

RECYCLENET: INTELLIGENT WASTE SORTING USING DEEP NEURAL NETWORKS

Cenk Bircanoğlu

Bahçeşehir University

Meltem Atay

Middle East Technical University

Fuat Beşer

Yıldız Technical University

Özgün Genç

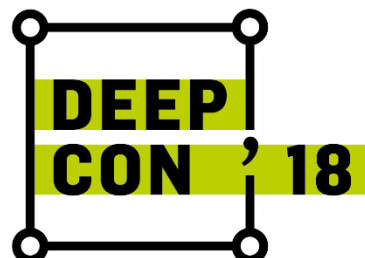
Koç University

Merve Ayyüce Kızrak

Yıldız Technical University



October 5-6, 2018



RECYCLENET: DERİN ÖĞRENME GERİ DÖNÜŞÜM MALZEMELERİNİ TANIMA

Cenk Bircanoğlu

Bahçeşehir Üniversitesi

Meltem Atay

Orta Doğu Teknik Üniversitesi

Fuat Beşer

Yıldız Teknik Üniversitesi

Özgün Genç

Koç Üniversitesi

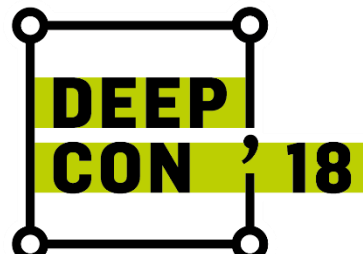
Merve Ayyüce Kızrak

Yıldız Teknik Üniversitesi



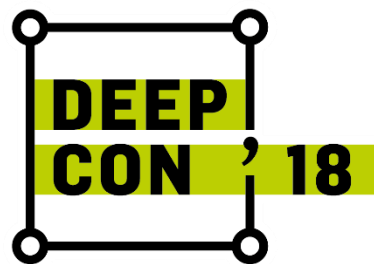
DEEP
LEARNING
TÜRKİYE

5-6 Ekim 2018



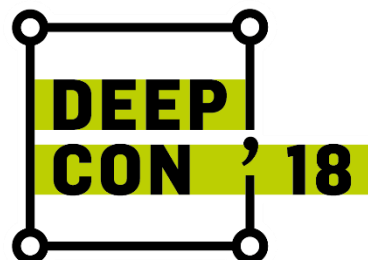
Özet

- Motivasyon
- Literatür
- Veri Kümesi
- Sinir Ağı Mimarileri
- Deneyler ve Sonuçları
- Sonuçlar



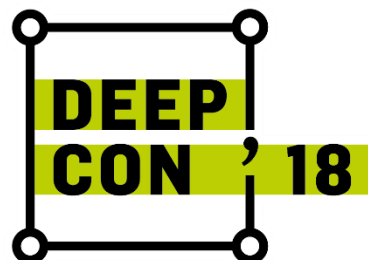
Motivasyon

- Ekonomik ve çevresel önemi
- İnsanlar tarafından yapılan ayrıştırma maliyetli ve zaman alıcı
- Geri dönüşüm işlemini otomatize etme



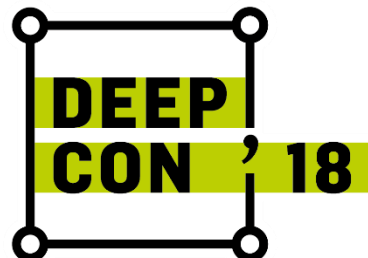
Literatür

- Bayes yöntemleri
- CNN mimarileri, nesne tanıma literatürüne etkileyici katkısı bulunmakta
- Stanford Üniversitesi, SIFT + SVM% 27 doğrulukta geri dönüştürülebilir malzemeleri tespit etti.



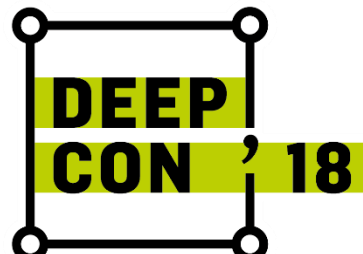
Veri Kümesi

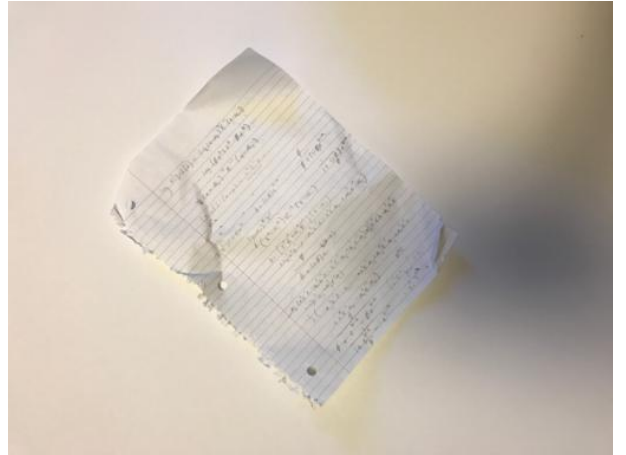
- TrashNet veri kümesi
- 6 Farklı sınıfa sahip
- Arka planı beyaz
- Farklı poz ve ışık bilgisi mevcut
- 512 x 384 piksel
- 3.5GB



Veri Kümesinin Detayları

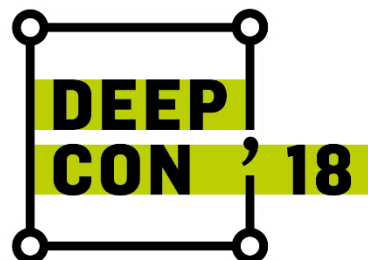
Madde Türü	#Eğitim (%70)	#Doğrulama (%13)	#Test (%17)	#Toplam
Kağıt	403	83	108	594
Cam	354	65	82	501
Plastik	347	61	74	482
Metal	286	56	68	410
Karton	287	46	70	403
Çöp	91	17	29	137
#Toplam	1768	328	431	2527



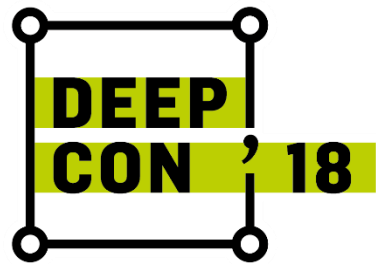
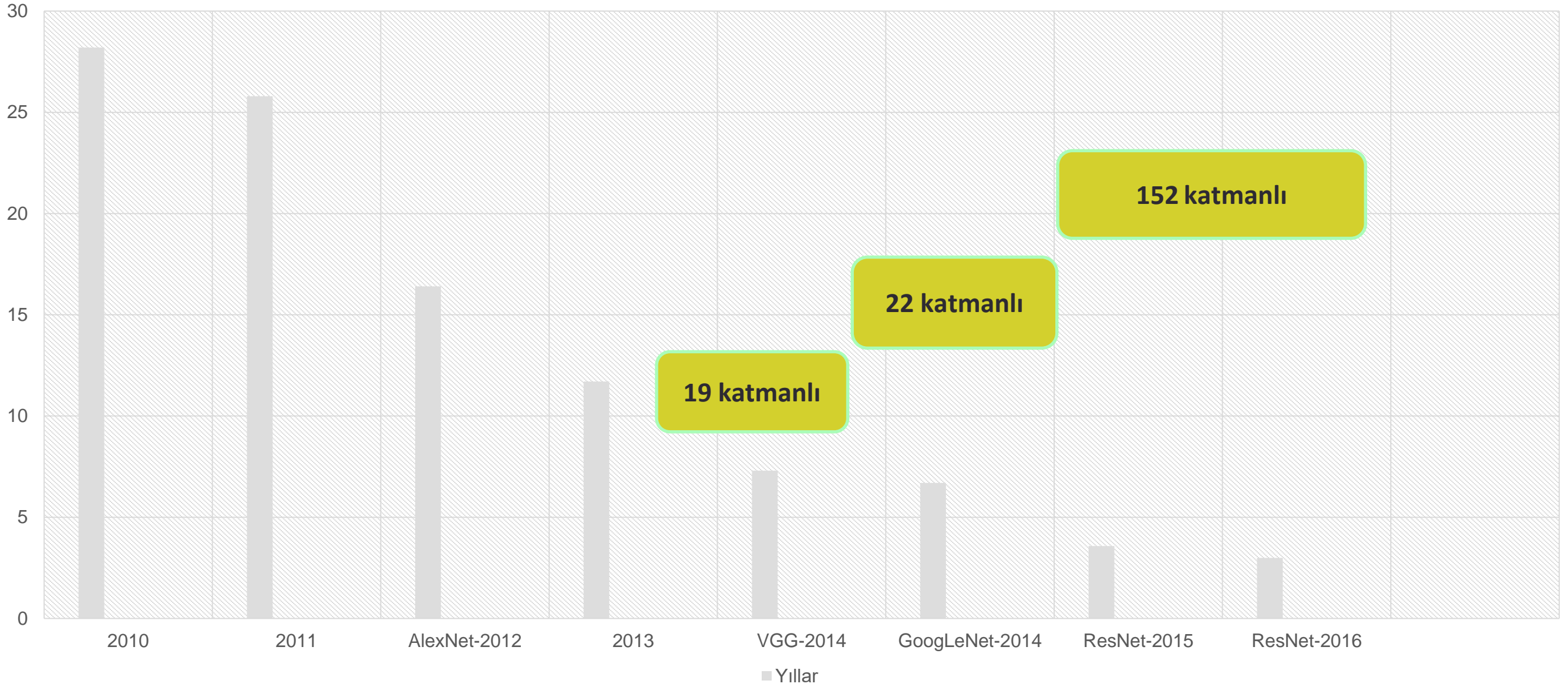


Sinir Ağı Mimarileri

- Derin Artık (Residual) Ağları
- MobileNet
- InceptionResNetV2
- Yoğun Bağlantılı Evrişimli Sinir Ağı (Densely Connected Convolutional Networks)
- Xception
- **RecycleNet**



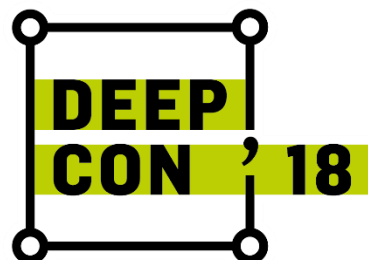
EĞİTİM HATASI (%)



