

**CVPR 2016**

**Inception-v4, Inception-ResNet and the Impact  
of Residual Connections on Learning**

2022.07.28

논문 리뷰

배성훈

# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

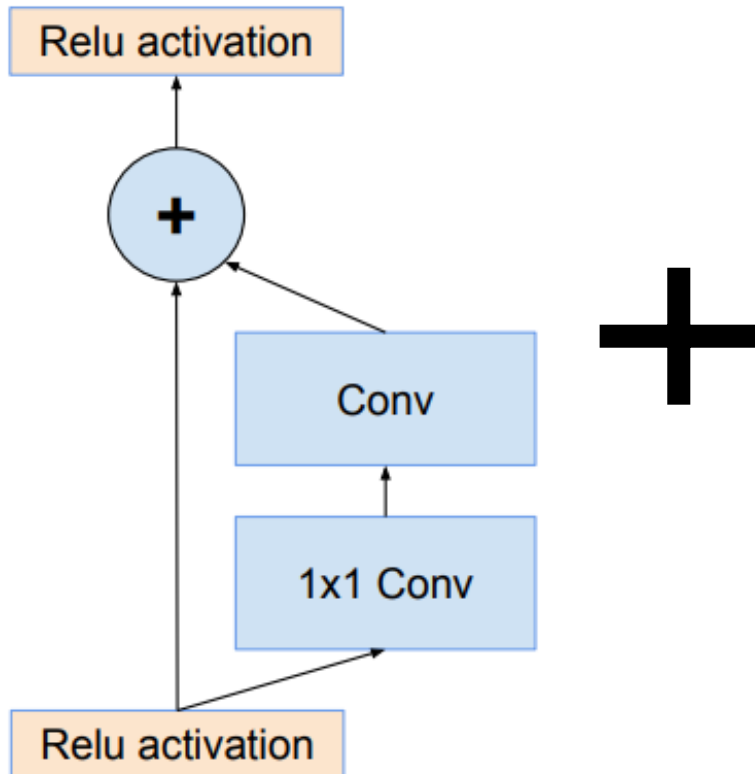
- **Research Background:**

- **Residual connection**과 **Inception architecture**를 합치면 어떤 **이점**이 있을까?
- **Network Depth와 Width를 증가**시켜 성능을 향상시키는 대표적인 방법들을 조합해 성능 향상

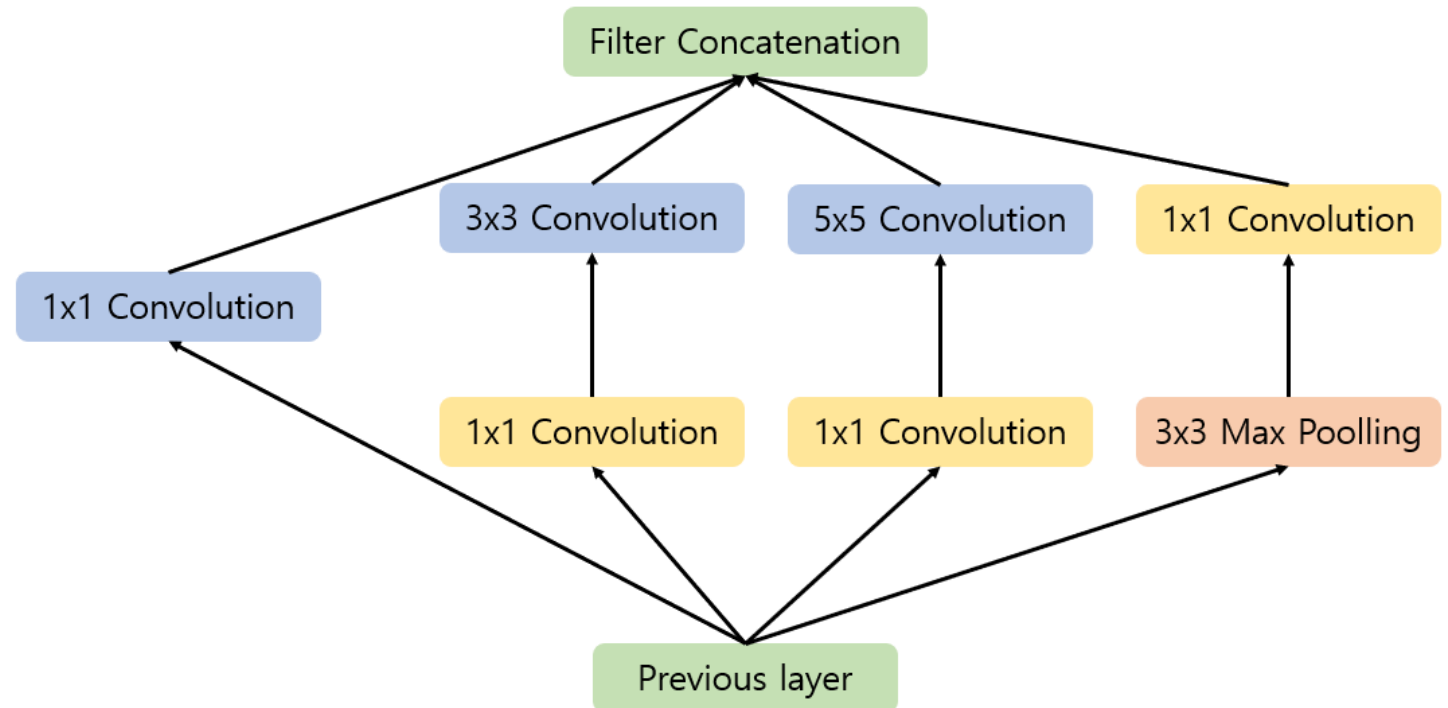
\*이점: Inception의 계산 효율성 유지 + residual block 이점

\*Network Depth와 Width 증가: 신경망 구조에서 Layer를 깊게 쌓고, filter 또는 channel의 수를 증가

**Residual Block**



**Inception module**



# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Method:**

- **Inception-ResNet-v1:** Inception-v3와 유사한 계산비용을 가진 하이브리드 버전
- **Inception-ResNet-v2:** Recognition 성능이 크게 향상된 계산 비용이 많이 드는 하이브리드 버전
- **Inception-v4:** Inception-ResNet-v2와 동일한 recognition 성능을 가진 Non-residual, Pure Inception 버전

