Transformer-Based Neural Video Compression on Solar Imagery

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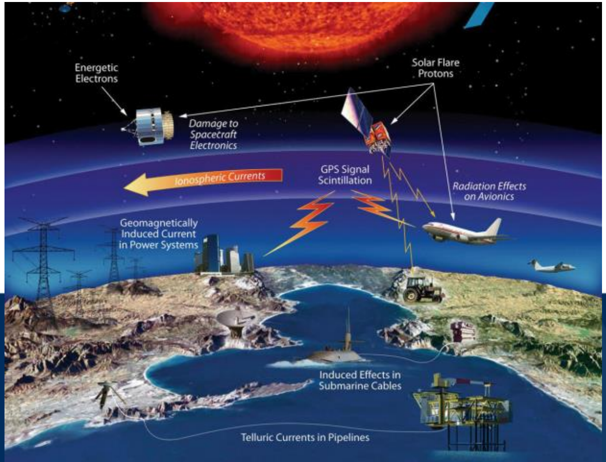
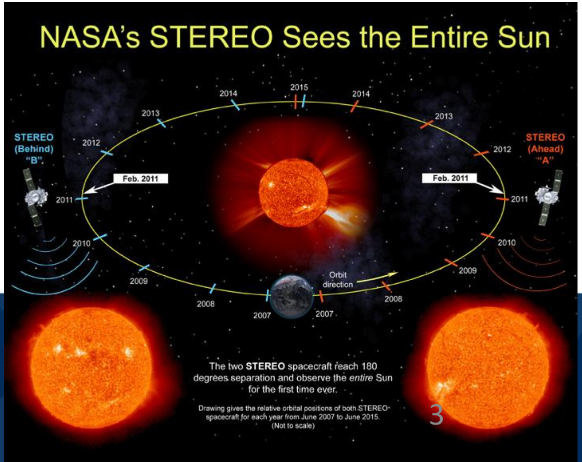
Overview

- Motivation
- Solar Dynamics Observatory (SDO)
- Neural Network-based Image Compression Approaches
- Neural Network-based Video Compression Approaches
- Our Contribution: Adaptation of Transformer-based Video Compression Scheme to SDO Image Dataset
- Results and Comparison
- Conclusions and future work

Motivation

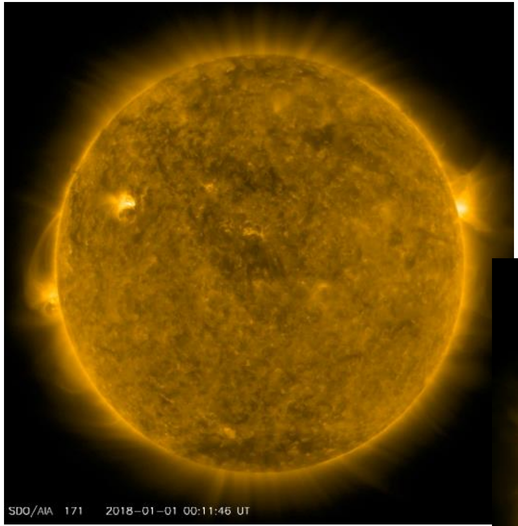
- The sun is essential for life in the solar system but can also wreak havoc on life and technology infrastructure in space and on ground (impacts of space weather)
- There is growing impetus on studying the sun for advanced scientific knowledge towards improved predictive capability
  - Multiple active and planned (deep-space) missions imaging the sun from different locations
    - SDO
    - SOHO
    - STEREO A and B
    - Solar Orbiter
    - Parker Solar Probe
    - Vigil (planned by ESA)
  - These missions (will) require effective and efficient data compression schemes to increase science and information return for operations

