Synamedia

Low-Complexity Quality Measurement for Real-Time Video Compression

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Mile High Video

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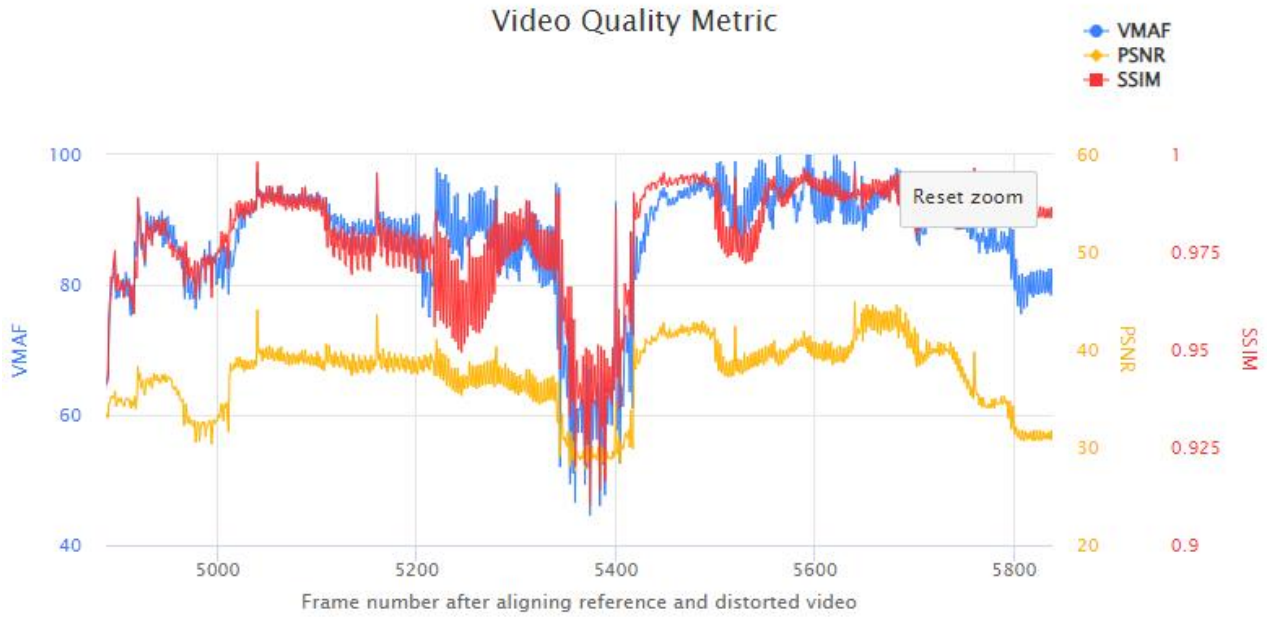
Video Quality (VQ) Measurement

Used in a variety of applications

- VQ tracking
- Encoder comparison
- Encoder configuration
- ABR ladder optimization
- A/B testing
- VQ monitoring
- …



Focus on live video

Millions of encoder decisions per second

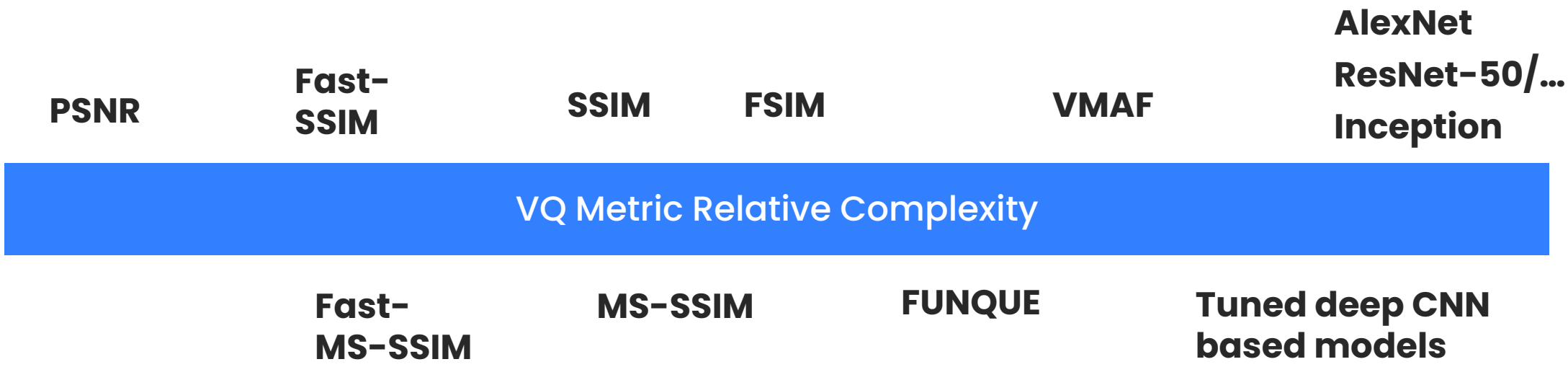
Maximize # of channels / server

Minimize cost and energy requirements

The Spectrum of Video Quality Metrics

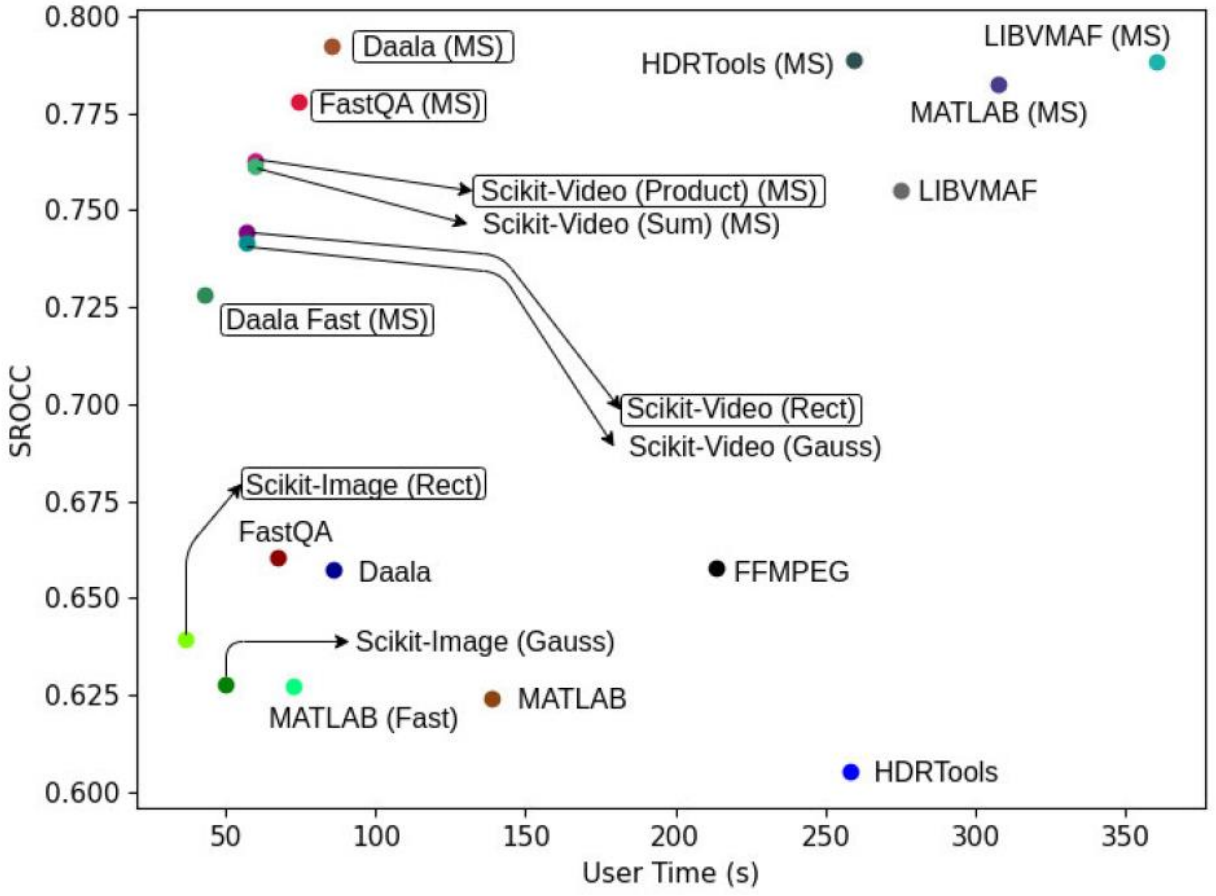
- Fast implementations of SSIM, MS-SSIM, VIF, VMAF, … available
  - Integer approximations
  - Multi-threading
  - AVX2, AVX-512 intrinsics

- Still, multiple orders of magnitude too costly
- At least one thread or core running full-time to calculate e.g. VMAF
- CPU time is important, not wall clock time



VQ Metric Complexity

Even for a single metric, many different implementations exist



A. K. Venkataramanan, C. Wu, A. C. Bovik, I. Katsavounidis and Z. Shahid, "A Hitchhiker's Guide to Structural Similarity," in *IEEE Access*, vol. 9, 2021.

Metrics for Live Encoding

- Is a metric suitable for live (or real-time) video when it runs at 30 fps on a dedicated GPU?
  - Yes, but… No
  - The execution cost is prohibitive in most circumstances

- **Cost / channel** (= server cost / # of streams processed)
  - E.g. 7 HEVC UHD channels on a single CPU, or 2 UHD ABR ladders
  - Add VQM without affecting server density

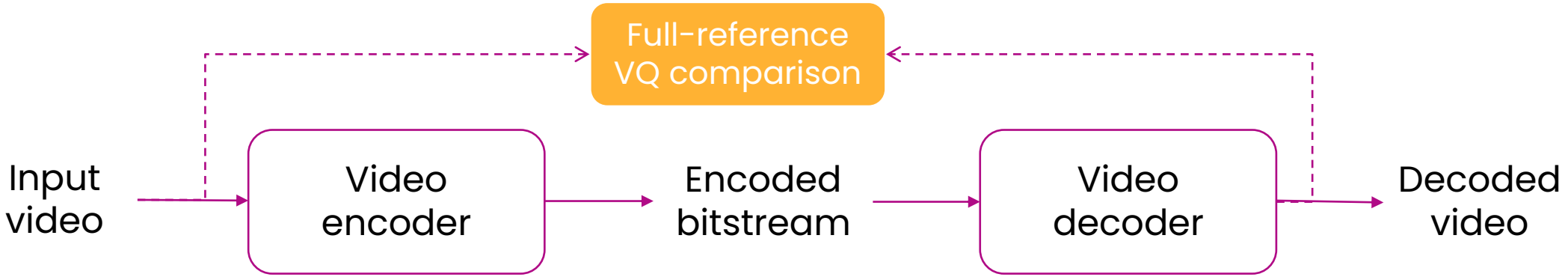
- Real-time video requires **millions of decisions per second**

Cost and energy efficiency are important!

Even though powerful servers are available,
only a fraction of CPU power should be used for VQ measurement

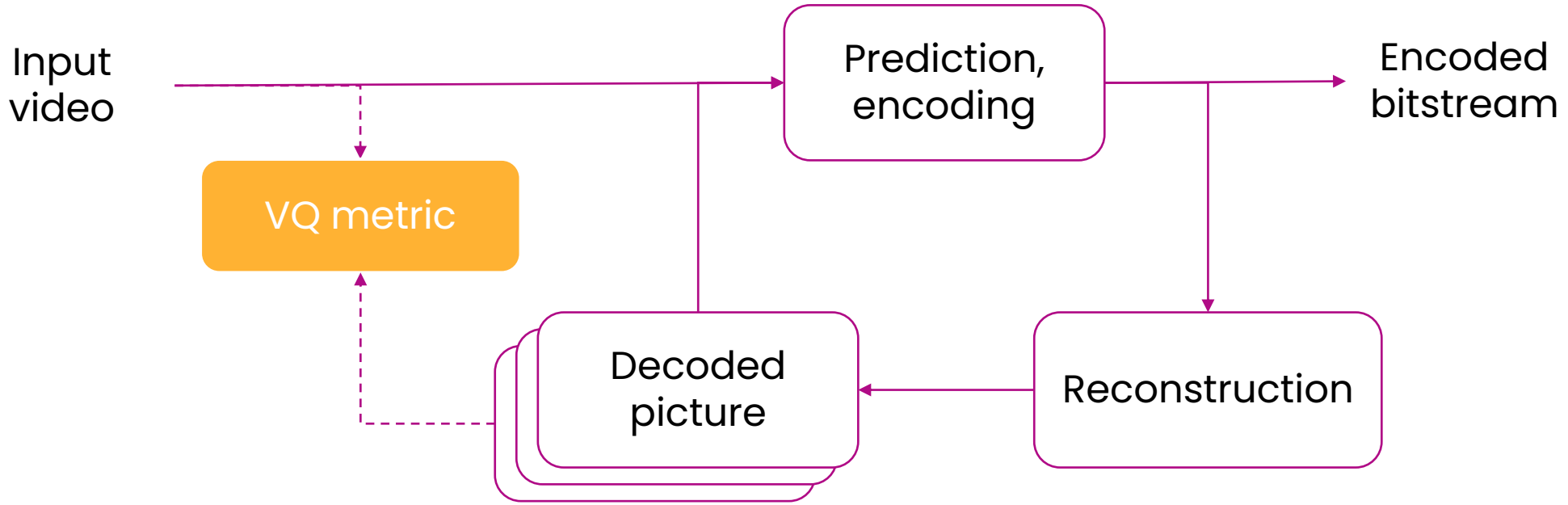
Traditional VQM Calculation

Least efficient: VQM outside of encoder/decoder



Better

Integrate VQM inside the encoder

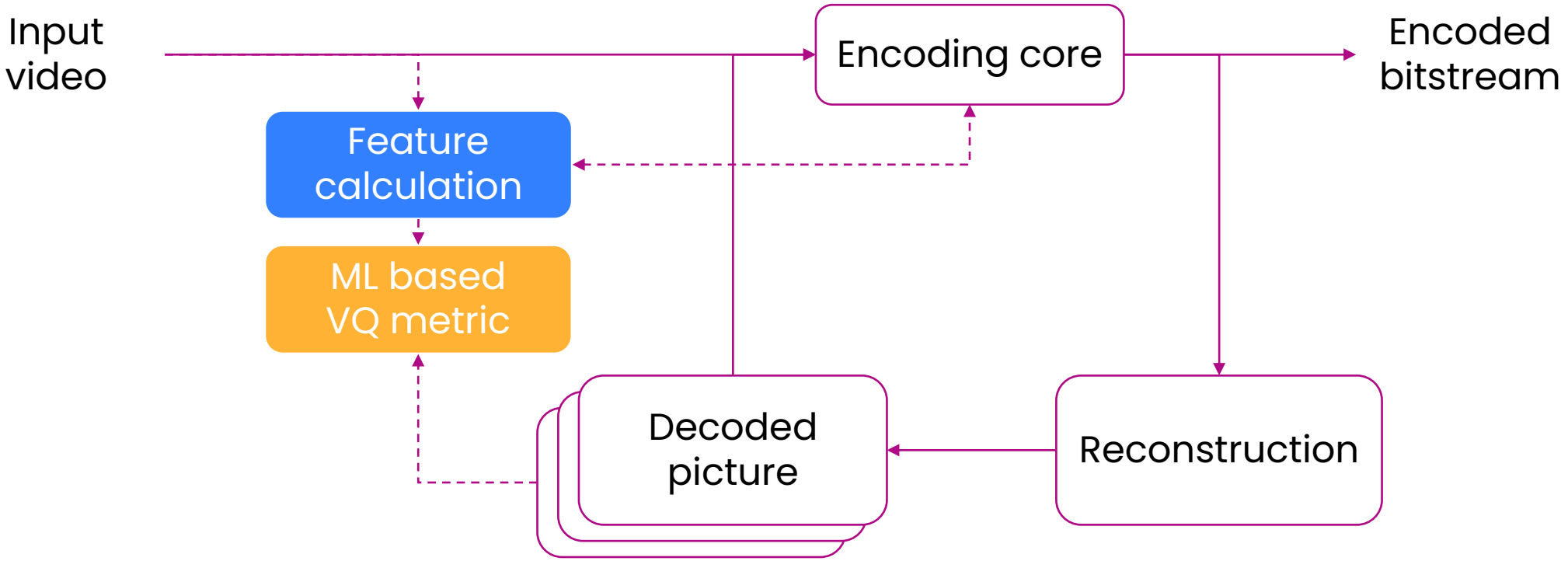


Even better

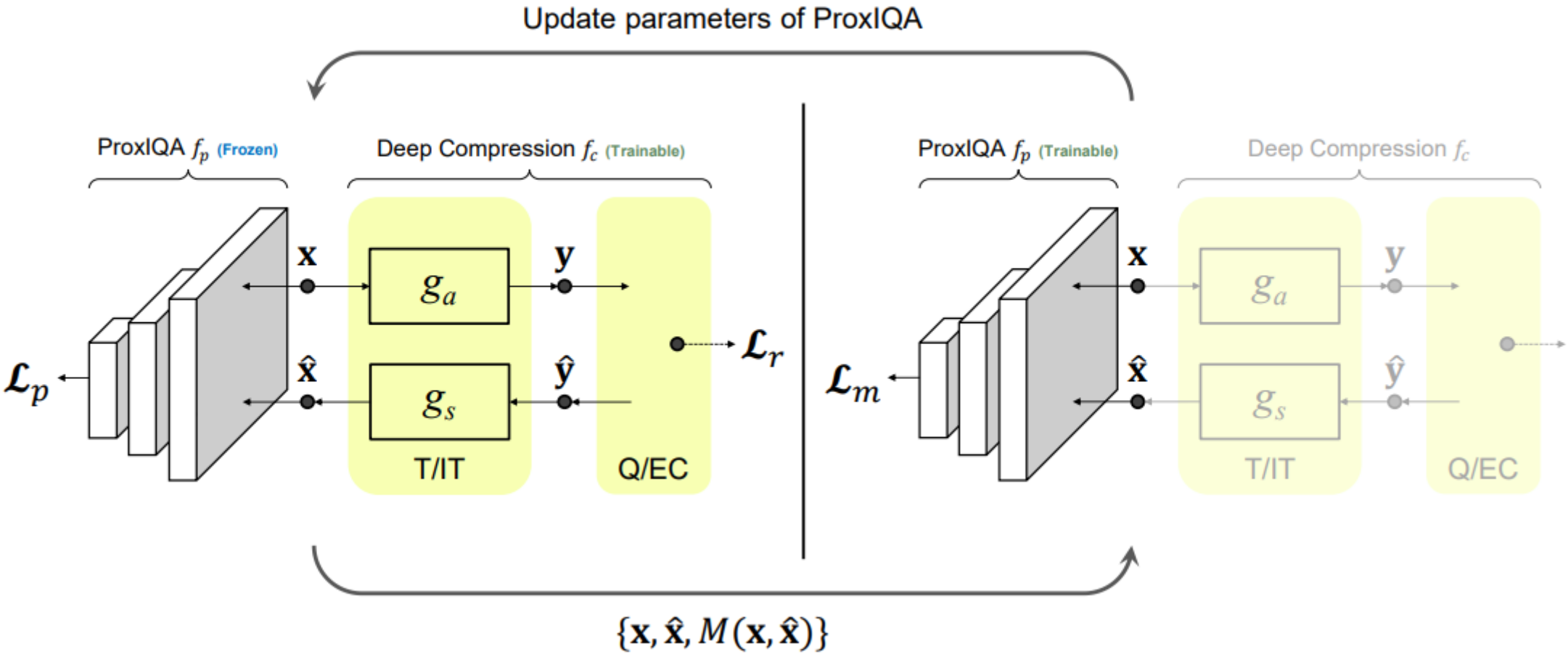
Reuse pre-analysis features

Approximate well-established VQ metrics

Simplify VQ network



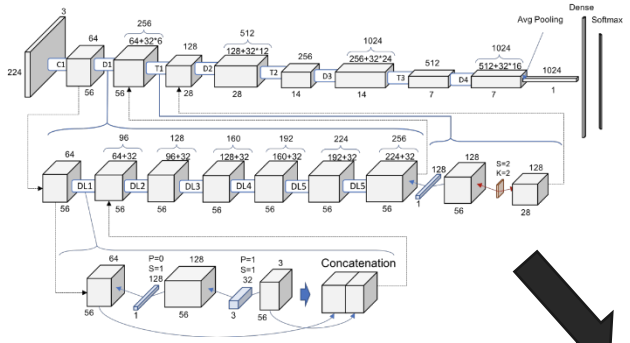
Similar Approach in Learned Image Compression



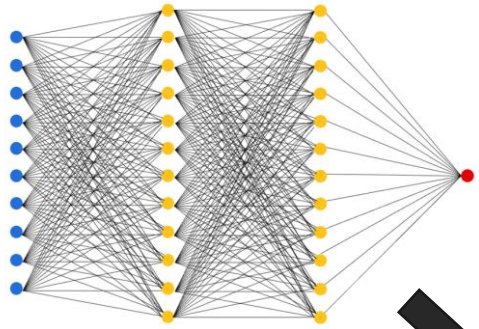
Li-Heng Chen, Christos G. Bampis, Zhi Li, Andrey Norkin, and Alan C. Bovik,
“ProxIQA: A Proxy Approach to Perceptual Optimization of Learned Image Compression”.

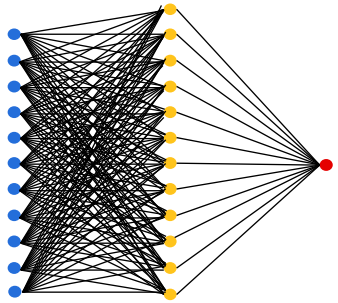
Reducing the Complexity of ML Inference Networks

- Network design
  - Lower # of layers
  - Intelligent design
- Feature design
  - Well-crafted features
- Optimization
  - Pruning
  - Quantization
- Implementation
  - CPU intrinsics (e.g. VNNI)
  - SW / HW



Deep CNNs





Shallow NNs

Fast ML-Based Approximations

- Approximations of popular metrics such as SSIM and VMAF
- High correlation can be reached using neural networks
- Decreasing marginal returns by adding more layers

	SSIM		VMAF		Complexity
	PCC	SROCC	PCC	SROCC	# of FLOPs per frame
Linear Regression	0.762	0.880	0.869	0.888	<10 operations
Decision tree	0.800	0.904	0.837	0.848	<50 comparisons
SVR (RBF)	0.839	0.678	0.929	0.937	<500 operations
NN (3 layers)	0.944	0.938	0.951	0.957	<1500 operations
NN (5 layers)	0.969	0.958	0.954	0.960	~15000 operations

Fast ML-Based Approximations

- High correlation can be reached using networks with 3 layers or less
- Less than 1500 floating-point operations per frame
- No deep networks needed

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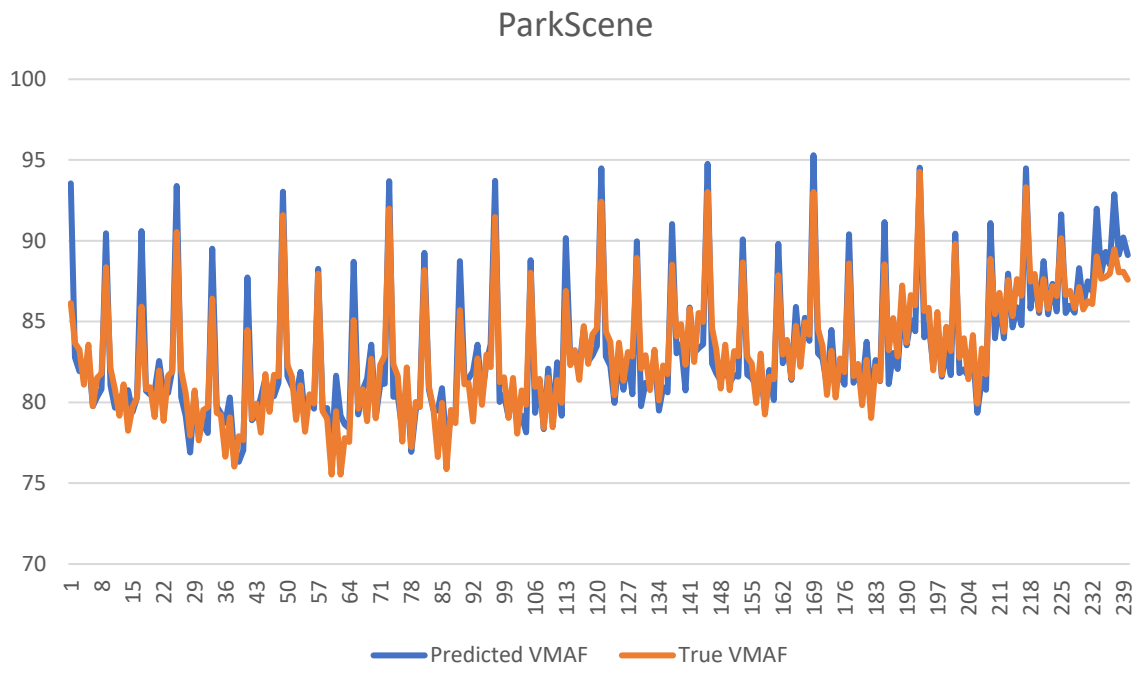
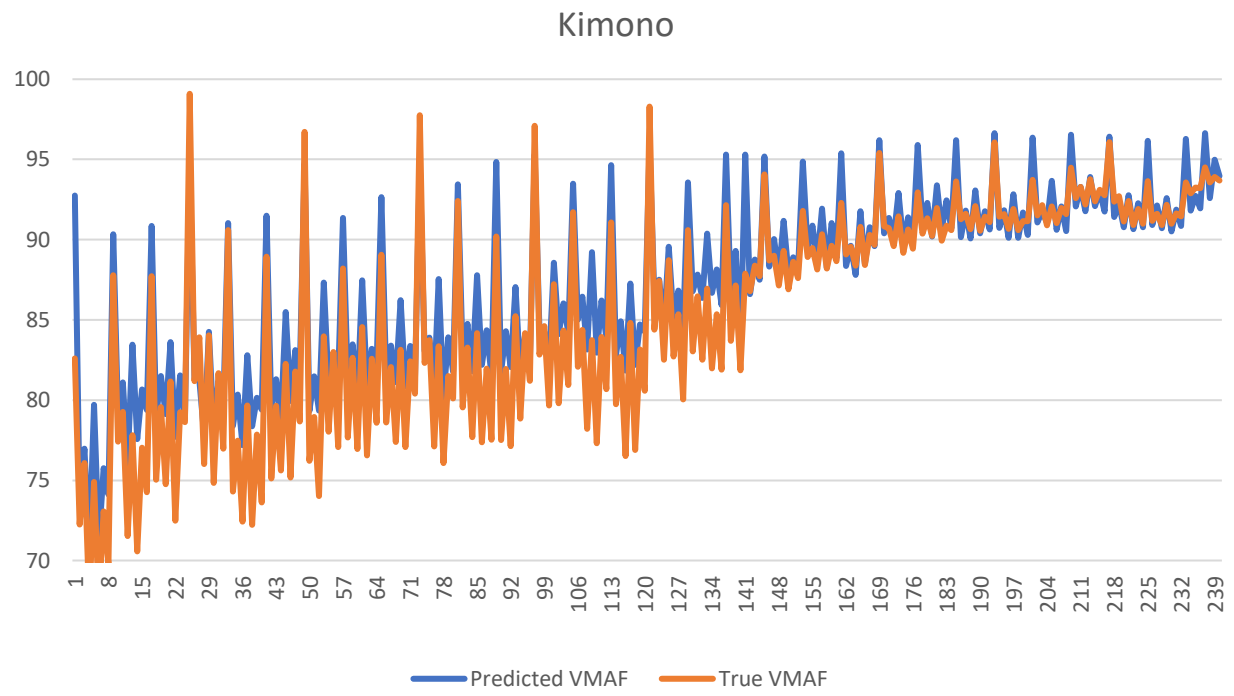
Fast ML-Based Approximations

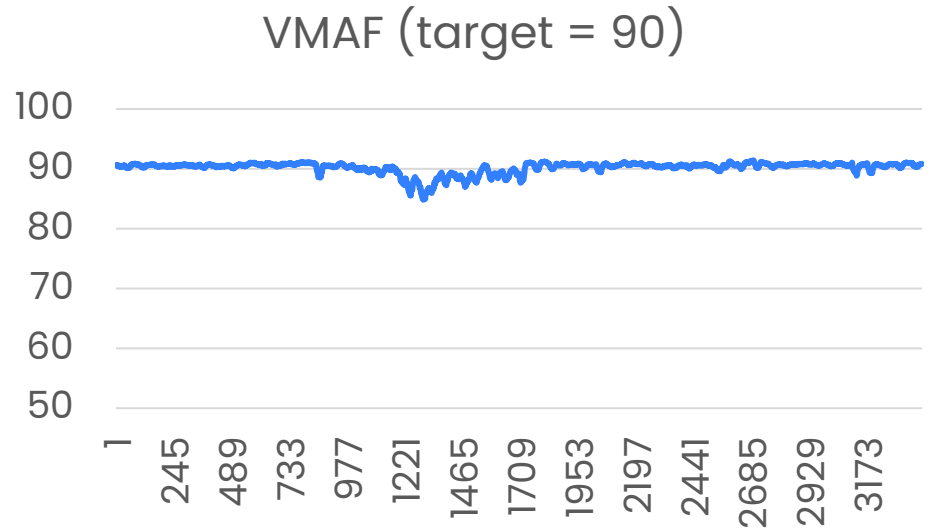
- Predicting VMAF allows quick analysis inside the encoder
- Faster than VMAF, higher accuracy than traditional decision metrics
- High correlation and accurate tracking

