EVOLVING DEEP ENSEMBLES FOR DETECTING COVID-19 IN CHEST X-RAYS

Piotr Bosowski[1], Joanna Bosowska[2], Jakub Nalepa[1]

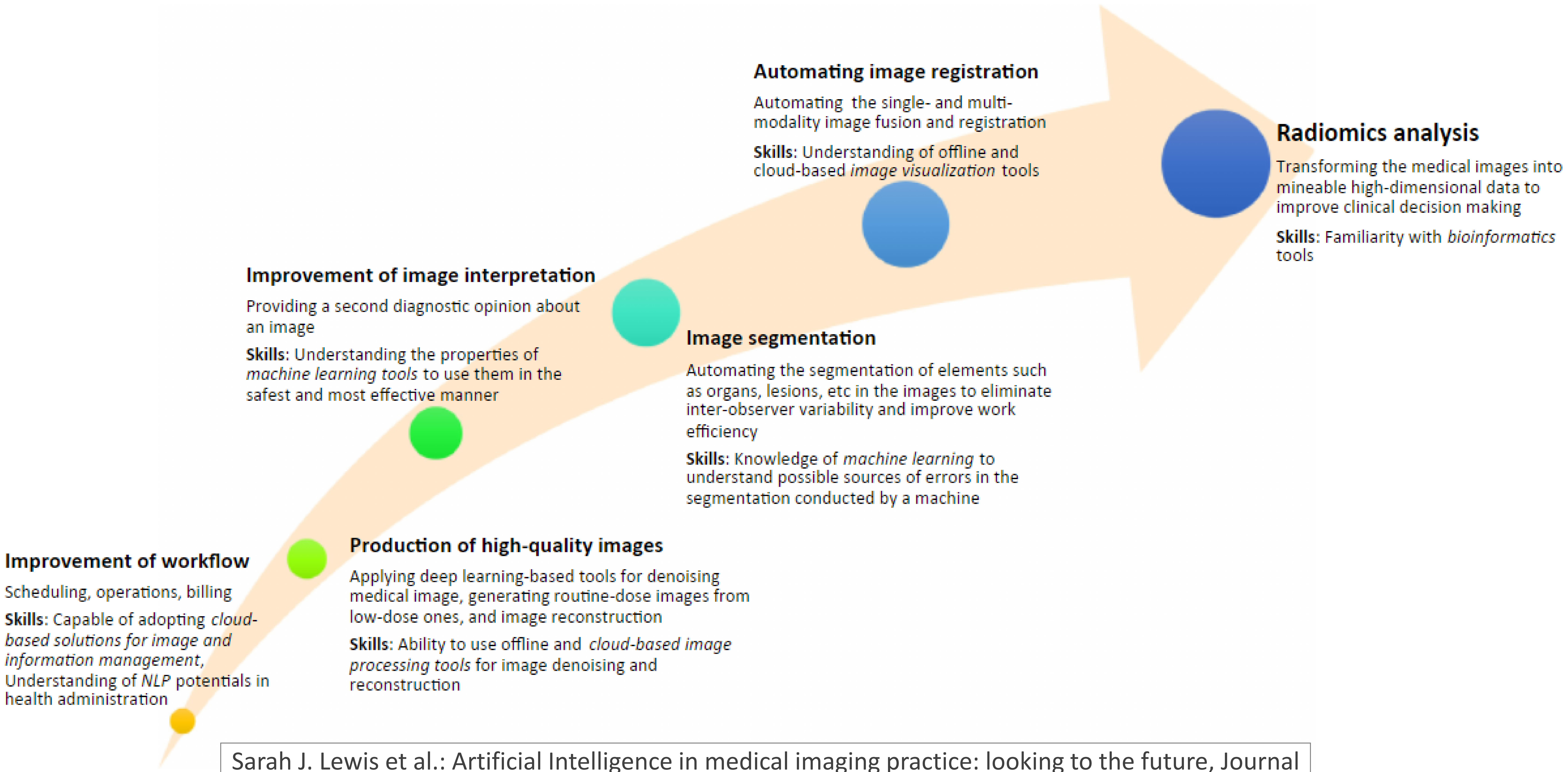
Silesian University of Technology, Gliwice, Poland
Dept. of Radiology and Nuclear Medicine, Medical University of Silesia, Katowice, Poland

jnalepa@ieee.org

2021 IEEE International Conference on Image Processing
19-22 September 2021 • Anchorage, Alaska, USA


JOHNS HOPKINS
UNIVERSITY & MEDICINE
CORONAVIRUS RESOURCE CENTER
Home
Topics
By Region
Events & News
About
Search Data by Region...
Tracking Home
Data Visualizations
Global Map
U.S. Map
Data in Motion
Tracking FAQ
COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)
Last Updated at (M/D/YYYY)
19.07.2021, 23:21
Cases
190 781 839
Deaths
4 093 496
Vaccine Doses Administered
3 644 918 207
Cases and Deaths by Country/Region/Sovereignty
34 124 341 | 609 204 US
31 144 229 | 414 108 India
19 376 574 | 542 214 Brazil
5 931 923 | 111 678 France
5 908 691 | 146 686 Russia
5 537 386 | 50 604 Turkey
5 494 847 | 129 007 United Kingdom
4 756 378 | 101 549 Argentina
Admin0
NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Esri, FAO, NOAA
Powered by Esri
Cumulative Cases
Daily Cases
2M
1M
0
lip
2021
lip
Daily Deaths
20k
10k
0
lip
2021
lip
Total Vaccine Doses
4B
2B
0
lip
2021
lip

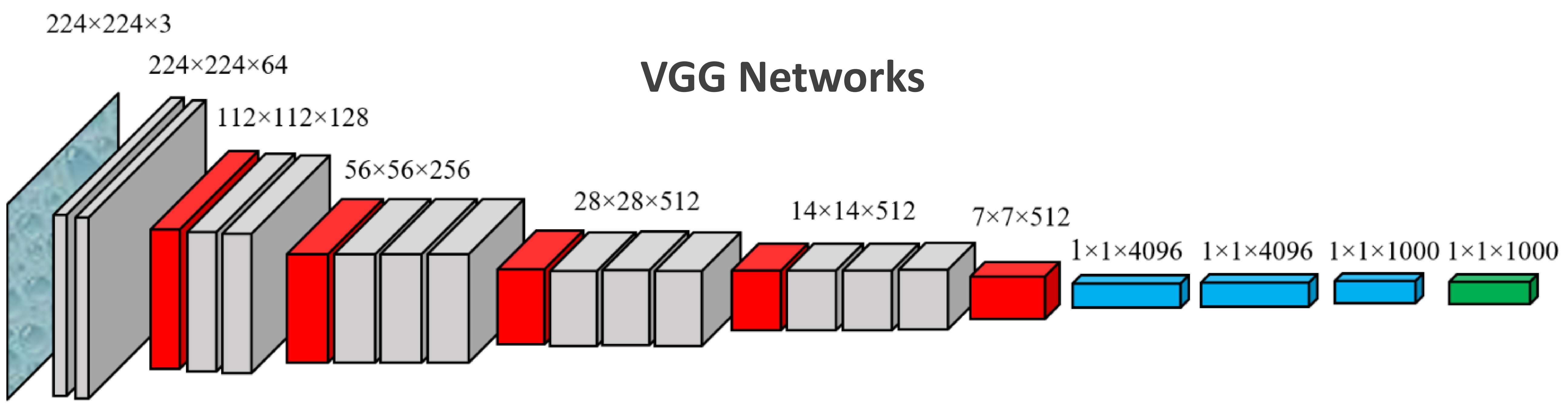
JOHNS HOPKINS
UNIVERSITY & MEDICINE
CORONAVIRUS RESOURCE CENTER
Home
Topics
By Region
Events & News
About
Search Data by Region...
Tracking Home
Data Visualizations
Global Map
U.S. Map
Data in Motion
Tracking FAQ
COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)
Last Updated at (M/D/YYYY)
19.07.2021, 23:21
Cases
190 781 839
Deaths
4 093 496
Vaccine Doses Administered
3 644 918 207
Cases and Deaths by Country/Region/Sovereignty
34 124 341 | 609 204 US
31 144 229 | 414 108 India
19 376 574 | 542 214 Brazil
5 931 923 | 111 678 France
5 908 691 | 146 686 Russia
5 537 386 | 50 604 Turkey
5 494 847 | 129 007 United Kingdom
4 756 378 | 101 549 Argentina
Admin0
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Esri, FAO, NOAA
Powered by Esri
Cumulative Cases
Daily Cases
2M
1M
0
lip
2021
lip
Daily Deaths
20k
10k
0
lip
2021
lip
Total Vaccine Doses
4B
2B
0
lip
2021
lip



Sarah J. Lewis et al.: Artificial Intelligence in medical imaging practice: looking to the future, Journal of Medical Radiation Sciences, First published: 10 November 2019 https://doi.org/10.1002/jmrs.369

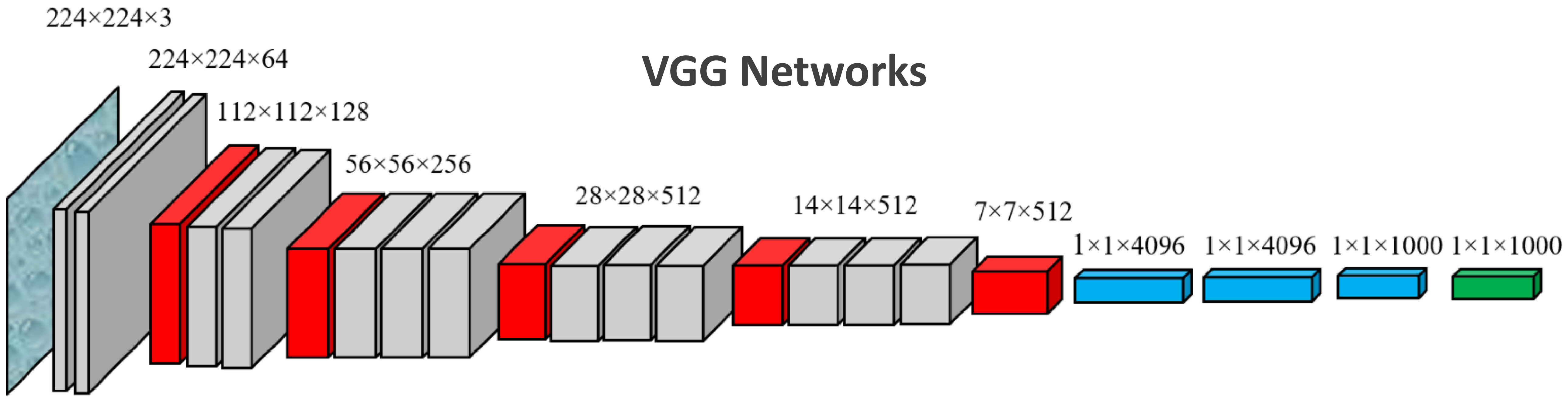
Selecting the „best” deep learning architecture?

Selecting the „best" deep learning architecture?

