

Pengantar Pemrosesan Citra

(Bagian 2 – Update 2024)

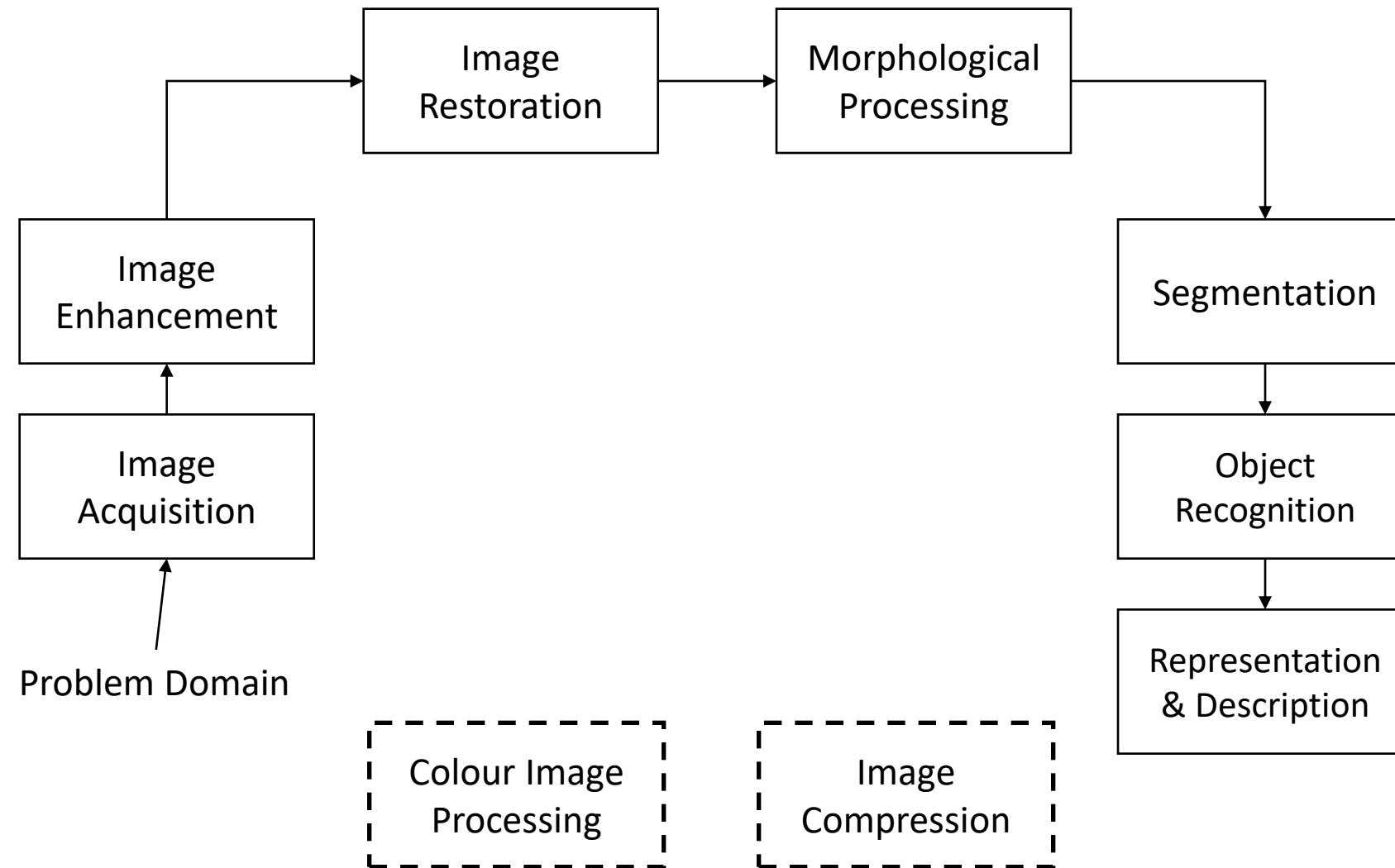
IF4073 Pemrosesan Citra Digital

Oleh: Dr. Ir. Rinaldi, M.T



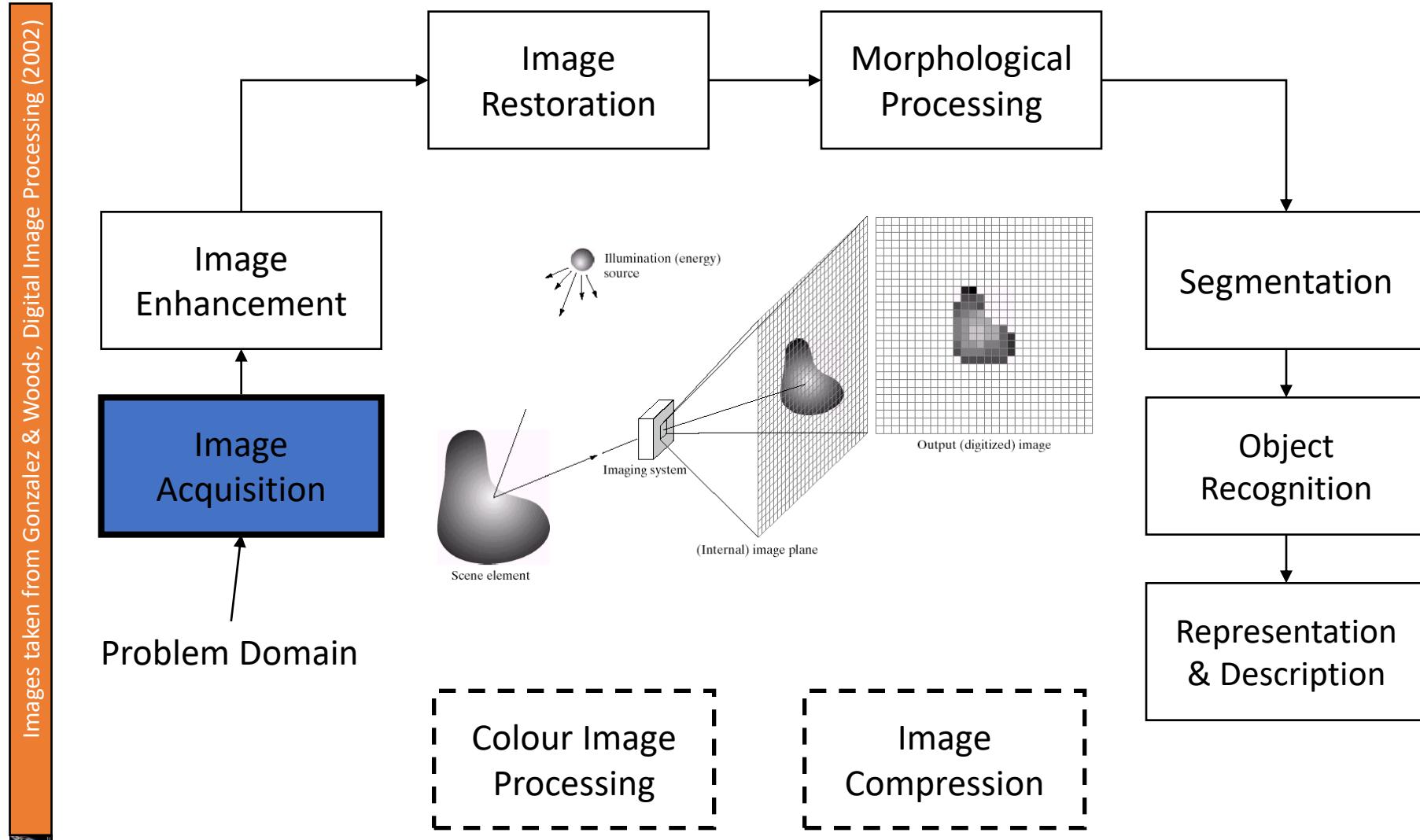
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung
2025

Key Stages in Digital Image Processing



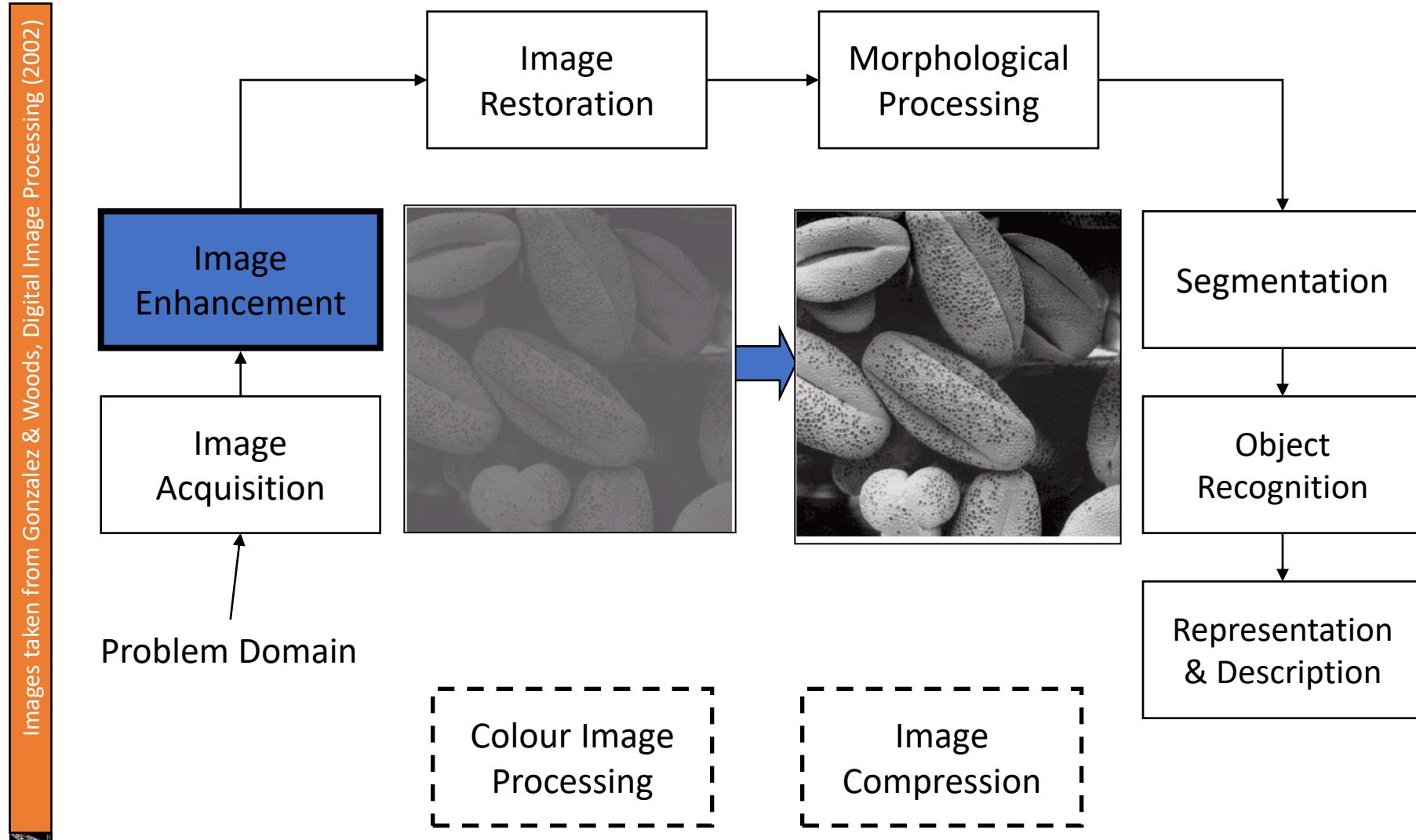
Key Stages in Digital Image Processing: Image Acquisition

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



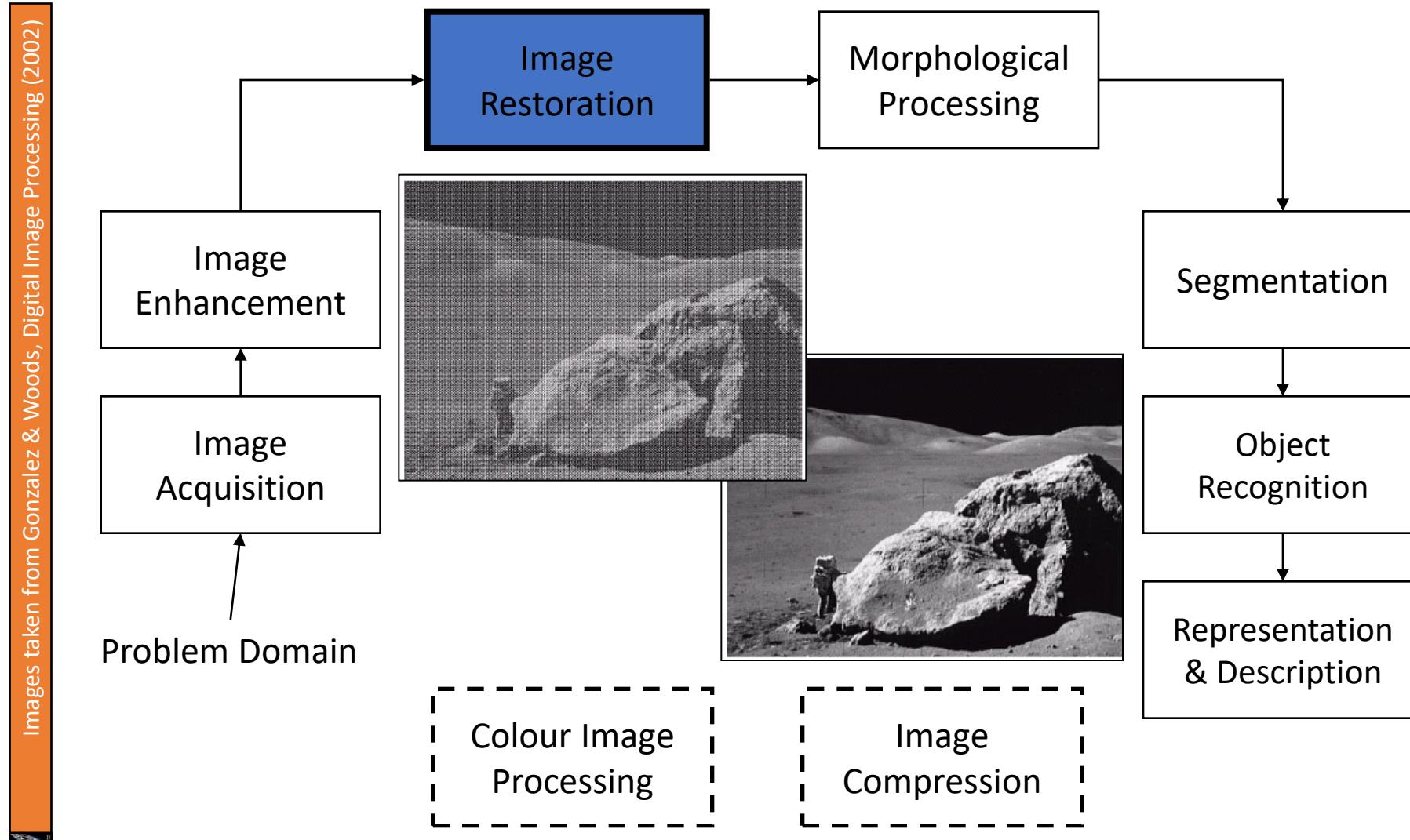
Key Stages in Digital Image Processing: Image Enhancement

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



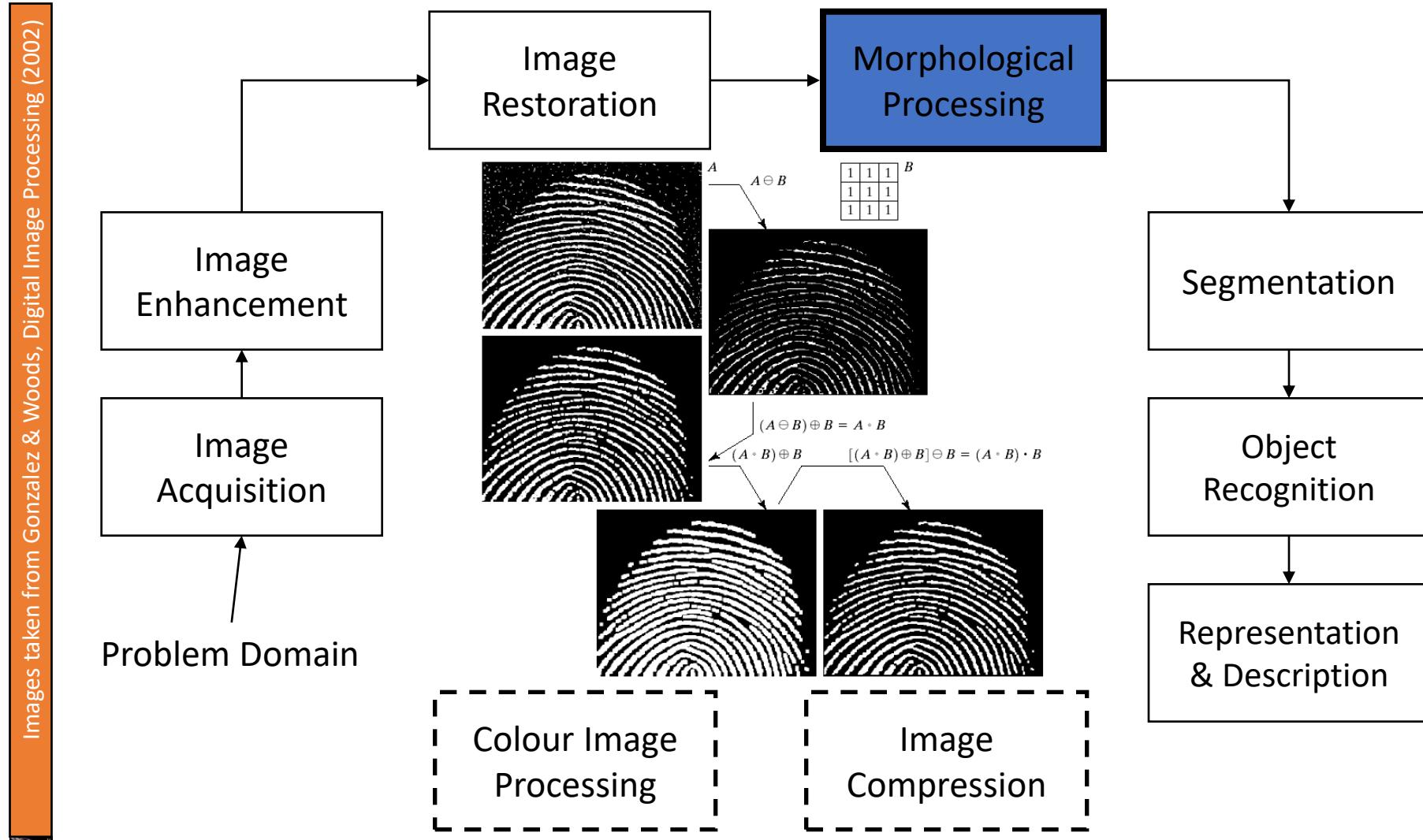
Key Stages in Digital Image Processing: Image Restoration

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



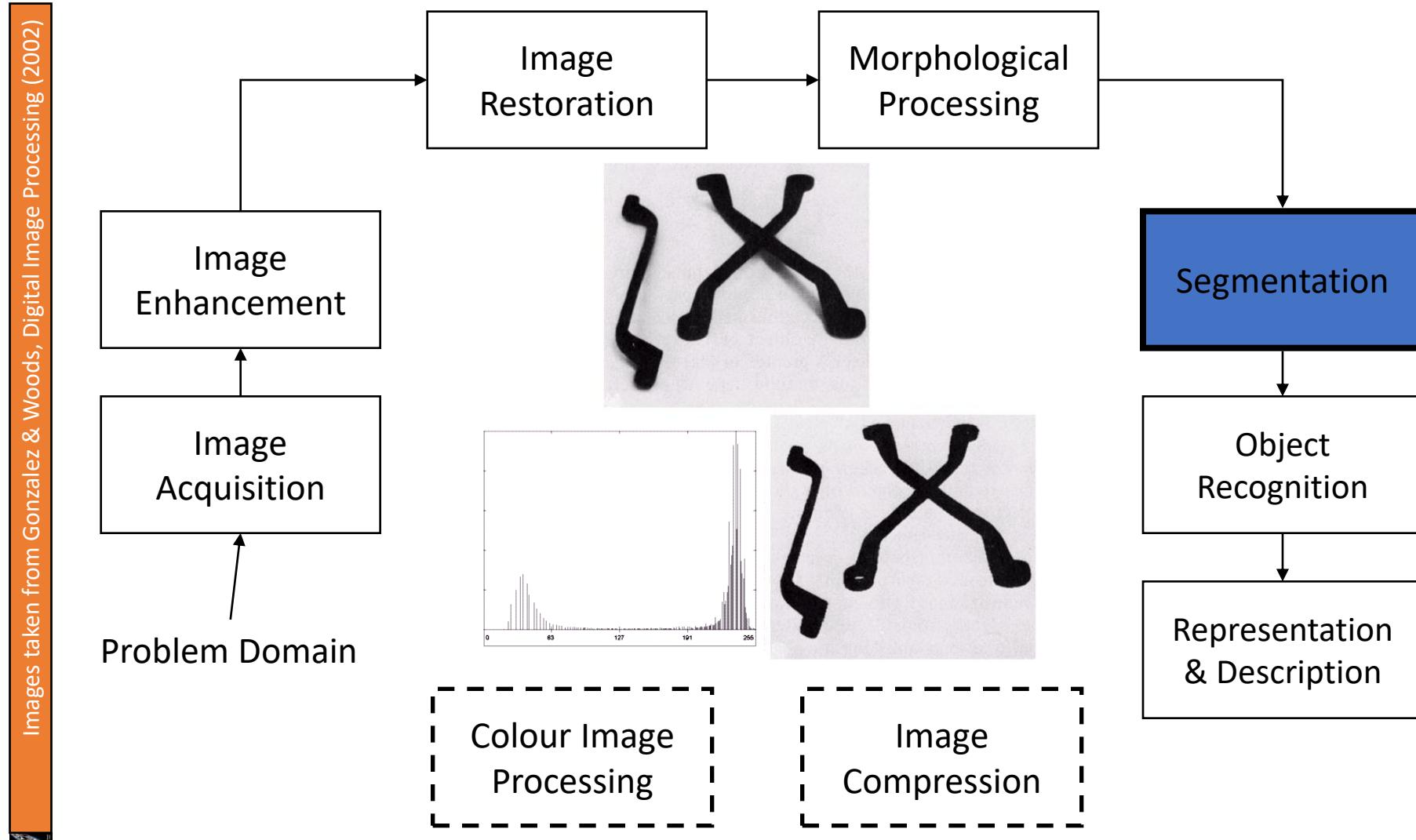
Key Stages in Digital Image Processing: Morphological Processing

