Department of Biomedical Engineering
National Taiwan University

Fundamentals of Biomedical Image Processing

Final Project Presentation

Unsupervised Segmentation of Pathology Images based on Haralick Textures

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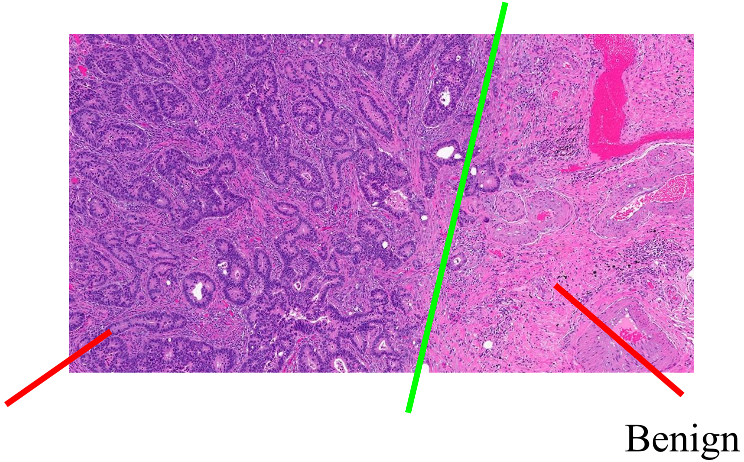
Introduction

- **Traits of Biopsy Images:**
  - ill defined margins
  - Image changes dramatically between regions and intra-regional areas.



→ Biopsy Image Segmentation with image processing → ***lower time spent, higher Accuracy***

→ Extract features for AI model training → ***Increase model decision-making ability***

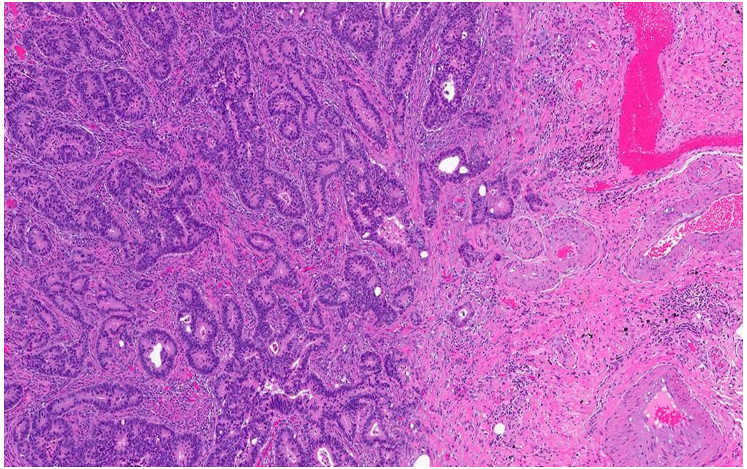
Introduction

- Traditional Methods
  - **Thresholding** (Local, Adaptive)
  - **Edge Detection** (Sobel Operator)
  - **Region-Based Methods** (Region Growing, Watershed Algorithm)
  - **Morphological Operations** (Erosion, Dilation …etc.)

→ Mostly are ***First Order Statistics*** image analysis

[1] Löfstedt, T., Brynolfsson, P., Asklund, T., Nyholm, T., & Garpebring, A. (2019). Gray-level invariant Haralick texture features. PLOS ONE, 14(2), e0212110. https://doi.org/10.1371/journal.pone.0212110

Introduction



Original Image

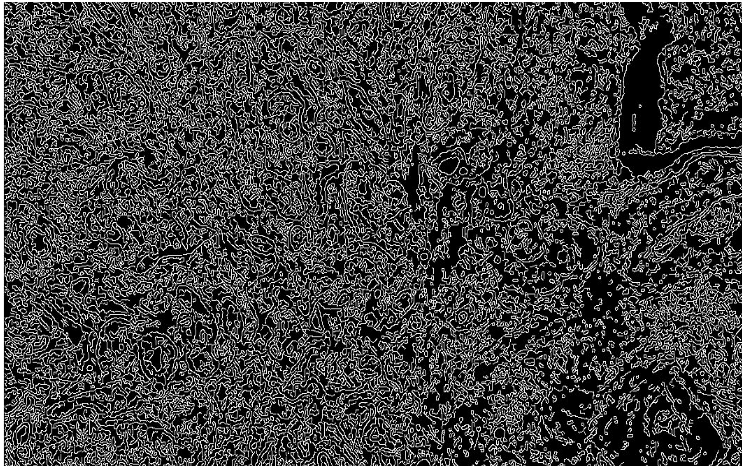


Image after applying Sobel Operator

➔ This inability makes first order statistics a blunt tool for quantifying changes in images, or any change in the spatial distribution of gray values.

