

Pengantar Pemrosesan Citra

(Bagian 2 – Update 2024)

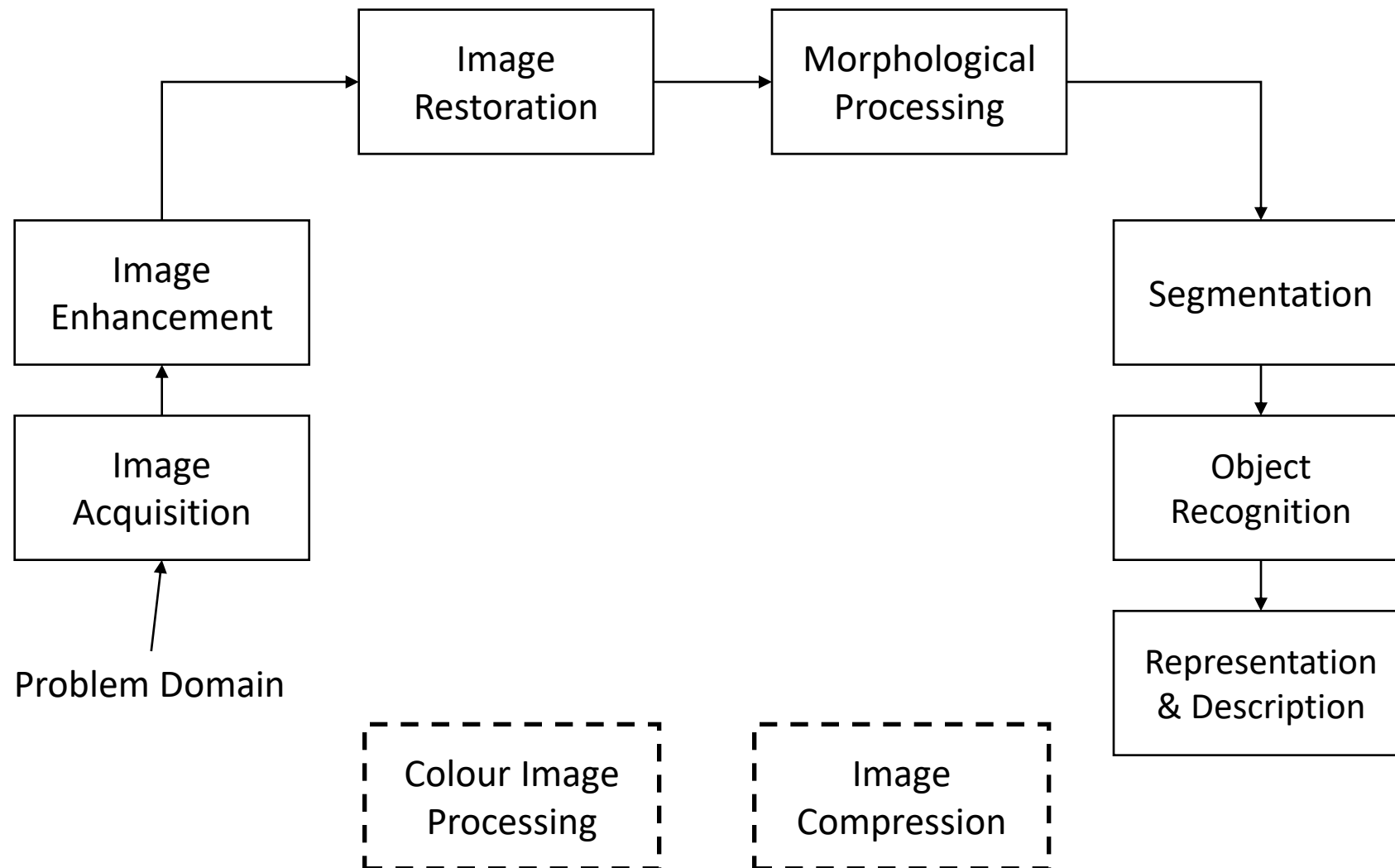
IF4073 Pemrosesan Citra Digital

Oleh: Rinaldi Munir



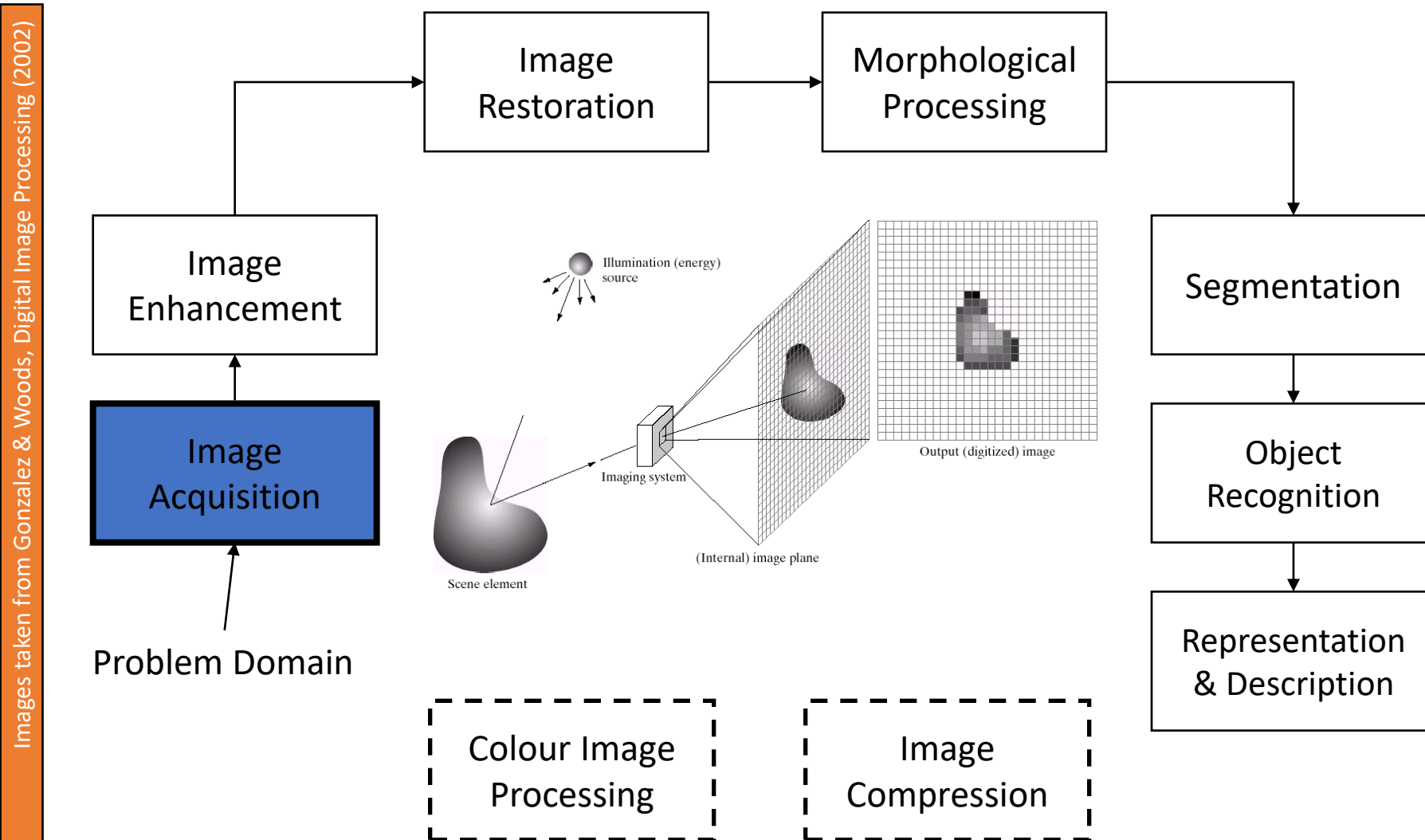
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung
2024

Key Stages in Digital Image Processing



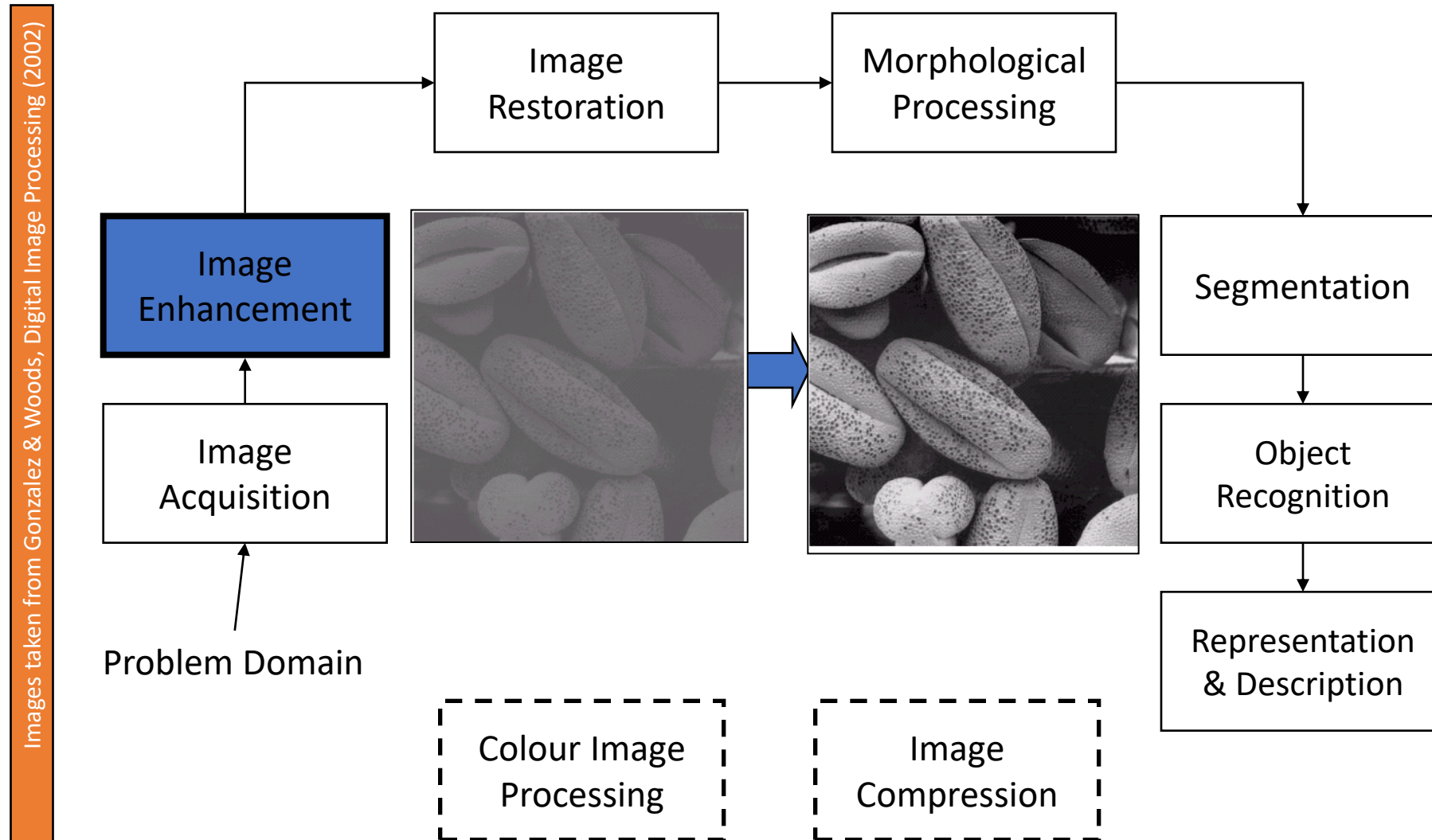
Key Stages in Digital Image Processing: Image Acquisition

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



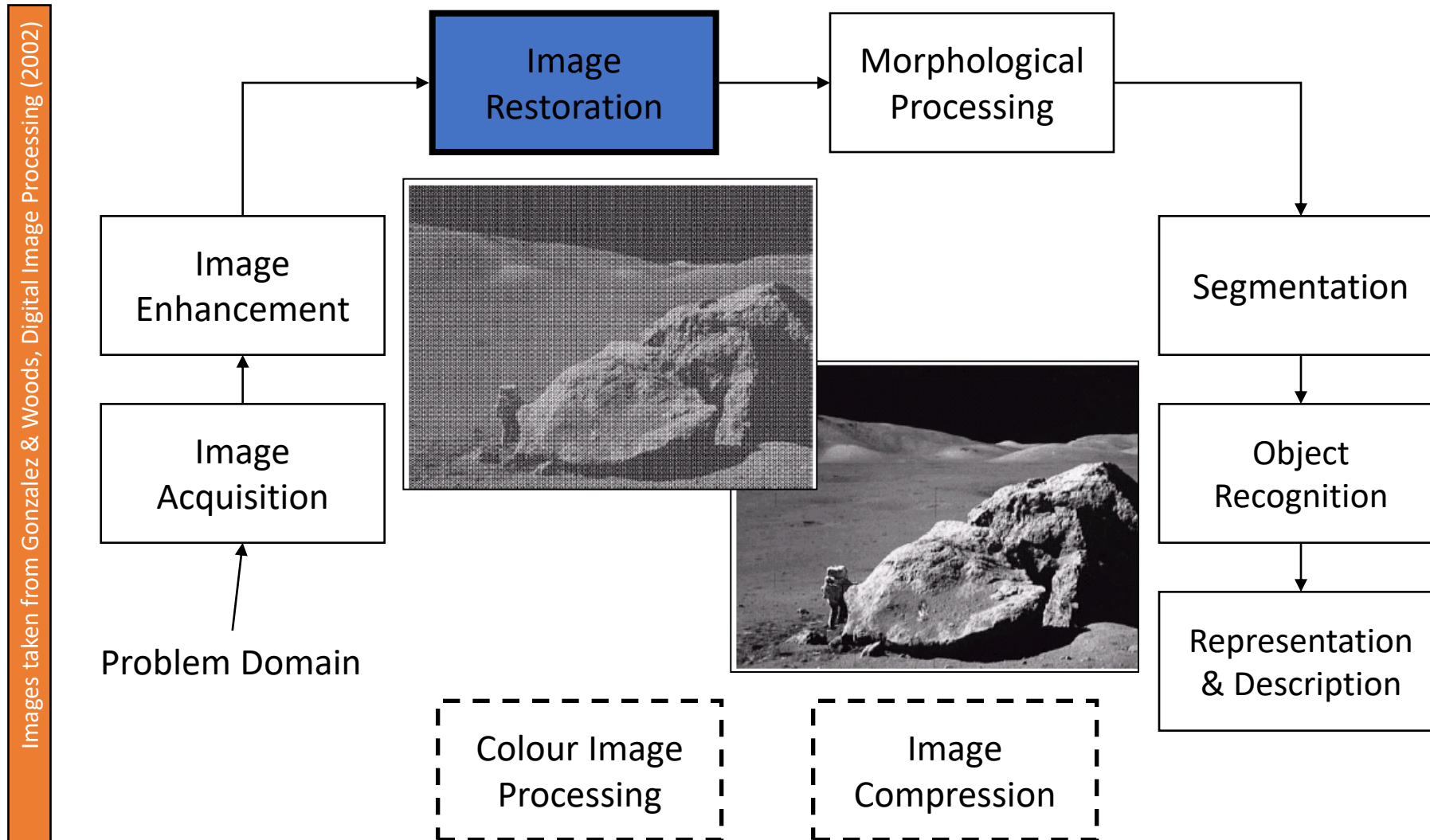
Key Stages in Digital Image Processing: Image Enhancement

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



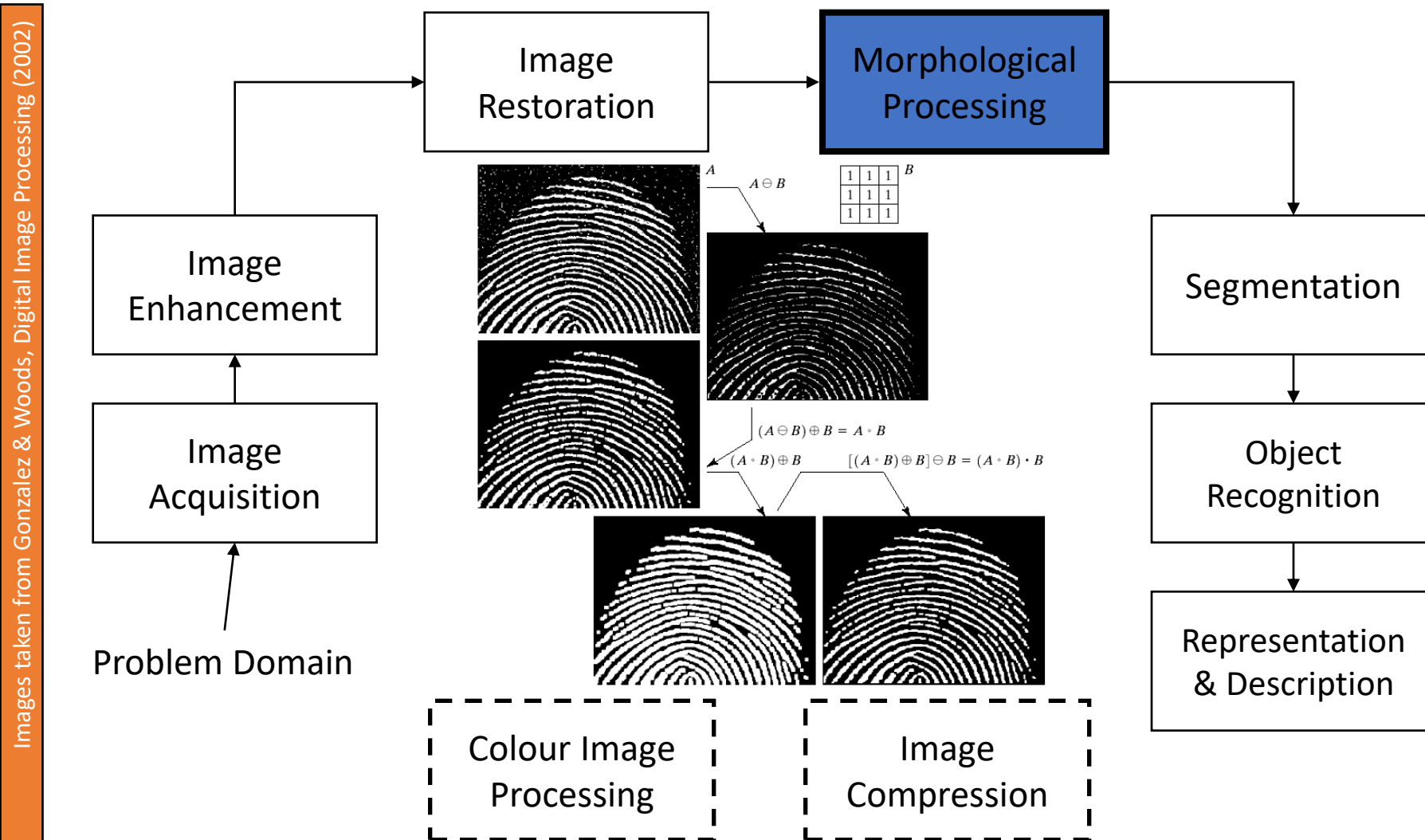
Key Stages in Digital Image Processing: Image Restoration

