Sequential Knowledge Transfer in Teacher-Student Framework Using Densely Distilled Flow-Based Information

Electronics and Telecommunications Research Institute

ICIP 2018

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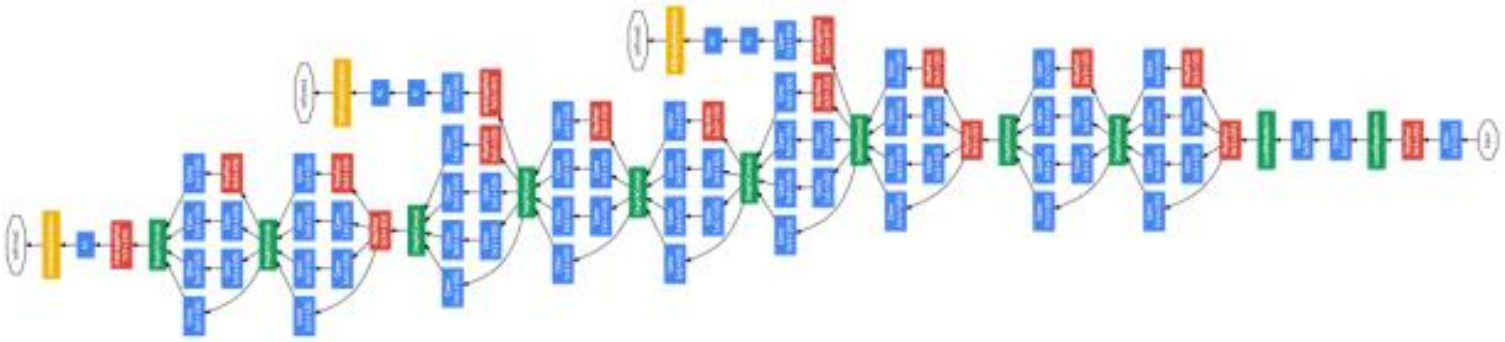
- Introduction & Motivation
- Previous Research
- Proposed Model
- Experimental Results
- Conclusion

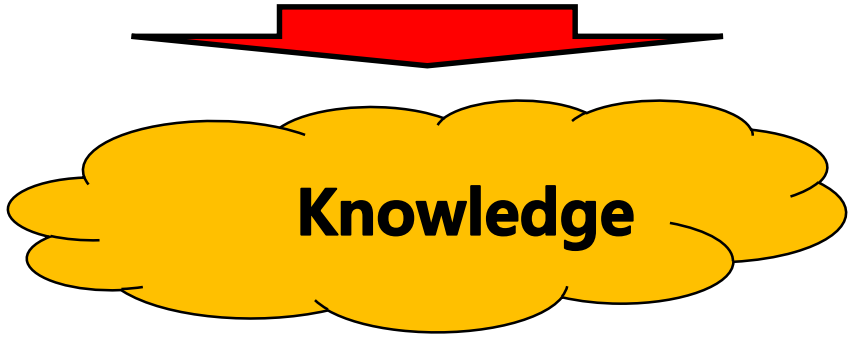
Introduction

- Knowledge Distillation

Deep Neural Network



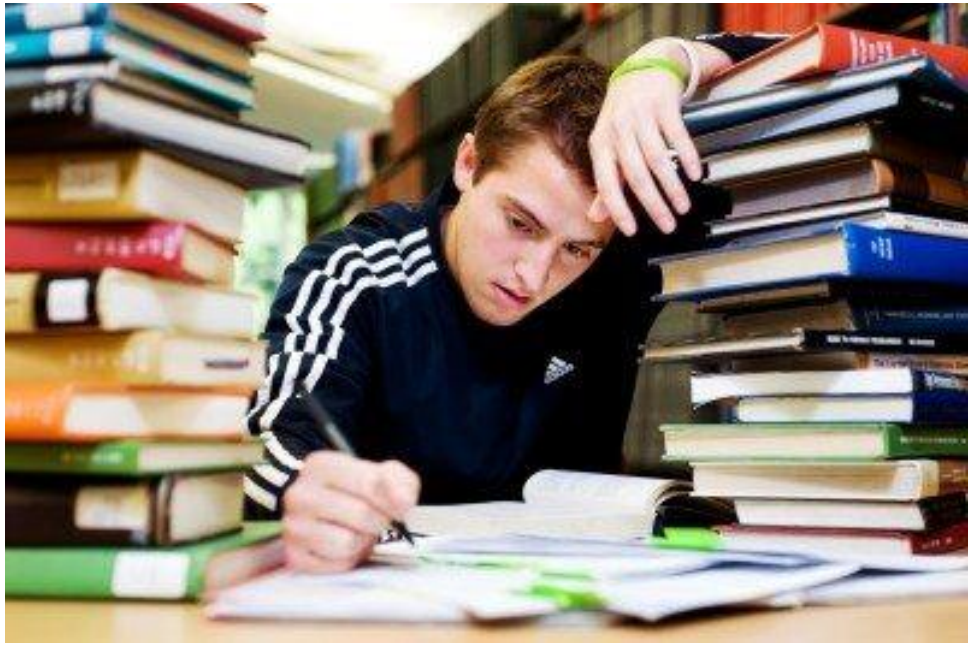
Extract the useful Knowledge



The Google "Inception" deep neural network architecture. Source: Christian Szegedy et. al. Going deeper with convolutions. CVPR 2015.

