Machine Learning the Anderson and the Percolation Transitions

D. Bayo[12] , A. Honecker[1] & R. Roemer[12]

[1] CY Cergy Paris Université, LPTM (UMR8089 of CNRS), F-95302 Cergy-Pontoise, France
[2] University of Warwick, Coventry, CV47AL, United Kingdom

Presented by:
Djenabou BAYO
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Machine Learning system can be classified in several categories, supervised, unsupervised, semisupervised and reinforcement learning. For our study we used supervised learning.

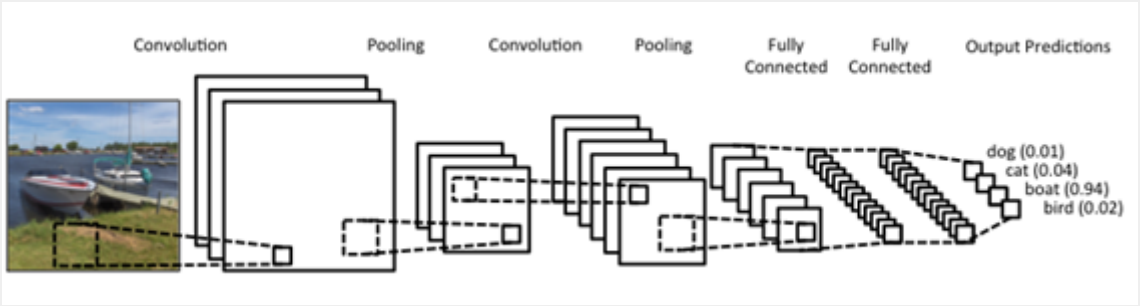


Figure 1: Example of CNN used for an image classification task

The Anderson model is a tight binding model with onsite disorder. For the 3D Anderson model we consider a cubic lattice of size $L \times L \times L$, its corresponding Hamiltonian is,

$$\mathcal{H} = -g(\sum_{\langle i,j \rangle} c_i^\dagger c_j + c_j^\dagger c_i) + \sum_i \epsilon c_i^\dagger c_j \tag{1}$$

- g is the hopping amplitude
- ϵ is the on-site energy, randomly and uniformly distributed in the range in $[-\frac{W}{2}, \frac{W}{2}]$
- $(c_i^\dagger, c_i)$ the fermionic creation/annihilation operator at site i

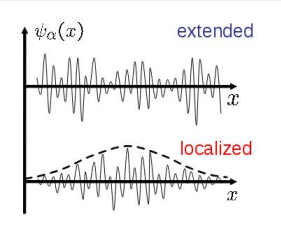
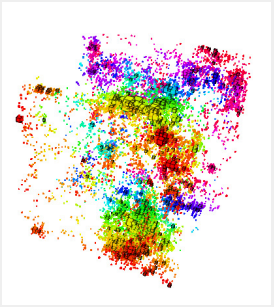


Figure 2: Extended and localized wavefunctions

We begun by performing and images classification on images of the electrons density, 17 disorder before and after the critical value $W_c = 16.54$. 2000 samples per classes were chosen as training data and we split the data with a ratio of 90% for training data and the remaining as a validation set. We trained the system with ResNet50 and Adadelta as optimizer, the batch size is 16.



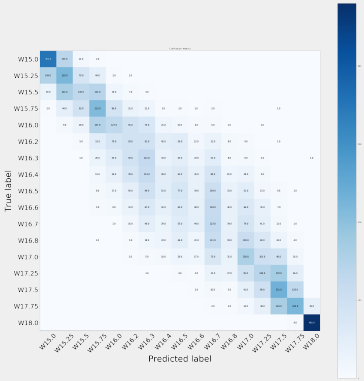


Figure 3: Example of images used during the training process (system at size $50 \times 50 \times 50$ at disorder $W16$) and confusion matrix after training.

The classical site percolation model is a well known model statistical physics. In this model a medium, for example a 2D square lattice sees its sites being randomly occupied with probability of occupation p. Similarly to the previous analysis we begun by performing an image classification on lattice at different density, 20 densities before and after the critical value $p_c = 0.5927$ with 2000 samples per classes. We split the data with a ratio of 90% for training data and the remaining as a validation set.