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



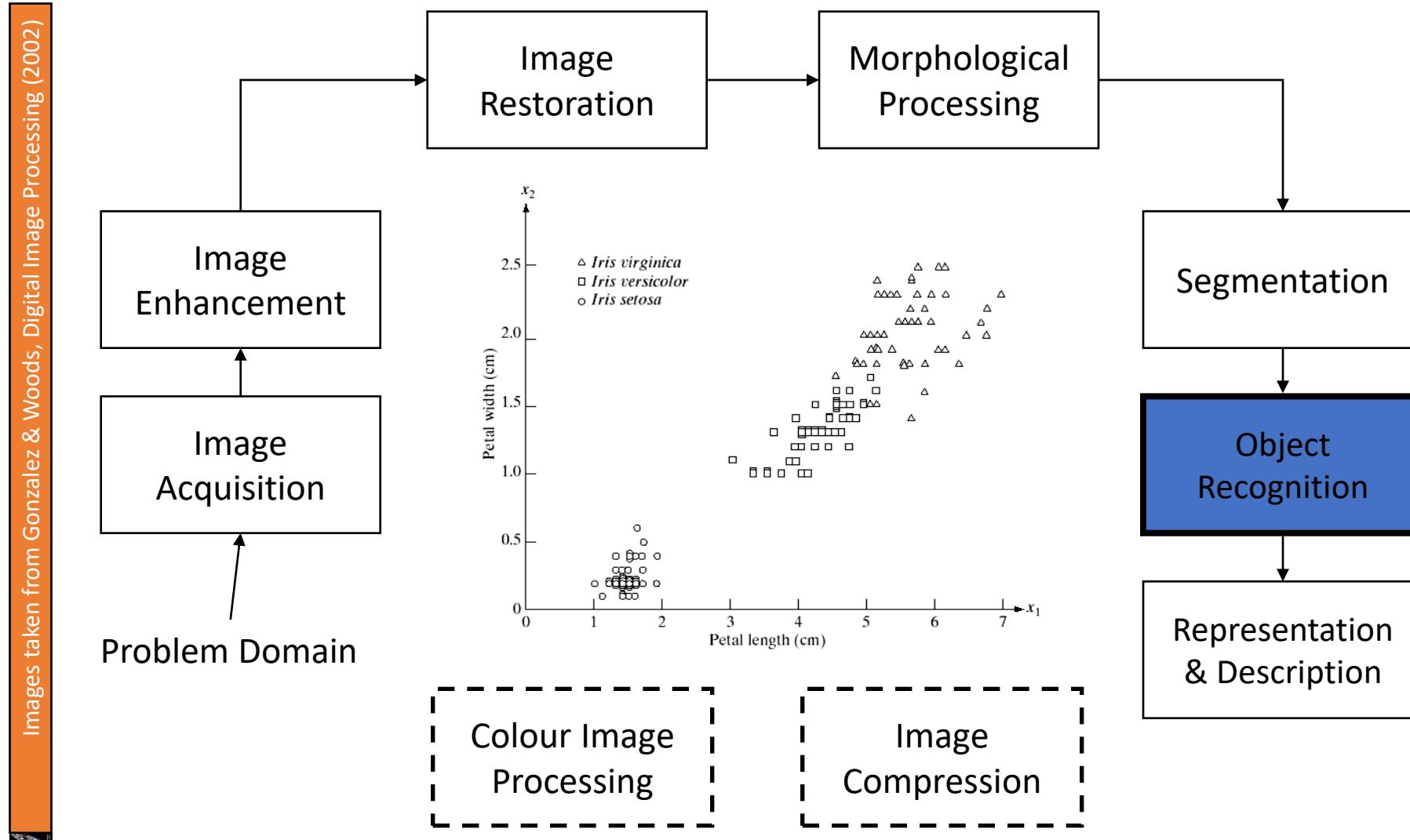
Key Stages in Digital Image Processing: Segmentation

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



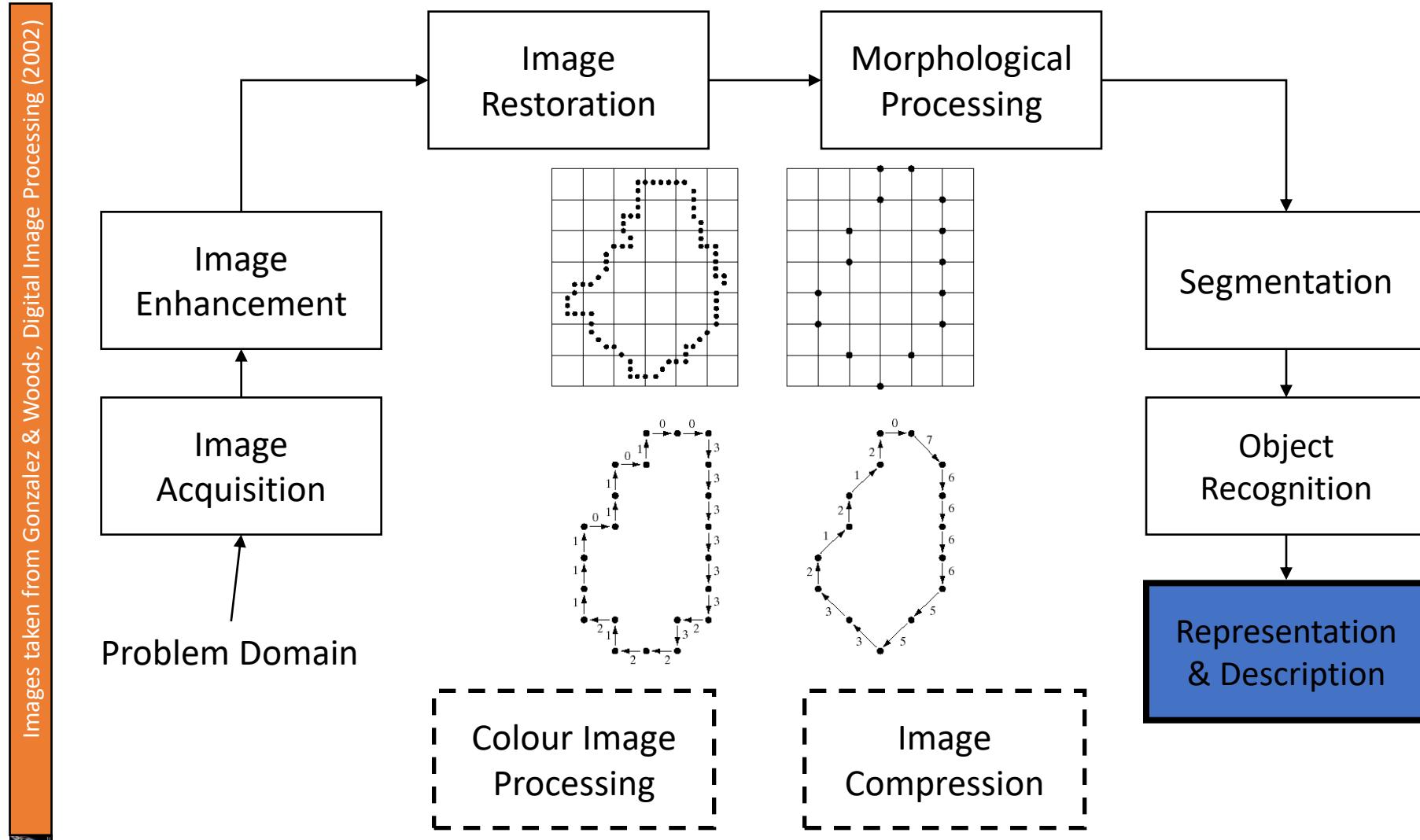
Key Stages in Digital Image Processing: Object Recognition

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



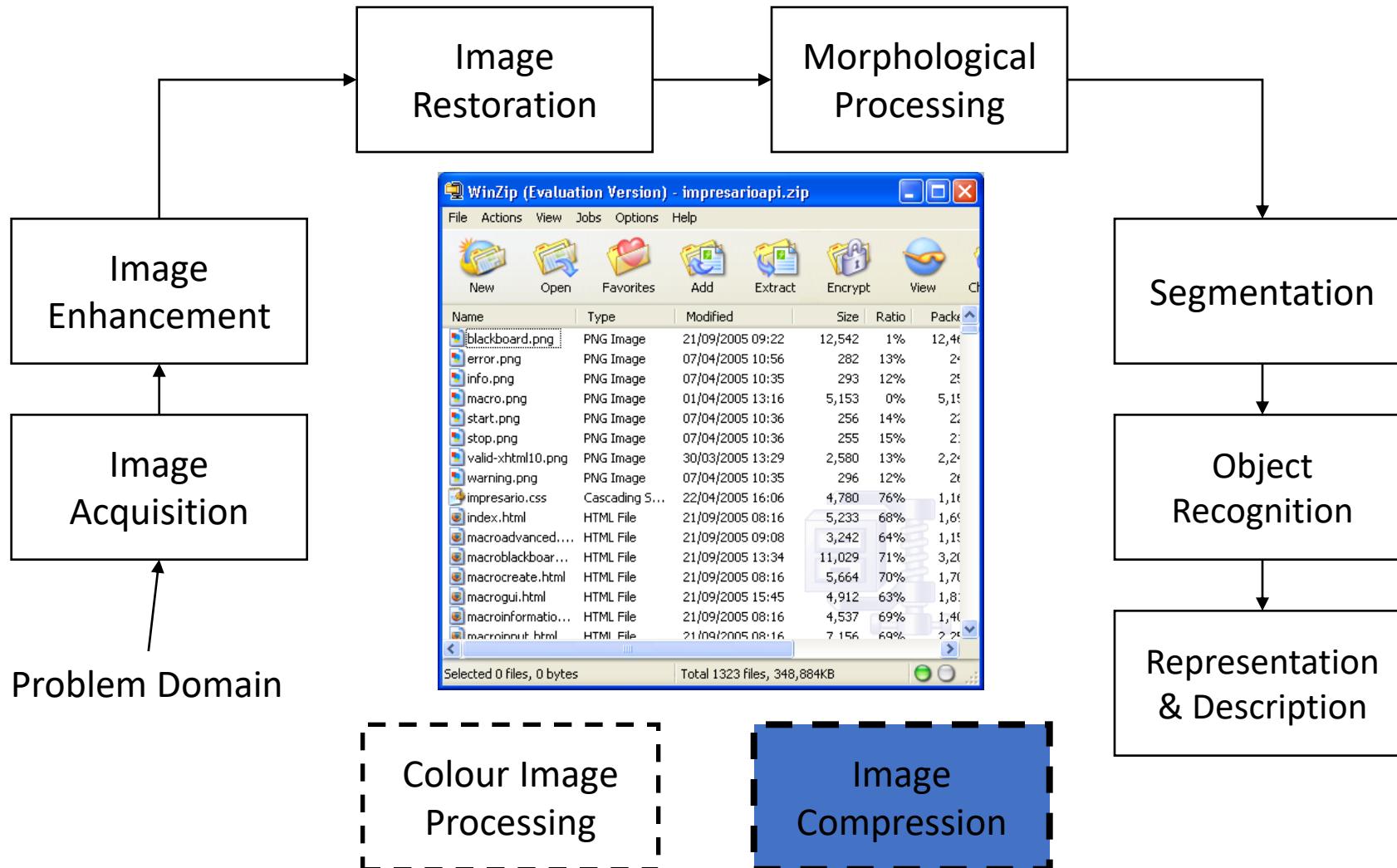
Key Stages in Digital Image Processing: Representation & Description

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



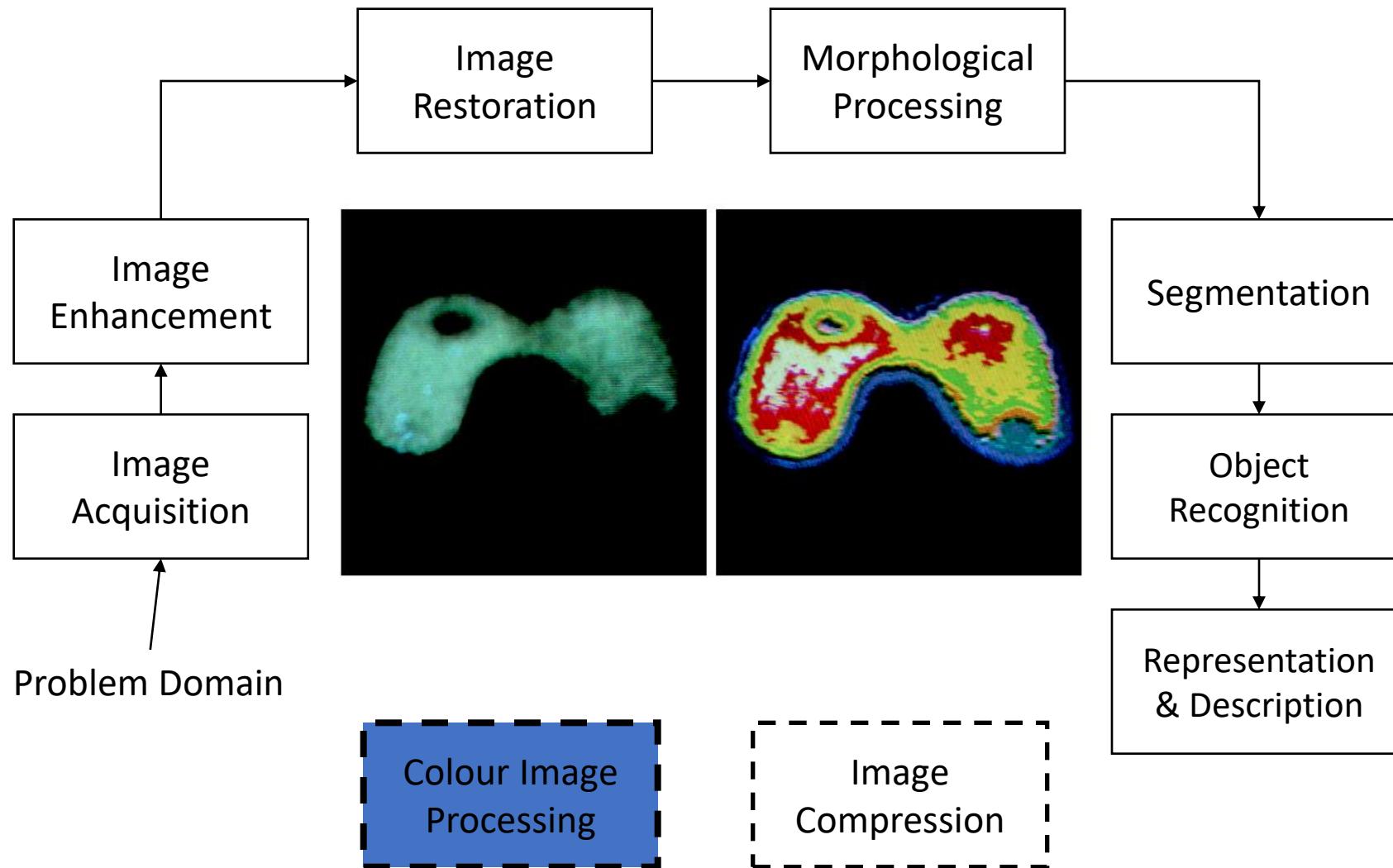
Key Stages in Digital Image Processing: Image Compression

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



Key Stages in Digital Image Processing: Colour Image Processing

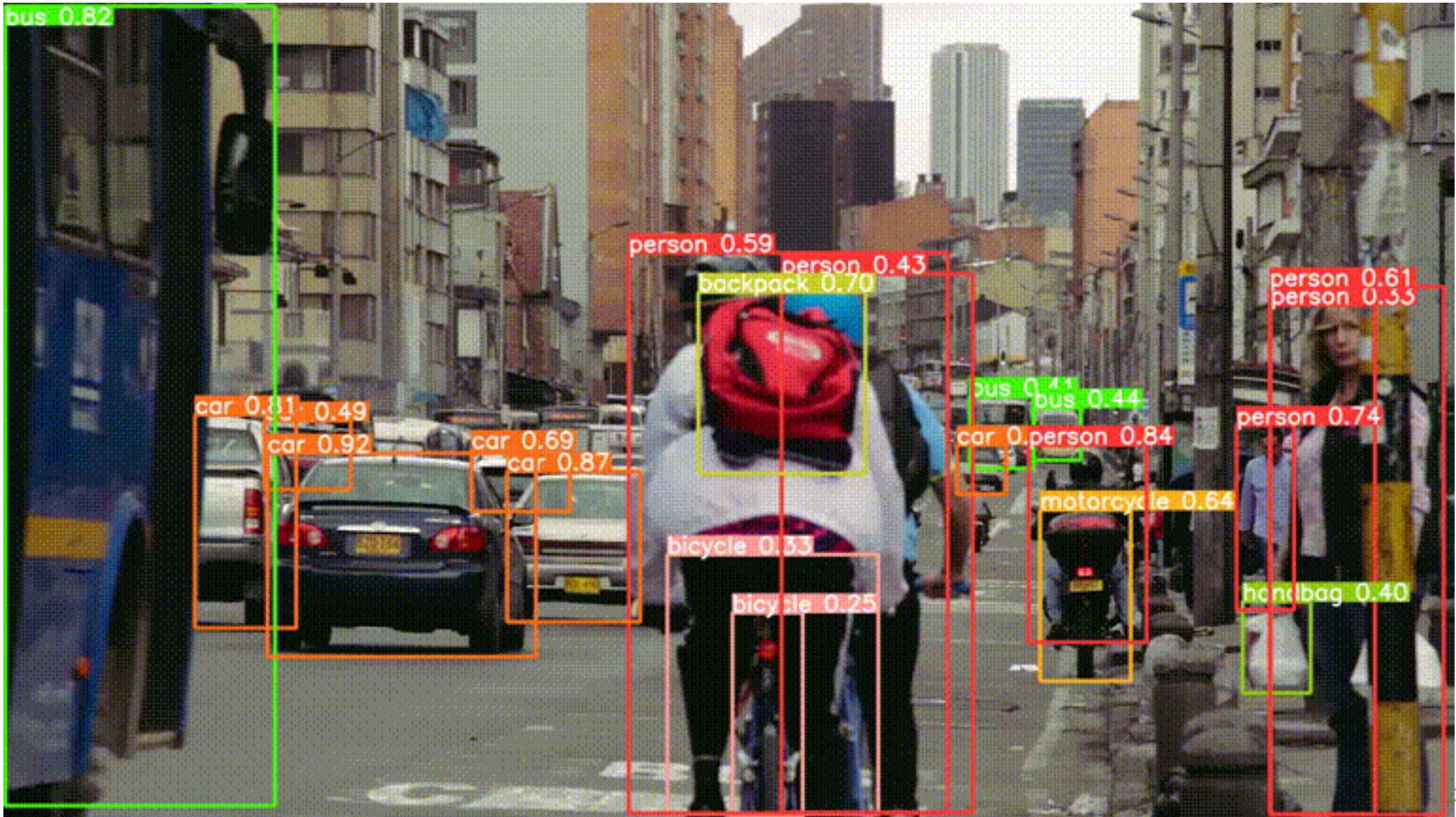
Sumber: Yacov Hel-Or, *Image Processing*, Spring 2010

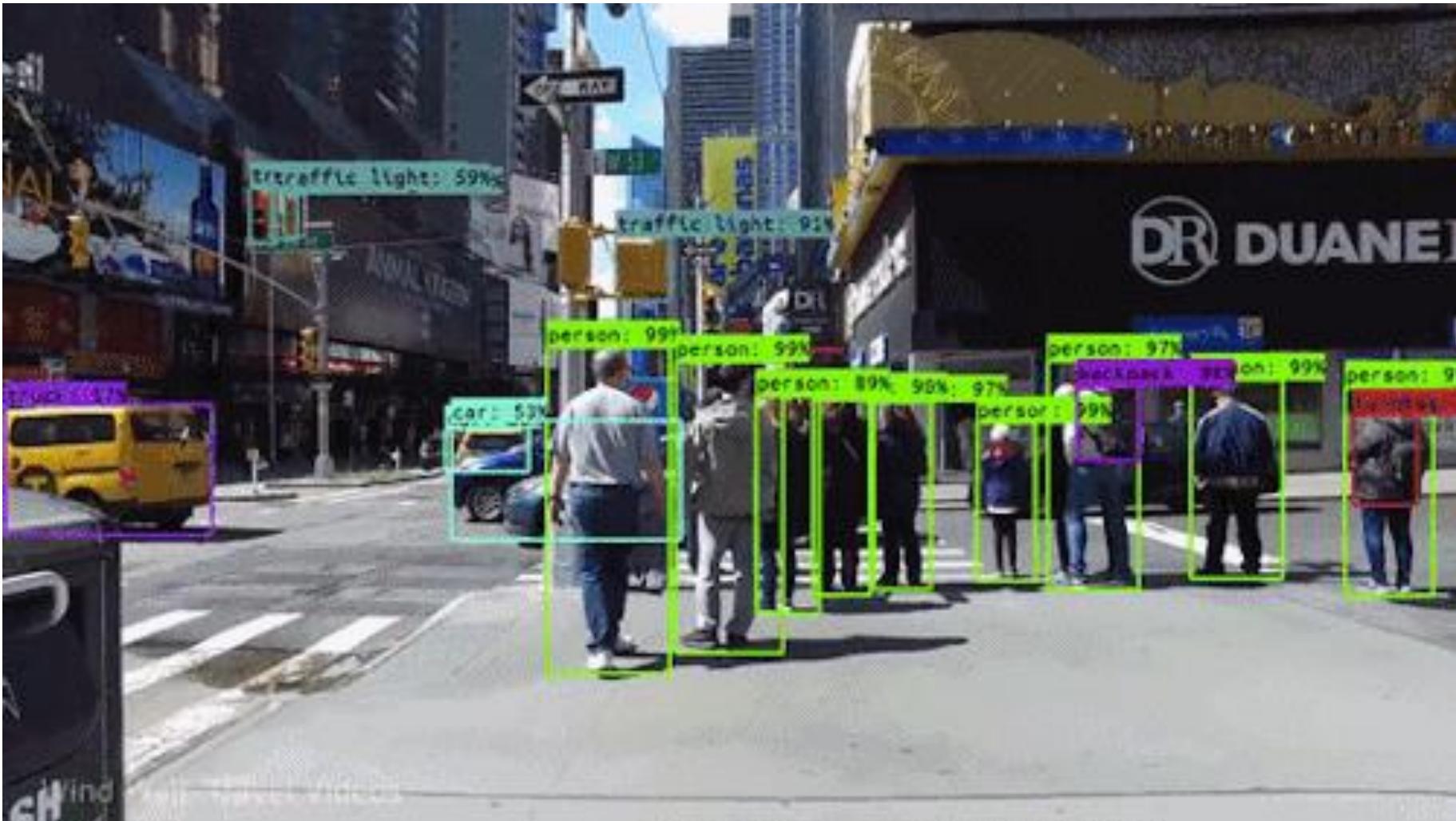


Computer Vision

- *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/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 :

