Fuzzy-Controlled Perceptual Coding of Videophone Sequences

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Outline

- Video compression and the need for fuzzy control.
- The fuzzy controller
  - Fuzzy inputs
  - Fuzzy Associative Memory (FAM) banks
  - Membership functions
  - Bit assignment and buffer control
- Results
- Conclusion
H.261 Video coder

- Each frame can be coded in a way similar to JPEG
- Frames do not change much over time => time domain compression
- Motion vectors represents the movement of a block from frame to frame
- Main issue: Rate control
  - Limited channel and fixed buffer length => encoder must produce ≈ fixed bit-rate
HVS based rate control

- Simplest way:
  - Quantization parameters chosen according to transmission buffer fullness
  - Bits may not be used in accordance with the Human Visual System (HVS)

- This paper:
  - A way of choosing the parameters in accordance with the HVS using Fuzzy-Control
The fuzzy bit-rate controller
Fuzzy system input

- **Energy**
  \[ E_k = \frac{1}{N^2} \sum_{(i,j) \in MB_k} (f_{i,j} - \bar{f}_k)^2 \]

- **Entropy**
  \[ H_k = - \sum_{i=0}^{L_{\text{MAX}}} p_i \log p_i \]

- **Current motion activity**
  \[ MV_k = u_k^2 + v_k^2 \]

- **Previous motion activity**
  \[ PMV_k = \bar{u}_k^2 + \bar{v}_k^2 \]
Relevance FAM bank

- Empirical tuning => Fuzzy Associative Memory (FAM) banks
- E.g:
Membership functions

Energy

Entropy

Motion activity
Block relevance

- Combining the total 31 FAM’s => block relevance (also fuzzy)
Bit assignment

- How bits are assigned to each block

\[ B_k = B_{\text{DCT}} \frac{R_k \tilde{B}_k}{\sum_{j=1}^{\text{NMB}} R_j \tilde{B}_j} \]

- \( B_{\text{DCT}} \): Available bits pr. frame
- \( \text{NMB} \): Number of blocks pr. frame
- \( \tilde{B}_k \): Bits as function of block activity
- \( R_k \): Relevance factor
Buffer control

- Choosing the quantization level
  - Function of activity level, $A_k$
  - and number of available bits, $C_k$. 

![Graphs showing quantization levels]

$m(A_k)$

$m(C_k)$

$m(q_k)$
Results 1

- Better use of the available bits
Results 2

- Better peak signal-to-noise ratio

- Available bit rate: 4369 bit/frame
- RM8: average of 4304 bit/frame
- Fuzzy: average of 4348 bit/frame
Results 3

- Clear visible difference

RM8

Fuzzy Controlled Coder
Conclusion

- Actual video coding standards allow significant compression factors, but degrades the quality.
- Better choice of quantization parameters will improve perception (HVS).
- Fuzzy Control gives the tools to simplify and implement this.
- Easy to reconfigure to other types of coders or tune to specific images because of the use of fuzzy rules.