Introduction to Scan Matching

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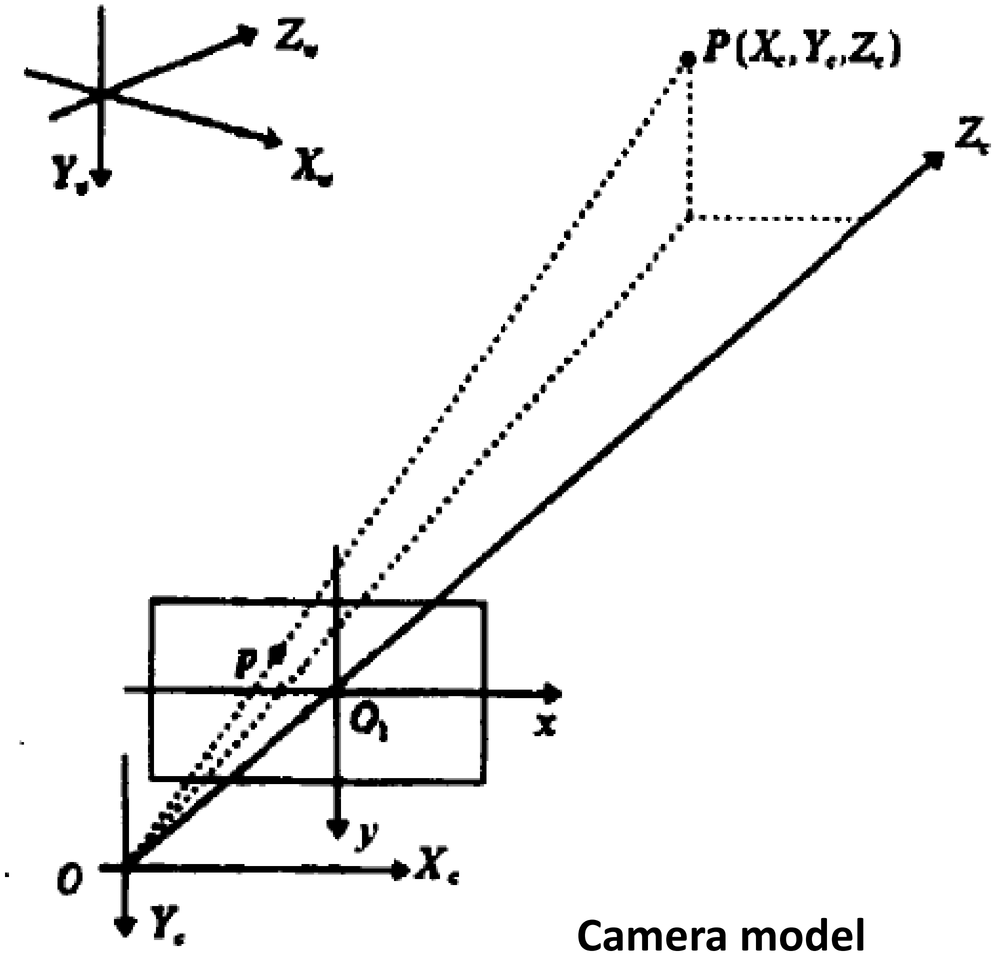
Pin-hole Imaging Model

- Generation of the 3D points
  (in the camera coordinate)

$$Z_C\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}\frac{1}{dx} & 0 & u_0\\ 0 & \frac{1}{dy} & v_0\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}f & 0 & 0 & 0\\ 0 & f & 0 & 0\\ 0 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}R & T\\ 0^T & 1\end{bmatrix}\begin{bmatrix}X_W\\Y_W\\Z_W\\1\end{bmatrix}$$