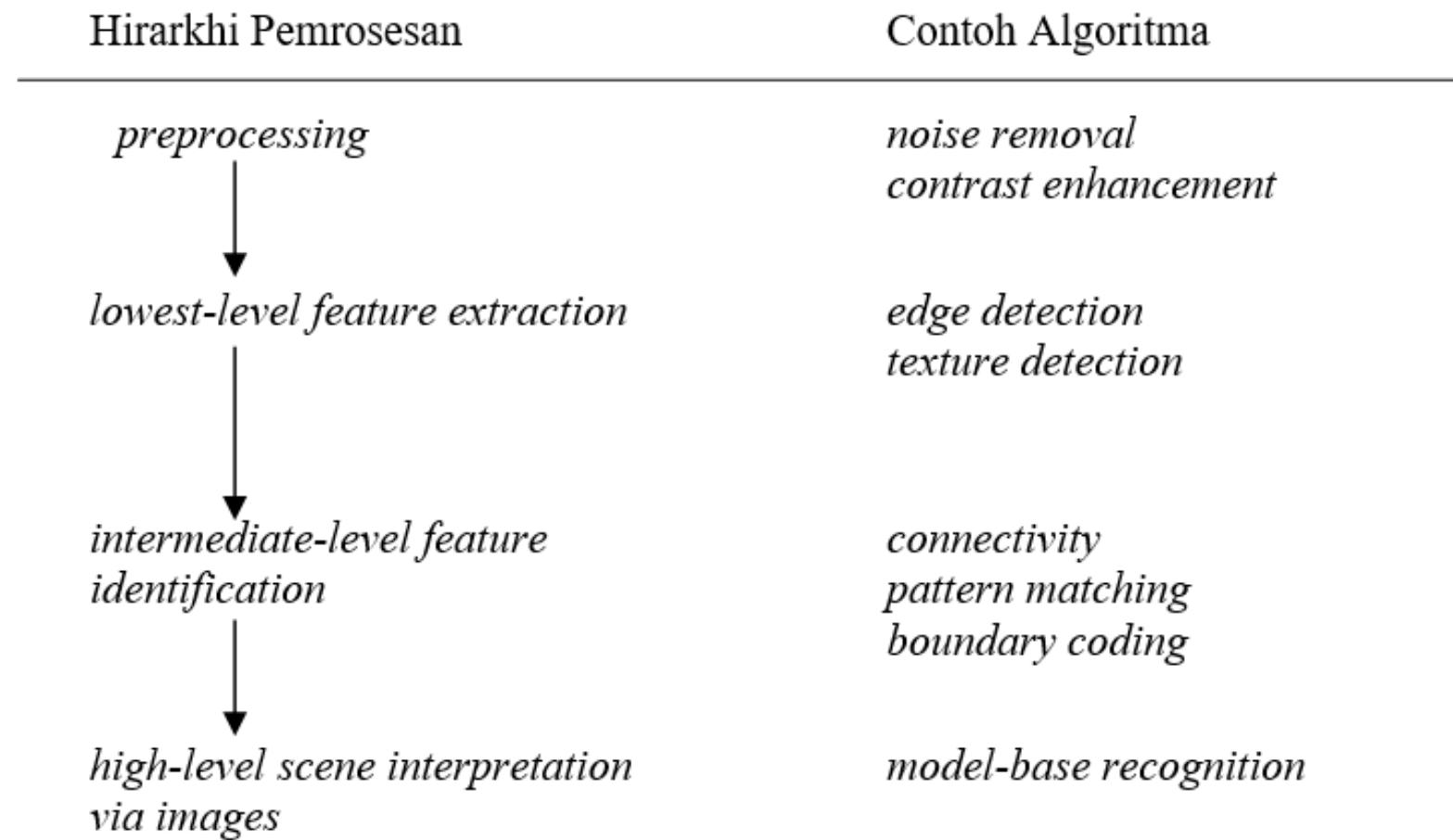
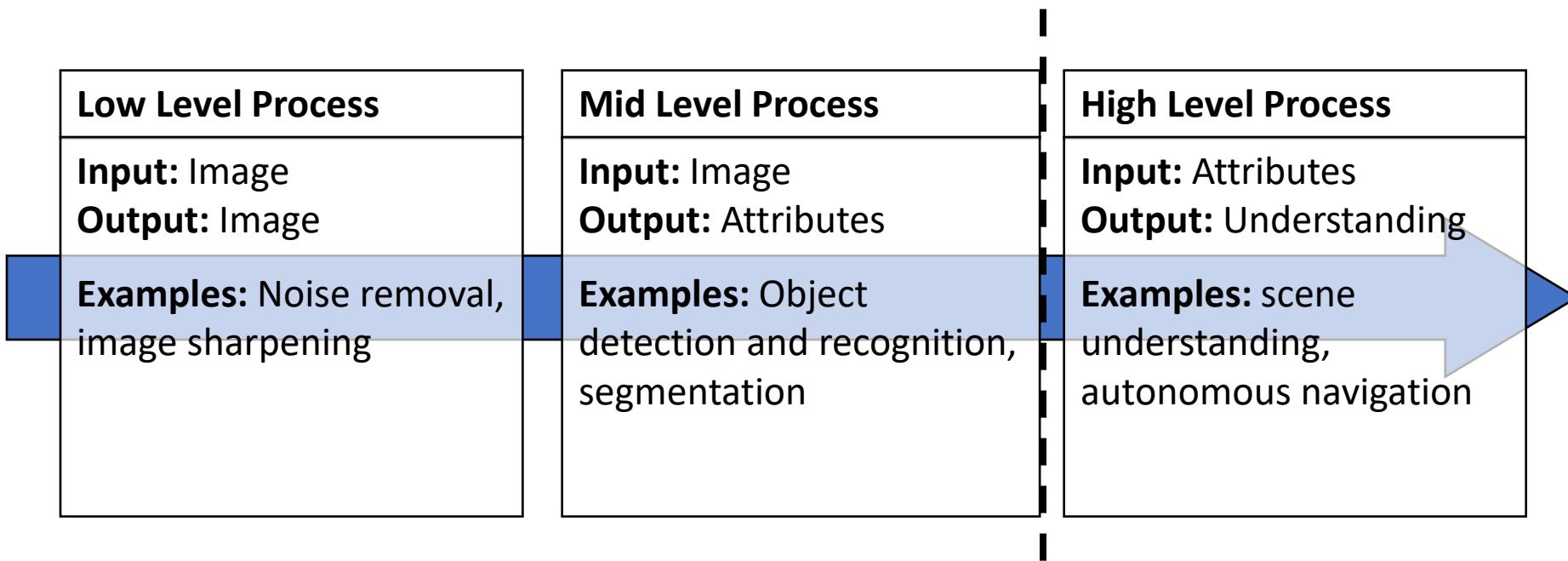


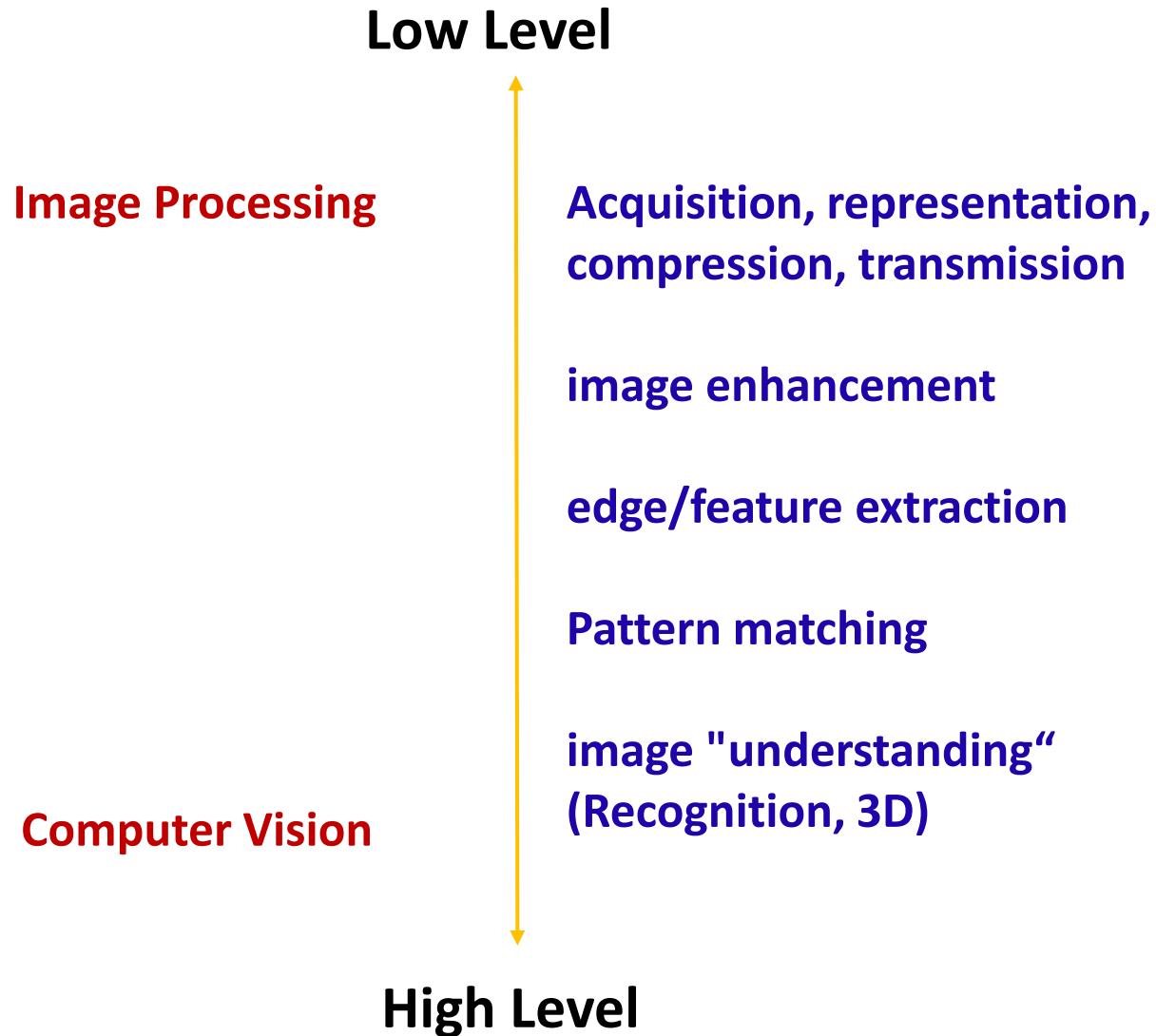
Image Processing → Computer Vision

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



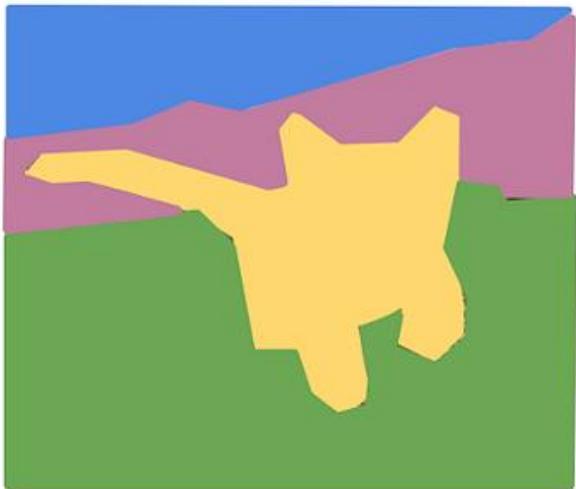
Kuliah IF4073 sampai di
sini saja

Image Processing v.s. Computer Vision





Semantic Segmentation



GRASS, CAT,
TREE, SKY

No objects, just pixels

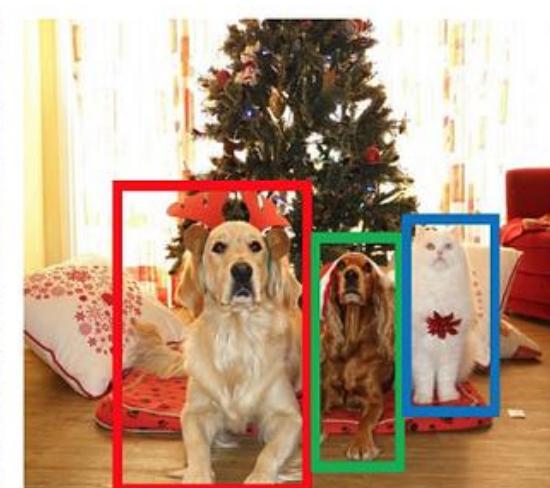
Classification + Localization



CAT

Single Object

Object Detection



DOG, DOG, CAT

Multiple Object

Instance Segmentation

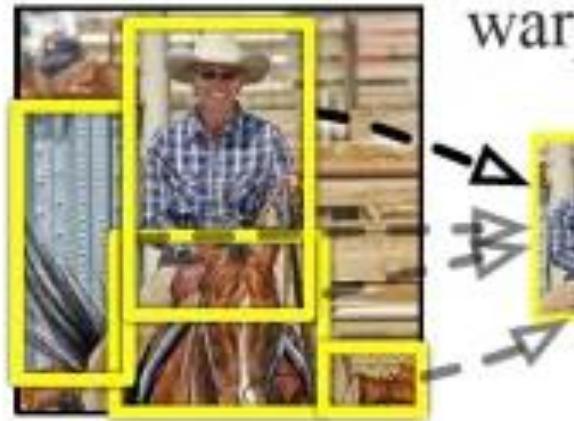


DOG, DOG, CAT

[This image is CC0 public domain](#)

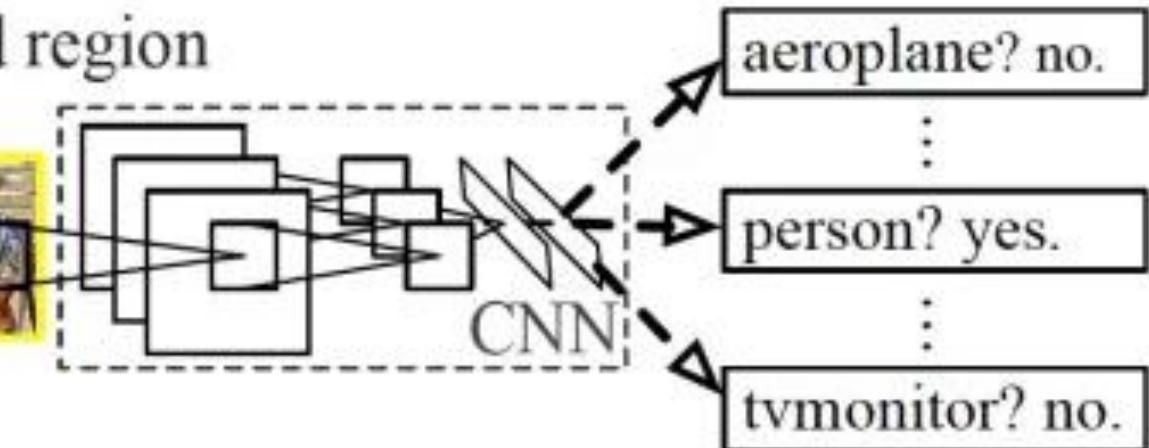


1. Input
image



2. Extract region
proposals (~2k)

warped region



3. Compute
CNN features

4. Classify
regions

Aplikasi Pemrosesan Citra (dan Computer Vision)

- *Image editing ...*

1. *Cropping*



2. Removal
of unwanted
element



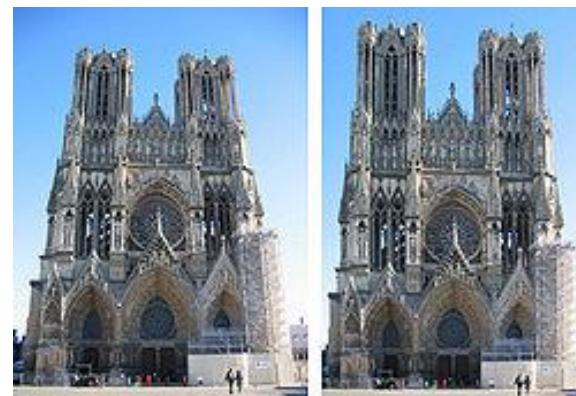
Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *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

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

Aplikasi Pemrosesan Citra (dan Computer Vision)



Image Inpainting 2

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

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

Aplikasi Pemrosesan Citra (dan Computer Vision)



Video Inpainting

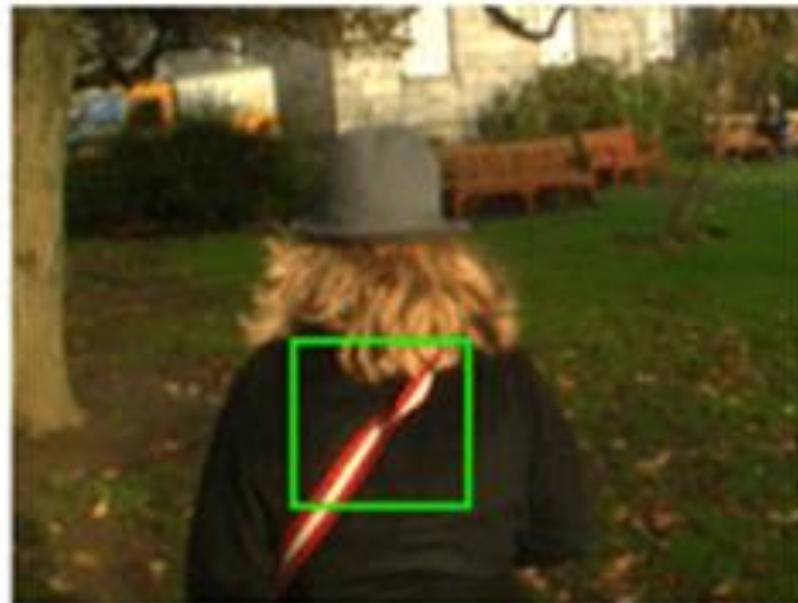
Y. Wexler, E. Shechtman and M. Irani 2004



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

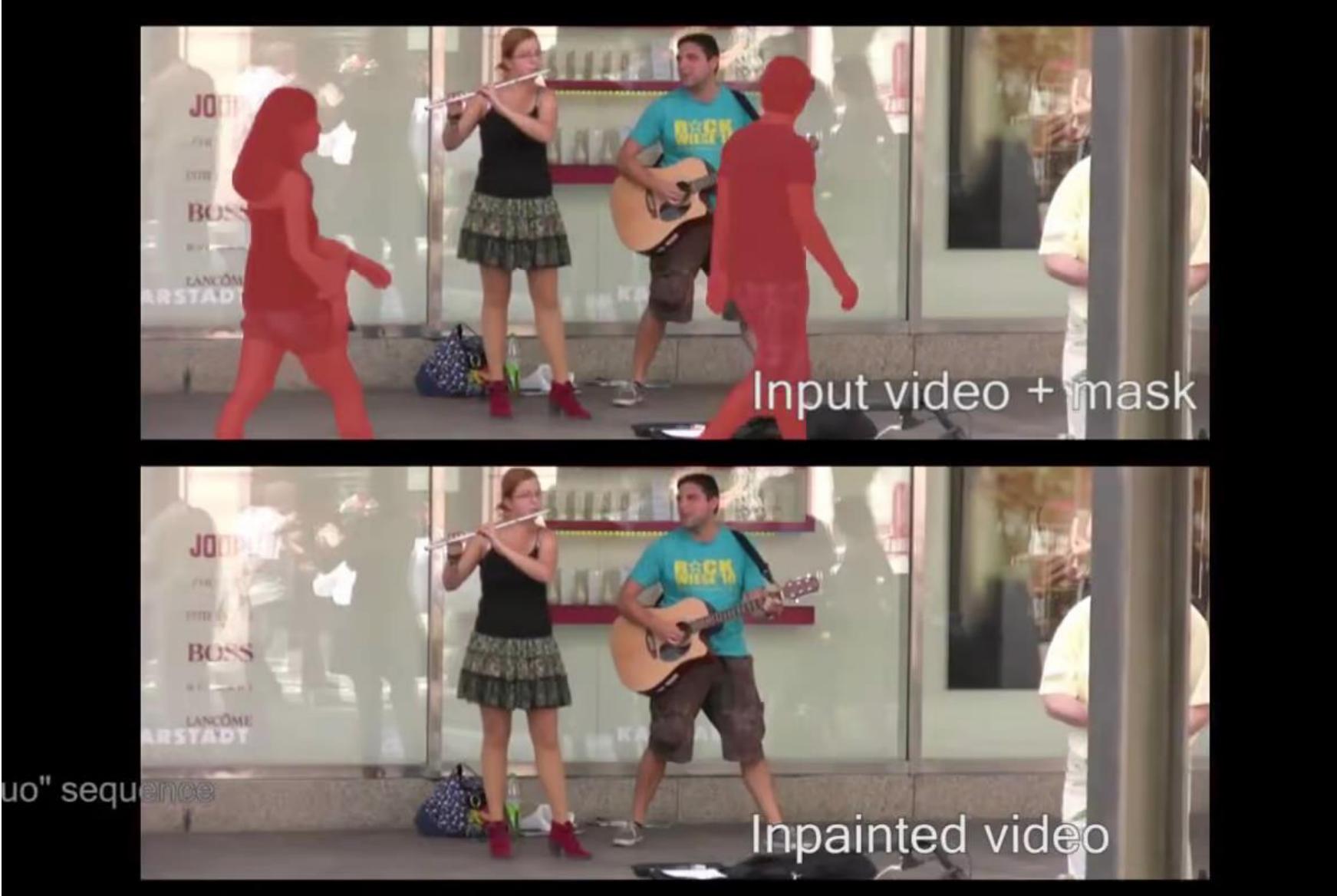


**Degraded image
with hole**



Reconstruction

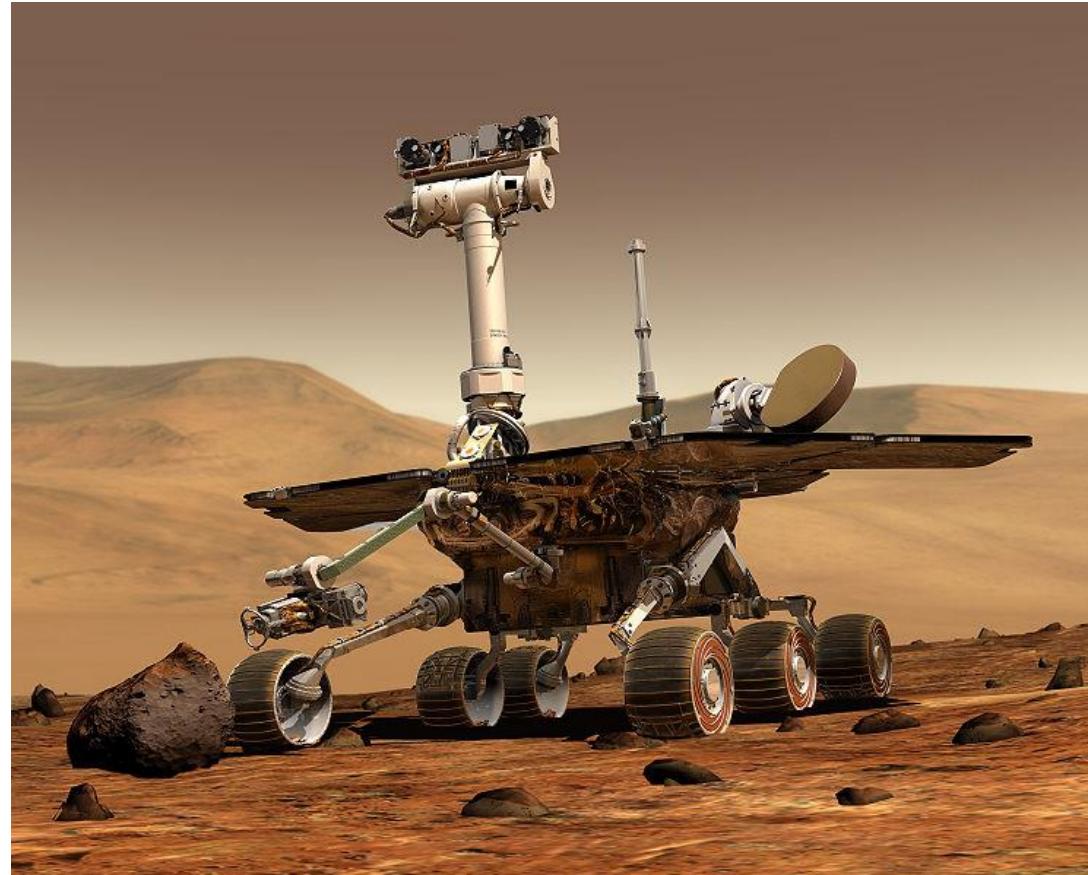
Video Inpainting



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

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Robotika*



Aplikasi Pemrosesan Citra (dan *Computer Vision*)

