DaViD: Data Transmission Using Video Devices – An Innovative System for Smart Media Applications

Ruediger Kays, Christian Brauers, Johannes Klein

Communication Technology Institute

TU Dortmund University

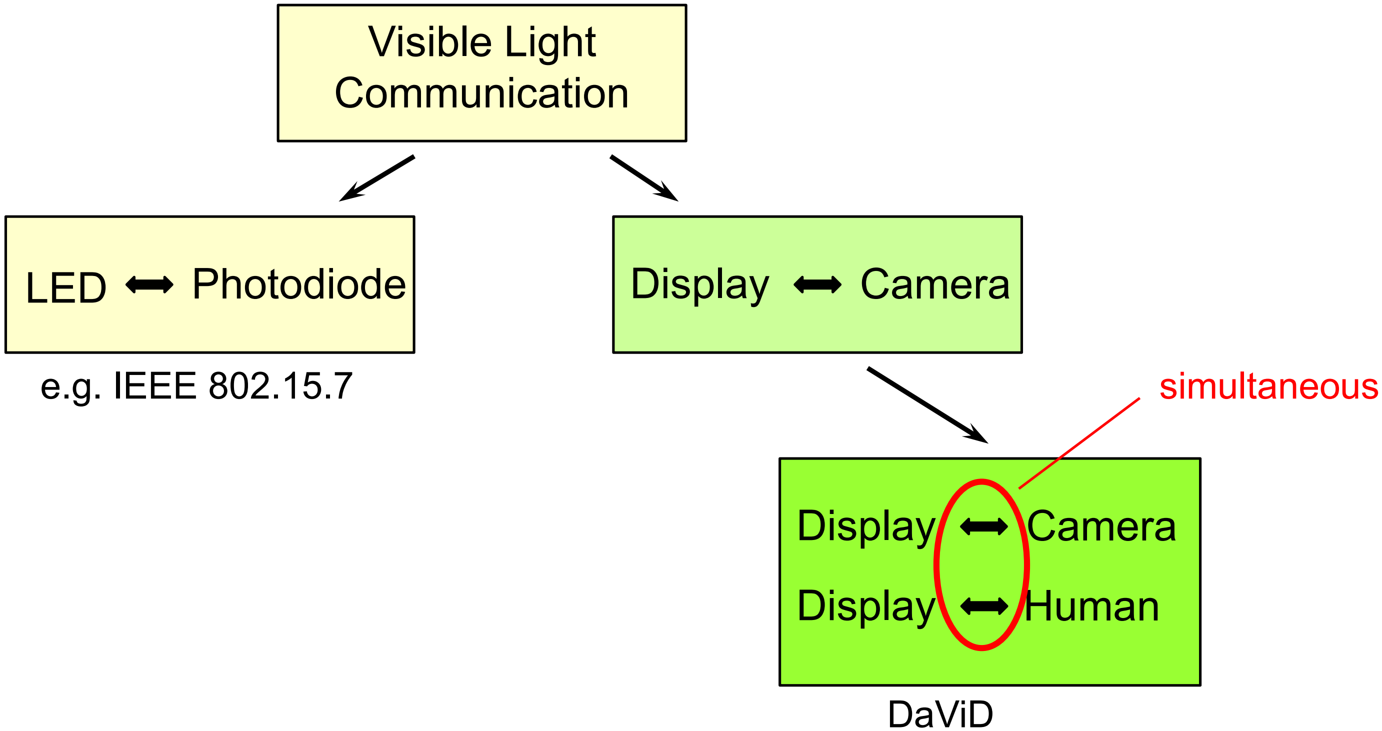
Contents

- Video Device Based VLC
- Application Scenarios
- System Concept
- Practical Results
- Outlook and Future Work

VLC: Pros and Cons

- **Advantages of Visible Light Communication (VLC):**
  - Does not occupy scarce spectrum ressources, no regulation
  - No invisible radiation, no health risks
  - Reduced security issues
  - Reuse of existing equipment possible (general lighting, traffic lights, brake lights in cars, ...)
- **Disadvantages of VLC:**
  - Limited coverage area
  - Line of sight required (usually)
  - Lower data rate, compared to recent WLAN versions