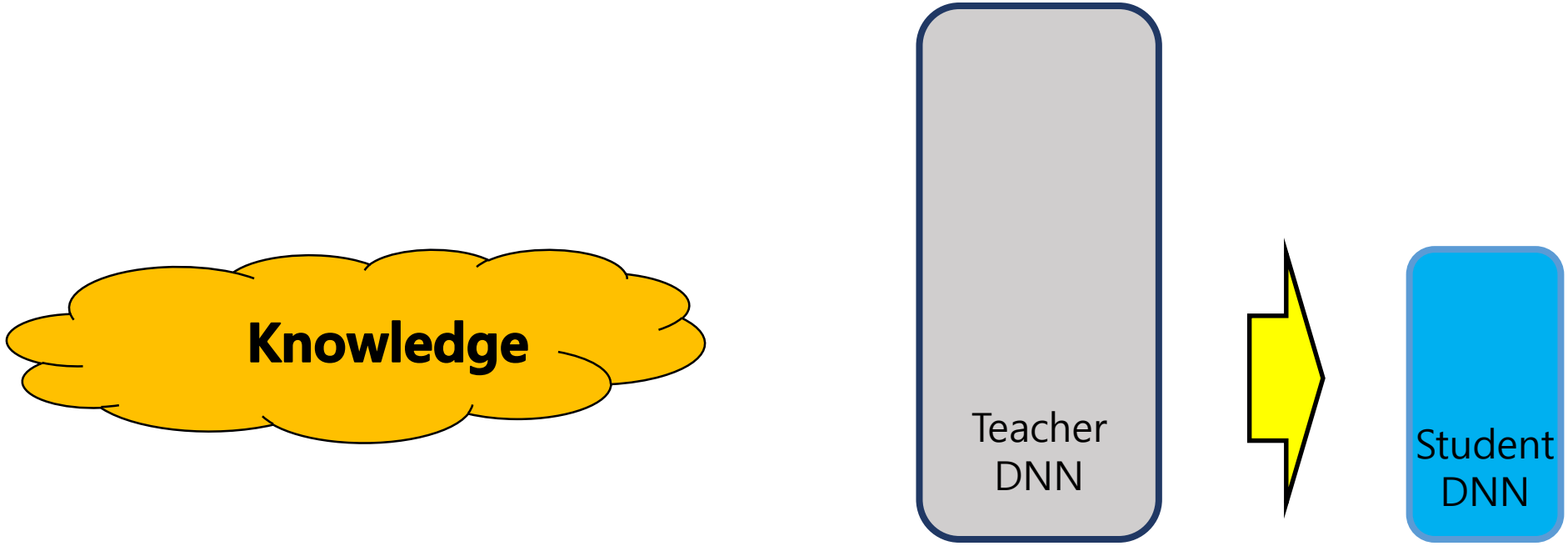
Motivation

- Knowledge Distillation with Teacher – Student framework



Motivation

- Two main issues in knowledge distillation method



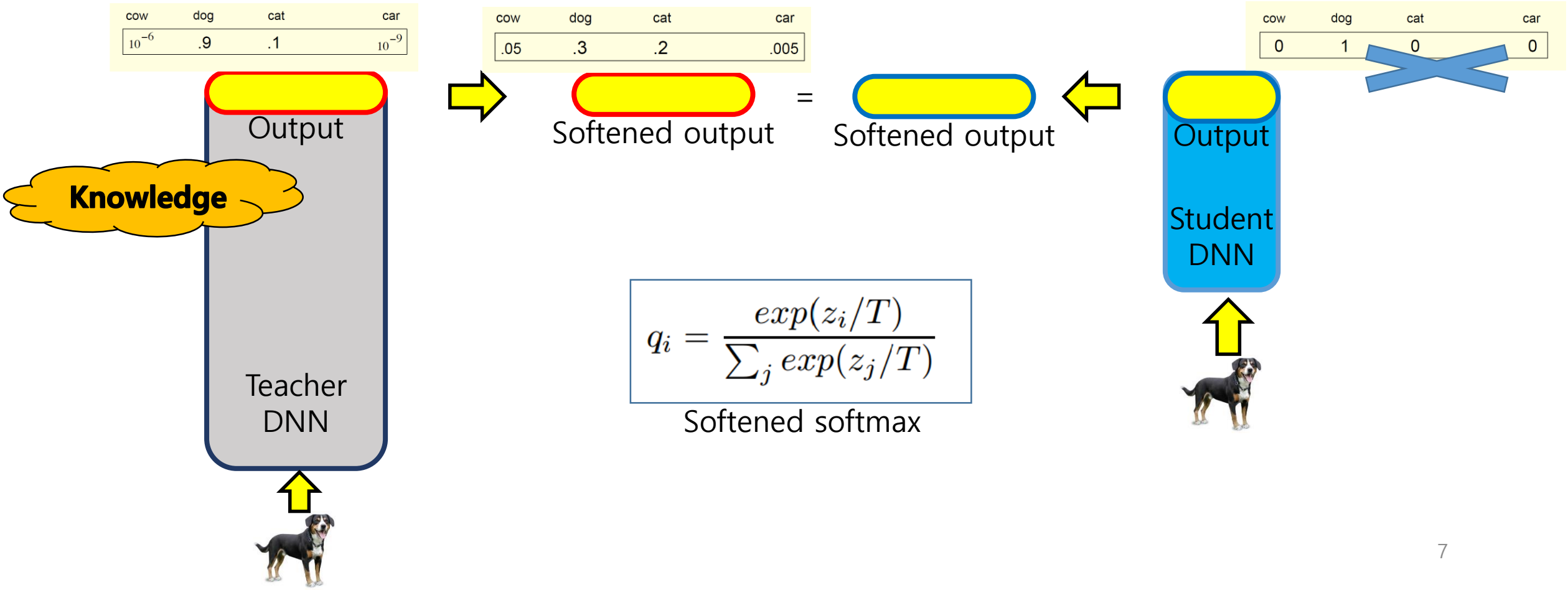
What kind of Knowledge?

How to transfer the knowledge?

Previous Research

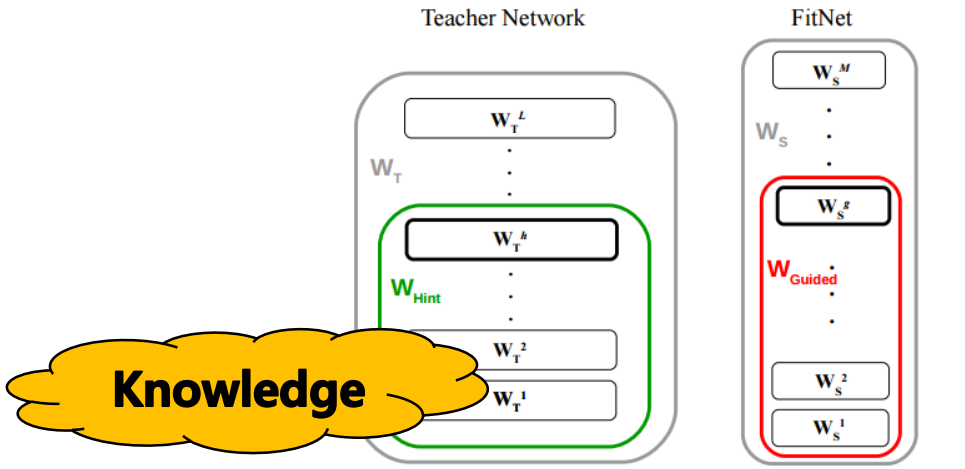
Previous Research Knowledge Distillation