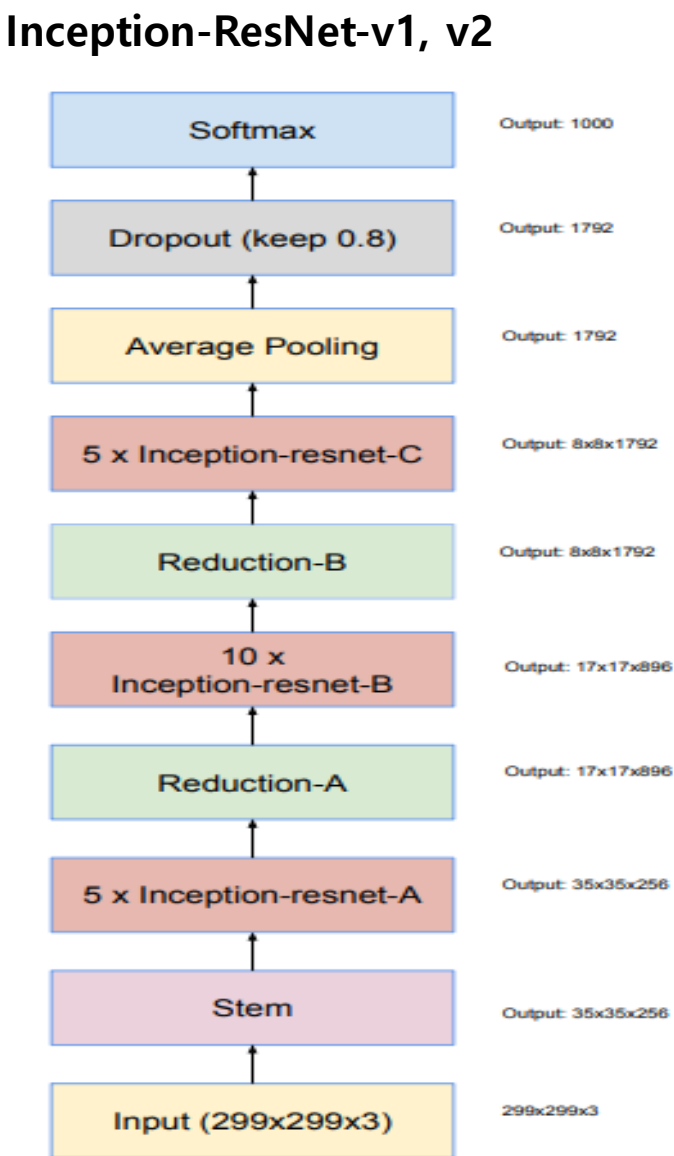
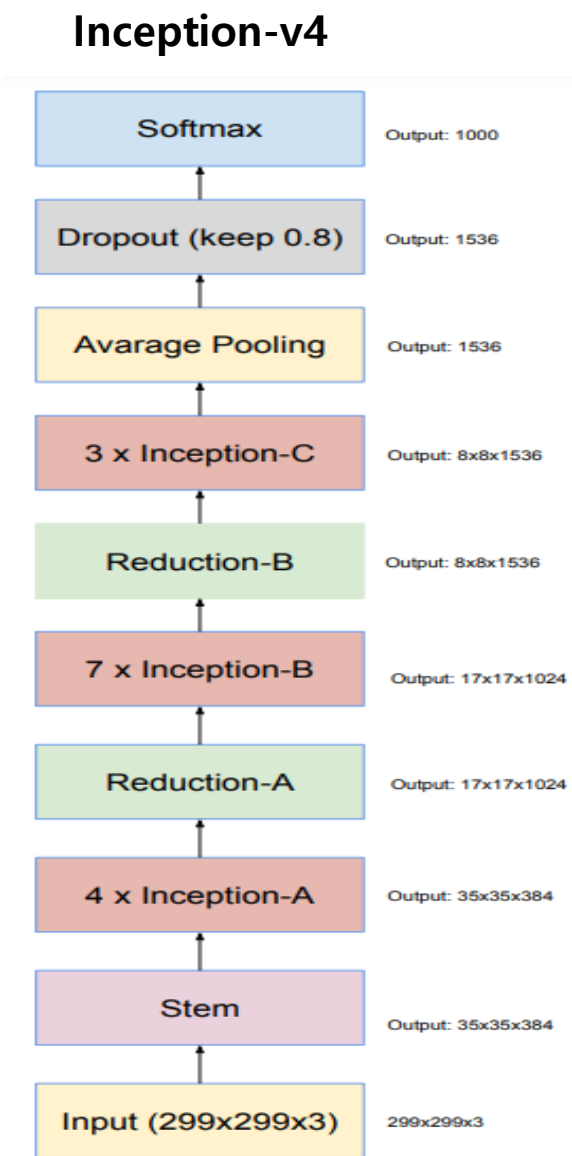
\*Residual Inception Blocks: 연산할 파라미터 수를 줄이기 위해 1x1 Conv를 먼저 진행해 입력 차원 수를 줄임

\*Activation Scaling: 잔차(Residual)를 Scaling해 학습의 안정성을 높임

\*병렬연산: 그리드 사이즈를 줄일 때 연산량을 줄이면서 특징 맵의 정보 손실 방지

# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

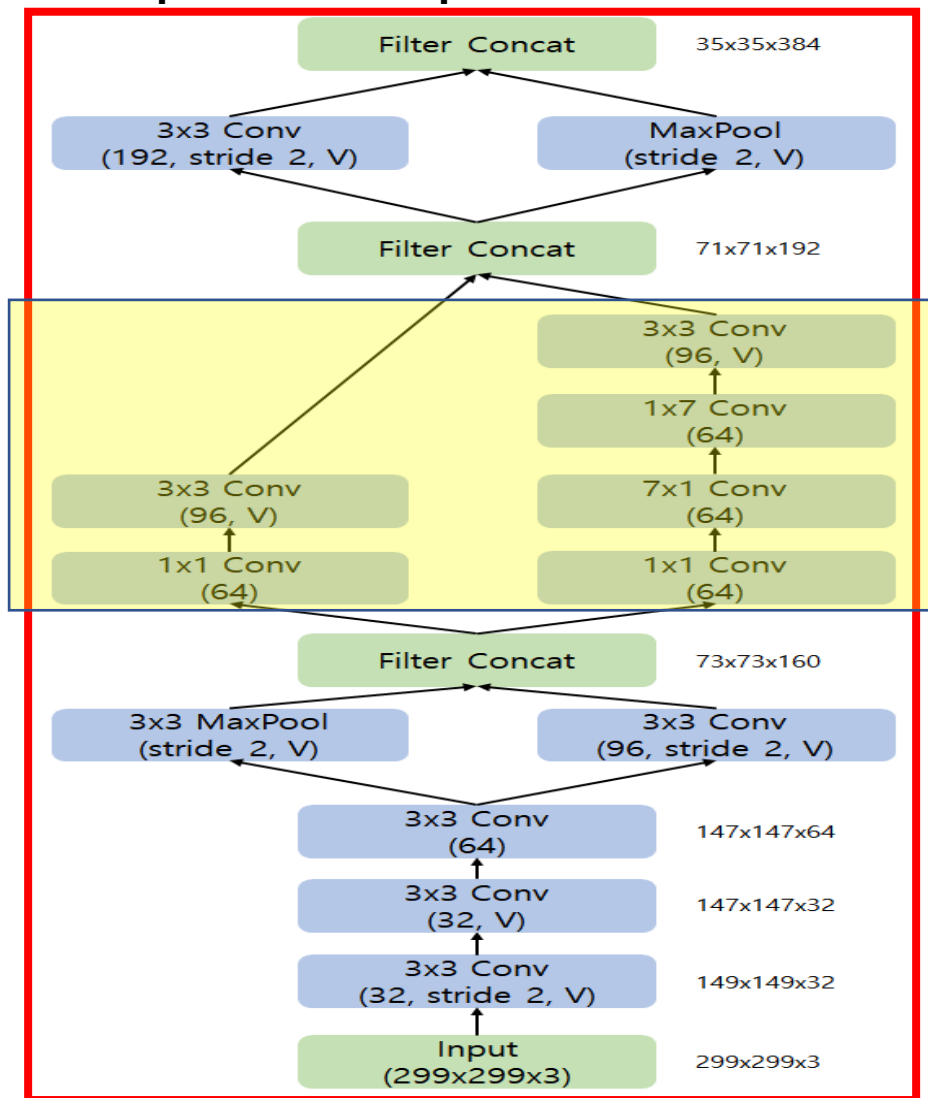
- **Method:** Residual Inception model vs Non-Residual Inception model



