ExCamera
[a one-second video encoder]

Keith Winstein

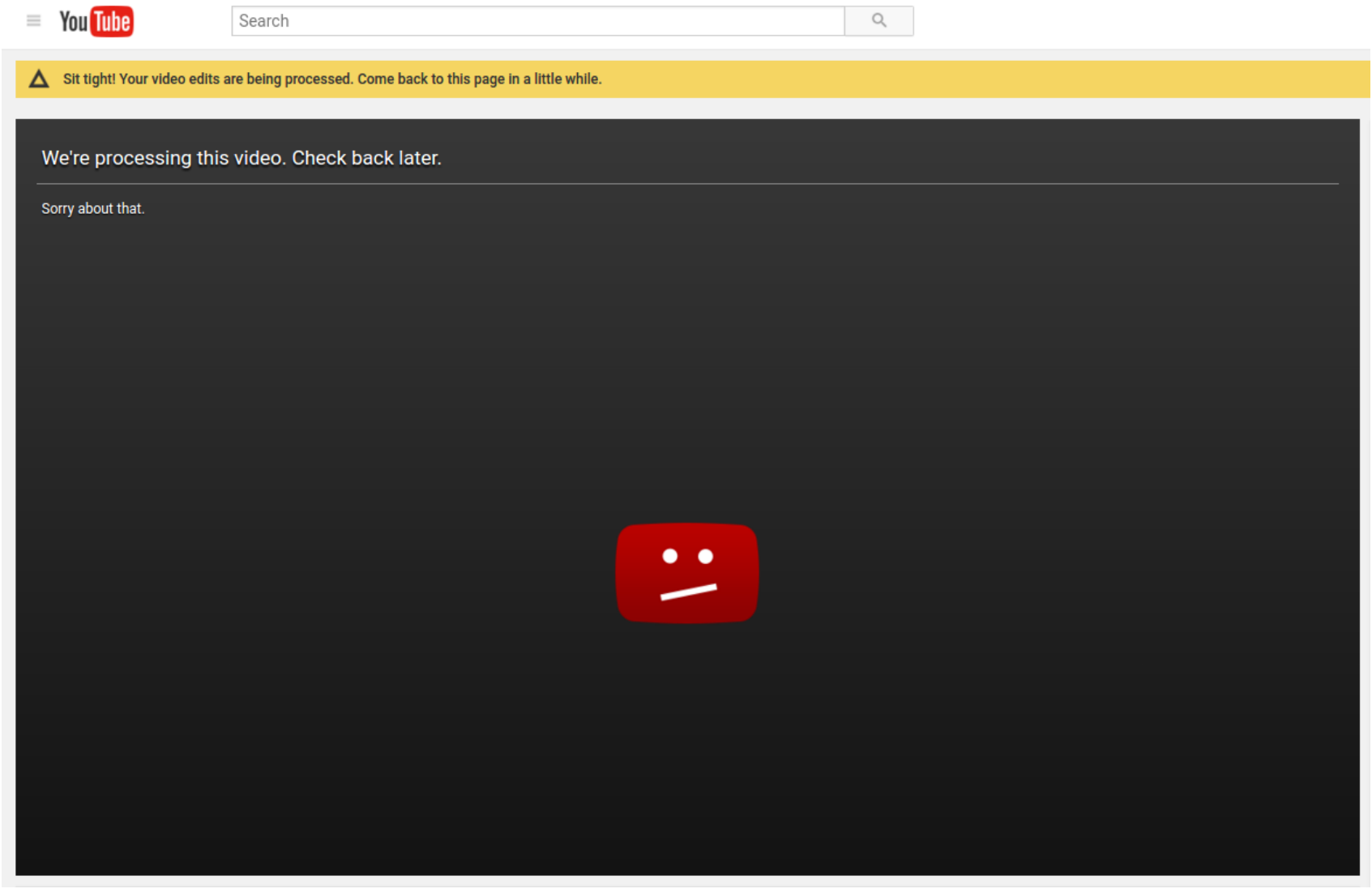
Assistant Professor of Computer Science
Assistant Professor of Law (by courtesy)

Stanford (with collaborators at UCSD)

