Improving Detection of Deformable Objects in Volumetric Data

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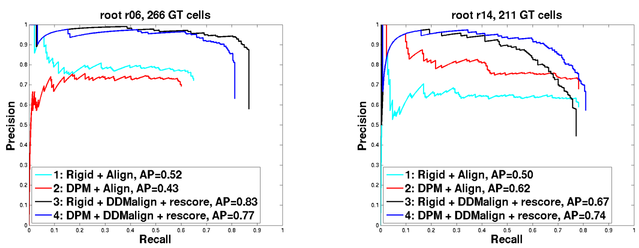
Overview. We investigate class level object detection of deformable objects. To this end, we aim for cell detection in volumetric images of dense plant tissue (*Arabidopsis Thaliana*), obtained from a confocal laser scanning microscope. In 3D volumetric data, the detection model does not have to deal with scale, occlusion and viewpoint dependent changes of the appearance, however, our application needs high recall and precision. We implement Felsenszwalb's Deformable Part Model for volumetric data. Corresponding locations for part training are obtained via elastic registration. We identify limitations of its star shaped deformation model and show that a pairwise connected detection model can outperform the DPM in this setting.

Contribution. We combine the ideas of discriminative detection and elastic registration by using a discriminative similarity measure with a pairwise deformation model. To this end, we show that deformable detection approaches can be formulated in a general elastic registration framework. We propose the *Discriminative Deformable Model* (Fig. 2(d,h)): A set of pairwisely connected patch detectors. Each patch detector is realized as a *linear Support Vector Machine*. The optimization of the model is cast as a discrete labeling problem (*Markov Random Field*) and efficiently solved with iterated graph cuts (*FastPD*). The patch detectors are trained jointly and yield the *unary costs*, while the relative motion of neighboring patches gives the *binary costs* of the model: Only connected patches that move inconsistently have to pay displacement penalties.

Results. We show that we can improve the detection of deformable objects in volumetric image data substantially by using the more meaningful scores from the *Discriminative Deformable Model*. We obtain the fine grained localization of the elastic deformation model combined with the expressive scores that stem from the discriminative data term. The strategies based on the *DDM* based alignment with rescoring outperform the rigid and DPM based detection approaches by a margin of 0.23 percentage points with a mean average precision of 0.75. The average intersection over union of the valid detections with the ground truth data is 0.69 (Precision Recall Graphs in Fig. 1).



(a) (b)

Figure 1: Precision-recall Graphs of the different detection strategies for the two roots (a) r06 and (b) r14. The alignment and rescoring with the proposed *Discriminative Deformable Model* (DDMalign, **black** curve and **blue** curve) produces the best results, independent of the underlying detector.

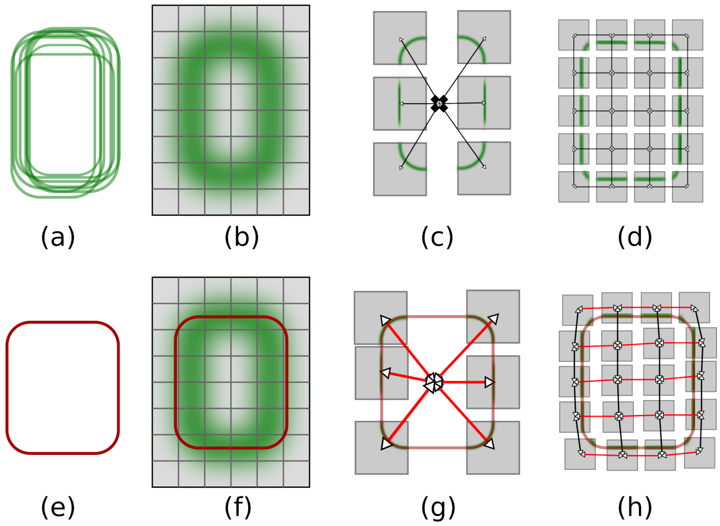


Figure 2: Illustration of different detection approaches and how they deal with deformation. (a) Overlay of the rigidly aligned positive training examples. (b) A rigid detection model allows for small local deformations due to the (soft-) binning of the gradients in the HOG cells. (c) The star shaped structure of the DPM allows parts to move independently. (d) *Proposed model*: The parts are connected pairwisely. (e) A Detection sample that is wider than most of the training examples. (f) The rigid filter barely detects the object. (g) Every part filter of the DPM has to pay a displacement penalty. (h) The parts of the proposed model only get penalties for horizontal displacements.

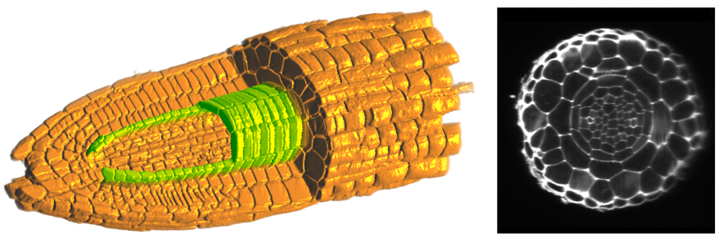


Figure 3: We work with 3D volumetric data of *Arabidopsis Thaliana* that was recorded with a confocal laser scanning microscope. Our goal is to detect and segment single cells of a specific layer. **(left)** A Volume rendering of the root *r06*, the layer used for training and detection is colored green. **(right)** A slice of the original raw data.