European Signal Processing Conference 2011

View Interpolation With Structured Depth From Multiview Video

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Outline

- Motivation
- Depth Consistency Testing
- Inter-view Connection Information
- Structured Depth Maps
- Virtual View Interpolation
- Experimental Results
- Conclusions

Imaging

Classical Imaging

Imaging

Multiview Imaging

Application

User

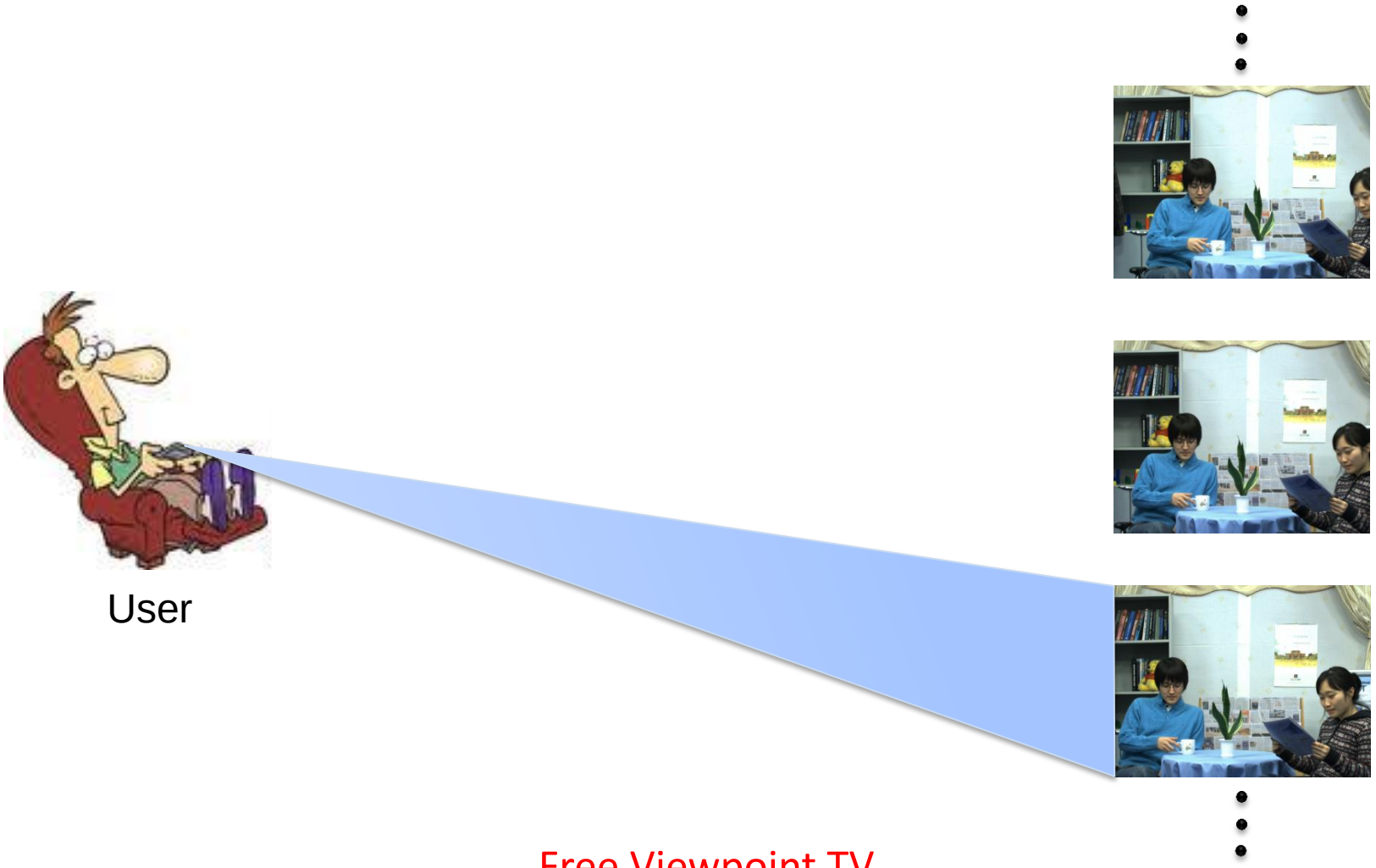
Free Viewpoint TV

Application

User

