SIGGRAPH2007

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KeyPoint Subspace Acceleration and SoftCaching

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Outline

- Motivation
- Basic Algorithm
  - KeyPoint Subspace Acceleration (KPSA)
  - SoftCaching
- Results
  - Facial Articulation
  - Rendering Indirect Illumination
- Conclusions and Future Work

Motivation

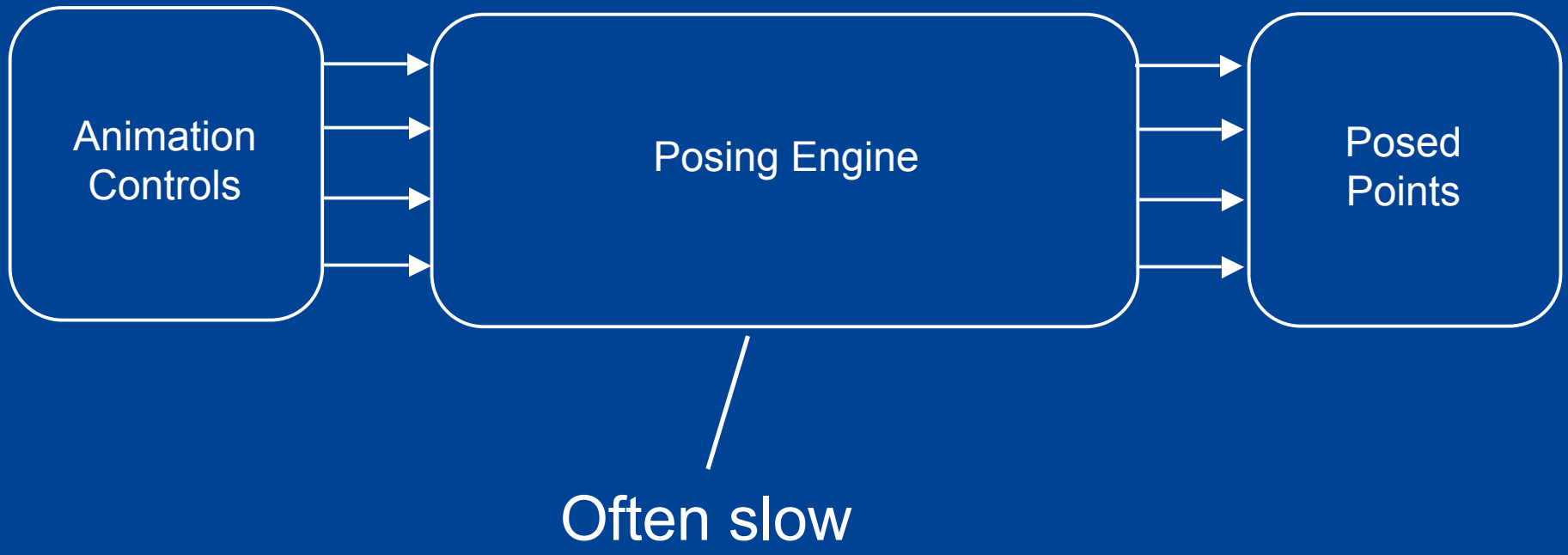
High quality articulated characters pose slowly

