Classifying Obstacles and Exploiting Knowledge about Classes for Efficient Humanoid Navigation

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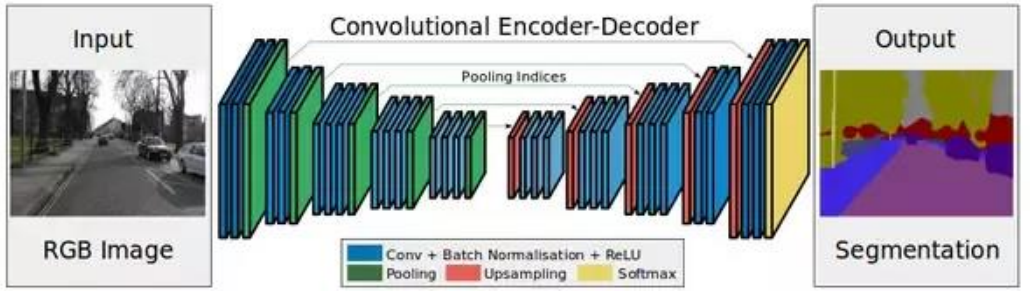
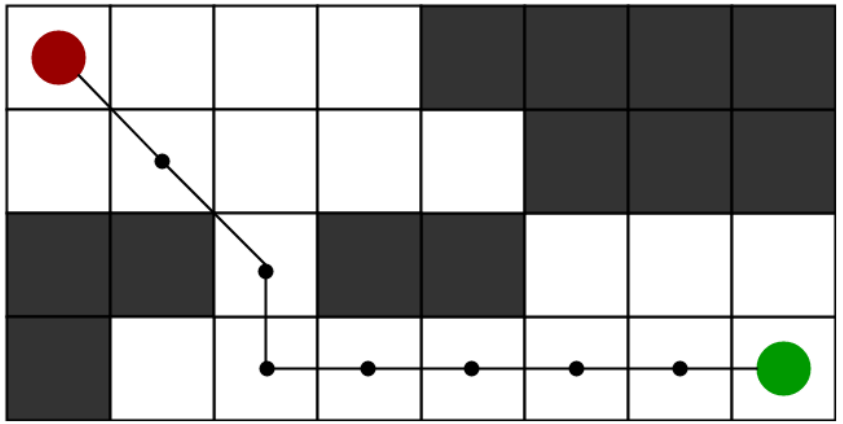
Terminologies

- Encoder & decoder



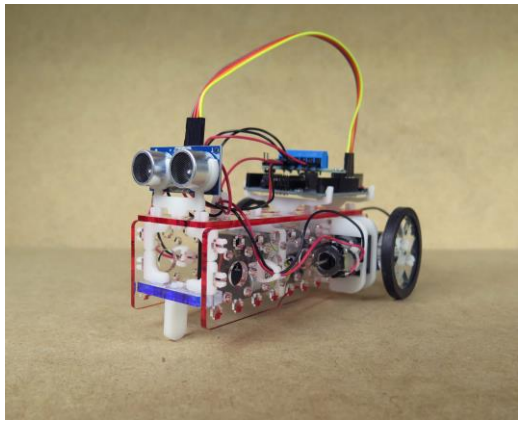
- A* search



Task: navigate in a complex environment

- What is special about humanoid robot navigation?