[1] Löfstedt, T., Brynolfsson, P., Asklund, T., Nyholm, T., & Garpebring, A. (2019). Gray-level invariant Haralick texture features. PLOS ONE, 14(2), e0212110. https://doi.org/10.1371/journal.pone.0212110

Introduction

- **Modified Haralick Texture Features (** Löfstedt *et al.* [1] **)**
    - Utilize a Normalized GLCM
    - Asymptotically invariant to image quantization.
    - Retains most interpretations of original Haralick features

- ***GOAL :*** Use modified Haralick texture features for image segmentation.
    1. Separate benign and malignant areas in microscopy images.
    2. Leverage feature vectors to build models

[1] Löfstedt, T., Brynolfsson, P., Asklund, T., Nyholm, T., & Garpebring, A. (2019). Gray-level invariant Haralick texture features. PLOS ONE, 14(2), e0212110. https://doi.org/10.1371/journal.pone.0212110

Materials and Methods

- **Dataset used in this project:**

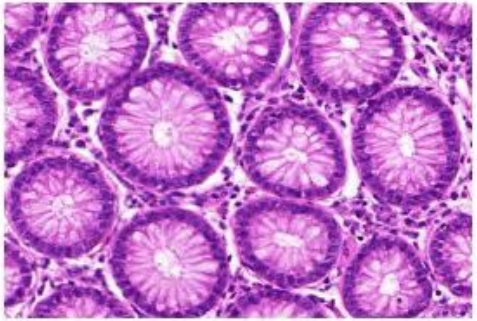
warwick-qu-changed-dataset [7]

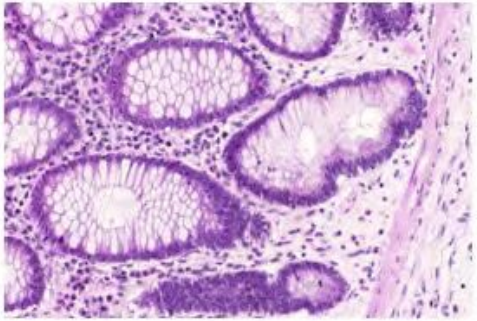
Data Card Code (1) Discussion (0) Suggestions (0)

➔ Benchmark dataset for biomedical image analysis.

➔ High-resolution histological images.

➔ Focus on segmentation, classification, and detection tasks.

