Interactive Display Algorithm for Interactive Frame Rates During Visualization Of Complex Virtual Environments

Goal

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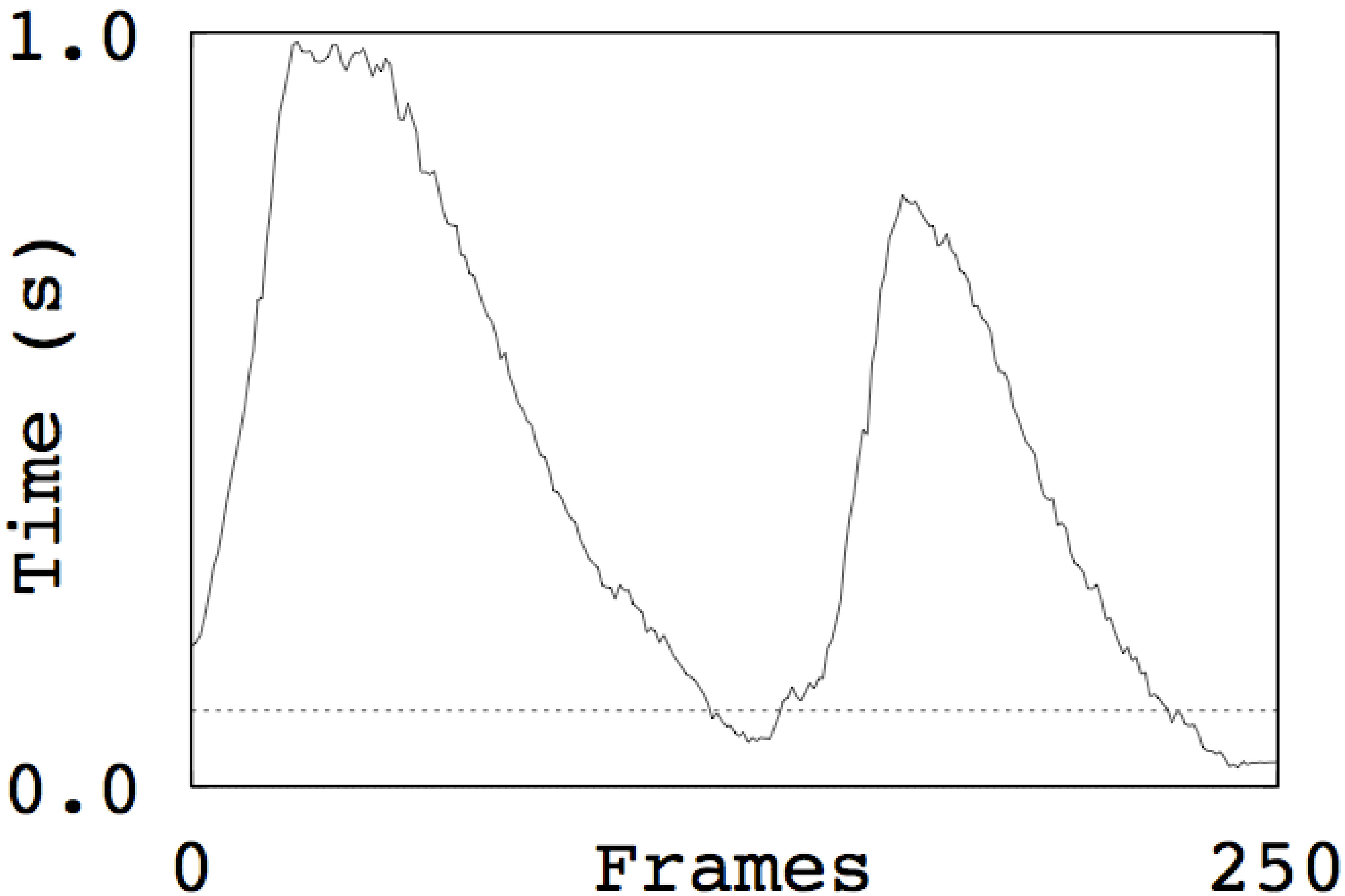
- Interactive walkthrough
- Frame rate should be
  - Interactive
  - Consistent

Frame Render Time



a) No detail elision.

