**Motivation**

Learning the mapping of 2D images onto 3D orientations defined by two hand orientation angles

Ambiguity in hand orientation regression dataset results in:

- Symmetry problem: opposite orientation $\leftrightarrow$ similar hand shapes
- Existing regression methods try to fit into the data
- Overcome using probabilistic regression

**Contributions**

- Enable CNNs to learn parameters of a mixture of Gaussians probability distribution
- Fully-differentiable $\rightarrow$ analytic closed form solution $\rightarrow$ works with standard optimizers
- Generalizable to $\rightarrow$ higher dimensional targets $\rightarrow$ multi-modal distributions
- Better generalization with 10x less model parameters

**Results**

- Hand Orientation Estimation
- Head Orientation Estimation

**PROPEL**

$$L = -\log \left[ \frac{2 \int P_{gt} P_{m} \, dx}{\int (P_{gt}^2 + P_{m}^2) \, dx} \right]$$

$P_{gt}^k = \frac{1}{(2\pi)^{n/2} \sqrt{\prod_{i=1}^{n} \sigma_{g_{x_i}}}} e^{-\frac{1}{2} \sum_{i=1}^{n} \frac{(x_i - g_{x_i})^2}{\sigma_{g_{x_i}}^2}}$

$P_{m} = \sum_{k=1}^{K} \frac{1}{(2\pi)^{n/2} \sqrt{\prod_{i=1}^{n} \sigma_{m_{x_i}}}} e^{-\frac{1}{2} \sum_{i=1}^{n} \frac{(x_i - m_{x_i})^2}{\sigma_{m_{x_i}}^2}}$