1. Document detection problem

**Input**: Image.

**Output**: Quadrilateral corresponding to the document location.

**Assumptions**: (1) one document in the image, (2) all document borders are visible, (3) document has an unknown internal structure, (4) possible complex background, (5) no camera intrinsic parameters.

**Fig 1. Image with complex background from MIDV-500**

2. Existing approaches

**Contour-based**: use contour score to rank quadrilaterals -> unstable on the complex background (red quadrilateral on Fig.1)

**Region-based**: use region (contrast) score to rank quadrilaterals -> works well even with the complex background (green quadrilateral on Fig. 1)

3. The ranking problem

**Input**: (1) Image \( I \), (2) set of \( N \) quads, (3) ground truth quad \( m \).

It is required to define a function \( F \) such that

\[
\begin{align*}
\{ & i^* = \arg \max_{i=0}^N F(q_i, I) \\
L(q_{i^*}, m) &= 1
\end{align*}
\]

where \( L \) is a binary quality metric.

4. Proposed function \( F \)

\[
F(q, I) = R(q, I) + kC(q, I)
\]

Region score is based on \( \chi^2 \) distance between foreground and background sets of RGB pixels. Contour score is based on integral statistics of edge map along borders of \( q \).

\( k \) is a combination coefficient.

5. Proposed algo

**Input**: image

- Edge map extraction & Line detection
- Set of quads formation

**Output**: quad with max \( F \) score

6. Error classification on MIDV-500

<table>
<thead>
<tr>
<th></th>
<th>Out of frame</th>
<th>No line</th>
<th>Ranking error</th>
<th>Total errors</th>
<th>Run-time (ms/frame)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prop. algo. (N=1)</td>
<td>2850</td>
<td>660</td>
<td>854</td>
<td>4366</td>
<td>82</td>
</tr>
<tr>
<td>Prop. algo. (N=11)</td>
<td>2803</td>
<td>627</td>
<td>509</td>
<td>3941</td>
<td>88</td>
</tr>
<tr>
<td>Relative improvement</td>
<td>+1.65%</td>
<td>+5%</td>
<td><strong>+40.4%</strong></td>
<td><strong>+9.73%</strong></td>
<td>-7.3%</td>
</tr>
</tbody>
</table>

Table 1. MIDV-500 is open dataset with 15000 images of ID cards; Detection is incorrect (error) if Jaccard Index < 0.945; Run-time measure on iPhone 6 in single thread mode

7. Comparison with top 2 system on SmartDoc

<table>
<thead>
<tr>
<th>System</th>
<th>MIDV-500</th>
<th>SmartDoc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full</td>
<td>Bgr 1</td>
</tr>
<tr>
<td>Prop. algo. (N=1)</td>
<td>0.861</td>
<td>0.980</td>
</tr>
<tr>
<td>Prop. algo. (N=11)</td>
<td><strong>0.870</strong></td>
<td>0.983</td>
</tr>
<tr>
<td>CS-NUST-2</td>
<td>0.626</td>
<td>0.988</td>
</tr>
</tbody>
</table>

Table 2. Mean Jaccard Index