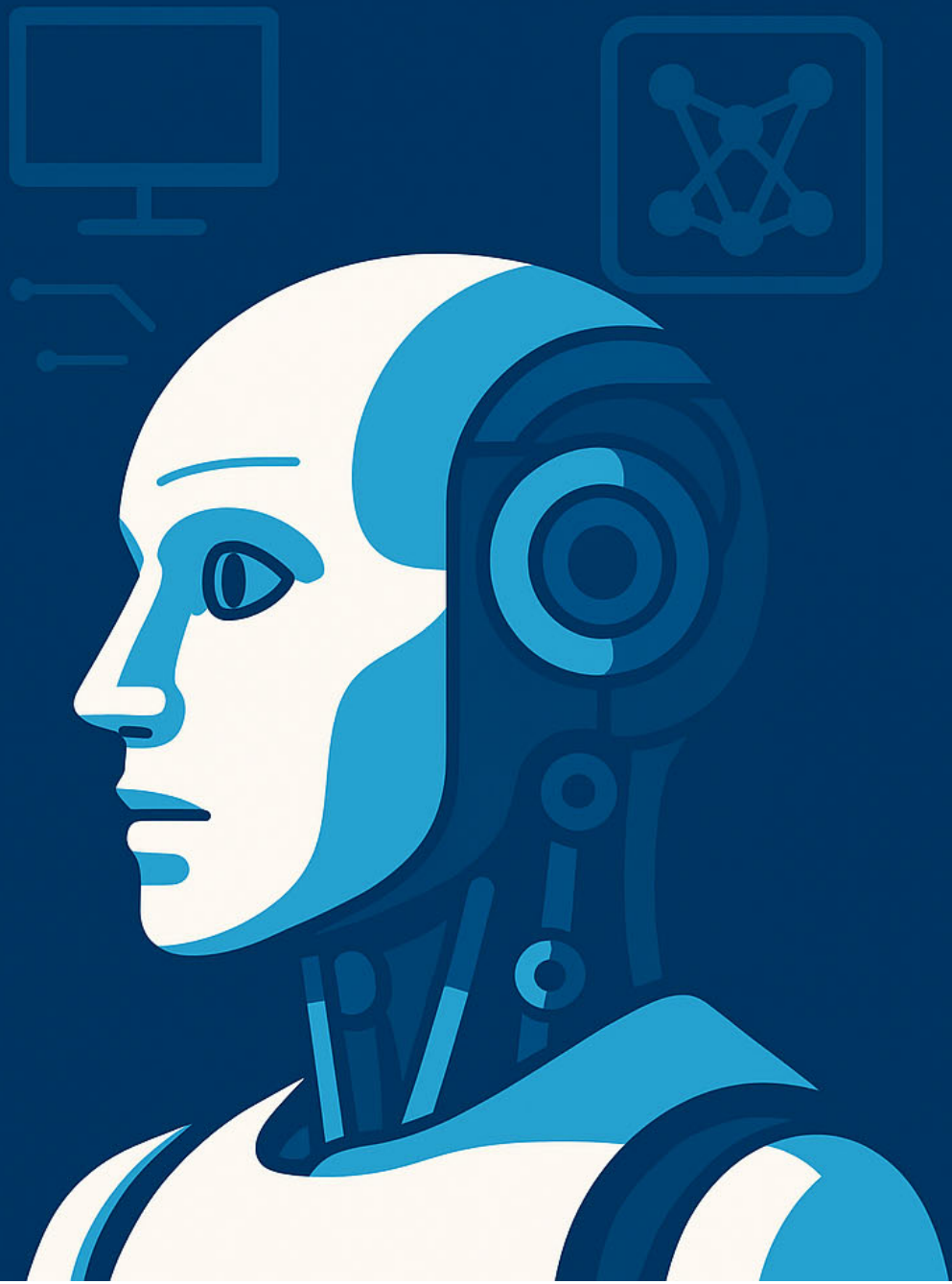
ME5411

ROBOT VISION AND AI

Dr. NG Hsiao Piau

Ng_h_p@nus.edu.sg



Lecture 0

Module Introduction

Introduction to Robot Vision

Module Introduction

- This course introduces:
  - fundamentals of robot vision (Part 1)
  - AI techniques used in robotics for learning and perception (Part 2)

- Instructors:
  - Adj. Assoc. Prof. Ng Hsiao Piau (Part 1)
  - Assoc. Prof. Peter Chen (Part 2)

