Image Processing
(Pengolahan Citra)

Semester Genap Tahun 2019-2020

Jam 08:00 s.d. 10:30

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STT Nurul Fikri

Slides by: Prof. Dr. Aniati Murni Arymurthy (FASILKOM UI)

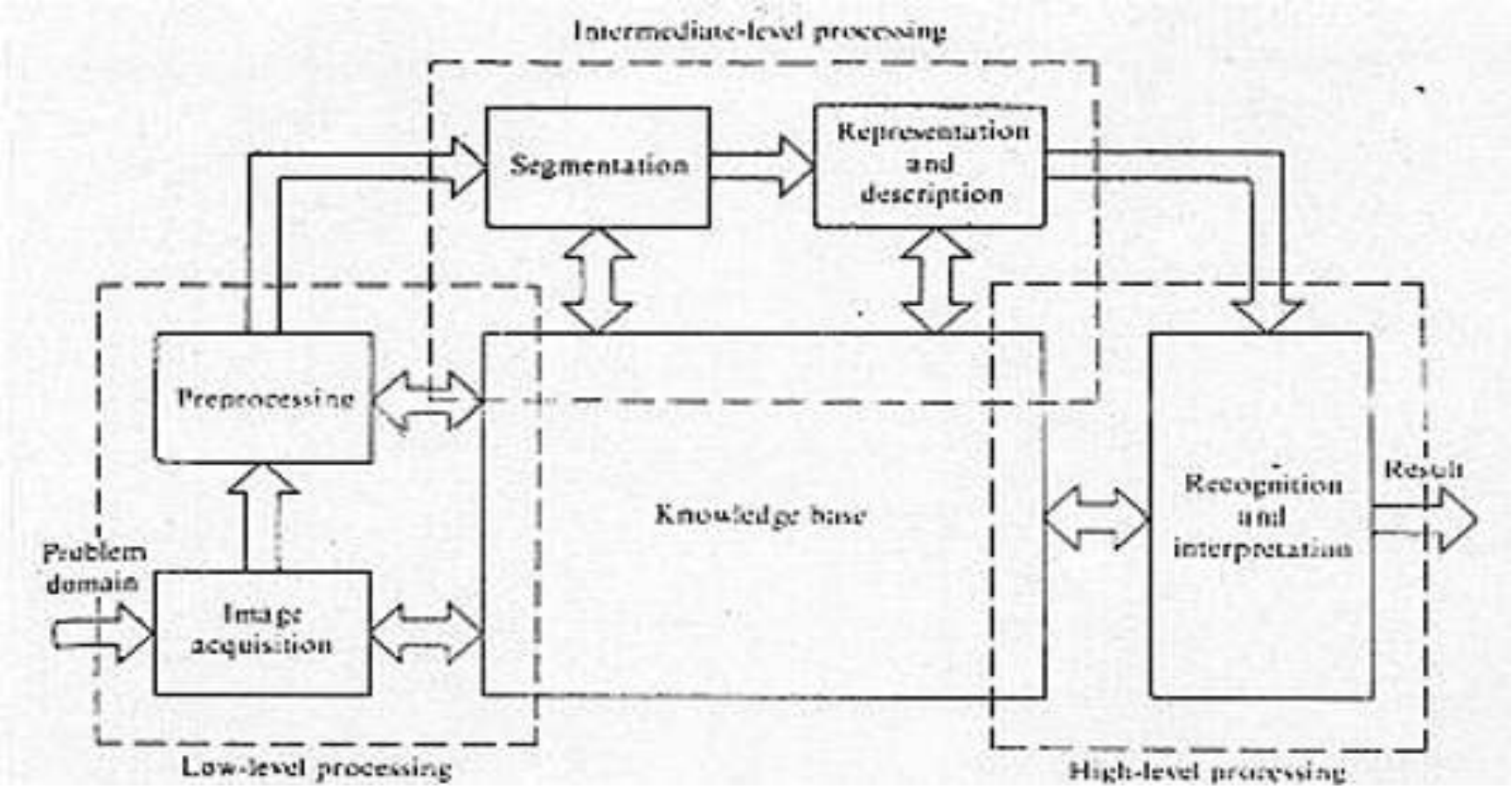
Topics

- Fundamental steps in Digital Image Processing
- Low-level Image Processing
- Intermediate-level Image Processing
- High-level Image Processing

Topic 1:
Fundamental steps in Image Processing

Elements of Image Analysis System

(Source: Gonzalez & Woods, 1992)



Fundamental Steps in Image Processing

(Source: Gonzalez & Woods, 2008)

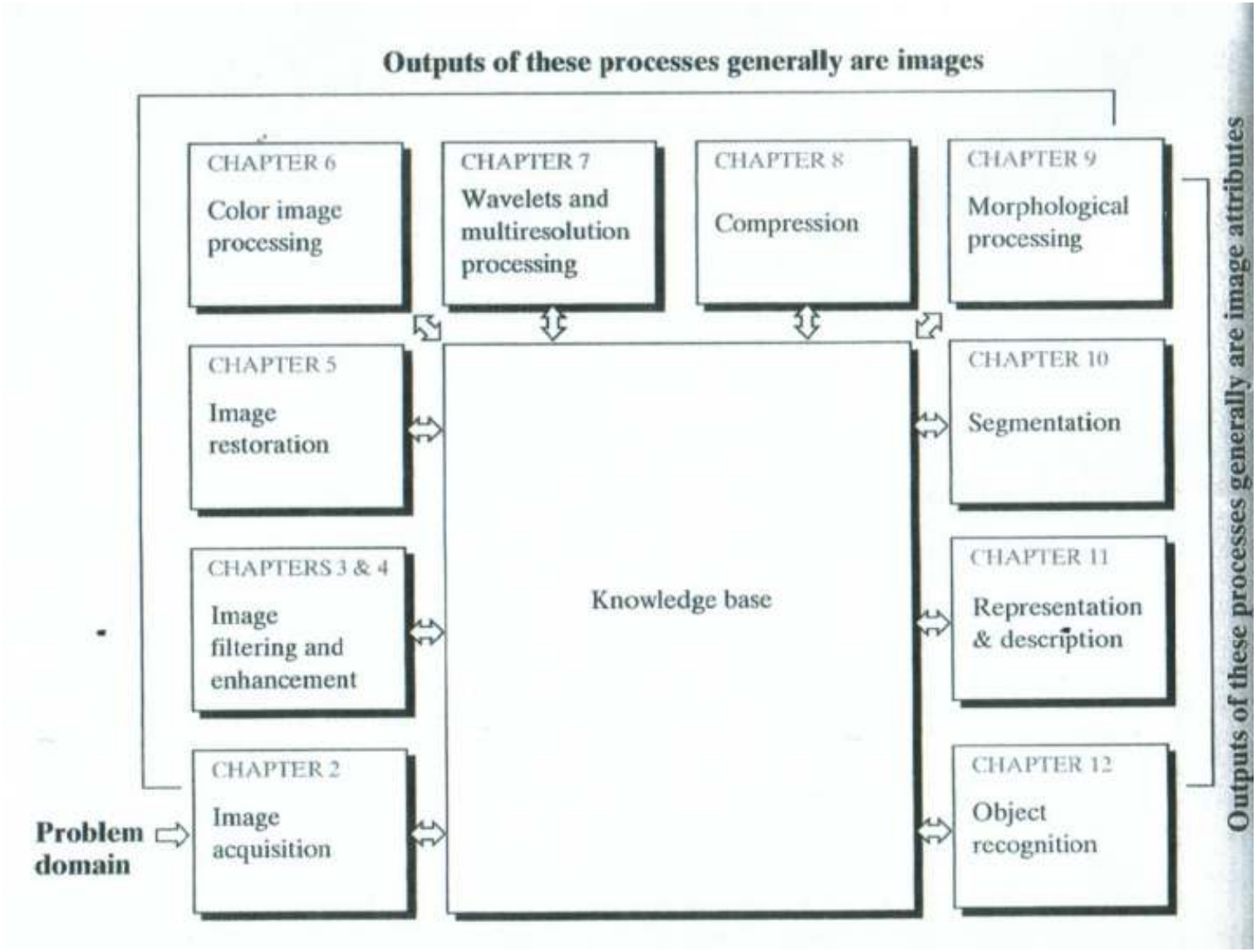


Image Processing Steps

- Contoh:
  - Feature extraction and selection
    - Ekstraksi color features termasuk pada step Low-level Processing (sering juga disebut sebagai Pre Processing)
    - Ekstraksi shape features termasuk step Intermediate-level Processing, karena ekstraksi dilakukan setelah segmentation yang sudah masuk ke Intermediate-level Processing
  - Noise elimination
    - Termasuk pada step Low-level Processing
    - Untuk noise elimination yang termasuk proses morfologi dilakukan pada Intermediate-level Processing, bahkan filtering juga ada yang dilakukan setelah proses classification yang termasuk High-level Processing (atau sering disebut sebagai Post Processing)

Components of an Image Processing System

(Source: Gonzalez & Woods, 2008)

