REAL-TIME FUSION OF VISIBLE AND THERMAL INFRARED IMAGES IN SURVEILLANCE APPLICATIONS ON SOC HARDWARE.

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Konrad Moren, Thomas Perschke

Institute of Optronics, System Technologies and Image Exploitation (IOSB)
Ettlingen Germany

konrad.moren@iosb,fraunhofer.de , thomas.perschke@iosb.fraunhofer.de

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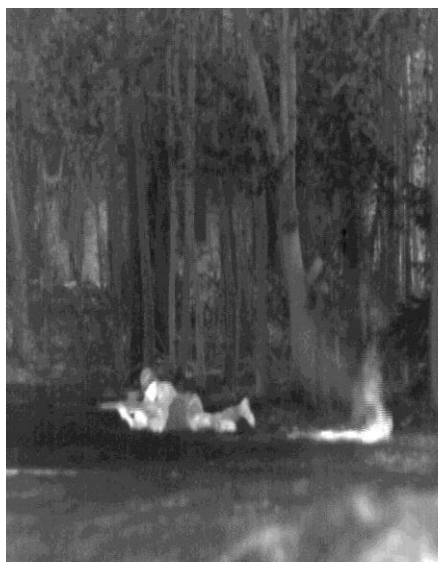
Fusion of visible and thermal infrared images - Applications

https://www.flir.com/products/duo/

http://www.dailymail.co.uk/sciencetech/article-2640869/Google-glass-war-US-military-reveals-augmented-reality-soldiers.html

https://www.bhphotovideo.com/c/product/1373861-REG/bosch_mic_9502_z30wqs_mic_ip_fusion_9000i.html

https://www.optik-pro.de/



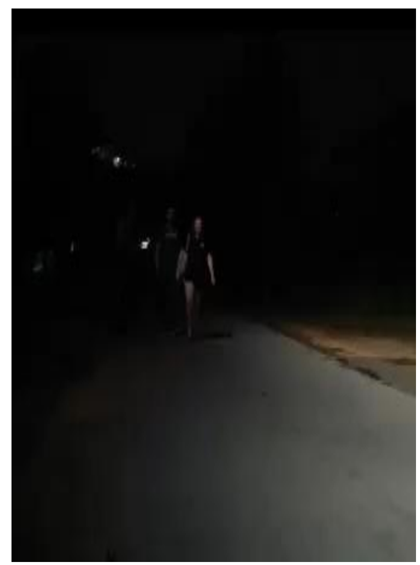
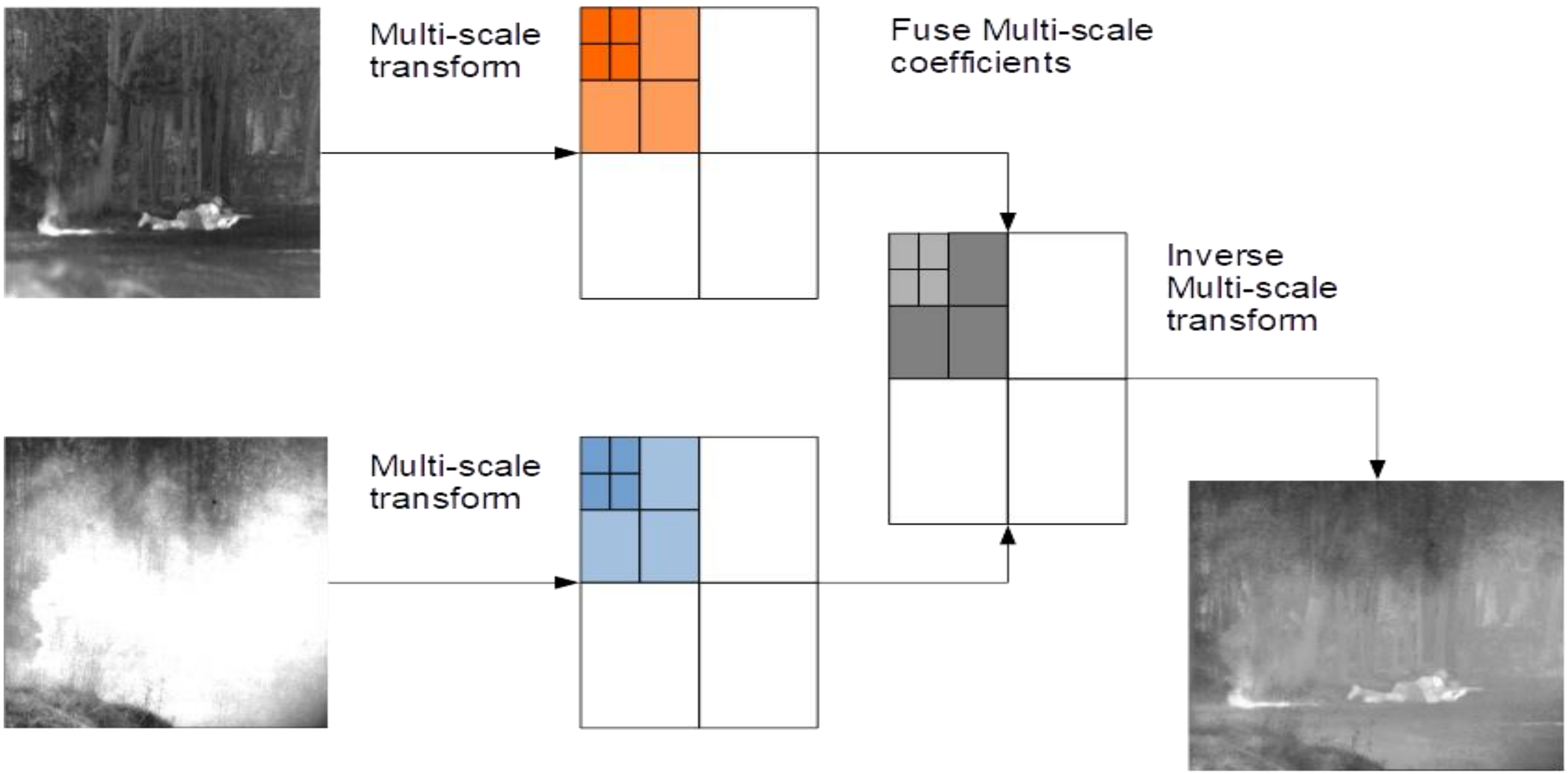


