Intelligent Compression for Synchrotron Radiation Source Image

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Motivation

- Synchrotron radiation source (SRS) facilities will generate a huge mount of data.
  - The High Energy Photon Source (HEPS) is one of the world's brightest fourth-generation synchrotron radiation facilities.
  - The HEPS beamlines in the first-stage project are estimated to produce an average of 200TB raw data per day. (150PB/year).
  - The SRS images generated by the hard X-ray imaging beamline account for the majority, which require the largest capacity of storage and bandwidth.

Challenge

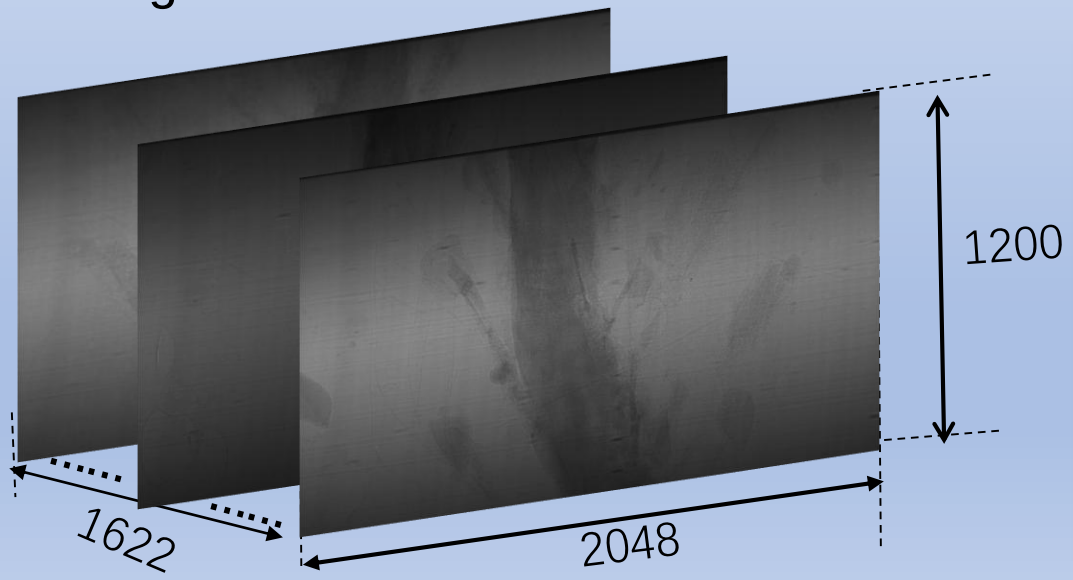
- The data produced by HEPS will not only increase continuously but also require long-term preservation.
  - A simple expansion of storage and bandwidth cannot solve the problem fundamentally, and it requires a lot of research funding.
- To ensure the scientific potential, data cannot be lost during preservation and transmission.

