

Why is sports photography hard?

(and what we can do about it using
computational photography)

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Sports photography operates
at the edge of current camera
performance and portability.

Computational techniques
might be able to help,
but it won't be easy.

What this talk is about

- ◆ sports, especially team sports on fields or in arenas
- ◆ what is challenging about photographing these sports
- ◆ the affordances and limitations of today's cameras
- ◆ opportunities for computational photography



What this talk is not about

- ◆ technical photography
 - e.g. finish-line slit photographs
- ◆ sports photography using point-and-shoot cameras
 - shutter lag makes it almost impossible
- ◆ non-sports action photography, family & recreation
 - harder to generalize about
- ◆ sports videography
 - except to the extent video could help still photography
- ◆ making every shot count
 - that's impossible; goal is to improve from 1 in 100 to 10 in 100
- ◆ once-in-a-lifetime shots
 - you can't plan for them

Once-in-a-lifetime shots



(Jerry Lodriguss)



(Dave Black)



◆ and extreme sports

Why is sports photography hard?

- ◆ sports move fast
- ◆ fields are big, arenas are dark
 - you don't control the subject distance or the lighting
- ◆ you barely control the composition
 - long lenses compress the perspective
 - put yourself in the right place at the right time
 - know the game, know the players
- ◆ spray and pray
 - take 2000 pictures in a typical game
- ◆ post-process
 - big disk, fast computer, good workflow
 - mine is Lightroom + Photoshop



Lightroom



- ◆ browsing, ratings, color labels, syncing across computers, etc.
- ◆ common tools are well done: white balance, exposure, touchups

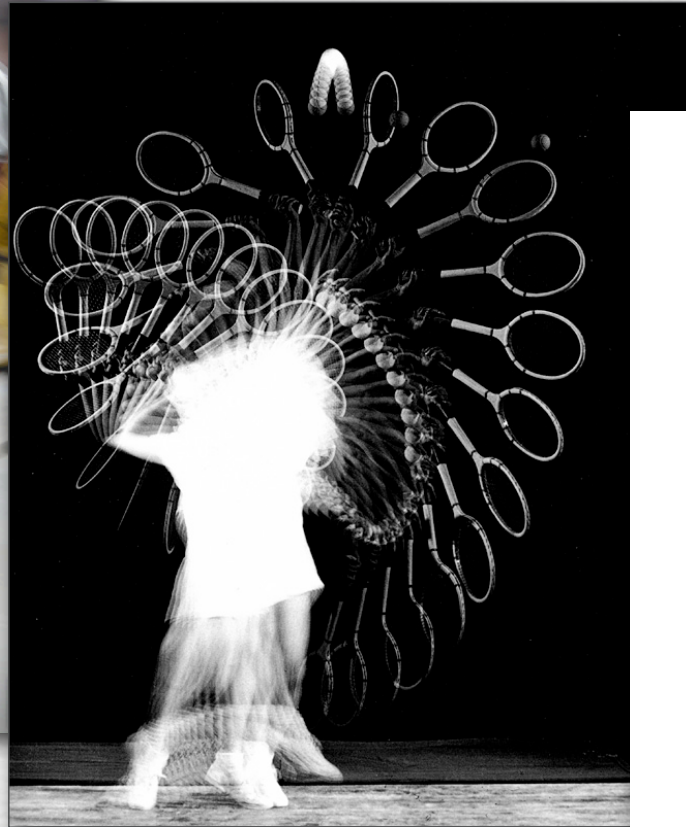
Ways of handling fast motion

(David Laird)



panning

(Harold Edgerton)



strobing

(Lois Greenfield)



freezing

- ◆ for most sports, “freezing” is the most interesting view
 - it’s also the easiest to capture reliably

Photographic variables

- ◆ shutter speed
- ◆ aperture
- ◆ ISO and noise
- ◆ focal length
- ◆ megapixels
- ◆ pixel size
- ◆ camera body
- ◆ metering/focusing modes
- ◆ frame rate
- ◆ burst size
- ◆ focus
- ◆ depth of field
- ◆ autofocusing

Shutter speed

Women's
volleyball

(Canon 1D III,
1/800 second)



- ◆ 1/1000 is min for typical framing and fast human motion
 - kicks, strokes, spikes, punches require 1/2000 or higher

Aperture

out of focus

Women's
volleyball

(Canon 1D III,
1/800 second,
ISO 3200, f/2.8)

