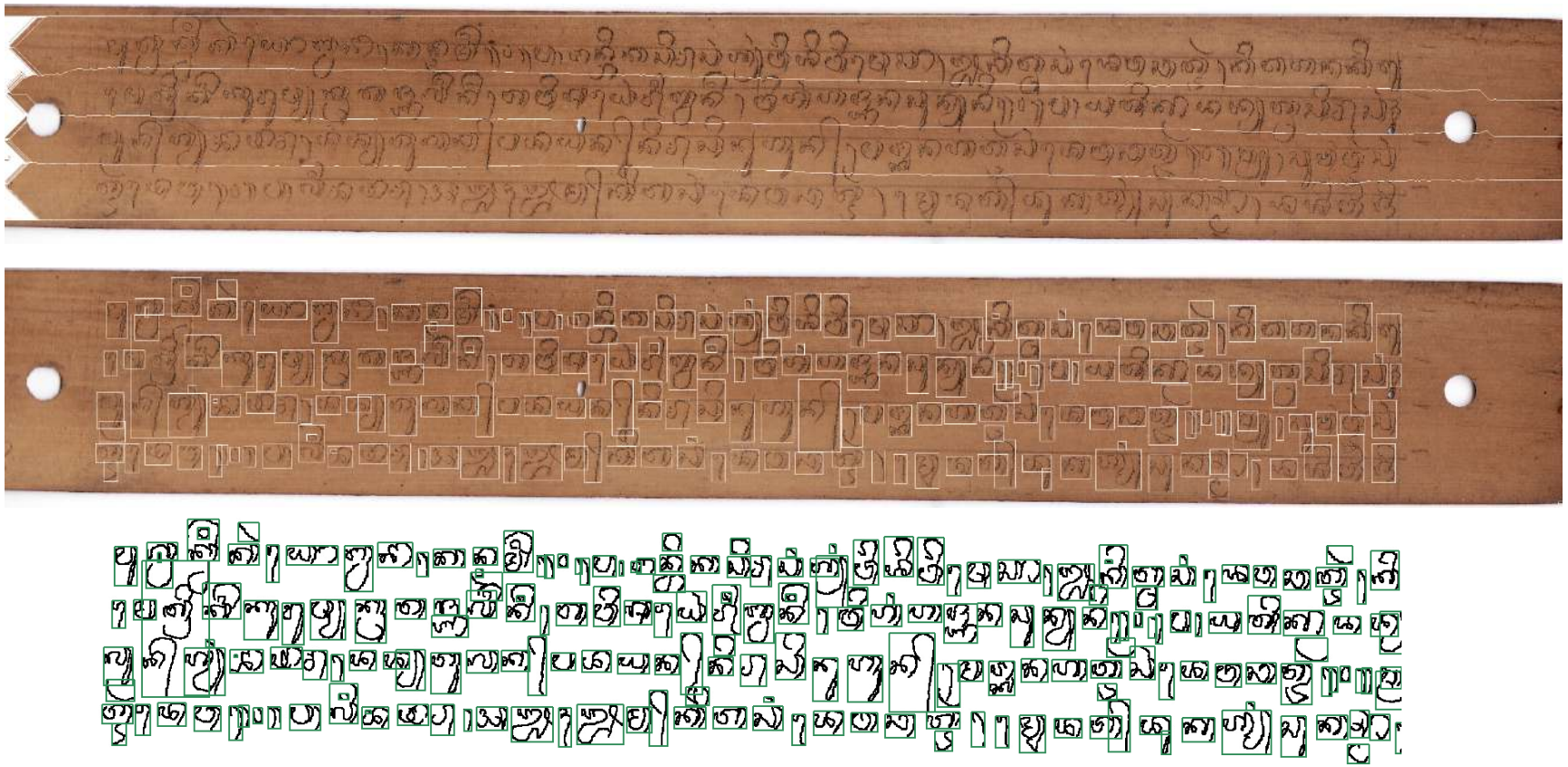
Text Line and Glyph Segmentation

Varying space between lines (leading)

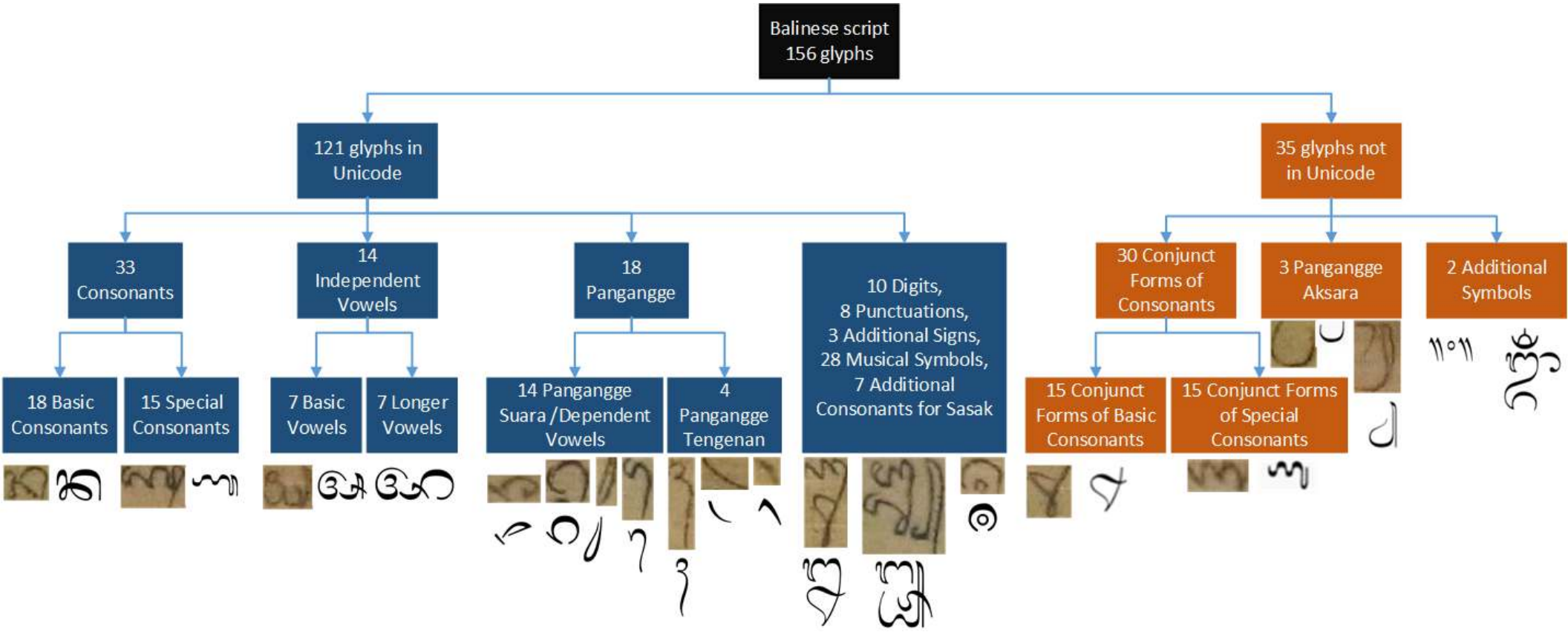
Merges, fractures and other deformations in the character shapes

Varying space between glyphs (kerning)

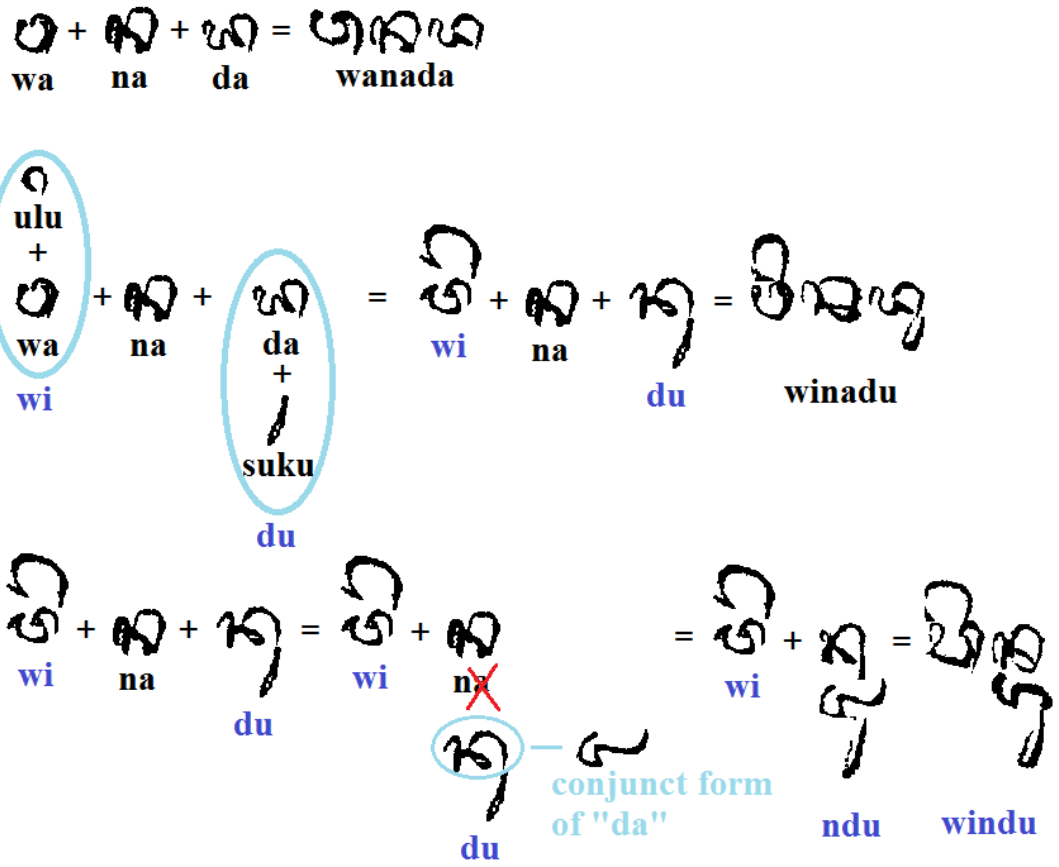
Challenges :: *Textline/Glyph Segmentation*



Challenges :: *Complexity of Balinese Script*

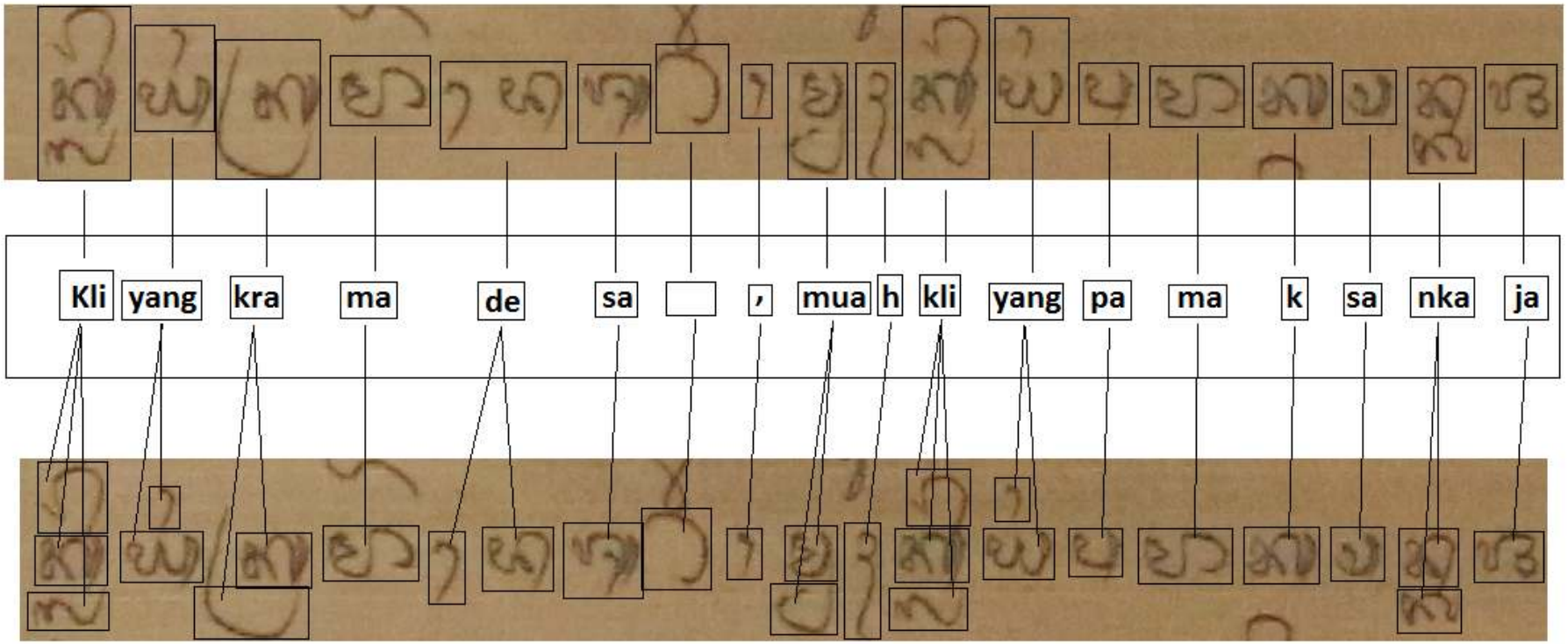


Challenges :: *Complexity of Balinese Script*

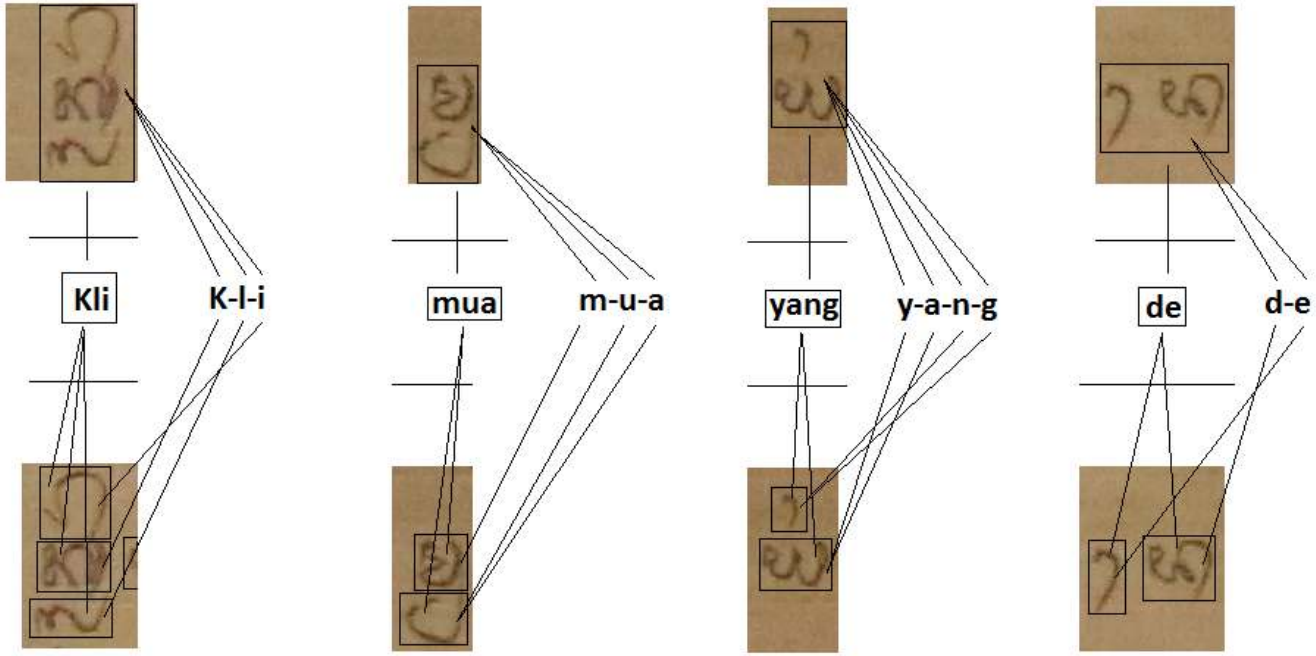


Challenges :: *Alignment of Balinese Script*

Kliyang krama desa, muah kliyang pamaksan kaja



Challenges :: *Alignment of Balinese Script*



For Balinese script transliteration, there are many :

- **Vertical Glyph Arrangement vs Horizontal Character alignments**
- **Alignment many-to-many**

Challenges :: *Character/Glyph Recognition*

Technical Challenges: Complexity of the Balinese script

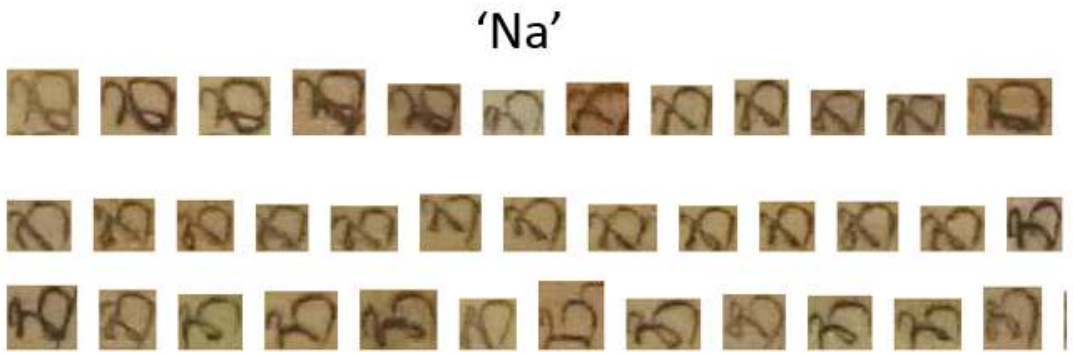
Challenges in Isolated Glyph Recognition

Different styles in writing Balinese script from different writers

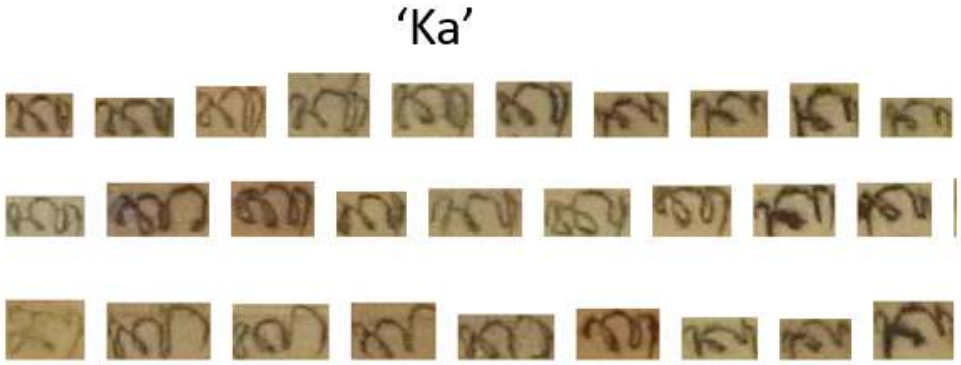
Interclass similarity between glyph

Different proportion size of glyphs

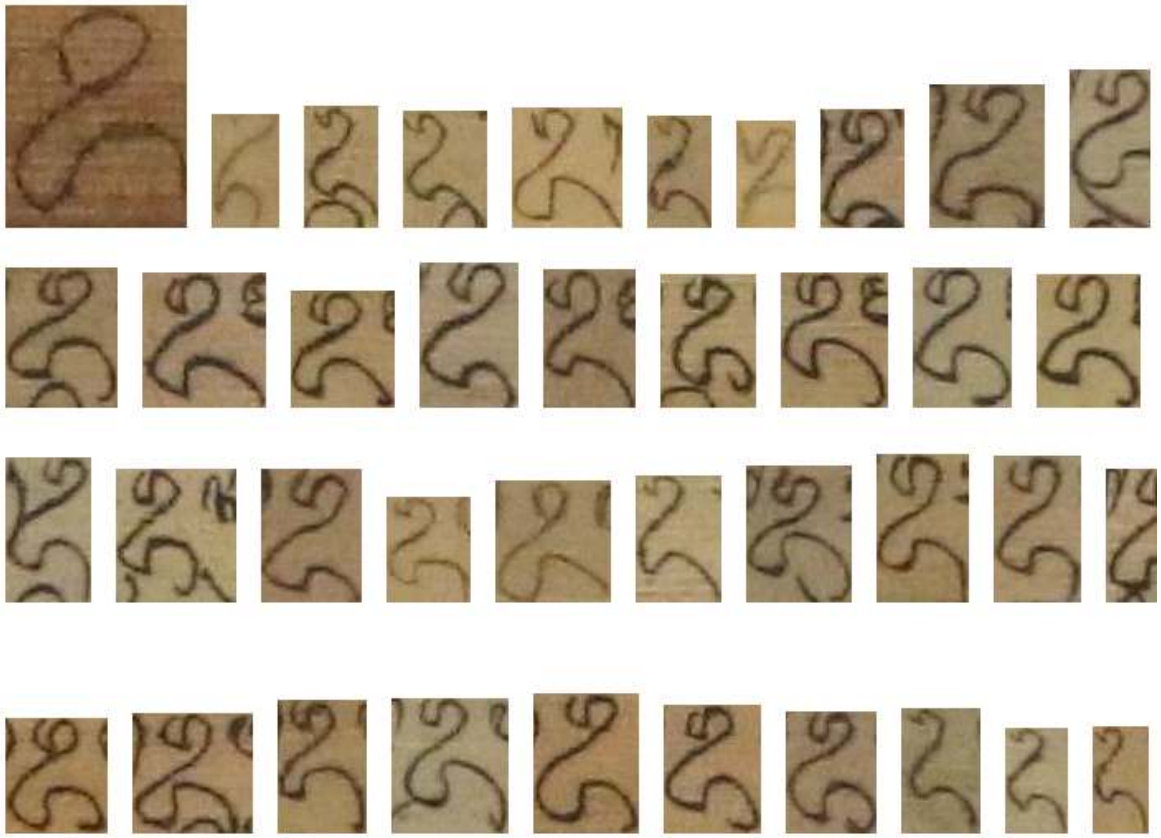
Challenges :: *Character/Glyph Recognition*