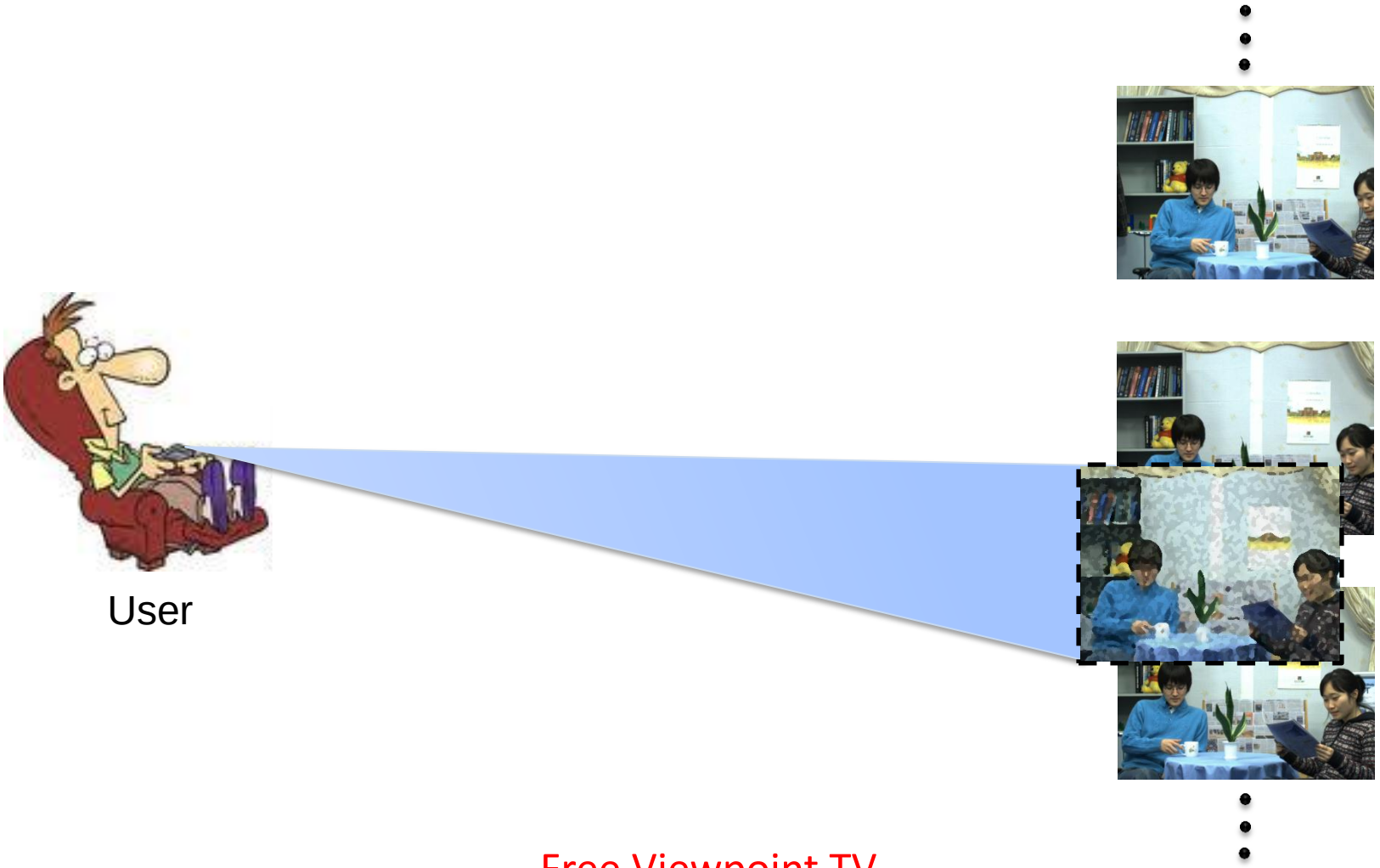
Free Viewpoint TV

Application



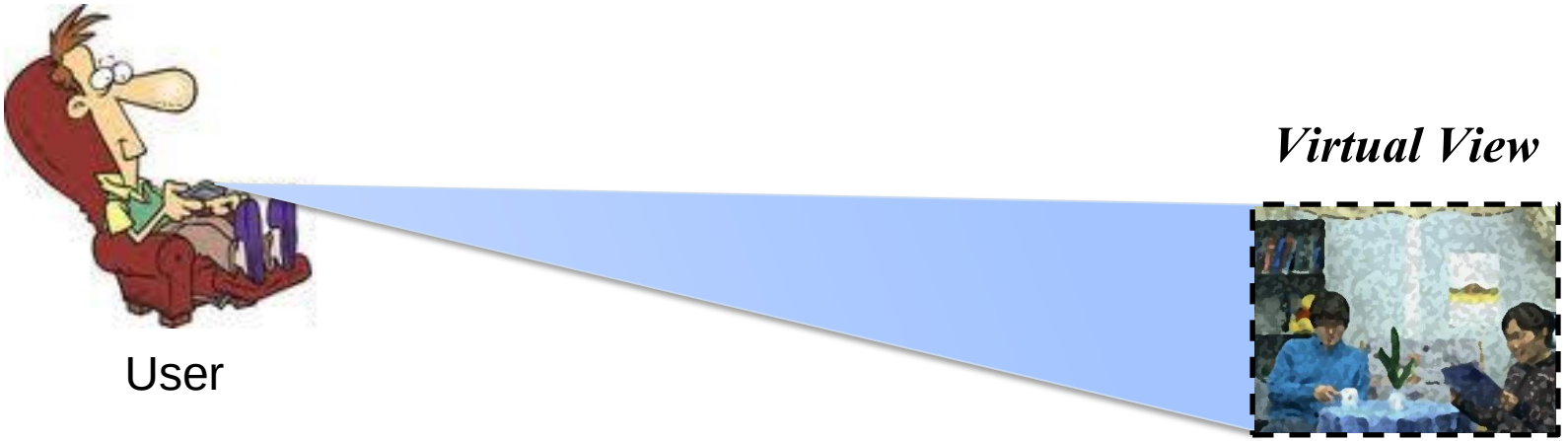
Free Viewpoint TV

Application



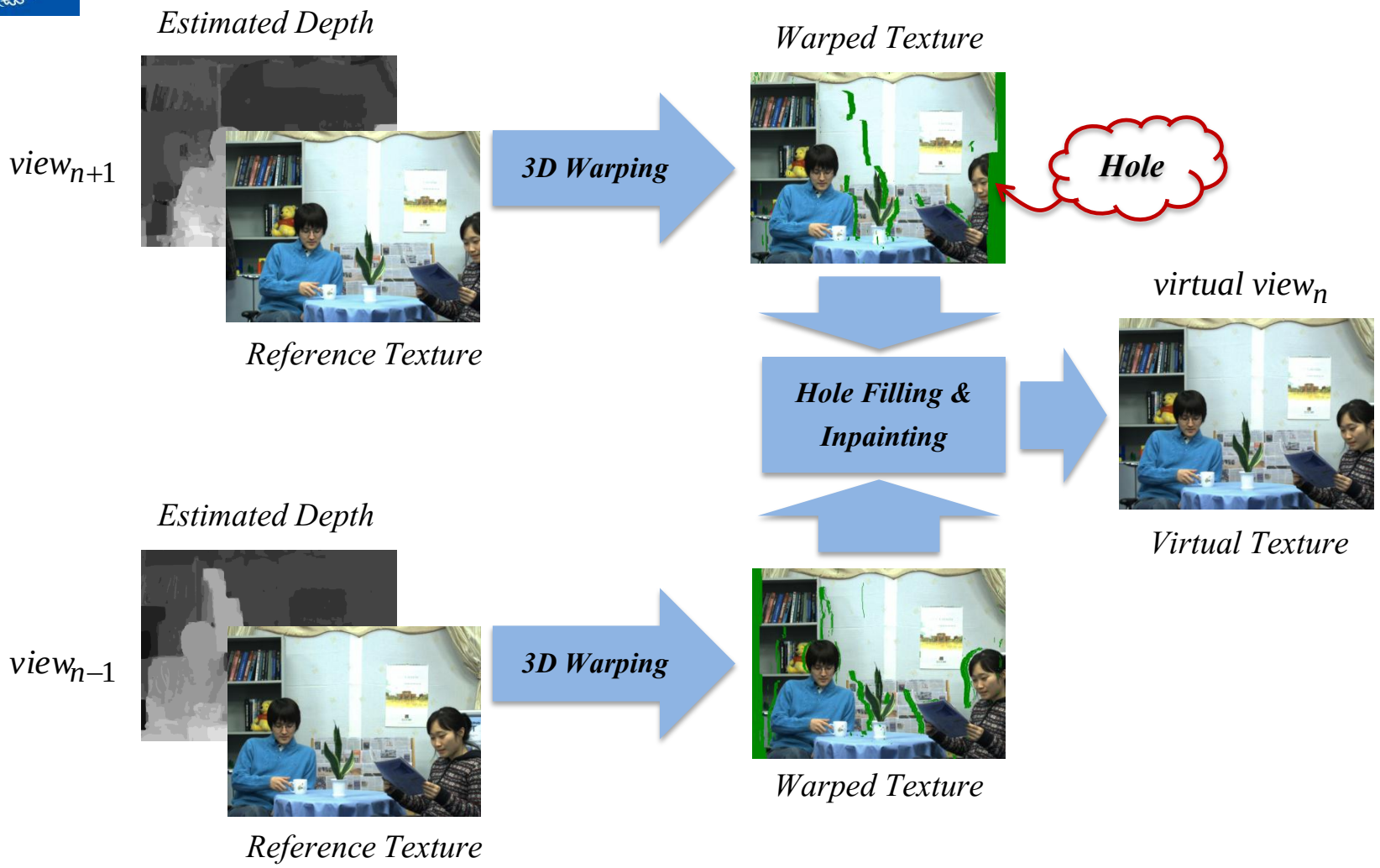
Free Viewpoint TV

Application



Free Viewpoint TV

Virtual View Rendering



MPEG View Synthesis Reference Software 3.5 (VSRS 3.5)

Depth Estimation

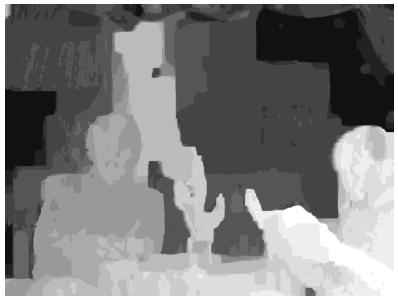
Reference Textures

$view_{n+1}$ $view_n$ $view_{n-1}$

Depth Estimation

(MPEG Depth Estimation Reference Software DERS)