- Hinton et al. "Distilling the knowledge in a neural network", arXiv 2014
  - Student DNN is penalized according to a softened version of the teacher DNN's output

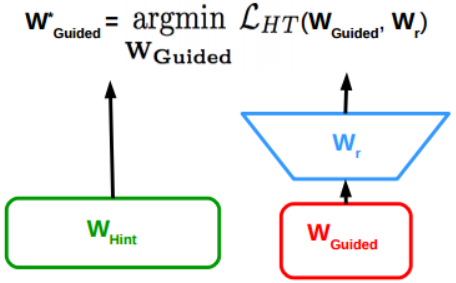


Previous Research Knowledge Distillation

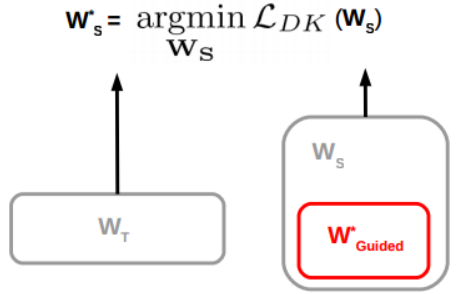
- Romero et al. “Fitnets: Hints for thin deep nets”, ICLR 2015
  - Student DNN is also penalized according to a intermediate features of the teacher DNN



(a) Teacher and Student Networks



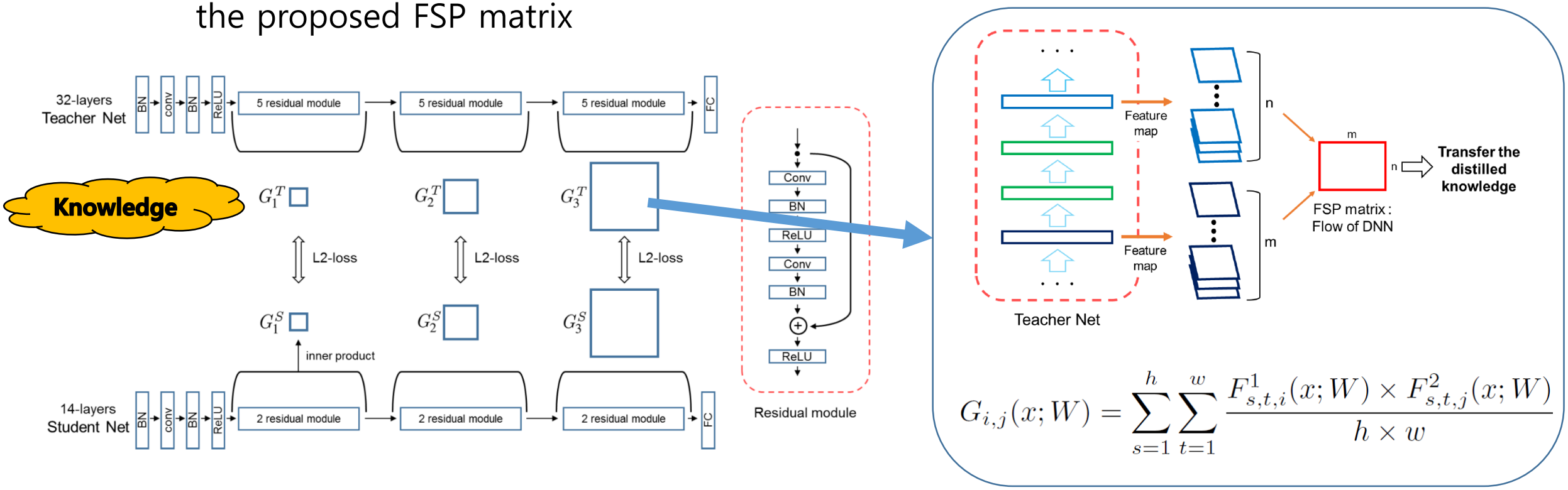
(b) Hints Training



(c) Knowledge Distillation

Previous Research Knowledge Distillation

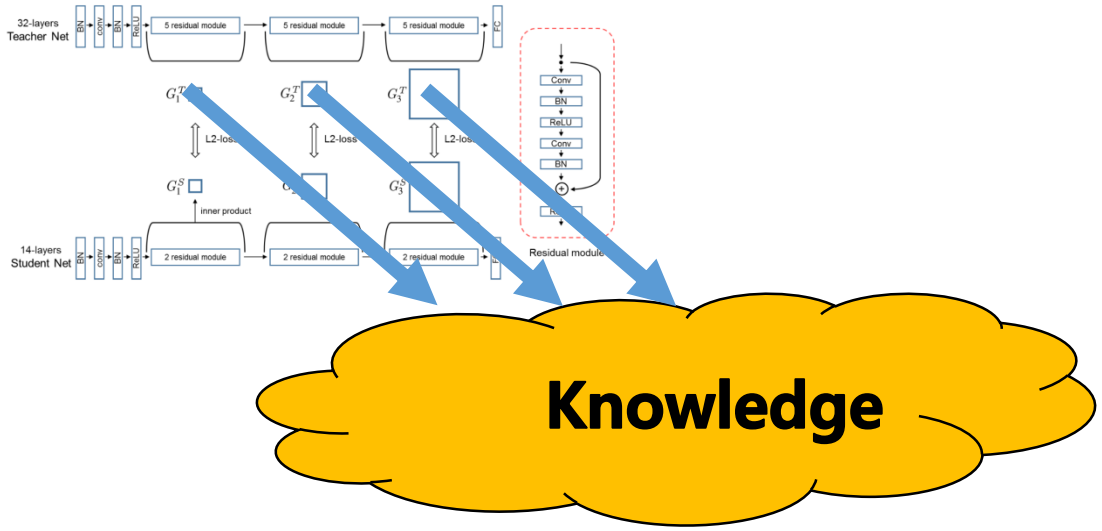
- Yim et al. “Gift from Knowledge distillation: Fast Optimization, Network Minimization and Transfer Learning”, CVPR 2017
  - Determine the distilled knowledge as the flow of the solving procedure calculated with the proposed FSP matrix

