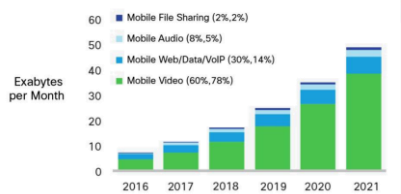
FLEXIBLE USER MODEL FOR HUMAN'S COGNITIVE JUDGMENT IN VIDEO STREAMING APPLICATIONS

Masayoshi Iwamoto, Tatsuya Otoshi,
Daichi Kominami, and Masayuki Murata

Graduate School of Information Science and Technology ,
Osaka University

Background - mobile data traffic explosion

- Rapid increase in the volume of traffic by mobile device[1]
  - From 2016 to 2021, the volume will be sevenfold
  - Video data traffic will account for 75% of the total traffic

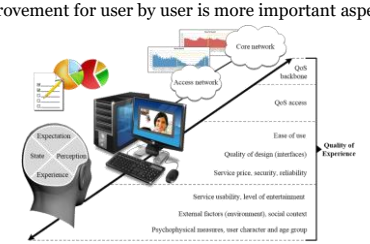


⇨ Guarantee of Quality of Service (QoS) in mobile networks becomes more difficult

[1] Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021.

Background - Quality of Experience (QoE)

- From QoS to QoE
  - QoE is a measure of the overall level of user satisfaction for application
    - Improvement of QoS is not necessary improvement of QoE for a user
    - QoE improvement for user by user is more important aspect



[2] http://www.fpz.unizg.hr/qoe4vr/index.php/2017/06/26/what-is-quality-of-experience-qoe /

Research Goal

- Problem
  - QoE degradation by QoS fluctuation and user's operation
    - e.g. A user watching a video sometimes underestimates the throughput and the delay time and selects higher bitrate video, which degrades user's own QoE
    - Misperception from cognitive limitations of human causes wrong decision
- Goal
  - QoE improvement by detecting and preventing user's wrong operation caused by recognition error of QoS

As a first step, we propose a human's cognition model that reflects misperception characteristics of human to analyze its behavior in video streaming applications

Approach

- 3 steps for creating human's cognition model in video streaming applications
  1. We clarify the reason of why misperception in human brain
  2. We propose a user agent model where the agent observes information about network performance, estimates the probability that observed performance is obtained, and makes some decisions on the operation for a video streaming application
  3. We reveal that the model proposed in step 2. has the misperception features of step 1.

Features in human perception

- Two factor of human perception
  - Probability estimation based on the Bayesian estimation
  - **Decision making from experiences**
    - Decision making from small samples[3]
      - Unwilling to take much time to search for information causes limited short-term memory for decision making
    - Decision making with noisy retrieval from brain memory[4]
      - Human sometimes makes a decision using relevant and irrelevant memory

  → Erroneous decision is made by over-estimation or under-estimation of probability caused by the above 2 reasons

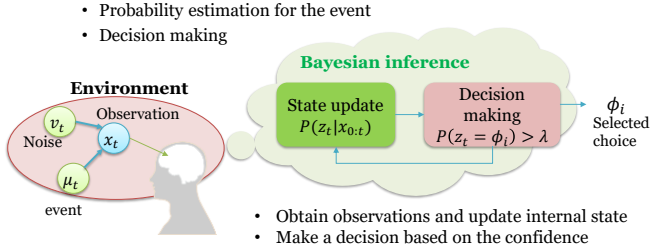
[3] Ralph Hertwig, Timothy J. Pleskac, "Decisions from experience: Why small samples?" Cognition, vol. 115, no. 2, pp. 225-237, 2010.

[4] D. Marchiori, S. Di Guida, and I. Erev, "Noisy retrieval models of over- and under-sensitivity to rare events," Decision, vol. 2, no. 2, pp. 82-106, 2015.