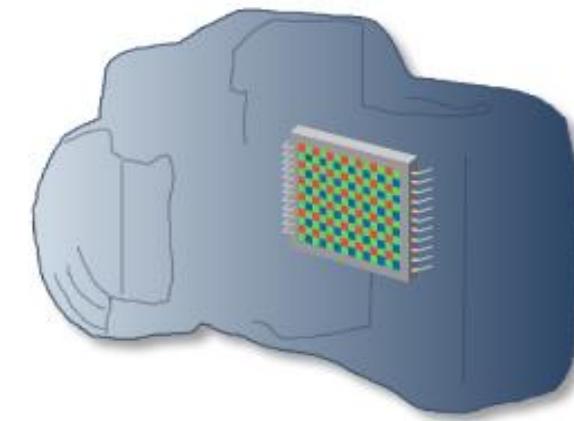
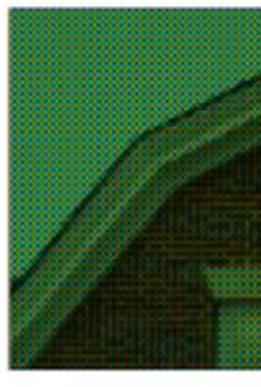
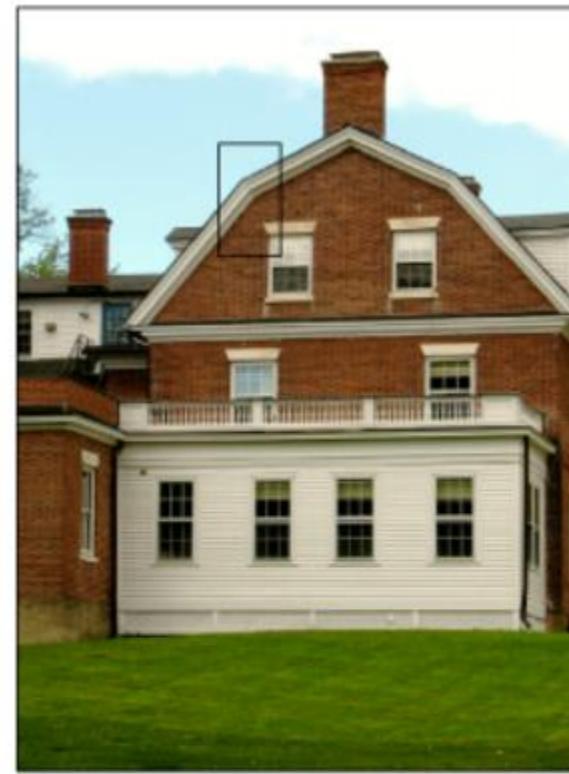


Image Demosaicing



Ground Truth

Raw Image

Label

Nearest

Bilinear

Malvar-He-Cutler

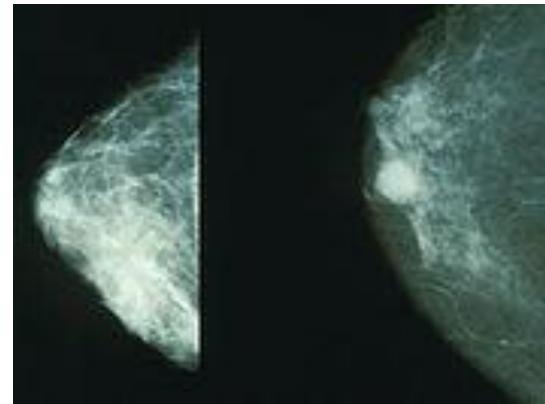
https://www.researchgate.net/figure/Comparision-of-common-demosaicing-methods-applied-to-an-image-of-a-brick-house-and-blue_fig2_220494111

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- Medis



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

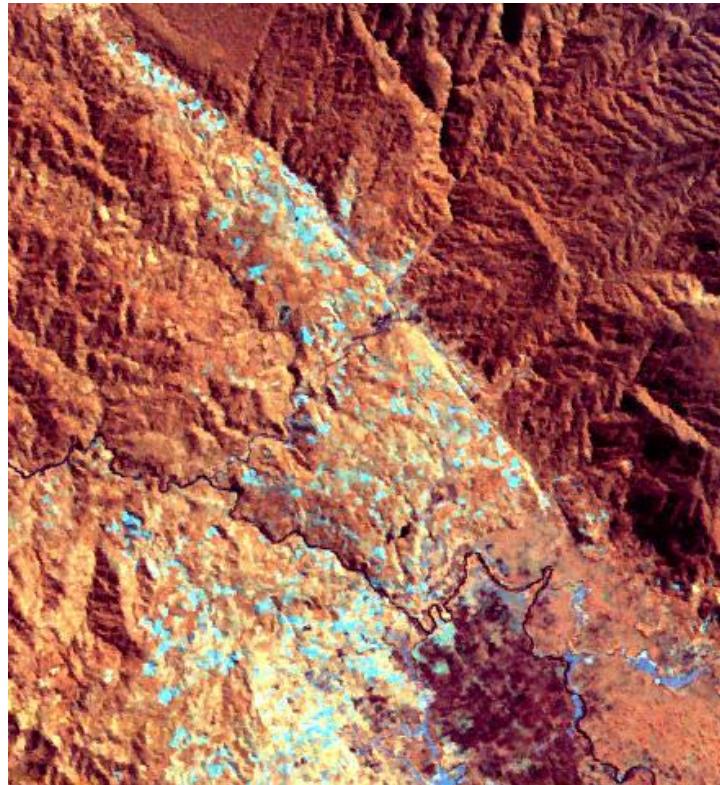


Normal (left) versus cancerous (right)
mammography image.



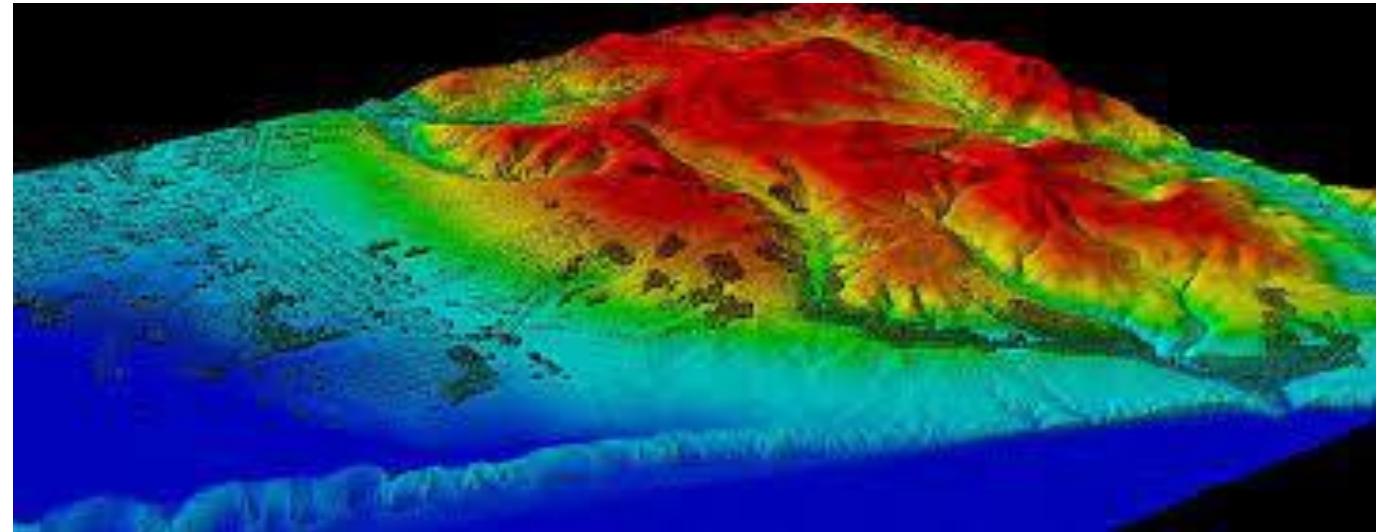
Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- *Remote sensing*



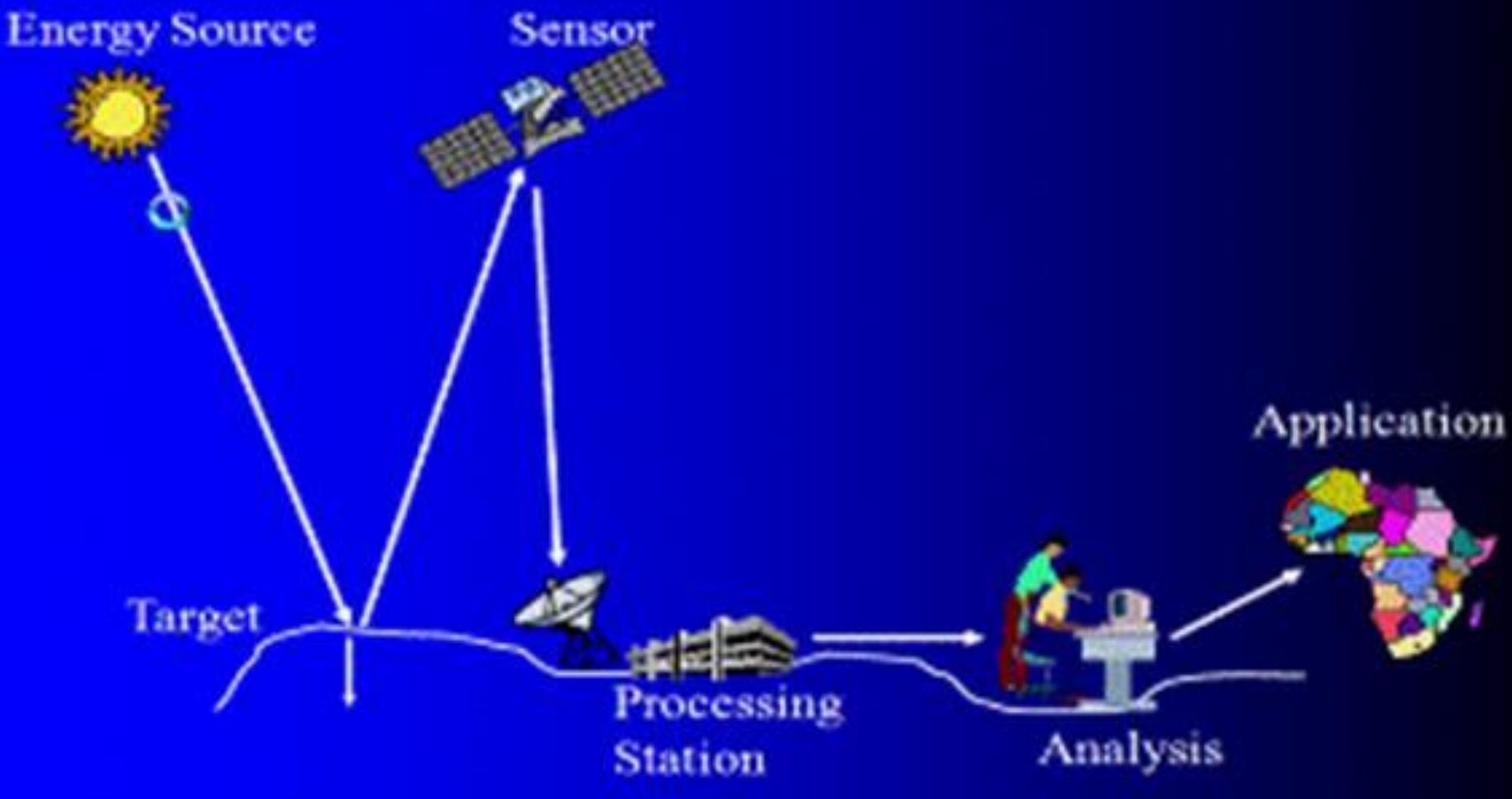
Remote sensing is **the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance** (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the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

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



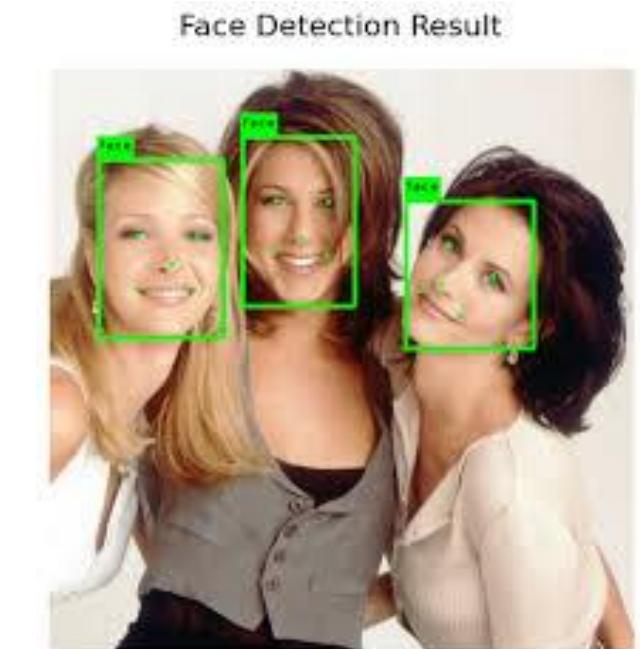
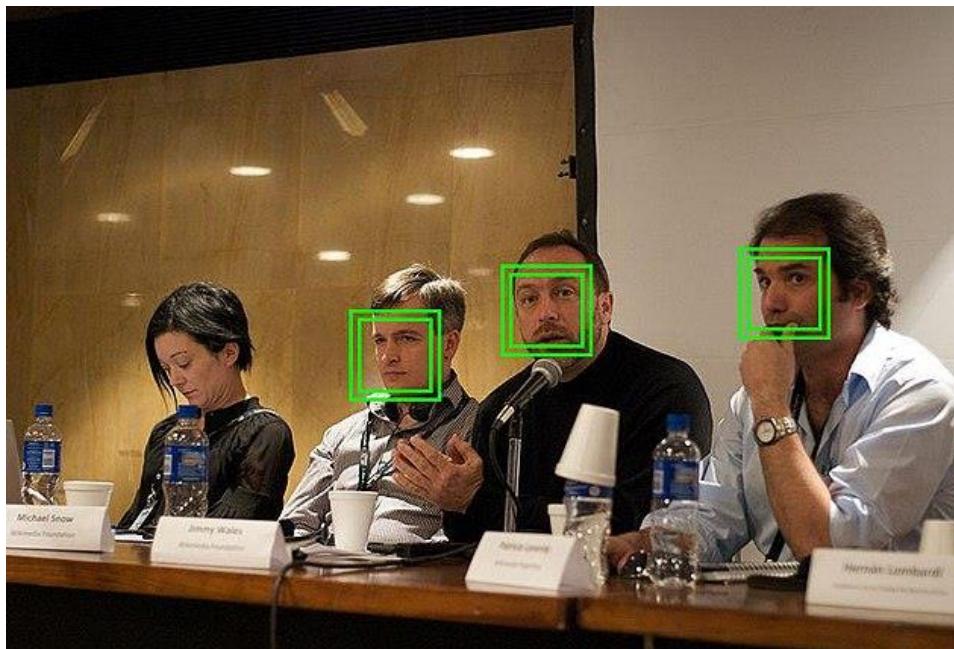
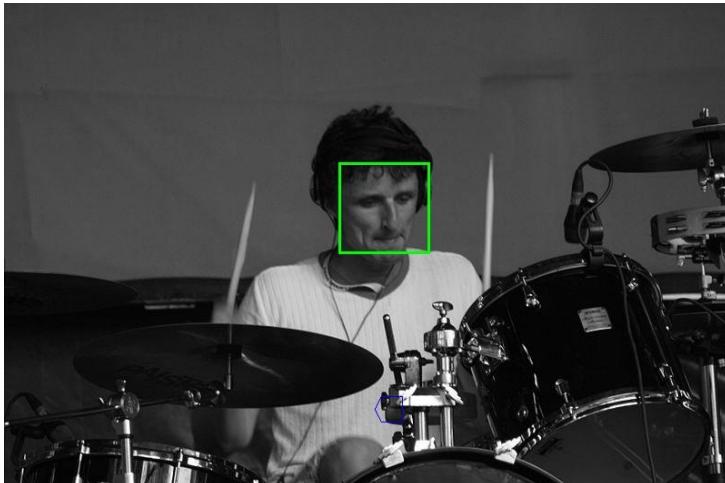
<https://oceanservice.noaa.gov/facts/remotesensing.html>

The Remote Sensing Process

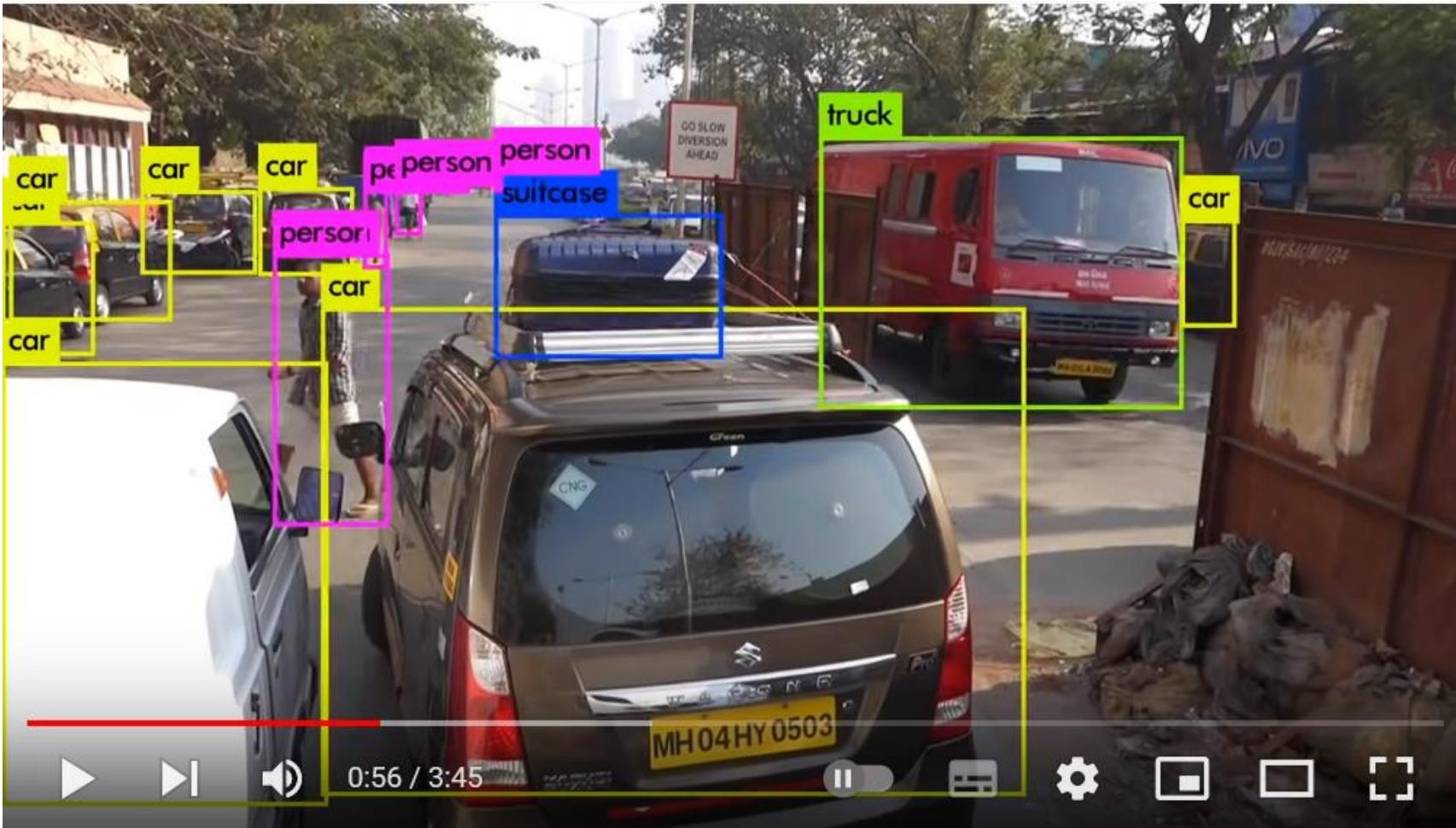


Aplikasi Pemrosesan Citra (dan Computer Vision)

