

RE-SEQUENCING A HISTORICAL PALM LEAF MANUSCRIPT WITH BOUNDARY-BASED SHAPE DESCRIPTORS



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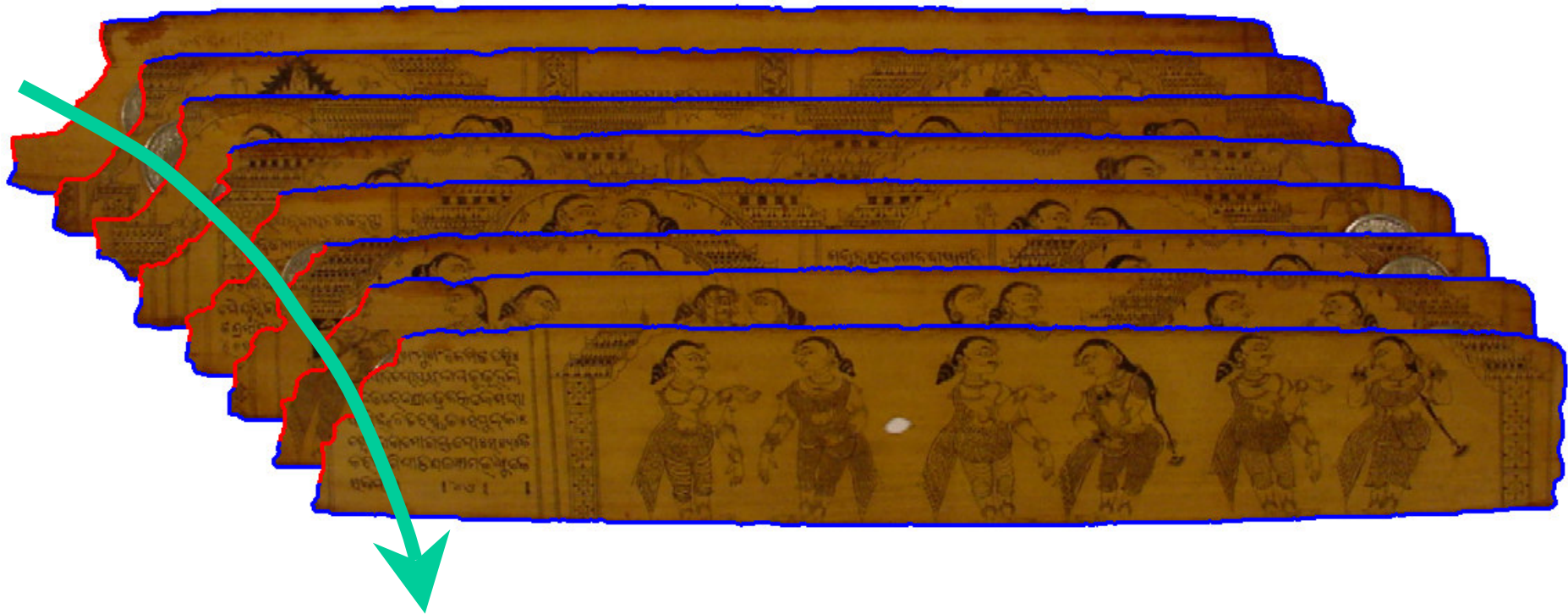
Introduction

- In the collection of [Museum Riethberg-Zurich](#) is a palm leaf manuscript from India, consisting **66** folios, inscribed on both sides.
- **100** erotic poems and more pictures were inscribed by **8th** century AD Sanskrit poet [Amaru](#).
- The [manuscript](#) was prepared about **200** years ago.
- Folios **1-18** were paginated. However the sequence of the rest is unknown.
- The stack was damaged by a [mouse](#) biting pieces off (**5-10 %** from left side).



The Goal

The geometry of the leaf perimeter, as left over after eating, should bear useful information to find the [original sequence](#).