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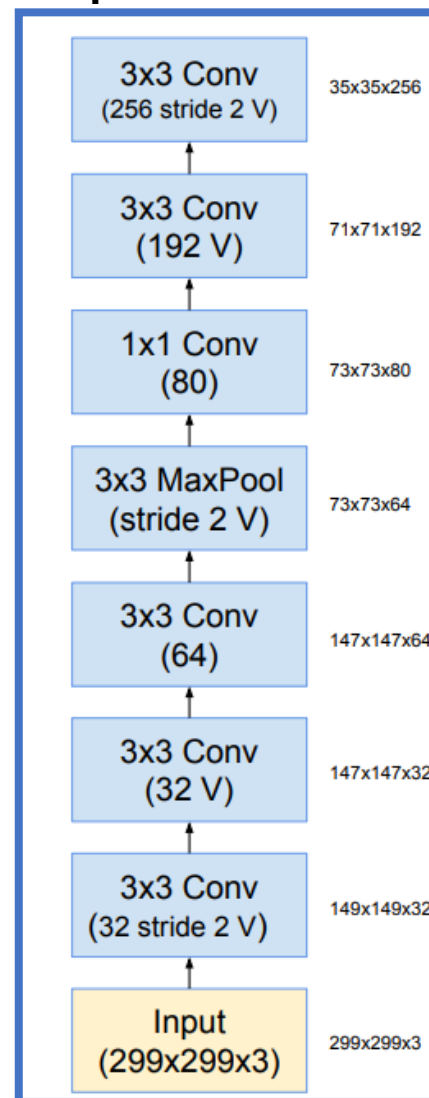
- **Method:** Residual Inception model vs Non-Residual Inception model

Stem:  
Inception-v4, Inception-ResNet-v2



병렬연산

Stem:  
Inception-ResNet-v1

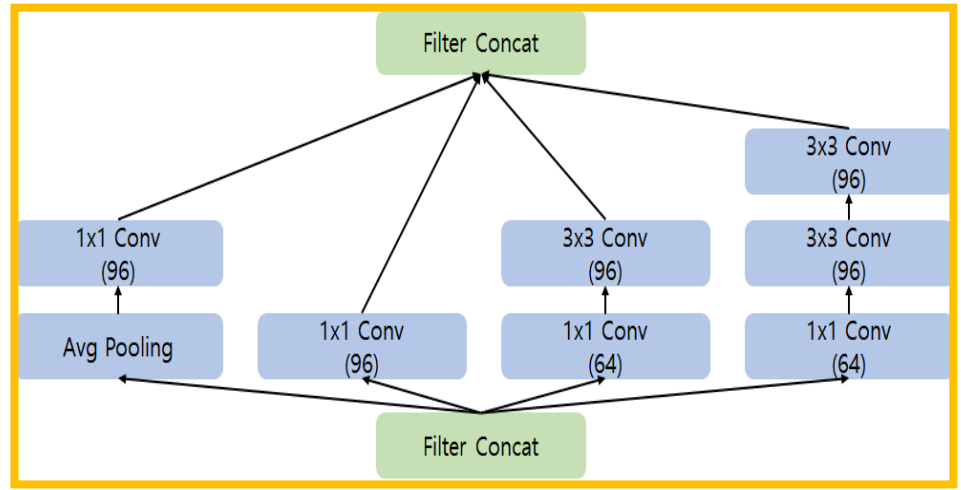


V: Valid padding,  
V 표시|x: Same padding

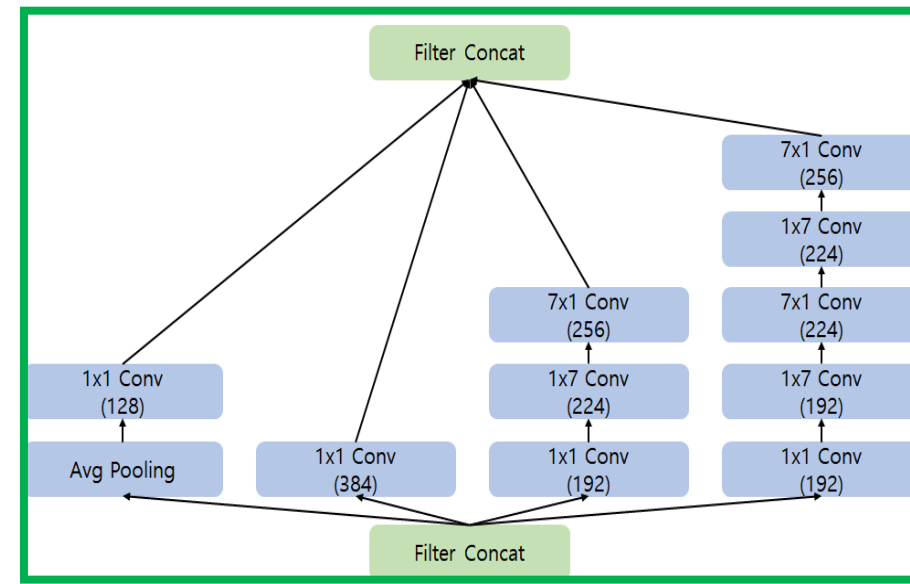
# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Method:** Inception-v4