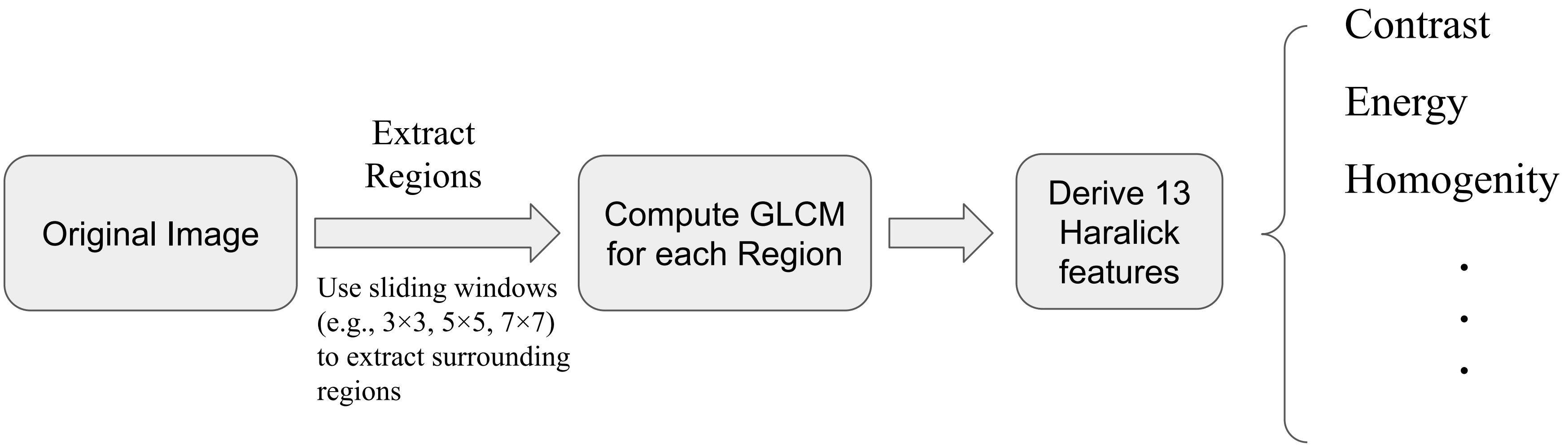




[7] Sirinukunwattana, K., Snead, D. R. J., & Rajpoot, N. M. (2015). A Stochastic Polygons Model for Glandular Structures in Colon Histology Images. IEEE Transactions on Medical Imaging, 34(11), 2366–2378. https://doi.org/10.1109/tmi.2015.2433900

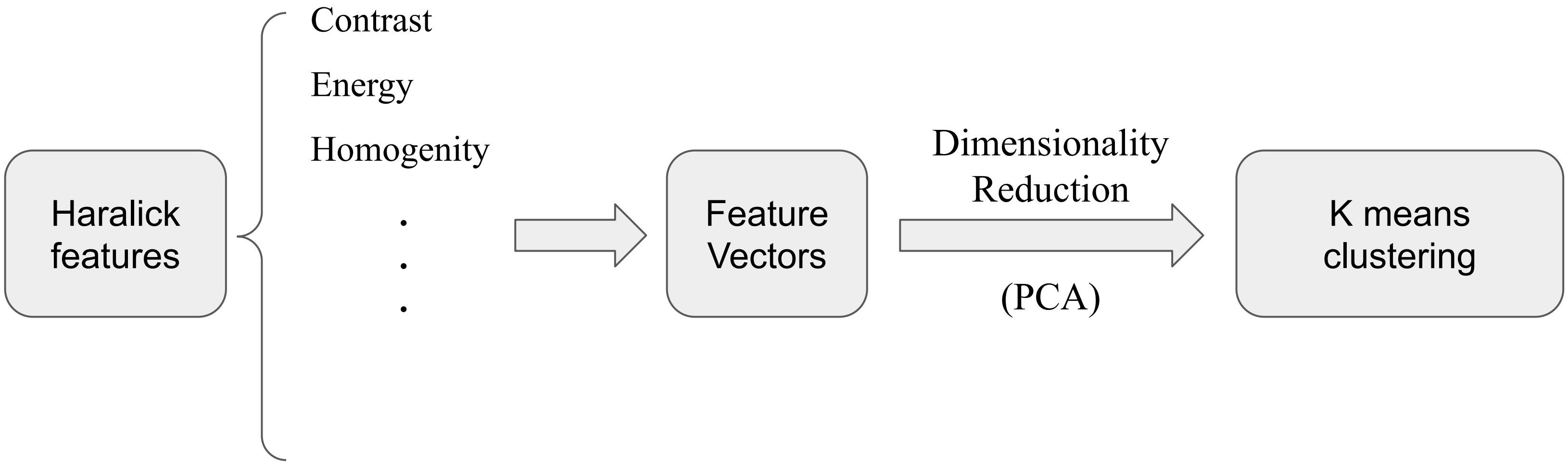
Materials and Methods

- **Texture Analysis**



Materials and Methods

- **Unsupervised Segmentation Model**



Materials and Methods

- **Equilibrium k means**

Algorithm 1: Equilibrium K-Means Algorithm

Input: A dataset $X = \{\mathbf{x}_n\}_{n=1}^{N}$, cluster number K, initial centroids $\{\mathbf{c}_k^{(0)}\}_{k=1}^{K}$, smoothing parameter α