- Expensive deformation calculations
- Performed at many points

Results are often correlated

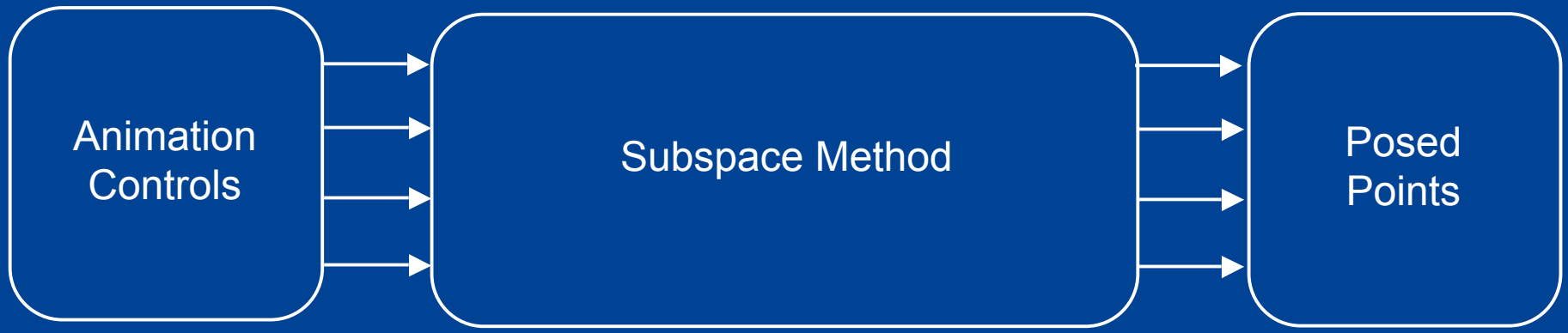
Motivation

Character Posing Block Diagram



Motivation

Subspace Acceleration Block Diagram

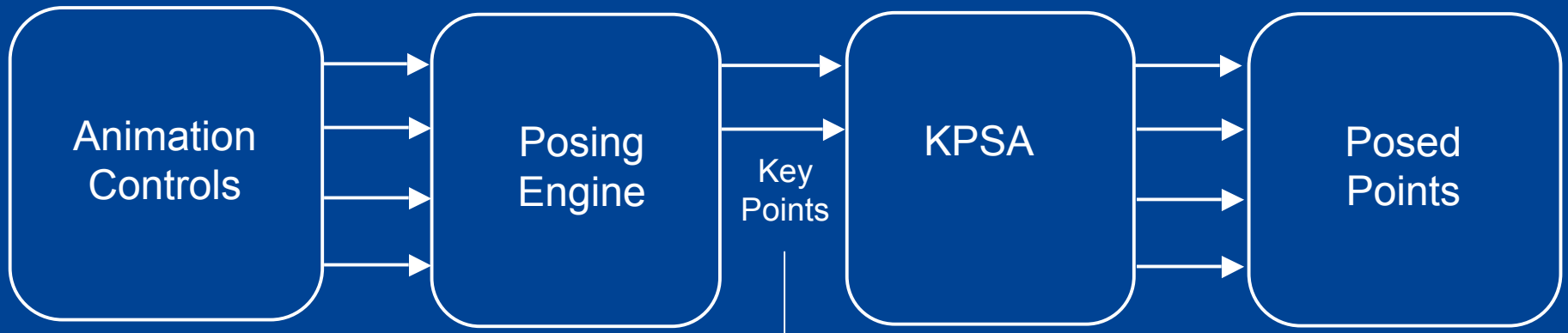


- Works well on jointed characters

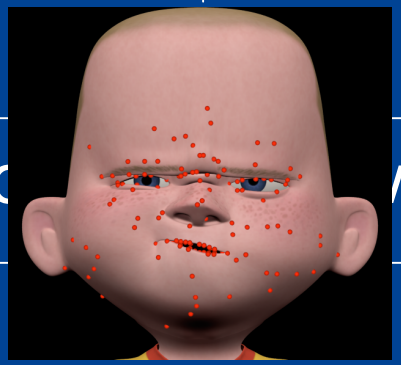
- More difficult on nonlinear areas such as faces

Motivation

KeyPoint Subspace Acceleration Block Diagram



Posing the Key Po



ith non-linearities

KPSA Algorithm

Subspace Approximation

$$\mathbf{f} \approx \hat{\mathbf{f}} = \mathbf{A}\mathbf{p}$$

- $\mathbf{f}$: Posed Points
- $\hat{\mathbf{f}}$: Subspace Approximation
- $\mathbf{A}$: Subspace Matrix
- $\mathbf{p}$: Subspace Coordinates

KPSA Algorithm

Subspace Coordinate Computation

- Pose only the key points: $\mathbf{f}_{key}$
- Project $\mathbf{f}_{key}$ onto the subspace using least squares

$$\mathbf{p} = \arg\min_{\mathbf{p}} \left\| \mathbf{f}_{key} - \mathbf{A}_{key}\mathbf{p} \right\|$$