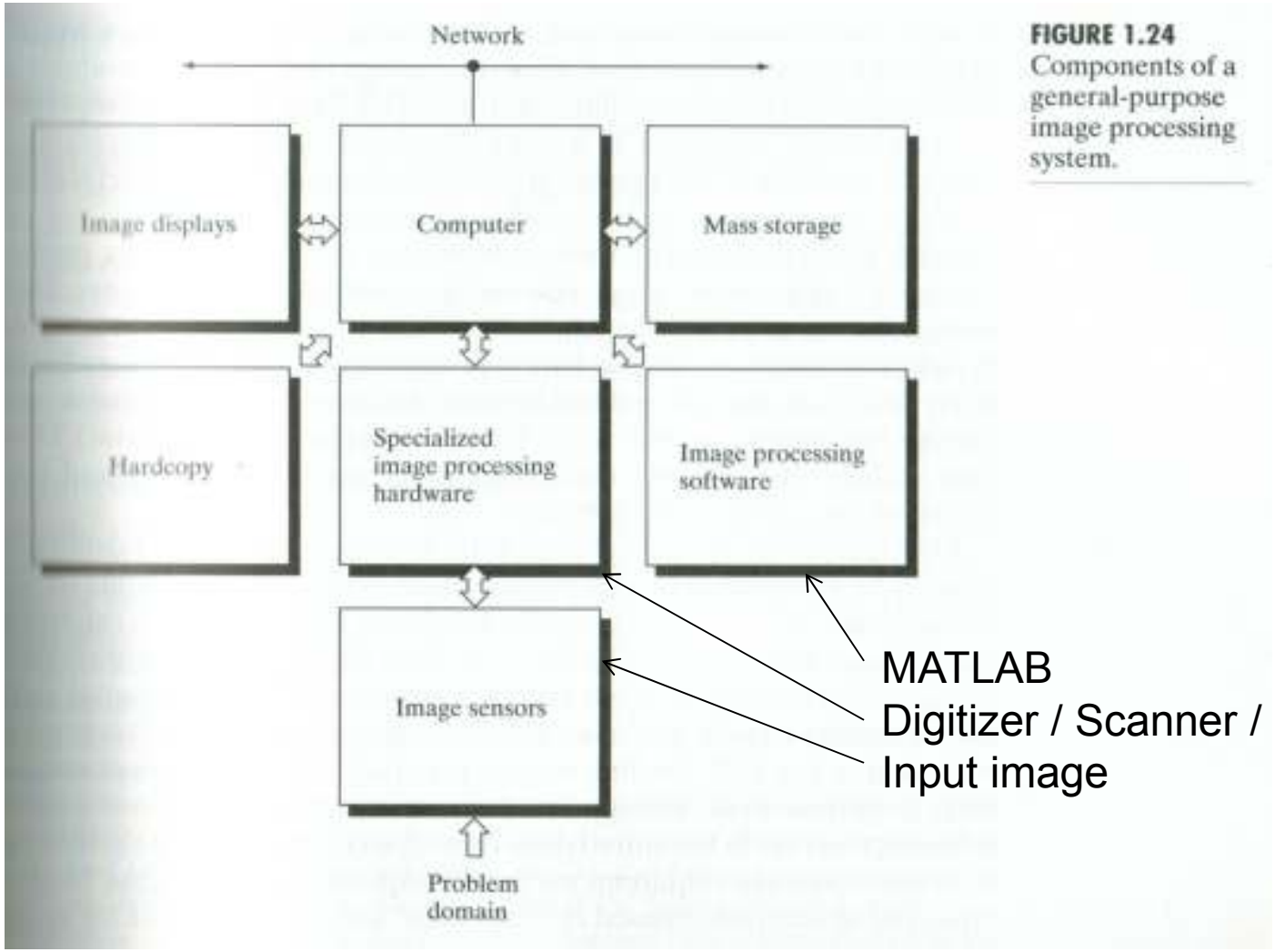


FIGURE 1.24 Components of a general-purpose image processing system.

Standard Image Processing Methodology (1)

- **Low-Level Image Processing**
  - **Data Acquisition**
    - Required Data and Sensor System
  - **Image Preprocessing:**
    - Image Filtering (radiometrik / kontras)
    - Image Registration (geometrik)
- **Intermediate-Level Image Processing**
  - **Edge Detection**
    - Object boundary (external shape characteristics)
  - **Image Segmentation**
    - Object area (internal properties)
  - **Feature Extraction & Selection**
    - Object descriptor
  - **Description and Representation**
    - Whole digital image as object or an object as part of image (object and background)

Standard Image Processing Methodology (2)

- **High-Level Image Processing**
  - **Recognition and Interpretation**
    - **Clustering (Unsupervised Classification)**
      - Pewilayahan tanpa label kategori objek (mirip ouput segmentasi)
    - **Classification (Supervised Classification)**
      - Pengenalan Pola (*Pattern Recognition*): Memberikan label kategori obyek pada setiap piksel citra berdasarkan informasi yang diberikan oleh deskriptor atau ciri piksel bersangkutan (pewilayahan jaringan keras dan pewilayahan berbagai jaringan lunak pada citra biomedik)
      - Interpretasi Citra (*Image Interpretation*): Memberikan arti pada obyek yang sudah berhasil dikenali (dari citra klasifikasi biomedik dapat dilihat adanya penyakit tumor)
    - **Knowledge-Based (Rule-Based) Object Recognition**
      - Penyusunan Basis Pengetahuan: Basis pengetahuan ini digunakan sebagai referensi pada proses *template matching / object recognition*.

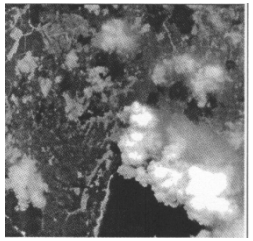
Topic 2:
Low-Level Image Processing

Data Acquisition

(Source: Lee Sider, Introduction to Diagnostic Imaging)

- Biomedical Instrument:
  - X-ray sensor: chest x-ray, abdomen
  - USG (Ultra Sound): gallstone, gas in the stomach
  - CT (Computed Tomography): fatty infiltration of the liver, renal cell carcinoma
  - Nuclear Medicine: thyroid, aortic angiogram
  - Magnetic Resonance: view of the brain

Pap Smear Image (Jantzen *et al.,* 2005)

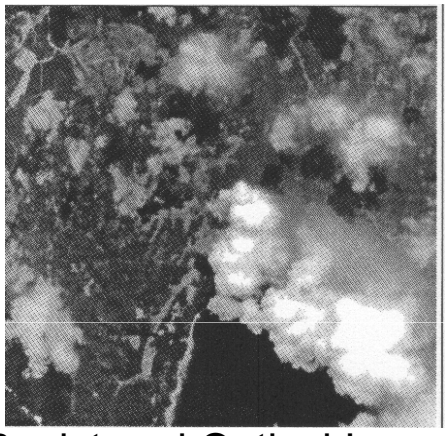


Optical-sensor image (Bakosurtanal RI, 1994)

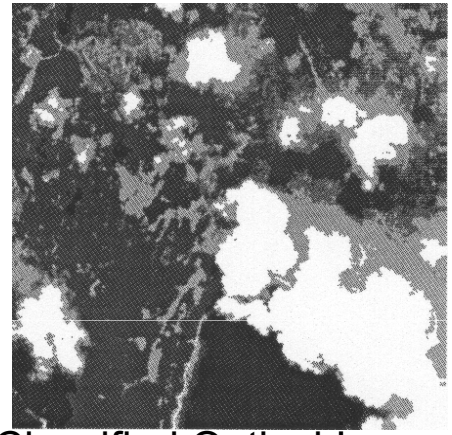
- Remote Sensing Instrument:
  - Optical (multiscanner, thematic mapper, hyperspectral sensor system)
  - Synthetic aperture radar (SAR) sensor system, including Lidar system
- Etc.

Image Restoration (Cloud Removal)

(Source: Original Image of Teluk Belantung, BAKOSURTANAL RI;
Processed Images, A. Murni, 1996 and 2000)