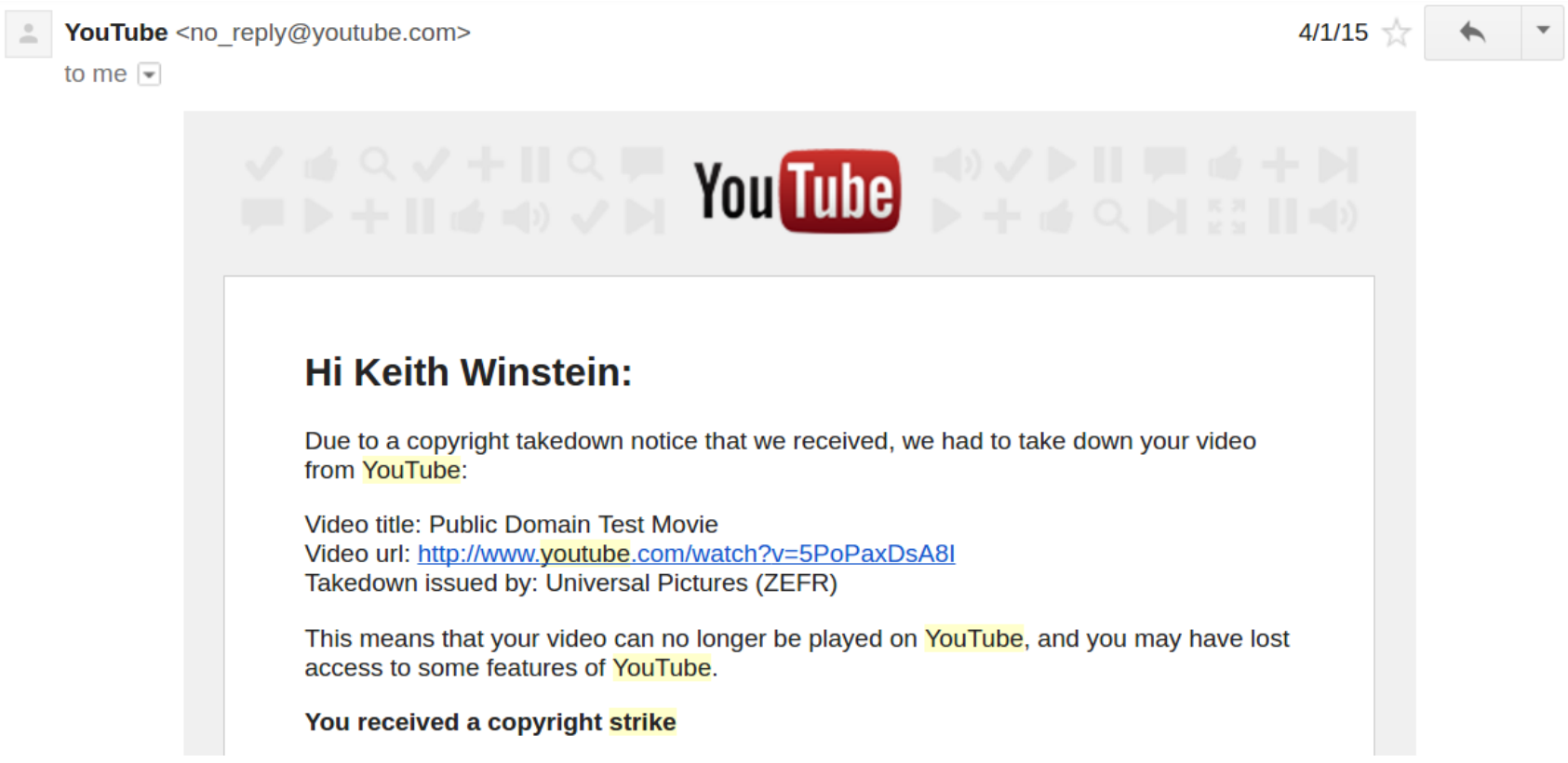
Video editing in 2006

Results

Video editing: 0.5–10 × { duration of video }



Video editing online (cont.)