DaViD – a Special Kind of VLC

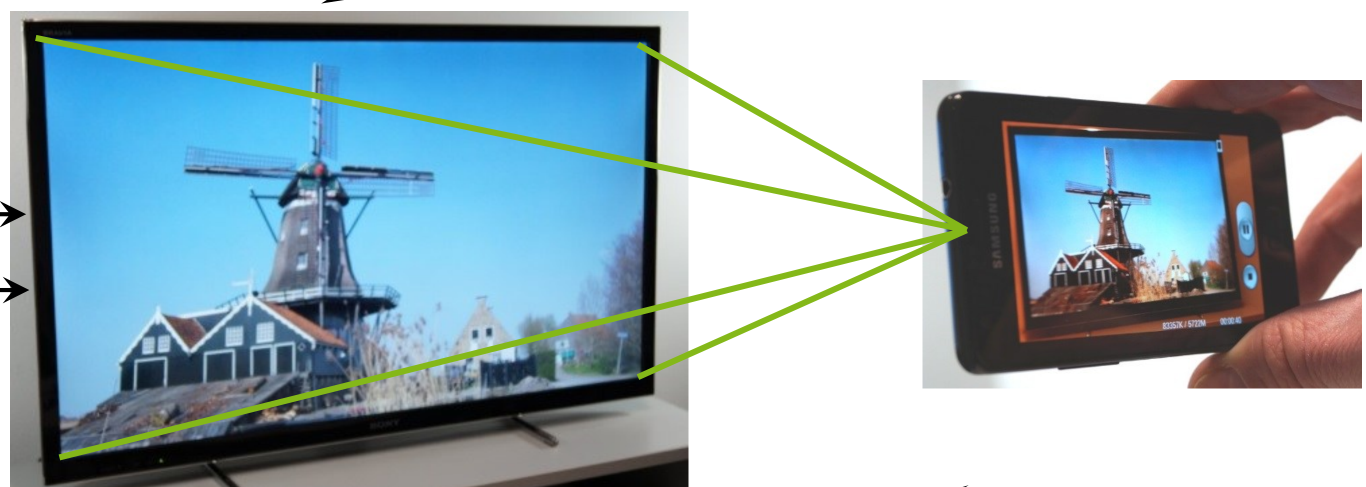


DaViD Concept

Display signal processor calculates individual data modulation of each pixel, piggybacked on video

Video

Data stream

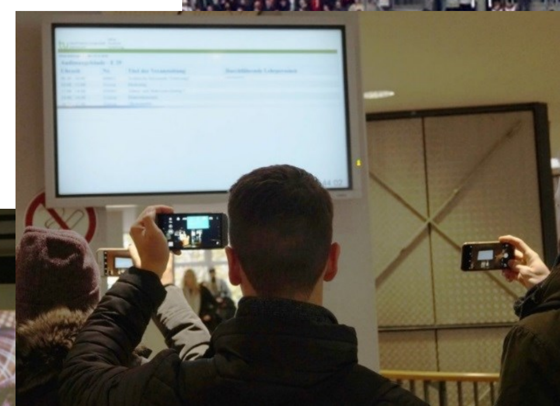


Camera of a smart phone records video, processor implements decoder. User directs camera to video display.

Application Areas

- **Application motivated by inherent advantages**
  - High data rate without cables
  - Multicast data distribution without registration procedure
  - Directed distribution, no interference
  - Apps can provide excellent user experience

- **Many application scenarios**
  - Digital Signage
  - Kiosk Systems
  - Information/Media Distribution
  - Factory Automation
  - ...



- **Preferably differential modulation, addition to video pixel pairs of same content**
- **Options:**
  - Temporal differential modulation
  - Spatial differential modulation
  - Modulation of luminance (R,G,B synchronously) or chrominance (R+B inverted to G) or one single colour (e.g. only B)
- **Modulation Amplitude A has to be selected carefully**
- **Example: Temporal differential modulation of luminance:**