$view_n$

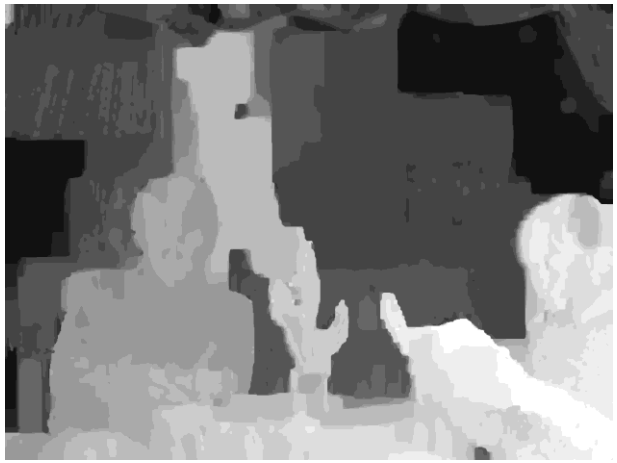


Estimated Depth Map

Common Practice

Inter-view Depth Inconsistency

$view_{n+1}$



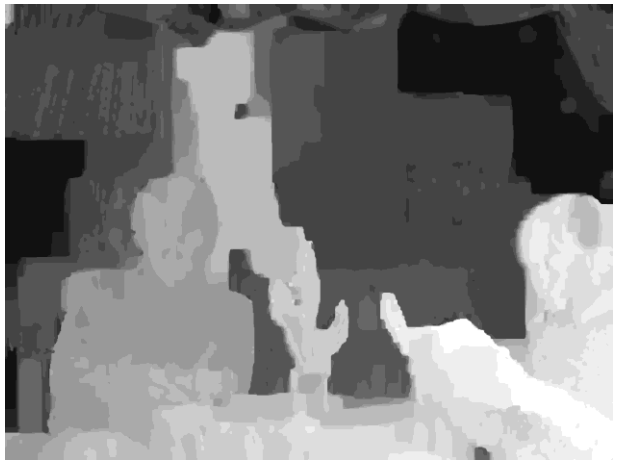
$view_{n}$

$view_{n-1}$

Newspaper

Inter-view Depth Inconsistency

$view_{n+1}$

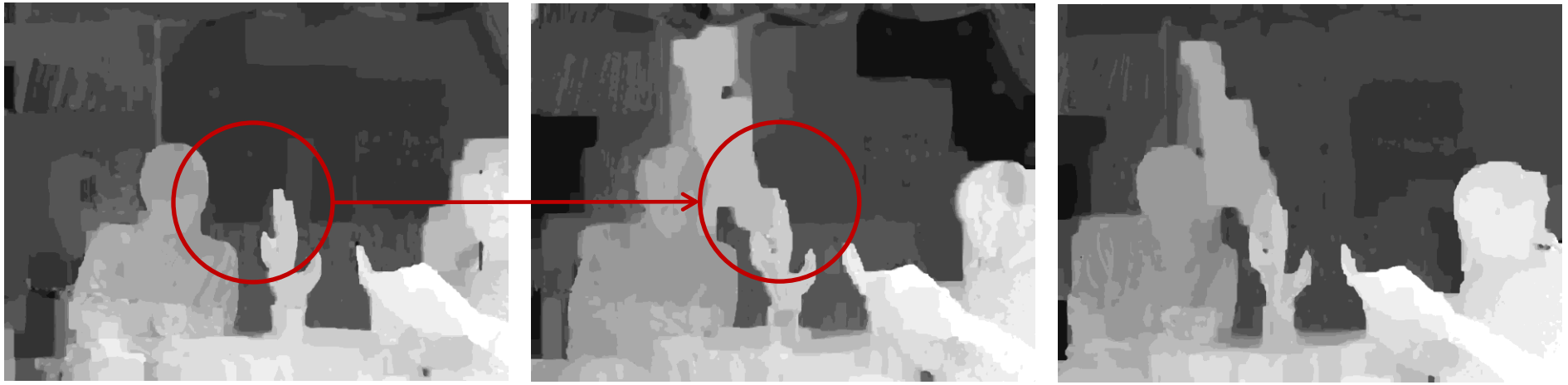


$view_{n}$

$view_{n-1}$

Newspaper

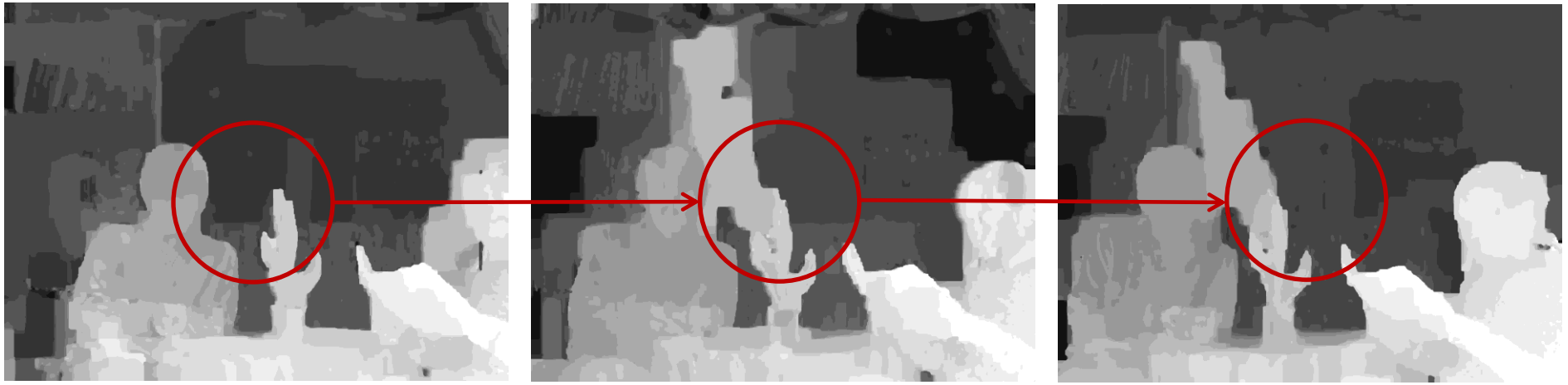
Inter-view Depth Inconsistency



$view_{n+1}$ $view_n$ $view_{n-1}$

Newspaper

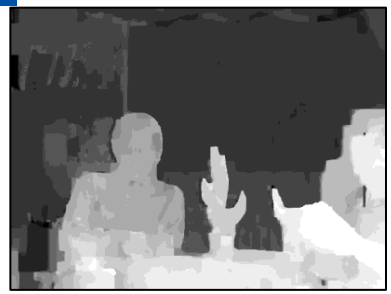
Inter-view Depth Inconsistency



$view_{n+1}$ $view_n$ $view_{n-1}$

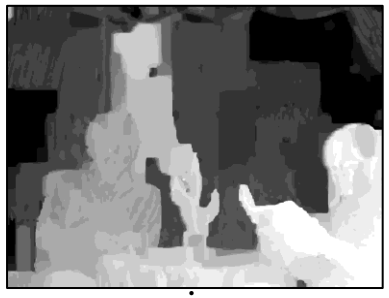
Newspaper

Multiple Depth Warping



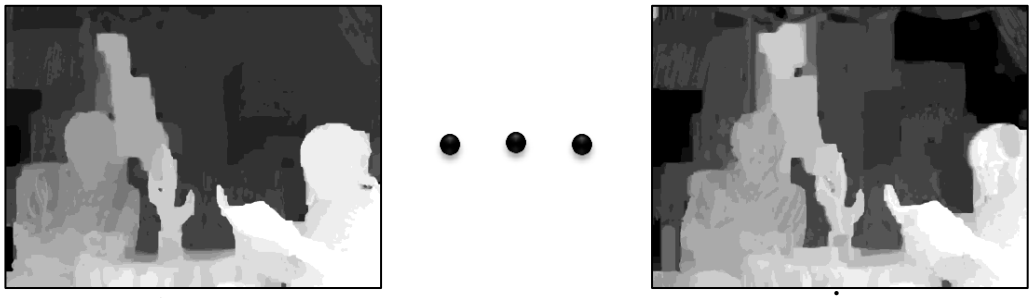
view 1

view 2

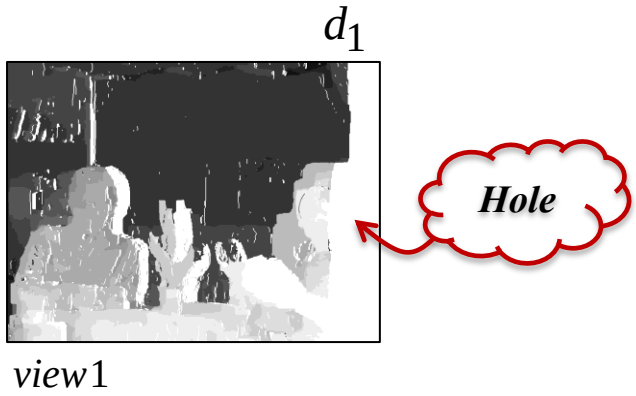


view n

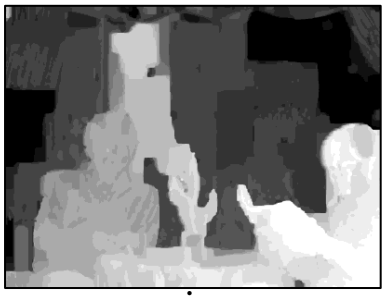
Multiple Depth Warping



3D Warping to a principal viewpoint p (1≤p≤n)