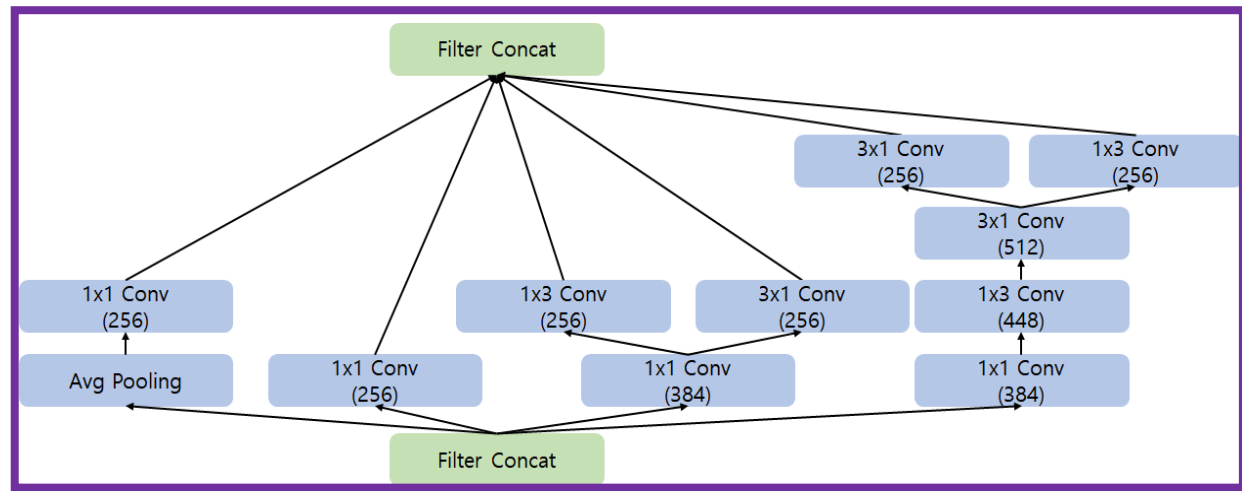
**Inception-v4 <Inception-A >**



**Inception-v4 <Inception-B >**



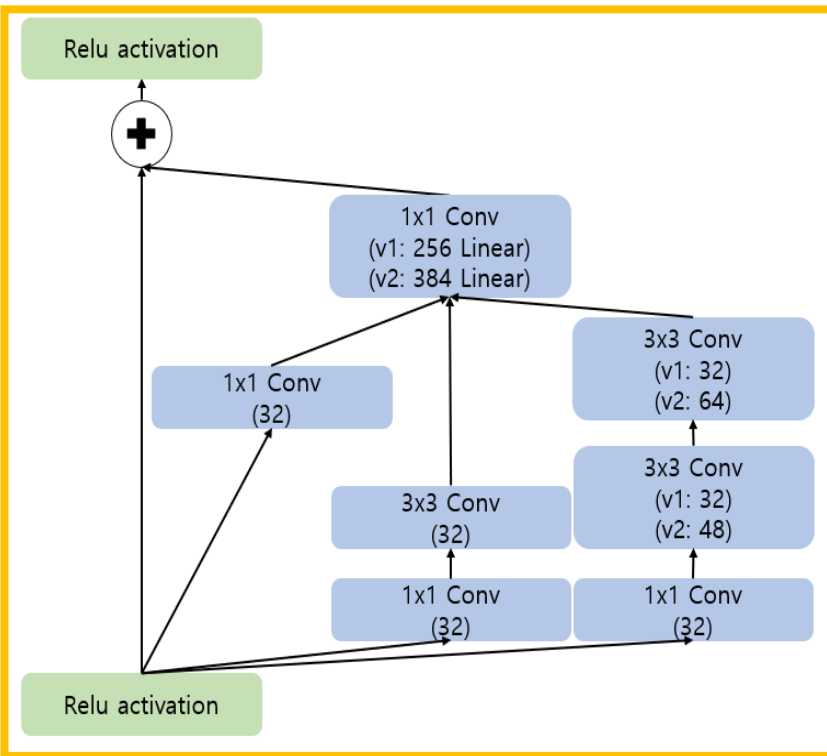
**Inception-v4 <Inception-C >**



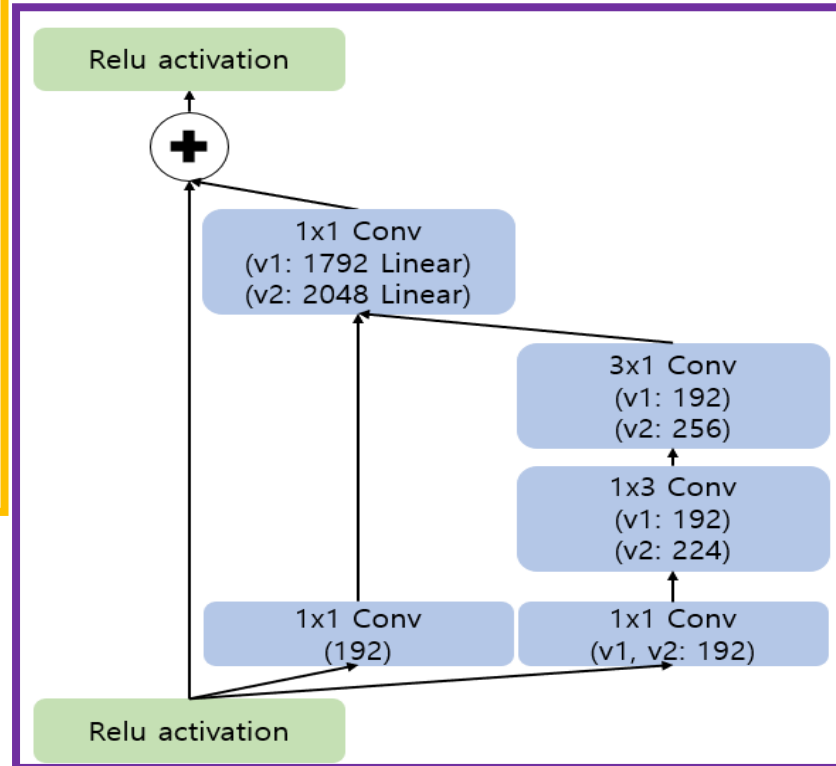
# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Method:** Inception-ResNet-v1, -v2
  - V1, V2는 구조는 같으나 filter size 차이를 가짐