KPSA Algorithm

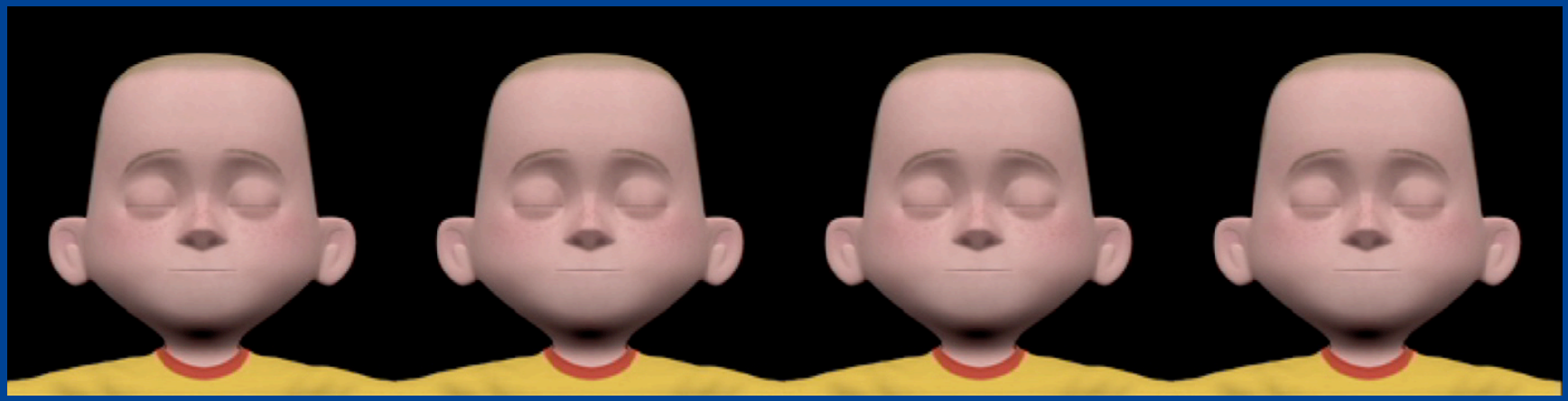
Basis Motion Computation

- Given a training set of example poses
- Perform *Principal Component Analysis* (PCA):
  - Choose the *M* most significant basis motions

The basis motions can be transformed without affecting the subspace

KPSA Algorithm

KeyPoint Computation

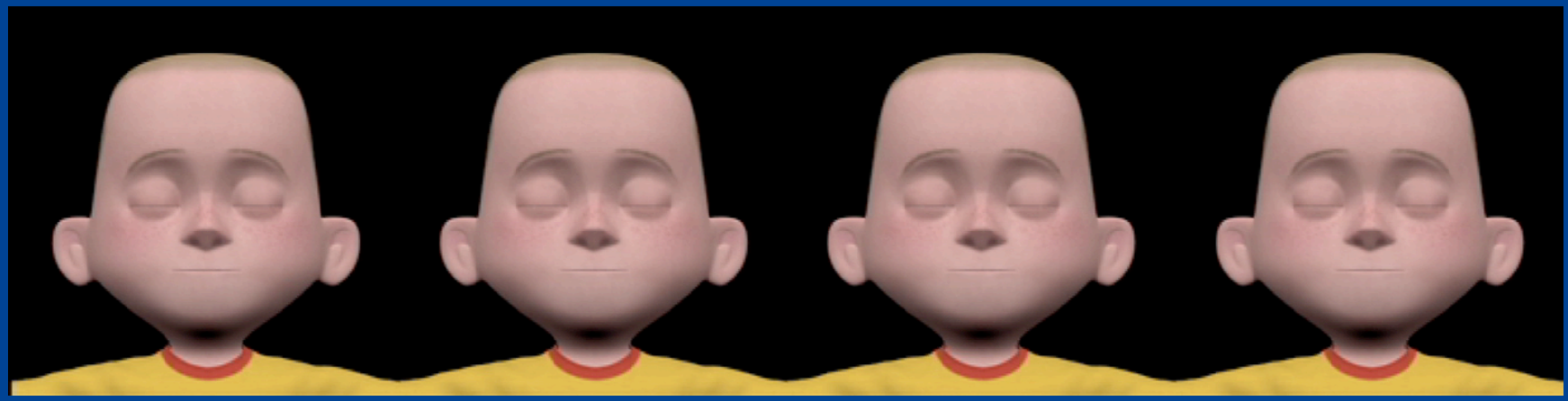


PCA basis motions (4 of 85)

The basis motions are global

KPSA Algorithm

KeyPoint Computation



Varimax rotated basis motions (4 of 85)

Key Points are points with maximal motion

KPSA Algorithm

- Preprocess:
  1) Build the subspace
  2) Choose the Key Points
- Runtime:
  1) Pose the Key Points: $\mathbf{f}_{key}$
  2) Compute the subspace coordinates: $\mathbf{p}$
  3) Compute the subspace approximation: $\hat{\mathbf{f}}$