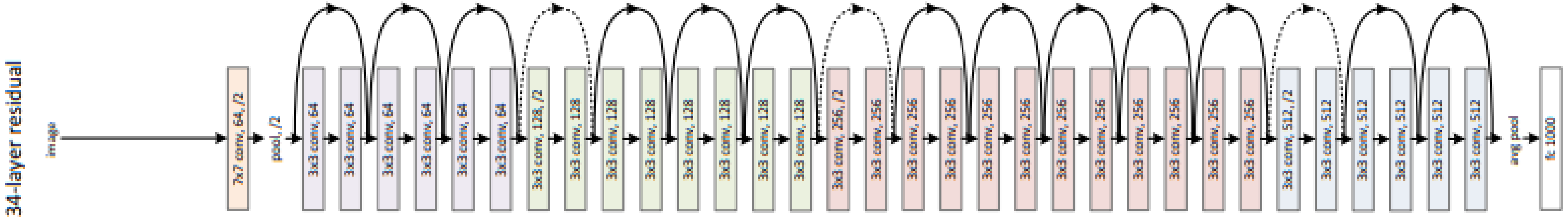


Selecting the „best" deep learning architecture?

VGG Networks

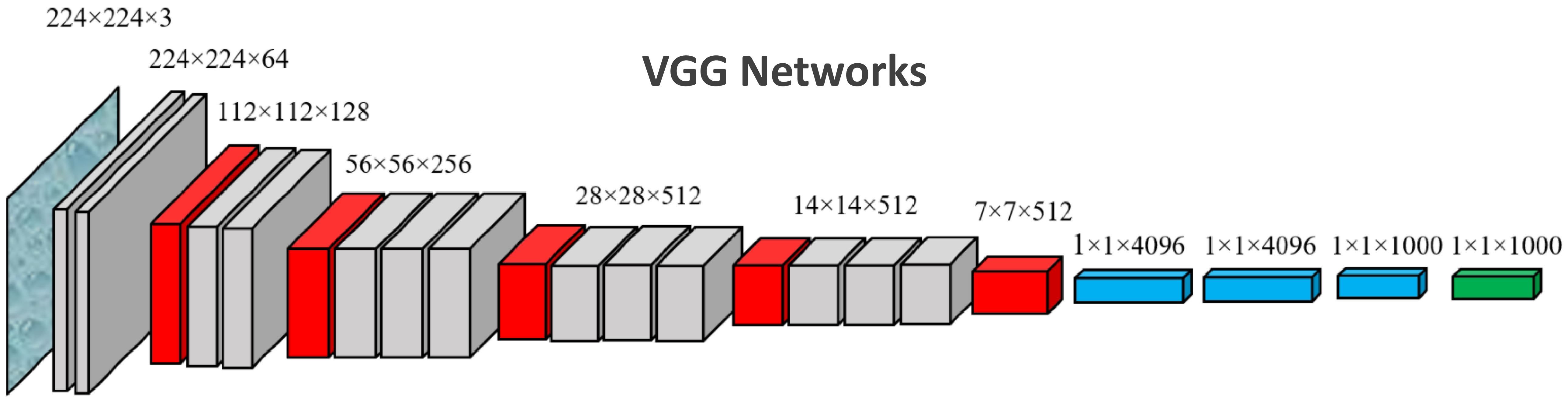


ResNets

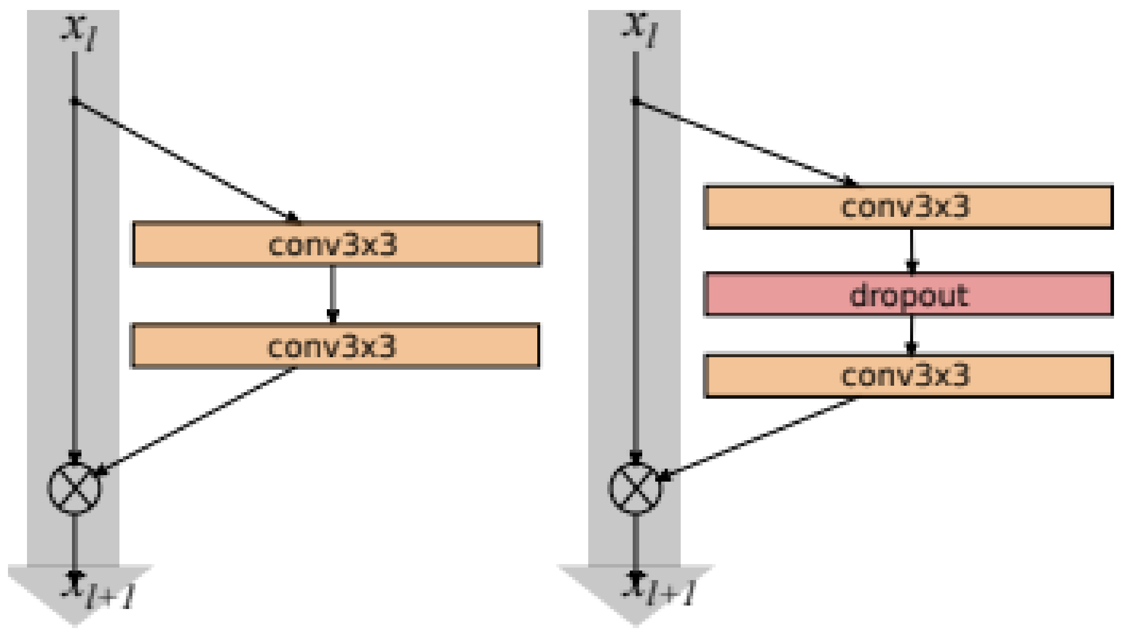


Selecting the „best” deep learning architecture?

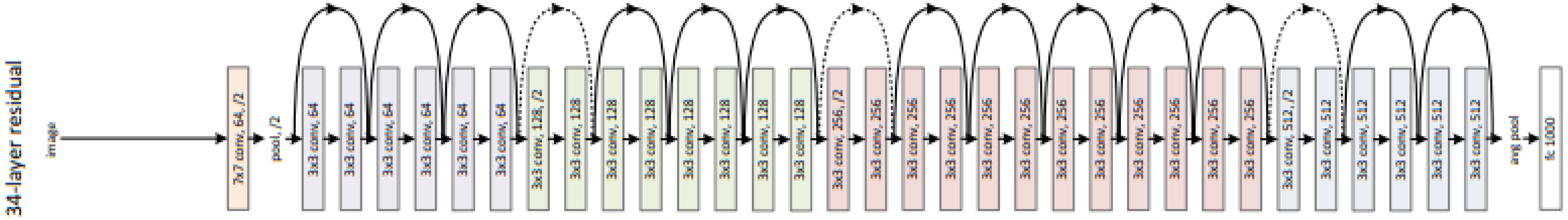
VGG Networks



Wide ResNets

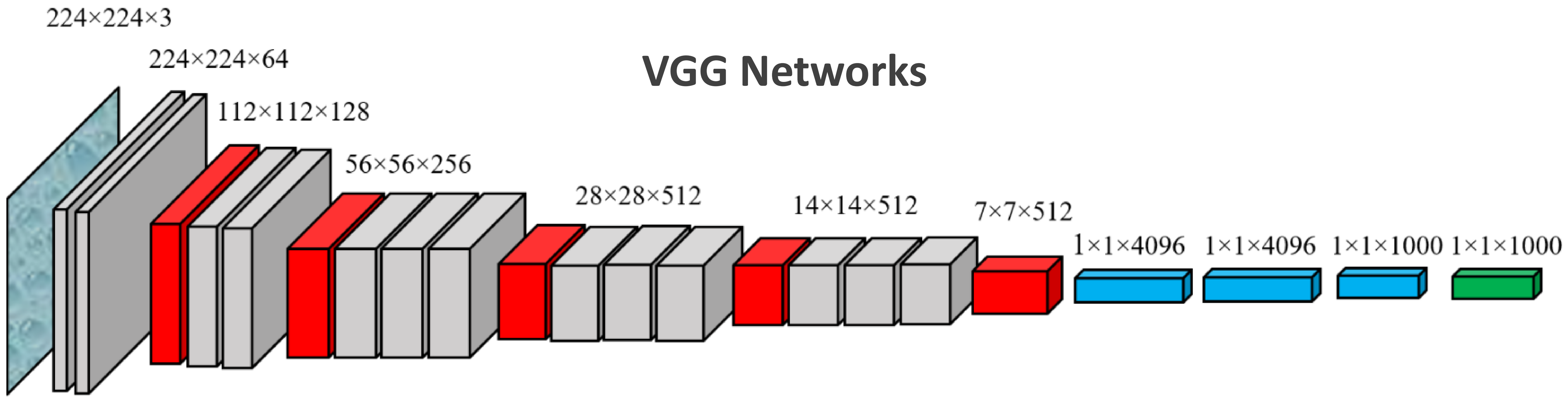


ResNets

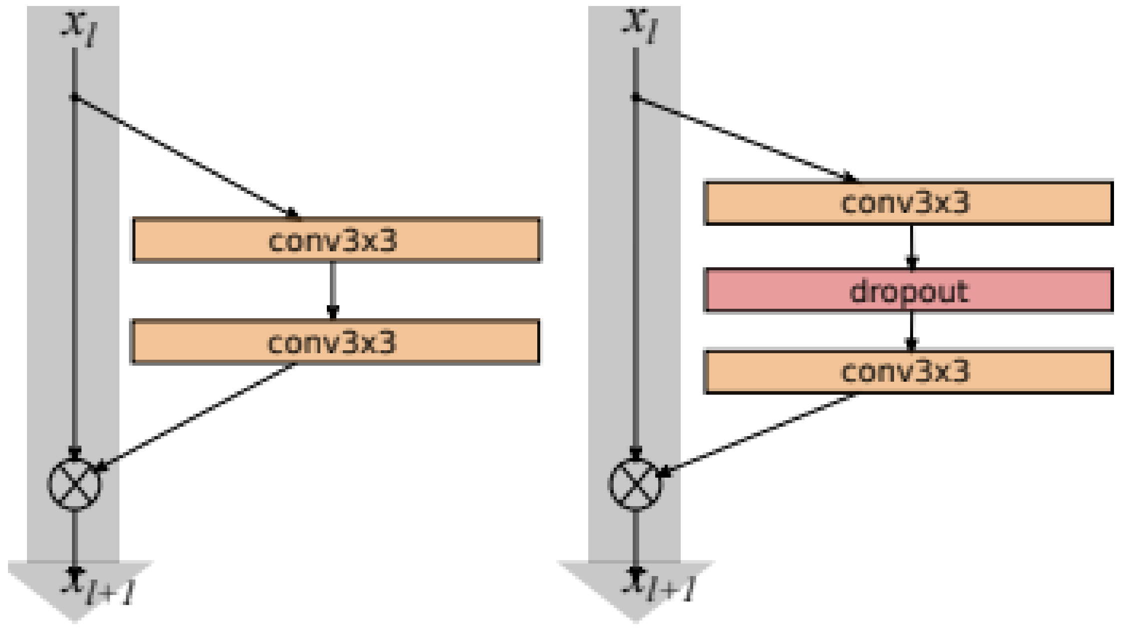


Selecting the „best” deep learning architecture?

