Functional Knowledge Transfer with Self-supervised Representation Learning

Prakash Chandra Chhipa[1,*], Muskaan Chopra[2], Gopal Mengi[2], Varun Gupta[2], Richa Upadhyay[1] , Meenakshi Subhash Chippa[1] , Kanjar De[1] , Rajkumar Saini[1] , Seiichi Uchida[3] and Marcus Liwicki[1]

[1]Machine Learning Group, EISLAB, Lulea˚ Tekniska Universitet, Lulea˚, Sweden
[2]Chandigarh College of Engineering and Technology, Punjab University, Chandigarh, India
[3]Human Interface Laboratory, Kyushu University, Fukuoka, Japan

*corresponding author-prakash.chandra.chhipa@ltu.se

Prakash Chandra Chhipa

Chandigarh College of Engineering and Technology

Problem Statement

✓ No direct human supervision to learn representations

But

- Need massive amount of training data (ImageNet 1.2 millions images)
- Large batch size which requires heavy parallel computing
- SSL remains inaccessible to small-scale datasets with lack of computing resources

Self-supervised Representation Learning[1,2,3] Approach

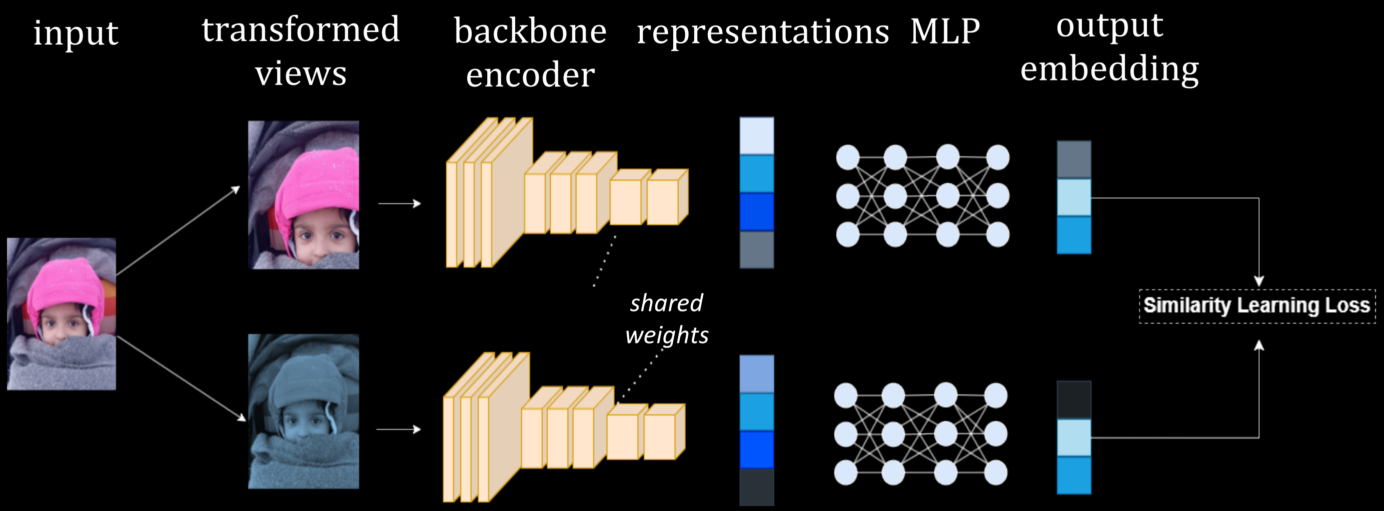


Figure Inspired : Chhipa, Prakash Chandra. "Self-supervised Representation Learning for Visual Domains Beyond Natural Scenes." Licentiate Thesis, Luleå tekniska universitet (2023).

[1] **Contrastive** - *Chen, Ting, et al. "A simple framework for contrastive learning of visual representations." International conference on machine learning. PMLR, 2020*

[2] **Distillation**- *Grill, Jean-Bastien, et al. "Bootstrap your own latent-a new approach to self-supervised learning." Advances in neural information processing systems 33 (2020).*

[3] **Information Maximization**- *Zbontar, Jure, et al. "Barlow twins: Self-supervised learning via redundancy reduction." International Conference on Machine Learning. PMLR, 2021.*

Prakash Chandra Chhipa

Hypothesis

Shifting the representational knowledge transfer paradigm to functional knowledge transfer[4] can enable the learning of efficient self-supervised representations for small-scale data.