Sources of Error

Projection Error

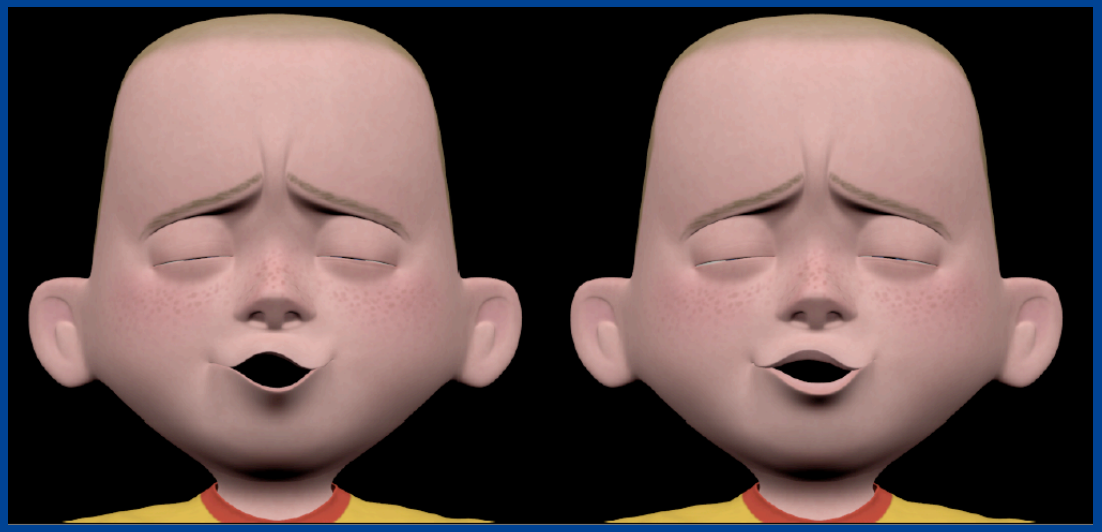
- Error due to the subspace not containing the pose

Cueing Error

- Error due to not finding the “closest” pose in the subspace

SoftCaching

Subspace approximations can fail



Fully Posed KPSA

Use the KeyPoint Error as a confidence metric:

- High Error: use the fully posed solution
- Low Error: use the KPSA solution

SoftCaching

Subspace approximations can fail

Fully Posed KPSA SoftCaching

Use the KeyPoint Error as a confidence metric:

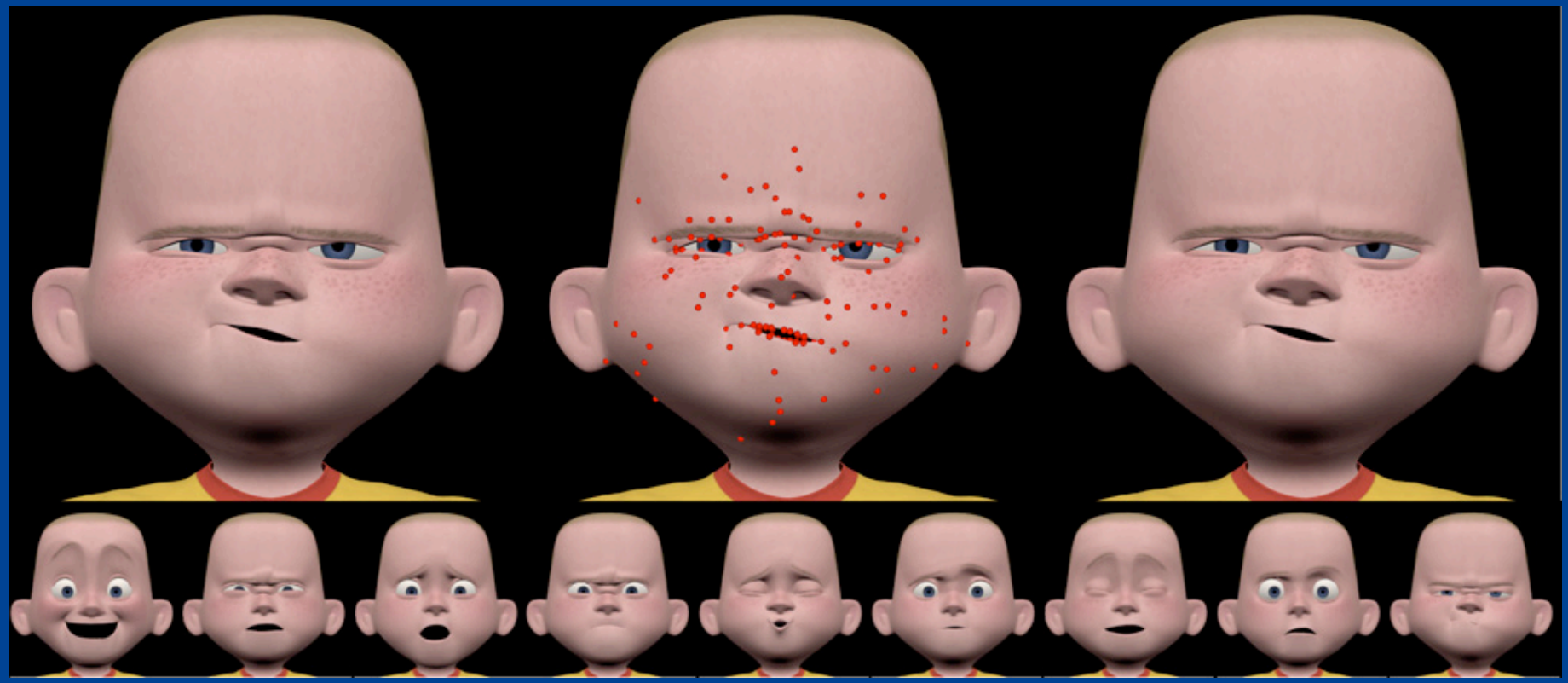
- High Error: use the fully posed solution
- Low Error: use the KPSA solution