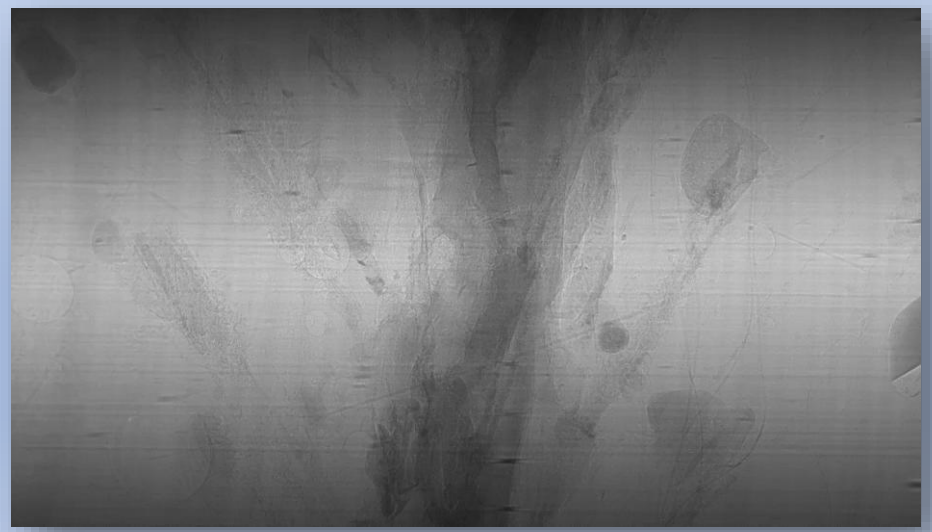
↓

- **Image lossless compression**

SRS Image

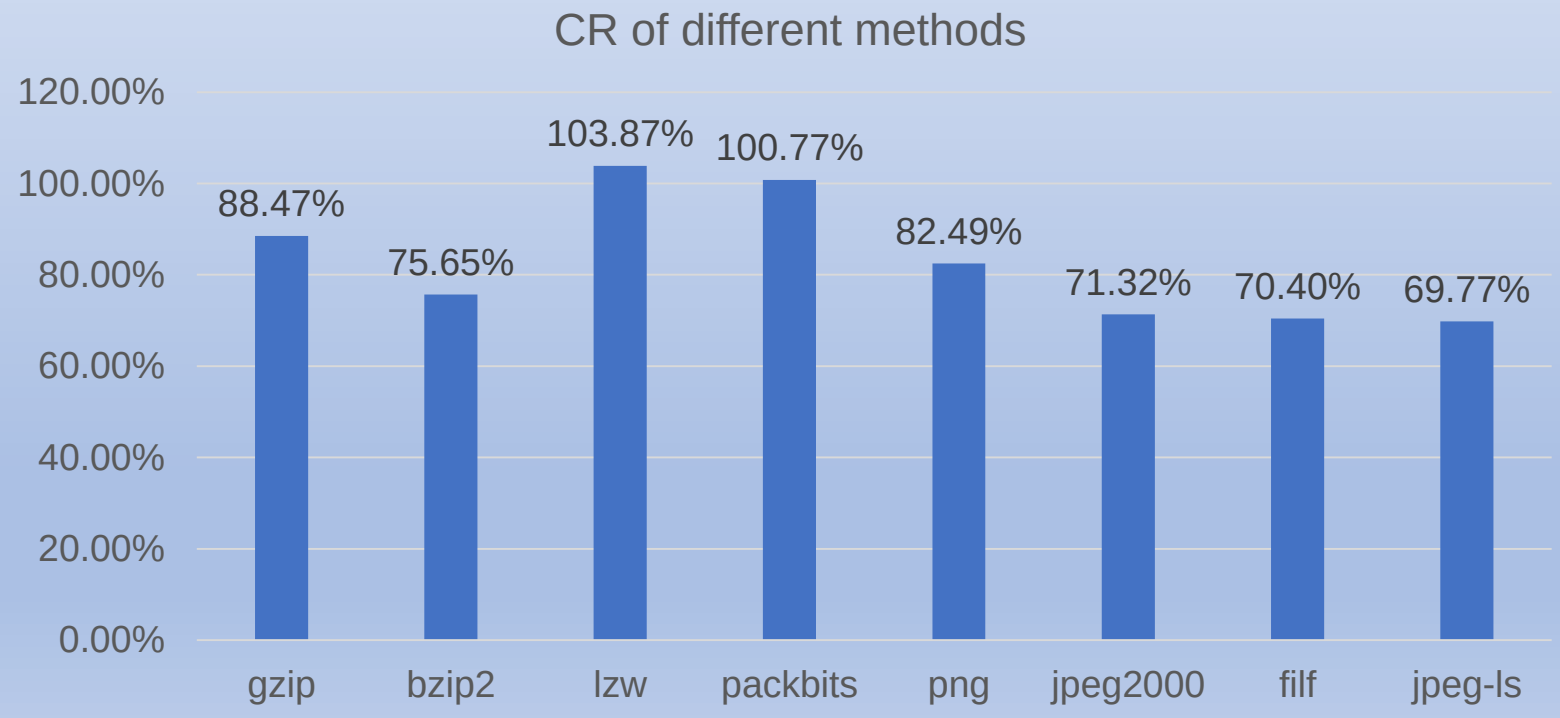
- The SRS images is the **sequence** of projections.
  - Different angles of **one** sample
  - High resolution, high frame rate and high contrast
    - Pixel value range: 0~65535
    - Image size: 2K×2K → 10K×10K(future)
    - Image number：thousands → tens of thousands(future)





Related work

- Compression Ratio (CR) = (Compressed size) / (Original size)
  - Indicate how much storage capacity is occupied after compression
- Traditional lossless compression methods can only save up to 30% in size.
  - CR ≈ 70%



Architecture

- STEP1. Image Difference
  - Remove linear relationship
- STEP2. Mapping
  - Narrow the range of pixel-value distribution
- STEP3. Modelling & Predicting
  - Learn nonlinear relationship among pixels
  - Predict the probability distribution of pixel-value
- STEP4. Arithmetic Coding
  - Get the final compressed data stream