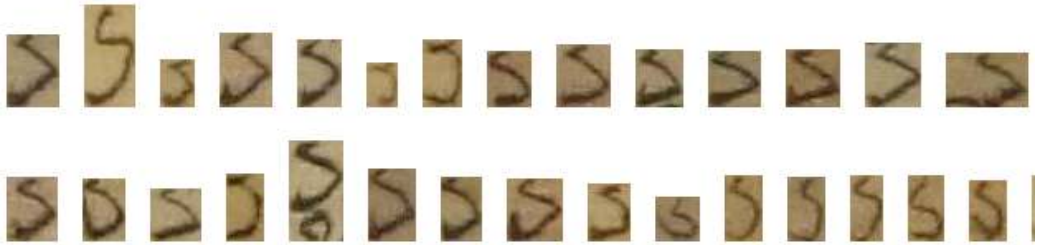
Model Classifier



Visual analysis of character appearance

U KARA Download Image(s)	118	

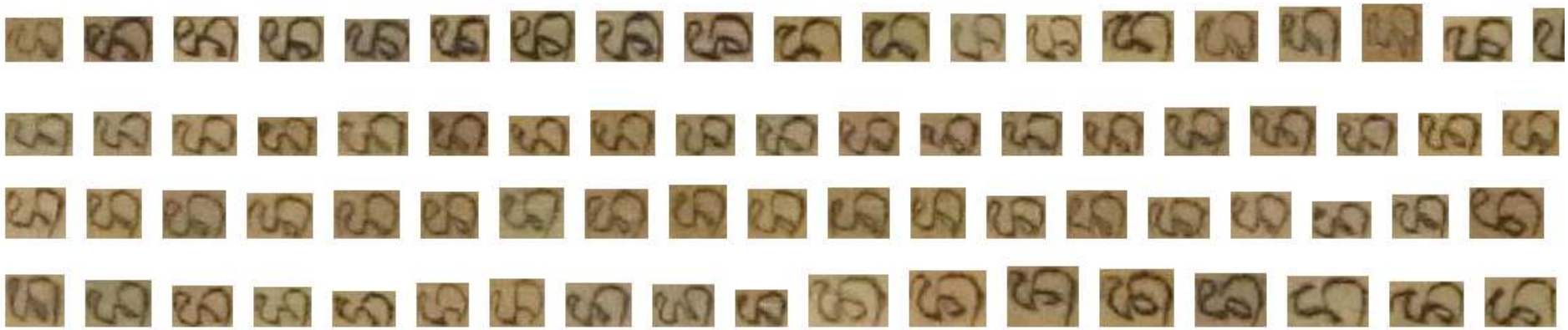
Visual analysis of character appearance

SUKU ILUT Download Image(s)	55	

Visual analysis of correlation

‘Ba Kembang’

‘Da’



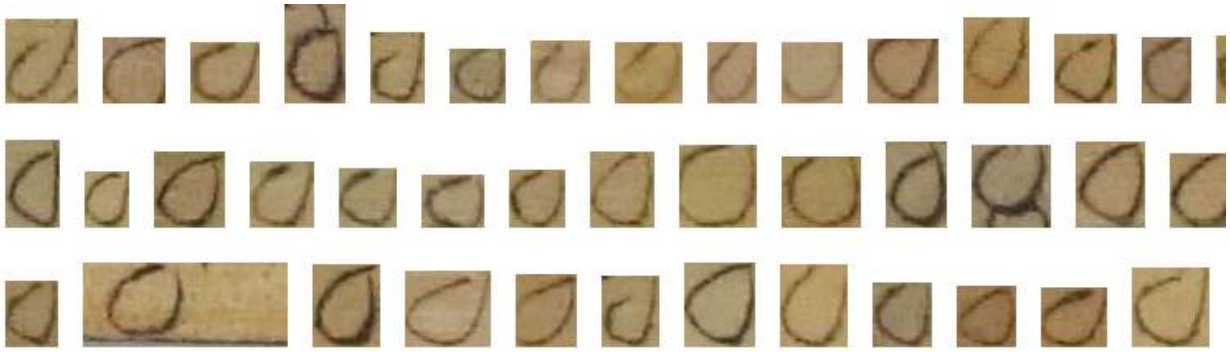
Visual analysis of correlation

‘A Kara’

‘Sa’

Visual analysis of correlation

‘Suku Kembung’

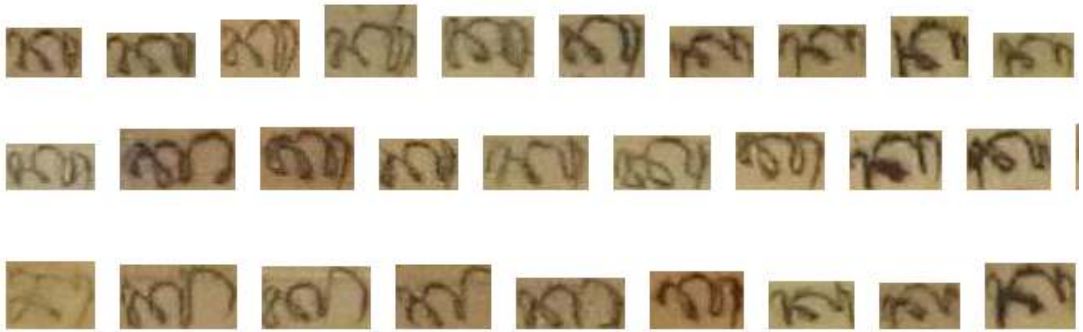


‘Nania’

Visual analysis of correlation

‘Na’

‘Ka’



Visual analysis of correlation

Character	NbTrain	Character	NbTrain	Correlation
BA KEMBANG	31	DA	605	37,5
A KARA	31	SA	294	35,7143
BA	337	A	756	27,7778
NGA	199	DA	605	27,7778
DA	605	NA	1029	25
PEPET	154	A	756	23,5294
NA RAMBAT	88	A	756	22,2222
GA	262	BA	337	21,0526

- Ba Kembang – Da

- A Kara – Sa

- Ba – A

- Nga – Da

- Da – Na

- Pepet - A

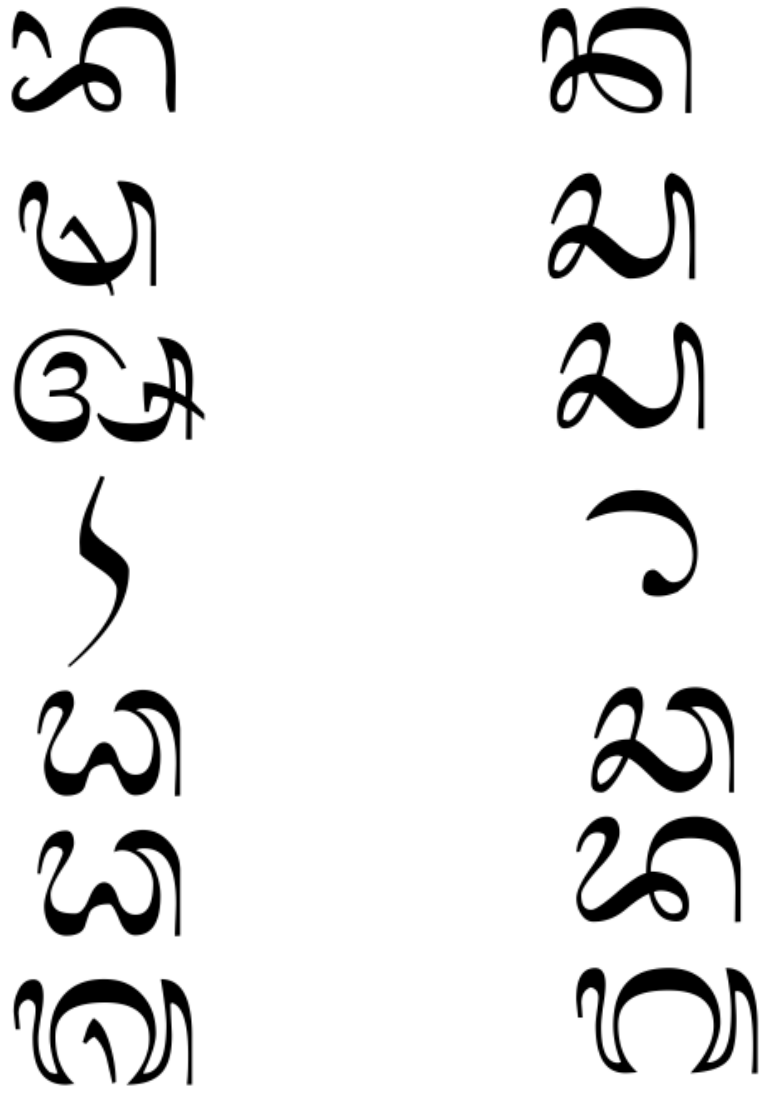
- Na Rambat – A

- Ga – Ba

Statistical correlation between characters

Correlation >= 20% :

Character	NbTrain	Character	NbTrain	Correlation
BA KEMBANG	31	NA	1029	55
SA SAPA	17	SA	294	40
A KARA	31	SA	294	31,5789
SUKU ILUT	35	TEDONG	212	27,7778
DHA MADU	85	CA	115	26,3158
DHA MADU	85	DA	605	21,0526
SA SAGA	51	GA	262	21,0526
NYA	23	BA	337	20



Size of ‘Adeg-Adeg’ ?

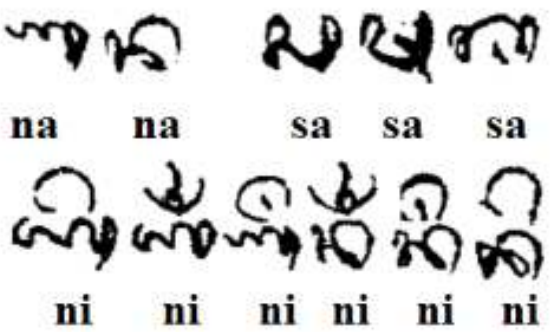
Challenges :: *Word/Text Recognition/Transliteration*

Challenges in Text Transliteration

- syllabic script
- speech sound = certain phonological rules [Antara Kesiman et al., 2018]
- problem of one-to-one mapping between linguistic symbols and images of symbols

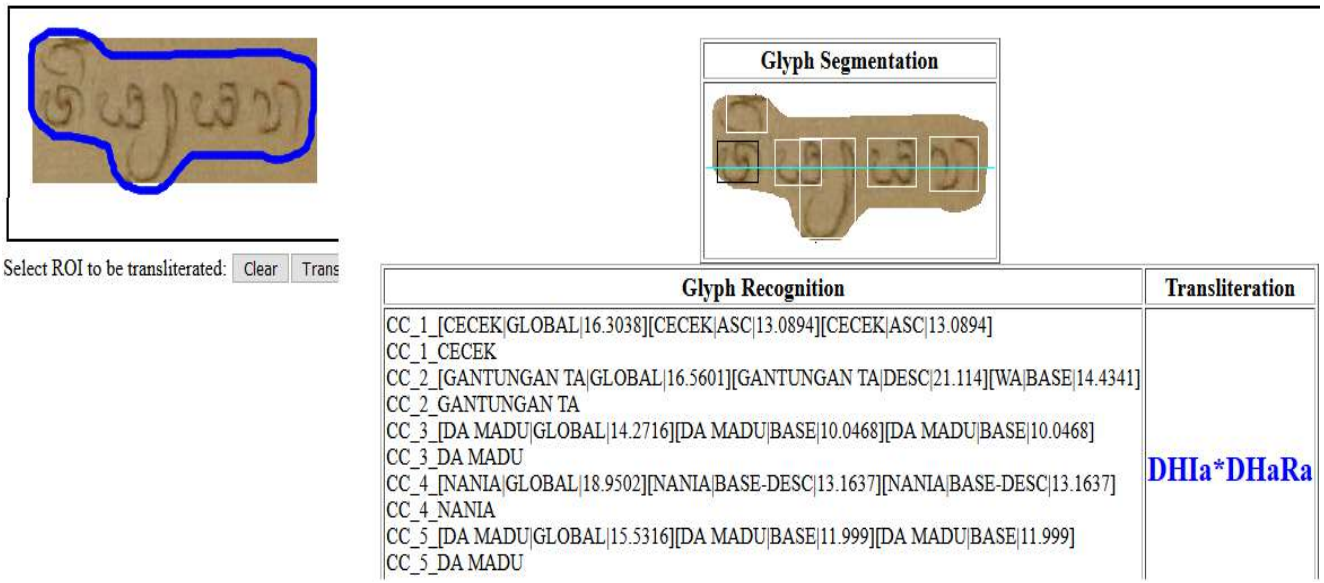
Huge combination of possible compound syllable

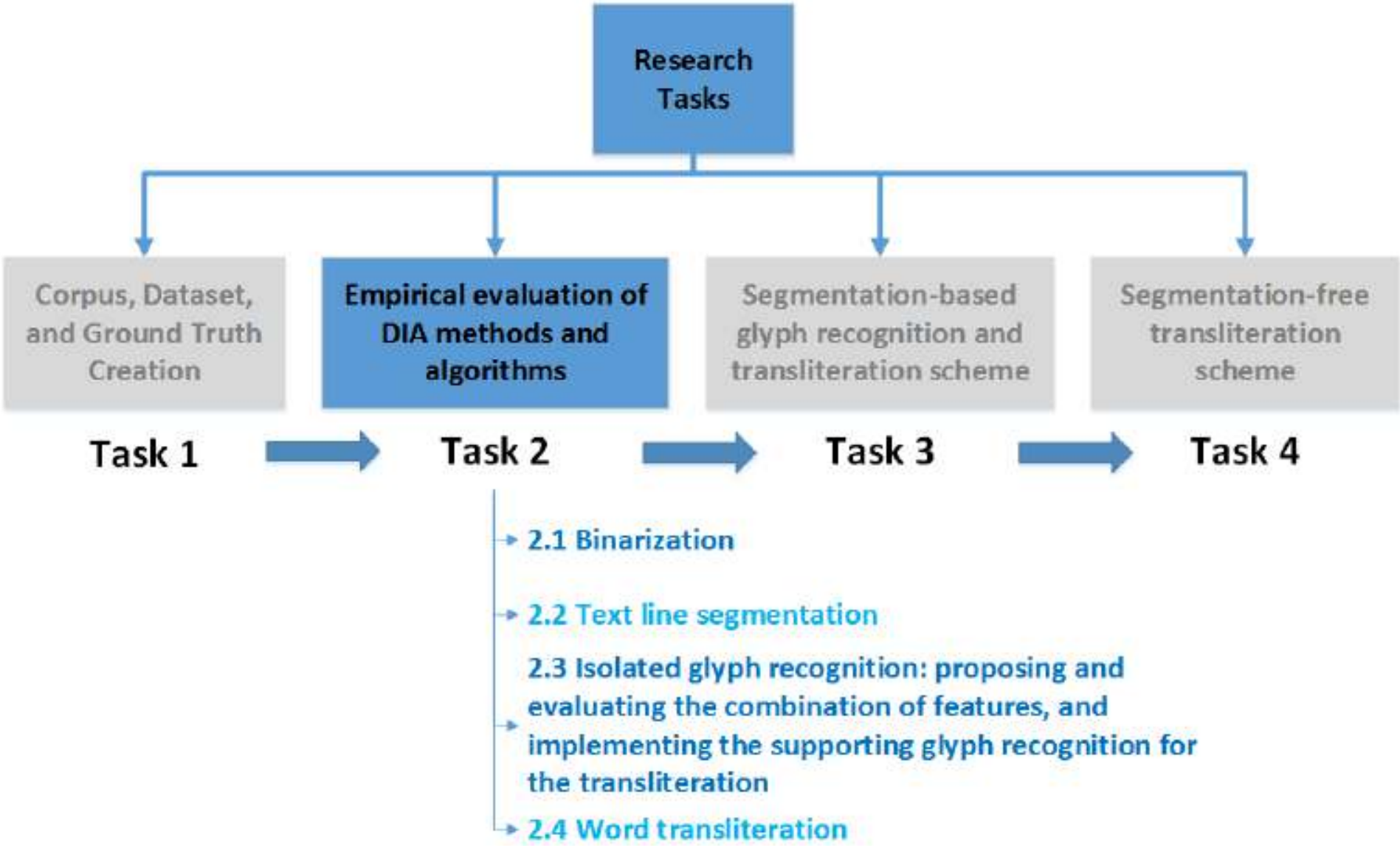
Problem of "allographs"



- more than one shape of glyph (image of symbol) is allowed to be used to represent a same sound of speech of syllable (linguistic symbol)[Doermann and Tombre, 2014]

Challenges :: *Word/Text Recognition/Transliteration*




Research Tasks
Corpus, Dataset, and Ground Truth Creation
Empirical evaluation of DIA methods and algorithms
Segmentation-based glyph recognition and transliteration scheme
Segmentation-free transliteration scheme
Task 1
Task 2
Task 3
Task 4
2.1 Binarization
2.2 Text line segmentation
2.3 Isolated glyph recognition: proposing and evaluating the combination of features, and implementing the supporting glyph recognition for the transliteration
2.4 Word transliteration

2.1 Binarization Methods

- Otsu
- Sauvola
- Niblack
- NICK
- Rais
- Wolf
- Howe
- ICFHR G1-G4

2.2 Text Line Segmentation Methods

- Adaptive Partial Projection (APP)
- A* Path Planning
- Shredding method
- Adaptive Local Connectivity Map (ALCM)
- Seam Carving
- Adaptive Path Finding Method

2.3 Isolated Glyph Recognition Methods

- Handcrafted Feature Extraction Methods:
  - Projection histogram
  - Celled projection
  - Distance profile
  - Crossing
  - Zoning
  - Moments
  - Histogram of Gradient (HoG)
  - Kirsch Directional Edges
  - Neighborhood Pixels Weights (NPW)
- Convolutional Neural Network (CNN)
- Unsupervised Feature Learning (UFL)

2.4 Text Transliteration Methods

Long Short Term Memory Network (LSTM)