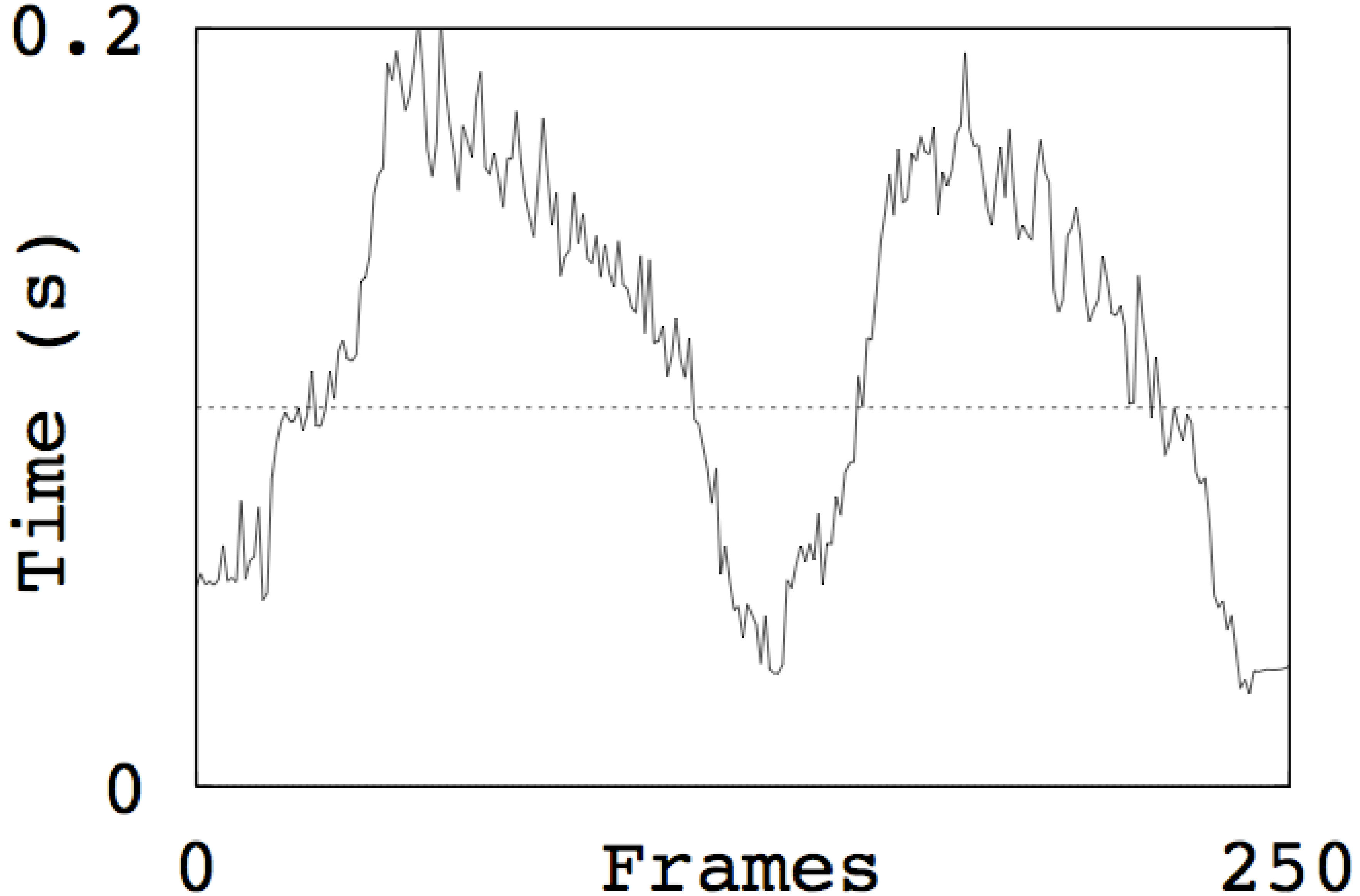
Level of Detail

- Can't render all potentially visible geometry
- Trade visual quality for speed

Level of Detail

