

Scan Alignment

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Announcements

- Demonstrations next week. Same time slots as the first demonstration.
- No lectures next week.

- We've looked at LIDAR feature extraction as a way of answering the question "have I been here before?" Today we're going to look at scan alignment, an alternative method for answering the same problem.

Scan Alignment

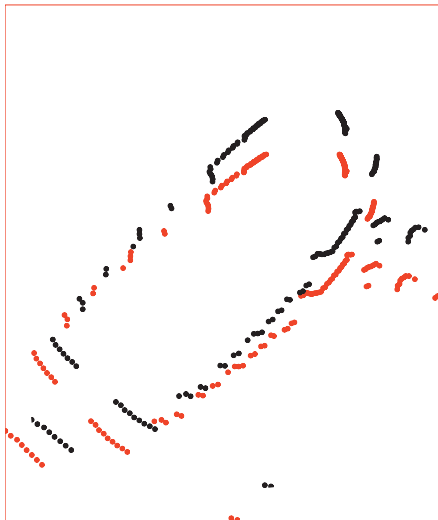


Figure: Scan Alignment

- Scans consist of points
- Points are relative to a *pose*
 - The pose is where we think the robot was when it took the scan
 - Typically x , y , and bearing
- Points typically stored in polar coordinates

Scan Alignment Problem Setting

- Restrict search to translation and rotation. I.e. rigid transform
- Minimise squared distance (i.e. squared error) between scans
 - How do we define this?
 - Minimise squared error between *matching points*
 - That is, given scan A and scan B, associate each point in A with a point in B and minimise the (squared) distance between them
- So:
 - Define matching points
 - Show how to find rigid transformation to minimise error

Iterative Closed Point

- The general family of algorithms are called iterative closest point (ICP).
- We'll look at the iterative dual correspondence (IDC) algorithm of [Lu and Milios(1997)]
- Used for 2D and 3D scan matching when you have a good initial estimate of pose
 - Find locally maximum transform
 - Fail when poses too far apart
- There is an extensive literature on IDC algorithms.

Iterative Dual Correspondence

- Remember, two problems:
 - Define matching points
 - Minimise error
- IDC uses two methods to define matching points, hence the name. They are:
 - Closest point
 - Matching range point

Closest Point

- The obvious rule – match two points that are closest together
- Typically informative of translation but not rotation

Matching Range Point

- Match points that have the same distance (range) from their respective poses *and* are within a predetermined rotation of one another
- Typically informative of rotation but not translation
- Assumes initial poses are close together

Dual Correspondence

- Experimental results show closest point is more informative of translation, and matching range point more informative of rotation
- Therefore use the (locally) optimal translation obtained by the closest point match and the (locally) optimal rotation from the matching range point match

Interpolation and Outliers

- When matching a two scans we label one the reference (normally the older one) and one the new scan. When we match the new scan against the reference scan, we can interpolate the reference scan to find the best match.
- Different rule for each point matching rule.
- If the distance between two matching points is higher than a threshold, they are rejected as outliers. This helps deal with occlusion.

Minimising Error

- We want to find the translation and rotation that minimise the squared distance between the matching points. That is, minimise:

$$E_{dist}(\omega, T) = \sum_{i=1}^n |R_{\omega} P_i + T - P'_i|^2 \quad (1)$$

where:

- ω is the angle
- T is the translation
- P_i and P'_i are matching points
- R_{ω} is the rotation matrix for a rotation of angle ω

Rotation in the 2D plane

- For a rotation of angle ω the rotation matrix R is

$$\begin{bmatrix} \cos \omega & -\sin \omega \\ \sin \omega & \cos \omega \end{bmatrix} \quad (2)$$

- Can expand R_ω giving

$$E_{dist}(\omega, T) = \sum_{i=1}^n (x_i \cos \omega - y_i \sin \omega + T_x - x'_i)^2 \quad (3)$$

$$+ (x_i \sin \omega + y_i \cos \omega + T_y - y'_i)^2 \quad (4)$$

- - To minimise the error we can take the partial derivatives for each variable (T_x, T_y, ω) , set to zero, and solve. Solution in the paper.

- Given reference S_{ref} and new scan S_{new}
- Find $P'_{cp} = \text{closestPoint}(S_{ref}, S_{new})$ and $P'_{mrp} = \text{matchingRangePoint}(S_{ref}, S_{new})$
- Minimise error giving (ω_{cp}, T_{cp}) and (ω_{mrp}, T_{mrp})
- Choose transformation of (ω_{mrp}, T_{cp})
- Repeat till change in both least squared error is below a threshold, or after a fixed number of iterations (15-20 iterations suggested in the paper).

- Iterative closest point algorithms are still very popular and they are many variants
- Lots of parameters to set – can be fiddly to getting working
- If the true translation between the poses is small, they work well
- If the true translation is large they fail. This is case is SLAM applications, when returning to a place after a lengthy travel
- I'm a fan of [Olson(2009)], which shows the brute force method can be made fast enough, and has low error regardless of the distance between poses



Feng Lu and Evangelos Miliotis.

Robot pose estimation in unknown environments by matching 2d range scans.

Journal of Intelligent and Robotic Systems, 18(3):249–275, March 1997.



E.B. Olson.

Real-time correlative scan matching.

In *IEEE International Conference on Robotics and Automation, 2009. ICRA'09.*, pages 4387–4393. IEEE, 2009.

URL http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5152375.