Comparison of People Detection Techniques from 2D Laser Range Data

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Motivation

As mobile robots slowly enter our daily lives and human environments a robot should be able to accomplish new tasks:

- Interaction with humans
- Motion planning considering human activity
- Learning by imitating and observing humans

Security Purposes:

- Recognition of abnormal behavior from humans in public places
People detection approaches based on sensor data:

- **Visual People Detection**
  - Data provided by camera sensors
  - Easily effected by the ambient conditions
- **Detection in Laser Range Data**
  - Popular application in other robotic tasks such as localization and mapping
  - Invariant to different lighting conditions, perspective change, etc.
  - Do not carry much information about humans
People Detection: 2D Laser Range Data

One scan of the environment gathered by a laser range sensor

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Comparison of People Detection Techniques from 2D LR Data
We based our research on comparing two methods:

- **Circle Fitting:** [Premebida and Nunes, 2005] propose a novel arc and circle detection method called Inscribed Angle Variance- IAV.

- **Boosting:** [Arras et al., 2008] and [Zivkovic and Kroese, 2007] suggest promising results for people detection by training and using AdaBoost.
Detection in Laser Range Data

- Features:
  - Geometric features
  - Motion features
- Two main phases of people detection in our work:
  - Segmentation
  - Detection: three approaches
- Goal: study effect of boosting several geometric features in comparison with IAV circle fitting method in people detection
Segmentation

- Segment data into sets related to the targets detected by the laser
- Simplify the detection phase
- Each segment is presented as a set of points in polar coordinates:

\[ S_i = \{ p_1(r_1, \alpha_1), \ldots, p_i(r_i, \alpha_i), \ldots, p_n(r_n, \alpha_n) \} \]  (1)
Algorithm

If $D(r_i, r_{i+1}) > D_{\text{thd}}$ Then, segments are separated Else segments are not separated

$$D_{\text{thd}} = C_0 + C_1 \min(r_i, r_{i+1}) \quad (2)$$

$$C_1 = \sqrt{2(1 - \cos(\Delta \alpha))} \quad (3)$$
Detection

- Bounding box as baseline
- IAV Circle fitting
- Boosting using AdaBoost
Baseline Approach - Bounding Box

- diagonal $d$ of the bounding box is the parameter for classification

$$\mathcal{H} = \begin{cases} 
d_{\text{lower bound}} < d_{S_i} < d_{\text{upper bound}} & \text{accept} \\
\text{Otherwise} & \text{reject} 
\end{cases}$$  

(4)
Circle Fitting

- Humans appear to be curved shaped in the laser range data
- Idea: Fit a circle with least square error with the Inscribed angle Variance (IAV) method
- Step 1: Determine the possibility of a segment being a circle
  - average angle value between 80 and 135 degree
  - standard deviation of angles between 8.6 - 23 degree

The inscribed angles of an arc are congruent
Circle Fitting - Inscribed Angle Variance

Determine the center of the circle

- Step 2: Determine parameters of the circle
  - compute the center of the circle
  - take the distance between one point and the center \( \Rightarrow \) radius
Boosting

- Question: Can a set of weak classifiers create a strong classifier?
- A weak classifier is only slightly better than random guessing
- Weighted sum of these weak classifiers constructs a strong classifier
- We would like to combine several features to form a strong classification
- Each feature is realized in a weak classifier
- AdaBoost is the most famous algorithm for implementation of this idea
A segment and corresponding fitted circle

- sum of the distances: 0.229877
- standard deviation of x coordinate: 0.0596496
- standard deviation of y coordinate: 0.0145876
- width: 0.198568
- jump distance to previous seg.: 1.11584
- jump distance to next seg.: 1.1456
- diagonal of bounding box: 0.203893
- number of points: 18
- fitted circle: radius: 0.166812, center: (0.35629, -1.26325)

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AdaBoost - Algorithm

• Input: Set of examples \((e_1, l_1), \ldots, (e_N, l_N)\), where \(l_n = +1\) for positive examples and \(l_n = -1\) for negative ones

• Initialize weights \(D_1(n) = \frac{1}{n}\)

• For \(t = 1, \ldots, T\) \{ 
  • For each \(h_j\) calculate: \(r_j = \sum_{n=1}^{N} D_t(n) l_n h_j(e_n)\), where \(h_j(e_n) \in \{+1, -1\}\)
  • Choose \(h_j\) that maximizes \(|r_j|\) and set \((h_t, r_t) = (h_j, r_j)\)
  • Update the weights: \(D_{t+1}(n) = D_t(n) \exp(-\alpha_t l_n h_t(e_n))\), where \(\alpha_t = \frac{1}{2} \log \left(\frac{1+r_t}{1-r_t} \right)\)
  • Normalize the weights: \(D_t(n) = \frac{D_t(n)}{\sum_{i=1}^{N} D_t(i)}\)

• The final strong classifier is given by: \(H(e) = \text{sign}(F(e))\), where \(F(e) = \sum_{t=1}^{T} \alpha_t h_t(e)\)
• Data was gathered using a SICK laser range finder
• 50 randomly selected scans were used for training purposes
• 1800 scans were used for testing
• Interval of acceptance for bounding box is set to \([0.1, 0.3]\)
  and for circle fitting is set to \([0.05, 0.6]\) meters
Experiments and Results

Histograms of the diagonals of the bounding boxes

- (a) human segments
- (b) nonhuman segments
Conclusion

- People detection and tracking is a key issue in many robotics tasks
- Two approaches were implemented and tested
- AdaBoost was compared to the new IAV circle fitting method
- Results of the experiment suggest that boosting several features can yield higher performance in comparison with a single individual feature
Thank you for your attention

Questions?