Improving RANSAC-Based Segmentation Through CNN Encapsulation

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**RANSAC as a CNN Output Layer**
- Allows model specificity; Avoids need for nontrivial post-processing
- Example: pupil segmentation (known to be approximately circular)

**RANSAC as a CNN Loss Layer**
- Works by suppression of strongest impostor
- Additional loss term: \( L_d = \log\left(\frac{S'}{S^*}\right) \), for true model score \( S^* \) and most convincing impostor score \( S' \).
- Could in theory be applied to other problem domains as well.

**Classical pre-RANSAC Methods as Utility Layers**
- Sensible for industrial migration
- Preserves mathematical structure of preexisting implementation, while providing optimizability of a CNN
- Example: L2-norm layer (think edge detection)

\[
\begin{align*}
z &= x_1^2 + x_2^2 \\
\frac{\partial L}{\partial x_1} &= 2x_1 \\
\frac{\partial L}{\partial x_2} &= 2x_2 \\
\frac{\partial L}{\partial z} &= 2 \\
\frac{\partial L}{\partial x_1} &= \frac{\partial L}{\partial z} x_1 \\
\frac{\partial L}{\partial x_2} &= \frac{\partial L}{\partial z} x_2 \\
\end{align*}
\]

- The above ideas can be used to initialize a CNN to behave nearly identical to an existing high-performance RANSAC segmentation algorithm.
- Such a CNN can then in principle be fine-tuned to achieve even better performance.

**Statistical Results**
- Statistically: biases significantly decreased; spread modestly decreased
- Pupil center absolute distance (pixels): \(1.20 \pm 0.69 \rightarrow 1.06 \pm 0.57\)
- Pupil radius absolute error (pixels): \(0.57 \pm 0.48 \rightarrow 0.47 \pm 0.42\)

**Notes**
- \( \downarrow = \text{ReLU} \)
- Not actually parallel
- Looks and behaves parallel on init due to zeroed out weights
- Thus “channel crossing” can and does occur in training

**Individual Results**
- These images show multiple errors that occurred before fine-tuning, which no longer occur after fine-tuning.
- Erroneous segmentation occurs on only 1 out of 1500+ testing images after fine-tuning (similar error to above).