A Machine Learning Perspective on Predictive Coding with PAQ by Knoll & de Freitas

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Overview

Introduction to PAQ

What is PAQ8

- What is it?
- How does it work?
- What makes it so famous?

Matt Mahoney

- Born 1955
- Recieved Ph.D in computer science at Florida Tech in 2003
- Released PAQ1 on January 6, 2002

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What is PAQ?

- A lossless, open-source compression algorithm
- Brings high perfomance at the cost of increased memory usage and time consumption
- Related to PPM, is envisioned as PPMs improvement

Principles of PAQ

- Modeling combined with adaptive arithmetic encoding
- Open to additions and improvements
- Improves perfomance of PPM by including several predictors (i.e. models of data)
- Combines the result of the predictors

Introduction to PAQ

Exemplary Predictors

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The order-n context predictor

- Examines the last n bits and counts the 1's and 0's
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The sparse context predictor
- Context consists of a specific amount of non-contiguous bytes before the current bit

PAQ & Predictors

- PAQ encoder looks at the beginning of input file for deciding which predictors are used
- Ways to combine predictions change through with the different versions

PAQ8L

8

PAQ8 - What's new?

- Predictors don't produce a pair of bit counts anymore
  $\hookrightarrow$ those counts get weighted and normalized into the interval $[0, 1] \subset \mathbb{R}$
- Instead each predictor already outputs a probability
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PAQ8L - Machine Learning Perspective
- paq8l is the version of PAQ used by *Byron Knoll & Nando de Freitas*
- They try to show the possibilities of PAQ beyond data compression

Architecture

Architecture of PAQ8

- Uses weighted combination of predictions from Large number of models
- Allows no-contiguous context matches
- paq8l uses **552** prediciton models
- Combines the output of them into a single one
  $\hookrightarrow$ Passes this through an *adaptive probability map* (APM) before using the arithmetic coder

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```
┌──────────┐   ┌──────────┐   ┌──────────┐   ┌──────────┐
│prediction│   │model     │   │adaptive  │   │arithmetic│
│models    │──▶│mixing    │──▶│probability│──▶│coding    │
│          │   │          │   │maps      │   │          │
└──────────┘   └──────────┘   └──────────┘   └──────────┘
```
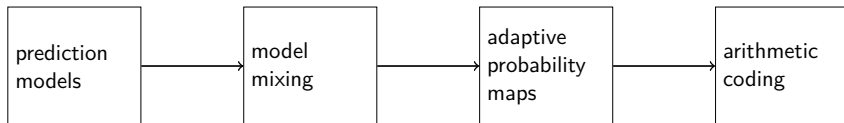
Figure: PAQ8 Architecture

Neurons of a neural network

A neuron takes one or more inputs and gives an output.
Within the topic of machine learning, the neuron can be understood as a function.

Neural network

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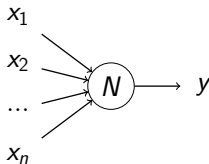Figure: Neural network architecture

Layer in neural network

A layer is a group of neurons.

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A neural network

Neural networks is defined by its layers:

- 1 input layer with n inputs where $n \in \mathbb{N} \setminus \{0\}$
- 1 output layer with k inputs where $k \in \mathbb{N} \setminus \{0\}$
- M layers between input and output layer with $M \in \mathbb{N}$,
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General structure of neural network

Let it be an generic neural network with:

- $x_1, ... x_n$ inputs and $l_1, ..., y_k$ outputs
- There are M different layers between input and output
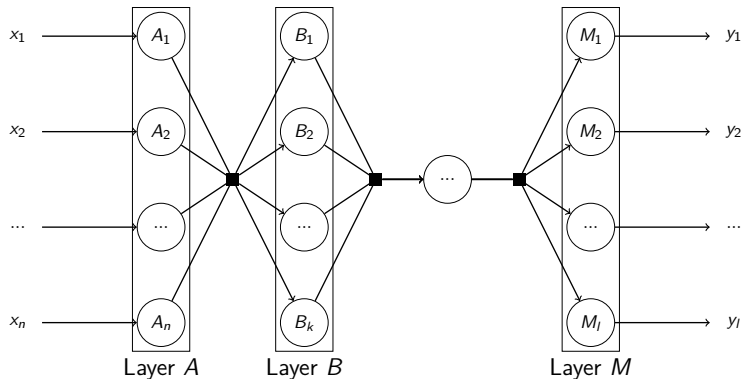
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Model Mixer

Model Mixer of paq8l

- Resembles a neural network with one hidden layer
- Hidden layer is between input and output layer
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Differences between paq8l and neural networks

1. Weights for first and second layers are learned online and independently for all nodes:
   - Each node trained separately
   - reduces predictive cross-entropy error (unlike back propagation)
2. Hidden nodes are partitioned into seven sets

Applications for PAQ8

References