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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

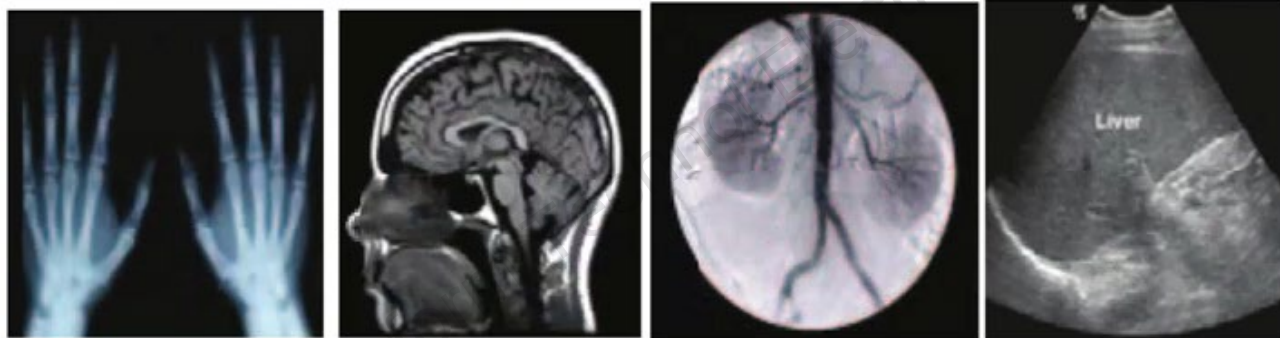
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Medical image compression quality control

- ❑ 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

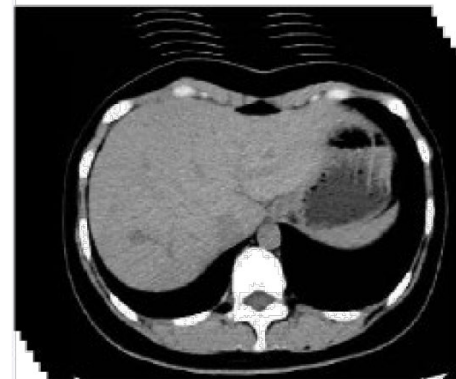
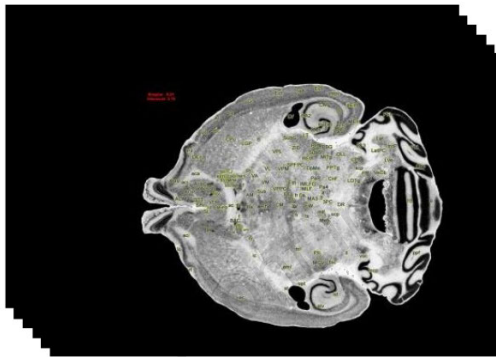
**Storage
requirements**

**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].



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**

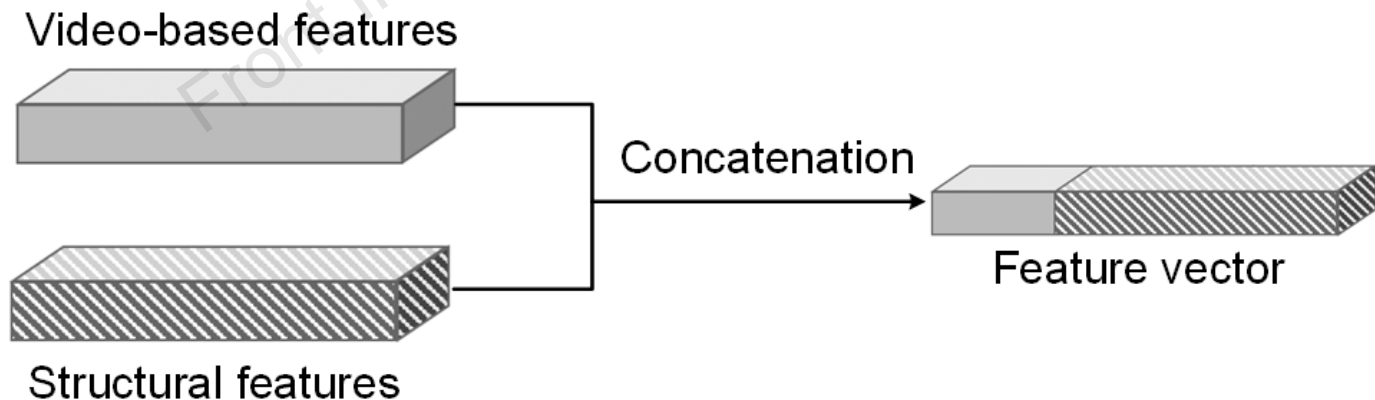
**Time/Space
efficient!**



Satisfied!

Proposed method

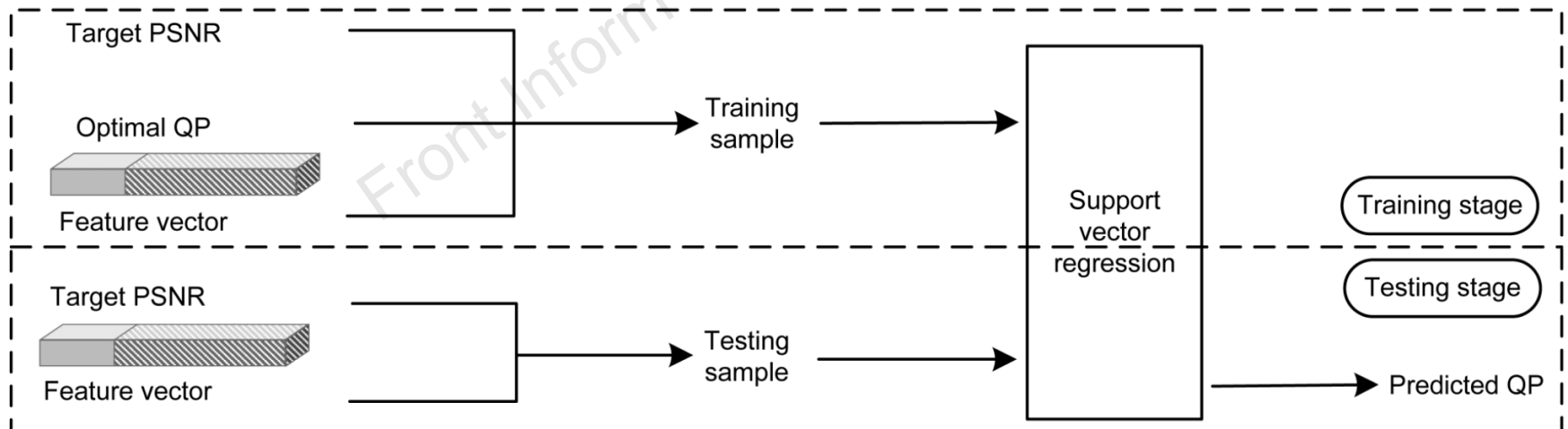
- ❑ Video-based features
 - ❑ Ratio of zero-valued voxels
 - ❑ Difference of adjacent frames
 - ❑ ...
- ❑ Structural features
 - ❑ Gray-level co-occurrence matrix (GLCM)
 - ❑ Contrast
 - ❑ Entropy
 - ❑ ...



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

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.

References

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