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



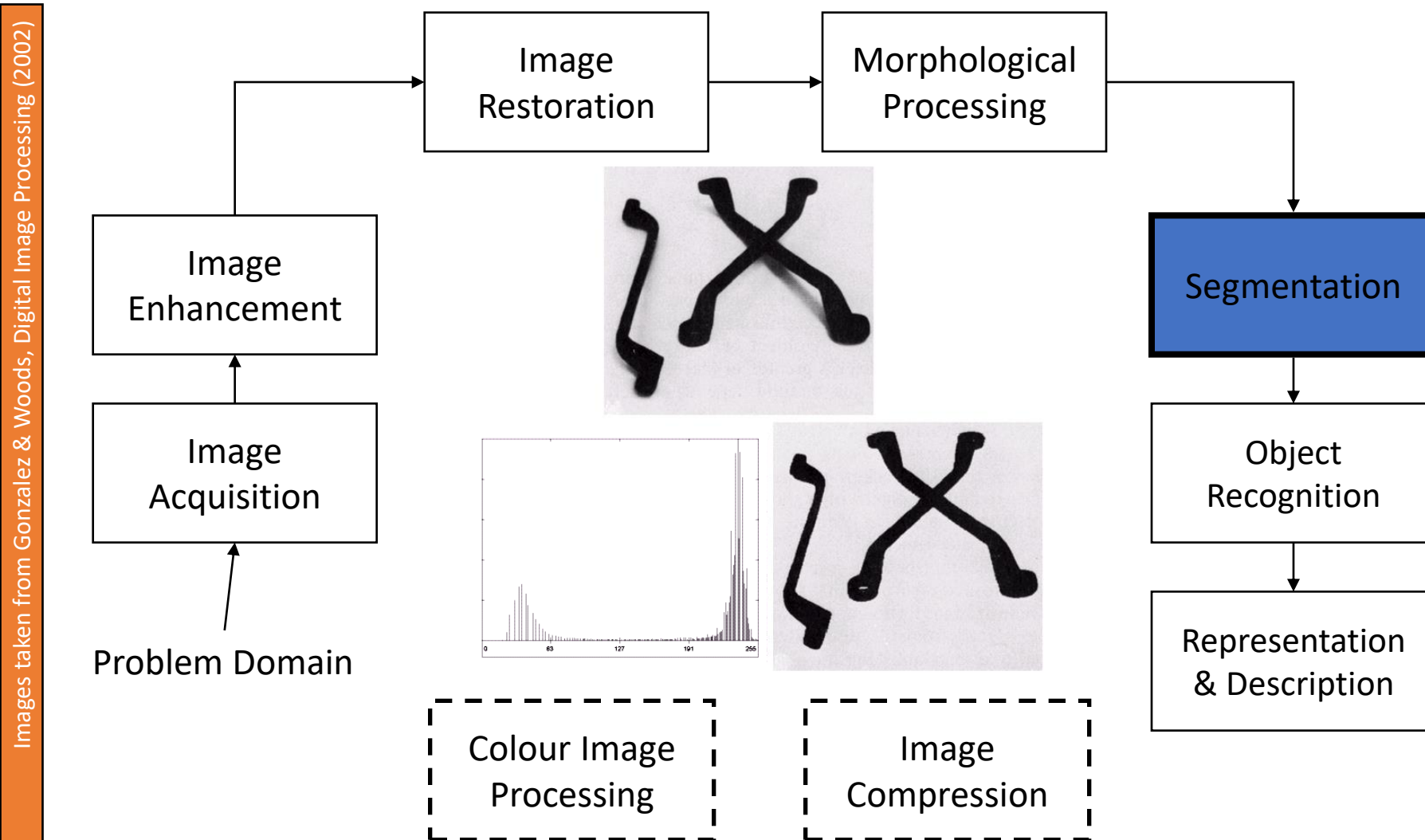
Key Stages in Digital Image Processing: Morphological Processing

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



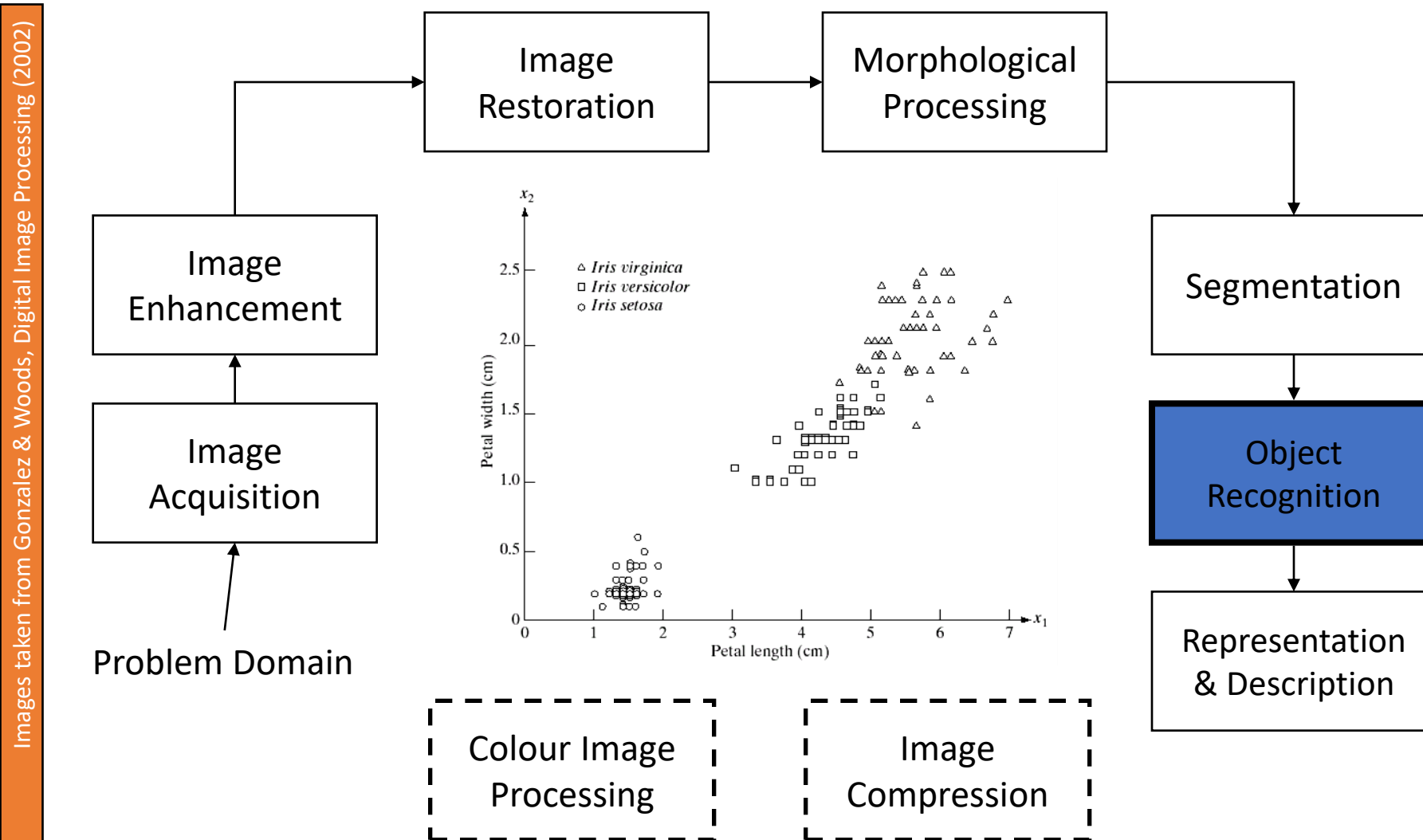
Key Stages in Digital Image Processing: Segmentation

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



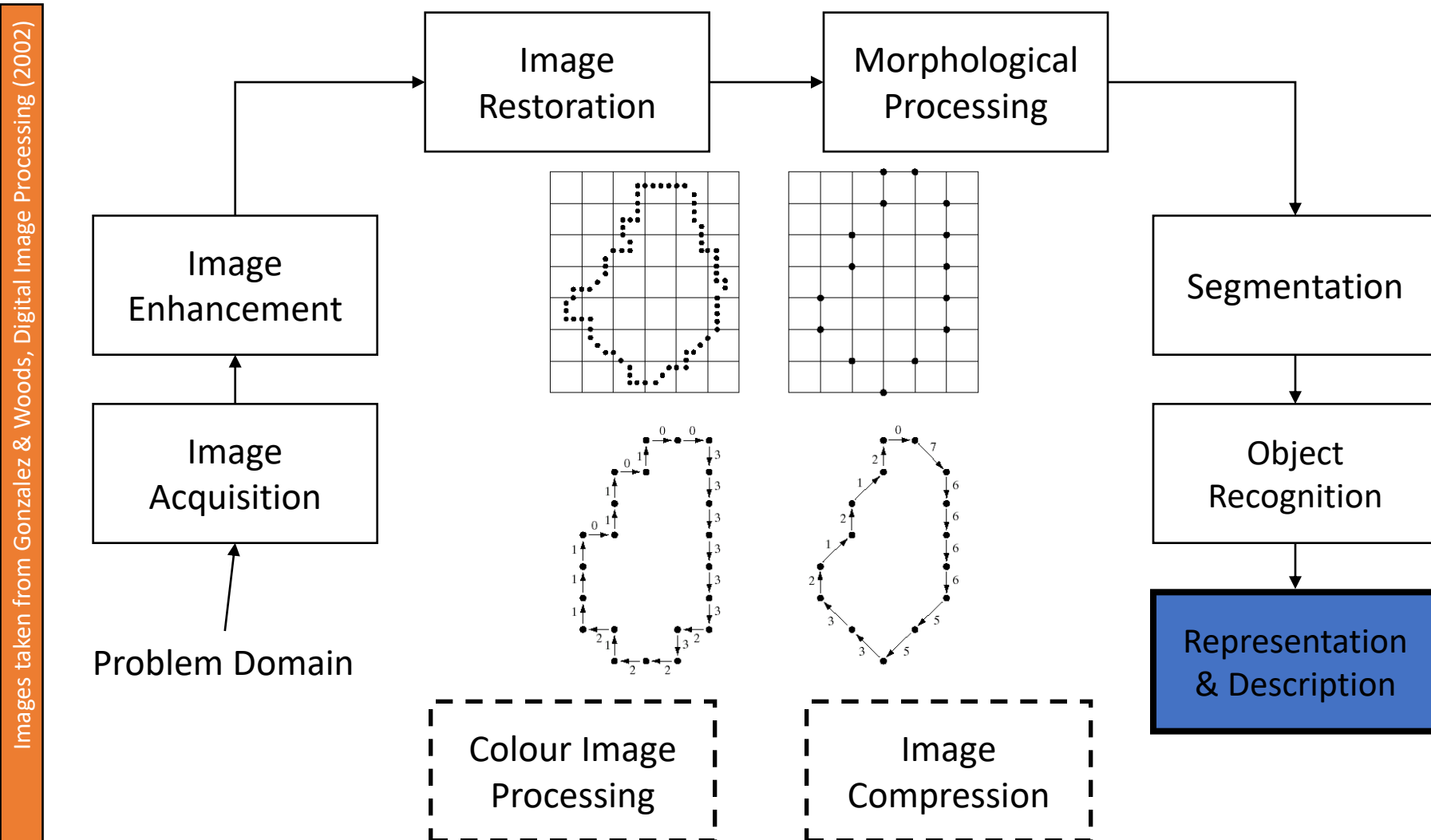
Key Stages in Digital Image Processing: Object Recognition

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



Key Stages in Digital Image Processing: Representation & Description

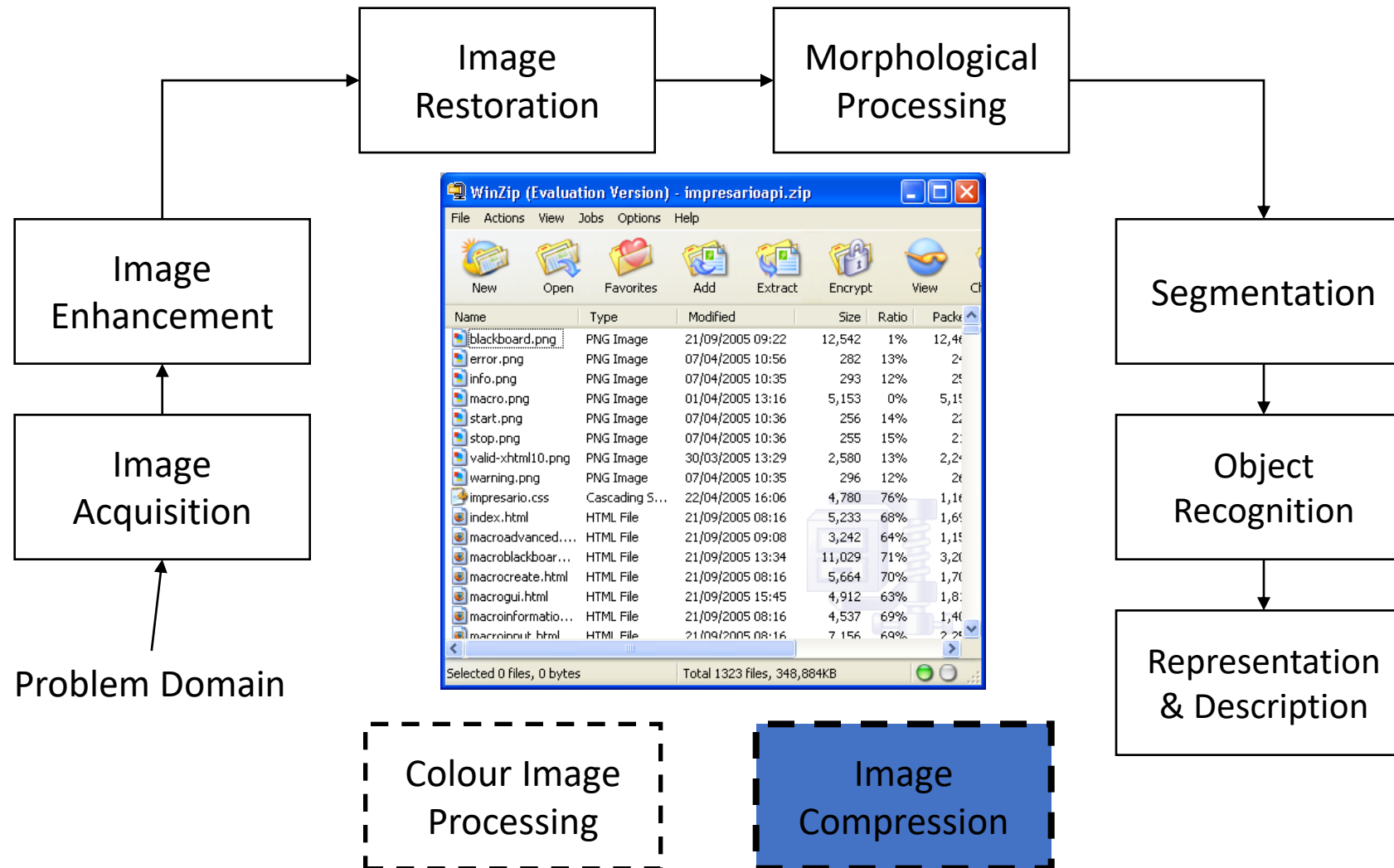
Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



Images taken from Gonzalez & Woods, *Digital Image Processing* (2002)

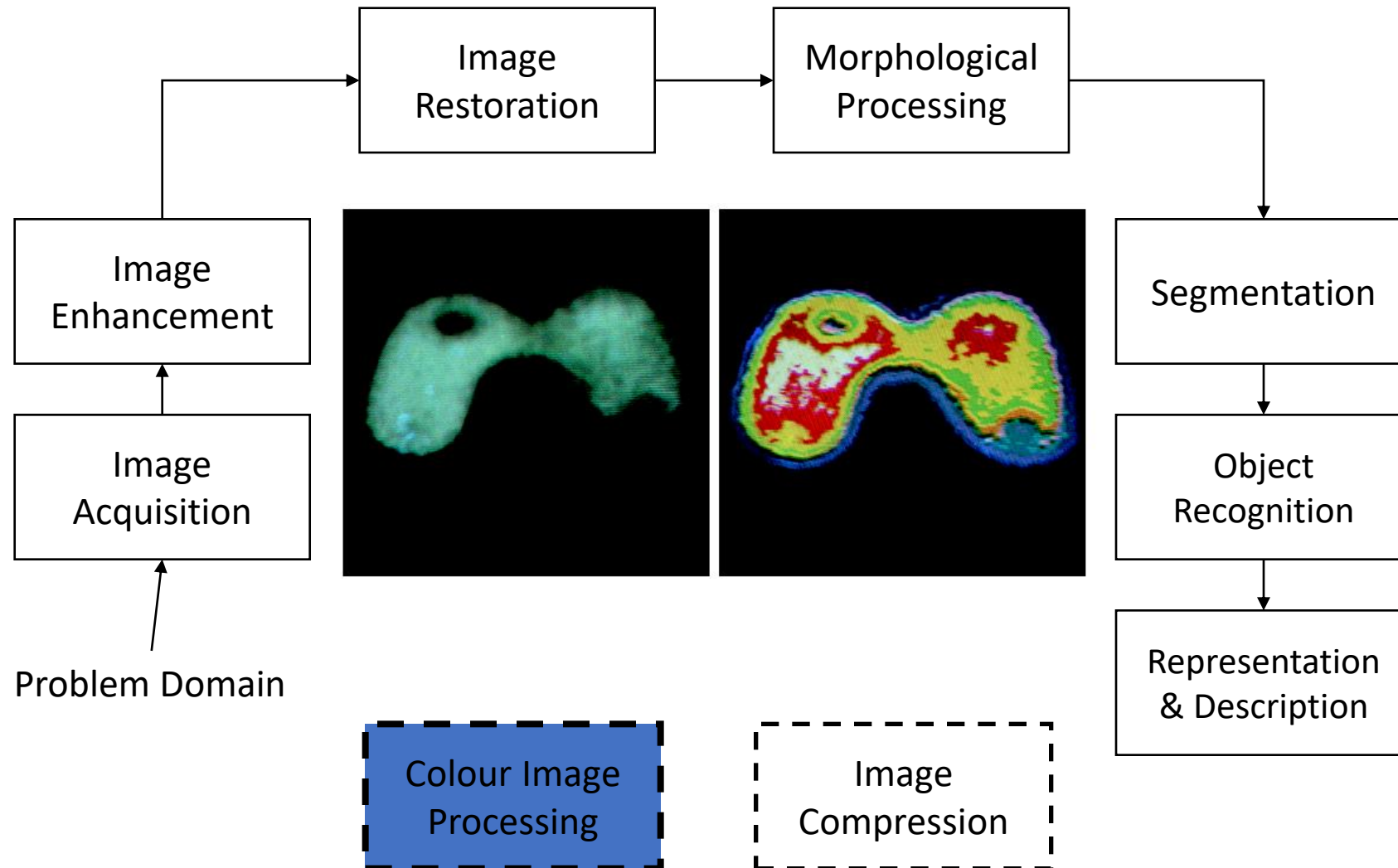
Key Stages in Digital Image Processing: Image Compression

Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



Key Stages in Digital Image Processing: Colour Image Processing

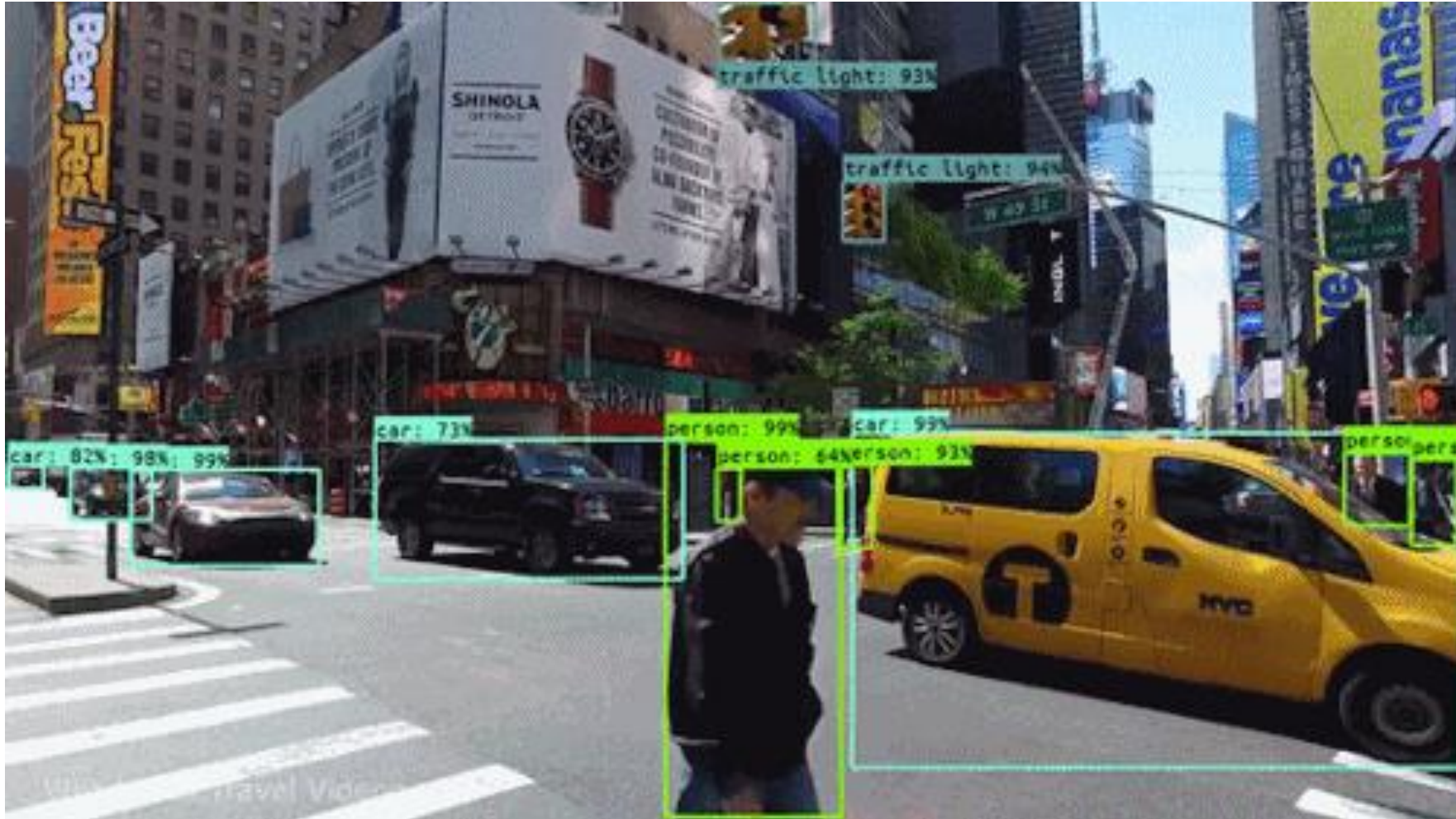
Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010



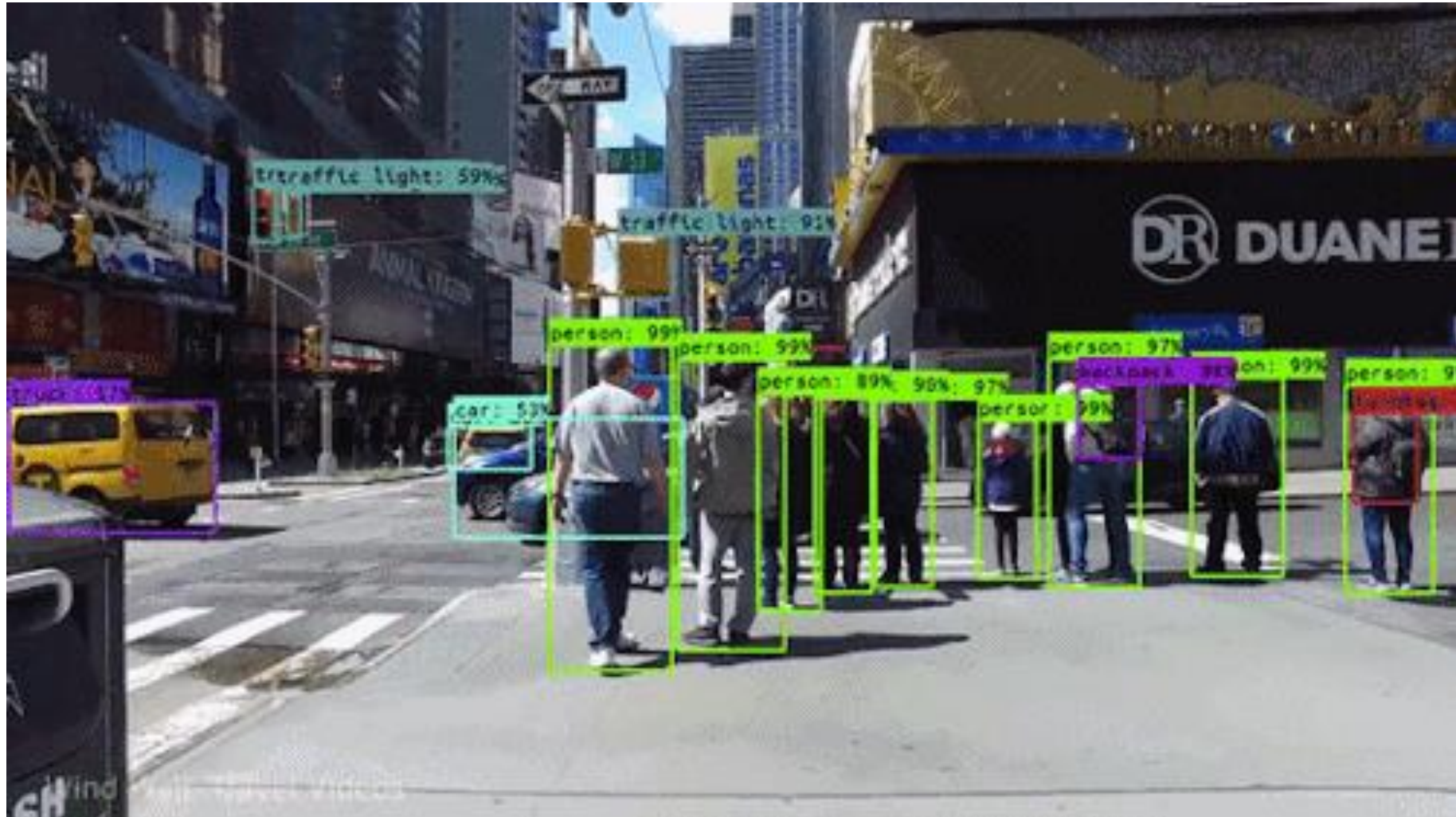
Computer Vision

- *Computer vision* merupakan proses otomatis yang mengintegrasikan sejumlah besar proses untuk persepsi visual, mulai dari akuisisi citra, pemrosesan citra, klasifikasi, pengenalan (*recognition*), dan membuat keputusan.
- *Computer vision* terdiri dari teknik-teknik untuk mengestimasi ciri-ciri objek di dalam citra, pengukuran ciri yang berkaitan dengan geometri objek, dan menginterpretasi informasi geometri tersebut.
- *Vision = Geometry + Measurement + Interpretation*

Computer Vision



Sumber: <https://towardsdatascience.com/what-even-is-computer-vision-531e4f07d7d0>



Sumber: <https://towardsdatascience.com/everything-you-ever-wanted-to-know-about-computer-vision-heres-a-look-why-it-s-so-awesome-e8a58dfb641e>

- Pada hakikatnya, *computer vision* mencoba meniru cara kerja sistem visual manusia (*human vision*).
- *Human vision* sesungguhnya sangat kompleks. Manusia melihat objek dengan indera penglihatan (mata), lalu citra objek diteruskan ke otak untuk diinterpretasi sehingga manusia mengerti objek apa yang tampak dalam pandangan matanya.
- Hasil interpretasi ini mungkin digunakan untuk pengambilan keputusan (misalnya menghindar kalau melihat mobil melaju di depan).

- Proses-proses di dalam *computer vision* dapat dibagi menjadi tiga aktivitas:
 1. Memperoleh atau mengakuisisi citra digital.
 2. Melakukan teknik komputasi untuk memproses atau memodifikasi data citra (operasi-operasi pemrosesan citra).
 3. Menganalisis dan menginterpretasi citra dan menggunakan hasil pemrosesan untuk tujuan tertentu, misalnya memandu robot, mengontrol peralatan, memantau proses manufaktur, dan lain-lain.

- Proses-proses di dalam *computer vision* dalam hirarkhi sebagai berikut :

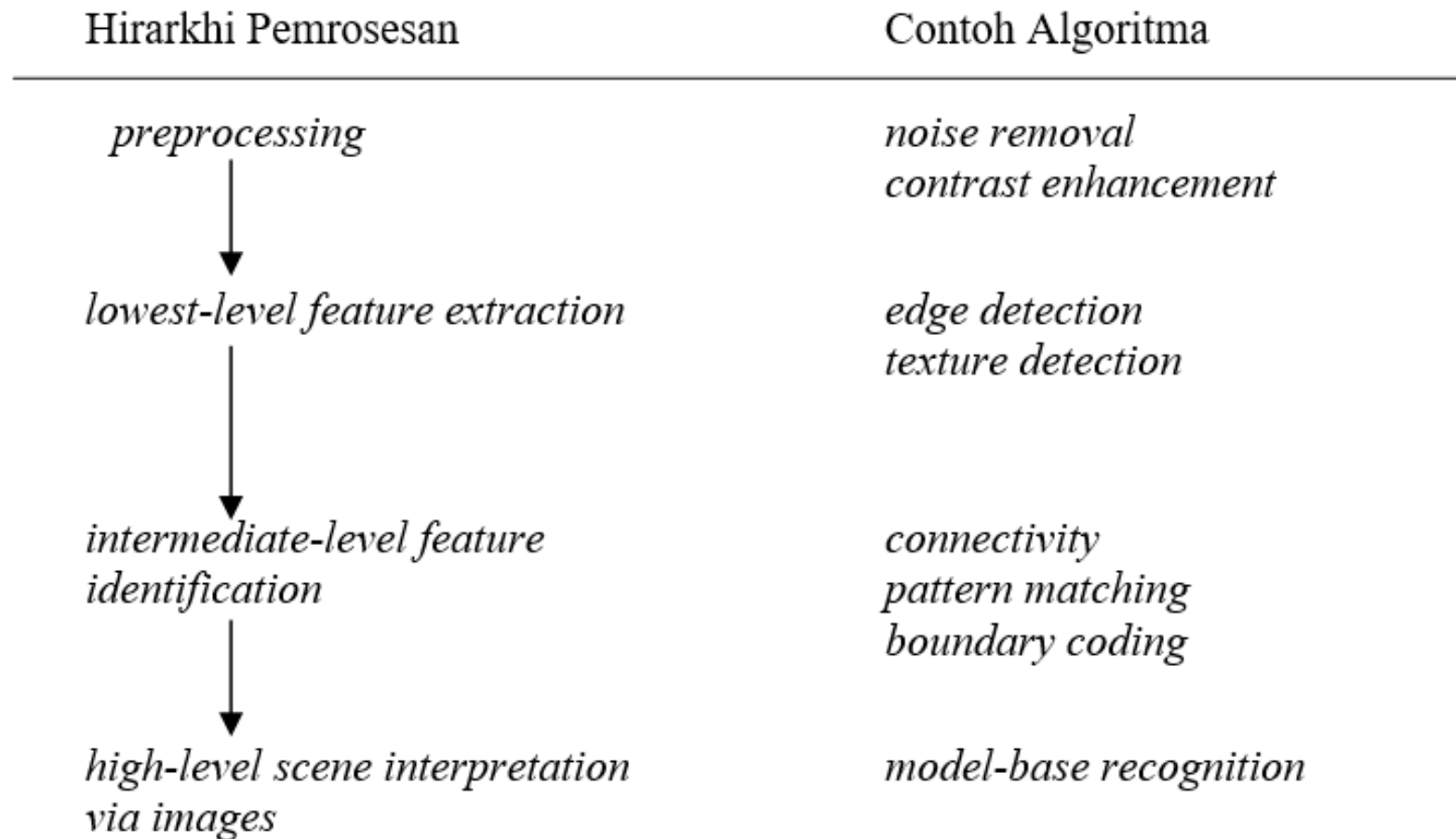
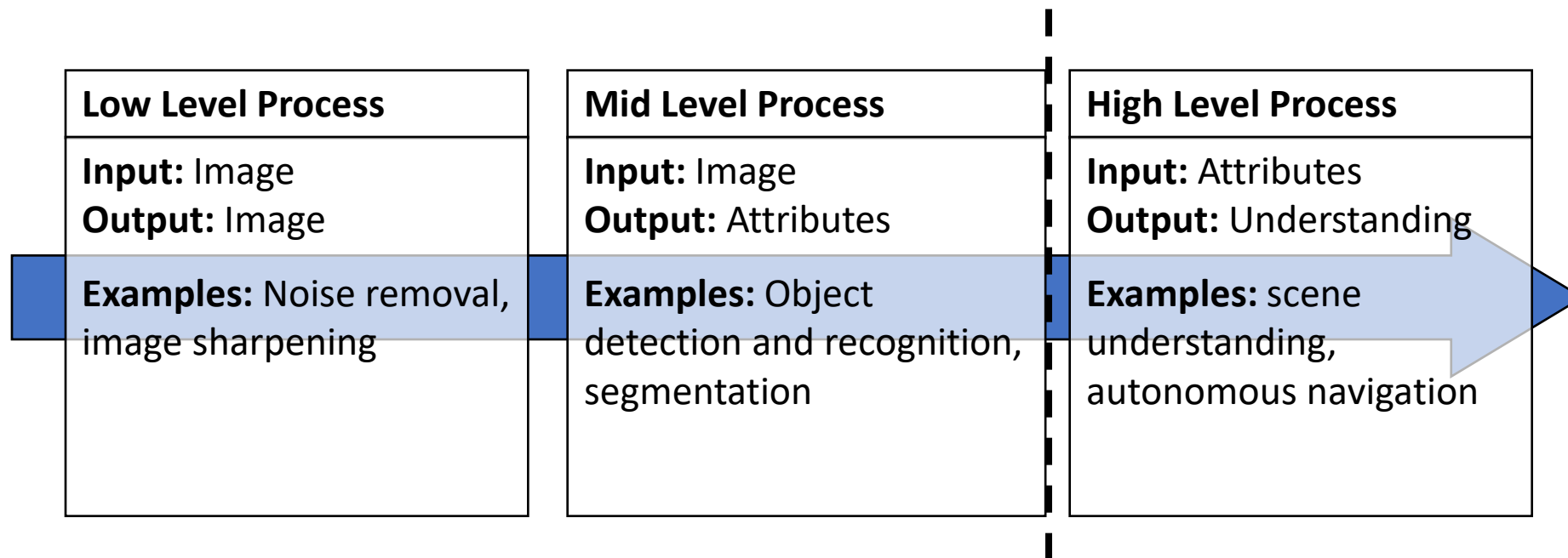


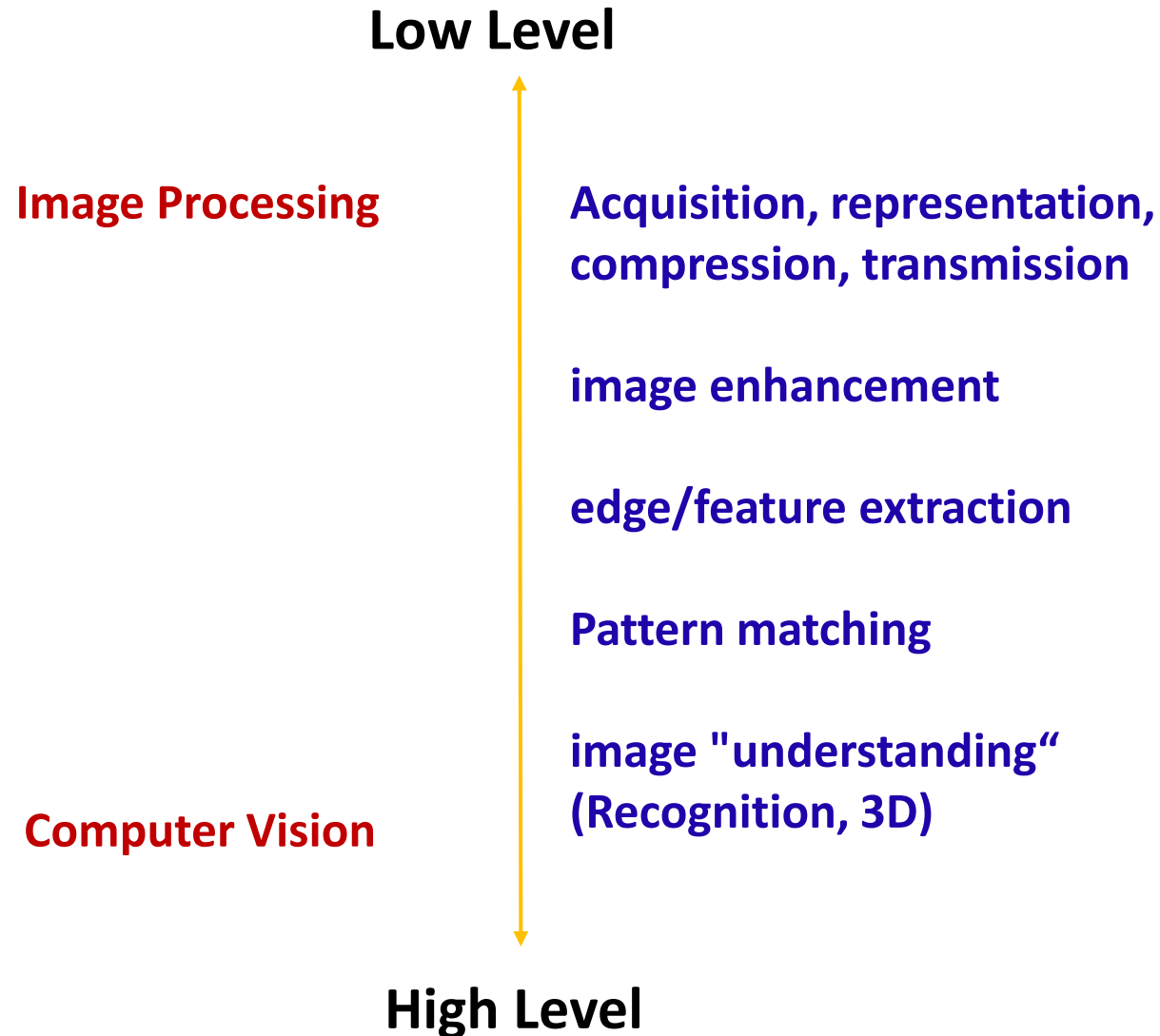
Image Processing → Computer Vision

- Rangkaian kesatuan dari *image processing* ke *computer vision* dapat dipecah menjadi *low-*, *mid-* dan *high-level processes*



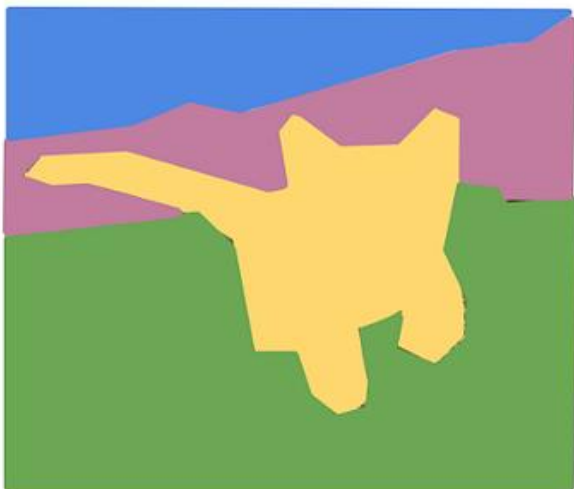
Kuliah IF4073 sampai di
sini saja

Image Processing v.s. Computer Vision





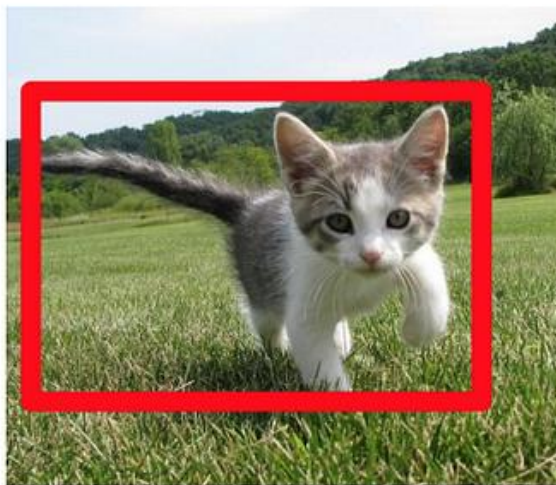
Semantic Segmentation



GRASS, CAT,
TREE, SKY

No objects, just pixels

Classification + Localization



CAT

Single Object

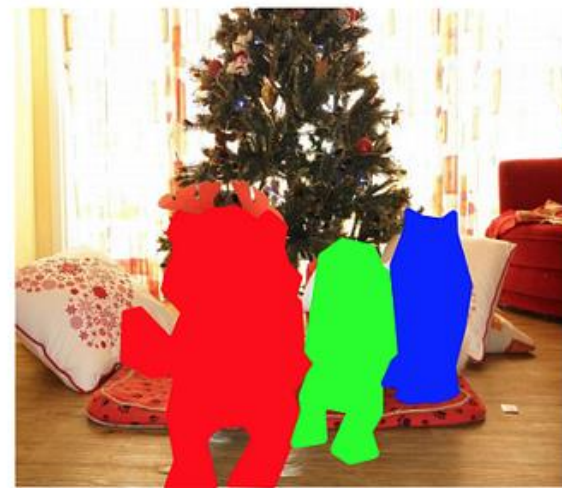
Object Detection



DOG, DOG, CAT

Multiple Object

Instance Segmentation



DOG, DOG, CAT

This image is CC0 public domain

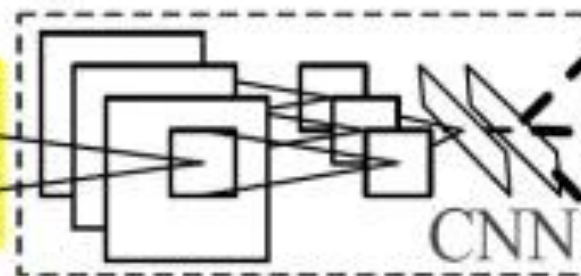


1. Input image



2. Extract region proposals (~2k)

warped region



3. Compute CNN features

aeroplane? no.