Differential drive robot

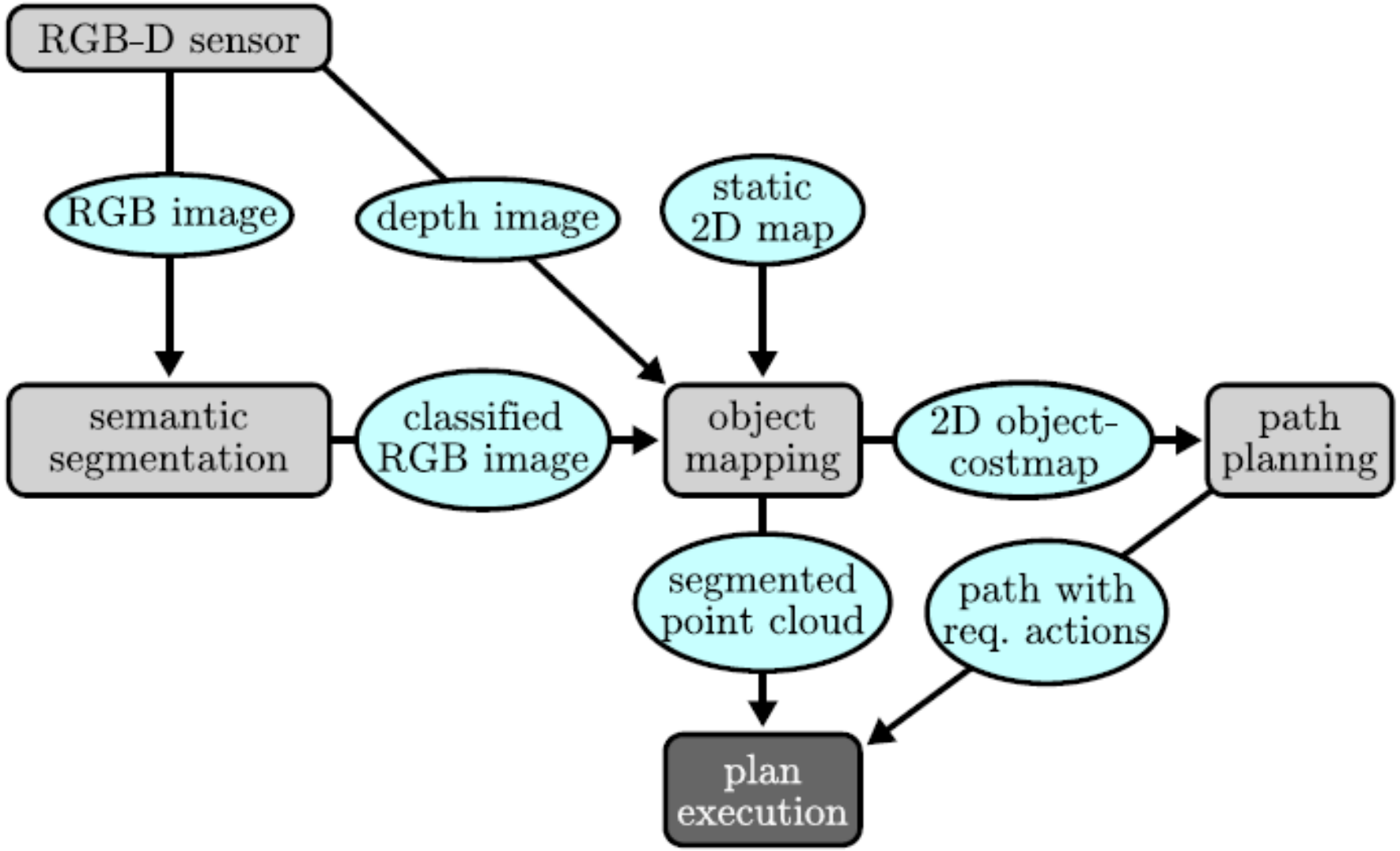


VS

Humanoid robot

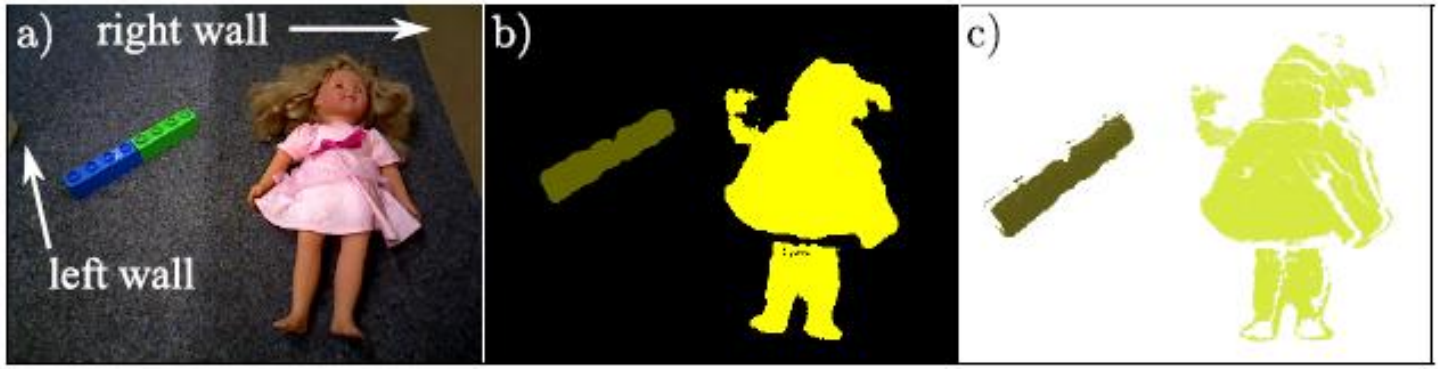
- How do we interact with obstacles?
  - Push? Step over? Pick up?