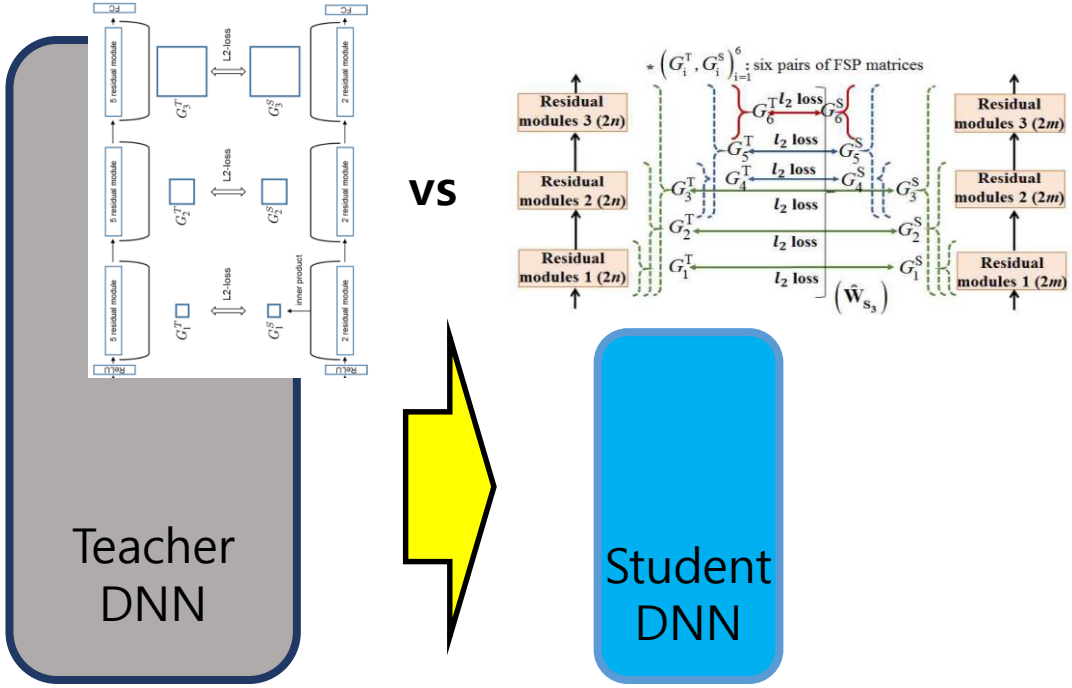


Proposed Model

Motivation

- Two main issues in knowledge distillation method





What kind of Knowledge?

How to transfer the knowledge?

Proposed Model Sequential Knowledge Transfer

- Part of Table of contents of Thomas' Calculus

2. Limits and Continuity
2.1 Rates of Change and Tangents to Curves
2.2 Limit of a Function and Limit Laws
2.3 The Precise Definition of a Limit
2.4 One-Sided Limits
2.5 Continuity
2.6 Limits Involving Infinity; Asymptotes of Graphs

3. Differentiation
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4.4 Concavity and Curve Sketching
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4.6 Newton's Method
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http://www.mypearsonstore.com/bookstore/thomas-calculus-9780321587992

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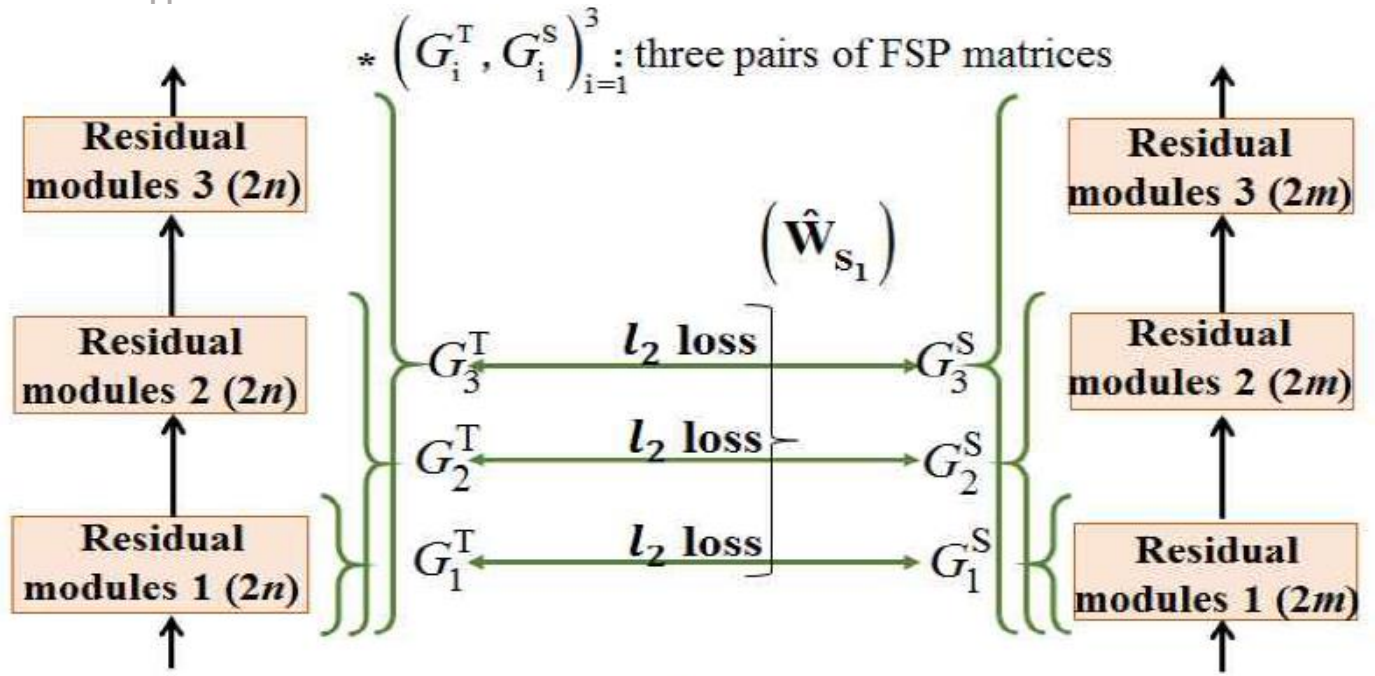

