Visual Genealogy of Deep Neural Networks (DNNs)

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Q. Wang, J. Yuan, S. Chen, H. Su, H. Qu and S. Liu.
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Jeffrey Goh

What are Deep Neural Networks (DNNs) ?

- A set of algorithms designed to recognize patterns. (Cluster and classify)
- Consists of multiple hidden layers between input and output.
- Examples : Language translation, speech recognition and music genre classification

Motivations for visualizing DNNs

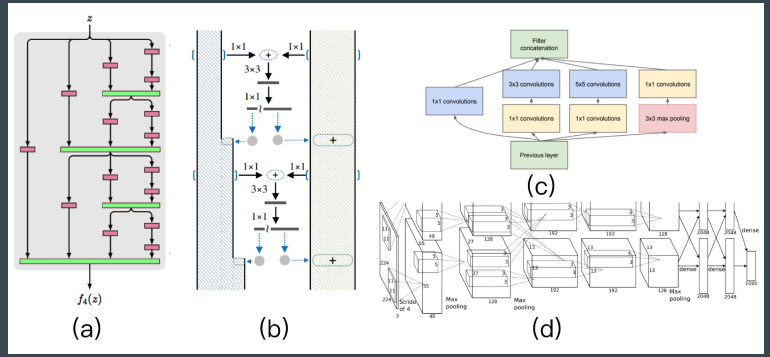
- Inspire and motivate the wide adoption and extensive use of DNNs.
- Working mechanisms remain unclear.

Goals

- Facilitate the exploratory analysis of different DNNs.
- Understand the pros and cons of each DNN.
- Summarize the large number of existing DNNs.

Challenges

- Rising number of DNNs.
  - Summarizing representative DNNs.
- Complexity of DNN architectures.
  - Deep layers (over 1200 layers), multiple branches and dense skip connections.
- Diversity of DNNs.
  - Identifying the evolutionary relationships among DNNs.



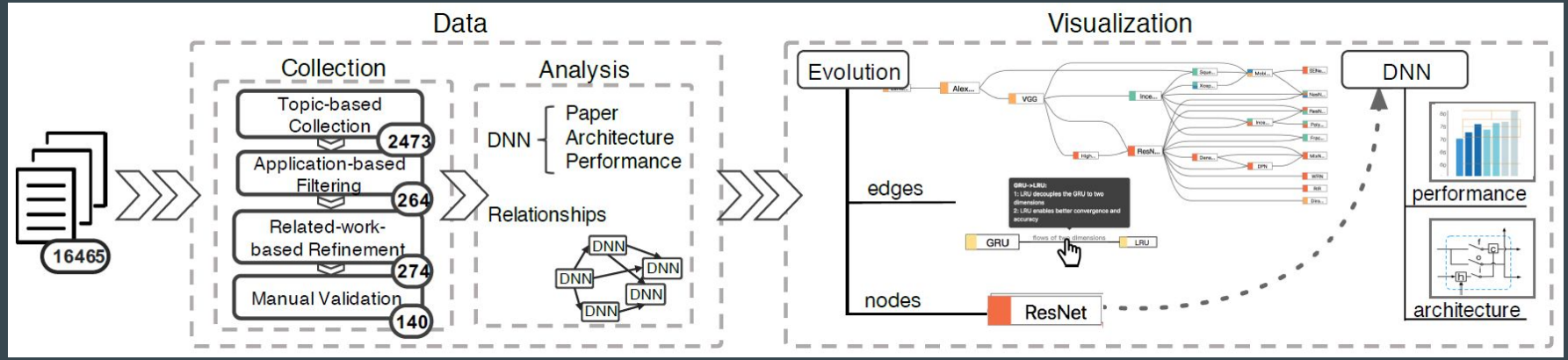
[Fig 5. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

Design Requirements

1) Learning the evolution of DNN architectures.
    a) Explaining the relationships among DNNs
    b) Identifying the evolution pattern of a DNN architecture
    c) Identifying representative DNNs
2) Investigating one particular DNN
    a) Understanding a DNN from different aspects
    b) Illustrating DNN architectures
    c) Comparing different DNNs