System Overview



Convolutional Neural Network

- RGB picture ⟶ semantic picture ⟶ semantic pointcloud



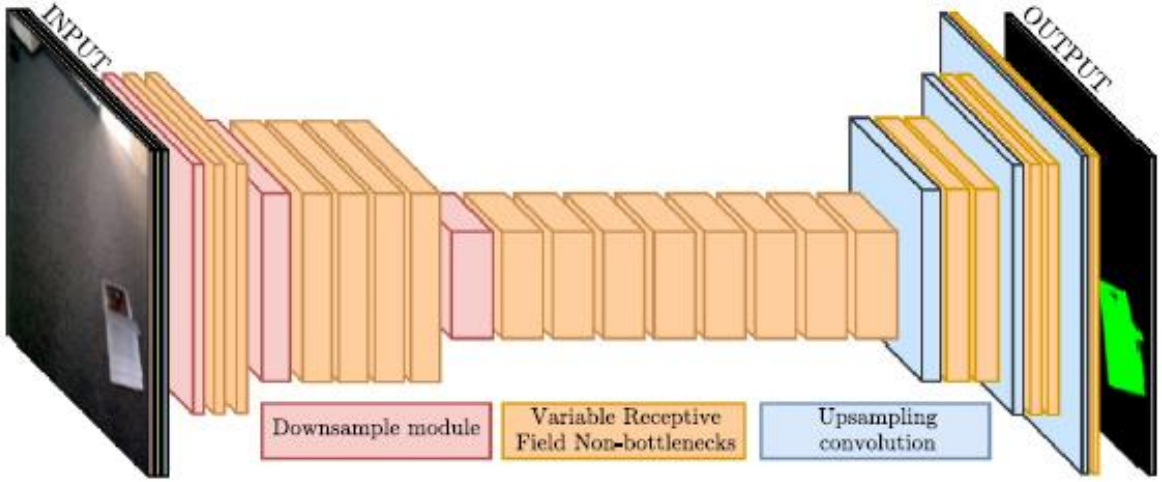
- Evaluate loss using *mean intersection over union* (mIoU) + *mean average precision* (mAP)

$$mIoU = \frac{1}{C}\sum_{i=1}^{C}\frac{tp_i}{tp_i + fp_i + fn_i},$$

$$mAP = \frac{1}{C}\sum_{i=1}^{C}\frac{1}{11}\sum_{r\in\{0,0.1,\ldots,1\}} p_i(r),$$

Convolutional Neural Network

- Eight classes:
  - ”balls”, ”books”, ”boxes”, ”cars”, ”dolls”, ”stuffed toys”, ”toy blocks”, and ”background”
- Architecture:
  - Based on ResNet and ENet
  - Non-bottlenecks
    - High speed
    - Relatively low accuracy
  - Different dilation rate



Training (Generating data)

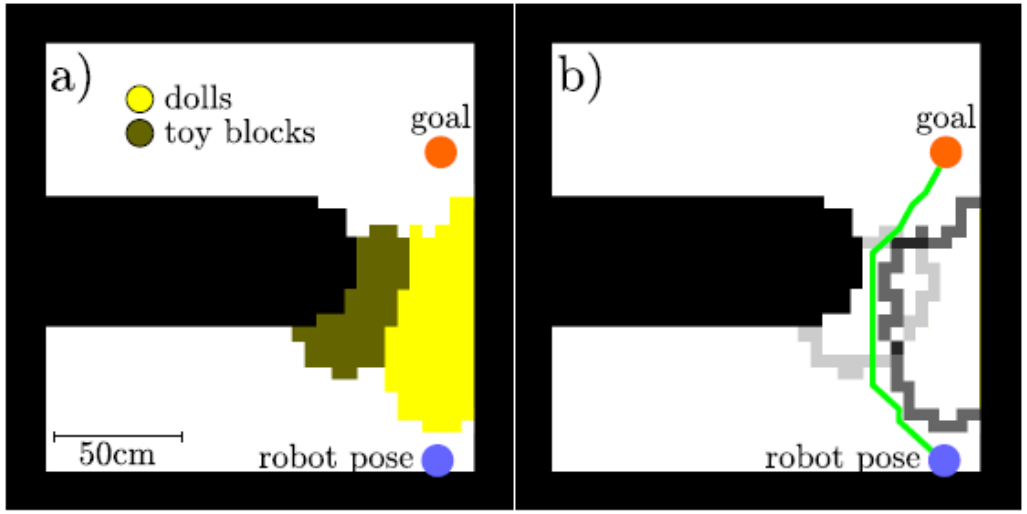
- Crawls pictures from Google
- Remix them and change background to generate new data
- Pre-trained network from Bonnet's library
- Focus on similar objects