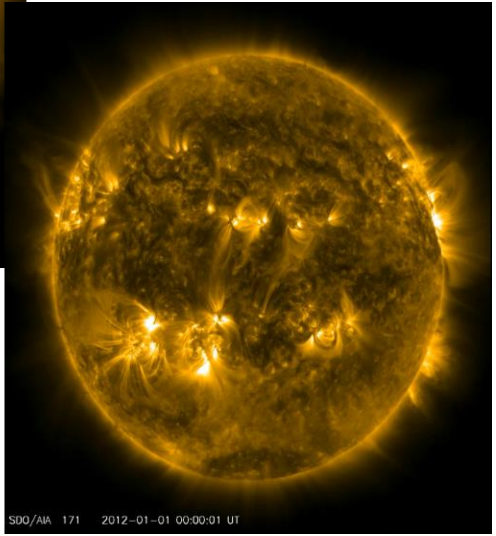




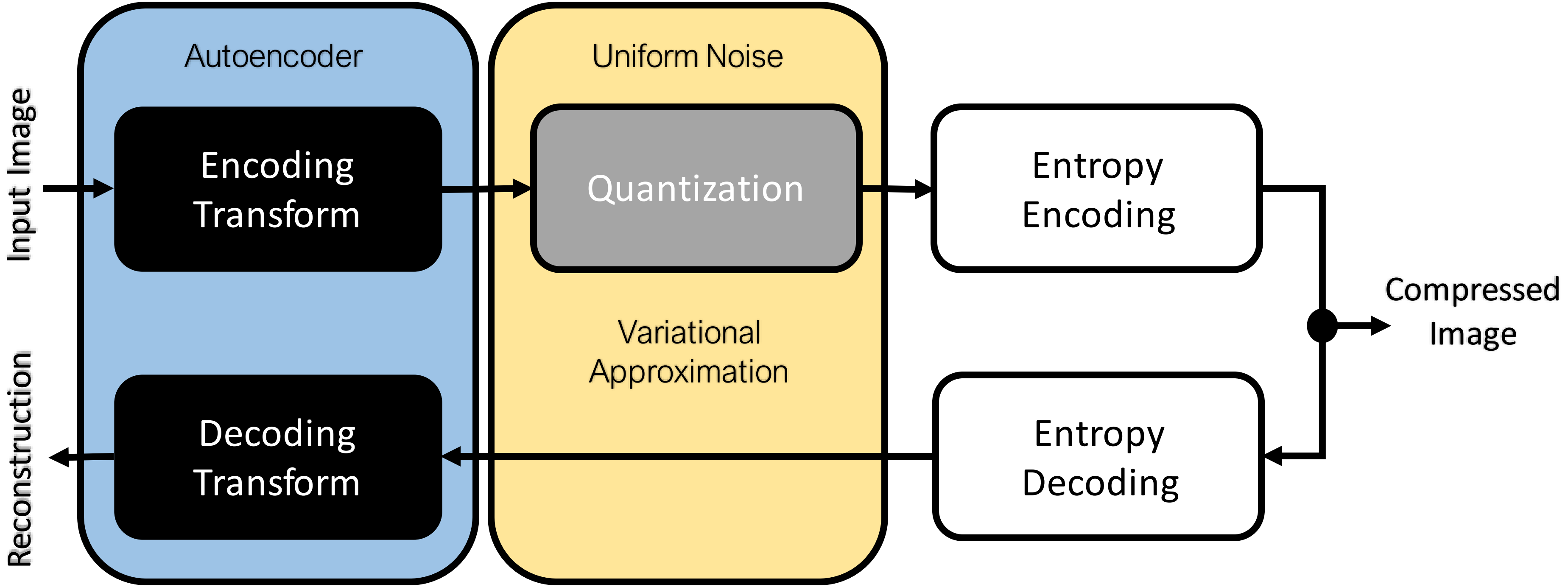
Solar Dynamics Observatory

- SDO is one-of-a-kind mission dedicated to continuously observe the sun from GEO
  - Launched in 2010, it has a dedicated ground station for data transmission
  - It captures a stack of 4K solar images across 9 different spectral wavelengths every 12 seconds
  - This results in 1.4TB of data each day, totaling multiple PBs thus far.
- The data collected has provided a wealth of scientific information about our star
- For this demonstration purpose, we use the curated ML-ready dataset (arXiv:1903.04538)