Data of frame m $\quad d(l) \in \{-1;1\} \quad 0 \le l < L$

2D data pattern $\quad d(l) \rightarrow d(i,j,m)$

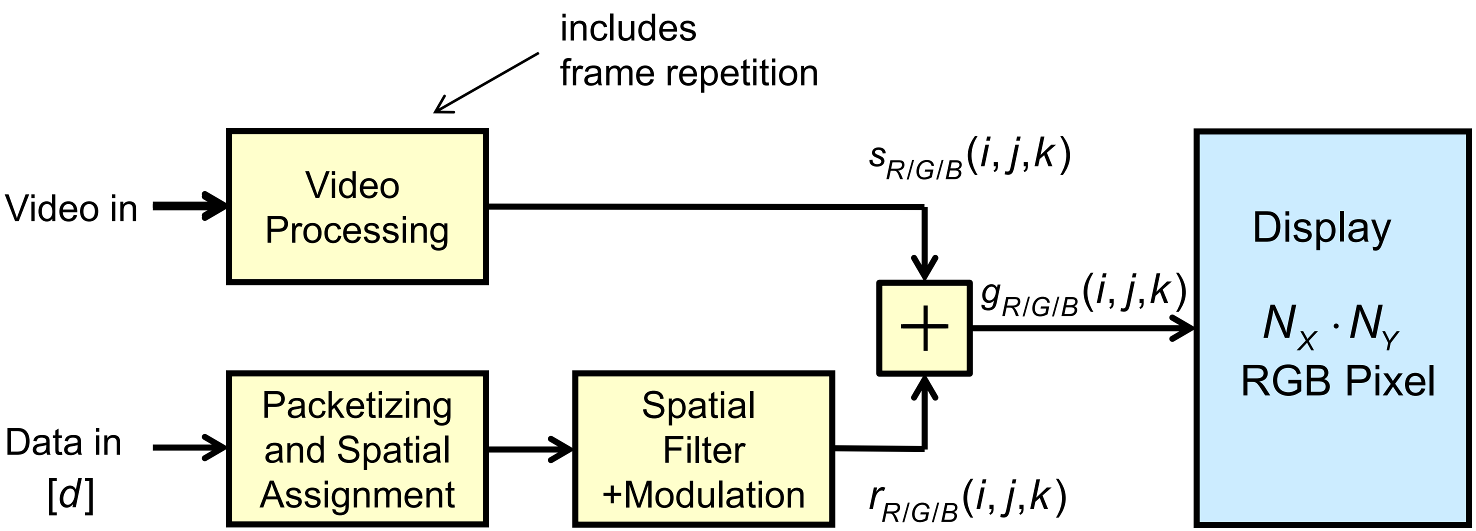
Video Input $\quad s(i,j,m)$

$$\left.\begin{matrix} d(l) \rightarrow d(i,j,m) \\ s(i,j,m) \end{matrix}\right\} 1 \le m \le N_{Frames}$$

Display Signal

$$\left.\begin{matrix} g(i,j,k) = s(i,j,k) + A \cdot d(i,j,k) \\ g(i,j,k+1) = s(i,j,k) - A \cdot d(i,j,k) \end{matrix}\right\} 1 \le k \le 2 \cdot N_{Frames}$$

Block Diagram: Temporal Differential Modulator



Direct Assignment: 1 bit per pixel („Block Size 1x1“):

$$d(l) \rightarrow d(i,j,m) \qquad 0 \leq l < L, L = N_X \cdot N_Y$$

$$i = l \bmod N_x$$

$$j = \lfloor l / N_x \rfloor$$

Assignment: 1 bit per block of pixels („Block Size B_X x B_Y“):