System Overview

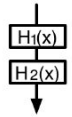
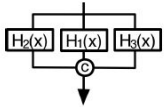
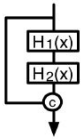
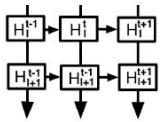
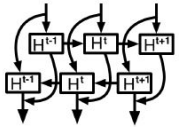
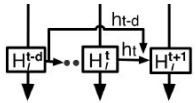
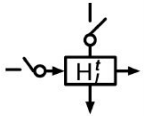
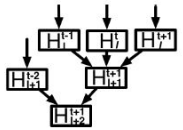
1) Extract papers → 2) Identify representative DNNs →
3) Identify common architectures → 4) Identify relationships →
5) Calculate performances → 6) Visualize



[Fig 3. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

DNN visualization

Network glyphs (abstract level)

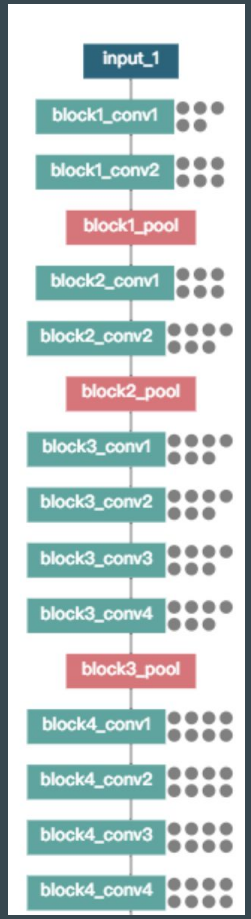
CNN				RNN				
Streamline	Depthwise separable conv	Multi-branch	Skip connections	Stacked	Bidirectional	Multiple time-scales	Gated	Tree-structured
								
Layers are stacked on top of one other	A standard convolution is split into depthwise convolution and a 1x1 convolution	The output of one layer goes through multiple branches and then converges	A connection skips one or more layers	Layers are stacked to increase the depth of a RNN	A standard recurrent unit is split into two parts to process the input sequence in two directions	Recurrent units operate at multiple time scales	Add the gate mechanism	The connection graph is structured as a tree
E.g., VGG [55]	E.g., Xception [14]	E.g., Inception [58]	E.g., ResNet [22]	E.g., EESEN [45]	E.g., BRNN [53]	E.g., Clockwork RNN [31]	E.g., LSTM [24]	E.g., Tree-LSTM [59]

[Table 1. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

DNN Visualization

Complete architecture graph (Concrete level)

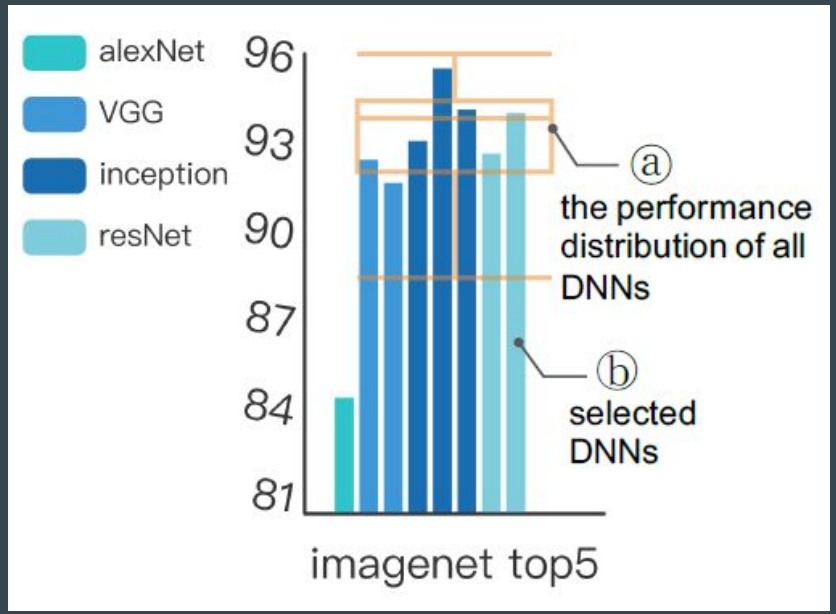
- Directed Acyclic Graph (DAG)
  - Sugiyama-style layered graph drawing
- Color coding
  - Different types of layers
- Dots representation
  - Number of parameters



