

# Supplementary Material

## Limited Evaluation Cooperative Co-evolutionary Differential Evolution for Large-scale Neuroevolution

Anil Yaman  
Eindhoven University of Technology  
Eindhoven, The Netherlands  
a.yaman@tue.nl

Decebal Constantin Mocanu  
Eindhoven University of Technology  
Eindhoven, The Netherlands  
d.c.mocanu@tue.nl

Giovanni Iacca  
University of Trento  
Trento, Italy  
giovanni.iacca@gmail.com

George Fletcher  
Eindhoven University of Technology  
Eindhoven, The Netherlands  
g.h.l.fletcher@tue.nl

Mykola Pechenizkiy  
Eindhoven University of Technology  
Eindhoven, The Netherlands  
m.pechenizkiy@tue.nl

### 1 EXTENDED EXPERIMENTS AND RESULTS

This section presents our preliminary results of the experiments performed on the MNIST dataset using the DE, LEDE, CCDE and LECCDE. The MNIST dataset consists of 60000 samples of 28 by 28 grayscale image instances of handwritten numbers between 0-9. Thus, the size of the input and output are 784 and 10 when each image pixel and its class label are considered as an input and output respectively.

We used the same architecture of the artificial neural networks that were used for the experiments performed on the other datasets (feed forward artificial neural networks with one hidden layer consisting of 50 neurons). Thus, the total number of parameters of the networks optimized for the MNIST is 47710. The parameters of the Differential Evolution algorithm are also initialized using the same settings used for the other experiments except for batch size, number of individuals in each subpopulation and the maximum number of function evaluations. Since MNIST is larger than the tested other datasets, we used a batch size of 1000, a population size of 60 and a maximum number of evaluations set to  $2.16e + 6$ .

Table 1 shows the training, validation and test accuracy results of the ANNs trained for the MNIST dataset. Each variant of the algorithm was executed for the same number of function evaluations. The total time required for computing every other algorithm is shown in relation to the computing time required for the LECCDE where  $t = 6.6e + 5$  seconds that is approximately 19 hours on a single-core Intel Xeon E5 3.5GHz computer. Due to time constraints, we were able to perform 3 independent runs for the LEDE and LECCDE, and a single partial run for the DE and CCDE. Thus, on DE and CCDE we report their accuracy at 12% of their total allocated computing time (the total computing times of DE and CCDE are estimated based on their current execution progress).

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from [permissions@acm.org](mailto:permissions@acm.org).

Conference'17, July 2017, Washington, DC, USA  
© 2018 Association for Computing Machinery.  
ACM ISBN 978-x-xxxx-xxxx-x/YY/MM...\$15.00  
<https://doi.org/10.1145/nnnnnnn.nnnnnnn>

Table 1: The accuracy the ANNs evolved for the MNIST dataset, and the runtime of the algorithms.

Alg.	Train	Validation	Test	Runtime
DE (% 12)	61.60	61.26	62.52	$27.2 \times t$
LEDE	$82.68 \pm 0.36$	$82.01 \pm 0.75$	$82.23 \pm 0.25$	$1.1 \times t$
CCDE (% 12)	62.40	61.80	63.20	$25.3 \times t$
LECCDE	$91.79 \pm 0.28$	$91.01 \pm 0.63$	$90.80 \pm 0.15$	$t$

We observe a significant advantage in using the LE scheme on MNIST from the computing time point of view: indeed, the DE and CCDE implementations of the algorithm require a computing time that is 25 times bigger than the computing time required by the corresponding algorithms that make use of the LE scheme.

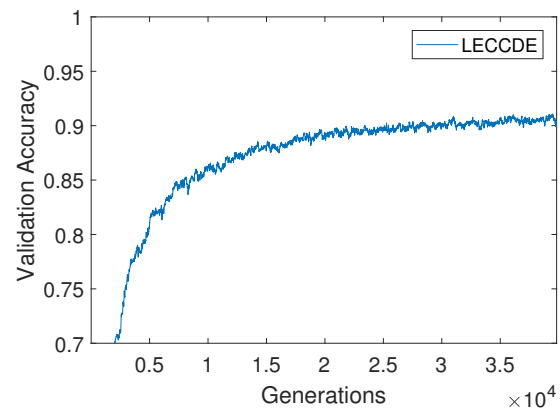


Figure 1: The change of the validation accuracy of the ANNs evolved using the LECCDE on MNIST dataset (only [0.7, 1] range is shown on the y-axis).

Figure 1 illustrates the change of the validation accuracy of the evolved ANNs using the LECCDE during an evolutionary process. The speed of the accuracy improvements slows down around 88% - 90% level. The best validation accuracy achieved during this evolutionary run was 91.62%.