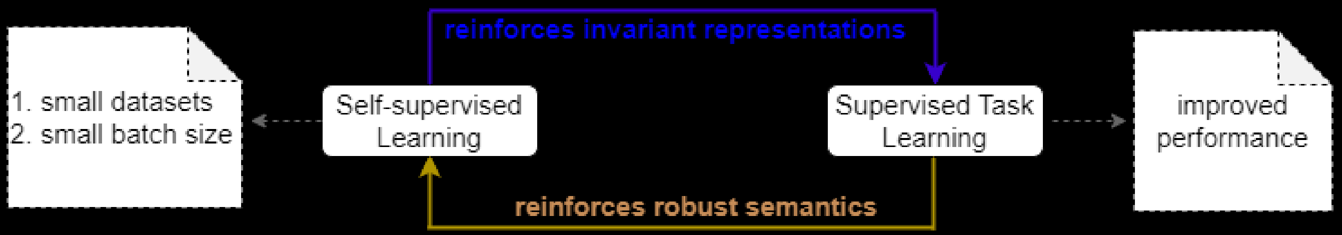
- Joint optimization in functional knowledge transfer is the key

representational knowledge transfer

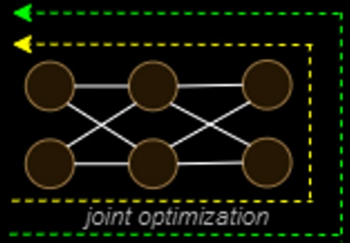
self-supervised

supervised

why it should work?



functional knowledge transfer



self-supervised + supervised together

[4]Functional Knowledge - R. Vilalta, C. Carrier, P. Brazdil, C. M. Soares et al., “Inductive transfer,” 2017.

Prakash Chandra Chhipa

LULEÅ TEKNISKA UNIVERSITET

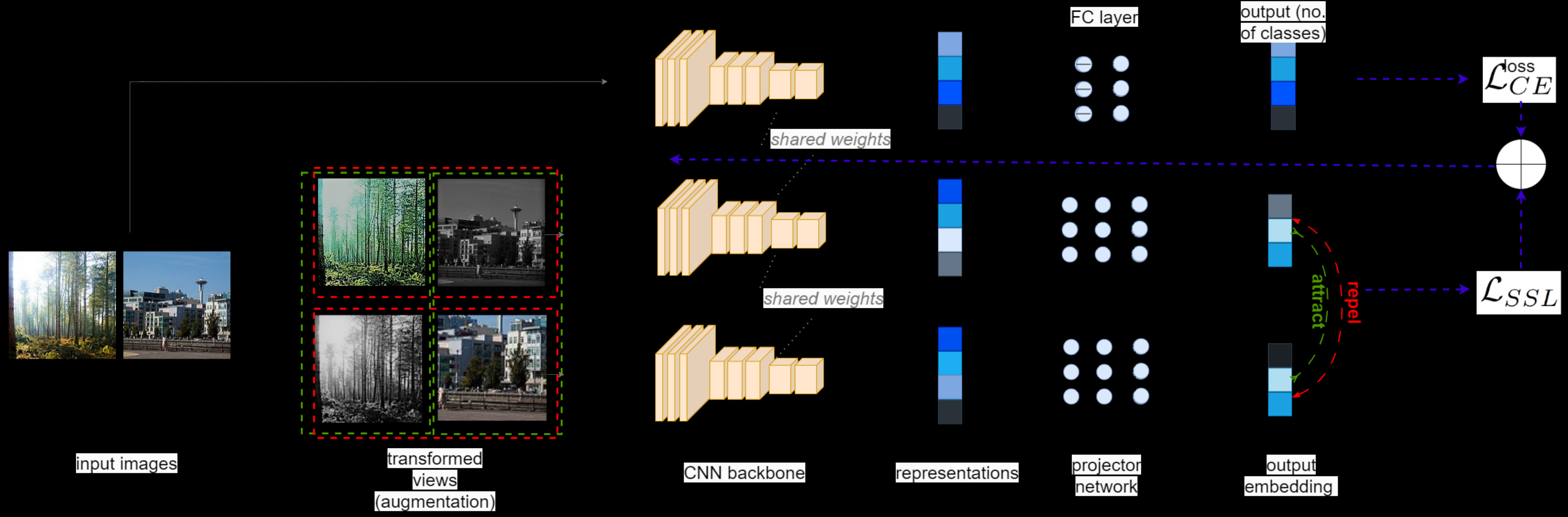
30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