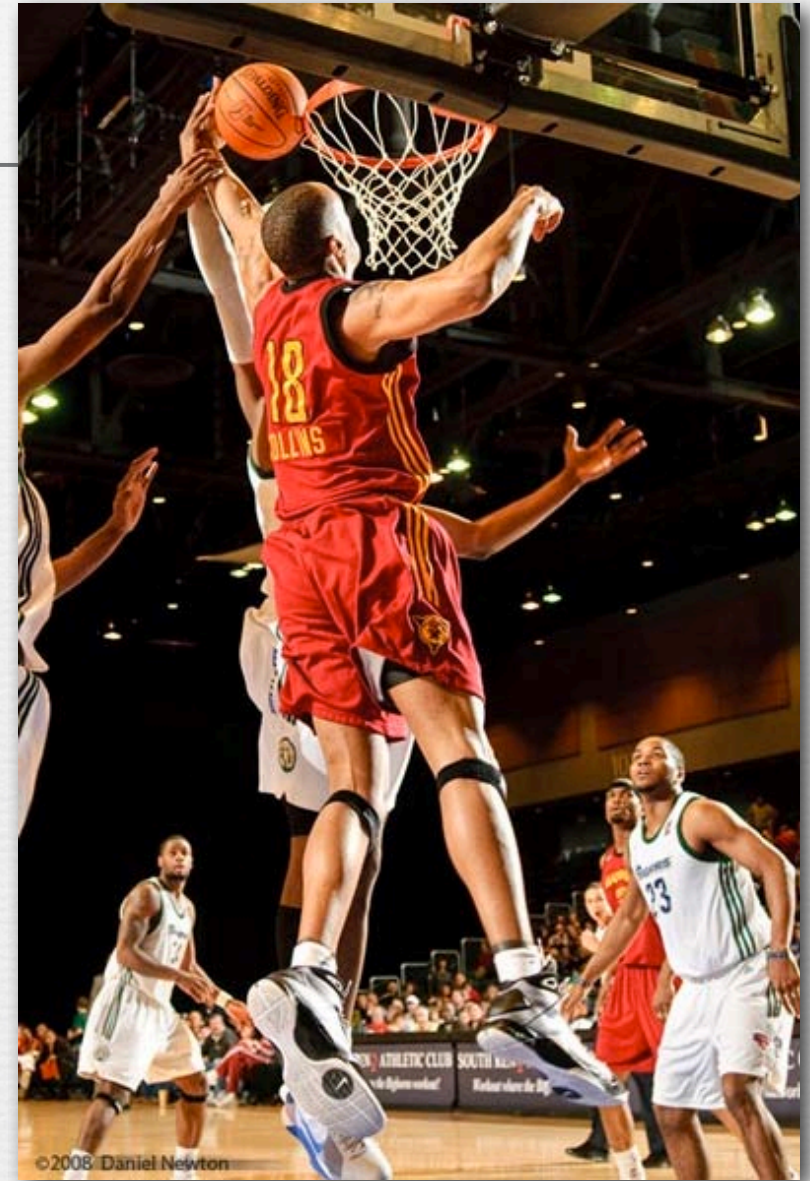


- ◆ fighting for every photon, so wide open (“big glass”)
- ◆ sacrifices depth of field even when you don't want to

ISO

Women's
volleyball

(Canon 1D III,
1/800 second,
ISO 3200)



- ◆ can sometimes control stadium strobes to add light

ISO and noise

Women's
gymnastics

(Canon 7D,
1/1000 sec,
ISO 3200,
f/1.8, 85mm)



original



denoised in
Lightroom 2

◆ with mild denoising,
ISO 3200 is fine on
high-end cameras

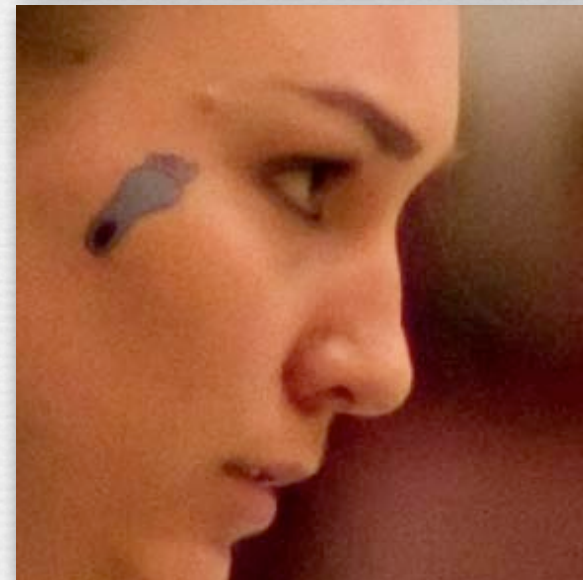
ISO and noise

Women's
gymnastics

(Canon 7D,
1/1000 sec,
ISO 3200,
f/1.8, 85mm)



original



denoised in
Noise Ninja

◆ with mild denoising,
ISO 3200 is fine on
high-end cameras

Focal length



Canon 600mm/4.0
\$8,000, 12 lbs

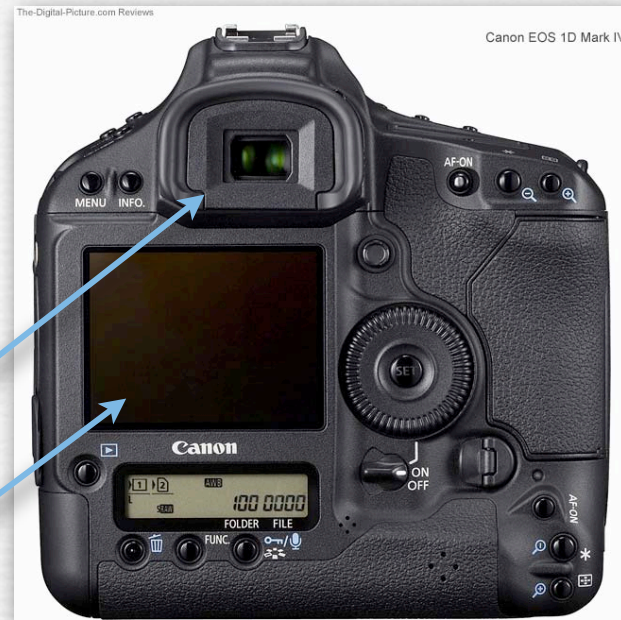


monopod



- ◆ the right view often means shooting from far away
- ◆ long lenses are heavy, and they compress perspective

Physical affordances



- ◆ optical viewfinder
 - infinite resolution, dynamic range
- ◆ small LCD, because you seldom have time to look
- ◆ 2nd set of shutter controls when rolled for vertical shots
- ◆ large and heavy, especially the battery, circa 1500 shots

Other useability considerations



**CANON 1DX
HAS WIFI & BT**

- ◆ analog “fighter pilot” controls, so requires lots of practice
- ◆ shoot RAW, M or Av, autofocus (AF) on, stabilization (IS) off
- ◆ hard to change lenses, so professionals carry multiple bodies
- ◆ few professionals use zooms - no time to fiddle, smaller aperture
- ◆ ~~why no radio to upload the “decisive moment” to your publisher?~~

Megapixels and pixel size

Canon 1D Mark III
\$3,800, 10 Mpix, 10 fps
 $7.2\mu \times 7.2\mu$ pixels

compare to 6.4μ
on 21Mpix 5DII



- ◆ modest # of megapixels
 - but the pixels are big, which means less noise in low light
 - also permits fast readout, hence frame rate, and small files
- ◆ crop factor is $1.3\times$ (APS-H)
 - not full-frame, which is too slow to read out
 - not $1.6\times$ like APS-C format, which gathers less light

Frame rate and burst size

Canon 1D Mark IV
\$5,000, 16 Mpix, 10 fps
5.7 μ × 5.7 μ pixels
“standard” ISO to 12,800



- ◆ frame rate is (probably) limited by readout rate
 - 16 Mpix × 10fps × 16-bit pixels = 320 MB/s
 - mirror flip and shutter reset may also be limiters
 - shutter life is > 300,000 (only 150 games!)
- ◆ burst size is limited by writing to card
 - 121 JPEG or 28 RAW shots before buffer is full