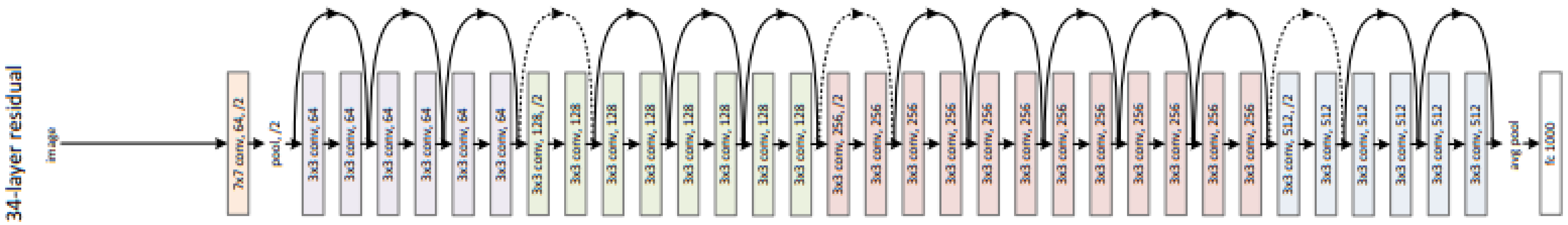
VGG Networks



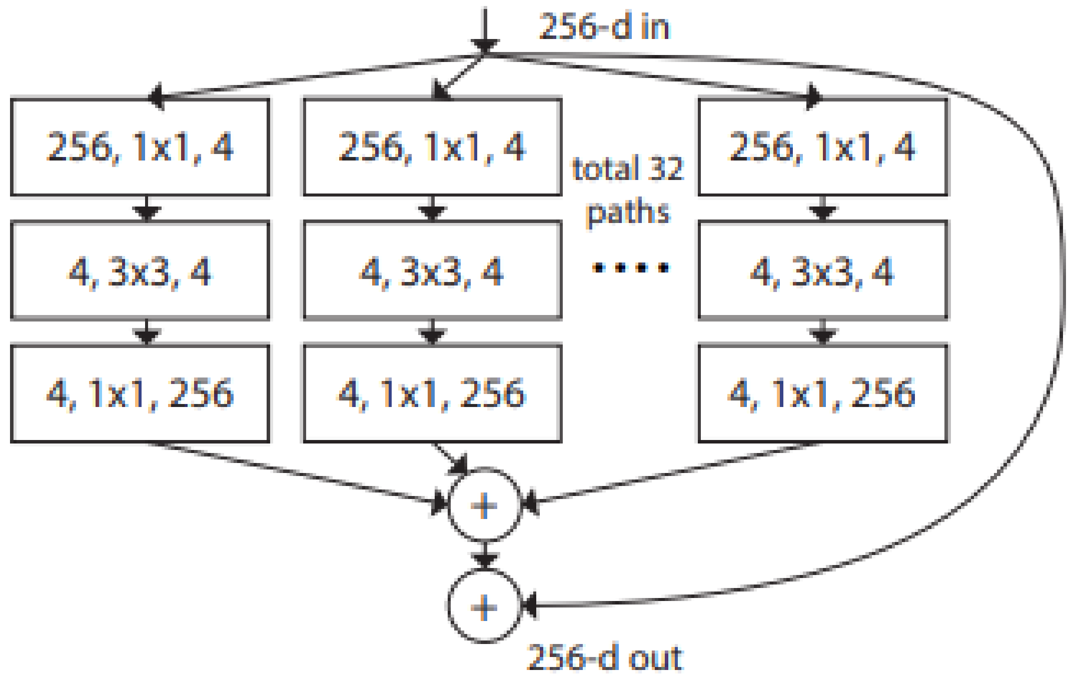
Wide ResNets



ResNets

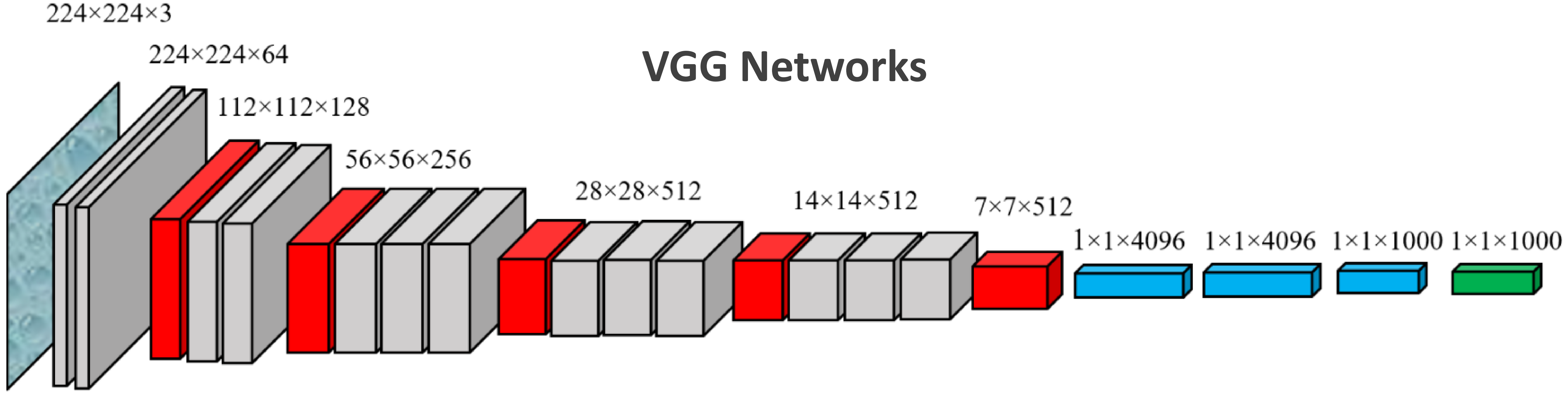


ResNeXts

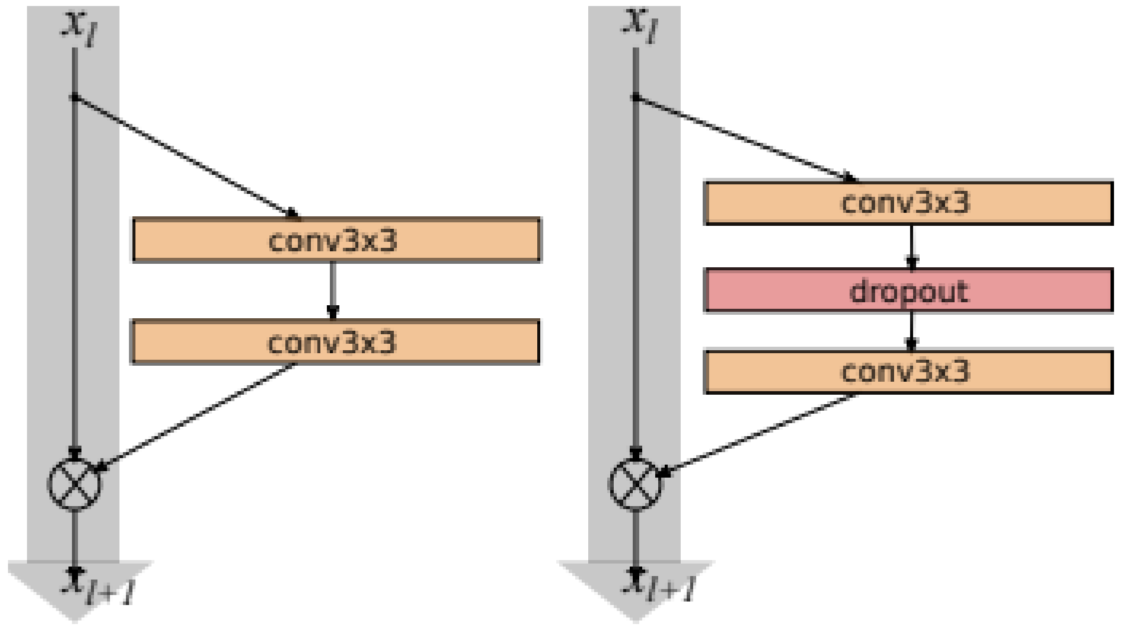


Selecting the „best" deep learning architecture?

