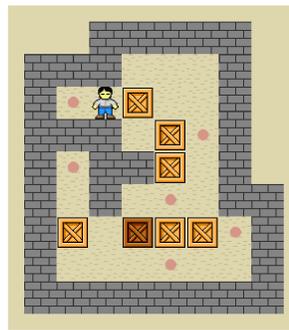


David Inkyu Kim

Gaurav S. Sukhatme

## Motivation

A robot enters a warehouse where it needs to rearrange disorganized boxes



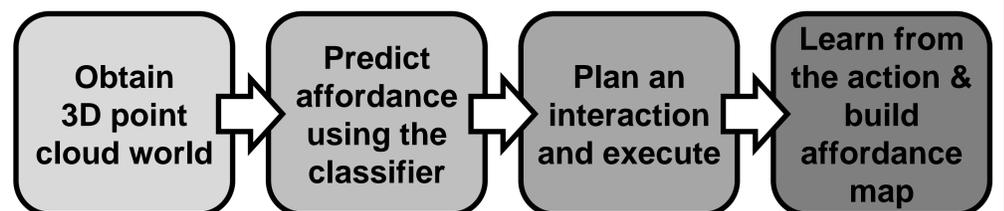
- Sokoban game (Warehouse keeper)
  - Goal - arrange boxes in desired positions by pushing
  - Limited action & action sequence matters
  - NP-hard problem
- Problem for the robot
  - Understanding the environment
  - Understanding objects' affordances

## Approach

Assumption  
Without any prior knowledge of map and objects

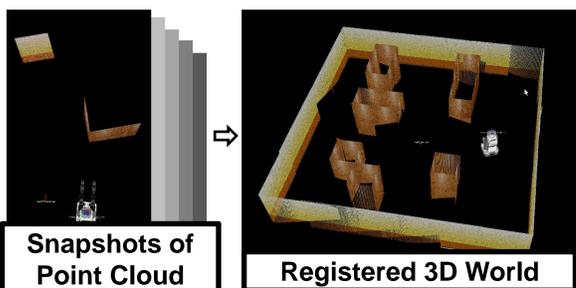
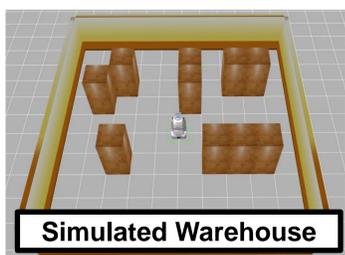
Goal  
Build an affordance labeled world map

Purpose  
A robot to figure out how to rearrange the world



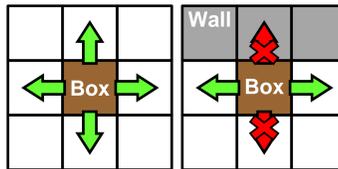
## Mapping

- 3D Point Cloud acquisition
  - Microsoft Kinect mounted on the head of PR2
- Grid world mapping
  - 2D occupancy grid map
  - Frontier-based exploration
  - Odometry based EKF SLAM



## Prediction

- Affordance labels
  - Pushability in 4 directions
  - Unit - one cell
  - Affected by relative positions
- Prediction [Kim et al. 2014]
  - Use geometric features
    - Unary features – shape, normal, centroid, span
    - Pairwise features – relative positions of neighboring cells
  - Learn parameters from examples scenes with randomly placed objects
  - Logistic regression
    - Predict each affordance labels



$$f^l(x) = \beta_0^l + \sum_{i=1}^n \beta_i^l x_i, \quad p^l(x) = \frac{e^{f^l(x)}}{1 + e^{f^l(x)}}$$

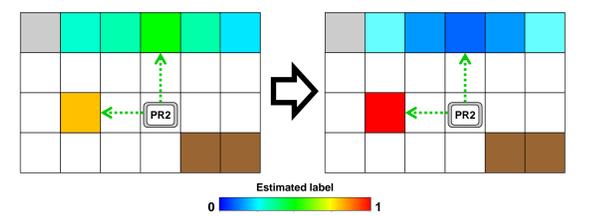
label parameters features

## Interaction

- Goal
  - Reduce overall belief entropy of the affordance map
- Solution
  - Interact with the object to discover its affordance
- Interaction Planning
  - Choose an action that reveals maximum information
- Probability distribution of Markov random field

$$P(x_1, x_2, \dots, x_N) = \frac{1}{Z} \prod_{i=1}^N g_i(x_i) \prod_{\langle i, j \rangle} f_{ij}(x_i, x_j)$$

Unary Potentials Pairwise Potentials



## Conclusion & Future work

- Semantic mapping of object affordance for interactive manipulation
  - Map the world with 2D occupancy grid
  - Predict affordances using geometric features
  - Estimate information gain of possible interaction
  - Train and learn for better prediction and optimal manipulation

- Future work
  - Various objects (e.g. household objects) for more generalized planning
  - Complex manipulation of affordances (e.g. pulling, lifting, etc.)
  - Adaptable classifier for different robot configurations