Image Fusion – Visual and IR Images



Input images

Fused image

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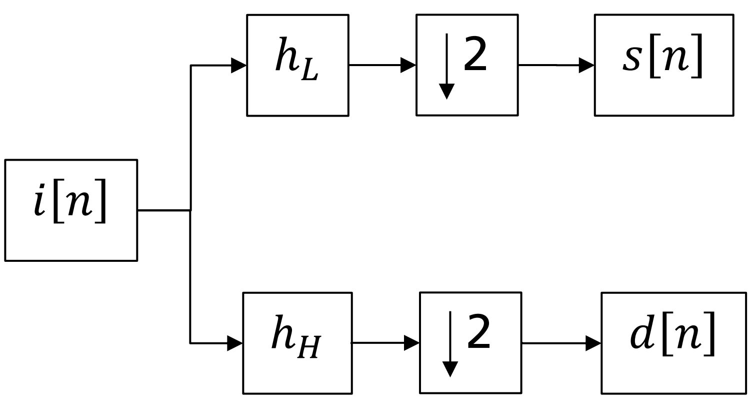
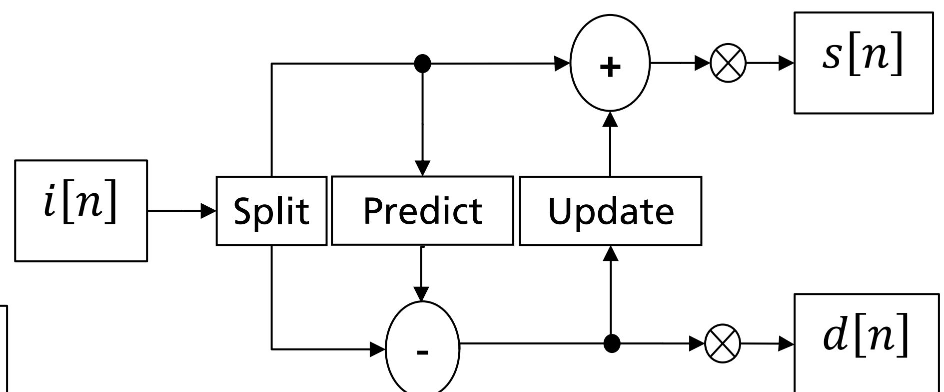
Multi-scale transformations

- Discrete Wavelet Transformation (DWT)
  - First generation wavelets - DWT Mallat Scheme
    - Standard method used to create the multi-scale representation
  - Second generation wavelets - DWT Lifting Scheme
    - Optimized method with reduced number of arithmetic operations