- Assessment:
  - CA – 40%
  - Written Exam – 60%

Part 1 – Robot Vision

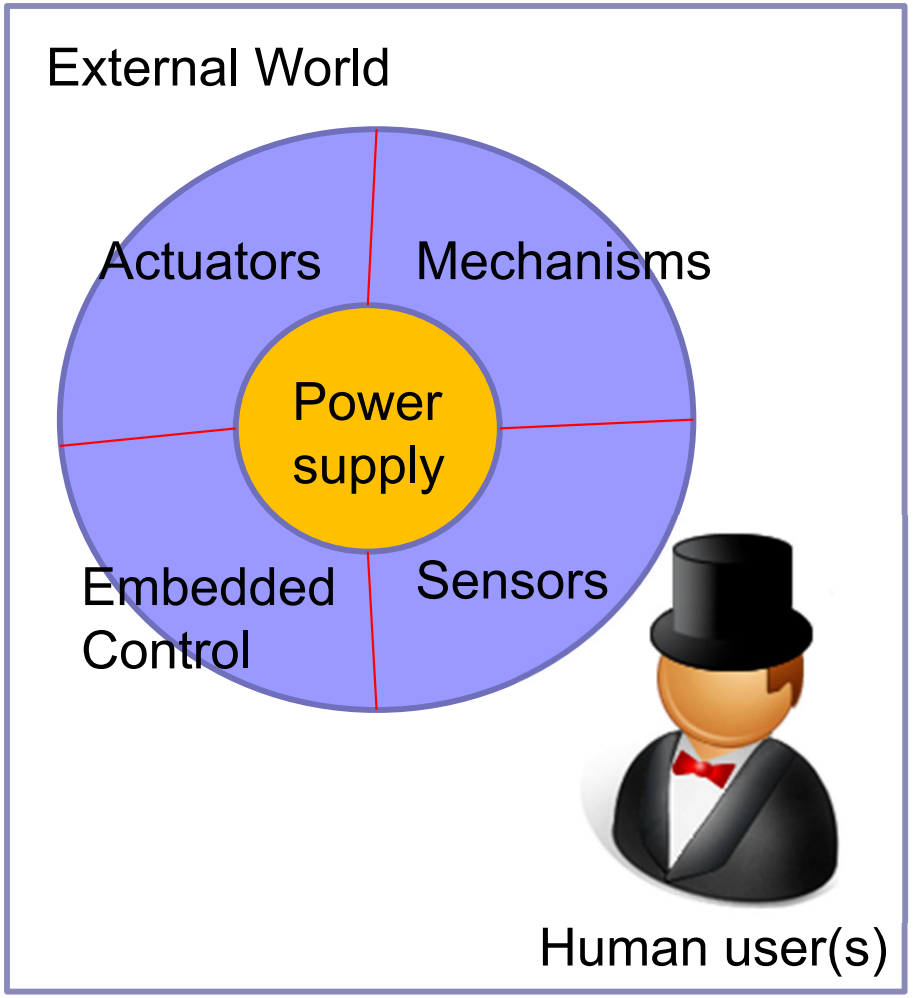
- Digital image representation and properties
- Low level vision
  - Image acquisition and camera calibration
  - Image preprocessing
    - Pixel brightness transformation/gray scale transformation
    - Geometric transformation
    - Image filtering
- High level vision
  - Image segmentation: process of partitioning an image into multiple image segments/regions/objects.
- Stereo vision
  - Process of extracting 3D information from multiple 2D views of a scene

Part 2 - AI

- By Assoc Prof Peter Chen
- Basics of neural networks, learning approaches, neural network topologies, examples in robotics, neurocontroller

Robots and Robotics

- Robotics is the engineering science and technology of robots, and their design, manufacture, application, and structural disposition



Robotics involves
- Perception
- Cognition
- Action

Robots and Robotics

- **Robot sensing** allows robot to interact with its environment

- Two categories of robot sensors:
  - Internal state sensor: detection of arm joint position, for robot motion control
  - External state sensor: detection of range, distance and touch, object identification and handling, for robot guidance

- Vision is most powerful of robot sensory capabilities.