Output: Centroids $\{\mathbf{c}_1, \cdots, \mathbf{c}_K\}$

$\tau = 0$;

repeat

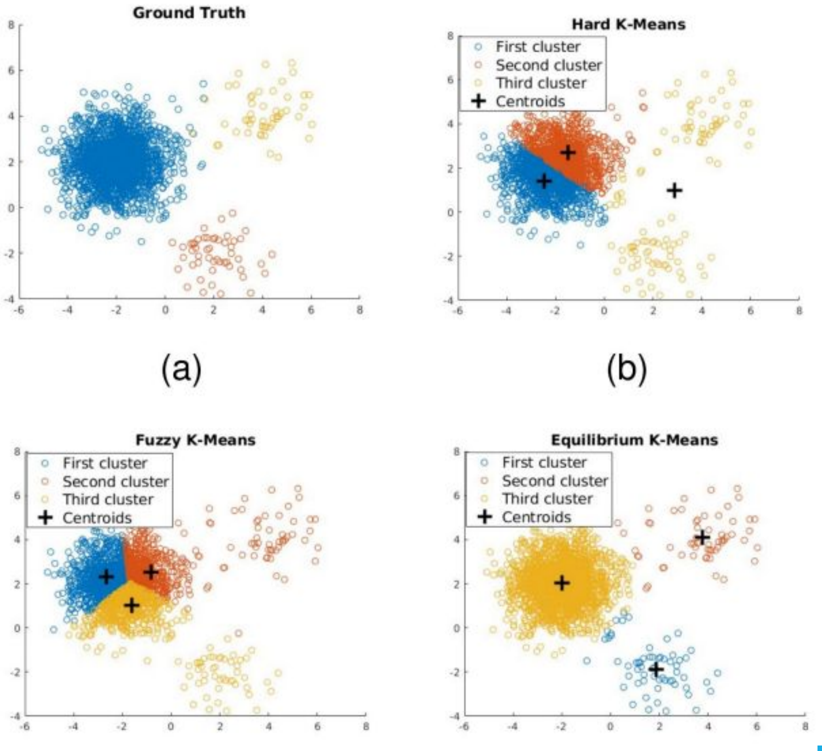
  Compute weight $w_{kn}^{(\tau)}$ by (38) for all k, n;

  Update centroid $\mathbf{c}_k^{(\tau+1)}$ by (39) for all k;

  $\tau = \tau + 1$;

until *convergence*;

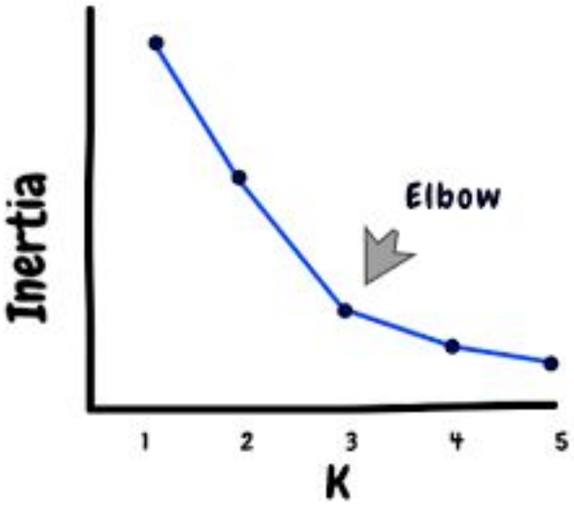
return $\{\mathbf{c}_k^{(\tau)}\}_{k=1}^{K}$



Materials and Methods

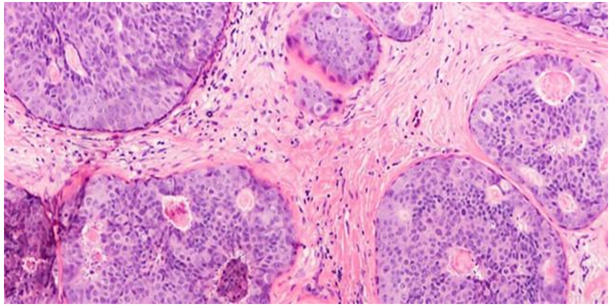
- **K-means Clustering with Automated Determination of Cluster Count**

$$\text{Inertia} = \sum_{i=1}^{K} \sum_{x \in C_i} \|x - \mu_i\|^2$$

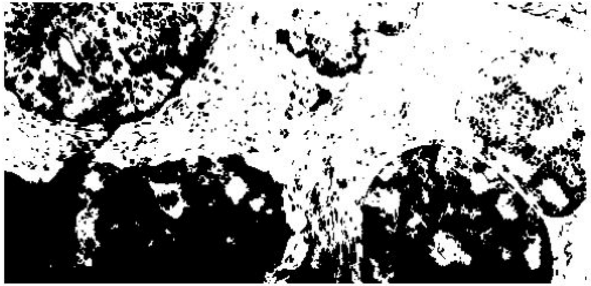


Results : Clustering Results Using Haralick Texture Features and RGB Pixel Values

