Correlation between Alignment-Uniformity and Performance of Dense Contrastive Representations

Jong Hak Moon¹, Wonjae Kim², Edward Choi¹
KAIST¹, NAVER AI²

Motivation & Contribution

✔ Unsupervised CL has developed to achieve superior performance by extending the feature representation from instance- to dense-level, but the properties of contrastive representation have not yet been studied.

✔ We analyze the theoretical ideas of dense CL through the lens of alignment and uniformity on the hypersphere and introduce a new scalar metric that summarizes the correlation between alignment-uniformity and downstream performance.

✔ We discover the core principle in constructing a positive pair of dense features and empirically proved its validity.

Alignment-Uniformity of Dense CL

- Quantifying correlation.
  - Kendall’s tau correlation metric:
    \[ \text{min-max norm} \left( \sum (L^1, L^2), P_{\text{corr}} \right) \]

- Distribution to be uniform property

Dense CL with InfoNCE loss.

- \[ \text{DenseCorr} = - \frac{1}{N} \sum_{i \in [1:B]} \sum_{j \neq i} \frac{\log \left( \frac{\exp \left( \frac{\text{sim}(h_i, h_j)}{T} \right)}{\sum_{k \neq i} \exp \left( \frac{\text{sim}(h_i, h_k)}{T} \right)} \right)}{\text{P}_{\text{corr}}} \]

- \[ \text{DenseCorr} = - \frac{1}{N} \sum_{i \in [1:B]} \sum_{j \neq i} \frac{\log \left( \frac{\exp \left( \frac{\text{sim}(h_i, h_j)}{T} \right)}{\sum_{k \neq i} \exp \left( \frac{\text{sim}(h_i, h_k)}{T} \right)} \right)}{\text{P}_{\text{corr}}} \]

- Correlation value varies between -1 and +1, with a value close to 0 indicating a weak correlation.

- Negative correlation indicate that pretraining is useful.

Experiments & Results

- How does the alignment-uniformity property of dense CL correlate with the performance of object detection and linear evaluation?

- How different is the behavior of dense feature representations on single or multi-object datasets?

- How effective is the index-wise matching strategy in terms of different augmentation techniques?

Single-object pretraining and fine-tuning

- Confusing positive samples in Dense CL
  - Single-object dataset
  - Multi-object dataset

- Positive pairs should share mutually agreeable information in multi-object datasets.