METHODOLOGY

- Image Acquisition
- Rectification of the Images
- Boundary Tracing
- Fourier Descriptors
- Spatial Boundary Intersection
- Evaluation of the Shape Data using Tree-search

RESULTS AND CONCLUSION

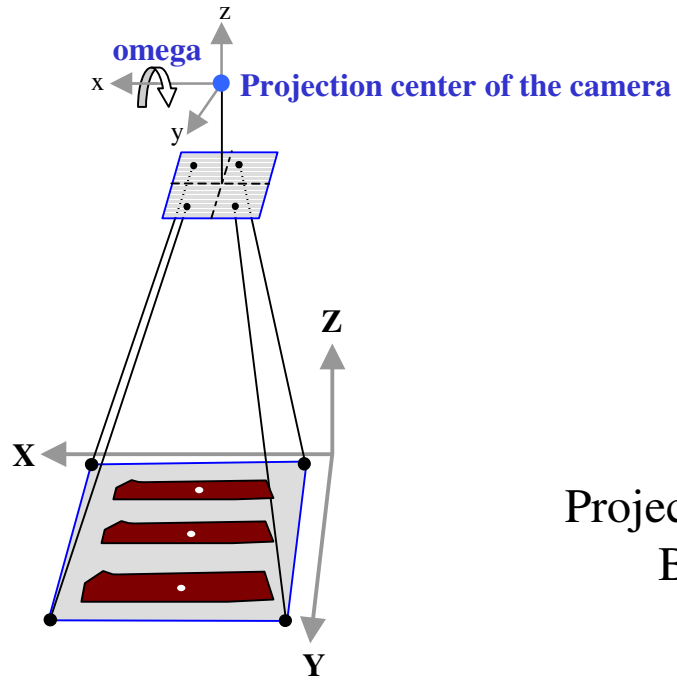
Image Acquisition



Sony DSC-F505 Cybershot
1600 x 1200 pixel
focal length : 7.1 mm

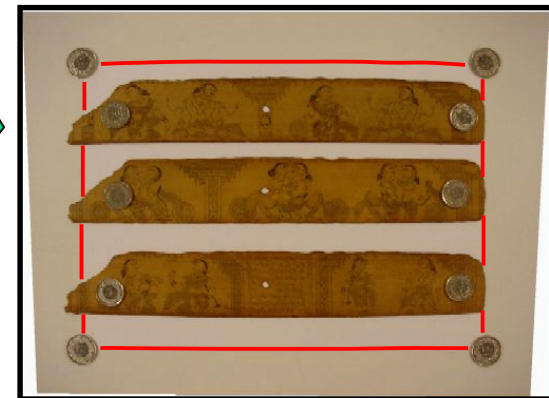
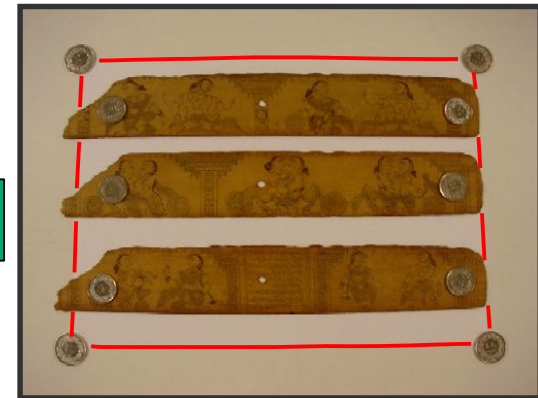