Robots and Robotics

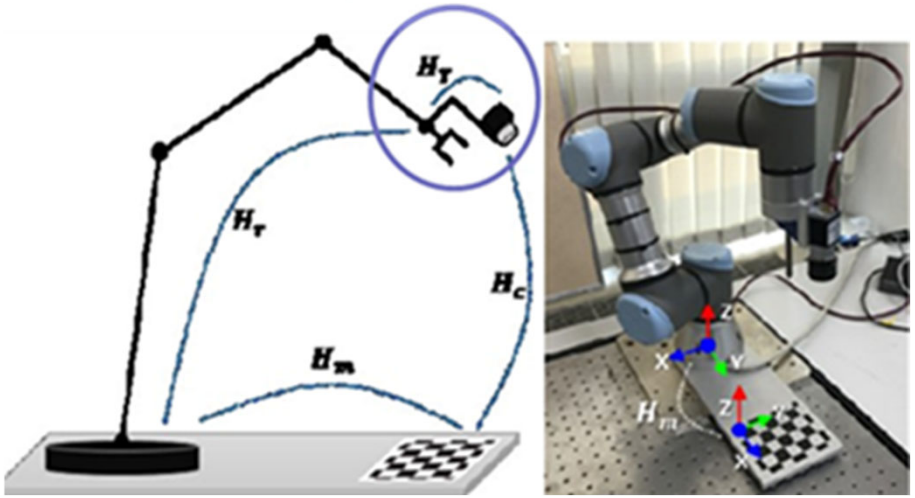
- **Robot vision** is the process of extracting, characterizing, and interpreting information from images of a 3D world.

- Processes:
  1) image acquisition/sensing
  2) preprocessing
  3) segmentation
  4) description
  5) recognition
  6) interpretation

Robots and Robotics

- Visual servo refers to vision-based robot control for control of robot motion
- Two configurations: eye-in-hand and eye-to-hand

eye-in-hand



eye-to-hand

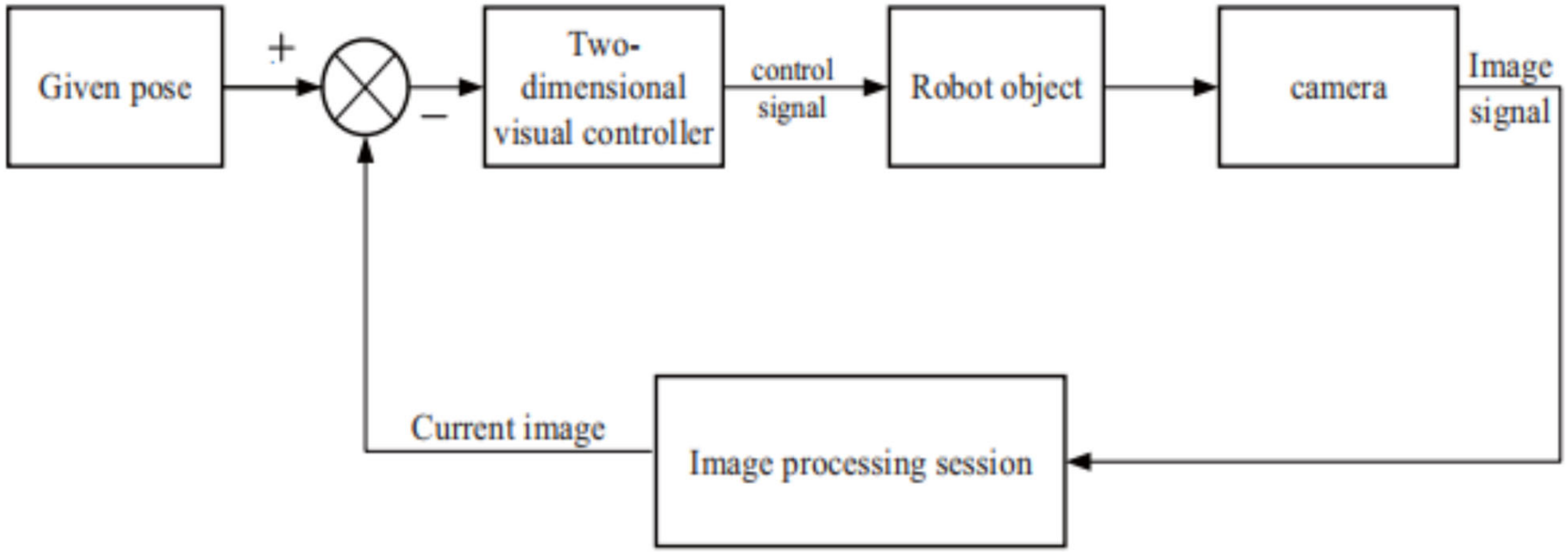
Robots and Robotics

- Visual servo refers to vision-based robot control for control of robot motion
- Two configurations: eye-in-hand and eye-to-hand