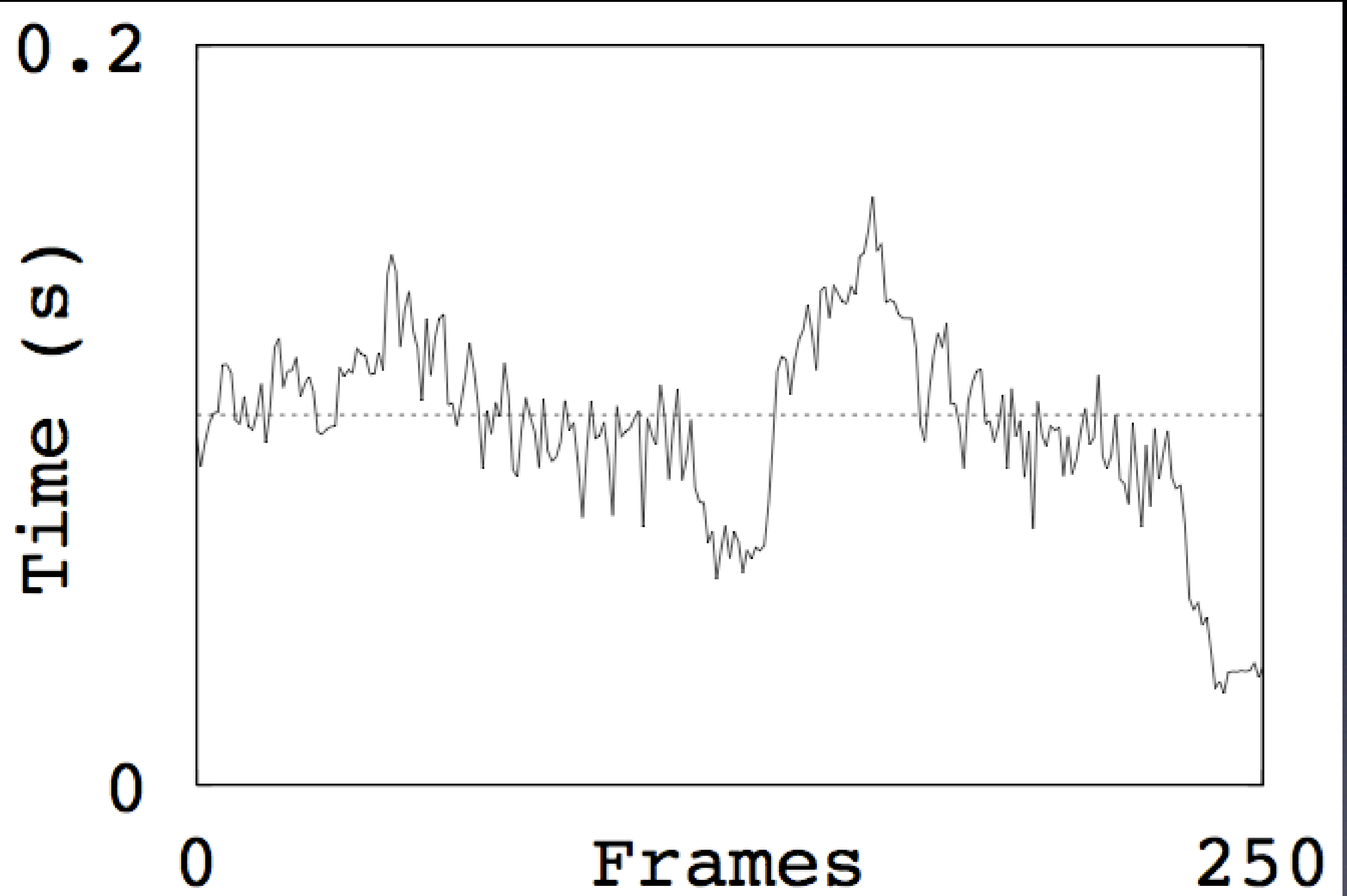
- How do we select the level of detail to render?
- Static
  - Distance, Approximate screen size
- Feedback
  - Update thresholds based on