Rectification of the Images

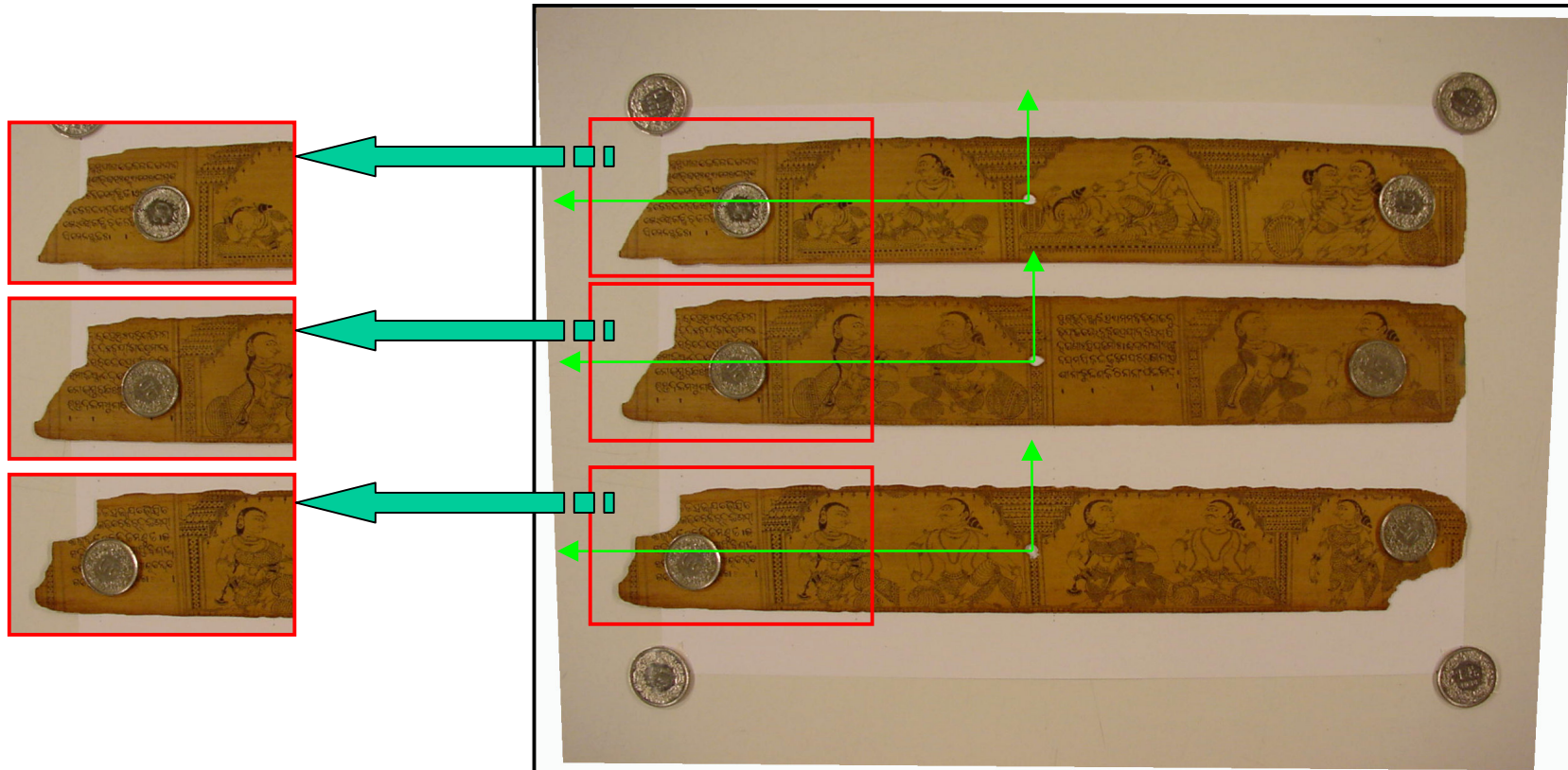


Imaging geometry

Projective transformation
Bi-linear resampling



Cropping the images

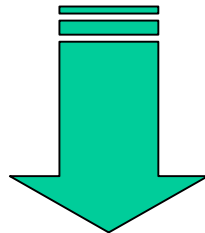


2D leaf coordinate systems according to holes

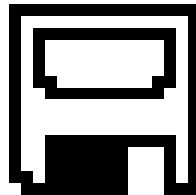
Boundary Tracing



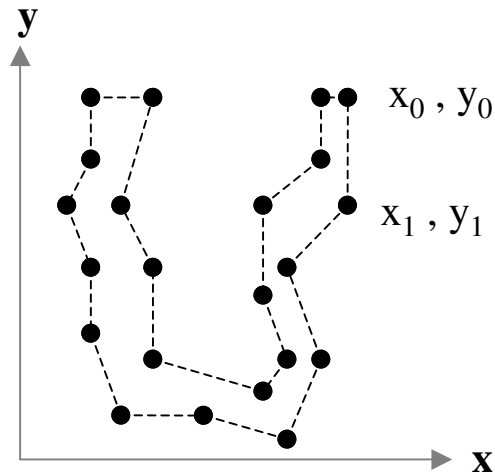
Inner boundary tracing
(8-connectivity mode)