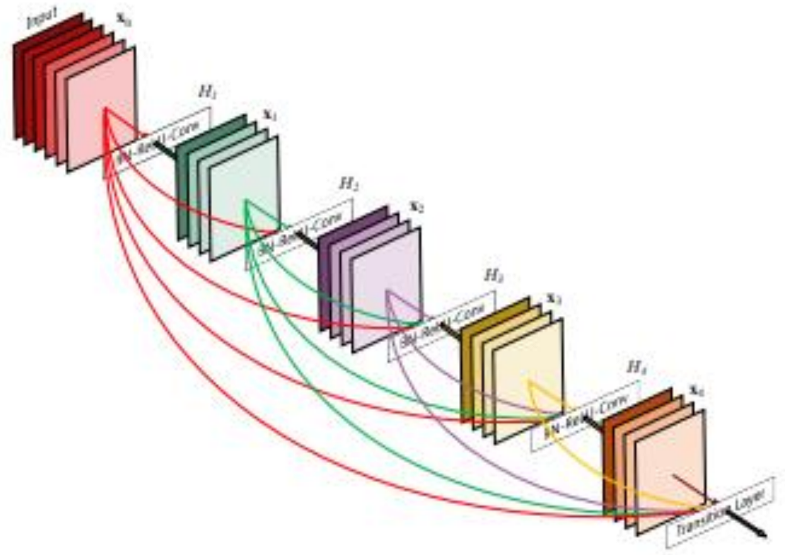
VGG Networks



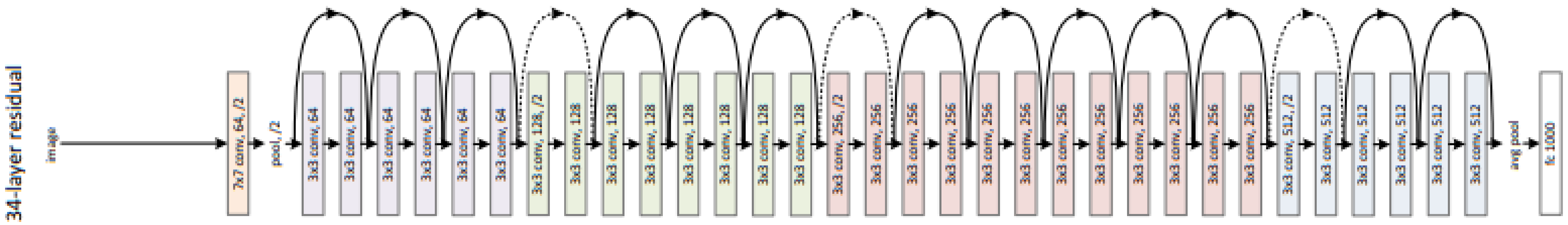
Wide ResNets



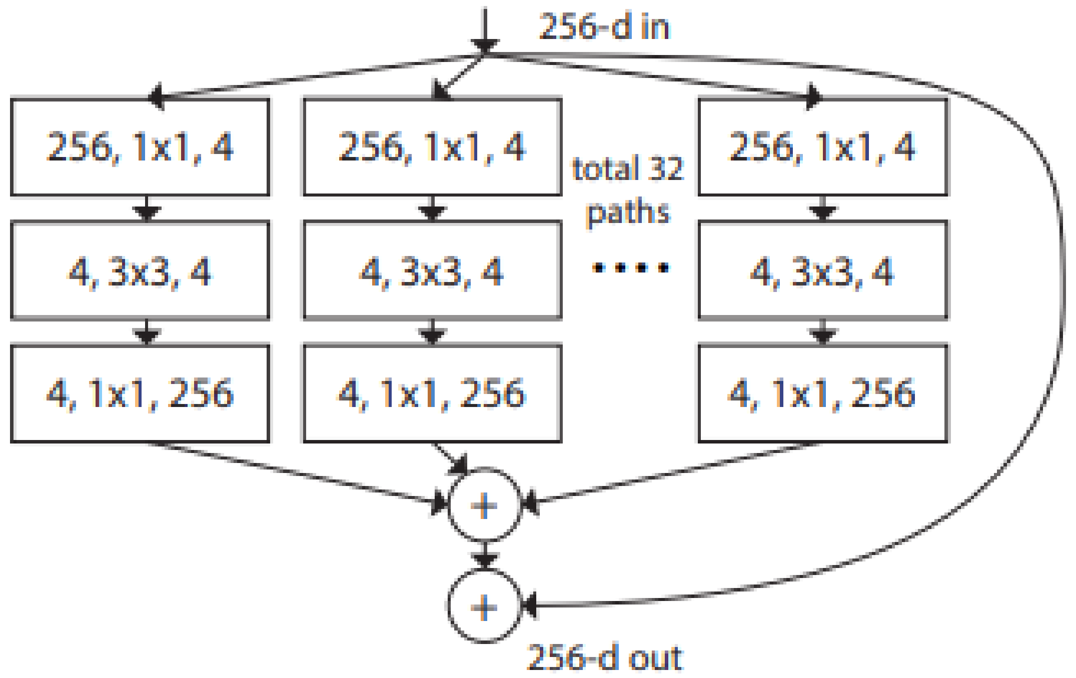
DenseNets



ResNets

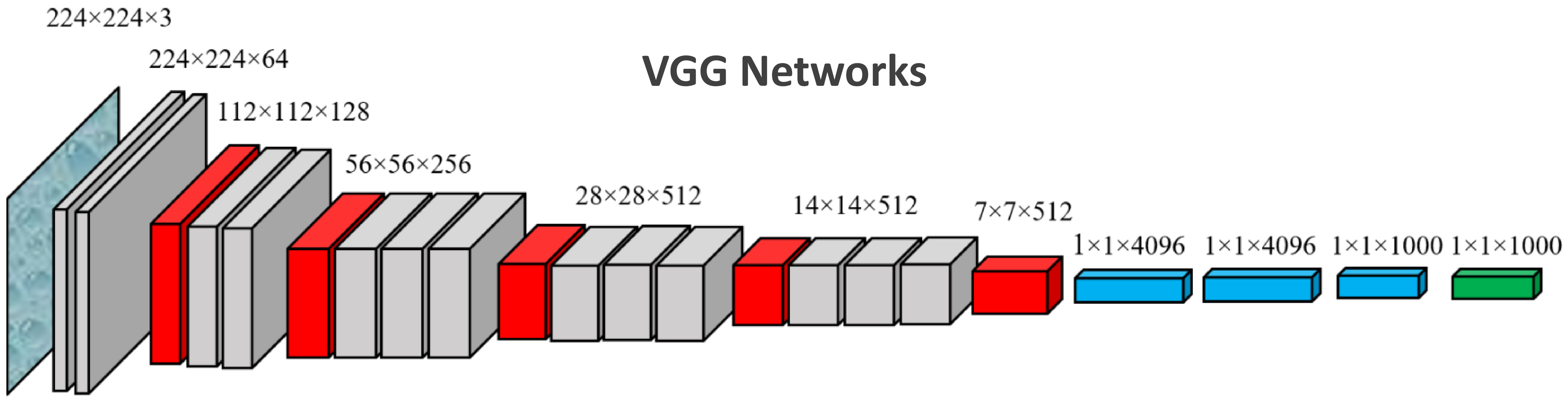


ResNeXts

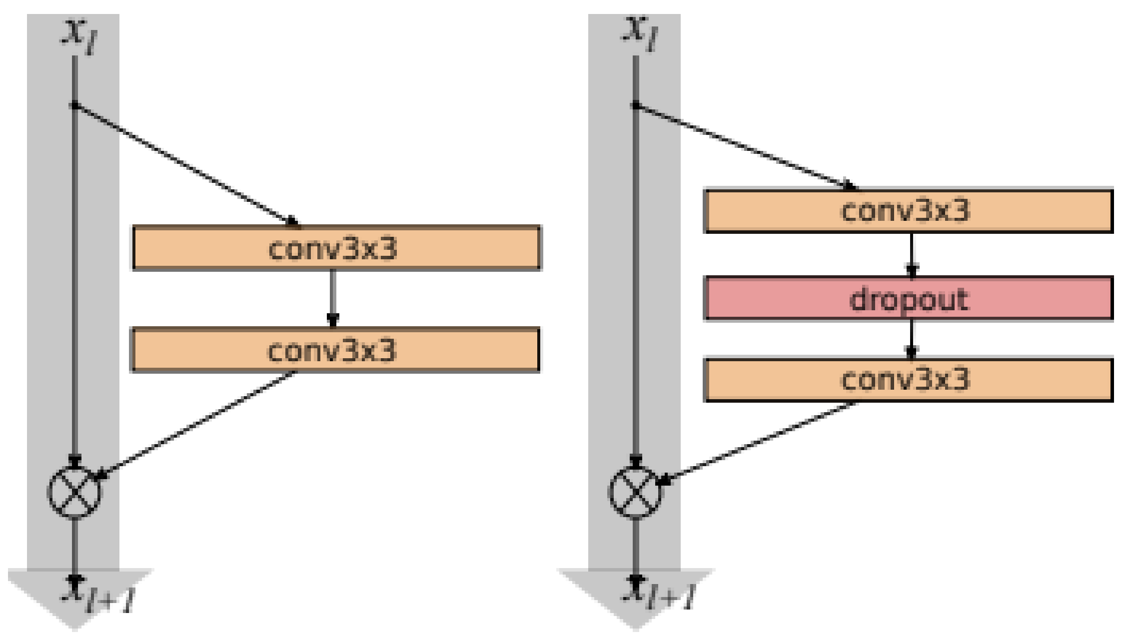


Selecting the „best” deep learning architecture?

