Implementation of Quantum Decision-Making Based Recommendation Method for Adaptive Bitrate Streaming

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Dynamic Adaptive Streaming

- Switch the rate according to the situation
  - Ex) Low bitrate for the low network throughput
- MPEG-dash (Dynamic Adaptive Streaming over HTTP)
  - Video server retains the multiple video profiles
  - Video divided into segments at regular intervals
  - Player dynamically selects the profile on the user terminal

QoE Control by Agent

- Your own choice
  - Choose something close to what you want
  - Include errors that people easily make
- Agent collects the user’s choice
  - Corrects mistakes while respecting the user’s wishes

QoE Modeling and Challenges

- Quality of experience (QoE) Model
  - Quantify user’s satisfaction for video streaming
  - Factor is basically only the communication quality
- Psychological Effect on QoE
  - User’s behavior includes cognitive bias
    - Ex) Cognitive dissonance
  - Users prefer what they select

Purpose and approach

- Purpose
  - Modeling user’s behavior, including psychological effects
  - Guiding the user to correct selection
- Approach
  - Modeling user by Quantum Decision Making, etc.
  - Induce appropriate selection based on the model

Quantum Decision Making

- Probabilistic decision based on cognitive status
- Cognitive status is modeled as a quantum state
  - Cognitive status changes after decision-making

\[ \psi' = |\alpha_f\rangle \]

Decision Making

Question: A Is True?

Answers: A is False (with Probability 70%)
Quantum State

- **Defined**
  - Quantum state: $|\psi\rangle \in \mathcal{H}$
  - $\mathcal{H}$ is the complex Hilbert Space

- **Superposition**
  - $|\psi\rangle = \psi_1|\psi_1\rangle + \psi_2|\psi_2\rangle$
  - $|\psi_1\rangle, |\psi_2\rangle$: Probability Amplitude

- **Cognitive state as quantum state**

User model by Quantum decision making

- **Cognitive status**
  - Superposition of available video profiles
    - $|\psi\rangle = \psi_0|\psi_0\rangle + \psi_1|\psi_1\rangle + \psi_2|\psi_2\rangle$

- **Decision Making**
  - $P(\alpha_i|\psi_1\rangle$: The probability to select the image quality $\alpha_i$

Quantum Observation

- **Observation value is obtained by quantum observation**
  - Probability of getting value A is probability amplitude
    - $P(\alpha = |A\rangle) = |\psi(\alpha = A)\rangle$

- **Convergence of probability**
  - When value A is observed, the quantum state changes into $|A\rangle$
  - If you do the same measurement immediately after observing A

Decision making as a quantum observation

Cognitive state update

- **Quantum Reinforcement Learning**
  - Amplify the probability amplitude of a particular observation
    - $Q_1(t + s) = Q_1(t) + \alpha Q_1(t)$
  - Steady state
    - $Q_1(t) = (1 - e^{0})|\psi_1\rangle|\psi_1\rangle$

User's State Updates

- **Probability of rational choice is increased by getting more information**
  - Amplify the probability of $Q_1 = \text{argmax} F(q_1)$
    - $F(q_1) = \sum |q_1(t + 1) - q_1(t)| - \lambda_1 \Delta q_1(t) Q_1(t) Q_0(t)$

A Model Behavior: Quantum Zeno effect

- **Choosing the same choice by frequent decision**
  - It has been confirmed by the psychological experiment

Challenges and approach in recommendation

- **Challenges**
  - Frequent recommendation occurs quantum Zeno effect

- **Approach**
  - Waiting until the user's cognitive state changes into the rational decision
  - Consider repeating recommendations
Recommendation Timing Selection

- Minimize the expected time to make the rational choice
  \[ \text{minimize: } E[t \times n] = \frac{t}{p(t)} \]

Implementation

- Extend Dash.js to communicate with recommendation agent
  - Notify the agent of the streaming information
  - Follow the instructions of the agent to perform the recommendation

Evaluation environment

- Video
  - Segment Length: 4 seconds
  - Video Profiles: 10 profiles from 200kbps to 12Mbps

- Network
  - Network emulator limits the bandwidth

- User behavior during recommendation
  - Follow the quantum decision-making model

Result

- Throughput is decreased by the network emulator
  - At time 30, throughput changes from 10Mbps to 4Mbps

Summary and future work

- Summary
  - Modeling user’s bitrate selection by quantum decision making
  - Proposed a method to perform recommendations in a timely manner
  - Implement the recommendation method in the MPEG-DASH

- Future work
  - Study of the agent placement (Edge or Core)
  - A study of fitting method of quantum decision-making model to user