# Discovering Object Classes from Activities


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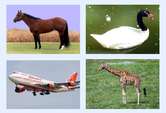
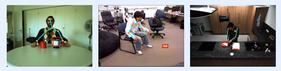
## 1.Quick Summary

- Object models require a vast amount of training data to perform well
- Recent shift of attention to utilize weakly annotated data in videos
- Fundamental assumption of present day methods:
  - Motion and/or appearance of the object of interest is dominant
  - Object of interest forms the main theme of the video



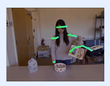
- **Problem: Work on small and medium sized objects**
  - Video data for objects like mugs, plates etc. is scarce
  - Labelled human activity data available in plenty
  - Previous assumptions do not hold: dominant human



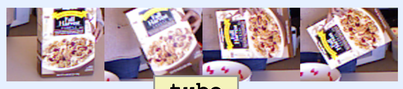
- **Input to the system**
  - Set of videos of similar activities
  - Automatically extracted Human Pose
- **Output from the system**
  - Object tubes common to all videos
  - One tube per video
- **Datasets for Experiments**
  - ETHZ (RGBD, TOI, Model Based Pose est.)
  - CAD-120 (RGBD, Kinect, OpenNI tracker)
  - MPII-Cooking (RGB, Pictorial structures)
- **Conclusions**
  - Appearance insufficient for small objects
  - Big gains from encoding Functionality
  - Present day pose estimation is good enough

## 2.Tubes Generation

$$p(T_v) = \sum_S \sum_\tau p(T_v|\tau, S)p(\tau)p(S)$$



random seeds

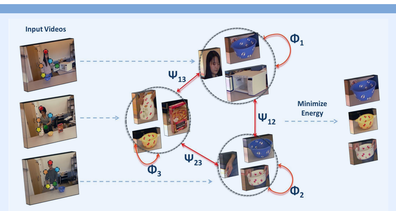


tube

- Tubes generated by randomly selected superpixel and tracking algorithms

## 3.Model

Input is a set of action videos with human pose. Instances of the co-mmon objects are discovered by defining similarity in apperance and functionality as:




$$E(L) = \sum_v \Phi(l_v) + \sum_{v,w} \Psi(l_v, l_w)$$

**Unary:** App (saliency) | Body avoidance | Pose-object-relation | Size

**Binary:** Shape | Functionality

APP | FUN | SIZ

$$\Phi(l_v) = \lambda_1 \Phi^{app}(l_v) + \lambda_2 \Phi^{pose}(l_v) + \lambda_3 \Phi^{body}(l_v) + \lambda_4 \Phi^{size}(l_v)$$

$$\Psi(l_v, l_w) = \lambda_5 \Psi^{shape}(l_v, l_w) + \lambda_6 \Psi^{func}(l_v, l_w)$$

## 4.Unary Terms

- Appearance saliency: chi$^2$ RGB(D) distance between inside a tube and around it

$$\Phi^{app}(l_v) = \frac{1}{K}\sum_{k=1}^{K}\left(1 - \frac{1}{2}\sum_i \frac{(I_{k,i} - S_{k,i})^2}{I_{k,i} + S_{k,i}}\right)$$

- Pose-object relation: median distance between closest joint and center of the tube

$$\Phi^{Pose}(l_v) = \frac{1}{K}\sum_{k=\alpha\cdot K}^{(1-\alpha)\cdot K} \|c_{D(k)} - j_{D(k)}\|$$

saliency

object-pose relation

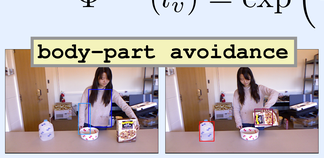
- Body avoidance: maximum response of the body-appearance/skin model

$$\Phi^{body}(l_v) = \max\{\bar{p}_{skin}(I), \bar{p}_{upper}(I), \bar{p}_{lower}(I)\}$$