- *Face detection*



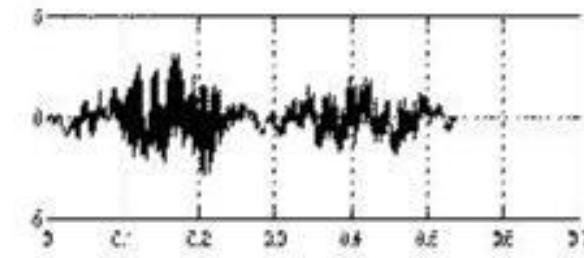
Aplikasi Pemrosesan Citra (dan Computer Vision): Object Detection



Object Detection

Video di Youtube: <https://www.youtube.com/watch?v=MPU2Histiv4&t=34s>

Aplikasi Pemrosesan Citra (dan Computer Vision)



John Smith

Biometrics

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

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

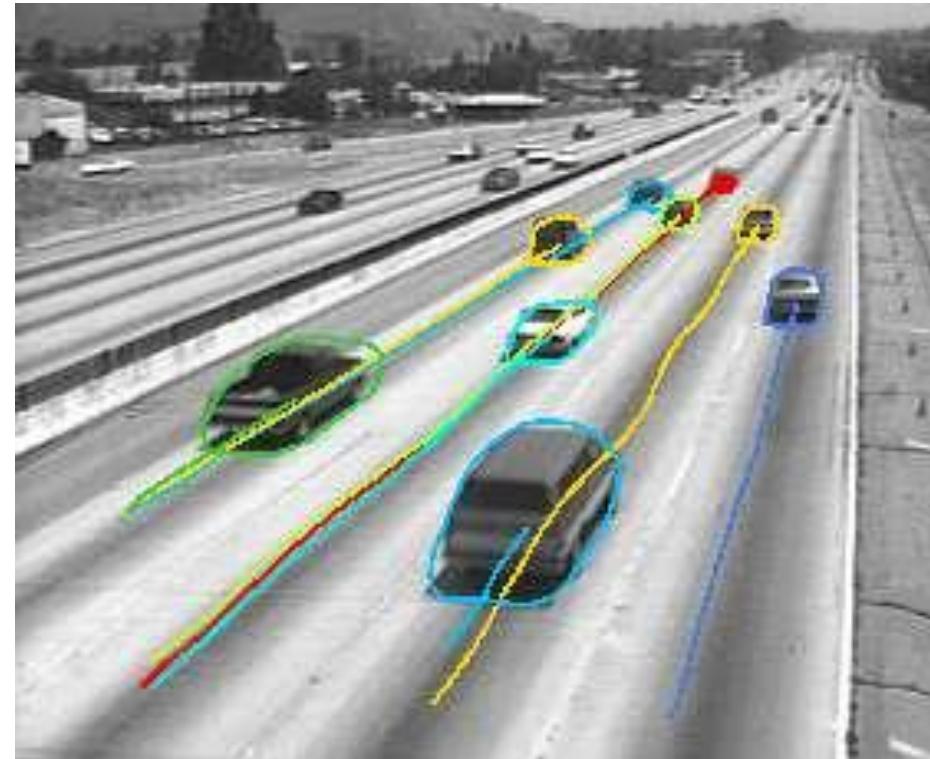
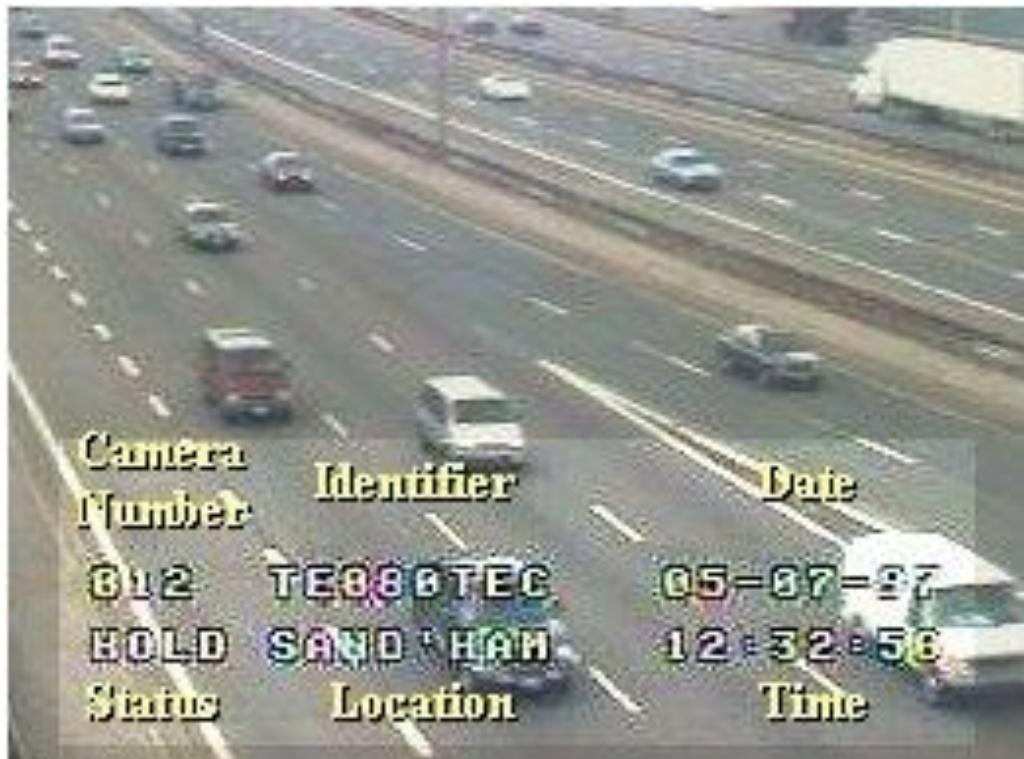
- Land, Underwater, Space

Autonomous Vehicles



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

Aplikasi Pemrosesan Citra (dan Computer Vision)

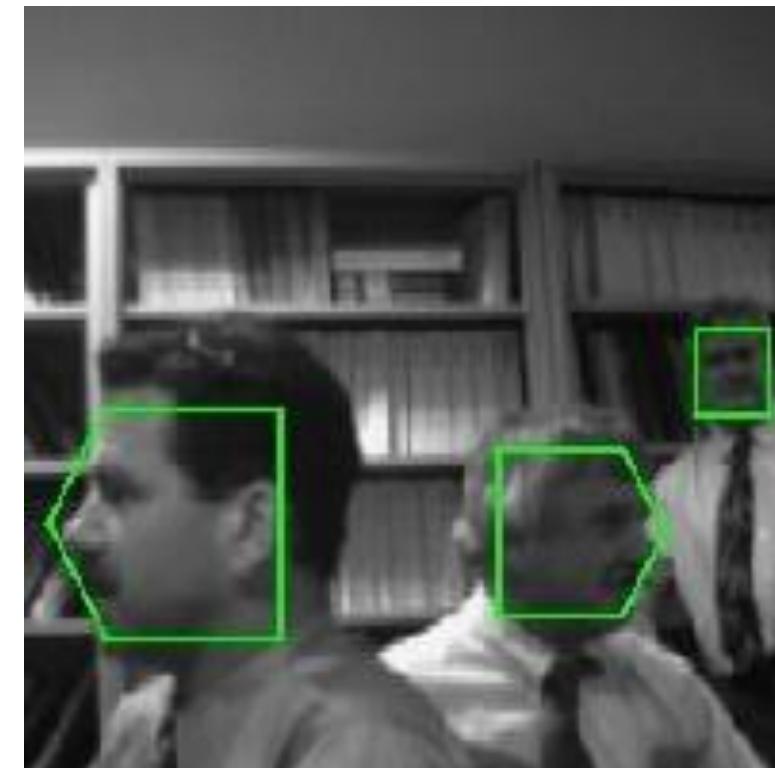


- Kemacetan:
- Lancar
 - Macet parah
 - Macet ringan

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

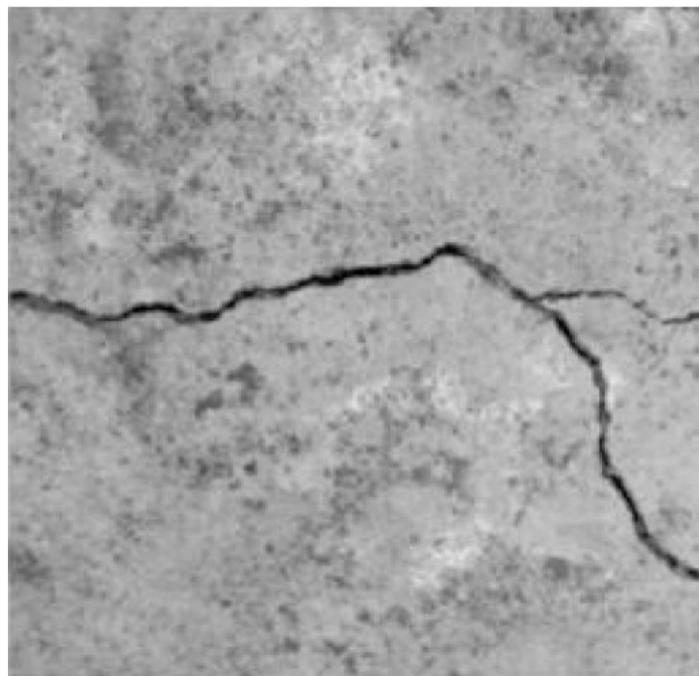
Aplikasi Pemrosesan Citra (dan Computer Vision)



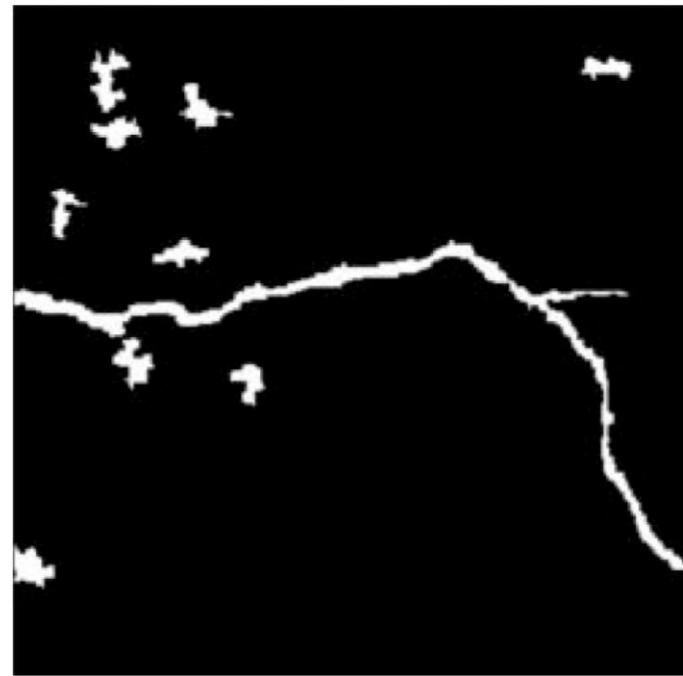
Gambar IV.25 Hasil percobaan pengujian menggunakan webcam dengan kondisi tambahan cahaya

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

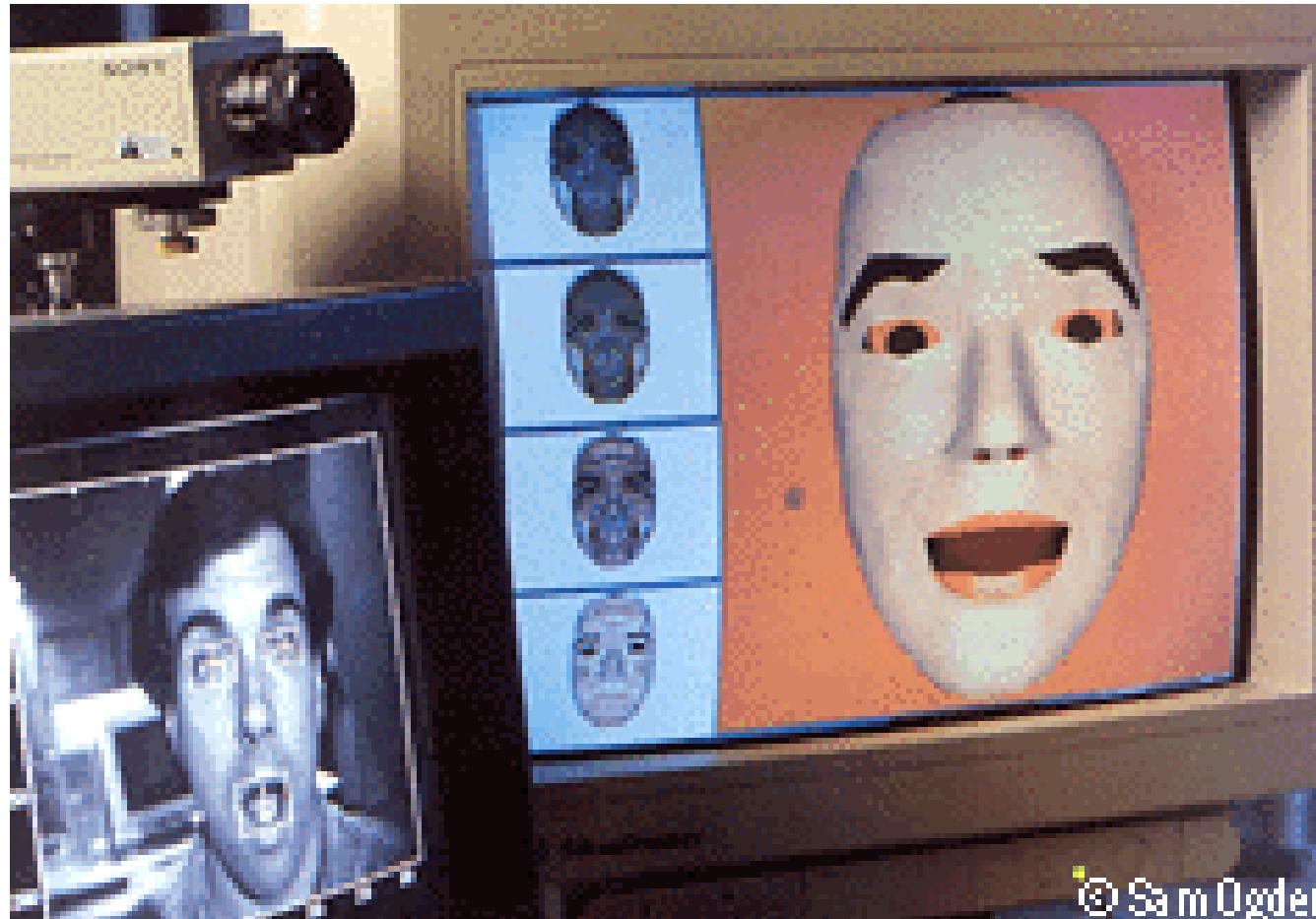
Nhat-Duc Hoang   ¹

[Show more](#)

Academic Editor: Pier Paolo Rossi

Received	Revised	Accepted	Published
11 Oct 2017	03 Mar 2018	14 Mar 2018	02 Apr 2018

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

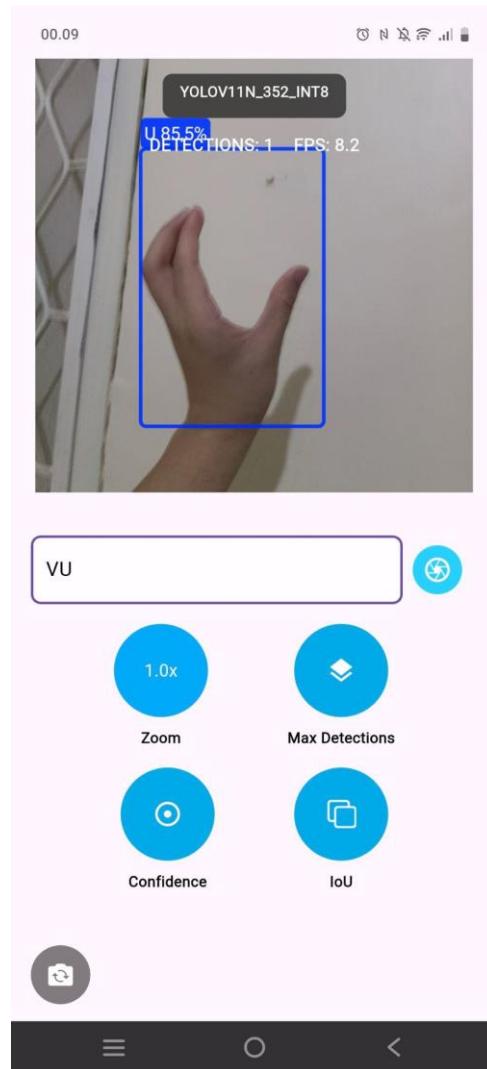
Aplikasi Pemrosesan Citra (dan *Computer Vision*)

- Sign Language Recognition

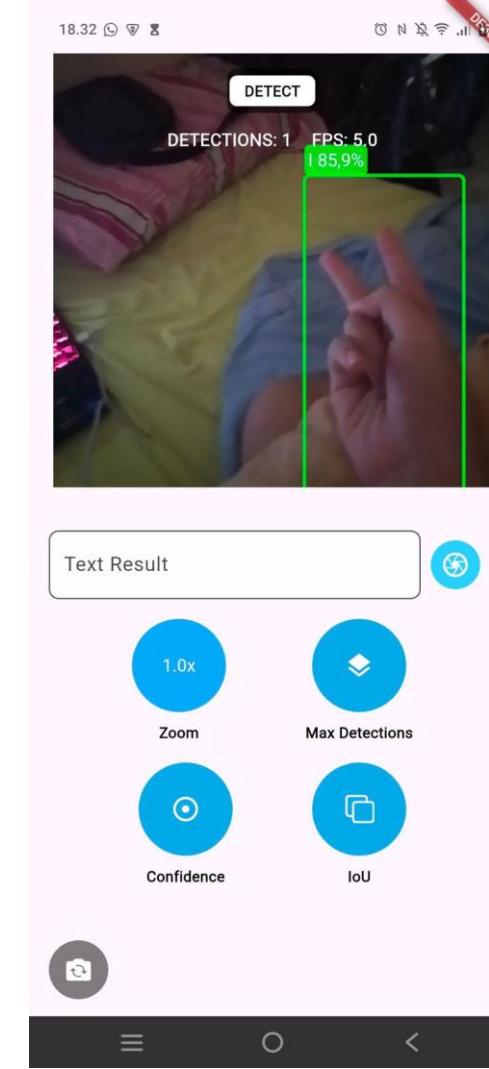
Tugas Akhir

Pengembangan Aplikasi
Pengenalan Alfabet Bahasa
Isyarat Indonesia (BISINDO)
Dengan Computer Vision

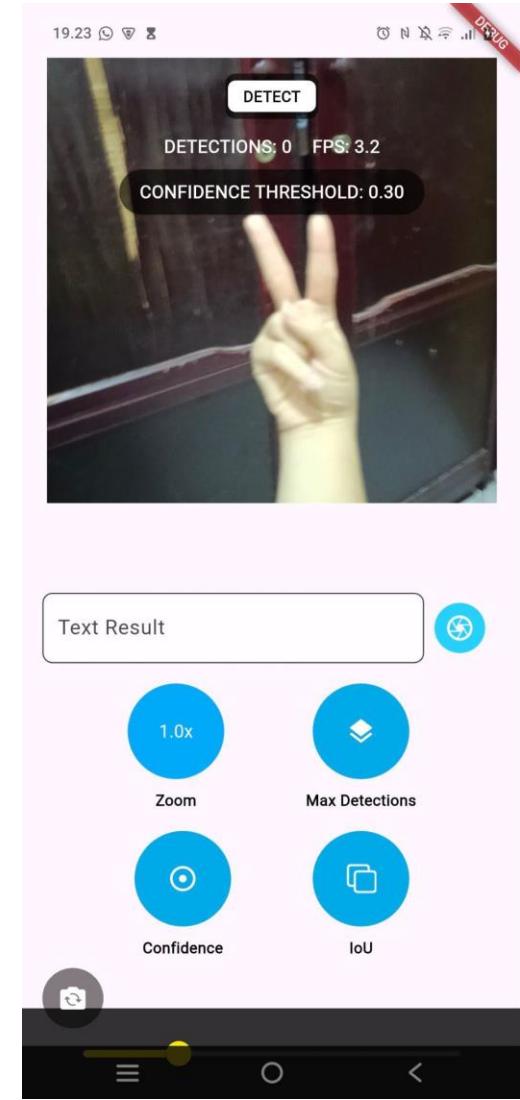
Jeremy Dharmawan Raharjo
13521131



True Positive

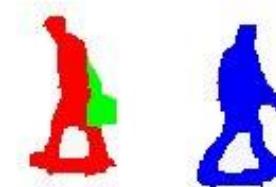
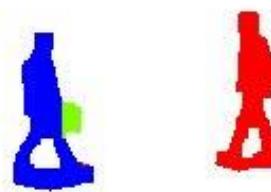
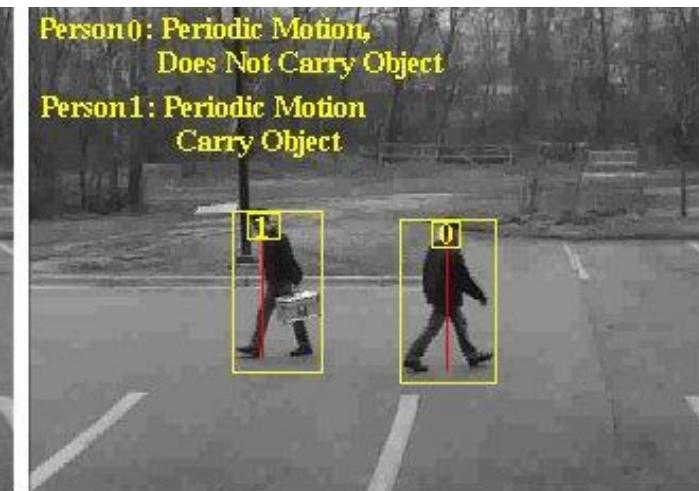
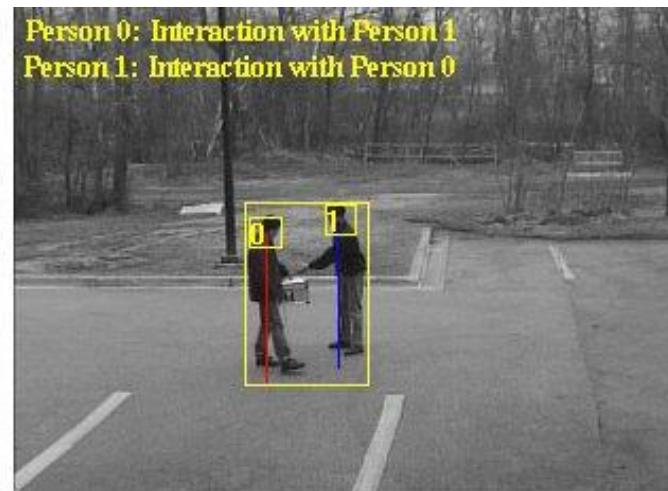
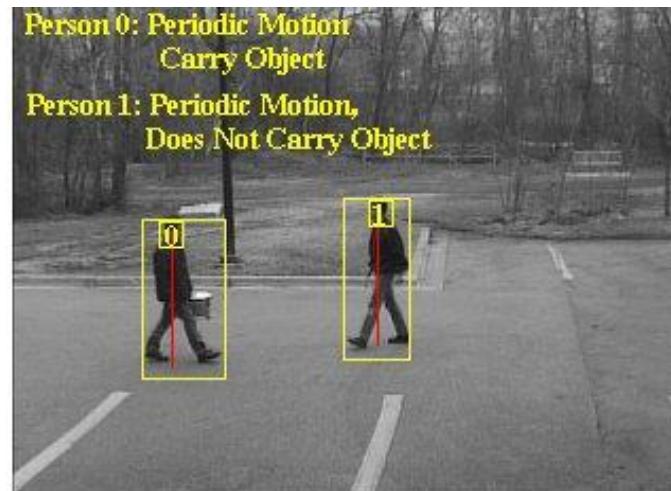


