Robots Towards Making Sense of 3D Data

Nico Blodow, Zoltan-Csaba Marton, Dejan Pangercic, Michael Beetz
Intelligent Autonomous Systems Group
Technische Universität München

RSS 2010 Workshop on Strategies and Evaluation for Mobile Manipulation in Household Environments
Zaragoza, May 2010
missingObjects(Meal, Missing):-
   instanceOf(Table, 'table'),
in(Table, Kitchen),
primaryFunction(Table, 'HavingAMeal'),
perceivedObjectsOnPlane(Table, Perceived),
neededObjectsForMeal(Perceived, Needed),
setOf(Obj, (member(Obj, Needed), 
            not(member(Obj, Perceived)),
          Missing).
Motivation

Assumptions:
- our robot is operating in a household environment,
- we have tables with objects on them,
- we want to reason about their arrangements,
- and perform manipulation.

For this we need:
- keeping track of tables and the clusters on them,
- classify the clusters to know their semantic meaning for reasoning,
- reconstruct the clusters to be able to grasp them.

Long term goal:
- bootstrap database of object-related knowledge (appearance, shape, feature descriptions), replacing need for expensive and cumbersome 3D modeling centers (kind of like what SLAM did to unify localization and mapping)
System Overview

Perception Pipeline

RSR 2010, Zaragoza, May 2010

Robots Towards Making Sense of 3D Data

Blodow, Marton, Pangercic, Beetz
System Overview

Perception Pipeline

Refinement Algorithms
- vision algorithms
- ... (omitted)
- GRSD classification
  - box_detection
  - rotational_detection
  - triangulation

User Modules
- high level planning
- grasp planning
- scene interpretation
- spatio temporal reasoning
- activity recognition
- machine learning
- ... (omitted)

Dynamic Object Store
- object clusters
  - oc_7
  - oc_8
  - oc_9
- tables
  - t_1
  - t_2
  - t_3
- cupboards, doors, drawers
  - d_1
  - d_2
- ... (omitted)

Vision Algorithms

Supported Structures
- Camera / ROI
- Laser scanner
- noise_removal
- normal_estimation
- floor_ceiling
- wall_detection
- table_detection
- furniture_detection
- supported_structures

RSS 2010, Zaragoza, May 2010

Robots Towards Making Sense of 3D Data

Blodow, Marton, Pangercic, Beetz
Remembering Objects

- is **multi-modal** (tilting laser, tof, stereo camera)
- based on **object descriptions**
- reasons about **object identities**
- maintains **belief state** through passive perception
- stores a **time-stamped memory** of perceptions
- computes **symbolic scene descriptions**

[Humanoids2010:] Blodow et al., Perception and Probabilistic Anchoring for Dynamic World State Logging

RSS 2010, Zaragoza, May 2010
Detect table locations and keeping track of object clusters, even if out of view.

Refine representation when needed and when computational resources allow.

Smooth data and compute accurate surface normals using Moving Least Squares fit of polynomial surfaces.
Radius-based Surface Descriptor

- Local variation of normal angles by distance:
  
  **Synthetic Data**
  
  - plane
  - sphere
  - sphere side
  - corner
  - cylinder
  - cylinder top
  - cylinder side
  - edge
  - handle

  **Real Data**
  
  - small cylinder
  - medium cylinder
  - big cylinder
  - handle1
  - handle2
  - handle3

- Estimate minimum and maximum curvature radius from minimum and maximum angle/distance pairs:

  \[
  d(\alpha) = \sqrt{2r} \sqrt{1 - \cos(\alpha)} \Rightarrow d(\alpha) = r\alpha + \frac{r\alpha^3}{24} + O(\alpha^5) \Rightarrow d = r\alpha
  \]

RSS 2010, Zaragoza, May 2010

Robots Towards Making Sense of 3D Data
Radius-based Surface Descriptor

- Voxelization of space and simple feature estimation to reduce computational complexity.
- Since the minimum and maximum radius have physical meanings, simple intuitive rule-based local surface classification is possible.