(b)

$$(\hat{\mathbf{W}}_{S_1}) = \arg\min_{\mathbf{W}_{S_1}} \sum_{i=1}^{n_0} \lambda_i \left\| G_i^T(x, \mathbf{W}_T) - G_i^S(x, \mathbf{W}_{S_1}) \right\|_2^2, \quad (1)$$

Proposed Model Sequential Knowledge Transfer

- Step 2

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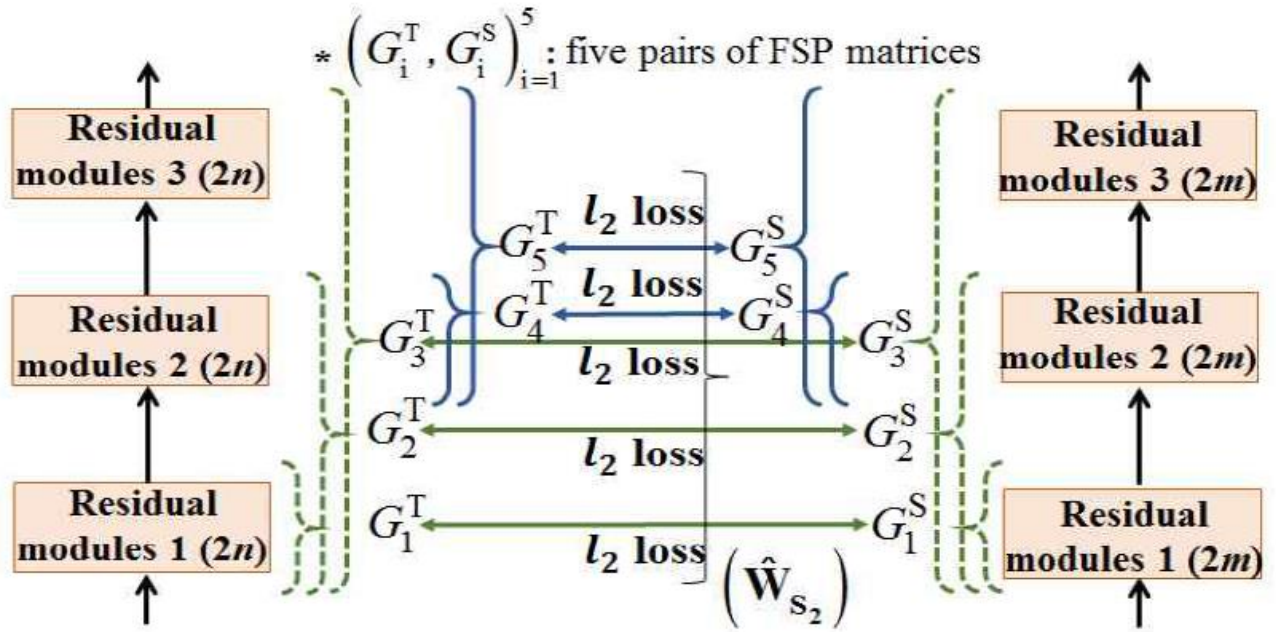

(c)

4.5 Monotonic Functions and the First Derivative Test

$$(\hat{\mathbf{W}}_{S_2}) = \arg\min_{\mathbf{W}_{S_2}} \sum_{i=1}^{2n_0-1} \lambda_i \left\| G_i^T(x, \mathbf{W}_T) - G_i^S(x, \mathbf{W}_{S_2}) \right\|_2^2, \quad (2)$$

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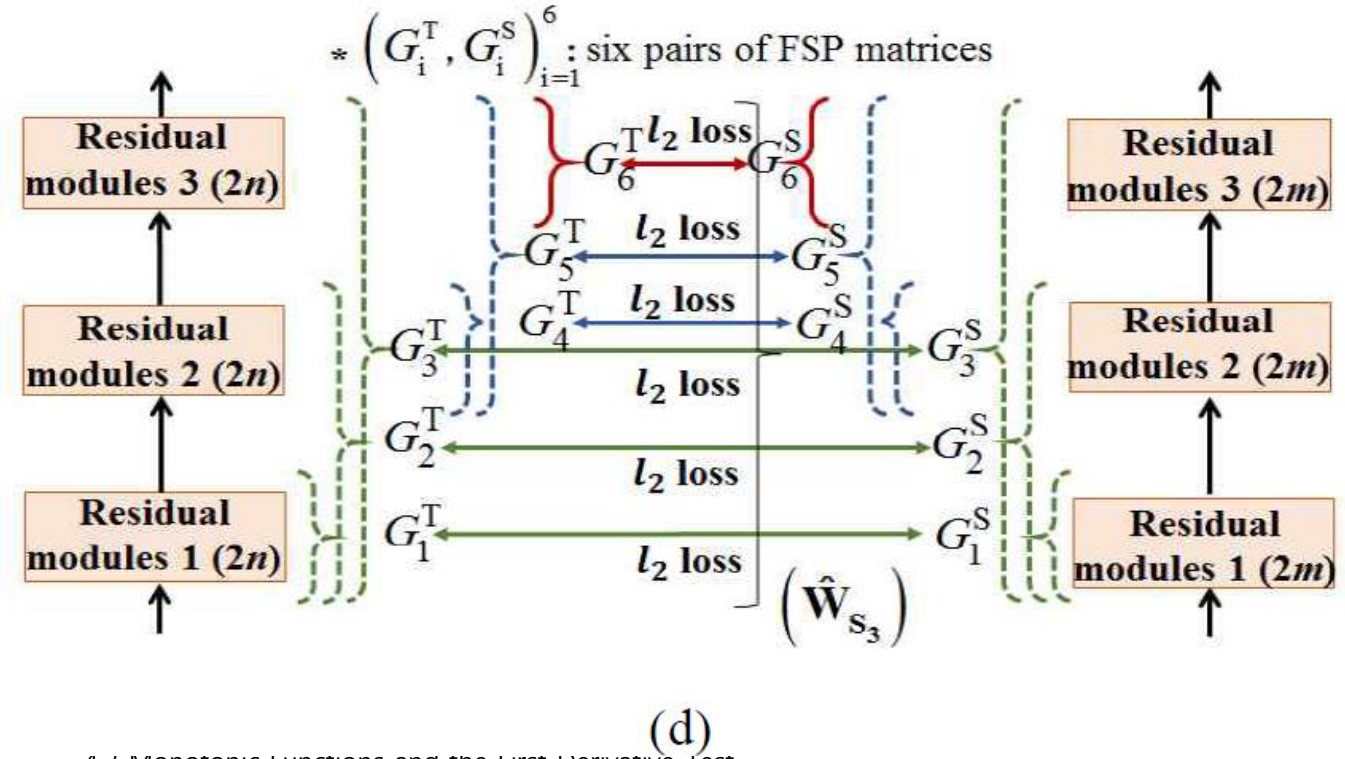
Proposed Model Sequential Knowledge Transfer