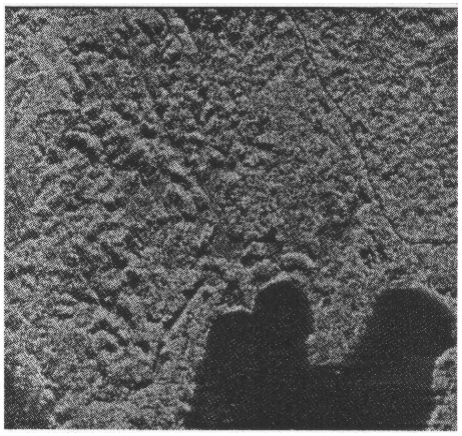


Registered Optical Image
Containing of Cloud

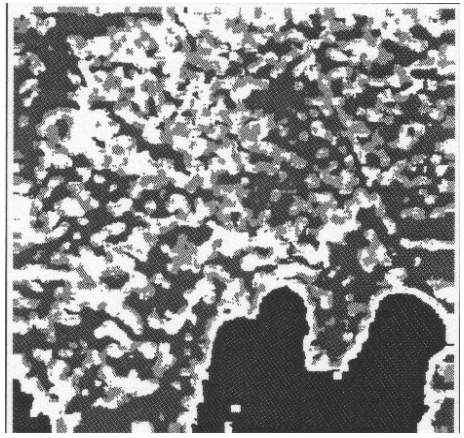


Classified Optical Image

Restored Cloud Free
Raw Optical Image Data



Registered SAR Image



Classified SAR Image

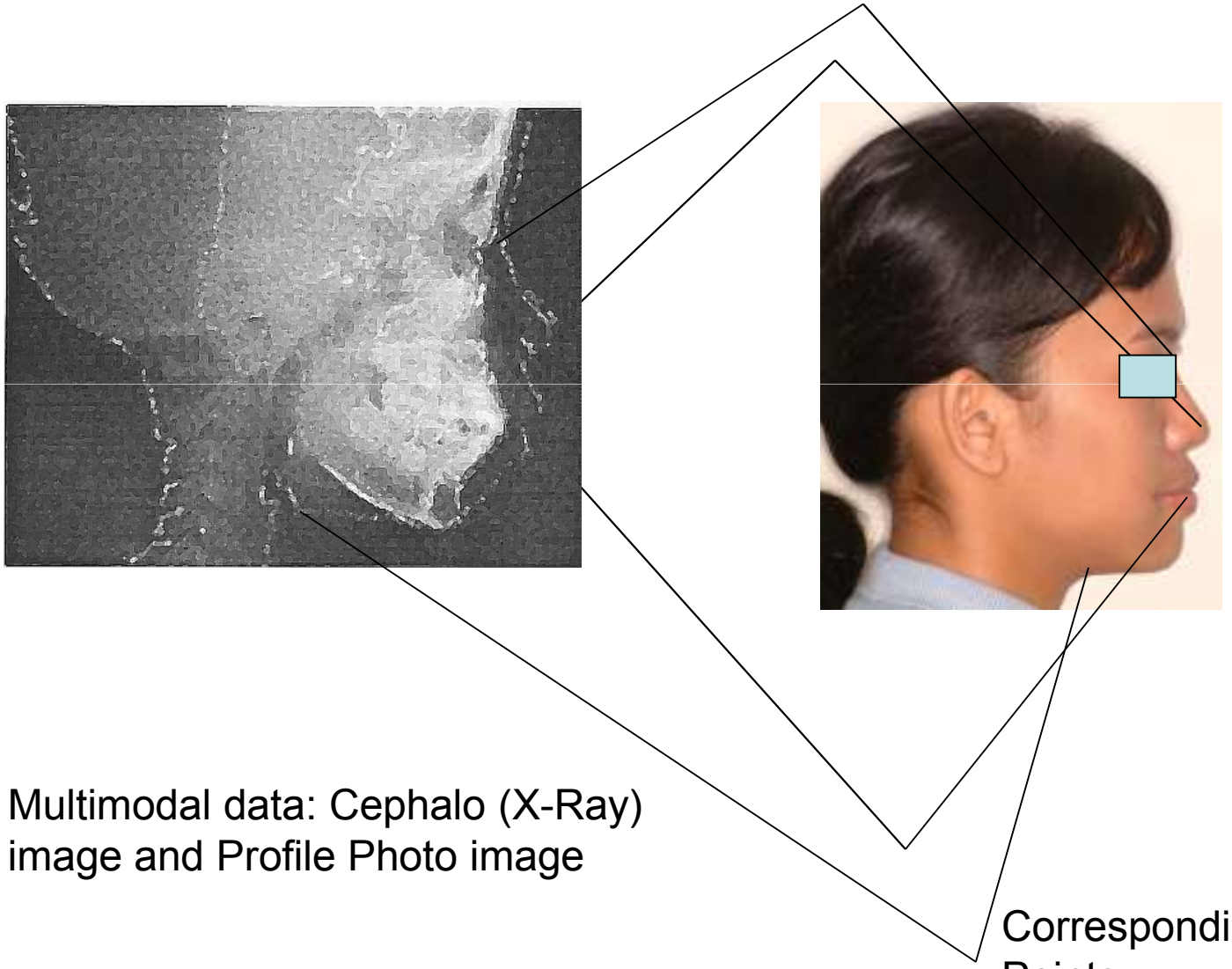
Fourier Transform & Image Enhancement

- *Citra masukan dengan gangguan band stripes:*

- *Citra hasil perbaikan:*

Image Registration

(Source: J. Kusnoto and A. Murni, 2007)



Multimodal data: Cephalo (X-Ray) image and Profile Photo image

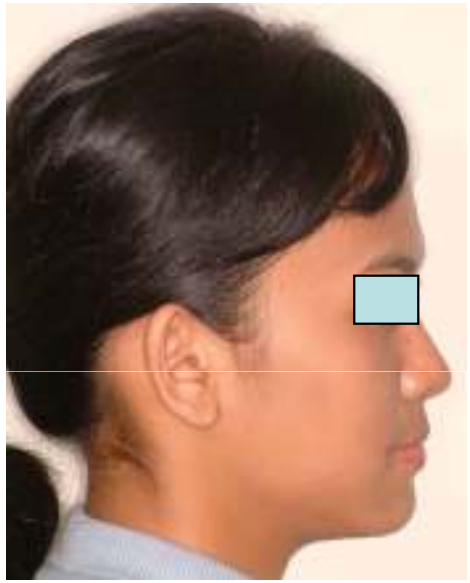
Corresponding Control Points

Geometric Correction: Image Morphing

(Sumber: Joko Kusnoto *et al*., AICBET-2007)

Cephalo Data/Image untuk menentukan nilai orthodontic metric

Indonesian Deuteromalay normative facial profile

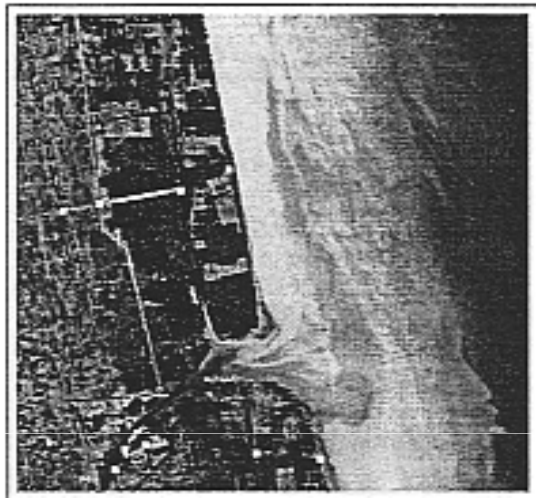


Preferred facial profile

Display simulasi facial profile dengan metrik normative atau preferred, untuk menampilkan simulasi hasil treatment yang akan diperoleh, menggunakan Dolphin Software

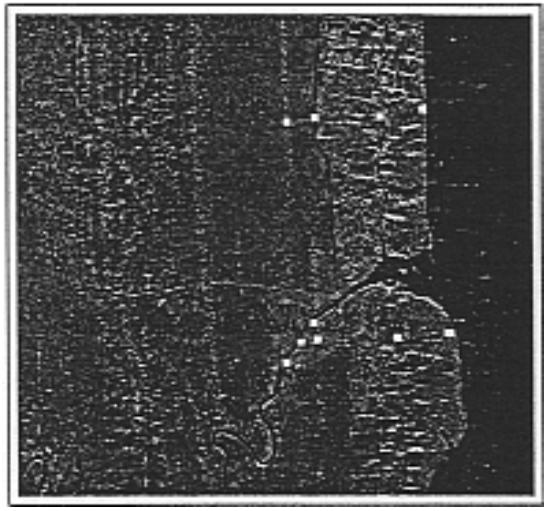
Optical and SAR Image Registration

(Source: A. Murni Arymurthy, 1996)

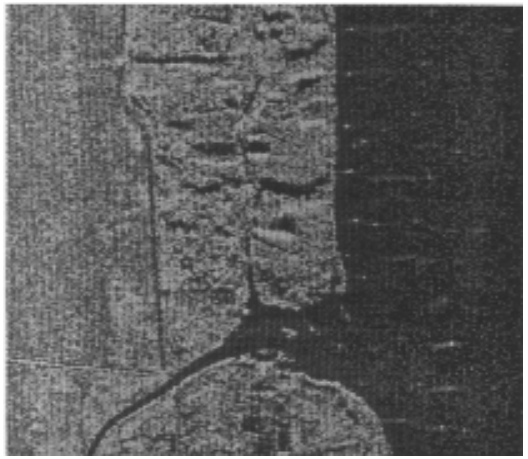


Optical Sensor Image

Registered Optical Sensor Image



SAR Sensor Image



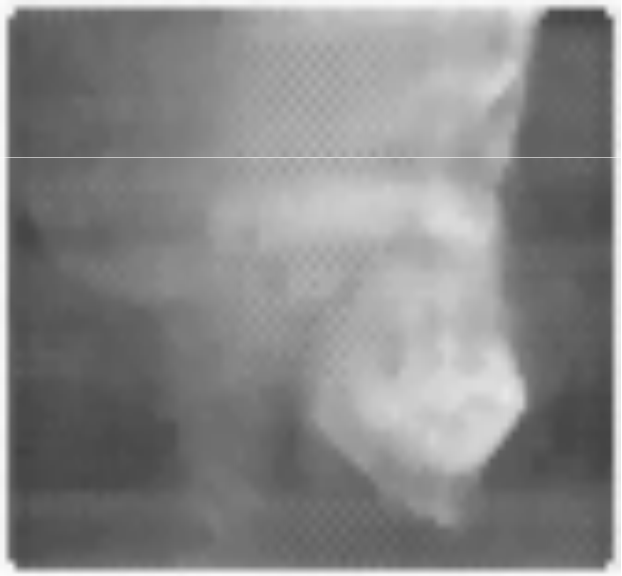
Registered SAR Sensor Image

Topic 3:
Intermediate-Level Image Processing

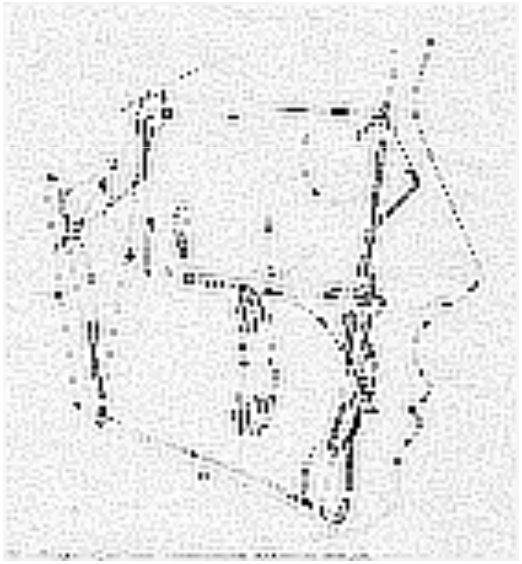
Conventional Method

(Source: Budhiantini Bagyo, D. Hardianto, and A. Murni, 1993)