$$d(l) \rightarrow d(i,j,k) \qquad 0 \leq l < L$$

$$L = \lfloor N_X / B_X \rfloor \cdot \lfloor N_Y / B_Y \rfloor$$

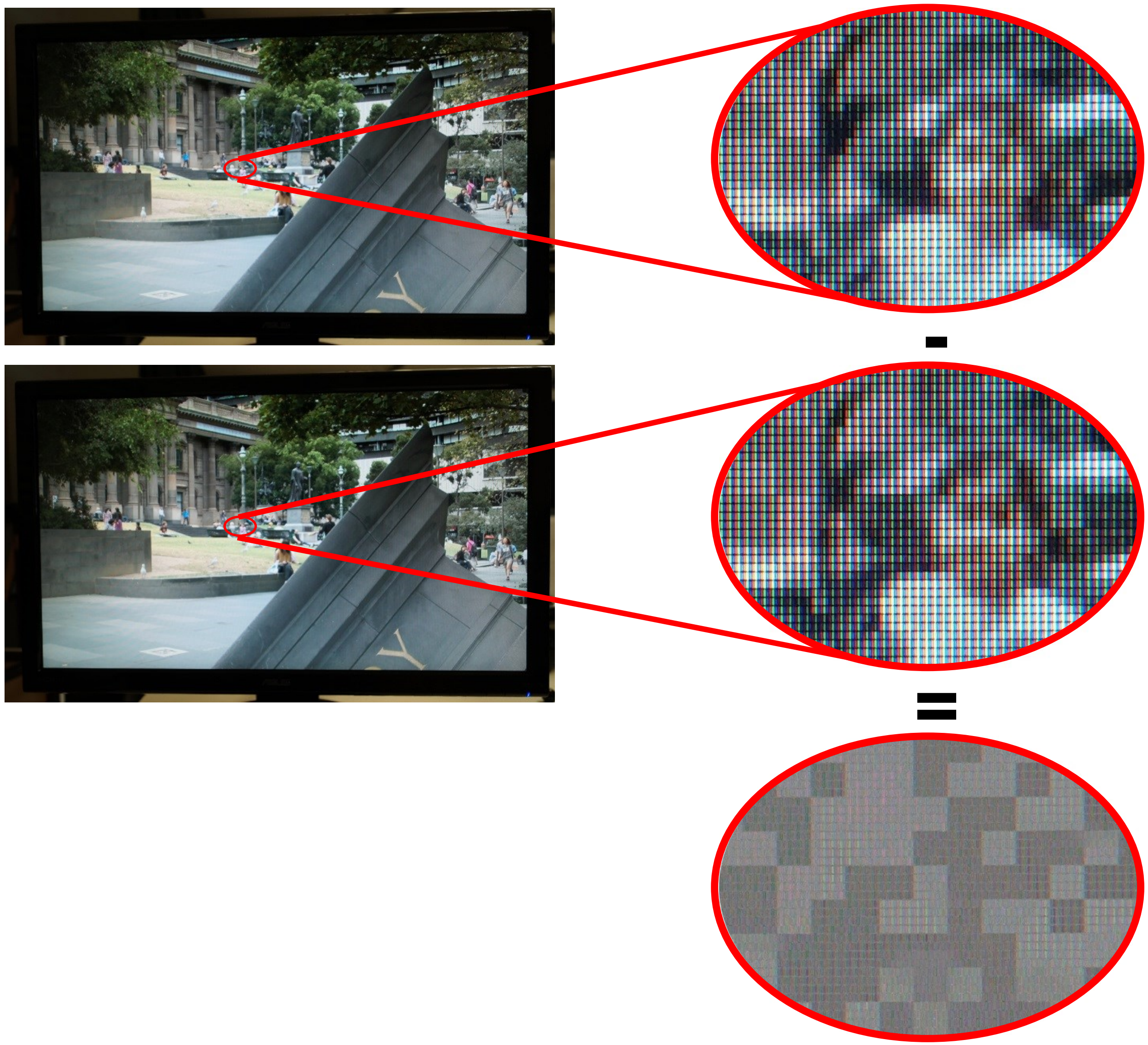
$$i = (l \cdot B_X) \bmod N_x + \varphi_X, \;\; \varphi_X = 0 \ldots (B_X - 1)$$

$$j = \lfloor l / N_X \rfloor \cdot B_Y + \varphi_Y, \;\; \varphi_Y = 0 \ldots (B_Y - 1)$$

