Coupled Joint Registration and Co-segmentation for Indoor Rigid Object Sets

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Abstract

Keywords: Co-segmantion, Joint Registration

Concepts: •**Computing methodologies** → **Image manipulation;** *Computational photography;*

1 Introduction

2 Related Work

3 Method Overview

3.1 Problem Statement

Given a set of point clouds which record the same group of rigid indoor objects with different layout. We intend to samutaneously partition the point clouds into objects and align the points of same object to recover layouts for corresponding object. Figure 1 shows an example of input point clouds set.

3.2 Formulation

To formulate the relation between the unknown object set and the input point clouds. We come up with a generation model as follows:

$$P(v_{mi}) = \sum_{n=1}^{N} p_n \sum_{k=1}^{K_n} p_k N(\phi_{mn}(v_{mi})|x_k, \Sigma_k) \tag{1}$$

which means, The observed point clouds are generated by N object model. Each object model is represented by a gaussian mixture model with K_n centroids. Our goal is to maximize the probability of the expected compelete-data log-likelihood. The object function can be written as:

$$\Theta = \operatorname{argmax} \sum_{Z} P(Z|V,\Theta) \ln P(V,Z;\Theta) \tag{2}$$

in which:

$$\Theta = \{\{p_n\}_{n=1}^{N}, \{p_k, x_k, \Sigma_k\}_{k=1}^{\sum K_n}, \{\phi_{mn}\}_{m=1,n=1}^{MN}\}$$

is the parameters of the generation model.
p_n is the prior probability that the point is generated by the n-th object.
p_k is the weight of the k-th Gaussian.
x_k is the center of the k-th Gaussian.
Σ_k is the standard deviation of the k-th Gaussian.
There are $\sum K_n$ Gaussian model in total and among them, K_n Gaussian models belongs to object n.

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V is the M input point clouds.
v_{mi} is the i-th point of the m-th point cloud.
Z is a latent variable set defined as:

$$Z = \{z_{ij}|j = 1...M, i = 1...N_j\}$$

among which if $z_{ij} = k(k = 1...\sum K_n)$ assign the observation of $\phi_{mn}(v_{mi})$ to the k-th component of Gaussian mixture model.Such formulation can be seen as an extention of joint registration formulation in [Evangelidis et al. 2014], upon which we add several gaussian mixture model together to express a group of objects. By solving this new problem we simutaneously solve the object co-segmentation of given observation.

4 Algorithms and Implementation

4.1 Expectation Conditional Maximization

Assuming the observed point clouds $\{V_m\}$ are independent and identically distributed, we can then write the (2) as:

$$\varepsilon(\Theta|V,Z) = \sum_{m,i,k} \alpha_{mik}(\log p_n + \log p_k + \log P(\phi_{nm}(v_{mi})|z_{ji} = k;\Theta)) \tag{3}$$

In which the $\alpha_{mik} = P(z_{mi} = k|v_{mi};\Theta)$,

Algorithm 1 Joint Registration and Co-segmentation (JRCS)

Input:
$\{V_m\}$:Observed point clouds
$\{\alpha^0_{mik}\}$:Initial posterior probabilities
Output:
Θ^q:Final parameter set

1. $q \leftarrow 0$
2. **repeat**
3. CM-step-a: Use α^q_{mik}, x^{q-1}_k to estimate $\{R^q_{mn}\}$ and $\{t^q_{mn}\}$
4. CM-step-b: Use α^q_{mik}, $\{R^q_{mn}\}$ and $\{t^q_{mn}\}$ to estimate the Gaussian centers x^q_k
5. CM-step-c: Use α^q_{mik}, $\{R^q_{mn}\}$ and $\{t^q_{mn}\}$ to estimate the covariances Σ^q_k
6. CM-step-d: Use α^q_{mik} to estimate the priors p^q_k,p^q_n
7. E-step: Use Θ^{q-1} to estimate posterior probabilities. $\alpha^q_{mik} = P(z_{mi}|v_{mi};\Theta^{q-1})$
8. $q \leftarrow q + 1$
9. **until** Convergence
10. **return** Θ^q

4.2 Initialization Techniques

A key advantage motivates our formulation is that the soft correspondence can be initialized more flexiblely comparing to the typical initialization techniques such as landmark point pairs in registration.
Initial Segment based on Planar Fitting
Block Based Feature Extraction and Clustering
The result of Clustering:

$$P(B_{mj} \in C_n)$$

Soft Correspondence Initialization
Then the α is initialized as:

$$\alpha_{ijk} = P(B_{mj} \in C_n)$$

on the condition that:

$$v_{ij} \in B_{mj} \wedge x_k \in O_n$$

5 Experiments and Discussion

5.1 Debugging The Smooth Step

Bug Description:
When the smooth step is added, the mixture of gaussian model won't expand to fit the input observations.
Test Case Generation:
In order to debug the problem, I generated a set of six synthetic point clouds. For the purpose of debugging, I deliberately made sure that the first 2657 points belonging to table, the following 2028 points belonging to chair, the last 3286 points belonging to teddy. The Test Cases are shown in Figure 1.