Frame Render Time



b) *Static* algorithm.

Frame Render Time



c) *Feedback* algorithm.

Predictive vs. Reactive

- Feedback approach is better
- But varies, sometimes above goal render time

- We need to ***predict*** the performance instead of ***reacting*** to it

Approach - Definitions

- Object tuple (O, L, R)
  - O - object
  - L - level of detail
  - R - rendering algorithm
- Cost(O, L, R)
- Benefit(O, L, R)

Approach

- Choose 1 object tuple for each object
- Maximize $\sum_{S} Benefit(O, L, R)$
- Subject to $\sum_{S} Cost(O, L, R) \leq TargetFrameTime$

Cost Heuristic

- Depends on hardware - measure and fit to model
- Model - assume per-primitive or per-pixel operations dominate frame time
- $Cost(O,L,R) = \max(\ C_1 Poly(O,L) + C_2 Vert(O,L),\ C_3 Pix(O)\ )$

Benefit Heuristic

- Value of object to user
  - Perceptual
  - Heuristic could be application dependent
- Simple heuristic - approximate # of pixels

Benefit Heuristic

- Accuracy = 1-Error = 1-BaseError/Samples^m
- Intuition - type of shading indicates avg error, error decreases with more samples
- m and BaseError set arbitrarily based on shading
- Samples = # pixels, vertices, or polygons

Benefit Heuristic

- Semantics - application specific
- Focus - eye-tracking, middle of screen
- Motion Blur - screen space speed
- Hysteresis - changing LOD can be bothersome

Optimization

- Choose 1 object tuple for each object
- Maximize $\sum_{S} Benefit(O,L,R)$
- Subject to $\sum_{S} Cost(O,L,R) \leq TargetFrameTime$

Optimization

- Multiple Choice Knapsack Problem
  - NP-Complete
- Approximate

Approximation

- Value = Benefit / Cost
- Consider tuples in order of descending value
  - If a tuple with same O is in S, keep the one with greater Benefit
  - Else add tuple to S
  - Terminate when adding another tuple violates cost

Approximation

- $O(n \lg n)$ for n potentially visible objects
- At least 1/2 as good as optimal solution