DWT first generation



DWT second generation



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DWT Convolution

- 2D convolution with a low and a high pass (FIR) filters
- Filters are separable – Decompose filtering into a vertical and horizontal 1D-convolution

n	0	1	2	3	4
Low pass $h_L[n]$	0.06029	0.26684	-0.07822	-0.01686	0.0267
High pass $h_H[n]$	0.5575	0.2956	-0.0287	-0.0456	0

- Coefficients for the Cohen-Daubechies-Feauveau 9/7 wavelet

- Filters are symmetric :
  - $s[n] = i[2n] \cdot h_L\ [0] + \sum_{k=1}^{4}(i[2n+k] + i[2n-k]) \cdot h_L[k]$
  - $d[n] = i[2n+1] \cdot h_H\ [0] + \sum_{k=1}^{3}(i[2n+1+k] + i[2n+1-k]) \cdot h_H[k]$

- Complexity minimum effort : 23 MAD = 9 MUL + 14 ADD per output pixel pair ($s[n]$, $d[n]$)

DWT Lifting

- Lifting method reduces computational complexity of convolutions
- Convolution operation changed in series of lifting steps
  - Split, Update, Predict, Normalize
- Complexity, minimum effort: 14 MAD = 6 MUL + 8 ADD per output pixel pair ($s[n]$, $d[n]$)

n	0	1	2	3
$\boldsymbol{\alpha_n}$	1.58613	0.05298	0.88291	0.44351
$\boldsymbol{\beta_n}$	0.81289	0.61508	/	/

Split

$$s_0[n] = i[2n]$$
$$d_0[n] = i[2n+1]$$

Update, Predict

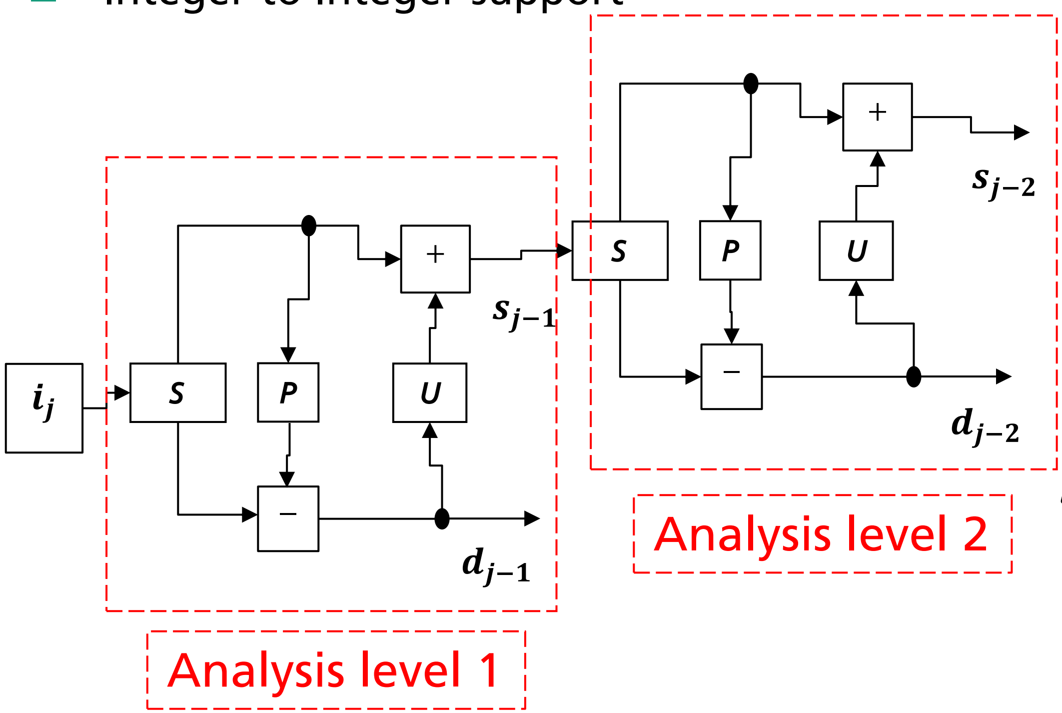
$$d_1[n] = d_0[n] - \alpha_0 \cdot (s_0[n+1] + s_0[n])$$
$$s_1[n] = s_0[n] - \alpha_1 \cdot (d_1[n] + d_1[n-1])$$
$$d_2[n] = d_1[n] - \alpha_2 \cdot (s_1[n+1] + s_1[n])$$
$$s_2[n] = s_1[n] + \alpha_3 \cdot (d_2[n] + d_2[n-1])$$