f, dx, dy, u_0, v_0 —— intrinsic parameters
R, T —— extrinsic parameters

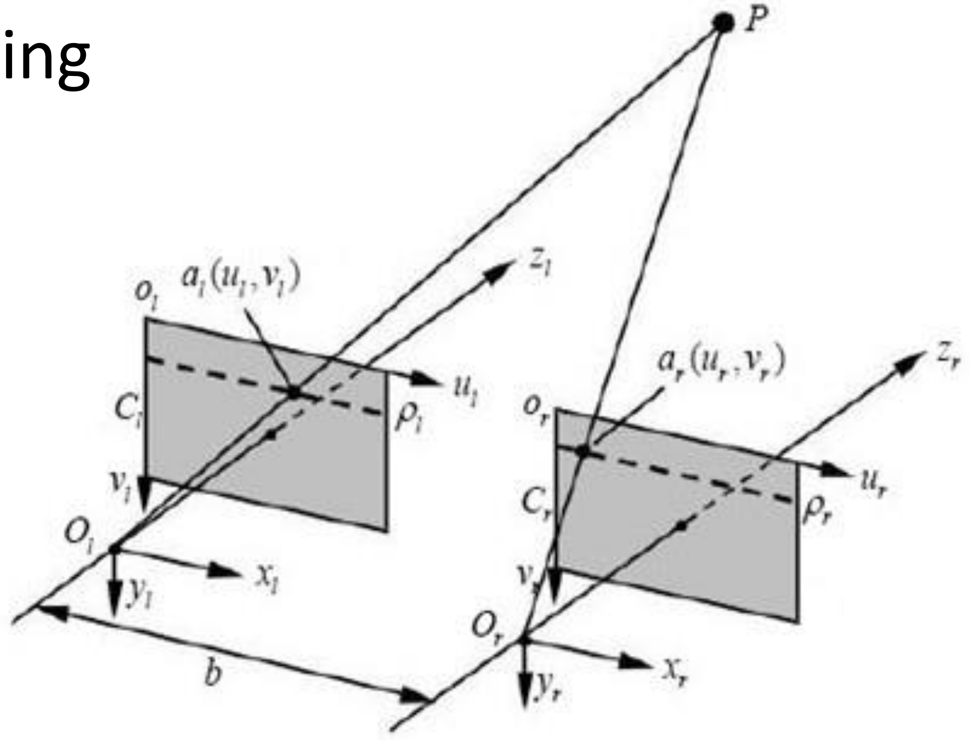


Camera model

Scan Matching

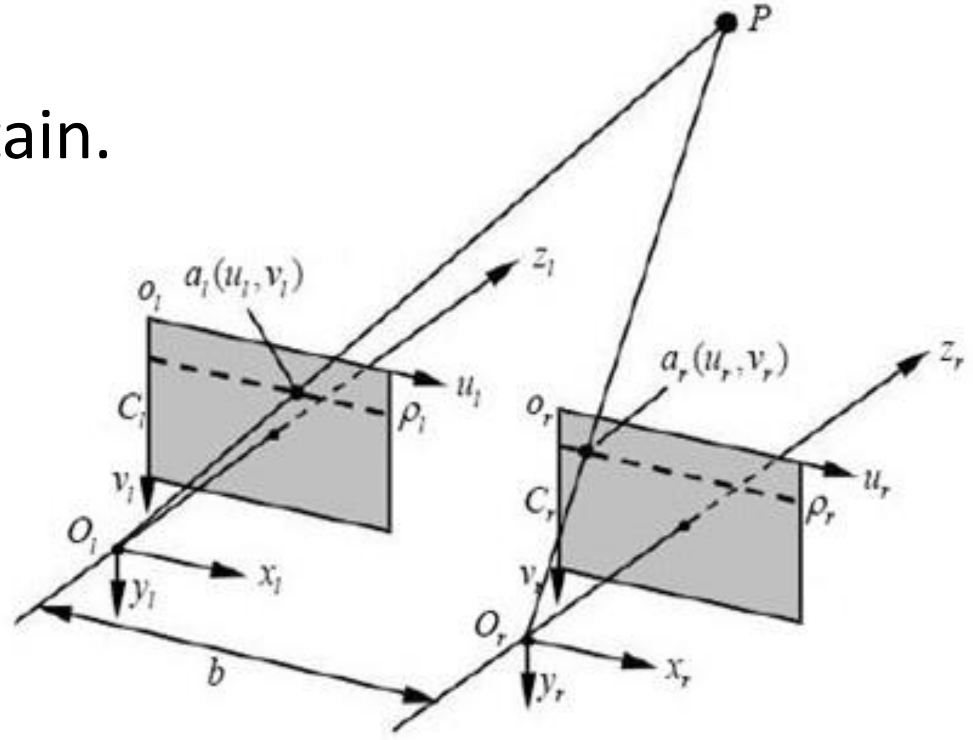
- Camera Movement (or Stereo Vision)
- Generated 3D points are in different coordinate system.
- Unified coordinate system →Scan Matching