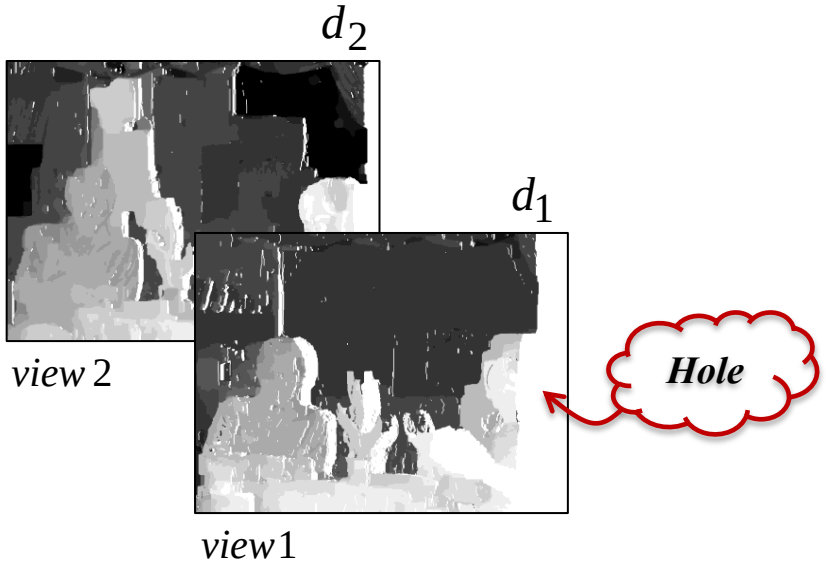


Multiple Depth Warping

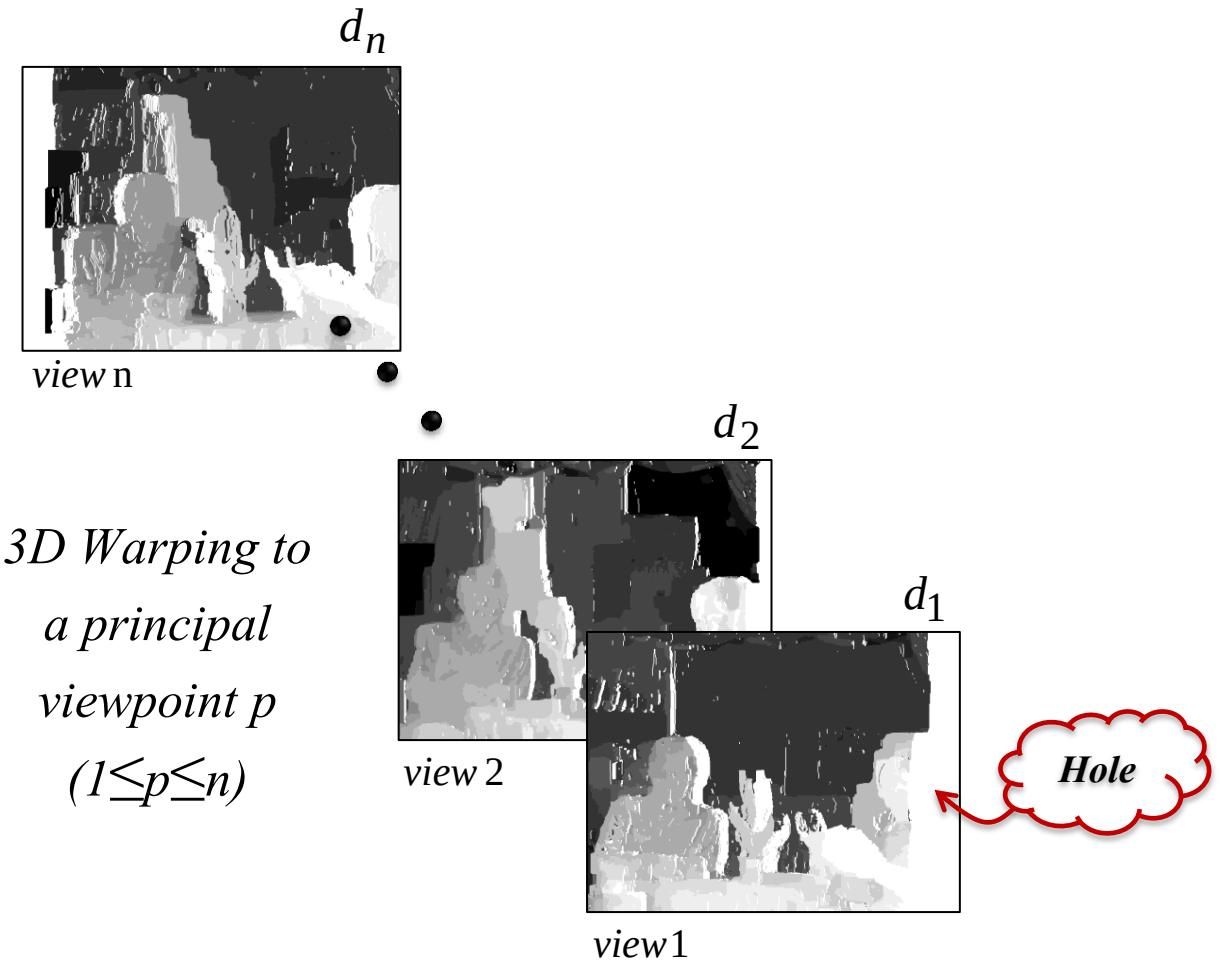


view n

3D Warping to a principal viewpoint p (1≤p≤n)



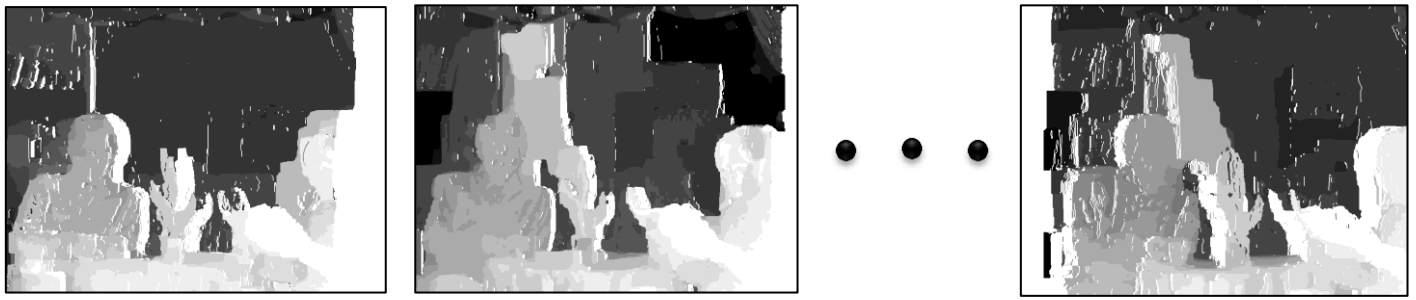
Multiple Depth Warping



3D Warping to a principal viewpoint p (1≤p≤n)

Multiple Warped Depth Maps at a principal viewpoint p

Connection Evidence



view 1 *view* 2 *view* n

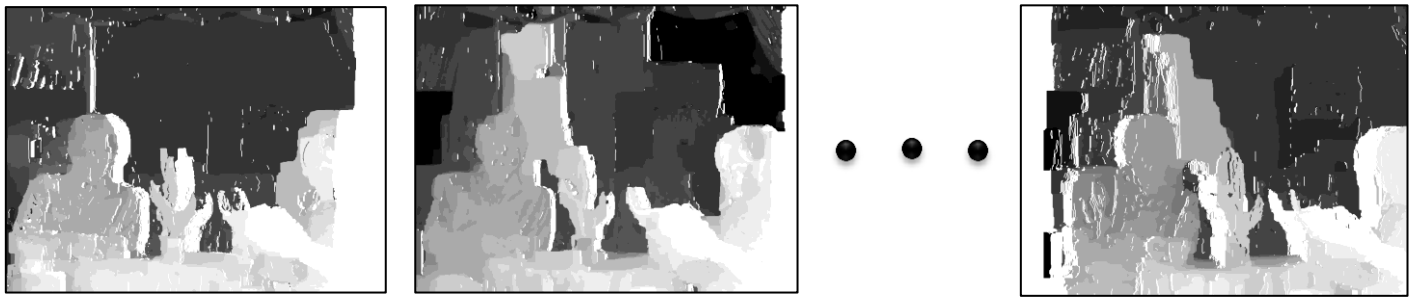
Absolute Difference Matrix (ADM) per pixel per frame =

$$\begin{pmatrix} 0 & \Delta_{1,2} & \cdots & \Delta_{1,n} \\ \Delta_{2,1} & 0 & \cdots & \Delta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{n,2} & \Delta_{n,2} & \cdots & 0 \end{pmatrix}$$

Pixel 1

where, $\Delta_{ij} = | d_i - d_j |$ *is the absolute difference of depth values between warped depth map* d_i *and warped depth map* d_j *at a principal pixel*

Connection Evidence



view 1 *view* 2 *view* n

Absolute Difference Matrix (ADM) per pixel per frame $=$

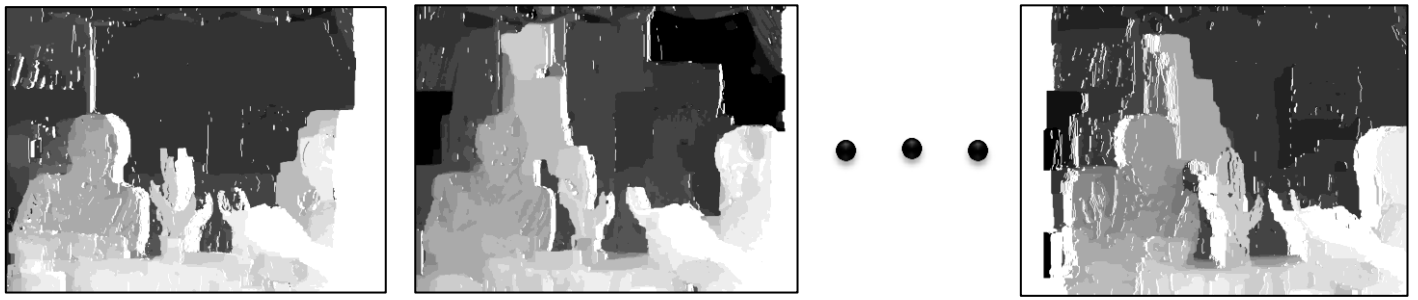
$$\begin{pmatrix} 0 & \Delta_{1,2} & \cdots & \Delta_{1,n} \\ \Delta_{2,1} & 0 & \cdots & \Delta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{n,2} & \Delta_{n,2} & \cdots & 0 \end{pmatrix}, \begin{pmatrix} 0 & \Delta_{1,2} & \cdots & \Delta_{1,n} \\ \Delta_{2,1} & 0 & \cdots & \Delta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{n,2} & \Delta_{n,2} & \cdots & 0 \end{pmatrix}, \bullet\bullet\bullet,$$

