Human Pose as Context for Object Detection

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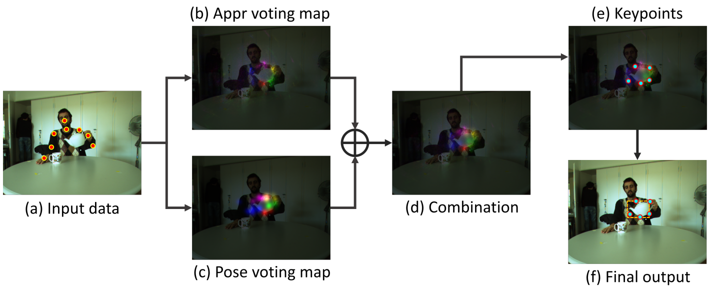

Figure 1: Detecting teapots: (a) Input is an image and automatically extracted human pose. (b) Object keypoint unaries based on appearance features and (c) using human pose features. (d) Linear combination of unaries. (e) Inferring keypoints (f) Regressing bounding box.

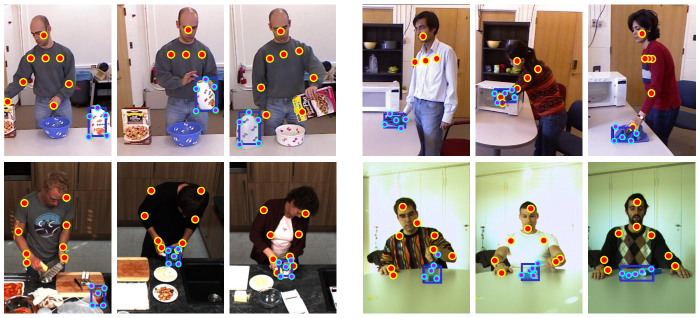

Figure 2: Qualitative results showing input human pose and most confident inferred bounding boxes as per Eqn (2). Successful detections are shown for classes *Milkbox, Cloth* from CAD-120; *Tin* from MPII-Cooking and *Roller* from ETHZ-Activity.

Object detection has seen considerable success, but the case of medium and small sized everyday objects still remains an open problem. Although such objects appear at low image resolutions, they often occur in the context of human interactions. Human context has been exploited in [1] which extends a deformable part model (DPM) to model spatial relations between body parts and parts of objects. This approach, however, only works well for images showing the instant of human-object interaction, i.e., when a human is closely in contact with an object. For images without an interaction, pose and objects are independently modelled, e.g., by having several models including either object or pose, or both together thereby leaving the human context unutilised.

In this work, we propose an approach that includes human pose as an additional context for object detection. Our approach is not limited to images showing explicit human-object interactions, but also works for general images where pose can be inferred. To this end, we model objects by a part based model and predict locations of parts from both image and pose data using regression forests. An outline of the approach is presented in Figure 1.

As illustrated in Figure 1(f), we represent an object by a set of descriptive keypoints $\mathcal{K} = \{\mathbf{k}_i\}$ where $\mathbf{k}_i$ encodes the image location of the i^{th} keypoint. Following pictorial structures model, an optimal keypoint configuration given an observation $\mathcal{D}$ is given by

$$p(\mathcal{K}|\mathcal{D}) \propto \prod_i \phi_i(\mathbf{k}_i) \cdot \prod_{i,j \in E} \psi_{ij}(\mathbf{k}_i, \mathbf{k}_j) \qquad (1)$$

While we retain binary potentials to model relative keypoint offsets in the tree structured graph E as in [1], our work focuses on extracting more discriminative unary potentials $\phi_i(\mathbf{k}_i)$ derived from observations in appearance $\mathcal{D}_A$ and human pose $\mathcal{D}_P$ and is given by

$$\phi_i(\mathbf{k}_i) = p(\mathbf{k}_i|\mathcal{D}_A, \mathcal{D}_P) \qquad (2)$$

$$\sim \left(K(\sigma_A) * \phi_i^A(\mathbf{k}_i)\right) + \alpha \left(K(\sigma_P) * \phi_i^P(\mathbf{k}_i)\right) \qquad (3)$$

where $*$ represents the convolution operation and σ is the standard deviation for the Gaussian blur kernel K. Since the human pose can only provide a rough prior for the location of an object class but is insufficient for accurate object localization, $\sigma_P > \sigma_A$. The probailities are estimated by random forests either trained on image patches [3] or on joint features [6]. The unary potential for any modality is defined by

Table 1: Average AUC measures for various datasets.

Dataset	Appr.	Pose	Gall [3]	Desai [1]	Concat.	Comb.
MPII-Cooking	0.38	0.22	0.37	0.19	0.25	**0.41**
ETHZ-Action	0.46	0.24	0.42	0.50	0.23	**0.51**
CAD-120	0.31	0.09	0.29	0.21	0.20	**0.32**

$$\phi_i(\mathbf{k}_i) = \sum_{m=1}^{M} \frac{1}{|\mathcal{T}_i|} \sum_{T \in \mathcal{T}_i} p_m(\mathbf{k}_i - \mathbf{y}|c, L_T) \cdot p(c|L_T), \qquad (4)$$

where $\mathcal{T}_i$ is the forest for the keypoint $\mathbf{k}_i$, anchor $\mathbf{y}$ is either the patch location for appearance or joint location for pose observations, L_T is the leaf resulting from the observation and $p(c|L_T)$ is the class probability stored at the leaf.

We evaluate the proposed approach on three datasets: ETHZ-Activity [2], CAD-120 [4] and MPII-Cooking [5]. Human pose is automatically inferred in all three datasets. We use the PASCAL-VOC measure for object detection. We compare our approach in various settings in Table 1. It can be seen that the appearance (Appr.) only features significantly outperform the pose (Pose) only features.

Comparing with state of the art methods, method [3] which uses appearance feature for object detection by voting for the center of the object performs slightly worse than the appearance only setup. The method [1] combines human pose estimation and object detection. The approach performs better than pose only features in ETHZ-Action and CAD-120 datasets, but significantly worse in the MPII-Cooking dataset.

As for combining appearance and pose features, we compare to an approach where a single forest is trained on a concatenation of both features (Concat). The accuracy of this approach, however, drops sharply in contrast to appearance only features. Finally, combining both modalities (Comb.) as per Eqn (2) yields the best results in all three datasets with gains ranging from 1% to 5%.

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