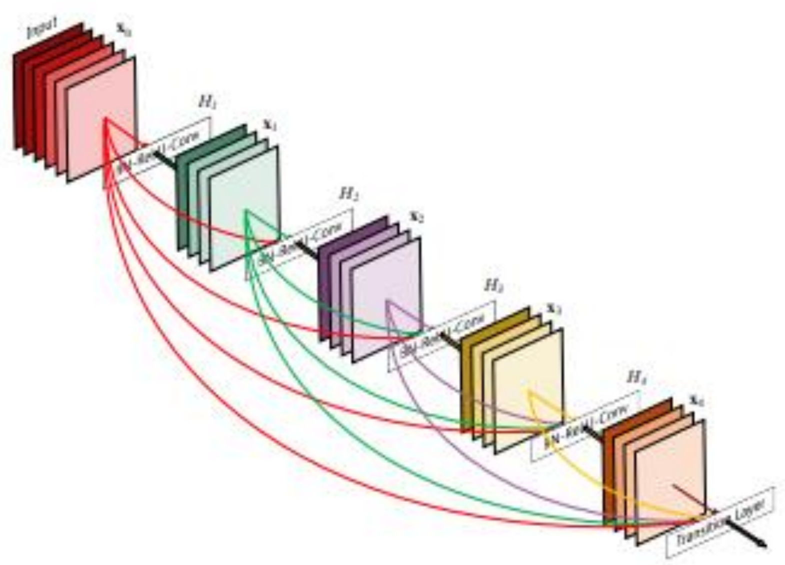
VGG Networks



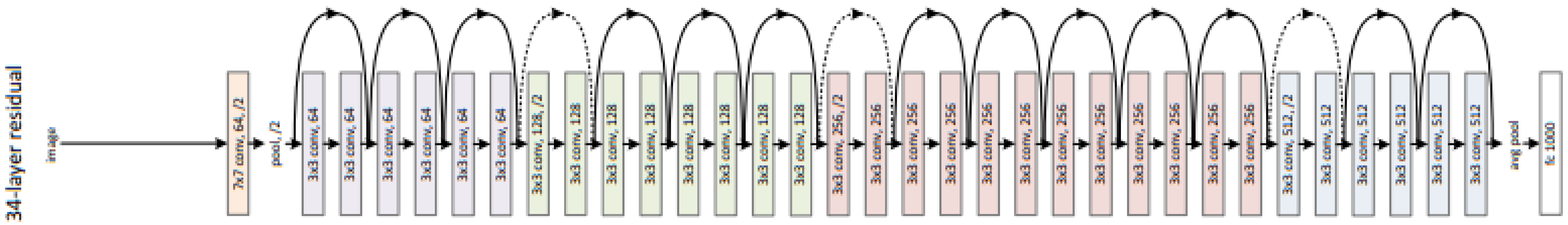
Wide ResNets



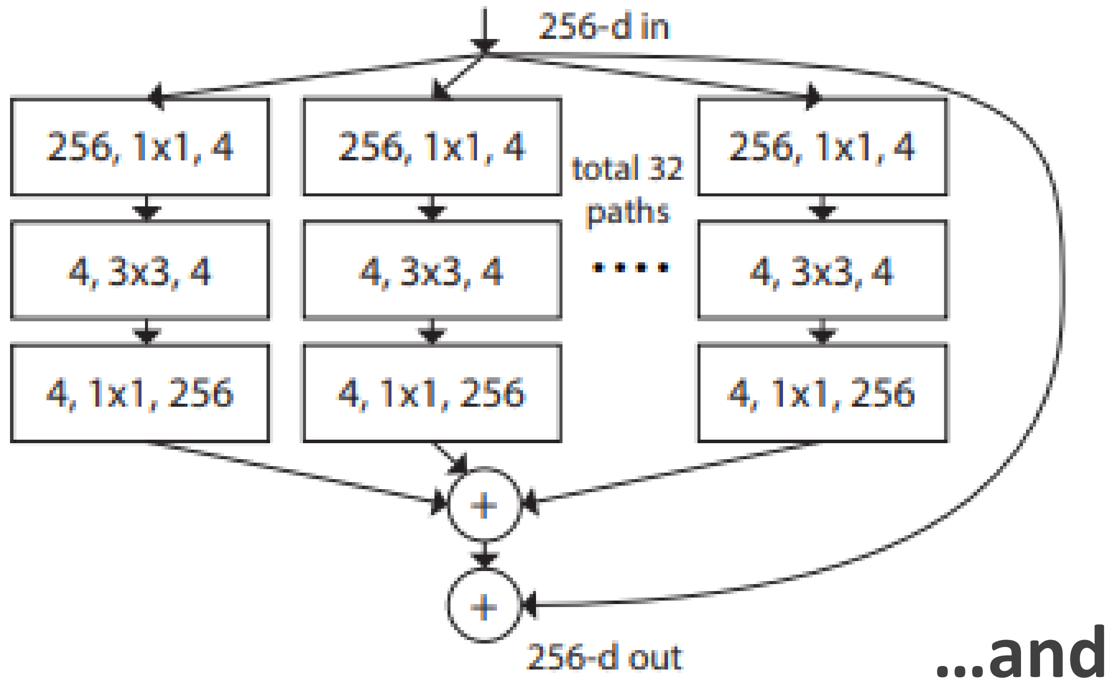
DenseNets



ResNets



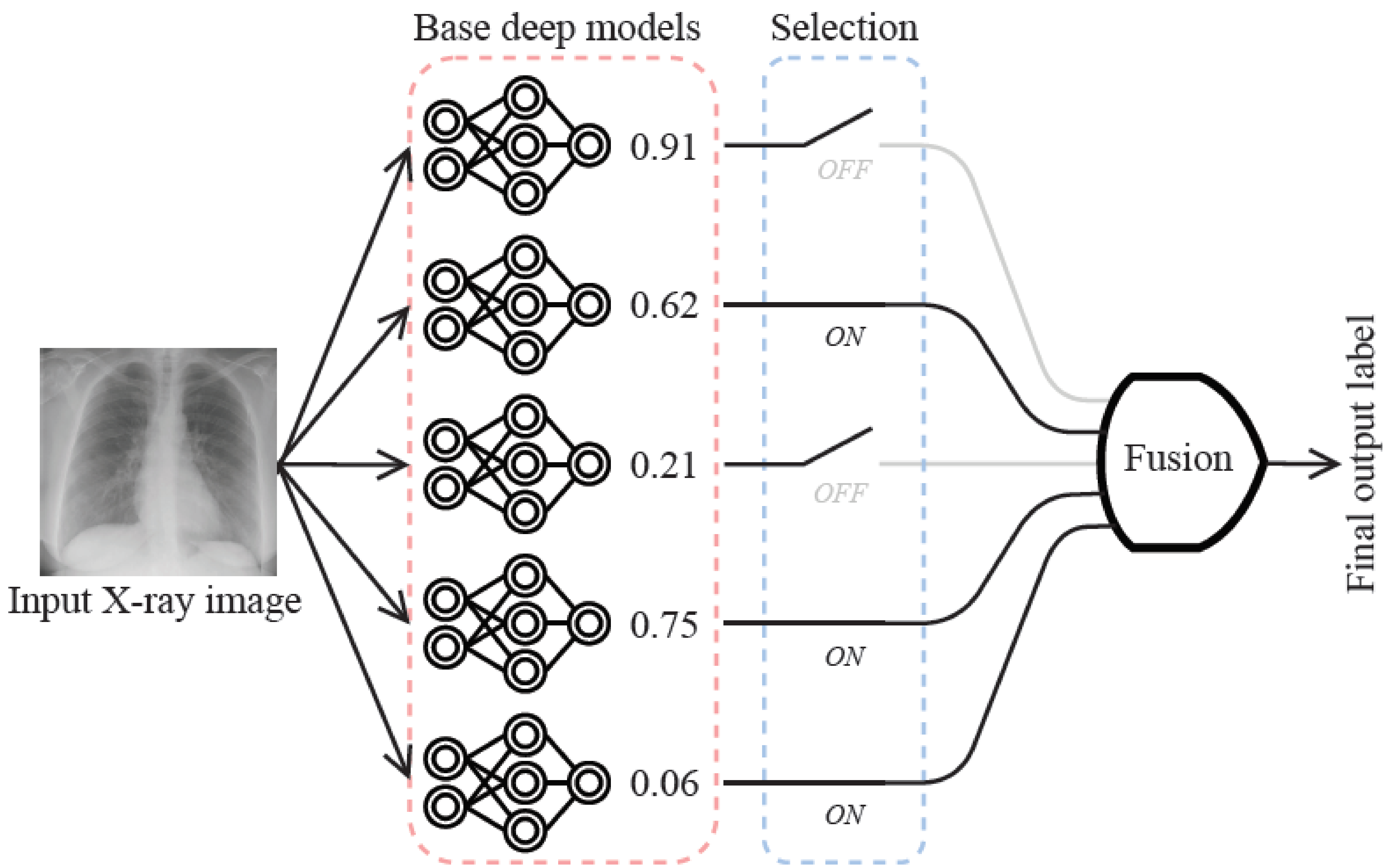
ResNeXts



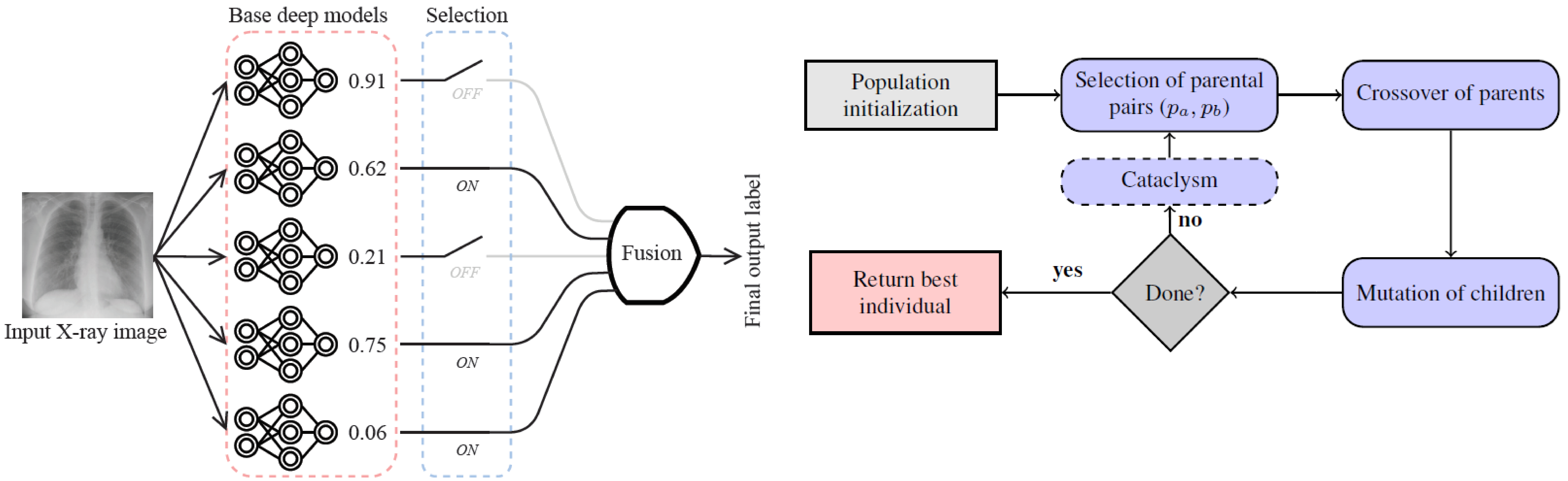
…and many more

OUR METHOD:
DEEP ENSEMBLES FOR DETECTING COVID-19 FROM X-RAYS

Evolving deep ensembles for detecting COVID-19



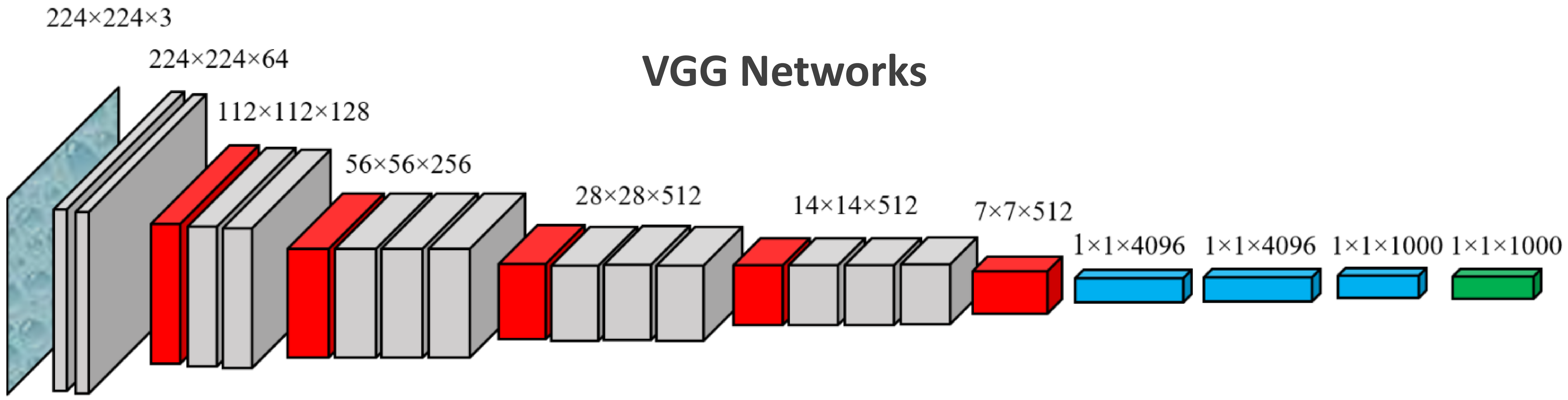
Evolving deep ensembles for detecting COVID-19



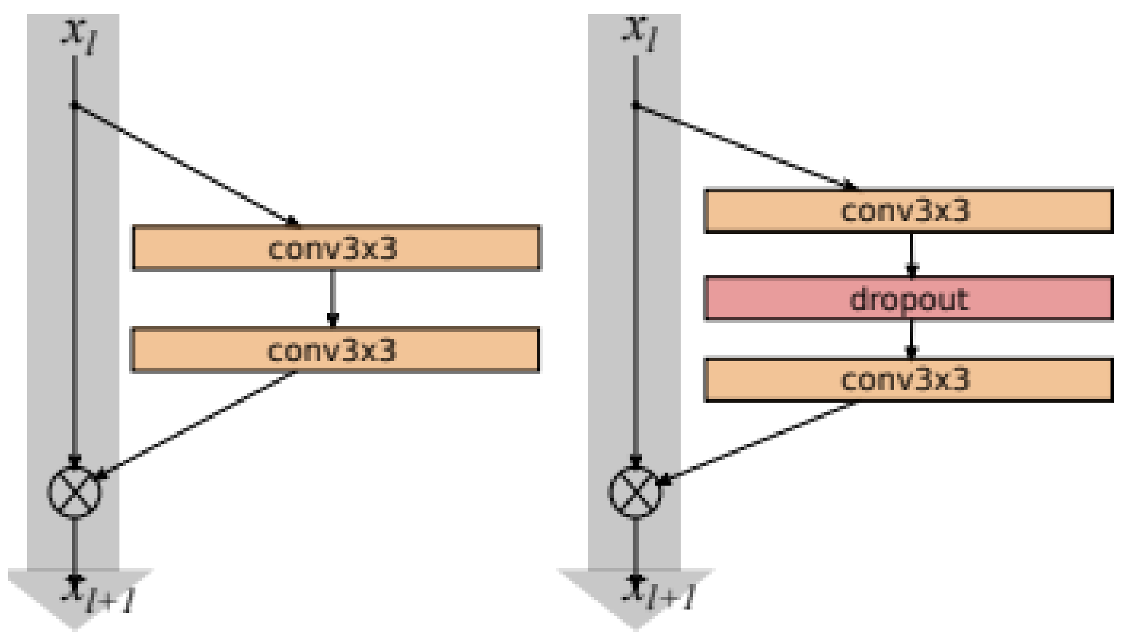
EXPERIMENTAL RESULTS

Selecting the „best” deep learning architecture?

