The Future of Photography

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View from the Window at Le Gras
Niépce 1826

Kodak Research Laboratory 1952

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View from the Window at Le Gras
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View from the Window at Le Gras Niépce 1826

Outline

- The Last 15 Years
- The State of Digital Photography
  - Mature Functions
  - Emerging Functions
- Post-Digital Photography

US Camera Sales

- SLR: 6%
- Point and Shoot: 74%
- Instant: 7%
- 110: 13%

Transition Film to Digital

PMAI 2009 Data

Excludes Camera Phones and Single Use Cameras

US Camera Sales

- 1994: Film 6%, SLR 10%, Point and Shoot 84%
- 2007: Film 7.5%, SLR 15.0%, Point and Shoot 22.5%, Digital 30.0%

US Film Sales

- 1994: 0
- 1995: 250
- 1996: 500
- 1997: 750
- 1998: 1000
- 1999: 1250
- 2000: 1500
- 2001: 1750
- 2002: 2000
- 2003: 2250
- 2004: 2500
- 2005: 2750
- 2006: 3000
- 2007: 3250
- 2008: 3500
- 2009: 3750

Transition Film to Digital

- 1994: Film 7.5%
- 1995: SLR 15.0%
- 1996: Point and Shoot 22.5%
- 1997: Digital 30.0%
- 1998: Film 7.5%
- 1999: SLR 15.0%
- 2000: Point and Shoot 22.5%
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- 2006: Film 7.5%
- 2007: SLR 15.0%
- 2008: Point and Shoot 22.5%
- 2009: Digital 30.0%
Why Digital Photo Won

- Instantaneous Feedback
- Automatic Operation
- Non-sequential Operation
- Sharing and Distribution
- Compact cameras
- Low Cost
- Good quality
- Printing and Display

My Thesis

Many of the motivations that lead us to photograph will be better served by new and different technology.

In the long term, photography as we know today will continue to exist just as a visual art.

Some of the first steps in that direction are observable now.
Mature Technologies

- Printing
- Resolution
- Compression
- Camera DSP
- Auto-Exposure
- Storage

Photo Printing is Decreasing

“When you print, the information leaks out of the computer eco-system ...”
Esther Dyson talking at HPLabs in 1993

Ever Increasing Pixel Density

Limits to Resolution

- Diffraction Limit
- Lens Cost
- Motion and Blur
- SNR
- Manufacturing Precision
- Operating Precision (AP)
- Array Size
- Dynamic Range
- Flare
- Artifacts
Evolution of Canon G Line

Mature Technologies
- Printing
- Resolution
- Compression
- Camera DSP
- Image Pipeline/AE
- Storage

The Age of the Camera Phone

Why Camera Phones?
- Quality approaching DSC
  - Low res OK - printing not required
  - Sensitivity high enough for most situations
- Large display for review and sharing
- Well integrated with metadata (GPS, date time, voice annotations)
- Well integrated with communications
- Small, low cost, always available

Current Image Quality Limitations for Camera Phones
- Low SNR and Dynamic Range
  - Small well capacity makes exposure critical
- Low quality Optics and limited AF
  - High F#, aberrations, vignetting, cross talk, flare
- Rolling exposure
  - Motion and lighting artifacts, no regular flash
- Poor IR filtering
  - Hot mirror causes IR contamination and purple spot

Poor IR Filtering

**Emerging Functionality**
- Motionless
- Smart Light
- RawFlow/Photon
- Augmented Reality
- High Speed
- Advanced CMOS Sensors
- Photo/Video Convergence
- Robotic Capture
- Total Recall
- Pulsed Flow Computing
- Breathing and Sleeping
- DIY Cameras

**HDR Video Capture**
- Pixm built the first video rate
- HDR capture CMOS sensor and DIP
- Per pixel ADC allows multiple
  reads with a single reset
- On-board memory allows very
  high frame rate
- Image is read hundreds of times
  during each video frame exposure
- Only the highest SNR data is
  saved to memory

**Convergence Video-Photo**
- Key factors driving the convergence:
  - CMOS sensors do not require mechanical
  shutter
  - Solid state storage instead of tape
  - Increases in bandwidth for RAW DIP and
  flash memory
  - Choice between stream low res and
  high res stills disappears with
  semiconductor progress
  - Difference may remain on the
  industrial design and usage

**Light Field Capture**
- Array of cameras can do much more than any element
- Steer or flip them at once
- HDR from multiple exposures across sensors
- Higher speed from exposure planes
- Better video and multimedia by having different channel per
  element
- Higher resolution by selecting or super-resolution methods
- Applicable to both
  - HD
  - 3D

**Smart Light**
- Spatial and temporal modulation of the light enables many new
  modes of capture, some examples:
  - Flashes from multiple angles slow
  better image segmentation and picture
  enhancement (Raskar et al, SIGGRAPH
  2004)
  - Pulsing micro-projectors with
  structured light enables 3D capture
  - Pulsing LED illumination on/off with fast
  capture above saturation of the ambient
  light illumination
  - Pulsing the LED illumination at random
  intervals allows motion-balking
  (Raskar et al, SIGGRAPH 2006a)
**Reflectance Field Capture**

- For a given scene, the hemisphere of ambient illumination is captured in HDR.
- Real objects are captured with multiple lights at high speed so that any complex illumination can be synthesized by a combination of base images.
- Real and artificial geometry can be inserted into any scene by this method.

**Photo Events**

- Weddings
- Birthdays
- Yearbooks
- Family Reunions
- Performing Arts
- Sports/Team
- Cruise Ships
- High School Proms
- Nursery/Day Care
- Graduations
- Church Events
- Tourism
- Nature

**Total Recall**

- Sense-Cam
  - Work at Microsoft Research originated by Gordon Bell
  - Capture 100% of one's daily life
  - Use to aid memory or as a form of note taking
- Alternative camera from Johan Frossen

**Robotic Capture**

- Most elements are already in place.
  - Sony Party-shot - Automatic Photographer
  - GigaPan Epic images
  - Tessera FotoNation face recognition for cameras and cell phones
  - Existing CCTV equipment combined with existing tracking software

**Why do we Photograph?**

- To document and preserve
- To share and communicate
- To understand, analyze
- To enjoy the craft and technology
- For social motivations
- To create

**Plenoptic Capture**

(Reuters/Kevin Lamarque)