⋮

person? yes.

⋮

tvmonitor? no.

4. Classify regions

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Image editing ...*

1. *Cropping*



2. Removal of unwanted element



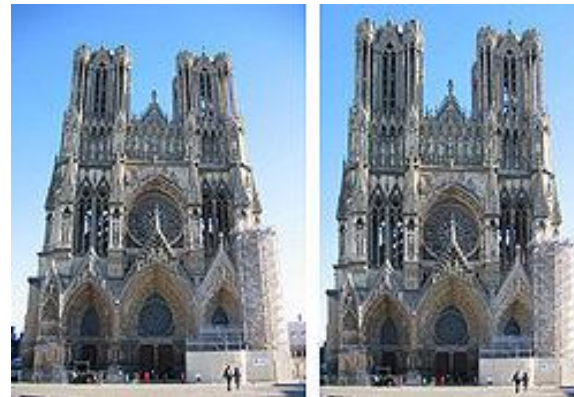
Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Image editing ...*

3. Selective color change



4. Perspective correction and distortion



Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Image editing ...*

- 5. Selecting and merging of images



Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Image editing*

6. Special effects



Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Image Inpainting 1

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Image Inpainting 2

Images of Venus taken by the Russian lander Venera-10 in 1975

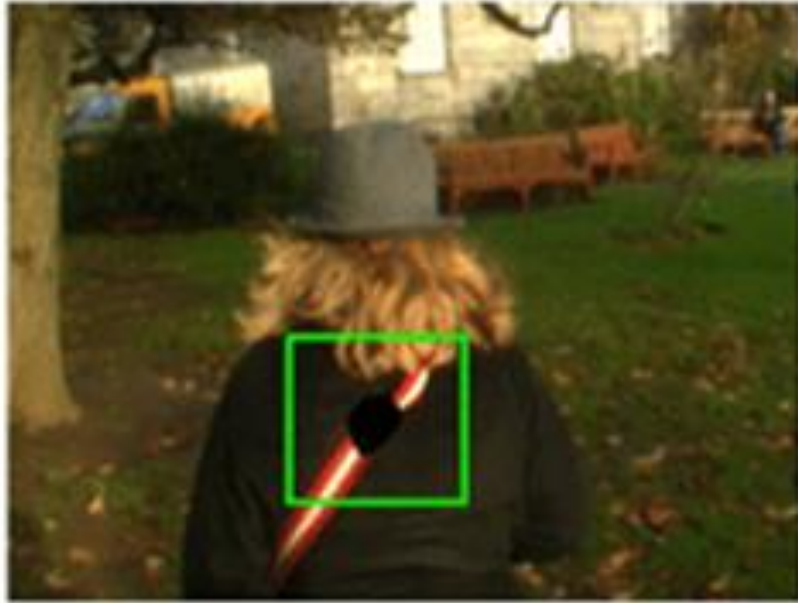
Aplikasi Pemrosesan Citra (dan *Computer Vision*)



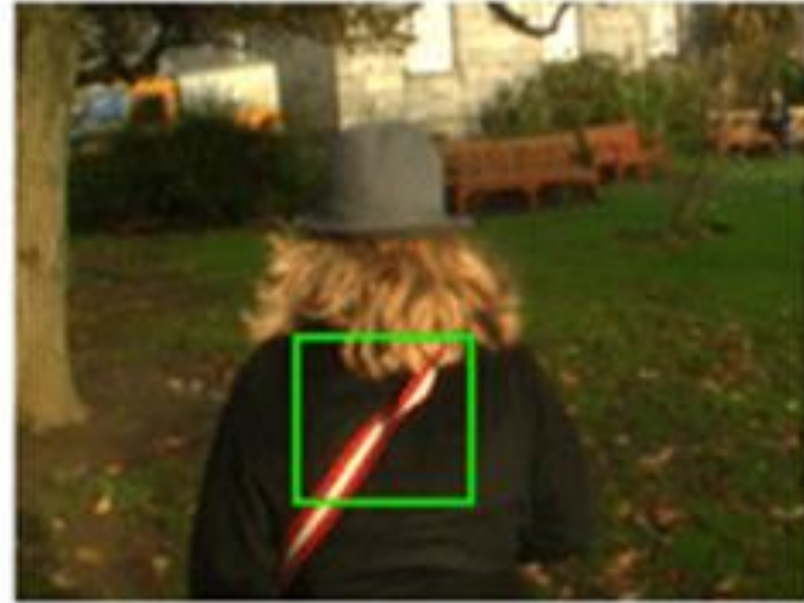
Video Inpainting

Y. Wexler, E. Shechtman and M. Irani 2004





**Degraded image
with hole**



Reconstruction

Video Inpainting

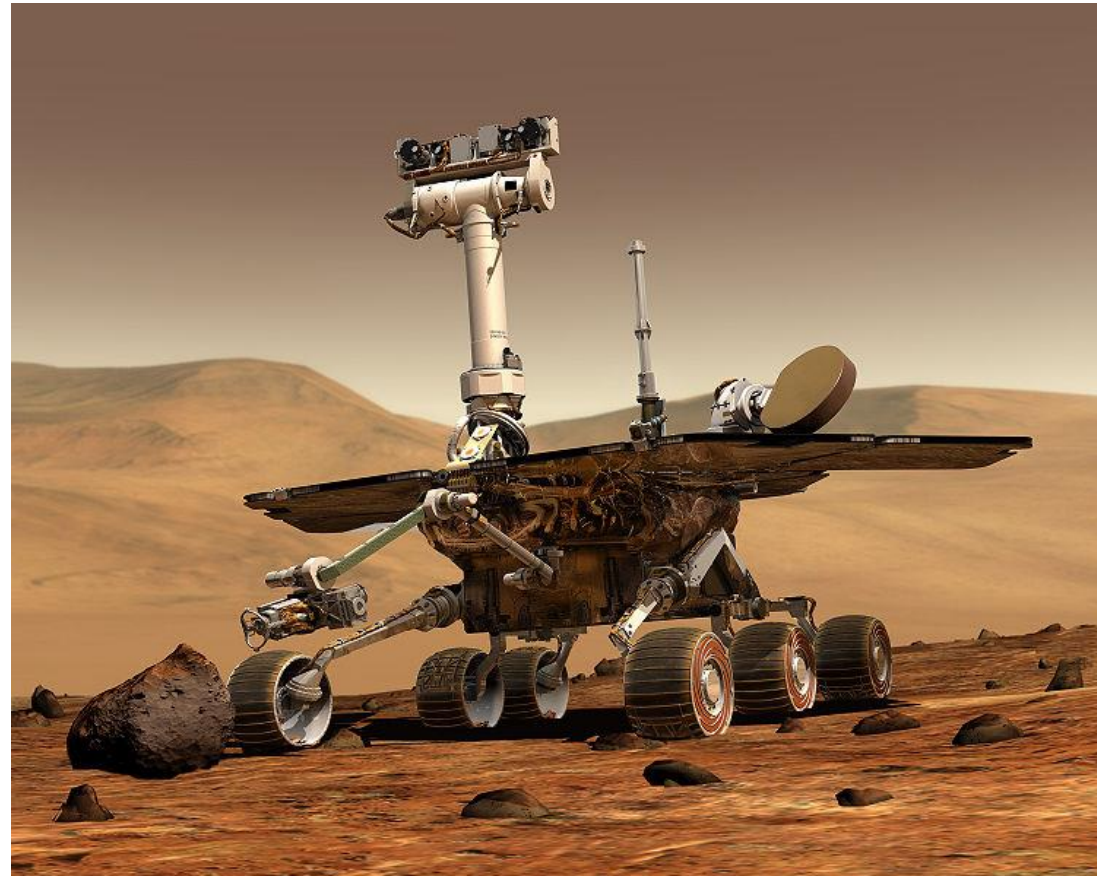


uo" sequence

<https://newatlas.com/video-inpainting-software-hd/26632/>

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Robotika*



Aplikasi Pemrosesan Citra (dan *Computer Vision*)

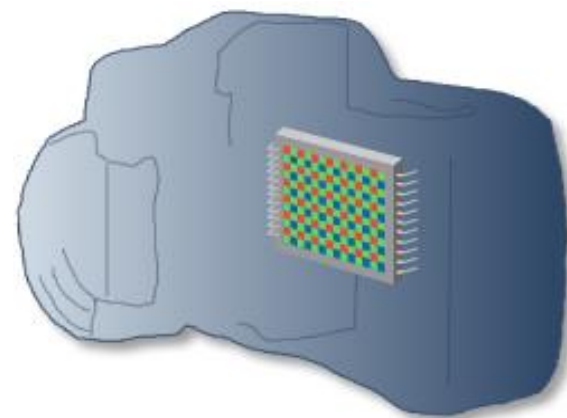
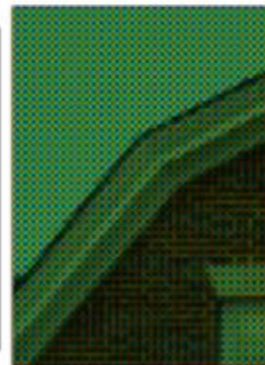


Image Demosaicing



Ground Truth

Raw Image

Label

Nearest

Bilinear

Malvar-He-Cutler

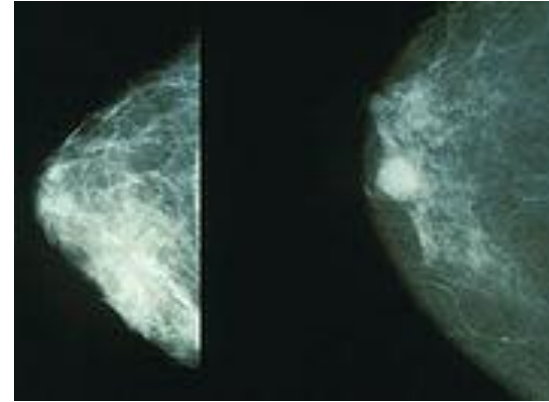
https://www.researchgate.net/figure/Comparision-of-common-demosaijing-methods-applied-to-an-image-of-a-brick-house-and-blue_fig2_220494111

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- Medis



**Magnetic resonance imaging
(MRI) of brain**

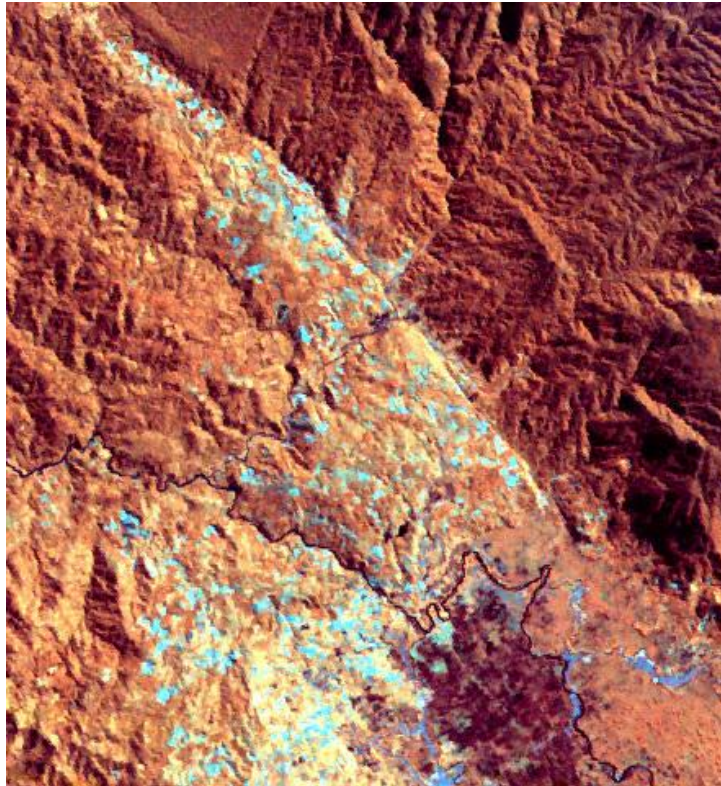


Normal (left) versus cancerous (right)
mammography image.



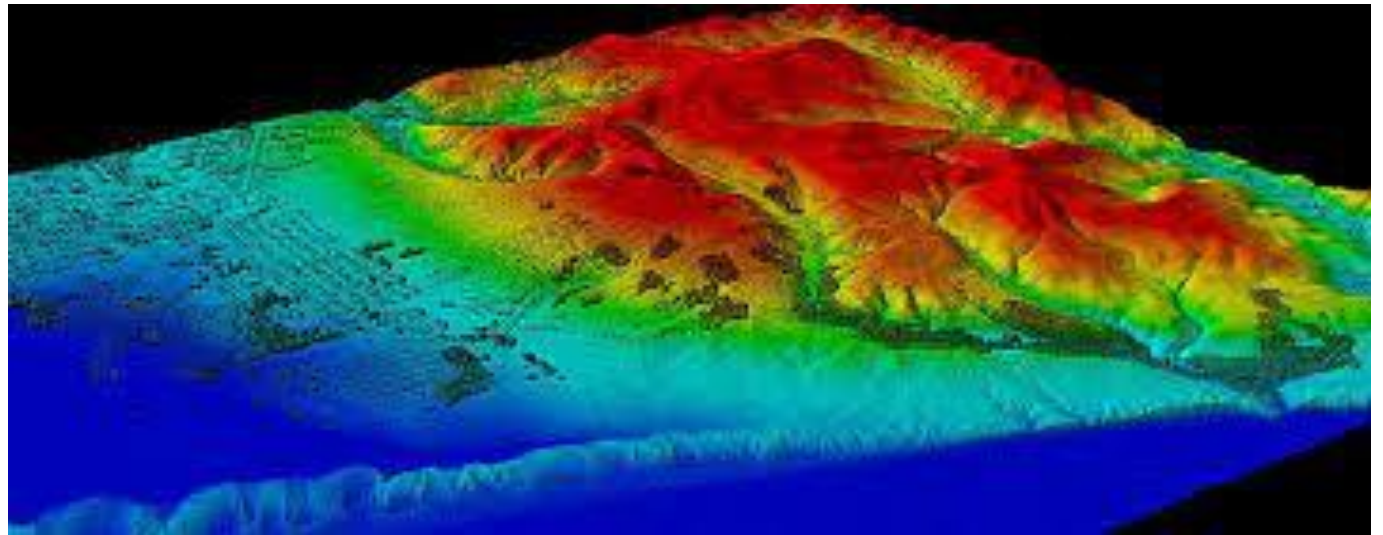
Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Remote sensing*



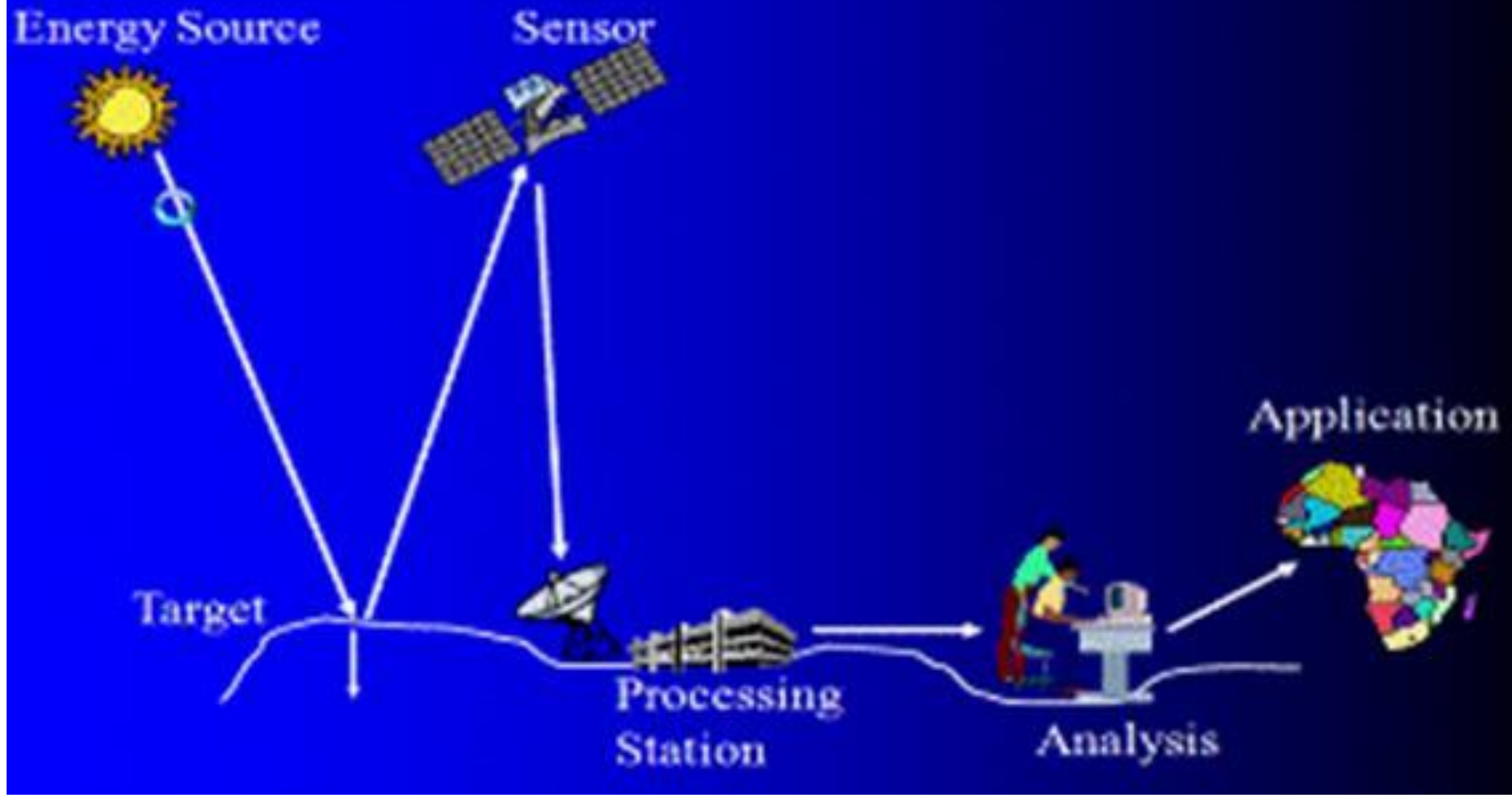
Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth.