KPSA-SC Algorithm

- Preprocess:
  1) Build the subspace
  2) Choose the Key Points
- Runtime:
  1) Pose the Key Points: $\mathbf{f}_{key}$
  2) Compute the subspace coordinates: $\mathbf{p}$
  3) Compute the subspace approximation: $\hat{\mathbf{f}}$
  4) SoftCache using KeyPoint error

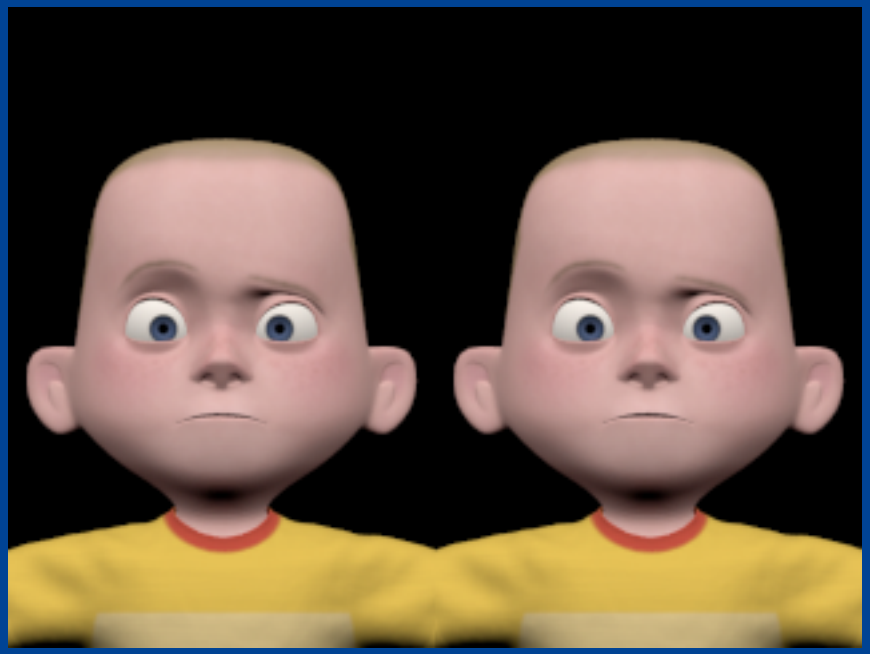
Results - Dash

Fully Posed | Key Points | KPSA



170 Key Points, 2986 Total Points, 8.7x speedup

Results - Dash



Fully Posed KPSA

170 Key Points, 2986 Total Points, 8.7x speedup

Results - McQueen

