CellVision: Automatic segmentation of overlapping objects for cell image analysis

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http://www2.it.lut.fi/project/cellvision/

Motivation
Segmentation of overlapping objects manually by experts can be too
- laborious,
- complex,
- expensive.
Thus, automated detection and segmentation of overlapping cells in microscopic images for biomedical applications such as cell counting, cell identification, and cell morphology could be useful. For example, for early diagnosis of the cancer in pap smear images the cervical cells need to be detected and segmented accurately. Poor contrast of cell images, presence of blood, and overlapping among cells make both manual and automated detection challenging.

Objectives
The goal of this project is to study the automatic segmentation of overlapping objects in digital microscopic images. Our previous studies have focused on segmentation of overlapping nanoparticle (NP) images [2, 3, 4, 5, 6] which is limited to silhouette images. The CellVision project focuses on the occlusion problem in cell segmentation to improve the accuracy of the current segmentation methods and to introduce novel methods for overlapping cell segmentation. Example images of overlapping cells are shown in Figure 1.

The objectives include the following tasks:
- Improve further our current segmentation framework for overlapping convex objects.
- Propose novel solutions for the ground truth annotation of images with a massive number of objects.
- Introduce novel methods for overlapping cell segmentation that outperforms the existing solutions.
- Evaluate the developed methods with publicly available datasets of cell images.
- Release a public software for cell and nanoparticle analysis for other researchers.

Framework
The framework consists of the following steps (see Figure 2):
1. Image binarization: The regions of the image that is covered by the object of interest, i.e., nanoparticles or cells are separated from the background.
2. Contour evidence extraction: The visible parts of the objects boundaries that can be used for inferring the occluded parts of the overlapped objects. The groups of edge points that belong to each object can be detected by one of the following approaches:
   - Seedpoint extraction, followed by edge-to-seedpoint association [2].
   - Convex point detection, followed by edge segment grouping [3, 4, 5, 6].
3. Contour estimation: The object contours and their visually missing parts are estimated using, for example, ellipse fitting or Gaussian processes.

Results
The proposed framework has been applied to three real-world nanoparticle datasets (see Figure 4). The results with the most challenging dataset (the leftmost image), the titanium dioxide NPs dataset are shown in Table 1.

<table>
<thead>
<tr>
<th>Methods</th>
<th>TPR [%]</th>
<th>PPV [%]</th>
<th>ACC [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBB [6]</td>
<td>77</td>
<td>80</td>
<td>64</td>
</tr>
<tr>
<td>SCC [2]</td>
<td>74</td>
<td>79</td>
<td>62</td>
</tr>
<tr>
<td>NPA [1]</td>
<td>57</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>CECS [5]</td>
<td>58</td>
<td>66</td>
<td>45</td>
</tr>
</tbody>
</table>

Figure 1: Examples of overlapping cells.

Figure 2: The proposed framework for overlapping object segmentation.

Figure 3: Results of the segmentation with the different Jaccard similarity (JSC) threshold values.

Figure 4: Segmentation results for three real-world applications of overlapping nanoparticles.

Future Work
The obtained results with NPs are very promising. The next step is to generalize the methods for other similar applications, especially including cell image analysis. The proposed framework can be further developed at the micro/nano level for important machine vision applications such as:
- Cancer research: Cell segmentation is one of the most important application areas. The cancer diagnosis should be comprehensive and reliable, and to enable to cope with large datasets and fine details. The developed methods could assist medical experts significantly, also for early diagnosis, improving personal health care considerably.
- Nanoparticle research: Characteristics of nanoparticles by sizes and shapes are needed in a wide range of applications including, but not limited to medicine, manufacturing, bioimaging, catalysis, water treatment, and electronics to enable safe, high-quality, resource-efficient, and cost-effective solutions.

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References