Rate adaptation with Bayesian attractor model for MPEG-DASH

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Background – Video streaming service

- MPEG-DASH (Dynamic Adaptive Streaming over HTTP) is widely used for video streaming service
- Using DASH, the video player can dynamically switch video quality
- Bitrate selection is based on an Adaptive bitrate (ABR) algorithms
- Estimate the instantaneous network quality
- Select a video bitrate of the next segment to be downloaded

Background – Quality of Experience (QoE)

- The QoE is attracting attention as an important factor in video streaming service
  - A measure of the degree of user satisfaction with a service
  - Improving QoE is the general goal of ABR algorithms
- The QoE is strongly correlated with video player events
  - Start-up delay, played bitrate, frequency of bitrate switch, rebuffering (video freezing), etc

Problem

- Bitrate selection degrading the user QoE due to a fluctuation of network quality
  - Difficulty in estimating of network quality in mobile network
  - Increase in mobile traffic intensifies the degree of fluctuation
  - Inaccurate estimation can lead to inappropriate bitrate selections
  - This results in degrading the user QoE

The factors that improve the QoE differ person by person

Research purpose and approach

- Purpose
  - To maximize the QoE of individual users

- Approach
  - Apply a process of the brain to bitrate selection in video streaming application
  - The brain can judge even when only incomplete and uncertain information can be obtained
  - User agent using a brain model selects a video bitrate
  - Provide an ABR algorithm according to a user’s preference

Bayesian attractor model (BAM) [7]

- The BAM models a human’s brain
  - Update a internal state \( x \) based on observation \( z \) using the Bayesian inference framework
- Typical conditions \( \phi_1, \ldots, \phi_K \) are defined in advance
- \( \phi_i \) is associated with a fixed point \( \mu_i \) in state space of \( z \) (\( i = 1, \ldots, K \))
- \( \phi_i \) is one of choices in the BAM’s decision making
- Make a decision according to the posterior density which is called "confidence"
- When \( \phi_i \) is selected, the current condition is estimated to be \( \mu_i \)

\[ P(\phi_i|z) > \theta \]

Selected choice
The estimation of the network and application condition

Observation

We evaluate our method in a network environment for simulation. The client device observes estimated available bandwidth and buffer occupancy.

- Observation $x$ is a set of them
- We predefine $K$ conditions $p_1, p_2, \ldots, p_K$ in advance, each of which is also a set of estimated available bandwidth and buffer occupancy.
- The condition expresses that
  - Which bitrate the available bandwidth can accommodate
  - Whether the current buffer is abundant or depleted
- With the BAM, our method estimates which of the predefined condition $p_i$ the current condition is closest to

Comparison

- Whether the average bitrate change is low
- The average bitrate change: How frequent and largely the bitrate switches
- The content of evaluation
- We simulate our proposed method assuming a 5 minute movie in a situation where the available bandwidth changes dynamically.
- We evaluate our method in terms of factors influencing user QoE:
  - How much the video quality is good
  - How frequent and largely the bitrate switches

Performance evaluation

- The content of evaluation
- We simulate our proposed method assuming a 5 minute movie in a situation where the available bandwidth changes dynamically.
- We evaluate our method in terms of factors influencing user QoE:
  - How much the video quality is good
  - How frequent and largely the bitrate switches
- Comparison method
- TCP-Like AIMD [8]: throughput-based ABR algorithm
- BOLA-O [4]: an algorithm used in dash.js which is a client-side reference implementation of MPEG-DASH

Simulation scenario

- Video content for simulation
  - The 5 minute video was encoded at 5 bitrates
  - It is partitioned into 2 second segments
  - ABR algorithms can switch a bitrate every time the download is completed
- Network environment for simulation
  - The average value of available bandwidth is changed every 30s
  - The value is switched to 0, 0.1, 0.2, 1, 2, 0, 2, 4, 0.4, and 0.9 Mbps in order
  - Additionally, we add a different noise to each average value
  - The noise follows a normal distribution having an average of zero and standard deviation of $\sigma_{\text{noise}}$ of each average value
  - $\sigma_{\text{noise}}$ is set to 10% and 30%

Simulation result

- For the average bitrate change (left figure)
  - The changes of the BOLA was larger than that of the other methods
  - In both AIMD and the BAM, the average bitrate change is low
  - The BAM achieves better performance at noise level of 20
- For the average bitrate (right figure)
  - The BAM had the highest results at both noise level of 10, 30

Additionally, we add a different noise to each average value
- The noise follows a normal distribution having an average of zero and standard deviation of $\sigma_{\text{noise}}$ of each average value
Summary and future work

Summary
- We focused on the cognitive model of a human's brain, the Bayesian attractor model (BAM).
- With the BAM, we proposed a method that recognizes the video player's condition and selects an appropriate video bitrate.
- Our computer simulation shows that our proposed method can perform appropriate bitrate control.
  - Even in the situation where network available bandwidth greatly fluctuates.

Future work
- Implement our proposed method in an actual video streaming application.
- Reflect a user's preference for video quality in bitrate selection.
  - Using feedback signal from EEG (Electroencephalogram), our method realizes bitrate selection according to a user's preference.