Example-Based 3D Object Reconstruction from Line Drawings

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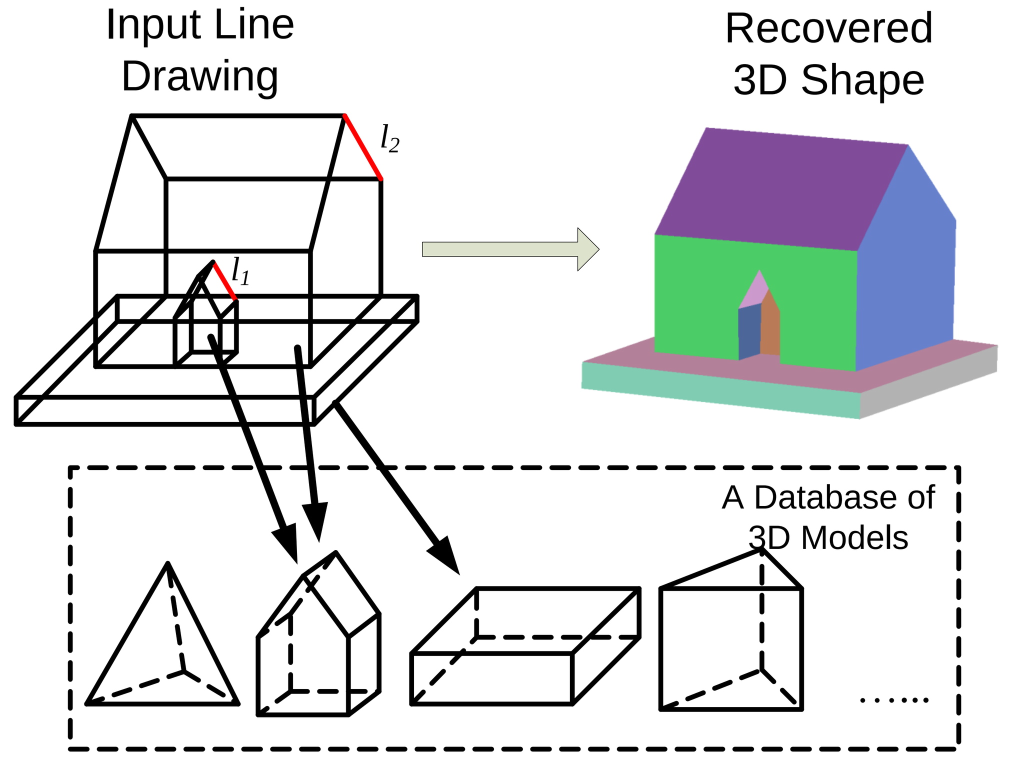
Introduction:

- **Objective**

  Develop an algorithm to automatically reconstruct complex 3D solid objects from line drawings



- **Previous method**

  3D reconstruction is to find a 3D object that is most consistent with some rules of our visual system. These rules includes:

  - Line Parallelism: Two parallel lines in a 2D sketch plane implies that they are also parallel in 3D.
  - Isometry: The ratio of the lengths of two lines in 2D sketch plane should near their ratio in 3D space.

  Limitation: These rules may break in some cases and require the carefully tuning of the weights for each rule.