Incremental Approximation

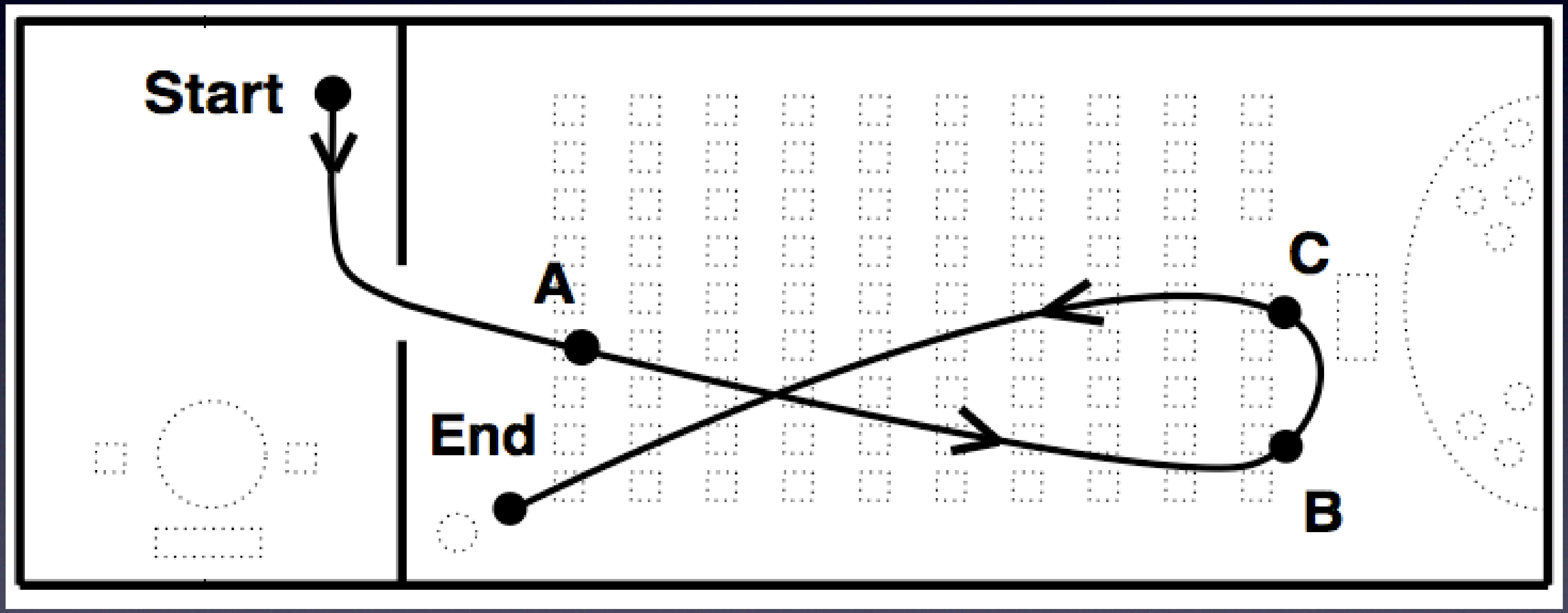
- Start with S from last frame + lowest LOD for newly visible objects
- Increment LOD for object with highest subsequent Value
- Decrement LOD of lowest Value objects until Cost criteria satisfied
- Terminate when same object LOD is both increased and decreased