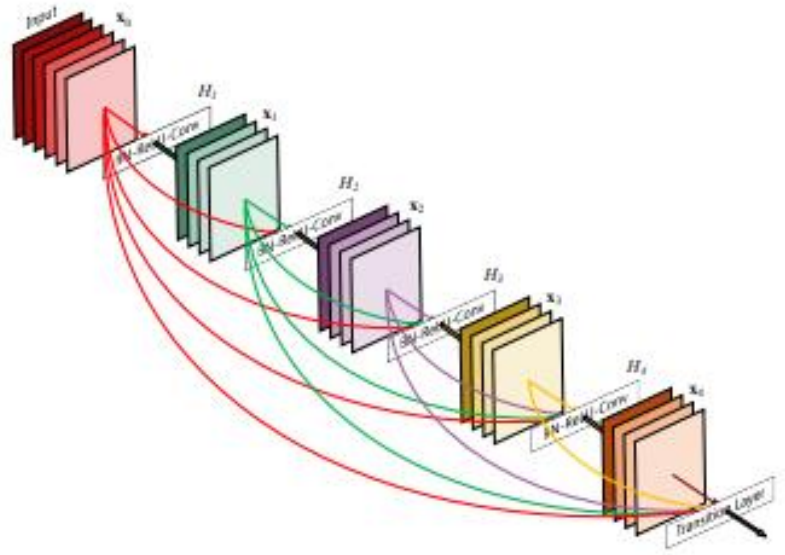
VGG Networks



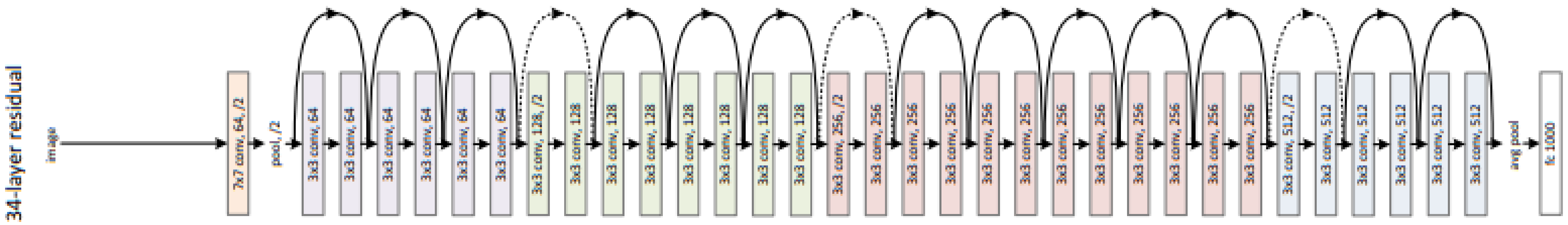
Wide ResNets



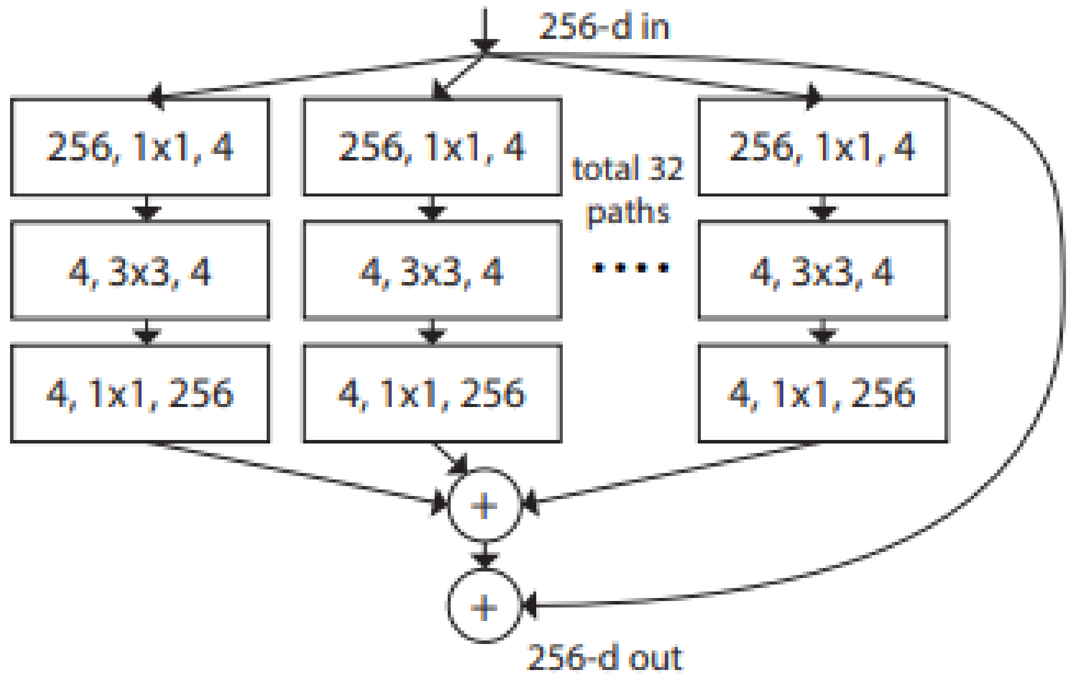
DenseNets



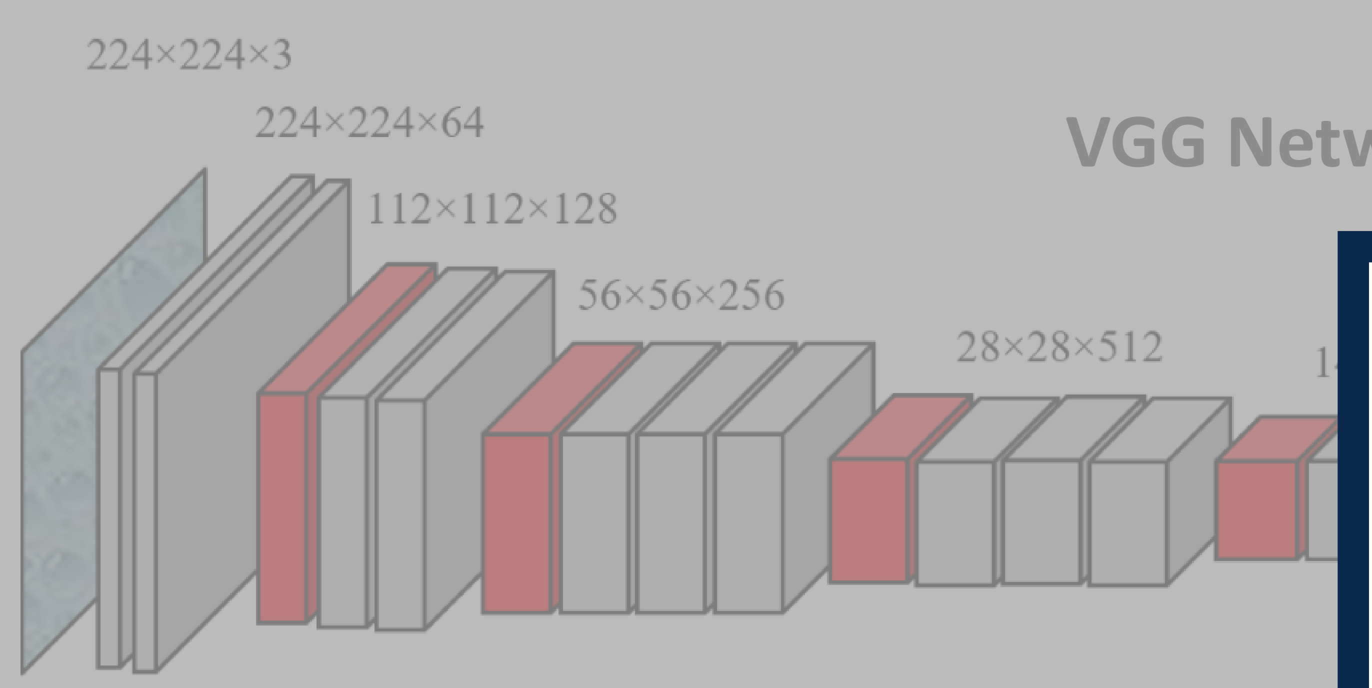
ResNets

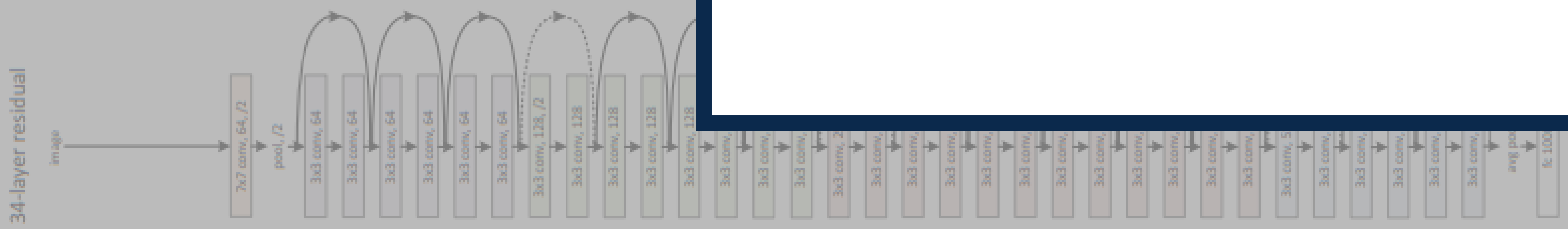


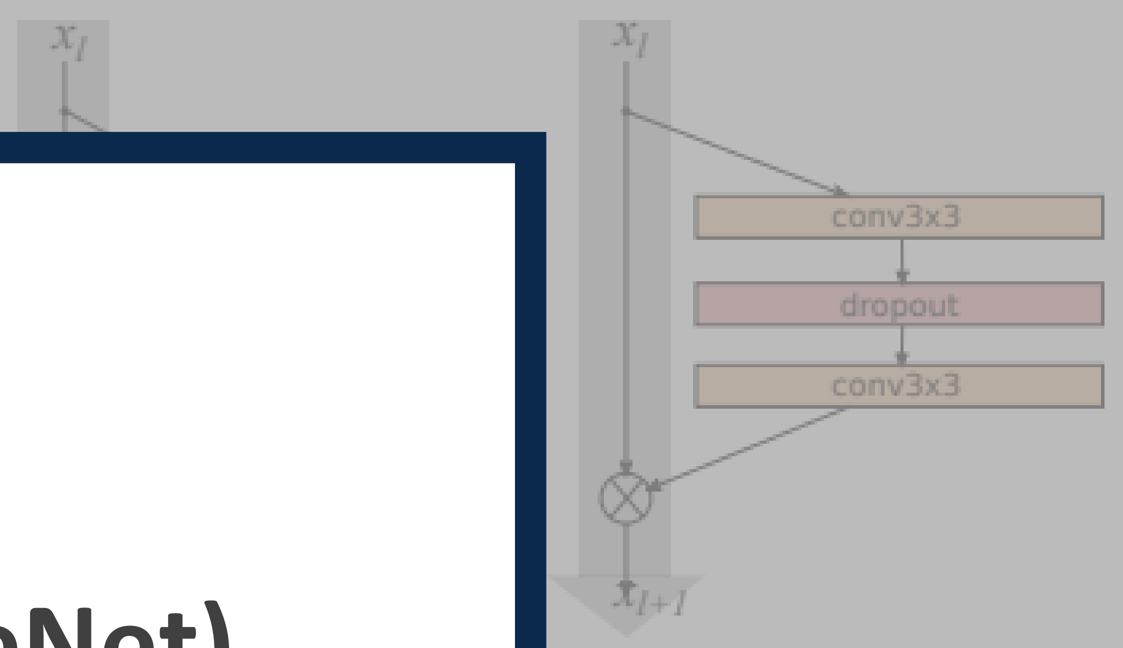
ResNeXts

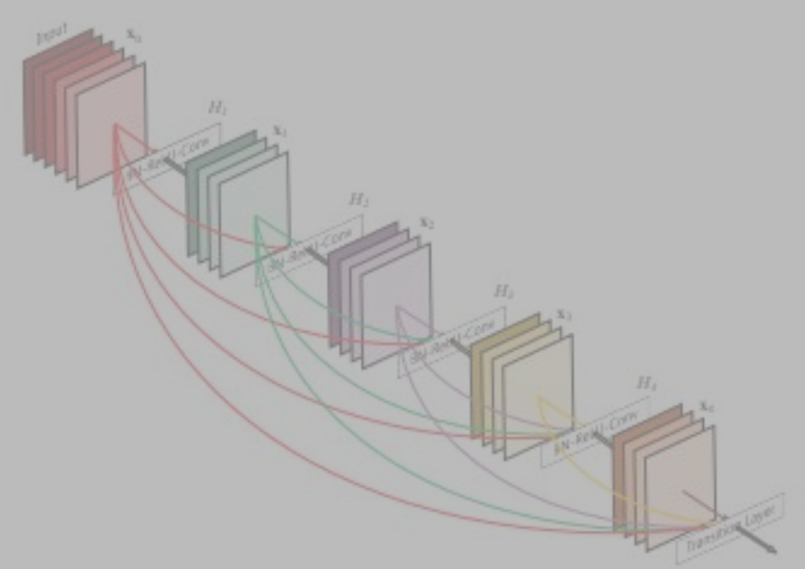


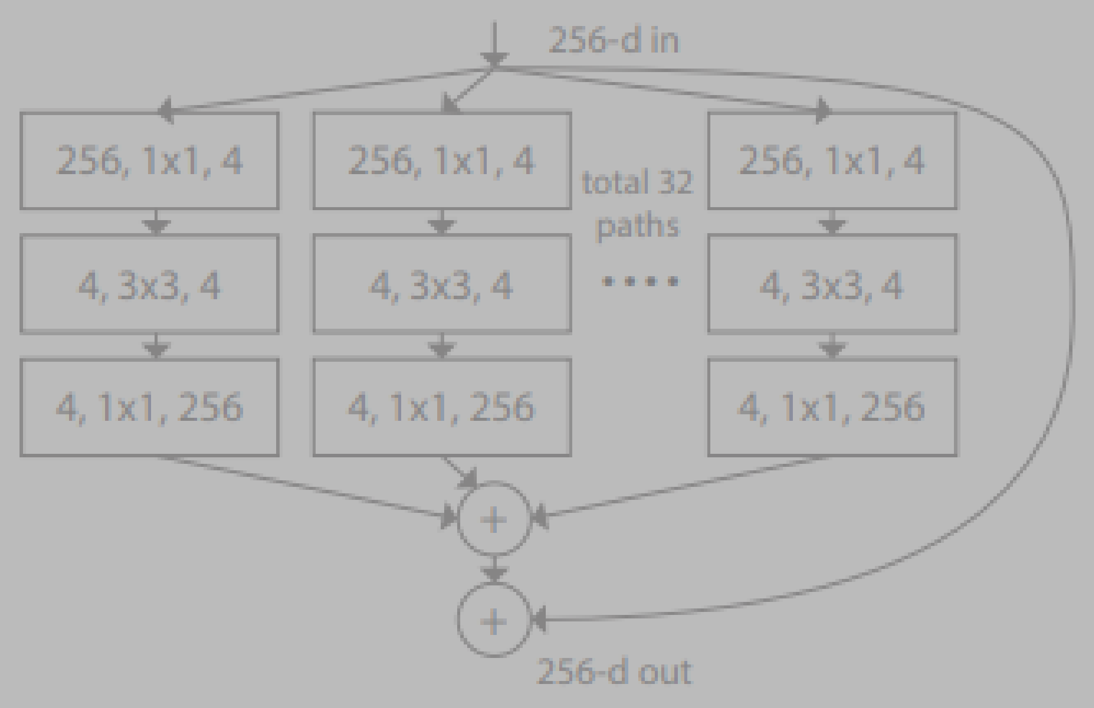
Selecting the „best” deep learning architecture?











170 deep models
(pre-trained over ImageNet)

X-ray datasets with COVID-19 and non-COVID-19 cases

ID	Dataset	C	COVID-19	non-COVID-19
1	covid-chestxray [25]	3	475	209
2	actualmed-covid-chestxray [26]	2	58	127
3	figure1-covid-chestxray [26]	3	33	5