- Step 3



(d)

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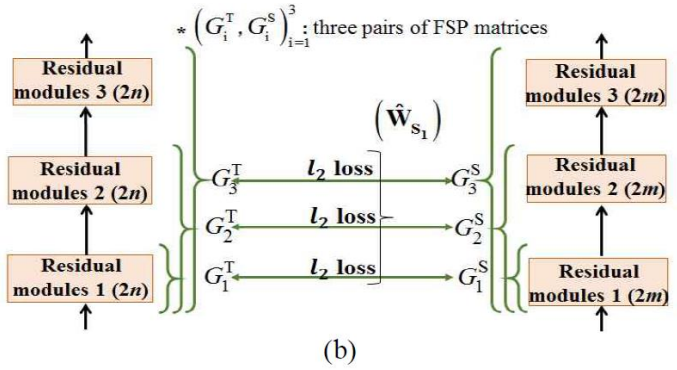
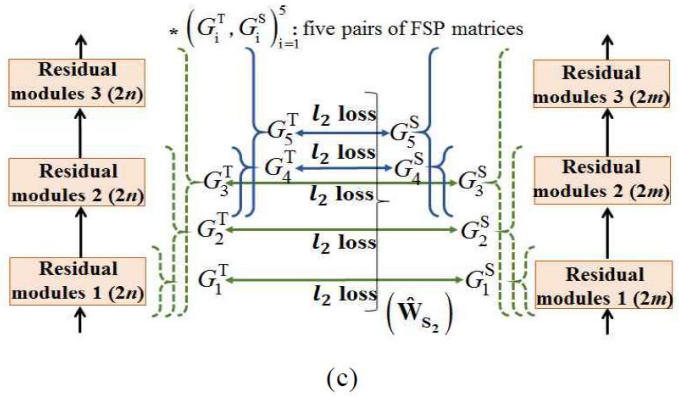
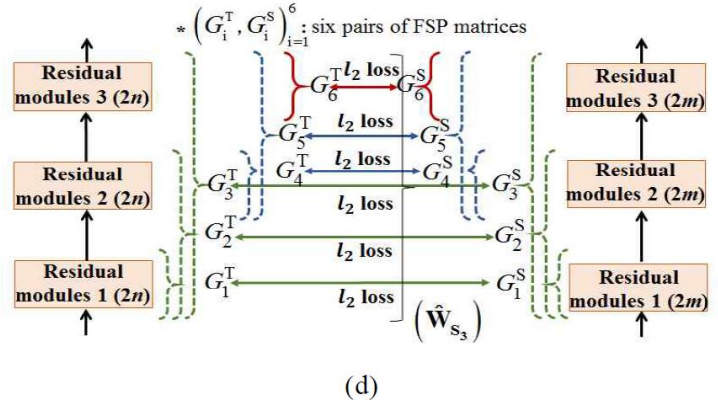
Proposed Model Sequential Knowledge Transfer