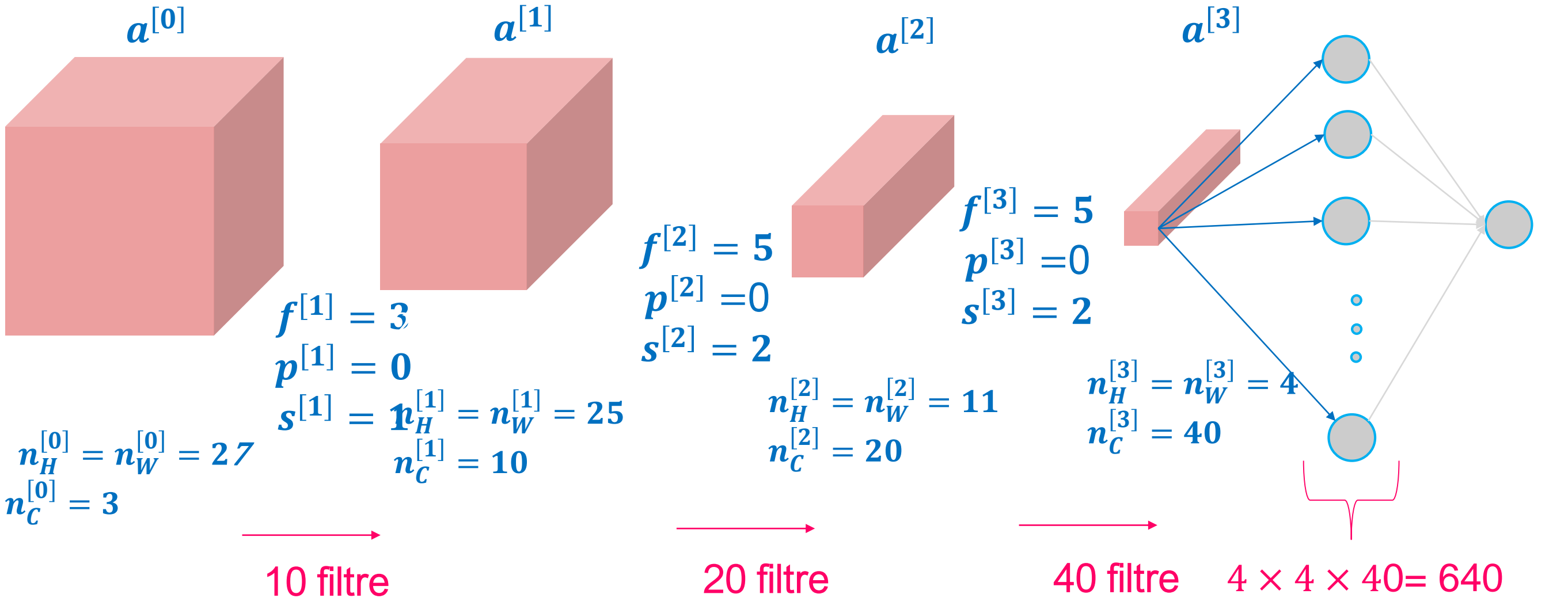
Derin Sinir Ağları Temelleri

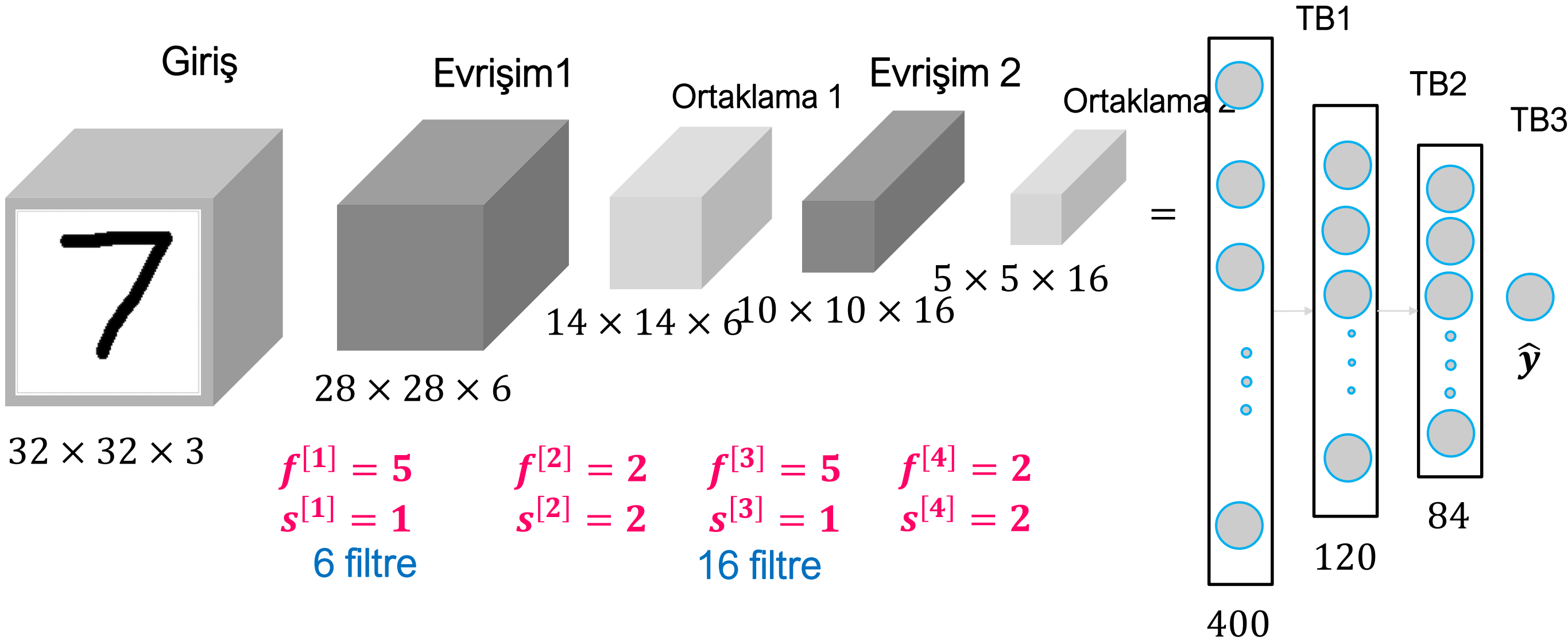
Bir Evrişimli Sinir Ağı için Gereken Katmanlar

- Evrişim Katmanı (Aktivasyon fonksiyonu, Bias değeri)
- Ortaklama Katmanı (Maksimum ya da ortalama ortaklama)
- Tam/Tüm Bağlantı Katmanı (Klasik yapay sinir ağı bağlantıları)



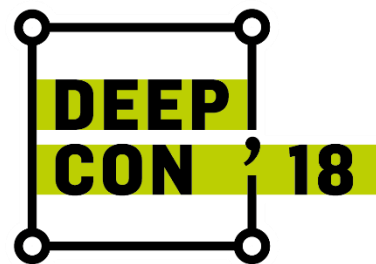
Derin Sinir Ağları Temelleri





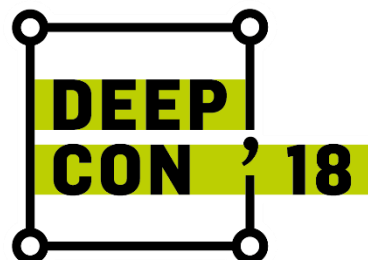
Çıkışta 10 sınıflı rakam tanıma yapılacaksa: softmax(10)

$n_H, n_W \downarrow$
 $n_C \uparrow$



Derin Artık (Residual) Ağlar

- 2015 ILSRVC (ImageNet Large Scale Visual Recognition Competition) yarışmasının kazananı
- Residual bloklar
- 3 Evrişim katmanı, Küme (batch) normalizasyon, ReLU
- 224x224 giriş boyutu

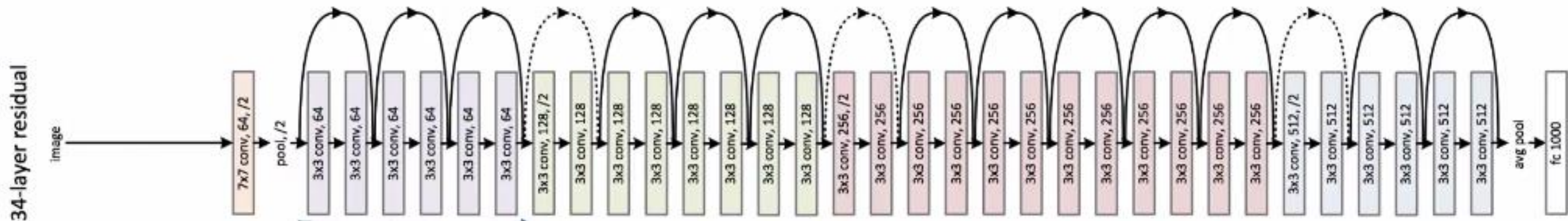


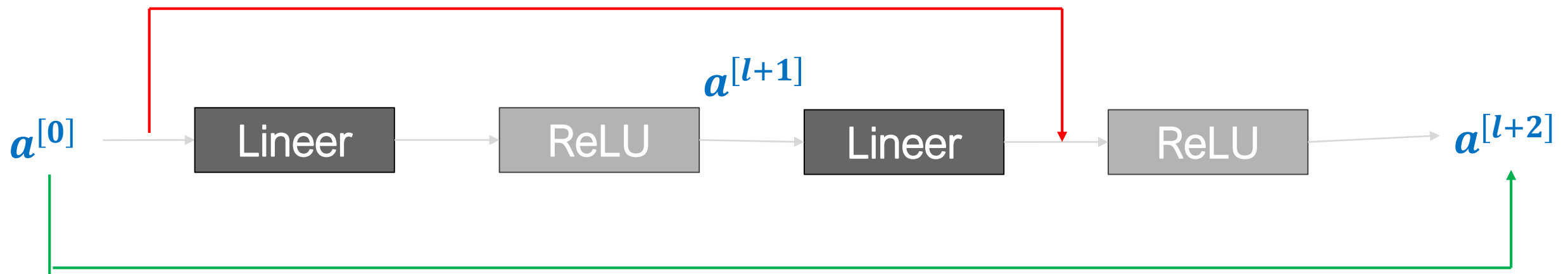
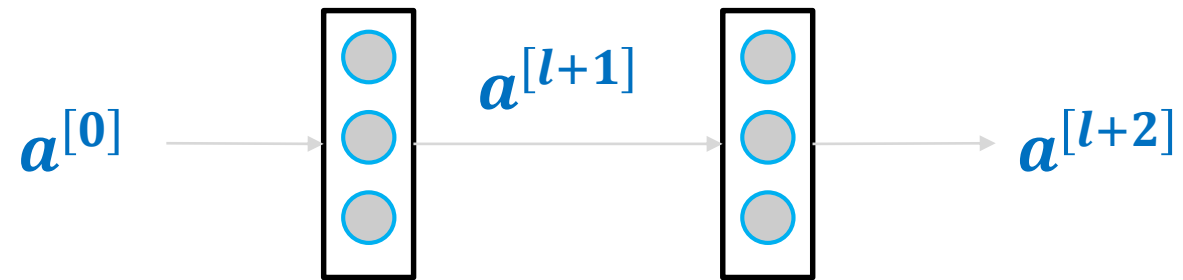
ResNets 152

Plain



ResNet





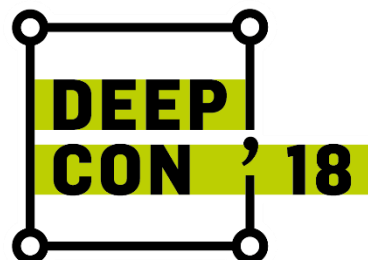
$$z^{[l+1]} = W^{[l+1]} a^l + b^{[l+1]}$$