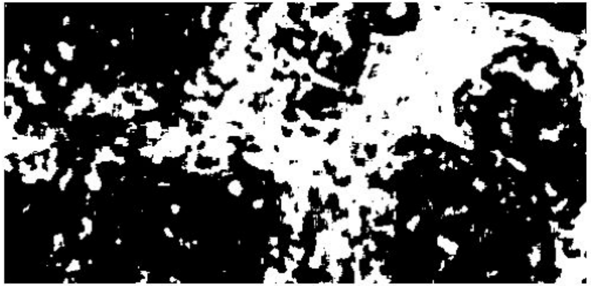
Original image



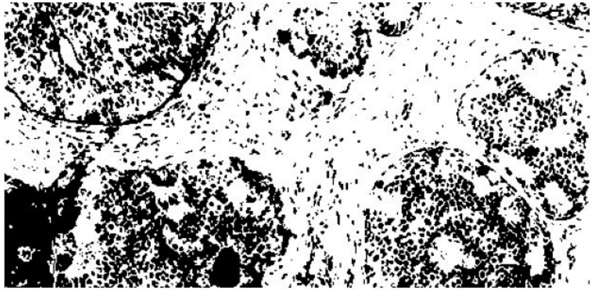
9*9 graly-level haralick features
combined with spatial and pixel features



9*9 gray-level haralick features only



9*9 RGB haralick features
combined with spatial and pixel features

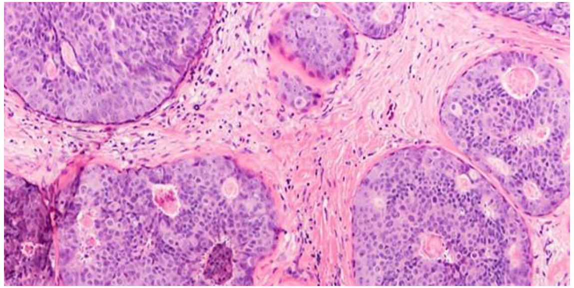


9*9 RGB haralick features only

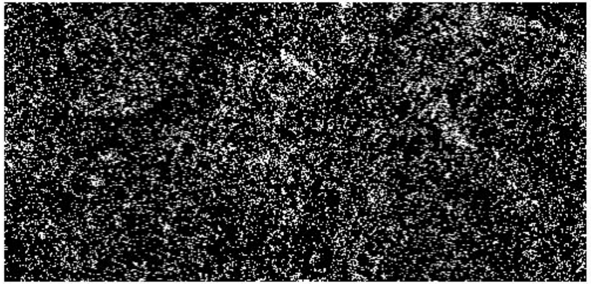
Black: malignant area
White: benign area

Results : Clustering Results Using Different Window Sizes for Extracting Haralick Texture Features

