USING CCSDS IMAGE COMPRESSION STANDARD FOR SAR RAW DATA COMPRESSION IN THE H2020 EO-ALERT PROJECT

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Overview

Started in Jan. 2018, duration: three years

6 partners:

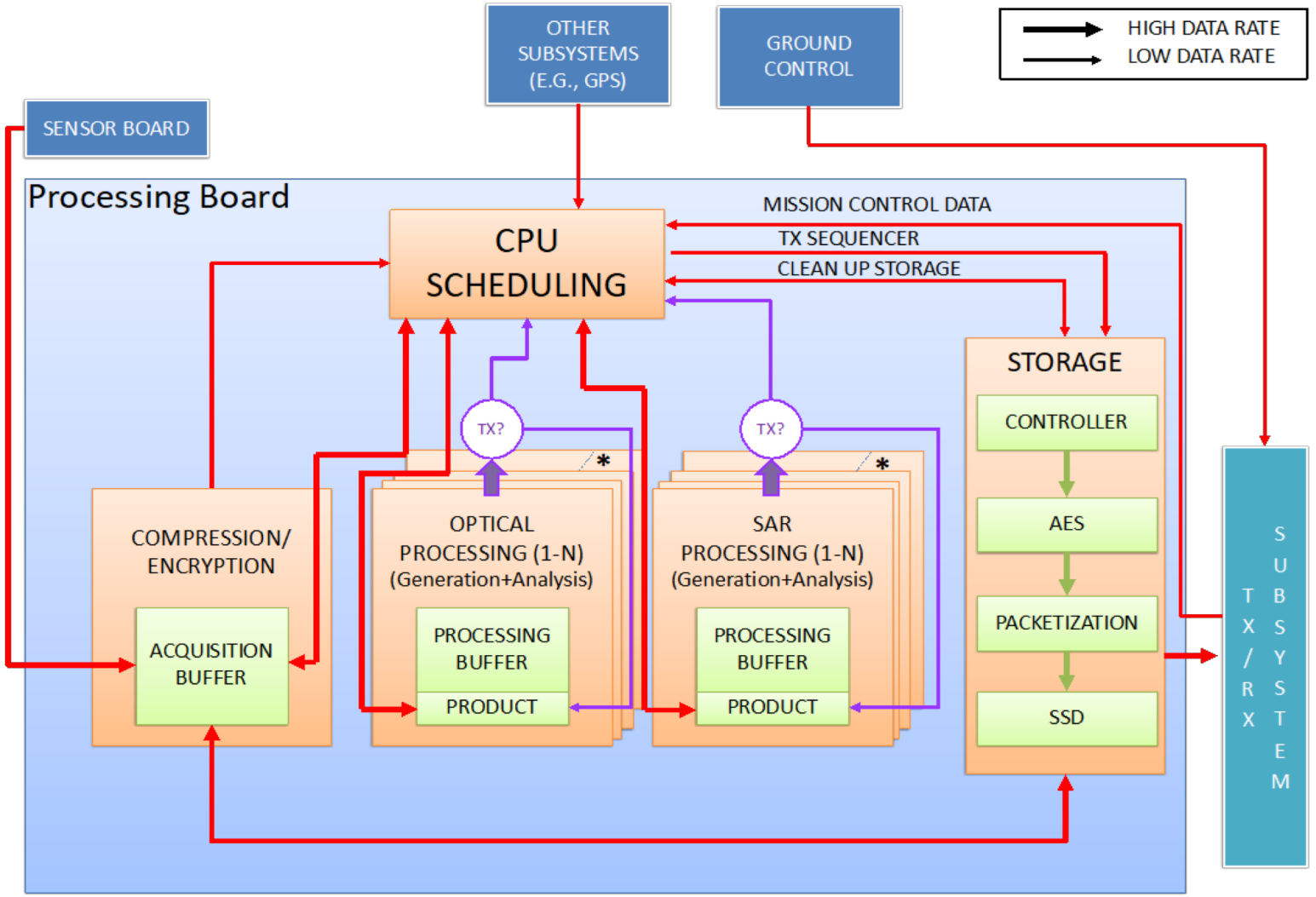
- Deimos space (Spain) – coordinator
- DLR (Germany)
- Technische Universitaet Graz (Austria)
- Politecnico di Torino (Italy)
- OHB Italia (Italy)
- Deimos Imaging SLU (Spain)