Up to depth resolution

Pixel 1 *Pixel 2*

where, $\Delta_{ij} = | d_i - d_j |$ *is the absolute difference of depth values between warped depth map* d_i *and warped depth map* d_j *at a principal pixel*

Connection Evidence



view 1 view 2 view n

Inter-view Connection Evidence

Absolute Difference Matrix (ADM) per pixel per frame =

$$\begin{pmatrix} 0 & \Delta_{1,2} & \cdots & \Delta_{1,n} \\ \Delta_{2,1} & 0 & \cdots & \Delta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{n,2} & \Delta_{n,2} & \cdots & 0 \end{pmatrix}, \begin{pmatrix} 0 & \Delta_{1,2} & \cdots & \Delta_{1,n} \\ \Delta_{2,1} & 0 & \cdots & \Delta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{n,2} & \Delta_{n,2} & \cdots & 0 \end{pmatrix}, \bullet\bullet\bullet,$$

Pixel 1 Pixel 2

Up to depth resolution

where, $\Delta_{ij} = | d_i - d_j |$ *is the absolute difference of depth values between warped depth map* d_i *and warped depth map* d_j *at a principal pixel*

Connection Evidence Testing

- ***Connection Threshold***
  - *Define quality of the inter-view connection per frame*

$$T = \mu + \lambda\sigma,$$

where,

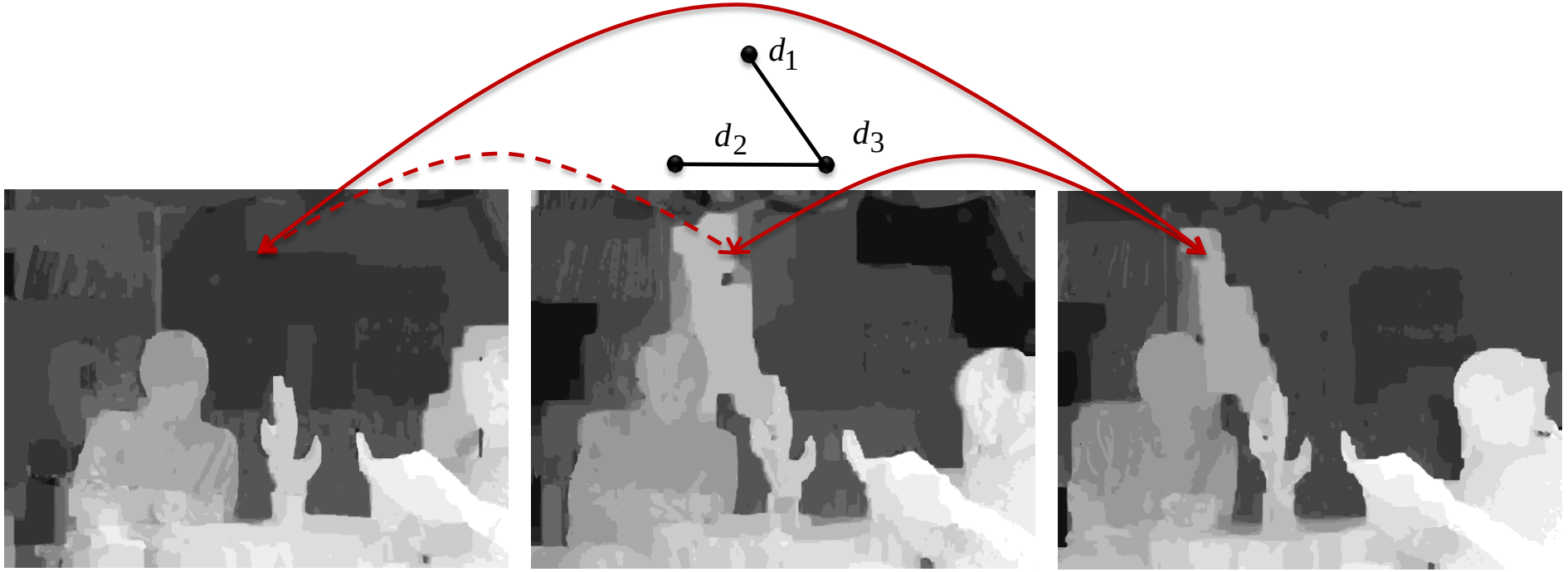
μ = *Mean of all ADM per frame*

σ = *Standard deviation of all ADM per frame*

λ = *Trade-off between quality of connection and number of connection, in the rendering experiment* $\lambda = 0.8$.

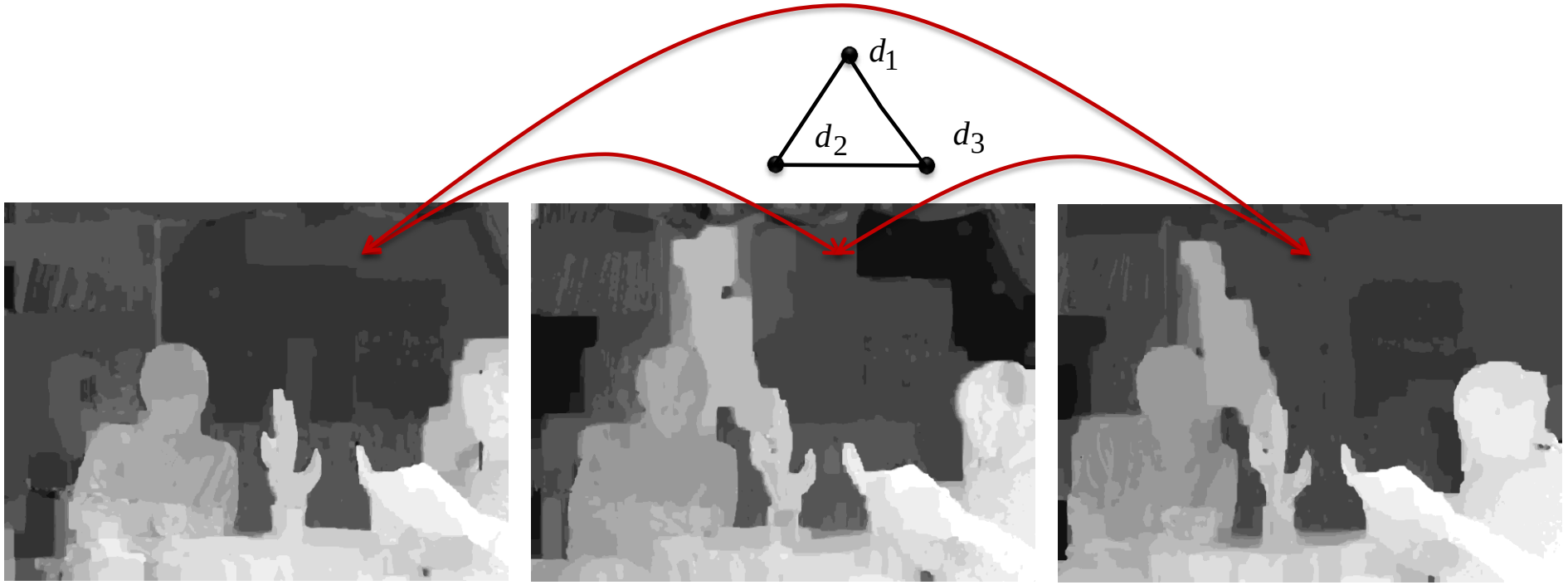
- ***Testing Rule***
  - $\Delta_{ij} < T$ *: Accept the connection evidence and assume the corresponding depth pair have a consistent depth representation*
  - $\Delta_{ij} \geq T$ *: Reject the connection evidence*

Inter-View Connection Information



Example for inter-view connection information with three reference views, n=3.

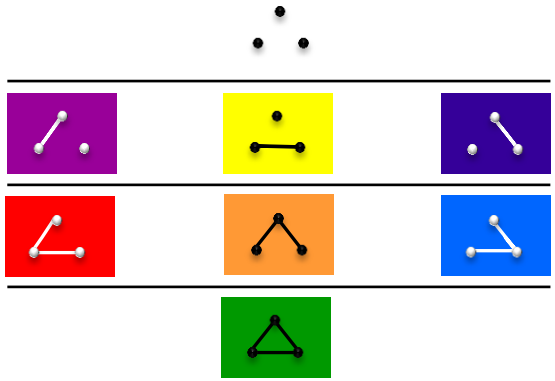
Inter-View Connection Information



Example for inter-view connection information with three reference views, n=3.

