A RATE DISTORTION FRAMEWORK FOR 3D BROWSING

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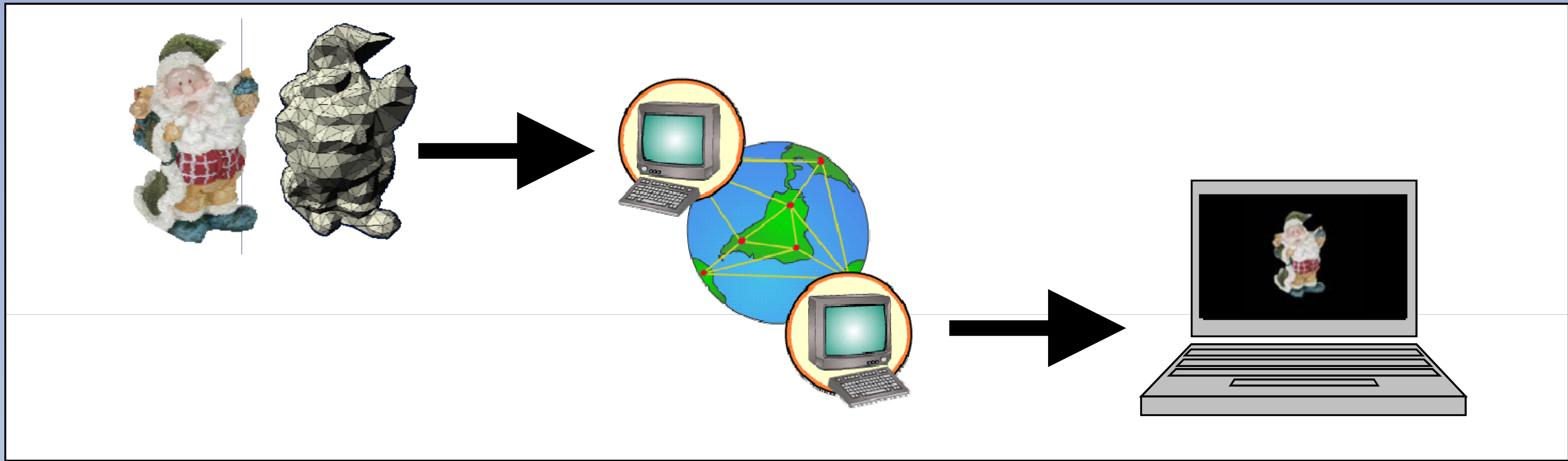
Objectives



- Interactive visualization system for 3D scenes
- Efficient remote browsing of complex 3D scenes
- Progressive transmission of the data available at server side
- Optimal bandwidth usage

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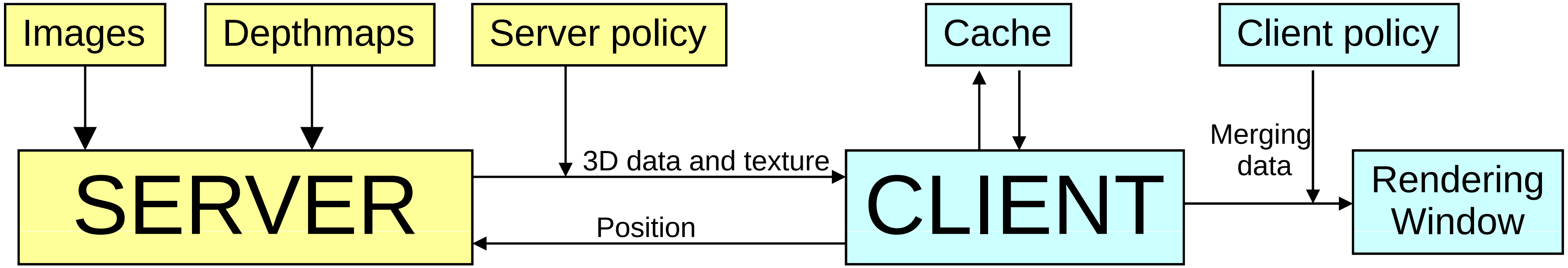
System Overview