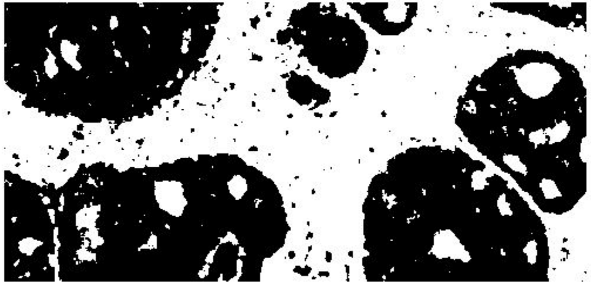
Original image



3×3 sliding window



5×5 sliding window



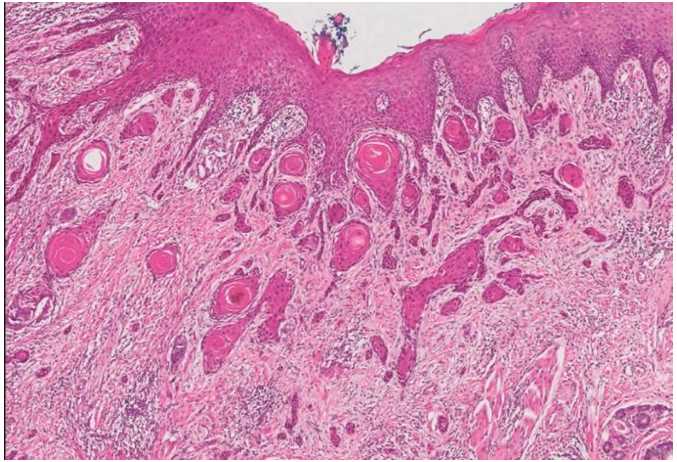
7×7 sliding window

9×9 sliding window

11×11 sliding window

Results : K-means Clustering with Automated Determination of Cluster Count

Original image

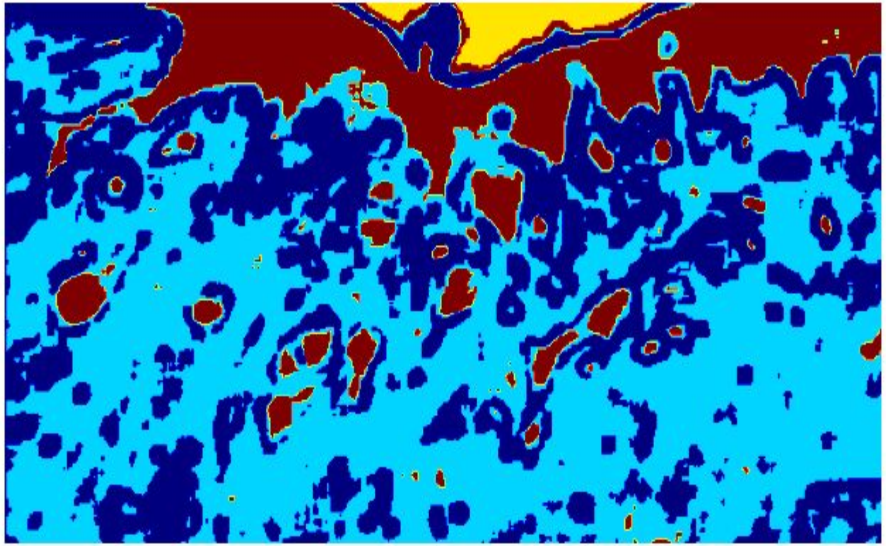


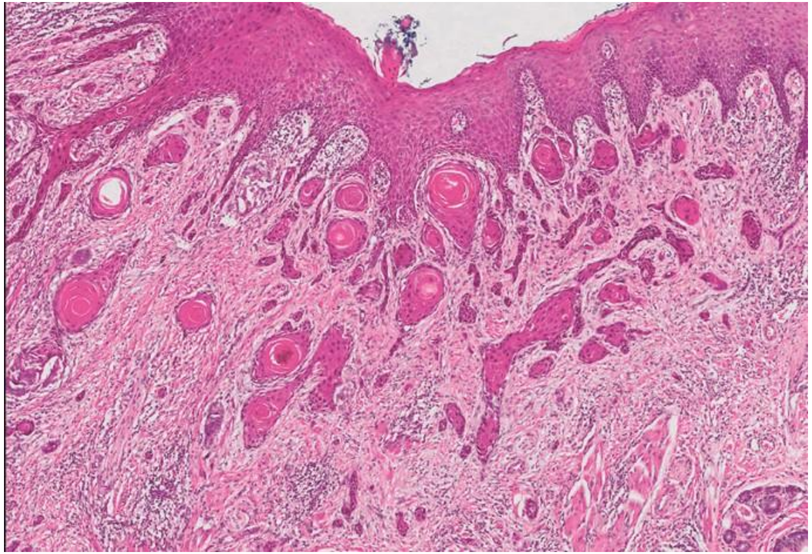
(Present with multiple components)