Figure 1: *The Synthetic Data for Test:they are composed of three objects (teddy table and chair) with different rigid motion*

The Example of α:
The α are caculated as

$$\alpha_{ijk} = p_n p_k N(\phi_n(v_{ij})|x_k, \Sigma_k)$$

The example α with no smooth:

5.2 Current Result

As shown in Figure 2

5.3 Initialization Experiments

Acknowledgements

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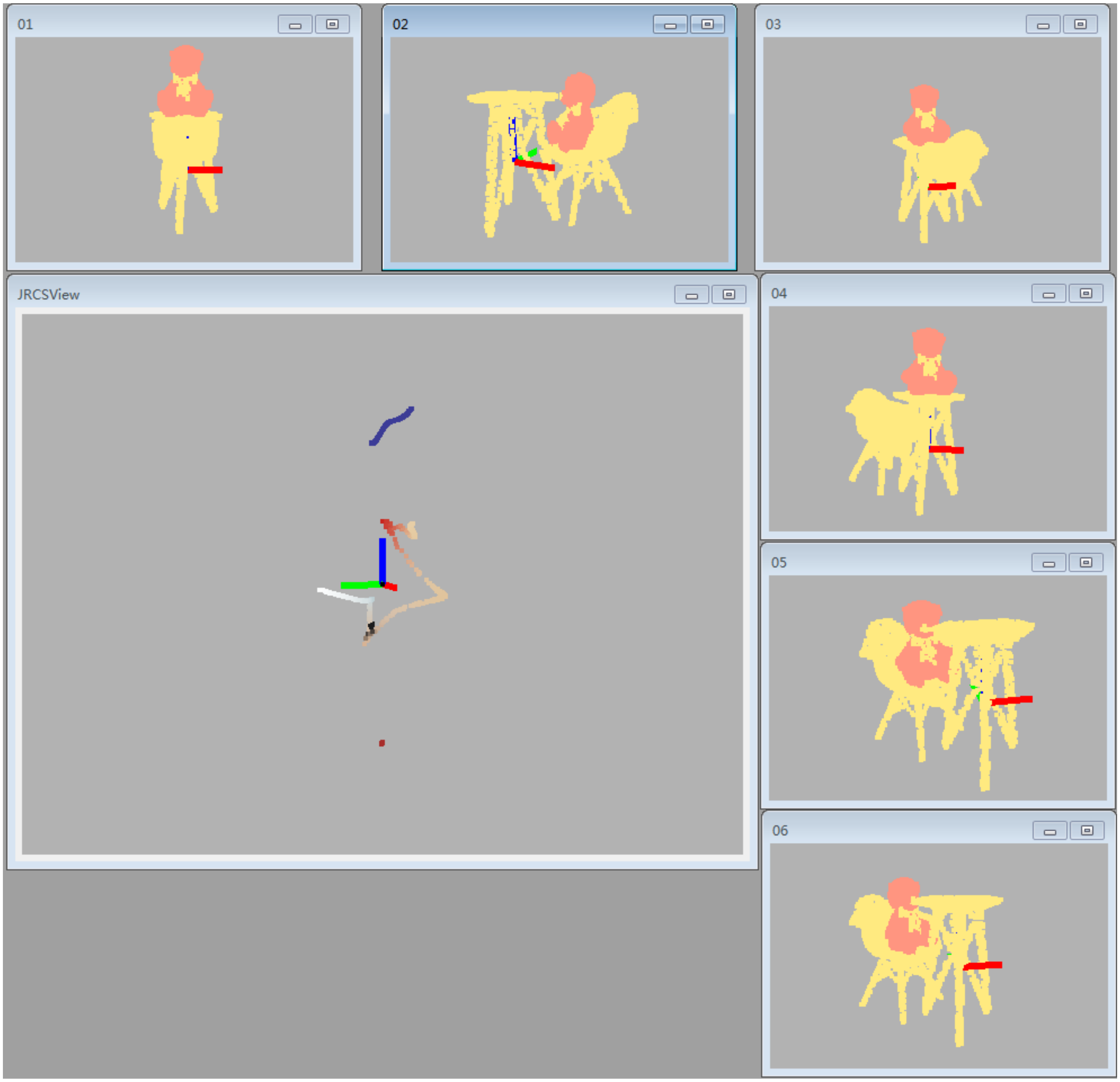