False Positive



False Negative 49

Aplikasi Pemrosesan Citra (dan Computer Vision)

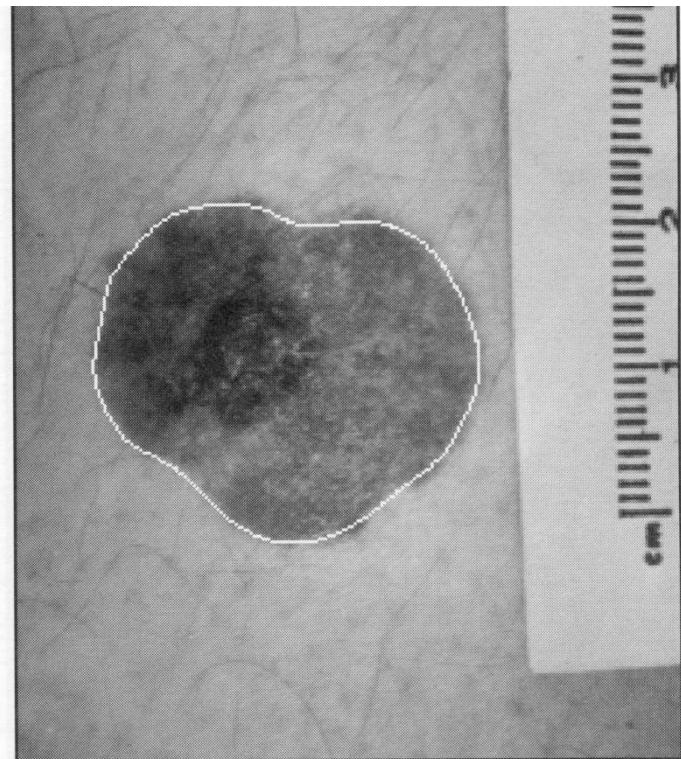


Human Activity Recognition

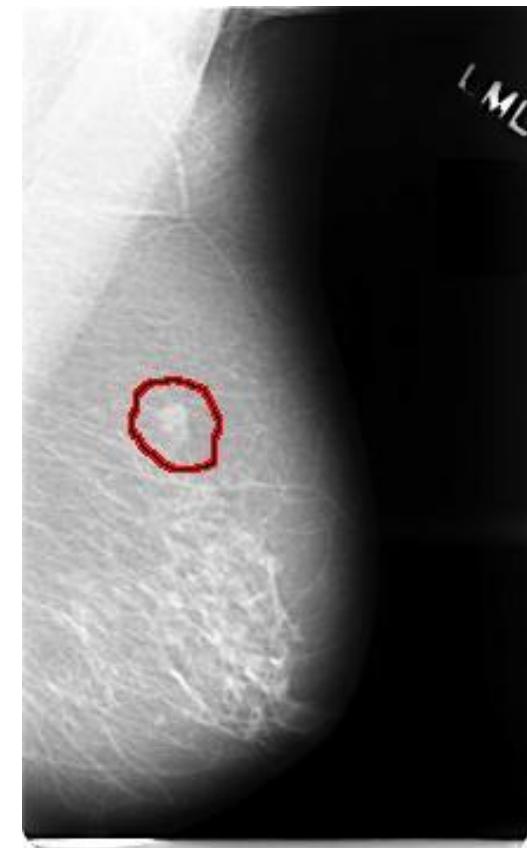
Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*, Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan *Computer Vision*)

skin cancer



breast cancer

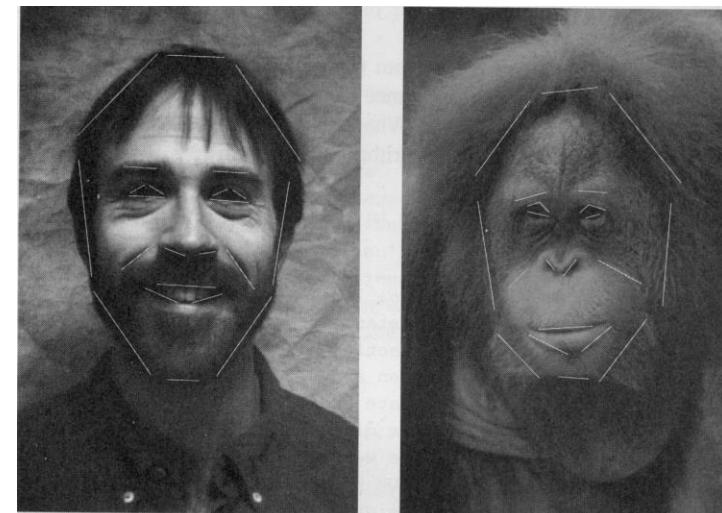


Medical Applications

Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Image Morphing



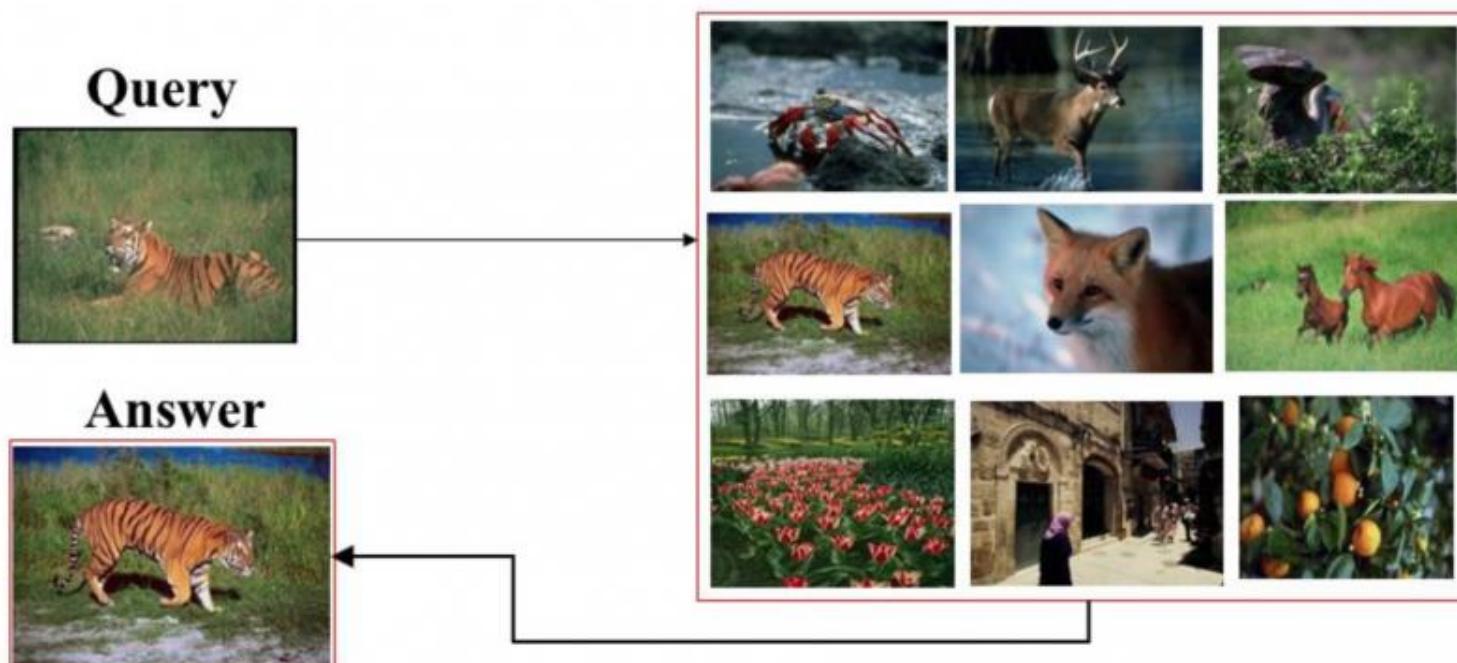
Sumber: Dr. Sanjeev Kumar, *Mathematical Imaging Techniques*,
Department of Mathematics, IIT Roorkee

Aplikasi Pemrosesan Citra (dan Computer Vision)

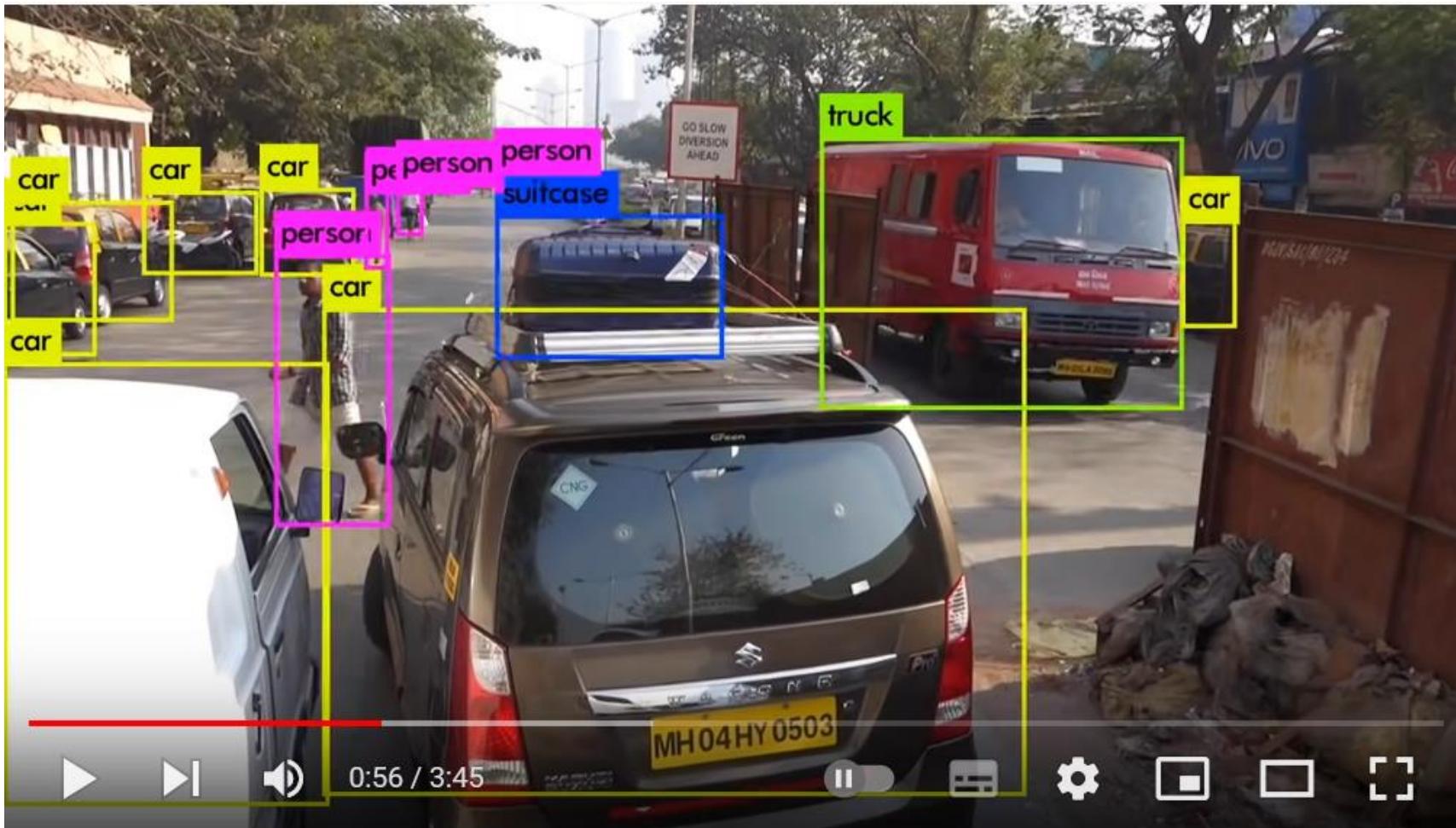
An image retrieval system is a computer system for browsing, searching and retrieving images from a large database of digital images

Content-based Image Retrieval

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



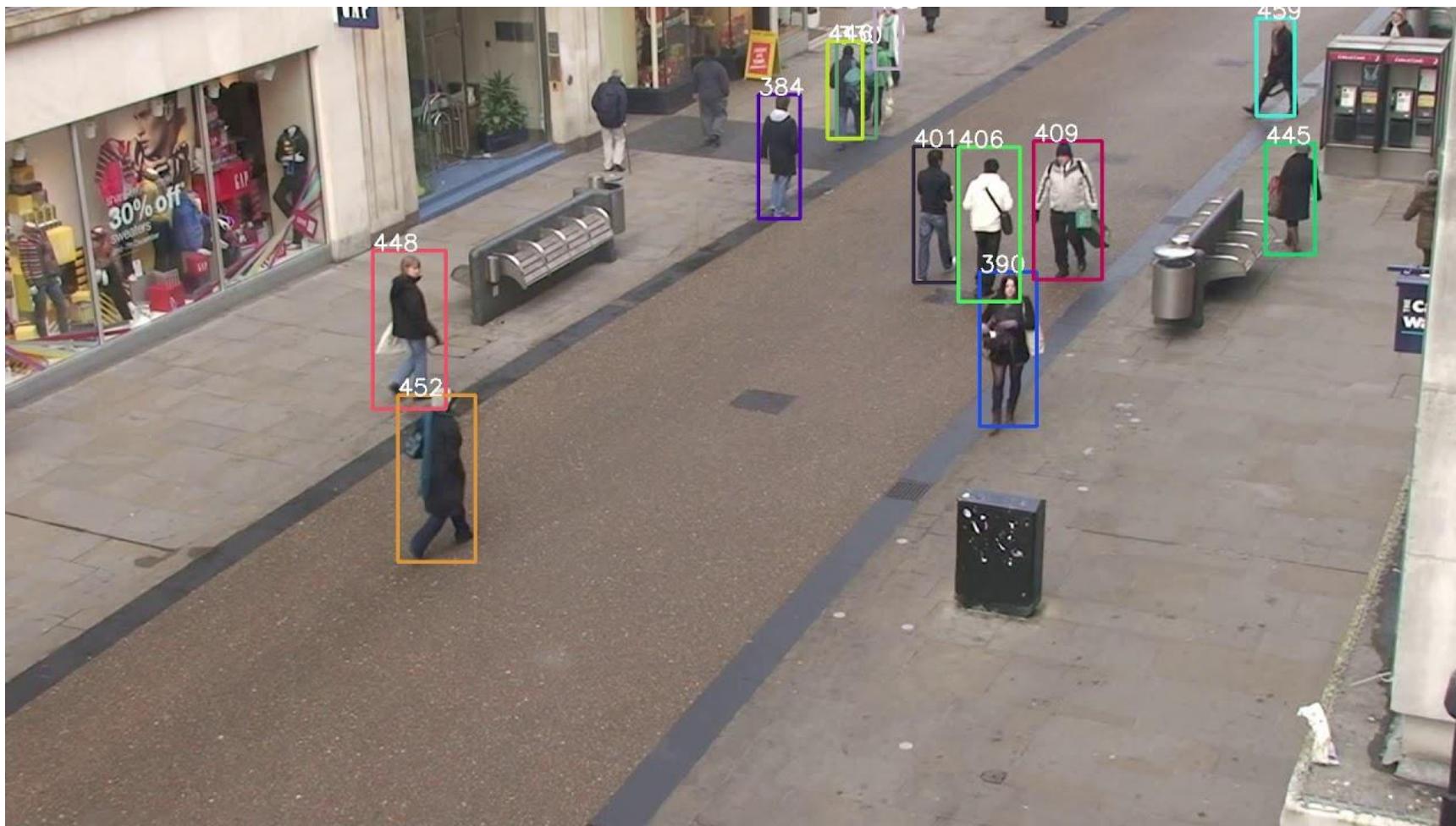
Aplikasi Pemrosesan Citra (dan *Computer Vision*)



Object Detection

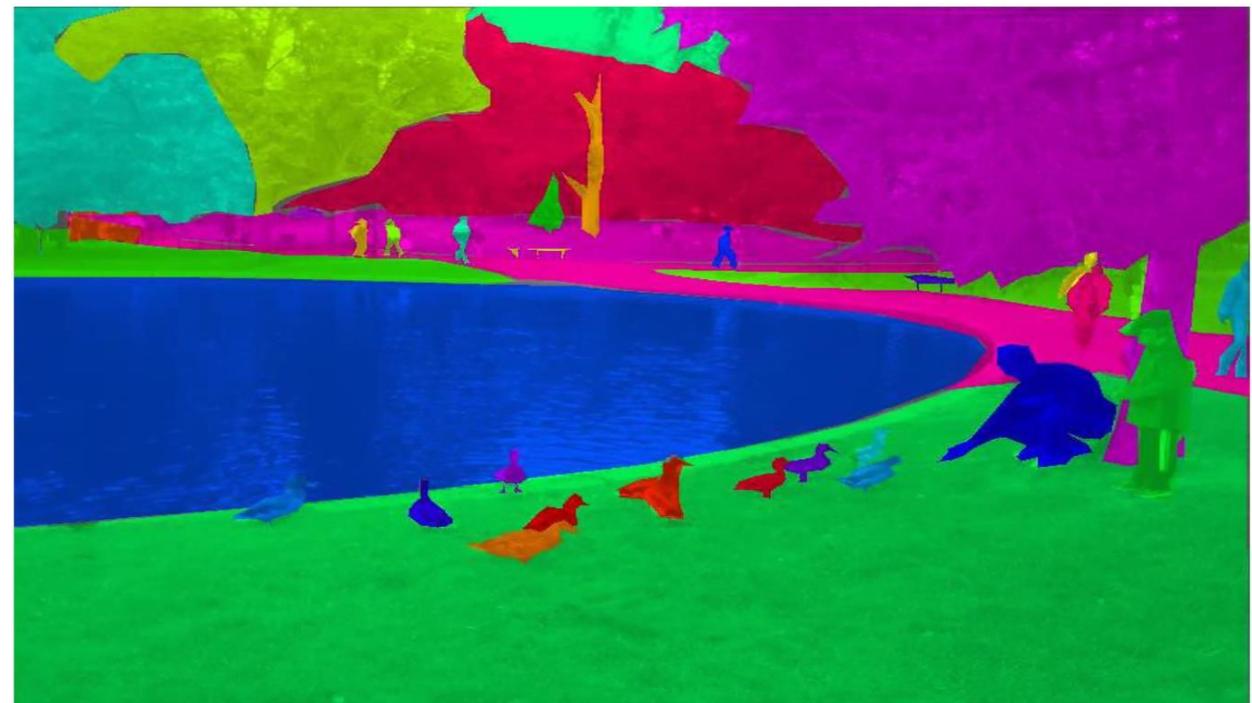
Video di Youtube: <https://www.youtube.com/watch?v=MPU2HistivA&t=34s>

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

Sumber: <https://www.sciencedirect.com/science/article/pii/S266591072030061X>

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

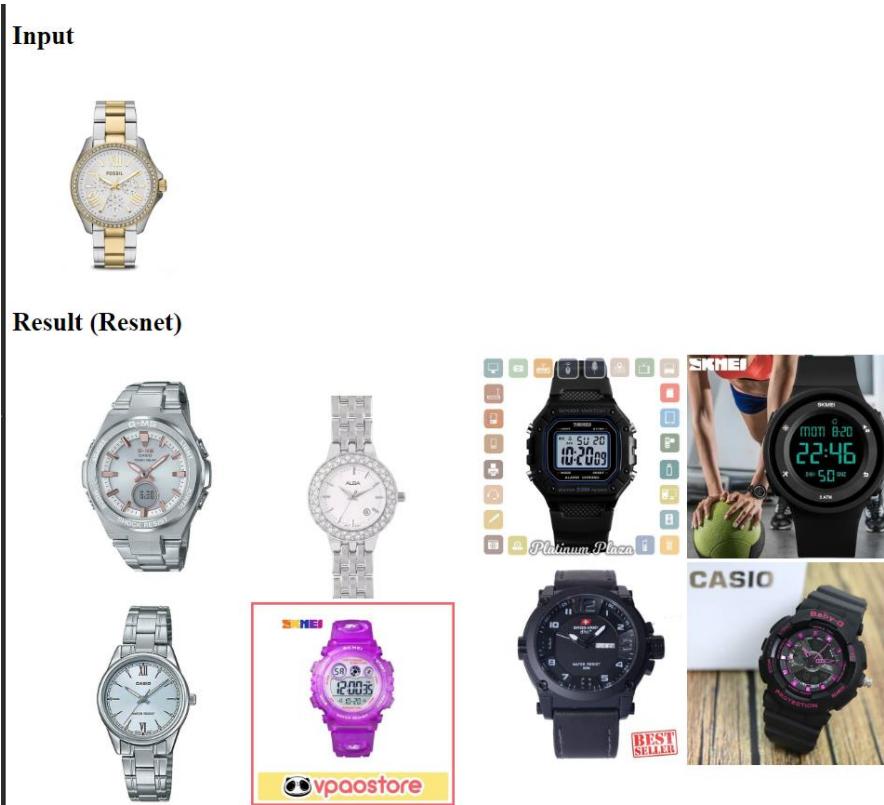
Federal intelligence agencies are studying ways to use computers and the Internet, rather than just leaflets and radio broadcasts, to shape and disseminate information designed to sway public opinion in the world's hot spots.