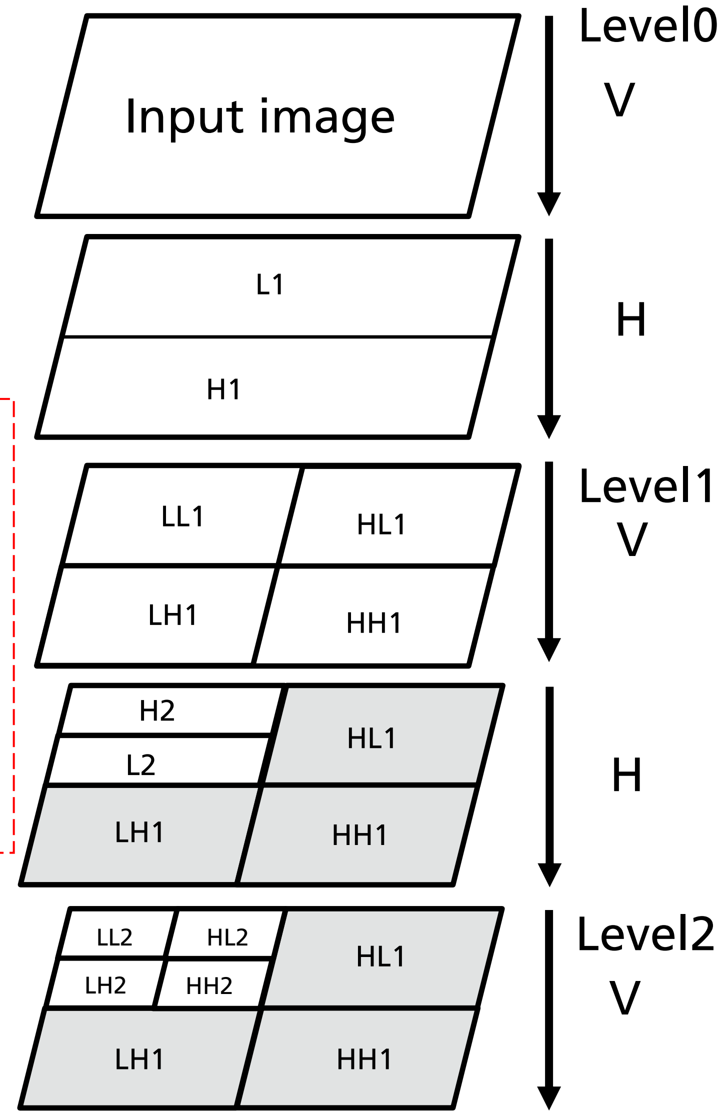
Normalize

$$\mathrm{s}[n] = \beta_0 \cdot s_2[n]$$
$$\mathrm{d}[n] = \beta_1 \cdot d_2[n]$$

Multi-level DWT Lifting

- Transformation in-place no auxiliary memory needed
- Efficient boundary extension handling
- Simple decoder structure , reversed order of encoder
- Integer to Integer support





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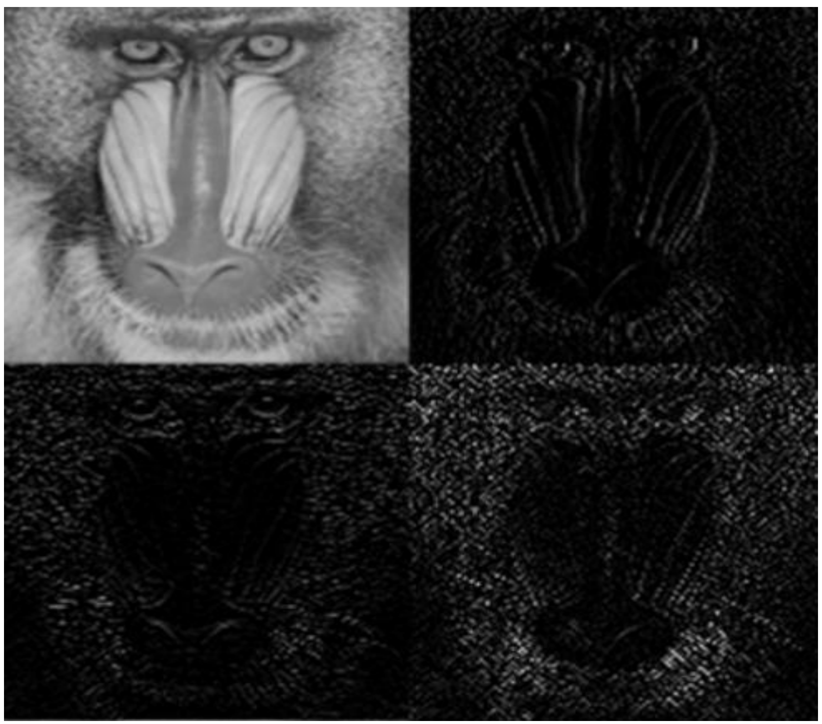
Multi-level fusion

