Digital Image Communication

Thomas Wiegand

Course at Technical University of Berlin
WS 2000/2001

Contact:
Dr.-Ing. Thomas Wiegand E-mail: wiegand@hhi.de
Image Processing Department URL: http://bs.hhi.de/~wiegand
Heinrich Hertz Institute Tel: 030 - 31002 617
Einsteinufer 37, 10587 Berlin Fax: 030 - 392 72 00

Picture: “Hotel“, 720x576, 414,720 Byte
JPEG-2000 Compressed to 12,960 Byte

JPEG-2000 Compressed to 3,240 Byte
Geometric Interpretation

414,720 Byte

32:1 → 12,960 Byte

128:1 → 3,240 Byte

250:1 → Typical compression rate for video

Nipkow Disk


(from J.-J. PETERS, “History of Television”)
Image Transmission by Line Scanning

The Image Matrix

Pixel at position $x, y$ $s[x, y]$
Digital Image Formats I

ITU-R 709

ITU-R 601

CIF

QCIF

Additionally inserted due to 16:9 ratio of horizontal to vertical size in HDTV

Digital Image Formats II

<table>
<thead>
<tr>
<th>QCIF</th>
<th>CIF</th>
<th>ITU-R 601</th>
<th>ITU-R 709</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel / row (Y)</td>
<td>176</td>
<td>352</td>
<td>720</td>
</tr>
<tr>
<td>Number of rows (Y)</td>
<td>144</td>
<td>288</td>
<td>576 (480)</td>
</tr>
<tr>
<td>Pixel / row (U,V)</td>
<td>88</td>
<td>176</td>
<td>360</td>
</tr>
<tr>
<td>Number of rows (U,V)</td>
<td>72</td>
<td>144</td>
<td>576 (480)</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>4:3</td>
<td>4:3</td>
<td>4:3</td>
</tr>
<tr>
<td>Pictures per second [Hz]</td>
<td>5-15</td>
<td>10-30</td>
<td>25 (30)</td>
</tr>
<tr>
<td>Bits per picture [kbyte] bei 8Bit-PCM</td>
<td>38,02</td>
<td>152,1</td>
<td>829,4 (691,2)</td>
</tr>
<tr>
<td>Bit-rate for image sequence [Mb/s]</td>
<td>0.84 - 3.8</td>
<td>10.1 - 30.4</td>
<td>165.9</td>
</tr>
</tbody>
</table>
Digital Image Formats and Applications

Examples for Storage Media

<table>
<thead>
<tr>
<th>Media</th>
<th>Capacity</th>
<th>QCIF</th>
<th>CIF</th>
<th>CCIR-601</th>
<th>CCIR-709</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floppy Disk</td>
<td>1.44 Mbyte</td>
<td>37.8</td>
<td>9.5</td>
<td>1.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Zip Disk</td>
<td>100 Mbyte</td>
<td>2623</td>
<td>659</td>
<td>118</td>
<td>21</td>
</tr>
<tr>
<td>Jaz Disk</td>
<td>1 Gbyte</td>
<td>26230</td>
<td>6590</td>
<td>1180</td>
<td>210</td>
</tr>
<tr>
<td>CD-ROM</td>
<td>650 Mbyte</td>
<td>17050</td>
<td>4283</td>
<td>767</td>
<td>136</td>
</tr>
<tr>
<td>DVD</td>
<td>4.7 Gbyte</td>
<td>123281</td>
<td>30973</td>
<td>5546</td>
<td>987</td>
</tr>
<tr>
<td>Flash</td>
<td>1-100 Mbyte</td>
<td>26-2623</td>
<td>7-659</td>
<td>1-118</td>
<td>0.2-21</td>
</tr>
</tbody>
</table>
### Examples for Transmission Media