Aspect	Eye-in-Hand	Eye-to-Hand
Camera Placement	Mounted on the robot's end-effector (e.g., hand)	Mounted in a fixed position looking at the workspace
Field of View (FOV)	Limited to where the robot moves	Wider, but fixed relative to the workspace
Camera Motion	Moves with the robot arm	Static, independent of robot motion
Calibration Complexity	Requires recalibration if camera position changes	Easier to calibrate and more stable
Occlusion Risk	Low (robot can move to avoid occlusion)	Higher (objects may block each other from view)

Robots and Robotics

- Image-based visual servo control



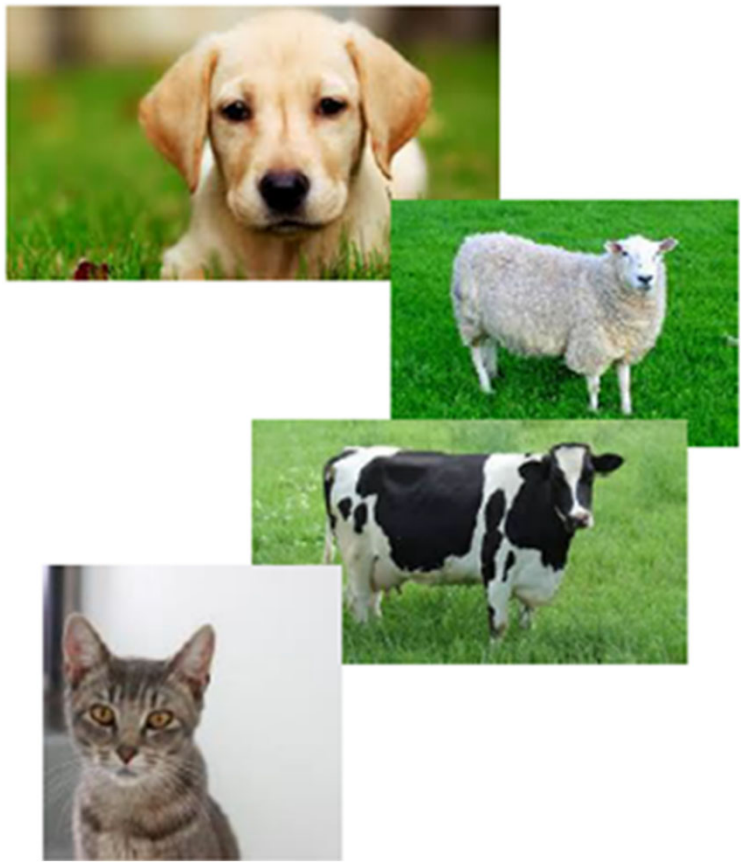
X. Sun, X. Zhu, P. Wang, and H. Chen, "A Review of Robot Control with Visual Servoing," *IEEE Xplore*, Jul. 01, 2018. https://ieeexplore.ieee.org/abstract/document/8688060 (accessed Dec. 30, 2022).

Robotic Vision

- Conventional Feature Extraction and Image Classification
  - Features – descriptions of images that can be represented by some scalar properties (area, perimeter, moments...)
  - Texture features, statistical features – image texture represented indirectly by non-deterministic properties
  - k-Nearest Neighbors (k-NN), Support Vector Machine (SVM)

- Learning-based Machine Vision
  - Deep Learning for Computer Vision
  - End-to-End: Image of a dog –> Black box –> Husky
  - Condition: the black box is trained (supervised training)
  - Convolutional Neural Networks (CNN)

Robotic Vision



References

- RC Gonzalez, RE Woods, “Digital Image Processing”, 2010, Pearson, ISBN: 9780132345637
  - http://www.imageprocessingplace.com/
- M Sonka, V Hlavac, R Boyle, “Image Processing, Analysis and Machine Vision”, Thomson Learning, 2008, ISBN 10:0-495-08252-X, ISBN 13:978-0-495-08252-1
  - Image Processing, Analysis, and Machine Vision – A MATLAB Companion (http://visionbook.felk.cvut.cz/)
- KS Fu, RC Gonzalez, CSG Lee, “Robotics – Control, Sensing, Vision and Intelligence”, 1987, McGraw-Hill
- Other references will be announced in class.