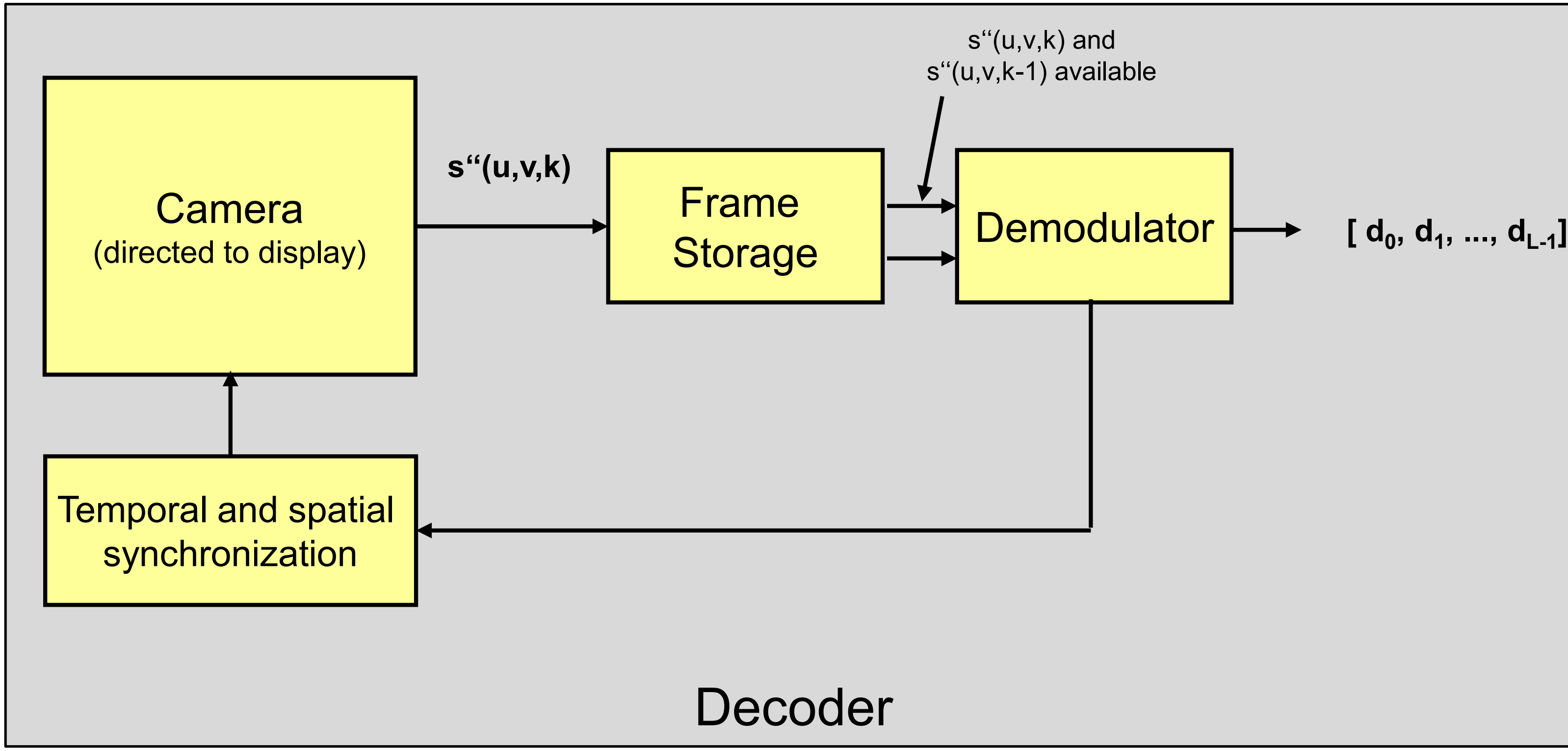
Example: Temporal Differential Modulation Y

