Popularity Prediction of Facebook Videos for Higher Quality Streaming

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Videos are Central to Facebook
8 billion views per day

9-year old singing on America’s Got Talent
44M views

Black bear roaming in Princeton
3.8K views

Small shop making frozen yogurt
122 views
Workflow of Videos on Facebook

Intensive processing needed to create multiple video versions for ABR streaming
Better Video Streaming from More Processing

• Better compression at the same quality
• QuickFire: 20% size reduction using 20X computation
• More users can view the high quality versions
Better Video Streaming from More Processing

• Better compression at the same quality
• QuickFire: 20% size reduction using 20X computation
• More users can view the high quality versions
How to apply QuickFire for FB videos

• Infeasible to encode all videos with QuickFire
  – Increase by 20X the already large processing fleet

• High skew in popularity
  – Reap most benefit with modest processing?
Opportunity: High Skew in Popularity

- Access logs of 1 million videos randomly sampled by ID
- Watch time: total time users spent watching a video

![Graph showing cumulative watch time ratio against video rank]
Opportunity: High Skew in Popularity

• We can serve most watch time even with a small fraction of videos encoded with QuickFire
• Can we predict these videos for more processing?

80%+ watch time
CHESS Video Prediction System

• Popularity prediction is important for higher quality streaming
  – Direct encoding on videos with the largest benefit

• Goal of CHESS video prediction system
  – Identify videos with highest future watch time
  – Maximize watch-time ratio with budgeted processing
CHESS Video Prediction System

Streaming Video Engine

Backend Storage

CDN

Predicted Popular Videos

CHESS-VPS

Access logs

Social signals

Facebook Graph Serving System
CHESS Video Prediction System

Streaming Video Engine
- Original
- QuickFire Encoded

Backend Storage

CDN

Predicted Popular Videos

CHESS-VPS

Access logs

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Facebook Graph Serving System
CHESS Video Prediction System

Streaming Video Engine

Backend Storage

Serving QuickFire-encoded versions!
Requirements of CHESS-VPS

• Handle working set of ~80 million videos
• Generate new predictions every few minutes
• Requires a new prediction algorithm: CHESS!
CHESS Key Insights

• Efficiently model influence of past accesses as the basis for scalable prediction

• Combine multiple predictors to boost accuracy
Efficiently model past access influence

- Self exciting process
  - A past access makes future accesses more probable, i.e. provides some influence on future popularity

![Influence of past accesses](chart)
Efficiently model past access influence

• Self exciting process
  – A past access makes future accesses more probable, i.e. provides some *influence* on future popularity
  – Prediction: sum up total future influence of all past accesses
Efficiently model past access influence

- Influence modeled with kernel function
- Power-law kernel used by prior works
  - Provides high accuracy
  - Scan all past accesses, O(N) time/space not scalable

\[
y = (x + \beta)^{-\alpha}
\]
Efficiently model past access influence

- Influence modeled with kernel function
- Power-law kernel used by prior works
- Key insight: use exponential kernel for scalability

\[
y = \exp\left(-\frac{x}{w}\right)
\]

\[
y = (x + \beta)^{-\alpha}
\]
Efficiently model past access influence

• Self exciting process with the exponential kernel

\[
\tilde{F}(t) = \frac{x}{w} + \exp \left( \frac{-(t - u)}{w} \right) \tilde{F}(u)
\]

Current Access Watch-time + Exponential Decay × Previous Prediction
Efficiently model past access influence

- Single exponential kernel is less accurate than power-law kernel
  - 10% lower watch time ratio

- O(1) space/time to maintain

Single exponential kernel is less accurate yet scalable
Combining Efficient Features in a Model

- Key insight: maintain multiple exponential kernels
- $O(1)$ space/time

Combining multiple exponential kernels is as accurate as a power-law kernel
Combining Efficient Features in a Model

Raw features

- Past access watch-time
- Likes
- Comments
- Shares
- Owner likes
- Video age

Multiple Kernels

Directly-used Features

Neural Network

Future Popularity

Social signals further boosts accuracy
CHESS Video Prediction System

Access logs

Shard\(_1\)

Shard\(_2\)

Shard\(_3\)

Shard\(_4\)

Streaming

Prediction workers

Worker\(_1\)

Worker\(_2\)

Worker\(_3\)

Worker\(_4\)

NN Models

Model

Model

Aggregated top videos

Aggr

Client

Client
Evaluation

• What is the accuracy of CHESS?

• How do our design decisions on CHESS affect its accuracy and resource consumption?

• What is CHESS’s impact on video processing and watch time ratio of QuickFire?
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• How do our design decisions on CHESS affect its accuracy and resource consumption?

• What is CHESS’s impact on video processing and watch time ratio of QuickFire?
Metrics

• Watch time ratio
  – Ratio of watch time from better encoded videos
  – Directly proportional to benefits of better encoding

• Processing time
Metrics

• **Watch time ratio**
  – Ratio of watch time from better encoded videos
  – Directly proportional to benefits of better encoding

• **Processing time (infeasible to encode all videos)**
  – Video length $\propto$ processing time
  – Video length ratio $\approx$ computation overhead
CHESS is Accurate

- Vary video length ratio (proxy for processing overhead)
- Observe watch time ratio of better encoded videos
CHESS is Accurate

- **Initial(1d):** initial watch time up to 1 day after upload
CHESS is Accurate

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- SESIMIC: handcrafted power-law kernel
CHESS is Accurate

- **Initial(1d)**: initial watch time up to 1 day after upload
- **SESIMIC**: handcrafted power-law kernel

CHESS provides higher accuracy than even the non-scalable state of the art
CHESS Reduces Encoding Processing

- Predict on whole Facebook video workload in real-time
- Sample 0.5% videos for actual encoding

CHESS reduces CPU by 3x (54% to 17%) for 80% watch time ratio
## Related Work

### Popularity Prediction
- Hawkes'71, Crane'08, Szabo'10, Cheng'14, SEISMIC'15
- CHESS is scalable and accurate

### Video QoE Optimization
- Liu'12, Aaron'15, Huang'15, Jiang'16, QuickFire'16
- Optimize encoding with access feedback

### Caching
- LFU‘93, LRU’94, SLRU‘94, GDS’97, GDSF‘98, MQ’01
- Identify hot items to improve efficiency
Conclusion

• Popularity prediction can direct encoding for higher quality streaming

• CHESS: first scalable and accurate popularity predictor
  – Model influence of past accesses with $O(1)$ time/space
  – Combine multiple kernels & social signals to boost accuracy

• Evaluation on Facebook video workload
  – More accurate than non-scalable state of the art method
  – Serve 80% user watch time with 3x reduction in processing