Computer Vision in Robotics

CS 6384 Computer Vision
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What is a Robot?

• A robot is a machine capable of carrying out a complex series of actions automatically (Wikipedia)

• A goal-oriented machine that can sense, plan and act

  • A robot senses its environment and uses that information, together with a goal, to plan some action

  • The action might be to move the tool of an arm-robot to grasp an object, or it might be to drive a mobile robot to some place
Humanoid Robots

• A humanoid robot is a robot with its body shape built to resemble the human body

Honda P series

iCub robot
Robot Manipulators

• A device used to manipulate materials without direct physical contact of the operator
Wheeled Robots

- Use wheels for locomotion
  - Self-driving cars

Starship Technologies  Amazon Astro Robot  Perseverance Rover
Walking Robots

- Legged robots, use articulated limbs to provide locomotion
Other Robots

• Flying robots
  • Drones

• Swimming robots
  • Underwater gliders

• Snake robots

Robotic Fish: iSplash-II

Two robot snakes. Left one has 64 motors (with 2 degrees of freedom per segment), the right one 10.
Robots vs. Humans

• Sensing
  • Robots: cameras, IMUs, joint encoders
  • Humans: vision, vestibular, proprioceptive senses

• Control
  • Robots: motors
  • Humans: muscles

• Computation
  • Robots: robot brain, AI?
  • Humans: human brain
Robotic Systems

Perception → Planning → Control

Tasks

Learning

World

Sensing

Action

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Computer Vision and Robotics

• Vision provides sensing capability to robots

• Robots can interact with the world to facilitate vision
Robot Manipulation

• The ways robots interact with objects

• Examples
  • Grasping an object
  • Placing an object
  • Pushing an object
  • Opening a door
  • Folding laundry
  • Etc.

https://am.is.mpg.de/research_projects/autonomous-robotic-manipulation
Robot Manipulation

Perception
Robust and Accurate

Planning
High degree of freedom
Multi-modal grasping

Control
Contact with objects

Sensed image
Planning scene
Real world execution

2X
6D Object Pose Estimation for Robot Manipulation
Object Segmentation for Robot Manipulation

Unseen Object Instance Segmentation:
Xie-Xiang-Mousavian-Fox, CoRL’19, T-RO’21
Xiang-Xie-Mousavian-Fox, CoRL’20

6-DOF GraspNet:
Mousavian-Eppner-Fox, ICCV’19
Cloth Segmentation for Robot Manipulation

Depth image is segmented into outer edges (yellow), inner edges (green) and corners (blue) using our cloth region segmentation network. Ambiguous regions are colored in orange. Our method selects a grasp location and direction, shown as a magenta arrow.

Cloth Region Segmentation for Robust Grasp Selection. Qian et al., IROS, 2020
SLAM for Robot Manipulation

NodeSLAM: Neural Object Descriptors for Multi-View Shape Reconstruction. Sucar et al., 3DV, 2020
SLAM for Robot Manipulation

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Robot Navigation

• Go from A to B without hitting anything

Perception → Planning → Control

Simultaneous localization and mapping (SLAM)
Path planning
Path following

Laser-based SLAM
2D occupancy grid map
Occupancy Grid Mapping

- Occupancy grid
  - Status: unknown, occupied, empty

Occupancy Grid Mapping
Navigation Demo using ROS

Credit: Gagan Bhat
Topological Navigation

Dense Trajectories

Reachability Estimator

Local Controller
A learned neural network

Sparse Topological Map

Meng-Ratliff-Xiang-Fox, ICRA’19, ’20
Meng-Xiang-Fox, RA-L’21
Robot Teleoperation

https://www.shadowrobot.com/jeff-bezos-tries-our-tech/
Hand Pose Estimation for Robot Teleoperation

Robot Learning

• How can robots learn various skills?
  • Navigation
  • Manipulation

• Reinforcement learning
  • Learning from trial and error

• Imitation learning
  • Learning from demonstrations
Reinforcement Learning

Kinesthetic Teaching

• A human teacher physically guides the robot in performing the skill.

Demonstrations from Teleoperation

RotoTurk: https://roboturk.stanford.edu/realrobotdataset#dataset
Demonstrations from VR

• Use VR in teleoperation to generate demonstrations

Demonstrations from VR

Summary

• Vision is important for robots to sense the world

• Robots can interact with the world to facilitate vision
  • Interactive perception

• Core problems in robotics
  • Manipulation
  • Navigation
  • Skill learning
Further Reading

- 6-DOF GraspNet: Variational Grasp Generation for Object Manipulation, 2019
- Cloth Region Segmentation for Robust Grasp Selection, 2020
- Learning Occupancy Grid Maps With Forward Sensor Models, 2002
- Scaling Local Control to Large Scale Topological Navigation, 2020
- DexPilot: Vision Based Teleoperation of Dexterous Robotic Hand-Arm System, 2019
- AVID: Learning Multi-Stage Tasks via Pixel-Level Translation of Human Videos, 2019
- Deep Imitation Learning for Complex Manipulation Tasks from Virtual Reality Teleoperation, 2017
  https://arxiv.org/abs/1710.04615