- Need to solve:
- Transformation between two coordinates
  - Rotation
  - Translation



Sparse method

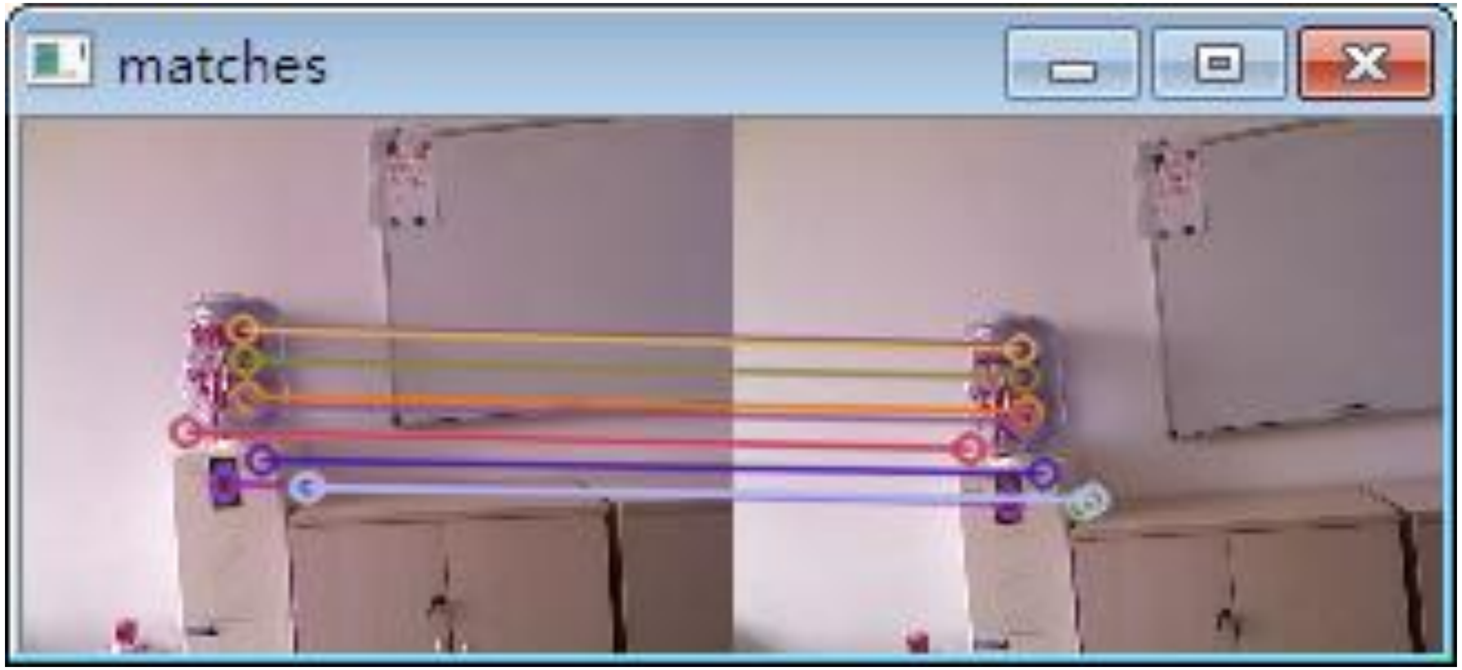
- Three corresponding point pairs would be enough to determine the transformation.
- Could be very fast.
- But the correspondence is not easy to obtain.



