Abstract
Leukocyte motion represents an important component in the innate immune response to infection. In inflammatory conditions, leukocytes may exhibit various motion behaviors such as flowing, rolling, and adhering. With many cells moving at a variety of speeds, collisions occur. These collisions result in abrupt changes in the motion and appearance of leukocytes. Analyzing the motion behavior of leukocytes is a difficult task. Manual analysis is tedious, error-prone, and could introduce technician-related bias. Automatic tracking methods are also challenging due to the noise inherent in the biomedical imaging process, varied cell appearance during collision, and abrupt change in cell motion patterns. This work presents a novel method to automatically track multiple cells undergoing collisions by modeling the collision states of cells and testing multiple hypotheses of their motion and appearance. We have found that: (1) the proposed method tracks 32% more cells than a previous approach; (2) the improvement of the proposed method is emphasized when the duration of collision increases; and (3) given good detection results, the proposed method can correctly track 88% of the total number of cells.

Challenges
Cells moving at varying speeds → Collision
1. Different motion and appearance patterns.
2. Abrupt change in motion and appearance.

Methods
1. Detect cells (Adaboost)
2. Predict motion (Kalman)
3. Predict collision (Multiple Hypotheses)
4. Calculate errors
5. Match cells (Greedy)
6. Update (Kalman)

Adaboost
Combine many “rule of thumbs” to a highly accurate prediction.
Training
- Cell Samples
- Background Samples
Features
1. Mean intensity
2. Standard Dev. of intensity
3. Normalized Radial Mean
Procedure
1. Detect cells (Adaboost)
2. Predict motion (Kalman)
3. Predict collision (Multiple Hypotheses)
4. Calculate errors
5. Match cells (Greedy)
6. Update (Kalman)

Kalman Filter
Predict
Update
Collision States
- No Collision (s=0)
- Collision (s=1)
Multiple Hypotheses
Greedy Search
Select the hypothesis that has minimum error first.
Match pair of cells in the selected hypothesis.

Data set: 8 real video sequences.
Colliding: 112 cell tracks | Treated colliding: 38 cell tracks
Non-colliding: 128 cell tracks

Evaluating Methods:
- Smoothness Constraints (SC)
- Single Hypothesis (SH)
- Multiple Hypotheses (MH)

Metric: positions tracked percentage (PTP)

Comparisons
Collision Duration
SC | SH | MH

<table>
<thead>
<tr>
<th>Dataset</th>
<th>SC</th>
<th>SH</th>
<th>MH</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cells</td>
<td>.49</td>
<td>+24</td>
<td>.73</td>
</tr>
<tr>
<td>Non-colliding cells</td>
<td>.53</td>
<td>+23</td>
<td>.76</td>
</tr>
<tr>
<td>Colliding cells</td>
<td>.40</td>
<td>+23</td>
<td>.63</td>
</tr>
<tr>
<td>Treated colliding cells</td>
<td>.51</td>
<td>+21</td>
<td>.70</td>
</tr>
</tbody>
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