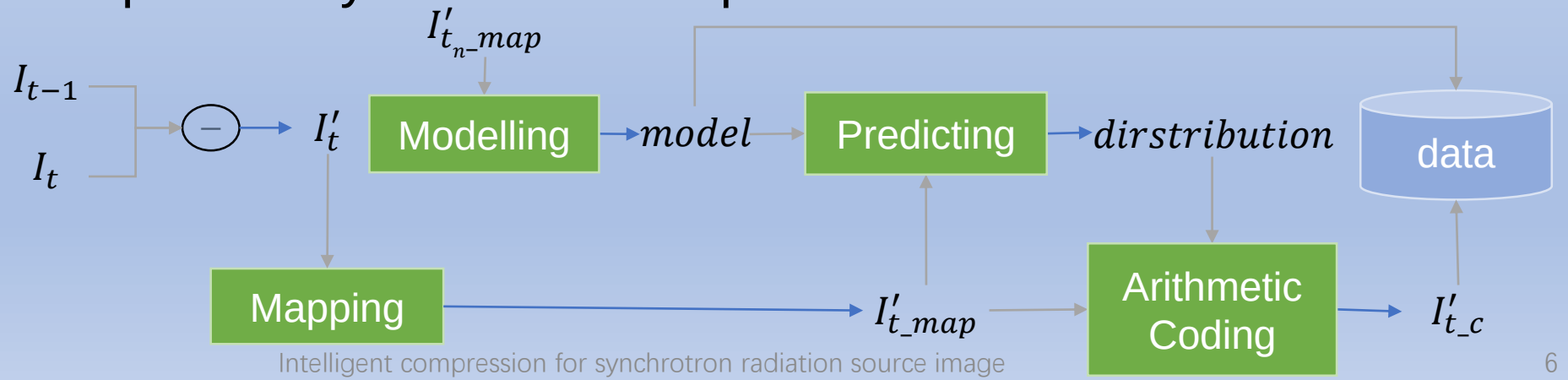
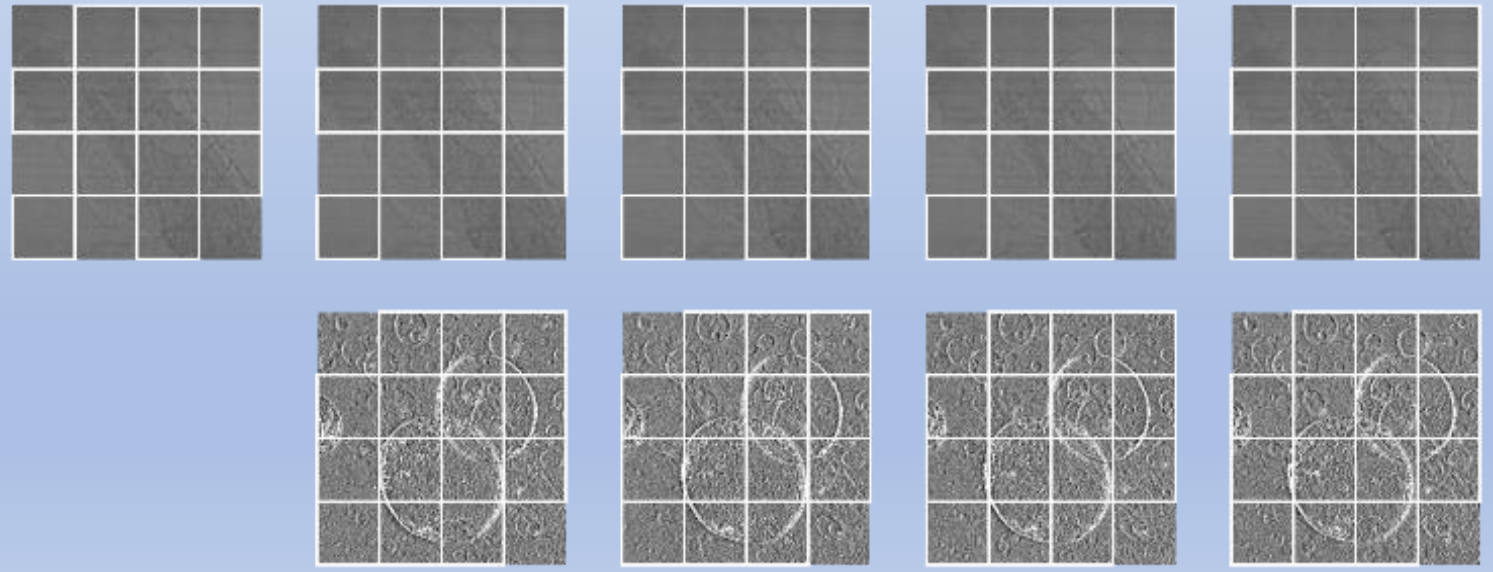