Get the correspondence

- For example,
- To detect feature points and match them in the image
- Project them to the 3D space using depth information

- Deficiency:
- Not robust
- Large uncertainty



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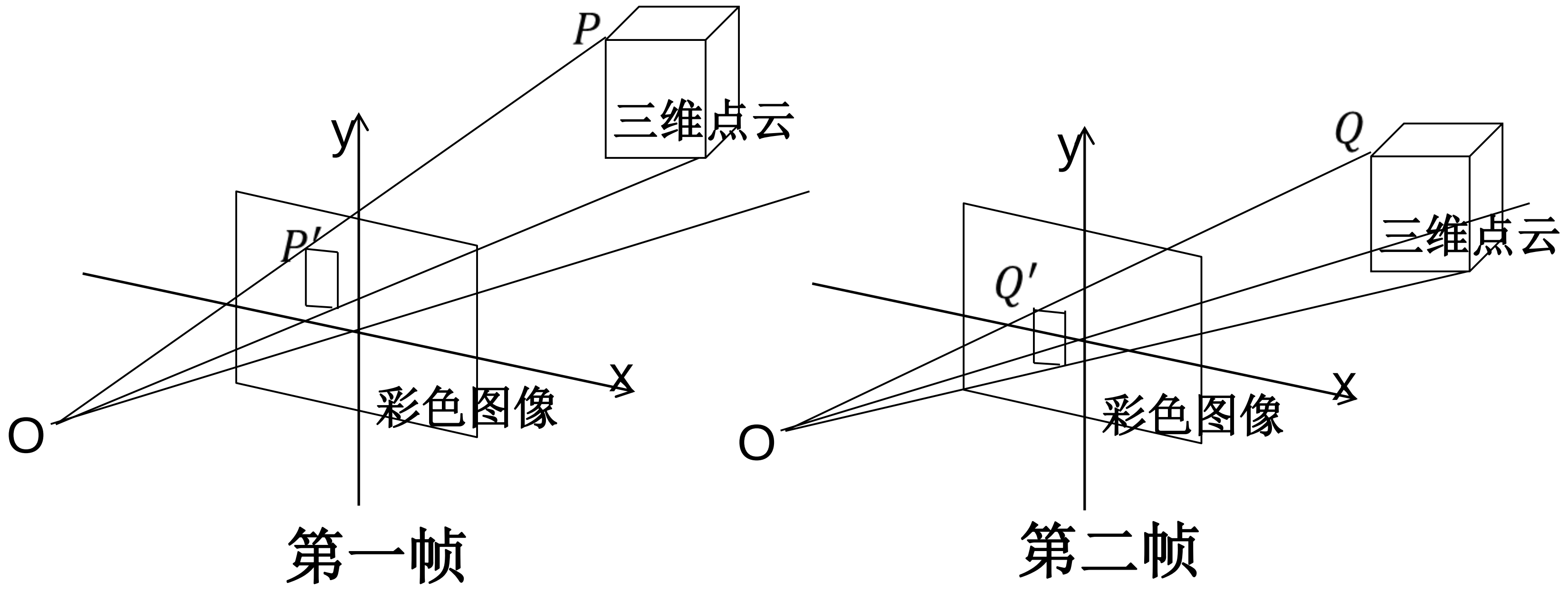


Dense method – Iterative Closest Point (ICP)[1]

- Key concept of ICP:

