Center for Bio-Image Informatics

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Generalized Simultaneous Registration and Segmentation

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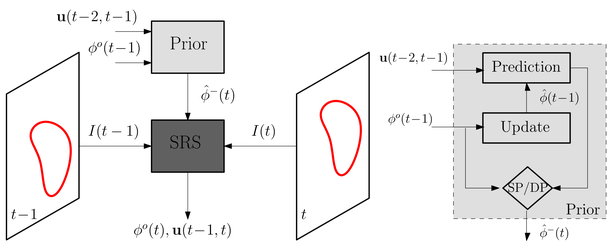
Problem Definition and Contributions

We consider the problem of segmentation and tracking in time sequence imagery. The key components are:

- A generalized model, robust to non-uniform additive illumination changes, is introduced for the level-set based simultaneous registration and segmentation (SRS) framework.
- The new model is derived in a principled way by formulating the SRS problem in a maximum *a posteriori* (MAP) framework.
- Multiple cues are tightly coupled for establishing correspondence and also compensates for the illumination changes over consecutive views.

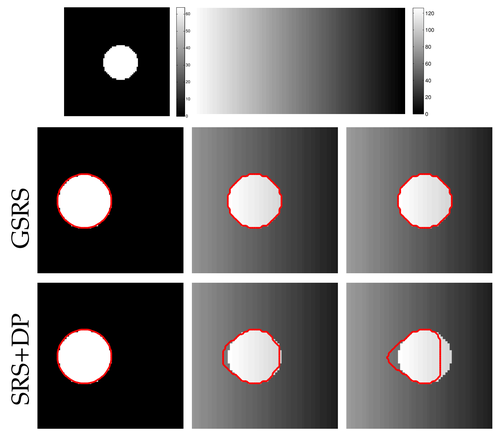
Overview of SRS+DP, Ghosh et al. ICCV'09

- SRS+DP simultaneously finds the segmentation for the current frame while estimating the registration between consecutive frames.
- The dynamic prior is designed based on all the past observations, thus providing robustness against noise/clutter.



Limitation of SRS+DP

- SRS+DP model can not handle for the constant/linear illumination change or other intensity based disturbances.

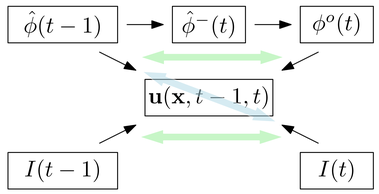


Proposed Model (GSRS)

- Consider the following maximum *a posteriori* (MAP) problem:

$$< u_{\text{opt}}, \phi^o_{\text{opt}}(t) >= \underset{\mathbf{u},\phi^o(t)}{\text{argmax}}\, \mathcal{P}(\mathbf{u}, \phi^o(t) | I(t), I(t-1), \hat{\phi}(t-1), \hat{\phi}^-(t))$$

- Dependency between different variables:



- MAP estimate can be obtained as:

$$< u_{\text{opt}}, \phi^o_{\text{opt}}(t) >= \underset{\mathbf{u},\phi^o(t)}{\text{argmax}} \underbrace{\mathcal{P}\big(\mathbf{u}\big|\phi^o(t), I(t), I(t-1), \hat{\phi}(t-1)\big)}_{\mathcal{A}_1} \underbrace{\mathcal{P}\big(\phi^o(t)\big|I(t), \hat{\phi}^-(t)\big)}_{\mathcal{A}_2}$$

Different Approximations for $\mathcal{A}_1$

- In SRS+DP (separated intensity and shape based cues):

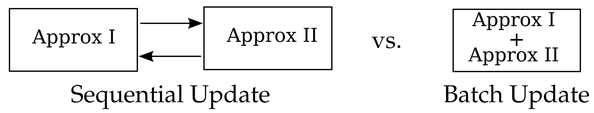
$$\mathcal{A}_1 \approx \mathcal{P}\big(\mathbf{u}\big|I(t), I(t-1)\big)\mathcal{P}\big(\mathbf{u}\big|\phi^o(t), \hat{\phi}(t-1)\big) \Rightarrow \quad \text{Approx I}$$

- Other alternative (with cross connection between multiple cues):

$$\mathcal{A}_1 \approx \mathcal{P}\big(\mathbf{u}\big|I(t), \hat{\phi}(t-1)\big)\mathcal{P}\big(\mathbf{u}\big|\phi^o(t), I(t-1)\big) \Rightarrow \quad \text{Approx II}$$

- Proposed approximation (Batch Update):

$$\mathcal{A}_1 \approx \underbrace{\mathcal{P}\big(\mathbf{u}\big|I(t), I(t-1)\big)}_{\mathcal{A}_1^1} \underbrace{\mathcal{P}\big(\mathbf{u}\big|\phi^o(t), \hat{\phi}(t-1)\big)}_{\mathcal{A}_1^2} \underbrace{\mathcal{P}\big(\mathbf{u}\big|I(t), \hat{\phi}(t-1)\big)}_{\mathcal{A}_1^3}$$