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



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 in CFD showing several people walking. Green bounding boxes are drawn around most of the pedestrians, indicating successful detections.	 The same street scene as above, but with more extensive green bounding boxes, suggesting a higher detection rate or a different detection strategy.
Jalan Pasar	 A street scene in Jalan Pasar with a blue van, a motorcycle, and some people. Green bounding boxes are present around the van and the motorcycle.	 The same scene as above, with additional green bounding boxes appearing around the people, similar to the CFD results.

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

Input



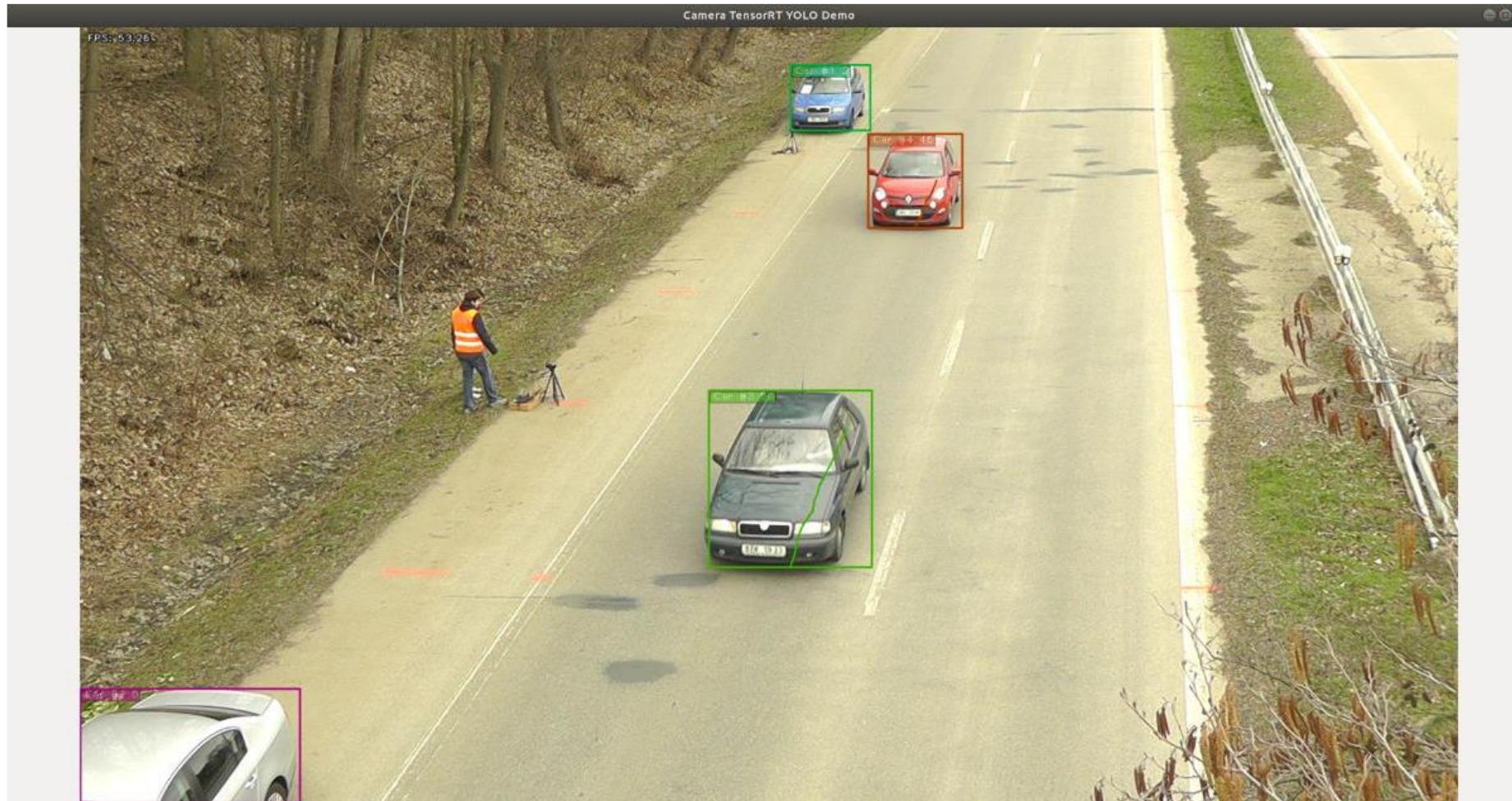
Result



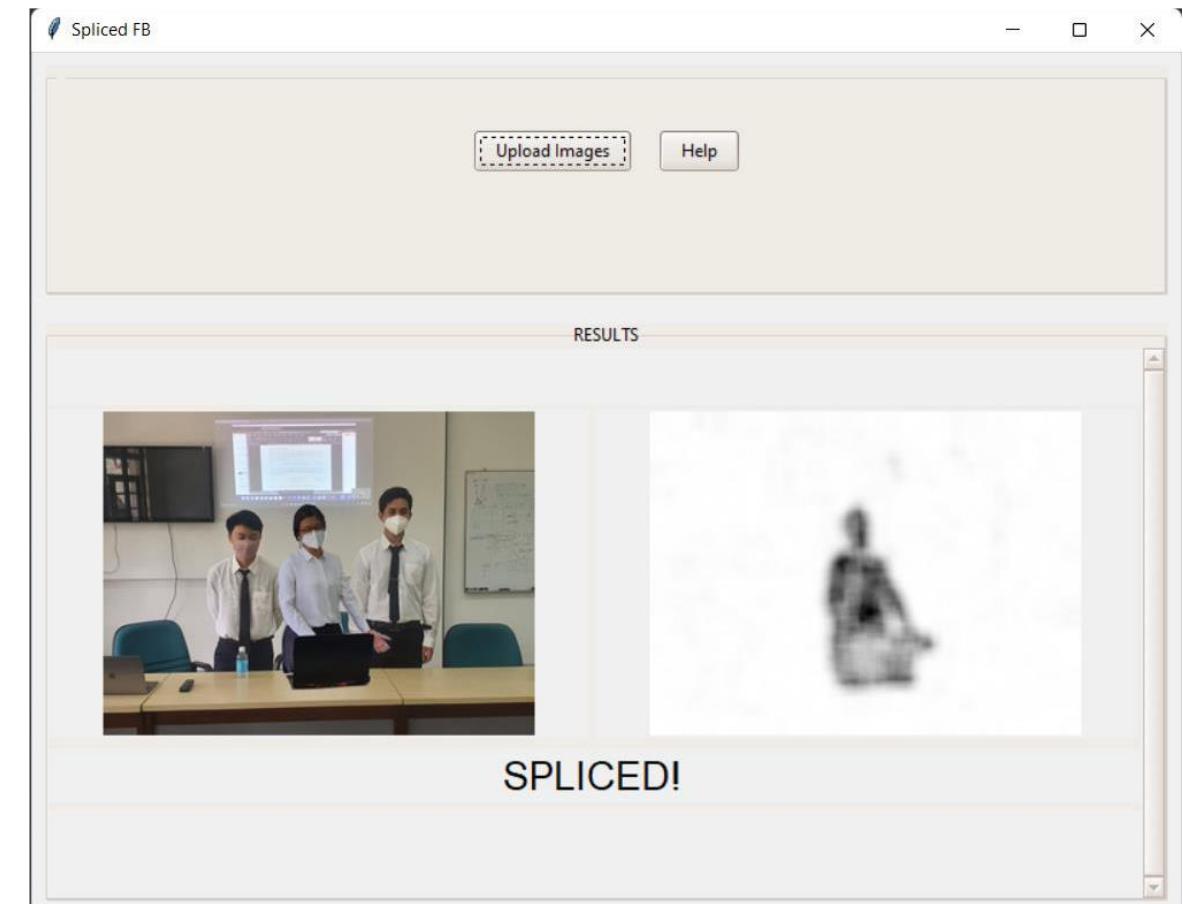
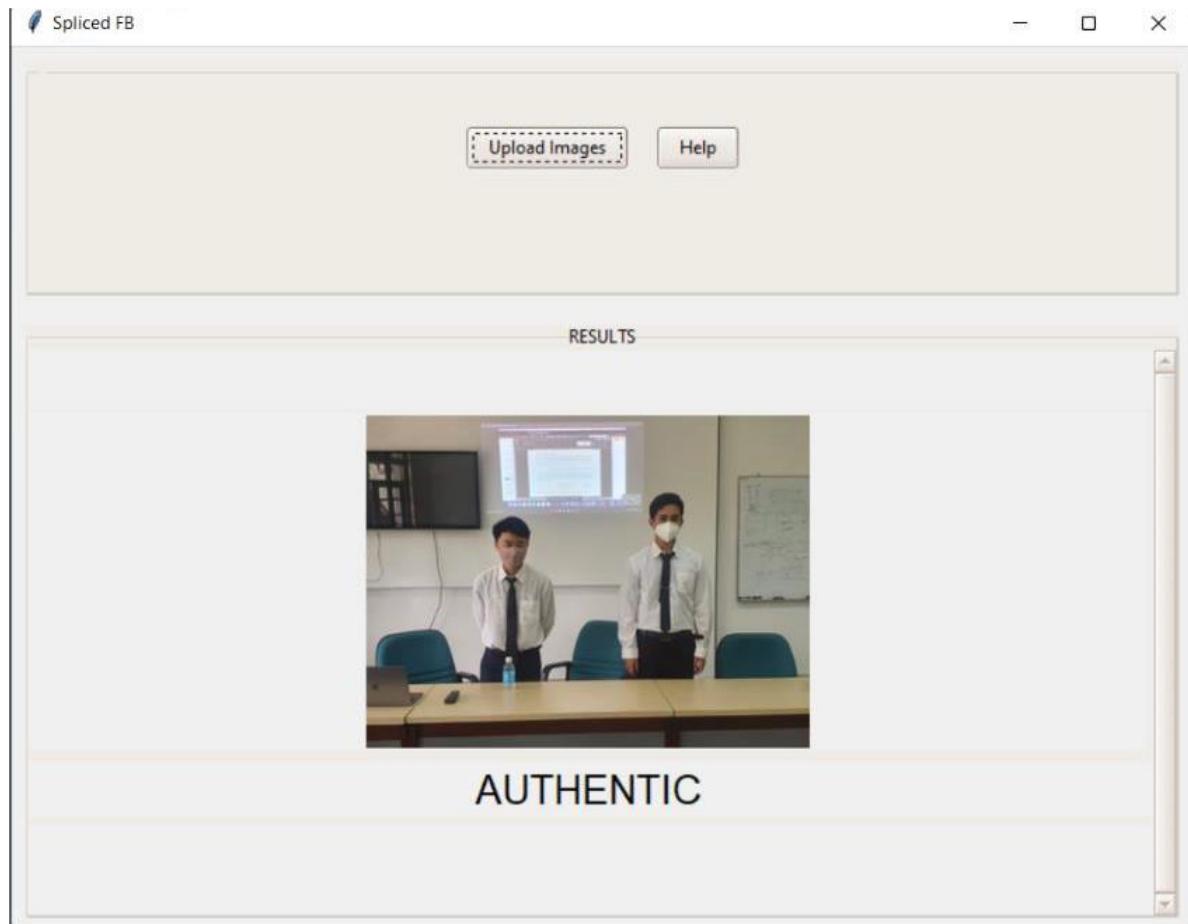
5. Abel Stanley (13517068): Pengembangan Sistem Penghitung Volume Kendaraan Lalu Lintas Pada Video CCTV Dengan Algoritma YOLO dan Segmentasi Semantik Berbasis Model Warna HSV Jalan



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



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

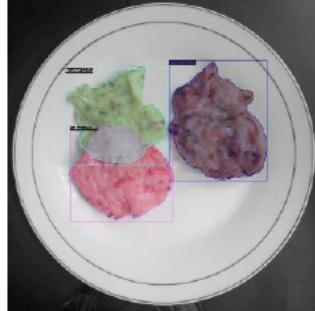


8. Fauzan Firdaus (23520011): Pengenalan Wajah Bermasker Menggunakan Deep Learning

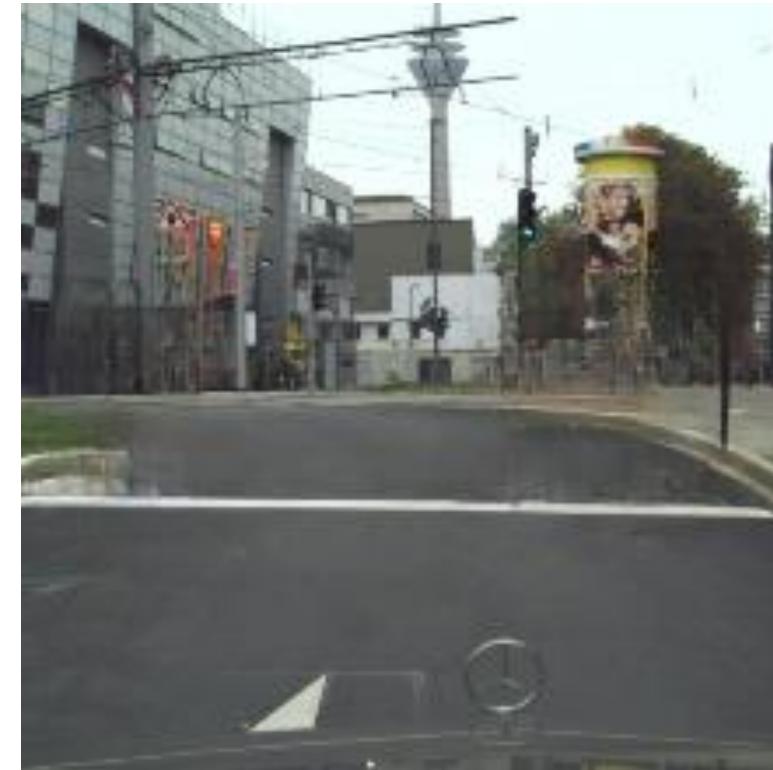


9. Nadya Aditama (23520039): Estimasi Kalori Pada Jajanan Pasar Di Indonesia Menggunakan Mask R-cnn Dan Regresi Linear Berganda

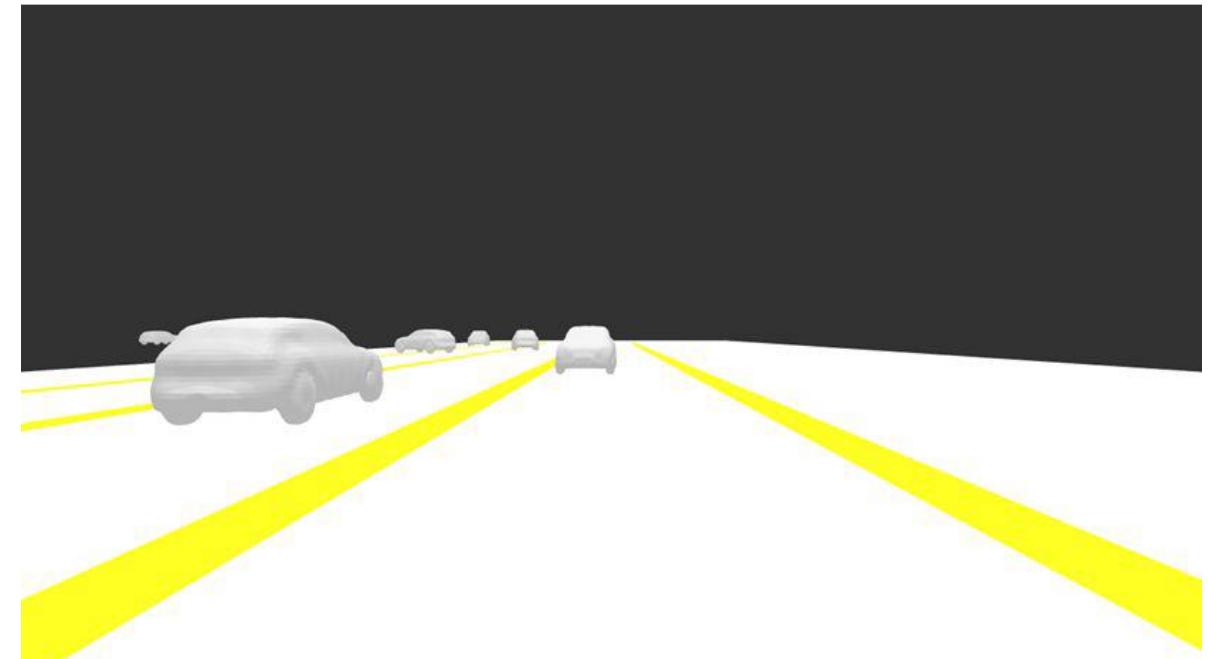
Tabel IV.15 Evaluasi kalori terhadap gambar input pada kasus yang benar

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 : 34.31gram 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



11. Bryan Amirul Husna / 13520146: Rekonstruksi 3D Lalu Lintas untuk Autonomous Vehicle dengan Gaussian Process Latent Variable Model (GPLVM)



12. Hansel Valentino/NIM: Pengembangan Aplikasi M-Health untuk Mengenali Seven-Segment Digit pada Alat Pengukur Tekanan Darah



Two screenshots of a mobile application interface for blood pressure monitoring.

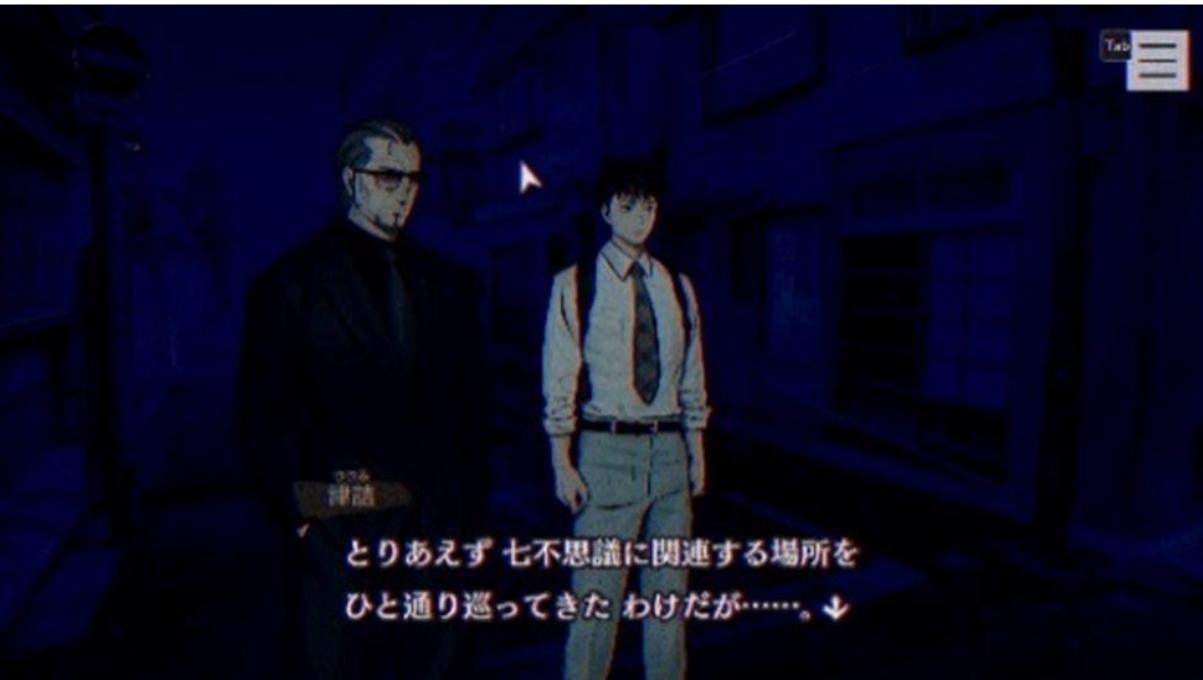
Screenshot 1 (Left): Shows a blood pressure reading of 117/93 mmHg and a pulse of 106 BPM. The category is labeled "HIGH: STAGE 1 HYPERTENSION". The timestamp is 10:14 and the battery level is 82%.