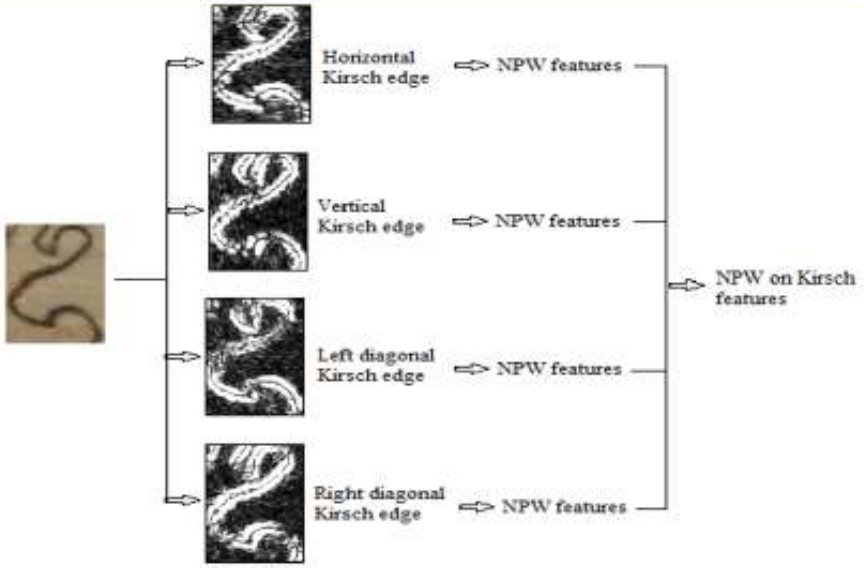
Isolated Glyph Recognition (Task 2.3)

Methods

- HoG features [Aggarwal et al., 2015, Fujisawa et al., 1999], NPW [Kumar, 2009], Kirsch Directional Edges [Kumar, 2009] and Zoning [R.N and Rao, 2014, Blumenstein et al., 2003, Kumar, 2009, Bokser, 1992] separately provide a very promising and good enough result.
- give the initial directional curve features for each glyph
- already serve as a good feature discriminants for Balinese script glyphs

Proposed Combination of Features

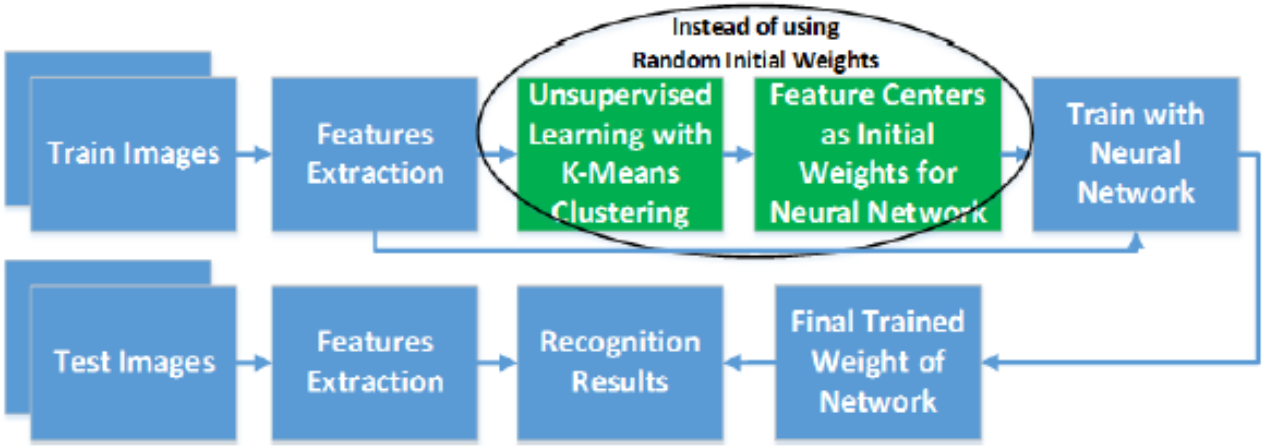
[Kesiman et al., 2016b]



NPW on Kirsch features + HoG + Zoning

Isolated Glyph Recognition (Task 2.3)

Schema of glyph recognizer with feature extraction method, unsupervised feature learning and neural network [Kesiman et al., 2017]



- inspired by [Coates et al., , Coates et al., 2011].
- sent combination of feature vector to a single layer neural network
- applied also an additional sub module for the initial unsupervised learning based on K-Means clustering
- The unsupervised learning calculates the initial learning weight for the neural network training phase from the cluster centres of all feature vectors

Isolated Glyph Recognition (Task 2.3)

Evaluation Metrics

the recognition rate = **C**/**N**, where **C** is the number of correctly recognized samples, and **N** is the total number of test samples [Burie et al., 2016].

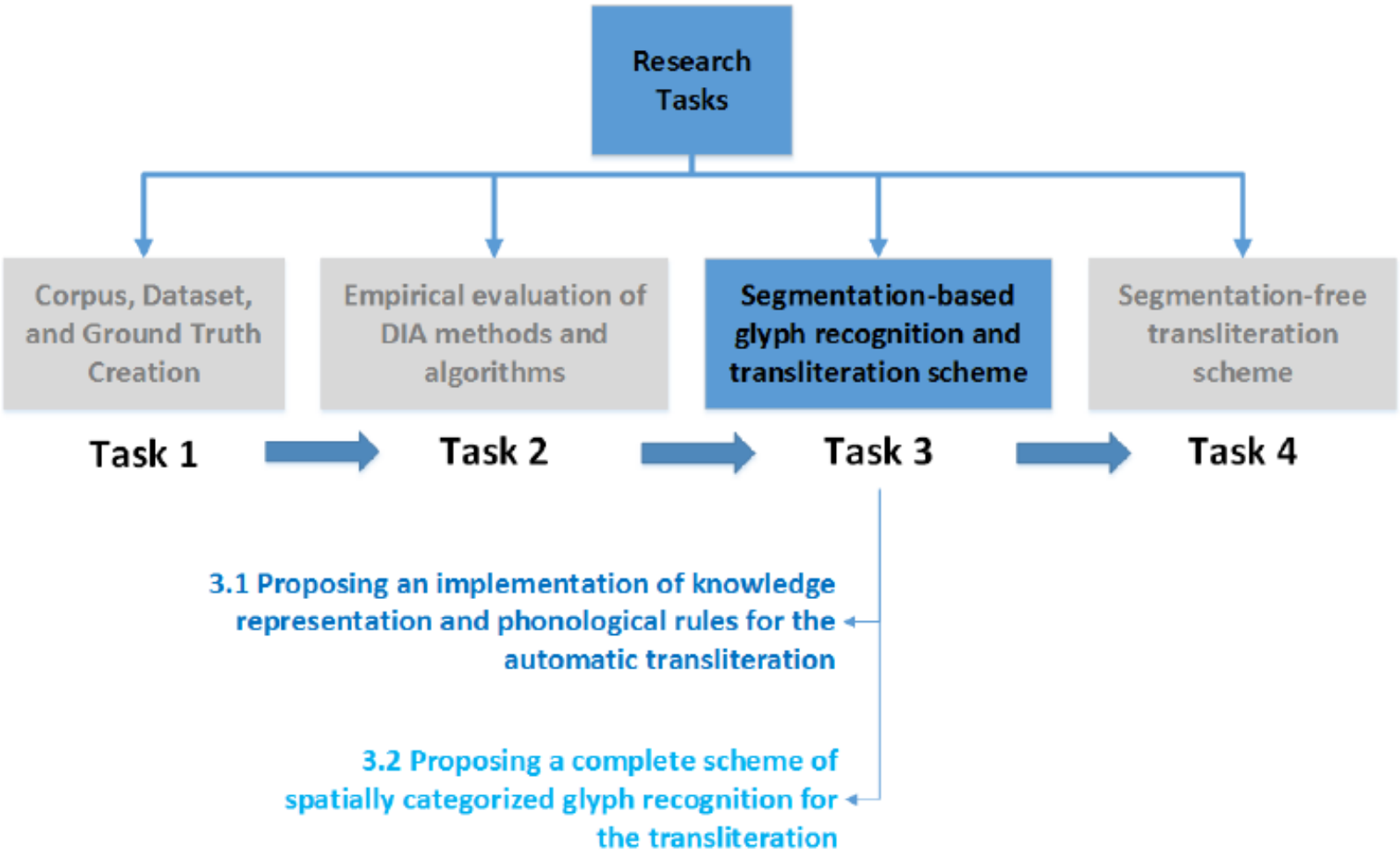
Recognition rate of the global glyph recognizer

Glyph Classes	Number of Data	CNN 1	k-NN	NN	NN UFL
133	Train : 11,710, Test : 7,673	84.31	85.16	85.51	**85.63**

Recognition rate of the categorized glyph recognizer

Category	Glyph Classes	Number of Data Subsets	NN	NN UFL
ASC	7	Train : 860, Test : 921	92.73	**93.16**
DESC	20	Train : 1,860, Test : 593	85.84	**88.03**
BASE	49	Train : 5,070, Test : 4,392	**87.46**	87.43
ASC-BASE	16	Train : 1,170, Test : 208	75.48	**75.96**
BASE-DESC	40	Train : 2,550, Test : 1,309	86.40	**86.63**

Segmentation-based Glyph Recognition and Transliteration Scheme



Knowledge Representation (Task 3.1)

Formalizing syllables: Speech sound = Onset+Nucleus+Coda

No	Consonant basic glyph name	Second glyph form name	Speech sound	Onset	Nucleus
1.	NA and NA TEDONG	GANTUNGAN NA	NA	N	A
4.	A and A TEDONG	GANTUNGAN A	A		
31.	U KARA		U		

Consonant basic glyphs and their second glyph form (conjunct form)

No	Consonant compound glyph name	Glyph component	Speech sound	Onset	Nucleus	Coda
1.	TU	TA + SUKU	TU	T	U	-
3.	I		I			-
4.	NI	NA + ULU	NI	N	I	-
13.	NING	NA + ULU + CECEK	NING	N	I	NG
46.	GRA	GA + GUWUNG	GRA	GR	A	-

Consonant compound glyphs

No	Glyph name	Type	Speech sound
1	0 - 9	Numeral	0-9
2	PAMADA	Punctuation	. (point)
3	TALING	Vowel	E
9	SURANG	Special Consonant	R
10	ADEG-ADEG	Special Consonant	-
16	SUKU ILUT	Vowel	U

Numeral, Punctuation, Vowel, and Special Consonant Glyphs

Alphabet / Dictionary for Glyph Category

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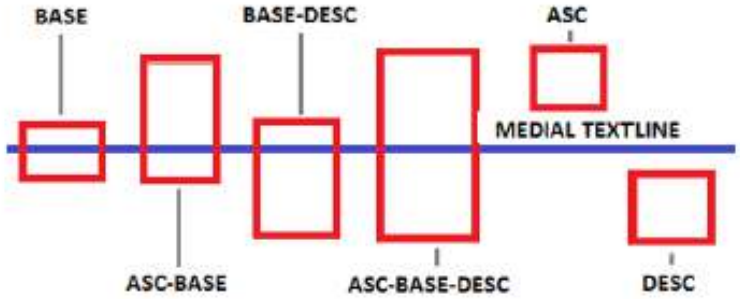
Level1 : Name of the glyph
Level2 : VOC, CON, GEM, GAN, NUM, PUN
Level3 : SPATIAL Information of the glyph
(ASC, ASC-BASE,BASE,BASE-DESC,DESC,ASC-BASE-DESC)
Id : class number of the glyph
Sound : root sound of the glyph
End : end sound of the glyph
Split : compound sound of the compound glyph

Level1	Level2	Level3	Id	Sound	End	Split
TALENG	VOC	BASE-DESC	1	E	*	*
NA	CON	BASE	2	N	A	*
KA	CON	BASE	3	K	A	*
TA	CON	BASE	4	T	A	*
A	CON	BASE	5		A	*
ULU	VOC	ASC	6	I	*	*
CECEK	VOC	ASC	7	NG	*	*
WA	CON	BASE	8	W	A	*
DA	CON	BASE	9	D	A	*
ADEG-ADEG	GEM	ASC-BASE-DESC	10	*	*	*
JA	CON	BASE	11	J	A	*
BISAH	VOC	BASE-DESC	12	H	*	*
LA	CON	BASE	13	L	A	*

Knowledge Representation (Task 3.1)

Building Glyph Dictionary: Glyph Properties and Categorizations

- Property "**Id**": identity number of the glyphs.
- Property "**Level1**": name of the glyphs.
- Property "**Level2**" is categorized in six groups:
  - **CON** for consonant,
  - **VOC** for vocal,
  - **GAN** for gantungan (conjunct form),
  - **GEM** for gempelan (conjunct form),
  - **NUM** for numeral, and
  - **PUN** for punctuation.
- Property "**Level3**": spatial position of the glyphs
- Property "**StartSyllable**": onset of syllable for the consonant basic glyphs or the speech sound for the consonant compound glyphs, numeral, punctuation, and special consonant glyphs.
- Property "**EndSyllable**": nucleus of syllable for the consonant basic glyphs.
- Property "**SplitSyllable**": onset, nucleus, and coda of syllable for the consonant compound glyphs.



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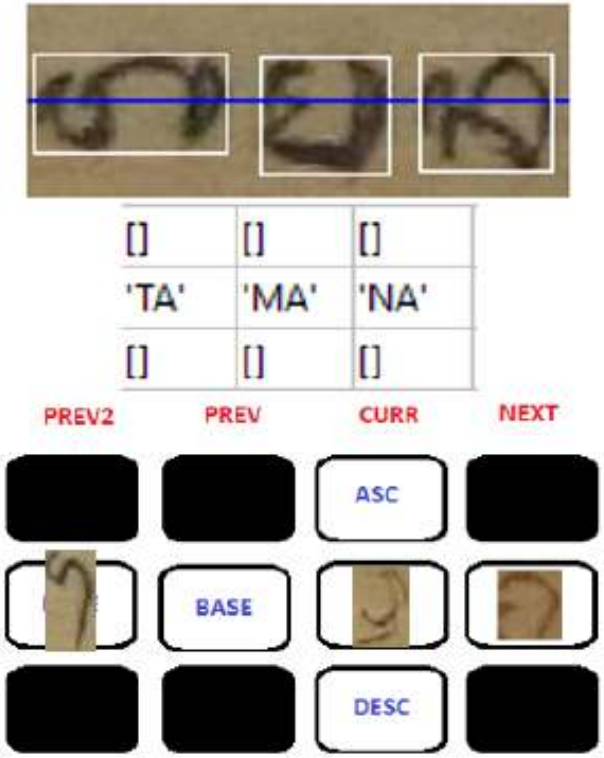
Phonological Rules (34 Rules) (Task 3.1)

Contribution: Formalization of phonological rules [Antara Kesiman et al., 2018]

- based on phonetics of traditional linguistic study of Balinese transliteration
- applied in sequential conditional checking order
- the final speech sound for a syllable of a current (**CURR**) base (**BASE**) glyph will be determined by :
  - the ascender (**ASC**) of current glyph,
  - the descender (**DESC**) of current glyph,
  - the **BASE** of the **NEXT** glyph,
  - the **BASE** of the previous (**PREV**) glyph,
  - the **BASE** of the two previous (**PREV2**) glyphs.

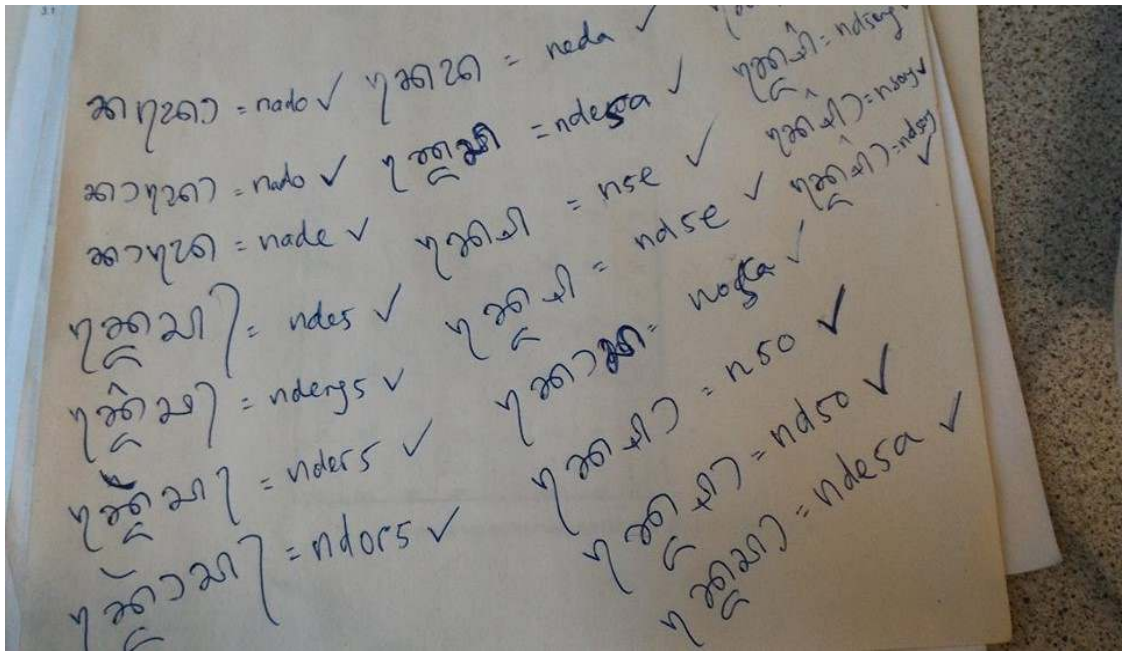


Example: a rule for TALING and TEDONG

RULE6: IF PREV2.BASE.LEVEL1 = "TALENG" AND CURR.BASE.LEVEL1 ≠ EMPTY AND CURR.BASE.LEVEL2 ≠ CON AND CURR.BASE.LEVEL2 = GEM AND CURR.BASE.LEVEL3 = BASE AND NEXT.BASE.LEVEL1 = "TEDONG" ⇒ SPEECH_SOUND = SPEECH_SOUND + "O"

Grammatical Rules

- Example :
  - *"The CONSONANT can apply the rule of TALENG and/or TEDONG if his next is not a GEMPELAN. If his next is a GEMPELAN, than the rule of TALENG and/or TEDONG will be applied for that next GEMPELAN. Meanwhile, the GEMPELAN can take into account the rule of TALENG and/or TEDONG if and only if TALENG can be found in the two previous position of this GEMPELAN."*