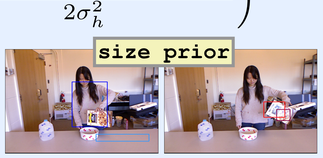
- Size: Variation of object size based on the size of the hand

$$\Phi^{size}(l_v) = \exp\left(\frac{(w_{l_v} - 2w_h)^2 + (h_{l_v} - 2h_h)^2}{2\sigma_h^2}\right)$$

body-part avoidance



size prior



## 5.Binary Terms

- Functionality: (Normalized) Head-Object distance after DTW alignment

$$\Psi^{func}(l_v, l_w) = \text{median}_k\left\{|d_{\omega_v(k)} - d_{\omega_w(k)}|\right\}$$

functionally dissimilar

functionally similar

- Shape: Median PHoG distance between frames after DTW alignment

$$\Psi^{shape}(l_v, l_w) = \text{median}_k\left\{\frac{1}{2}\sum_i \frac{\left(P_{\omega_v(k),i} - P_{\omega_w(k),i}\right)^2}{P_{\omega_v(k),i} + P_{\omega_w(k),i}}\right\}$$

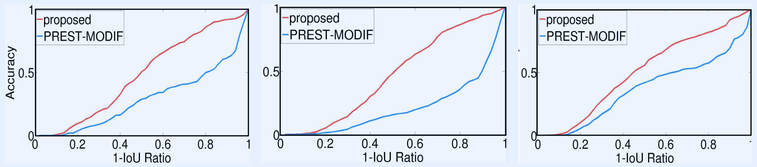
dissimilar shape

similar shape

## 6.Inference

- Model parameters set using Validation Dataset (one class per dataset)
- Use loopy belief propogation (TRW-S) algorithm for inference

## 7.Results




IOU distribution: Cumulative frame IOU distribution for MPII, ETHZ and CAD-120

Comparison with state-of-the-art: Prior art full model, prior art using proposed tubes, full proposed model

| | prest-exact | prest-modif | proposed |
|---|---|---|---|
| ETHZ | 0.063 | 0.249 | 0.447 |
| CAD | 0.039 | 0.246 | 0.410 |
| MPII | 0.023 | 0.221 | 0.342 |

| | proposed | APP | APP+SIZ | FUN | APP+FUN | FUN+SIZ |
|---|---|---|---|---|---|---|
| ETHZ-Action | 0.447 | 0.192 | 0.305 | 0.292 | 0.312 | 0.390 |
| CAD-120 | 0.410 | 0.168 | 0.191 | 0.147 | 0.202 | 0.350 |
| MPII-Cooking | 0.342 | 0.079 | 0.149 | 0.229 | 0.235 | 0.288 |

Evaluating potential groups: Average class IOUs for various combinations

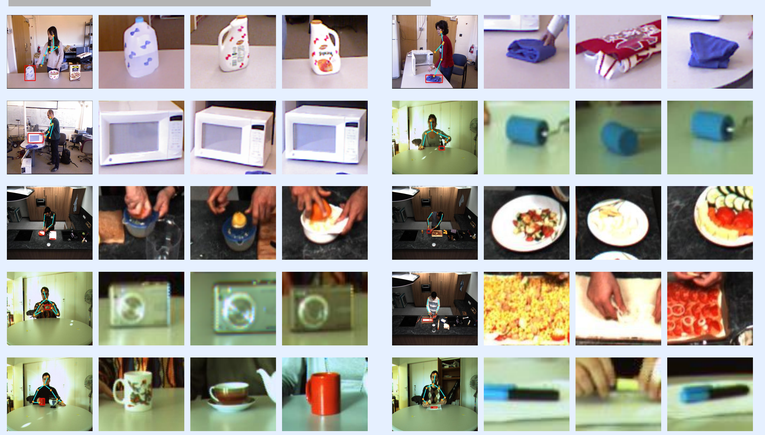
| | $\Phi^{app}$ | $\Phi^{pose}$ | $\Phi^{body}$ | $\Phi^{size}$ | $\Psi^{shape}$ | $\Psi^{func}$ |
|---|---|---|---|---|---|---|
| ETHZ-Action | 0.35 | 1.88 | -25.49 | -13.50 | -4.62 | -8.86 |
| CAD-120 | -48.66 | -15.73 | -18.89 | -20.80 | -40.15 | -9.19 |
| MPII-Cooking | -15.85 | 0.06 | -31.09 | -10.70 | 0.058 | -60.95 |

Evaluating individual potentials: (%) change in average class-IoU when discarded

| | ETHZ | CAD | MPII |
|---|---|---|---|
| GTruth | 60.6 | 29.4 | 47.8 |
| Inferred | 53.2 | 24.4 | 35.3 |

Comparing object models: Average precision (%) of object detectors from groundtruth and inferred tubes

## 8.Inferred Tubes

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