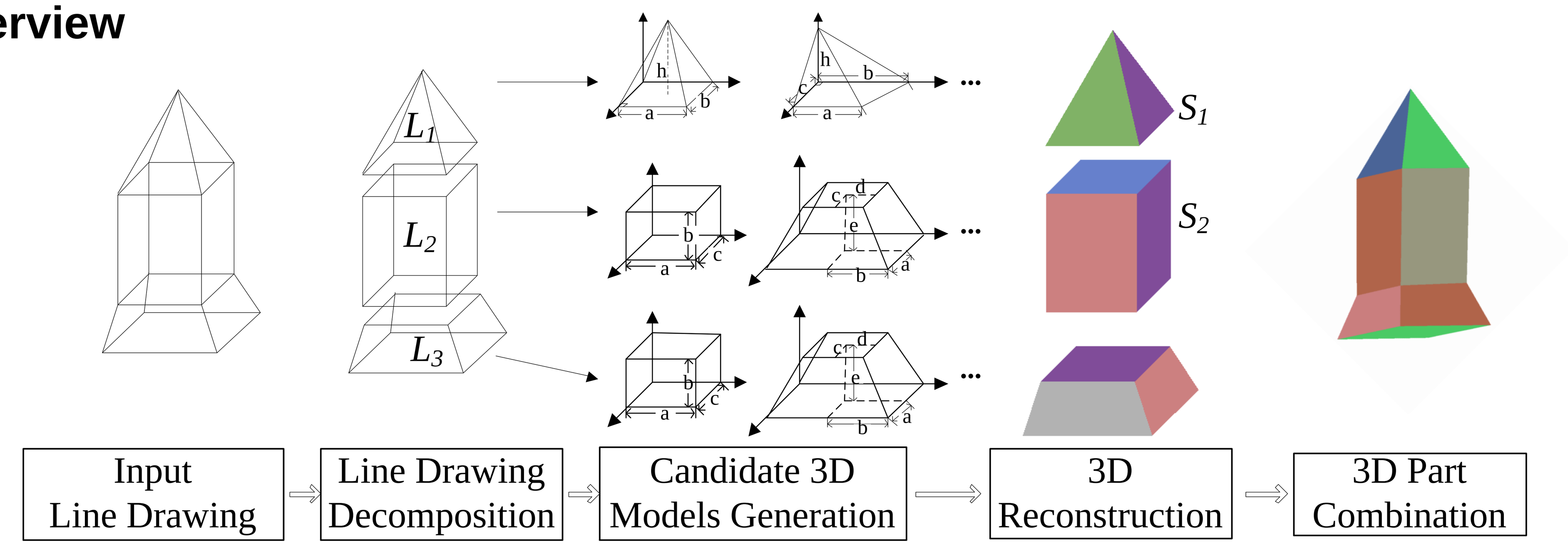
- **Our Approach**

  Observation: a natural or man-made complex 3D object normally consists of a set of basic 3D objects

  Method: Recover the 3D shape by finding a combination of basic 3D models in a database that best fits the input line drawing.

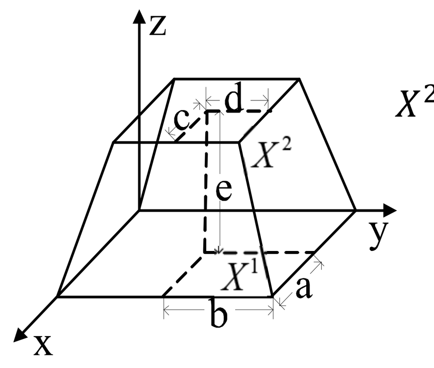
Reconstruction Algorithm:

- **Overview**



- **Models in 3D database**

The 3D shape of each model is controlled by a set of parameters. The coordinates of each point is a linear combination of these parameters.



$$X^2 = \begin{pmatrix} a+c \\ b+d \\ e \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \alpha,$$

where $\alpha = (a, b, c, d, e)^T$

- **3D Reconstruction**

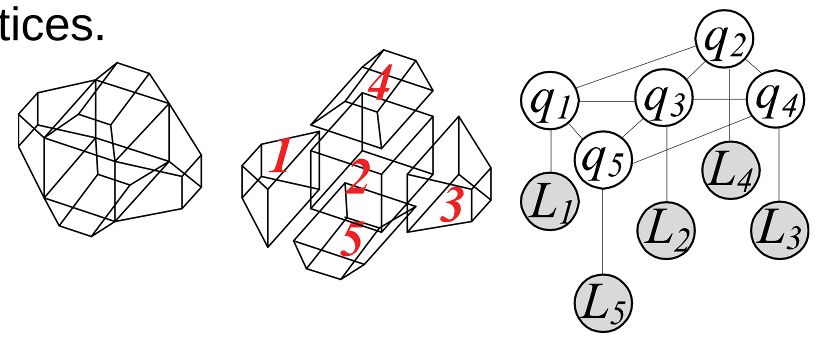
Each 3D part is determined by a set of random variables $q_i = \{c_i, R_{i,1}, t_{i,1}, \alpha_{i,1} \ldots, R_{i,n_i}, t_{i,n_i}, \alpha_{i,n_i}\}$