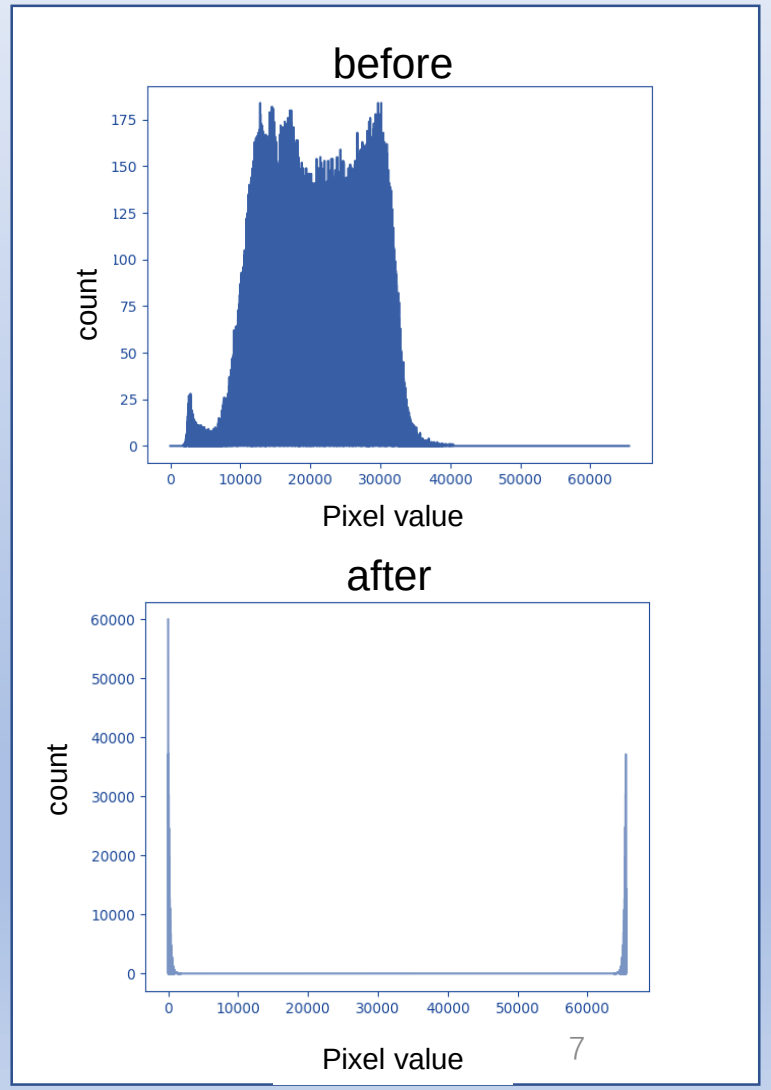