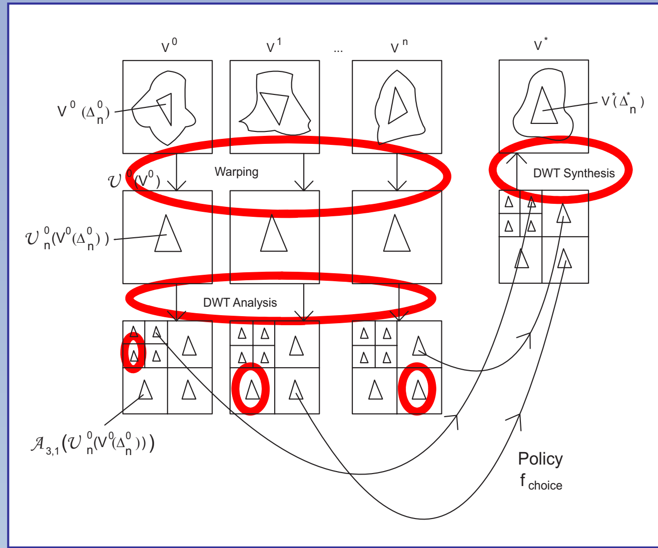
SERVER

- Stores images and depth information compressed in a scalable way (JPIP)
- A server policy to decide how to allocate transmission resources for geometry and texture

CLIENT

- Interactive 3D viewer
- Shows the best possible rendering with the information received from the server (client policy)
- Stores the received data

Client Overview



- The received views are reprojected on the target view using depth information
- The warped views are decomposed using the DWT
- A **minimum-distortion policy** is used to select samples from different views
- DWT synthesis is performed to reconstruct the required rendering

Distortion Framework

Scalable image compression

Perceptual factors

$$D_d^{i\to *}[\mathbf{p}] = \sum_b W_{b\to d}[\mathbf{p}] \cdot D_b^i\left[\left(\mathcal{W}_{b\to d}^i\right)^{-1}(\mathbf{p})\right] + \overline{|\delta Z_d^*|^2}[\mathbf{p}] \cdot \overline{g_d^{i\to *}}[\mathbf{p}] \cdot \overline{|\omega_d|^2} \cdot \overline{E_d^{i\to *}[\mathbf{p}]} + \gamma \tan\left(\max\left\{0, \cos^{-1}\left\langle \mathbf{e}^i, \mathbf{e}^*\right\rangle\right\}\right) \cdot \overline{E_d^{i\to *}[\mathbf{p}]} \quad +P$$

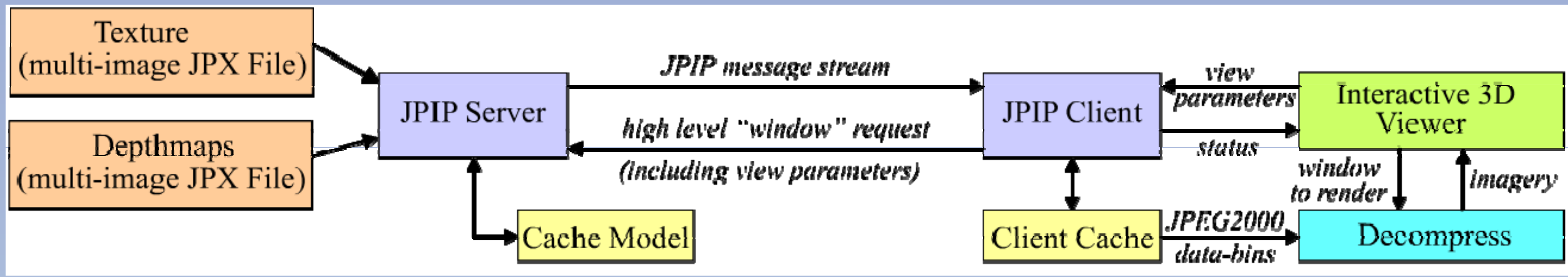
Geometry compression and acquisition uncertainty

Lighting

- Estimation of how the various sources of distortion affects the rendered views [1]
- Samples' sources are chosen in order to minimize the distortion
- Used also for depth information