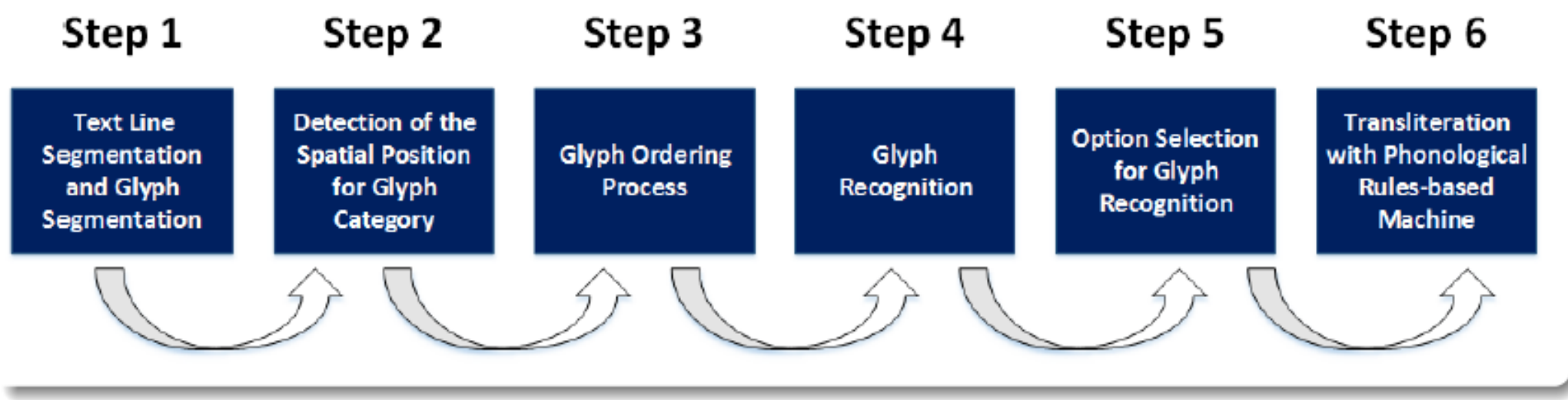
Defined 34 grammatical rules

Grammatical Rules

NO	PREV2	PREV	CURR								NEXT		RESULT
	BASE	BASE	ASC	BASE					DESC		BASE		
	LEVEL1	LEVEL1	LEVEL1	LEVEL1	LEVEL2	LEVEL3	END	SPLIT	LEVEL1	SOUND	LEVEL1	LEVEL2	
1				~EMPTY	CON/GEM	BASE							result=CURR_SOUND_BASE
2				~EMPTY	CON/GEM	BASE			~EMPTY				result=result+CURR_SOUND_DESC
3		TALENG		~EMPTY	CON&~GEM	BASE					~TEDONG		result=result+PREV_SOUND_BASE
4		TALENG		~EMPTY	CON&~GEM	BASE					TEDONG		result=result+"o"
5	TALENG			~EMPTY	~CON&GEM	BASE					~TEDONG		result=result+"e"
6	TALENG			~EMPTY	~CON&GEM	BASE					TEDONG		result=result+"o"
7				~EMPTY	CON/GEM	BASE					NANIA		result=result+NEXT_SOUND_BASE
8		~TALENG	EMPTY	~EMPTY	CON	BASE	"A"		EMPTY		~ADEG-ADEG	~GEM	result=result+"a"
9		~TALENG	EMPTY	~EMPTY	GEM	BASE	"A"		EMPTY		~ADEG-ADEG	~GEM	result=result+"a"
10		~TALENG	CECEK/SURANG	~EMPTY	CON	BASE	"A"		EMPTY		~ADEG-ADEG	~GEM	result=result+"a"
11		~TALENG	CECEK/SURANG	~EMPTY	GEM	BASE	"A"		EMPTY		~ADEG-ADEG	~GEM	result=result+"a"
12		~TALENG	EMPTY	~EMPTY	CON/GEM	BASE			~EMPTY	"A"	~ADEG-ADEG	~GEM	result=result+"a"
13		~TALENG	CECEK/SURANG	~EMPTY	CON/GEM	BASE			~EMPTY	"A"	~ADEG-ADEG	~GEM	result=result+"a"
14			~EMPTY	~EMPTY	CON/GEM	BASE							result=result+CURR_SOUND_ASC
15				~EMPTY	CON/GEM	BASE					BISAH		result=result+NEXT_SOUND_BASE
16				~EMPTY	CON	ASC-BASE/BASE-DESC		~"*", root_part=split_part1(CURR_SPLIT_BASE)	~EMPTY				result=root_part
				~EMPTY	CON	ASC-BASE/BASE-DESC		"*", root_part=""	~EMPTY				result=root_part
17				~EMPTY	CON	ASC-BASE/BASE-DESC			EMPTY				result=CURR_SOUND_BASE
18				~EMPTY	CON	ASC-BASE/BASE-DESC			~EMPTY				result=result+CURR_SOUND_DESC
19		TALENG		~EMPTY	CON	ASC-BASE/BASE-DESC					~TEDONG	~GEM	result=result+PREV_SOUND_BASE
20		TALENG		~EMPTY	CON	ASC-BASE/BASE-DESC					TEDONG	~GEM	result=result+"o"

A Complete Scheme Of Spatially Categorized Glyph Recognition For The Transliteration (Task 3.2)

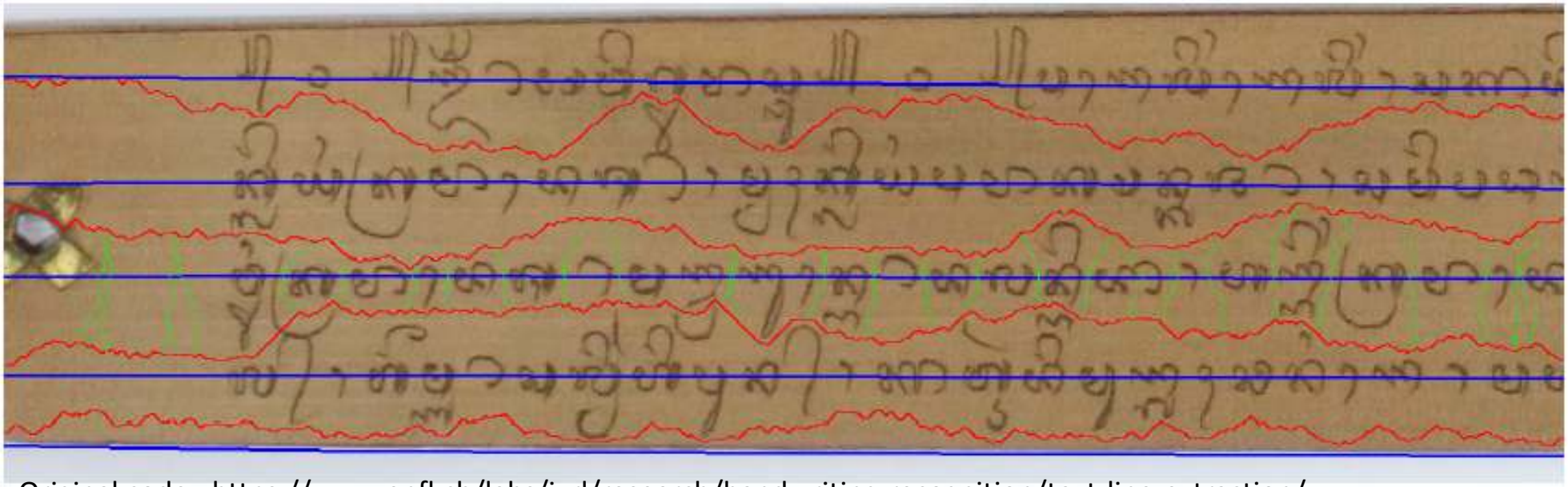
Contribution: Proposed Scheme [Kesiman et al., 2017]



STEP 1: Text Line and Glyph Segmentation (Task 3.2)

Two types of seams are calculated: the medial seams and separating seams.

Seam carving method [Arvanitopoulos and Susstrunk, 2014]

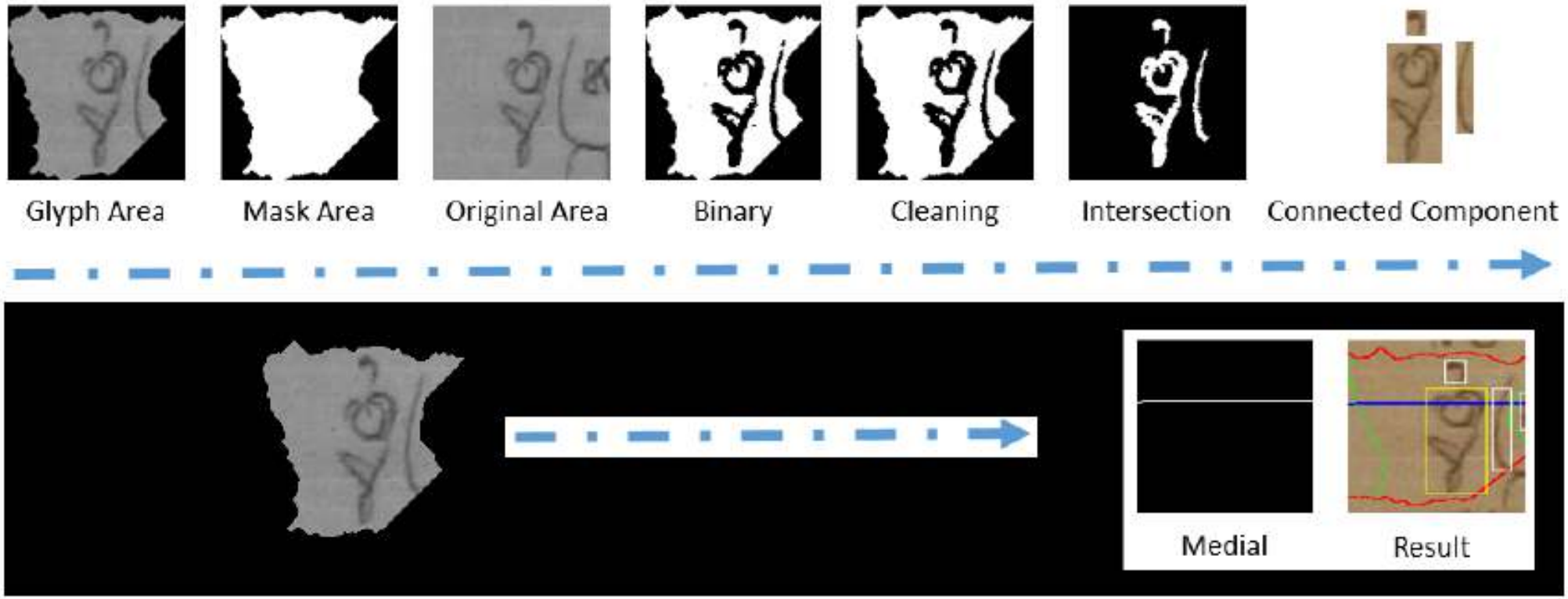


Original code : https://www.epfl.ch/labs/ivrl/research/handwriting-recognition/text-line-extraction/

Applied seam carving also for glyph area detection

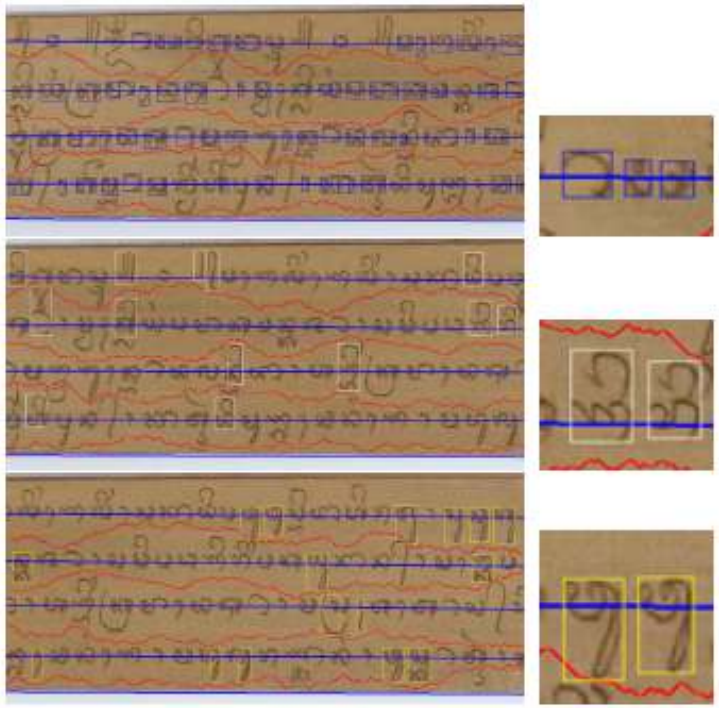
STEP 1: Text Line and Glyph Segmentation (Task 3.2)

Glyph area detection and glyph segmentation process



STEP 2: Detection of the Spatial Position for Glyph Category (Task 3.2)

6 spatial positions for categorized glyph recognizer and phonological rules

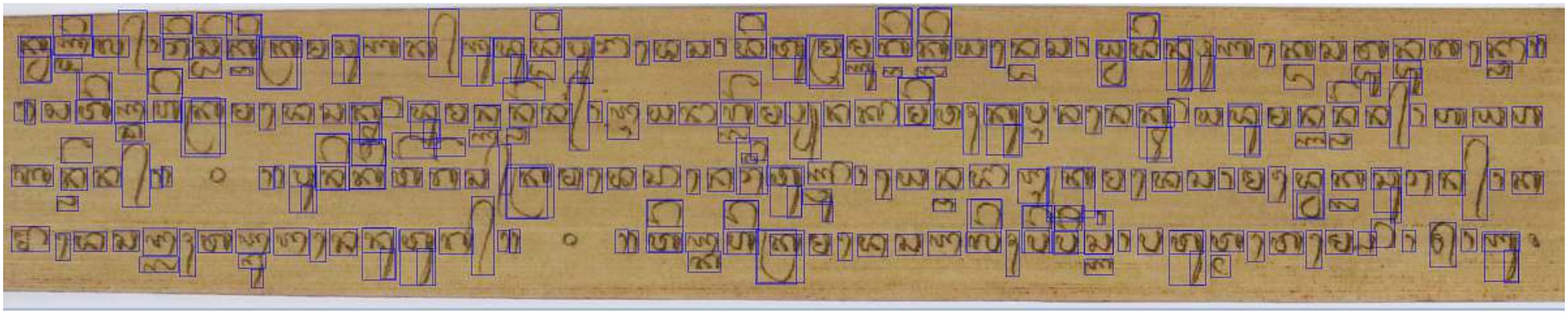


BASE Glyphs, ASC-BASE Glyphs, DESC-BASE Glyphs

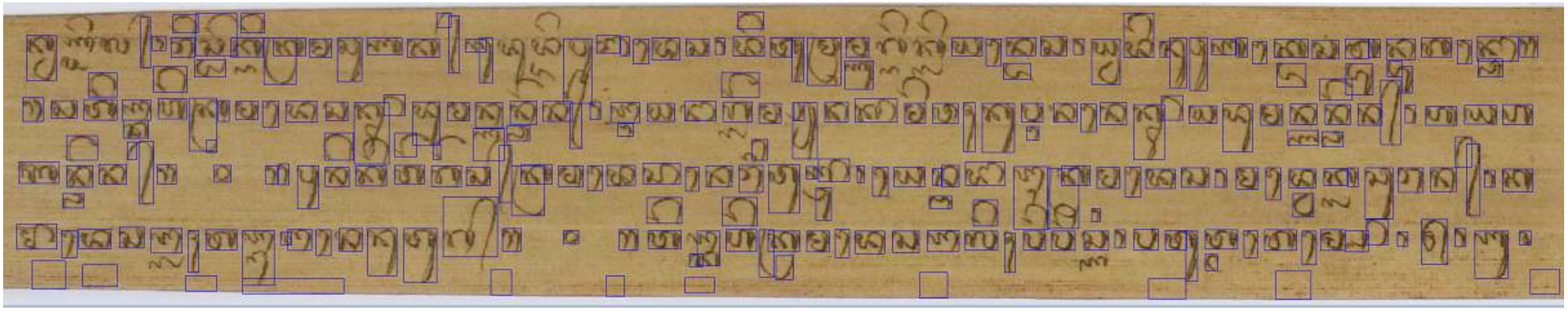
ASC-BASE-DESC Glyphs, ASC Glyphs, DESC Glyphs

Evaluation of Glyph Segmentation and Glyph Recognition

Ground Truth Glyph Segments

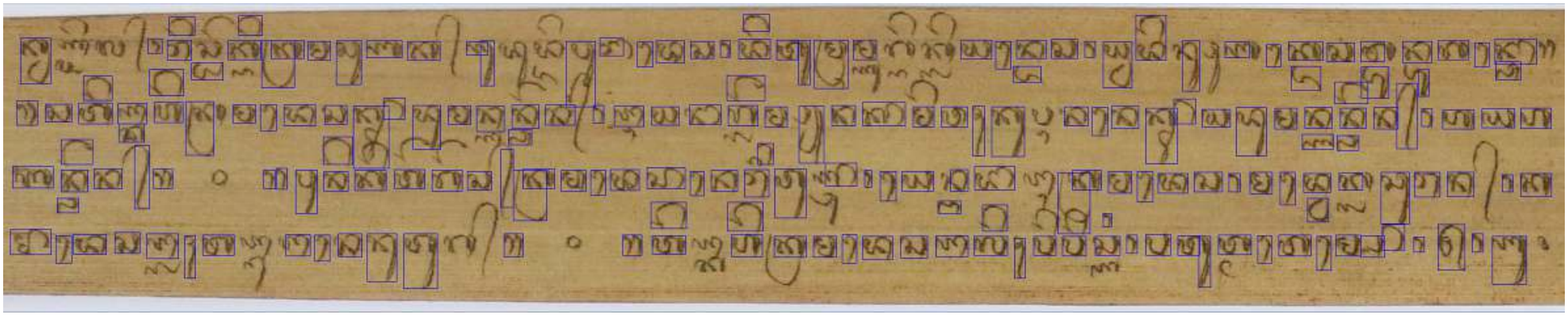


Result of Glyph Segments

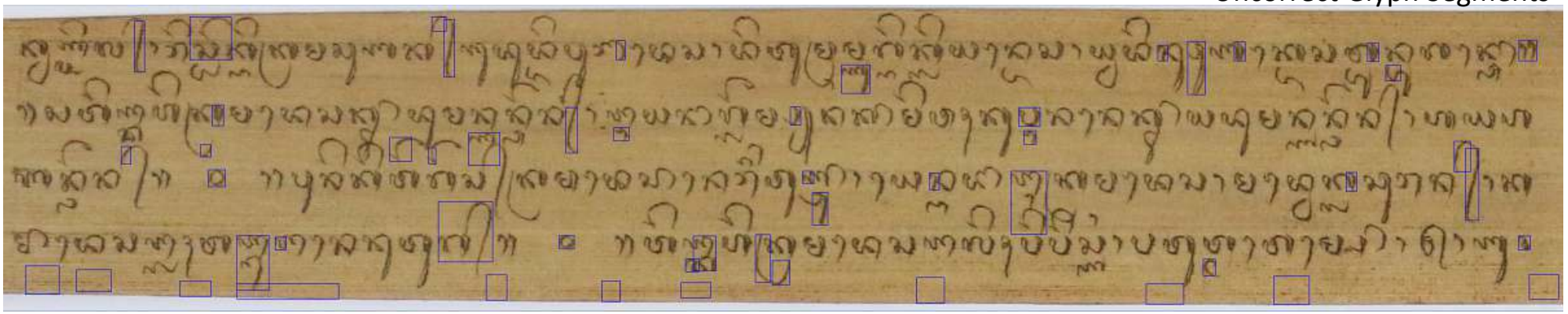


Evaluation of Glyph Segmentation and Glyph Recognition

Correct Overlapped Glyph Segments



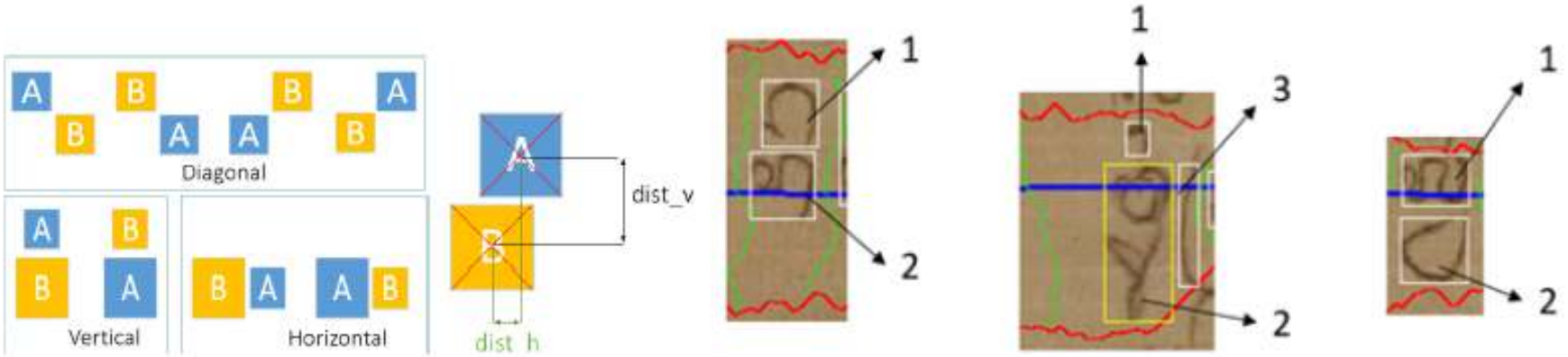
Uncorrect Glyph Segments



STEP 3: Glyph Ordering Process (Task 3.2)

Ordering rule: "BASE-ASC-BASE-DESC-BASE Order"