Save as ASCII file



Fourier Descriptors



$(x_0, y_0), (x_1, y_1), \dots, (x_{N-1}, y_{N-1})$



$$s(k) = x(k) + jy(k) \quad k = 0, 1, \dots, N-1$$

$$a(u) = \mathbf{F}_N \{ s(k) \}$$

$$\tilde{s}(k) = \mathbf{F}_M^{-1} \{ a(u) \} \quad M < N$$



Original boundary
708 elements



Inv.Fourier Trf. using
250 coefficients



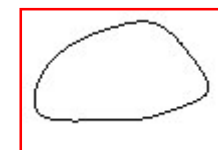
Inv.Fourier Trf. using
150 coefficients



Inv.Fourier Trf. using
75 coefficients



Inv.Fourier Trf. using
25 coefficients



Inv.Fourier Trf. using
10 coefficients

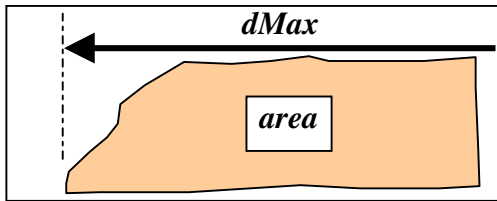


Original boundary (1532 elements)

F, F^{-1}



250 Fourier coefficients



Additional shape features

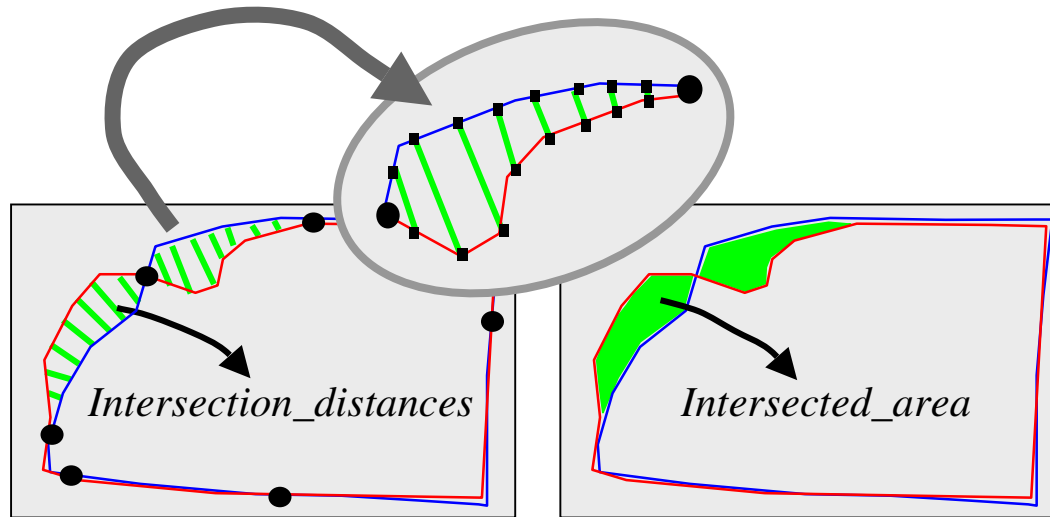
$$v_{ij} = \begin{bmatrix} a(u_0)_i - a(u_0)_j \\ a(u_1)_i - a(u_1)_j \\ \dots \\ dMax_i - dMax_j \\ area_i - area_j \end{bmatrix}$$

$$P = \begin{bmatrix} 1 & 0 & \dots & 0 & 0 \\ 0 & 1 & \dots & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & W_{dMax} & 0 \\ 0 & 0 & \dots & 0 & W_{area} \end{bmatrix}$$

$$d_{ij} = \sqrt{v_{ij}^T P v_{ij}} \quad i, j = \{0, 1, \dots, 65\} \quad i \neq j$$

$$D_{\text{fourier}} = \begin{bmatrix} 0 & \mathbf{d}_{0,1} & \dots & \mathbf{d}_{0,65} \\ \mathbf{d}_{1,0} & 0 & \dots & \mathbf{d}_{1,65} \\ \dots & \dots & \dots & \dots \\ \mathbf{d}_{65,0} & \mathbf{d}_{65,1} & \dots & 0 \end{bmatrix}_{66 \times 66}$$