[1] Zanuttigh et Al, "A Novel Framework for the Interactive Transmission of 3D Scenes", Signal Processing: Image Communication, October 2006

Server Overview



The server:

- Extends the functionalities of a standard JPIP server
- Holds JPEG2000 images divided in codeblocks
- Makes his own decisions on how to improve rendered views at client side

How should the server distribute available transmission resources amongst the various elements of the original view images ?
(Assuming geometry already available at client side)

Distortion Optimization

Distortion due to image compression

$$D^* \approx \sum_d \sum_{\mathbf{p}} \sum_i \left(\rho_d^i[\mathbf{p}]\right)^2 \left(\Theta_d^{i\to *}[\mathbf{p}] + \sum_b W_{b\to d}^i[\mathbf{p}] \cdot D_b^i\left[\left(\mathcal{W}_{b\to d}^i\right)^{-1}(\mathbf{p})\right]\right)$$

Blending choices

Distortion due to geometry and lighting

- Minimize the total distortion D* in the rendered views
- Blending choices depend on the received data
- Lagrangian optimization subject to bandwidth constraint
- Can't recalculate blending weights after every iteration: two steps procedure

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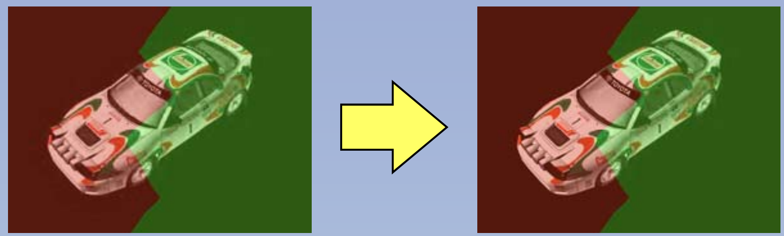
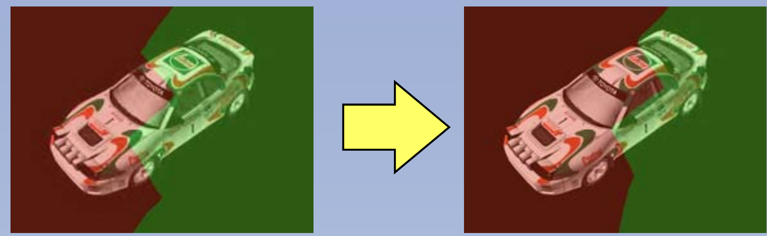
Two step optimization