KPSA results

70 Key Points, 2625 Total Points, 15x speedup

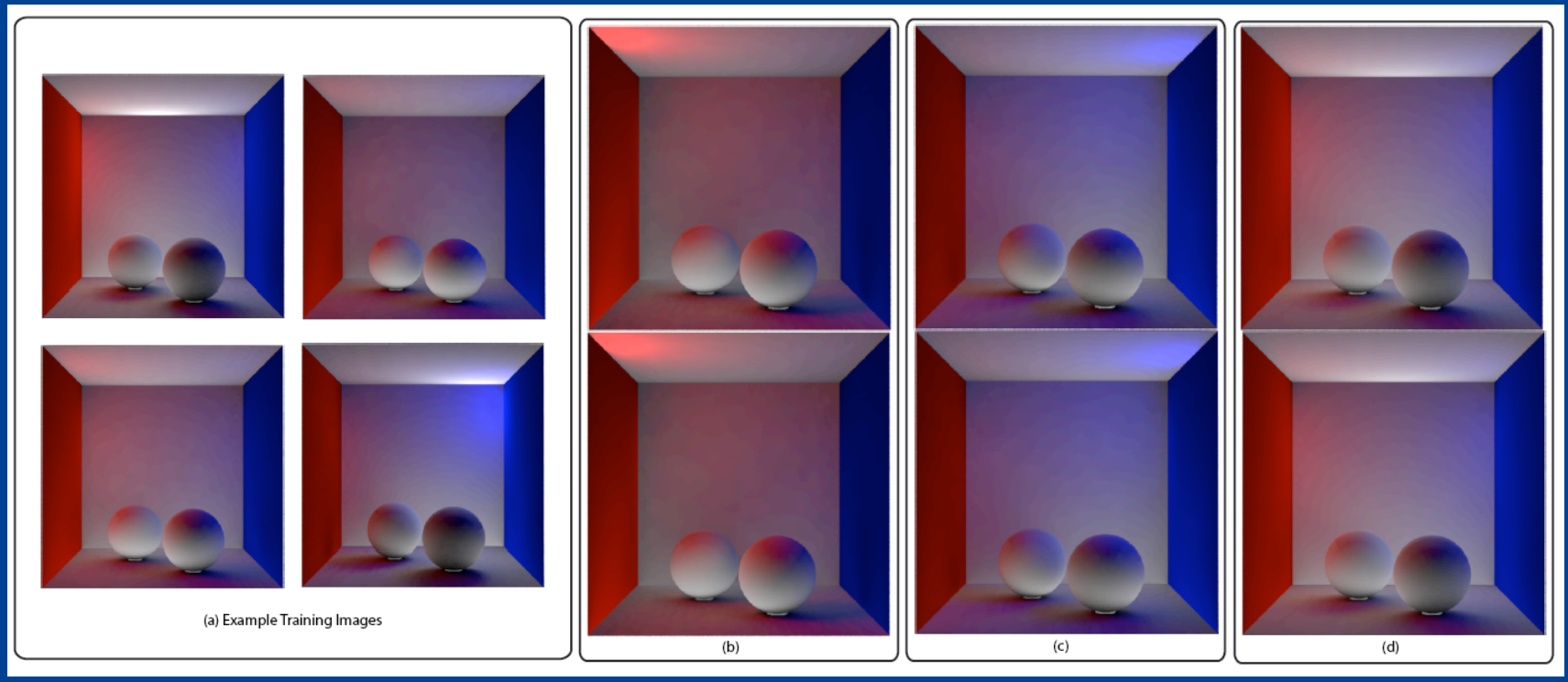
Results - Ratatouille

KPSA results

80 Key Points, 4150 Total Points, 20.75x speedup

Results - Global Illumination

Fully Rendered Results



Example Training Images

KPSA Results

200 Key Points, 160000 Total Points

Conclusions

- KPSA - acceleration
  - General
  - Automatic Key Point Selection
  - Soft Caching
- Limitations
  - Subspace quality dependent on training set
  - Acceleration determined by time to pose Key Points

