University Defence Research Centre (UDRC)
In Signal Processing

Sponsored by the UK MOD

Scalable Information Fusion: Adaptivity for Complex Environments and Secure Data
Theme: Distributed Signal Processing

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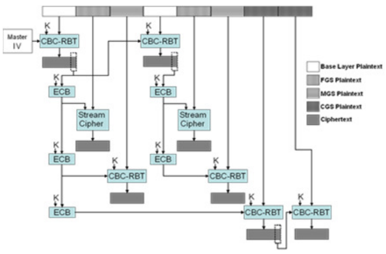
Research Objectives

- Produce scalable video encryption / fusion technique
- Produce effective scalable fusion and coding technique (in the compressed domain)

Scalable Video Encryption

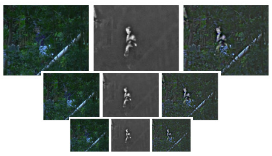
- Novel scalable encryption technique developed applicable to video fusion
- Using Cipher Block Chaining (CBC)
  - Dependencies of the chain encryption mirror the dependencies of the scalable levels in an SVC codec
  - Transcoding and scalability therefore possible without leaving the remaining video undecipherable



- ECB: Electronic Code Book (ECB) mode encryption
- Cipher Block Chaining (CBC)
- Residual Block Termination (RBT)

Scalable Fusion using 3D Wavelet Transform

Introduction / Motivation



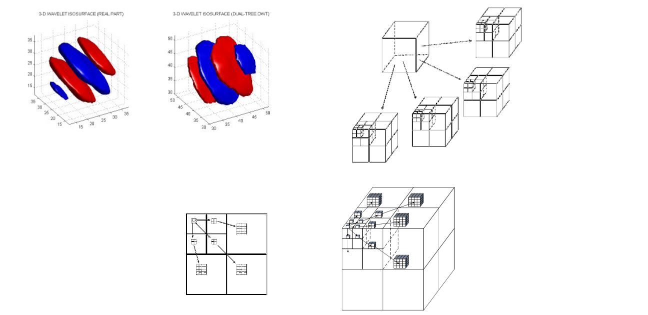
- Fusion in the compressed domain of video is difficult due do spatial and temporal dependencies necessary for efficient compression (as used by standards such as SVC and AVC).
- The aim is therefore to develop a video compression technique that uses neither temporal or spatial prediction and therefore has neither temporal or spatial dependencies.
- Simple 3D wavelet compression only generates good compression results when motion compensation is also used (motion compensated temporal filtering MCTF).
- The 3D dual-tree wavelet transform gives directional subbands and is therefore able to effectively compress the signal without any motion compensation.

Compression Using the 3D DT-CWT

- The 3D dual-tree wavelet transform gives directional subbands and is therefore able to effectively compress the signal without any motion compensation.
- There are therefore no temporal and / or spatial dependencies in the system enabling fusion in the compressed domain.
- The dual-tree wavelet transform is over-complete and therefore difficult to compress.
  - A noise shaping algorithm is able to sparsify the compressed coefficients, concentrating the compressed data into a small number of significant coefficients.
  - The resulting subbands are compressed using a 3D zero-tree coding algorithm (based on SPIHT)
  - Results show that the fusion performance in the 3D dual tree wavelet domain gives at least as good results to fusion techniques developed using 2D wavelet transforms.
  - Much better compression results are possible: Integration of entropy coding, exploitation of inter-tree correlation in the complex wavelet coefficient domain.

3D Dual Tree Wavelet Transform

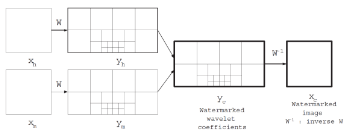
Video "cube" transformed into 28 subbands per scale

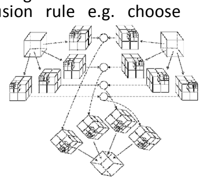


SPHIT coding (2D and 3D). Dual tree SPIHT coding is effected using 4 3D cubes (right) of orientated subbands.

Fusion using 3D DT-CWT

- Fusion of multi-modal images usually done in the transform domain of a multi-scale image transform such as a 2D wavelet transform.
- Fusion in the 2D wavelet transform domain
  - The two images are transformed and the resultant coefficient in each subband is generated by a fusion rule (e.g. choose maximum)
- Fusion in the 3D wavelet transform domain
  - Equivalent to the 2D wavelet transform fusion but fusing coefficients in the 3D spatio-temporal subbands (using a similar fusion rule e.g. choose maximum)



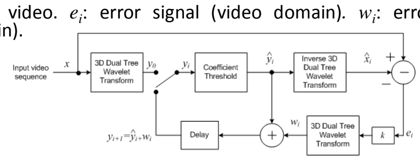


Fusion in the 2D dual tree domain

fusion in the 3D dual tree domain

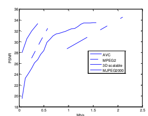
Noise Shaping for 3D Wavelet Video Compression

x: Input video. y_i: wavelet coeffs. y_i: thresholded wavelet coeffs. $\hat{y}_i$ $\hat{x}_i$ Reconstructed video. e_i: error signal (video domain). w_i: error signal (transform domain).

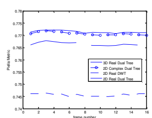


Results

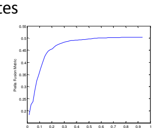
Rate distortion graph of the 3D wavelet transform method



Comparison 3D and 2D fusion methods.



Piella fusion metric for two sequences decoded at different rates



Conclusions

- Effective scalable encryption system developed for fusion applications
- Scalable fusion system developed using 3D dual tree wavelet
  - Better compression results than frame-by-frame wavelets (e.g. JPEG2000)
  - Fusion results at least as good as frame by frame complex wavelets

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MINISTRY OF DEFENCE

EPSRC
Engineering and Physical Sciences Research Council

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