Design of a New Functional and Modification to $\mathcal{A}_1^1$

- New functional, $\mathcal{A}_1^3$, connecting multiple cues:

$$E(\mathbf{u}; \hat{\phi}(t-1), I(t)) = \int_\Omega g_{I(t)}(\mathbf{x}) \big|\nabla H_\epsilon(\hat{\phi}(\mathbf{T}(\mathbf{x}), t-1))\big| d\mathbf{x}$$

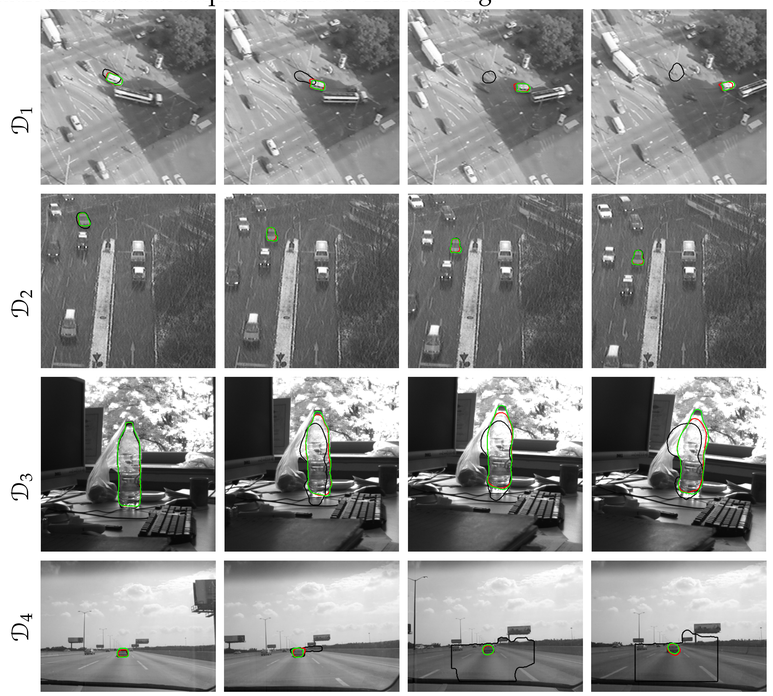
- Adapted $\mathcal{A}_1^1$ to cope with the illumination change:

$$\mathcal{A}_1^1 = \frac{1}{2}\int_\Omega \left[\Big(I(\mathbf{x},t) - I(\mathbf{T}(\mathbf{x}), t-1) + \mathcal{G}(\mathbf{x})\Big)^2 + \alpha\, \text{trace}(\nabla\mathbf{u}\, \nabla\mathbf{u}^T) + \gamma|\nabla\mathcal{G}|^2\right] d\mathbf{x}$$

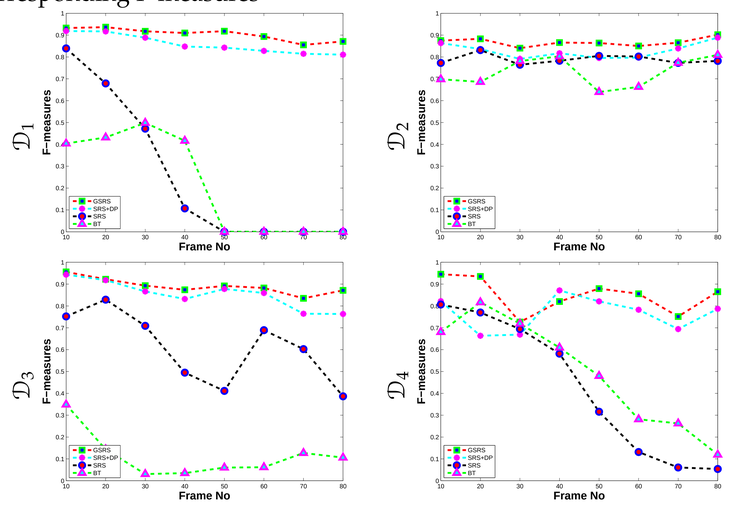
- GSRS Algorithm:
  - ≫ Optimize over $\mathcal{A} = \mathcal{A}_1^1\mathcal{A}_1^2\mathcal{A}_1^3$ ($\mathbf{u}$ related functionals).
  - ≫ Optimize over $\mathcal{A} = \mathcal{A}_1^2\mathcal{A}_2$ ($\phi^o(t)$ related functionals).
  - ≫ Optimize over $\mathcal{A} = \mathcal{A}_1^1$ ($\mathcal{G}$ related functionals).
  - ≫ Update $\mathbf{u}$ and $\phi^o(t)$ and $\mathcal{G}$.

Experimental Results and Conclusions

- Each of these test sequences are 80 frames long.



- Corresponding F-measures-



- Conclusions:
  - ♦ GSRS tracking is invariant to additive non-uniform illumination changes, inter-reflection and scattering.
  - ♦ Illumination changes is explicitly modeled as a non-parametric function.
  - ♦ Additional complexity is linear in terms of the size of the image.