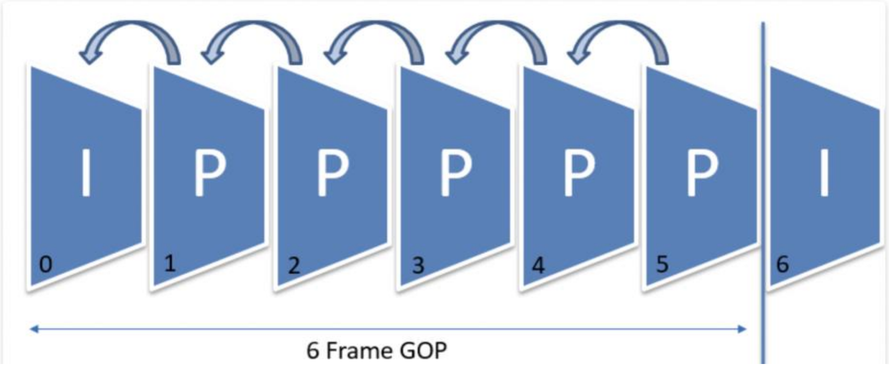


Neural-based Image Compression

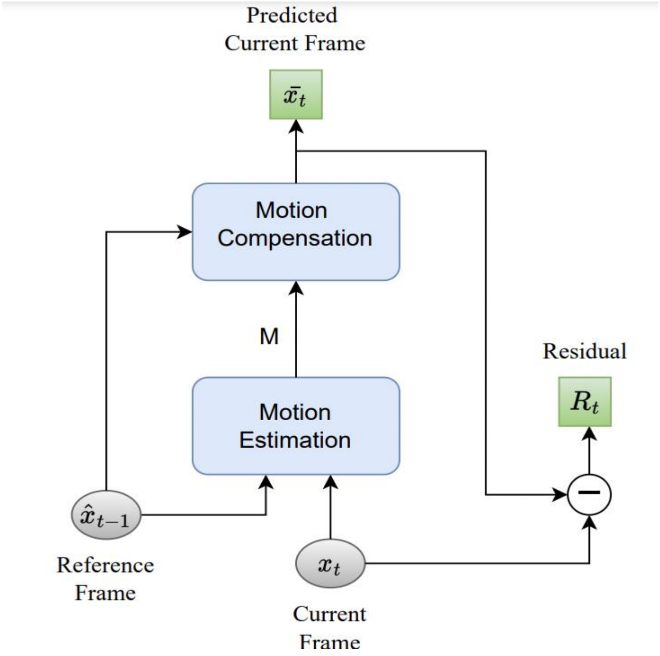


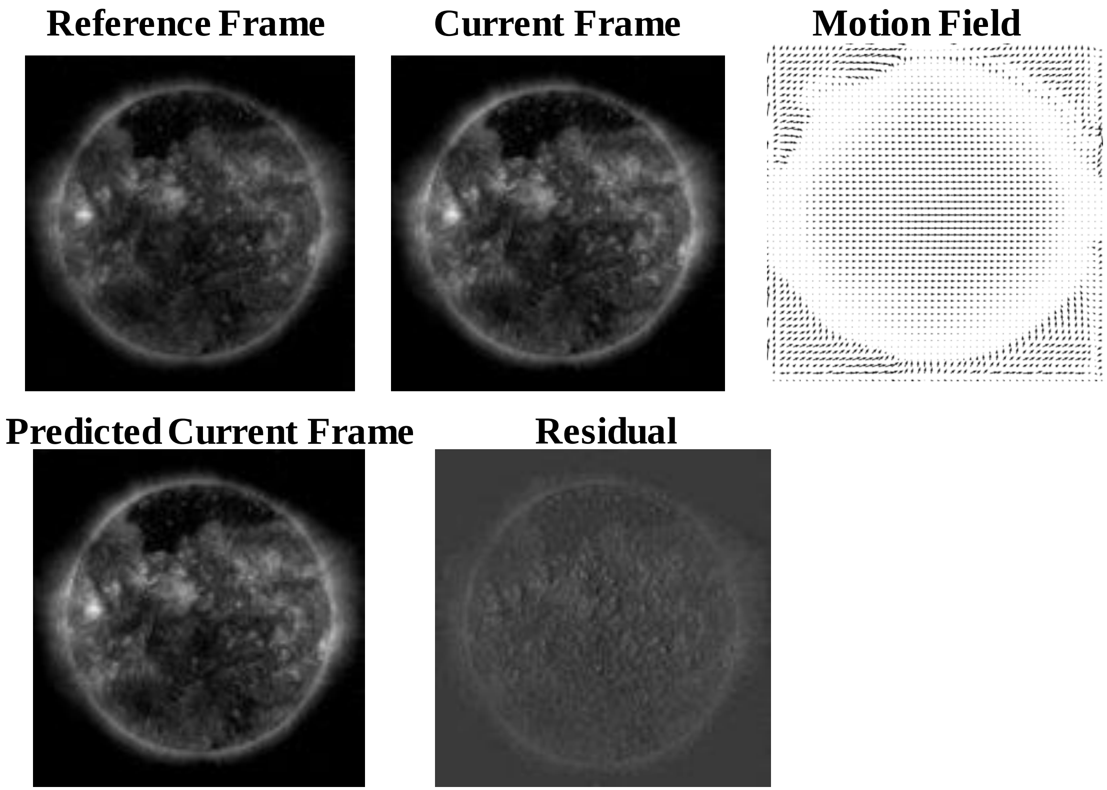
Video Compression

- Video Compression: Remove **temporal redundancy** + **spatial redundancy**
- There are two types of coding: Intraframe coding, Interframe coding
- **Intraframe coding** : Image compression **Interframe coding**: Using reference frame + motion information