Frame 1

Frame 2

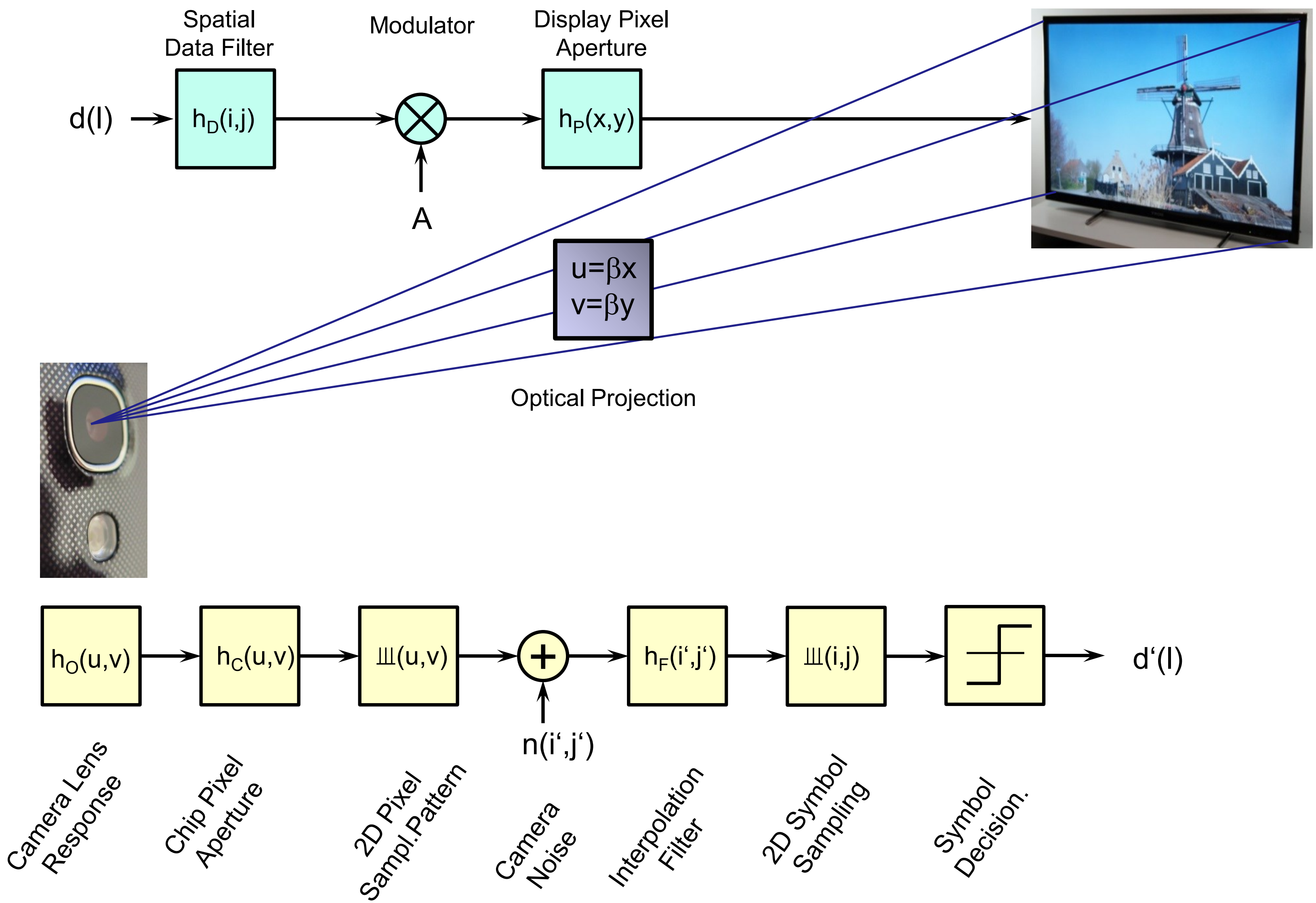


Block Diagram Decoder



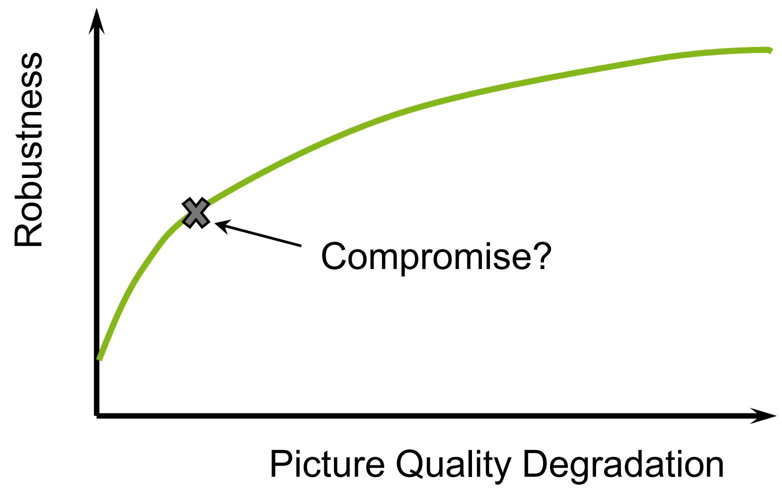
Decoder might be implemented in a Smart Phone ...