Human's cognition model

x_t : Observation
z_t : State
ϕ_i: i^{th} choice
λ : Confidence threshold

- Bayesian Attractor Model (BAM)[5]
  - represents human-brain's perceptual decision making
    - Event sensory
    - Probability estimation for the event
    - Decision making



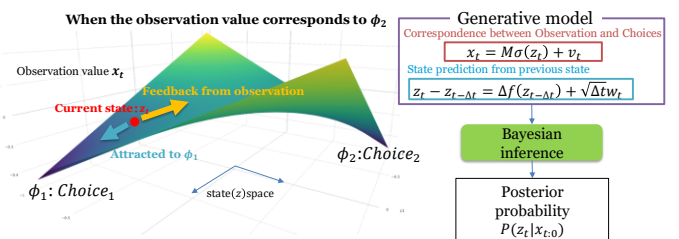
- Obtain observations and update internal state
- Make a decision based on the confidence

[5] S. Bitzer, et. al, "A Bayesian attractor model for perceptual decision making," *PLOS Computational Biology*, vol. 11, no. 8, Aug. 2015.

State update in BAM

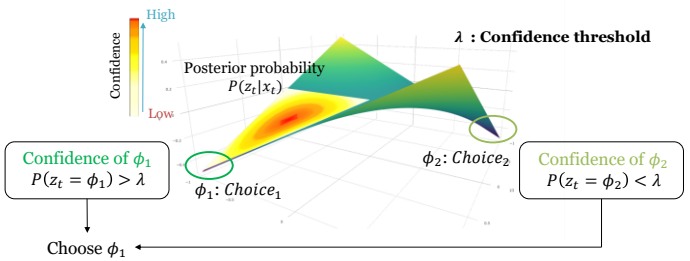
M:Observation matrix
σ: Sigmoid function
f: Hopfield dynamics
v_t, w_t: Noise

- Update the state every time BAM obtains observation value
  - To approach decision-making state corresponding to observation
  - To be attracted to the choice close to the current state



Decision making in BAM

- Calculate posterior probability as a confidence of a choice
- Choose a choice with higher confidence than threshold λ



Simulation for validation

- Run simulation of BAM to see if a feature appearing in people who make a decision based on small observation information can be captured by BAM or not
  - The feature is "The smaller the observation information is, the lower the accuracy rate becomes"[3]
  - The accuracy rate corresponds with the height of confidence in BAM
  - The number of observation information corresponds with the time taken for decision-making
- Consider the correspondence between the two tradeoffs
  - The smaller the observation information is, the lower the accuracy rate becomes
  - The shorter the time taken for decision-making is, the lower confidence threshold becomes

[3] Ralph Hertwig, Timothy J. Pleskac, "Decisions from experience: Why small samples?" Cognition, vol. 115, no. 2, pp. 225-237, 2010.

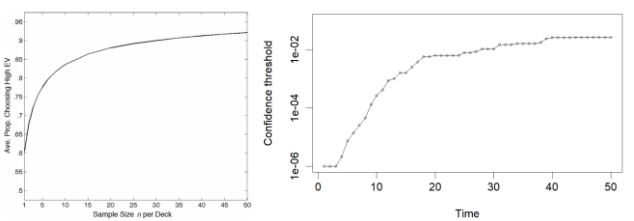
Simulation scenario

- The feature "The smaller the observation information is, the lower the accuracy rate becomes" [3]
  - A problem of choosing higher payoff distributions (decks) from two decks.
  - Each deck consisting of two outcomes of the type a probability p to win amount x; otherwise win amount y
  - (x, p, y) randomly sampled from certain range
- BAM
  1. Prepare an environment where there are three choices.
  2. At first, BAM receives observation value corresponding to ϕ_1, and the state is shifted to a state where ϕ_1 is adopted.
  3. After this, BAM receives Observation value corresponding to another choice B. The confidence of ϕ_2 changes.
  4. Then, the time taken for making decision ϕ_2 is measured for various confidence threshold

[3] Ralph Hertwig, Timothy J. Pleskac, "Decisions from experience: Why small samples?"

Result

- Left figure [3]: the rate of correct making-decision for the number of observation in the feature "decision making from small samples"
- Right figure: the time taken for decision-making for the height of confidence threshold in BAM



[3] Ralph Hertwig, Timothy J. Pleskac, "Decisions from experience: Why small samples?"

Conclusion

- We propose a human's cognition model
  - We show that our proposed model show the typical characteristics of human's misperception
  - By adjusting confidence threshold of the model, different behaviors of individual user's can be modelled
- Future work
  - Consider expressing the feature of Decision making with noisy retrieval from brain memory[4] with BAM
  - Capture the features of human perception by BAM with fitted parameter and prevent human error of misrecognition