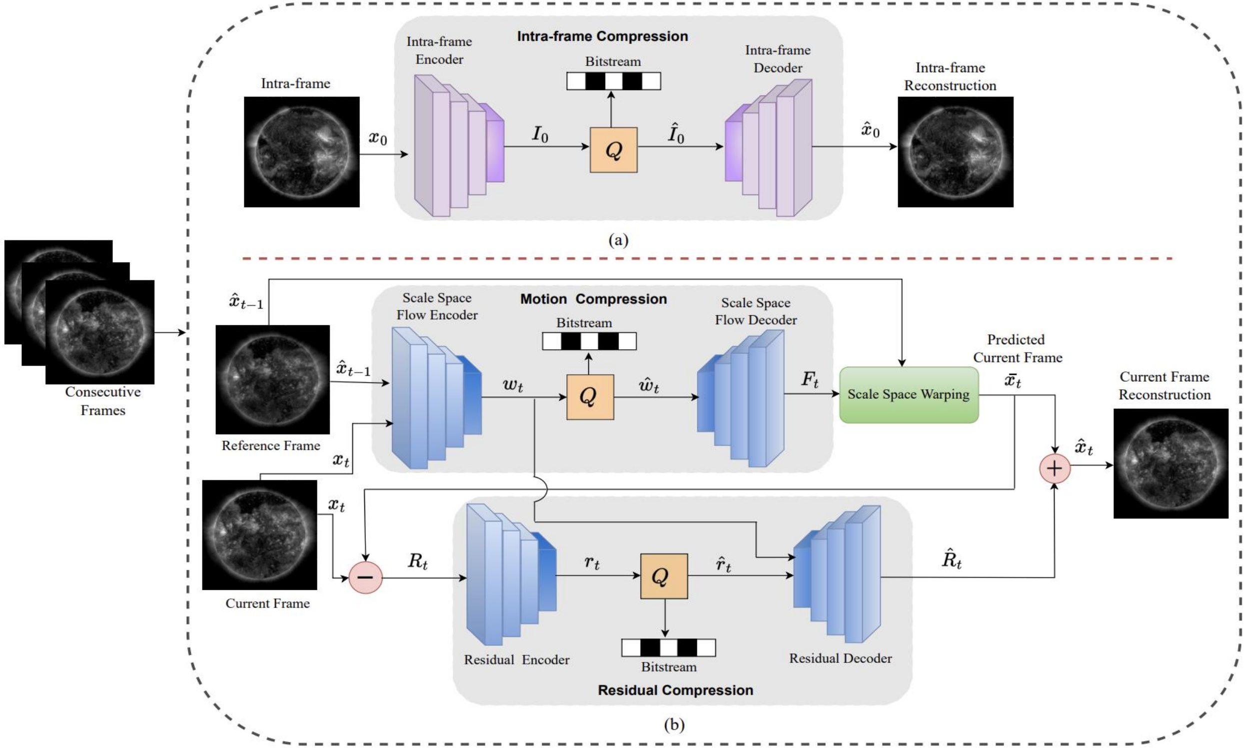


Inter-frame Pipeline





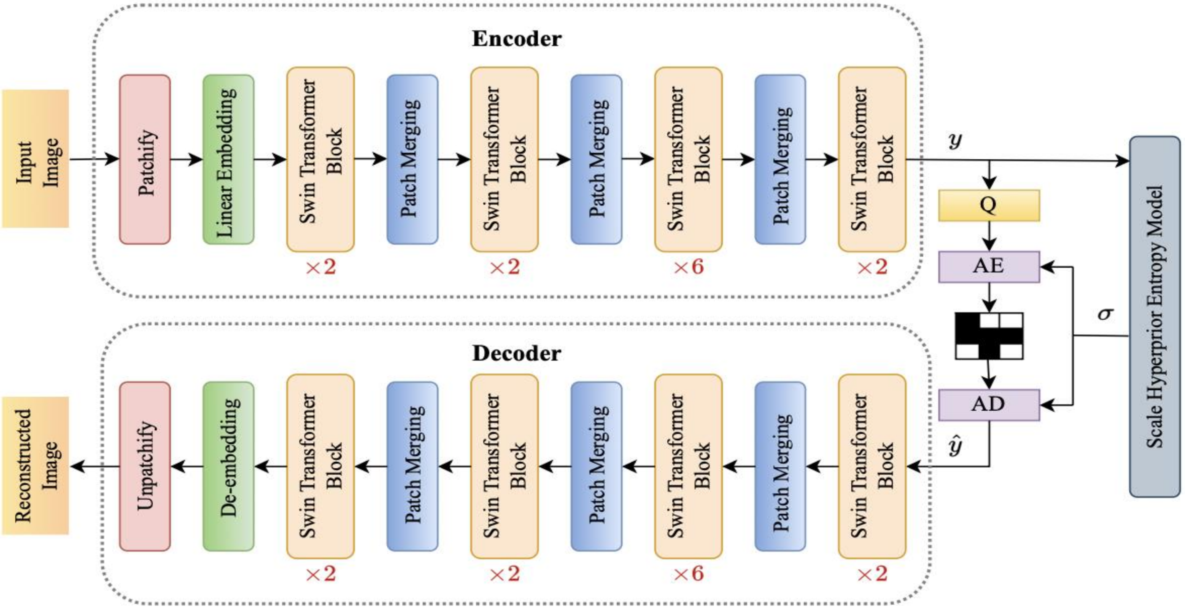
SSF: Neural-based Video Compression



Total rate–distortion loss over Sequence with N frames:

$$D+\lambda R=\sum_{t=0}^{T-1} d(x_t,\hat{x}_t)+\lambda\Big[R(I_0)+\sum_{t=1}^{T-1} R(w_t)+R(r_t)\Big]$$

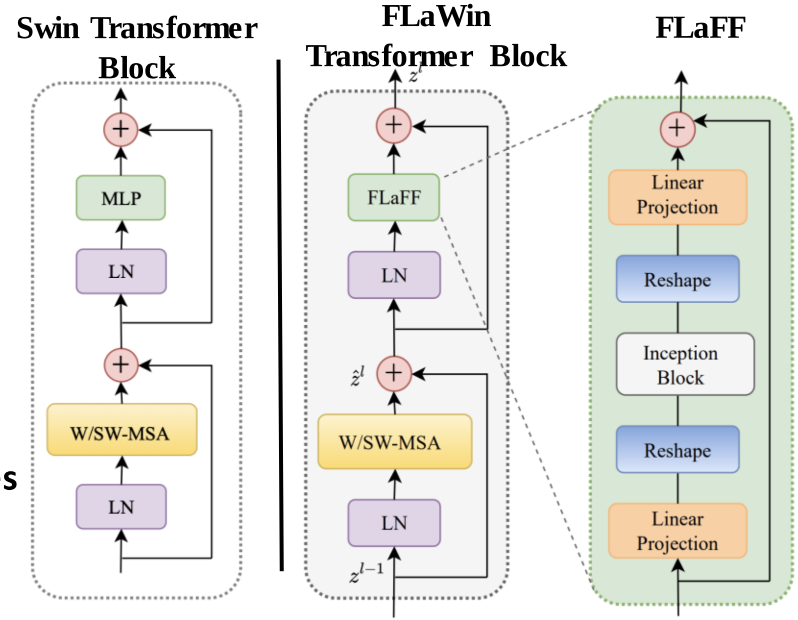
Swin Transformer-based Compression



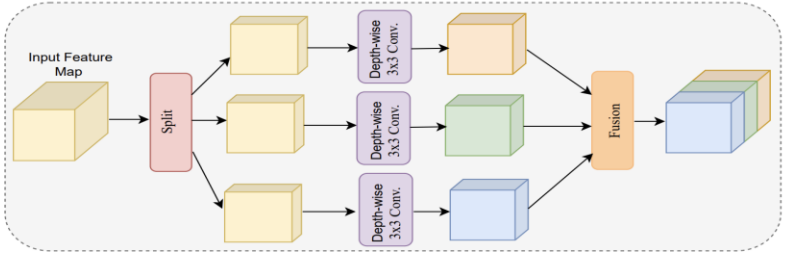
(a)