Frame rate

Men's water
polo

(Canon 1D III,
1/2000 sec,
ISO 200,
f/4.5, 300mm)



+0.0s

Frame rate

Men's water polo

(Canon 1D III,
1/2000 sec,
ISO 200,
f/4.5, 300mm)



+0.1s

Frame rate

bursts are not identified
on any current camera,
so it's hard to find them

Men's water
polo

(Canon 1D III,
1/2000 sec,
ISO 200,
f/4.5, 300mm)



+0.2s

◆ even 10fps is not fast enough for many sports

Another example

Women's
soccer

(Canon 1D III,
1/1600 sec,
ISO 200,
f/4, 300mm)



+0.0s

Another example

Women's
soccer

(Canon 1D III,
1/1600 sec,
ISO 200,
f/4, 300mm)

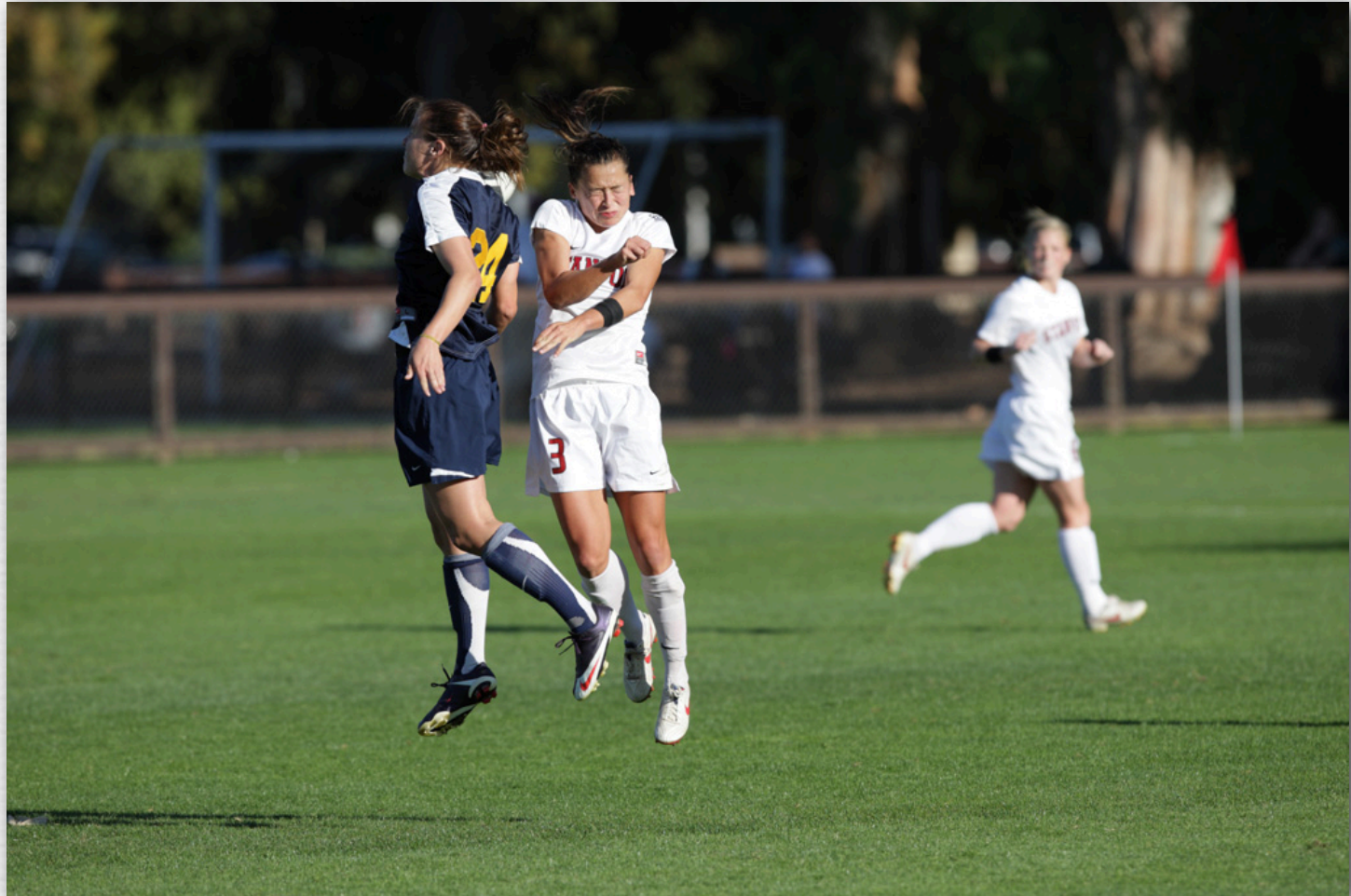


+0.1s

Another example

Women's
soccer

(Canon 1D III,
1/1600 sec,
ISO 200,
f/4, 300mm)



+0.2s

Another example

Women's
soccer

(Canon 1D III,
1/1600 sec,
ISO 200,
f/4, 300mm)



+0.3s

◆ argh, missed again!

Another example

might be able to adjust shutter speed in next frame based on motion blur in current frame

Women's
soccer

(Canon 1D III,
1/1600 sec,
ISO 200,
f/4, 300mm)



+0.4s

- ◆ motion estimation / optical flow is unlikely to work
 - to adjust shutter speed, perform denoising, view interpolation,...

Nailing the shot: could the camera help?

- ◆ detect the ball, detect faces, trigger when they are close
- ◆ but can't capture 60fps burst at full res on today's cameras, so must be detectable from low-res viewfinder stream

-
- ◆ if cameras were faster, could capture a 60fps burst at full-res and save the decision. Moore's Law will help

- ◆ or let the photographer choose which frames to save (like Casio EX-F1), but when do they have time for this?