- Pixel-wise combine functions:
  - Average, Abs-max fusion $F_j[n] = Max(Abs((V_j[n] + IR_j[n]) * 0.5)))$
  - Fusion operators independent at different DWT analysis/synthesis levels



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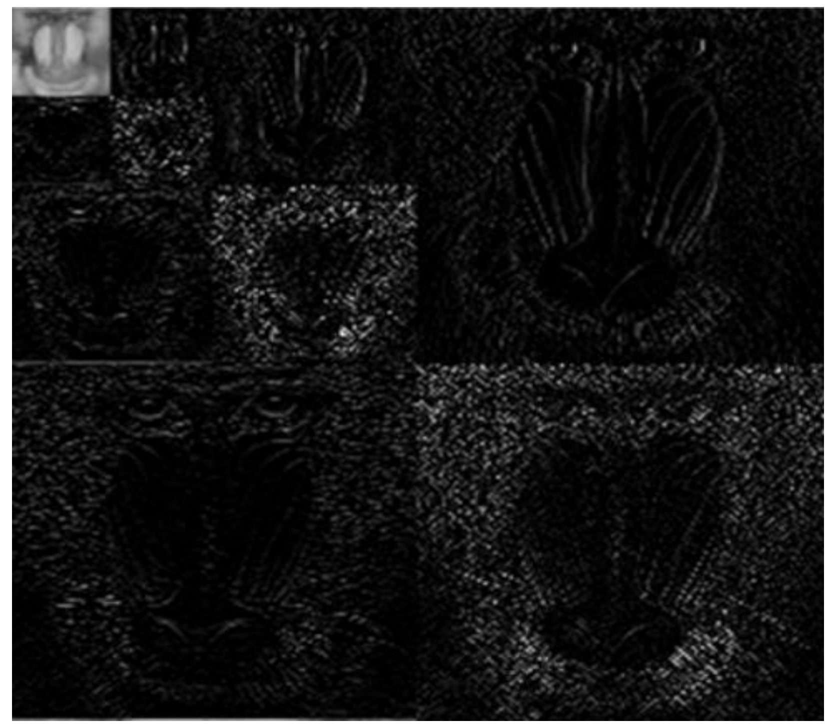

