I. Goals

<table>
<thead>
<tr>
<th>P = [p_{1,1} \ldots p_{1,w}]</th>
<th>p_{i,j} = (L_{L,j}, a_{i,j}, b_{i,j})</th>
</tr>
</thead>
<tbody>
<tr>
<td>f: X → Y</td>
<td>c_j = (a_{i,j}, b_{i,j}), p_{i,j} = (a_{i,j}, c_j)</td>
</tr>
</tbody>
</table>

**Image colorization:**
- The process of recoloring (B&W) images authentically
- Images are made of pixels, which are represented in **Lab** space
- Goal: to consistently colorize images realistically with no context
  - Mathematically, retrieve \( \hat{p}_{i,j} = p_{i,j} \) \( i,j \in l,w \) via some \( f \)

II. Model Architecture

**Convolutional Neural Networks:**
- Set of algorithms, modeled after the brain, to recognize patterns
- Takes an image and employs filters to learn characteristics
  - Initial filters primitive (diagonal lines)
  - Deep filters are advanced (tire, headlight)
- This is done with a convolutional kernel, which moves along the image and computes values to extract high-level features

III. Regressive and Classifying Approaches

**Regressive approach:**
- Goal: predict \( c_j \) by minimizing absolute difference between \( c_j \) and \( c_i \) \( i,j \in l,w \)
- Akin to minimizing the distance between two vectors in **L**^2
  - The loss function is given by,
  \[
  L_p(X) = \frac{1}{n} \sum_{i=1}^{n} \| f(X)^j - Y^j \| _2^2
  \]

**Classifying approach:**
- The continuous color space is quantized into discrete bins, allowing each bin to be treated as a class.
  - Task is now to select the optimal class for each pixel rather than distance minimization problem
  - The loss function (with \( Q \) classes) is given by,
  \[
  L_c(X) = \frac{1}{n} \sum_{i=1}^{n} \sum_{q=1}^{Q} Y^{i,q} \log(f(X)^i,q)
  \]

IV. Results

<table>
<thead>
<tr>
<th>Black &amp; White</th>
<th>Regressive Model</th>
<th>Classifying Model</th>
<th>Ground Truth</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

V. Conclusion

- Image colorization is an underconstrained problem
- CNN’s are powerful tools to solve unstructured problems
- Regressive approaches are risk-averse, thereby suffering from the “brown well” problem
- Coupling a classifying approach with a discretized color space renders vibrantly colored, visually appealing images

Next Steps:
- Creating a generalized colorization algorithm by training on a variety of images
- Making the algorithm more robust to different image sizes or media types (videos, gifs, etc.)