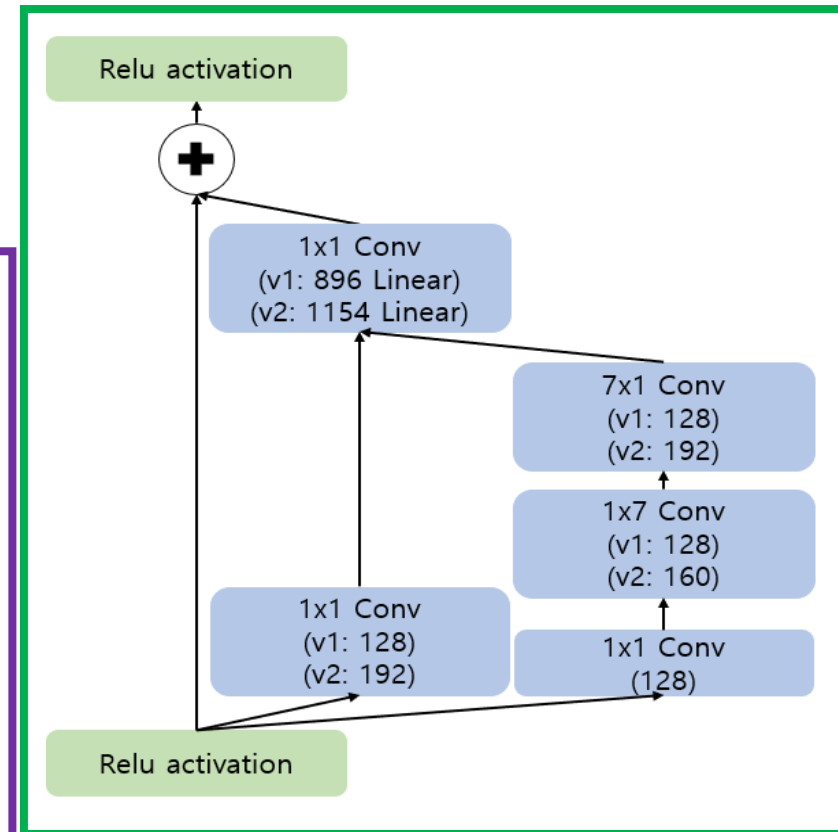
Inception-ResNet-A



Inception-ResNet-C

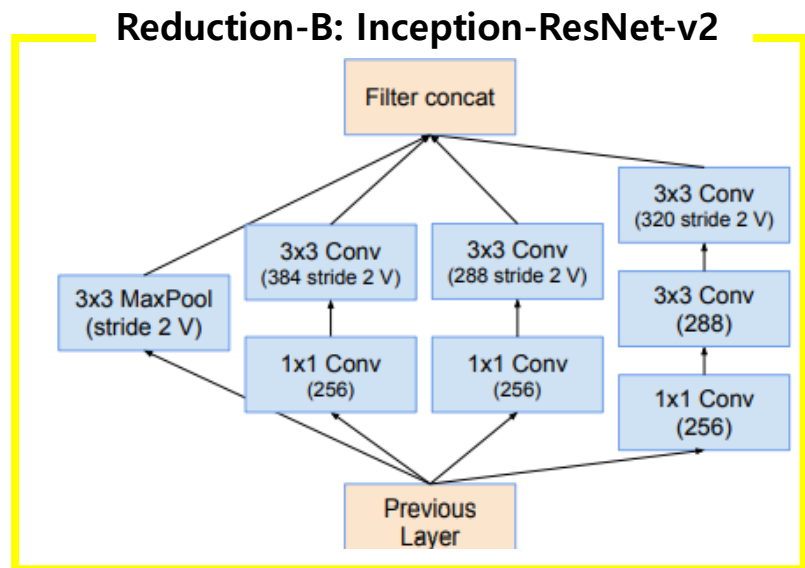
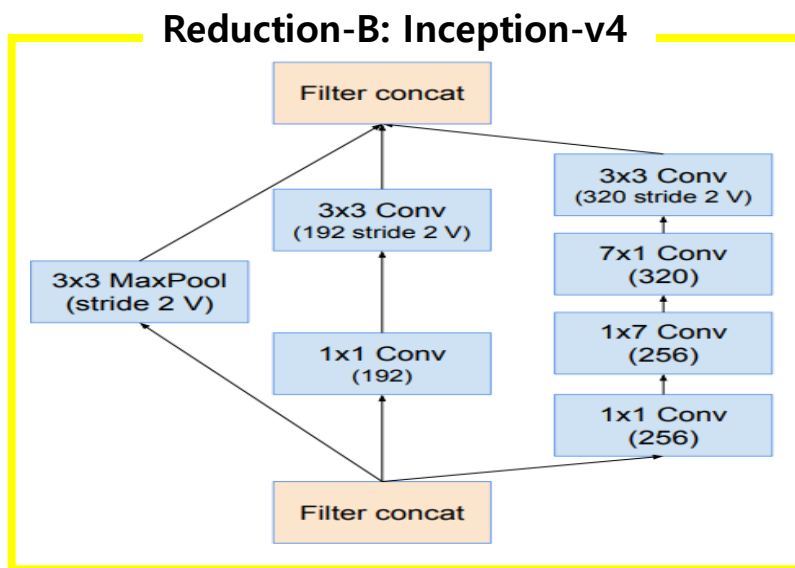
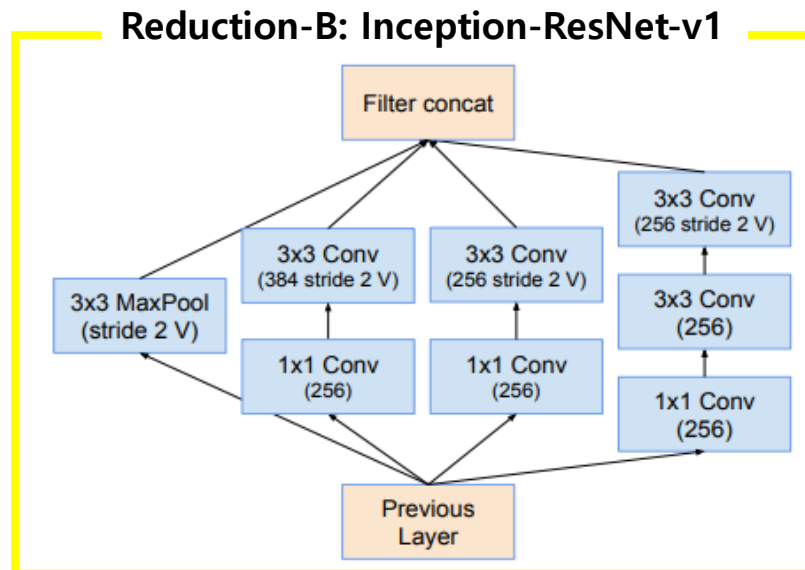
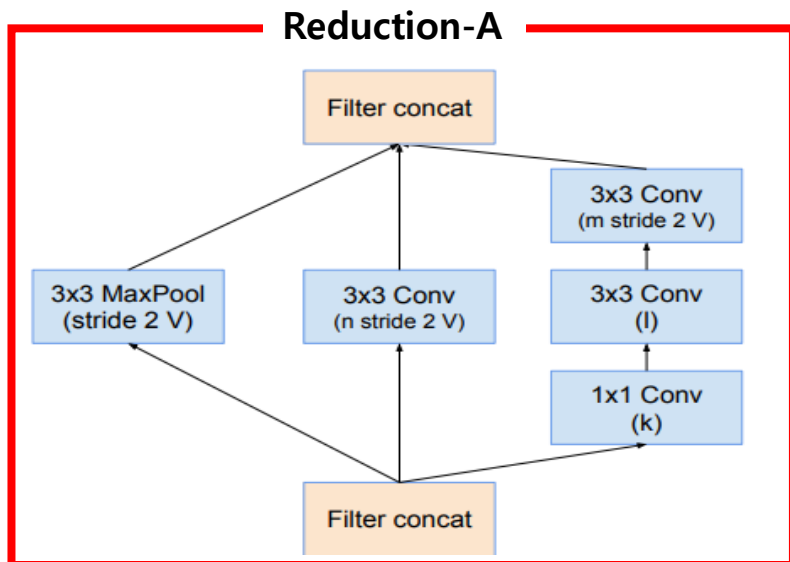