- glyphs on the medial text line are ordered from left to right based on their left border position on the glyph area
- Spatial Relation between Glyphs: the **ASC** → before their associate **BASE** glyph, and the **DESC** glyph → after their associate **BASE** glyph



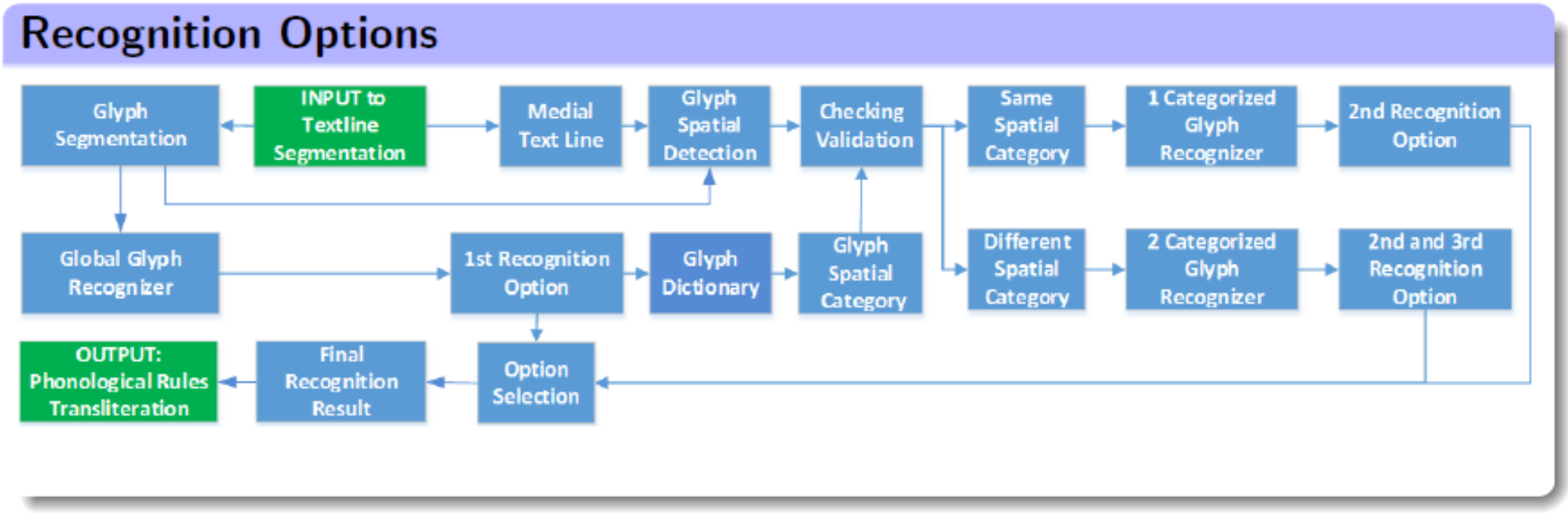
Spatial Relation between Glyphs: In the second example, glyph 1 (**ASC**) and glyph 2 (**BASE-DESC**): vertical relation, glyph 1 and glyph 3 (**BASE-DESC**):diagonal relation, and glyph 2 and glyph 3: horizontal relation. Glyph 1 belongs to glyph 2, glyph 1 does not belong to glyph 3

STEP 4: Glyph Recognition (Task 3.2)

Global Glyph Recognition and Categorized Glyph Recognition

- using the same glyph recognizer schema from Task 2.3
- one global glyph recognizer and five different categorized glyph recognizers were built.
  - global recognizer: complete 133 glyph classes
  - five different categorized glyph recognizers: subset of glyph classes for each different spatial position category
    1. BASE
    2. ASC
    3. DESC
    4. ASC-BASE
    5. BASE-DESC

STEP 5: Option Selection for Glyph Recognition (Task 3.2)



- Global Recognition (**G**)
- Categorized Recognition based on Glyph Dictionary (**D**)
- Categorized Recognition based on Glyph Spatial Position (**S**)

STEP 5: Option Selection for Glyph Recognition (Task 3.2)

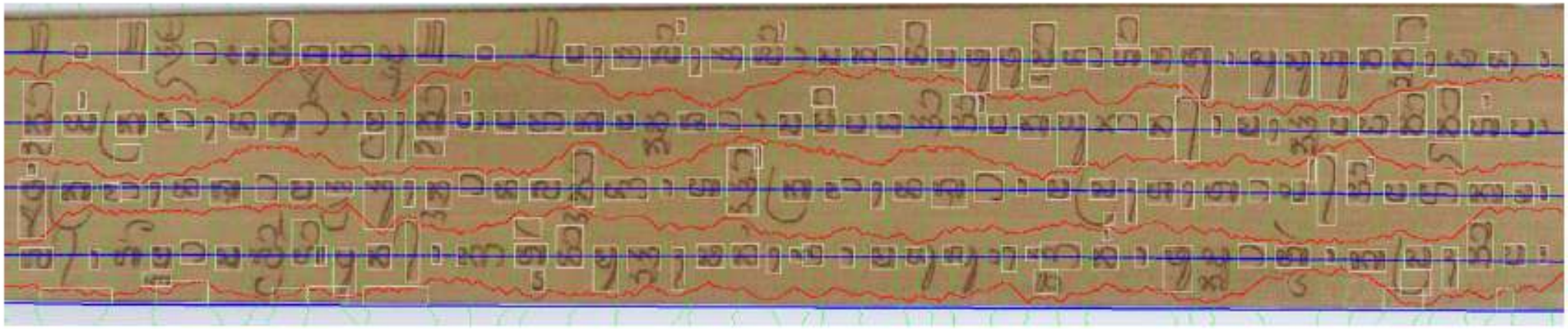
Option selection rules

- If **D** = **S**, there are two possibilities:
  - If **G** = **D** = **S**, the final recognition is **G**/**D**/**S**
  - If **G** ≠ (**D** = **S**), the final recognition is **D**/**S**
- If **D** ≠ **S**, there are three possibilities:
  - If (**G** = **S**) ≠ **D**, impossible case
  - If (**G** = **D**) ≠ **S**,
    - If (**S** = **BASE**/**ASC-BASE**/**BASE-DESC**/**ASC-BASE-DESC** and **D** = **ASC**/**DESC**) or vice-versa, the final recognition is **S**
    - If (**S** = **ASC** and **D** = **DESC**) or vice-versa, the final recognition is **G**/**D**
    - For all other sub-cases, it may be a bad glyph segmentation. The final recognition is **G**/**D**
  - If **G** ≠ **D** ≠ **S**, the final recognition is **G**

STEP 5: Option Selection for Glyph Recognition (Task 3.2)

Example 1: Option selection rules

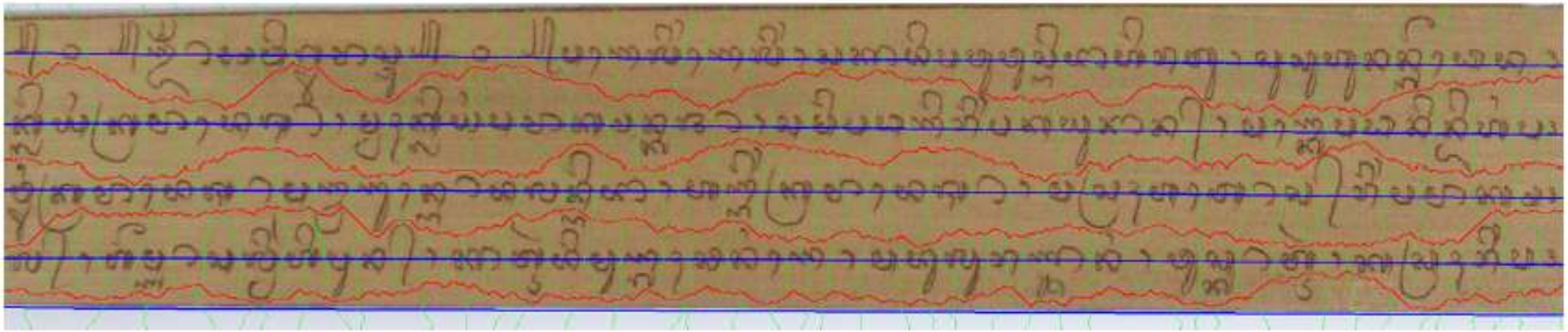
- If the spatial category detection is the same with the glyph dictionary, there are two possibilities:
  - If **G** = **D** = **S**, there is only one option. It is a high confidence of correct segmentation and recognition. The final recognition result is **G**/**D**/**S**



STEP 5: Option Selection for Glyph Recognition (Task 3.2)

Example 2: Option selection rules

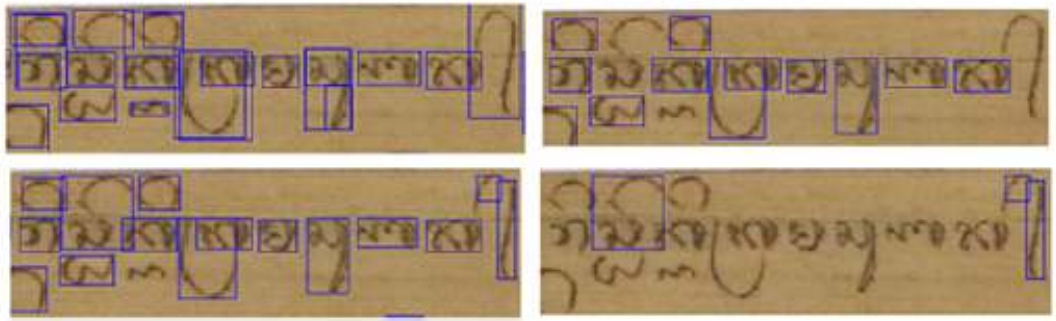
- If the spatial category detection is different with the glyph dictionary, there are three possibilities:
  - If $(\mathbf{G} = \mathbf{D}) \neq \mathbf{S}$, there are two different options. There are three sub-cases.
    - If ($\mathbf{S} = \mathbf{BASE}/\mathbf{ASC\text{-}BASE}/\mathbf{BASE\text{-}DESC}/\mathbf{ASC\text{-}BASE\text{-}DESC}$ and $\mathbf{D} = \mathbf{ASC}/\mathbf{DESC}$) or vice-versa, it means that there are a big difference between spatial category detection and the glyph dictionary. The final recognition result is **S**



Evaluation: Glyph Segmentation and Recognition (Task 3.2)

Evaluation Metrics

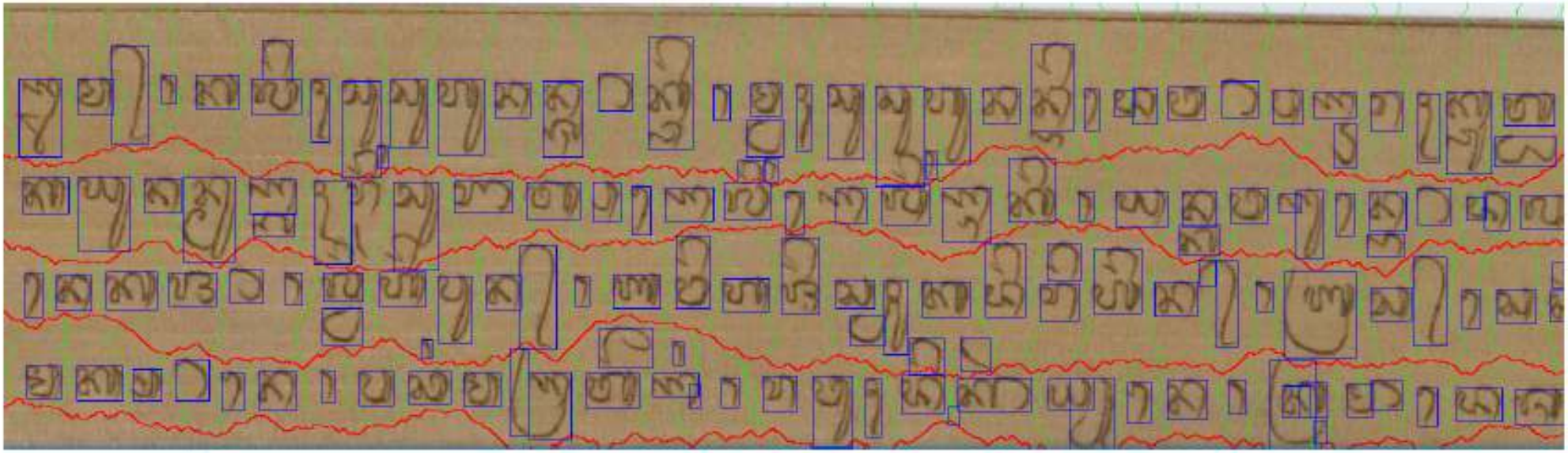
- Number Segments Result (**NSR**) = total number of glyph segments in result file
- Number Segments Overlapped (**NSO**) = number of correctly overlapped (>50%) glyph segments between result file and ground truth file
- Number Recognized Result (**NRR**) = number of correctly recognized glyph segments in result file
- Segmentation Rate (**SR**) = the percentage of **NSO** / **NSR**)
- Segmented Recognition Rate (**SRR**) = the percentage of **NRR** / **NSO**



Top left: ground truth, Bottom left: glyph segments result, Top right: correctly overlapped glyph segments, Bottom right: wrong glyph segments

Evaluation: Glyph Segmentation and Recognition (Task 3.2)

Results

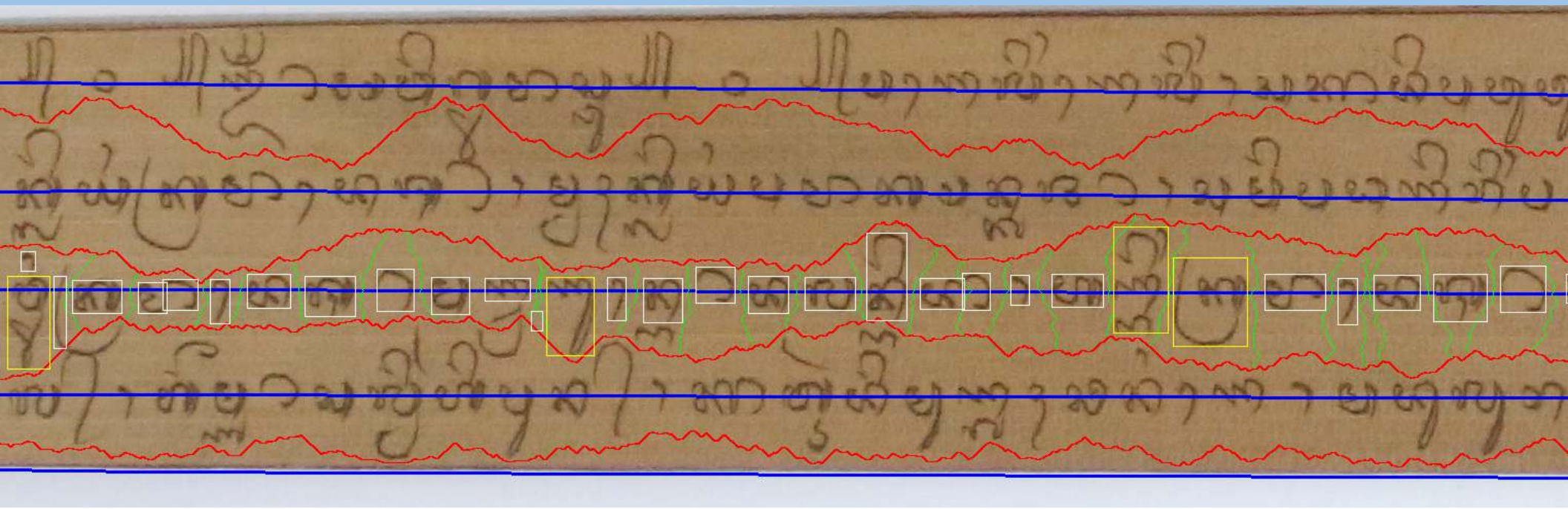


IIA-5-789-P2.jpg.txt - Notepad

File Edit Format View Help

```
[][][][2|][MA|][ADEG-ADEG|][CECEK|][KA|][LA|ULU|][BISAH|][NANIA|CECEK|][SU|][TU|][RA|][RI|][TEDONG|][RI|]
TALENG|][KI|][][PA|][DA MADU|][NI|][GANTUNGAN DA|NI|][A|CECEK|][PA|][SUKU ILUT|][][][][][][KA|][YU|][NA|]
A|][MA TEDONG|][KA|][GEMPELAN SA SAPA|][4|][][][][CECEK|][NA|][KA|][JA|][TEDONG|BISAH|][SUKU KEMBUNG|LA|]
|][TEDONG|][WA|TA|][SUKU|][BISAH|][KA|][SUKU KEMBUNG|][SUKU|SA|][BISAH|][RI|][PA|][4|][][][][][][][MA|][K
```

Checking Validation



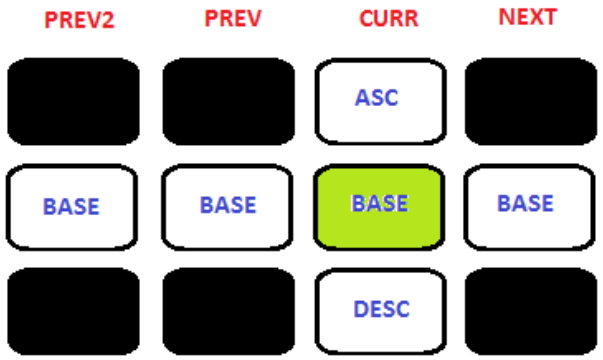
White Box	: Valid
Yellow Box	: 2 Options
Blue Box	: 3 Options

OCR Result and Data Representation

IIA-5-789-P2.jpg_OCR.txt - Notepad

File Edit Format View Help

```
[][][][][RU_ADEG-ADEG|][0|][I KARA_I_NANIA|][3_ADEG-ADEG_U KARA|][TEDONG|][NI_4|GEMPELAN SA SAPA|WI|][GA|][MA TEDONG|][LA LENGA_MU|I|][0|][][GEMPELAN PA_WI|0_DI_4|][PA|TALE
[][SA SAGA_KA|][][][KI|GANTUNGAN LA|][CECEK|YA|][U KARA|][KA|GUWUNG|][MA|][TEDONG|][TALENG|][][][DA|][SA SAPA|][KU_SA SAGA|][3_WI_U KARA|][BISAH_TEDONG|][MA|SUKU KEMBUNG|][
[NI_7_NING|][][][][][][CECEK|LA LENGA_WU|U KARA|][KA|][MA|TEDONG|][TALENG|][DA|][SA SAGA|][TEDONG|][MA|KA|][SUKU|][][][NGU_BU|TALENG|][NA|][TEDONG|][DA|][LA|][NI|][DA|][TED
[][][][][][LA|][ADEG-ADEG|][][SUKU|][][CECEK|][A_TA|JA|][MA|GANTUNGAN BA|][TEDONG|][SA|][WI_ADEG-ADEG|][I|][SURANG|PU|][NA|ADEG-ADEG|][BISAH_TEDONG|][4|][KA TEDONG_TA TEDON
[][SURANG|][SURANG|][SURANG|][SURANG|][][][SURANG|][SURANG|][][SURANG|][][SURANG|][SURANG|][][SURANG|][PEPET|][PEPET|][SURANG|][][PEPET|][SURANG|][SURANG|][SURANG|][][][PEP
```



arr_line_ocr <3x218 cell>

	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	[]	[]	[]	[]	[]	'CECEK'	[]	[]	'ULU'	'CECEK'	[]	[]	[]	[]	[]	[]
2	'GEMPELA...	'0_DI_4'	'PA'	'TALENG'	'NGA'	'LA'	'TALENG'	'NGA'	'LA'	[]	'BISAH_TED...	'SA'	'KA TEDONG'	'DI'	'PA'	'WU'
3	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]

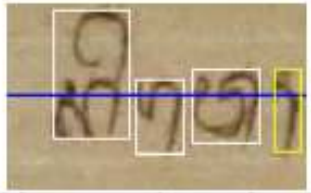
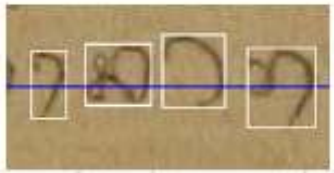
Evaluation: Glyph Segmentation and Recognition (Task 3.2)