Image Difference

- Subtract the pixel value of the previous image from the current image.
  - Highlight different parts
  - Reduce the noise information
  - Pixel values are more concentrated

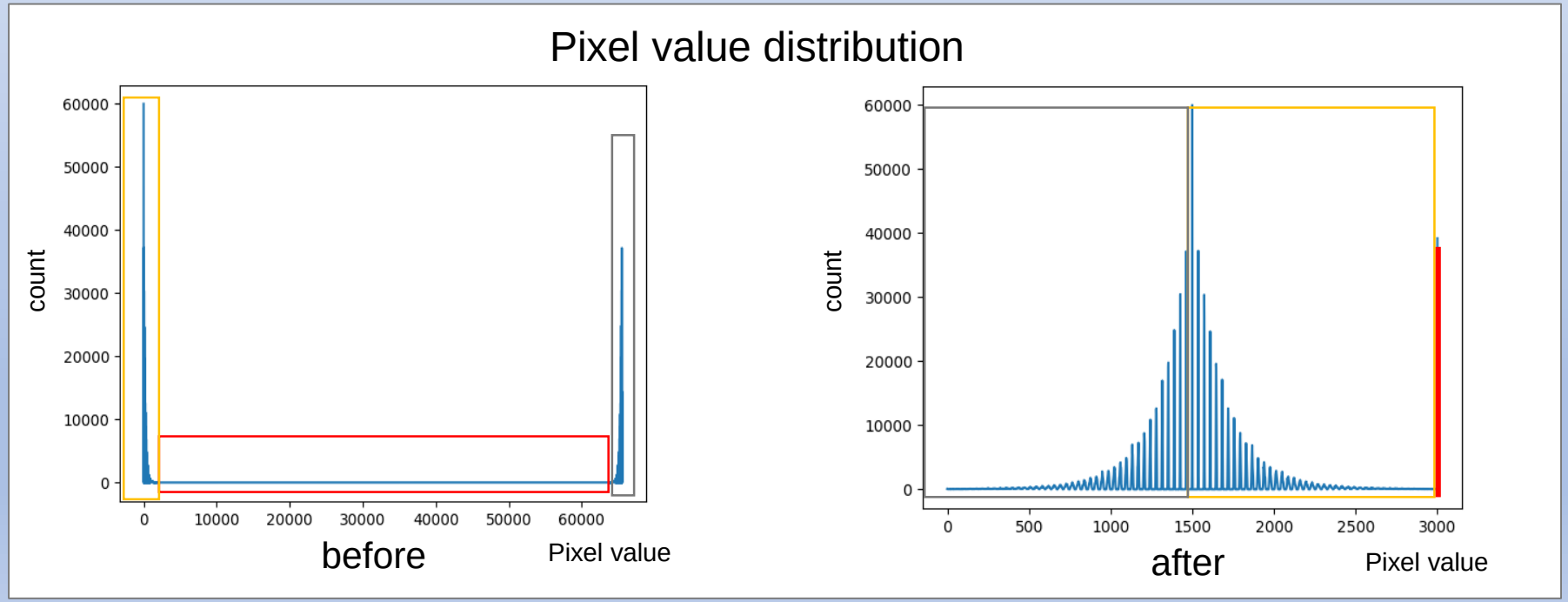


Pixel value distribution



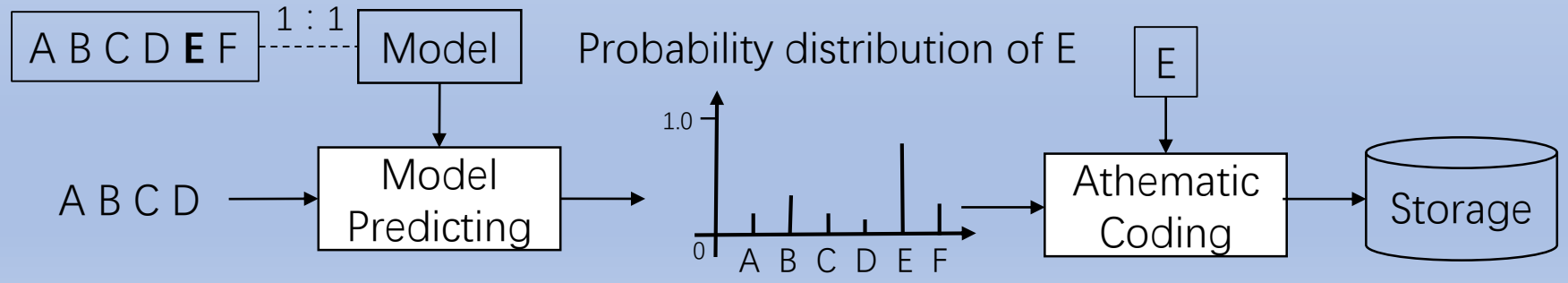
Mapping

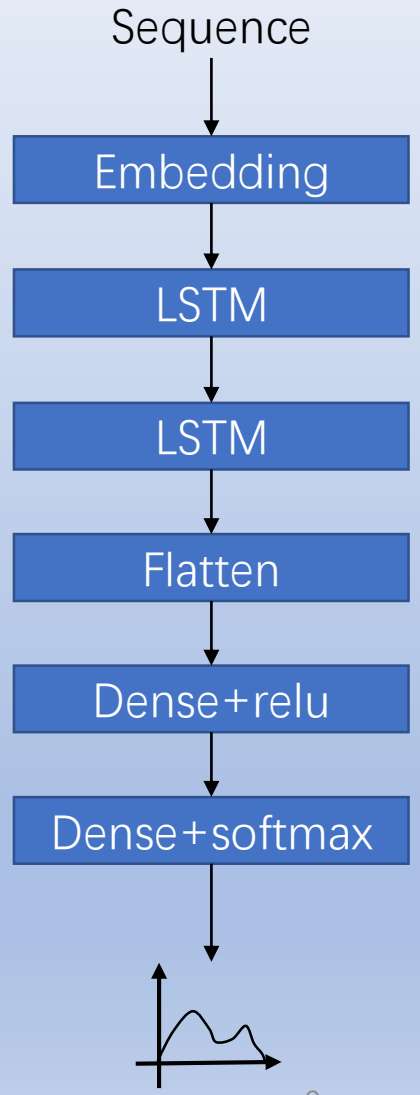
- Narrow the range of pixel-value distribution by saving a small portion (~2%) of uncompressed data.
  - Narrow the range of values.
  - Ensure that the process is reversible and no information is lost.