<https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used>



<https://oceanservice.noaa.gov/facts/remotesensing.html>

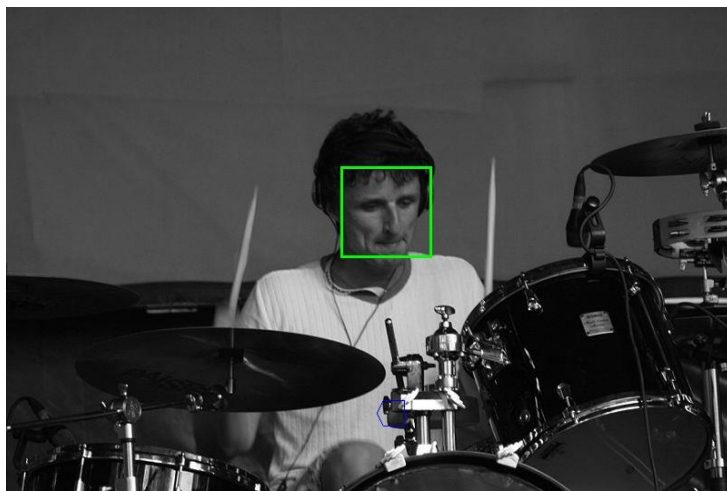
The Remote Sensing Process



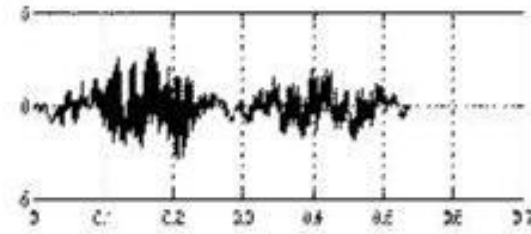
http://dgl.salemstate.edu/geography/profs/young/Imaging%20Earth/Glacier-webpage/home_Page301.htm

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Face detection*



Aplikasi Pemrosesan Citra (dan *Computer Vision*)



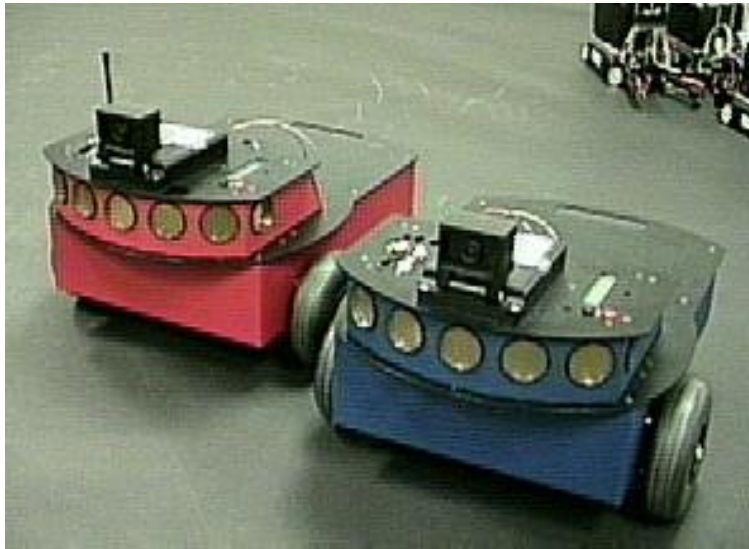
Biometrics

Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

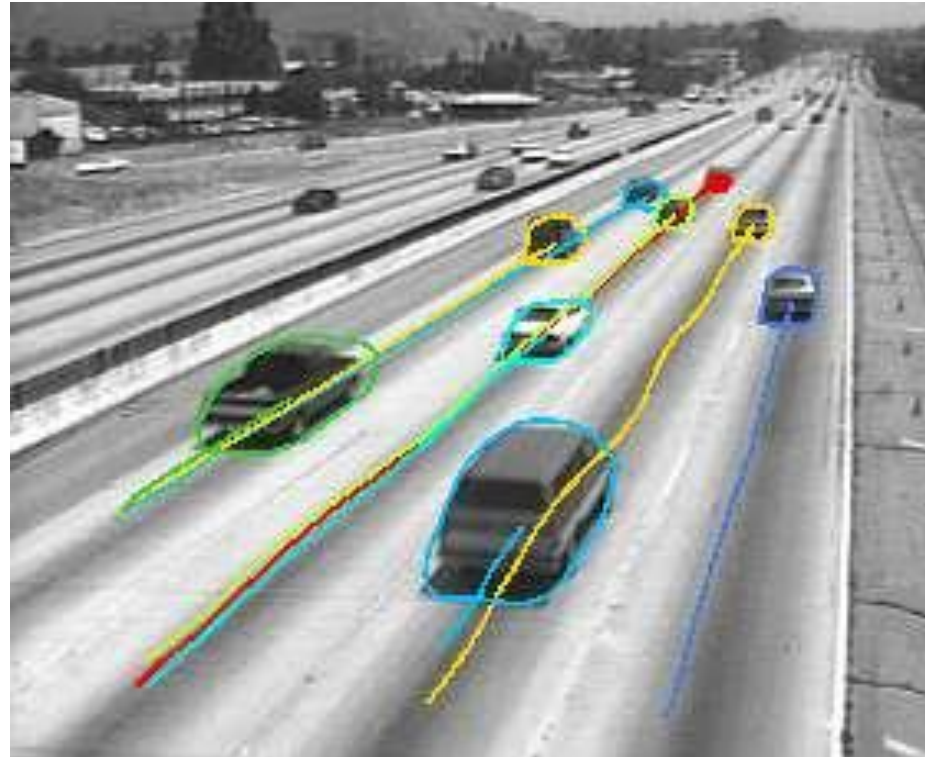
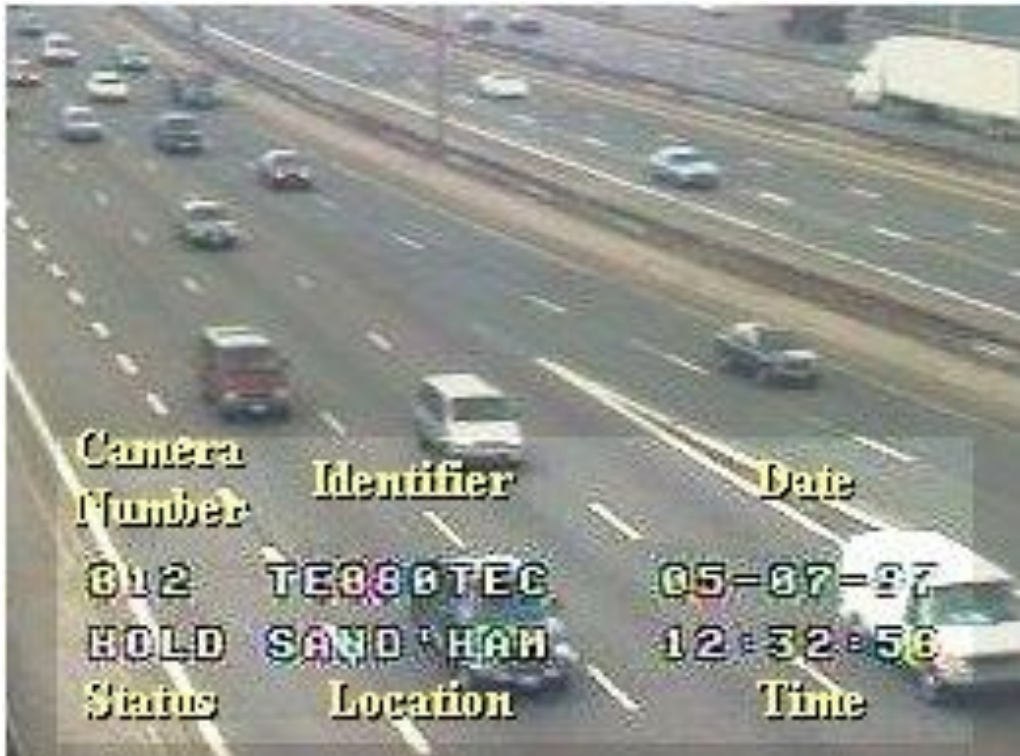
- Land, Underwater, Space

Autonomous Vehicles



Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



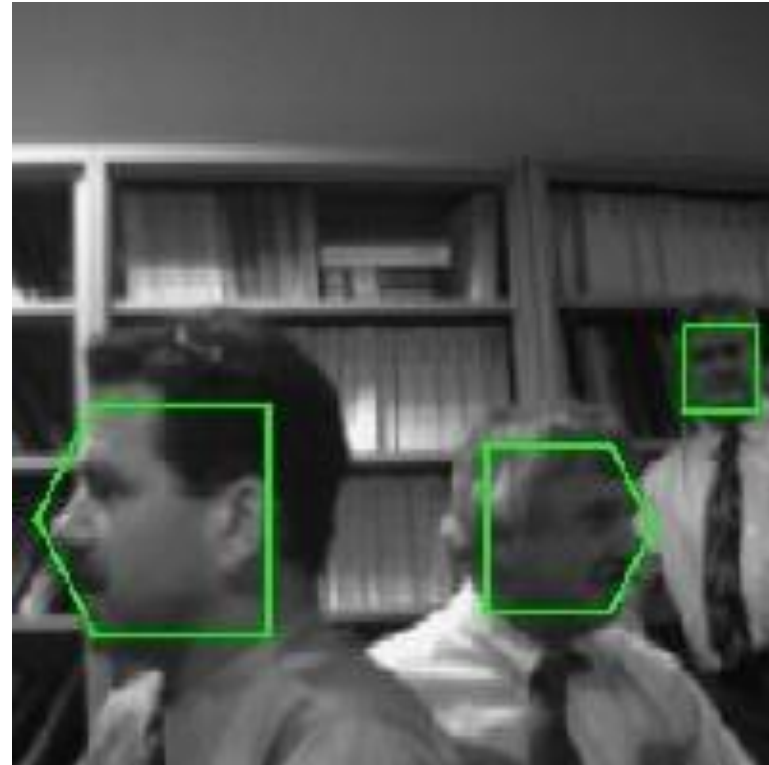
Kemacetan:

- Lancar
- Macet parah
- Macet ringan

Traffic Monitoring

Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Face Detection

Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

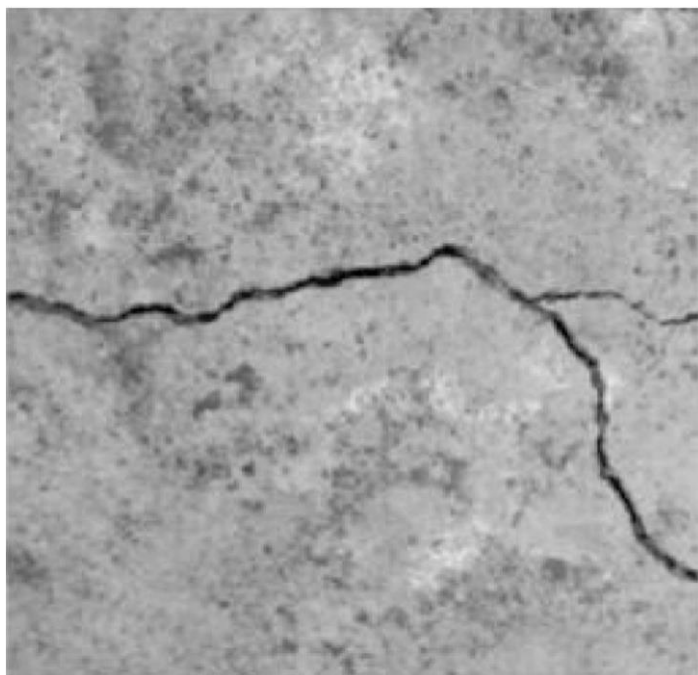


Face Recognition

Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee⁴³

Aplikasi Pengolahan Citra (dan *Computer Vision*)

Original gray image



Binarized image



Crack detection image





Crack detection

Research Article | Open Access

Volume 2018 | Article ID 3924120 | <https://doi.org/10.1155/2018/3924120>

[Show citation](#)

Detection of Surface Crack in Building Structures Using Image Processing Technique with an Improved Otsu Method for Image Thresholding

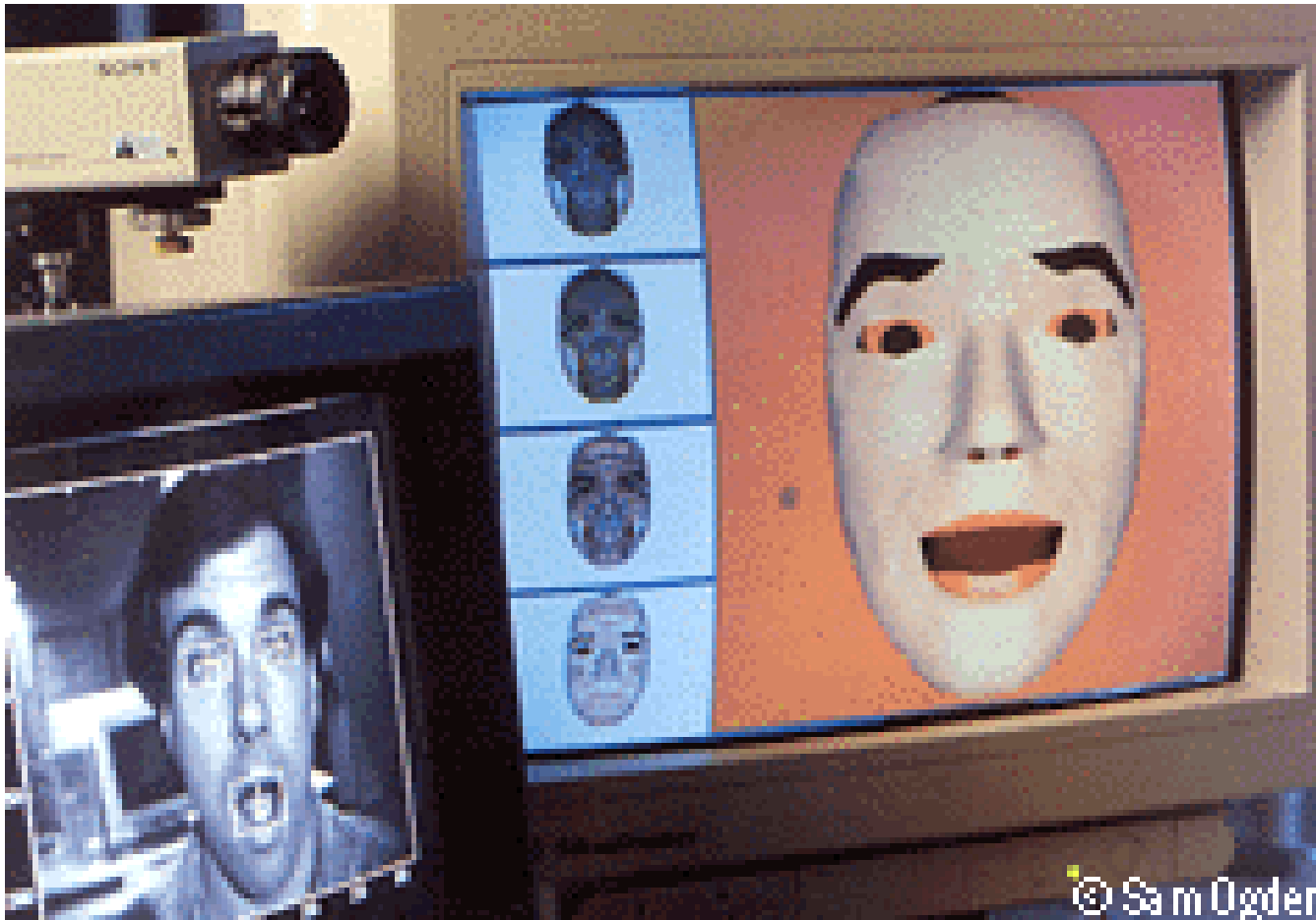
Nhat-Duc Hoang   ¹

[Show more](#)

Academic Editor: Pier Paolo Rossi

Received 11 Oct 2017	Revised 03 Mar 2018	Accepted 14 Mar 2018	Published 02 Apr 2018
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Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Ekspresi:

- Sedih
- Gembira
- Marah
- Kaget
- Netral

Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Facial Expression Recognition

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

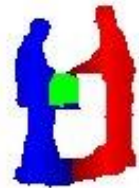
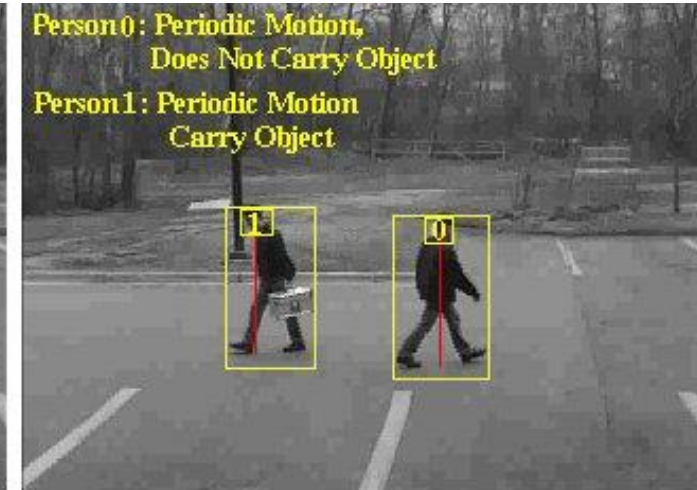
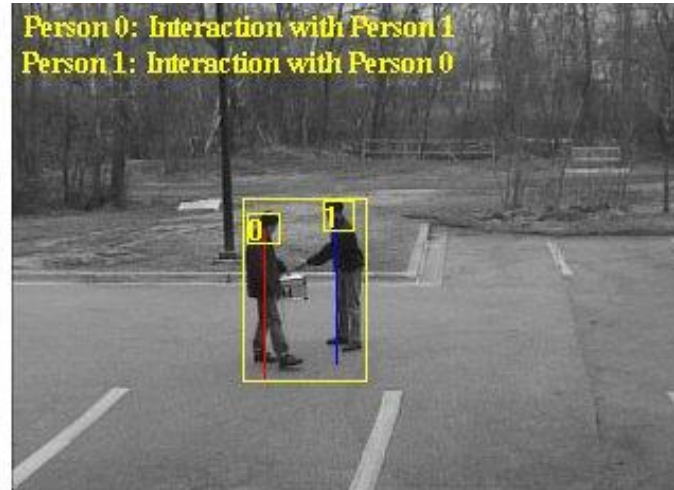
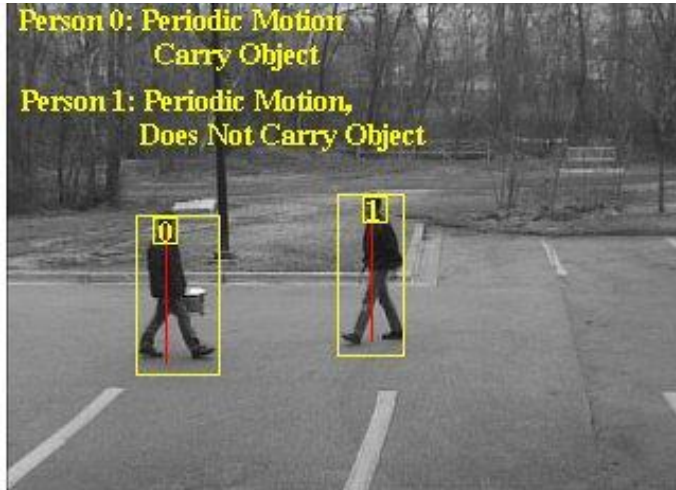
- Smart Human-Computer User Interfaces
- Sign Language Recognition



Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Hand Gesture Recognition

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

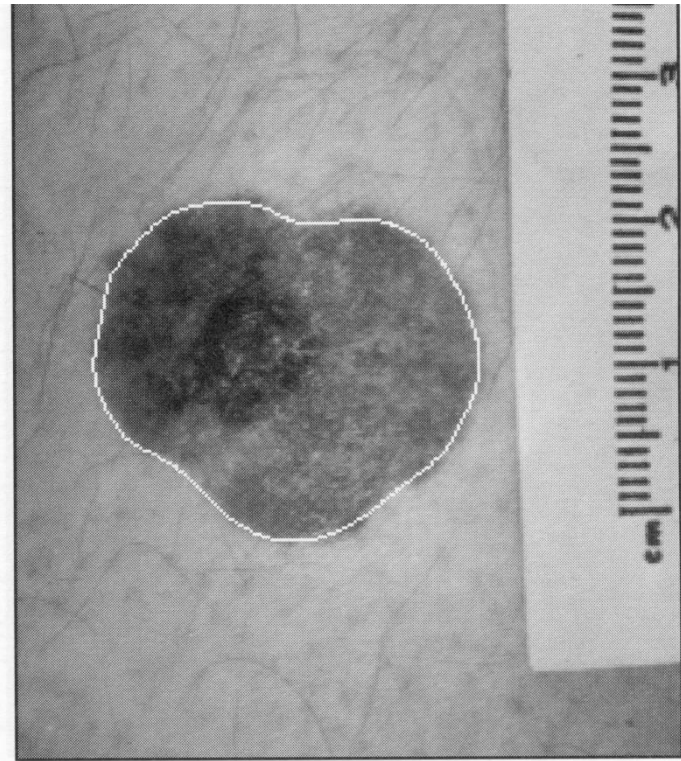


Human Activity Recognition

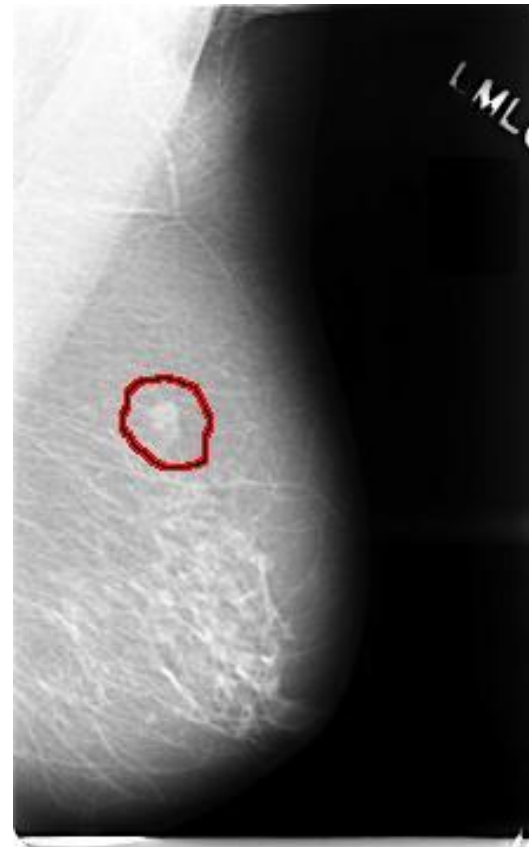
Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

skin cancer



breast cancer



Medical Applications

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

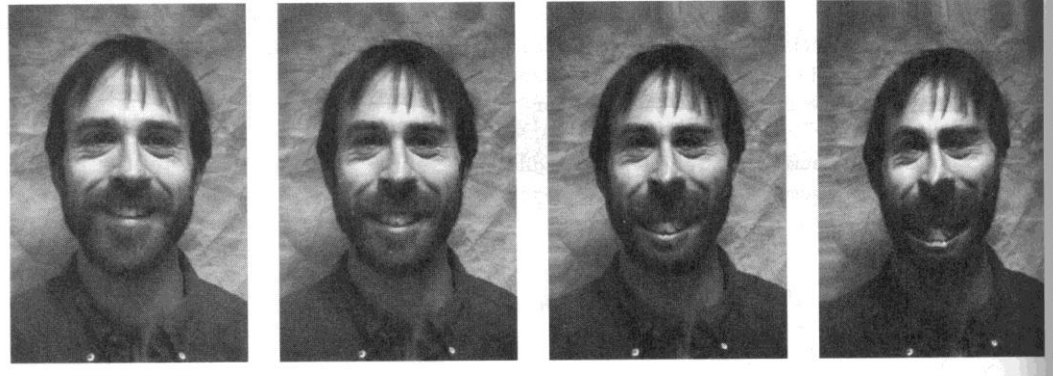
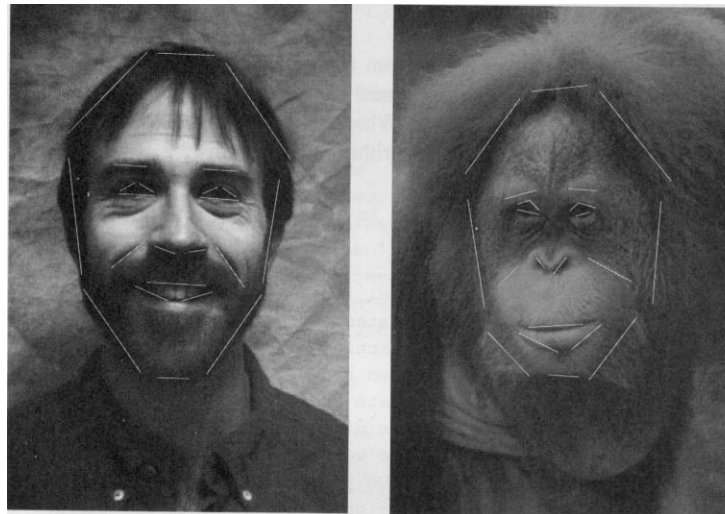


Image Morphing

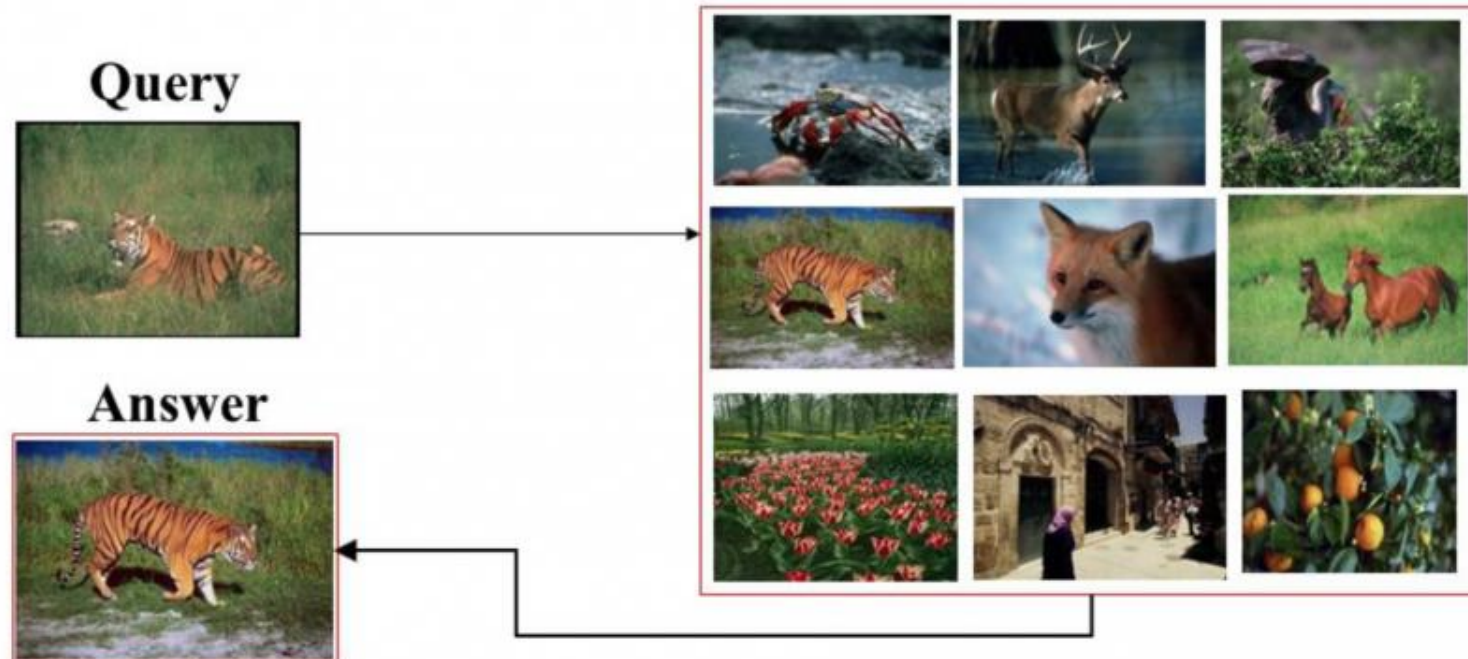


Aplikasi Pemrosesan Citra (dan *Computer Vision*)

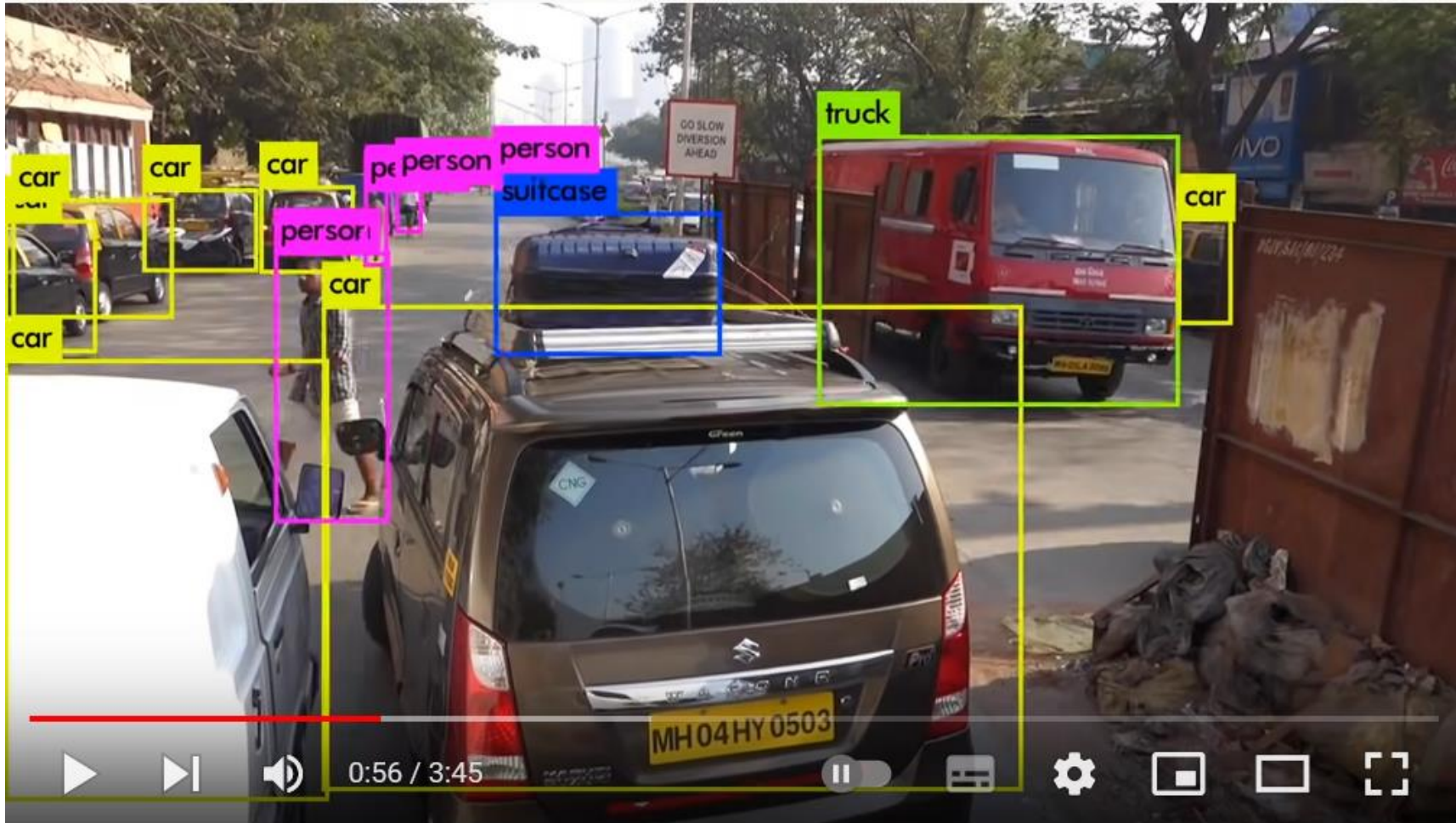
An image retrieval system is a computer system for browsing, searching and retrieving images from a large database of digital images

Content-based Image Retrieval

Given a query image, try to find visually similar images from an image database



Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Object Detection

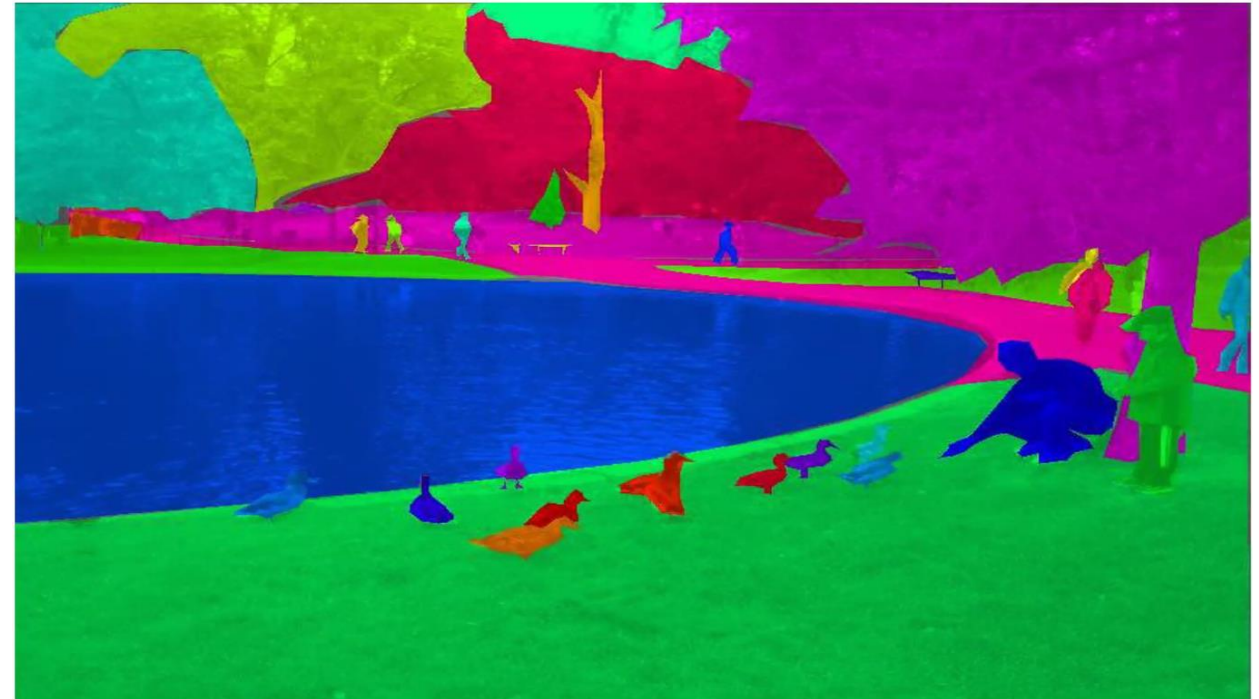
Video di Youtube: <https://www.youtube.com/watch?v=MPU2Histiv&t=34s>

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Human tracking

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Scene understanding



Scene understanding

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

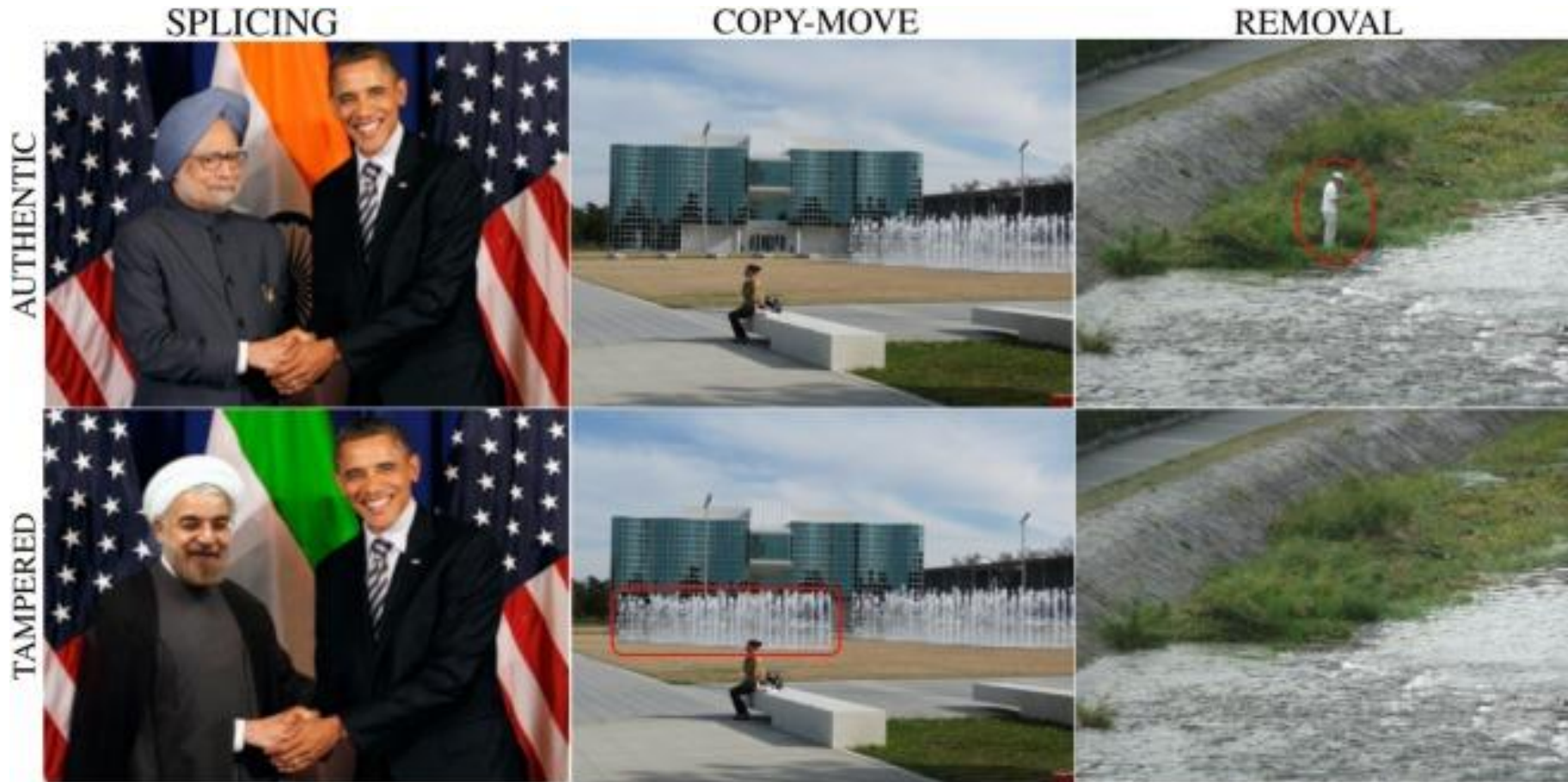


Image forgery detection

INTERNET

Spies turn to high-tech info ops

PCs, Internet used for manipulating images, public opinion

**ALTERED
IMAGE**



Altered Egos

The top photo, of a fictitious meeting between President Clinton and Saddam Hussein, was generated by digitally altering and combining elements from three photos, shown below the altered image. Intelligence agencies plan to use similar techniques to create images and then disseminate them via the Internet in their efforts to influence events in foreign countries, such as Iraq.