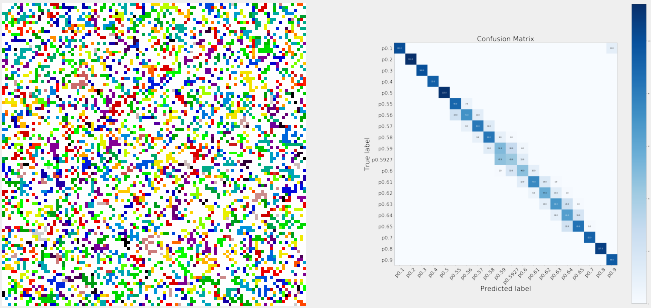


Figure 4: Example of lattice (here at p=0.4) used during the training process and confusion matrix obtained after training.

Following training on images, we decided to trained the data on the array that generate the images. We used a Resnet18 with optimizer Adam and batch size 256. After 100 epochs, we obtained a 88% validation accuracy and a 87% accuracy on average. Following the training process we plotted several curves:

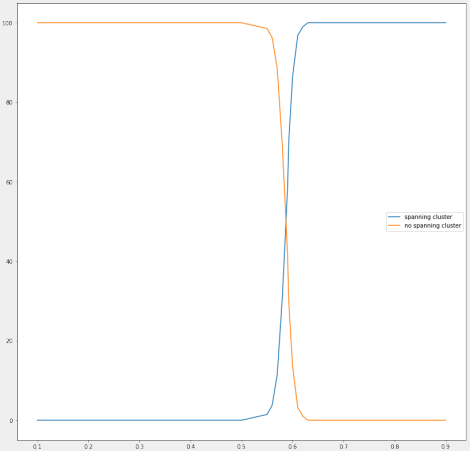
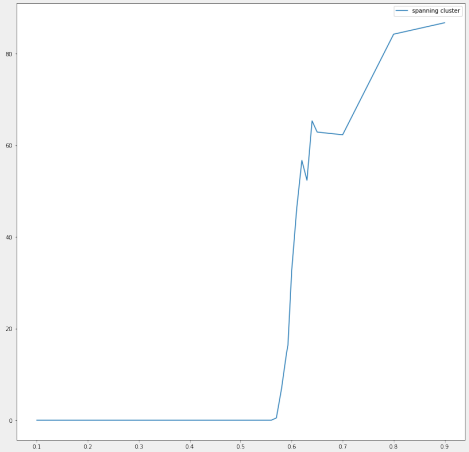


Figure 5: Graph showing the occurrence of a lattice to have a spanning cluster as a function of the probability of occupation

We plotted the probability of percolation of our system at the end of the training on array, we obtained:



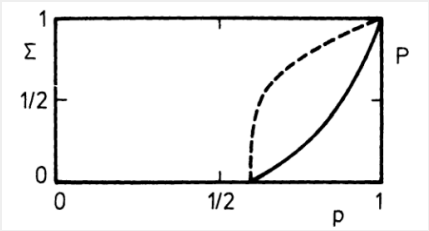


Figure 6: Probability of percolation obtain through ML and probability of percolation in literature

Conclusion

- ML seemed to recognize density and percolating system without big issues.
- Introducing more samples increase the learning in our system but we need to go around memory issues.

Thank you

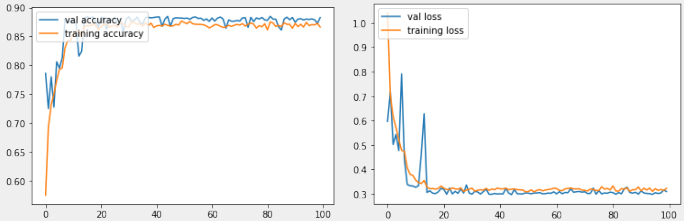


Figure 7: Accuracy and loss obtained during the training process, with Resnet18 without pretraining

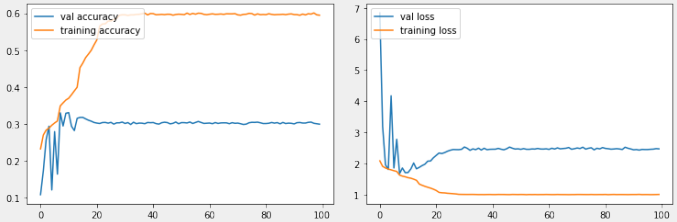


Figure 8: Accuracy and loss obtained during the training process on images of disorder, with Resnet50 with pretraining