Method

Joint optimization of self-supervised representation learning ans supervised learning task



$$\mathcal{L}_{SSL} = \sum_{(x',x'')\in\mathcal{T}(X)} -\log \frac{e^{\mathcal{A}}}{\sum_{k=1}^{2|X|} 1_{[k\neq x']} e^{\mathcal{B}}}$$

$$\mathcal{A} = (sim(g(\Theta_g; f(\Theta_f; x')), g(\Theta_g; f(\Theta_f; x''))))/\tau)$$

$$\mathcal{B} = (sim(g(\Theta_g; f(\Theta_f; x')), g(\Theta_g; f(\Theta_f; x^k))))/\tau)$$

$$\mathcal{L}_{CE} = -\frac{1}{|D|} \sum_{(x,y)\in D} \sum_{c\in\mathcal{C}} y_c \log(f(\Theta; x_c))$$

$$\mathcal{L}_{FKT} = \mathcal{L}_{CE} + \lambda\, \mathcal{L}_{SSL}$$

Prakash Chandra Chhipa

Investigation Protocol

1. Identify small-scale datasets and task – Aptos, CIFAR, Intel Images
2. Chose self-supervised learning method – Contrastive Learning
3. Experimentation on Representational and Functional knowledge transfer – Details on experimental configuration and parameters in paper
4. Performance evaluation
   - ✓ quantitative analysis
   - ✓ qualitative analysis

Prakash Chandra Chhipa

LULEÅ TEKNISKA UNIVERSITET

30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

Datasets – from diverse domains

CIFAR10[1] Dataset

CIFAR

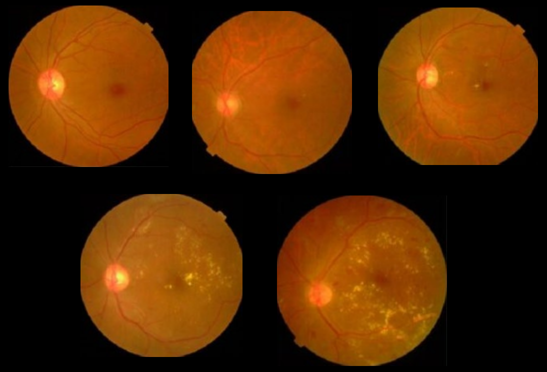
10 classes and 60,000 examples

Classes - airplanes, cars, birds, cats, deer, dogs, frogs, horses, ships, and trucks

Aptos[2] Dataset

Aptos

5 classes and 3660 examples



Classes - diabetic retinopathy severity level in eye fundus images

Intel Images[3] Dataset

Intel Image

6 classes and 25000 examples

Classes – buildings, forest, glacier, mountain, sea, street

[1] *CIFAR10, https://www.cs.toronto.edu/~kriz/cifar.html*

[2] *Aptos, https://www.kaggle.com/c/aptos2019-blindness-detection*

[3] *Intel Images, https://www.kaggle.com/datasets/puneet6060/intel-image-classification*

Prakash Chandra Chhipa

LULEÅ TEKNISKA UNIVERSITET

30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

Results

Dataset	Method	Accuracy	Precision	Recall
CIFAR10	Representational Transfer [$]	92.20±0.11	92.18±0.10	92.21±0.10
	Functional Transfer	**93.60±0.10**	**93.62±0.13**	**93.59±0.11**
Intel Image	Representational Transfer	93.18±0.15	93.15±0.18	93.17±0.20
	Functional Transfer	**93.70±0.13**	**93.33±0.11**	**93.31±0.11**
Aptos 2019	Representational Transfer	83.10±0.10	83.05±0.09	**83.05±0.12**
	Functional Transfer	**83.32±0.11**	**83.14±0.10**	83.04±0.10