Inter-View Connection Information

Possible cases of inter-view connectivity for $n = 3$:



Use of Connection Information:

- *To obtain consistent depth values*
- *To combine texture pixels from multiple viewpoint reliably*

Principal Depth Map

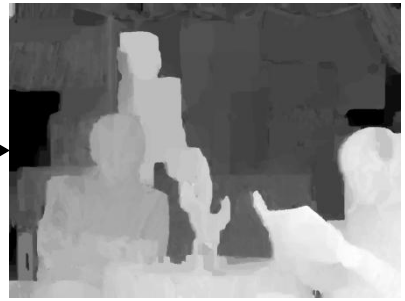
Estimated Depth Maps

Depth Consistency Testing

Inter-view connection Information

Inter-view Connection Information

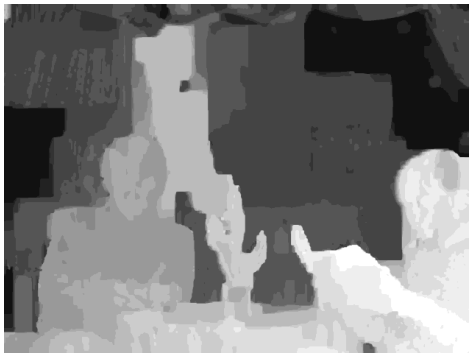
Consistent Depth Values



Principal Depth Map

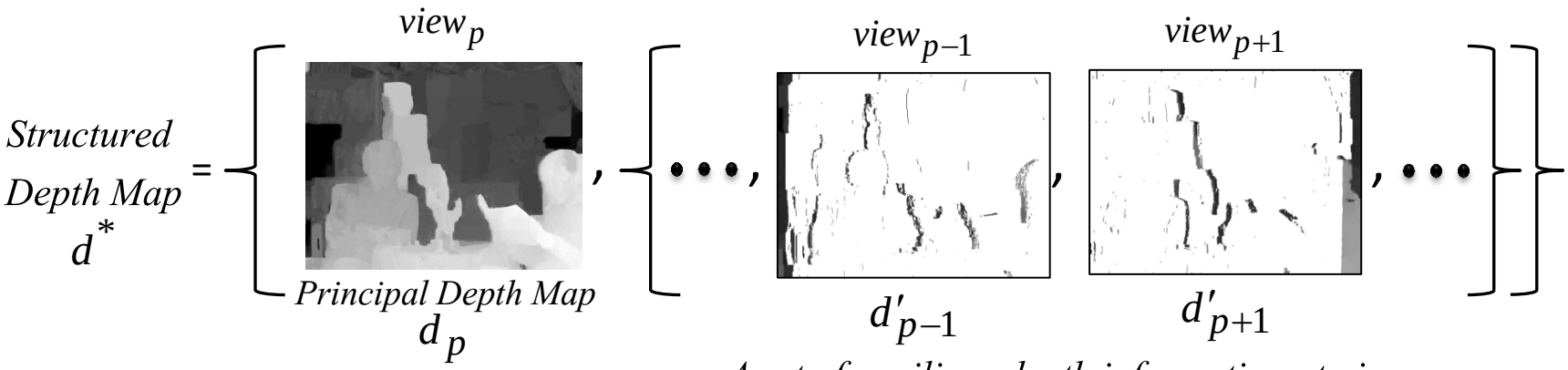
d_p

Structured Depth Maps


- *To have **inter-view consistent** depth maps*
- *To remove **redundancy** from depth maps*

Structured Depth Maps



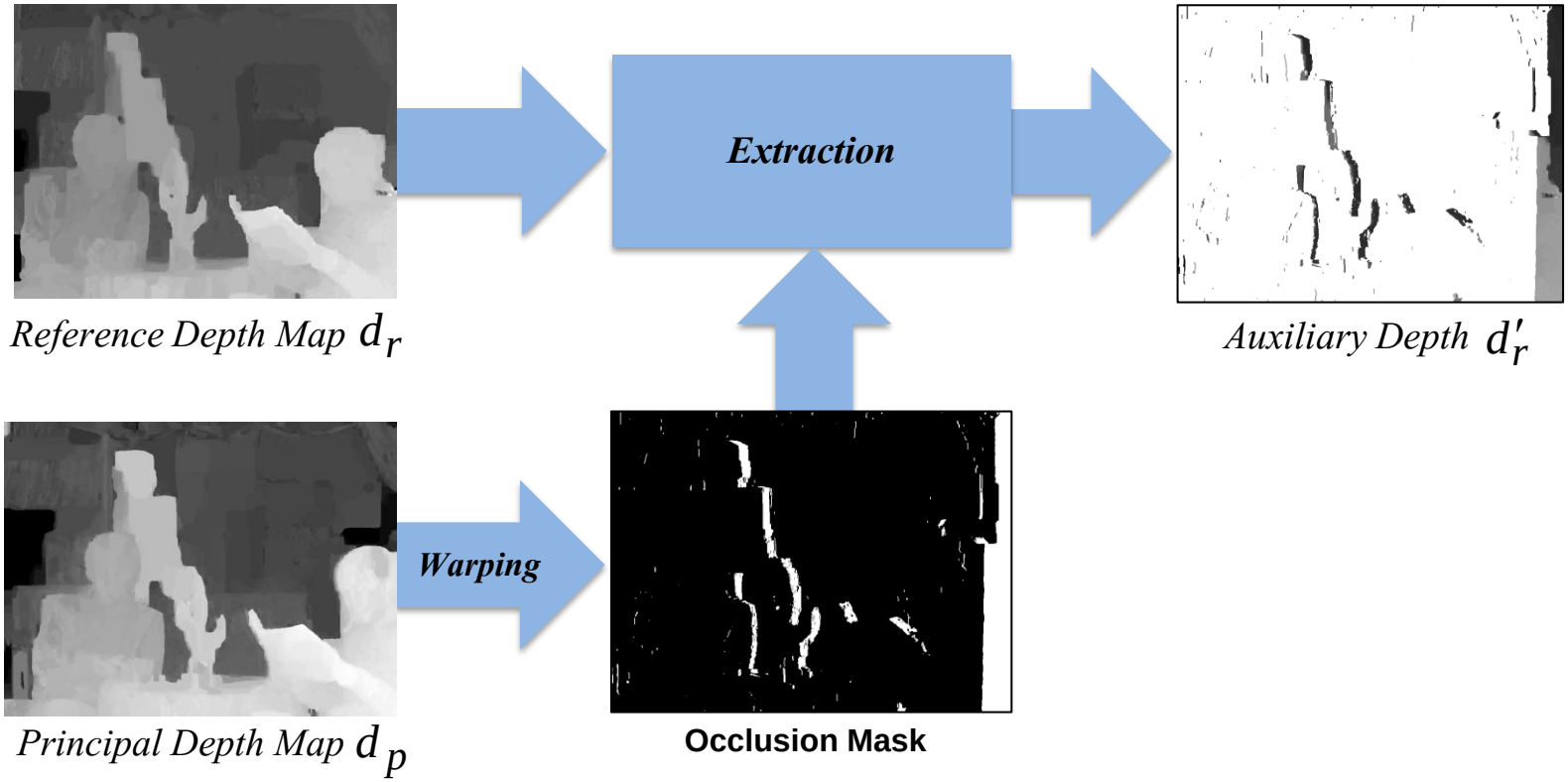
A set of auxiliary depth information at given auxiliary points

Cardinality of the set of auxiliary depth information:

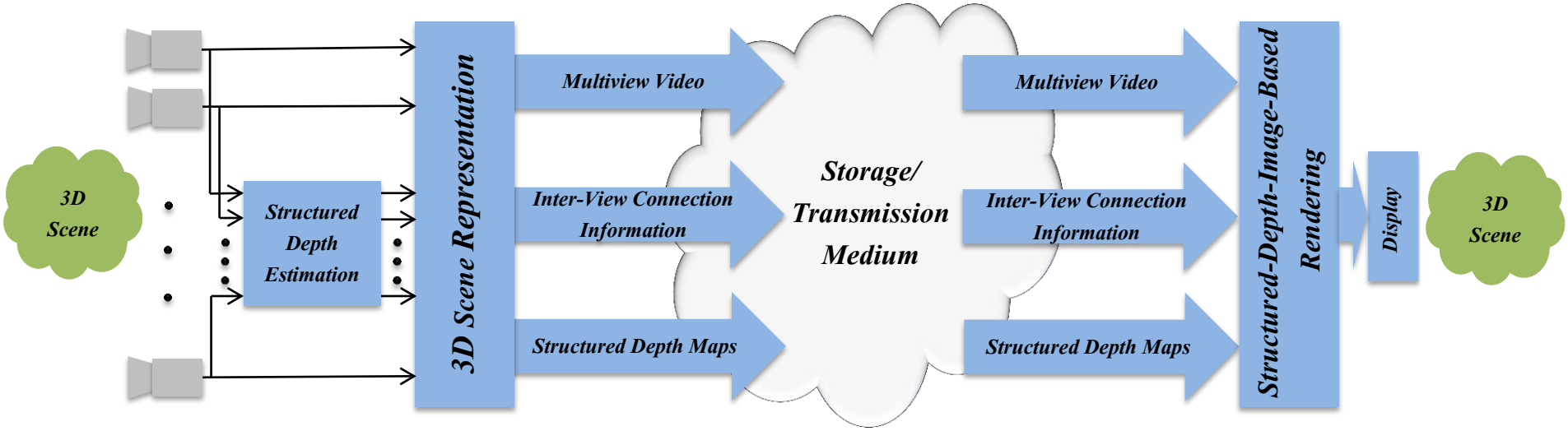
$$|d'| = \begin{cases} (N-1) & \text{if } p=r, \text{ for all reference viewpoint } r, \\ N & \text{if } p \neq r \text{ for all reference viewpoint } r, \end{cases}$$

where, N= total number of reference views used in the depth consistency testing.