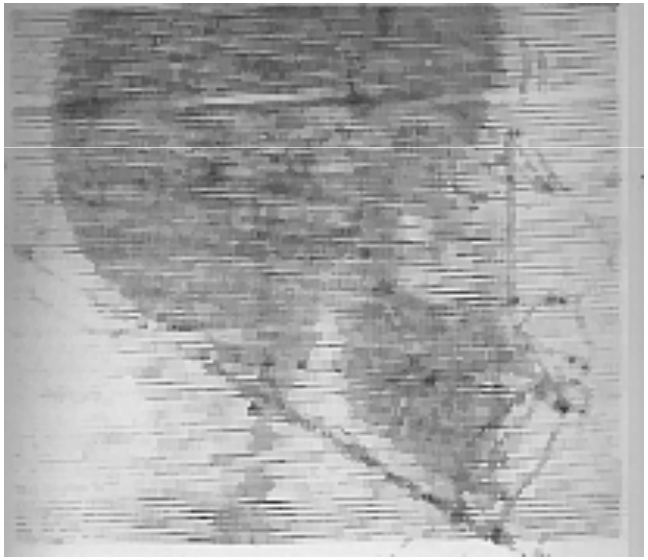
- Manual landmarks tracing is done on cephalo image using light table



(a)
Cephalo Image



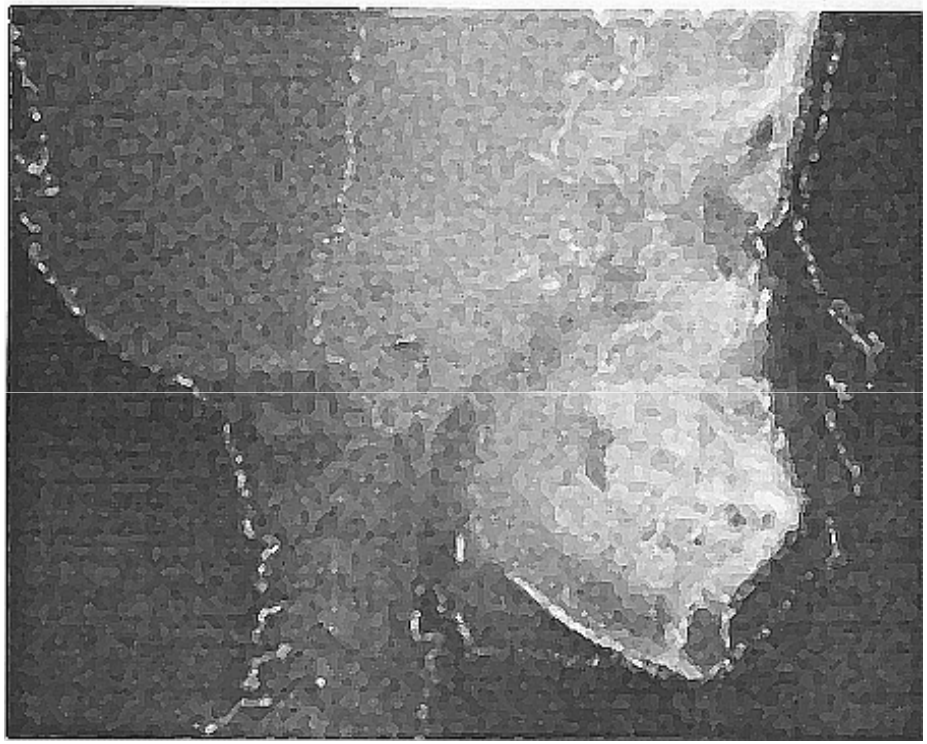
(b)
Landmark Reference



(c)
Manually Landmark
Tracing on Light Table.

Edge Detection

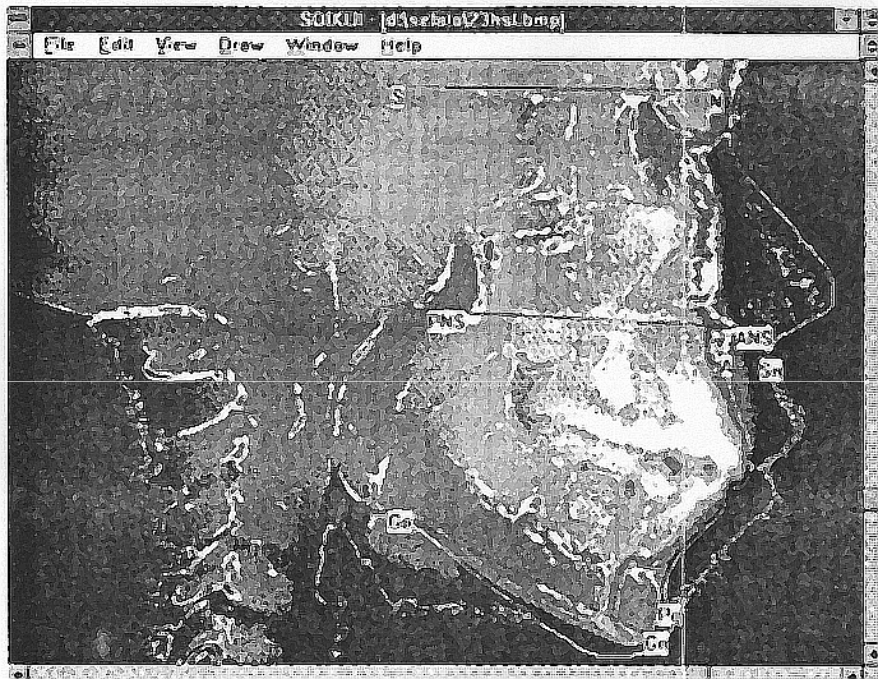
(Source: Budhiantini Bagyo, D. Hardianto, and A. Murni, 1993)

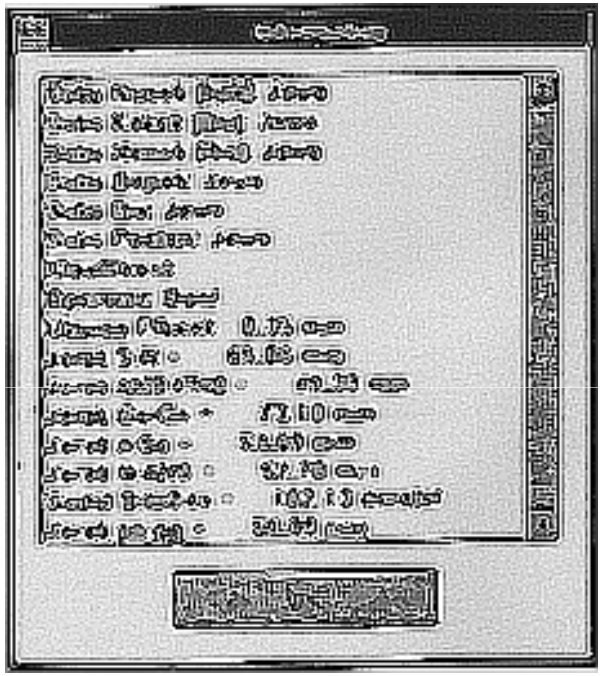


Edge detection is obtained by using Sobel operator.
The result of composing the original cephalo image
with the soft and hard tissue enhanced image.