Results

No	Manuscript Page	SR	SRR
1	Bangli-P41	49,54	57,94
2	Bangli-P47	58,96	55,70
3	IIA-10-1534-P8	77,37	**84,00**
4	IIIC-24-1641-P8	77,29	68,56
5	JG-01-P3	70,40	77,28
6	JG-02-P6	30,77	27,50
7	JG-02-P7	40,71	52,63
8	JG-05-P8	60,74	66,67
9	MB-AdiParwa(Purana) -5338.2-IV.a-P30	**77,78**	77,81
10	MB-AjiGriguh -5783-107.2-P11	30,00	74,07
11	MB-AjiGriguh -5783-107.2-P8	21,83	58,06
12	MB-ArjunaWiwaha -GrantangBasaII-P15	64,97	74,87
13	MB-ArjunaWiwaha -GrantangBasaII-P28	75,78	71,60
14	MB-TaruPramana-P3	71,11	64,58
15	MB-TaruPramana-P4	43,90	70,05
16	MB-TaruPramana-P6	44,52	54,35
17	WN-P5b	46,06	44,52
18	WN-P7a	11,17	15,00
19	WN-P9a	21,86	42,62

STEP 6: Transliteration with Phonological Rules-based Machine (Task 3.2)

OCR Output	Phonological Rules Output
 [] [] [] 'A' 'KA' 'BISAH_... [] [] []	RULE1:... RULE8:...a a RULE1:...K RULE8:...Ka RULE15:...KaH aKaH RULE32:...* aKaH* Final Output: AKAH
 [] [] 'KA' 'NA' 'SUKU KEMBUNG' []	RULE1:...K RULE2:...KW RULE12:...KWa KWa RULE1:...N RULE8:...Na KwaNa Final Output: KWANA

OCR Output	Phonological Rules Output
 [] [] [] [] 'NI' 'TALENG' 'WA' 'BISAH_... [] [] [] []	RULE17:...NI NI RULE32:...* NI* RULE1:...W RULE3:...WE RULE15:...WEH NI*WEH RULE32:...* NI*WEH* Final Output: NIWEH
 [] [] [] [] 'TALENG' 'NA' 'TEDONG' 'RA' [] [] [] []	RULE32:...* RULE1:...N RULE4:...No No RULE32:...* No* RULE1:...R RULE8:...Ra No*Ra Final Output: NORA

Evaluation: Text Line Transliteration (Task 3.2)

Evaluation Metrics

- The text pattern → generalized suffix tree [Kesiman, 2006] between two transliterated texts
- Pattern rate (**PR**) = percentage of the same text pattern between the transliteration text and the ground truth text
- Minimal length of pattern text = 4 characters = minimal length of Balinese word with two basic glyphs
- Recall pattern rate (**RPR**) = **PR** / length of ground truth text
- Precision pattern rate (**PPR**) = **PR** / length of the transliteration result

Left : Example of Generalized Suffix Tree between GT string " *madewinduantarakesiman*" and Evaluated string " *malewinduandarakeriman*" , Right : the Pattern Tree

Evaluation: Text Line Transliteration (Task 3.2)

MB-AdiParwa(Purana)-5338.2-IV.a-P30.jpg_line_1

GT:73.5484

tadharMANINGATUNGGATUNGga,leGASARATADANASARWAbARANAarTAMASwastramulIADAWALA.yakaTAMADIANINGASARAPATUNGAN.NIS TASARATUNGA,legADANASARWAboJARAPAna.uTAMANINgsa

Result:56.3758

wadhewrene0,waNGATUNGA,2GASARAsADANAwwabhARANAhARWAMASumuIADAWALA,,yenadAMADhIANIASARAPAwaNGANINi,jah,NISTAS ARATU2gnabhanayarwuaneJARANA,,3TAMANIsa4a

MB-AdiParwa(Purana)-5338.2-IV.a-P30.jpg_line_2

GT:72.619

RATUNGA,LEGASARASAsAJININGMATI,DINuLURASARwasekARWIJAWIJAN,NINGAsep,yekAUTAMANINGDHARmasuRATUNGA.mUAHNIStAPA MidARATekengTUNON,anruWUSKArSAWASumeNGKAhengPATAWUlan,tiNADI

Result:64.9425

dha5RATUNGA,LEGASARASAcAJINIMATI,DINiLURAyawua,rngWIJARWIJAN,NINGAupapa,,yerAUTAMANIdhmamasngRATUNGA,,,,wUAHNISAPA Mm,DHARATkeiTUNON,jnsatuaWUSKASAWASaNGKAiePATAWUpanr,tarNADI

MB-AdiParwa(Purana)-5338.2-IV.a-P30.jpg_line_3

GT:71.5232

nan.madiANINGAMIDARA,RIhUWUSNINGsawATINUNU,TikaADIN.uTAMANINGAMIDARA,brasTATAANAWUTIkangsaWA,TinADINAN.yeKATATAk ausAPARIPAMIDANGAn,muangKAUCAPATATABASA

Result:60.2564

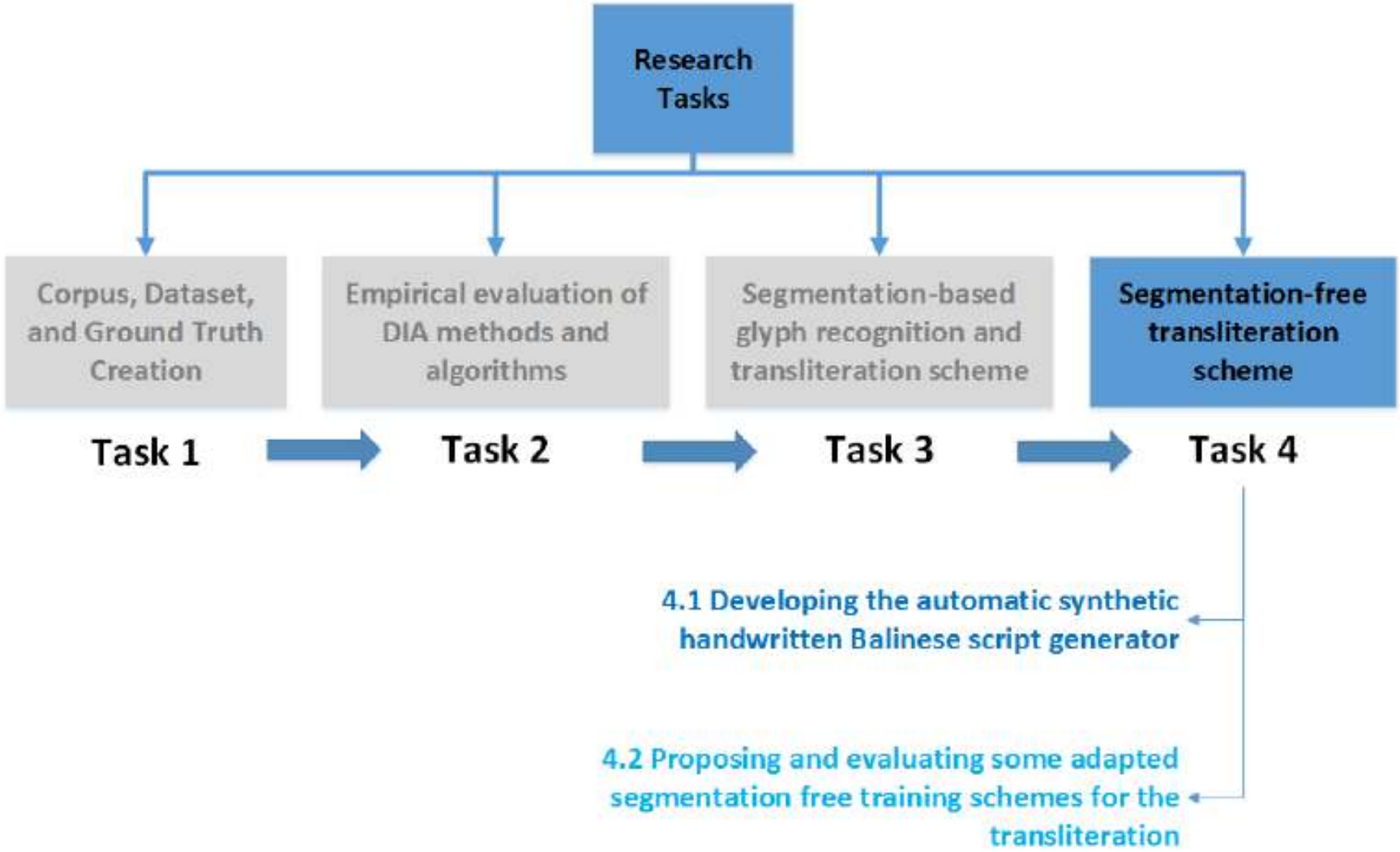
5nrabamadhwANINGAjmwidhARA,RIUWUSuwuATINUNU,TarkADINAca,,waTAMANIAMIDharaung4stajATAANAWUTIisngWA,TunnnINAN,,pena KATATAlAUCAPARIPAMadhANGA,wiKAUCAPATATABASA

The text pattern (in red) extracted between ground truth text and result text

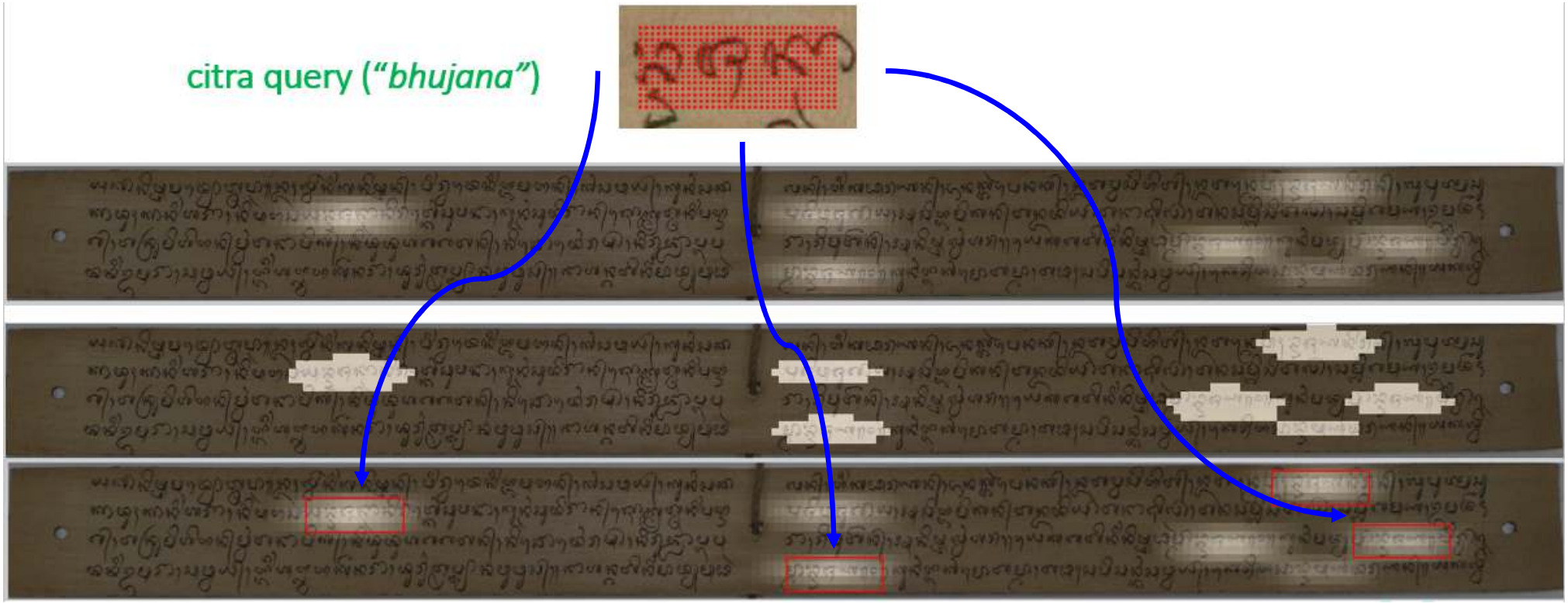
Evaluation: Text Line Transliteration (Task 3.2)

No	Manuscript Collection	RPR		PPR	
		Max	Avg	Max	Avg
1	Bangli	69,23	6,26	53,13	7,36
2	IIA-10-1534	73,13	47,78	68,16	43,73
3	IIA-5-789	76,25	50,27	**77,85**	48,67
4	IIB-2-180	72,63	**54,04**	69,61	**52,69**
5	IIIB-12-306	67,78	34,84	64,91	33,43
6	IIIB-42-1526	78,61	51,50	71,43	50,06
7	IIIB-45-2296	65,09	40,29	65,61	39,15
8	IIIC-19-1293	60,38	35,52	63,40	36,56
9	IIIC-20-1397	75,58	34,44	60,48	34,46
10	IIIC-23-1506	54,46	27,98	56,82	25,02
11	IIIC-24-1641	60,44	40,61	54,49	41,91
12	JG-01	56,47	23,88	57,72	20,70
13	JG-02	11,11	0,80	22,86	1,53
14	JG-03	25,83	4,91	23,88	7,34
15	JG-04	14,49	1,37	15,38	1,64
16	JG-05	27,37	4,55	41,94	8,85
17	JG-06	0,00	0,00	0,00	0,00
18	JG-07	4,94	0,15	12,90	0,39
19	MB-AdiParwa(Purana) -5338.2-IV.a	**83,13**	37,43	72,44	36,54
20	MB-AjiGriguh -5783-107.2	4,71	0,28	10,81	0,64
21	MB-ArjunaWiwaha -GrantangBasaII	65,81	26,83	68,18	32,89
22	MB-TaruPramana	70,15	17,69	66,67	18,99
23	WN	20,00	0,72	10,53	0,68
	All: 390 pages				

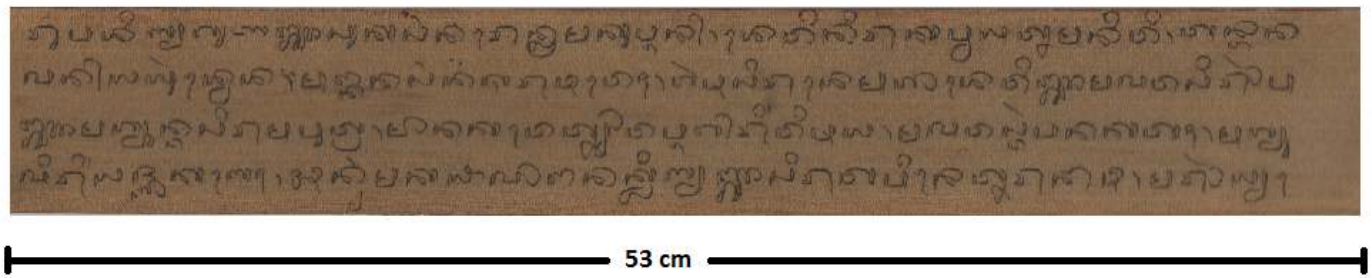
Segmentation-free Transliteration Scheme



Towards Word Spotting System .....



Word Spotting Challenges



- One leaf = 2 pages
- One page = 4 text lines
- Number of leafs in one collection, example :
  - ✓ Collection of **Kakawin Ramayana - 07.41/5634.3** = 140 leaves
  - ✓ Collection of **Kakawin Ramayana - 07.40/5634.3** = 155 leaves

❑ **The segmentation-based word spotting:**

✓ not trivial to be applied

✓ no spaces between each word.

✓ the use of ascender, descender and conjunct form: it can be written jointly with the previous word.

❑ **The segmentation-free word spotting method:**

✓to extract all possible word patches in the manuscript pages: Offline Patch Images Extraction

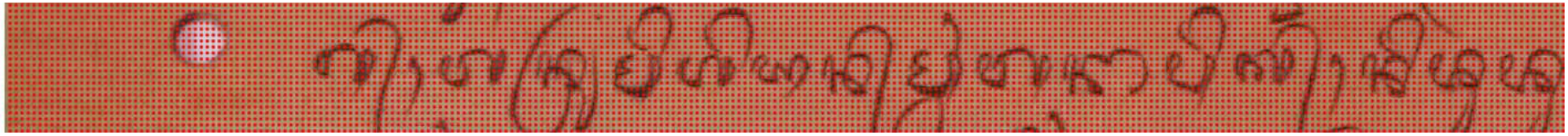
✓to detect and to separate possible text area from the textured image of palm leaf

- ❖ cover all text areas in manuscript page
- ❖ spot as close as possible all words in manuscript

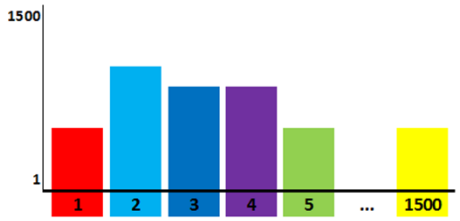
✓to reduce the amount of processing time,

✓to ignore many false patch image positions: non text area and the area between the unstraight textlines.

In this paper, we present our proposed segmentation-free word spotting method for the Balinese palm leaf manuscripts.