Extraction of Auxiliary Depth



Rendering Using Structured Depth Images



Virtual View Rendering

User

$view_{n+2}$

$view_{n+1}$

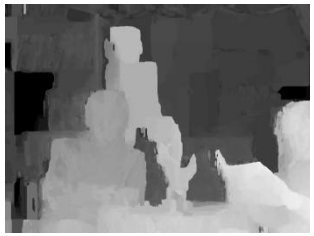
$view_n$

$view_{n-1}$

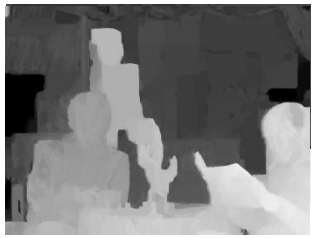
Free Viewpoint TV

Virtual View Rendering

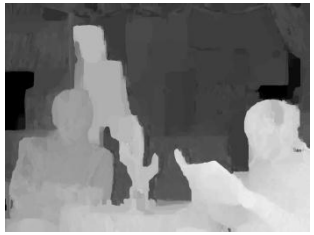
$view_{n+2}$



$view_{n+1} = p$



$view_{n-1}$



Enhanced depth maps resulting from SDI

Virtual View Rendering

$view_{n+2}$

$view_{n+1} = p$

$view_{n-1}$

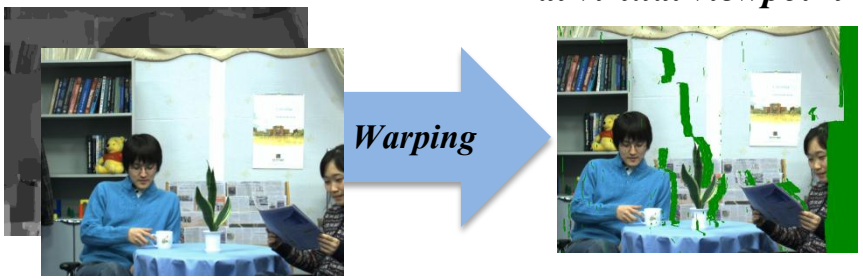
Multiview Texture

Virtual View Rendering

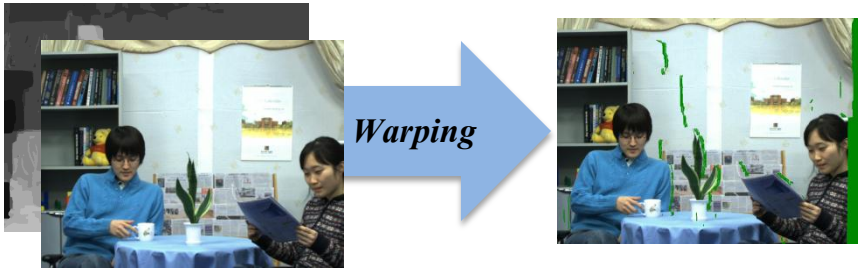
Warped views

at virtual viewpoint n

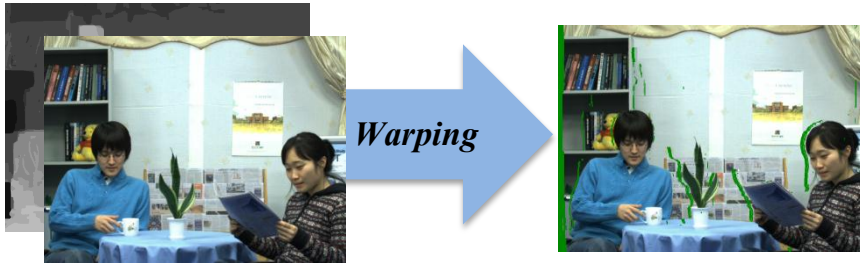
$view_{n+2}$



$view_{n+1} = p$



$view_{n-1}$



Virtual View Rendering

$view_{n+2}$

Warping

Warped views at virtual viewpoint n

$view_{n+1} = p$

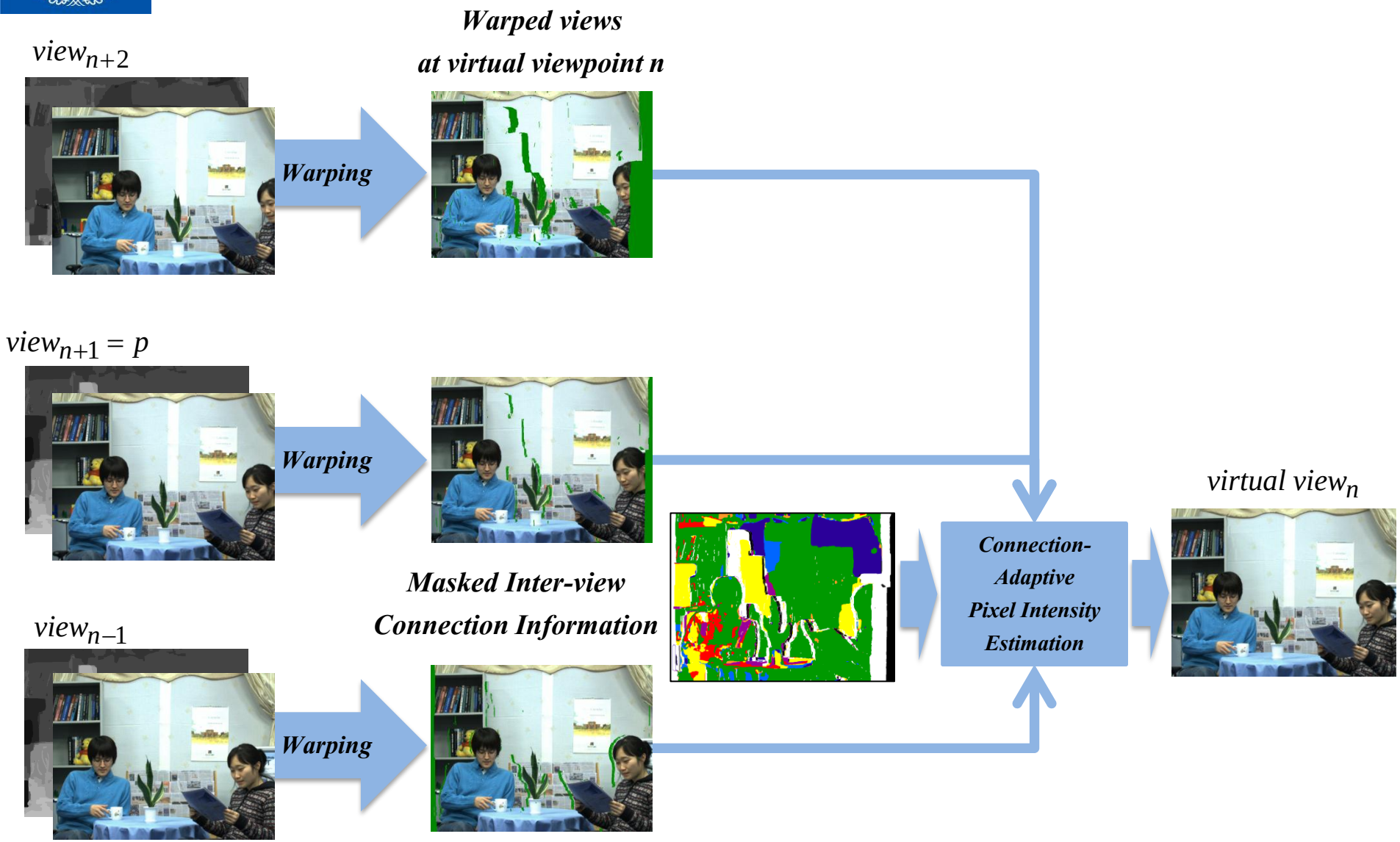
Warping

Masked Inter-view Connection Information

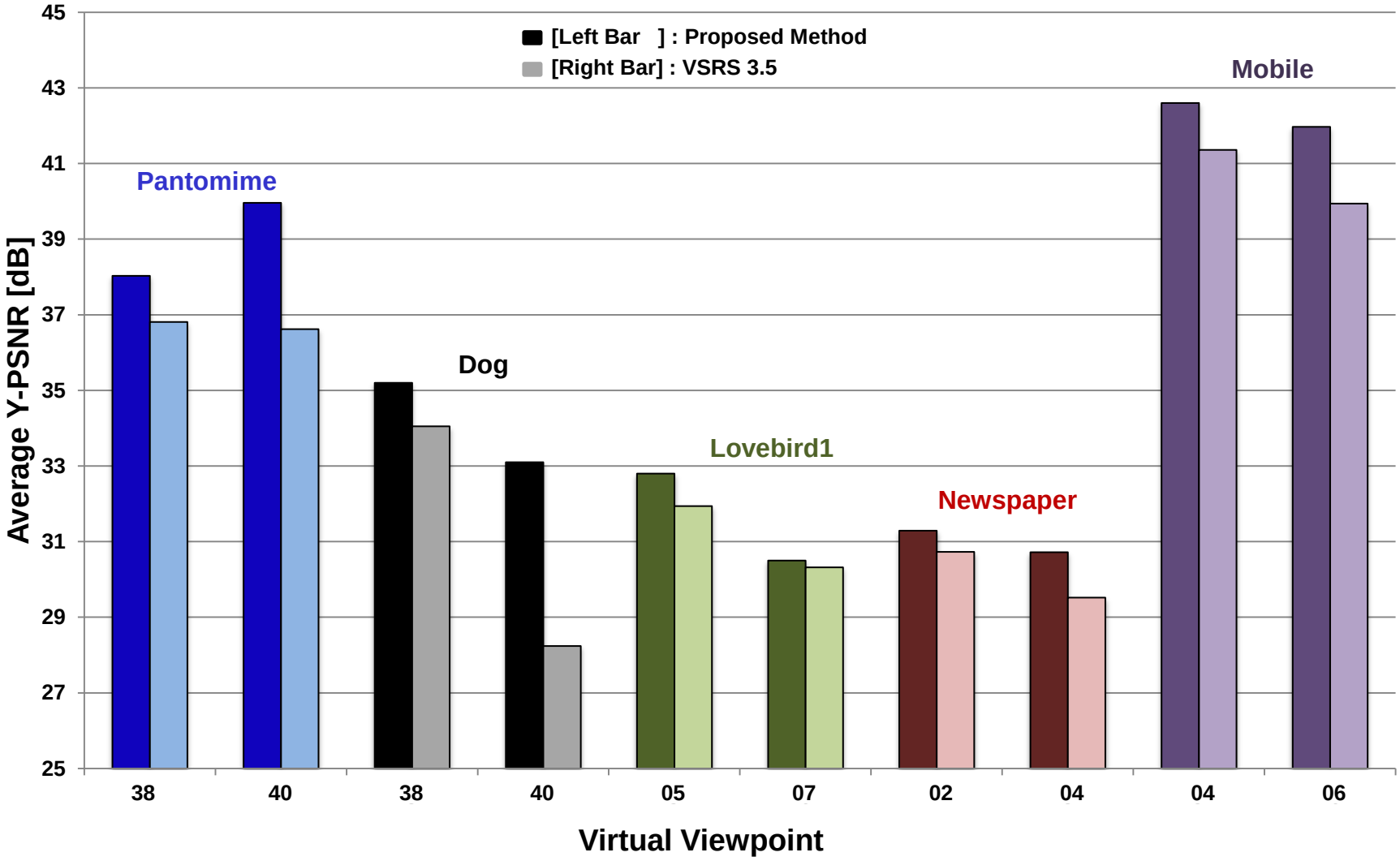
$view_{n-1}$

