Project Outlines

- We examine lossless data compression from an average delay perspective.
- Status updating system model:
  - A source generates time-stamped status update messages that are transmitted through a communication system to one or more receivers.
  - Updates must be as timely as possible.
- Timeliness metric: status update age.
- Real-time lossless source coding is a problem of status updating.
- We evaluate the average status age in lossless sequential block coding systems.
- We connect average age to the source coding error exponent.
- We propose the age-optimal block coding scheme.

System Model

- An encoder receives input symbols one per unit time from an i.i.d. source and submits binary codewords to a FIFO buffer that transmits bits at a fixed rate to a decoder.
- Each input symbol at the encoder is viewed as an average system time of symbol $k$.
- We connect average age to the source coding error exponent with delay.
- System performance is characterized by the average status update age:
  - The number of time units (symbols) the decoder output lags behind the encoder input.
  - Example of status age for block coding schemes.

Status Age Analysis

- Average age for block coding:
  - The average status update age is the normalized area under the sawtooth.
  - $\Delta = \lim_{N \to \infty} \frac{1}{N} \sum_{k=1}^{N} (D_k - kB) + \frac{B}{2} = E[T] + \frac{B}{2}$
  - average system time of symbol $k$
  - average waiting time
  - average service time

- D/G/1 queue model:
  - The average status update age is the time of $G/G/1$ queue.
  - With same blocklength, age-optimal Huffman code is only optimal when the system is idle.
  - With same blocklength, age-optimal code outperforms Huffman code significantly when the system is heavily loaded.

Age-optimal Block Code

- Alternative upper bound on the average waiting time of $G/G/1$ queue:
  - $\Delta \leq \frac{\text{Var}[L]}{2R(BR - E[L])} + \frac{E[L]}{R} + \frac{B}{2}
  - quasi-linear function of expected code length
  - second moment of code length

Future Work

- Techniques to handle large blocklengths.
- Sources with memory.
- Age-optimal universal coding scheme.
- Coding with shared network resources.