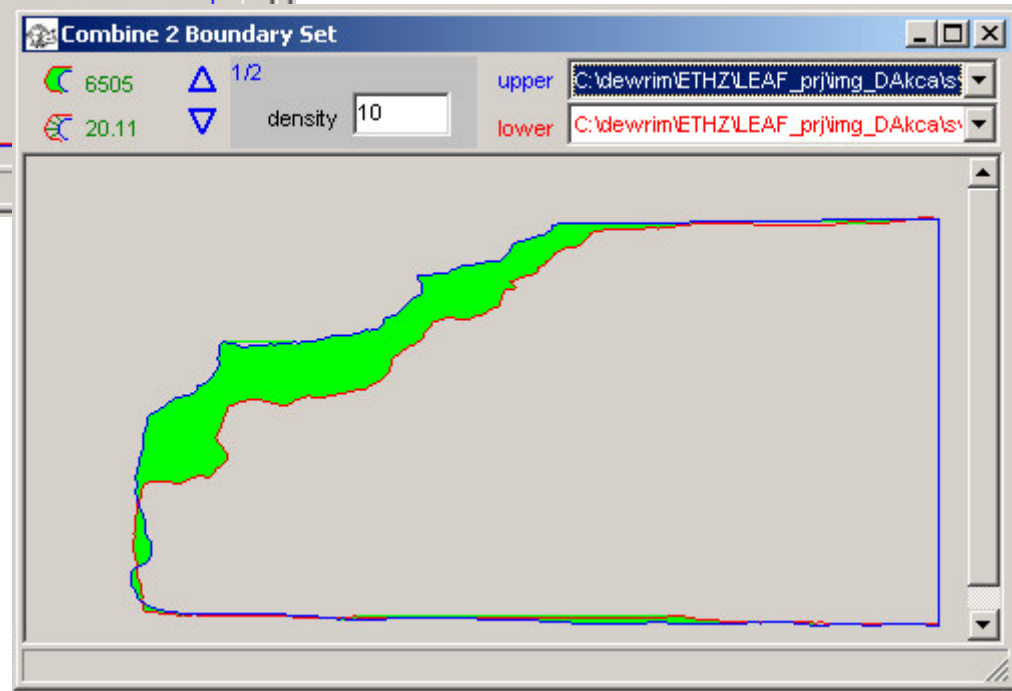
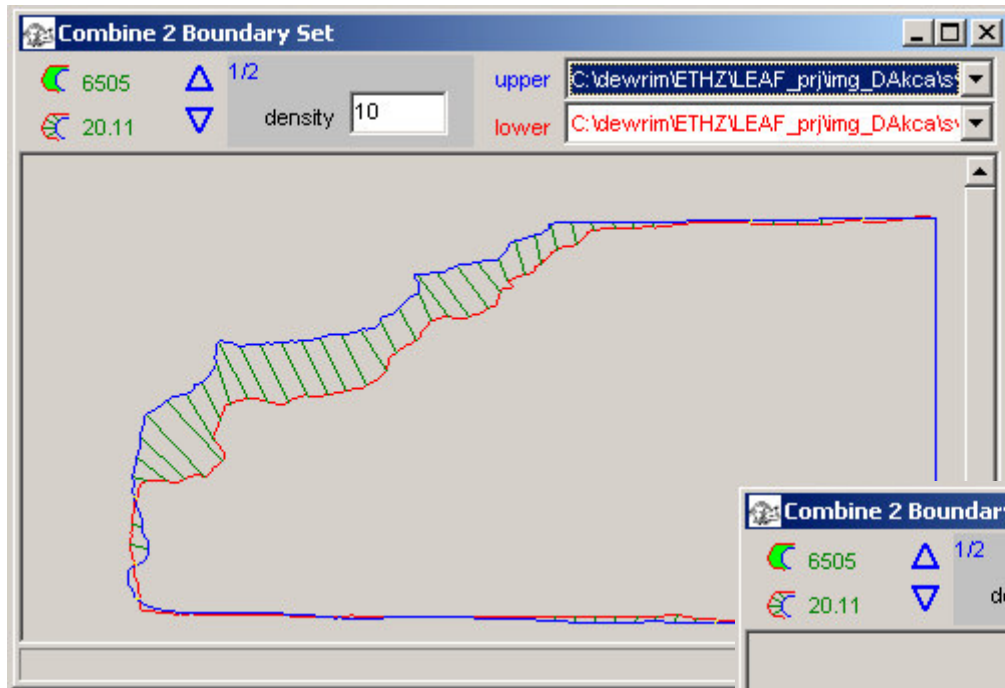
Spatial Boundary Intersection



$$\text{int_dist} = \sqrt{\frac{\sum \Delta d^2}{n}}$$

$$dI_{ij} = \text{int_dist}_{ij} \cdot W_{\text{int_dist}} + \text{int_area} \cdot W_{\text{int_area}}$$

$$\mathbf{D}_{\text{intersection}} = \begin{bmatrix} 0 & dI_{0,1} & \dots & dI_{0,65} \\ dI_{1,0} & 0 & \dots & dI_{1,65} \\ \dots & \dots & \dots & \dots \\ dI_{65,0} & dI_{65,1} & \dots & 0 \end{bmatrix}_{66 \times 66}$$