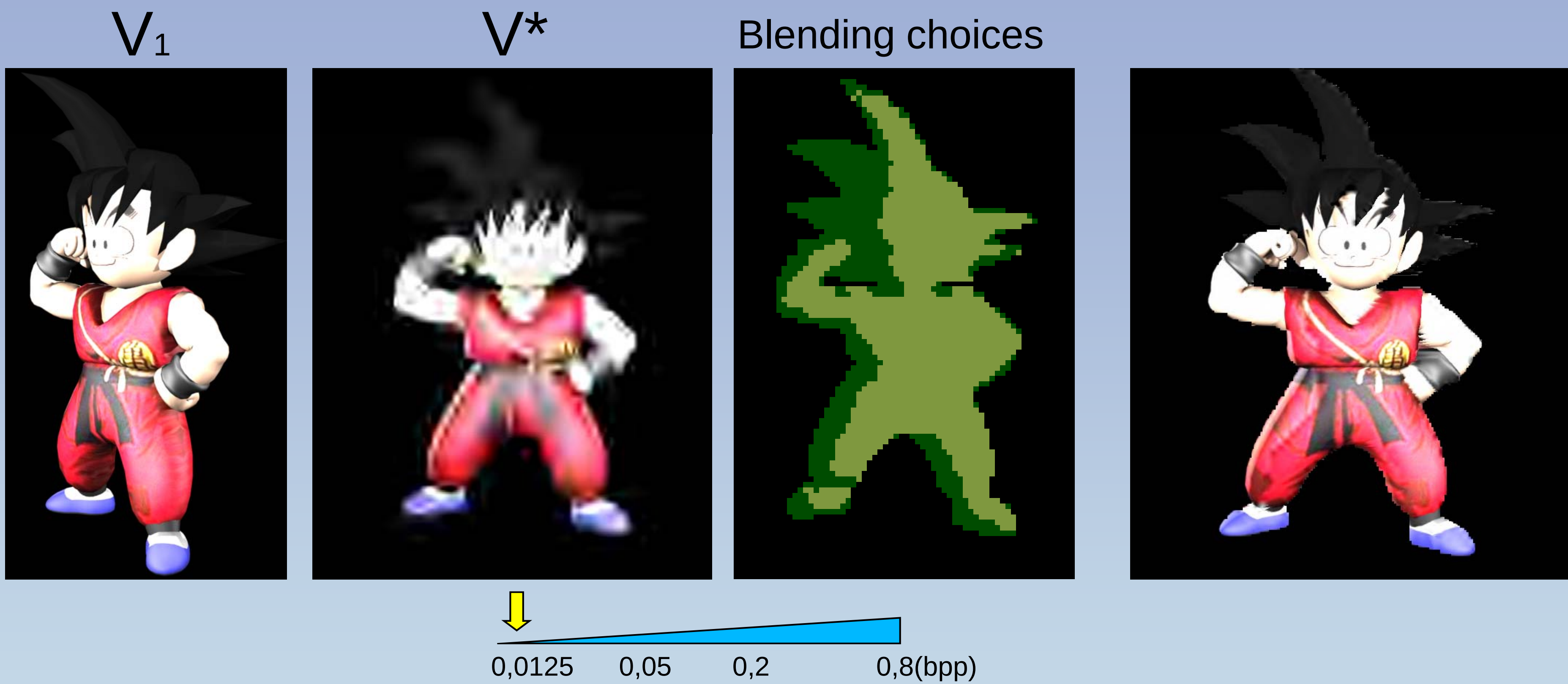
Reinforcing Enhancements

- Optimization solved with the assumption that the blending weights will not change
- θ_d constant, not considered in optimization
- Improvement of the code-blocks which contribute most strongly to the current view

Disruptive Enhancements

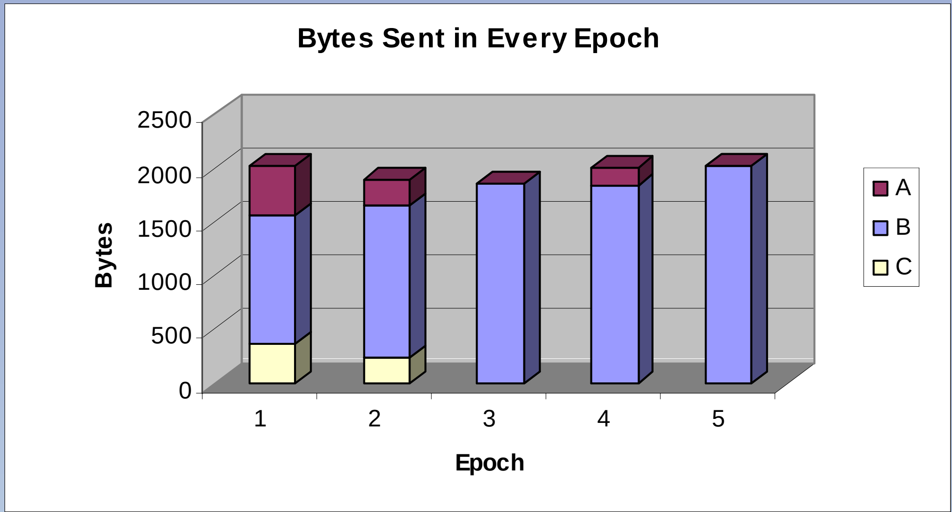
- Take into account changes in the blending choices due to new data transmitted to the client
- Force transmission of data from new images