Prakash Chandra Chhipa

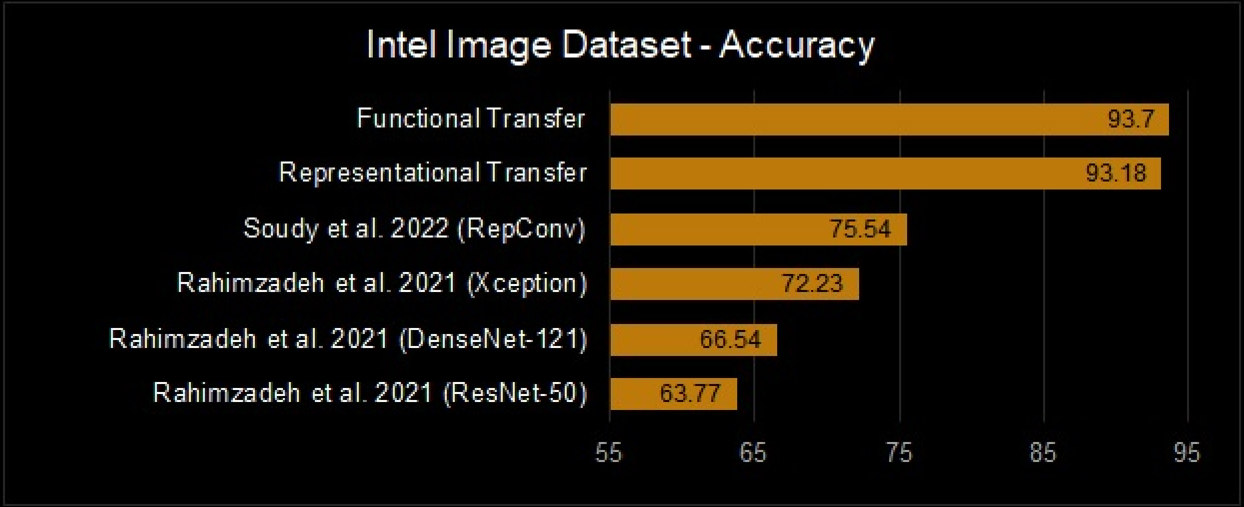
LULEÅ TEKNISKA UNIVERSITET

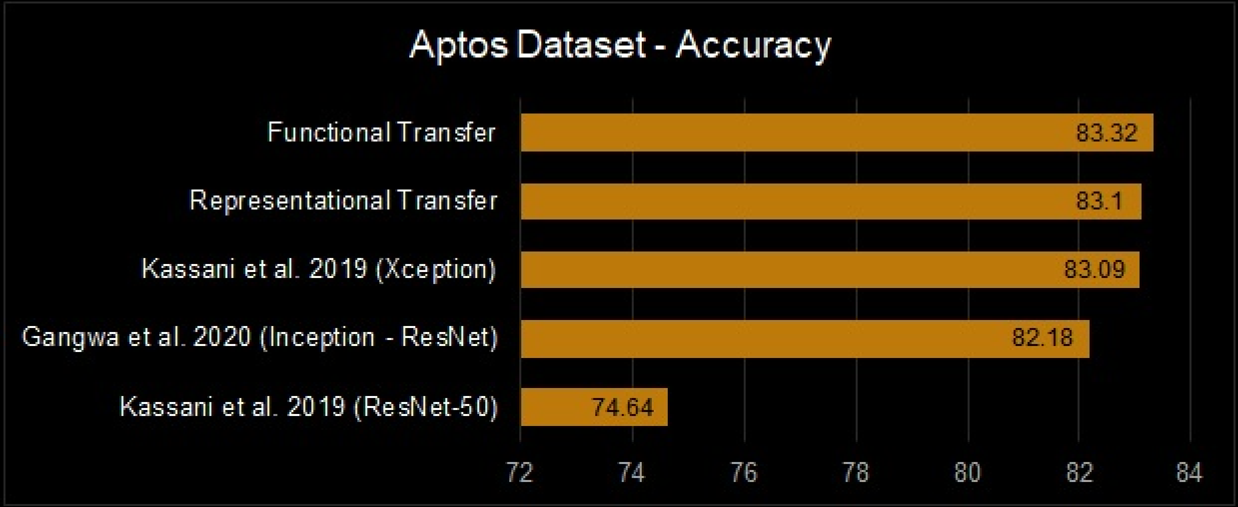
30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