Evaluation of the Shape Data using Tree-Search

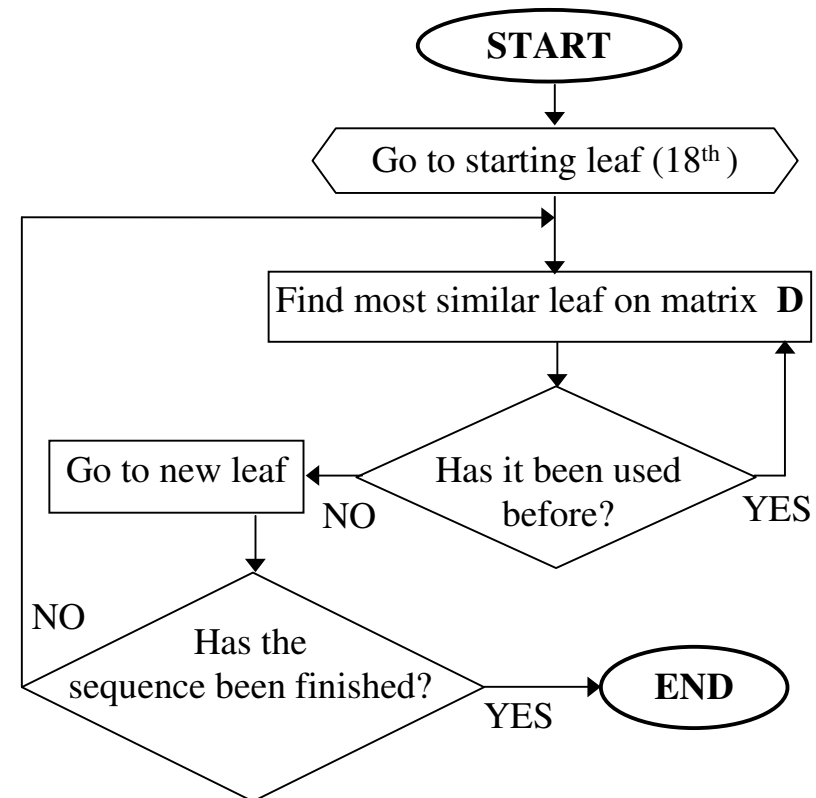
The partial problems:

Which leaves might be ancestor or successor for a pointed leaf in the sequence?

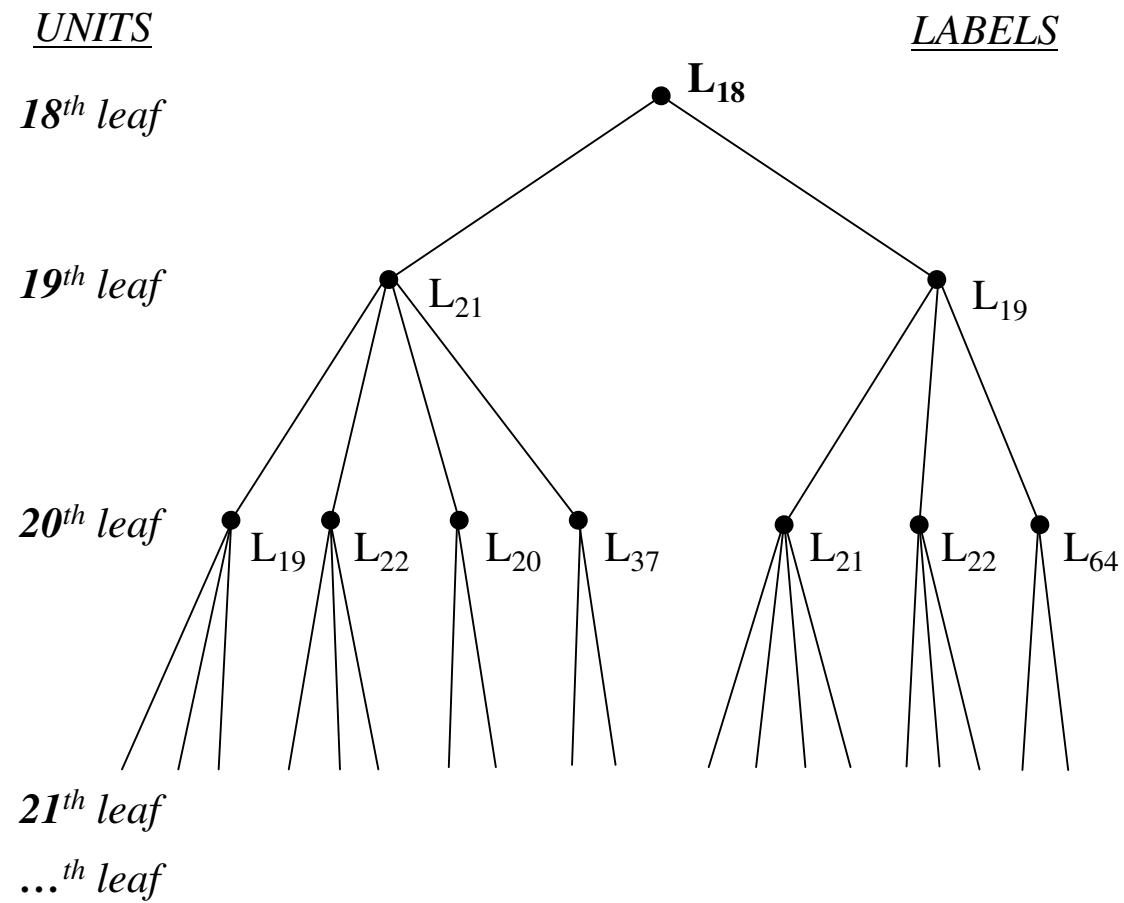
➡ D_{fourier} and $D_{\text{intersection}}$