Manual Tracing on Computer Screen

(Source: Budhiantini Bagyo, D. Hardianto, and A. Murni, 1993)





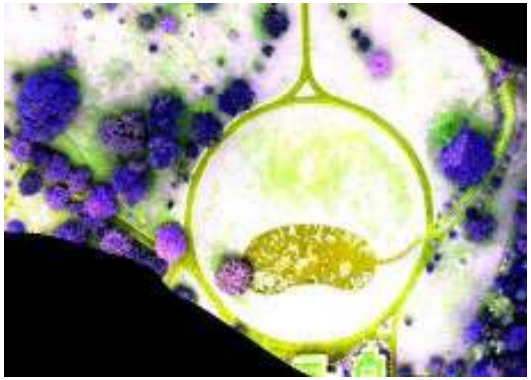
Orthodontic Measures

The doctor can do tracing on the enhanced image easily and ask the system to compute the distance between landmarks and the angle between two lines to get the orthodontic measures that will be used for further patient's treatment

Image Segmentation

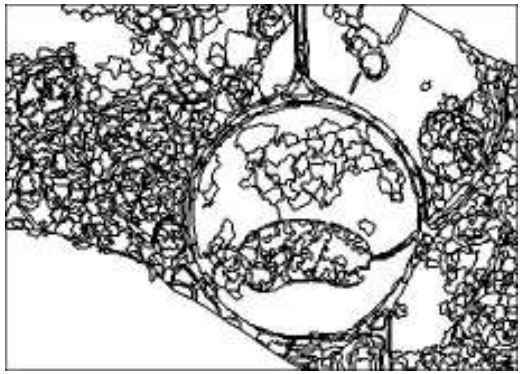
(Sumber: Wiweka, H. and A. Murni)

Segmentasi citra: membagi suatu citra menjadi wilayah-wilayah yang homogen

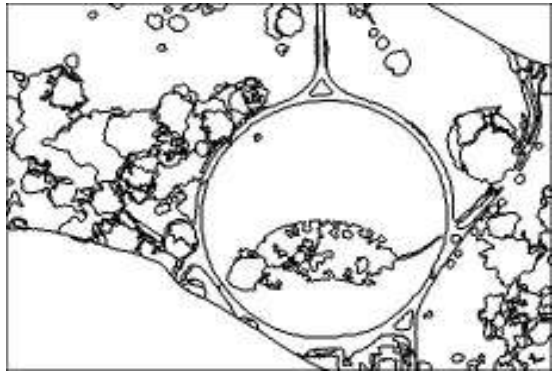


Citra CASI Kebun Raya Bogor

(PT. The Map Indonesia Data)



Jumlah cluster banyak

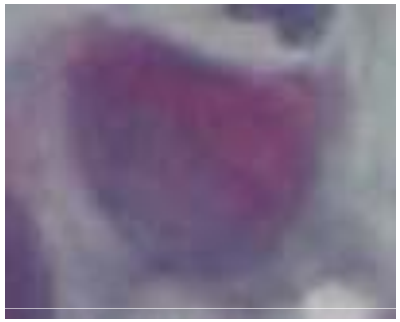


Jumlah cluster sedikit

(Source: Wiweka H. and A. Murni)

Feature Extraction

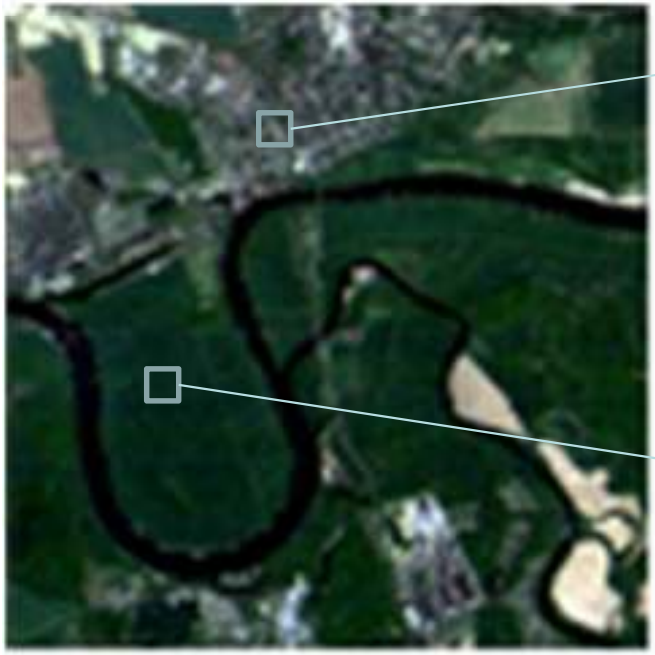
20 shape features extraction (Jantzen *et al.*, 2005):



- *nucleus area, cytoplasm area, ratio between nucleus and cytoplasm area, nucleus brightness, cytoplasm brightness, nucleus shortest diameter, nucleus longest diameter, nucleus elongation, nucleus roundness, cytoplasm shortest diameter, cytoplasm longest diameter, cytoplasm elongation, cytoplasm roundness, nucleus perimeter, cytoplasm perimeter, nucleus position, maxima in nucleus, minima in nucleus, maxima in cytoplasm, and minima in cytoplasm*

Feature Extraction

- Feature extraction based on shape
- Pixel-based feature extraction
- Texture-based feature extraction



Topic 4:
High-Level Image Processing

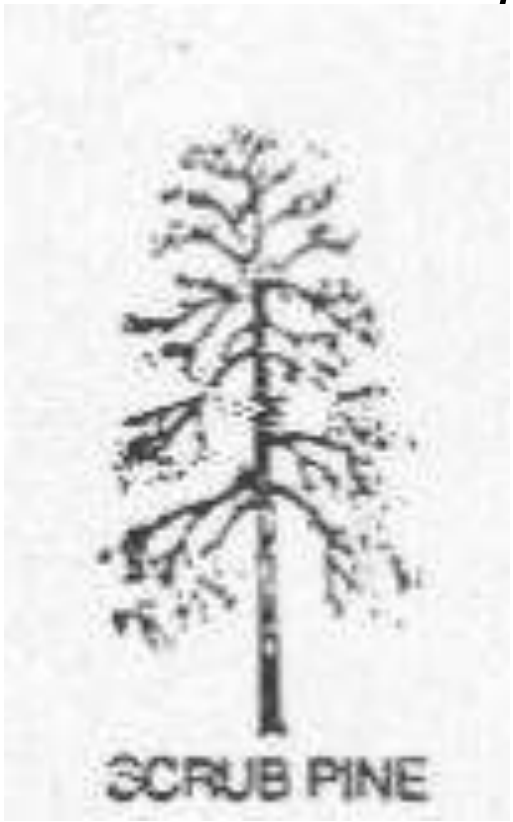
Pattern Recognition – Pengenalan Pola

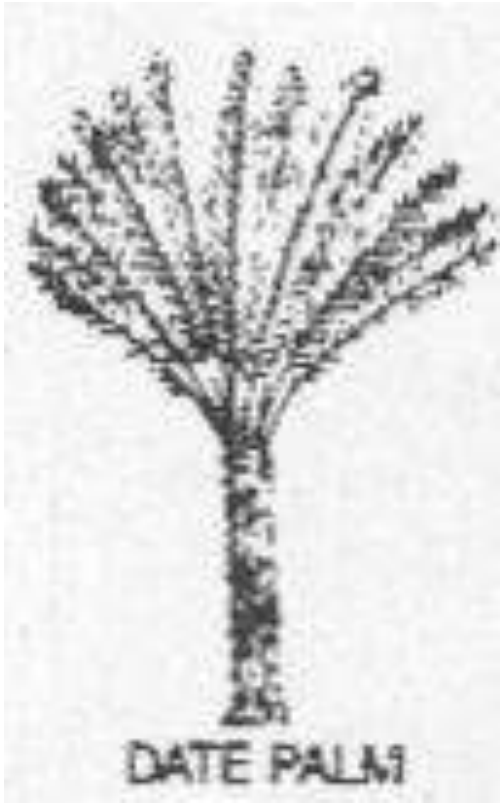
- *Pengertian pola (pattern):*
  - *Pola adalah suatu entitas yang dapat didefinisikan (mungkin secara samar) dan dapat diberi suatu identifikasi atau nama. Contoh: gelombang suara / sidik jari / raut wajah (milik si A, B, C), penutup lahan (hutan, air). dll.*
- *Pengertian object descriptors / features / ciri:*
  - *Suatu ukuran yang bersifat kwantitatif yang merupakan deskriptor suatu obyek tertentu pada citra*
  - *Merupakan kumpulan deskriptor (features / ciri) suatu obyek pada citra*
- *Pengertian kelas pola (kategori obyek):*
  - *Sekumpulan pola yang mempunyai sifat / properties / ciri yang sama*
  - *Contoh: pola-pola pada kelas hutan, pola-pola pada kelas air dst.nya*

Pattern Recognition System

(Sumber: Scientific American Journal, 1997)

- *Bagaimana membedakan tiang telepon dari pohon? Mereka mempunyai ciri sama: ada batang dan ranting!*





Operasi Sistem Pengenalan Pola

- ***Tahap Latihan**: terdiri dari rancangan ekstraksi ciri, rancangan aturan keputusan, evaluasi hasil pengenalan pola, dan pembentukan data pengetahuan – membangun model*
- ***Tahap Pengenalan**: terdiri dari penentuan pola yang akan diamati, pengukuran ciri, proses pengenalan kategori pola dengan memberlakukan aturan keputusan serta penggunaan data pengetahuan – menggunakan model*
- ***Tahap Evaluasi**: apakah hasil pengenalan (dengan real – world pattern) sudah optimal, ataukah masih perlu untuk diperbaiki dengan mencari ciri yang lebih efektif dan aturan keputusan yang lebih akurat – menguji model*