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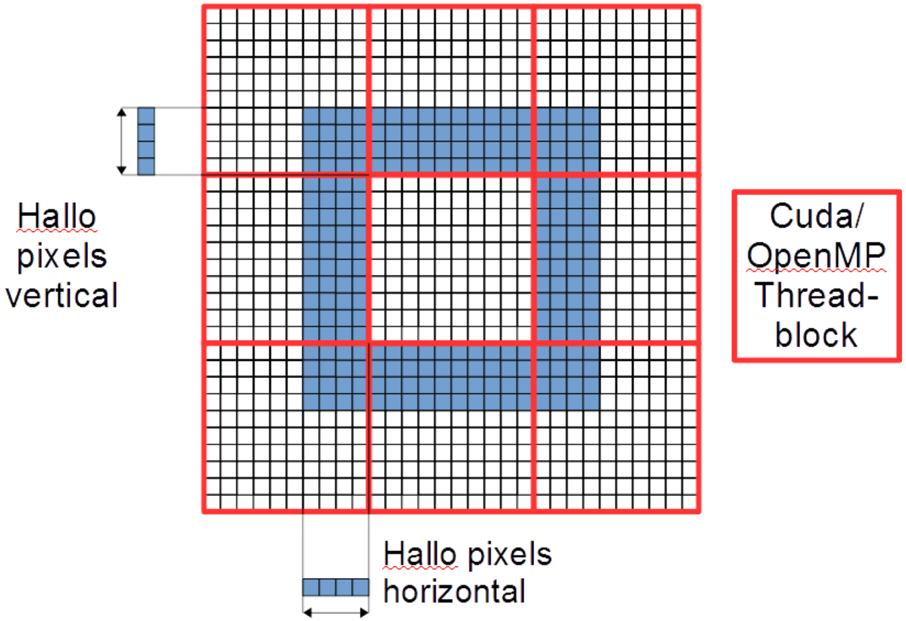
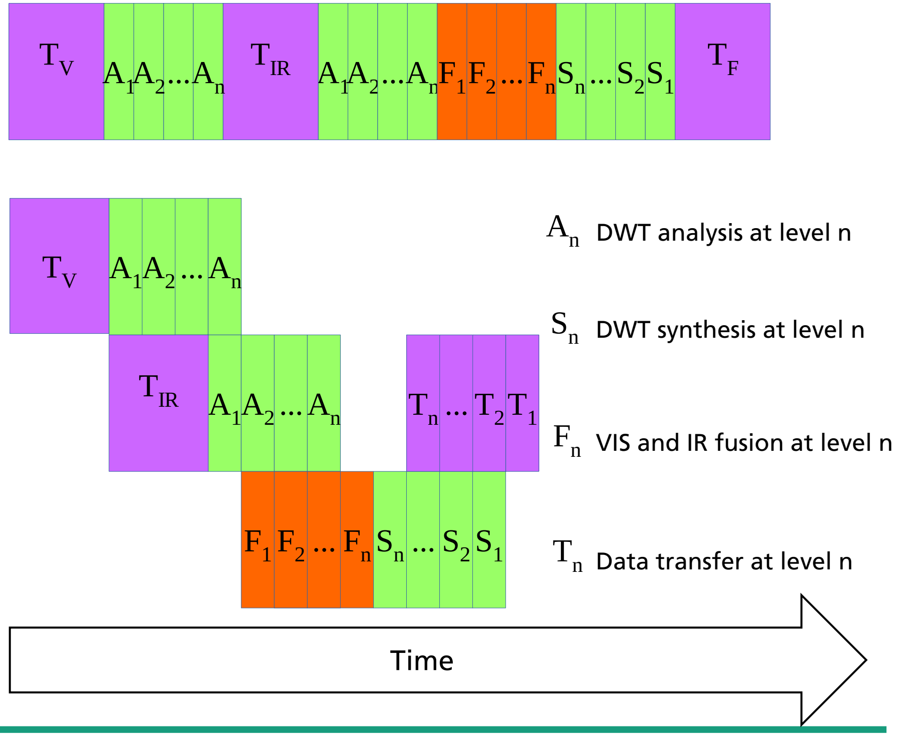
Data parallel, pipelined Fusion

- DWT- Lifting parallelized on CPU and GPU
  - Each output pixel pair computed independently
- Pipelined data transfers between I/O and CPU/GPU
  - Overlapped data transfers with computation





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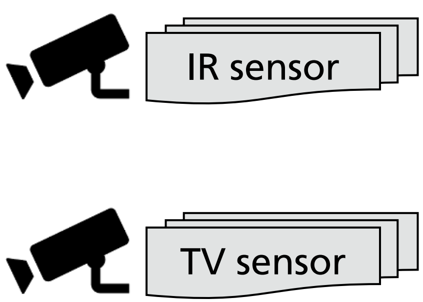
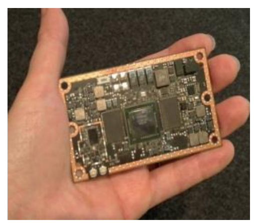
Evaluation - SoC Hardware