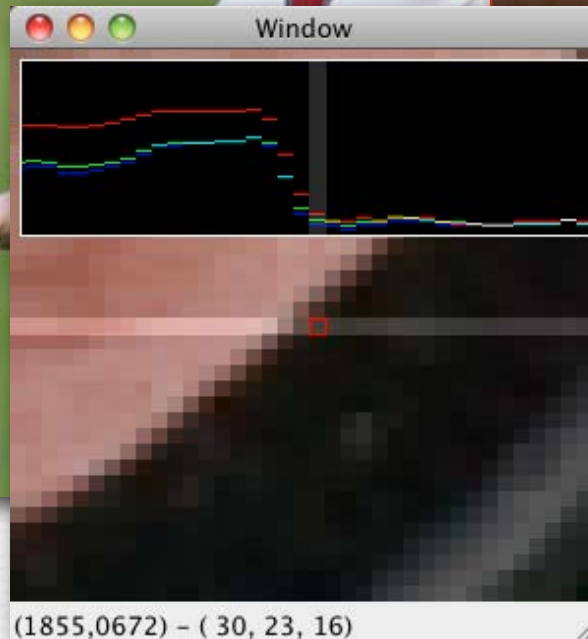
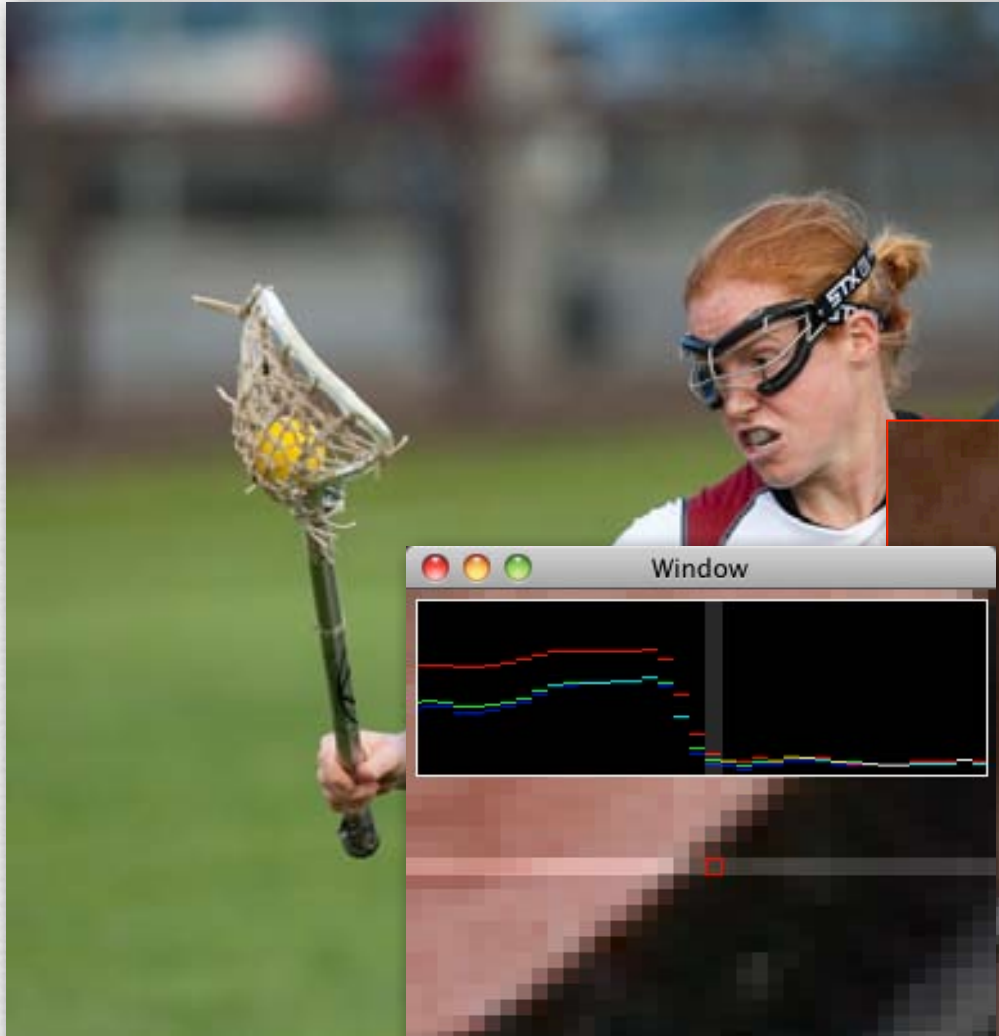


(Hector Garcia-Molina)