System Model of Spatial Data Processing



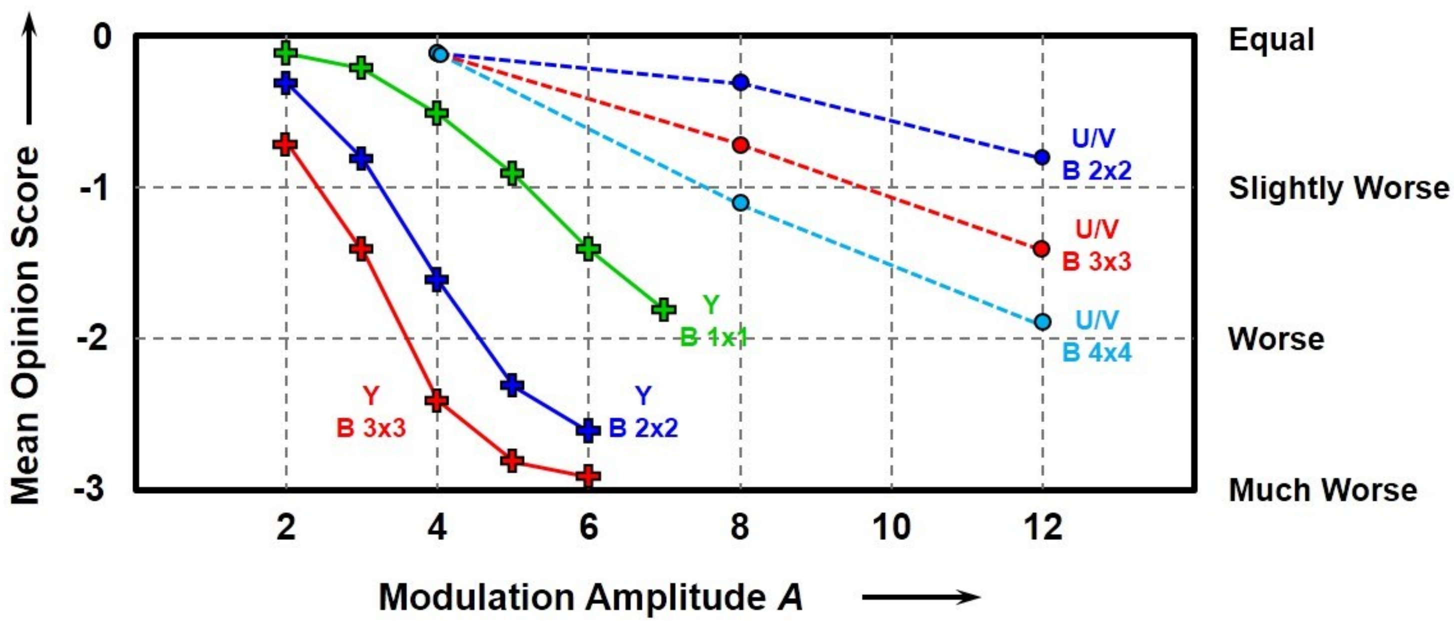
Modulation Characteristics

- **Temporal differential modulation requires pairs of frames with same video content (frame repetition)**
- **Receiver camera needs frame synchronisation**
- **Visibility of modulation depends on modulation amplitude, structure of data overlay, and frame rate**