Project goals

Goal: to address the need for increased data chain throughput

- New approach for the provision of low latency EO data products, exploiting the flight segment processing capabilities
  - ✓ ideally: latency < 1 minute
- Move key EO data processing elements from the ground segment to the satellite
- Full data chain testing to be performed on an Avionics Test Bench using experimental EO data

EO-ALERT architecture



Compression needs

Different types of data to be compressed:

- **Optical raw/image data**: will employ **CCSDS 123.0-B-2** recommendation
  - High compression performance, relatively low complexity, very flexible quality management
  - Lossy/lossless compression
    - ➢ Will typically be used to compress raw data, and occasionally to compress generated data as part of verification of image generation algorithms
  - May be used with prequantization and deep-learning based restoration (see companion paper)
- **SAR raw data**: subject of this paper
- **Data products** generated on board («Alerts»)

SAR raw data compression

Computationally challenging problem:

- Data are coming in at very high rate
- At the same time, data are very noisy
  - ✓Simple techniques, lossy compression
- **Block adaptive** quantization (Kwok ’89) (BAQ, FBAQ) and variants
  - ✓Adaptive on data blocks (slowly varying σ) → employs blockwise normalization
  - ✓Lloyd-Max quantizer (Gaussian data)

SAR raw data compression

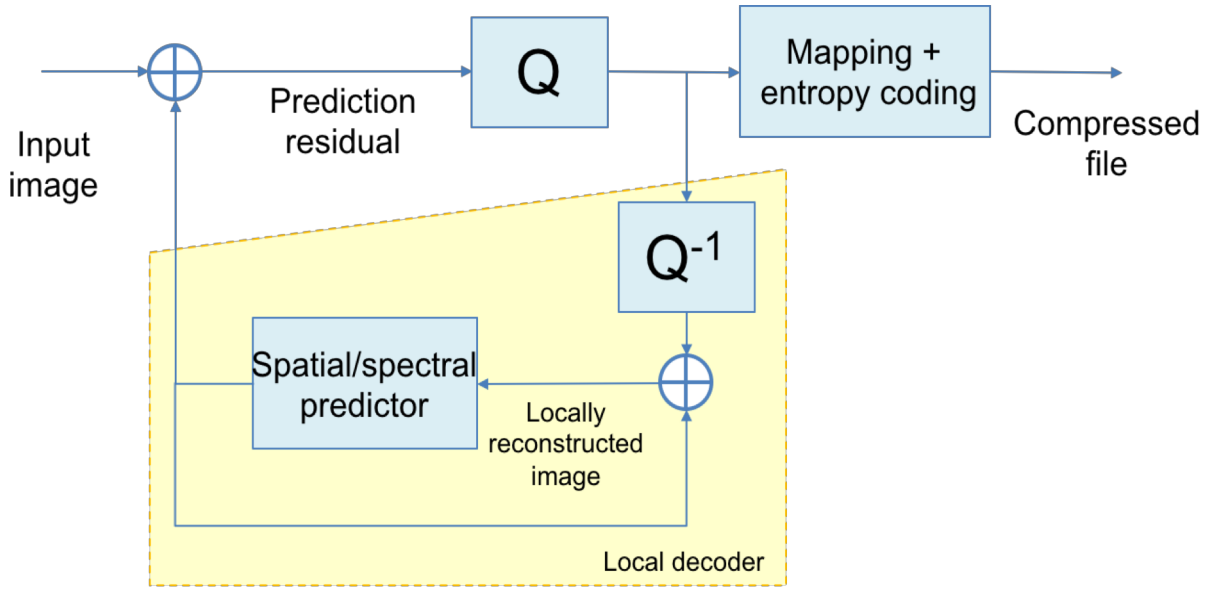
- **Vector** quantizers (Moreira, Blaeser ’93)
- **Trellis-coded** quantizers (Owens, Marcellin ’99)
- **Predictive** compression (Olmo, Magli ‘02)
  - ✓Correlations in the SAR raw data stemming from chirp spectrum and antenna pattern