Inception-ResNet-B



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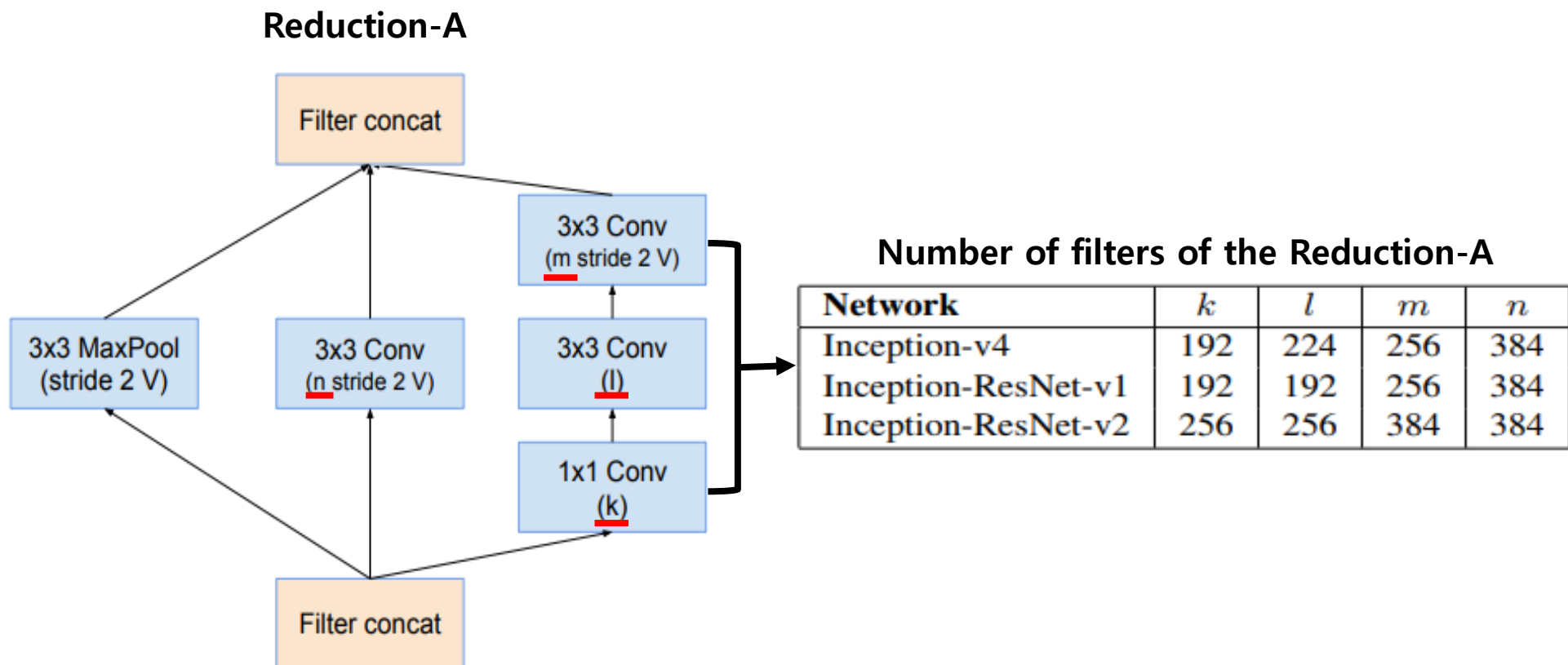
- **Method:** Reduction-A, -B





# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

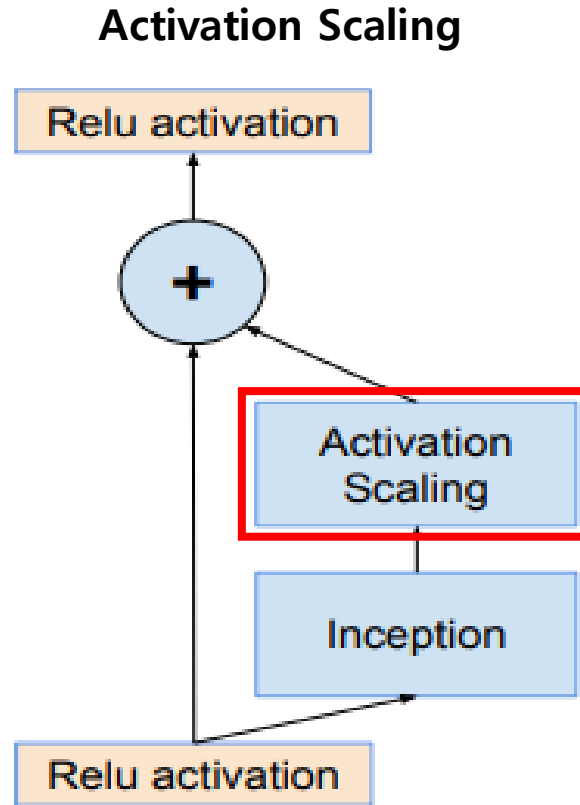
- **Method:** Reduction-A, -B



# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Method:** Activation Scaling

- Filter size가 1000을 넘어가기 시작하면, residual variant의 불안정화와 학습 초반에 네트워크가 죽는 것을 발견
- 이를 해결하기 위해 잔차를 더하기 전에, Scaling factor를 사용해 잔차의 값을 줄여 **학습 안정화**