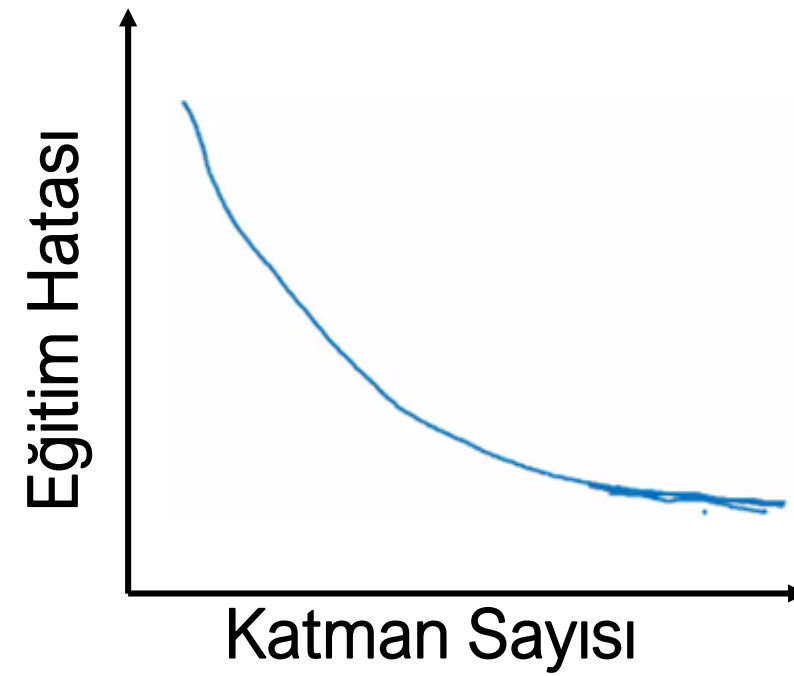
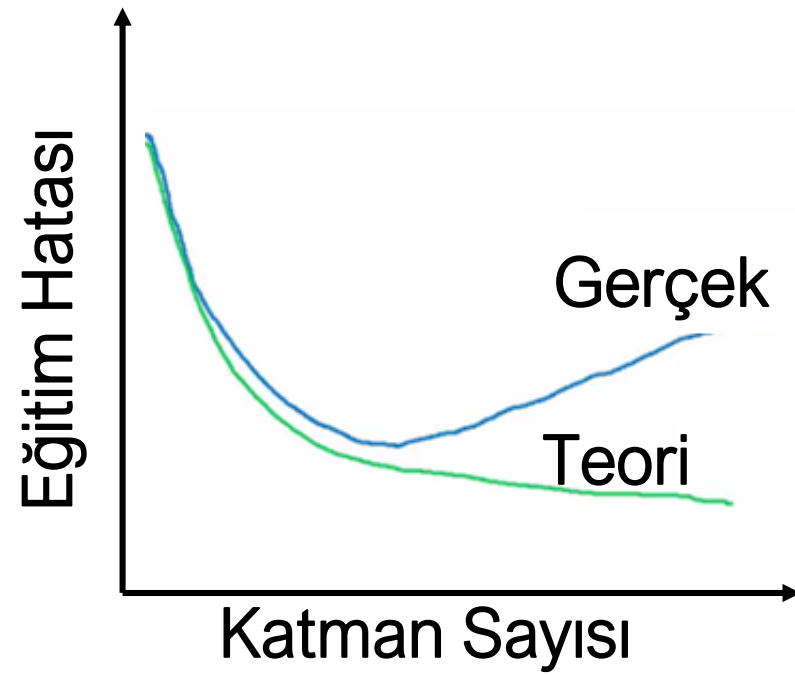
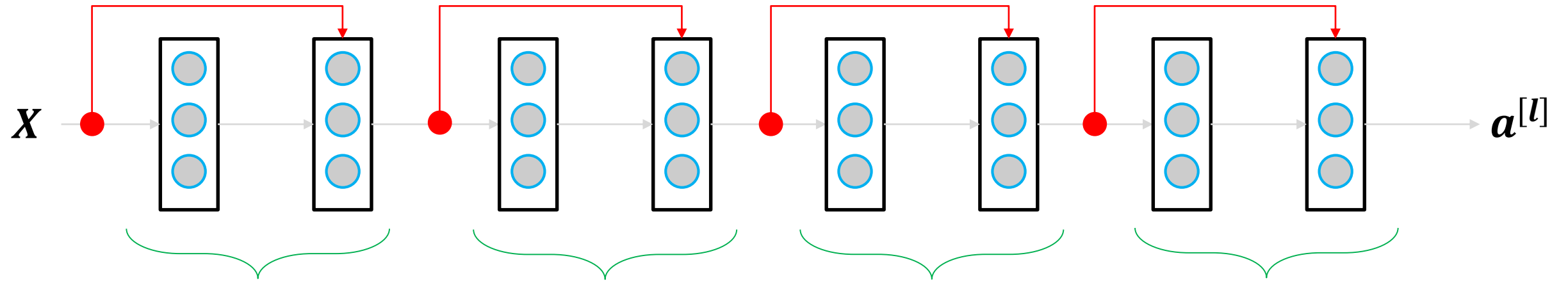
$$a^{[l+1]} = g(z^{[l+1]})$$

$$z^{[l+2]} = W^{[l+2]} a^{[l+1]} + b^{[l+2]}$$

~~$$a^{[l+2]} = g(z^{[l+2]})$$~~

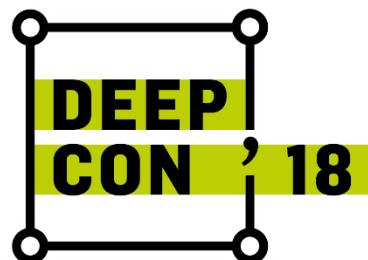
$$a^{[l+2]} = g(z^{[l+2]} + a^{[l]})$$





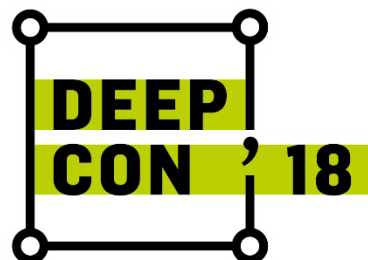
MobileNet

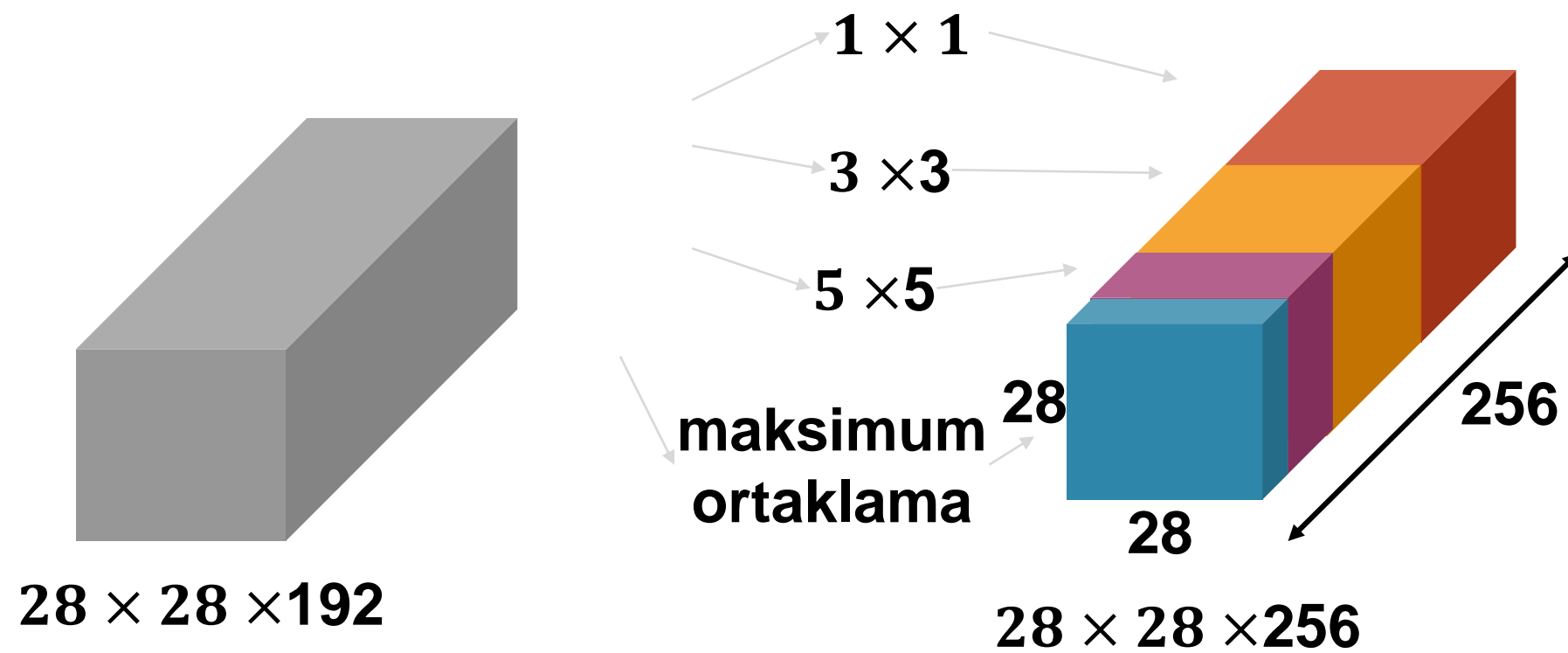
- Google araştırma grubu
- Mobil araçlar için
- Daha az parametrelili ince katmanlar
- 224x224 giriş boyutu



InceptionResNetV2

- Başlangıç modülleri ve artık bağlantılar birlikte kullanılır
- Artık (Res) bağlantılar daha az hiperparametre ile daha derin ve daha geniş inception ağlarını daha verimli hale getirir
- 299x299 giriş boyutu