Figure 2: *Current Result*

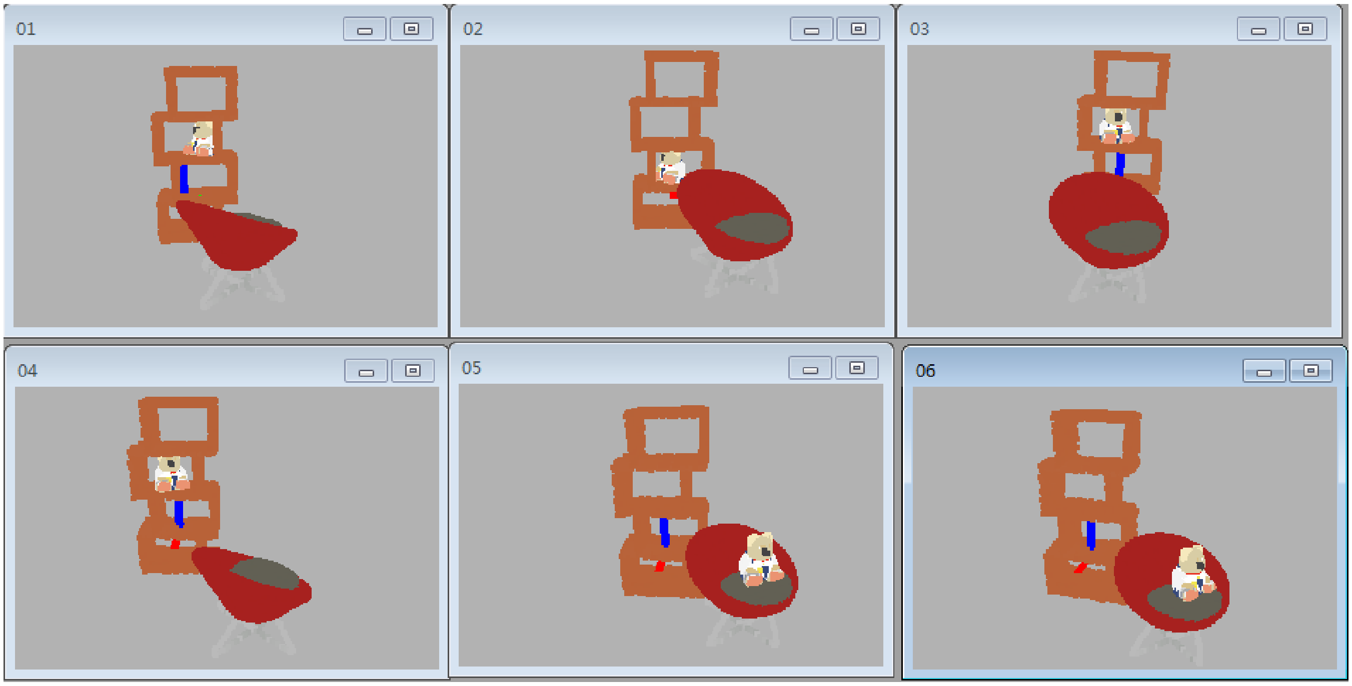

Figure 3: *Input for Initialization Experiments*

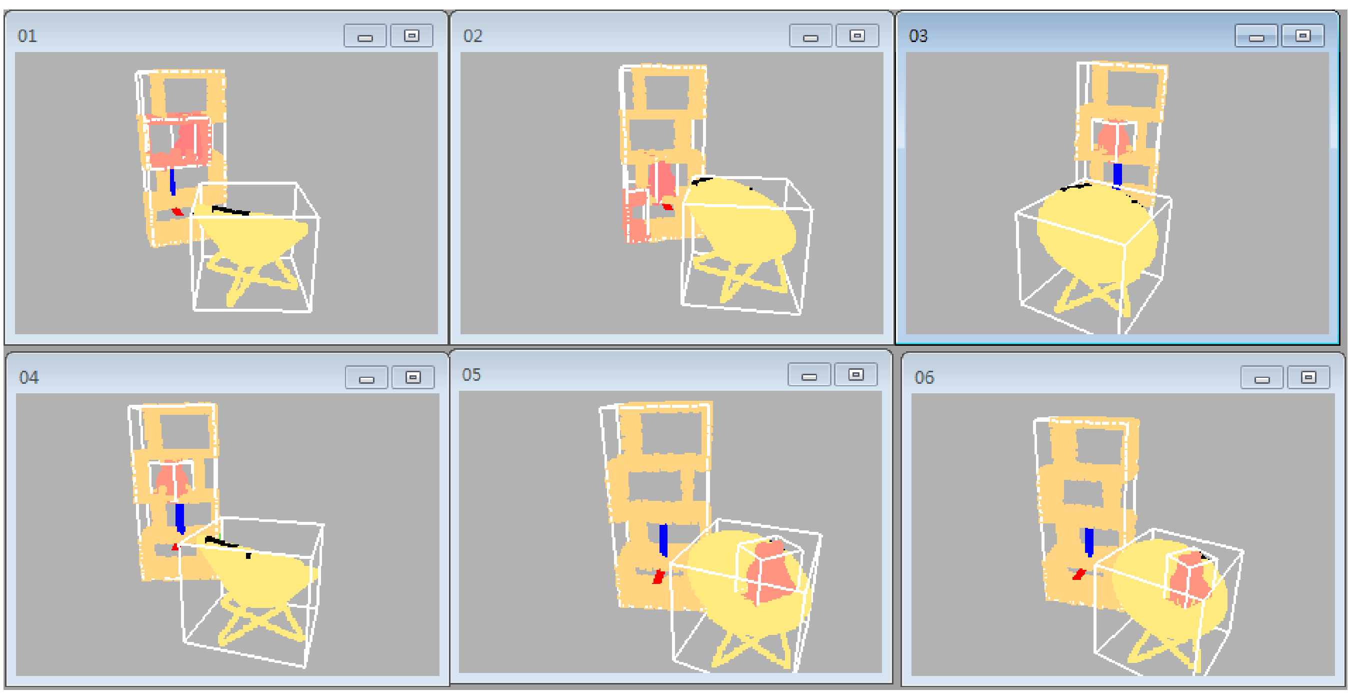