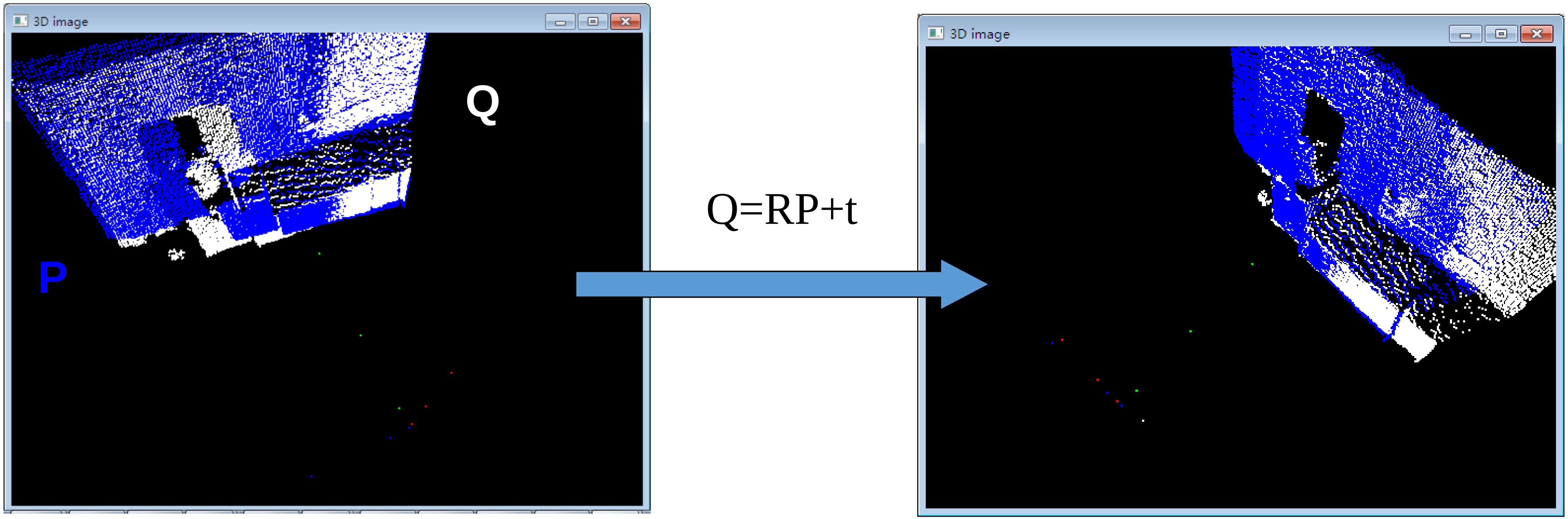
input : Two pointclouds: $A = \{a_i\}, B = \{b_i\}$
An initial transformation: T_0
output: The correct transformation, T, which aligns A and B

$T \leftarrow T_0$;
while *not converged* **do**
  for $i \leftarrow 1$ **to** N **do**
    $m_i \leftarrow \texttt{FindClosestPointInA}(T \cdot b_i)$;
    if $||m_i - T \cdot b_i|| \leq d_{max}$ **then**
      $w_i \leftarrow 1$;
    else
      $w_i \leftarrow 0$;
    end
  end
  $T \leftarrow \underset{T}{\operatorname{argmin}} \{\sum_i w_i ||T \cdot b_i - m_i||^2\}$;
end

[1] P. Besl, N. McKay. "A Method for Registration of 3-D Shapes," IEEE Trans. on Pattern Analysis and Machine Intel., vol. 14, no. 2, pp. 239-256, 1992.

