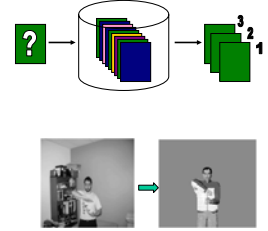## Fast Pose Estimation with Parameter Sensitive Hashing
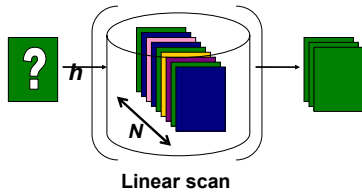
G. Shakhnarovich, P. Viola, T. Darrell

Main idea

- Fast (sub-linear time) search for examples similar in a *parameter* space
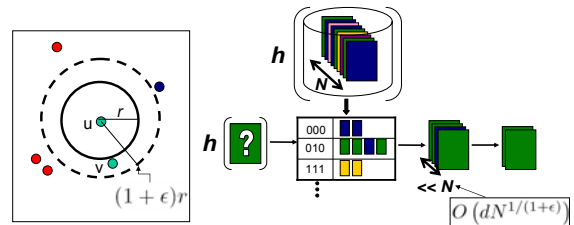

- Application to single frame human body pose estimation

Sub-linear time search

Linear scan

P(h(x)=h(y)) ≈ sim(x,y)

Sub-linear time search with LSH

$$(1+\epsilon)r$$

$$O\left(dN^{1/(1+\epsilon)}\right)$$

$$\text{if } d(\mathbf{u},\mathbf{v}) \leq r \text{ then } \Pr_{\mathcal{H}}\left(h(\mathbf{u}) = h(\mathbf{v})\right) \geq p_1$$

$$\text{if } d(\mathbf{u},\mathbf{v}) > (1+\epsilon)r \text{ then } \Pr_{\mathcal{H}}\left(h(\mathbf{u}) = h(\mathbf{v})\right) \leq p_2$$

need $p_1 > p_2$
and $p_1 > 1/2$

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

Indexing for parameter estimation

$$(\mathbf{x}_1, \theta_1), \ldots, (\mathbf{x}_N, \theta_N)$$

Input space
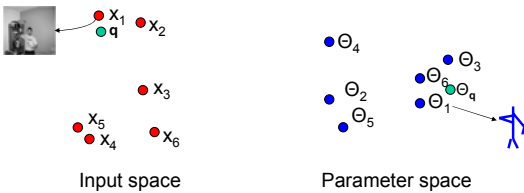
Parameter space

Index with LSH and randomized hash functions that respect *input space* locality

This work: learn hash functions that respect *parameter space* locality

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Learning PSH functions

Posed as a paired classification problem:

For each pair of examples $(\mathbf{x}_i, \mathbf{x}_j)$ assign label

$$y_{ij} = \begin{cases} +1 \text{ if } d_\theta(\theta_i, \theta_j) < r, \\ -1 \text{ if } d_\theta(\theta_i, \theta_j) > R, \\ \text{not defined otherwise,} \end{cases}$$

Paired examples

Learning PSH functions

- Interpret a binary hash function *h* as a classifier:

$$\hat{y}_h(\mathbf{x}_i, \mathbf{x}_j) = \begin{cases} +1 \text{ if } h(\mathbf{x}_i) = h(\mathbf{x}_j) \\ -1 \text{ otherwise.} \end{cases}$$

$p_2(h)$ -> probability of false positive

> Examples collide, but not similar in parameter space

$1\text{-}p_1(h)$ -> probability of false negative

> Examples similar in parameter space, but no collision

Learning PSH functions

- Assemble some decision stumps for hash functions that have high accuracy on paired problem for database examples

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

- 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
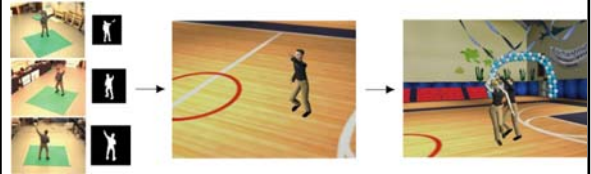

Results

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