4	bimcv-covid-19-nega [27]	2	—	4535
5	padchest [28]	2	—	2589
6	bimcv-covid-19-posi [27]	1	9171	—
7	tcia-covid-19 [29]	1	251	—
8	covid-19-radiography [30]	1	66	—
9	chexpert [31]	2	—	2589
		Total:	10054	10054

C – number of classes

X-ray datasets with COVID-19 and non-COVID-19 cases

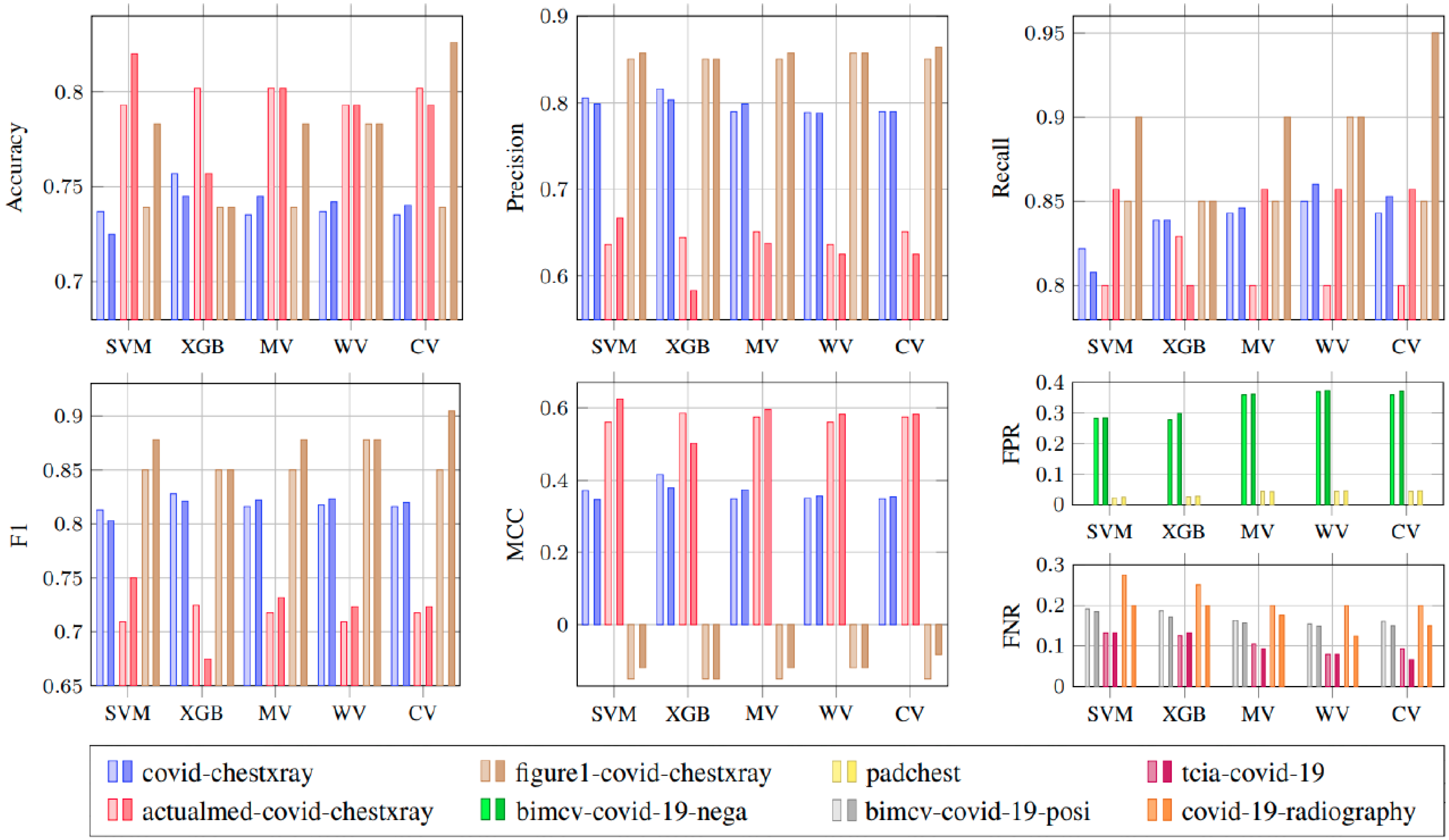
ID	Dataset	C	COVID-19	non-COVID-19
1	covid-chestxray [25]	3	475	209
2	actualmed-covid-chestxray [26]	2	58	127
3	figure1-covid-chestxray [26]	3	33	5
4	bimcv-covid-19-nega [27]	2	—	4535
5	padchest [28]	2	—	2589
6	bimcv-covid-19-posi [27]	1	9171	—
7	tcia-covid-19 [29]	1	251	—
8	covid-19-radiography [30]	1	66	—
9	chexpert [31]	2	—	2589
		Total:	10054	10054

