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Learning-based parameter prediction for quality control in three-dimensional medical image compression

Key words: Medical image compression; High efficiency video coding (HEVC); Quality control; Learning-based

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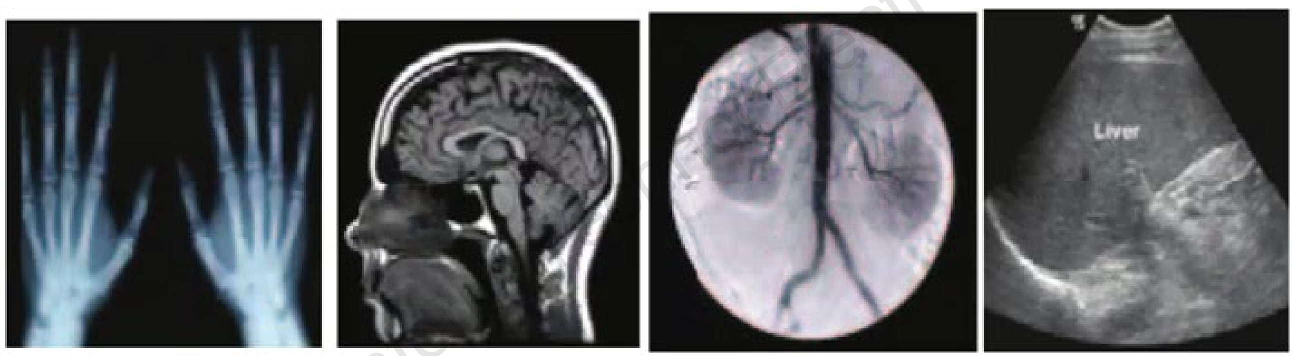
Medical image compression quality control

- 3D medical image data: high storage occupation (always larger than 500 MB per volume)
- Clinical information storage: long storage period
- Telemedicine system: requirement of sufficient image quality under limited transfer bandwidth



Hand_Xray Brain_MRI Kidney_CT Liver_US

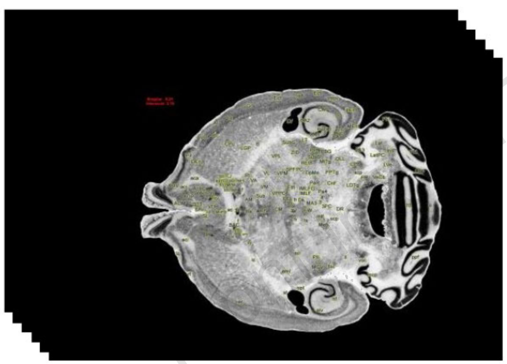
Storage requirements

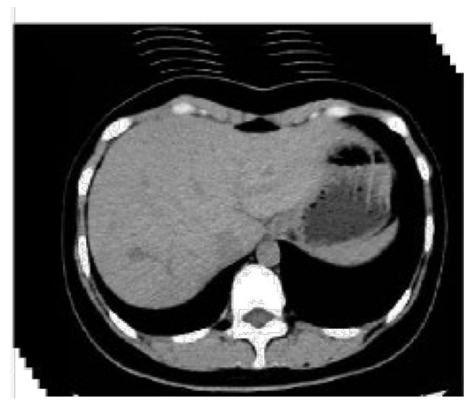
Quality requirements

Quality control in the medical image compression process is important

HEVC compression method for medical images

- Video and 3D medical data share the same modality.
- High efficiency video coding (HEVC) is the state-of-the-art model in video compression.
- The Digital Imaging and Communications in Medicine (DICOM) group has proposed to add HEVC to the official standard of communication in medical imaging [1].





HEVC
H.265 - HIGH EFFICIENCY VIDEO CODING

DICOM
Digital Imaging and Communications in Medicine

Motivation

- The quantization parameter (QP) plays a dominant role in controlling the quality of HEVC. Different QPs will achieve the tradeoff between image quality and the image size.

- Medical images are large, so the compression process will cost much time.