Plan & Execute

- One action per object (depends on the robot)

Object class	Action type
balls	push
toy blocks	step over
boxes, books	step onto
stuffed toys, dolls, cars	pick up

- Certain cost for executing each action
- A* search based on the modified cost
- Footstep planning if necessary
- Update and re-plan



Video Demo

- https://www.youtube.com/watch?v=WO94iXT3V1I

Innovation & Key points

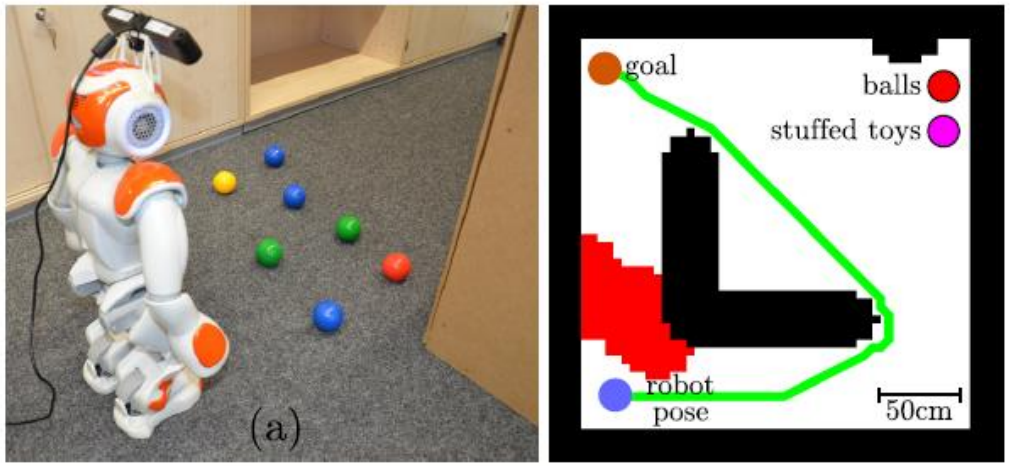
- Exploiting knowledge about obstacle classes
- Lightweight CNNs through non-bottlenecks
- Innovative way of generating real-world training data
- Easy to incorporate with other techniques
  - Foot step planning
  - Whole-body motion planning
  - Multi-contact planning

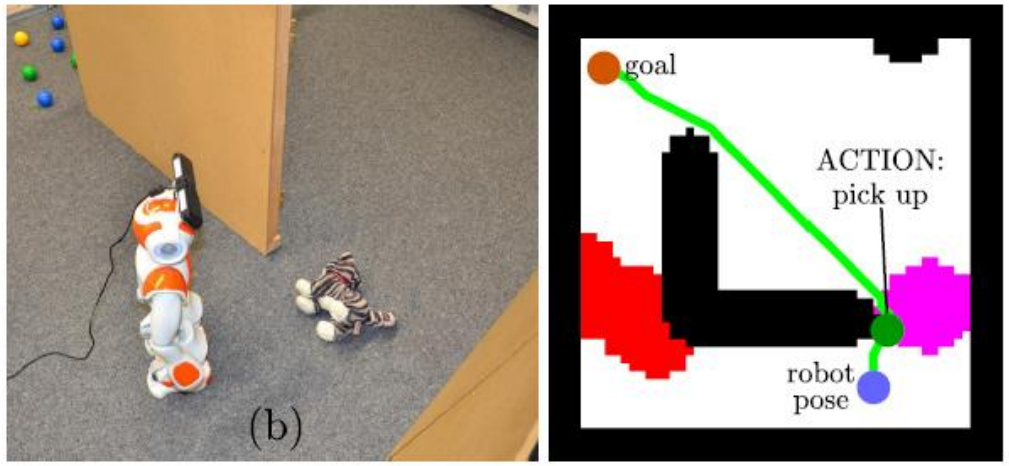
Potential Problem (Personal Thoughts)

- Movement is not continuous
  - Has to update and re-plan every frame
- Directly placing the object behind the robot may not be a good idea
  - What if the robot is not allowed to relocate the object?
- Need an expert to set object – action correspondence
  - How to generalize?
- Assume the same types objects are of similar size
  - What if there's a big box that the robot can't step onto? How about cost?

Potential Improvement (Personal Thoughts)

- Directly generate semantic point cloud
  - Should improve accuracy and speed simultaneously
- D* (field D*) instead of A* when re-planning
  - Improve speed when the map is large
- Increase the default weight of unexplored territories





Thank you!