n_i: No. of candidate 3D models for the i-th part

c_i: n-dim vector indicates which candidate is selected

$R_{i,k}$, $t_{i,k}$: Rotation matrix and translation vector

The relationship of L_i and q_i is modeled as the following undirected graphical model. q_i and q_j are connected if they have some common vertices.



The reconstruction is to minimize the following objective function:

$$\min_{\{q_i\}} \left(\sum_i E(L_i|q_i) + \sum_{(i,j)\in Ne} E(q_i, q_j) + \sum_i E(q_i) \right)$$

1. Projection Constraint $E(L_i|q_i)$: The projection of a 3D part on the 2D plane should be consistent with the original line drawing:

$$E(L_i|q_i) = \lambda_p \sum_{i=1}^{n_i} c_i(k) \sum_{v\in V_i} \left|\left|K X_{i,k}^v - x_{i,k}^v\right|\right|^2$$

2. Construction Constraint $E(q_i, q_j)$:The common 3D vertices of two neighboring 3D parts should be as close as possible.

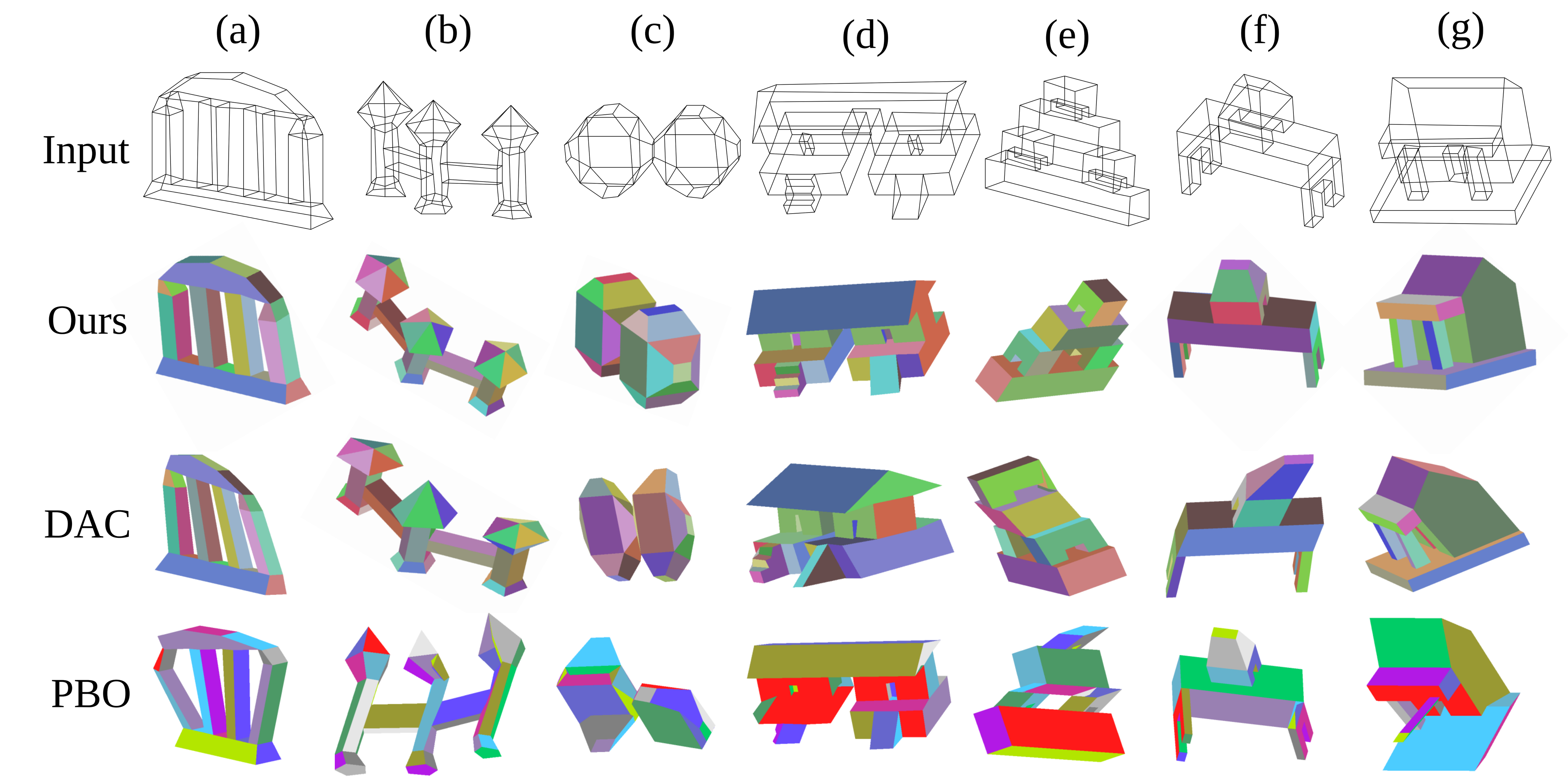
$$E(q_i, q_j) = \lambda_c \sum_{k=1}^{n_i} \sum_{l=1}^{n_j} \left(c_i(k) c_j(l) \sum_{v\in V_i \cap V_j} \left|\left|X_{i,k}^v - X_{i,k}^v\right|\right|^2 \right)$$