- Medical image compression should meet specific quality requirements.

- **Task**: Given the target image quality constraint, recommend the optimal QP before compression, to reduce the storage cost as far as possible, thus achieving the best quality control process.

Challenges

- The direct application of video-based quality control methods to medical image compression cannot guarantee satisfactory results.

- Challenge I: Conventional methods do not pay attention to 3D structural information, which is important in medical images.

- Challenge II: Conventional methods need much time and space, while medical applications are typically time-critical or space-bounded, especially in real-time telemedicine systems.

Based only on frame information

Cannot catch structural information!

Need pre-encoding or long-term iteration

Time/Space consuming!

Not satisfied!

Proposed method

- Solution I: Extract both video-based information and structural information from raw data

- Solution II: An efficient support vector regression (SVR) method is proposed to predict the optimal QP of HEVC

Extraction of both video and structural information

More precise QP estimation!

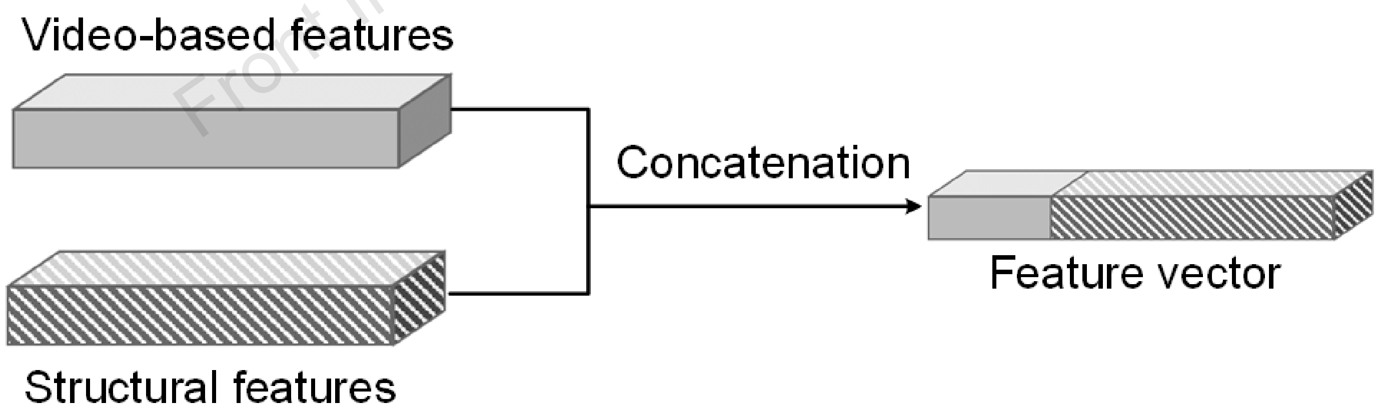
Without pre-encoding or long-term iteration

Time/Space efficient!

Satisfied!

