Motivation
Creation of geometrically coherent 3-D histological volumes from serial 2-D sections is difficult due to sectioning process introducing artifacts and distortions (holes, folding, tears)

Current approaches:
• Registration between consecutive sections [e.g. Cifor et al, 2009] 
  Problem: Drifts in stack direction
• Registration of sections to external reference (e.g. block-face) images [e.g. Bardinet et al, 2002] 
  Problem: Smaller resolution, structural homogeneity between consecutive sections not guaranteed

Our approach: Registration of histological sections simultaneously to their corresponding reference images and to their neighboring sections

Problem Formulation
Given a set of histology images \( I = \{ I_1, \ldots, I_n \} \) and their corresponding block-face images \( J = \{ J_1, \ldots, J_n \} \), we seek a set of sufficiently smooth transformations \( T^* = \{ T_1, \ldots, T_n \} \) which align each \( I_i \) to \( J_i \) and to its adjacent neighbors \( T_{i-1}, T_{i+1} \):

\[
T^* = \arg \min_T E_R(I, J, T) + E_C(I, T) + E_S(T)
\]

- \( E_R(I, J, T) \): energy between histology images and block-face images
- \( E_C(I, T) \): energy between consecutive histology slices
- \( E_S(T) \): independent in-plane regularizer

Evaluation

**Synthetic data:**
- Including tubular structures, tearing, random FFDS, staining, intensity variability, Gaussian noise
- Quantitative evaluation

**Real data:**
- Rat kidney, HE staining
- 580 sections of 9 \( \mu \)m thickness

Conclusion

• Fully automatic reconstruction of 3-D histology stacks
• Geometrical coherence by simultaneous registration approach
• Increased accuracy and robustness against artifacts

Results

<table>
<thead>
<tr>
<th>Method</th>
<th>AE</th>
<th>EE</th>
<th>IE</th>
<th>NE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial alignment</td>
<td>50.84</td>
<td>1.57</td>
<td>26.06</td>
<td>13.28</td>
</tr>
<tr>
<td>Histology-to-block-face reg.</td>
<td>36.26</td>
<td>1.22</td>
<td>17.70</td>
<td>9.13</td>
</tr>
<tr>
<td>Registration</td>
<td>57.41</td>
<td>1.91</td>
<td>25.76</td>
<td>12.35</td>
</tr>
<tr>
<td>Sequential approach</td>
<td>36.56</td>
<td>1.23</td>
<td>24.97</td>
<td>11.72</td>
</tr>
<tr>
<td>Simultaneous approach</td>
<td>34.09</td>
<td>1.17</td>
<td>16.69</td>
<td>8.66</td>
</tr>
</tbody>
</table>

AE: relative angular error
EE: absolute endpoint error
IE: interpolation error
NE: normalized IE

Acknowledgments
We want to thank...