SAR raw data compression

- **Transform** coding
  - ✓ FFT (Benz, Strodl, Moreira ’95)
  - ✓ DCT (Benz, Strodl, Moreira ’95)
  - ✓ wavelet (Pascazio, Schirinzi ’99)
  - ✓ wavelet packets (Pascazio, Schirinzi ’00)
- **Partial focusing** (Bolle ’98, Poggi, Ragozini, Verdoliva ’00)
  - ✓ perform reversible operations similar to focusing the complex image, e.g. matched filtering
  - ✓ these transformed data are more correlated, and more similar to the focused image

Proposed approach

- Employing the CCSDS 123.0-B-2 standard (which is designed for optical images) also for SAR raw data
  - ✓ Employs prediction → may work well on the raw data
  - ✓ Employs entropy coding → improved compression efficiency
  - ✓ May benefit from blockwise normalization



Data and setup

- Raw data from four X-SAR scenes
  - ✓ Two prequantized on 6 bpp (Innsbruck, Jesolo)
  - ✓ Two prequantized on 2 bpp (Matera, Pantelleria)
- I and Q components are compressed independently
- Predictor in full mode, wide neighbor-oriented local sums
- Optional normalization on 32x32 blocks followed by 16-bit quantization
- Compared with BAQ (rates of 2 and 3 bpp)
  - ✓ CCSDS 123 yields variable rate

Results – without normalization

2 bpp	Rate I	Rate Q	SNR BAQ (I)	SNR BAQ (Q)	SNR CCSDS (I)	SNR CCSDS (Q)
Innsbruck	2.065	2.082	9.8481	9.8035	11.4928	11.3151
Jesolo	1.73	1.723	8.8841	8.5045	7.5489	7.3603
Matera	1.8	1.797	9.88	9.8461	10.449	10.4998

- CCSDS 123 works generally outperforms BAQ at equal rate

Results – without normalization

3 bpp	Rate I	Rate Q	SNR BAQ (I)	SNR BAQ (Q)	SNR CCSDS (I)	SNR CCSDS (Q)
Innsbruck	2.76	2.739	15.4039	15.3034	16.4663	16.2952
Jesolo	3.148	3.14	13.0329	12.7464	Inf	Inf
Matera	2.9	2.908	14.5174	14.4831	Inf	Inf

- CCSDS 123 works generally outperforms BAQ at equal rate, and may also reach lossless compression in some cases

Results - normalization

2 bpp	Rate I	Rate Q	SNR BAQ (I)	SNR BAQ (Q)	SNR CCSDS (I)	SNR CCSDS (Q)
Innsbruck	2.007	2.008	9.8481	9.8035	8.9919	9.1329
Jesolo	1.996	1.995	8.8841	8.5045	8.5598	8.4063
Matera	2.009	2.003	9.88	9.8461	8.008	9.7033

3 bpp	Rate I	Rate Q	SNR BAQ (I)	SNR BAQ (Q)	SNR CCSDS (I)	SNR CCSDS (Q)
Innsbruck	3.001	3.001	15.4039	15.3034	15.5343	15.6767
Jesolo	2.987	2.986	13.0329	12.7464	15.0281	14.8777
Matera	2.979	2.985	14.5174	14.4831	14.8777	16.2203

- Normalization does not seem to bring any benefit

Conclusions

- The CCSDS 123.0-B-2 standard also works well at compressing SAR raw data
  - ✓ it outperforms BAQ
  - ✓ it does not require blockwise normalization (the predictor seems to be able to adapt to changes in the statistics)
  - ✓ caveat: test data are prequantized (this is expected to harm CCSDS 123.0-B-2 more than BAQ)