BY DANIEL VERTON

Federal intelligence agencies are studying ways to use computers and the Internet, rather than just leaflets and radio broadcasts, to shape and disseminate information designed to sway public opinion in the world's hot spots.

As part of its so-called "perception management" program, the intelligence community has for decades created misinformation to trigger political change without direct political or military involvement in countries where the United States has vested interests, such as Iraq and North Korea.

Acting on congressional recommendations to bolster research and development in information technology, intelligence agencies are turning to PCs to develop more sophisticated means of manipulating and delivering digital photos, video clips and recorded sound to portray fictitious events in hopes of provoking desirable outcomes.

Beberapa TA/Tesis tentang Image Processing dan Computer Vision

1. Ahmad Faishol Huda (13516094): **Pengembangan Sistem Pencarian Gambar Produk E-commerce Dengan Convolutional Neural Network**

Input



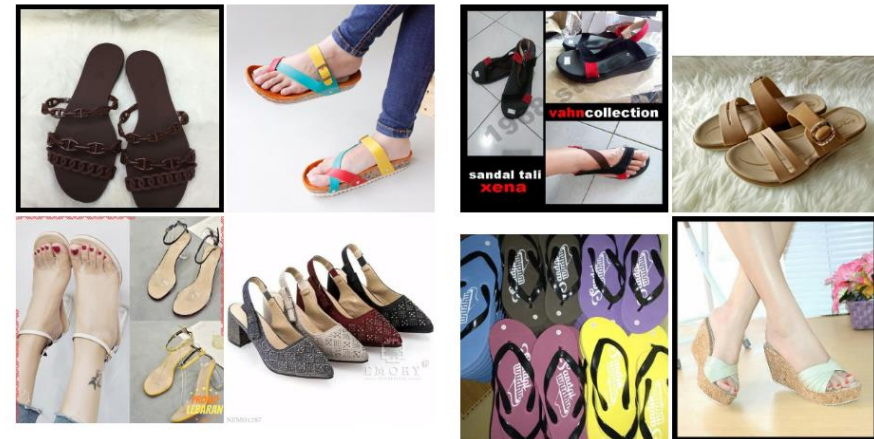
Result (Resnet)



Input



Result (Resnet)



2. Hagai Raja Sinulingga (13516136): Sistem Pengenalan Jalan Raya Pada Sistem Autonomous Vehicle (Av) Dengan Metode Heuristik Dan Pembelajaran Mesin


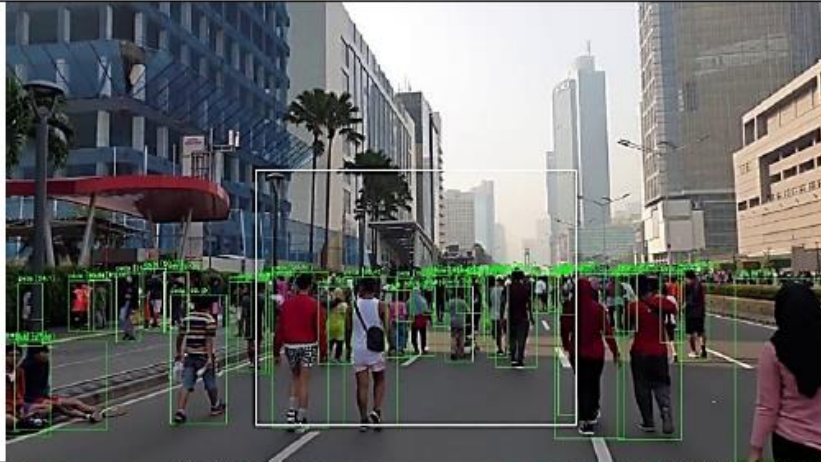




Gambar IV.6 Deteksi pada citra dengan warna latar yang jauh berbeda



Gambar IV.7 Deteksi pada citra dengan warna kendaraan yang jauh berbeda dan

3. Renjira Naufhal Dhiaegana (13516014): Penerapan Convolutional Neural Network Untuk Deteksi Pedestrian Pada Sistem Autonomous Vehicle

Kasus Uji	YOLOv4-416	YOLOv4-416-double
CFD	 A street scene with many pedestrians. Green bounding boxes are drawn around each pedestrian, indicating detection. The model is YOLOv4-416.	 The same street scene as the left image. Green bounding boxes are drawn around pedestrians. A white bounding box highlights a specific pedestrian in the center-right. The model is YOLOv4-416-double.
Jalan Pasar	 A busy market street scene with many pedestrians and vehicles. Green bounding boxes are drawn around pedestrians. The model is YOLOv4-416.	 The same market street scene as the left image. Green bounding boxes are drawn around pedestrians. A white bounding box highlights a specific pedestrian in the center. The model is YOLOv4-416-double.

4. Trian Annas Thoriq Sumarjadi (13516148): **Pembangunan Model Clustering Untuk Pengelompokan Citra Near Duplicate**

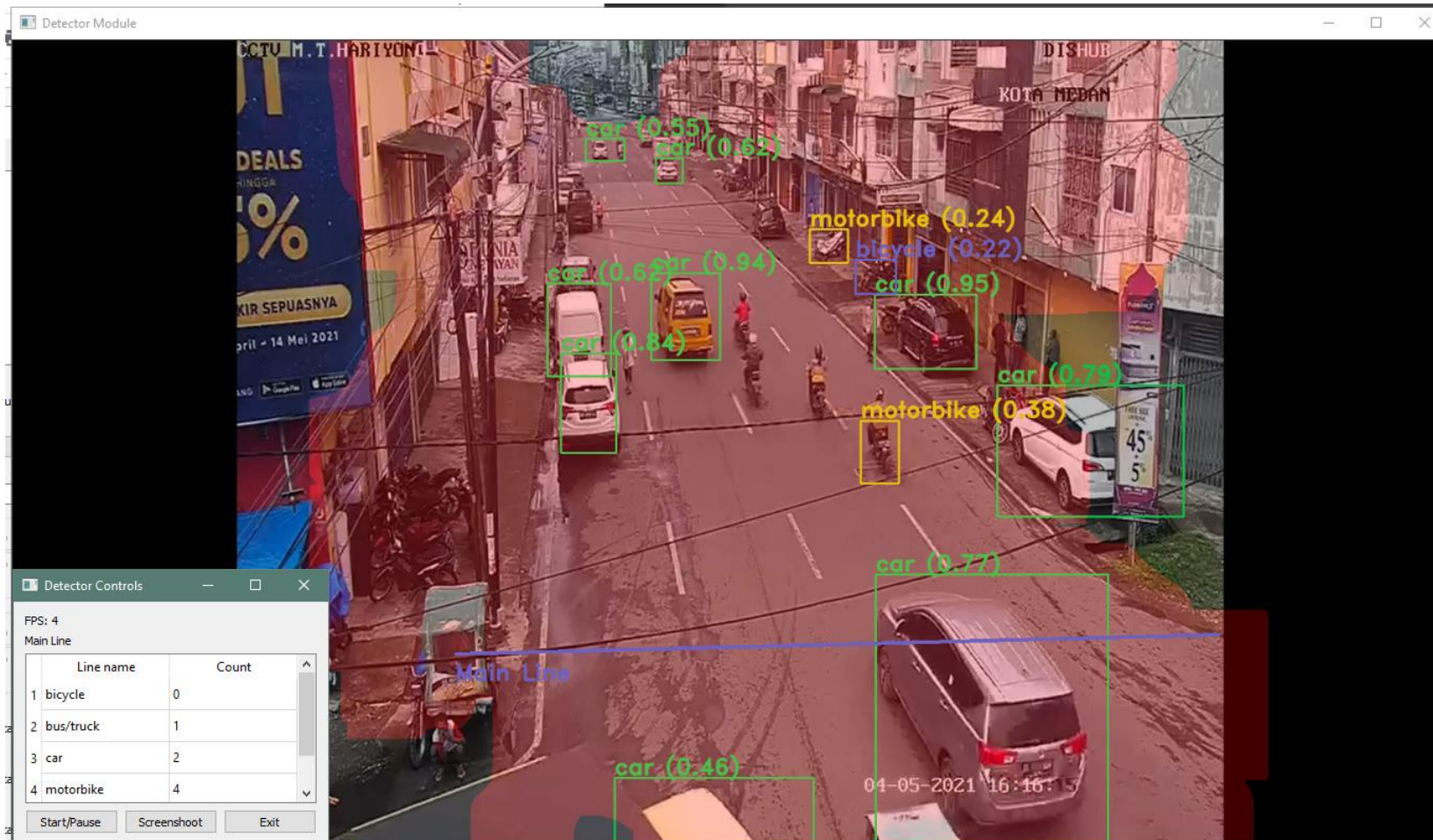
Input



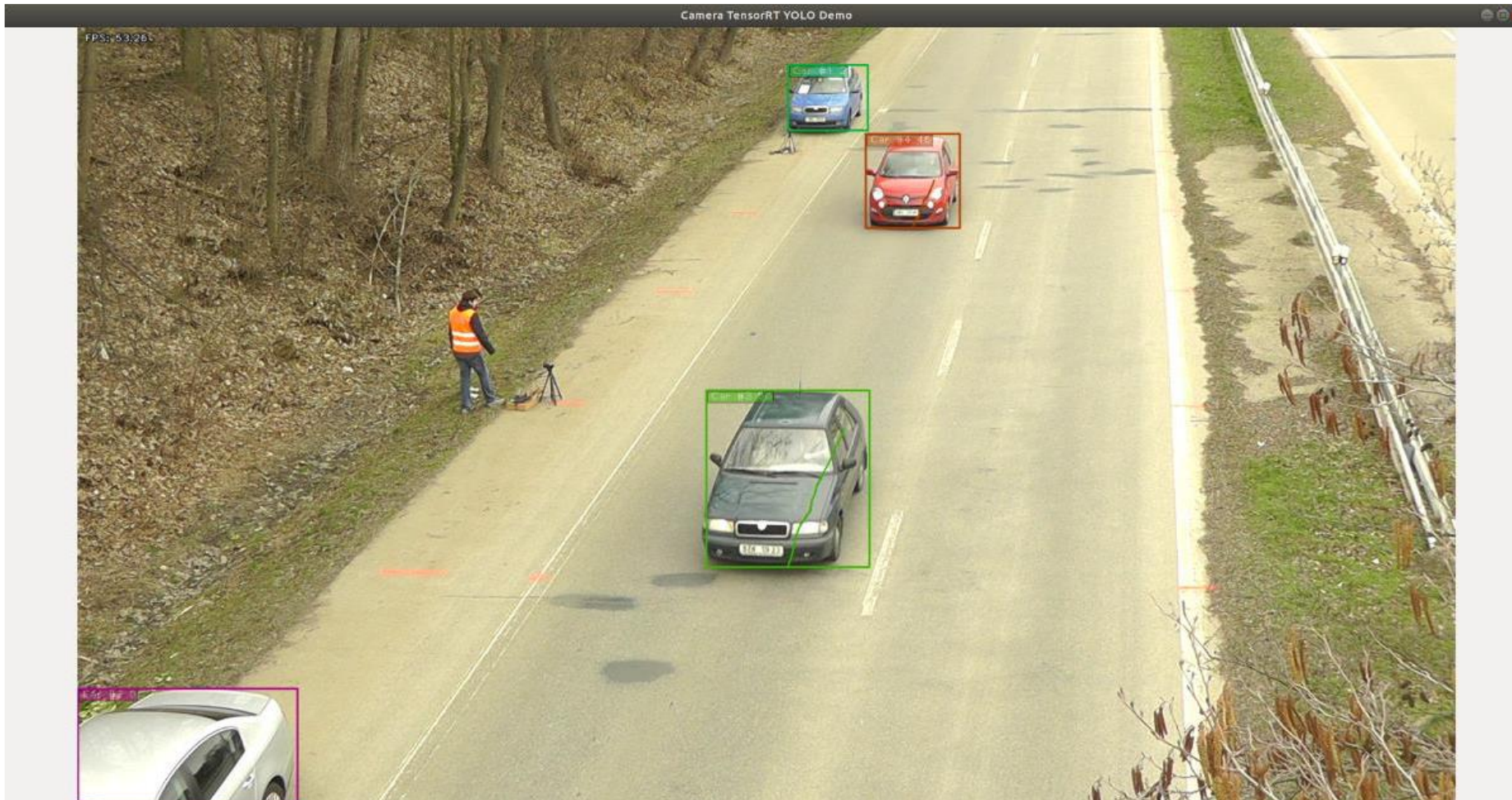
Result



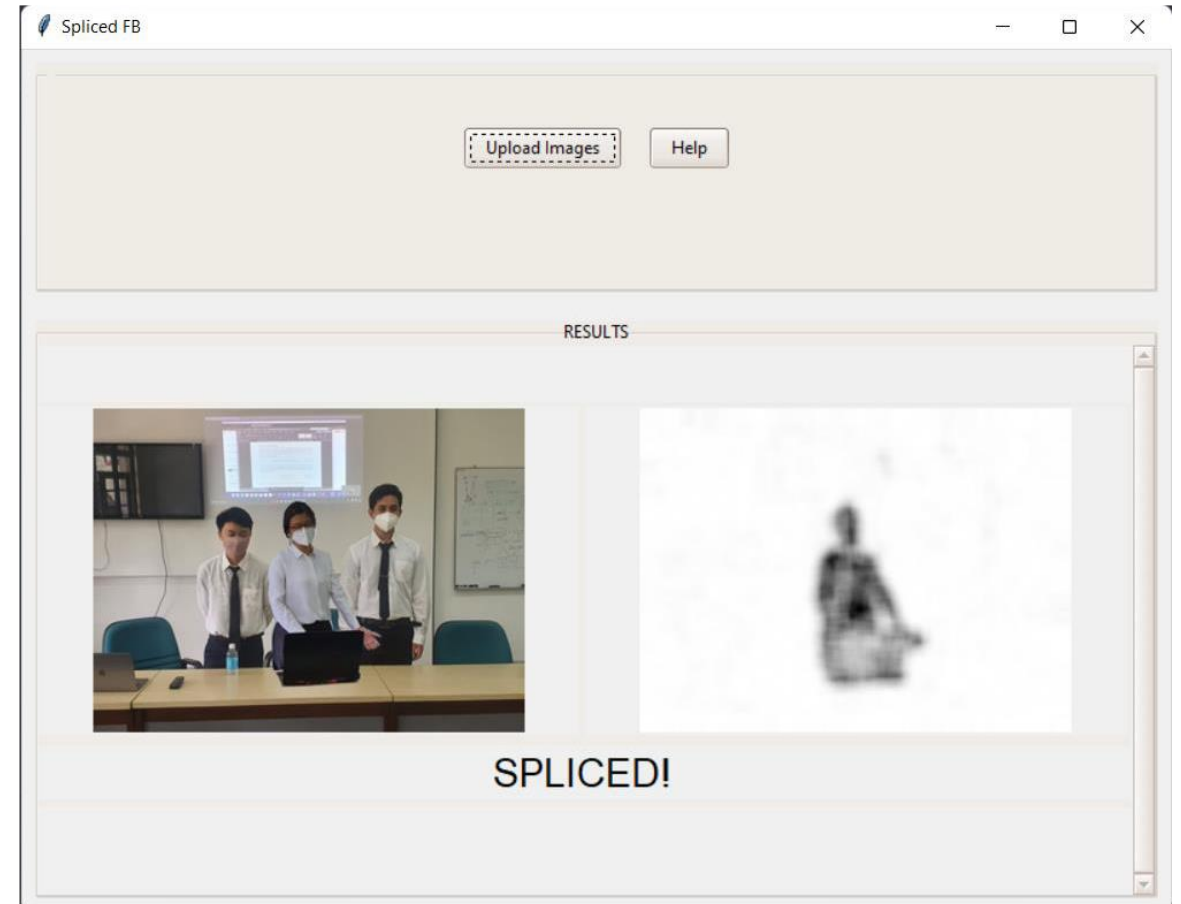
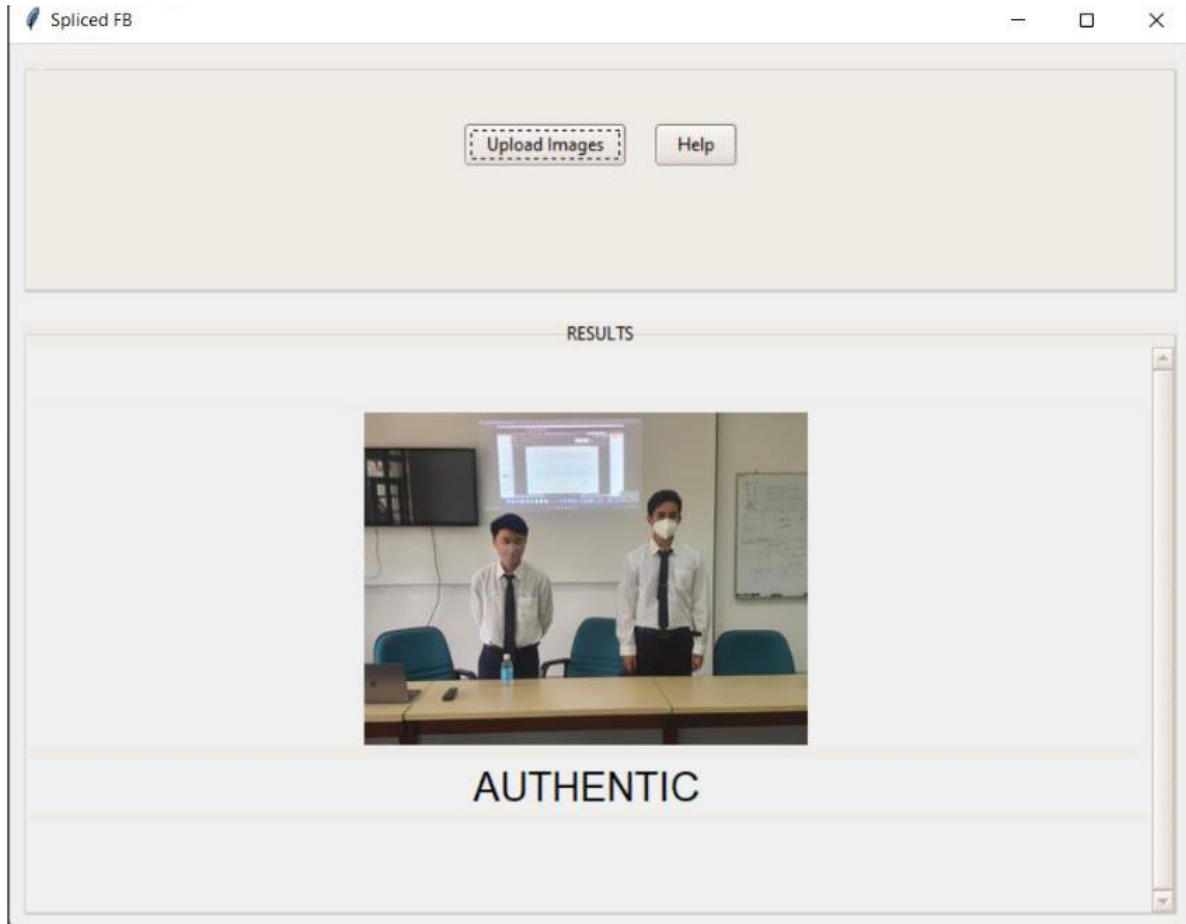
5. Abel Stanley (13517068): Pengembangan Sistem Penghitung Volume Kendaraan Lalu Lintas Pada Video Cctv Dengan Algoritma YOLO dan Segmentasi Semantik Berbasis Model Warna Hsv Jalan