Beberapa pendekatan interpretasi citra

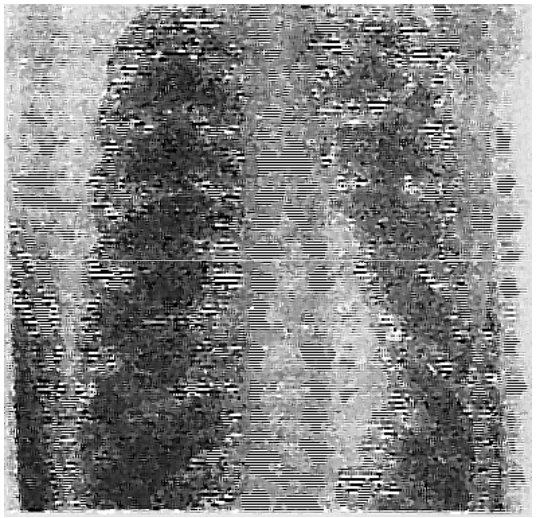
- ***Clustering* (*unsupervised classification*):**
  - *Memasukkan suatu pola obyek yang diamati ke suatu kelas pola yang belum diketahui dan disebut sebagai kluster pola*
- ***Classification* (*supervised classification*)**
  - *Melakukan identifikasi suatu pola obyek yang diamati sebagai anggota dari suatu kelas pola yang sudah diketahui*
- ***Object Recognition* (*knowledge based system*)**
  - *Mencocokkan atau membandingkan pola obyek yang dikandung dalam suatu citra dengan template / deskriptor obyek yang telah diketahui (rule-based object recognition)*
- ***Perkembangan Lanjut***
  - *Berbagai bentuk fusion untuk memperbaiki hasil (fusi feature, fusi classifier, ensemble classifier, dll)*
  - *Deep learning (feature extraction yang dilakukan secara otomatis)*

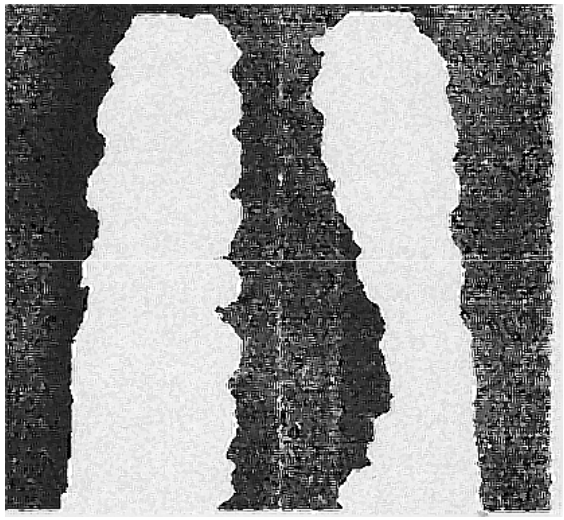
Clustering
(Unsupervised Classification)

- *Pengertian pendekatan unsupervised (tanpa pengarahan): tidak ada bantuan dari expert (tanpa pelatihan)*
- *Informasi yang tersedia: jumlah kluster, informasi ini digunakan untuk mendapatkan hasil clustering yang cocok*
- *Pengelompokan dilakukan sepenuhnya berdasarkan karakteristik data*
- *Sering juga dimasukkan ke taksonomi segmentation*

Image Clustering

Cluster yang dihasilkan masih belum mempunyai label kategori objek





- K-Means Clustering
- AND operation to obtain soft tissue of the lungs

(Source: Kartono dan A. Murni)

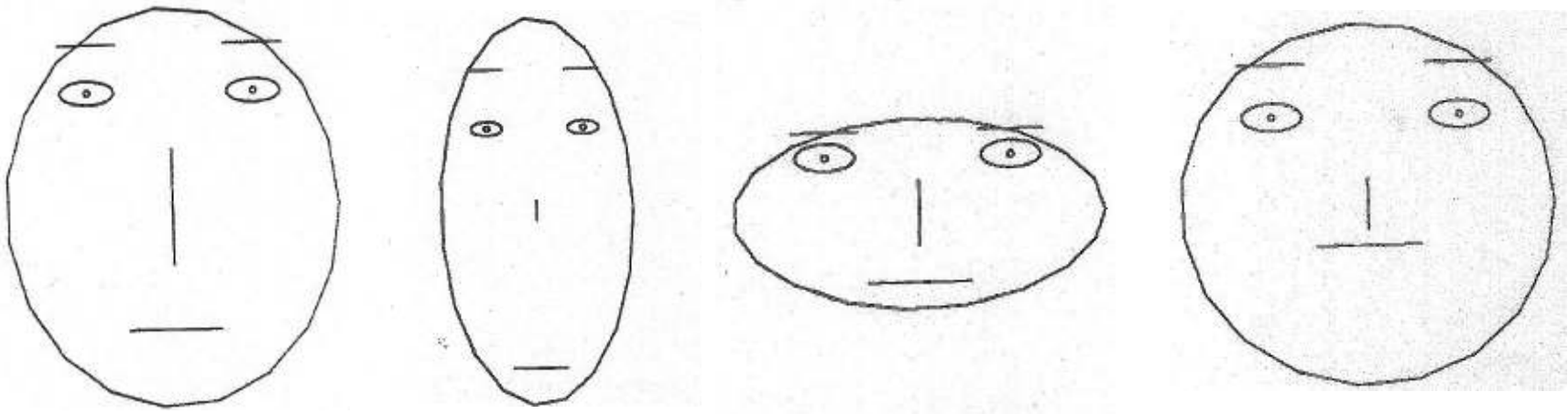
Input image TUD Reference
(Jantzen *et al.,* 2005)

Clustered image (T. Farida, 2007)
FCM Clustering

Clustering secara grafis – Chernoff's Faces

(Sumber: A. Murni, MSU, 1989)

- *Penggambaran kluster dengan representasi Chernoff's faces of wood, cloud, sand, and snake skin based on average texture measures*



Wood Cloud Sand Snake Skin

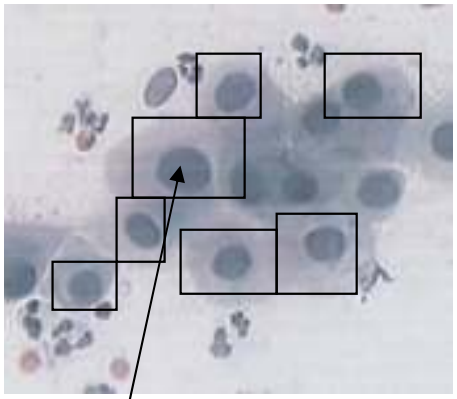
Classification

(Pendekatan Supervised)

- *Pengertian pendekatan supervised (**dengan pengarahan**): ada pakar yang mengarahkan atau memberi informasi dan pengetahuan tentang kategori obyek-obyek yang ada*
- ***Bantuan pakar dimanifestasikan dalam bentuk pemilihan sampel untuk pelatihan (training sample set)***
- *Training sample set terdiri dari contoh-contoh pola dengan kategori / kelas obyeknya yang akan digunakan untuk melatih sistem*
- *Dari training sample set dapat **diestimasi ukuran-ukuran karakteristik / ciri obyek** yang akan membantu proses pengenalan obyek*

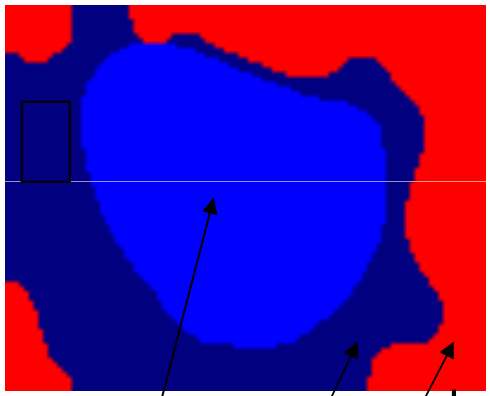
Diagnosing a Pap Smear Cell Image Based on Image Segmentation and Classification Methods

(J. Indarti, FKUI)



Single pap smear cell image

(T. Farida, Fasilkom UI)

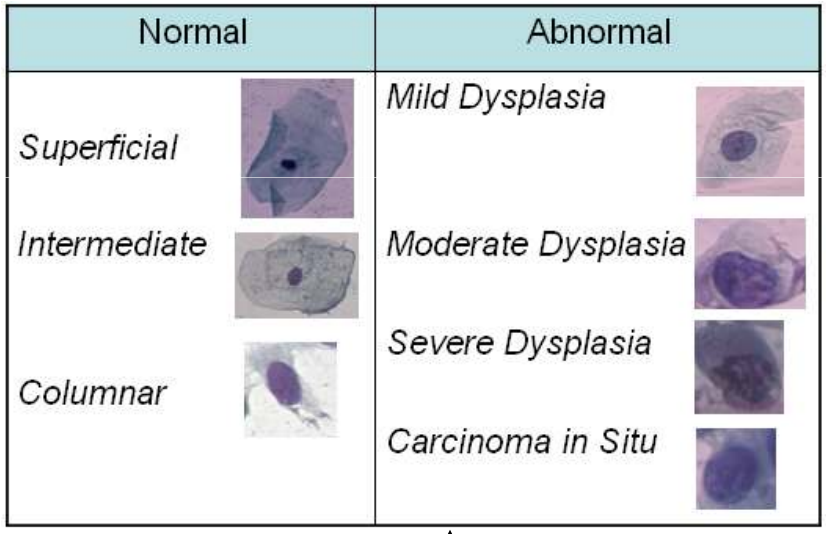


Nucleus

Cytoplasm

Background.

