Analysis and Design of Deep Neural Networks

Ahmad Kalhor- Babak Araabi

School of Electrical and Computer Engineering

University of Tehran

Fall 2023

Some Questions about the new course

1. What is the goal of the course “Analysis and Design of Deep Neural Networks”?
2. Why this course is necessary?
3. Which questions are answered through this course?
4. What are other benefits of using analysis and design methods in DNNs?
5. How can we analysis and design DNNs?

What is the main purpose of the course “Analysis and Design of Deep Neural Networks”?

- The main purpose of the course is to develop concepts, Metrics, and Indices which improve and ease the designing and learning process in DNNs.

Why "Analysis and Design of DNNs" is necessary?

1. The diversity of the proposed architectures for DNNs is considerably high. It is necessary to evaluate and rank them in a systematic way in order to know which ones are nearer to the optimal architecture with lower redundancy.

2. The main learning approach in DNNs (error-back propagation) is blind and suffers from sensitivity to initialization and getting stuck in local optimal points. It is necessary to develop learning methods which provide more interpretable and robust optimization ways. Metric Learning and ranking losses are more interpretable and appropriate learning methods.

Why "Analysis and Design of DNNs" is necessary?

3. The are not any systematic methods to evaluate, and rank pre-trained DNNS. In addition, we need more straightforward methods for compressing Networks, to ensemble some available networks or provide more reliable and generalized model.

4. There are some open problems such as feature representation, active learning, evolvable learning, one shot learning, multi-task learning which can be addressed and solved by new analyzing and designing methods .

Which questions may be answered by “Analysis and Design of Deep Neural Networks”?

- In Analysis and Design of DNNs, beyond the former conventional methods, we try to develop methods to answer following questions:
  1. How can we suggest better architectures of DNNs for a learning problem?
  2. How can we give geometrical interpretation about the functionality of a DNN.
  3. How can we evaluate the architecture and layers of a pre-trained DNN?
  4. How can we being sure that DNNs do not have any redundancy in their layers and units?
  5. How can we develop more interpretable methods in designing and learning DNNs?
  6. How can we compare different DNNs in accuracy and generalization?
  7. How can we give guarantee and confidence about the predictability of ours DNNs?
  8. How can we provide better transfer learning and domain adaptation?
  9. How can we make a reliable defense strategy against attacks, Trojans, backdoors and biases.

What are the benefits of using analysis and design for DNNs?

1. Analysis
   - Structural and Layer-wise evaluation.
   - Data scoring, cleaning, division and augmentation to achieve better training and generalization
   - Ranking pre-trained DNNs in transfer-learning and find most suitable model.
   - Developing Guarantee and confidence indices for the predictability of DNNs.

2. Design
   - Layer-wise pruning to achieve more compact form of DNNs
   - Layer-wise Learning to achieve faster and more accuracy
   - Layer-wise branching and designing more advanced architecture
   - Layer-wise fusion among some pre-trained DNNs.
   - Layer-wise self supervised learning, feature representation

How can we analysis and design DNNs?

1. Structure Analysis:
    - We can analyze and design by studying the functionality of layers, blocks and modules which define the architecture of DNNs
2. Deep Metrics Learning
    - We can develop some distance, angular, or other metrics and losses to have more reliable and better learning in classification, and similarity learning problems.
3. Layer-Wise Design and Analysis
    - We can analysis and design DNNS be developing some complexity measures.

"Structural analysis" versus "Layer-wise analysis and design"

1. "Structural analysis" suggests a formal architecture for DNNs including topology, layers, blocks, and modules.
2. "Layer-wise analysis and design" improve the architecture and learn it by reducing a complexity measure.

1. Structural analysis	2. Deep Metric Learning	3. Layer-wise analysis and design
Suggest an architecture for a DNN Piping/Shell Designing	(Geometric Analysis)	Improving by local metric learning and Complexity measures Data-flow Control/ Core learning

Course Evaluation

Chapter	Items	Sum
2	Homework1 – Data Evaluation-Subset Selection	15%
4	Homework2 – Model Evaluation, Extra: Feature Representation	15%
6	Homework3 – Model Compressing	15%
6	Homework4 -Layer wise Learning	15%
7	Homework5– Metric Learning	15%
Exam	Final Exam 25%	25%

Contacts and addresses

Course Homepage	https://addnn.github.io/
Chief TA	Ali Karimi, Email: aliiikarimi@ut.ac.ir
Channel Address	https://t.me/AD_DNNs_Kalhor
Email	Ahmad Kalhor, akalhor@ut.acir
Office Address(teacher)	School of Electrical and Computer Engineering Building N0. 2, No. 322, Tel: +98 (21) 61119780

Analysis and Design of Deep Neural Networks

1. Layers, Blocks and Modules

- Fully Connected layers and blocks
- Convolution Layers-Blocks-Modules
- Recurrent Layers – Modules
- Attention Layers – Modules
- Pooling layers
- Normalization Layers

2. Complexity Indices and Data analysis

2.1 Complexity Indices

1. Separation index and methods (Classification Problems)

   si, cross_si, high_order_si, soft_si, center_si, anti_si, score_si, triplet_local_si...

2. Smoothness index and methods (Regression Problems)

   smi, cross_smi, high_order_smi, soft_smi, anti_smi, score_smi, triplet_local_smi ...

3. Linear Density Index and methods (Unsupervised Problems)

2.2 Data analysis

- Dataset evaluation (ranking, cleaning, dividing, augmentation)
- Supervised Data Subset Selection
- Data Clustering
- Unsupervised Data Subset Selection
- Data Labeling in semi supervised datasets

3. Architectures

- CNNs
- Region Based CNNs
- Transformers

4. Layer Wise Analysis Algorithms

- Layer-wise Model evaluation
- Pre-train Model ranking
- Model Confidence and Guarantee
- Other Layer-wise Analysis Algorithms

5. Layer Wise Design Algorithms

- Model Compressing
- Layer-wise forward learning (supervised, self supervised, unsupervised)
- Layer-wise branching/Fusion
- Layer-wise encoding and Feature Representation
- Other Layer-wise Design Algorithms

6. Deep Metric Learning

2.1 Introduction

- An introduction to Metric Learning
- An introduction to Similarity Learning

2.2 Deep Metric Learning

- Contrastive Loss (Siamese Networks)
- Triplet loss
- Circle Loss
- Softmax loss
- SphereFace(Angular-Softmax)
- CosineFace Loss
- ArcFace loss

End of Introduction