Modeling

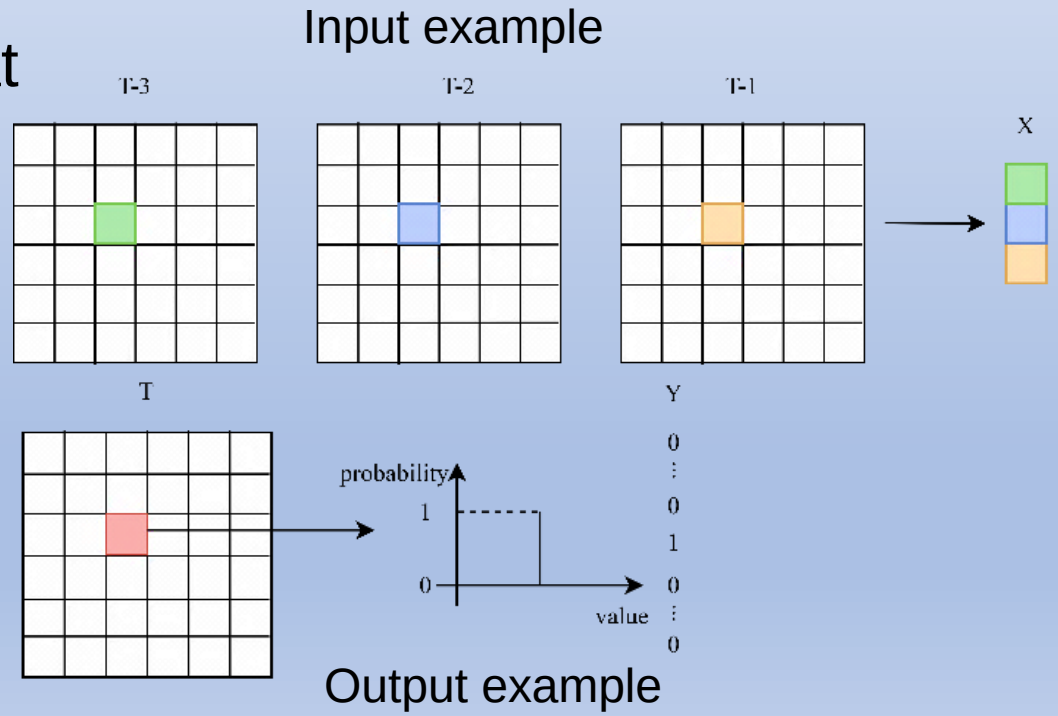
- Model
  - Based on Deepzip
    - Output the probability distribution of the pixel-value
    - Compressed by arithmetic coding
    - Save the model for lossless compression
  - Model architecture
    - LSTM for example