(Jantzen *et al.*, TUD)



Seven condition categories

20 Features → Classification Method

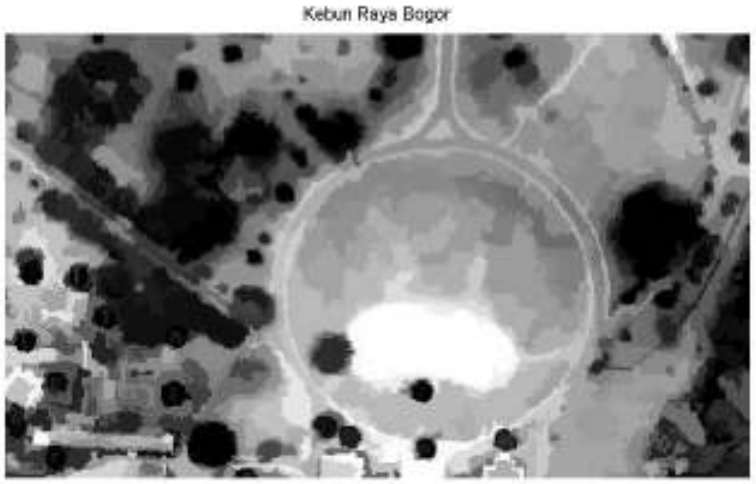
Recognition Rates

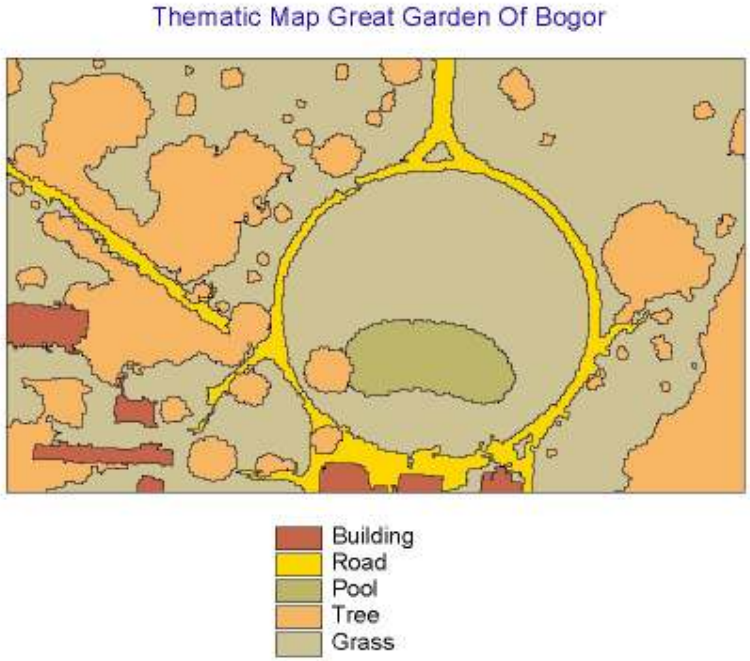
Performance Measures	Minimum Distance	Back Propagation Neural Network Gradient Descent	Least Square	Nearest Class Gravity Center	Back Propagation Neural Network Scaled Conjugate Gradient	SVM ERBF
Overall Error	32.28%	17.82%	28.03%	20.91%	15.42%	11.34%
False Negative	24.96%	17.83%	32.13%	19.62%	7.98%	6.37%
False Positive	42.24%	16.57%	9.32%	22.59%	12.33%	8.79%

Metode segmentasi: *Fuzzy C-Means Clustering; dan Metode klasifikasi: Support Vector Machine* memberikan *recognition rate* terbaik dengan *overall error* 11.34%; dengan *Back Propagation Neural Network* menghasilkan *overall error* 15.42%.

Rule-Based Object Recognition

(Sumber gambar asli: PT. Map Indonesia
Sumber gambar hasil: Wiweka H. and A. Murni)





Original Image

Thematic Image

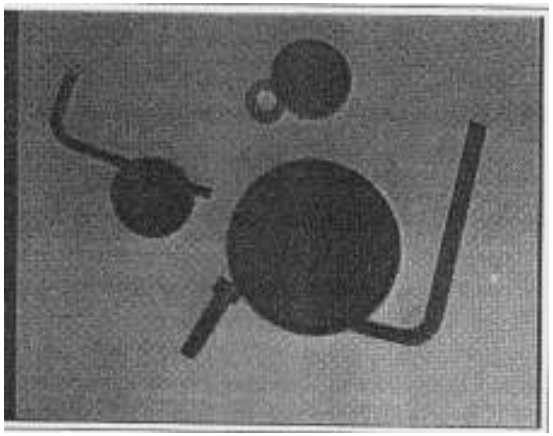
Kita dapat mengamati feature vector library untuk setiap objek, menggunakan nilai rata-rata, atau minimum dan maksimum, sehingga kemudian dapat disusun suatu rule-based decision untuk klasifikasi.

Shape-Based Object Recognition

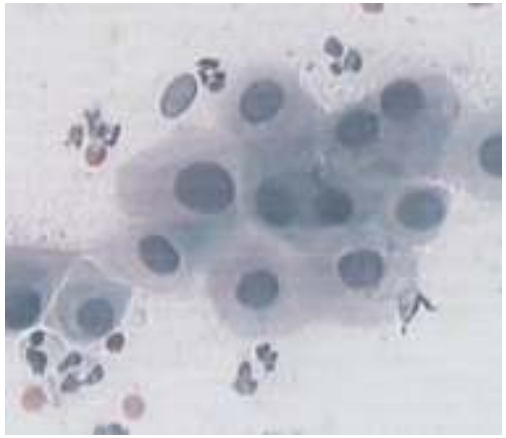
- *Dapat dilakukan antara lain dengan pendekatan:*
  - *Berdasarkan ciri bentuk region obyek, contoh bentuk circular dengan metode Hough transform*

Object Recognition
(Shape Matching)

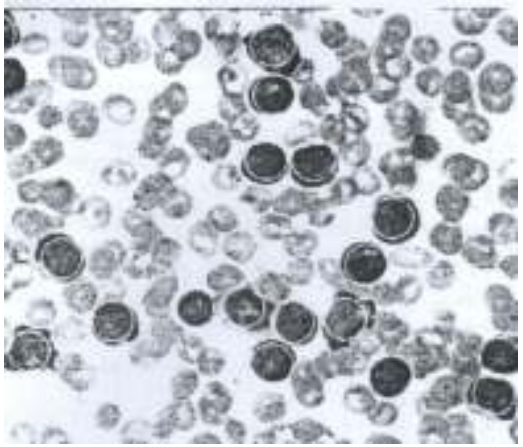
Problem: Identify circular objects in the input image
(aplikasi biomedis: pengenalan jaringan kanker atau sel darah)



(MSU, 1990)



(dr. Yuanita, FKUI)

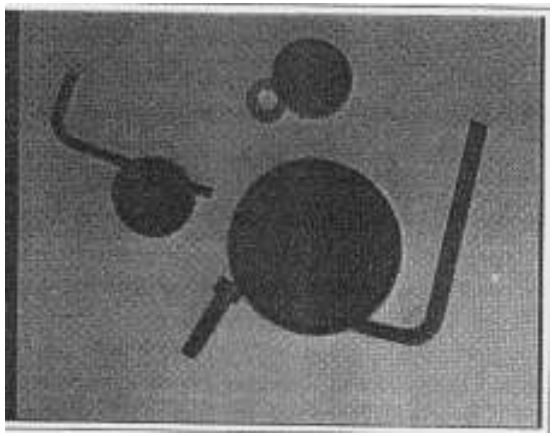


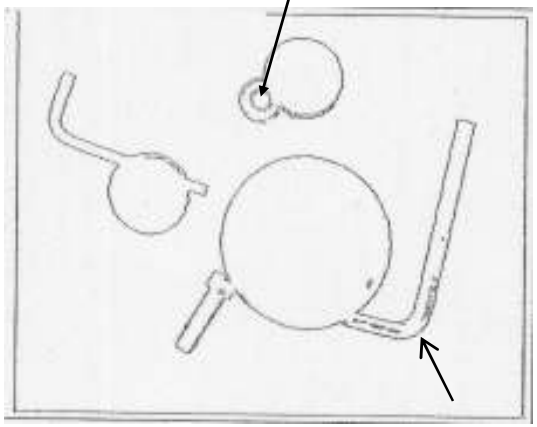
(Karkavitsas and Rangoussi, 2004)

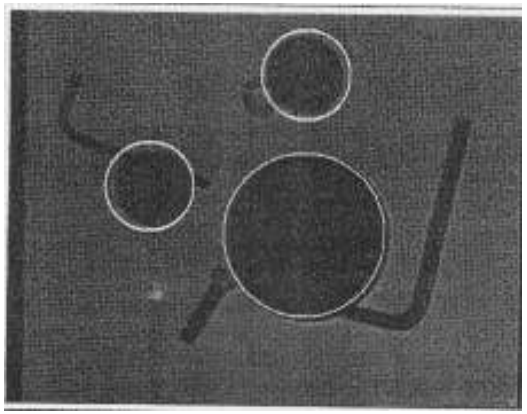
Object Recognition – Shape Matching

(Sumber gambar asli: MSU, 1990
Sumber gambar hasil: Aniati Murni, 1990)

- *Hasil pada citra studi kasus:*
  - *Ada satu obyek lingkaran kecil yang tidak berhasil terdeteksi. Hal ini disebabkan karena jumlah voting masih dibawah nilai ambang yang diambil. Kalau nilai ambang diperlunak, kemungkinan lingkaran kecil tersebut terdeteksi tapi lingkaran palsu lainnya juga akan muncul sebagai obyek.*