3. Candidate Prior: We assign high prior to those 3D models with less parameters to ensure robustness.

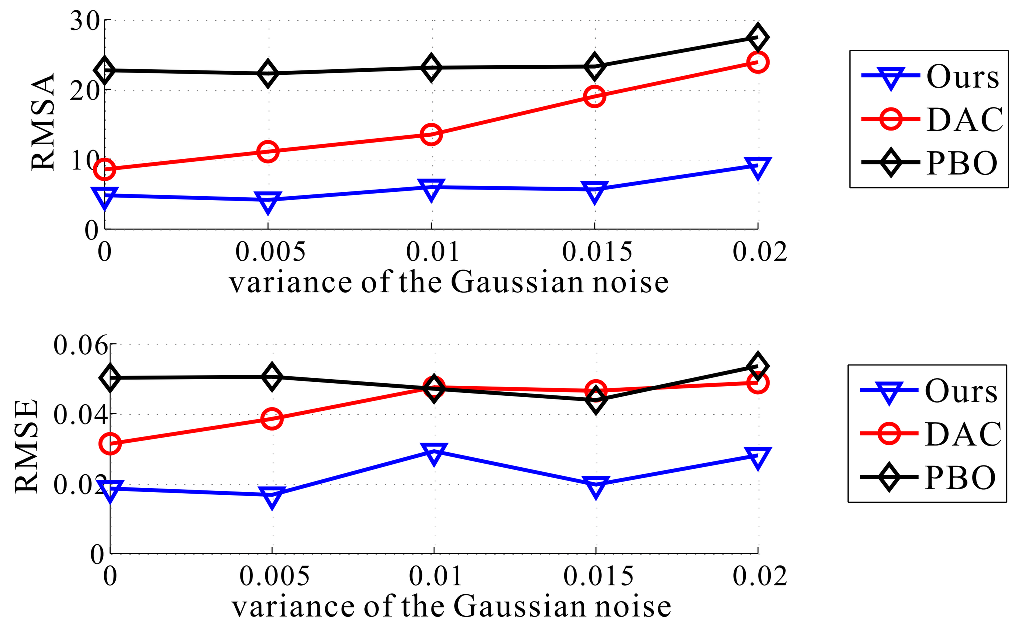
$$E(q_i) = \sum_{k=1}^{n_i} c_I(k) \eta_{i,k}$$

This problem is solved by an alternative minimization algorithm (See our paper for more details).

Experimental Result:



- **Quantitative experiment**



- **3D from Images**