ExCamera
[a one-second video encoder]

Keith Winstein

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Assistant Professor of Law (by courtesy)

Stanford (with collaborators at UCSD)
Video editing in 2006
Results
Video editing: 0.5–10 \times \{ \text{duration of video} \}
Hi Keith Weinstein:

Due to a copyright takedown notice that we received, we had to take down your video from YouTube:

Video title: Public Domain Test Movie
Video url: http://www.youtube.com/watch?v=5PoPaxDsA8I
Takedown issued by: Universal Pictures (ZEFR)

This means that your video can no longer be played on YouTube, and you may have lost access to some features of YouTube.

You received a copyright strike
Dear Keith Winston,

Thank you for your counter notification. It has been forwarded to the party that sent the takedown notification.

If we receive no response, your material will be restored in 10 to 14 business days from today. Please understand that submitting additional counter notifications for this URL will not accelerate your video’s reinstatement.
Hello,

Thank you for your counter-notification. It appears that you do not have the necessary rights to post the content on YouTube. Therefore, we regretfully cannot honor your request.

Please take some time to review the educational information in our Copyright Center.

Keep in mind that a copyright strike may expire in 6 months, subject to certain conditions, as long as no additional copyright strikes are received during that time.

We unfortunately are unable to assist further in this matter.

Regards,

The YouTube Legal Support Team
[email colleagues who work at Google]
Hello,

In accordance with the Digital Millennium Copyright Act, we’ve completed processing your counter-notification regarding these video(s):

- [http://www.youtube.com/watch?v=5P0PaxDsA8I](http://www.youtube.com/watch?v=5P0PaxDsA8I)

This content has been restored unless you have deleted the video(s). Your account will not be penalized.

Regards,

The YouTube Legal Support Team
Options for online video editing

- Edit locally, encode, then upload
  - $O(n)$ encode + $O(n)$ upload

- Share all raw media, edit locally, share EDL
  - $O(n)$ upload

- Upload raw media, edit online
  - $O(n)$ upload + $O(n)$ encode
ExCamera: MapReduce for video

- **map:** “for all frames”
  - select which frames
  - per-frame operations (crop, color, convolve)

- **reduce**
  - encode back to a video

- **Goal:** encode a one-hour movie in one second
Platform for distributed video processing

- 3,600 threads
- Each thread runs for one second
- On AWS lambda $\rightarrow$ $0.09
Challenges to parallelism

- **map**: easy to parallelize
  - frame fetch and transform are independent ops
- **reduce**: hard to parallelize
Strategies for parallel video encoding

- **Tile within frame**
  - Used by H. 265, VP9
  - Limits predictions across boundary
  - Limited number of tiles

- **Split video into contiguous chunks**
  - Used by Netflix
  - Dependency fence at boundary
    [aka SAP, closed GOP, key frame]
Rule of Thumb

In coded video, every dependency fence costs $1/2$ second of filesize.
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In coded video, every dependency fence costs $\frac{1}{2}$ second of filesize.

1/2-second parallelism $\Rightarrow$ waste $= 100\%$
Our vision: enjambing encoder
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Stanza: To poets en-jambment refers to de-coupling the syntax (phrase endings) from line breaks as written. Ex-Camera's "en-jambing" en-coder de-couples the video syntax from how many threads get run.
Our vision: enjambing encoder

- Decouple parallelism at runtime from fences in output
- Allow encoder thread to begin from prior state
- Result: playable video with efficient coding
Goal: MapReduce-like language to manipulate video in cloud

Economics of lambda (and similar services) makes interactive processing possible

Challenge: runtime parallelism in tension with good output

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