Visual Word


1500
1
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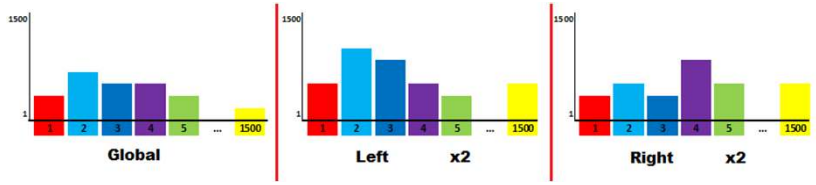
...
1500


1500
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Global
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Left
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5
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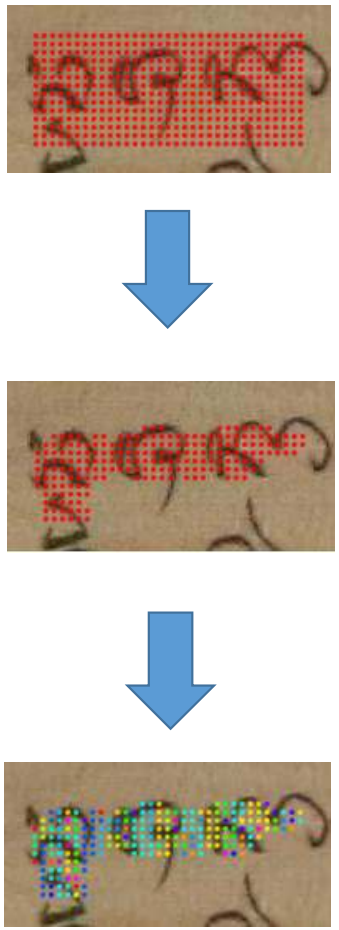
1500
Right
x2


1500
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1 2 3 4 5 ... 1500
Global
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1 2 3 4 5 ... 1500
Left x2
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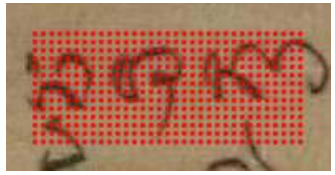
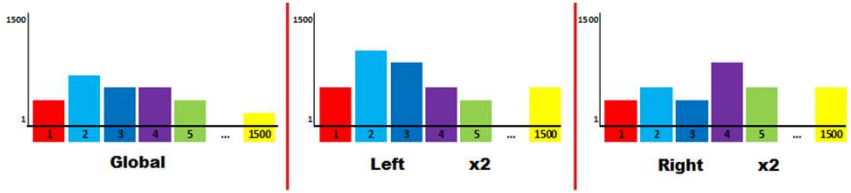
1 2 3 4 5 ... 1500
Right x2




1500
1
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Global
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1 2 3 4 5 ... 1500
Left x2
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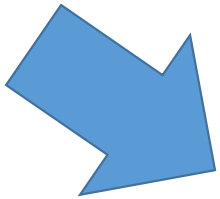
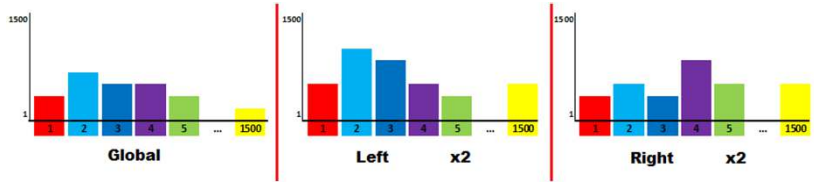
1 2 3 4 5 ... 1500
Right x2




1500
1
1 2 3 4 5 ... 1500
Global
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1 2 3 4 5 ... 1500
Left x2
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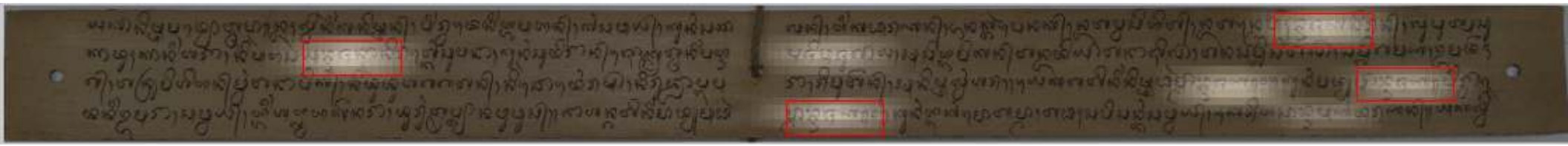
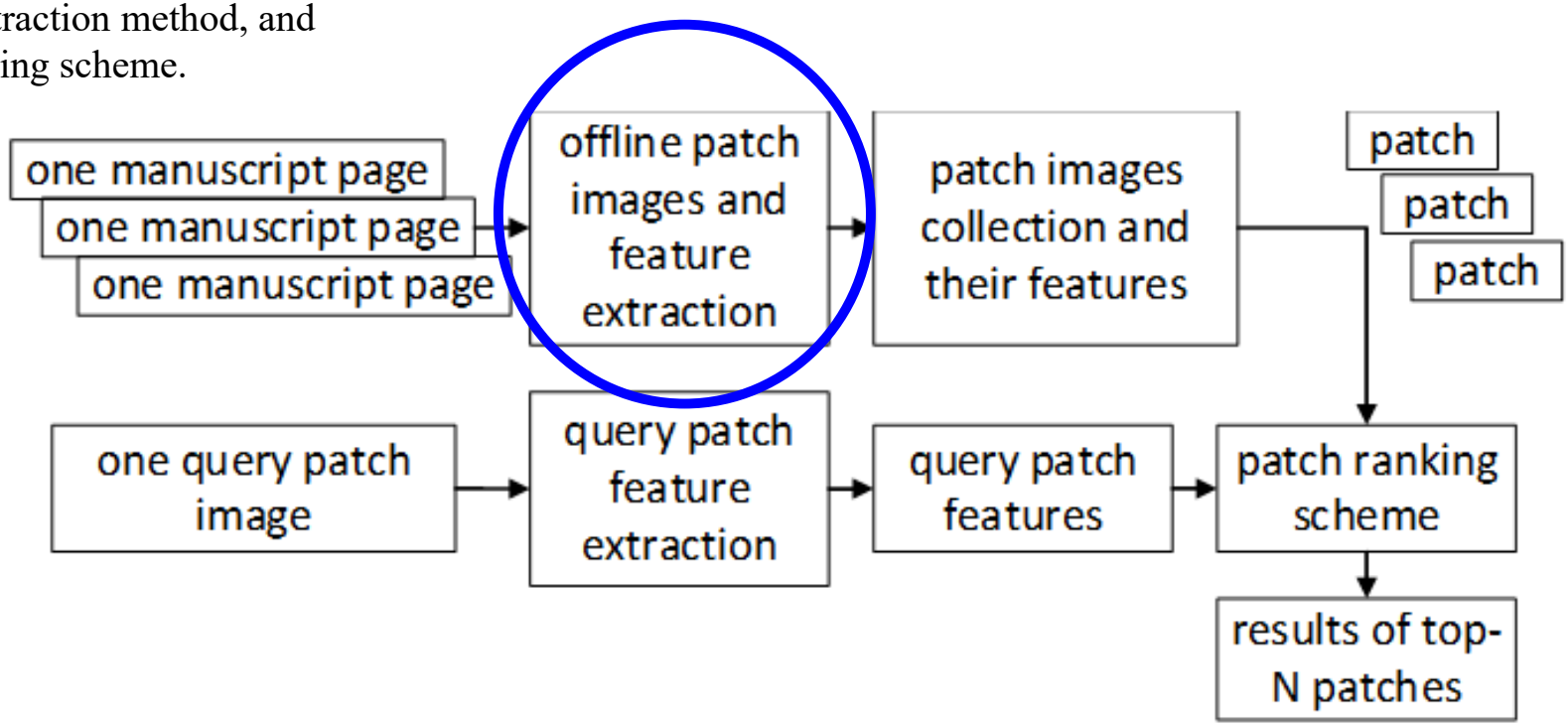
1
1 2 3 4 5 ... 1500
Right x2



Proposed Scheme :
Global Workflow of Word Spotting Scheme

Three main sub schemes:

- ✓ the offline patch images extraction process,
- ✓ the feature extraction method, and
- ✓ the patch ranking scheme.



Challenges in Word Patch Extraction

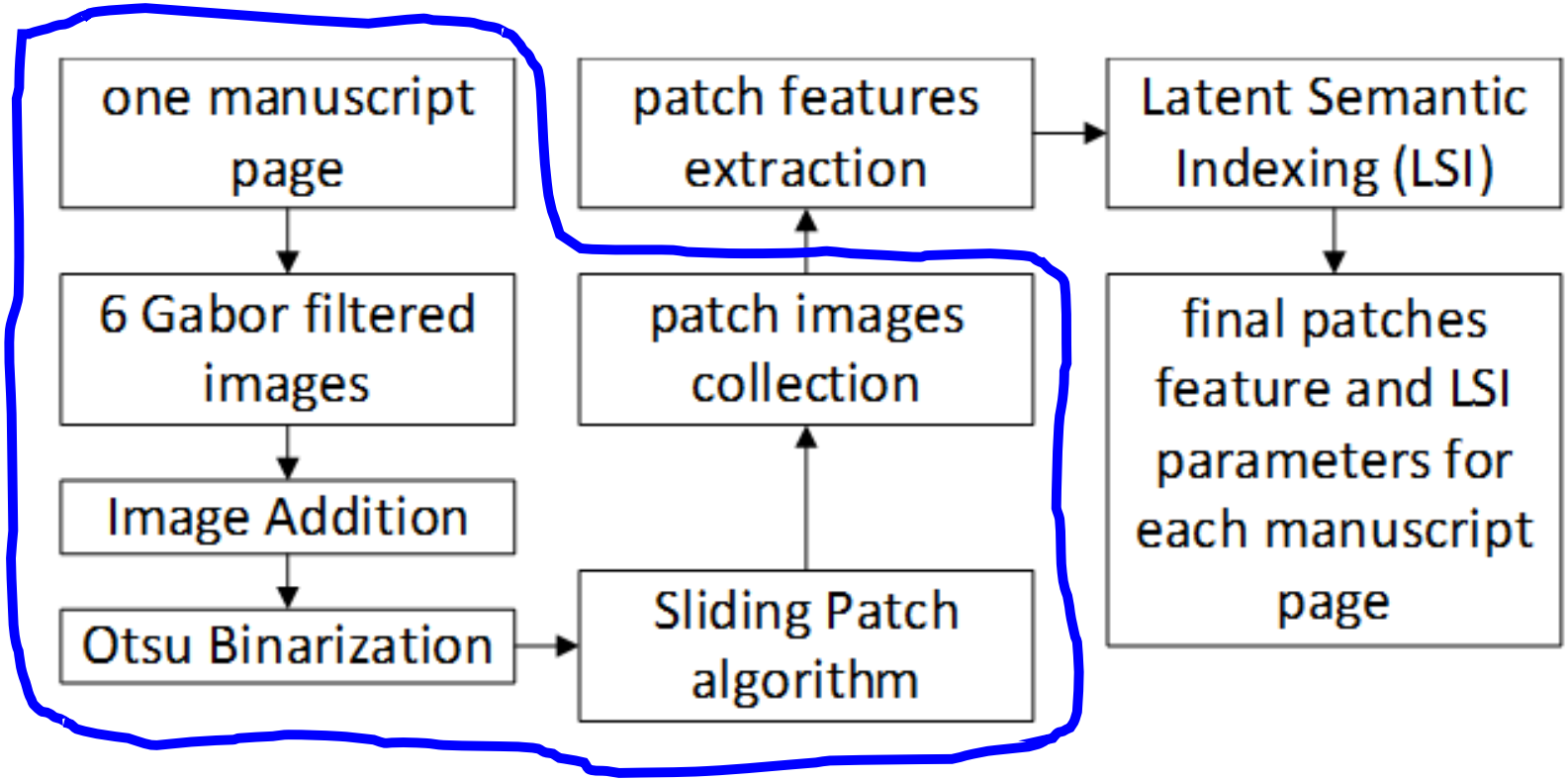
- to detect the text area of the degraded image of Lontar with many different text layouts
  - ❖ only full text, contain graphics with large blank area, the text is written in table-like format
- to cover all text area: optimally avoiding the blank area
- to reduce the possible number of word patches: less number of extracted word patches, the word spotting system will perform faster
- the text lines are not always written in straight position from left to right

Fig. 4. Lontar page with full text

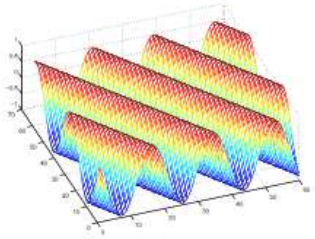
Fig. 5. Lontar page with blank area

Fig. 6. Lontar page with table-like format

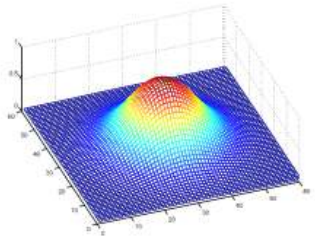
Offline Patch Images Extraction Process



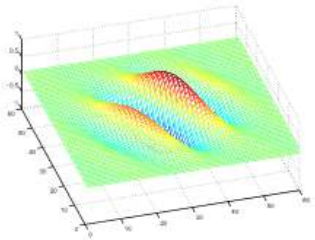
Gabor Filters



(a)



(b)

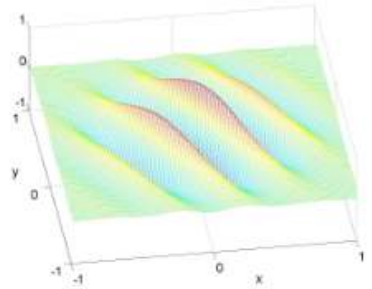


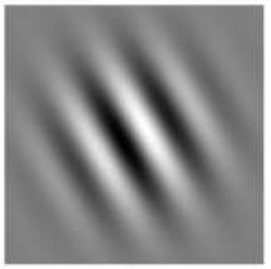
(c)

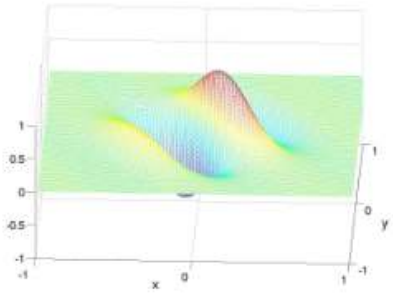
Gabor filter composition: (a) 2D sinusoid oriented at 30◦ with the x-axis, (b) a Gaussian kernel, (c) the corresponding Gabor filter. Notice how the sinusoid becomes spatially localized.

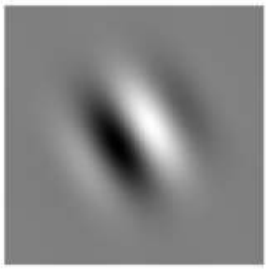
Prasad, V.S., & Domke, J. (2005). Gabor Filter Visualization.

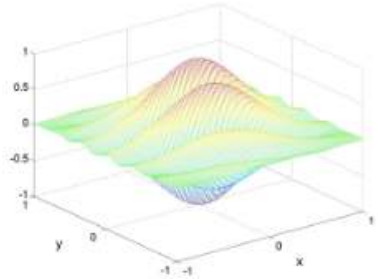
- ✓ Lontar:
  - The writing: shows the spatial texture informations.
  - The different writers: different frequencies and orientations of the textures.
- ✓ Gabor filter:
  - Modulation between sinusoid and Gaussian filter.
  - A texture filter with many orientations and frequencies
  - Bank of Gabor filters : orientation, wavelength, aspect ratio and bandwidth
  - Provide initial information about the existence of textures in the document.
  - Detect the preliminary informations about text and non text area on Lontar.

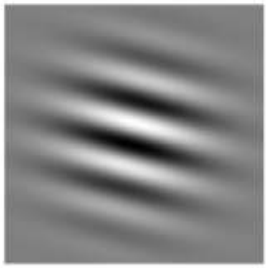






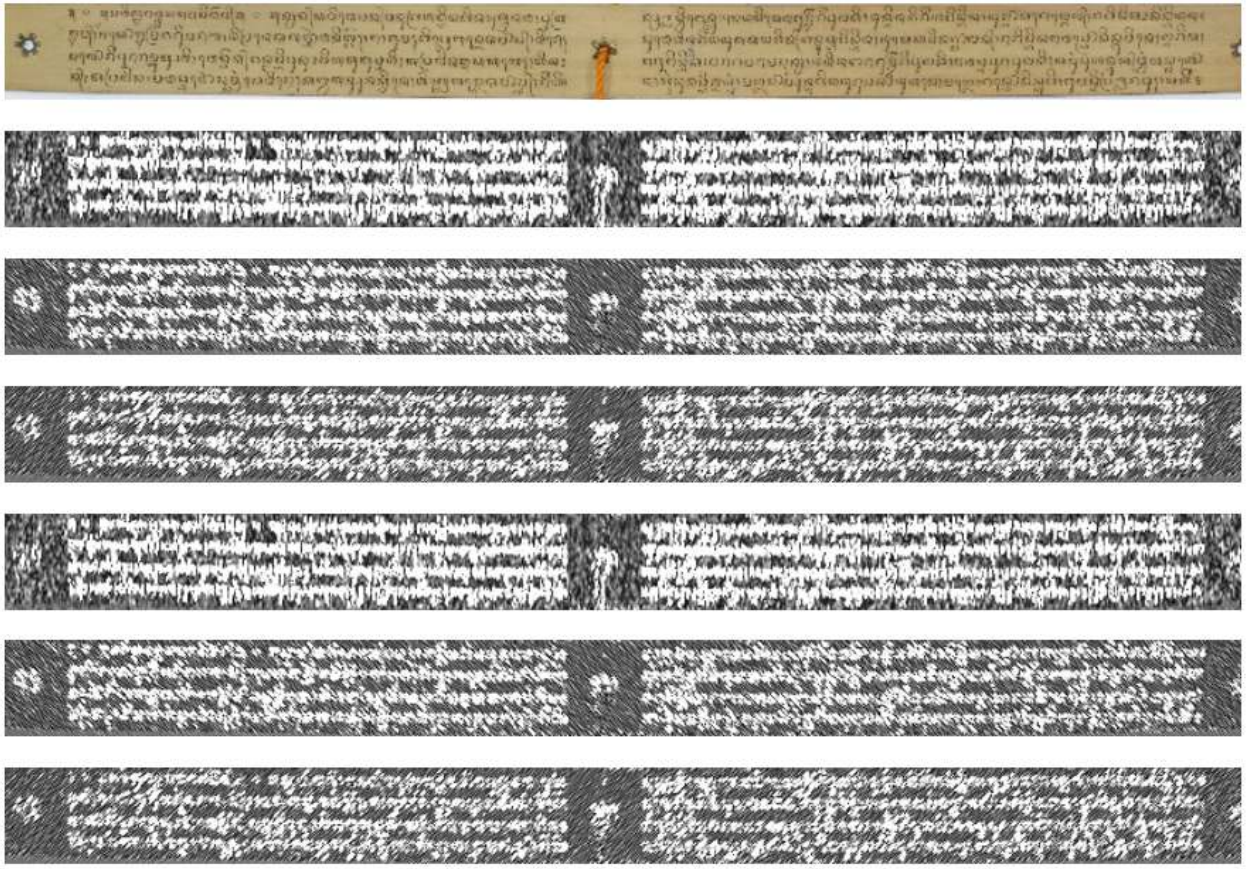






Example of Gabor filters with differentfrequencies and orientations. First column showstheir 3D plots and the second one, the intensity plotsof their amplitude along the image plane.

Gabor-filtered Images



Six Gabor-filtered images of a manuscript page

- Six different orientations:
  0^o, 45^o, 135^o, 180^o, 225^o, and 315^o.
- Wavelength: 8,
- Aspect ratio: 0.5,
- Bandwidth: 1.

The result of six Gabor-filtered images will be joined (with a simple image addition operation) to produce one grayscale Gabor image.

The Binary Mask Image

Next step: Binarization with the global Otsu's : a binary mask image for the adaptive sliding patch algorithm.

The binary mask image for the adaptive sliding patch algorithm

Optimized Sliding Window Algorithm

To optimally extract the image patches only in the text line area of the Gabor filtered images

The algorithm :

1. A sliding patch of size 125 (height) x 300 (width) pixels will be moved (from left to right with 100 pixels step and up to down with 50 pixels step)
   - ✓ Will be spotted many patch images in manuscript page.
2. On each spotted patch position :
   - ✓ calculate the ratio (R) of the number of white pixels (text) and the total number of pixels in patch image.
   - ✓ calculate the number of white pixels (text) only in upper (U), middle (M) and lower (U) part of the patch image.
3. A conditional rule is then applied :
   - ✓ whether this patch image contains a significant number of text area (when R>0.1)
   - ✓ and a good centered-spotting position on the manuscript (when M>U and M>L).
4. If the condition is met : save the patch image position.
5. Otherwise : move the sliding patch 2 pixels in a lower vertical position repetitively until the condition is met.
   - ✓ It should be noted that during this repetitive patch searching in vertical position, the horizontal position of the patch is kept.

