Beyond the Content: Considering the Network for Online Recommendation

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Background & Motivation

- Short video apps have become extremely popular.
  - Tiktok, Shorts on Youtube, Kuaishou, etc.
  - Nearly 2h of average daily viewing time [1].
- Attractive to users, easy to view videos
  - Sports, make-up, daily life, etc.
  - Swipe, click, etc.
- Video viewing time $\uparrow \rightarrow$ display opportunity of products $\uparrow \rightarrow$ revenue $\uparrow$

1. The 50$^{th}$ Statistical Report on China’s Internet Development
Background & Motivation

The quality of video recommendation determines the viewing time of users!
Background & Motivation

- A request fetches 6 videos in 3s typically.
Background & Motivation

• The difference in transmission time between videos is large
  • The difference in video duration between 90\textsuperscript{th} and 10\textsuperscript{th} is 1.769s at 1Mbps bitrate and 1MBps bandwidth.

Cooperate with the network conditions to achieve greater video playing time
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NetRec Overview

- **Sorted Video Set**
  - Video 1
  - Video N
  - Video X

- **Candidate Set**
  - Video 1
  - Video M
  - Video N

- **Network Measurement**
  - Bandwidth
  - Client
  - Server
  - $\text{ddl: } T \text{ s}$

- **Video Quality Estimation**
  - Multi-objective Re-ranking
Video Quality Estimation

We do not change the internal recommendation mechanism of the model.
Multi-objective Re-ranking

How to choose $M$ videos?

$M$ videos (half of $N$)

The highest total video quality of $M$ video

Choose or not.

Choose or not.

$$\max_{i=1 \ldots M} \sum_{i=1}^{M} E_{\text{Video}[i]} x_{\text{video}[i]}$$

$$\sum_{i=1}^{M} T_{\text{Video}[i]} x_{\text{video}[i]} \leq T_{\text{overall}}, x_{\text{video}[i]} \in \{0, 1\}$$

Total transmission time of $M$ videos

$T$ Deadline

Video playing time estimated by models

Video 1

Video 2

Video 3

Video N

Video 1

Video 2

Video 3

Video N

Video 1

Video 2

Video 3

Video N

Video 1

Video 2

Video 3

Video N

Video 1

Video 2

Video 3

Video N
Multi-objective Re-ranking

\[
\max_{i=1 \ldots M} \sum_{i=1}^{M} E_{\text{Video}[i]} x_{\text{video}[i]}
\]

\[
\sum_{i=1}^{M} T_{\text{Video}[i]} x_{\text{video}[i]} \leq T_{\text{overall}}, x_{\text{video}[i]} \in \{0, 1\}
\]

Candidate Set

\(\times\) videos Set

Knapsack Algo.

How to map the corresponding relationship?

**Weight of good \(i\)**

**Value of good \(i\)**

**Capacity of the Knapsack**

\(T_{\text{Video}[i]}\)

\(E_{\text{Video}[i]}\)

\(T_{\text{overall}}\)
Network Measurement

Server

Bandwidth

Data size, txTime

Client

Network Measurement

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Evaluation

• Dataset
  • KuaiRec [1], 10K videos watched by millions of users

• Metrics
  • The real playing time of the displayed videos, also called $\textit{revenue}$

• Schemes Compared with Baseline
  • Choose top-$M$ videos with highest video quality

• Network Environments
  • Lab LAN
    • Server and client are directly connected through 1Gbps cables and several switches.
  • Campus Network
    • 40K users, about 10K wired and wireless switches and routers.
  • Internet
    • The server and the client locates in Nanjing and Changsha, respectively.

1. https://kuairec.com/
Evaluation—Testbed Setup

In Baseline, the top $M$ videos will be selected in descending order according to video quality.
Evaluation—Overall Performance

RQ1: Can NetRec improve the overall recommendation revenue in different network conditions?

• Improvement of Revenue
  • 109.29%-12357.31% in 0-2MBps, 13.26%-1545.86% in 2-10MBps, 0.18%-72.82% in 10-150MBps.
  • Improve the revenue more under small bandwidth.

• Improvement of successful transmission rate
  • NetRec reduces the timeout ratio regardless of the network environment and bandwidth.
Evaluation—Bandwidth Estimation

RQ2: How does the bandwidth estimation algorithm affect the overall performance?

- Improve revenue even at bandwidth estimation error
- The worse the network, the larger the influence of bandwidth estimation error on performance.

Improving the accuracy of bandwidth estimation is valuable.

- 10% estimation error results in up to 15% decrease in revenue at 1MBps, still achieves 162% improvement compared to Baseline.
Evaluation—Multi-objective Re-ranking

RQ3: How does the multi-objective re-ranking algorithm affect the overall performance?

• Comparison with other two greedy algorithms
  • Greedy1: video quality divided by time desc
  • Greedy2: transmission time asc
• Greedy2 performs better than Greedy1, and Greedy1 performs similarly to our knapsack algorithm.

The inaccurate video quality limits the ability of the re-ranking algorithm to select better videos?
RQ3: How does the multi-objective re-ranking algorithm affect the overall performance?

- Replace estimated \( PlayingTime \) with the optimal \( PlayingTime \) in NetRec and Baseline.
- Achieve more benefits to optimize the multi-objective re-ranking algorithm as the improvement of the accuracy of estimated video playing time in the recommendation models.
  - Greedy2 is worse than Baseline, not considering video quality.
  - The Knapsack algorithm performs better than Greedy1.
Evaluation—Ideal Quality Estimation

RQ4: Can NetRec still be effective as the content recommendation algorithm becomes increasingly accurate?

- Replace \( \text{estimatedPlayingTime} \) with the optimal \( \text{PlayingTime} \) in NetRec and Baseline.
- Achieve 3% to 12% revenue improvement → the lower bound of NetRec’s revenue improvement in Campus Network.
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Conclusion

- NetRec is the first framework to take network information into short video recommendation.
  - Overall Performance: 109.29%-12357.31% in 0-2MBps, 13.26%-1545.86% in 2-10MBps, 0.18%-72.82% in 10-150MBps.
  - Even though the model estimation accuracy reaches 100%, NetRec can still bring a revenue improvement.

- There are some problems worth future study.
  - It’s necessary to improve the accuracy of bandwidth estimation.
  - How to cooperate with the transport layer?
  - Can video information from the application layer be used to accelerate the transmission of the transport layer?
Thanks for listening!

Q & A

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