- Whole procedure







Step 1 Step 2 Step 3

Experimental Result

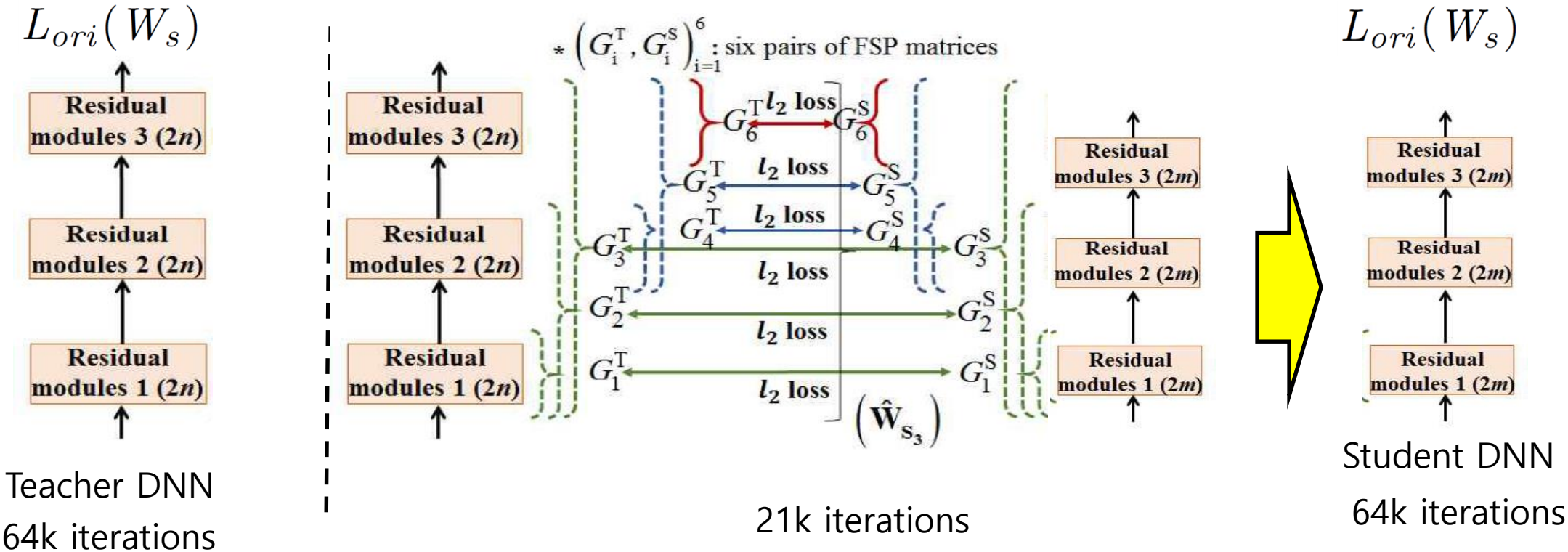
Experimental Result

- Contents
  - Performance Improvement
  - Network Minimization

Experimental Result

Performance improvement

- Experimental setting
  - CIFAR-10 dataset
  - Using 26-layers Residual network for the Teacher DNN
  - Using 8-layers Residual network for the Student DNN



Experimental Result

Performance improvement

- Experimental setting
  - CIFAR-10, Using 8-layers Residual network
  - 21k Iter for stage 1 and 64k Iter for stage 2
  - 26-layer teacher ResNet with an accuracy of 91.91%

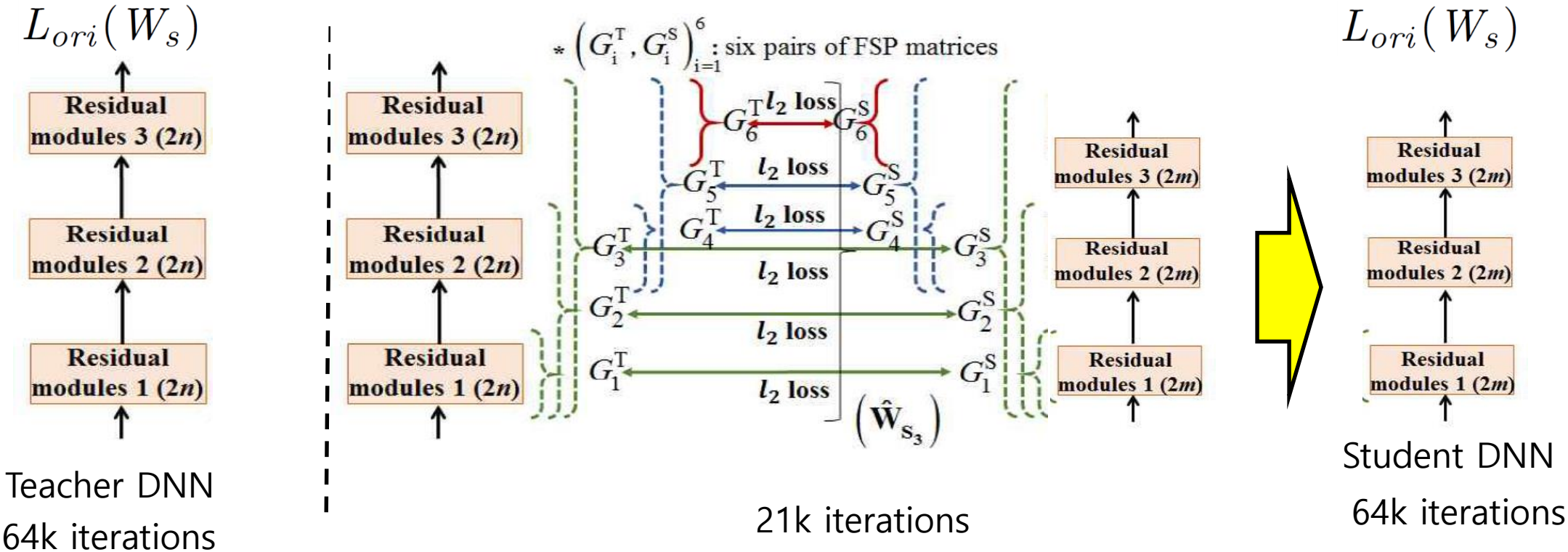
Method	Accuracy [%]	Reference
Hint-based method [25]	88.4	$P_c = 87.94\%$ for the original eight-layer ResNet
Original flow-based method [27]	88.72	
Proposed method	**88.96**	

CIFAR-10

Experimental Result

Performance improvement

- Experimental setting
  - CIFAR-100 dataset
  - Using 32-layers Residual network for the Teacher DNN
  - Using 14-layers Residual network for the Student DNN



Experimental Result

Performance improvement

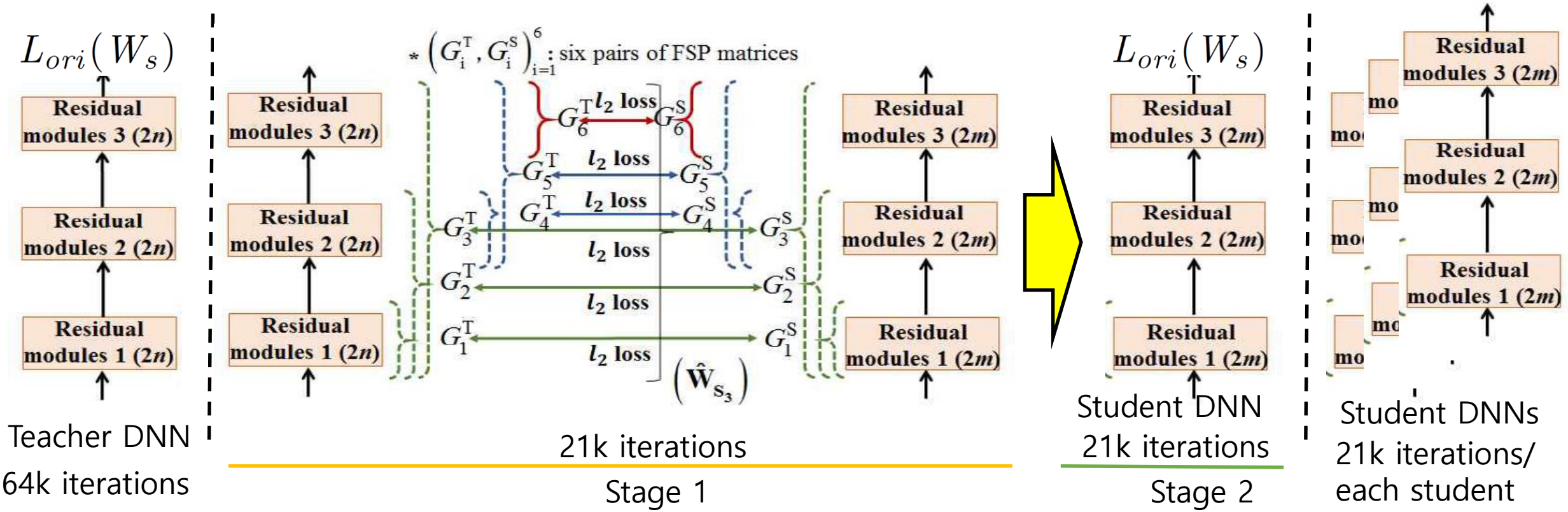
- Experimental setting
  - CIFAR-100, Using 14-layers Residual network
  - 32k Iter for stage 1 and 64k Iter for stage 2
  - 32-layer teacher ResNet with an accuracy of 64.69%