Transformer Blocks

- Transformer block is the main part of the Transformer architecture.
- The Transformer block consists of multiple layers of self-attention, feed-forward neural network, layer normalization and residual connection.
- Self-attention helps model to capture long-range dependencies.
- FLaWin is constructed by replacing the feed-forward network in the Swin Transformer block with the fused local-aware feed-forward network(FLaFF) :Extracting **local dependencies + global dependencies**



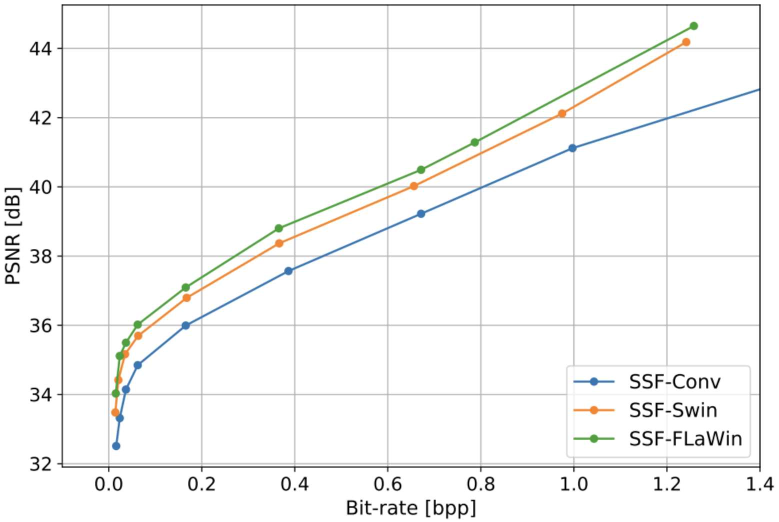
Inception Block

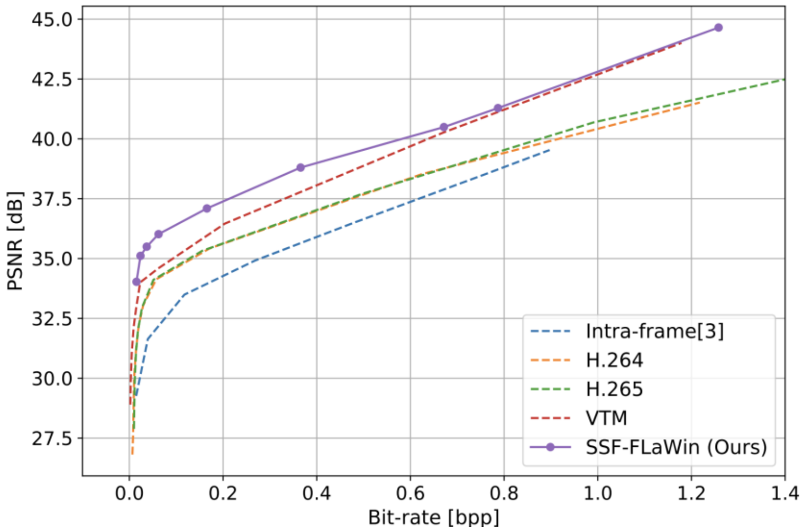


Inception block: dividing the input along the channel dimension and directing these split components into three separate branches.

Results and Comparison

- Comparison Metric for Distortion:
  PSNR: Signal-to-noise ratio





Conclusion and Future Work

- Applying the video compression approach on the dataset boost the compression ratio because of the high temporal correlation between the images.
- Utilizing Transformers-based autoencoder, we improve the network capability to capture correlations more robustly, leading to a more decorrelated latent code.
- We demonstrate that our Transformer-based compression scheme outperform traditional codes for the SDO data.
- Next step involves adaptation of the proposed compression scheme to Level 0 (no post-processing) data.
- The more accurate entropy model is needed to estimate the distribution of the latent representations.
- Other types of Transformer networks can be designed to improve the compression efficiency.

THANK YOU!

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