Analyzing the Training Processes of Deep Generative Models

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Why visualize – after iterative user studies

- Identify root cause of a failed training process
  - Loss function can become NaN or Inf
  - Multiple sources - inappropriate network structure, bug in code, lack of numerical stability
- R1: Connecting the overall statistics with detailed training dynamics
  - Summary statistic serves as entry point
  - Detailed training dynamic can be used for root cause analysis

Background – deep neural networks

Neuron level analysis

- Idea - Root cause analysis
  - Credit assignment
  - Influenced by both previous and next layer
  - Use forward and backward propagation to find neurons of interest

Overview

- Data flow visualization module
  - How data flows in a DGM (R2)
  - How other neurons influence the output of the neuron of interest (R4)
  - Credit assignment problem

Stitching it all together

- Training dynamics analysis module
  - Loss as a function of time (R1)
  - Samples time series to preserve outliers (R5)
  - Blue noise polyline sampling to reduce visual clutter

Snapshot level analysis

- Idea - which layer caused the issue?
  - DAG - illustrates how layers are connected
    - Hierarchical structure to reduce clutter in case of 100s of layers

Why visualize – after iterative user studies

- R2: Examining how data flows through the network
  - Different layers have different roles in DGM
  - A failed training process is usually caused by a specific layer
- R3: Facilitating the detection of outliers
  - Outliers in training process is a potential reason for failed training process
- R4: Examining how neurons interact with each other
  - Poor understanding on how neurons interact with each other in a DGM
  - Even after identification of abnormal neuron, it is hard to identify the root cause.

Stitching – Examine the loss function

What to visualize - data

- Network diagram of neurons and its characteristics
  - Activations, gradients, weights of each neuron (MILLIONS)
- Summary statistics of the model
  - Loss/accuracy of the model
- Dynamic time-series data [MILLIONS]
  - How activations/gradient/weights changes over time
  - How loss/accuracy changes over time
Stitching – Neuron level root cause analysis

- Millions of neurons in each layer and 100s of layers
  - In snapshot level view, use expandable hierarchy groups
  - In layer level view, use filtering, clustering
  - In neuron level view, use filtering and clustering
- Large amount of training dynamics data [5TBs]
  - Keep a few in memory
- Millions of snapshot-level data come as time-series
  - Use sampling (blue-noise polyline)

Analysis - scalability

- Pros
  - Case studies to prove that it works
  - User study to understand the requirements
  - Extendible to CNNs and MLPs
- Cons
  - Does not work in case neural networks have cycles
  - Works only for offline analysis
- My views
  - Not sure of responsiveness
  - Not sure what is the level of change required for other NNs

Analysis - critique

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Conclusion/ Highlights

- Effective tool to diagnose DGMs
- Three level of analysis in DGMs
  - Snapshot level
  - Layer level
  - Neuron level
- Idioms
  - focus+context, filtering, aggregation, interaction
  - blue-noise polyline sampling to reduce clutter

Overview

- Examine loss changes to identify abnormal snapshot
- High level averaged statistics of each layer to identify layer of interest (hybrid viz) at the snapshot level
- Print the training dynamics of the layer of interest (layer level analysis)
- Interactively select a set of neurons and explore how other neurons are related though the data-flow visualization

Neuron level analysis

- Idea - Root cause analysis
  - Credit assignment
    - Influenced by both previous and next layer
    - Use forward and backward propagation to find neurons of interest
  - Other ideas for conv/deconv layers
    - Relative position of the image patch that each neuron is influenced
    - Represent neurons as feature maps - neurons which share the same weights
    - By tracing behind, we identify the corresponding image patch.

What to visualize - challenges

- Handle large amount of time series data from the training process
- Activation/ gradient/ weight changes over time (training dynamics)
- Millions of time series (as DGMs has millions of above)
- Simple viewing => visual clutter

Neuron Level analysis

- Visualization
  - Cluster neurons and show them in a grid form
  - Show only which highly contribute to the output

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