Dense method – Iterative Closest Point (ICP)

- An example of using ICP



Generalized ICP[2]

- Two point clouds $A = \{a_i\}_{i=1,\cdots,N}, B = \{b_i\}_{i=1,\cdots,N}$
- Assume that $a_i \sim N\left(\hat{a}_i, C_i^A\right), b_i \sim N\left(\hat{b}_i, C_i^B\right)$
- consider each sampled point to be distributed with high covariance along its local plane, and very low covariance in the surface normal direction

$$\mathbf{T} = \underset{\mathbf{T}}{\operatorname{argmin}} \sum_i d_i^{(\mathbf{T})^T} (C_i^B + \mathbf{T} C_i^A \mathbf{T}^T)^{-1} d_i^{(\mathbf{T})}$$

$$d_i^{(T)} = b_i - Ta_i$$

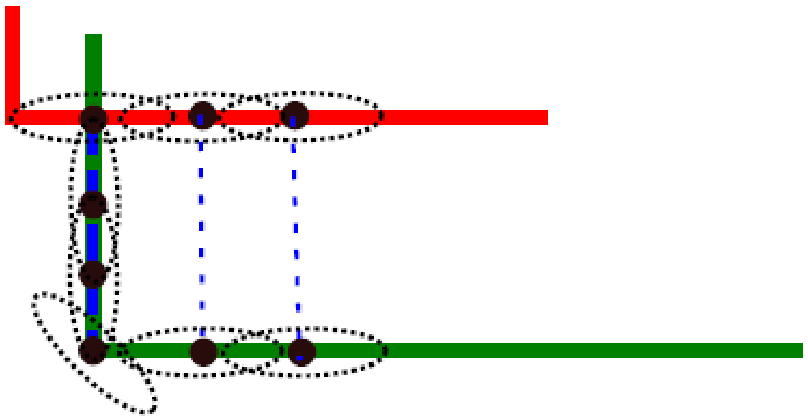
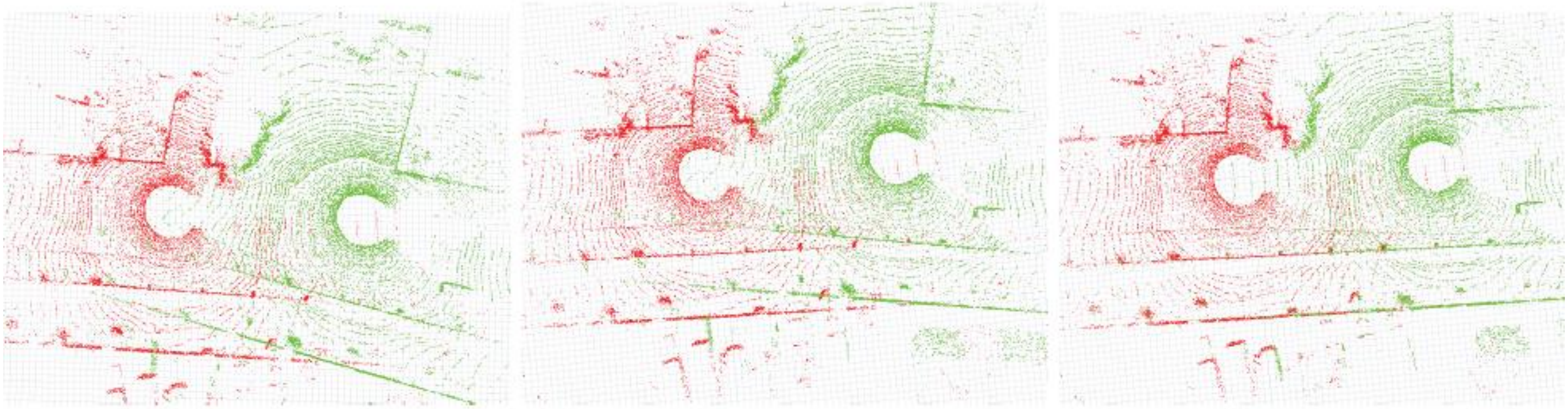


illustration of plane-to-plane

[2] Generalized-ICP
A. V. Segal , D. Haehnel , S. Thrun, In Robotics: Science and Systems, 2009

Generalized ICP



(a) Initial alignment (b) Point-to-plane (c) Generalized-ICP

Thank you