K = 2

Results : K-means Clustering with Automated Determination of Cluster Count

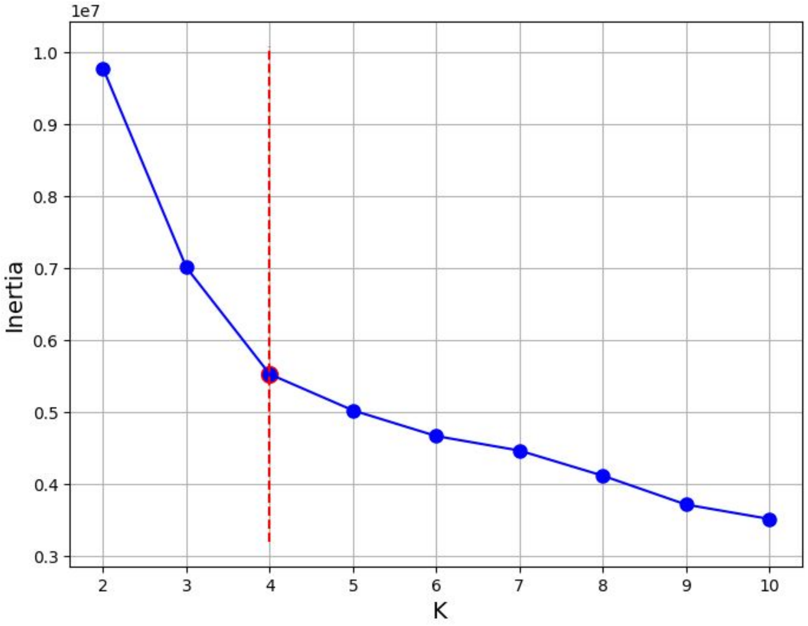
K=4





Results : K-means Clustering with Automated Determination of Cluster Count

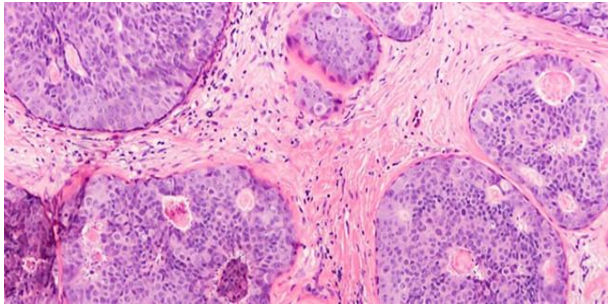
Inertia



Conclusions

- Using regional Haralick texture features with clustering methods is an effective approach for performing unsupervised segmentation of biopsy images
- A sliding window of 7×7 pixels or larger for extracting RGB image features yields better segmentation performance.

Original image



9*9 RGB haralick features only

References

[1] Löfstedt, T., Brynolfsson, P., Asklund, T., Nyholm, T., & Garpebring, A. (2019). Gray-level invariant Haralick texture features. PLOS ONE, 14(2), e0212110. https://doi.org/10.1371/journal.pone.0212110

[2] Naira Elazab, Wael Gab Allah, & Elmogy, M. (2024). Computer-aided diagnosis system for grading brain tumor using histopathology images based on color and texture features. BMC Medical Imaging, 24(1). https://doi.org/10.1186/s12880-024-01355-9

[3] Öztürk, Ş., & Akdemir, B. (2018). Application of Feature Extraction and Classification Methods for Histopathological Image using GLCM, LBP, LBGLCM, GLRLM and SFTA. Procedia Computer Science, 132, 40–46. https://doi.org/10.1016/j.procs.2018.05.057

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[5] Eizan Miyamoto1 and Thomas Merryman Jr.2, Fast calculation of haralick texture features

[6] Haralick, R. M., Shanmugam, K., & Dinstein, I. (1973). Textural Features for Image Classification. IEEE Transactions on Systems, Man, and Cybernetics, SMC-3(6), 610–621. https://doi.org/10.1109/tsmc.1973.4309314

[7] Sirinukunwattana, K., Snead, D. R. J., & Rajpoot, N. M. (2015). A Stochastic Polygons Model for Glandular Structures in Colon Histology Images. IEEE Transactions on Medical Imaging, 34(11), 2366–2378. https://doi.org/10.1109/tmi.2015.2433900

[8] Yudong He, Imbalanced Data Clustering using Equilibrium K-Means https://doi.org/10.48550/arXiv.2402.14490

Thanks!