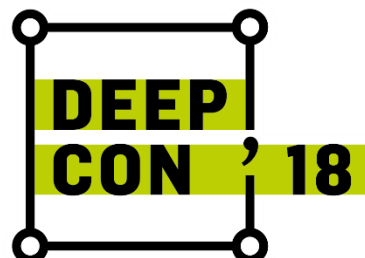




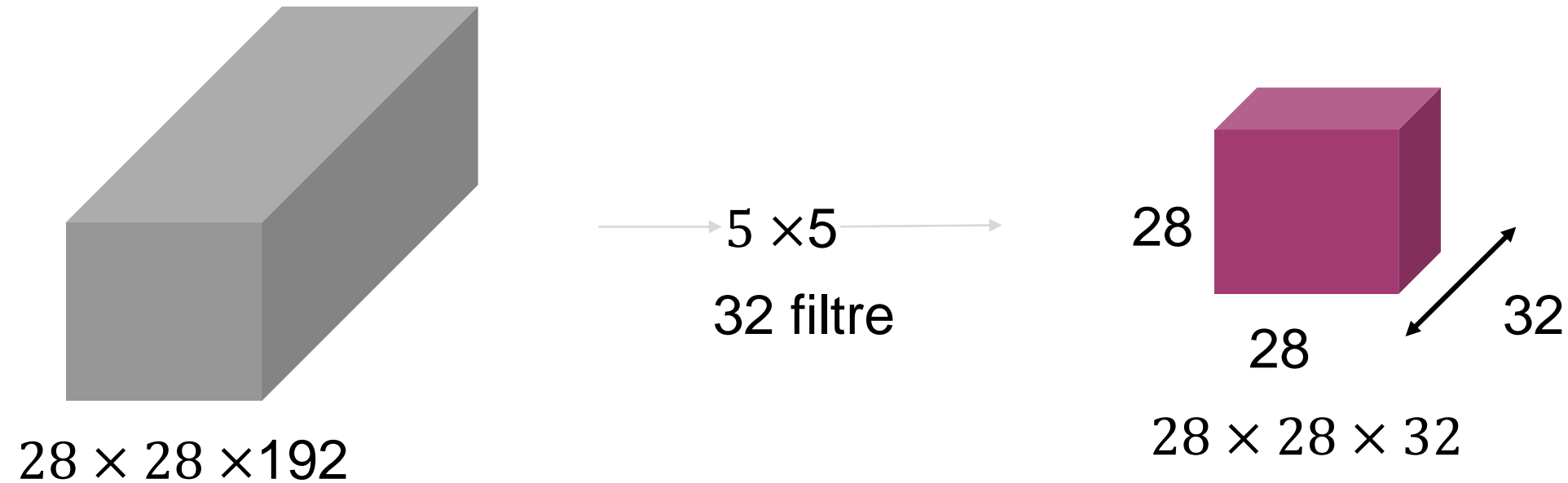
<https://arxiv.org/pdf/1312.4400.pdf>

Merve Ayyüce Kızrak

<https://www.deeplearning.ai/>



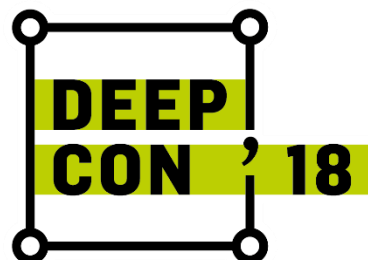
Yalnızca bu işlem adımı için $(28 \times 28 \times 32) \times (5 \times 5 \times 192) = 120$ milyon parametre hesaplanması gerekir.



<https://www.deeplearning.ai/>

<https://arxiv.org/pdf/1312.4400.pdf>

Merve Ayyüce Kızrak

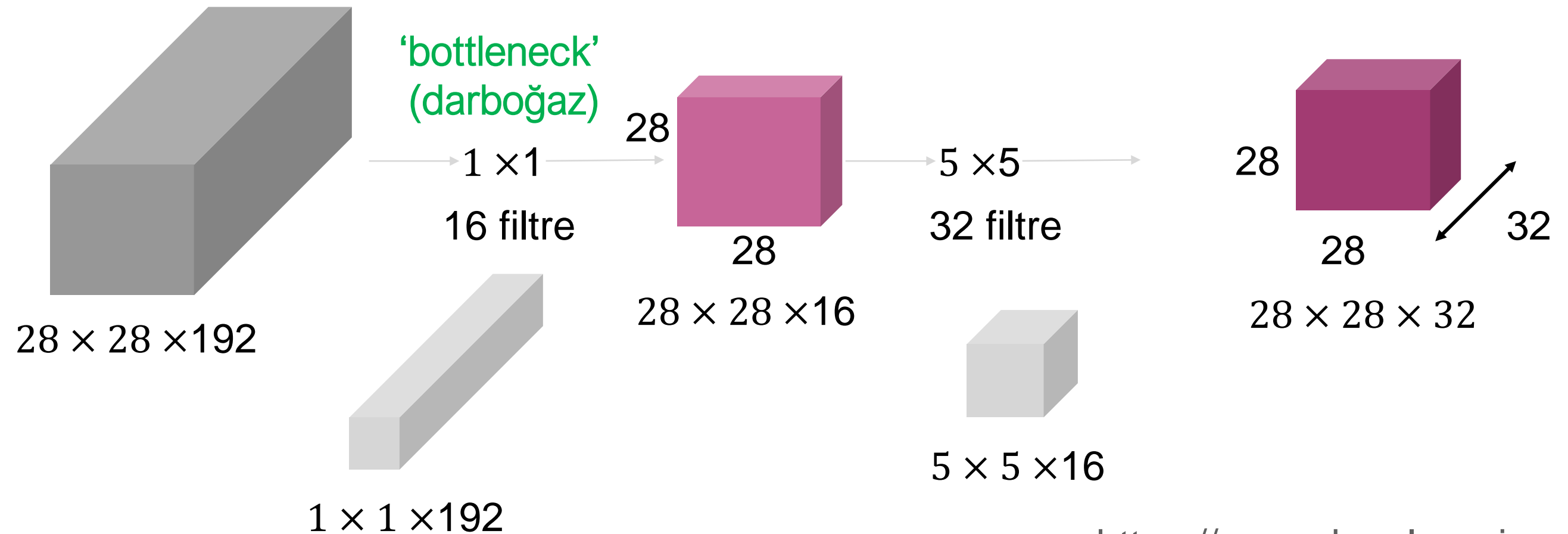


Bu koşulda; 1x1 evrişim katmanında: $(28 \times 28 \times 16) \times (1 \times 1 \times 192) = 2,4$ milyon parametre

5x5 evrişim katmanında: $(28 \times 28 \times 32) \times (5 \times 5 \times 16) = 10$ milyon parametre

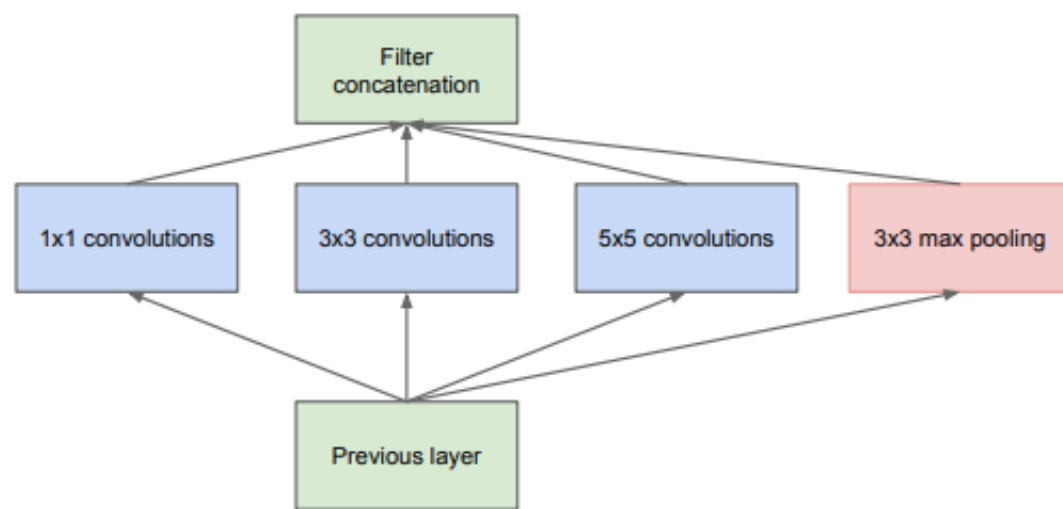
Toplamda 12.4 milyon parametre

İlk duruma göre yaklaşık 10 kat daha az parametre hesabı son derece çarpıcıdır.

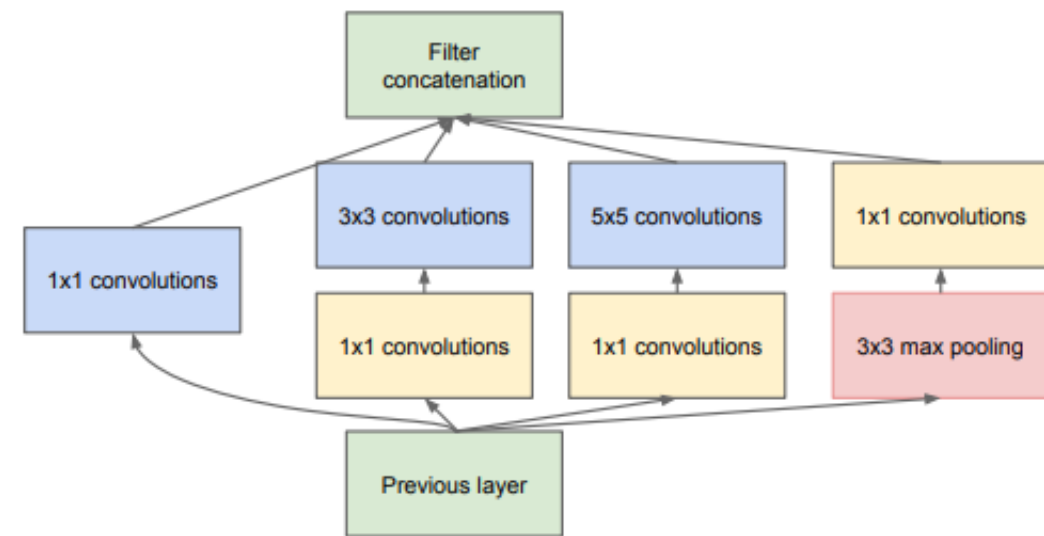


<https://www.deeplearning.ai/>

<https://arxiv.org/pdf/1312.4400.pdf>



(a) Inception module, naïve version



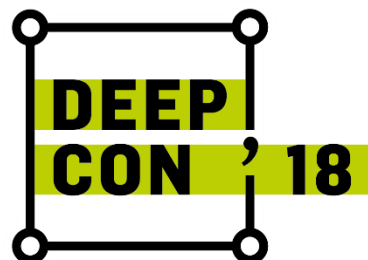
(b) Inception module with dimension reductions

Figure 2: Inception module

Yoğun Bağlantılı Evrişimli Sinir Ağı

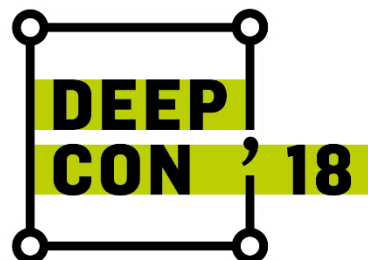
(Densely Connected Convolutional Neural Networks)