**Scaling Factor:** 0.1 ~ 0.3  
**General Scaling Factor:** 0.1

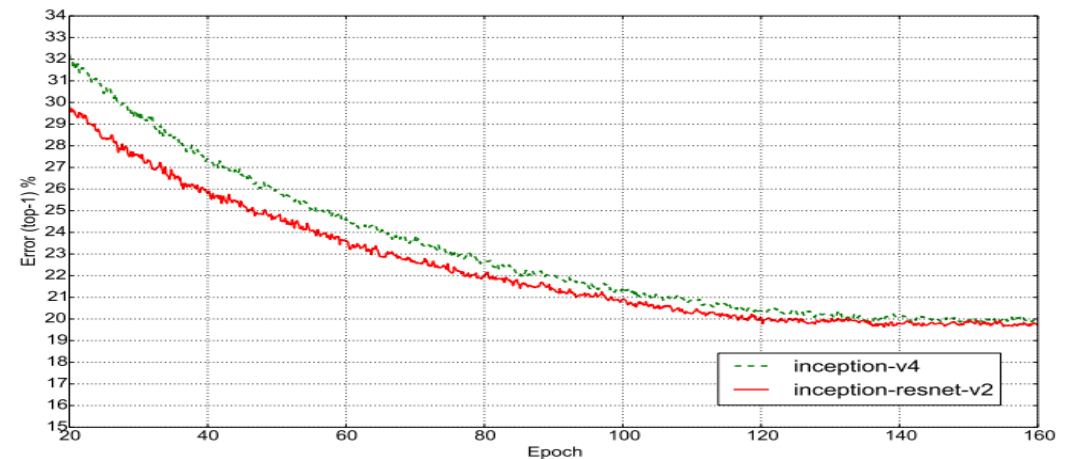
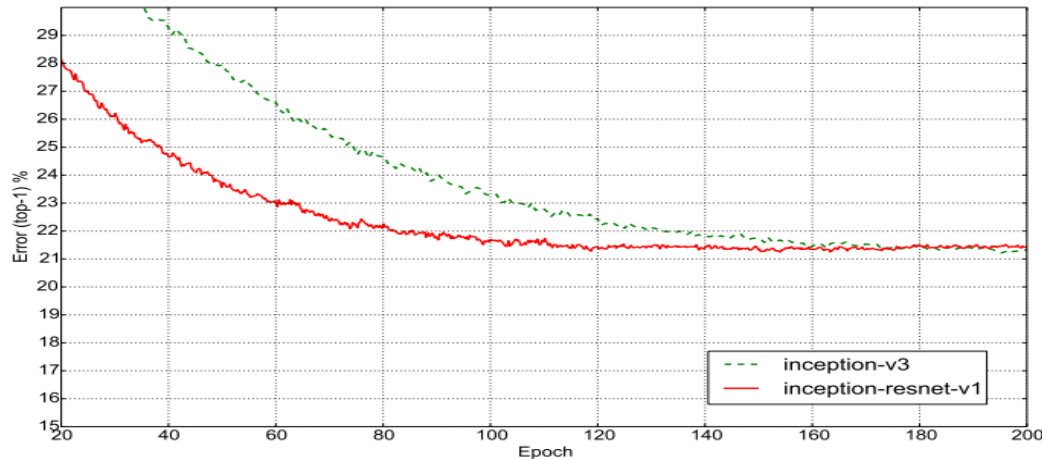
# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Experiment:**

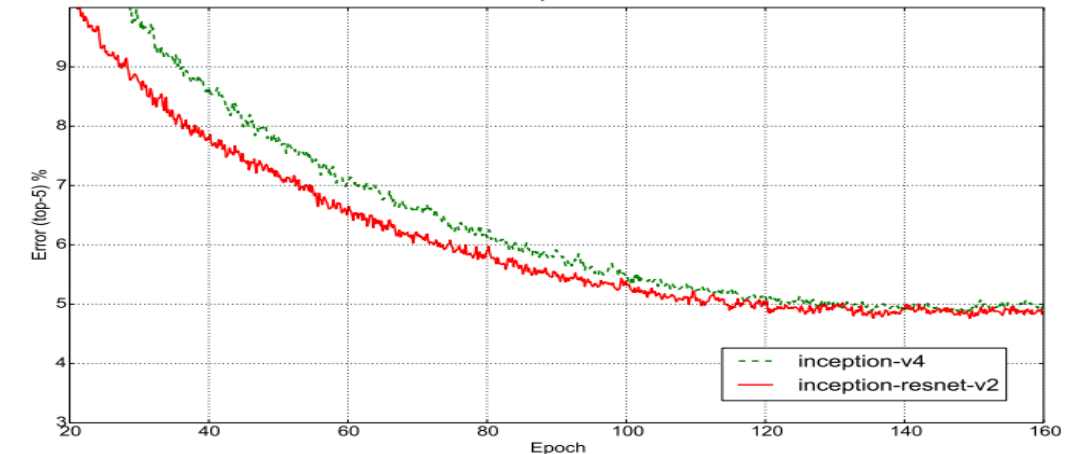
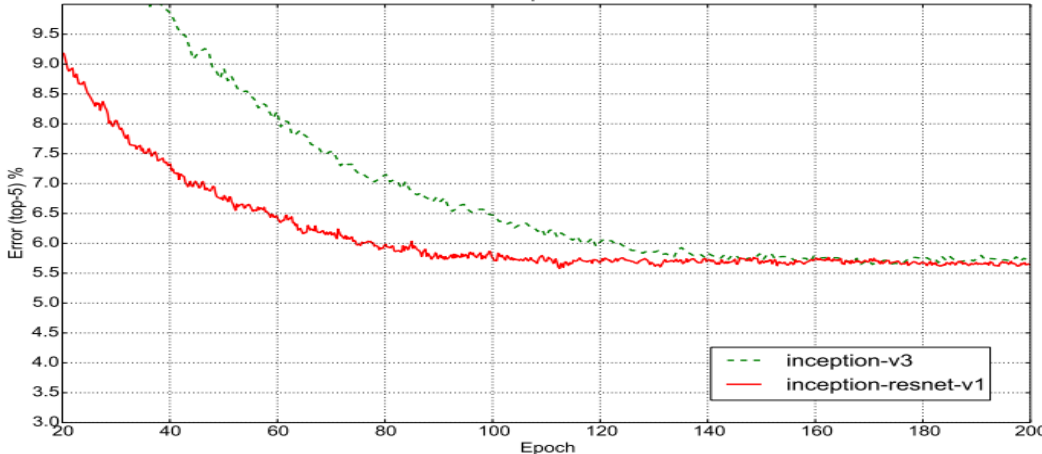
Residual connection의 도입으로 Inception 구조의 학습속도가 향상되고, 기존의 성능을 증가  
(계산 효율성 유지 + 학습 속도 향상)

Top-1, -5 error measured on a single crop on the non-blacklist images of the ILSVRC-2012 validation set (Inception-v3 vs **Inception-ResNet-v1**), (Inception-v4 vs **Inception-ResNet-v2**)

Top-1



Top-5



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- **Experiment:**

Residual connection의 도입으로 Inception 구조의 학습속도가 향상되고, 기존의 성능을 증가  
(계산 효율성 유지 + 학습 속도 향상)

Top-1, -5 error on the non-blacklisted subset of the validation set of ILSVRC 2012.

Best Performance

Network	Top-1 Error	Top-5 Error
BN-Inception [6]	25.2%	7.8%
Inception-v3 [15]	21.2%	5.6%
Inception-ResNet-v1	21.3%	5.5%
Inception-v4	20.0%	5.0%
Inception-ResNet-v2	19.9%	4.9%

Ensemble results on all 50000 images of the validation set of ILSVRC 2012

Network	Models	Top-1 Error	Top-5 Error
ResNet-151 [5]	6	–	3.6%
Inception-v3 [15]	4	17.3%	3.6%
Inception-v4 + 3× Inception-ResNet-v2	4	16.5%	3.1%