Incremental Approximation

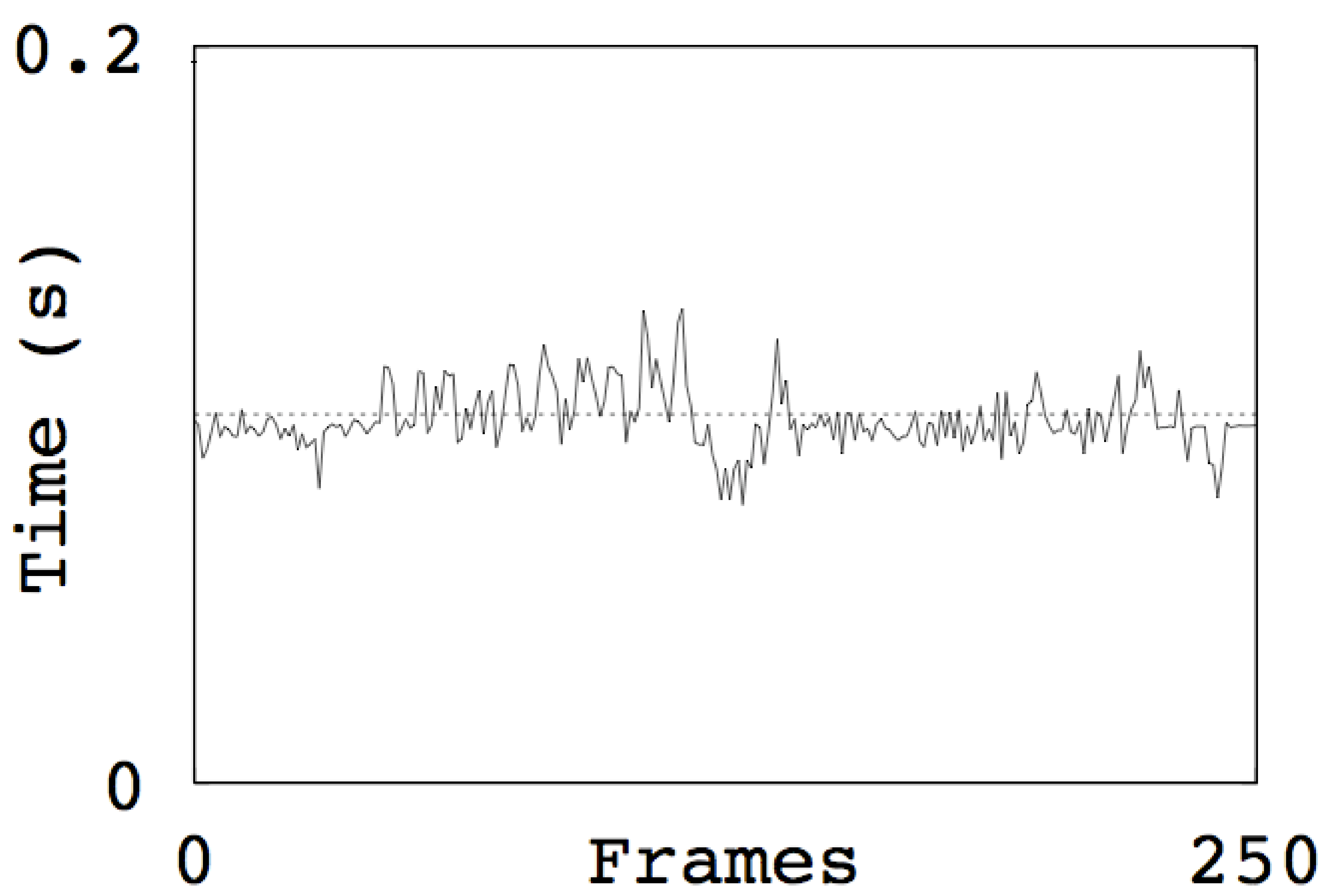
- Finds same set as regular implementation if Value decreases monotonically for object LODs
- Worst case O(n lg n)
- But usually better since initial set is usually close to selected set
- Rendering and optimization parallelized

