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

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November 26, 2019

Overview

Introduction to PAQ

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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

Exemplary Predictors

Introduction to PAQ

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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

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        │    │             │
└─────────────┘    └─────────────┘    └─────────────┘    └─────────────┘
```
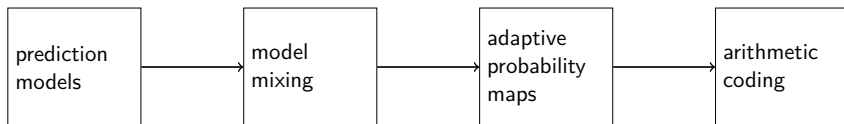
Figure: PAQ8 Architecture

Layers of a neural Network

A layer, in the context of a neural network, is a group of neurons, which take an input and provide and output.

Neural Network

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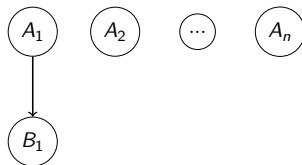
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A neuron takes one or more inputs and gives an output.
Within the topic of machine learning, the neuron can be understood as a function.

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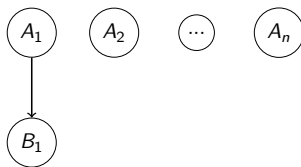Figure: Neural network architecture

Model Mixer

Model Mixer of paq8l

- Resembles a neural network with one hidden layer
- Hidden layer is between input and output layer
  $\hookrightarrow$ Artificial neurons take a set of weighted inputs
  Output is produced through activation function

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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

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