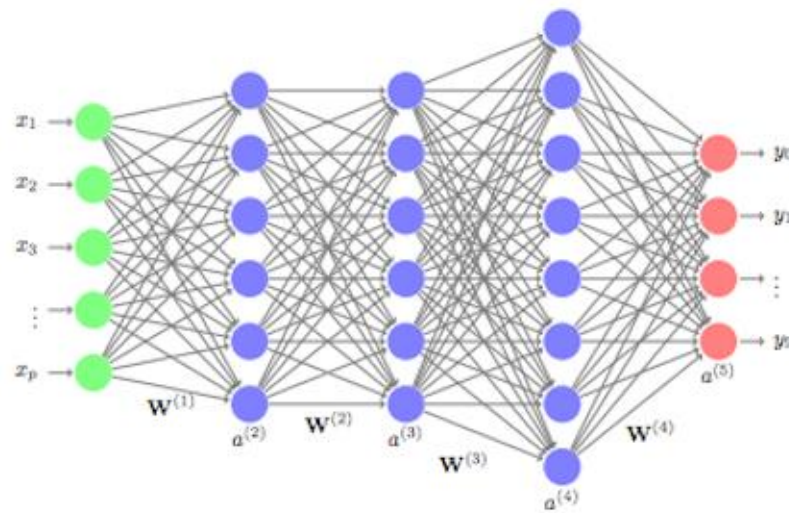
- En verimli mimarilerden biri
- Yoğun bağlantı
- Çok veri olmadan da iyi çalışır
- 224x224 giriş boyutu



Xception

- Inception yerine daha geniş ve derin bir mimari
- inception-v3'e göre hem daha hızlı hem de daha başarılı
- 229x229 giriş boyutu





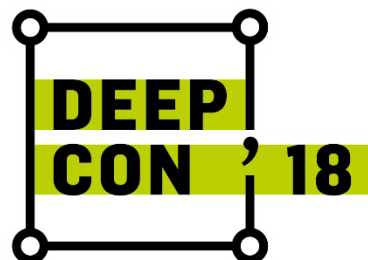
Fikirler



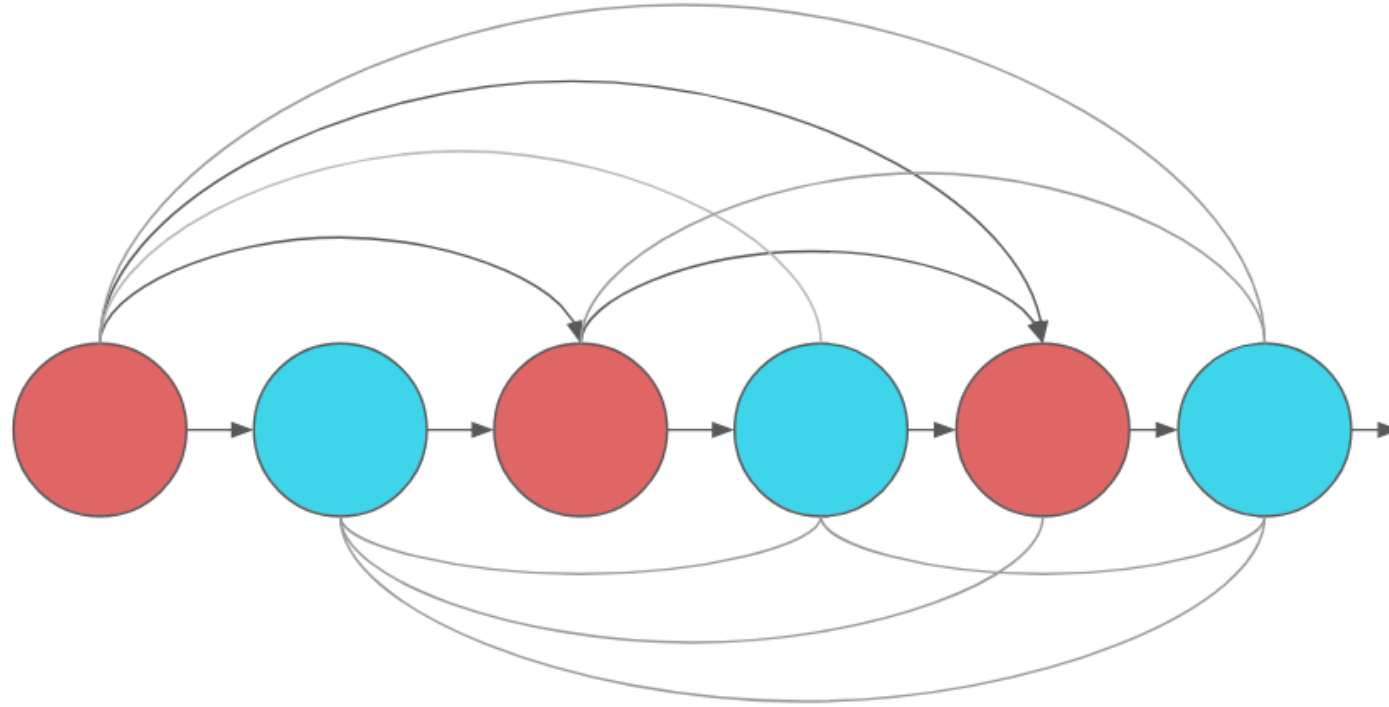
- Daha çok veri toplamak
- Veri kümesini çeşitlendirme
- Gradyan iniş algoritması ile eğitimi daha uzun tutmak.
- Gradyan iniş dışında farklı optimizasyon yöntemleri denemek (Adam, AdaDelta vb.)
- Daha büyük bir ağ denemek
- Daha küçük bir ağ denemek
- Seyreltme uygulamak
- Düzenleme yöntemleri uygulamak
- Ağ mimarisi
 - Aktivasyon fonksiyonları
 - Gizli katman sayısı
 - ...

RecycleNet

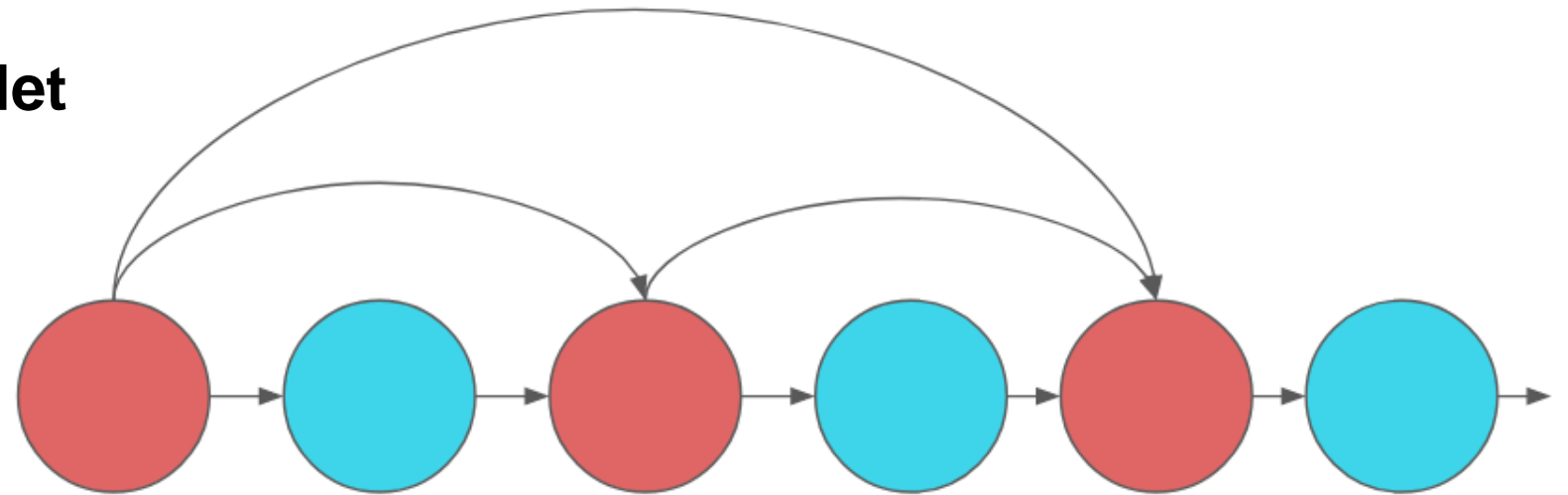
- Dense blokların içindeki atlama bağlantılarının düzenlerini değiştirdi
- Atlama bağlantılarının sayısını azaltıldı
- 7 milyon parametre yaklaşık 3 milyon parametreye indirildi (DenseNet121)