Focus

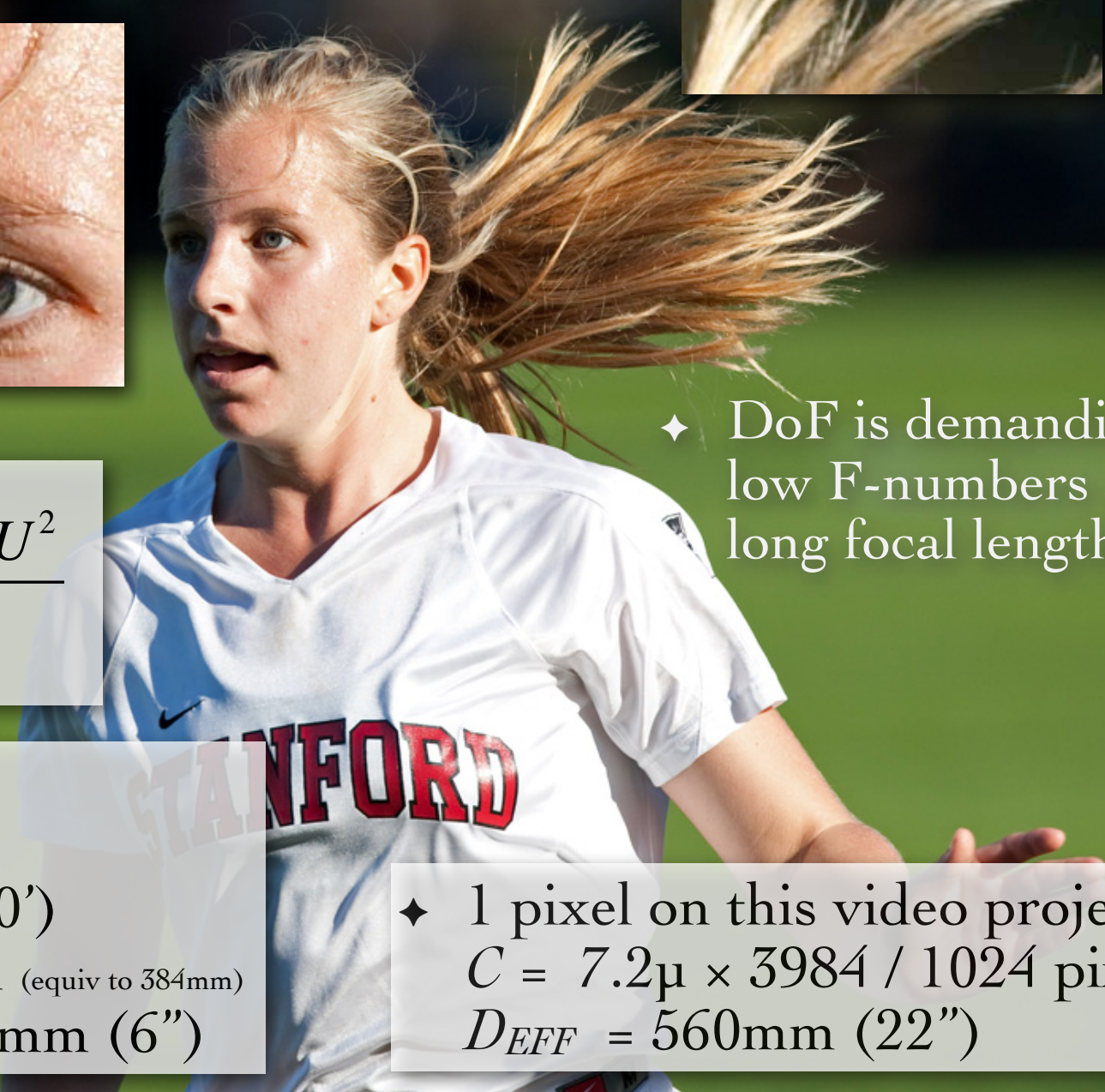
Women's lacrosse

(1D III, 300mm, 1/4000 sec, ISO 800, f/3.2)



✓ critical focus

Depth of field



- ◆ DoF is demanding at low F-numbers and long focal lengths!

$$D_{TOT} \approx \frac{2NCU^2}{f^2}$$

- ◆ $N = f/4$
 $C = 7.2\mu$
 $U = 15\text{m (50')}$
 $f = 300\text{mm (equiv to 384mm)}$
 $D_{TOT} = 144\text{mm (6")}$

- ◆ 1 pixel on this video projector
 $C = 7.2\mu \times 3984 / 1024$ pixels
 $D_{EFF} = 560\text{mm (22")}$

Shallow depth of field is useful

Women's
lacrosse

(1D III,
400mm,
1/4000 sec,
ISO 400,
f/4)





(Hector Garcia-Molina)



(Hector Garcia-Molina)



(Hector Garcia-Molina)

Depth of field can be too shallow

Big Game 2009

(7D, 300mm,
1/1250 sec,
ISO 1600, f/2.8)



- ◆ ability to extend depth of field would be useful
 - different problem from fixing misfocus
 - fighting for photons, so can't stop down the aperture

Autofocusing

Women's lacrosse

(1D III, 400mm,
1/5000 sec, ISO 400, f/4)

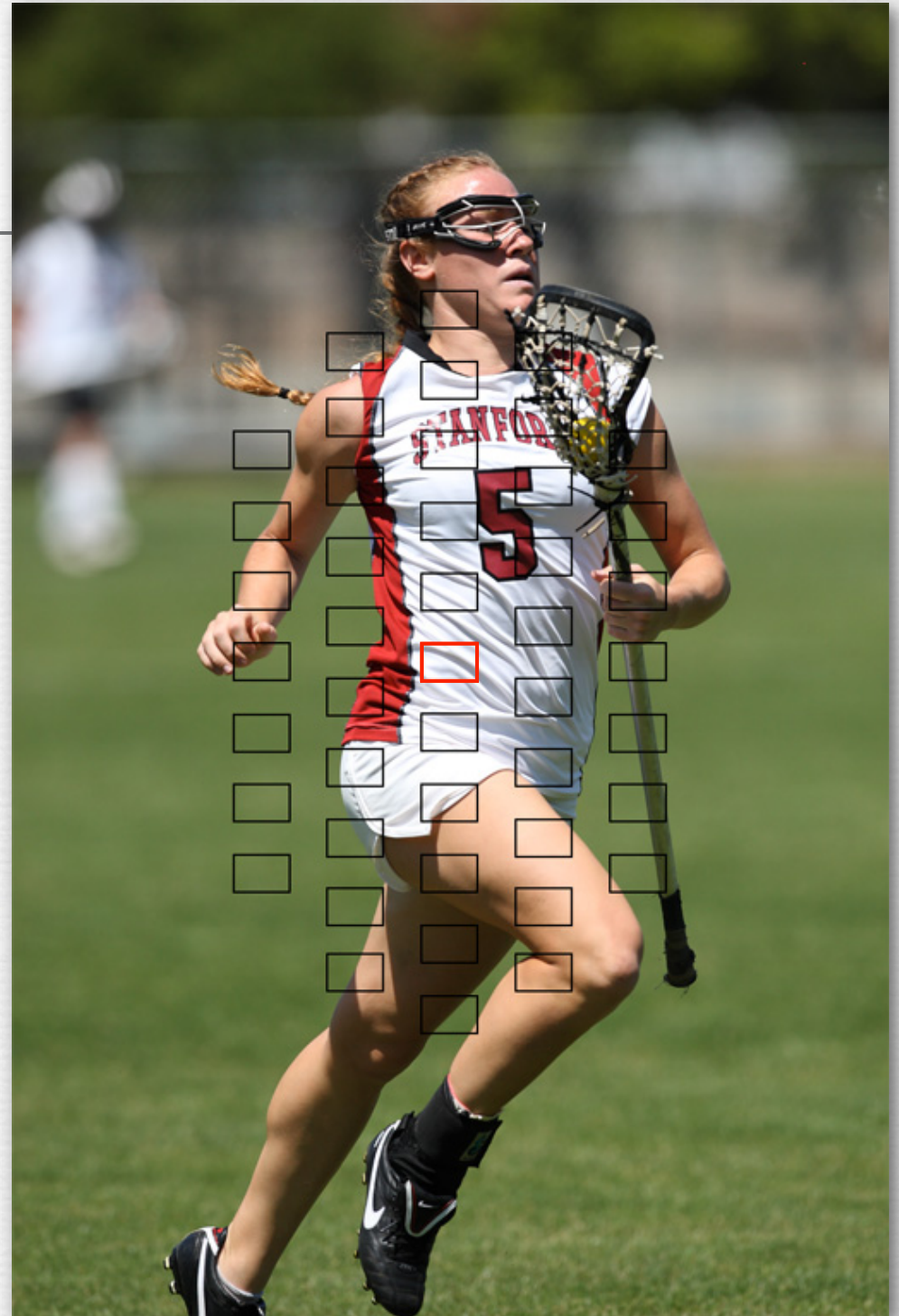


Autofocusing

Women's lacrosse

(1D III, 400mm,
1/5000 sec, ISO 400, f/4)