Method	Accuracy [%]	Reference
Hint-based method [25]	63.38	$P_c = 62.37\%$ for the original 14-layer ResNet
Original flow-based method [27]	64.74	
Proposed method	**65.06**	

CIFAR-100

Experimental Result Fast optimization

- Experimental setting
  - CIFAR-10 dataset
  - Using 26-layers Residual network for the Teacher and Student DNN



Experimental Result Fast optimization

- Experimental setting
  - CIFAR-10,
  - 21k Iter for stage 1, 21k Iter for stage 2

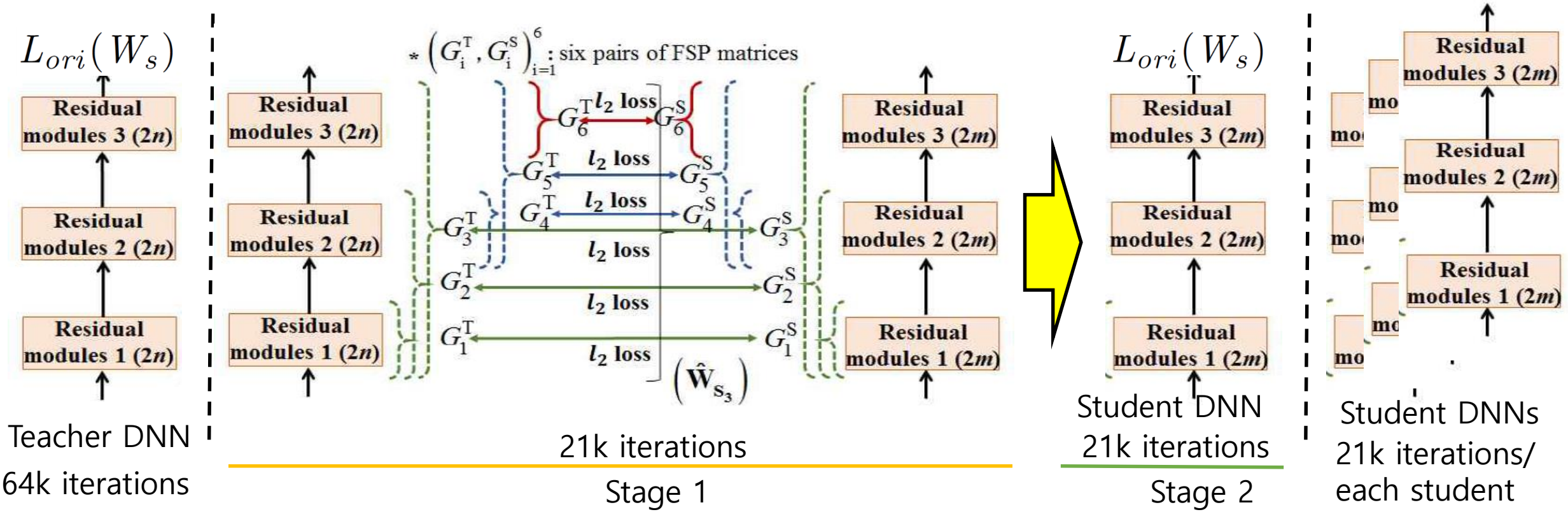
Method	Net1	Net2	Net3	Avg.	Ensemble	#Iter
Original teacher[a]	91.91	91.68	91.68	91.75	93.29	192k
Original teacher[b]	90.92	90.85	90.69	90.82	92.7	63k
Hint-based method [25]	92.07	91.75	91.81	91.87	93.02	138k
Original flow-based method [27]	91.84	92.13	92.25	92.07	93.59	126k
Proposed method	92.36	92.34	92.15	**92.28**	**93.68**	126k

a. *The 26-layer teacher ResNet was trained with 64,000 iterations.*

b. *The 26-layer teacher ResNet was trained with 21,000 iterations.*

Experimental Result Fast optimization

- Experimental setting
  - CIFAR-100 dataset
  - Using 32-layers Residual network for the Teacher and Student DNN



Experimental Result Fast optimization

- Experimental setting
  - CIFAR-100,
  - 32k Iter for stage 1, 21k Iter for stage 2

Method	Net1	Net2	Net3	Avg.	Ensemble	#Iter
Original teacher[a]	64.69	63.29	64.52	64.16	69.79	192k
Original teacher[b]	62.96	62.69	60.82	62.15	67.91	63k
Hint-based method [25]	63.54	64.43	64.07	64.01	68.68	168k
Original flow-based method [27]	64.16	64.3	64.48	64.31	69.5	159k
Proposed method	66.65	66.52	64.54	**65.9**	**69.98**	159k

a. *The 26-layer teacher ResNet was trained with 64,000 iterations.*

b. *The 26-layer teacher ResNet was trained with 21,000 iterations.*

Conclusion

- Propose a novel approach for **enhancing** knowledge distillation and knowledge transfer between teacher and student DNN models
- Help to obtain a **fast optimization** with high accuracy using the **densely distilled** flow-based knowledge and its **sequential** transfer
- Proposed method outperforms state-of-the-art knowledge transfer method in the **network minimization**