Fast Pose Estimation with Parameter Sensitive Hashing

G. Shakhnarovich, P. Viola, T. Darrell

Main idea

- Fast (sub-linear time) search for examples similar in a parameter space
- Application to single frame human body pose estimation

Sub-linear time search

\[ P(h(x) = h(y)) = \text{sim}(x,y) \]

Sub-linear time search with LSH

Locality Sensitive Hashing [Gionis, Indyk, Motwani, 1999]

Indexing for parameter estimation

Posed as a paired classification problem:

For each pair of examples \((x_i, x_j)\) assign label

\[ y_{ij} = \begin{cases} +1 & \text{if } d_p(\theta_i, \theta_j) < r, \\ -1 & \text{if } d_p(\theta_i, \theta_j) > R, \\ \text{not defined otherwise,} & \end{cases} \]
Paired examples

- Interpret a binary hash function $h$ as a classifier:
  \[ \hat{y}_h(x_i, x_j) = \begin{cases} 
  +1 & \text{if } h(x_i) = h(x_j) \\
  -1 & \text{otherwise.}
  \end{cases} \]

  \[ p_2(h) \rightarrow \text{probability of false positive} \]
  \[ 1 - p_1(h) \rightarrow \text{probability of false negative} \]

Learning PSH functions

- Set threshold so that #false positives + #false negatives minimal (obtained with two passes over training examples)
- Assemble some decision stumps for hash functions that have high accuracy on paired problem for database examples

  \[ h_{\phi, T}(x) = \begin{cases} 
  +1 & \text{if } \phi(x) \geq T, \\
  -1 & \text{otherwise.}
  \end{cases} \]

  - Set threshold so that #false positives + #false negatives minimal (obtained with two passes over training examples)

Pose estimation with PSH

- Describe images with multi-scale edge histograms
- Learn PSH functions
- Enter training examples into hash tables
- Query database with LSH
- Estimate pose from approximate NN using locally weighted regression

Results
Pose tracking application

• Model-based approach
• Example-based matching with PSH combined with local optimization

[Demirdjian, Taycher, Shakhnarovich, Grauman, Darrell, ICCV 2005]

Animation application

[Ren, Shakhnarovich, Hodgins, Pfister, and Viola, ACM Transactions on Graphics 2005]

Strengths and contributions

• General method that allows fast indexing more attuned to parameter space
• Practical, scalable system for example-based learning
• Single-frame 3D pose estimation
• Interesting use of realistic synthetic data

Assumptions / Limitations

• System requires good body detection and localization
• Training examples must be representative of problem space
• Need good guess for radius parameter

Next time

• Fast indexing techniques for local feature matching