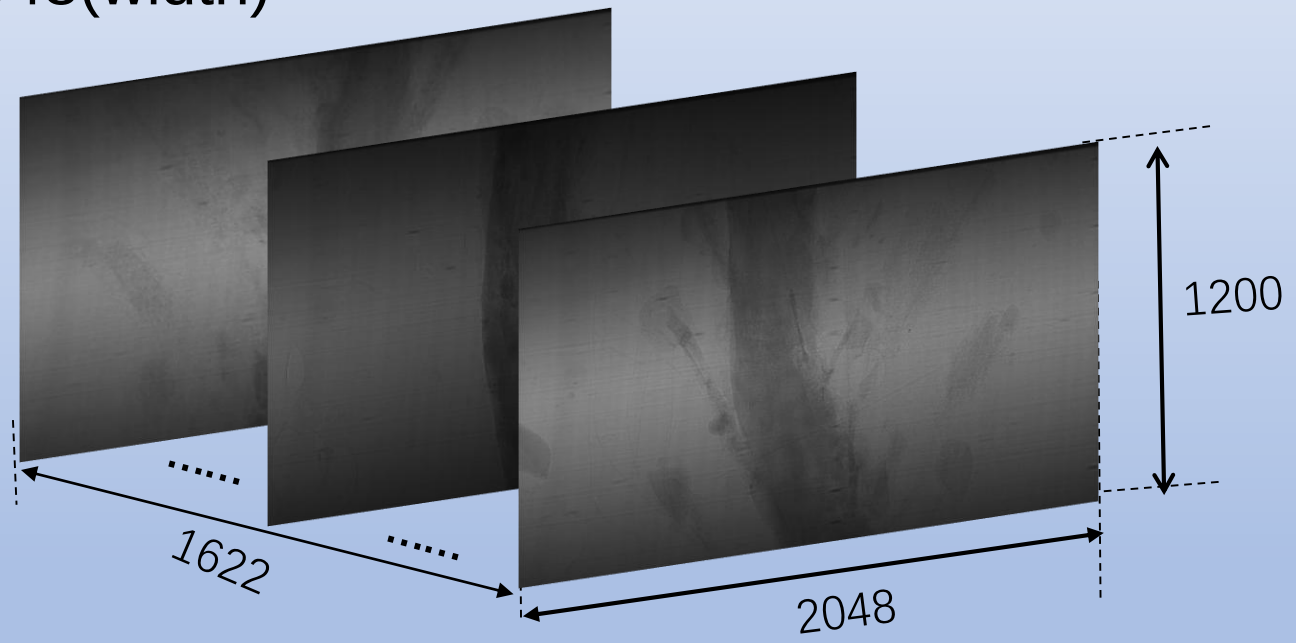
Modeling - Input & Output

- Train the model for prediction
  - Predict the probability distribution of pixel-value at the red position at time T using the first K (K=3 for example) images at the same position.
- Input
  - The sequence is the first K pixel values at the same position in chronological order.
- Output
  - Probability distribution of red position pixel-value at time T.
  - Only the probability corresponding to the true value is 1, others are 0.