[IROS2010:] Marton et al., General 3D Modelling of Novel Objects from a Single View

RSS 2010, Zaragoza, May 2010

Robots Towards Making Sense of 3D Data
Global Radius-based Surface Descriptor (GRS)

- A global feature is computed from each cluster by counting transitions between surface types
- As for GFPFH, but, to further reduce computation time, no distribution of transition histograms is built
- Partial matching is also facilitated, but not explored yet, each view is considered a training example
- Use geometric class to decide on what model to fit

[ICCV2009:] Rusu et al., Detecting and Segmenting Objects for Mobile Manipulation

Robots Towards Making Sense of 3D Data

Blodow, Marton, Pangercic, Beetz
Appearance-based Classification

CAD model & SURF matching

Color detection

RSS 2010, Zaragoza, May 2010
Robots Towards Making Sense of 3D Data
Blodow, Marton, Pangerlic, Beetz
Interpretations of Scenes

Missing Objects

missingObjects(Meal, Missing):-
    instanceOf(Table, 'table'),
    in(Table, Kitchen),
    primaryFunction(Table, 'HavingAMeal'),
    perceivedObjectsOnPlane(Table, Perceived),
    neededObjectsForMeal(Perceived, Needed),
    setOf(Obj, (member(Obj, Needed),
                not( member(Obj, Perceived)),
                Missing).

K-Copman perception server

First-Order Probabilistic Reasoning

perceivedObjectsOnPlane(Plane, Perceived) :-
    onPlane(Plane),
    setOf(Obj-Hyp, ( on(Obj, Plane),
                    category(Obj,Cat),
                    uniqueld(Id),
                    objectInstance(Obj,KnownObj),
                    Obj-Hyp = [Id,Obj,Cat,KnownObj]),
        Perceived).

[IROS2010:] Pangercic et al., Combining Perception and Knowledge Processing for Everyday Manipulation

RSS 2010, Zaragoza, May 2010

Blodow, Marton, Pangercic, Beetz
Grasping of Unmodelled Objects

- Estimating surface type and reconstruction using symmetries

RSS 2010, Zaragoza, May 2010
Open Questions

- Processing vs storing data and processing in an offline phase
- Building up and using knowledge about the objects in the environment
- Texture-less objects (entity resolution)
- Scaling
- Combination of 2D/3D information in one feature (e.g. SIFT3D)
CoTeSys-ROS Fall School on Cognition-enabled Mobile Manipulation
Munich, 1.-6. November 2010

Description and Objectives
The CoTeSys ROS Fall School on Cognition-enabled Mobile Manipulation will introduce the participants into the exciting research area of autonomous mobile manipulation. Introductory lectures will be given by world renowned experts in the fields of 2D/3D perception, learning, reasoning and planning. The lectures will be complemented with hands-on practical exercises using various modules of the open-source ROS framework. Many of principle developers will be present and available for support and interaction. The application domain for the fall school will be everyday manipulation in human living environments.

Intended audience
PhD students and researchers interested-in or working in the fields of personal robotics, robot perception, mobile manipulation as well as robotics middle-ware.

Important dates
• Application deadline: August 1, 2010
• Notification of acceptance: August 15, 2010
• Fall school: November 1 - 6, 2010

Organizers
• Michael Beetz, IAS, Technische Universität München
• Gary Bradski, Willow Garage
• Dejan Pangercic, IAS, Technische Universität München
• Radu Bogdan Rusu, Willow Garage

Topics
• ROS Introduction
• From Sensors to Data and Processing
• Knowledge Processing & Learning
• Perception of Scenes
• Planning & Control
• Presentation Day

Tuition Fee and Registration
To apply, students should register on the [http://ias.cs.tum.edu/events/cotesys-ros-school](http://ias.cs.tum.edu/events/cotesys-ros-school). During the summer school, all the students will get an opportunity to present a poster describing their research. School fee is Euro 300. Limited number of scholarships will be made available by the sponsors.

Location
Technische Universität München
CCRL - CoTeSys Central Robotics Laboratory
Barer Str. 21
80333 München, Germany

RSS 2010, Zaragoza, May 2010
Robots Towards Making Sense of 3D Data
Blodow, Marton, Pangercic, Beetz
Thanks!

Intelligent Autonomus Systems Group:
http://ias.cs.tum.edu

Fall School:
http://ias.cs.tum.edu/events/cotesys-ros-school

TUM ROS Package Repository:
http://tum-ros-pkg.svn.sourceforge.net/

Contact:
dean.pangercic@cs.tum.edu