Does the choice of display system influence perception and visibility of clinically relevant features in digital pathology images?

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We study the impact of the display on perception and visibility of clinically relevant features in digital pathology

- Quantify the difference of display systems
- Study the difference of display systems in clinical performance

Agenda:
- Background
- Methods
- Results
- Conclusions and future work
Background: Digital pathology systems

- Digital pathology systems typically consist of
  - Slide scanner
  - Processing and visualization/rendering software
  - A medical display

- The display is a very important component since it presents the final images to the pathologist
Background: State-of-the-art medical color displays

- Clinical use of color medical images is low in comparison to gray scale images

- Today’s state-of-the-art medical color display systems don’t yet fully address [1; 2]
  - Whitepoint variations between displays and over time
  - Color gamut variations between displays and over time
  - Color non-uniformity throughout the display
  - Optimal rendering of colors (maximizing color discrimination)

- Research is ongoing to define and standardize a color calibration target [3] for medical color displays that guarantees optimal visualization of medical color images
Methods: Clinically Relevant Features

- Four digital pathology images of different subspecialties were selected, and clinically relevant features were marked by a pathologist.

Muscle core biopsy involved by Ewing sarcoma (image: Core14)
Methods: Clinically Relevant Features

mediastinal lymph node biopsy with Hodgkin lymphoma (image: Core03)

cytology fine needle aspirate from a lymph node showing non-Hodgkin lymphoma (image: Lymph Node 124)
Methods: Clinically Relevant Features

frozen section from a bone lesion due to metastatic urothelial carcinoma (image: FS6)
Methods: Display Systems

- Three different display systems have been compared in this study:
  - DELL 1907FP, resolution 1280 x 1024, sRGB, luminance 210 cd/m², contrast ratio 700:1
  - Barco MDCC-6230, resolution 3280 x 2048, DICOM GSDF calibrated, luminance 500 cd/m², contrast ratio 900:1
  - Barco MDCC-6230, resolution 3280 x 2048, CSDF calibrated, luminance 500 cd/m², contrast ratio 900:1

- The focus of the comparison was on the color behavior (rather than on other aspects such as resolution/contrast/luminance):
  - sRGB
  - DICOM GSDF (Grayscale Standard Display Function) [4]
  - a newly proposed perceptually uniform color space “CSDF” [3]
Methods: Comparison of display systems

“Do pathology images look different on different display systems?”

- analyzing perceived differences between display systems
  - calculations [5] to quantify perceived differences
    - DeltaE2000 calculations between different display
    - The same clinically relevant area
  - Visible Difference Predictor (VDP)/JNDMetrix like analysis [6; 7] to determine the location of perceived differences
Methods: Comparison of display systems

“Do differences in displays mean that there is difference in clinical performance?”

- analyzing perceived contrast of clinically relevant features
  - DeltaE2000 calculations between the background and foreground of clinically relevant areas on the same display.
  - Compare the DeltaE2000 calculations of different displays
Results: perceived differences between display systems

Intra-case difference between display systems (color spaces), measured in deltaE2000
- Important remark: not ranking or quality score
- Purely quantifying how different sRGB, GSDF, CSDF images are from each other

- The degree of difference depends on the subspecialty
- The choice of color target (sRGB / GSDF / CSDF) has a large impact on appearance of images
Results: perceived differences between display systems

Visible Difference Predictor (VDP) / JNDmetrix: perceived differences are located in clinically relevant areas

DICOM GSDF vs. CSDF
Results: perceived contrast of clinical relevant features

- GSDF and sRGB approximately offer the same perceived contrast
- **CSDF always results in higher perceived contrast of clinically relevant features** (on average 50% higher perceived contrast with min 25% and max 70% higher contrast)

### Difference between feature foreground and background

<table>
<thead>
<tr>
<th>Image</th>
<th>CSDF / GSDF</th>
<th>CSDF / sRGB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core03</td>
<td>1.399</td>
<td>1.244</td>
</tr>
<tr>
<td>Core14</td>
<td>1.74</td>
<td>1.617</td>
</tr>
<tr>
<td>FS6</td>
<td>1.674</td>
<td>1.589</td>
</tr>
<tr>
<td>Lymph Note 124</td>
<td>1.24</td>
<td>1.239</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CSDF / GDSC</th>
<th>CSDF / sRGB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average dE2000 difference between feature and background</td>
<td>1.513</td>
</tr>
<tr>
<td>Standard deviation of dE2000 difference between feature and background</td>
<td>0.235</td>
</tr>
</tbody>
</table>
Conclusions

- The color space of the display has a significant impact on the perception of clinically relevant areas of digital pathology images
  - The degree of difference depends on the subspecialty
  - The choice of color target (sRGB / GSDF / CSDF) has a large impact on appearance of images

- A newly proposed color calibration target (CSDF) has shown to increase perceived contrast of clinically relevant features ~50%

- Future work
  - Confirmation of these findings in a clinical study
  - Working towards standardization (mRGB) [8]
References


Questions

Answers

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