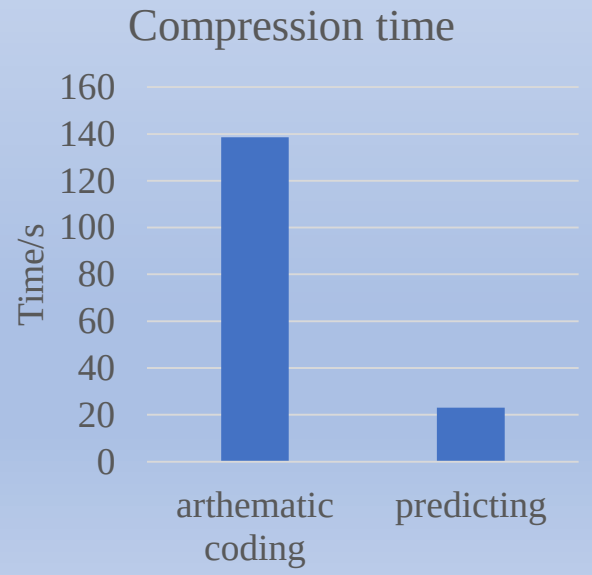
Test

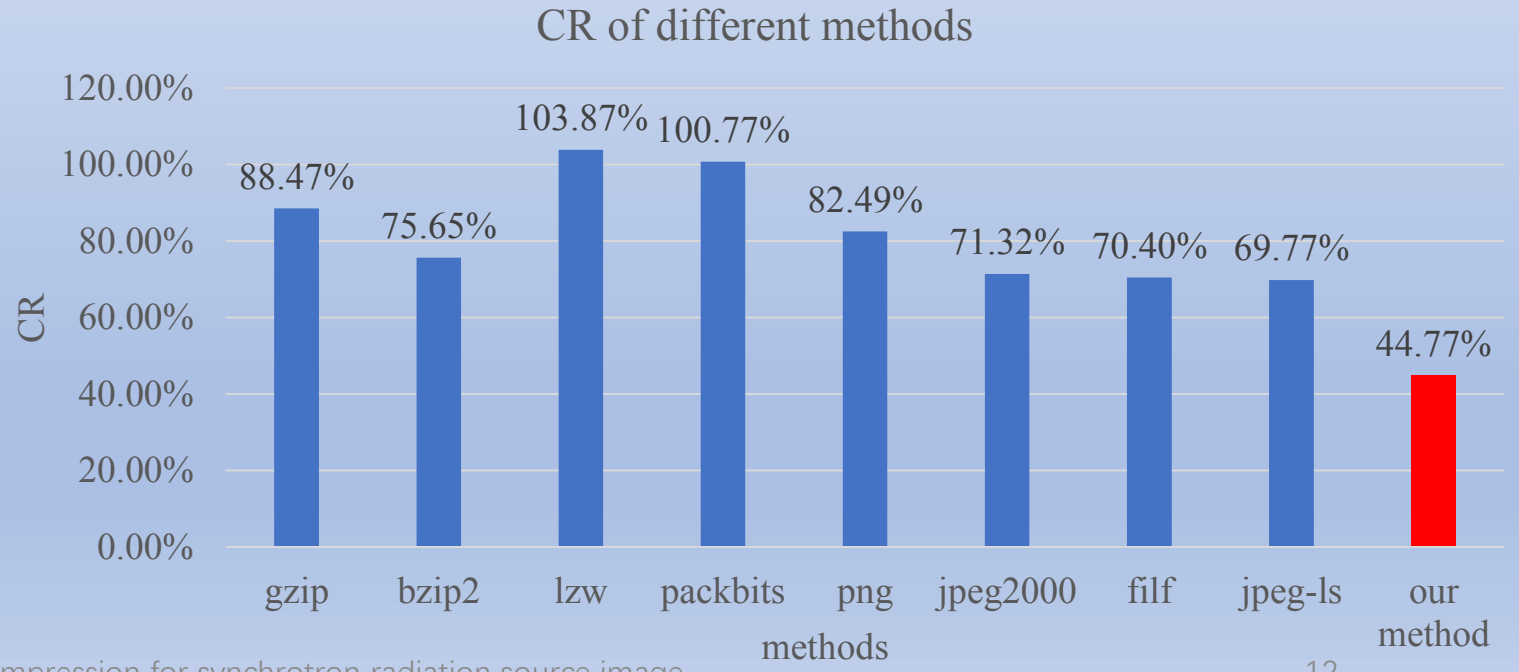
- Dataset:
  - From Shanghai Synchrotron Radiation Facility
  - 1622(frames)×1200(height)×2048(width)
- Environment
  - Python 3.6
  - GPU Tesla V100
  - Tensorflow (gpu) 1.8
- Train the model
  - K=8
  - 5 epoch
  - Loss function: Cross Entropy Loss Function



Result

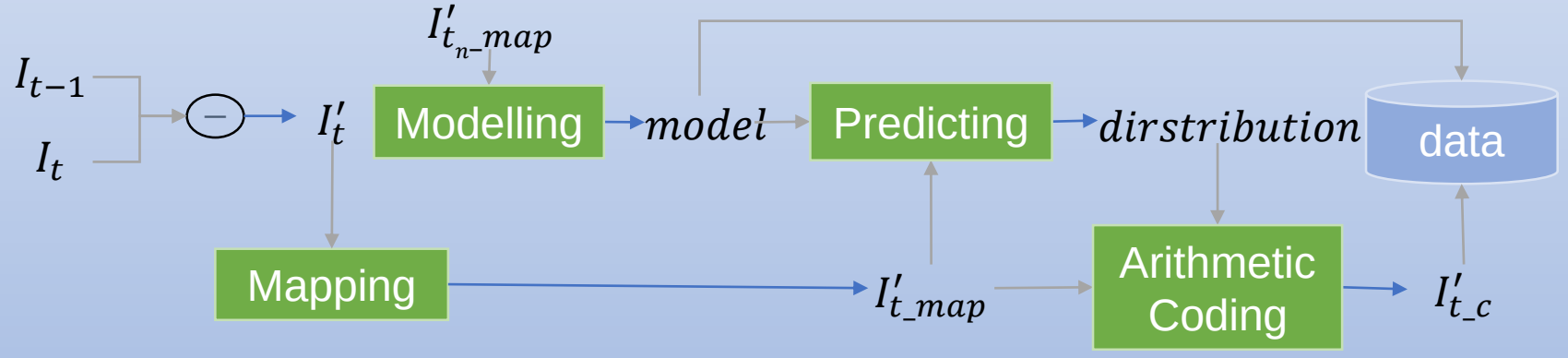
- CR = 44.77% (20%↑)
  - Compared with common compression methods, our method can save more than 20% capacity of storage and bandwidth.
  - Need more than 2 minutes to compress one image.
    - Athematic coding: ~140s
    - Predicting: ~20s





Summary & Next step

- Summary
  - We proposed an intelligent compression for SRS image.
    - Save more than 20% resource compared comman image compression methods.
    - Need more time during compression and decompression.



Thanks!

- Next step
  - Save compression and decompression time through parallel computing.
  - Try more models (TCN/Transformer) to get more accurate predictions.