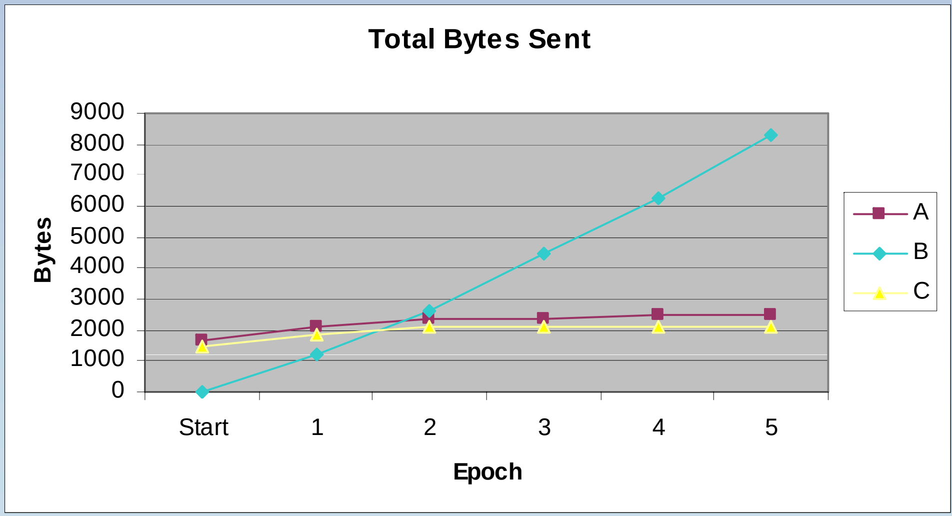
Experimental Results: Client



- At the beginning most samples warped from V_1 , good quality except for the region not visible in V_1
- As soon as more data become available for V*, more and more samples are taken from it
- Finally almost all the samples are taken from V*

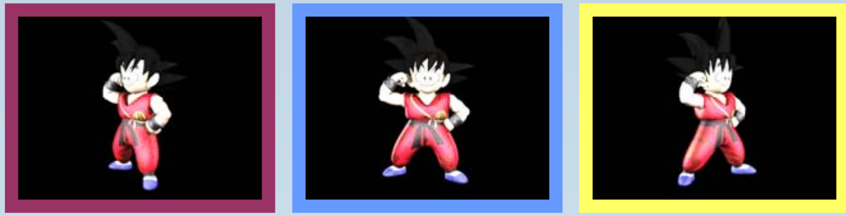
Experimental Results: Server





- Rendering from position B (no data available)
- ~2Kb available for A and C
- Improve A and C or start sending data for B ?

- In early epochs* improvement of A and C
- Data for B from disruptive enhancements
- Later most of the data transmitted for B



A B C

*In each epoch the server can deliver up to 2 Kb

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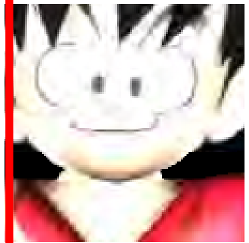
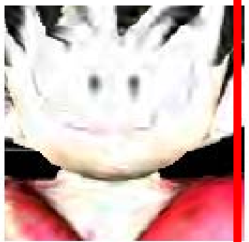
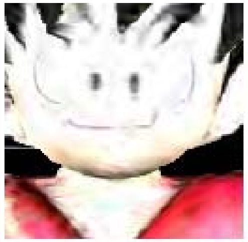
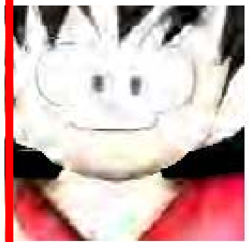
Experimental Results: Image quality

1 View	*No Data*					
3 Views						
Epochs	0	1	2	3	4	5

- Information from nearby views allows better image quality in early epochs
- At the end all samples taken from the closest view
- Exploit previously received data for interactive response
- Improve available views in fast movement

Conclusions

- Novel remote visualization scheme for 3D scenes
- Exploit progressive image compression and transmission techniques for 3D browsing
- Rate-distortion policy for view-synthesis and optimal allocation of the available bandwidth

Further Research

- Progressive geometry transmission
- Inclusion of perceptual factors within the distortion estimation
- Combined framework for optimal allocation of bandwidth between texture and geometry
- Extension to animated scenes (3Dvideo)