Multi-Channel Film Dosimetry

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ISP proprietary technology, patents pending
Outline

- Single channel dosimetry
- Multi-channel dosimetry
- Consistency Control
- FilmQA Pro examples
  - Multi-channel uniformity correction
  - Multi-channel scanner lateral correction
Single Channel Film Dosimetry

- Calibration Curve $X = R$
  
  $$R_{ave} = R_{ave}(D) \leftrightarrow D_R = D_R(R_{ave})$$

- Color channels $X = RGB$

  $$D_X = D(X_{ave})$$
  correlates average response of film-scanner system

- Robust method

  any $X$ value delivers dose $D_X(X)$
Single Channel Film Dosimetry

Problem:

Specific pixel does not behave like average

Disturbance $\Delta X$ generates $\Delta D_X$

$X + \Delta X \leftrightarrow D(X) + \Delta D_X$

- Film Uniformity variations
- Scanner non-linearities
- Noise, finger prints ...

Any $X$ value delivers dose $D_X(X)$

- Each channel specific $\Delta D_X$
- No indication of ‘big’ $\Delta D_X$
- What dose $D_X$ is best?
RGB Calibration Curves

- Dose induced color \( C \)
  \[ C(D) = \{R(D), G(D), B(D)\} \]

Dose exposure generates only 'certain' colors \( C \)

- Not all \( C \) deliver dose value

Observed color \( C_{\text{scan}} \) is superposed with disturbance \( \Delta C \)

- \( C_{\text{scan}} = C(D) + \Delta C \)

Solution: Optimize dose \( D \) value, i.e. minimize \( \Delta C \)

- \( | C_{\text{scan}} - C(D) | \rightarrow \min_D \)
Triple Channel Film Dosimetry

Definition:
Color channels in terms of ‘optical density’ $d_X$
- $d_X = -\log(X)$ for $X = \text{RGB}$ (generally wave length)

Model:
Scanned density $d_{X,\text{scan}}$ is (simple) product
- $d_{X,\text{scan}}(D) = d_{X,D}(D) \times \Delta d$
- $d_{X,D}$ is calibration function (average behavior)
- ! disturbance $\Delta d$ independent of dose + $X$ (wave length)!
  but $\Delta d = \Delta d(\text{thickness, scanner, noise, film artifacts})$

Solution:
- Minimized disturbance $\Delta d$:
  $$\phi(\Delta d) = (D_R - D_B)^2 + (D_B - D_G)^2 + (D_G - D_R)^2 \rightarrow \min_{\Delta d}$$
Triple Channel Film Dosimetry Example

Signal split into dose dependent and dose independent part

\[ D_{\text{RGB}} + \Delta d \]

Dose map (D dependent) and disturbance \( \Delta d \) map (D independent, mostly uniformity) and horizontal profiles
Triple Channel Correction

What happen to the Marker Dye?

Marker Dye needed at ‘lower’ dosage:
- \( \Delta d \approx \frac{d_{B,\text{scan}}(0)}{d_{B,D}(0)} \)

otherwise ‘scanner noise’ dominates \( \Delta d \)
(sufficient low dosage \( \sim 100 \text{ – 200 cGy} \))

At ‘higher’ dosage Red channel is saturating
and has function like Marker Dye
(sufficient high dosage \( > 400 \text{ cGy} \))
Triple Channel Dosimetry
Film Consistency

Film consistent with Calibration Patches

- Film has same dose response for $X=$RGB i.e. same dose values $D_X$ are calculable
- Dose $D_X$ offset measures calibration consistency

Example: Profiles original calibration patch and 90° rotated scan
Triple Channel Dosimetry Consistency Map

- Dose map - Result
- Disturbance map – removed error
- Consistency map – remaining error
  ideal case: noise only

Example: dominated by scanner belt slippage

Consistency Map
(contrast maximized, dark = +, light = -)
Consistency Map Comparison

Triple Channel Dosimetry  Single Channel Dosimetry

same patch, same contrast scaling, dark = +, light = -
Triple Channel Dosimetry
Lateral Scanner Non-Linearity

Scanner signal changes with lateral position (sensor direction)

- EBT film polarization amplifies lateral effect
- Non-dose-dependent part of lateral effect is compensated
- Partial compensation only
Triple Channel Dosimetry Calibration Consistency

Inconsistent calibration patches also inconsistent with application film

- Minimize inconsistency (numeric value)
  - is uniformity corrected

- Detect ‘abnormal’ patches
  - 90° rotation, ‘top sheets’ anomaly, curling, Newton rings
Triple Channel Film Dosimetry Features and Advantages

- Separate Dose and Dose-independent effects
  - Compensates for film thickness variation
  - Noise reduction without dose change
  - Mitigates scanner distortions
- Enables full film dose range without RGB channel transition
  - Ebt2 range 20 cGy - >100 Gy
- Significant improvement of dose map accuracy
- Indication of inconsistency between film and calibration
Multi-Channel Film Dosimetry
FilmQA Pro Implementation

Film Dosimetry Package
Single, Dual & Triple Channel Dosimetry
Scanner Linearization
Free data exchange
DICOM, tiff, png ...
.NET platform
Windows XP, Vista, 7
Open concept,
User programmable
Download at
www.FilmQAPro.com