Figure 4: *Segmentation for Initialization Experiments*

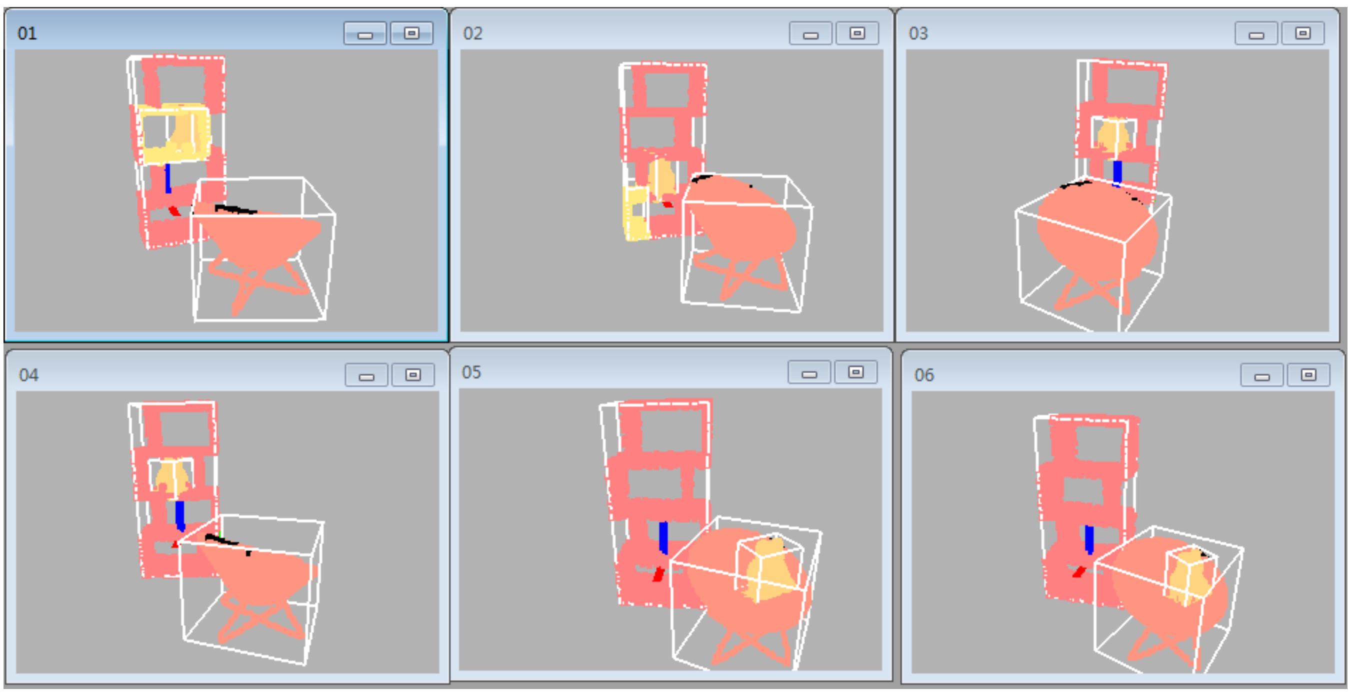

Figure 5: *Clustering for Initialization Experiments*