PROPEL: Probabilistic Parametric Regression Loss for Convolutional Neural Networks

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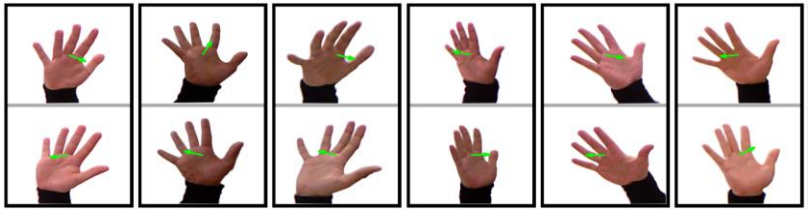
Motivation

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

Ambiguity in hand orientation regression dataset results in:

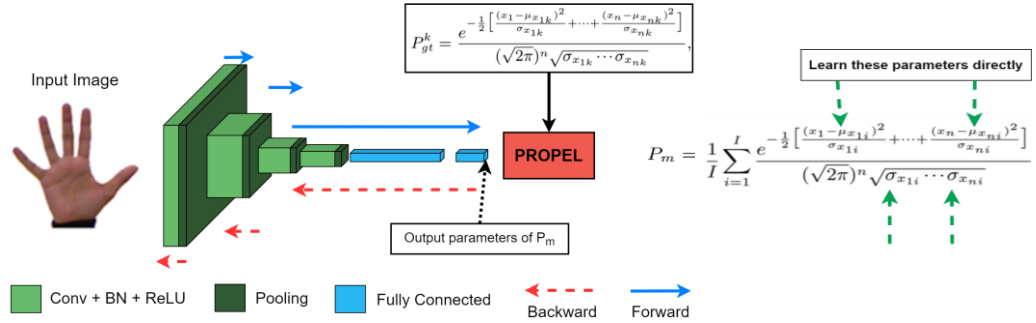
- Symmetry problem:
  opposite orientation ←→ similar hand shapes



- 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 → analytic closed form solution → works with standard optimizers
- Generalizable to → higher dimensional targets → multi-modal distributions
- Better generalization with **10x less model parameters**

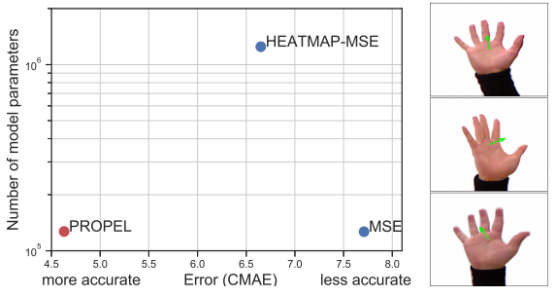


PROPEL

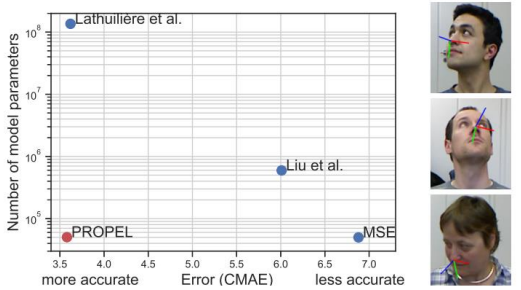
$$L = -\log\left[\frac{2\int P_{gt}P_m\,d\underline{\mathbf{x}}}{\int({P_{gt}}^2+{P_m}^2)\,d\underline{\mathbf{x}}}\right]$$

$$P_{gt}^k = \underbrace{\frac{e^{-\frac{1}{2}\left[\frac{(x_1-\mu_{x_{1k}})^2}{\sigma_{x_{1k}}}+\cdots+\frac{(x_n-\mu_{x_{nk}})^2}{\sigma_{x_{nk}}}\right]}}{(\sqrt{2\pi})^n\sqrt{\sigma_{x_{1k}}\cdots\sigma_{x_{nk}}}}}_{\text{Ground Truth Distribution}}, \quad P_m = \underbrace{\frac{1}{I}\sum_{i=1}^{I}\frac{e^{-\frac{1}{2}\left[\frac{(x_1-\mu_{x_{1i}})^2}{\sigma_{x_{1i}}}+\cdots+\frac{(x_n-\mu_{x_{ni}})^2}{\sigma_{x_{ni}}}\right]}}{(\sqrt{2\pi})^n\sqrt{\sigma_{x_{1i}}\cdots\sigma_{x_{ni}}}}}_{\text{Model Output Distribution}}$$

Results



Hand Orientation Estimation



Head Orientation Estimation