6. Asif Hummam Rais (13517099): Inferensi Kecepatan Kendaraan Menggunakan Yolo, Filter Kalman, Dan Pensampelan Bingkai



7. Michelle Theresia (13518050): Pendeteksian Image Forgery Kelas Spliced Image Pada Aplikasi Pesan Instan

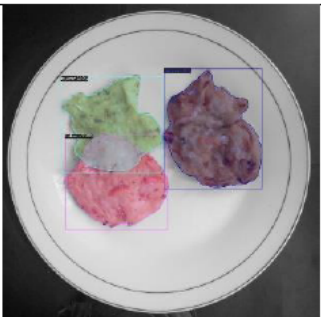


8. Fauzan Firdaus (23520011): Pengenalan Wajah Bermasker Menggunakan Deep Learning



9. Nadya Aditama (23520039): Estimasi Kalori Pada Jajanan Pasar Di Indonesia Menggunakan Mask R-cnn Dan Regresi Linear Berganda

Tabel IV.15 Evaluasi kalori terhadap gambar input pada kasus yang benar

Hasil Segmentasi	Informasi Sesungguhnya	Model Regresi Linear		
		Fitur Panjang Lebar	Fitur Panjang Lebar, Luas, Perimeter	Fitur Luas
	Kelas : bakwan Berat : 31.5 Kalori : 71.82	Berat : 30.79 gram Kalori : 70.21 kal Absolute Error : 1.60 Relative Error : 0.022	Berat : 32.48 gram Kalori : 74.06 kal Absolute Error : 2.24 Relative Error : 0.031	Berat : 34.31 gram Kalori: 78.24 kal Absolute Error : 6.42 Relative Error : 0.08

10. Eiffel Aqila Amarendra (13520074): **Sistem Penghapusan Objek pada Citra Perkotaan Menggunakan Image Segmentation dan Inpainting dengan Pendekatan Deep Learning**



Citra Uji Standard

- Terdapat sejumlah citra yang sering dipakai sebagai citra uji di dalam pengolahan citra atau *computer vision*.
- Citra-citra tersebut sering disebut sebagai *standard test image*, baik citra *grayscale* maupun citra berwarna.
- Umumnya citra uji berukuran persegi ($N \times N$) untuk memudahkan beberapa operasi pengolahan citra yang mengasumsikan citra masukan sebagai citra persegi.
- Empat citra uji standard yang populer dan digunakan secara luas adalah citra *Lena*, *mandrill*, *camera*, dan *pepper*.
- Koleksi citra uji dapat dilihat di laman situs web saya:
<http://informatika.stei.itb.ac.id/~rinaldi.munir/Koleksi/Citra%20Uji/CitraUji.htm>



Lena, 256 × 256



Peppers 512 × 512



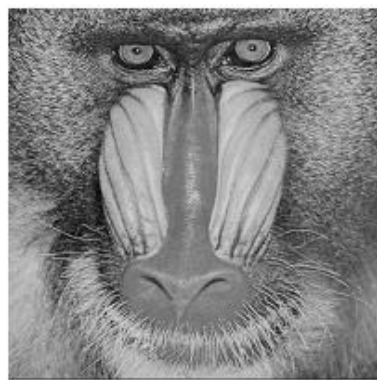
Zelda 512 × 512



Bird 256 × 256



Camera 256 × 256



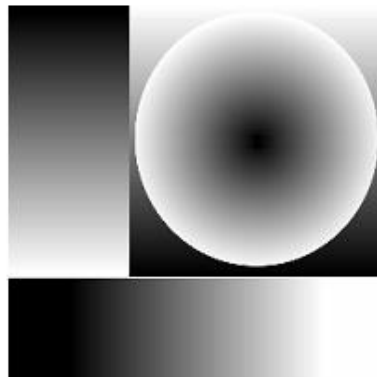
Mandrill 512 × 512



Barbara 512 × 512



Boat 512 × 512



Slope 256 × 256



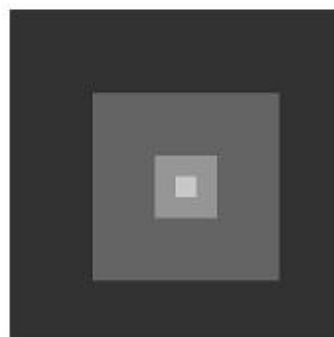
San Fransisco 256 × 256



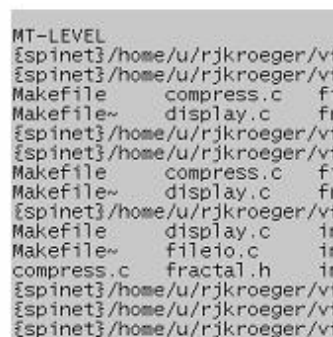
Collie 256 × 256



Circle 256 × 256



Squares 256 × 256



Text 256 × 256



Mountain 640 × 480



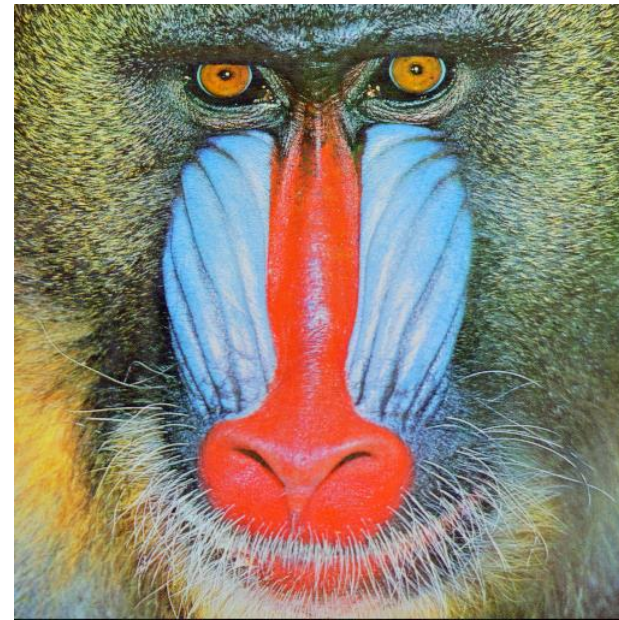
Goldhill 512 × 512



Eltoro 512 × 512



Girl 256 × 256



Citra uji lainnya:



Empat citra populer dalam bidang *image processing*

Koleksi standar citra uji lainnya:

1. The USC-SIPI Image Database

<https://sipi.usc.edu/database/>

2. Computer vision test images

<https://www.cs.cmu.edu/afs/cs/project/cil/ftp/html/v-images.html>

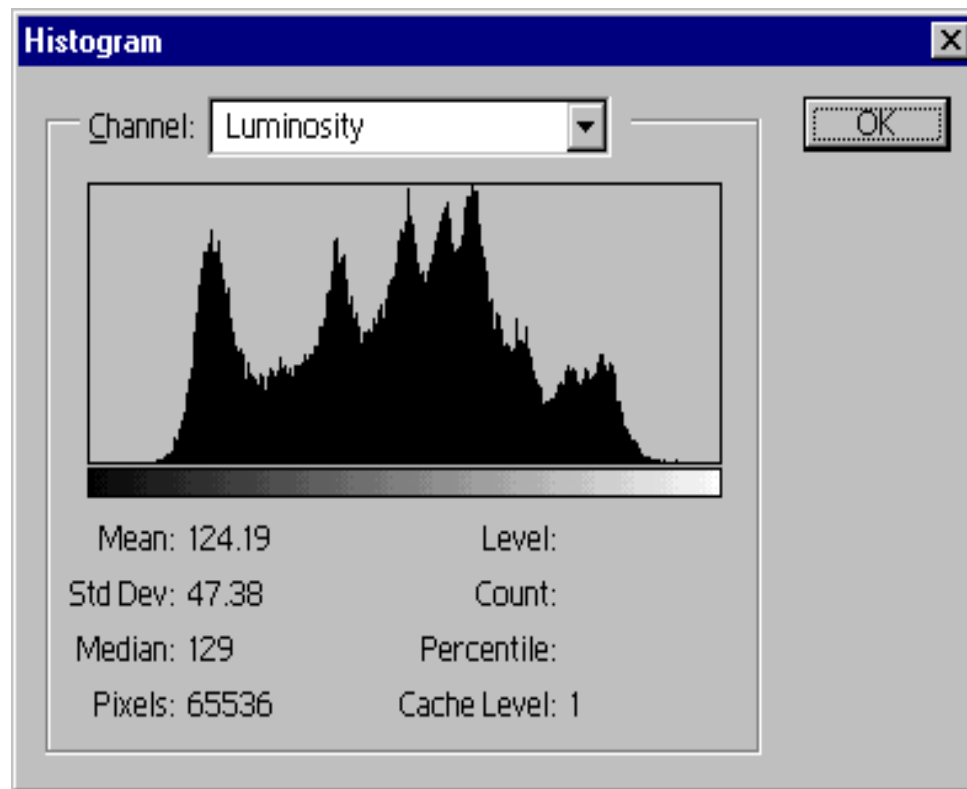
3. TESTIMAGES

<https://testimages.org/>

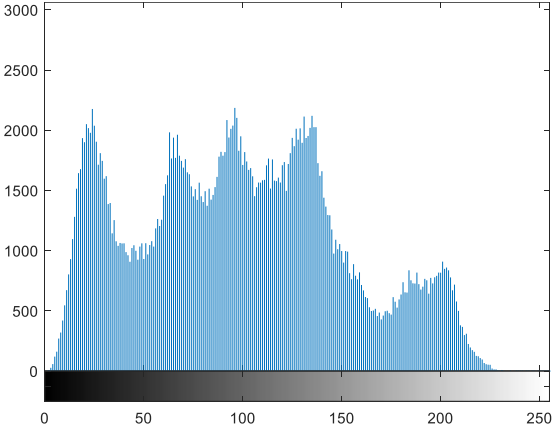
Sejarah Citra Lena



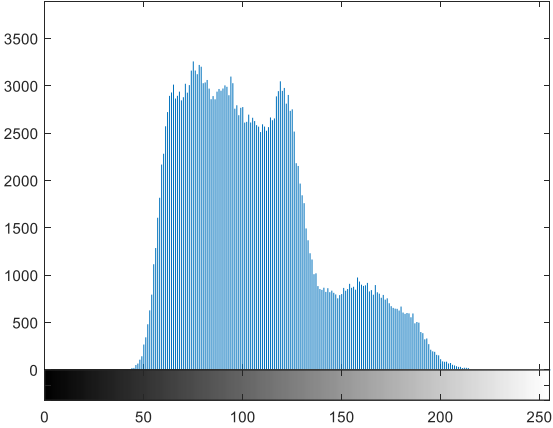
- **Lenna** atau **Lena** adalah nama citra uji standard yang terkenal secara luas di dalam bidang pengolahan citra sejak tahun 1973.
- Lena adalah citra seorang model Swedia bernama Lena Söderberg, yang dipotong dari majalah *Playboy*.
- Foto Lena dari majalah tersebut dipindai oleh Alexander Sawchuk, dia memerlukan foto wajah untuk ditampilkan di dalam sebuah artikel ilmiahnya di sebuah konferensi IEEE.
- Alasan penggunaan citra Lena sebagai citra uji adalah karena citra ini memiliki detail yang bagus, tekstur, dan bayangan, tetapi yang paling penting adalah nilai-nilai *pixel*-nya tersebar secara merata (histogram).
- Tidak dipungkiri juga alasan karena ia seorang wanita cantik, seorang model, dan seorang artis.



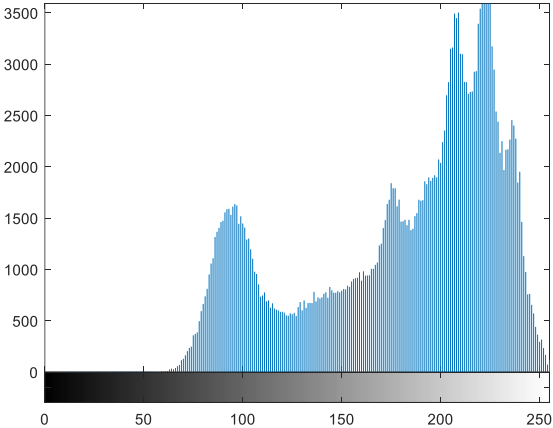
Citra Lena (*color*):



Red



Green



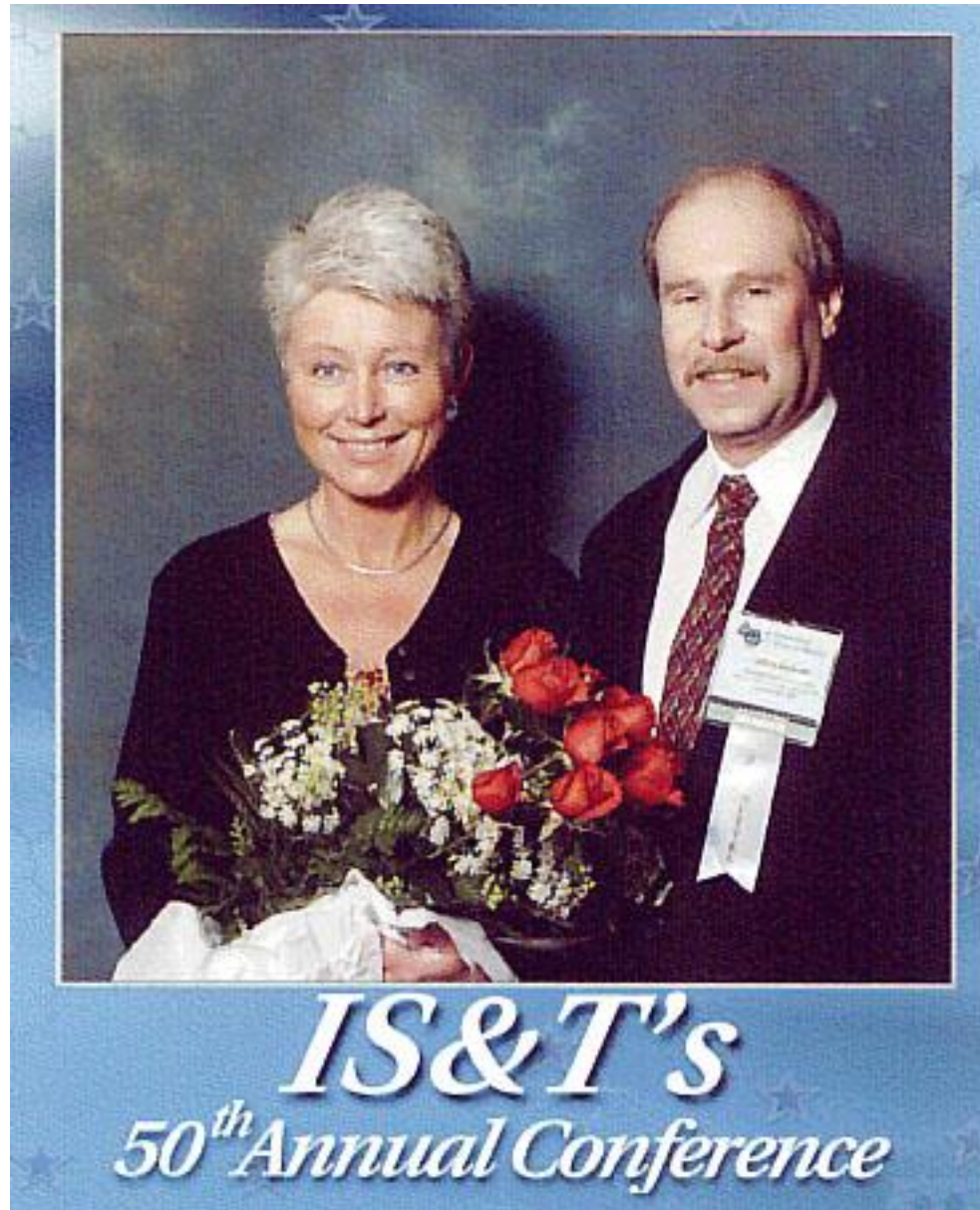
Blue

- Sejarah pertama kali citra Lenna dipakai sebagai citra uji ditulis sebagai berikut:

Alexander Sawchuk estimates that it was in June or July of 1973 when he, then an assistant professor of electrical engineering at the [University of Southern California](#) Signal and Image Processing Institute (SIPI), along with a graduate student and the SIPI lab manager, was hurriedly searching the lab for a good image to scan for a colleague's conference paper. They got tired of their stock of usual test images, dull stuff dating back to television standards work in the early 1960s. They wanted something glossy to ensure good output dynamic range, and they wanted a human face. Just then, somebody happened to walk in with a recent issue of *Playboy*.

The engineers tore away the top third of the centerfold so they could wrap it around the drum of their Muirhead wirephoto scanner, which they had outfitted with analog-to-digital converters (one each for the red, green, and blue channels) and a [Hewlett Packard 2100](#) minicomputer. The Muirhead had a fixed resolution of 100 lines per inch and the engineers wanted a 512×512 image, so they limited the scan to the top 5.12 inches of the picture, effectively cropping it at the subject's shoulders.

Lena Söderberg tahun 1997:



Currently, Lenna lives near Stockholm and works for a government agency supervising handicapped employees archiving data using, appropriately, computers and scanners.

Sumber:

<http://www.ee.cityu.edu.hk/~Impo/lenna/Lenna97.html>

Lena saat ini:



I discovered that the last time she'd appeared in public was in 2015, as a "special guest" at an image processing industry conference in Quebec City.

"I'm just surprised that it never ends," Forsen says about her unusual fame.

Sumber: <https://www.wired.com/story/finding-lena-the-patron-saint-of-jpegs/>

Citra Lena sudah dilarang oleh IEEE

- Sejak tahun 2023, citra "Lena" sudah tidak diperbolehkan lagi oleh IEEE. Makalah yang memuat citra Lena sebagai test image akan ditolak dari semua publikasi IEEE. Ini sesuai dengan keinginan Lena

...

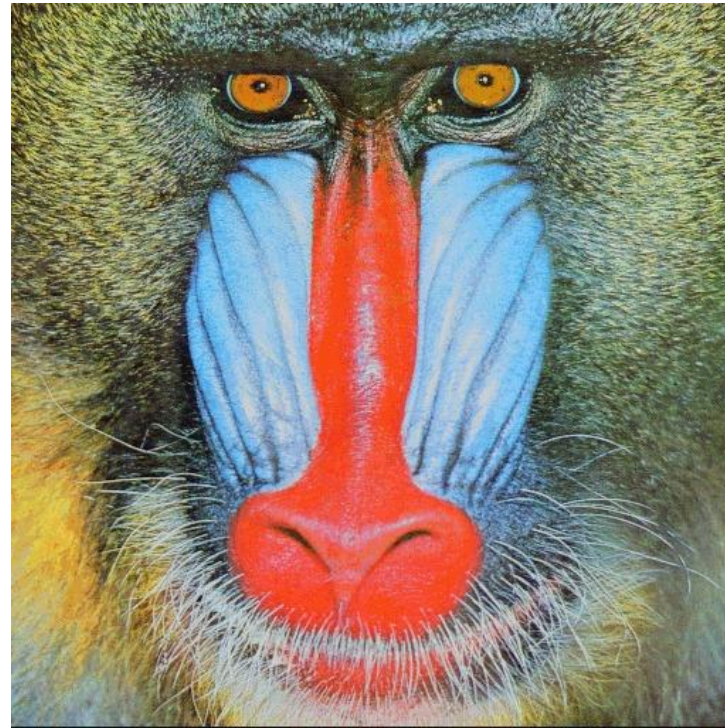
IEEE's diversity statement and supporting policies such as the IEEE Code of Ethics speak to IEEE's commitment to promoting an inclusive and equitable culture that welcomes all. In alignment with this culture and with respect to the wishes of the subject of the image, Lena Forsén, IEEE will no longer accept submitted papers which include the 'Lena image'.

...

Consequently, article submissions containing the "Lena image" will be rejected from all IEEE publications."

https://conferences.ieeeauthorcenter.ieee.org/write-your-paper/improve-your-graphics/?fbclid=IwY2xjawFKTSFleHRuA2FlbQlxMAABHUqUJcQhwhH56yyVxv25XFuuYPn5BlnXUiiwbpLxZo4ZwUc10-GEZ2mHcrg_aem_zMIZFnv7BIAhhXytQhOsNA

- Alternatif citra selain Lena: cameraman, mandrill, peppers



Sumber bahan ajar ini

1. Yacov Hel-Or, *Image Processing*, Spring 2010
2. Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee