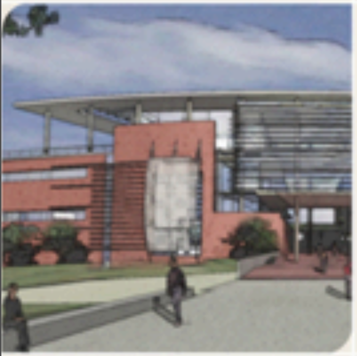

Dynamic Tuning of Feature Set in Highly Variant Interactive Applications

Tushar Kumar, Romain Cledat,

and Santosh Pande

Georgia Tech College of Computing

EMSOFT 2010

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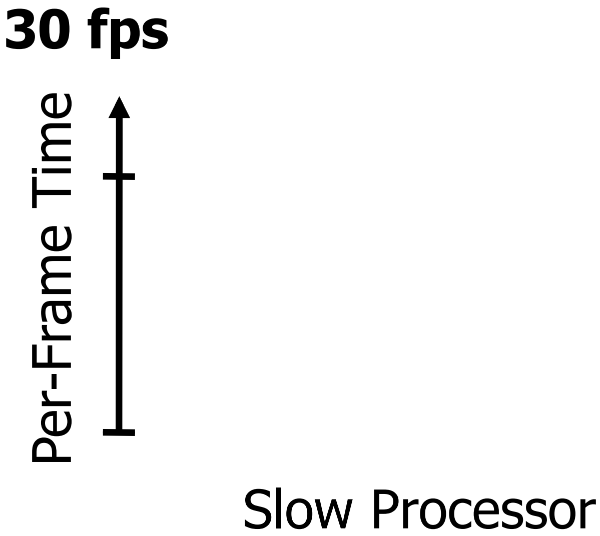

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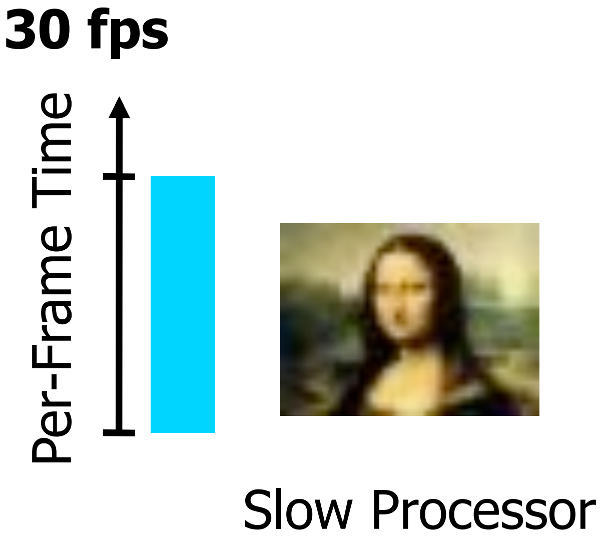

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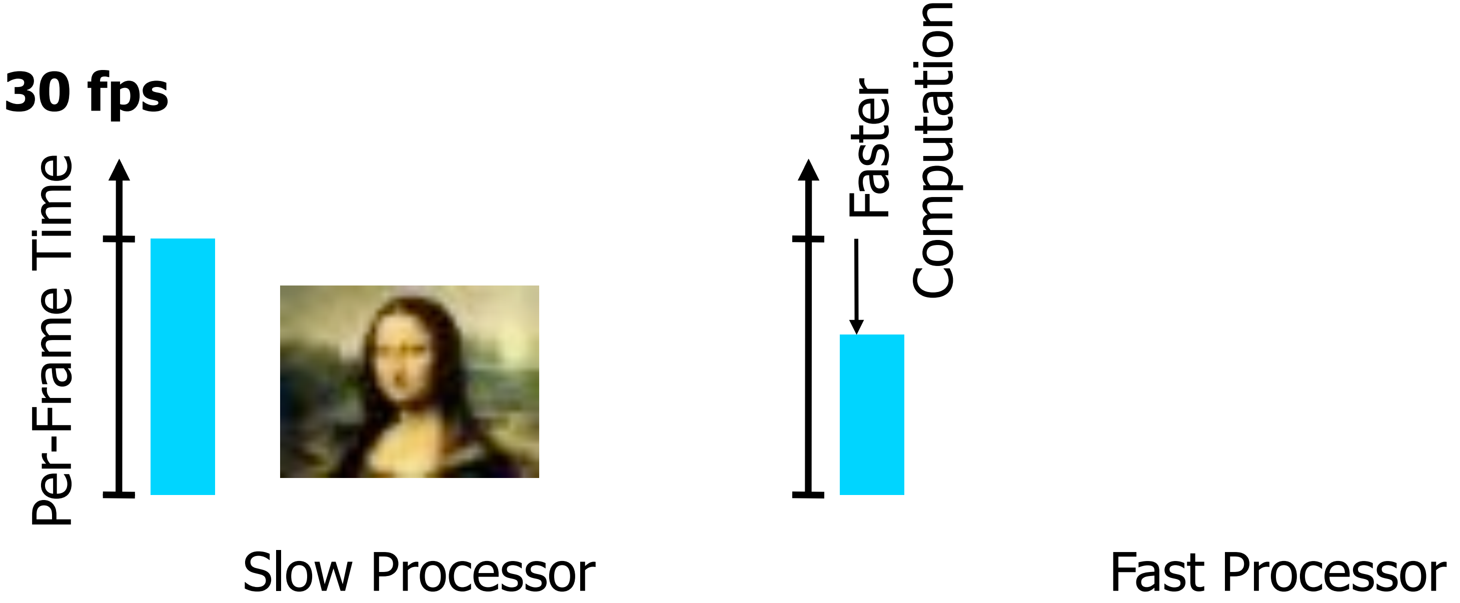

30 fps

Per-Frame Time

Slow Processor

Faster Computation

Fast Processor

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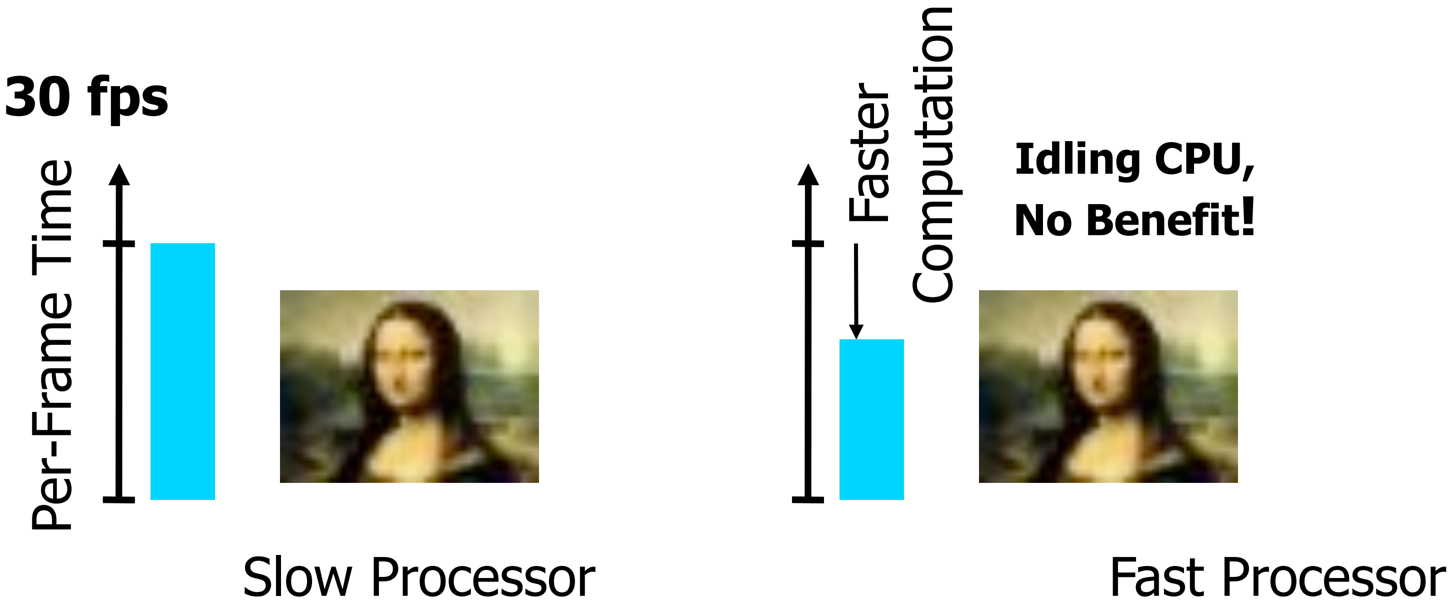

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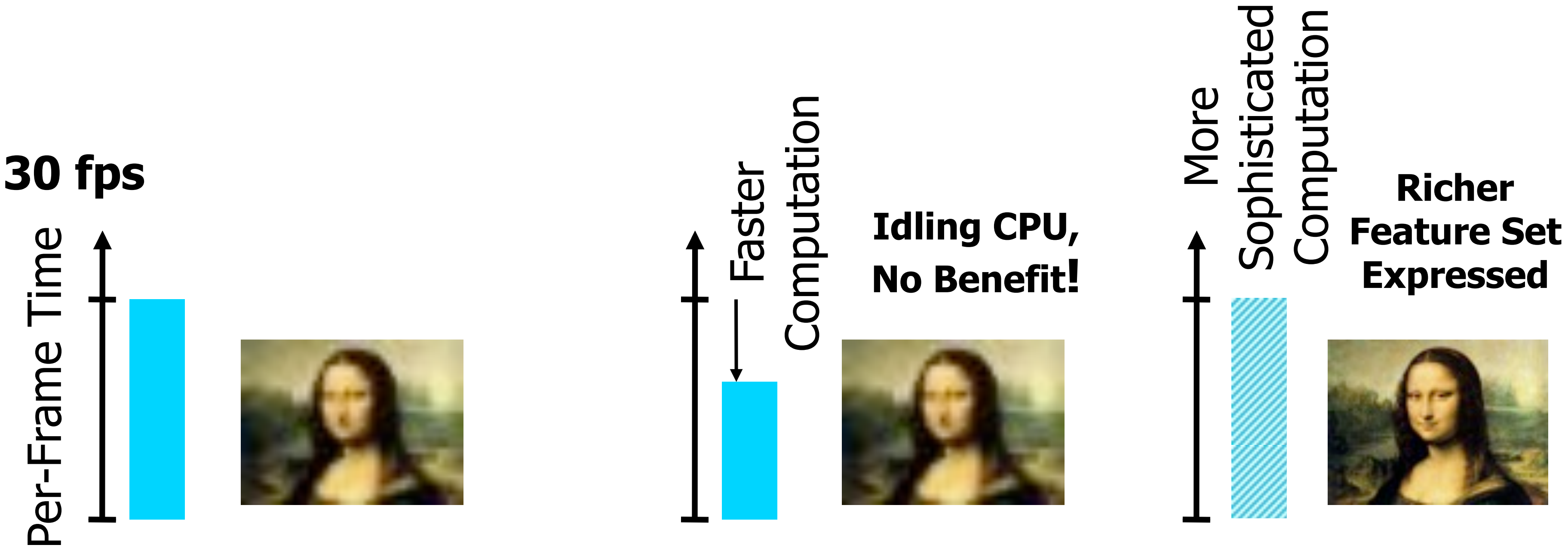

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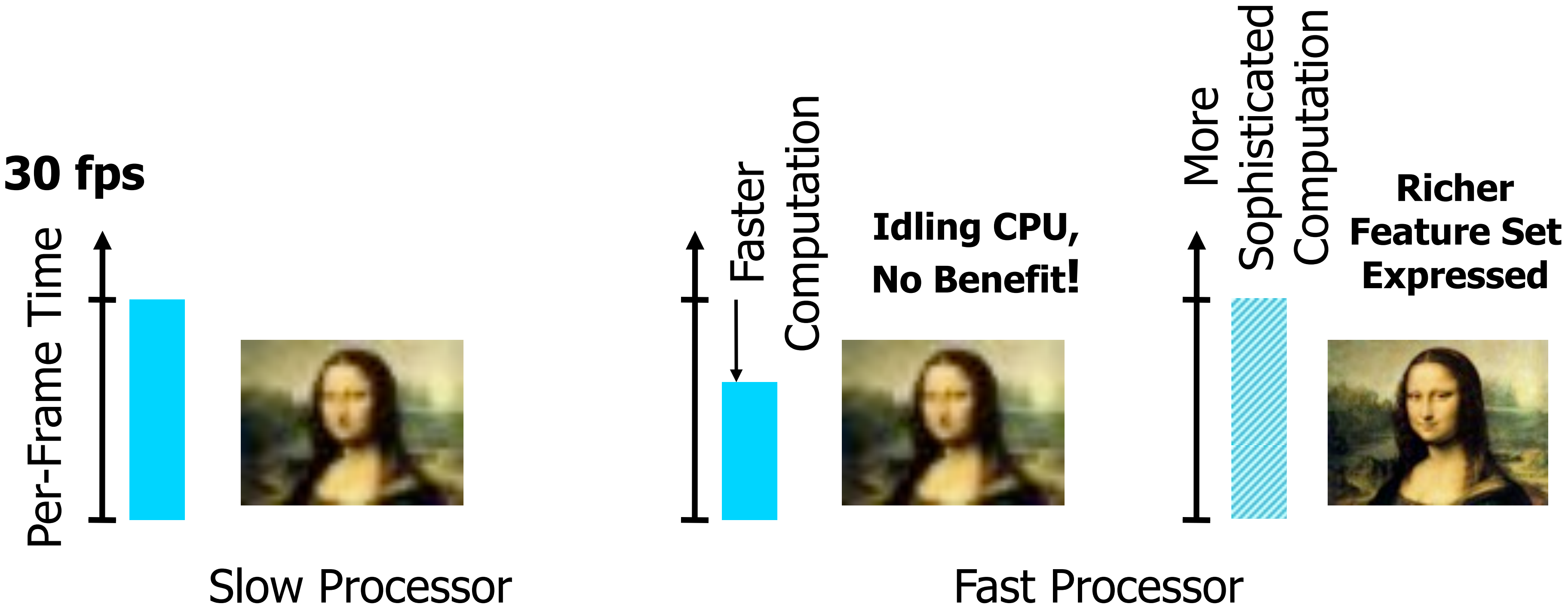

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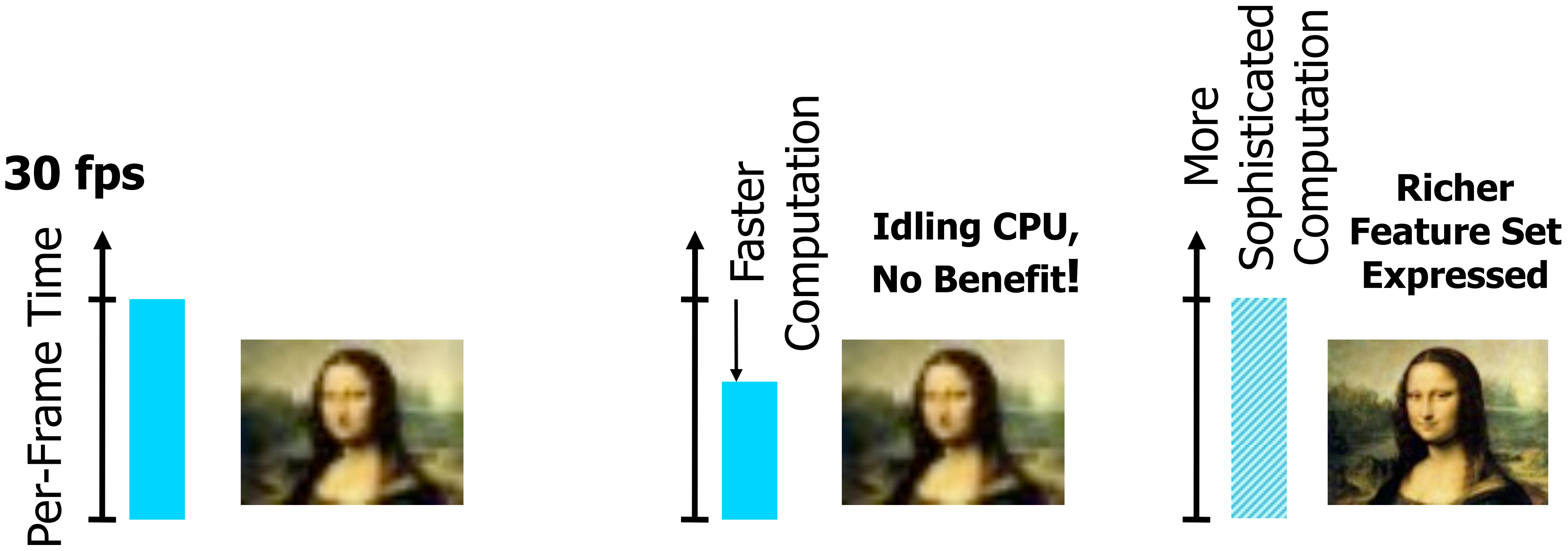

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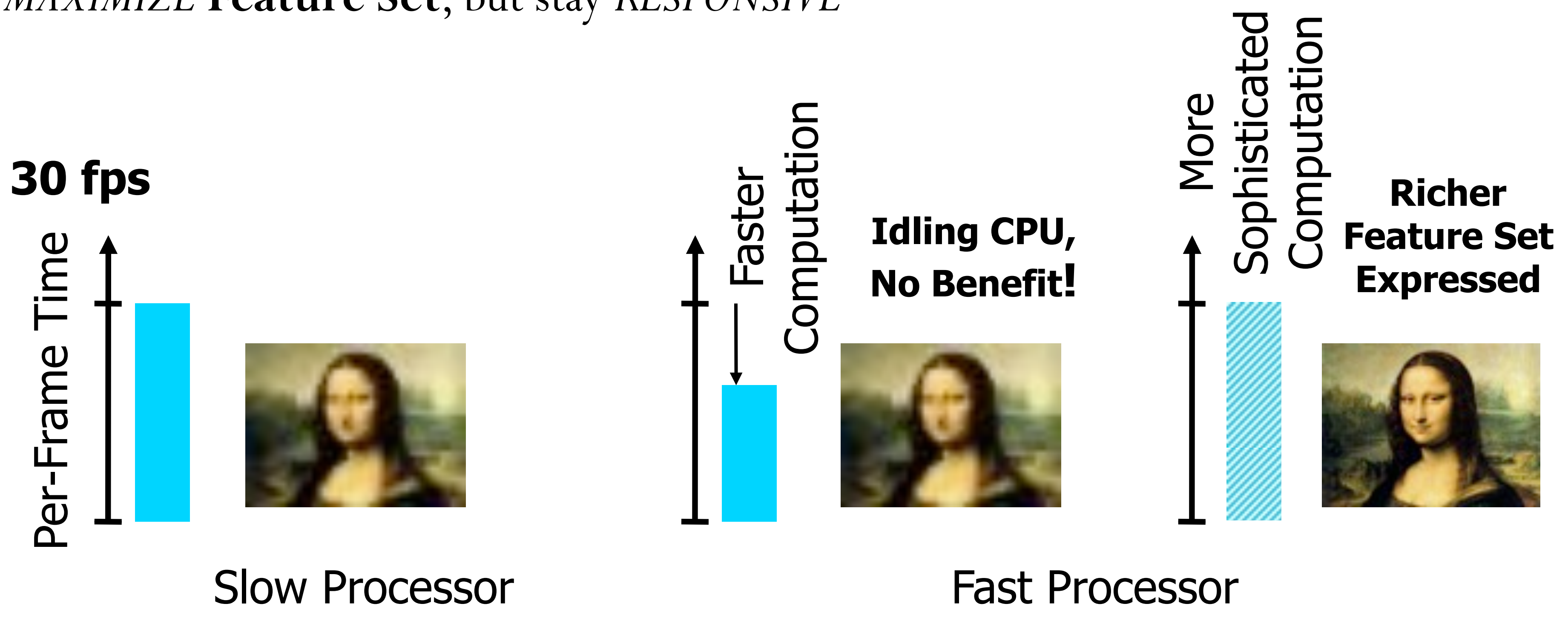
  - *MAXIMIZE* **Feature Set**, but stay *RESPONSIVE*



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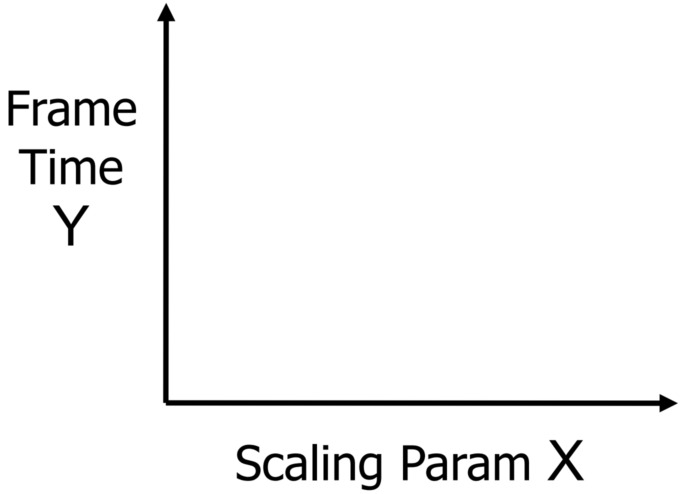
  - Let X denote the *scaling parameter* (application-specific choice)

Challenges in Tuning Feature Set



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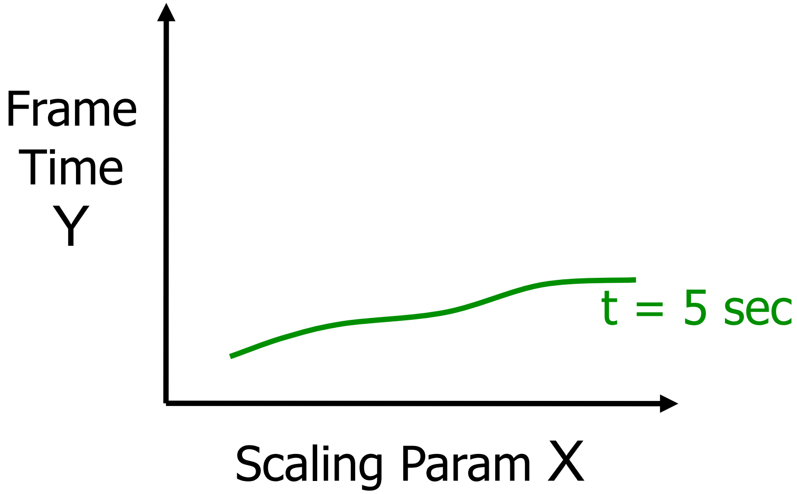

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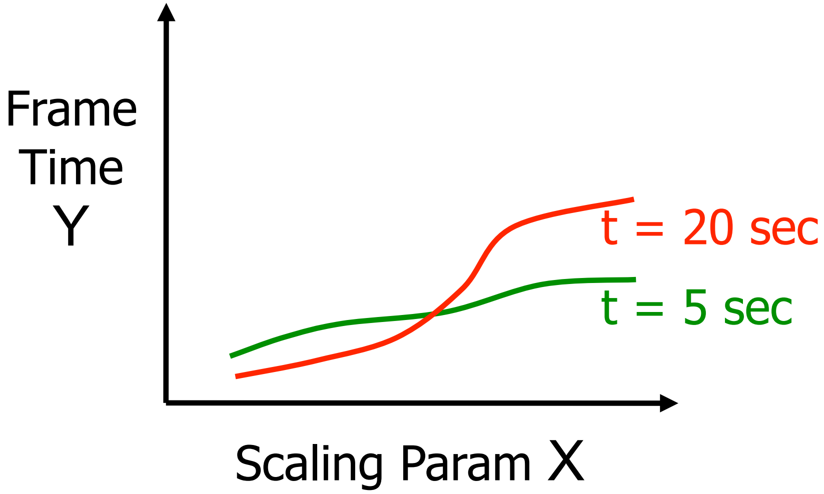

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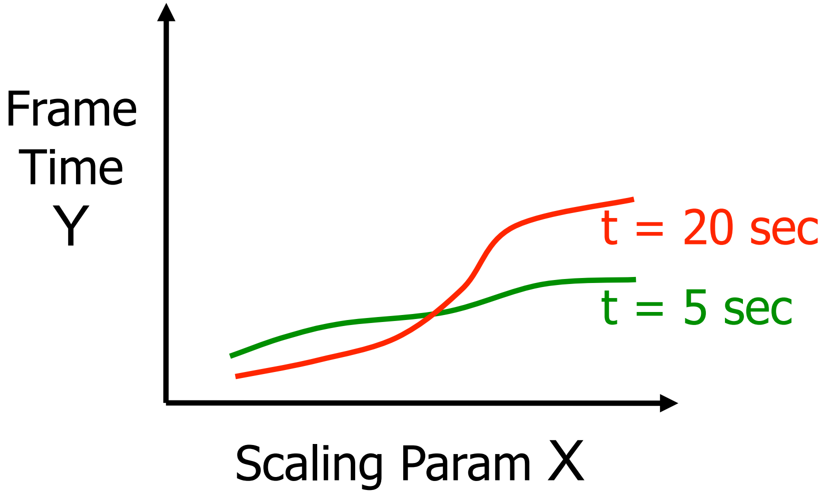

Data-Set #1
(e.g., 320x240 video)

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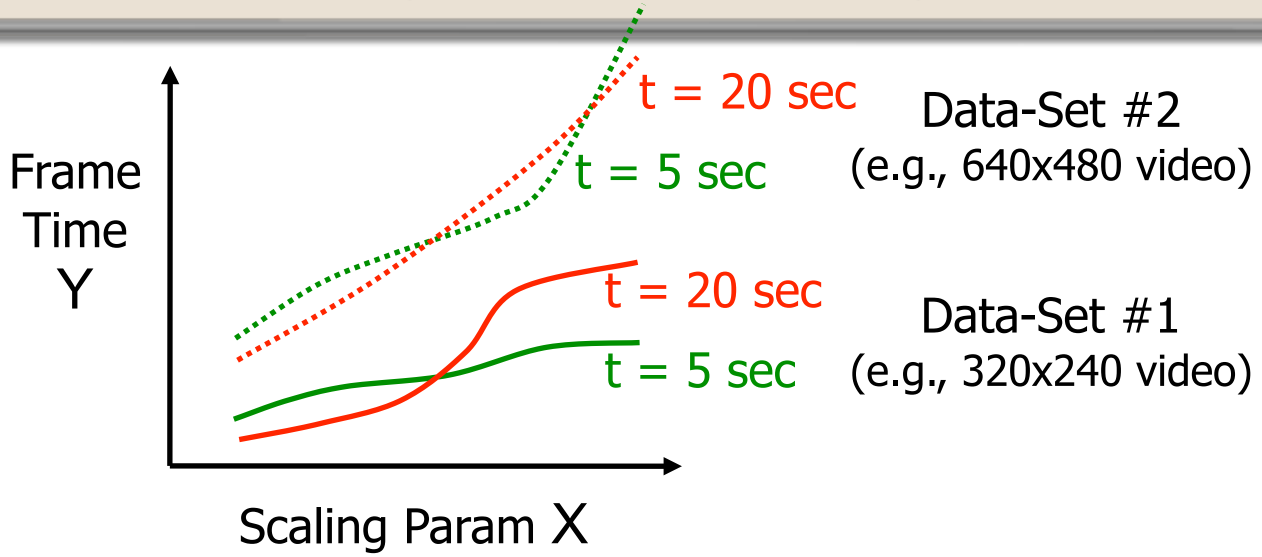

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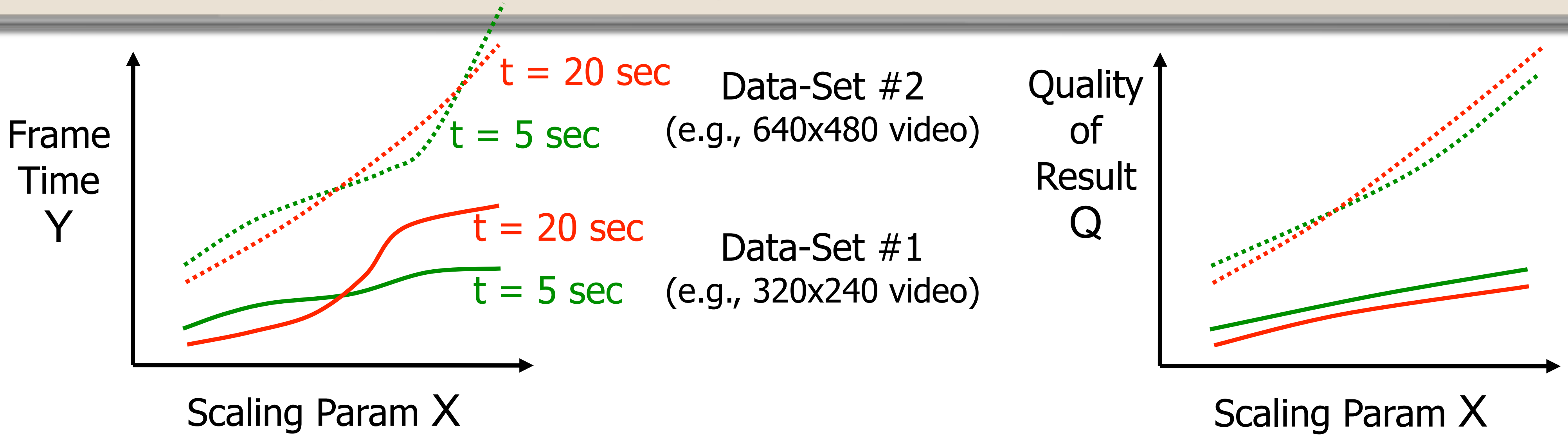

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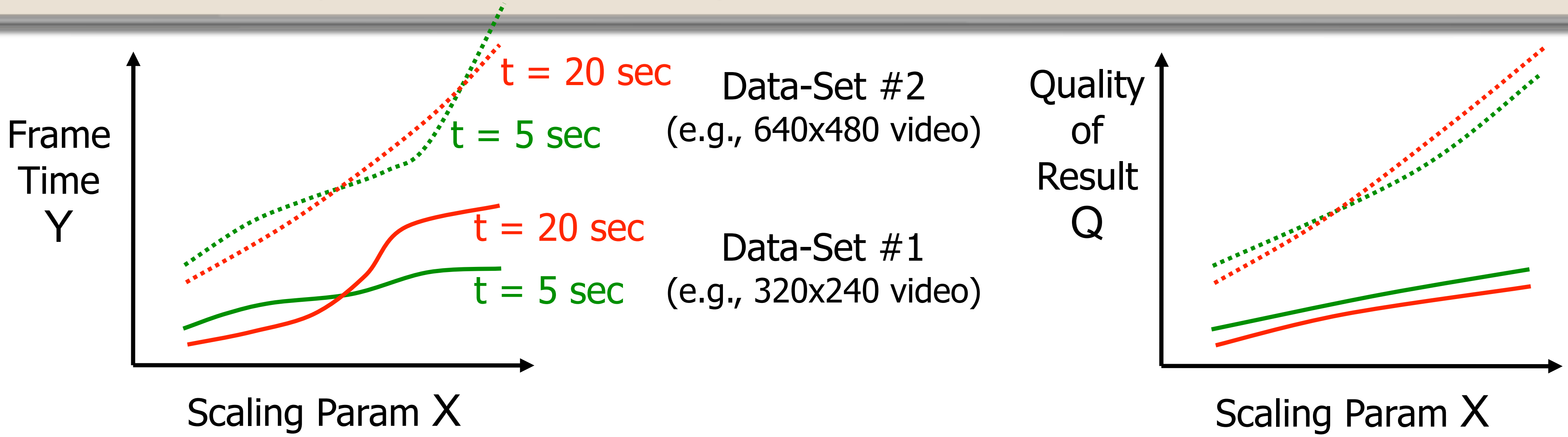

X-Y, X-Q Response Characteristics

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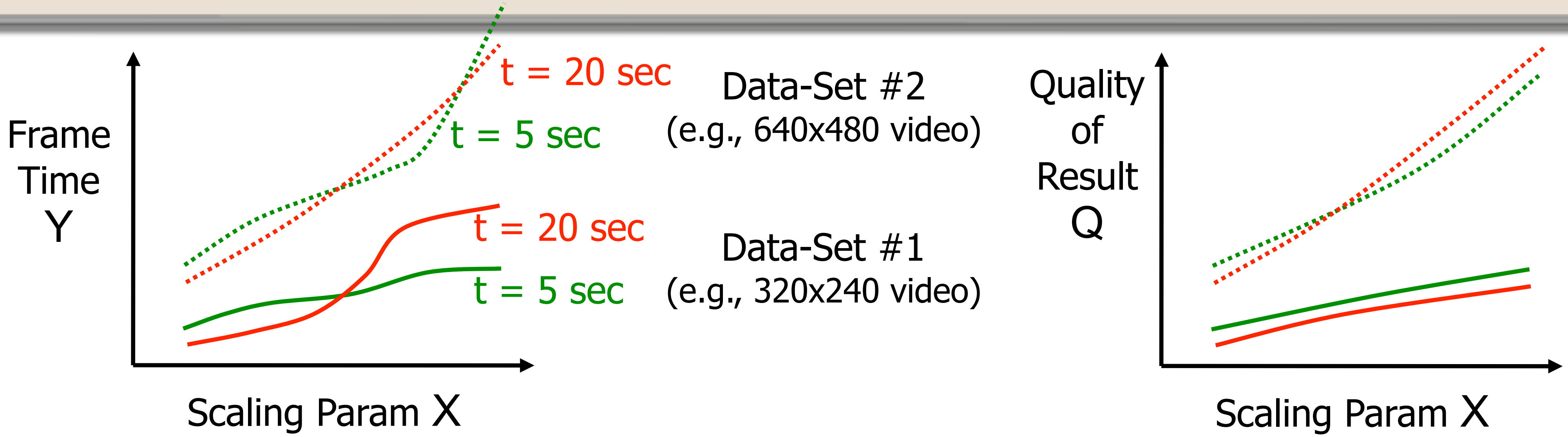

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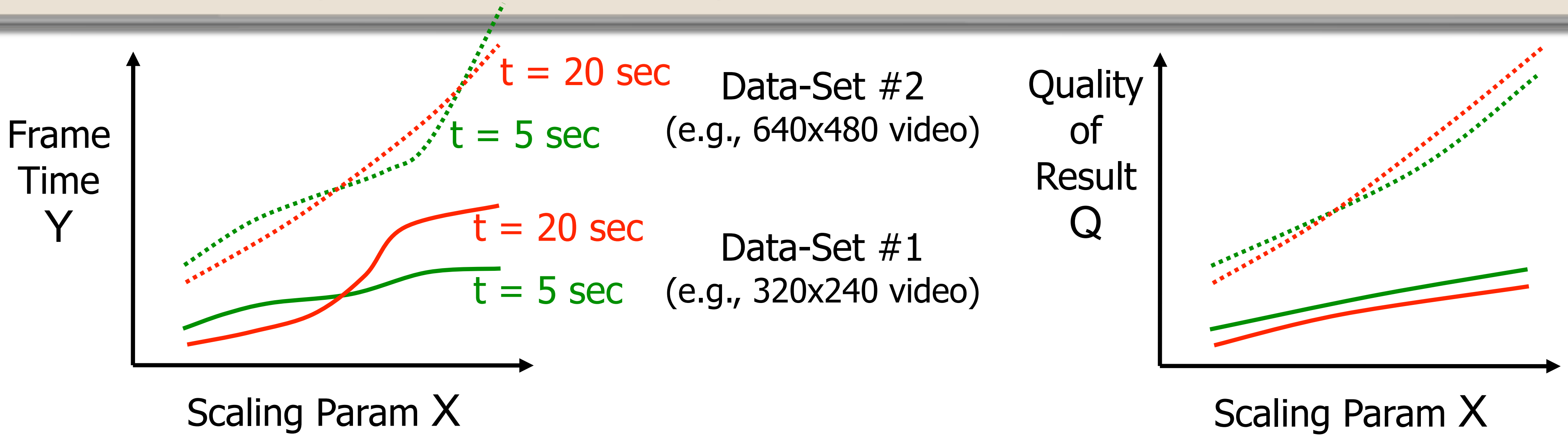

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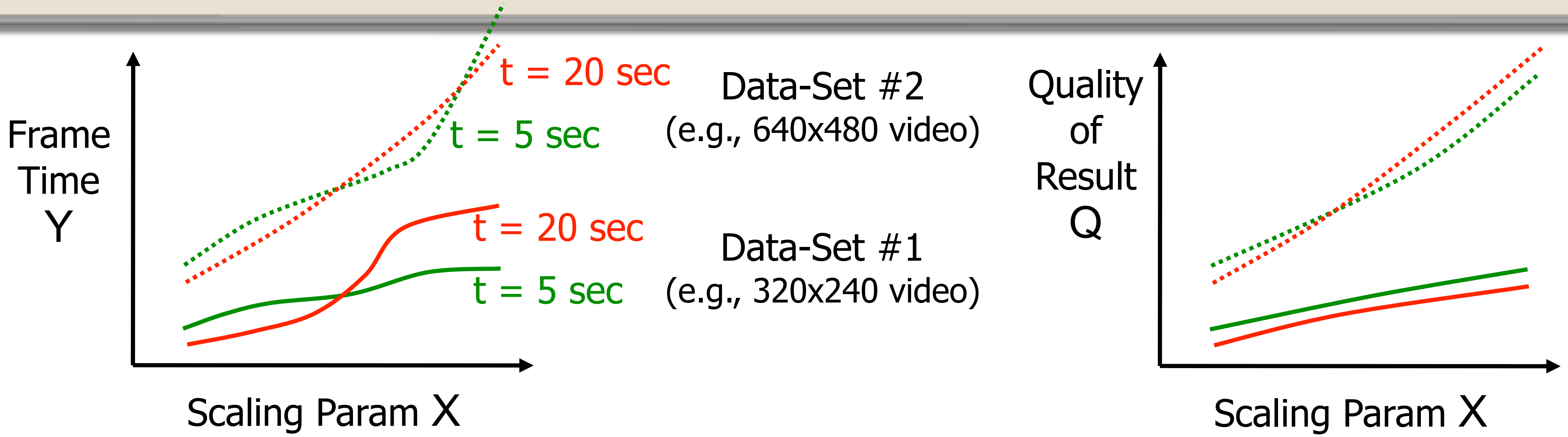

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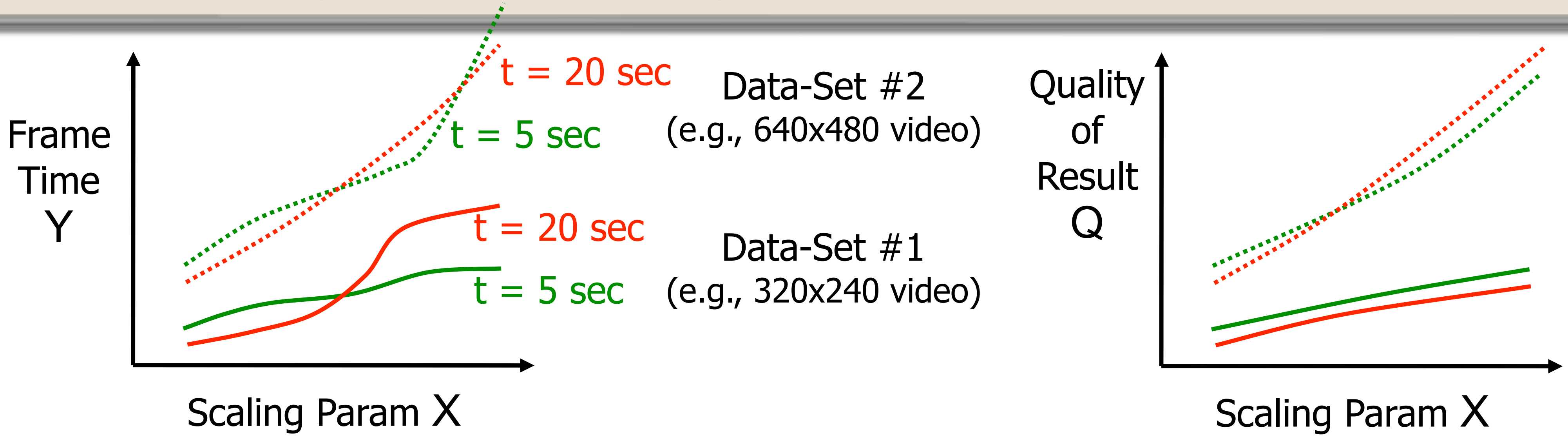

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- Or, manually tune to ***each game-play scenario***, tune for Xbox vs PS3

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Main Contribution

Simplicity of Use,

Generality of Application

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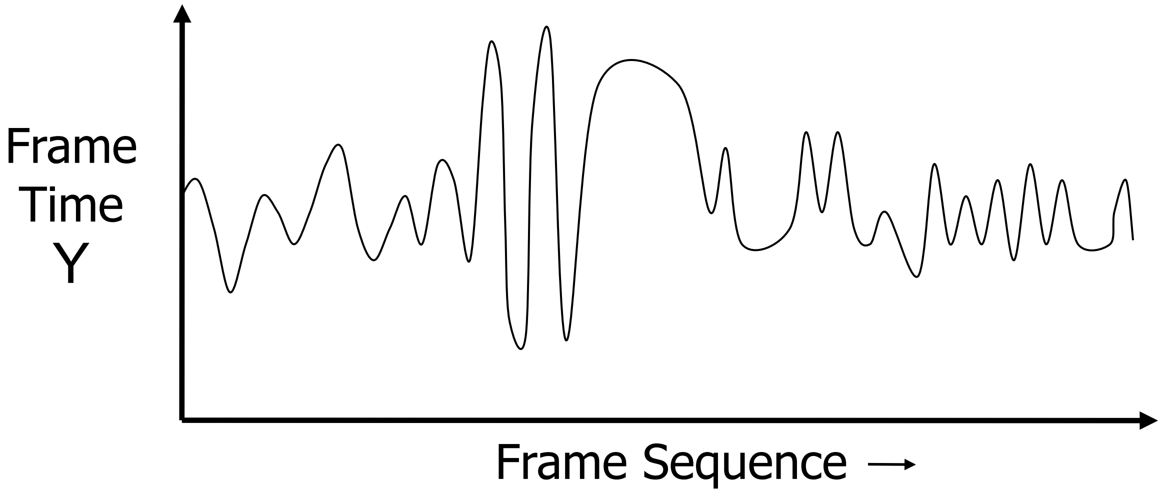

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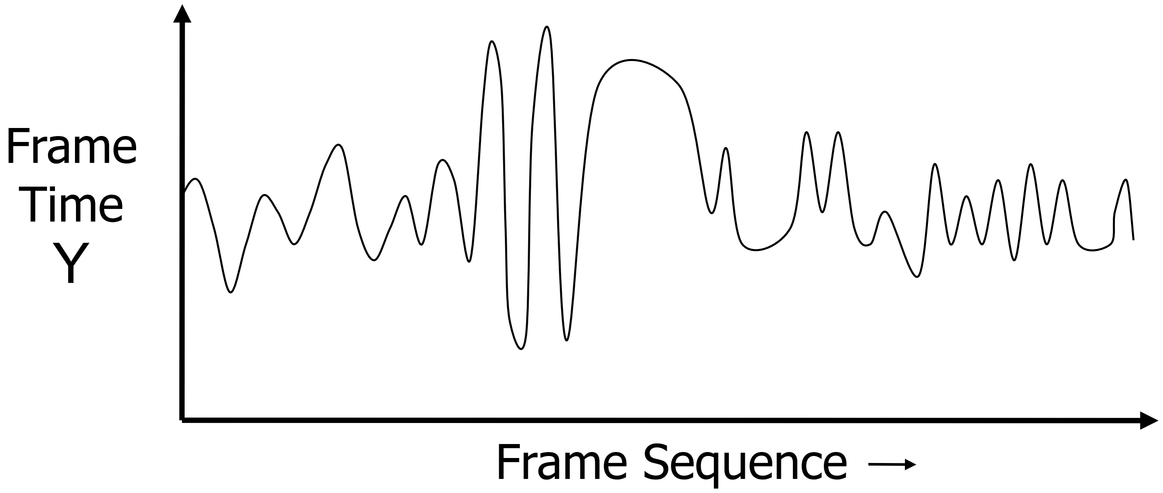

- Soft Real Time nature

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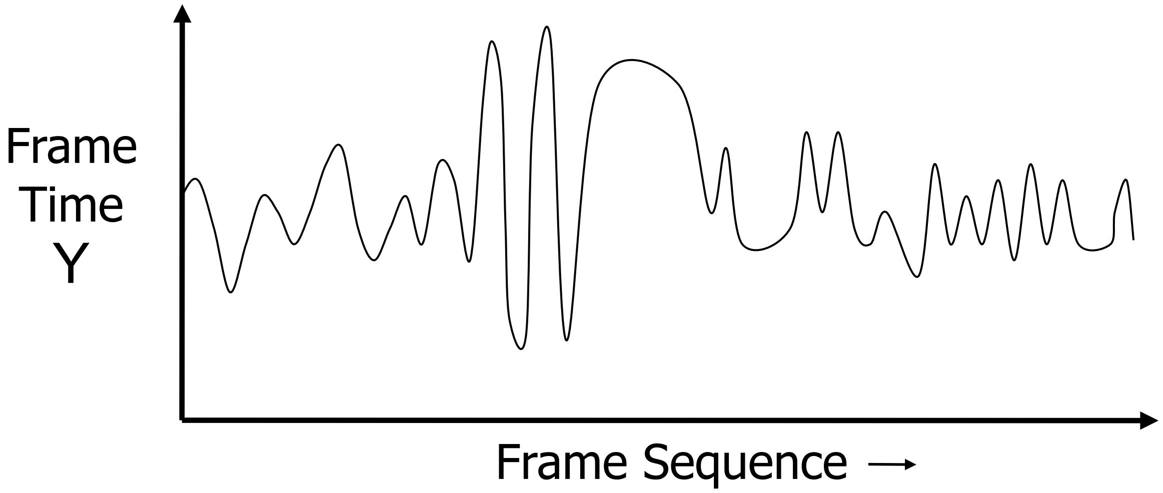

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    "Maintain 25-35 frames-per-second with high probability"

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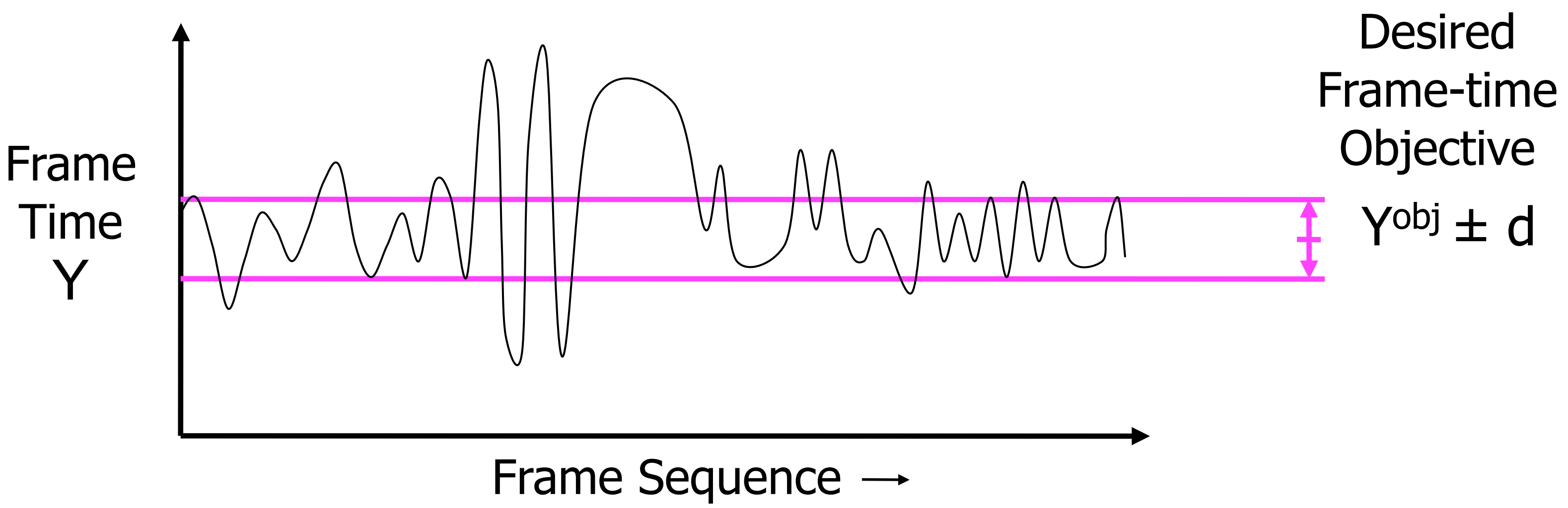

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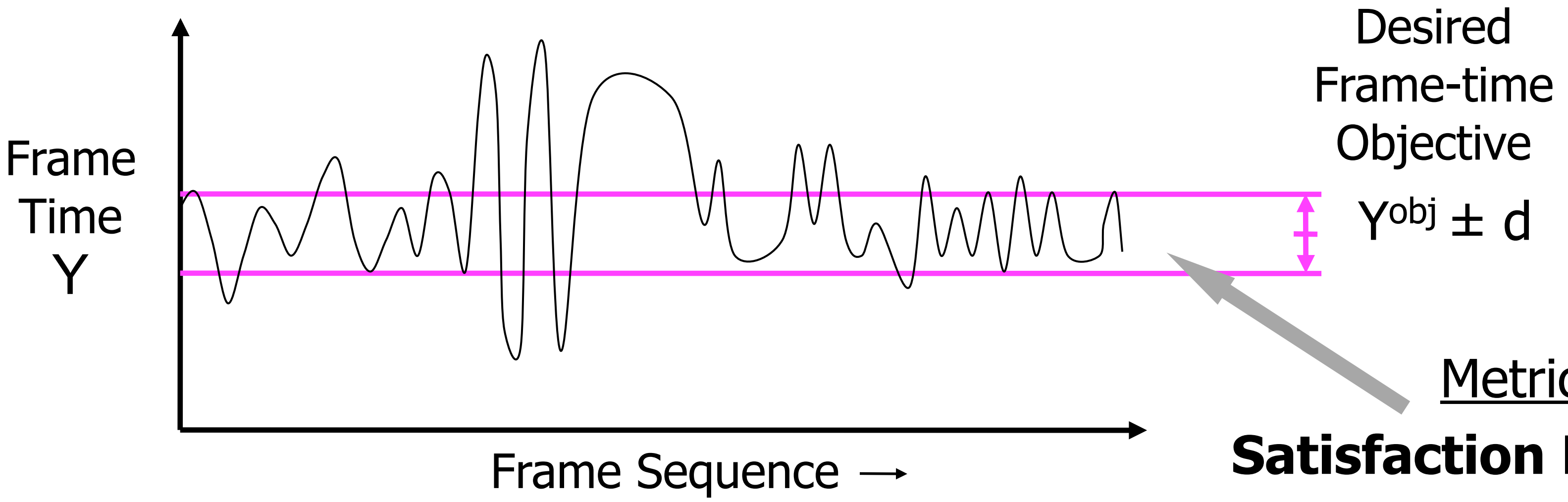

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Satisfaction Ratio (SR):

Fraction of frames with Y within $Y^{obj} \pm d$

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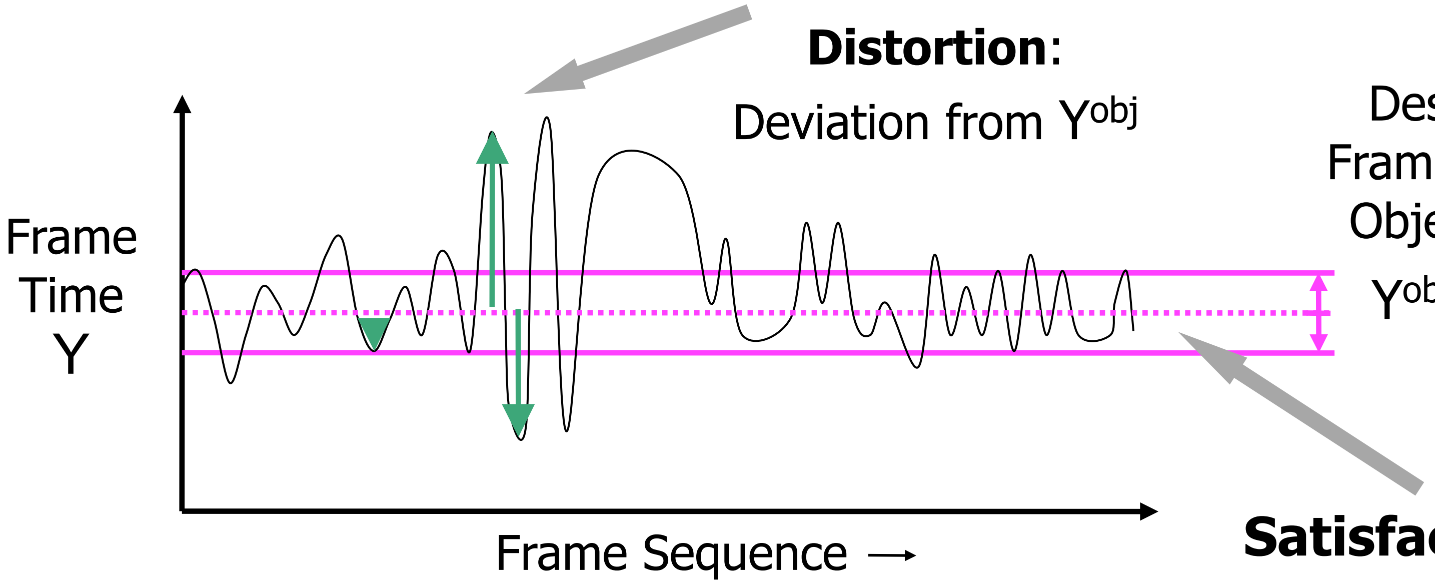

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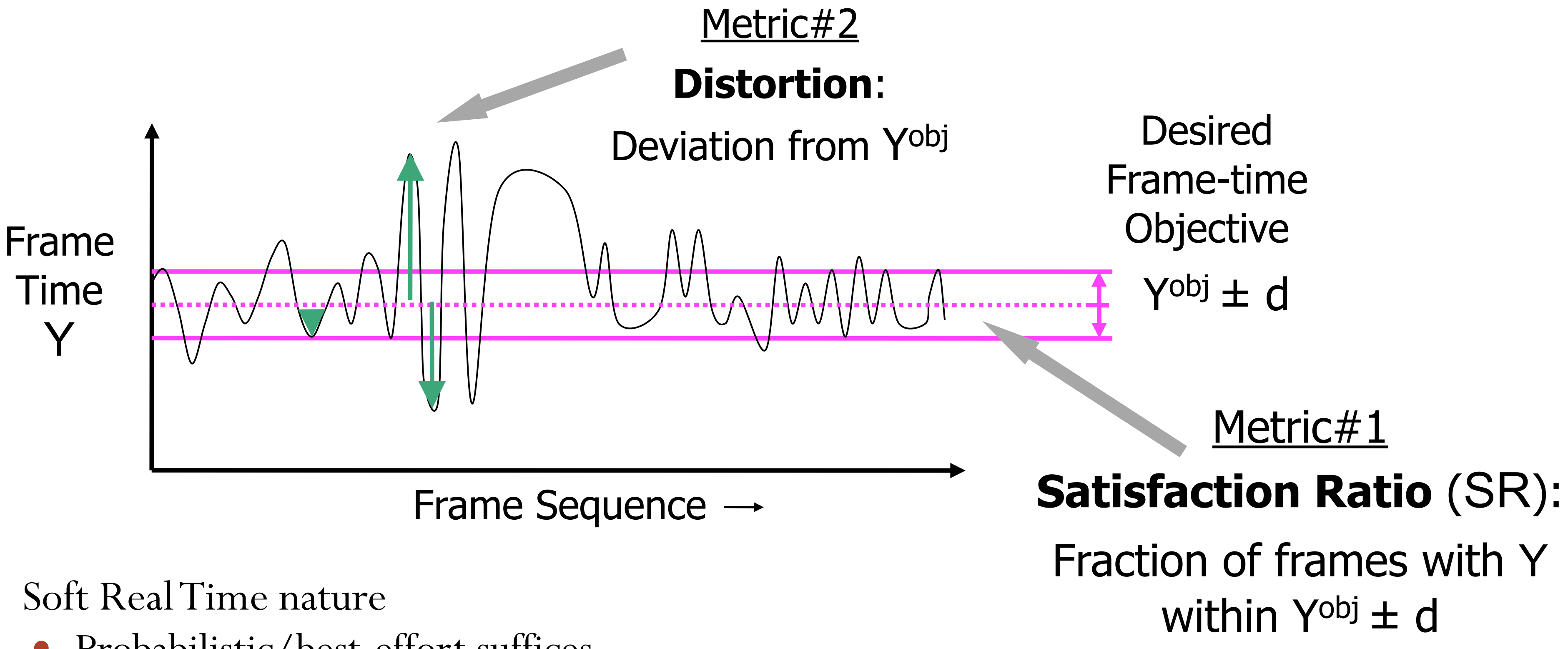

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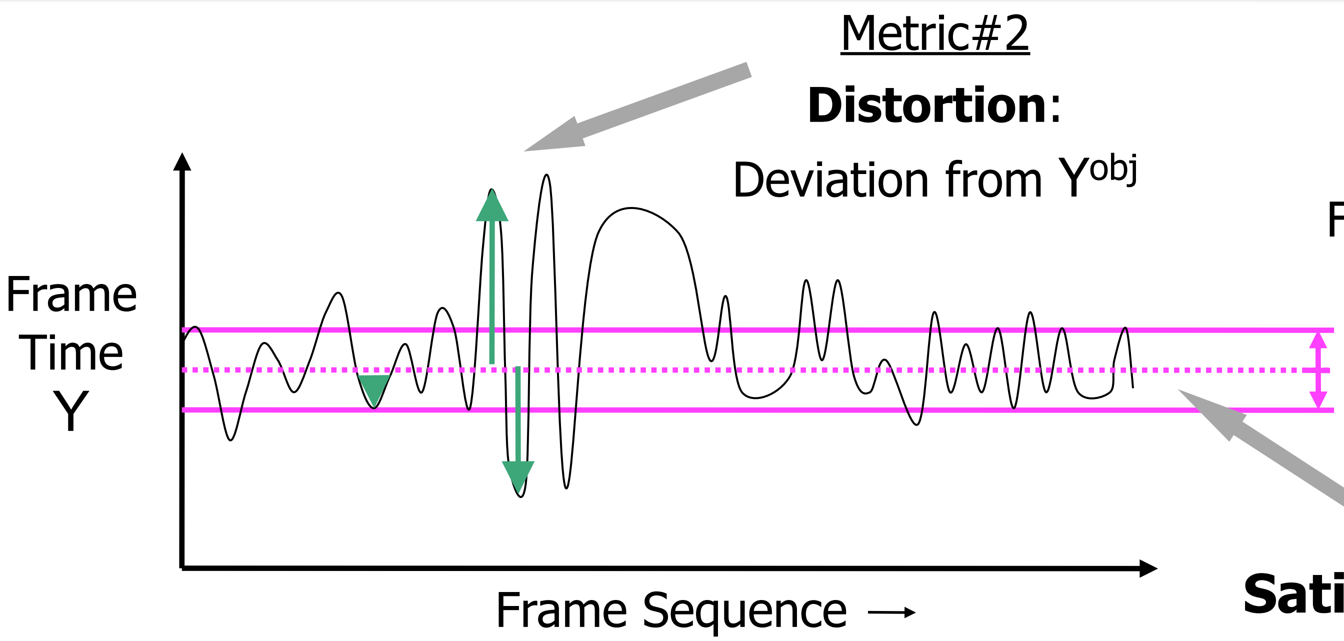

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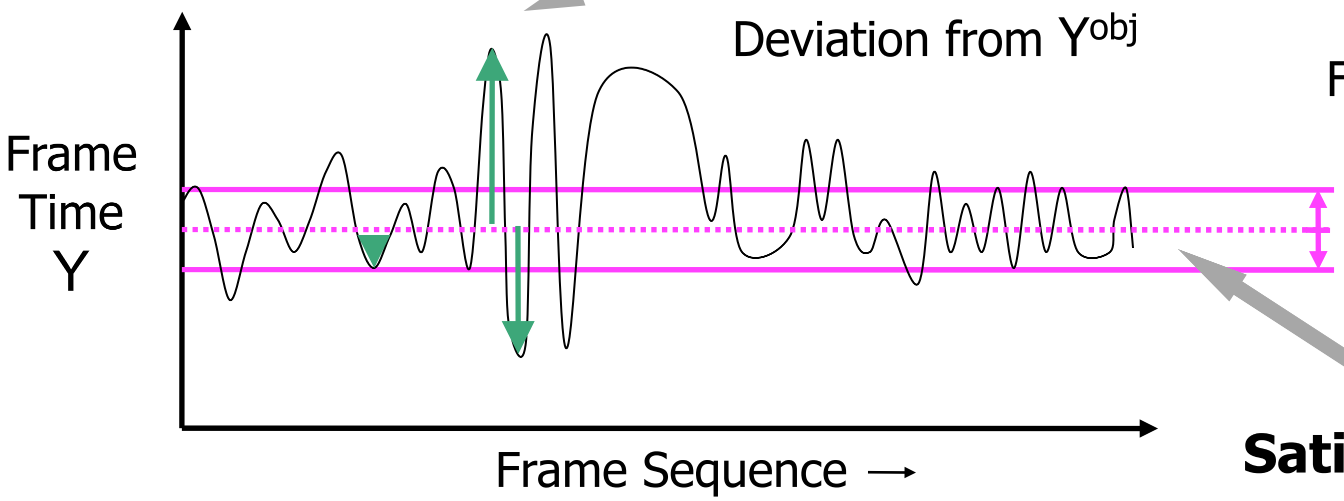

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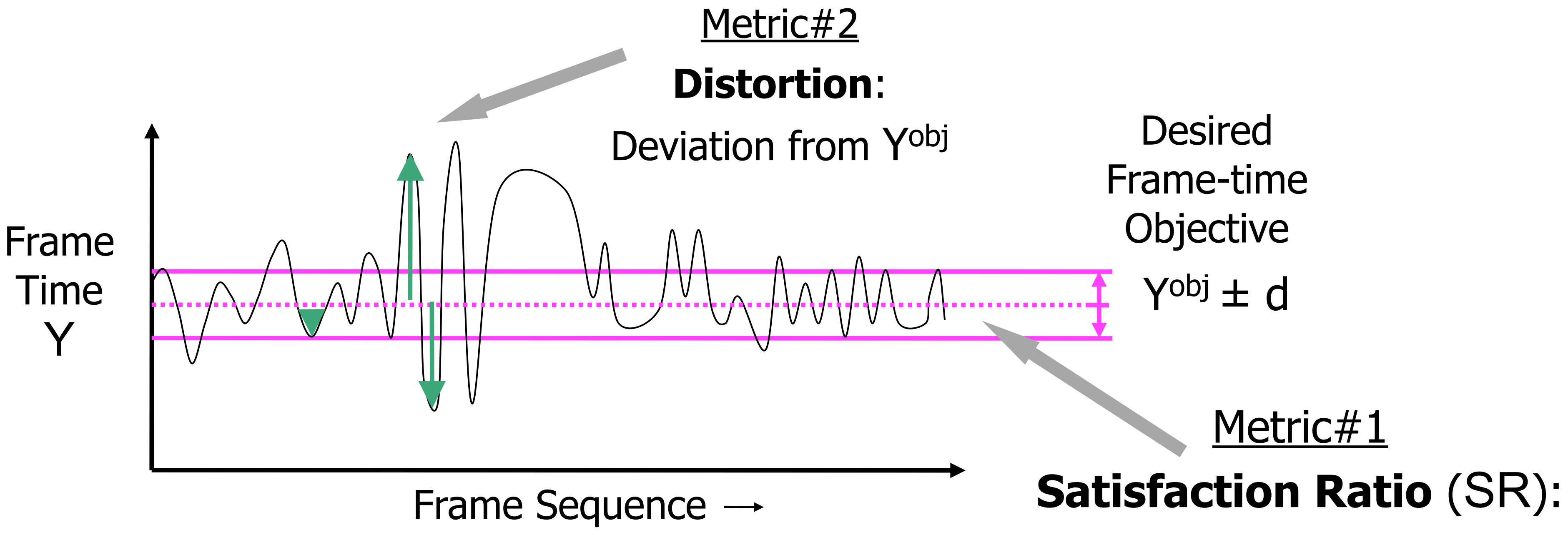

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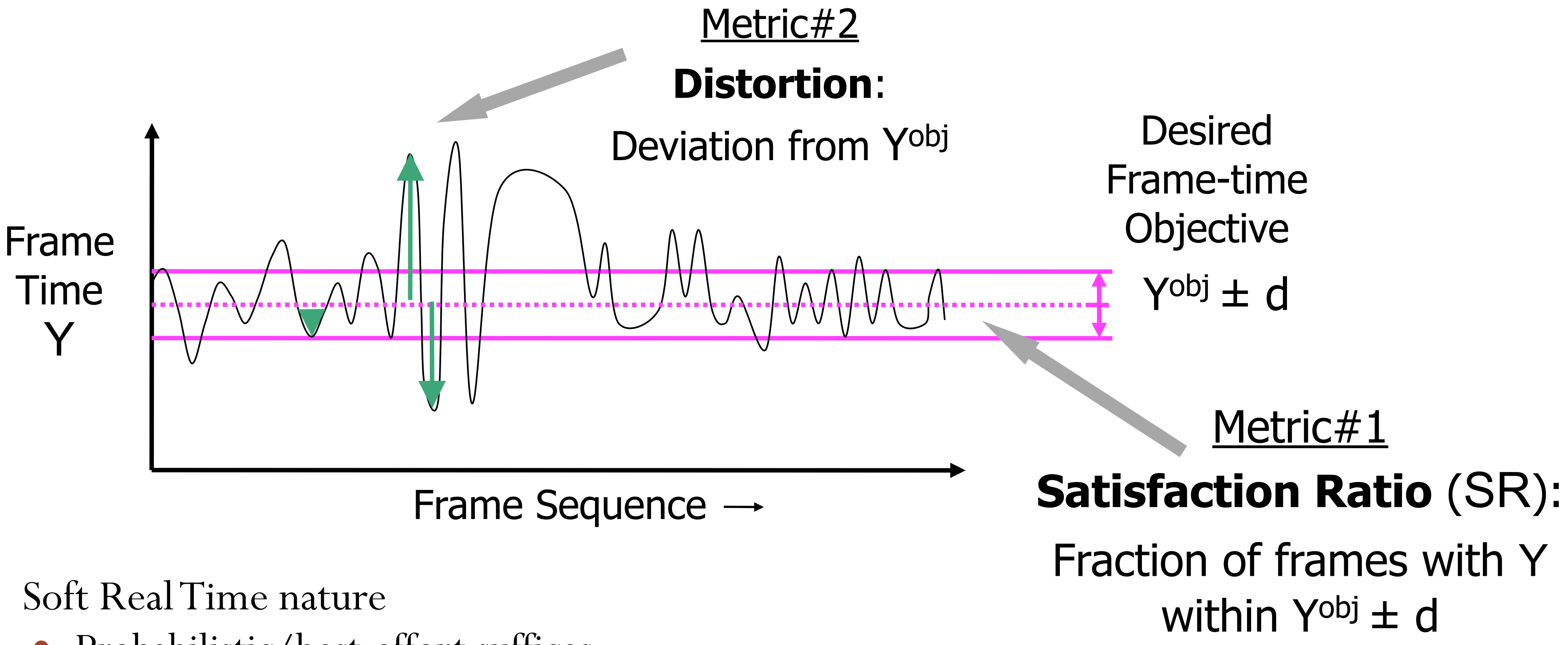

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” Only option: compare against SR when X has ***best fixed setting***

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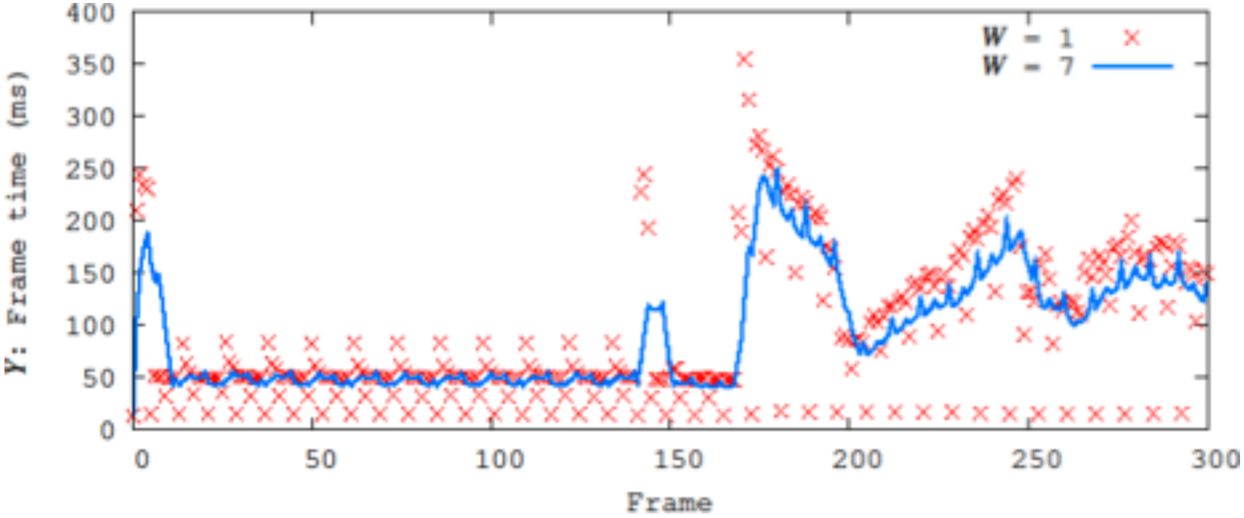

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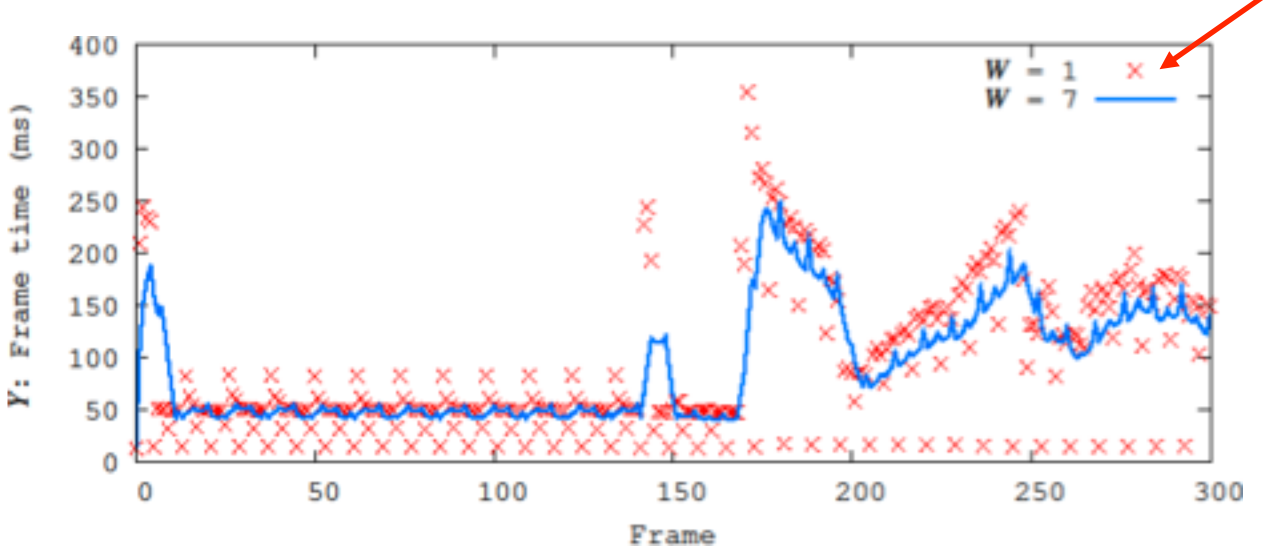

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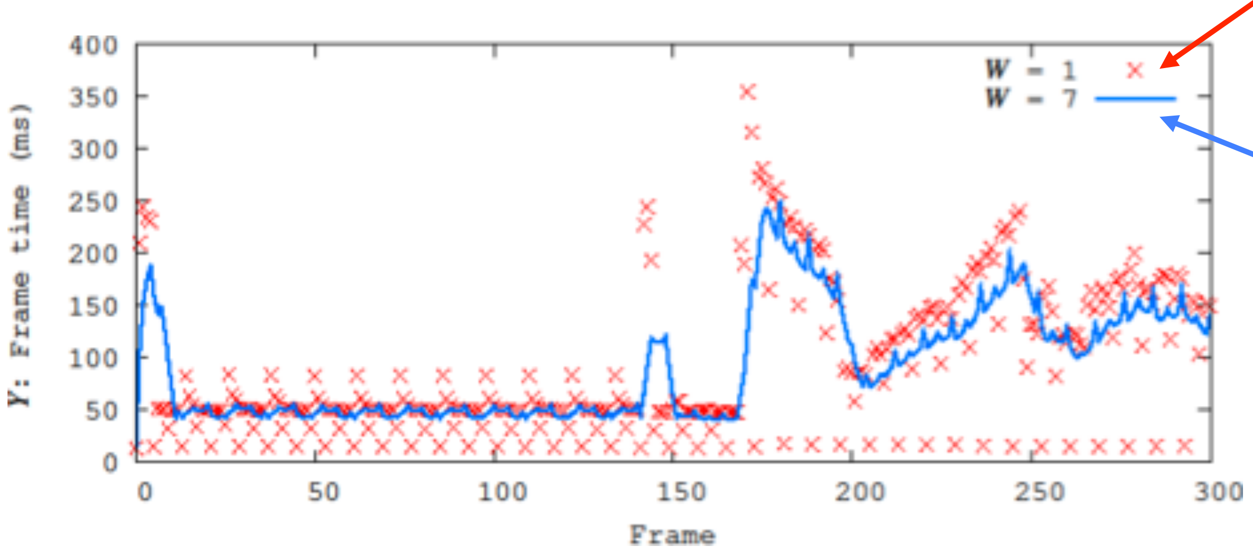

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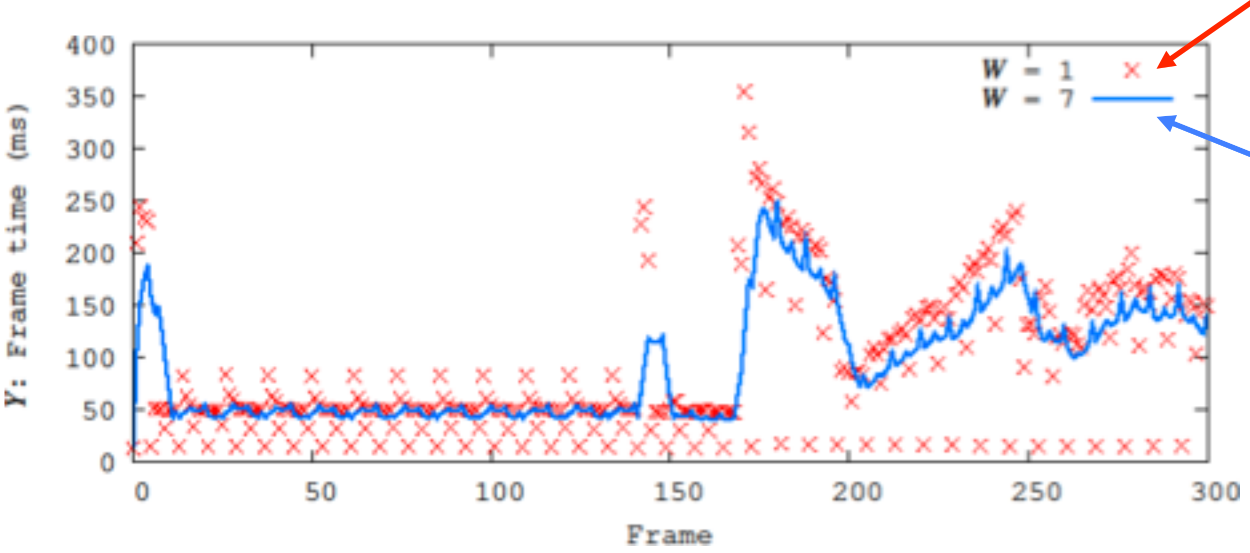

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Lesson#1

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-Programmer specifies: Window of Perception W

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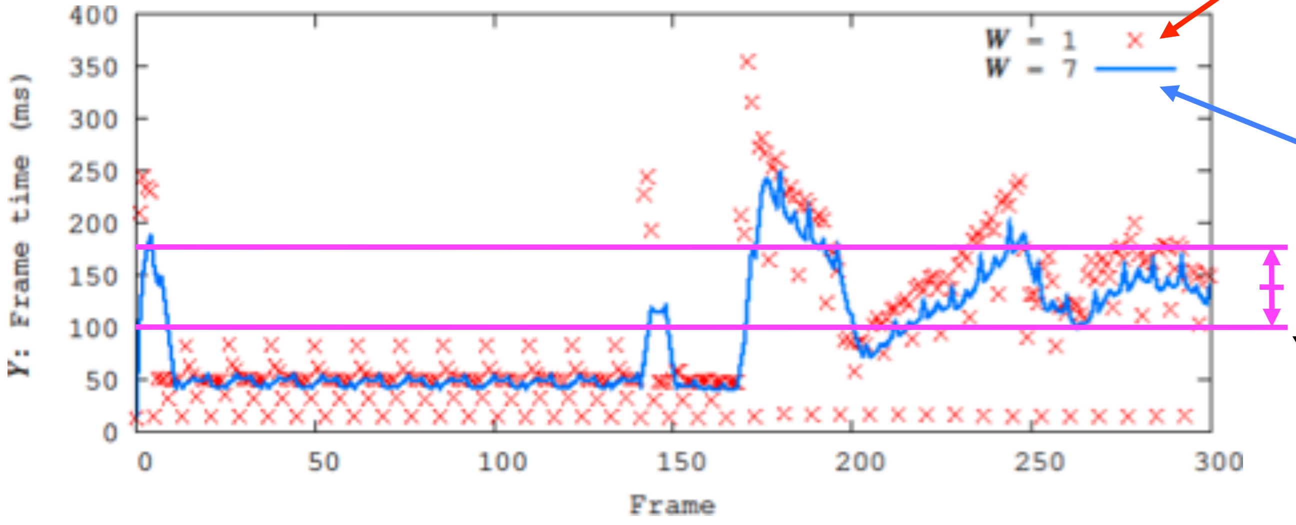

Instantaneous frame-times have significant transients *(Not perceived by user!)*

Moving average of previous 7 frames is mostly smooth *(Closer to user perception)*

$Y^{obj} \pm d$

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-Control **perceived** frame-time (much easier)

-Programmer specifies: Window of Perception W

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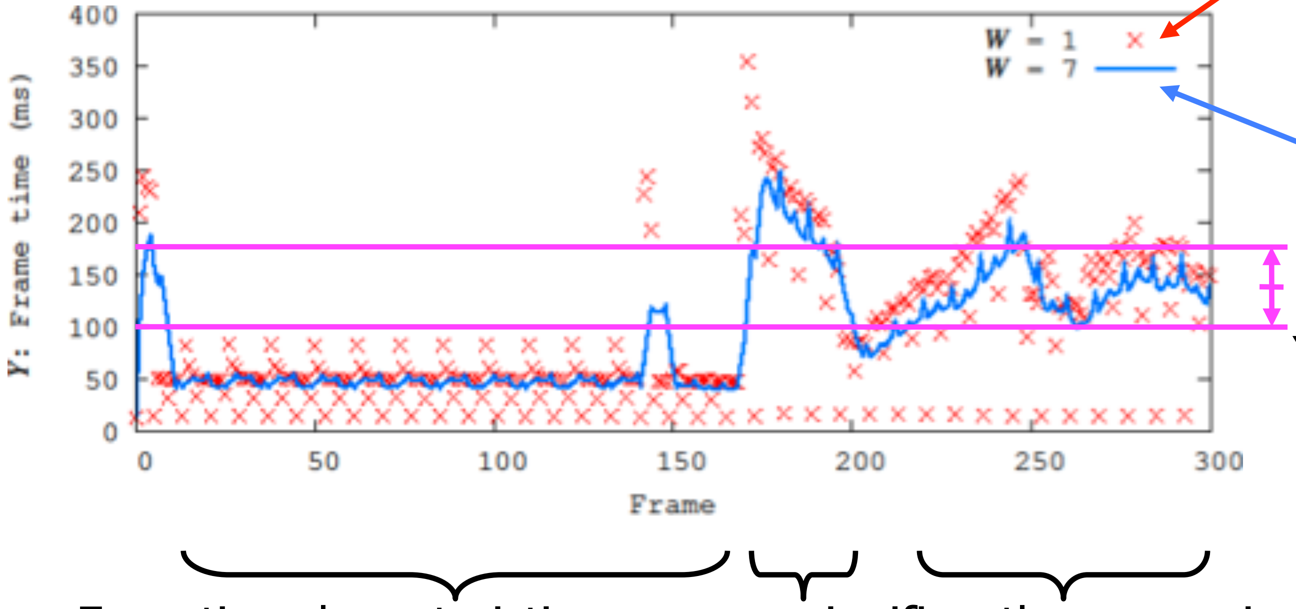

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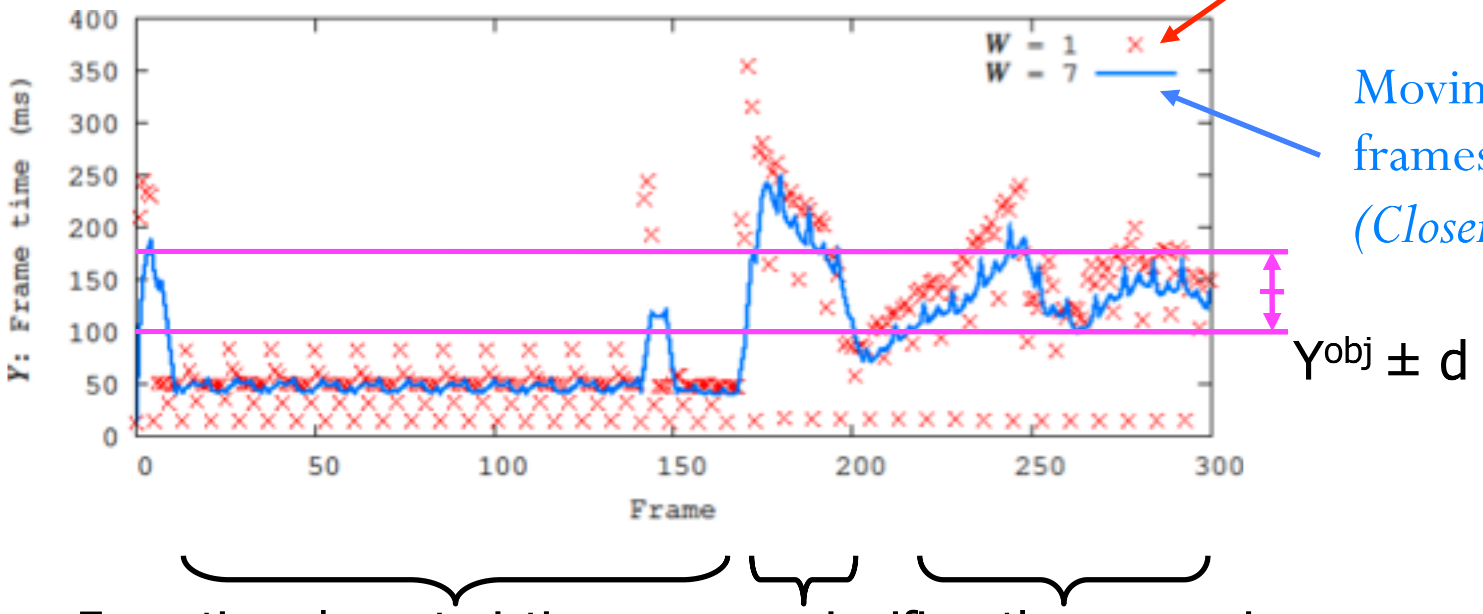

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Lesson#2

Train X to each region!

Lesson#1

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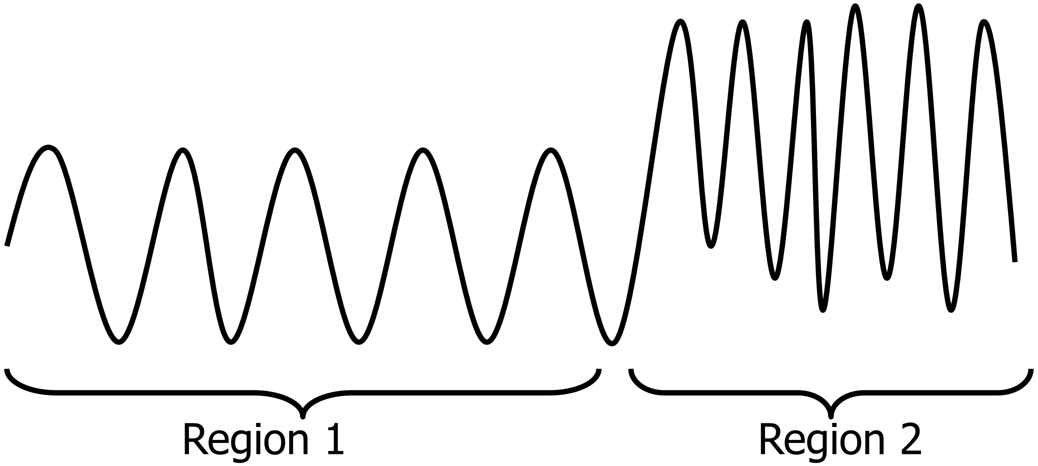

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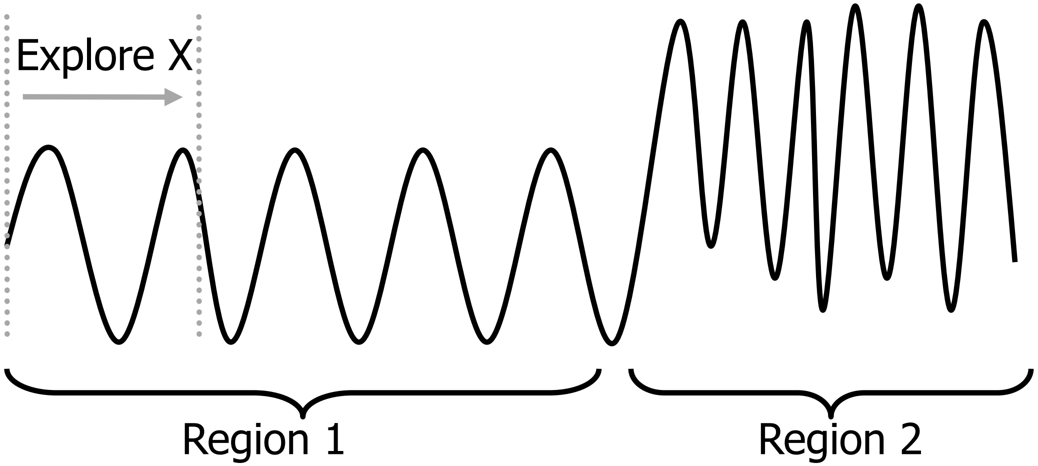

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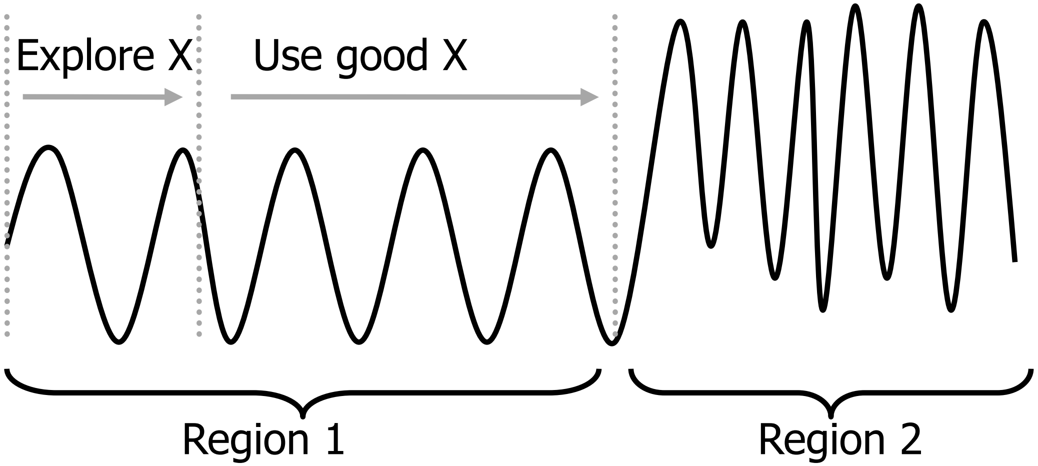

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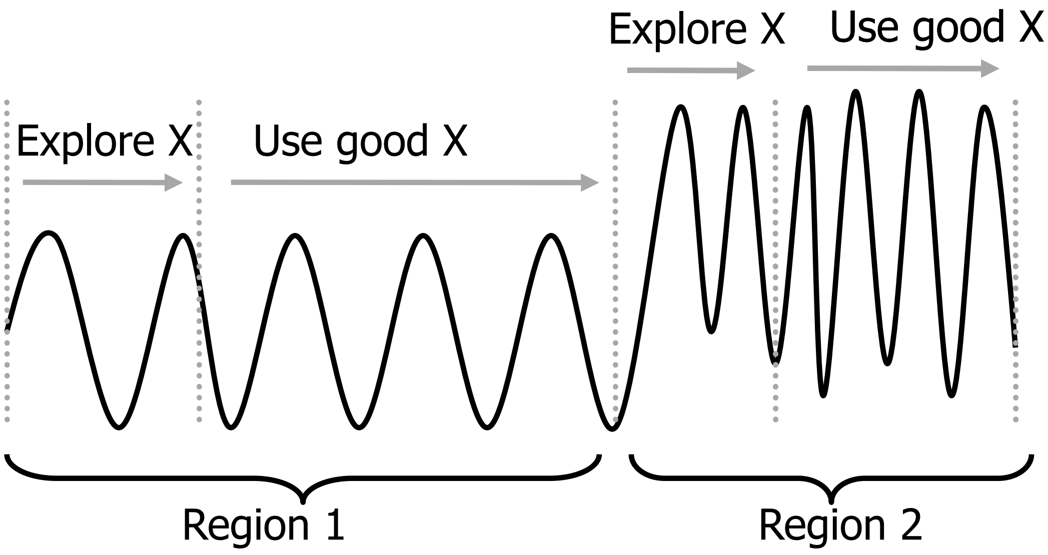

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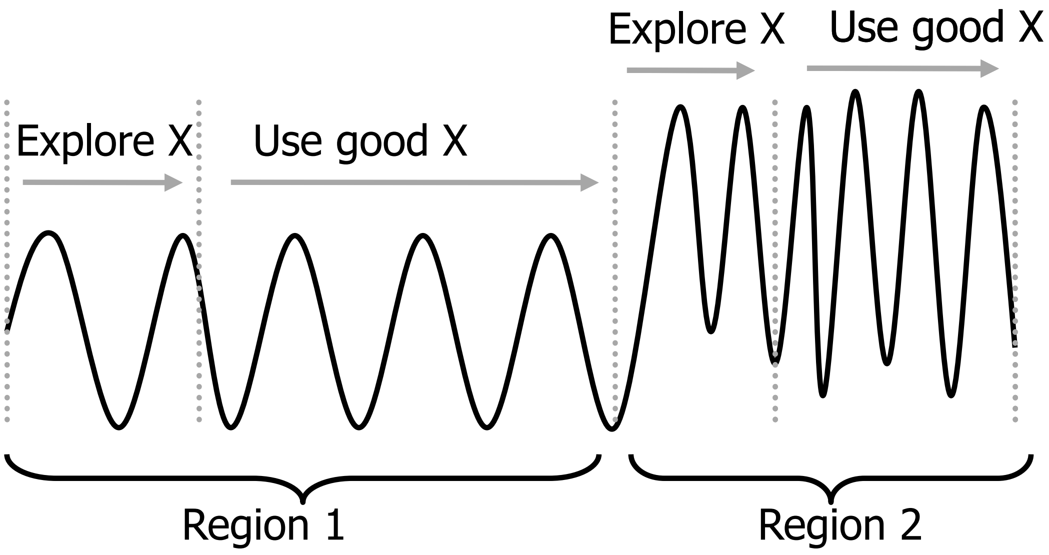

<u>Observation</u>

Application “world state” does not change dramatically faster than user perception time

<u>Lesson#3</u>

Stable Region Length >> W, with high probability

Runtime Controller: Attempt#3

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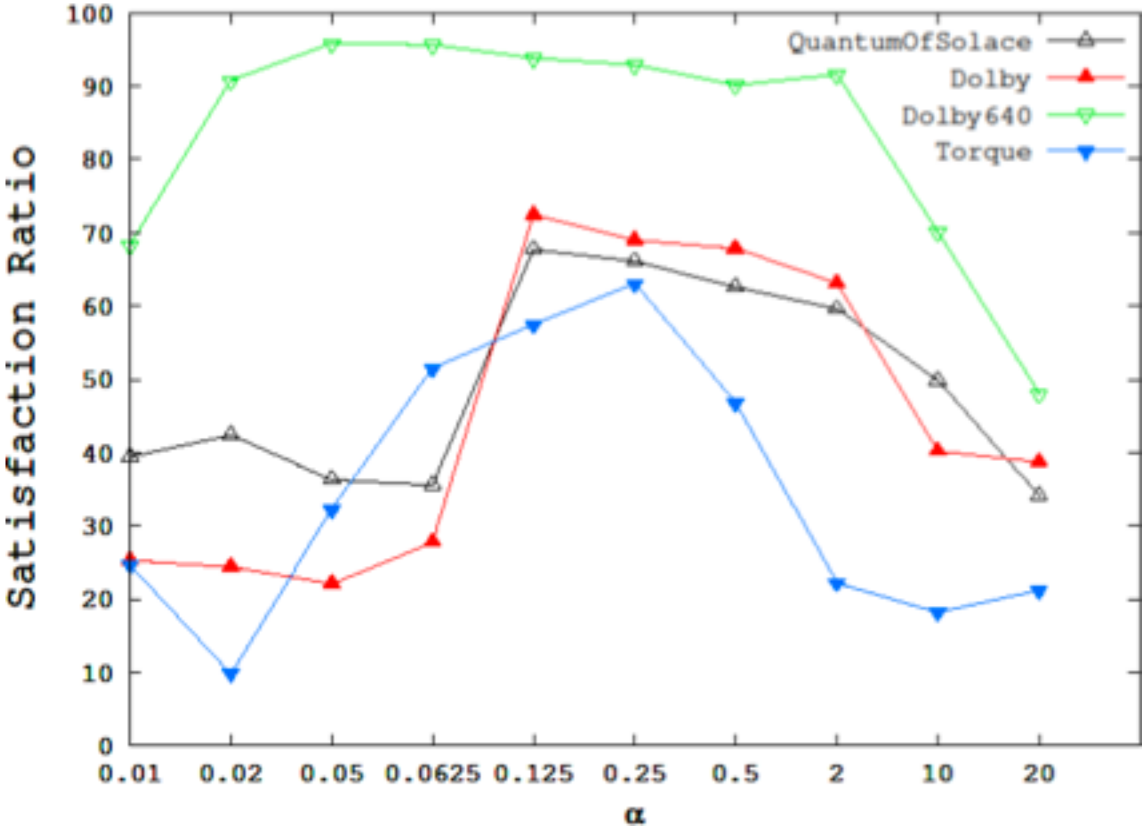

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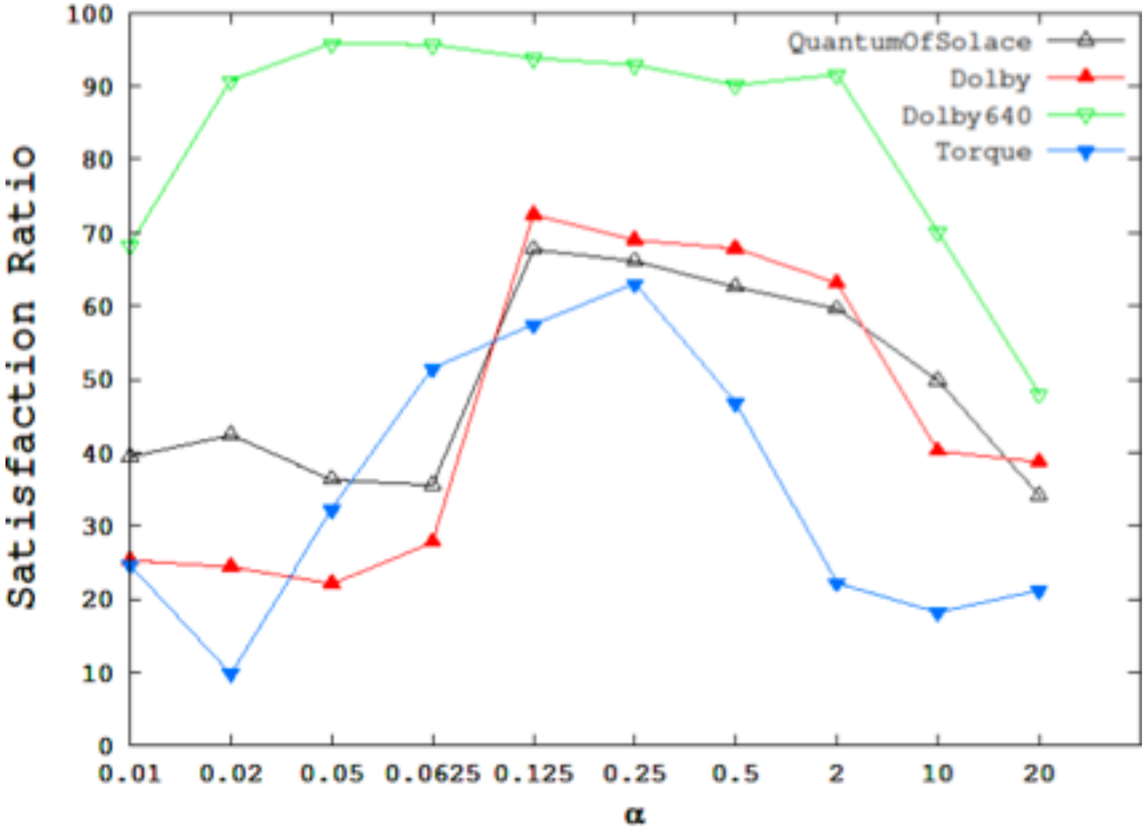

<u>Lesson#3</u>

Feedback Control works poorly, unless α is in a narrow range determined by data-set

Adaptive Feedback Controller

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- Programmer specifies: X, $Y^{obj} \pm d$, W

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} Sufficient to deliver significant improvements in SR

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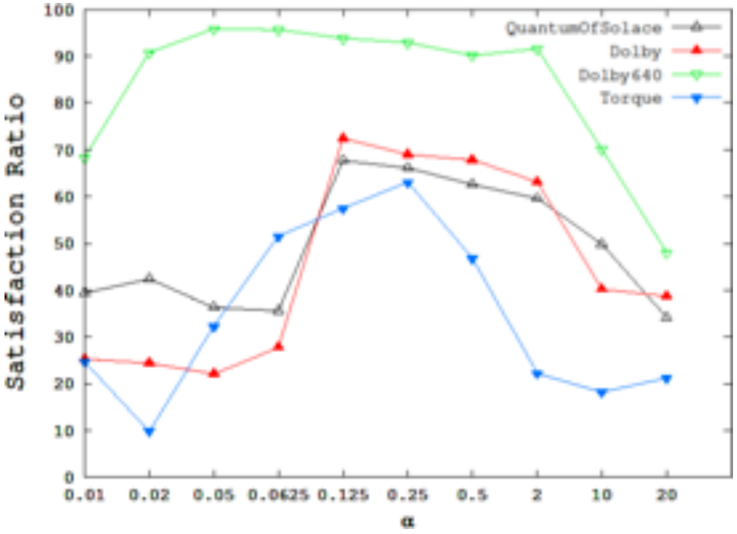

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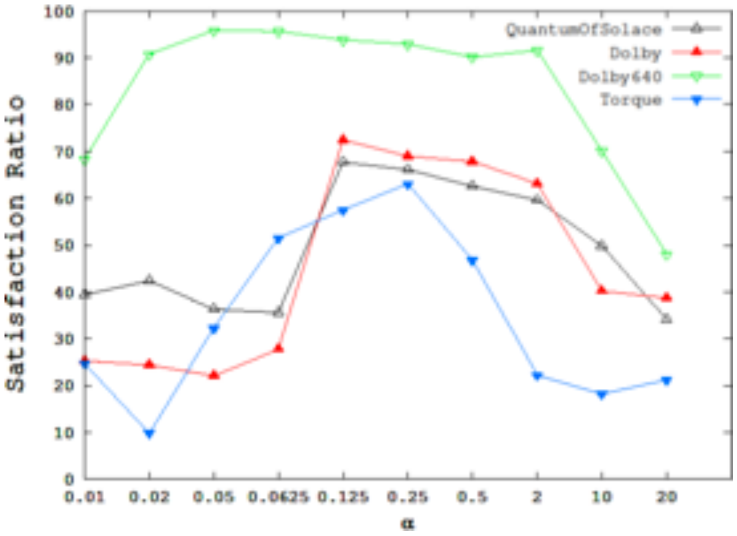

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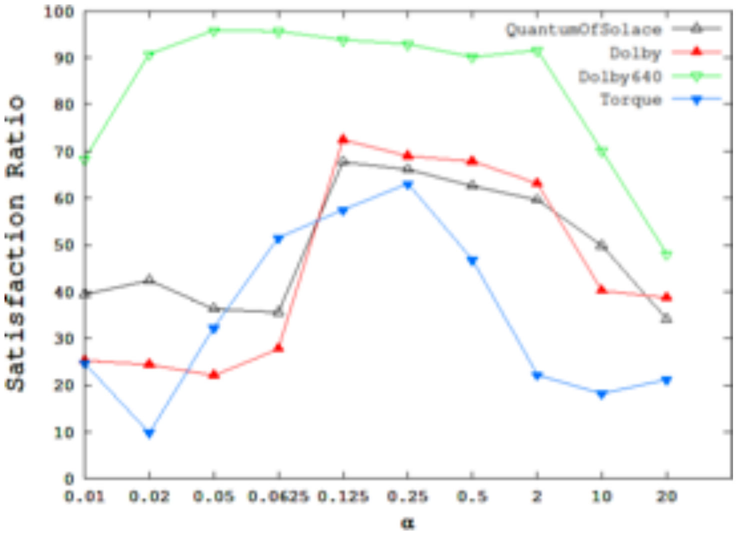

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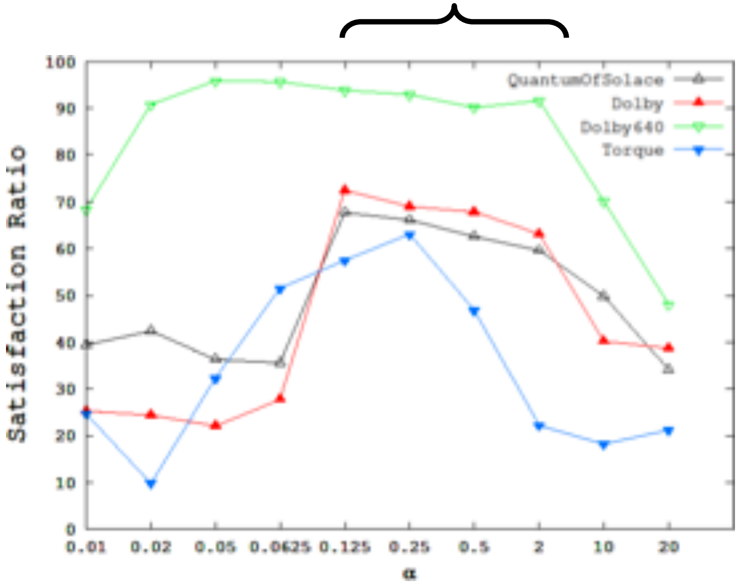

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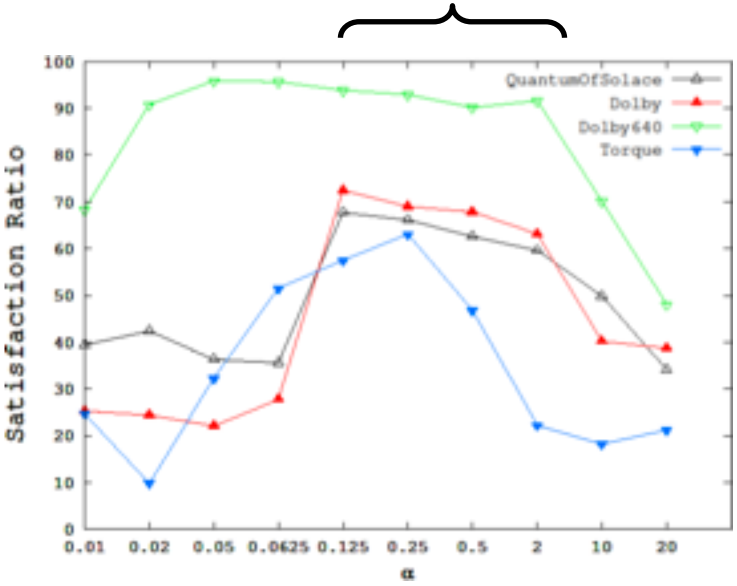

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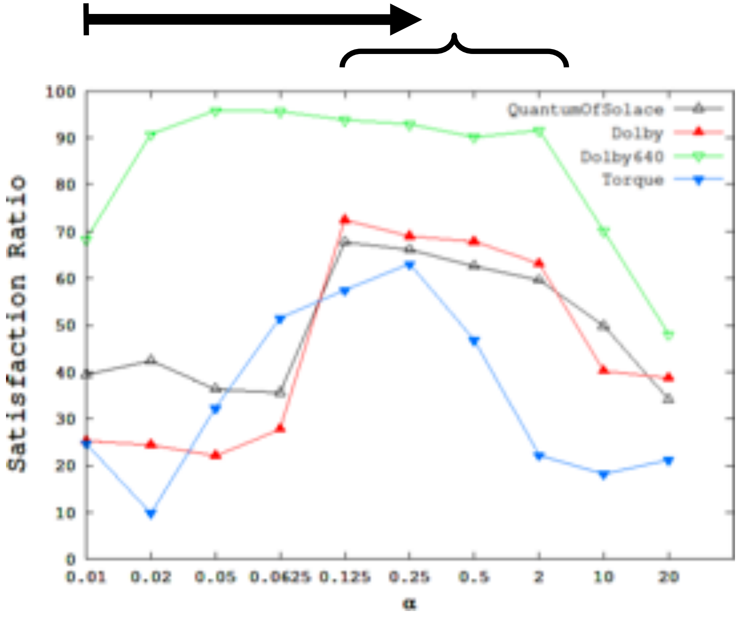

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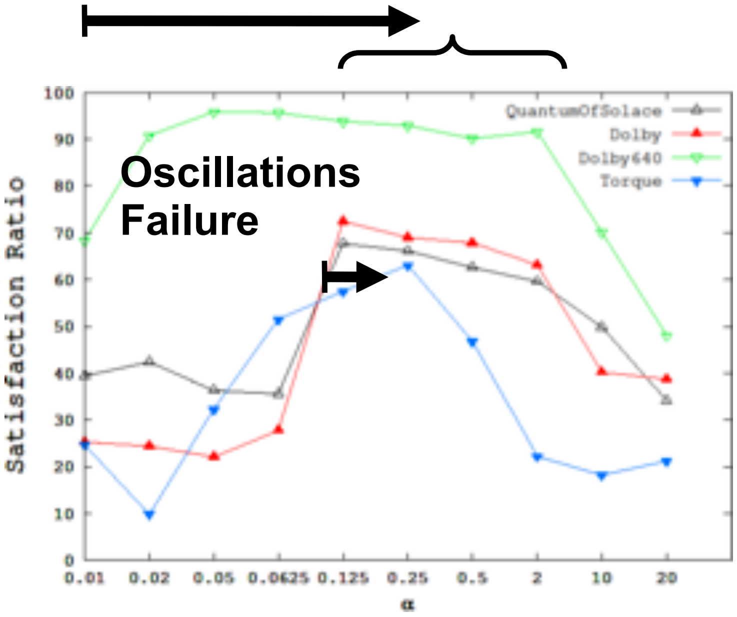

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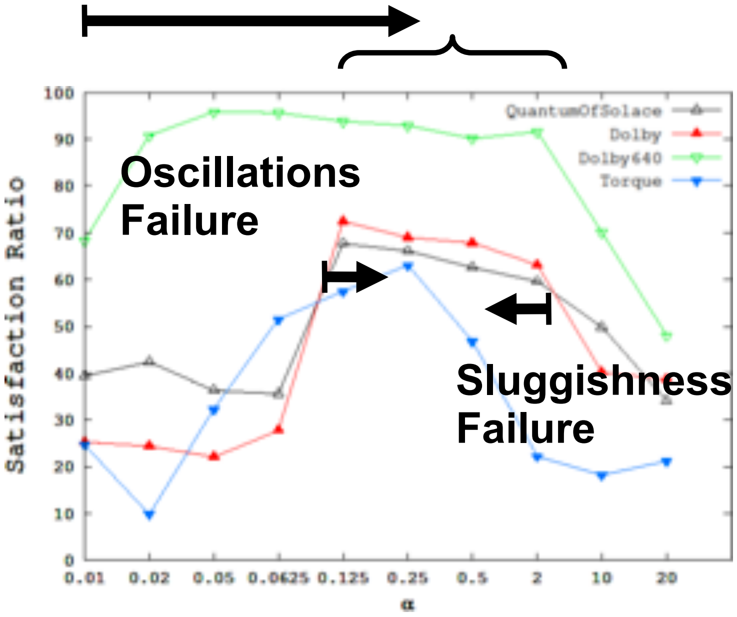

Oscillations Failure

Sluggishness Failure

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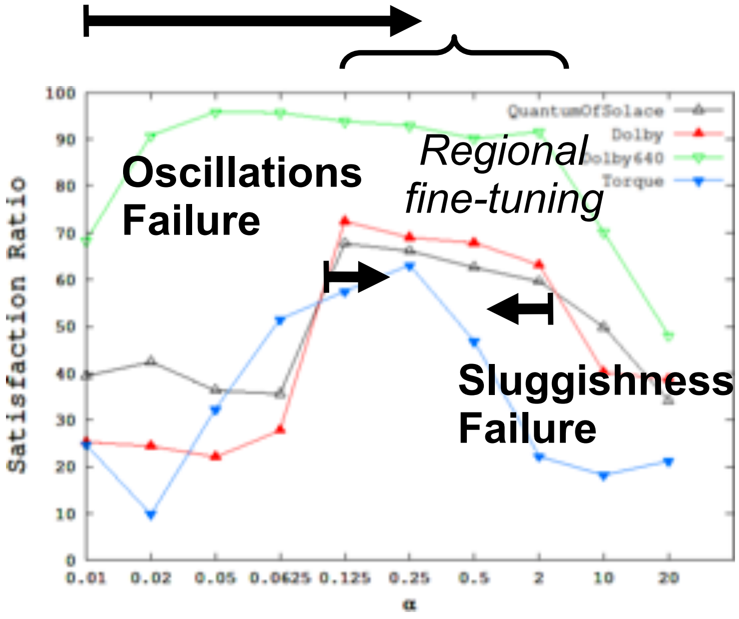


Oscillations Failure

Regional fine-tuning

Sluggishness Failure

Illustration of Oscillation Failure Mode

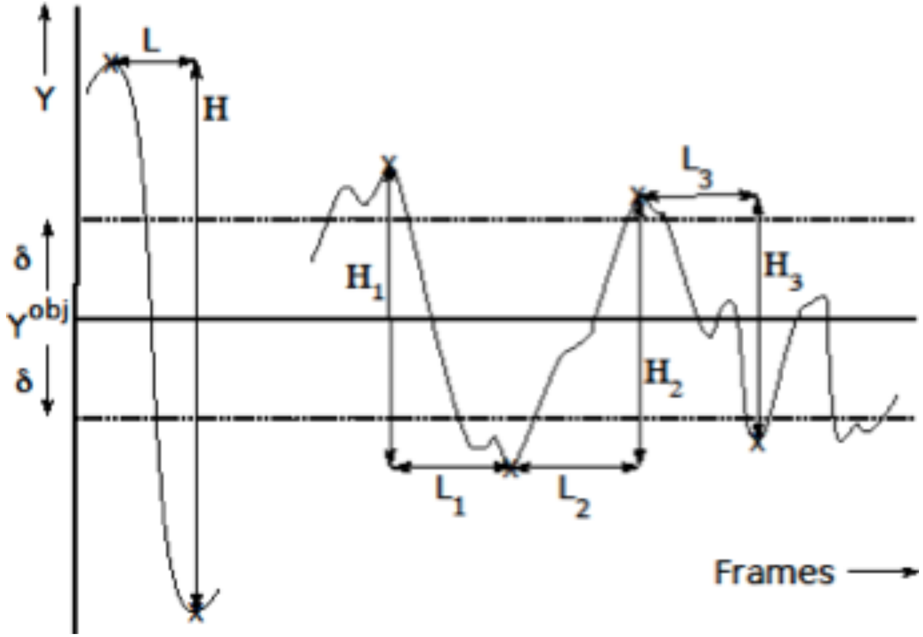
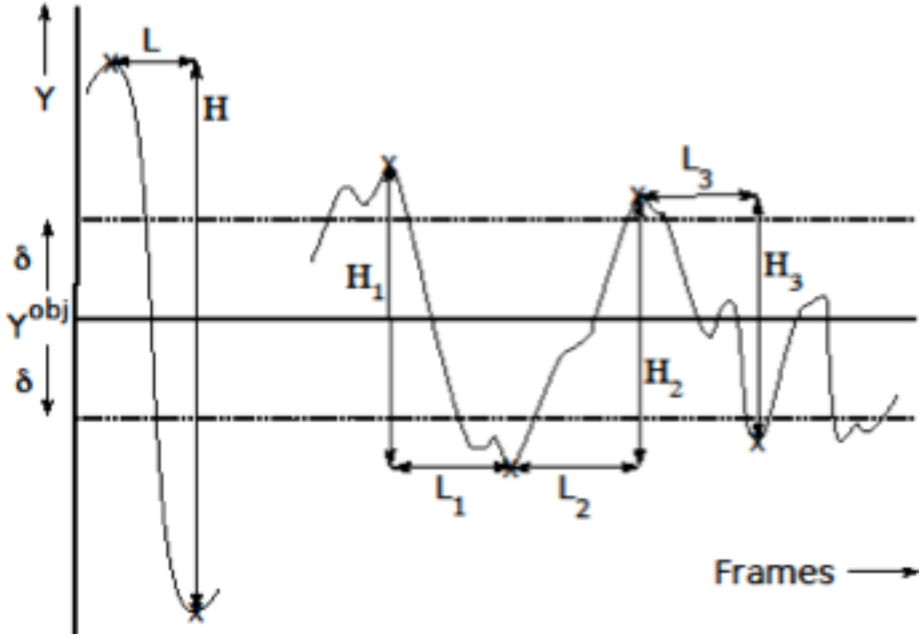


Illustration of Oscillation Failure Mode

- Failure Metrics
  - H, L
  - $\eta^{\sim}\ d * \eta + H * W / L, \ (0 < d < 1)$



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  - $\eta > t$

    with $t = 1/(1-d) * 2d * 1.0$

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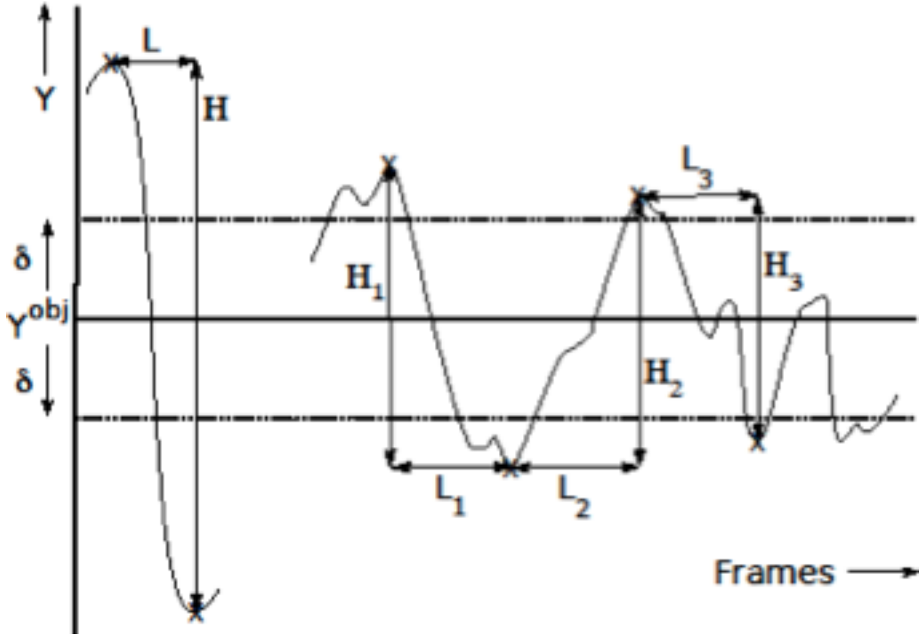

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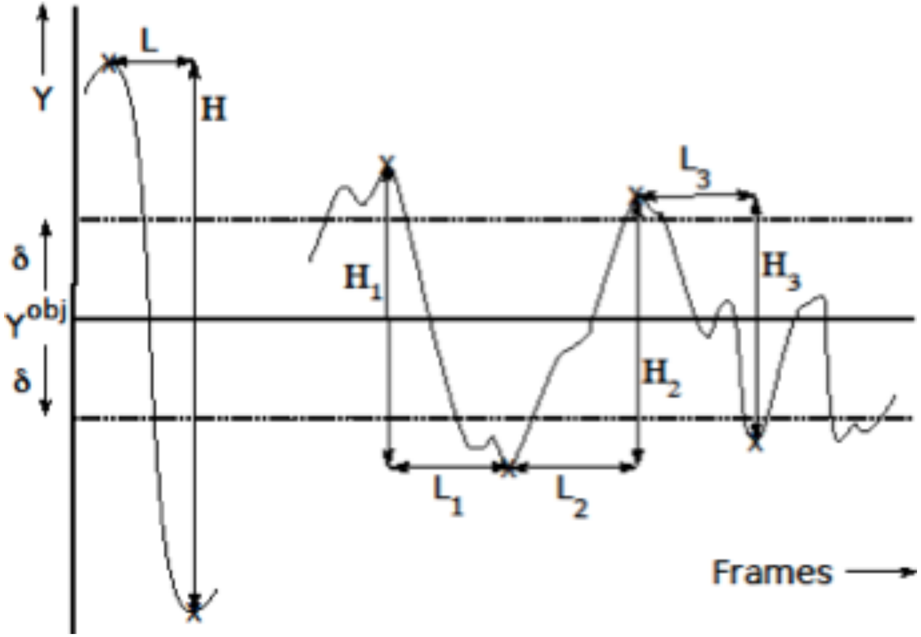
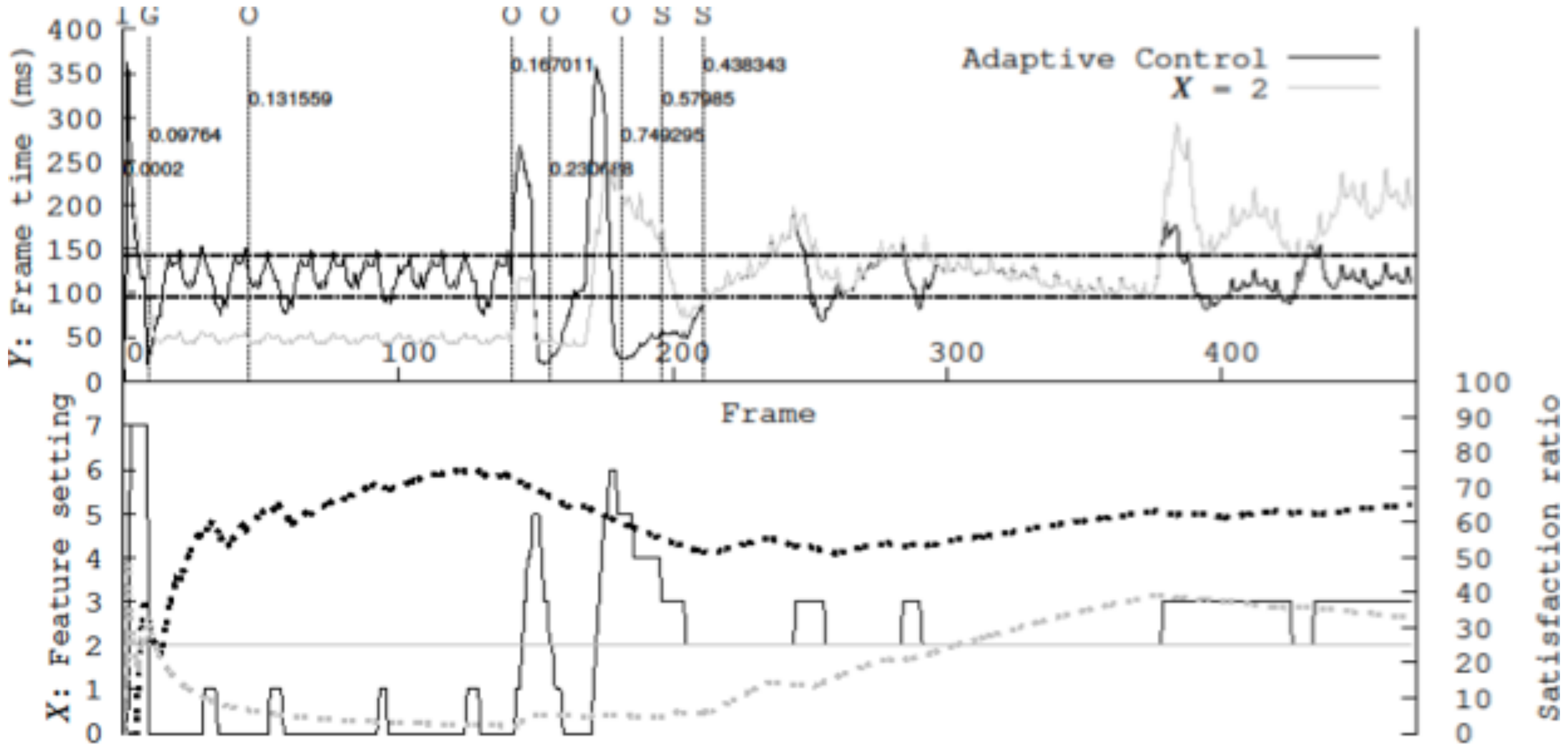
- Policy Adaptation
  - $\alpha^{new\sim} \alpha * \eta / t$
- ***Accumulative metrics*** for failure
  - Weighted to gradually forget old learning, at rate d
  - Robustness against transients
  - Responsive to persistent changed behavior
  - Constant state ” very low runtime overhead of controller



Execution Trace: MPEG2 Encoder



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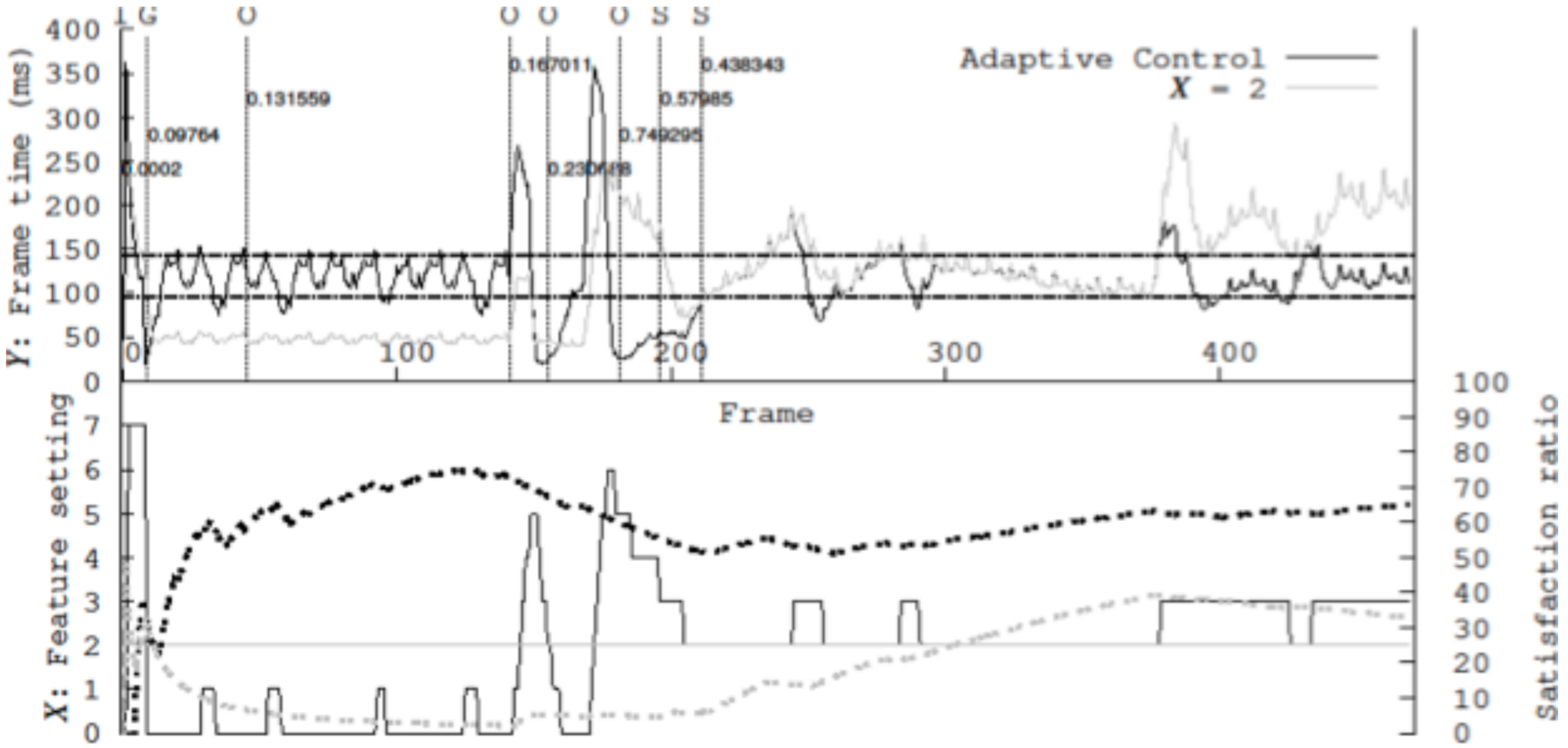
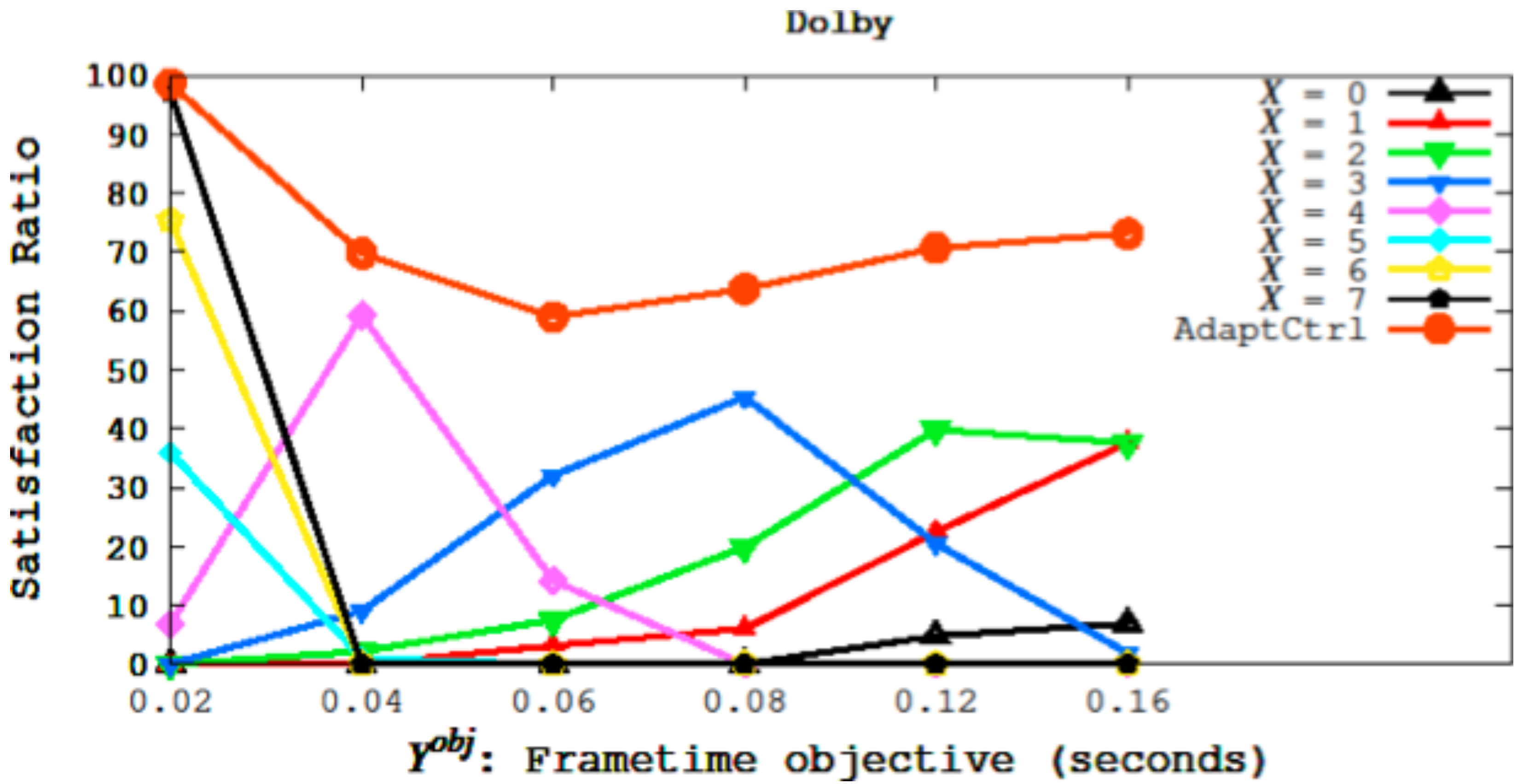


X → *Search Window Size* : $\{0 \to 30, 1 \to 20, 2 \to 15, 3 \to 10, 4 \to 5, 5 \to 2, 6 \to 1, 7 \to 0\}$

Integral X: Easier for programmer to just **sample** ***Search Window Size*** over sufficient range

Benchmark Result: MPEG2 Encoder



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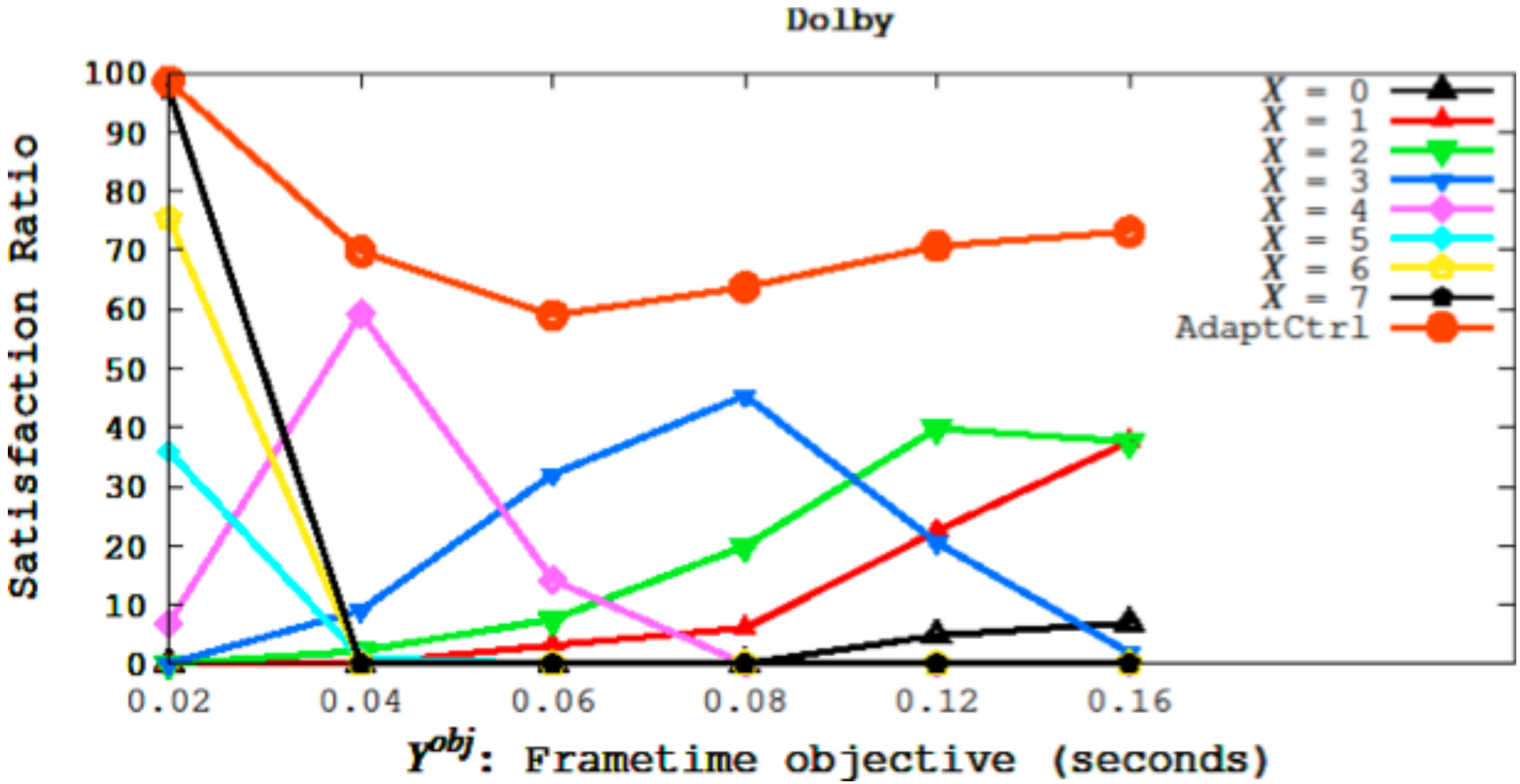
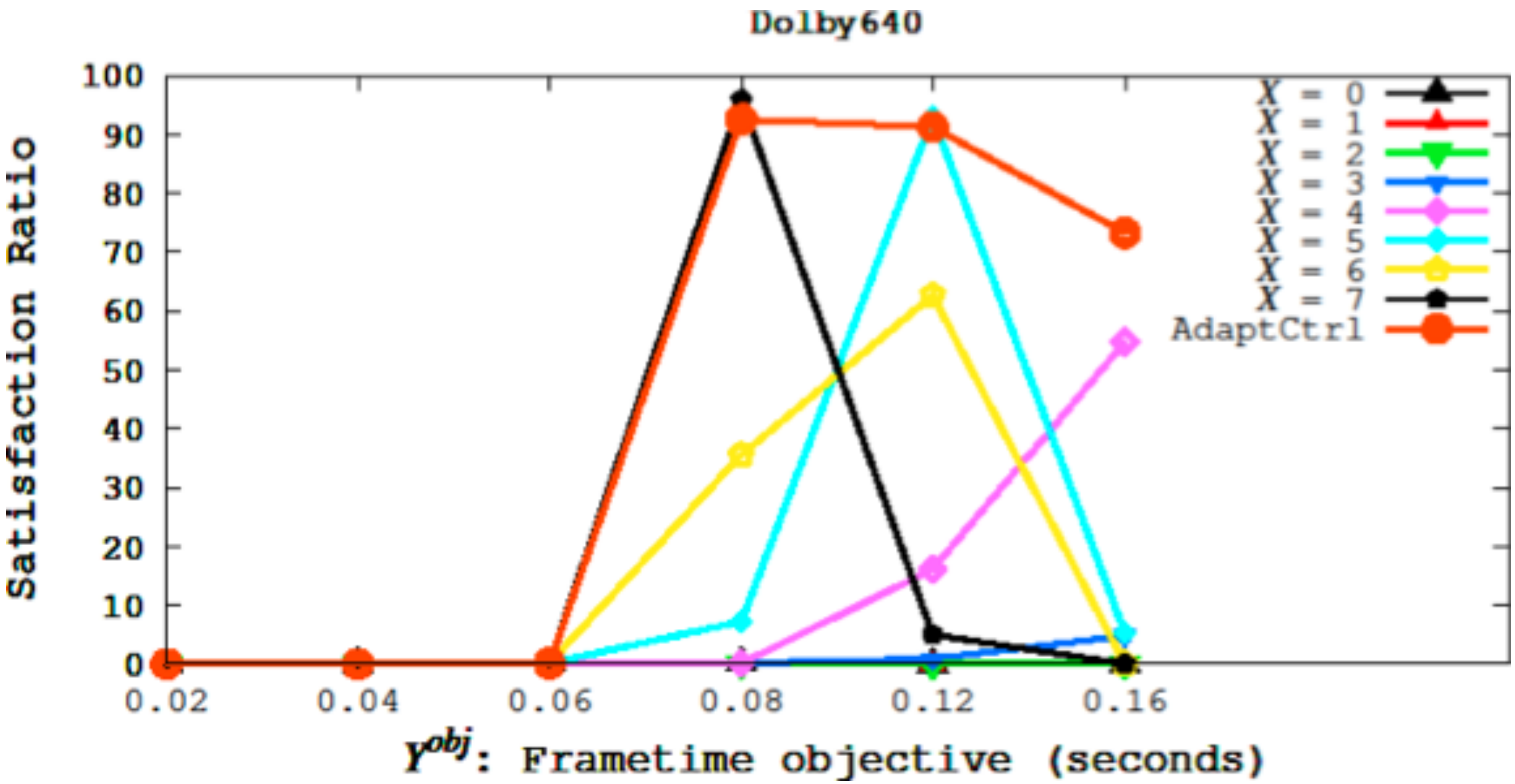


- Video sequence: dolbycity320x240
- Adaptive Controller better than ***envelope of best fixed*** Xs
  - Due to Regional tuning of X vs only global tuning

Benchmark Result: MPEG2 Encoder



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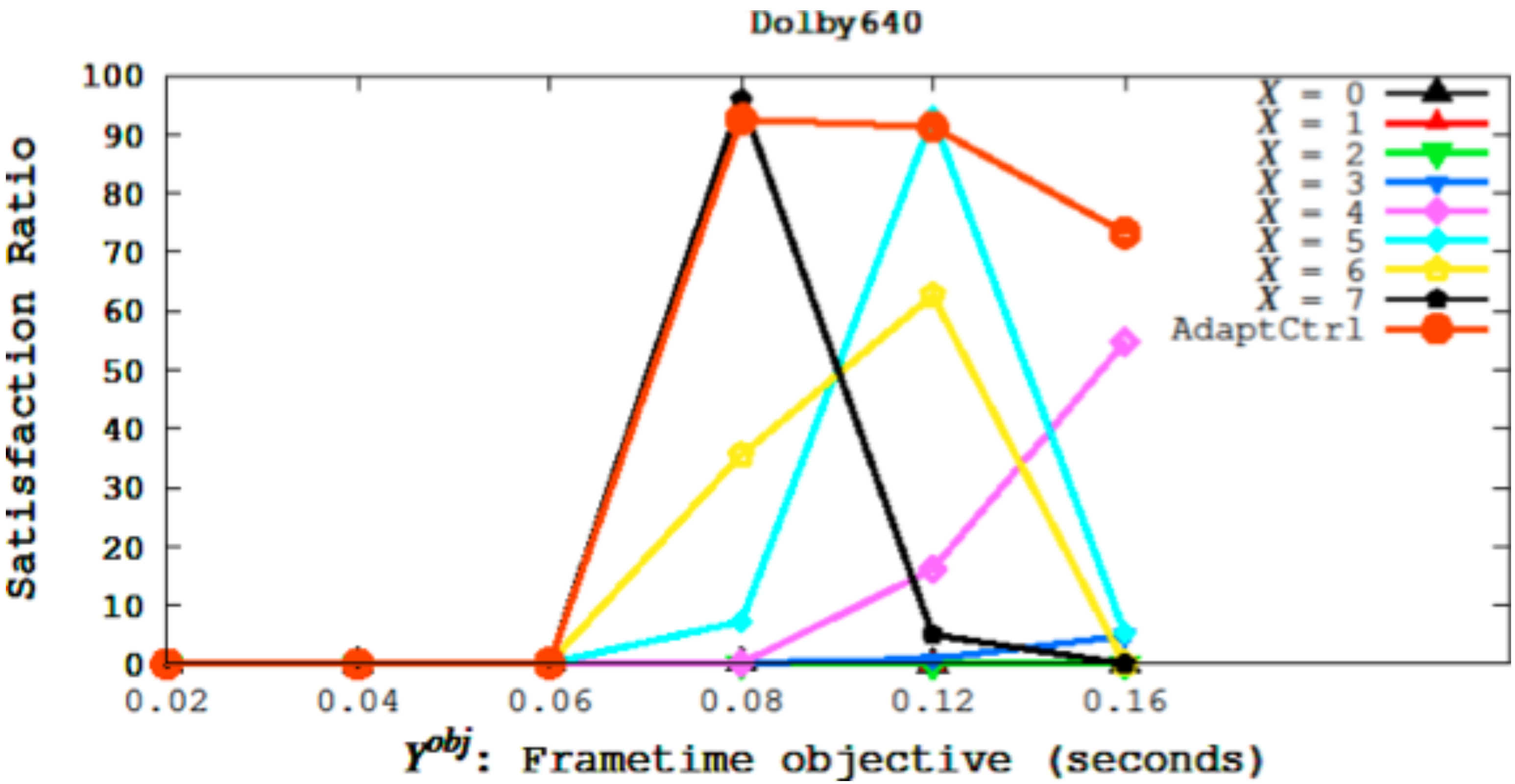
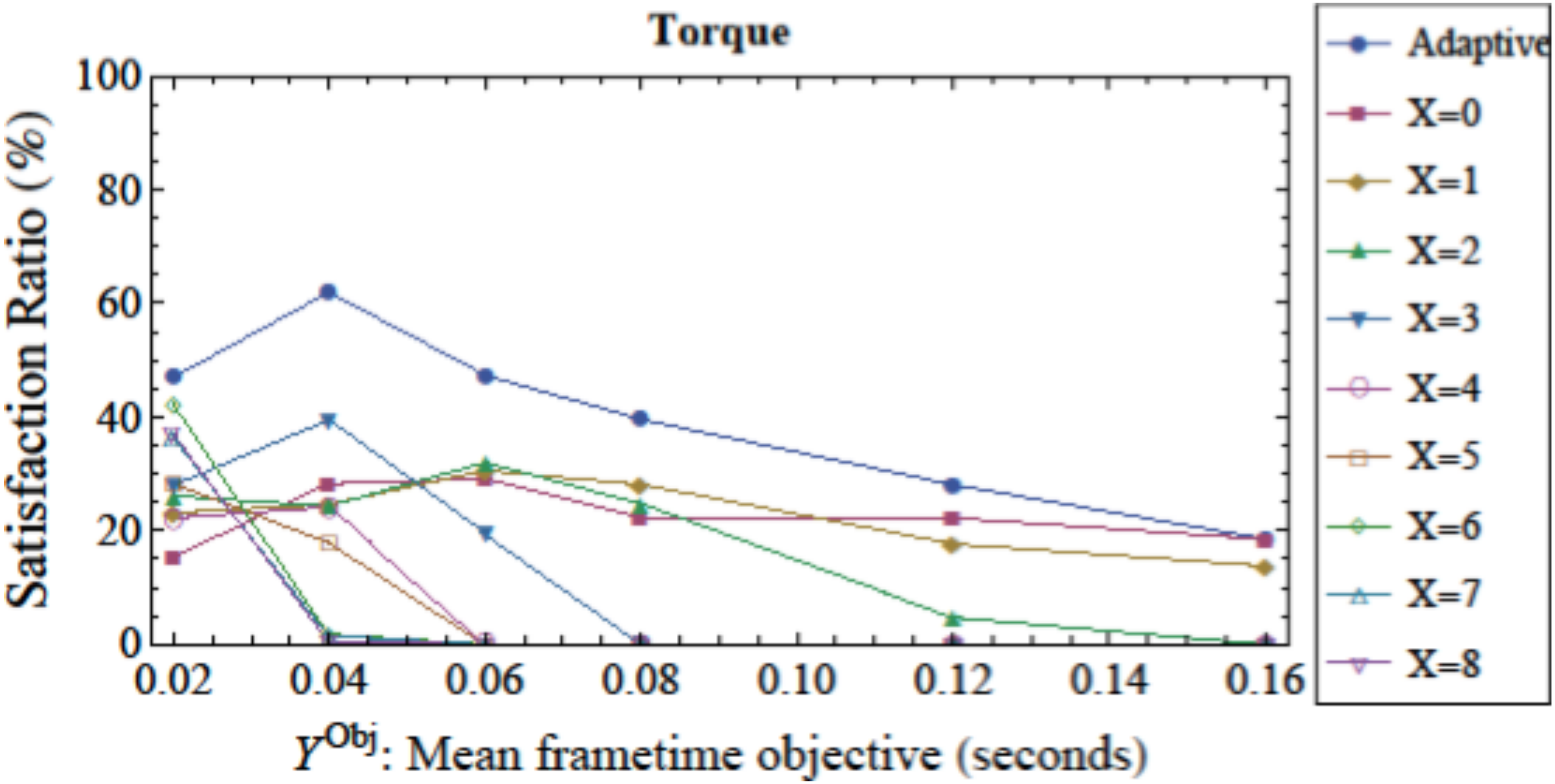


- Video sequence: dolbycity 640x480
- Adaptive better than every Fixed X case overall
  - Even though for a given Y^{obj}, a particular Fixed X might match or exceed Adaptive

Benchmark Result: Torque Game Engine



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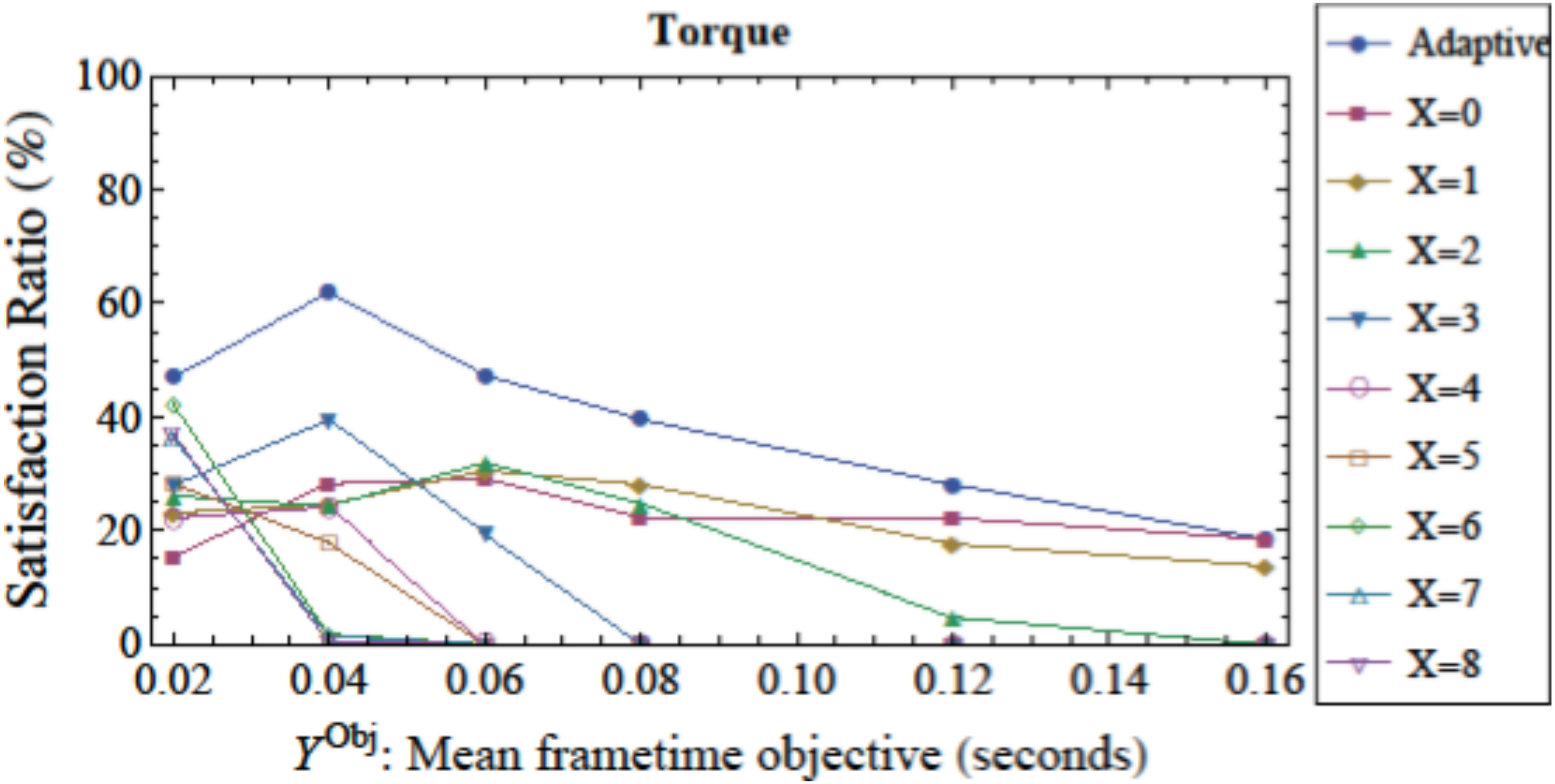

- Quality of Result: ***Gameplay Intelligence***

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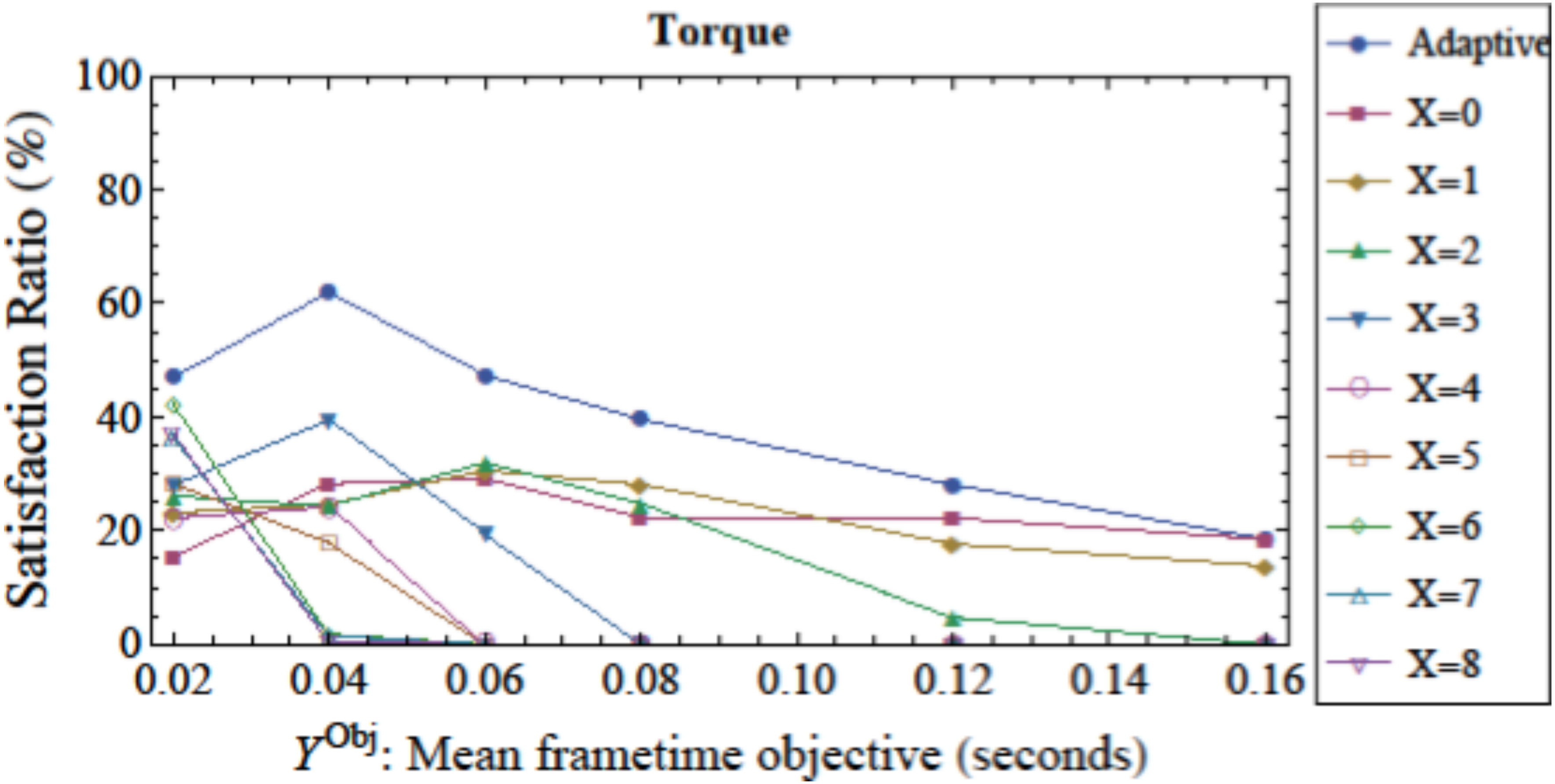

- Quality of Result: ***Gameplay Intelligence***
- For $Y^{obj} = 0.04$ secs
  - Adaptive: 24ms of AI/frame
  - Best fixed X: 14ms of AI/frame

Related Work

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- Real-time techniques already address QoS and Soft Real-time. BUT:
  - Application needs to be implemented as Task-Graphs
  - With execution-time properties specified for nodes [Mejia-Alvarez et al. RTSS 2000]
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- Application-specific techniques
  - Rate-distortion control in H.264 encoder
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- Very effective, but Best-Effort:
  - No guarantees on Safety, Robustness, Reachability

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  - Programmers avoid having to model emergent behaviors
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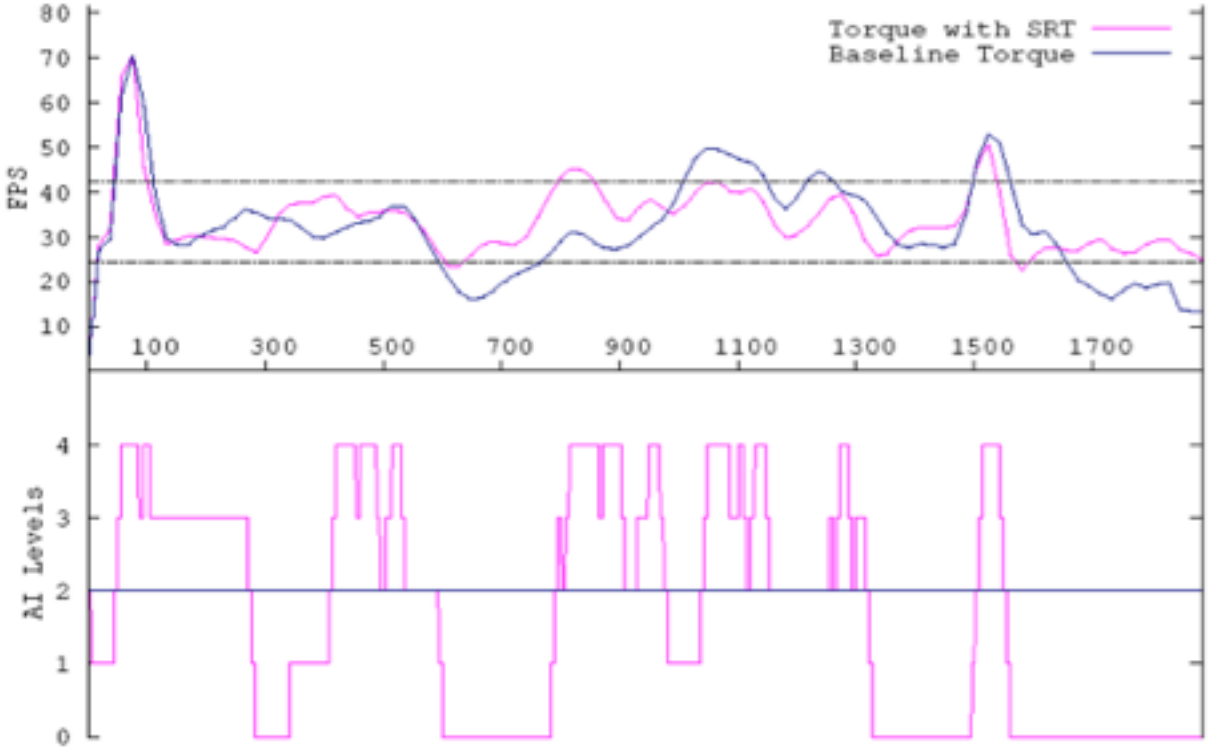
- Future Work
  - Multiple X, Multiple prioritized Y, Explicit Q
  - Domain Observations ”Adaptive Control + Least-Squares Function Estimation
  - But, much more compute intensive controller

Thank you!

- Questions?

Torque Game Engine: Measured Behavior



objective:
25 to 42 fps

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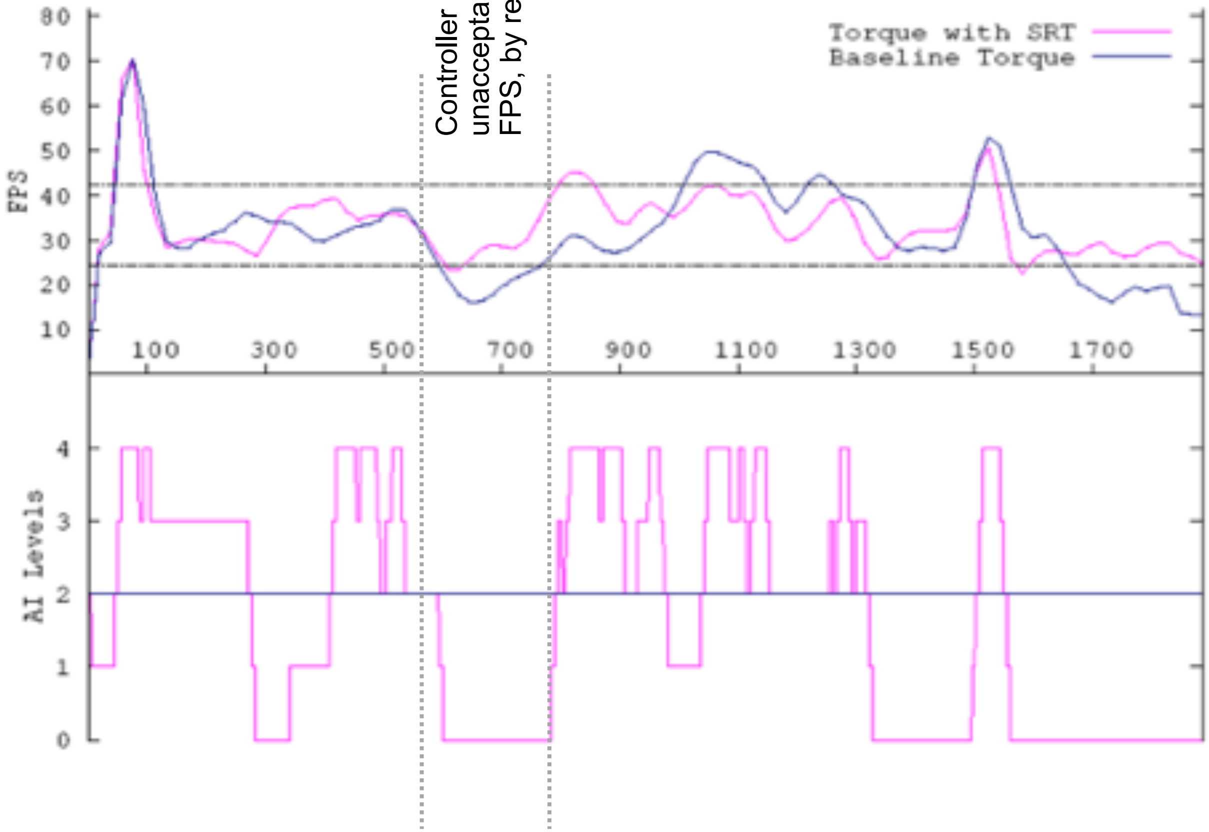

Controller avoids unacceptably low FPS, by reducing AI

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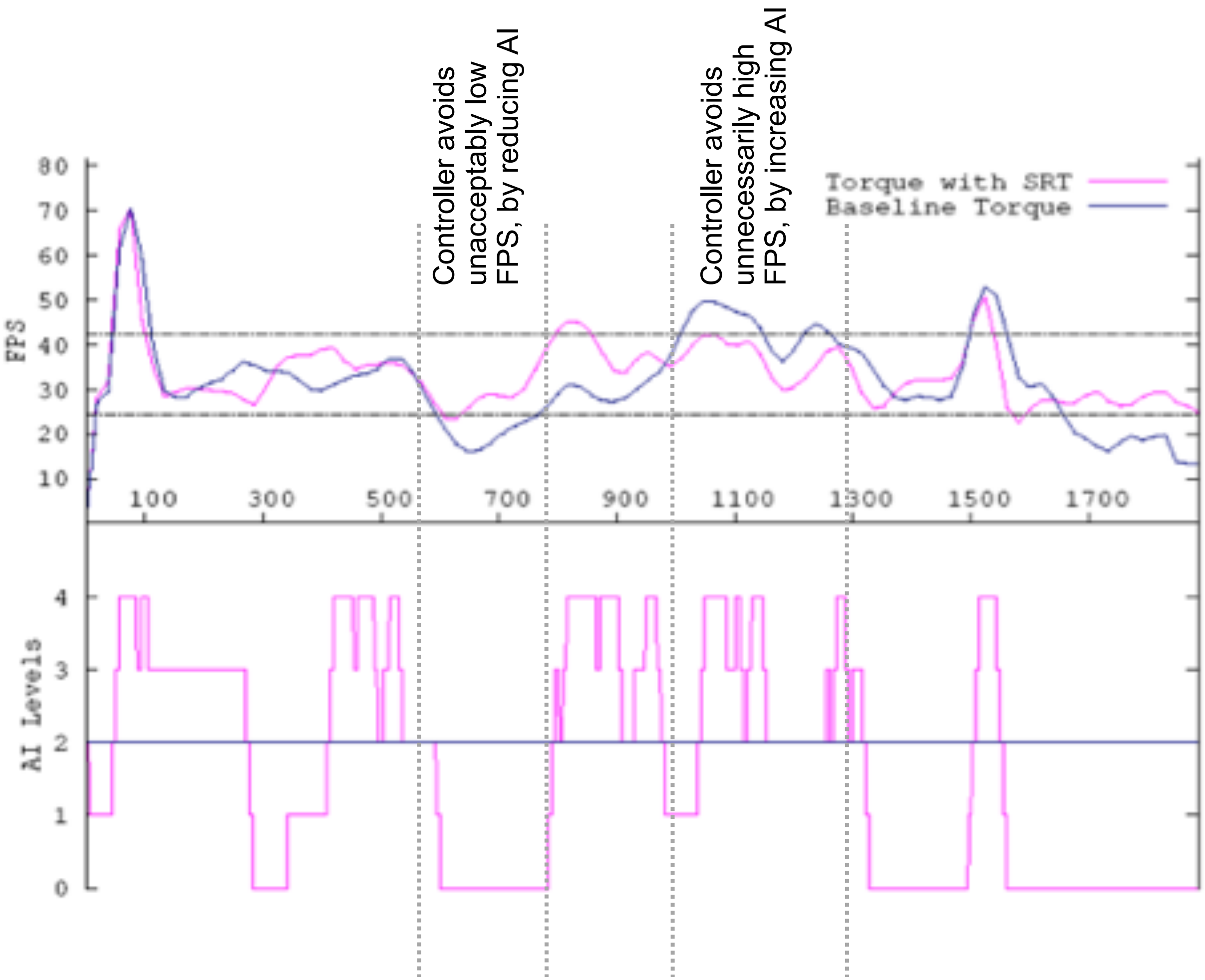

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Controller avoids unnecessarily high FPS, by increasing AI

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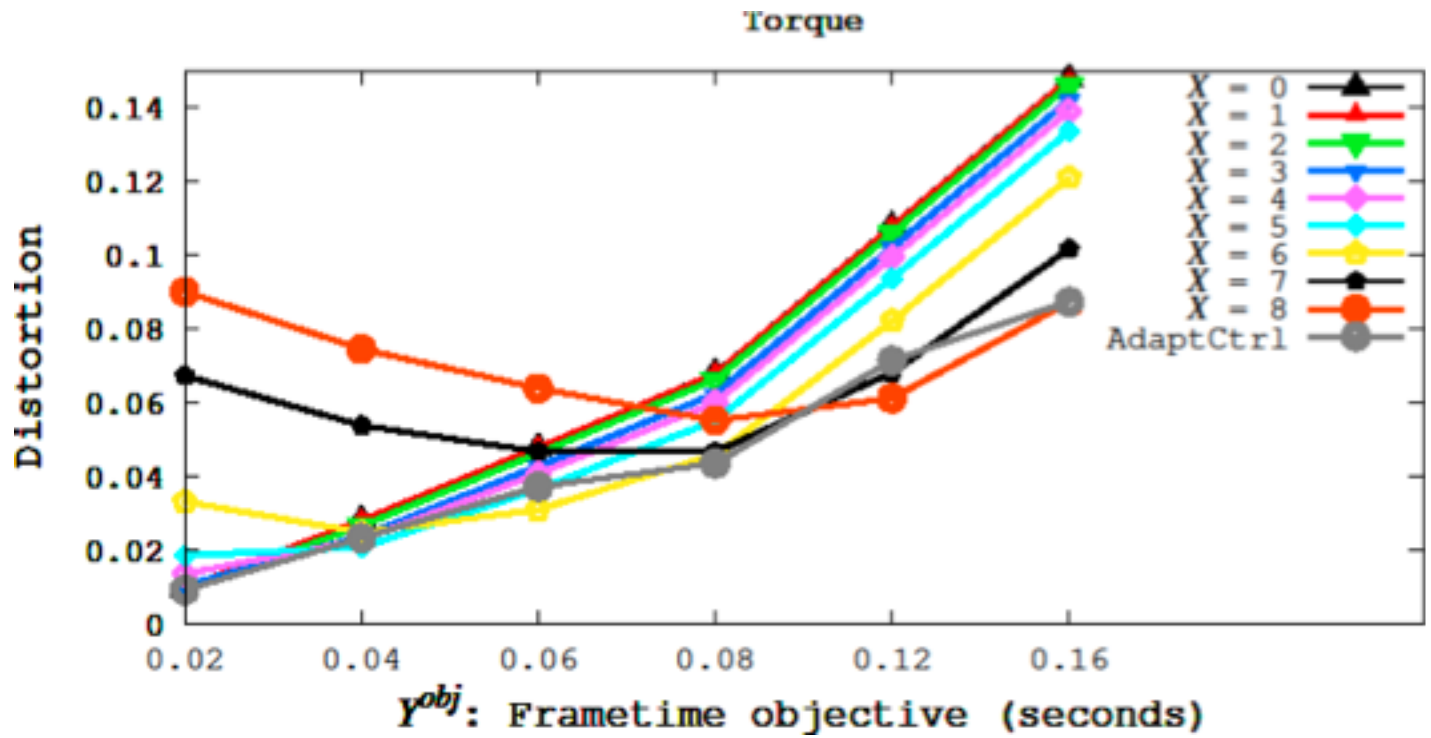
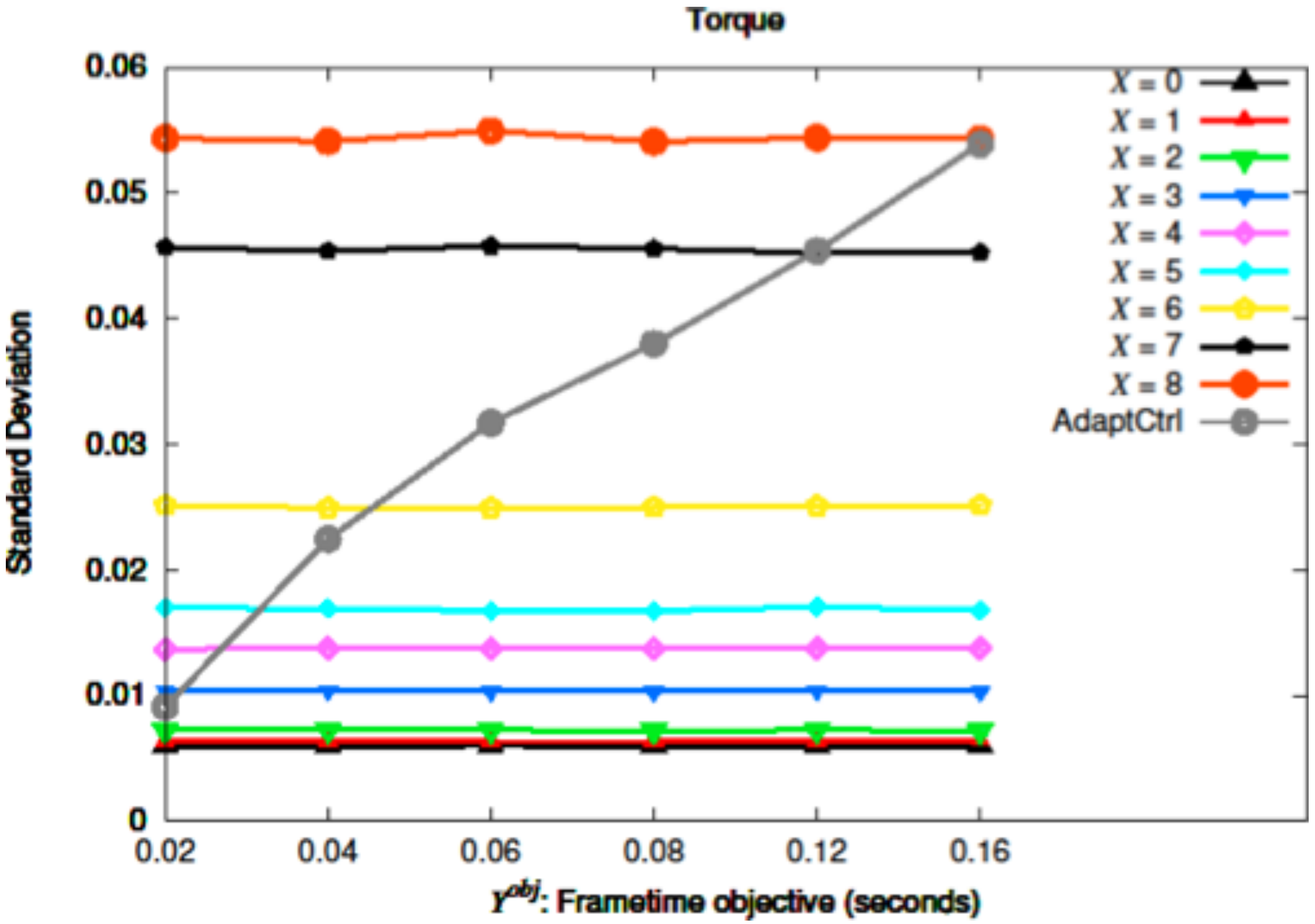
Distortion in Torque



Standard Deviation in Torque



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Games, Multimedia, Interactive Viz

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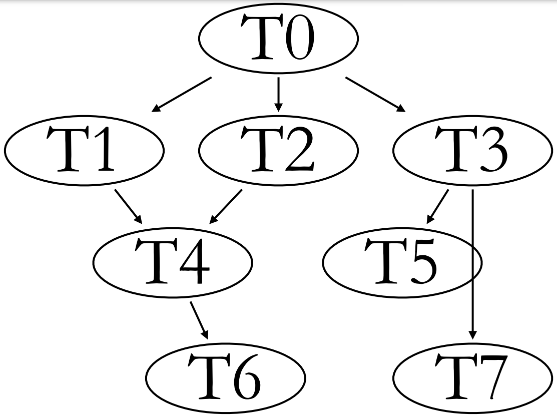

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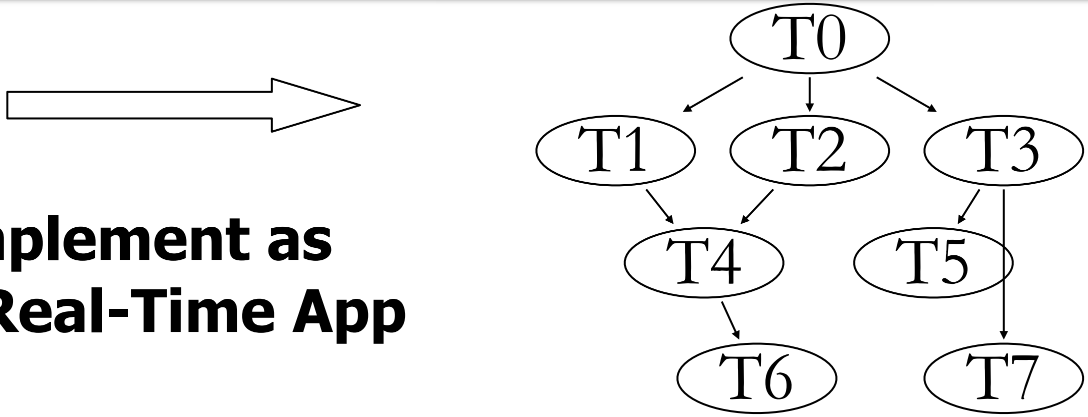

<u>Real-Time Task-Graph</u>

- Application decomposed into Tasks and Precedence Constraints

- Responsiveness guaranteed by Real-time semantics (hard or probabilistic)

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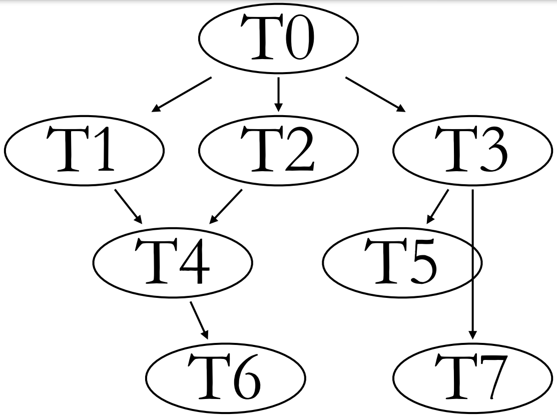

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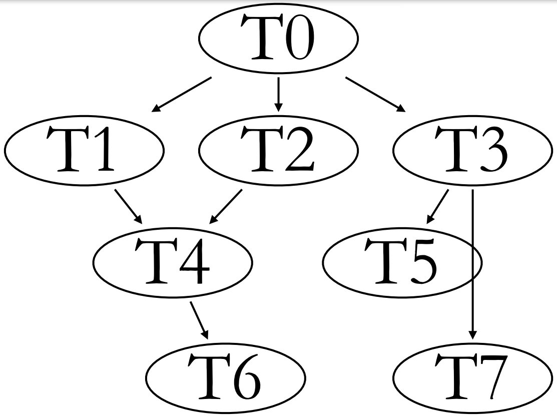

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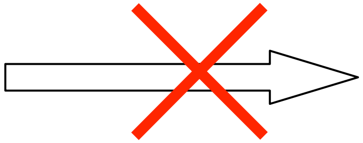

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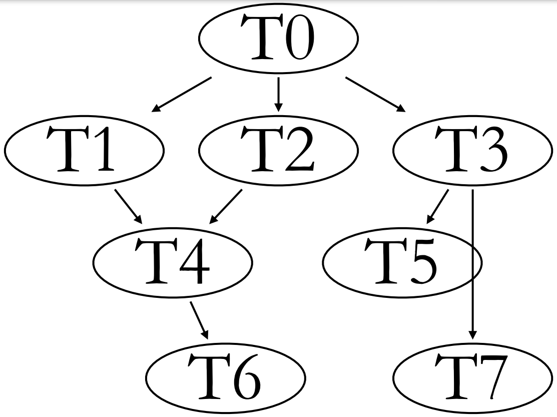

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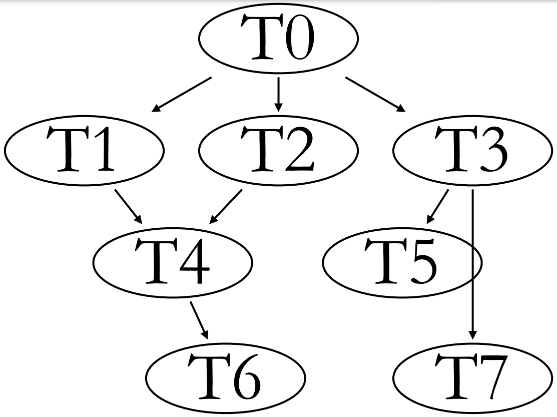

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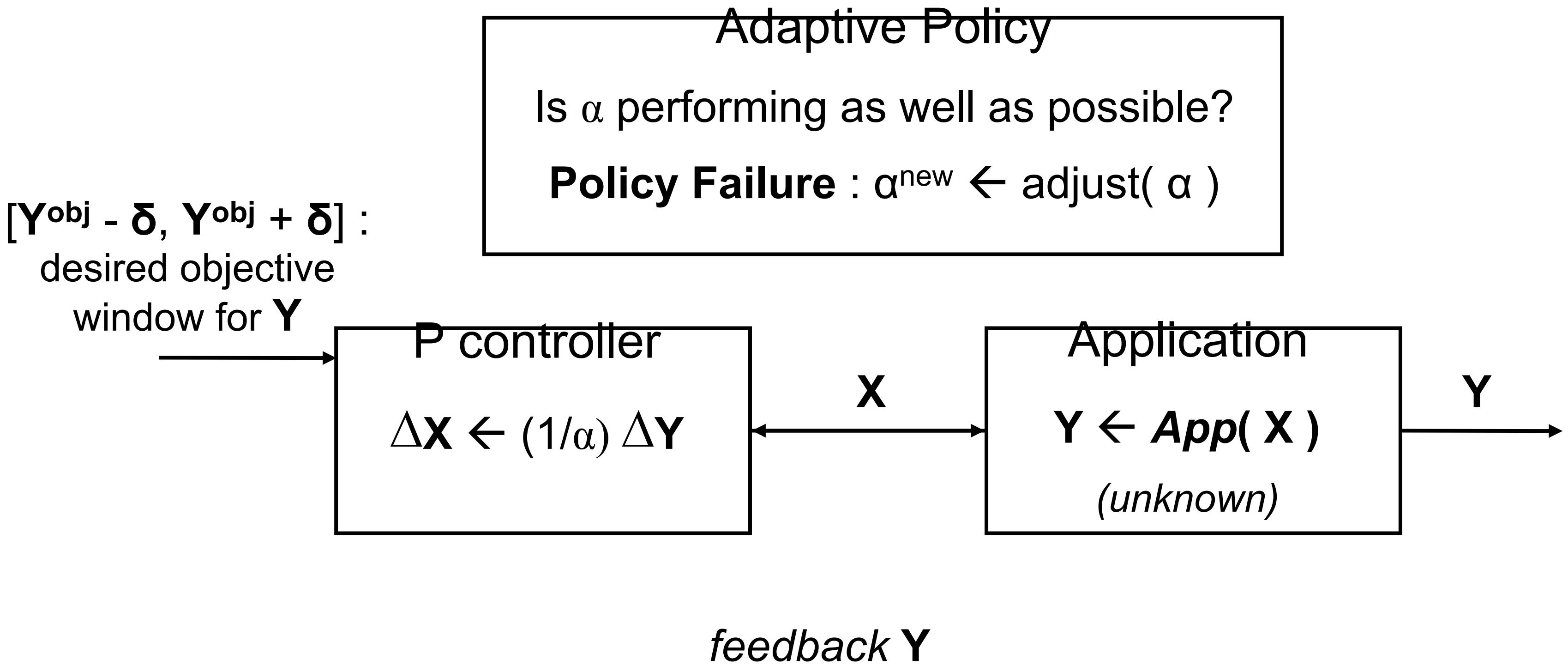
Need a new bag of tricks to Scale Semantics in Monolithic Applications

Runtime Controller



Adaptive Policy

Is α performing as well as possible?

Policy Failure : α^{new} ← adjust(α)

[Y^{obj} - δ, Y^{obj} + δ] : desired objective window for **Y**

P controller

Δ**X** ← $(1/\alpha)$ Δ**Y**

X

Application

Y ← ***App*(X)**

(unknown)

Y

feedback **Y**