C – number of classes

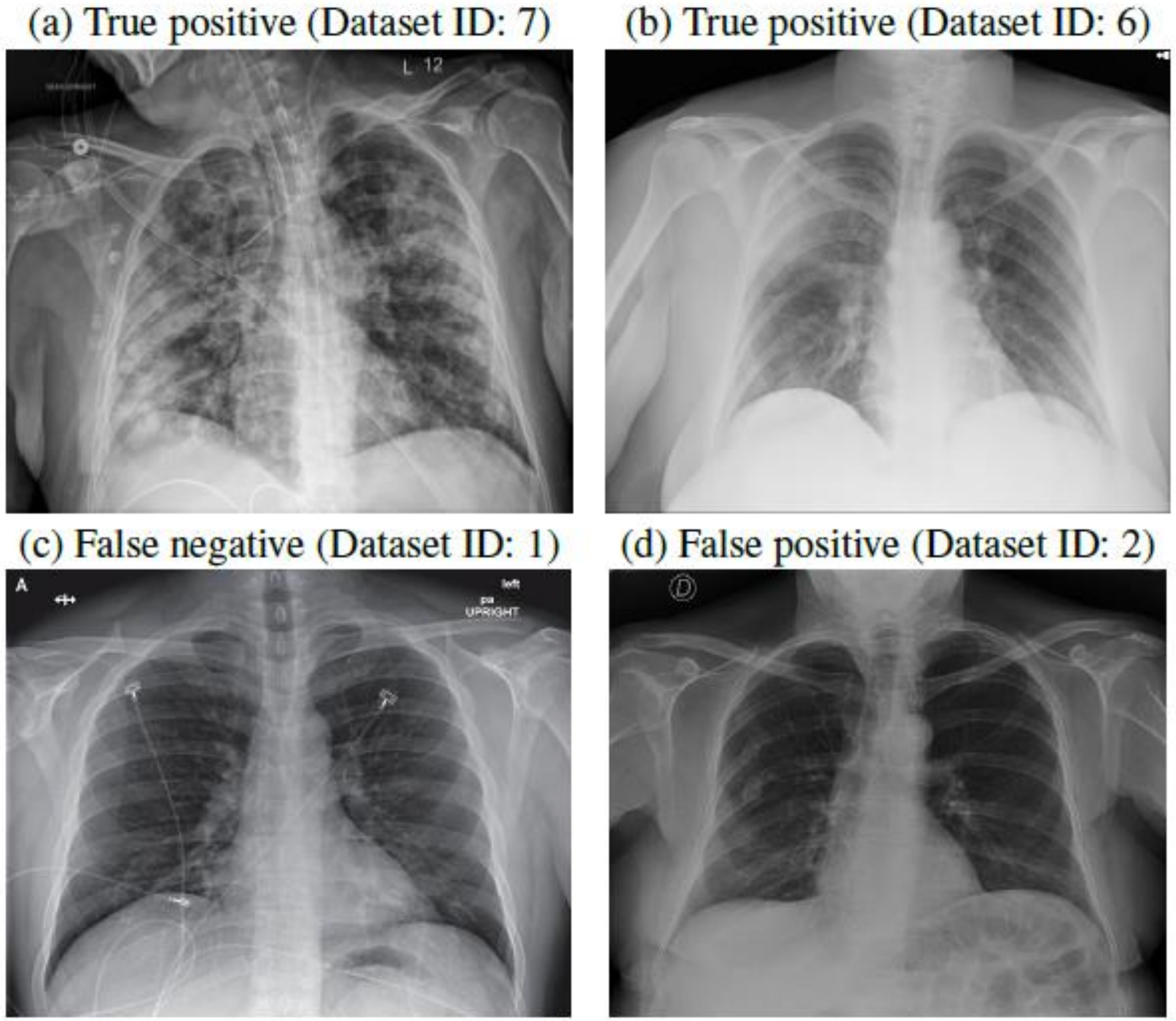
25% T, 5%V, 75% Test with stratification

The results: quantitative analysis

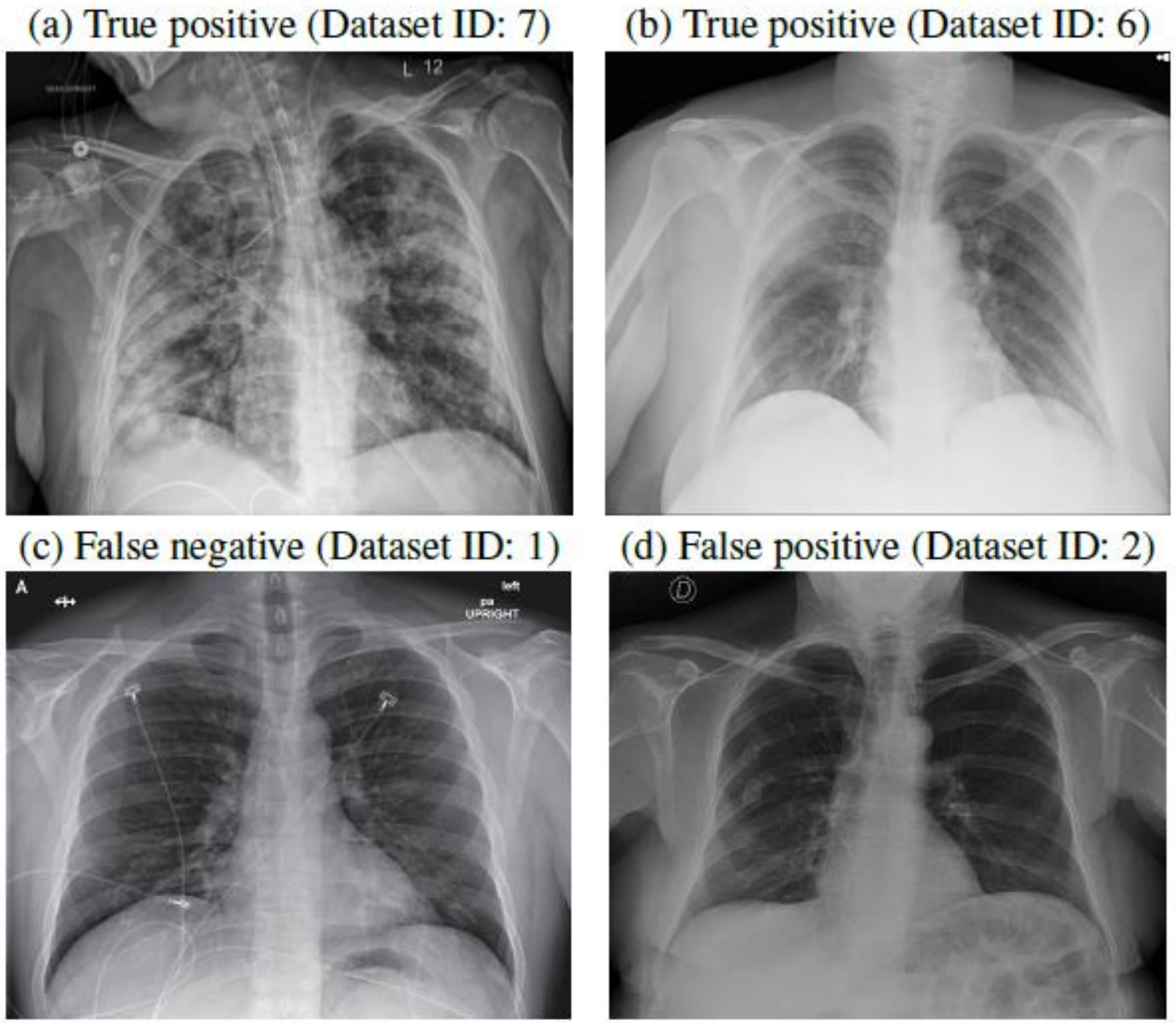
Algorithm	Ensemble size	Train. Accuracy	Valid. Accuracy	Test Accuracy	Test Precision	Test Recall	Test F1	Test MCC
Wide ResNet-50	—	—	**0.8280**	0.8220	0.8130	**0.8370**	0.8240	0.6440
ResNeXt-101($32 \times 8d$)	—	—	0.8270	0.8190	0.8120	0.8290	0.8200	0.6370
DenseNet-161	—	—	0.8270	**0.8240**	**0.8190**	0.8310	**0.8250**	**0.6480**
ANN	170	0.8723	0.8380	0.8335	0.8371	0.8288	0.8327	0.6675
SVM	170	**0.8830**	0.8393	0.8322	**0.8472**	0.8107	0.8285	0.6651
Evolved SVM	59	0.8760	0.8623	**0.8345**	0.8470	**0.8165**	**0.8315**	**0.6694**
XGBoost	170	0.9350	0.8417	0.8355	0.8492	0.8158	0.8322	0.6715
Evolved XGBoost	73	0.9370	**0.8583**	0.8376	0.8425	**0.8305**	0.8365	0.6753
MV	170	0.8210	0.8260	0.8256	0.8177	0.8381	0.8278	0.6515
Evolved MV	31	**0.8240**	**0.8547**	**0.8294**	**0.8188**	**0.8459**	**0.8321**	**0.6591**
WV	170	0.8210	0.8323	0.8282	**0.8159**	0.8477	0.8315	0.6569
Evolved WV	33	**0.8270**	**0.8523**	**0.8299**	0.8148	0.8538	**0.8338**	**0.6605**
CV	170	0.8180	0.8277	0.8270	**0.8181**	0.8411	0.8295	0.6543
Evolved CV	26	**0.8280**	**0.8527**	**0.8298**	0.8154	**0.8527**	**0.8336**	**0.6602**


Accuracy
0.8
0.75
0.7
SVM XGB MV WV CV
Precision
0.9
0.8
0.7
0.6
Recall
0.95
0.9
0.85
0.8
F1
0.9
0.85
0.8
0.75
0.7
0.65
MCC
0.6
0.4
0.2
0
FPR
0.4
0.3
0.2
0.1
0
FNR
0.3
0.2
0.1
0
covid-chestxray
actualmed-covid-chestxray
figure1-covid-chestxray
bimcv-covid-19-nega
padchest
bimcv-covid-19-posi
tcia-covid-19
covid-19-radiography

The results: qualitative analysis



The results: qualitative analysis (human rater, 4 YOE)



(a) Multifocal ill-defined and partially diffuse opacifications throughout both lungs with a predilection to the peripheral zones. (…) **The presented image may correspond to advanced inflammatory changes, including COVID-19**

(b) An ill-defined area of increased density in the upper and mid zone of the right lung with air bronchogram and without volume reduction. (…) **COVID-19 not excluded, further diagnostics is necessary**

(c) The left and right lungs are properly dilated with no visible consolidations. The boundaries of the heart are clear. There are no obvious signs of inflammation in the pulmonary parenchyma

(d) Small round consolidation in the lower zone of the right lung—small nodule or summation of the shadows. Past fracture of the III, IV, V, VI, and VII ribs on the right side. No visible signs of pneumonia

GitLab `https://gitlab.com/jnalepa/icip2021`

CONCLUSIONS

Conclusions

- We can benefit from various architectural advances **at the same time**

Conclusions

- We can benefit from various architectural advances **at the same time**
- Evolutionary ensembles with supervised fusers **outperform base models** and **classical fusers**

Conclusions

- We can benefit from various architectural advances **at the same time**
- Evolutionary ensembles with supervised fusers **outperform base models** and **classical fusers**
- We maintain fast inference (38.59 s/15 081 images/model → **2.6 ms/image/model**)

Conclusions

- We can benefit from various architectural advances **at the same time**
- Evolutionary ensembles with supervised fusers **outperform base models** and **classical fusers**
- We maintain fast inference (38.59 s/15 081 images/model → **2.6 ms/image/model**)
- Reduction of ensemble size through evolution (→ **faster inference, better classification abilities**)

Conclusions

- We can benefit from various architectural advances **at the same time**
- Evolutionary ensembles with supervised fusers **outperform base models** and **classical fusers**
- We maintain fast inference (38.59 s/15 081 images/model → **2.6 ms/image/model**)
- Reduction of ensemble size through evolution (→ **faster inference, better classification abilities**)
- Validation protocol is important **to really capture generalization abilities**

EVOLVING DEEP ENSEMBLES FOR DETECTING COVID-19 IN CHEST X-RAYS

Piotr Bosowski[1], Joanna Bosowska[2], Jakub Nalepa[1]

Silesian University of Technology, Gliwice, Poland
Dept. of Radiology and Nuclear Medicine, Medical University of Silesia, Katowice, Poland

jnalepa@ieee.org

2021 IEEE International Conference on Image Processing
19-22 September 2021 • Anchorage, Alaska, USA