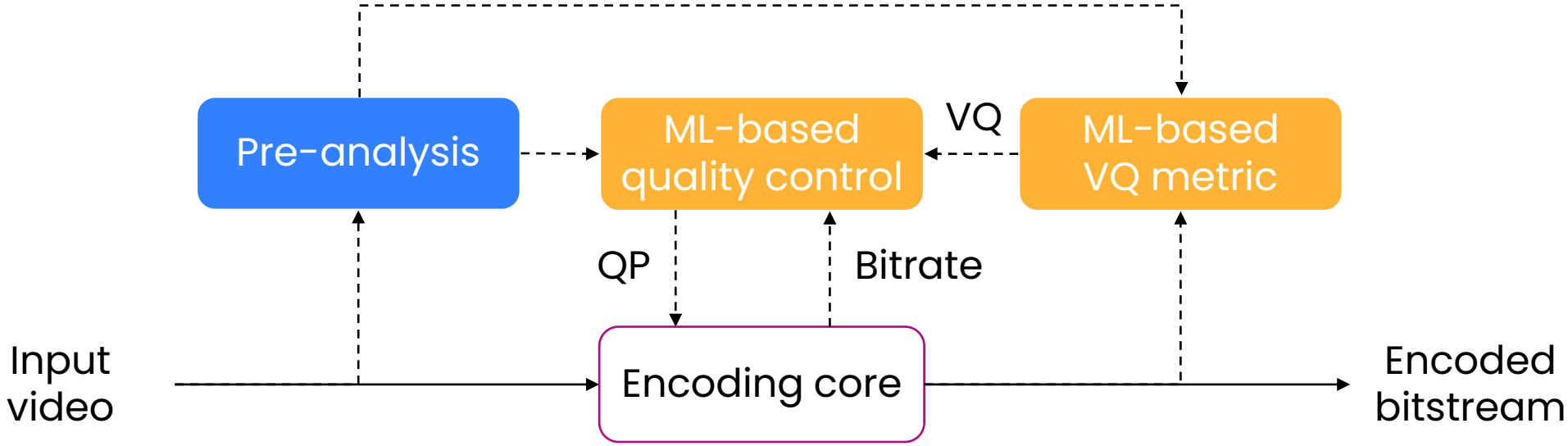




From Rate Control to Quality Control

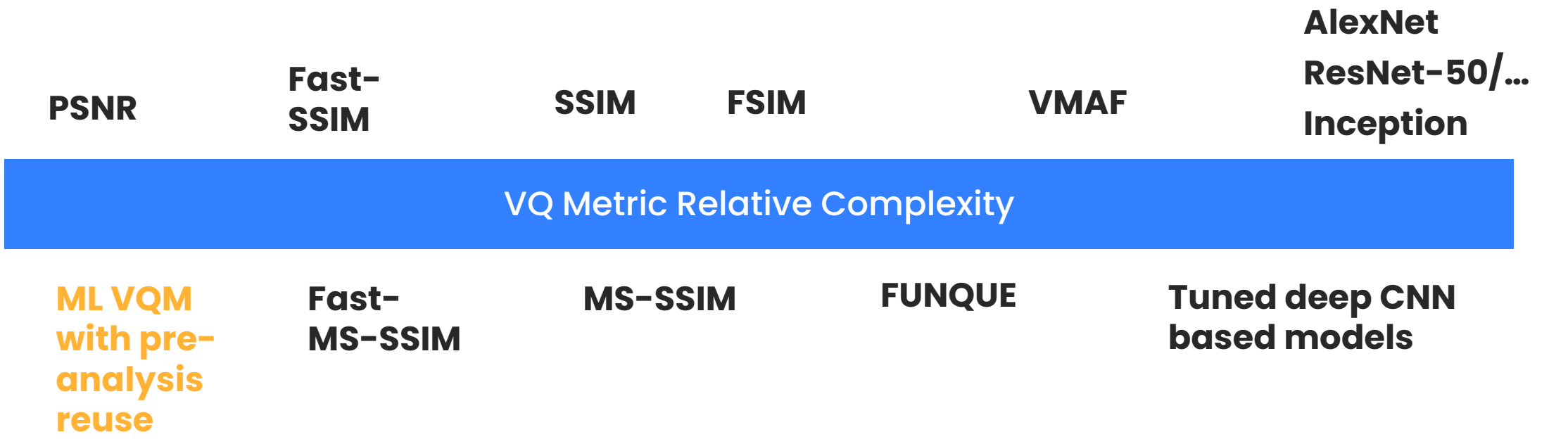
- Fast and accurate VQ measurement is only the first step
- Proactive system: integrating VQM inside rate controller
- **Rate control becomes quality control**

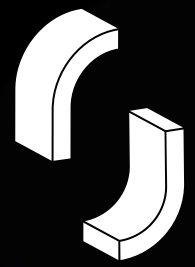




Conclusions

- Many VQ metrics have been developed
- Live / real-time video compression requires metrics with ultra low complexity
- ML approaches can be leveraged for fast approximations with high accuracy
- Well-suited for integration in real-time encoders and quality control





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