Results

- For comparison, Benefit = Object size

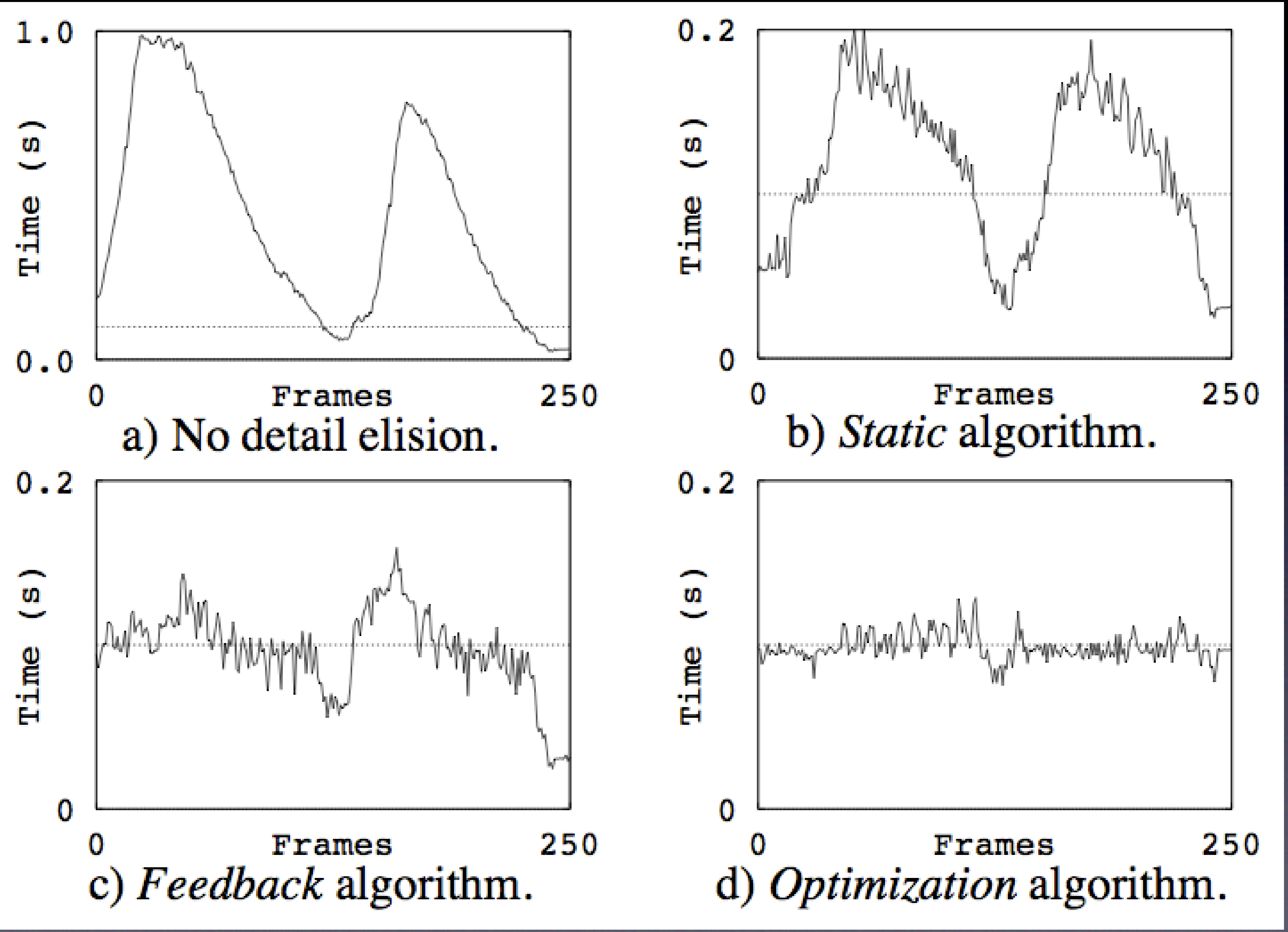


Frame Render Time



d) *Optimization* algorithm.

Results


1.0
0.0
Time (s)
Frames
0
250
a) No detail elision.
0.2
0
Time (s)
Frames
0
250
b) *Static* algorithm.
0.2
0
Time (s)
Frames
0
250
c) *Feedback* algorithm.
0.2
0
Time (s)
Frames
0
250
d) *Optimization* algorithm.

Results

LOD Selection Algorithm	Compute Time		Frame Time		
	Mean	Max	Mean	Max	StdDev
None	0.00	0.00	0.43	0.99	0.305
Static	0.00	0.01	0.11	0.20	0.048
Feedback	0.00	0.01	0.10	0.16	0.026
Optimization	0.01	0.03	0.10	0.13	0.008

Results

Results

b) *Optimization* algorithm (0.15 seconds)

Results

c) *Optimization* algorithm (0.10 seconds)

Discussion

- Complementary to PVS, culling
- Flexible - applicable to other systems
- No results for more complicated Benefit heuristic
- Conservative Heuristics? Perceptually based?
- Accurate Heuristics?

Discussion

- Blending LODs
- Continuous Level of Detail (e.g. Progressive Meshes)
- Hierarchical Level of Detail
- This paper isn't winning any awards for its title.

Questions?