- ◆ single centered AF point is most reliable
 - otherwise it often focuses on peripheral players or objects



Subjects aren't always centered



(Hector Garcia-Molina)

- ◆ use manual AF button, before or during action
 - requires a lot of practice

Auto-misfocusing

Women's lacrosse

(1D III, 400mm,
1/4000 sec, ISO 400, f/4)



Auto-misfocusing

Women's lacrosse

(1D III, 400mm,
1/4000 sec, ISO 400, f/4)

- ◆ solve by prohibiting focusing on the grass?
 - trainable before the game, to allow unusual fields
 - use color & texture?
- ◆ or focus on moving objects?
 - as detected by motion blur
 - must overlook/compensate for panning the camera



Auto-misfocusing

Women's soccer

(1D III, 400mm,
1/2000 sec, ISO 200, f/4)



Auto-misfocusing

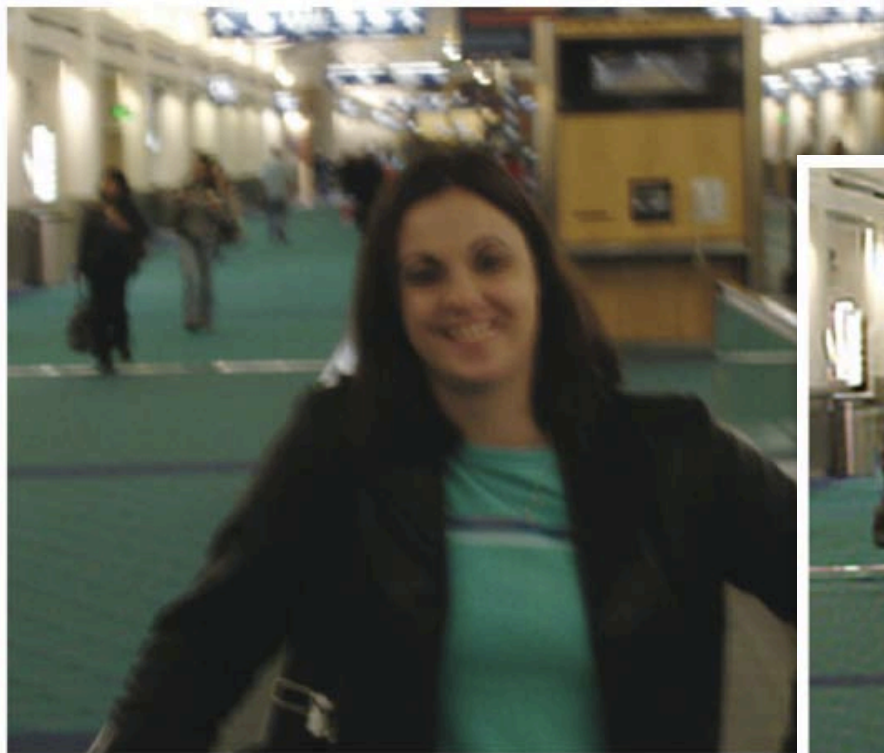
Women's soccer

(1D III, 400mm,
1/3200 sec, ISO 200, f/4)

- ◆ fix focus in blurry shot using information from sharp shot later in the same burst?

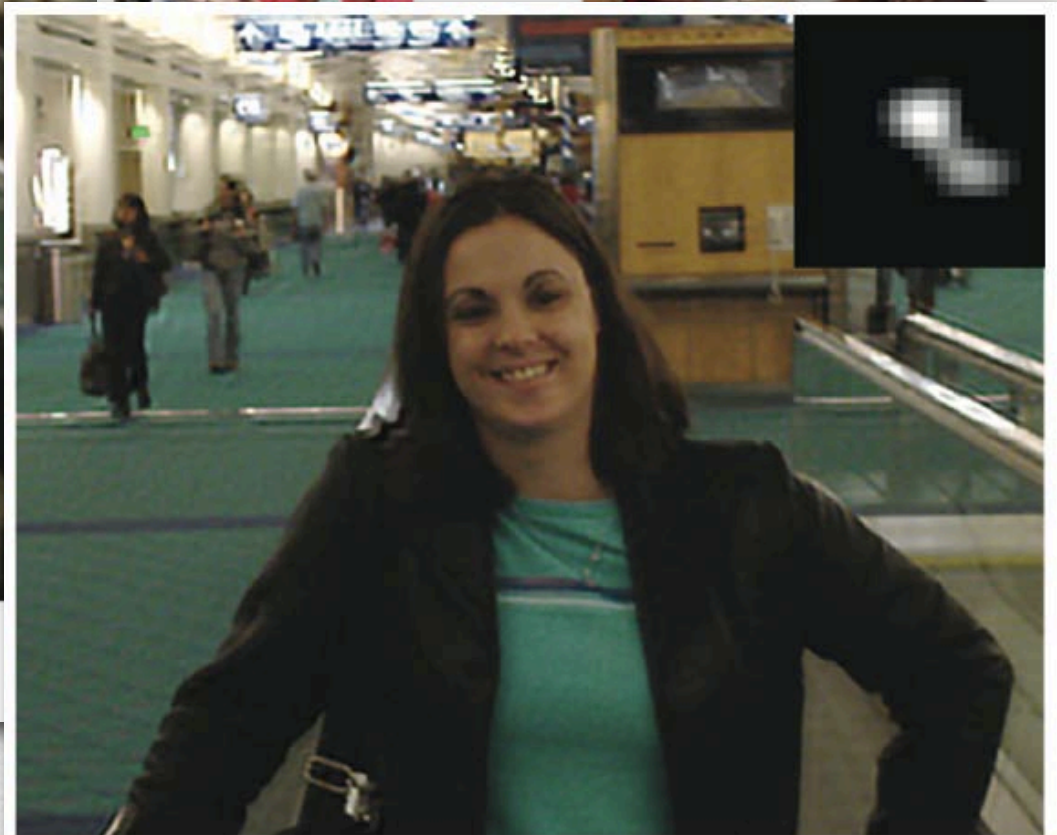
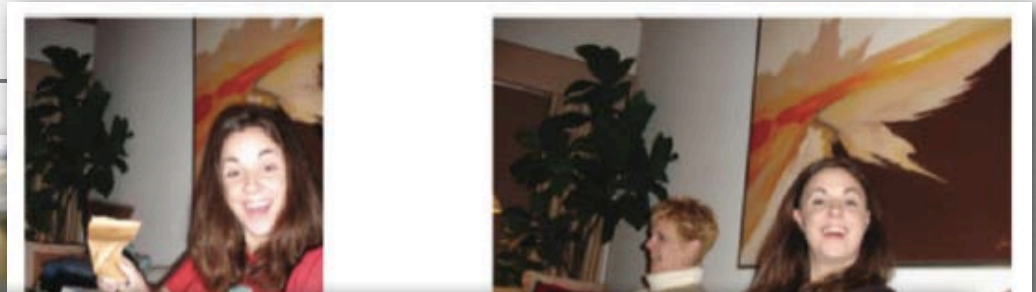