Future Work

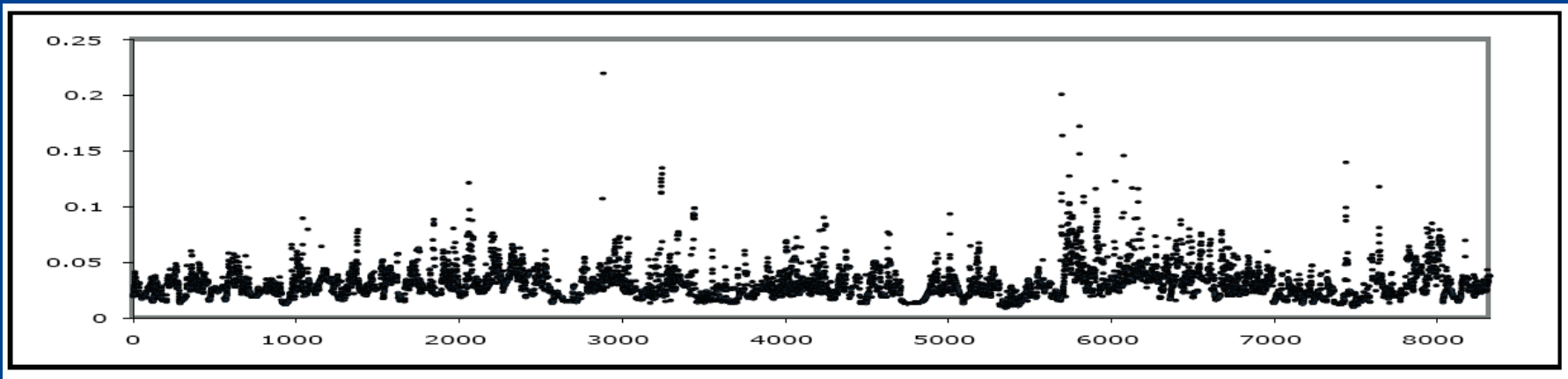
- Alternate Key Point selection algorithms
  - Incorporate posing cost into key point selection
- “Local” cache misses
  - Only fully compute locally for a cache miss

Acknowledgements

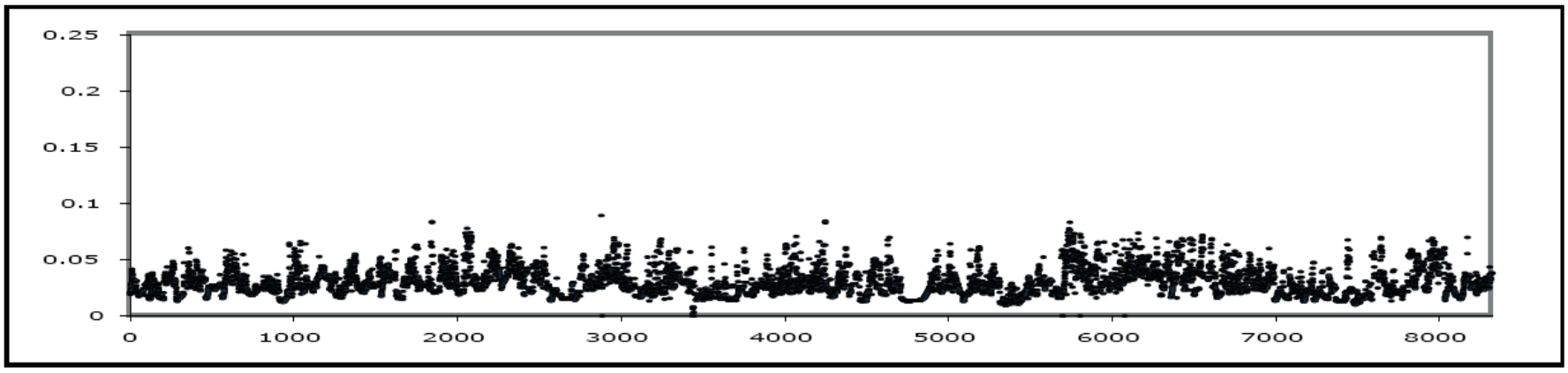
We would like to thank:

- Pixar Animation Studios
- Pixar Studio Tools
- Pixar Research

Error Plots



RMS Error for KPSA Results



RMS Error for SoftCaching Results

Error Equations

Projection Error

$$e_{proj} = \|\mathbf{f} - \mathbf{A}\,\mathbf{p}_{proj}\|$$
$$\mathbf{p}_{proj} = \arg\min_{\mathbf{p}} \|\mathbf{f} - \mathbf{A}\,\mathbf{p}\|$$

Cueing Error

$$e_{cue} = \|\mathbf{A}\,\mathbf{p}_{proj} - \mathbf{A}\,\mathbf{p}\|$$