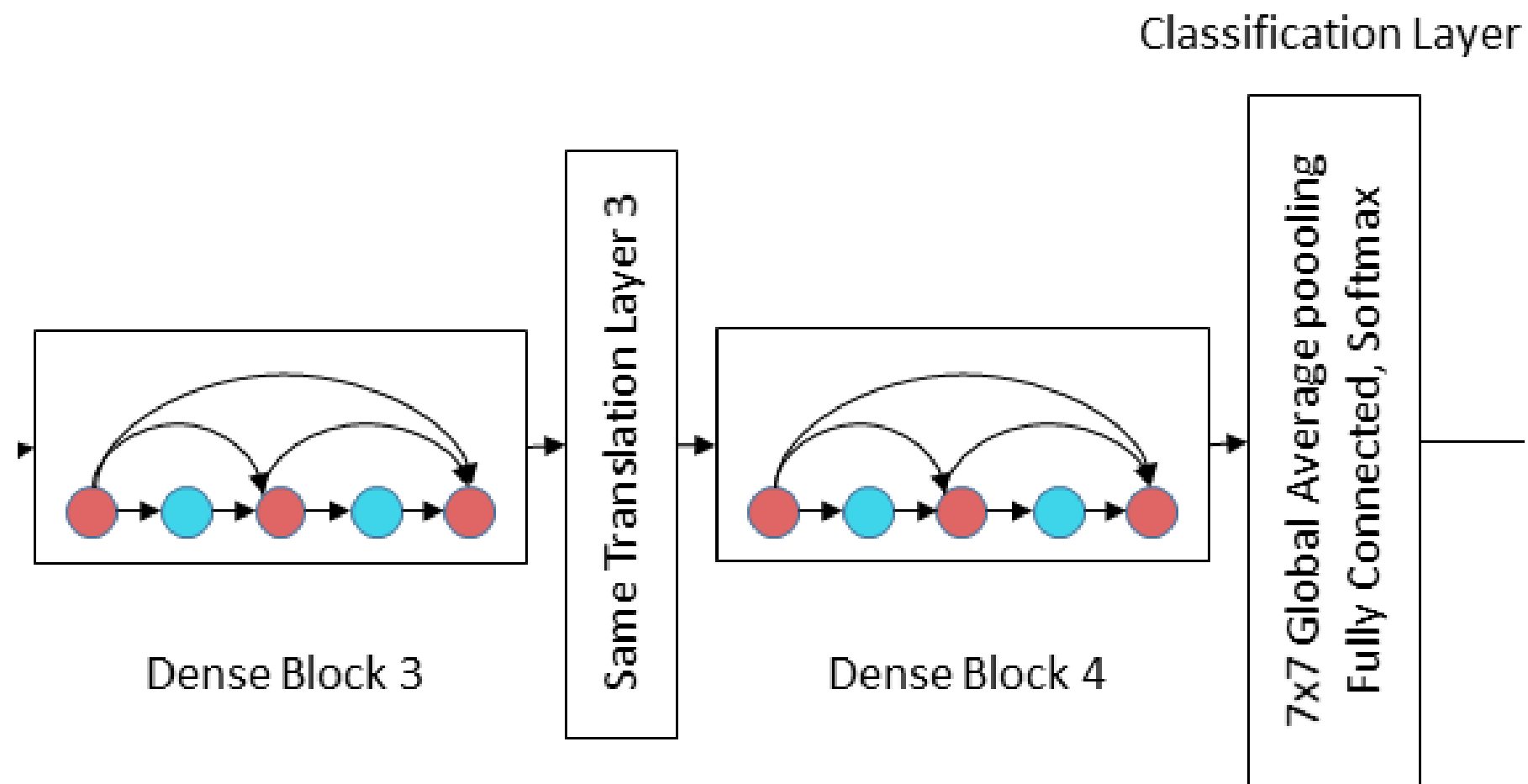
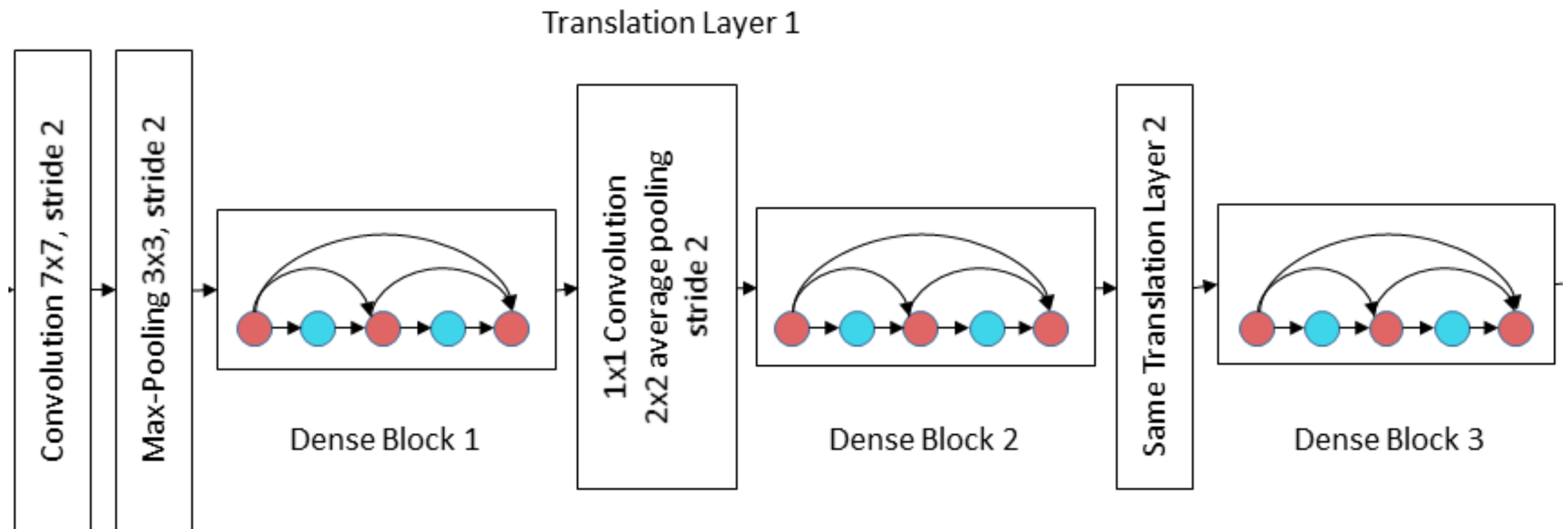


Bağlantı atlamaları DenseNet121



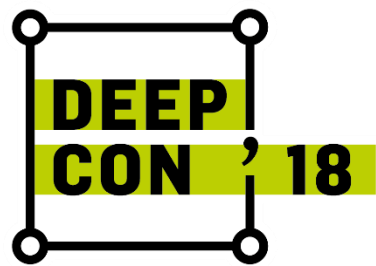
Bağlantı atlamaları RecycleNet





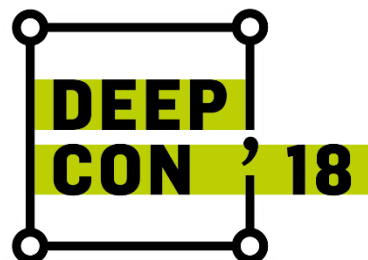
Farklı Optimizasyon Yaklaşımları

- Adam
- Adadelata



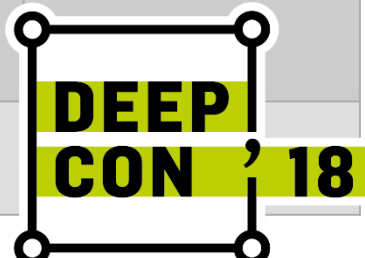
Deneyler ve Sonuçlar

- Keras (Tensorflow backend), Jupyter Notebook
- Google Colaboratory, GTX1080 Ti, GTX 980 GPU
- Küme boyutu 32
- Optimizasyon: Adam ve Adadelta
- Çok sınıf çapraz entropi kaybı



Eğitim Sonuçları

Model	Test Acc.	Optimizasyon	Veri Artırma	#Epochs	CPU (ms)	GPU (ms)
ResNet50	75%	Adam	-	100	478	15.4
DenseNet121	75%	Adam	15° rotation	100		
MobileNet	76%	Adam	-	500	202	8.3
DenseNet121	76%	Adadelata	15° rotation	100		
InceptionResNetV2	80%	Adam	-	100	513	39.9
DenseNet201	80%	Adam	15° rotation	200		
DenseNet169	82%	Adadelata	15° rotation	100	783	31.7
DenseNet121	83%	Adam		100	649	22.2
DenseNet121	84%	Adadelata		100		
Xception	85%	Adam	15° rotation	100	553	17.1
DenseNet121	85%	Adam		200		
DenseNet201	85%	Adam		200	1010	39.9
InceptionResNetV2	87%	Adadelata	15° rotation	100	-	-
InceptionResNetV2	88%	Adadelata	15° rotation	300	-	
InceptionResNetV2	90%	Adadelata	15° rotation	200	-	

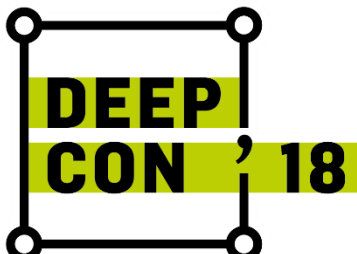


Sonuçların Fine-Tune Edilmesi Deneyi

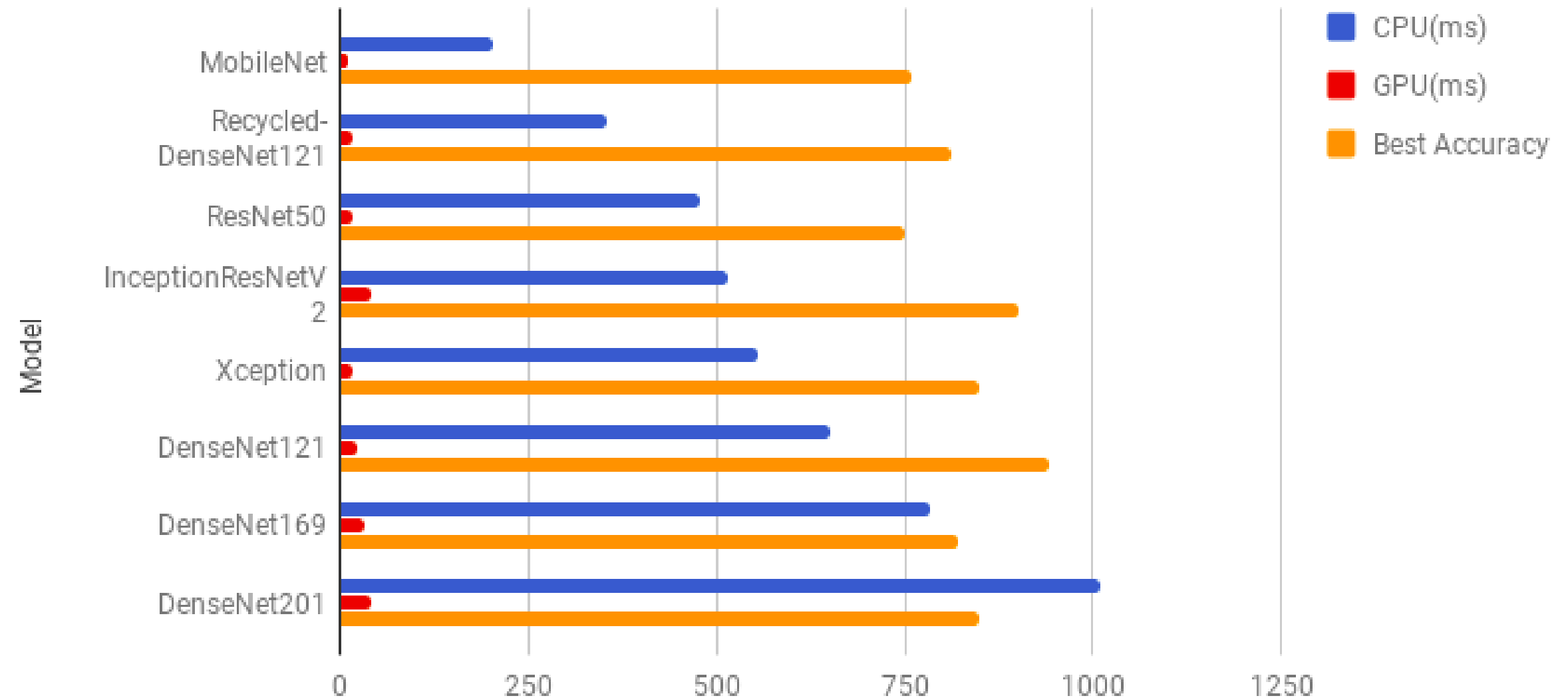
Model	Test Acc.	Optimizasyon	Veri Artırma	Epochs
InceptionResNetV2	87%	Adam for initialization, SGD	15° rotation	10 + 200
DenseNet121	95%	Adam for initialization, SGD	15° rotation	10 + 200