Personal photo enhancement using example images [Joshi 2011]



original blurry image

- ◆ how much better could this be if the sharp priors were taken a few seconds before the blurry shot?



our automatically deblurred output

Auto-misfocusing

Women's soccer

(1D III, 400mm,
1/3200 sec, ISO 200, f/4)

- ◆ fix focus in blurry shot using information from sharp shot later in the same burst?
- ◆ also applicable to casual photography - use imagery captured while aiming and focusing to fix noise, blur,...



Auto-misfocusing

Women's soccer

(1D III, 400mm,
1/2000 sec, ISO 200, f/4)



Auto-misfocusing



Women's soccer

(1D III, 400mm,
1/3200 sec, ISO 200, f/4)

- ◆ need “soccer ball focus”
 - plug-in for sports
 - trainable before the game, to allow unusual balls
 - specialized algorithm to recognize any rotation
 - could also use to set white balance and exposure



“Pre-game warmup” for cameras



+



=

Courtney Verloo

- ◆ train on ball
- ◆ train on each player
- ◆ adjust focus and exposure for best shot
- ◆ adjust depth of field to span player and ball



This is harder than it sounds

player carries
wireless chip?



+



=



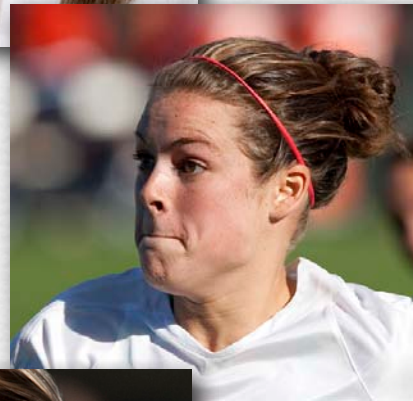
Courtney Verloo



?



The many faces of Kelley O'Hara



◆ top U.S. collegiate soccer player 3 years in a row

Auto-misfocusing

Women's
lacrosse

(1D III, 400mm,
1/4000 sec,
ISO 400, f/4)



Auto-misfocusing

Women's
lacrosse

(1D III, 400mm,
1/4000 sec,
ISO 400, f/4)



- ◆ solve by prohibiting focusing beyond a certain distance?
 - tricky since camera often pans and field is rectangular

Plenoptic camera + post-focusing

Big Game 2009

(Canon 50D with
microlens array,
300mm, 1/500 sec,
ISO 1600, f/4)



(FLASH DEMO)

How much refocusing do we need?

Big Game 2009

(Canon 50D with
microlens array,
300mm, 1/500 sec,
ISO 1600, f/4)

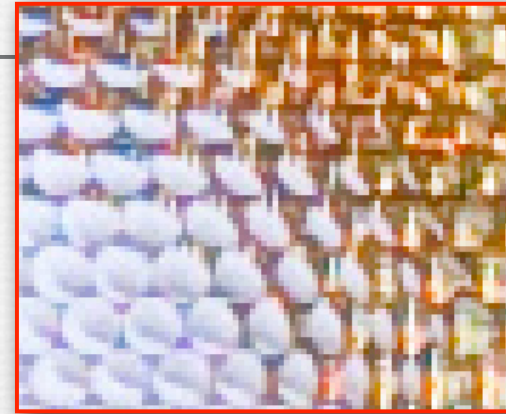
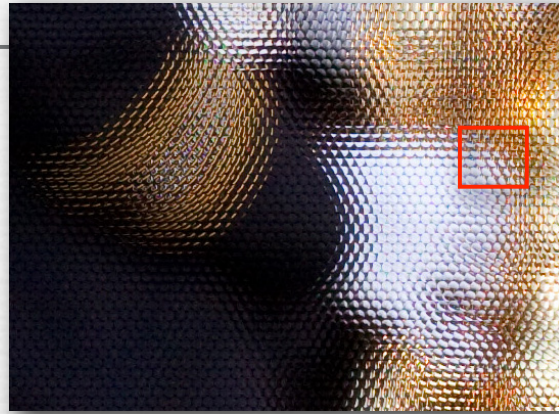


$$D_{TOT} \approx \frac{2NCU^2}{f^2}$$

- ◆ $N = f/4$
- $C = 4.7\mu$
- $U = 25\text{m (82')}$
- $f = 300\text{mm (equiv to 480mm)}$
- $D_{TOT} = 261\text{mm (10")}$

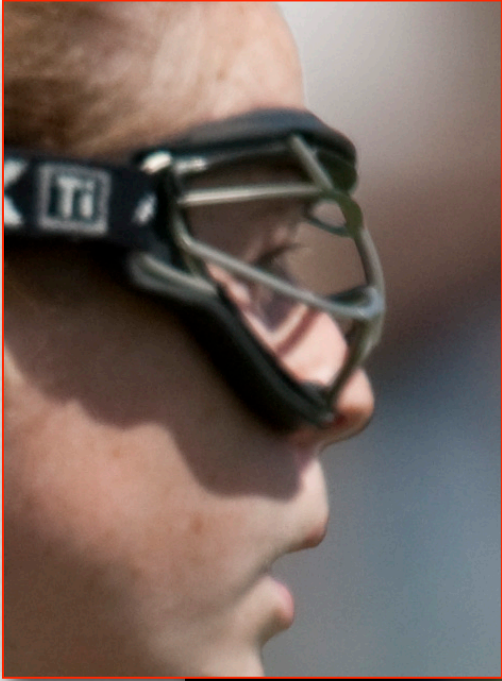
- ◆ 1 pixel on this video projector
 $C = 4.7\mu \times 4752 / 1024$ pixels
 $D_{EFF} = 1.2\text{m (4')}$

How much refocusing do we need?