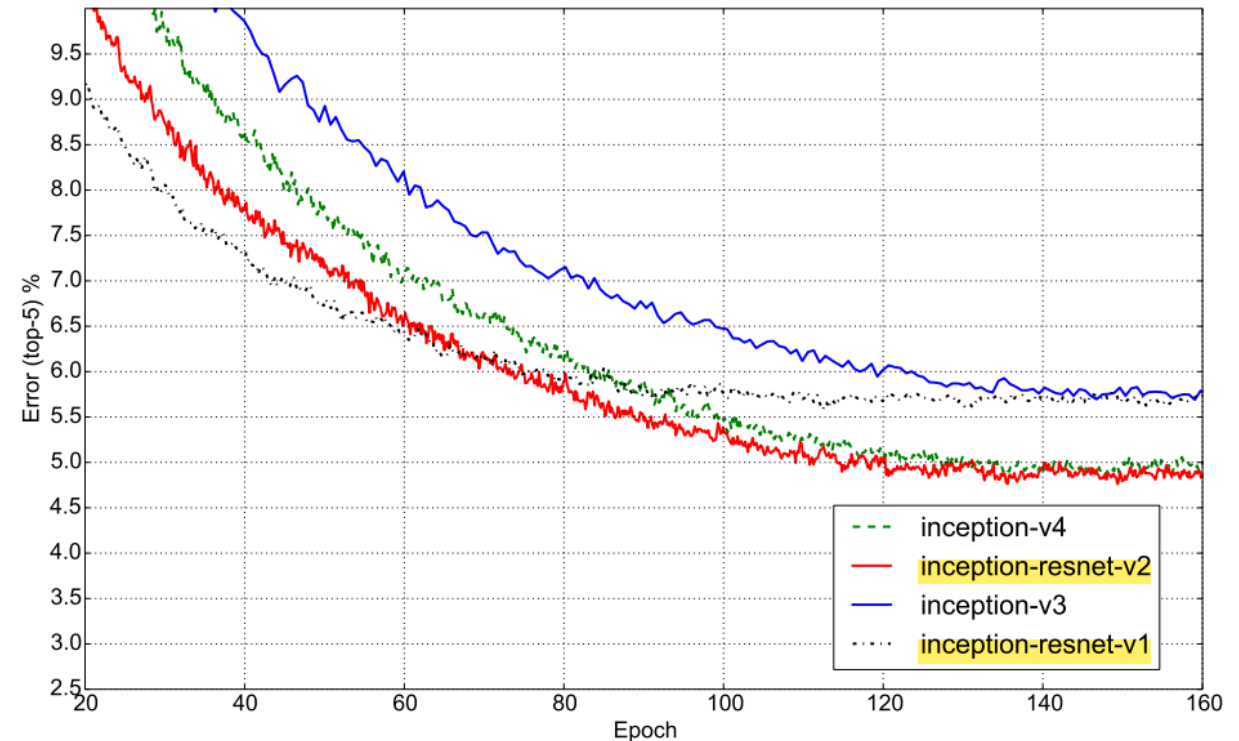
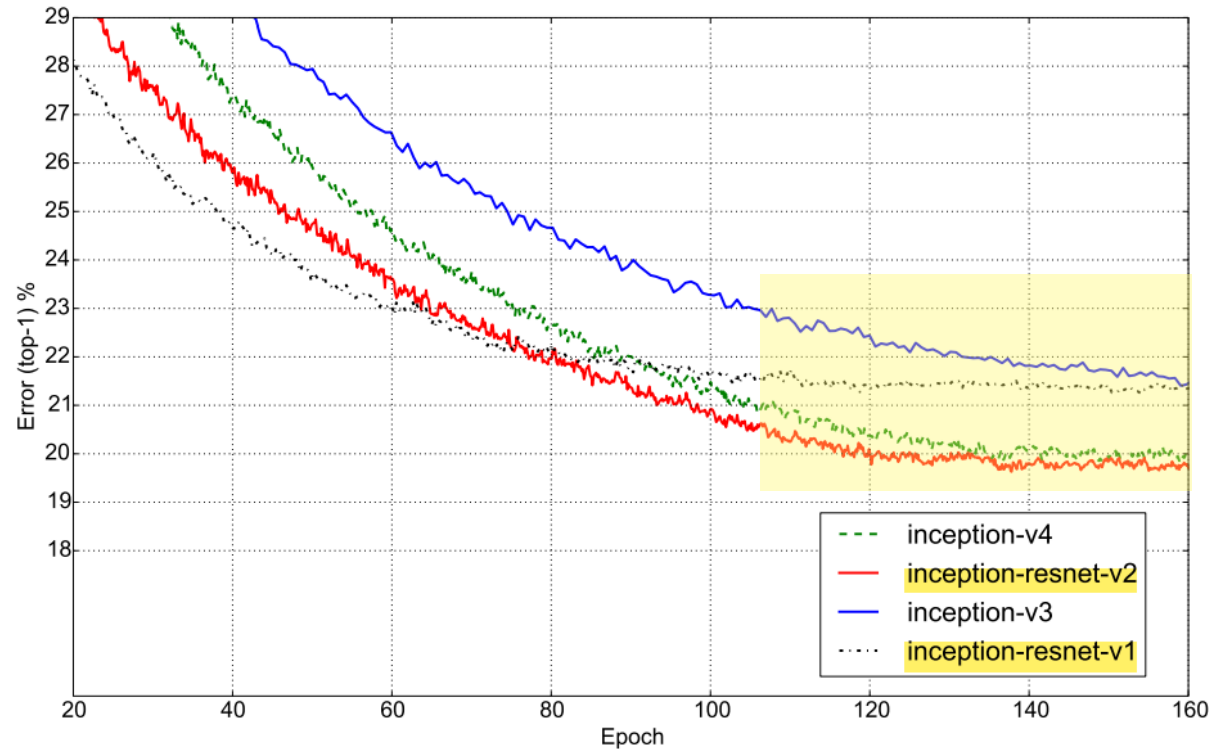
Best Performance

# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- **Experiment:**

Residual connection을 도입한 Inception-ResNet-v1, -v2가 더 빠르게 학습이 수렴하는 모습을 보임

Top-1, -5 error evolution of all four models (Single model, crop)



# Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning (CVPR 2016)

- Experiment:

Residual connection의 유무에 상관없이 모든 이전 네트워크 성능을 능가하는 모습을 보임 (Inception-v4)

Evaluation of various number of crop on all 50000 images of the validation set of ILSVRC 2012

Network	Crops	Top-1 Error	Top-5 Error
ResNet-151 [5]	10	21.4%	5.7%
Inception-v3 [15]	12	19.8%	4.6%
Inception-ResNet-v1	12	19.8%	4.6%
Inception-v4	12	18.7%	4.2%
Inception-ResNet-v2	12	18.7%	4.1%

Network	Crops	Top-1 Error	Top-5 Error
ResNet-151 [5]	dense	19.4%	4.5%
Inception-v3 [15]	144	18.9%	4.3%
Inception-ResNet-v1	144	18.8%	4.3%
Inception-v4	144	17.7%	3.8%
Inception-ResNet-v2	144	17.8%	3.7%

한줄평: ResNet의 이점과 Inception의 이점을 합쳐 성능이 향상하는지 확인하는 논문으로, Residual connection의 도입으로 model의 수렴이 더 빠른 결과를 보이지만, 성능 평가 결과 그렇게 필수적이지 않다는 모습을 보임