[Fig 9. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

Performance Visualization

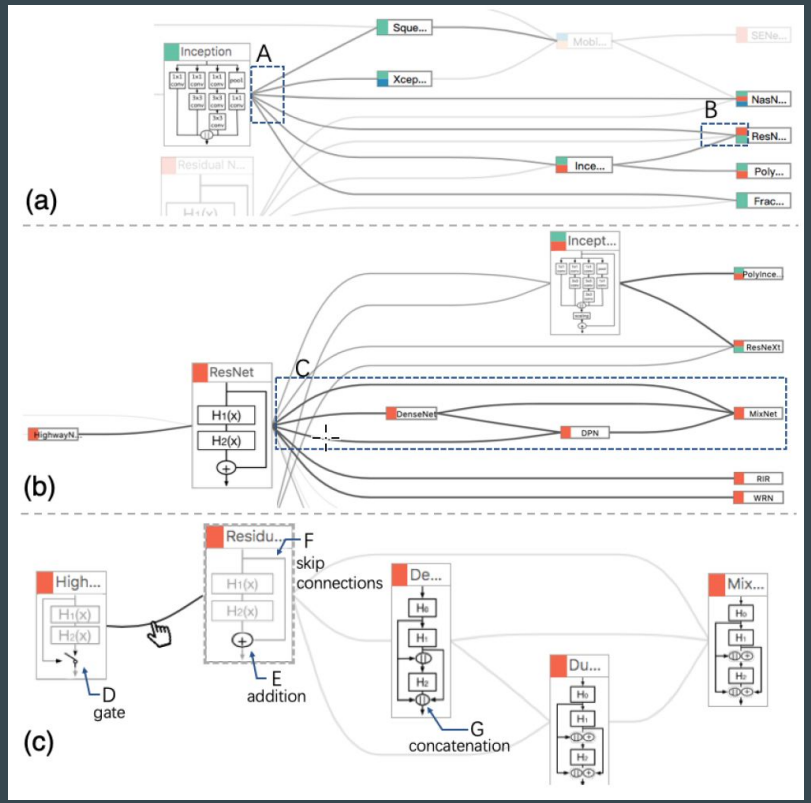
- Bar charts
  - Performance of DNNs
- Box plot
  - Performance distribution
- Color coding
  - Type of DNN
- Datasets used:
  - imagenet top5/top1
  - cifar10/ cifar100



[Fig 4. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

Evolution Visualization

- Nodes: DNN
- Edges: Relationships
- Focus + Context
  - Nodes vs Network Glyphs
  - Degree of Interest (DOI)
- Color encoding



[Fig 8. Visual Genealogy for Deep Neural Networks. Qianwen Wang, Jun Yuan, Shuxin Chen, Hang Su, Huamin Qu, and Shixia Liu. IEEE Transactions on Visualization and Computer Graphics. doi: 10.1109/TVCG.2019.2921323]

DEMO

Limitations and future work

1) Training methods not included in visualization.
2) DNN scope only limited to 3 benchmarks (Classification, detection and segmentation).
3) DOI heuristic algorithm only considers limited aspects.
    a) Performance and complexity of architecture may be added in future.

Critique

Strengths

- Well justified design choices
- Simple and neat layout
- A wide variety of DNNs covered consistently
- Effective in achieving what it was meant to do

Weaknesses/Limitations

- Insufficient case studies
- Unintuitive functions
- Inconsistencies in design
- Poor DOI algorithm

Questions?