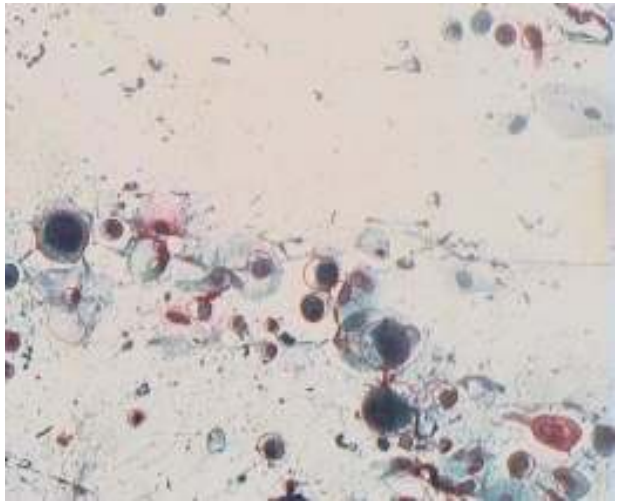




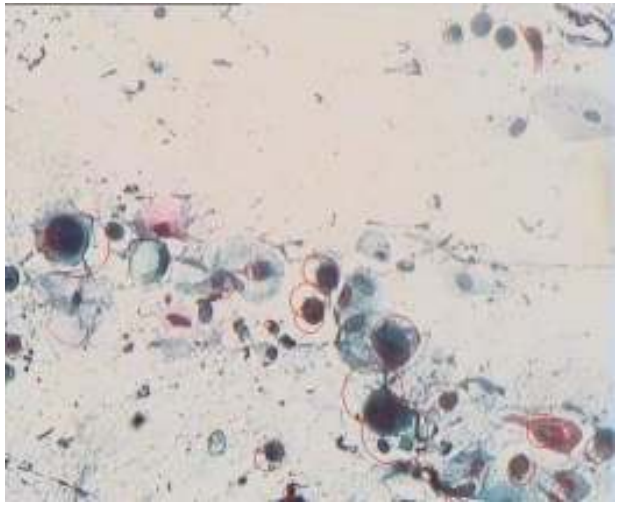
Hasil ekstraksi citra sel Pap Smear tunggal

(Sumber: A. Kosasih dan A. Murni, 2010)

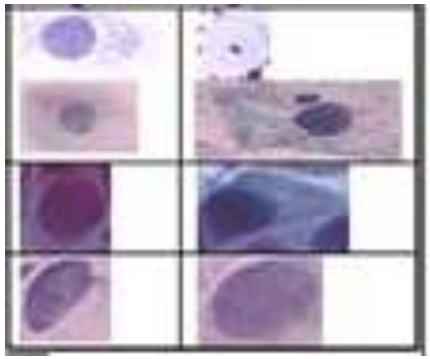
- Hasil Metode Hough Transform



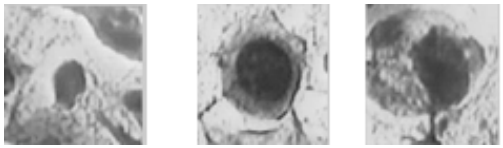
- Hasil Metode Genetic Algorithm



- Citra sel Pap smear tunggal



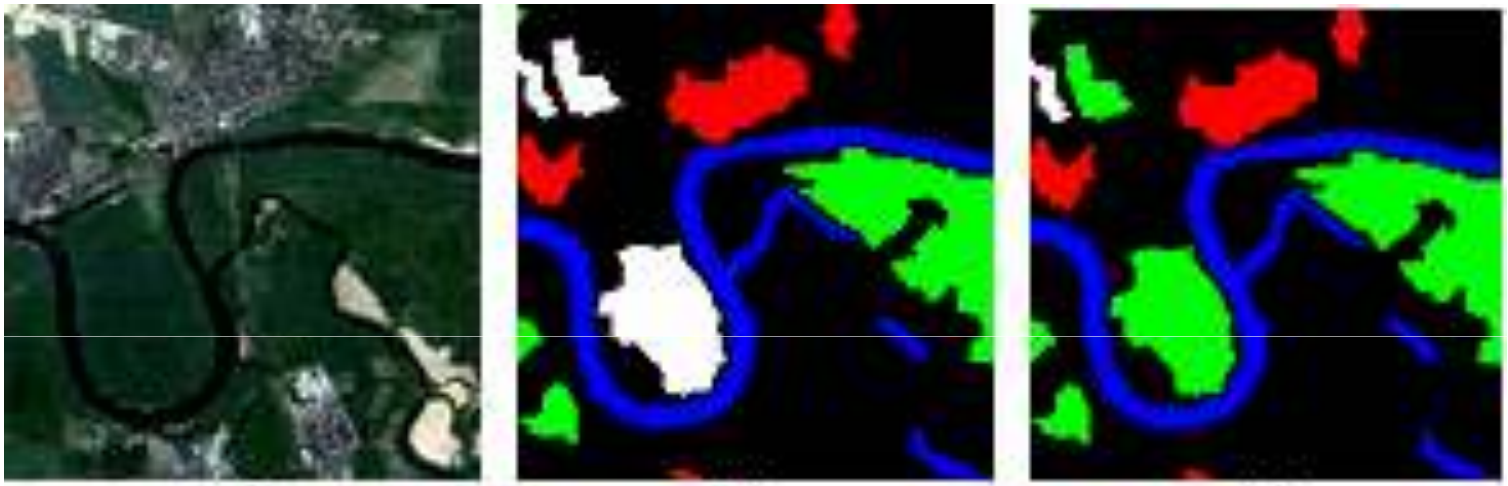
(Jantzen *et al.*, 2005)



(A. Kosasih *& A. Murni*, 2010)

Data and Information Fusion

(Sonny Widjaja and A. Murni, 2007)



(a) (b) (c)

Figure 2: The multispectral and ground truth images;

(a) original color image; (b) ground truth image;

(c) the corrected ground truth image.

(Source of images: eCognition User Guide 2005)

Feature & Classifier yang Digunakan

- Pixel-based feature selection
  - RGB features
  - Gabor Filter features
  - GLCM features
- Classifier
  - Gaussian Maximum Likelihhod

Best Classification Results

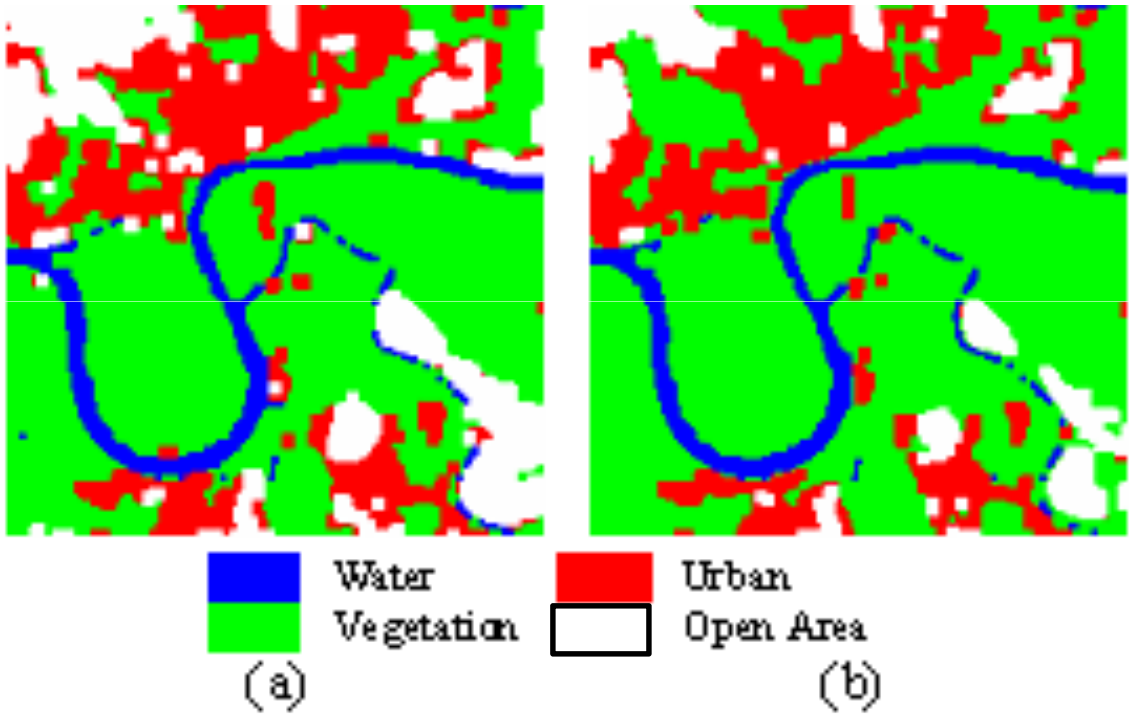


Fig. 3. Classified Images: (a) Data Fusion using RGB and GLCM features (b) Information Fusion using RGB, GF and GLCM features.

Data and Information Fusion Classification Accuracy

No.	Data Fusion	Overall Accuracy (%)			
		Product	Sum	Max	Majority
1	GF and GLCM	53.07	60.63	55.36	64.41
2	RGB and GF	55.54	77.94	62.04	82.16
3	**RGB and GLCM**	64.06	**86.12**	76.80	80.67
4	RGB, GF and GLCM	62.74	75.57	63.18	68.45
	Average	58.85	75.06	64.35	73.92
	Information Fusion	**Overall Accuracy (%)**			
	RGB, GF, and GLCM	**85.85**			

The End of Presentation