Warping

Virtual View Rendering



Experimental Results



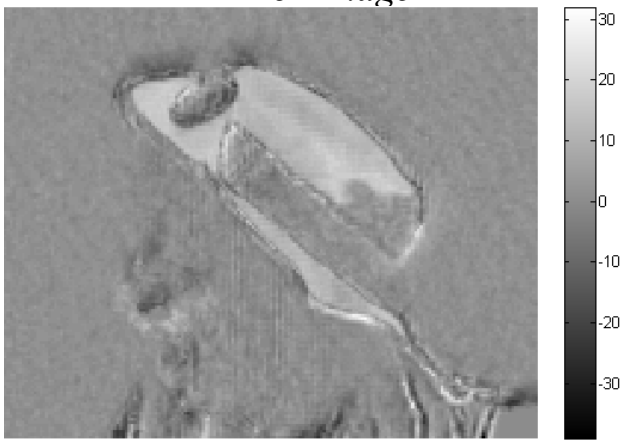
Experimental Results

Original

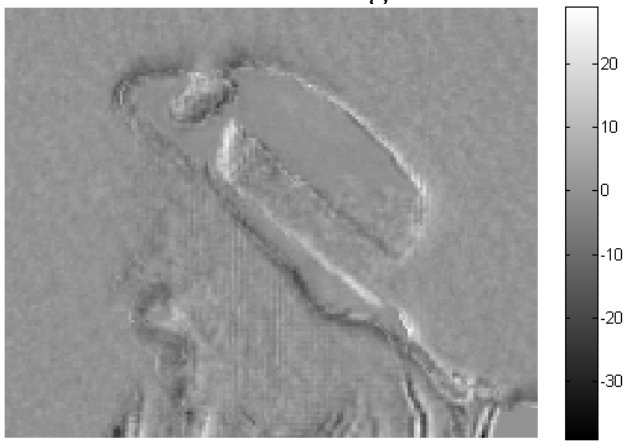
Virtual View by VSRS 3.5

Virtual View by Proposed Method

Error Image



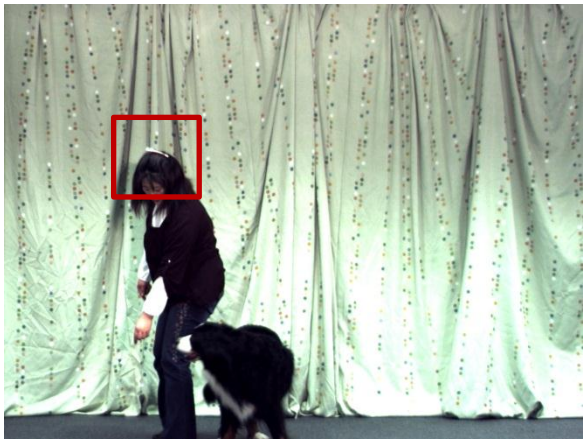
Error Image



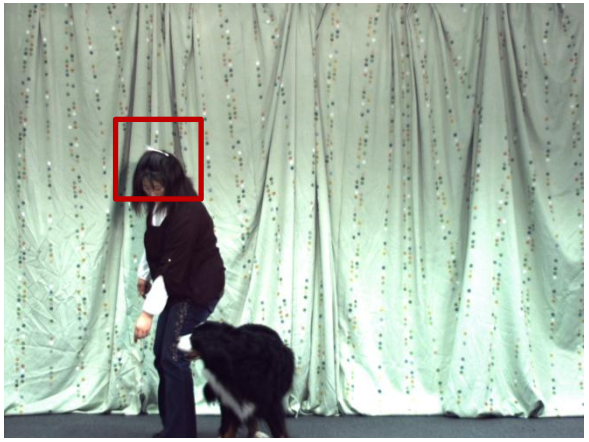
VSRS 3.5 ***Pantomime*** *Proposed Method*

Experimental Results

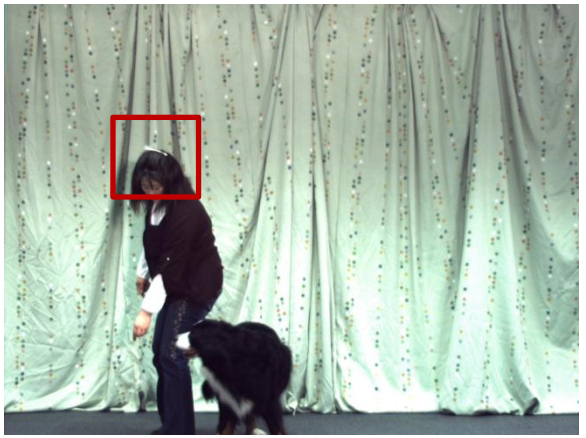
Original



Virtual View by VSRS 3.5



Virtual View by Proposed Method



Original

Virtual View by VSRS 3.5

Virtual View by Proposed Method

Conclusions

- *Depth consistency testing and resulting the inter-view connection information allow to exploit consistency among depth maps*
- *Structured depth addresses the problems of inter-view depth inconsistencies*
- *Structured depth permit an appealing 3D scene representation*
- *Structured depth maps and connection information improves the quality of rendered views*

Thank You