RecycleNet Sonuçları

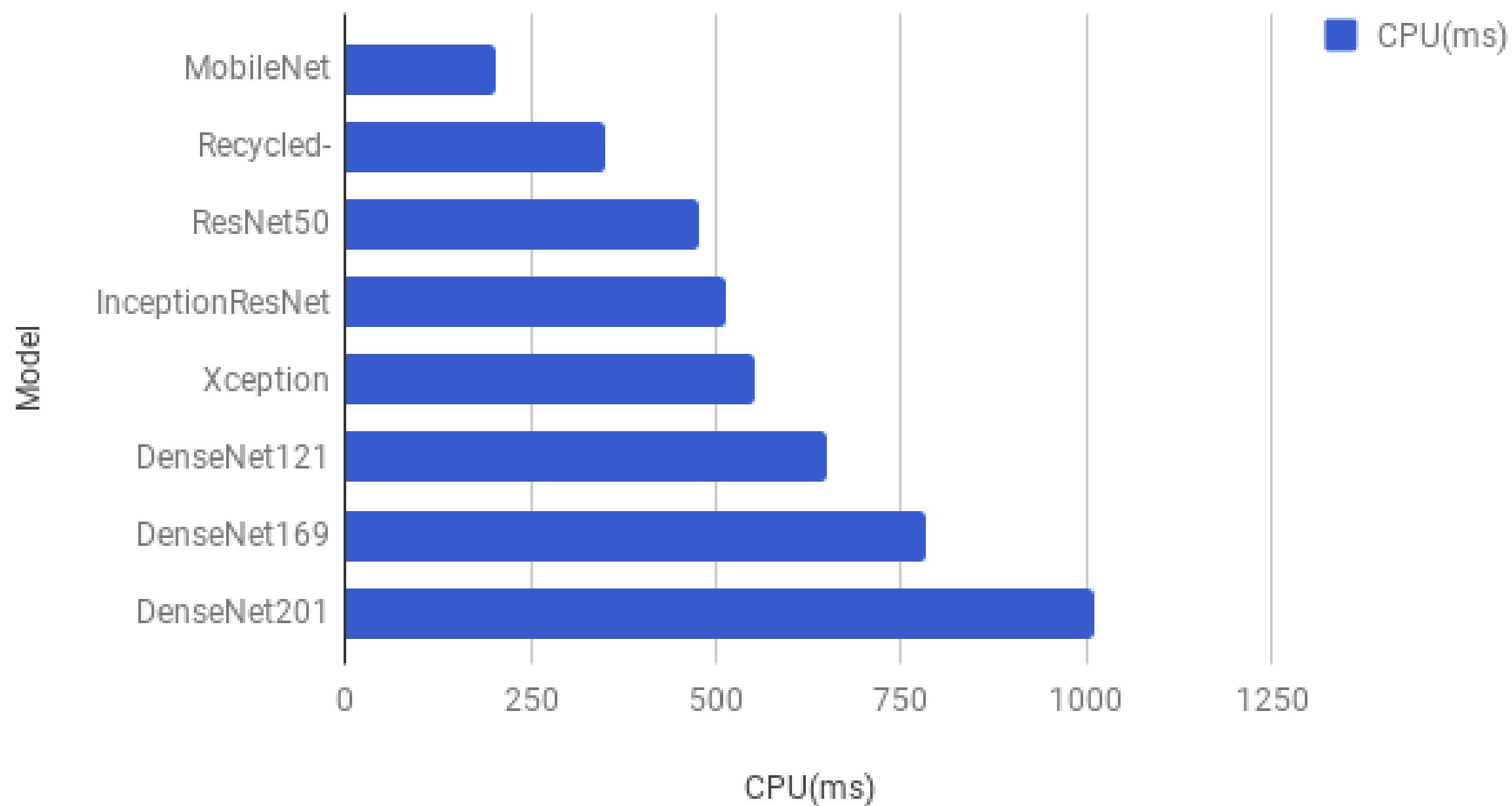
Model	Test Acc.	Optimizasyon	Veri Artırma n	Epochs	CPU (ms)	GPU(ms)
RecycleNet	81%	Adam	15° rotation	200	352	15.9