The global problem:

How can this information be used efficiently to generate the full sequence?



Tree-Search



The Proposed Sequence



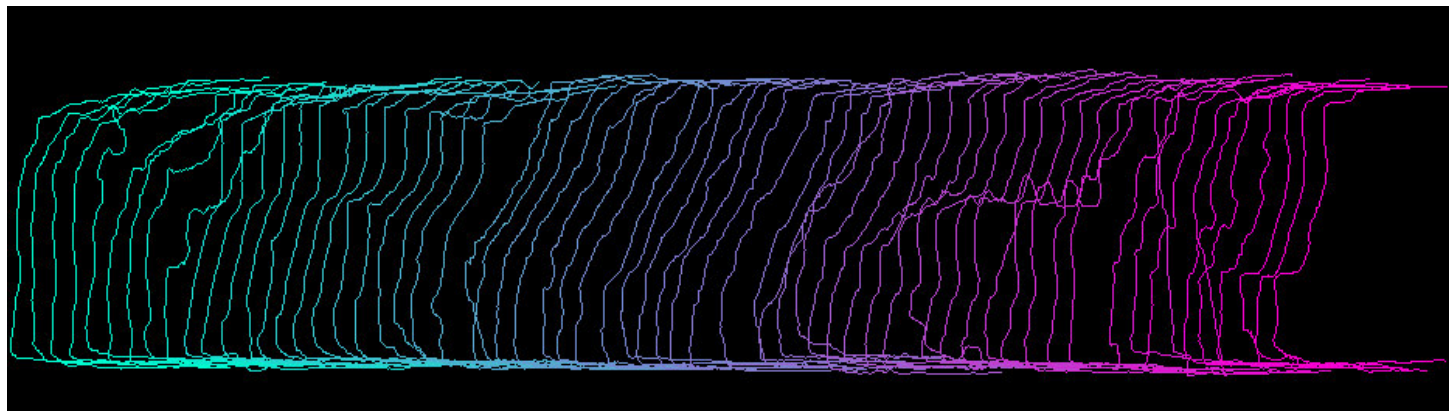
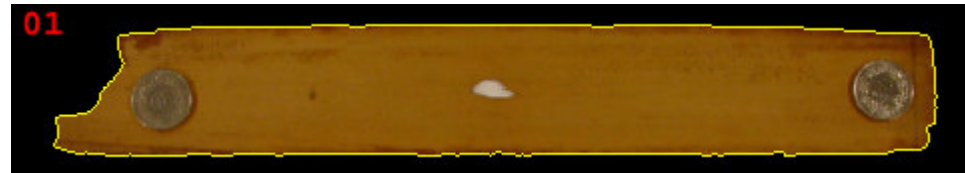
Orthographic view of the proposed sequence



Texture mapped model of the palm leaf manuscript

Conclusion

The missing sequence of the historical palm leaf manuscript was found by using shape descriptors.





THANK YOU FOR YOUR ATTENTION!