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

✦

and extreme sports

(Jerry Lodriguss)

(Dave Black)
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

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

(David Laird)  (Harold Edgerton)  (Lois Greenfield)
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

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)

- should have been 1/1600s at ISO 6400
- 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)

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

denoised in Lightroom 2

original
ISO and noise

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

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

original
denoised in Noise Ninja
Focal length

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

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

- 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
7.2µ × 7.2µ pixels

♦ 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× (APS-H)
  • not full-frame, which is too slow to read out
  • not 1.6× like APS-C format, which gathers less light

compare to 6.4µ on 21Mpix 5DII
Frame rate and burst size

Canon 1D Mark IV
$5,000, 16 Mpix, 10 fps
5.7\(\mu\) \times 5.7\(\mu\) pixels
“standard” ISO to 12,800

- frame rate is (probably) limited by readout rate
  - 16 Mpix \times 10\text{fps} \times 16\text{-bit pixels} = 320 \text{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)
Frame rate

Men’s water polo

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

✦ even 10fps is not fast enough for many sports

Men’s water polo

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

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

+0.2s
Another example

Women’s soccer
(Canon 1D III, 1/1600 sec, ISO 200, f/4, 300mm)
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)
Another example

Women's soccer

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

✦ argh, missed again!
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 and save the decisive shot

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

Moore’s Law will help
Focus

Women’s lacrosse

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

✓ critical focus
Depth of field

\[ D_{TOT} \approx \frac{2NCU^2}{f^2} \]

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

- DoF is demanding at low F-numbers and high magnifications!
- 1 pixel on this video projector
  \( C = 7.2 \mu \times 3984 / 1024 \) pixels
  \( D_{EFF} = 560mm \ (22'') \)
Depth of field is useful

Women’s lacrosse

(1D III, 400mm, 1/4000 sec, ISO 400, f/4)
Depth of field can be too shallow

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

✦ 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

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

Women’s soccer
(1D III, 400mm, 1/3200 sec, ISO 200, f/4)
“Pre-game warmup” for cameras

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

Courtney Verloo
This is harder than it sounds

player carries wireless chip?

Courtney Verloo
The many faces of Kelley O’Hara

✦ soccer, #19, top U.S. collegiate 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 800, f/4)
Plenoptic camera + post-focusing

Big Game 2009

(Canon 50D with microlens array, 300mm, 1/500 sec, ISO 1600, f/4)
How much refocusing do we need?

Big Game 2009

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

\[ D_{TOT} \approx \frac{2NCU^2}{f^2} \]

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

- 1 pixel on this video projector
  \( C = 4.7 \mu \times 4752 / 1024 \) pixels
  \( D_{EFF} = 1.2m \ (4') \)
How much refocusing do we need?

- recipe shown is approximately $400 \times 300$ microlenses, with $\sim 12 \times 12$ pixels behind each microlens = 18 megapixels
- depth of field for this shot (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: $1200 \times 900$ microlenses, with $4 \times 4$ 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

- 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

- easily done with plenoptic 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)
Parting thoughts:
swing the camera around once in a while

(Marc Levoy)