Adaptive Sliding Patch Algorithm

Input: IMG_MASK : binary image as mask
IMG : manuscript gray scale image
Output: all possible word patch images

Algorithm:
h=125 (*sliding patch height*)
w=300 (*sliding patch width*)
h_from=1; h_to=h_from+h-1; (*sliding patch height position*)

while (h_from and h_to are still inside height image)
w_from=1; w_to=w_from+w-1; (*sliding patch width position*)
allow_slide=0;

while (w_from and w_to are still inside width image AND
h_from and h_to are still inside height image)

Get **PATCH** from **IMG**
Get **PATCH_MASK** from **IMG_MASK**
Calculate **R** of **PATCH_MASK**
Calculate **U** of **PATCH_MASK**
Calculate **M** of **PATCH_MASK**
Calculate **L** of **PATCH_MASK**

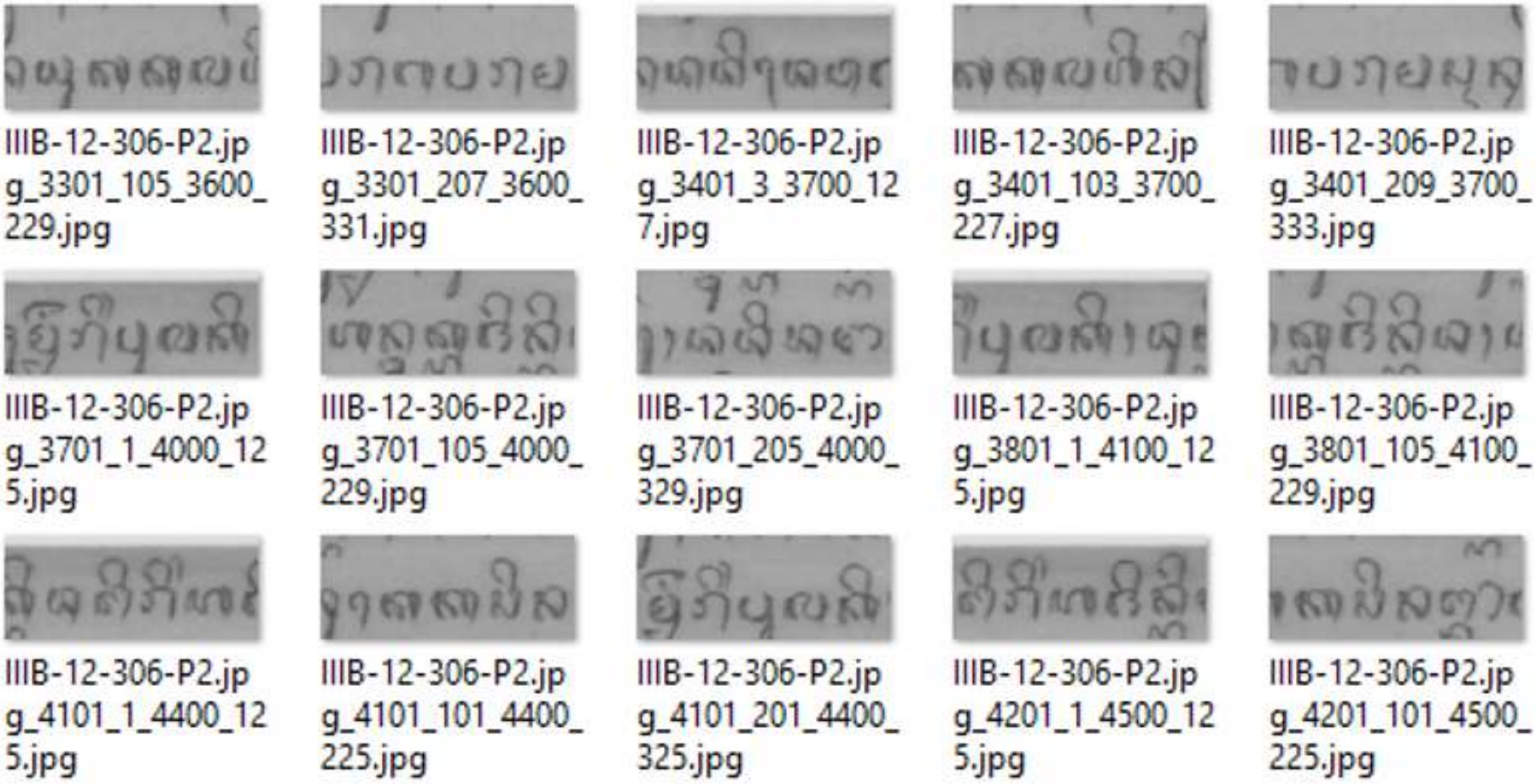
if (R>0.1 and M>U and M>L) (*condition is met*)
Extract this **PATCH**
if (allow_slide~=0)
h_from=h_from_save;
h_to=h_to_save;
allow_slide=0;
end (of if)
else (*condition is not met*)
if (allow_slide==0) (*remember the patch height position*)
h_from_save=h_from;
h_to_save=h_to;
end (of if)
if (allow_slide<10) (*maximum slide 10 times*)
h_from=h_from+2; h_to=h_to+2;
w_from=w_from-w_step; w_to=w_to-w_step;
allow_slide=allow_slide+1;
else (*no more slide, back to the saved patch height position*)
h_from=h_from_save;
h_to=h_to_save;
allow_slide=0;
end (of if-else)
end (of if-else)

w_from=w_from+w_step; w_to=w_to+w_step;
end (of while)
h_from=h_from+h_step; h_to=h_to+h_step;
end (of while)

Experimental Results

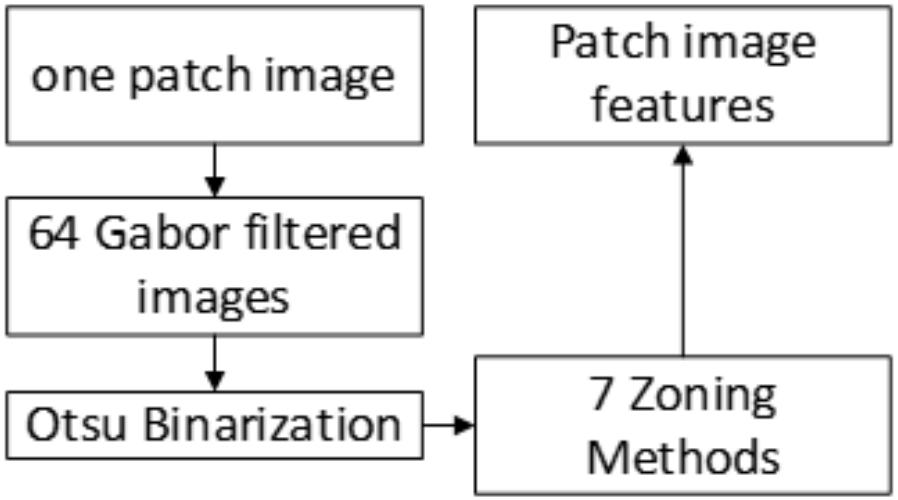
Examples of text patch area extraction from the manuscript pages

- The combination of Gabor filter with the optimized sliding window algorithm is effectively able to detect and to extract image patches from the text area of the Balinese palm leaf manuscripts
- This procedure is well adapted to cope with the unstraight text line in manuscript.



Some examples of the extracted patch images from a manuscript page

Feature Extraction Method



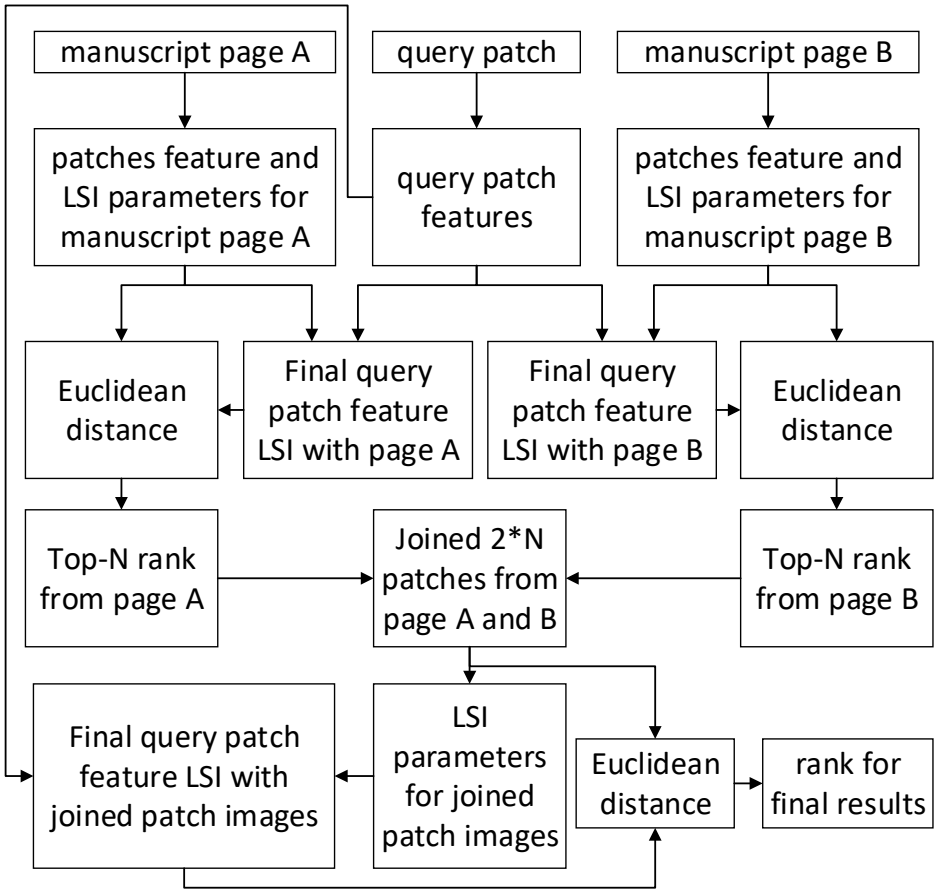
The different Zoning methods

64 Gabor filters + seven different Zoning methods.

A patch image:

- Preprocessed by resizing into 100 x 200 pixels.
- 64 different combinations of Gabor filter parameters
  - 0^o, 45^o, 90^o, 135^o, 180^o, 225^o, 270^o, and 315^o for the orientation,
  - 4 and 8 for the wavelength,
  - 0.5 and 0.9 for the aspect ratio, and
  - 0.5 and 1 for the bandwidth.
- Global Otsu's binarization method.
- Seven Zoning methods: (distance between zone area is 50 pixels)
  - vertical, horizontal, block, left diagonal,
  - right diagonal, radial and circular
- Feature value: ratio of the number of white pixels (text) and the total number of pixels in zoning area
- Produce the total of 2,240 feature dimensions for each patch image.

Patch Ranking Scheme



We are not directly rank the similarity (or it can be the dissimilarity) between the query patch features and the patch image features all together. However, we first rank the patch image features page per page.

The original patch image feature values and the original query patch feature values will be mapped into new feature values with new feature dimensions by using the Latent Semantic Indexing concept with Single Value Decomposition [9].

In the first LSI step, the feature dimensions will be reduced depending on the number of patches in each manuscript page (*0.5*nb_patch*). And in the second LSI step, the feature dimensions will be reduced depending on the number of pages in all manuscript collections (*nb_page*).

Experiments and Results: Dataset and Evaluation

A published dataset of AMADI_LontarSet [10]:

- ✓ Already proposed for word spotting challenge in ICFHR 2016 competition [6].
- ✓ For query-by-example word spotting dataset, it consists of 100 manuscript pages and 36 query patch images for test and evaluation.

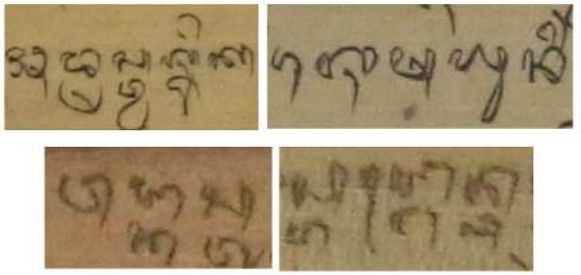


Fig. 13 Some examples of query patch images ("*adrestwasnika*", "*sesayuning*", "*wangkas*" and "*anggen*")

- ➢ Two evaluation measures: mean Recall (mR) and mean average Precision (maP) [1], [5], [9], [11].
- ➢ Based on the number of relevant patch spotting area from the spotting results.
- ➢ A relevant spotting area: overlapped in more than 30% patch area and the height and width of the spotting patch area are not twice bigger than the height and width of the ground truth patch area.

Experiments and Results

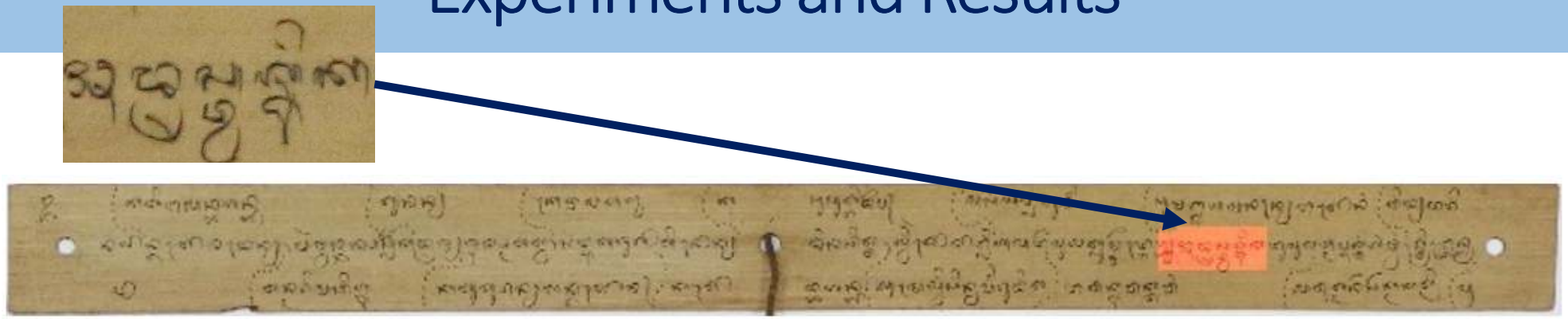


Fig. 14. Relevant spotting for query "*adrestwasnika*"

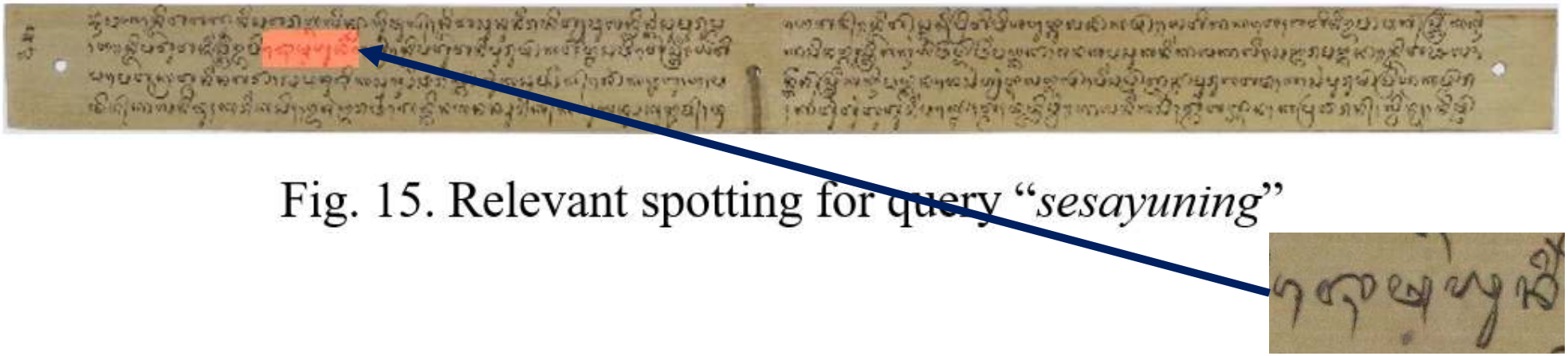


Fig. 15. Relevant spotting for query "*sesayuning*"

Experiments and Results

"*wangkas*"

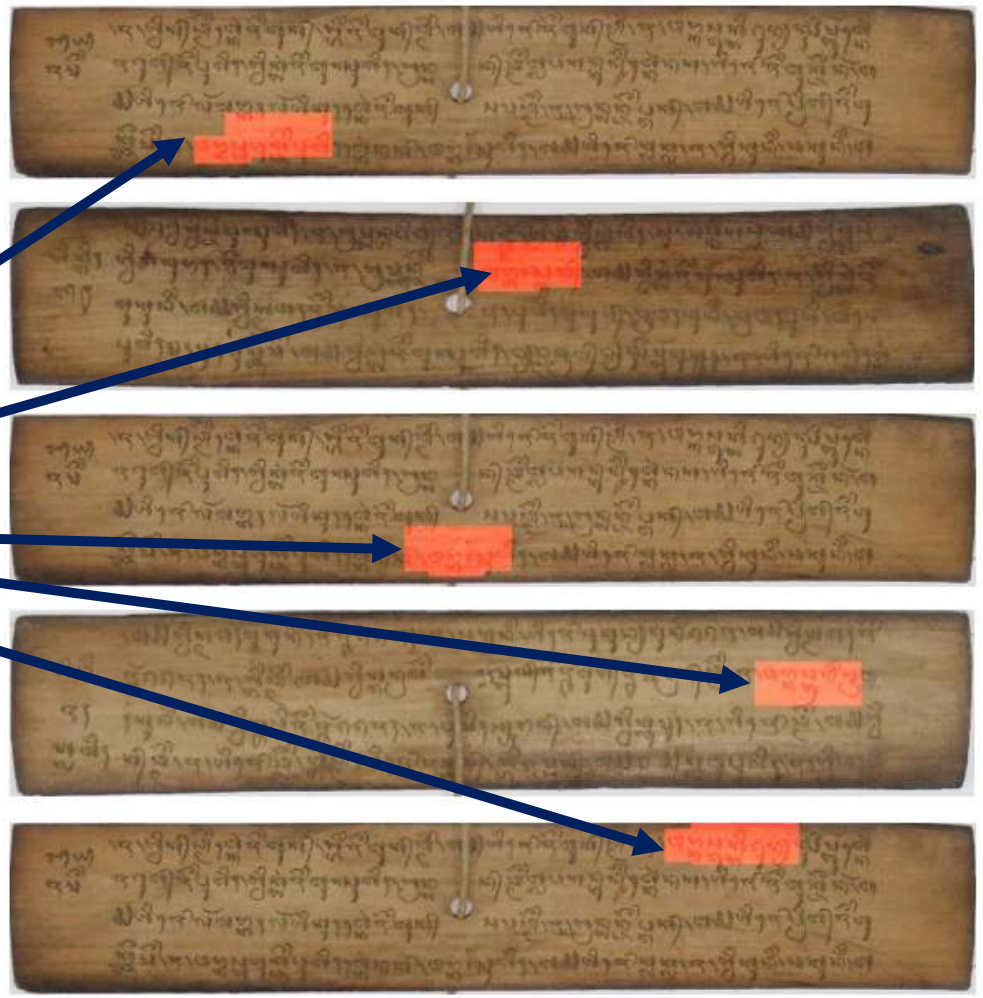


Fig. 16. Five relevant spotting for query "*wangkas*"

Experiments and Results

1. Achieve a high Recall value for longer query words.
2. This finding can be very useful to define an optimal patch size in patch extraction algorithm for the futur works.
3. The intra-similarity between patches from the same manuscript page is stronger than the intra-similarity between patches from the same query word image.
4. Our proposed patch ranking scheme is able to rank hierarchically all patches from the same page, but still shows low performance in ranking the patches from different pages. It makes the mean average Precision (maP) values are low.

Query Patch Image	Nb Patch		Recall	maP
	Ground Truth	Relevant Spot		
adrestwasnika_query1.jpg	1	1	100,00	0,19
agung_query2.jpg	10	1	10,00	6,50
akah_query3.jpg	19	5	26,32	0,50
alungguh_query4.jpg	2	1	50,00	0,06
anggen_query5.jpg	22	14	63,64	1,01
banten_query6.jpg	7	4	57,14	0,47
banyu_query7.jpg	4	2	50,00	0,34
candra_query8.jpg	4	0	0,00	0,00
dharma_query9.jpg	14	0	0,00	0,00
dina_query10.jpg	6	0	0,00	0,00
dumlada_query11.jpg	14	1	7,14	0,30
dwijendra_query12.jpg	1	0	0,00	0,00
paturunan_query13.jpg	3	1	33,33	0,13
pawikretan_query14.jpg	2	1	50,00	0,08
sarwa_query15.jpg	13	0	0,00	0,00
sekar_query16.jpg	1	0	0,00	0,00
sesayuning_query17.jpg	1	1	100,00	0,54
siwa_query18.jpg	11	0	0,00	0,00
sri_query19.jpg	9	0	0,00	0,00
stri_query20.jpg	12	0	0,00	0,00
suara_query21.jpg	9	0	0,00	0,00
sudamala_query22.jpg	3	0	0,00	0,00
sunia_query23.jpg	7	0	0,00	0,00
susuhunan_query24.jpg	3	1	33,33	0,06
tadanganing_query25.jpg	1	1	100,00	0,39
taman_query26.jpg	4	1	25,00	0,07
titiange_query27.jpg	14	10	71,43	0,94
tri_query28.jpg	9	0	0,00	0,00
tuan_query29.jpg	9	2	22,22	0,19
tunggal_query30.jpg	17	11	64,71	0,55
wangkas_query31.jpg	5	5	100,00	0,48
widiadara_query32.jpg	3	1	33,33	0,12
widiadari_query33.jpg	3	1	33,33	2,56
windu_query34.jpg	6	2	33,33	0,25
yogiswara_query35.jpg	4	1	25,00	0,13
yuarantaraning_query36.jpg	4	1	25,00	0,07
		mean	30,95	0,44

Thank you

VIRTUAL VISION
IMAGE
PATTERN

https://research.undiksha.ac.id/vvip-rg/