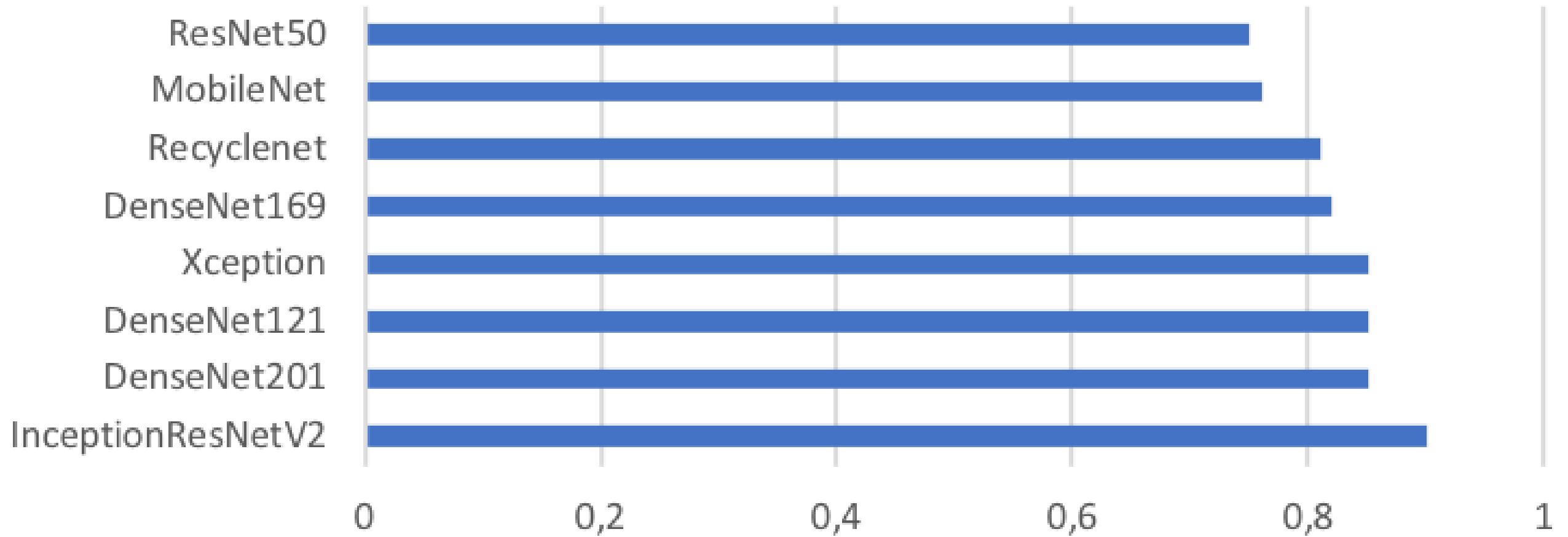
CPU(ms), GPU(ms) and Best Accuracy



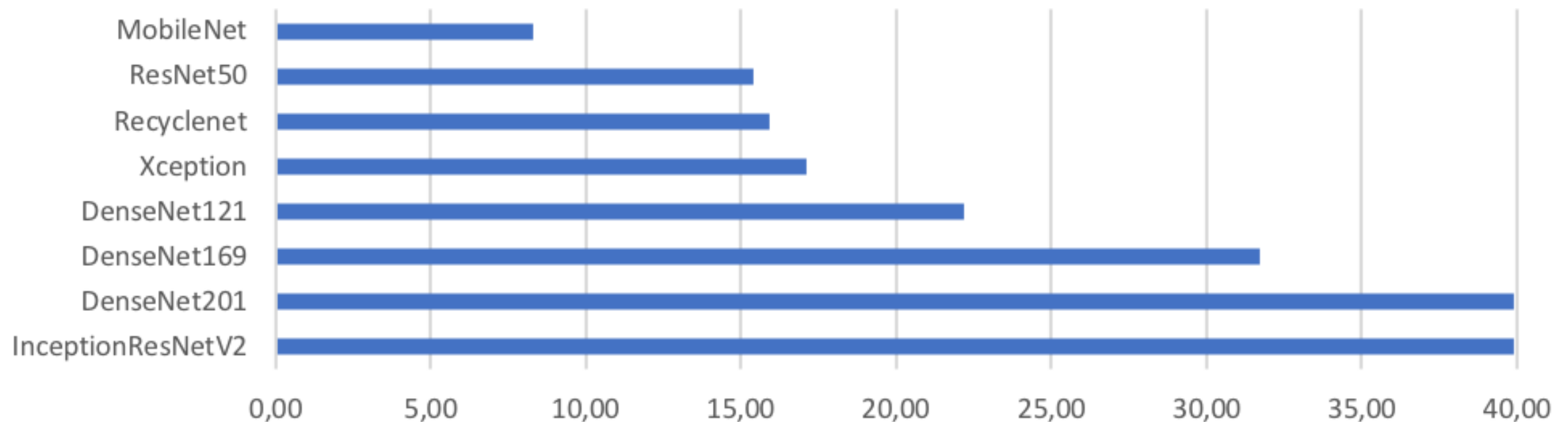
CPU(ms) vs. Model

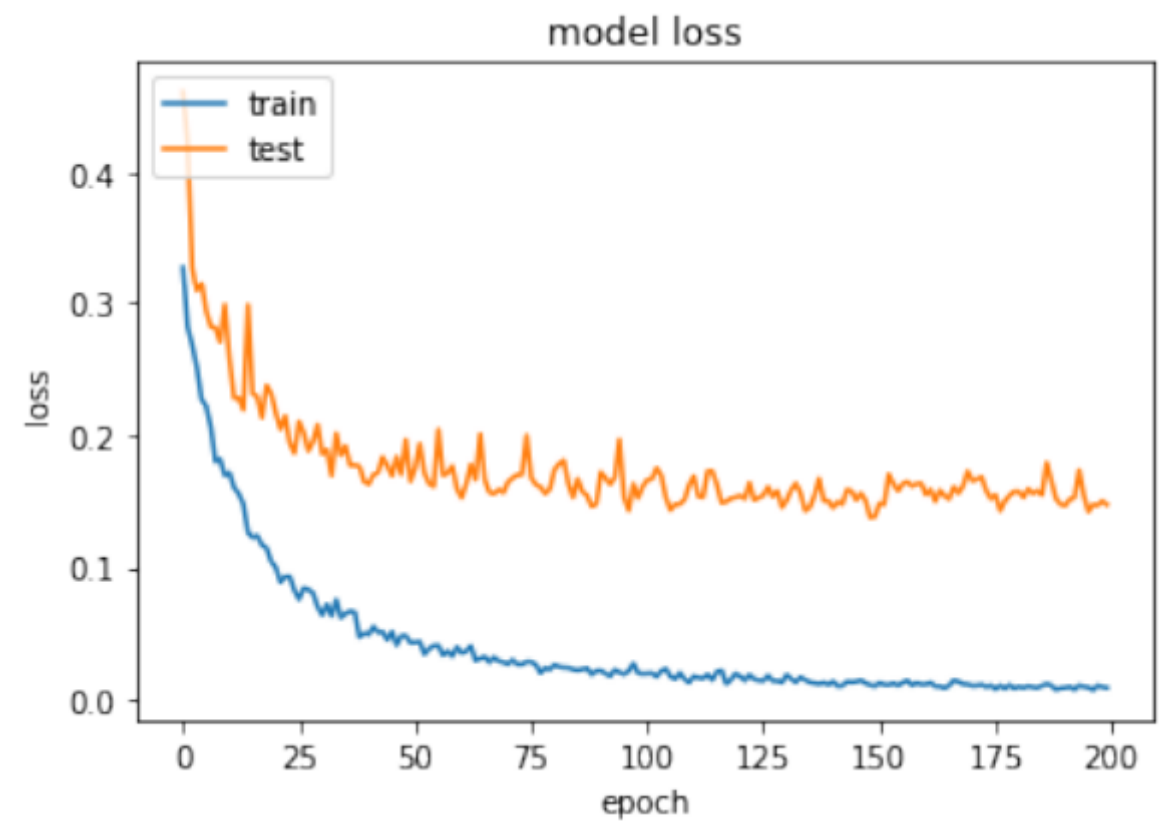
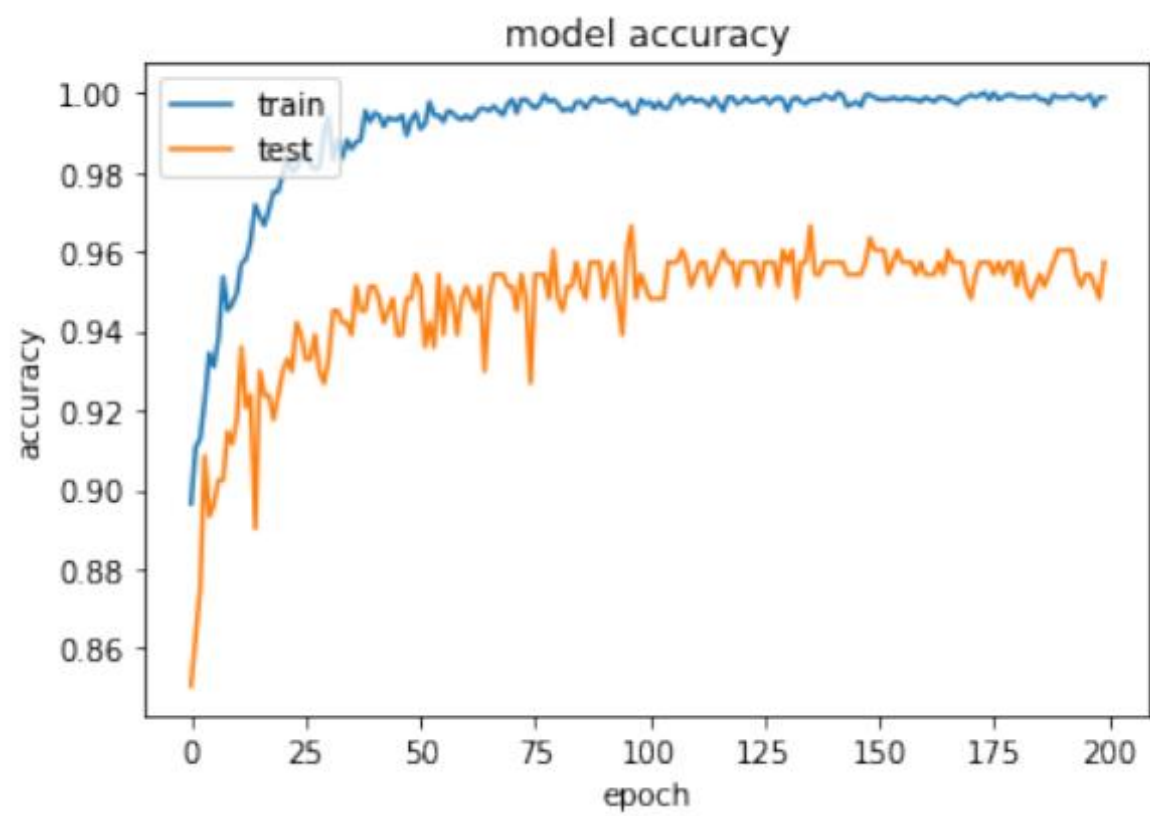


Test Accuracy



Training Time for One Epoch





```
model.load_weights('Results4/best_weights.h5')
```

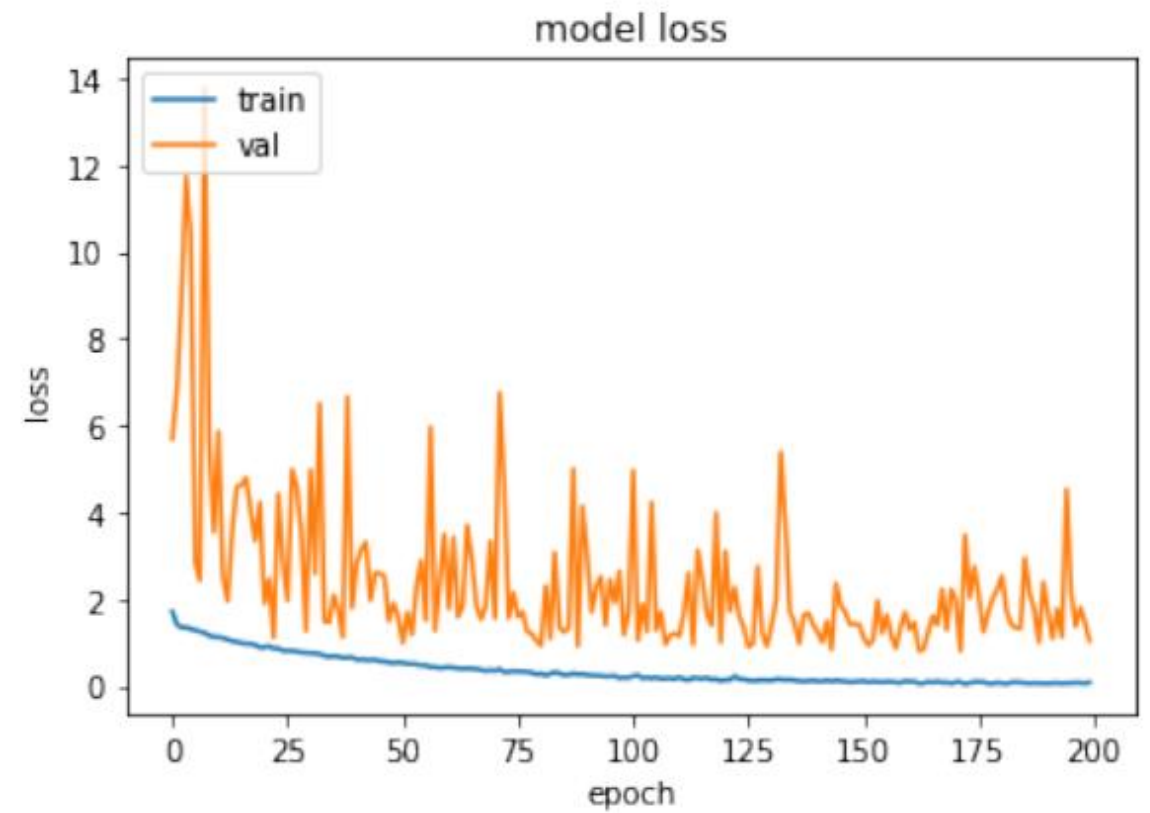
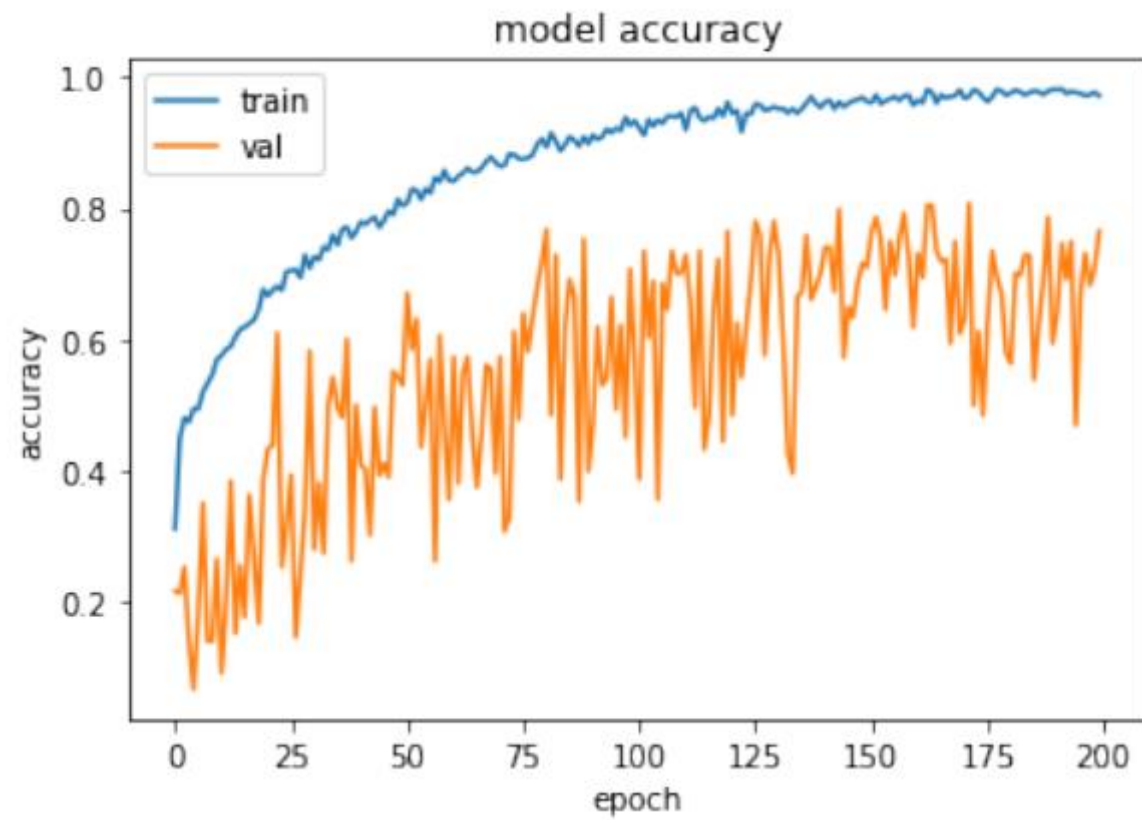
```
sonuc = model.evaluate_generator(test_generator)
```

```
print('Loss = %.2f' % (sonuc[0]))
```

```
print('Accuracy = %.2f' % (sonuc[1]))
```

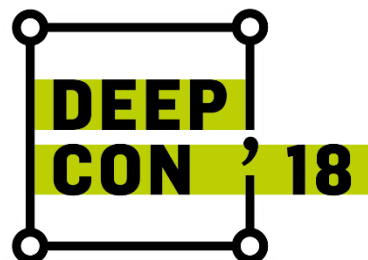
Loss = 0.69

Accuracy = 0.85



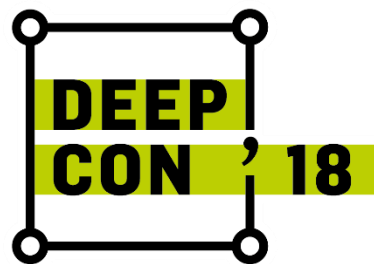
Sonuçlar

- Minimum test doğruluğu 75%, Önceki çalışmalardan %27 daha başarılı
- Fine-tuning DenseNet121 95% test doğruluğu
- RecycleNet 81% test doğruluğu
- Hızlı ve daha esnek geriye yönelik ceza vb.



Kaynaklar

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