YouTube <no_reply@youtube.com> 4/1/15

to me

YouTube

Hi Keith Winstein:

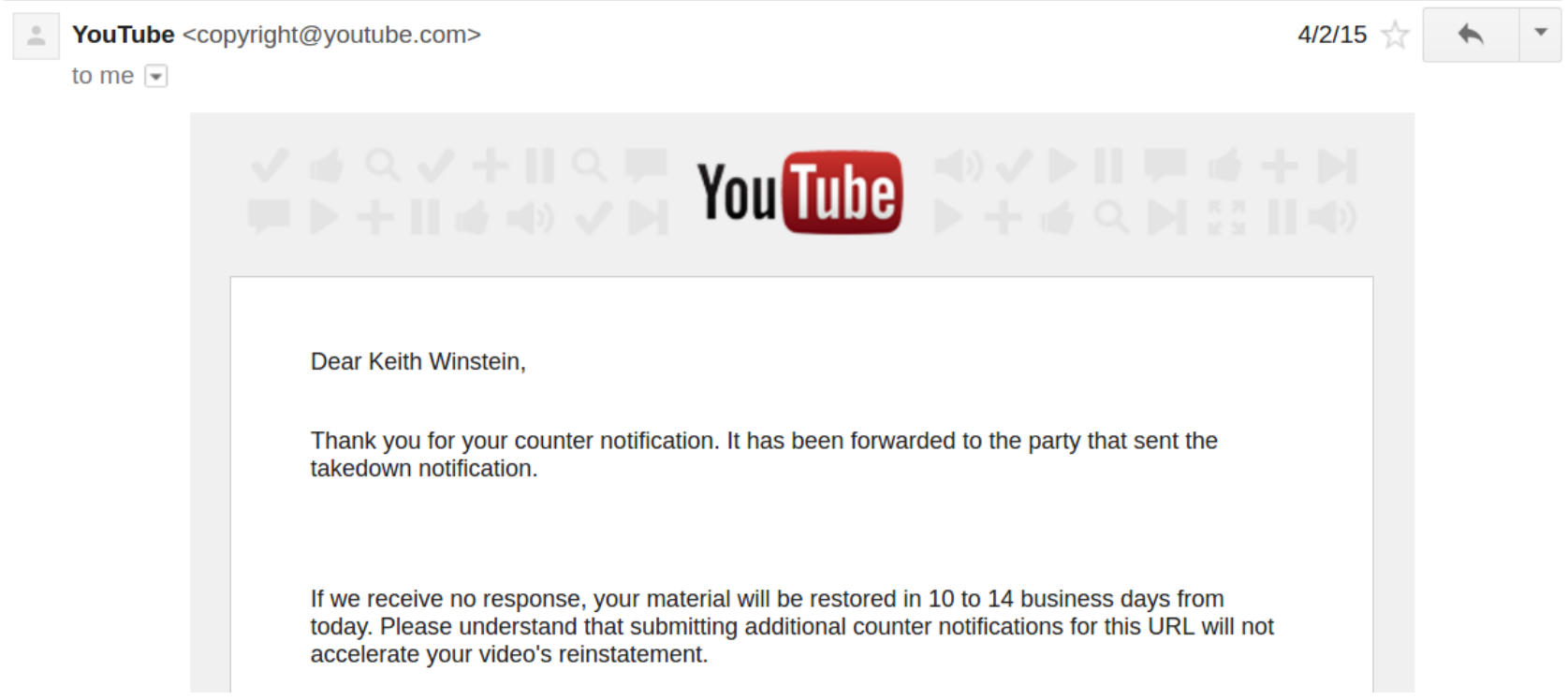
Due to a copyright takedown notice that we received, we had to take down your video from YouTube:

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

Video editing online (cont.)



YouTube <copyright@youtube.com> 4/2/15

to me

YouTube

Dear Keith Winstein,

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.

Video editing online (cont.)

copyright@youtube.com 5/1/15

to me

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

Video editing online (cont.)

[email colleagues who work at Google]

Video editing online (cont.)

copyright@youtube.com 7/13/15

to me

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=5PoPaxDsA8I

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 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 re-
fers 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

ExCamera

- 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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