Category	Systolic	Diastolic	Pulse
HIGH: STAGE 1 HYPERTENSION	117 mmHg	93 mmHg	106 BPM

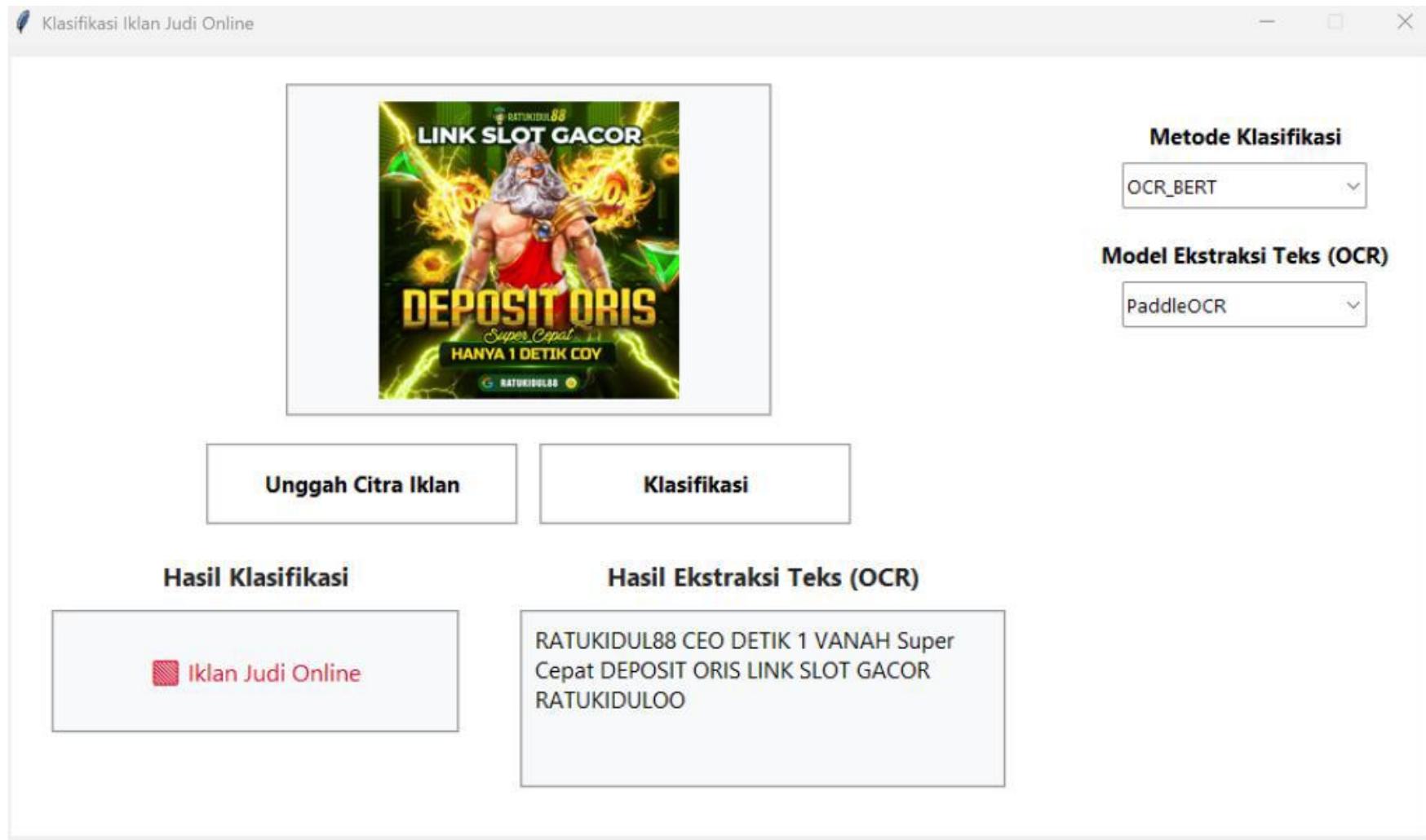
Screenshot 2 (Right): Shows a blood pressure reading of 145/89 mmHg and a pulse of 71 BPM. The category is labeled "PREHYPERTENSION". The timestamp is 10:49 and the battery level is 77%.

Category	Systolic	Diastolic	Pulse
PREHYPERTENSION	145 mmHg	89 mmHg	71 BPM

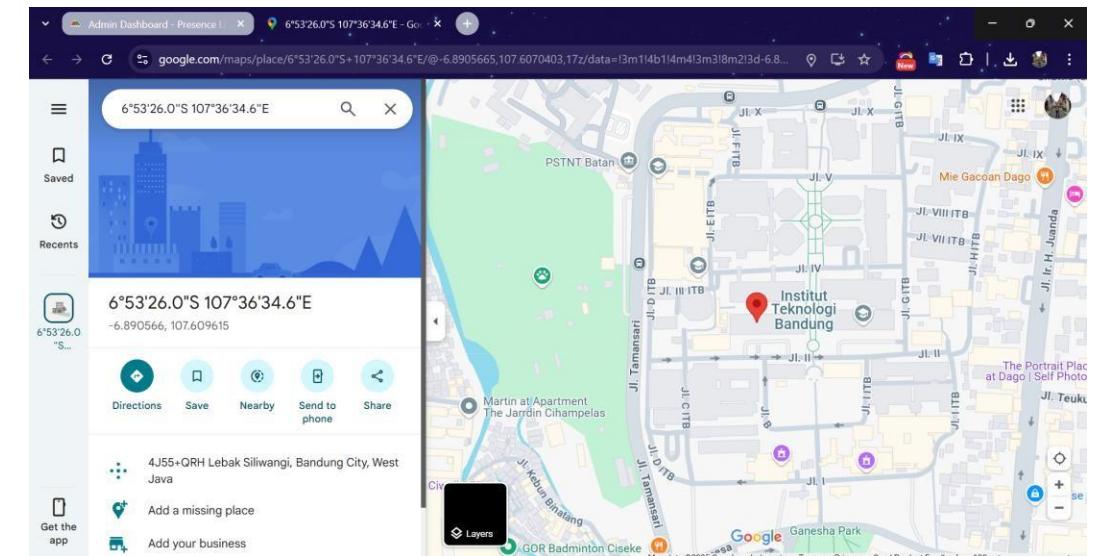
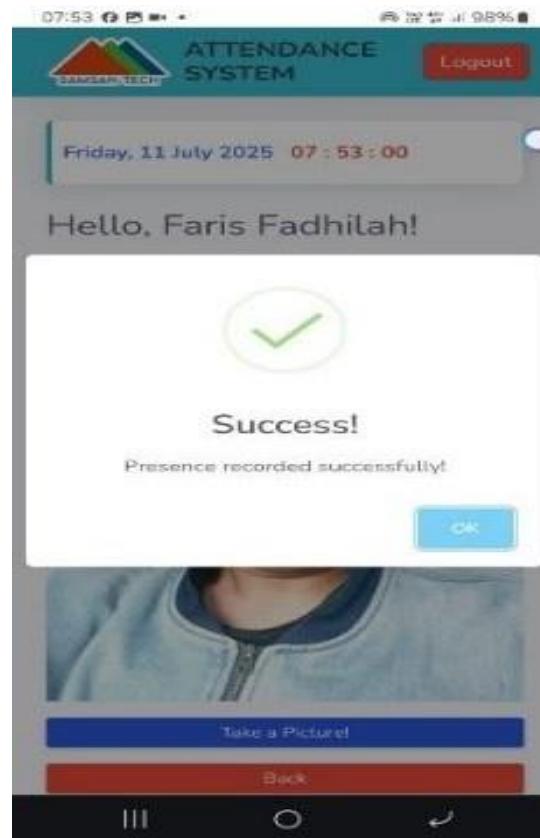
13. Raka Wirabuana Ninagan/13520134: Pengembangan Aplikasi Screen Text Translation Menggunakan Computer Vision



14. Muhammad Equilibrie Fajria/13521047: Sistem Klasifikasi Citra Iklan Judi Online Menggunakan Visi Komputer



15. Faris Fadhilah/13518026: Aplikasi Android untuk Presensi Berbasis Pengenalan Wajah dan Deteksi Lokasi

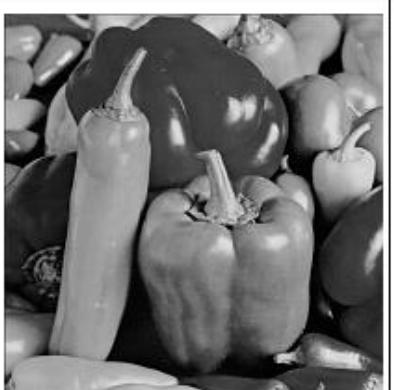


Citra Uji Standard

- 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 popular 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



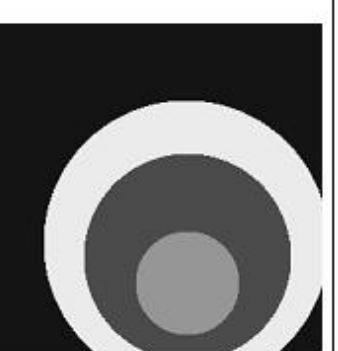
Zelda 512 × 512



San Fransisco 256 × 256



Collie 256 × 256



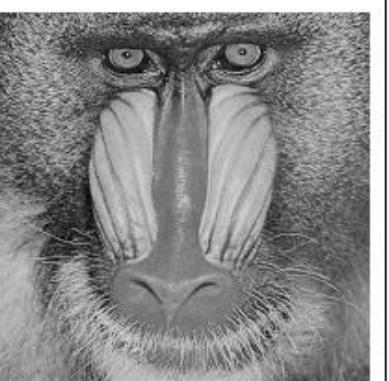
Circle 256 × 256



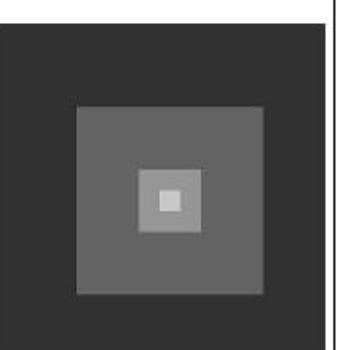
Bird 256 × 256



Camera 256 × 256



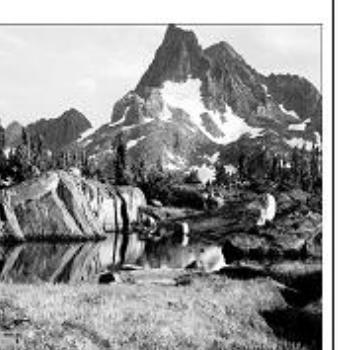
Mandrill 512 × 512



Squares 256 × 256



Text 256 × 256



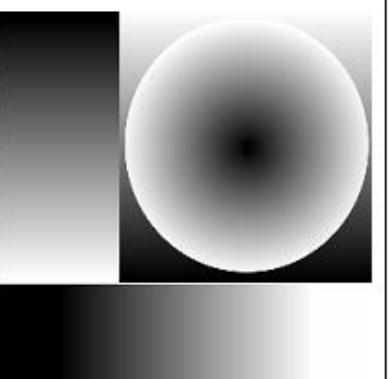
Mountain 640 × 480



Barbara 512 × 512



Boat 512 × 512



Slope 256 × 256



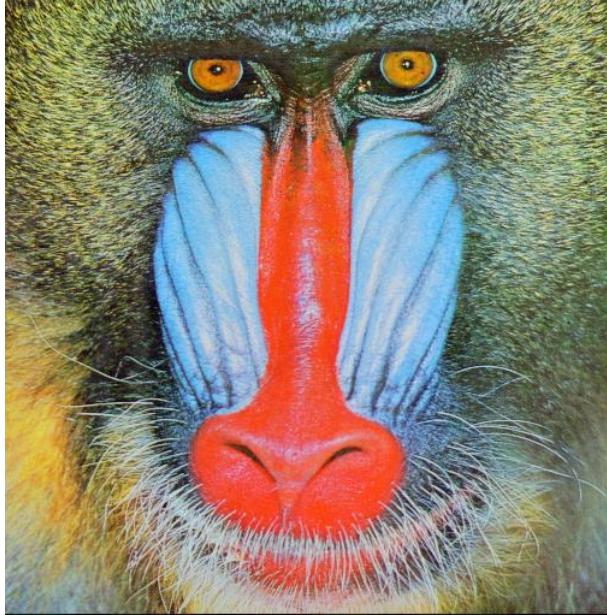
Goldhill 512 × 512



Eltoro 512 × 512



Girl 256 × 256



Citra uji lainnya:



Empat citra popular 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>

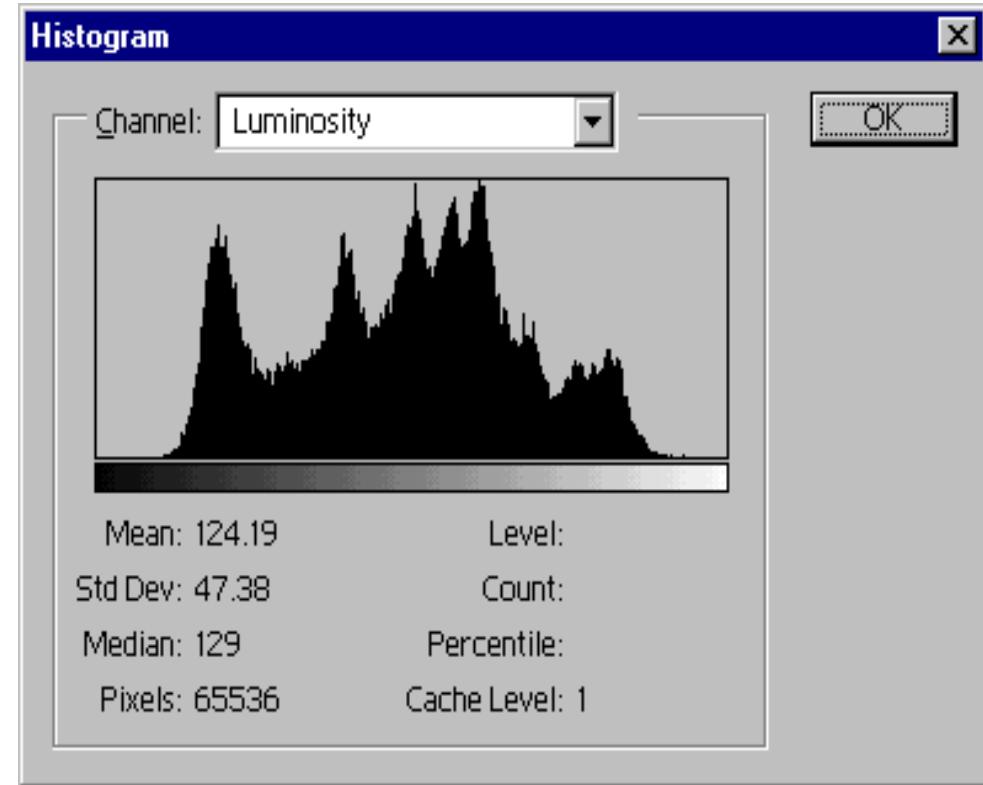
3. TESTIMAGES

<https://testimages.org/>

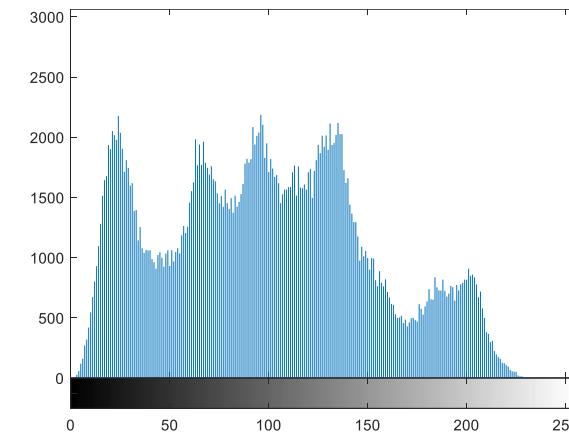
Sejarah Citra Lena



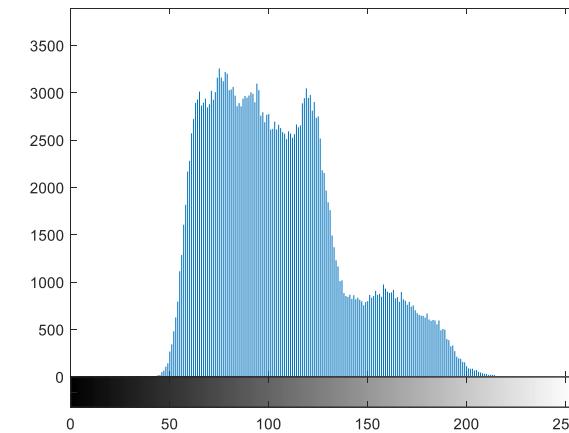
- **Lenna** atau **Lena** adalah nama citra uji standard yang terkenal secara luas di dalam bidang pengolahan citra sejak tahun 1973.
- Lena adalah citra seorang model Swedia bernama Lena Söderberg, yang dipotong dari majalah *Playboy*.
- Foto Lena dari majalah tersebut dipindai oleh Alexander Sawchuk, 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 detil 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.



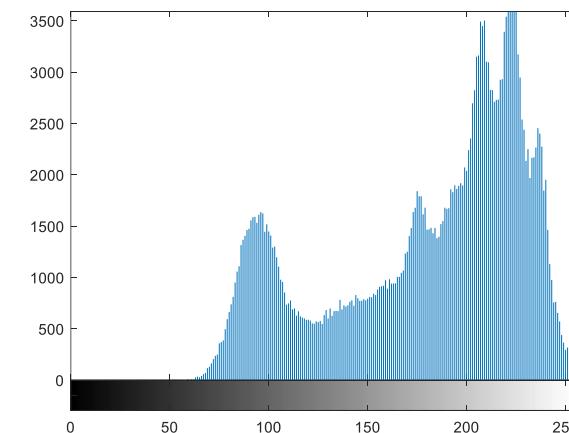
Citra Lena (*color*):



Red



Green



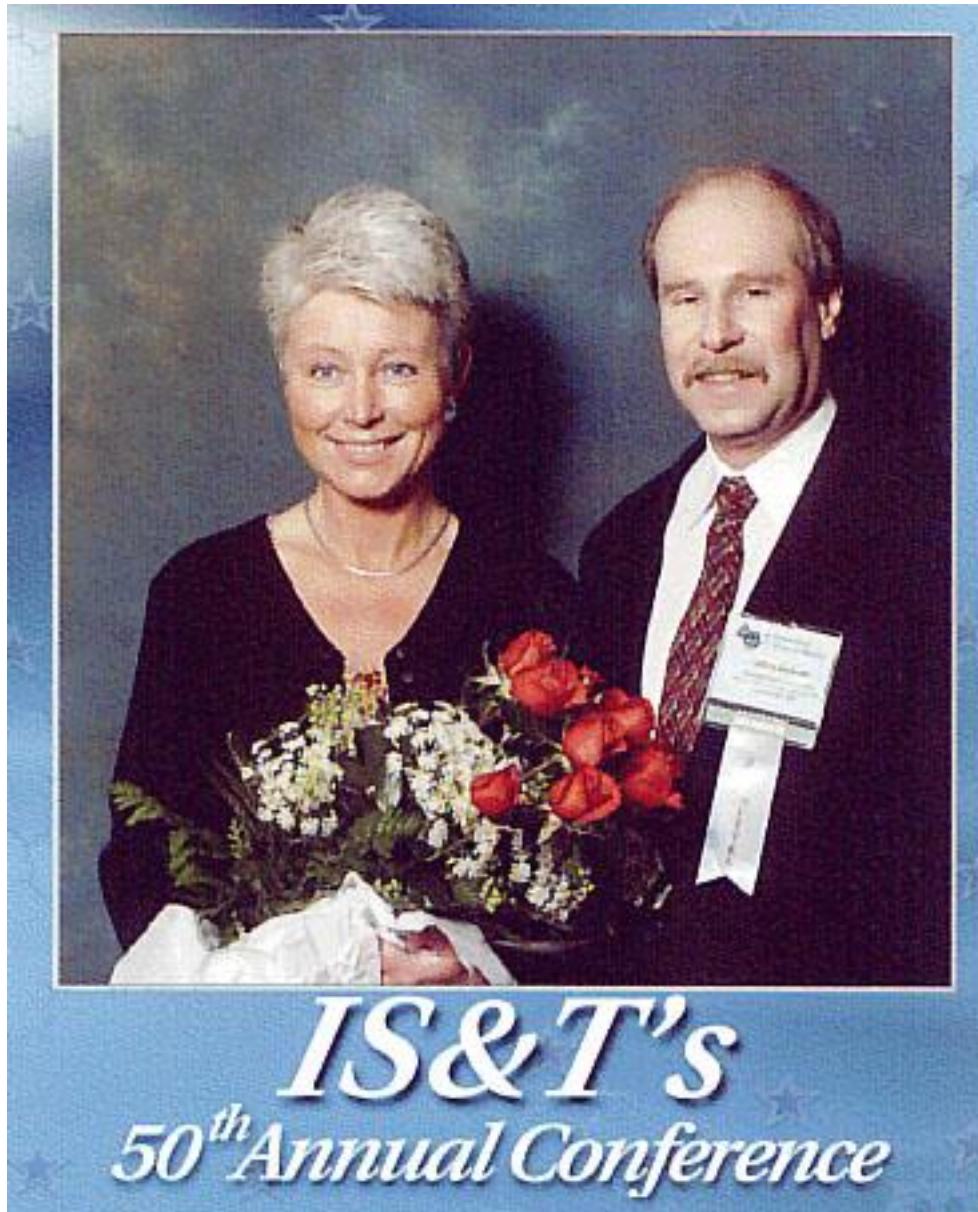
Blue

- 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, Lena 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/~lmpo/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-leena-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

...

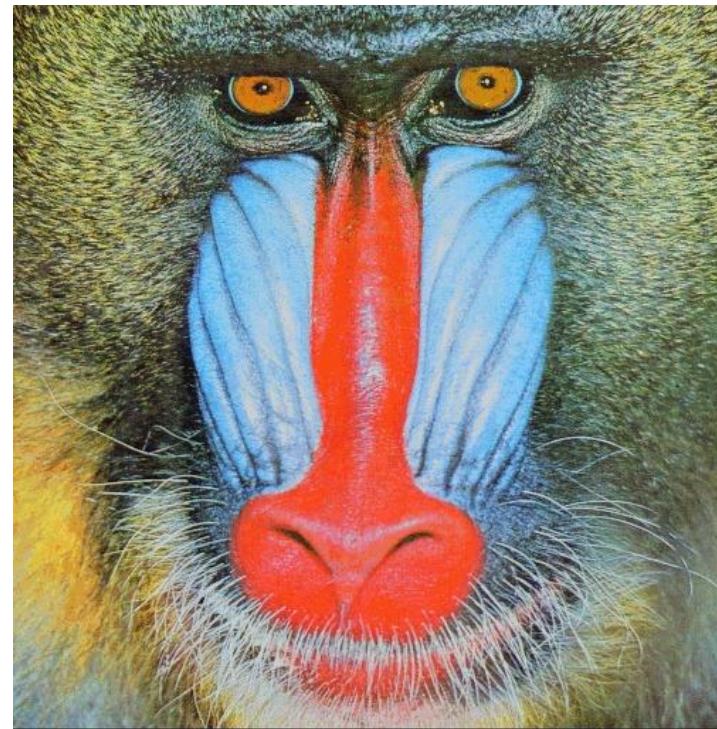
IEEE's diversity statement and supporting policies such as the IEEE Code of Ethics speak to IEEE's commitment to promoting an inclusive and equitable culture that welcomes all. In alignment with this culture and with respect to the wishes of the subject of the image, Lena Forsén, IEEE will no longer 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=IwY2xjawFKTSFleHRuA2FlbQIxMAABHUqUJcQhwH56yyVxv25XFuuYPn5BInXUiwbplxzo4ZwUc10-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