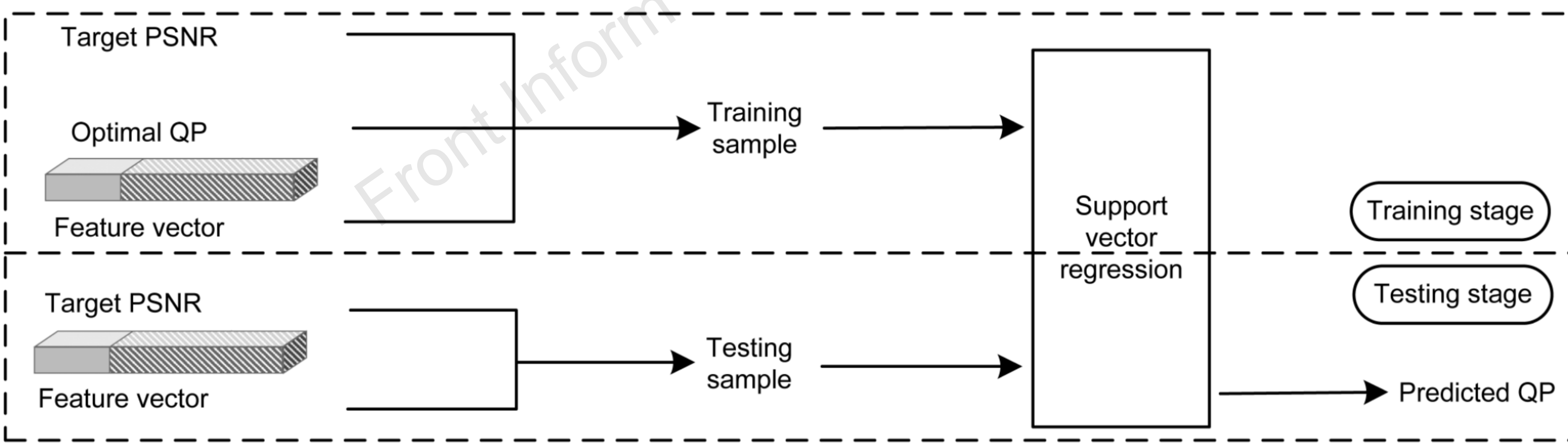
Proposed method

- Video-based features
  - Ratio of zero-valued voxels
  - Difference of adjacent frames
  - …
- Structural features
  - Gray-level co-occurrence matrix (GLCM)
  - Contrast
  - Entropy
  - …



Proposed method

- Support vector regression
  - SVR is good at solving sparse feature space problems, and runs very efficiently.
  - Use PSNR as the metric for image quality.
  - Prepare some training images and encode them with every possible QP to form the training dataset.
  - In the testing stage, just use the feature vector and the target PSNR to obtain the optimal QP.



Testing results

- Five related methods [2-6] together with our proposed method are tested in five public medical image datasets, i.e., LIDC-IDRI, RIDER Lung CT, LungCT-Diagnosis, REMBRANDT, and TCGA-HNSC [7].

- Metric: $$\text{Correction} = 1 - \text{mean}\left(\frac{\left|\text{PSNR}_{\text{target}} - \text{PSNR}_{\text{pred}}\right|}{\text{PSNR}_{\text{target}}}\right),$$

  where $\text{PSNR}_{\text{target}}$ denotes the target PSNR, and $\text{PSNR}_{\text{pred}}$ the PSNR reached using the predicted optimal QP.

Table 5 The correction of D-Q models

Dataset	Correction					
	Model I	Model II	Model III	Model IV	Model V	Ours
LIDC-IDRI	0.935	0.951	0.940	0.946	0.951	**0.973**
RIDER Lung CT	0.879	0.930	0.956	0.955	0.949	**0.959**
LungCT-Diagnosis	0.964	0.962	0.966	0.957	0.965	**0.980**
REMBRANDT	0.967	0.932	0.965	0.941	0.961	**0.980**
TCGA-HNSC	0.958	0.962	0.962	0.968	0.967	**0.977**
Average	0.941	0.947	0.958	0.953	0.959	**0.974**

Testing results

- The inference time performance of the models is also tested in the largest dataset, LIDC-IDRI.

- Models I and II are the simple regression models which need pre-encoding. Model III and our method use the SVR model. Models IV and V are neuron network based methods, which do not need feature extraction, but will cost extra time to split the large medical volume into small blocks.

Table 6 The inference time of the models (per query)

Model	Inference time (ms)			
	Encoding/Decoding	Feature extraction	Prediction	Total
I	16 526	–	6	16 532
II	16 526	2120	2	18 648
III	–	2165	2	2167
IV	–	9506*	7539	17 045
V	–	4720*	15 566	20 286
Ours	–	3339	2	3341

* For data splitting

Conclusions

- A learning-based quantization parameter prediction scheme is proposed for quality control in 3D medical imaging data compression.
- Experimental results show that our proposed method outperforms existing solutions in precision, achieving good results in time consumption.
- Our approach has much potential in solving the quality control problem of medical images in real applications, such as telemedicine or medical imaging database regulation.

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