<table>
<thead>
<tr>
<th>Media</th>
<th>Bit-Rate</th>
<th>QCIF</th>
<th>CIF</th>
<th>CCIR-601</th>
<th>CCIR-709</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice Modem</td>
<td>33.4 kb/s</td>
<td>0.11</td>
<td>0.03</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td>ISDN</td>
<td>64 kb/s</td>
<td>0.21</td>
<td>0.05</td>
<td>0.010</td>
<td>0.002</td>
</tr>
<tr>
<td>T1 (24xISDN)</td>
<td>1.544 Mb/s</td>
<td>5.1</td>
<td>1.3</td>
<td>0.2</td>
<td>0.04</td>
</tr>
<tr>
<td>Ethernet</td>
<td>10 Mb/s</td>
<td>32.9</td>
<td>8.2</td>
<td>1.5</td>
<td>0.28</td>
</tr>
<tr>
<td>FDDI</td>
<td>100 Mb/s</td>
<td>328.7</td>
<td>82.2</td>
<td>15.1</td>
<td>2.83</td>
</tr>
<tr>
<td>GSM</td>
<td>15 kb/s</td>
<td>0.05</td>
<td>0.01</td>
<td>0.002</td>
<td>0.0004</td>
</tr>
<tr>
<td>UMTS</td>
<td>384 kb/s</td>
<td>1.3</td>
<td>0.32</td>
<td>0.06</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### Transmission System

[Diagram showing the transmission system with labeled components: Capture, Source Encoder, Channel Encoder, Modulator, Channel, Display, Source Decoder, Channel Decoder, Demodulator.]
Optimum Scenario

Minimize costs of the complete transmission system, such that the visual information is perceived by the human observer with the desired quality.

Problems:
• Desired accuracy differs for the various applications
• Different applications permit different costs
• Transmission system is interferred by others
• Horizontal integration: design system components seperately (How about storage applications ?)
• How can we measure perceived quality ?

Why Digital Image Communication ?

• Separation of source coding and channel coding allows independent adaptation to the - Properties of information source and sink - Properties of the transmission channel

• Digital circuitry allows very large scale integration and low manufacturing costs

• Today, signals are stored and transmitted over digital media
The Human Visual System (HVS)

- **Resolution limits:**
  - Textures with frequencies higher than the limit of the HVS are not recognizable
  - Resolution limits for color are much lower than for luminance
  - Resolution limits are higher for horizontal and vertical structures than for diagonal structures
  - Still objects are recognized much sharper than moving objects
  - Temporal resolution limit of the eye: flicker

- **Contrast recognition at edges:**
  - Contrast changes at edges are enhanced
  - The HVS is especially sensitive to edges

- **Seeing:**
  - Combining color, motion, and depth into a collection of interferences about the world
  - Regions of interest in images and videos (various dependencies)

---

**Scope of this Lecture**

We will be discussing this part
Digital Image Communication

- Information and entropy
- Rate-distortion theory and quantization
- Predictive coding
- Transform coding
- Resolution pyramids and subband coding
- Interframe coding
- Motion estimation
- Motion compensated coding
- Image coding standards JPEG, JPEG-2000
- Video coding standards H.261, H.263, and MPEG-2
- Video processing standards MPEG-4 and MPEG-7
- Laboratory Excursion (HHI)

Organisation

Lecture:  Monday 14:00-16:00, room EMH25

Lecturer:  Dr.-Ing. Thomas Wiegand
Head of Image Coding and Transmission Group
Image Processing Department
Heinrich Hertz Institute Berlin
wiegand@hhi.de
http://bs.hhi.de/~wiegand

Copies of transparencies can be downloaded at URL:
http://bs.hhi.de/~wiegand/DIC.html
Literature I

**Image Processing Basics**

**Human Visual System**

**Information Theory**

Literature II

**Rate-Distortion Theory & Quantization**

**Image Coding**

**Journals**
- IEEE Transactions on Image Processing
- IEEE Transactions on Circuits and Systems for Video Technology
- IEEE Signal Processing Magazine
- IEEE Communications Magazine