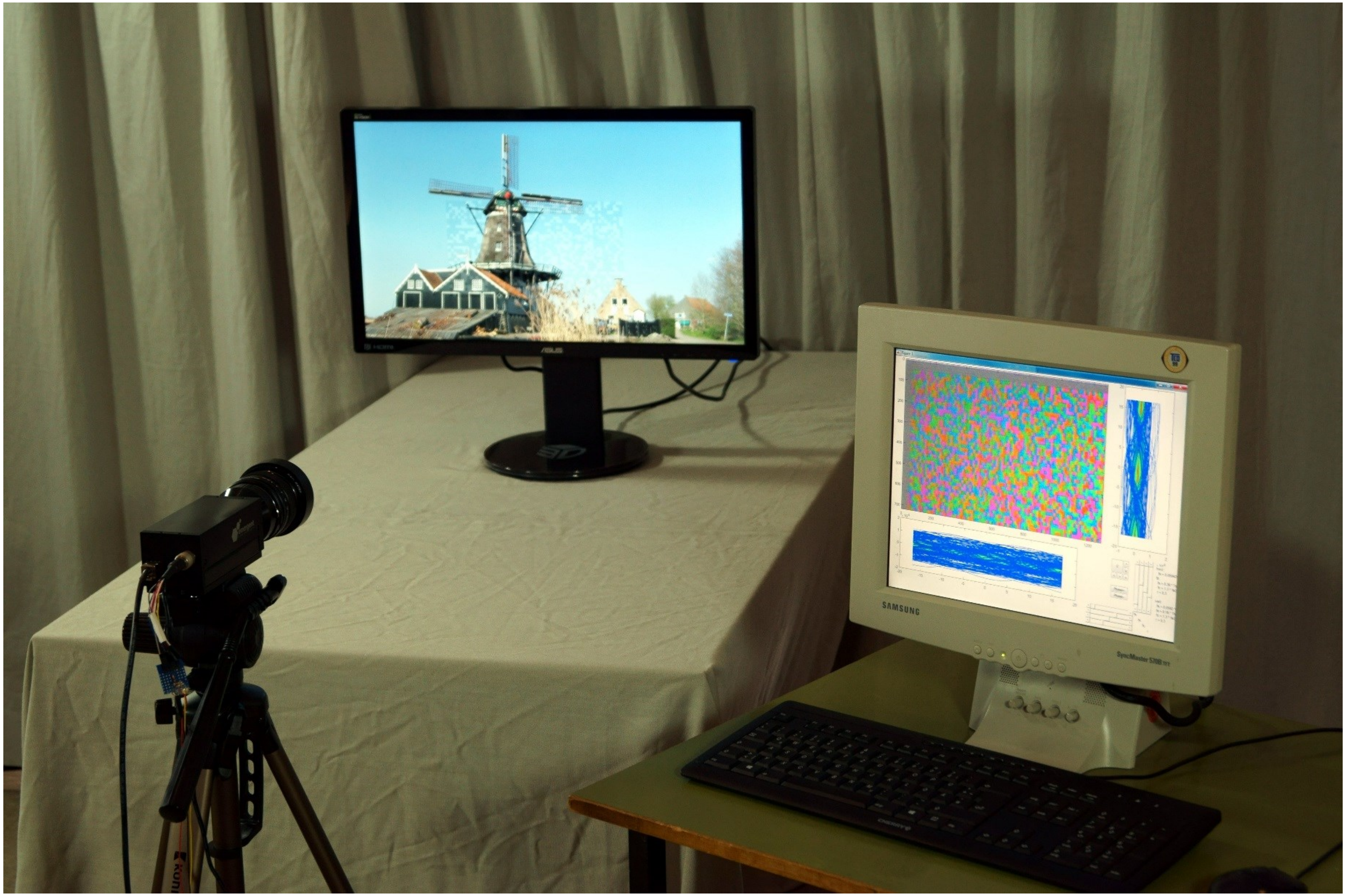


Subjective Evaluation Results

- Subjective test with 15 expert viewers, 3H viewing distance, 60 frames per second, 1920 x 1080 pixels, 24“ computer monitor
- Three different HD video scenes
- Evaluation of Y and U/V Modulation, different block sizes



Transmission Testbed



TU Dortmund Experimental Setup: First Results

- **First experimental transmission uses simple protocol to stream picture data or audio files**
- **„Version 0.1“: differential modulation of chroma components**
- **Modulation amplitude A=8, block size 4x4**
- **Only part of the screen modulated**
- **Resulting data rate: 4,5 Mbit/s**
- **Error probability (without FEC) 0.3 – 2.8 x 10^{-3}, depending on video content**
- **With simple FEC (RS-Code) almost error free transmission of picture and audio files**

Outlook and Future Work

- **New concept of video device based communication appears very promising and attractive for different media applications**
- **First experimental setup achieves 4.5 Mbit/s at reasonable error rate**
- **Fine tuning of parameters and filter algorithms should provide much better performance**
  - soft decision
  - forward error correction
  - optimized spatial filtering
  - temporal synchronisation of camera
- **Demonstrators will show feasibility in different scenarios:**
  - Personal Indoor
  - Multiuser Indoor
  - Multiuser Outdoor

technische universität
dortmund

Thank You for Your Attention!