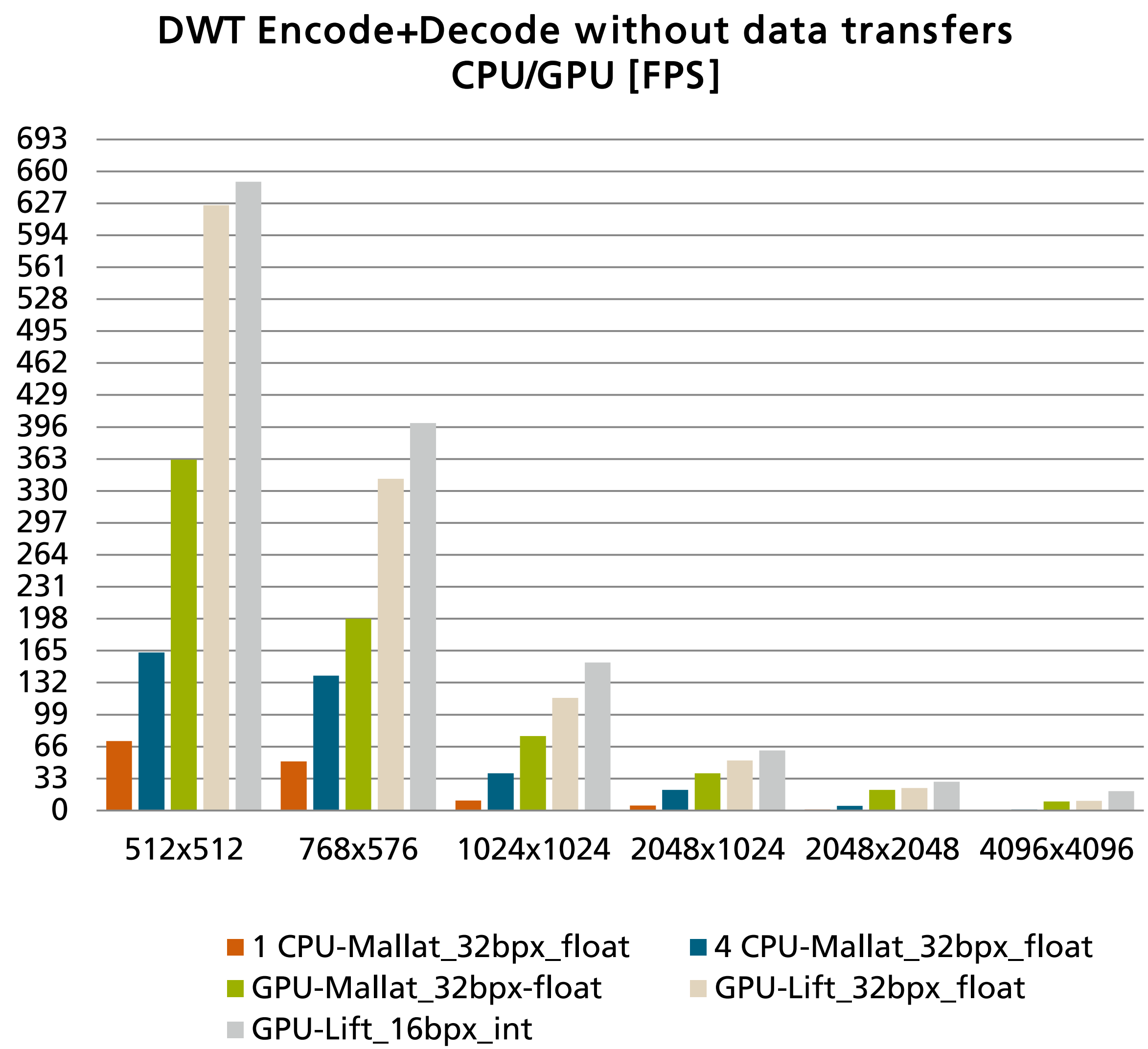
- Jetson TX2 NVidia
  - Programmable multi-core CPU / GPU
  - More than a 1 TFLOP/s of performance at 7.5Watt





Results

- Performance DWT:
  - DWT-Lifting performance 1.41x better than DWT-Mallat
  - GPU performance 4.7x higher than CPU
  - Real-time (30 Hz) performance with GPU for Full-HD resolution



