**Problem**
- Given bounding box, track object causally in video.
- Object appearance changes:
  - deformation, viewpoint, illumination, occlusions, ...
- Thus want to update object model online:
- but avoid drift due to outliers.
- Mixed regression (state) and classification (inlier vs. outlier) problem.

**Proposal**
- Represent object as collection of discriminative parts
  - Superpixels or tracked patches
- Parts belonging to the object follow dynamic model

\[
\begin{align*}
\dot{x}(t+1) &= \dot{x}(t) + \nu(t) \\
\dot{w}(t+1) &= \text{stochSubgrad}(w(t), y(t), \chi(t)) \\
\chi(t) &= \text{argmin} \left[ E(g(\hat{w}(t), \nu(t), \chi(t)) \right) \\
\hat{h}(\chi(t) \in \chi(t)) &= C(x(t) + w(t))
\end{align*}
\]

- Multiple instance learning perspective:
  - One positive bag per frame (search area)
  - Each positive bag defined by state prediction
  - Infer labels subject to additional side information
  - Side information can be color, motion, occlusions...

\[
\hat{w}, \hat{\chi} = \text{argmin}_{w, \chi} \left[ \frac{1}{2} \| w \|^2 + \frac{1}{2} d \sum_{i=1}^{n} \sum_{j=1}^{k} \max(0, 1 - \chi(t)(w, \phi(y(t)))) + E(g(t), \chi(t), \hat{h}(t)) \right]
\]

**Multiple Instance Filtering**
- Bootstrap SVM with inside vs outside box samples
- Alternating optimization steps at each new frame:
  - given decision boundary estimate inliers
  - enforce constraints from side information
  - given new set of inliers update classifier

\[
\begin{align*}
\hat{w}, \hat{\chi} &= \text{argmin}_{w, \chi} \left[ \frac{1}{2} \| w \|^2 + \frac{1}{2} d \sum_{i=1}^{n} \sum_{j=1}^{k} \max(0, 1 - \chi(t)(w, \phi(y(t)))) + E(g(t), \chi(t), \hat{h}(t)) \right]
\end{align*}
\]

**Implementation and Experiments**
- incremental SVM: PEGASOS
- approximate 2nd eq. with CRF on superpixel graph

**Evaluation on PROST dataset**

**Summary**
- A viable incremental alternating approach to the joint regression and classification problem of tracking and inliers/outlier selection
- Flexible representation allows objects to deform
- General framework can be used with other part representations and variety of side information