- ◆ prototype camera was approximately 400×300 microlenses, with $\sim 12 \times 12$ pixels behind each microlens = 18 megarays
 - ◆ depth of field (on video projector) = 6'
 - ◆ refocusability with this recipe = $6' \times 12 = 72'$
-
- ◆ length of a football line of scrimmage = $\sim 20'$ (not including the wide receivers)
 - ◆ alternative recipe: 1200×900 microlenses, with 4×4 pixels behind each microlens
 - ◆ refocusability with alternative recipe = $6' \times 4 = 24'$

Shots that could have been saved



◆ almost well focused

Shots needing a bit more DoF



(Marc Levoy)

(Hector Garcia-Molina)



- ◆ refocus to create focal stack, apply all-focus algorithm
 - or another EDoF technique: coded aperture, lattice focal, etc.

Shots that could use a tilted focal plane



(Hector Garcia-Molina)

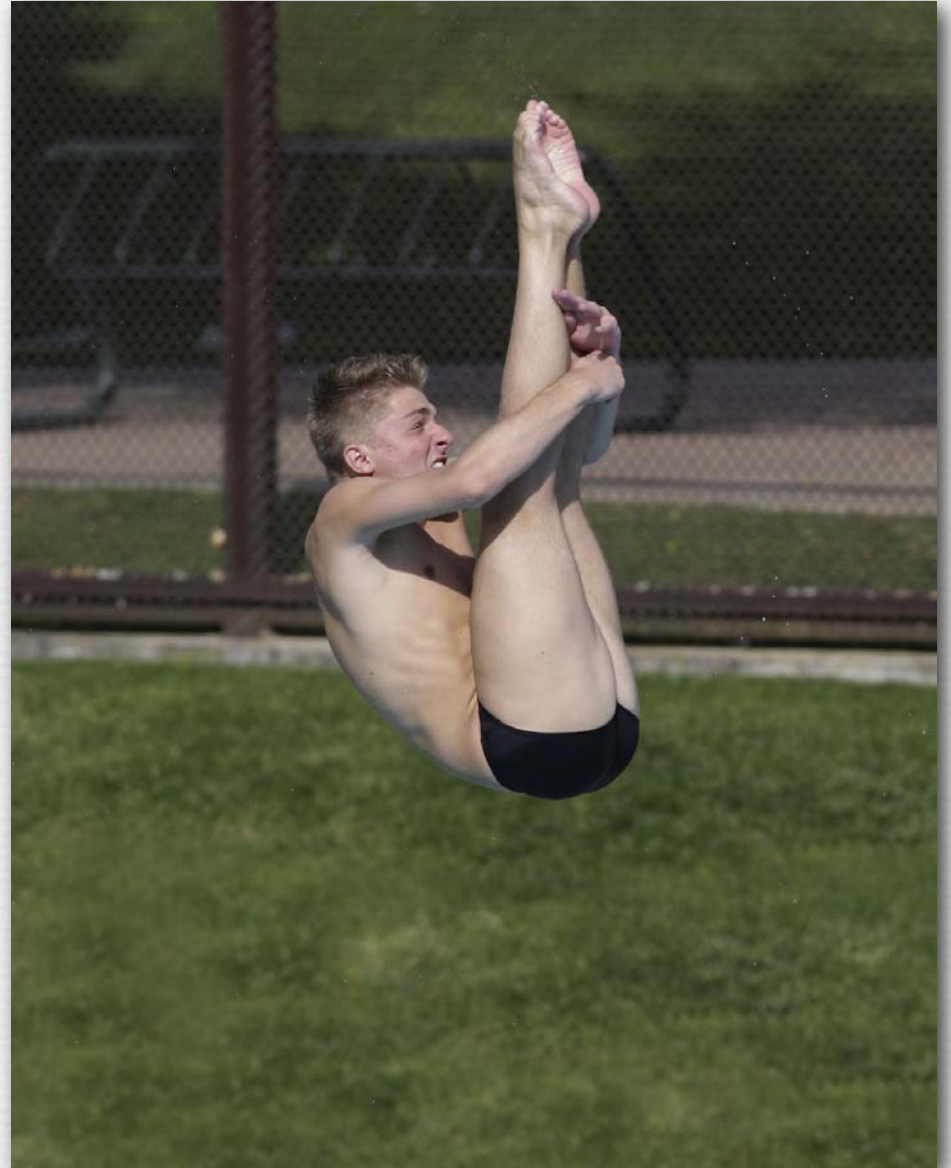


- ◆ easily done with light field camera
- ◆ curved focal surfaces also possible

Meaningless backgrounds

(Hector Garcia-Molina)

- ◆ no solution except to look for a different vantage point



Cluttered backgrounds

Women's gymnastics

(Canon 7D, 1/1000 sec,
ISO 3200, f/1.8, 85mm)

- ◆ common problem in most indoor and stadium sports



Fixing cluttered backgrounds

Women's soccer

(1D III, 400mm,
1/2500 sec, ISO 200, f/4)



Fixing cluttered backgrounds

Women's soccer

(1D III, 400mm,
1/2500 sec, ISO 200, f/4)

cropped
original

- ◆ this took a long time to do
 - darkened and desaturated using Lightroom 2's "auto-masked" brush
 - need focus-based region selector for editing



Conclusions

- ◆ some aspects of sports photography are intrinsically hard
 - ◆ some might yield to comp photo / vision algorithms
 - ◆ faster bursts (or video) would help
-
- ◆ camera as light field probe - frameless photography?
 - ◆ new ways of depicting sports action?

Parting thoughts: good sports photographers make it look easy



(Hector Garcia-Molina)



Another parting thought: sports can be rough



(Hector Garcia-Molina)



© Marc Levoy

Parting thoughts: swing the camera around once in a while



(Marc Levoy)



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