*Mean values of 100 tests per image , 5 DWT levels , CDF 9/7 Wavelet

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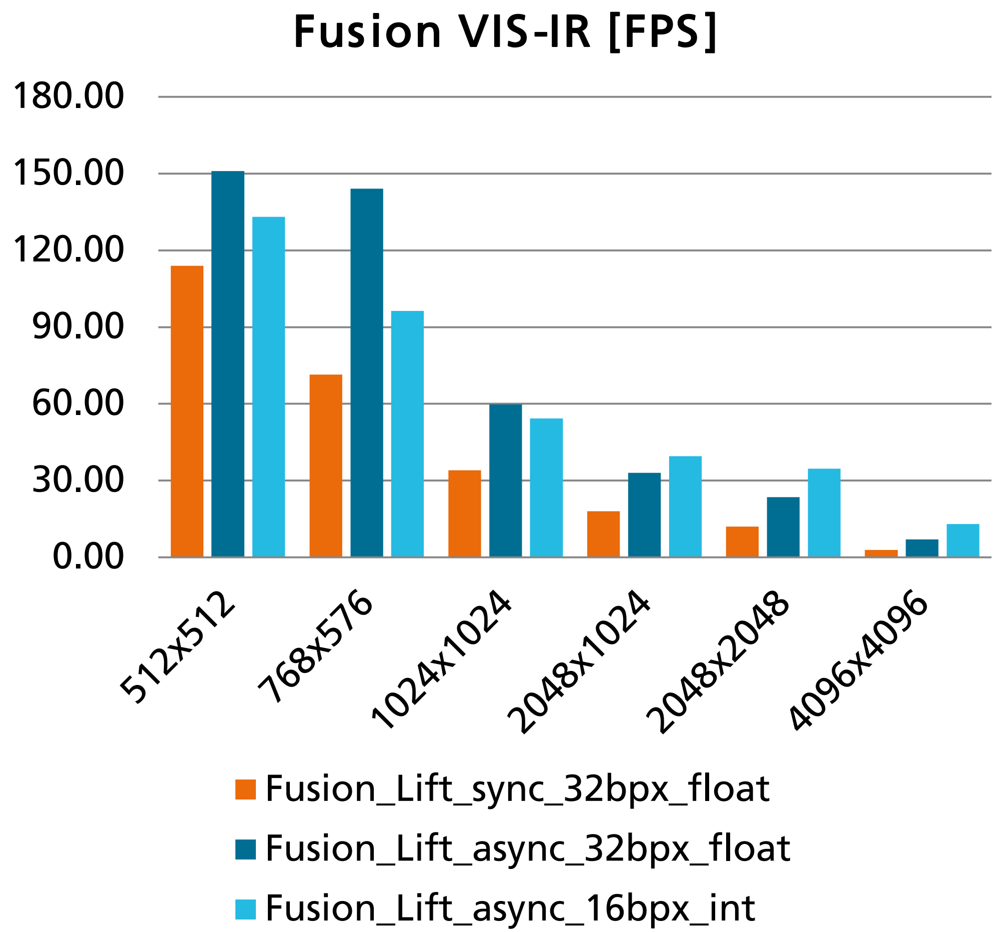
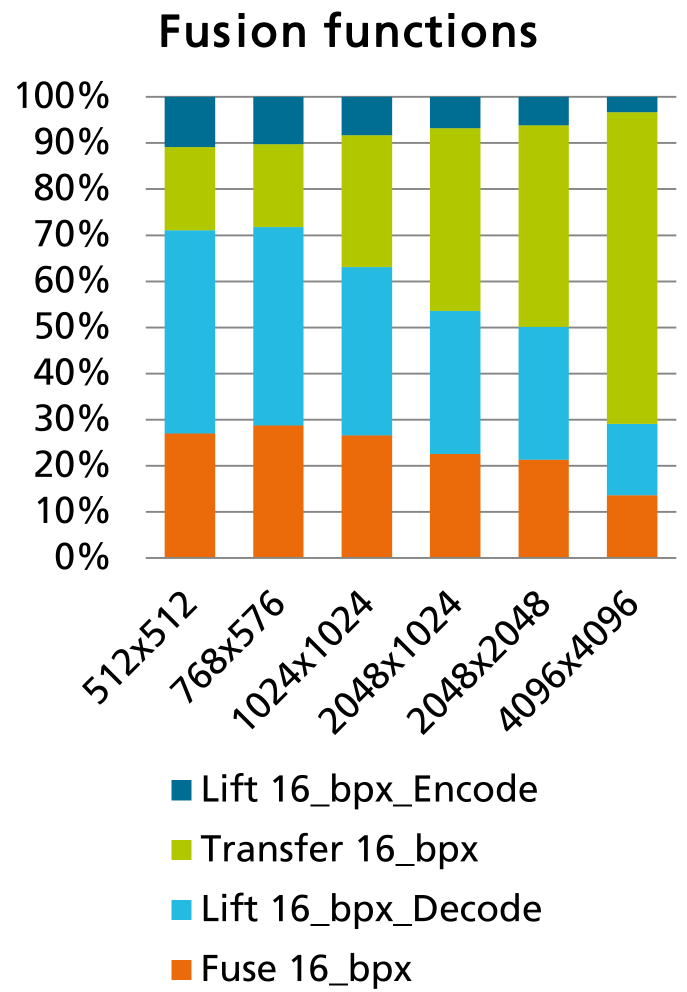
Results





*Mean values of 100 tests per image , 5 DWT levels , CDF 9/7 Wavelet

Conclusion, Future work

- We show that the pipelined fusion method provides a real-time performance.
- The CPU is less suited than the GPU for a data-parallel DWT.
- The higher memory throughput of GPU is crucial for performance.
- The data transfers are bottleneck to further improve the performance.
- We plan to optimize the data transfers between I/O sensors and processing units.

Thanks for you attention! Questions?