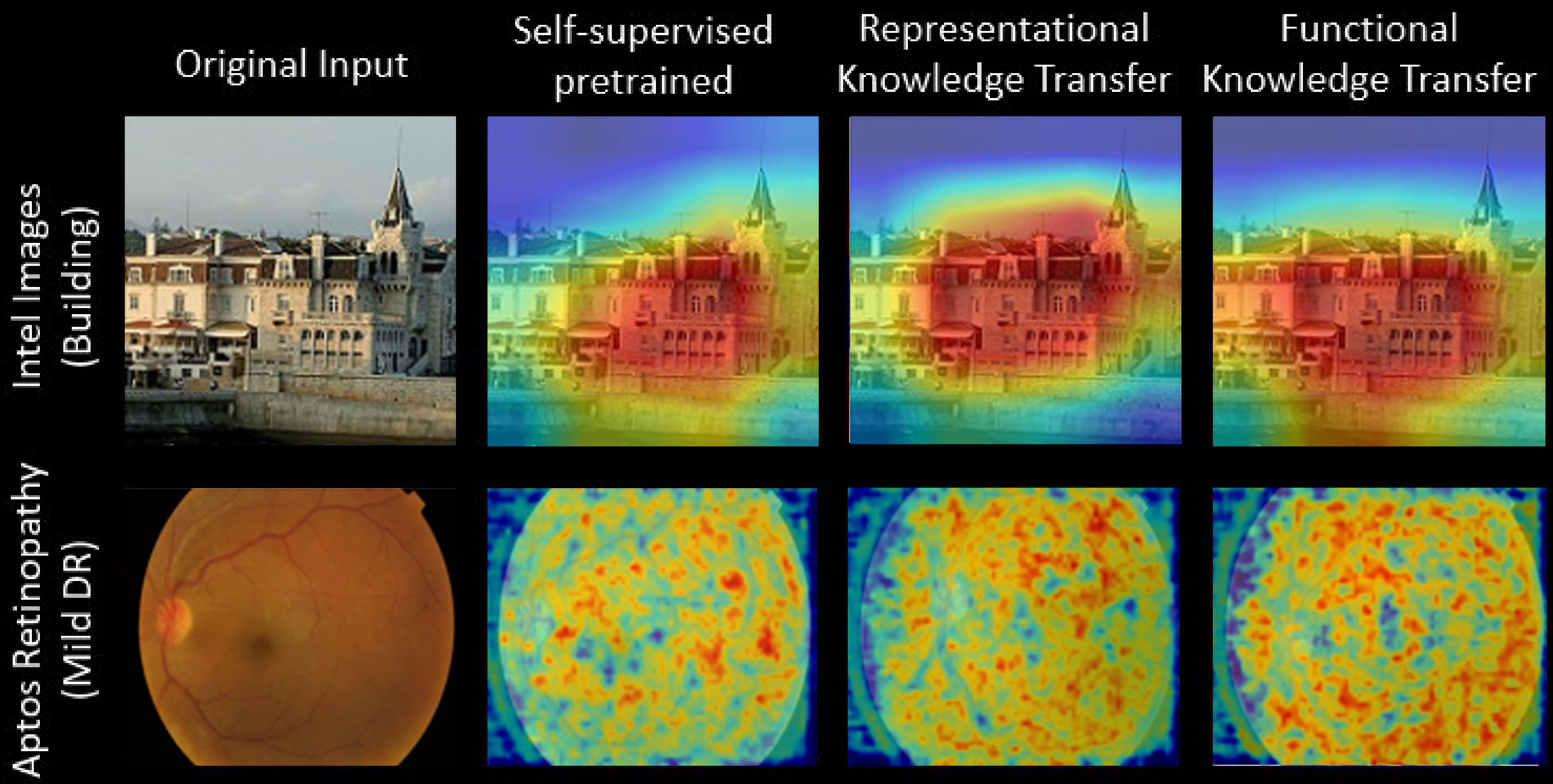
Results - Comparing SoTA





Prakash Chandra Chhipa

Qualitative Analysis



Prakash Chandra Chhipa

LULEÅ TEKNISKA UNIVERSITET

30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

Conclusions

Contribution

Introduces functional knowledge transfer to overcome the inaccessibility of SSL due to small-scale and small batch by formulating and examining joint optimization hypothesis

Achievements

Achieved improved downstream task results across diverse datasets supported by qualitative analysis

Future Work

Further investigation on adapting other SSL approaches and evaluating representational knowledge transfer capability of jointly optimized models

Prakash Chandra Chhipa

LULEÅ TEKNISKA UNIVERSITET

30th ICIP 2023 Kuala Lumpur

Chandigarh College of Engineering and Technology

九州大学 KYUSHU UNIVERSITY

Thank you

prakash.chandra.chhipa@ltu.se

GitHub
https://github.com/prakashchhipa

Scholar
https://scholar.google.com/citations?hl=en&user=AF-zbRoAAAAJ&view_op=list_works&sortby=pubdate

LinkedIn
https://www.linkedin.com/in/prakash-chandra-chhipa/recent-activity/all/

LTU profile
https://www.ltu.se/staff/p/prachh-1.201078?l=en

Prakash Chandra Chhipa