Multiple Active Camera Assignment for High fidelity 3D video

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3D video technology

- An interactive video system
- A viewer can freely choose and change his viewpoint.

Some proposed systems:

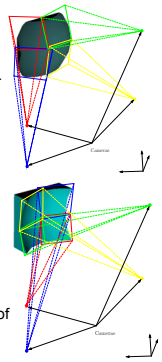
- Virtualized reality [Kanade et al. 1997]
- Real-Time 3D Shape Reconstruction, Dynamic 3D Mesh Deformation, and High Fidelity Visualization for 3D video [T. Matsuyama et al. 2004]
- Free-Viewpoint Video of Human Actors [Carranza et al. 2003]
- A real time system for robust 3d voxel reconstruction of human motions [G. Cheung, T. Kanade, 2000]

3D video technology

- Characteristics:
  - An acting human body
  - A distributed fixed camera system for a real-time observation
- Processing:
  - Off-line : [Kanade et al. 1997] and [Carranza et al. 2003] .
  - A volume intersection method on a PC cluster for real-time 3D shape reconstruction: [T. Matsuyama et al. 2004] and [G. Cheung et al. 2000]
- Key problem to solve (among others):
  - High fidelity : Images of high resolution are needed.

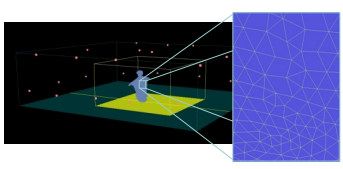
3D video technology

- Fixed Camera system:
  - The entire observable area must be covered.
  - The resolution cannot be increased without affecting the observable area.
- Active camera system:
  - Only the area occupied by the moving object must be covered.
  - The resolution can be increased.
  - Camera control is needed.
- With high resolution cameras:
  - Partial views of the object.
  - One camera needs to be assigned the part of the object to which it has the best visibility.



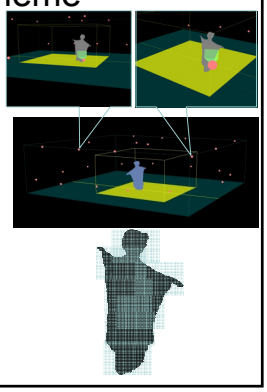
Assignment scheme

- Input 3D shape
  - Polyhedral surface (mesh surface) defined by:
    - A set of facets
    - Each facet is defined by a set of vertices
    - The order of the vertices defines the outward face (outward normal vector)



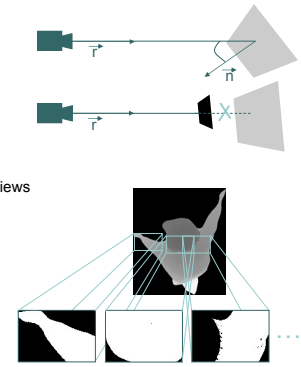
Assignment scheme

- Goal:
  - Assign each camera to a specific part of the object so as to achieve a high visibility of the whole surface
- How:
  1. Project the 3D surface to the panoramic plan of each camera
  2. Evaluate the different orientations of each camera: Each orientation corresponds to a window in the image plane.
  3. Seek for the best assignment between the cameras and the windows that maximize the global visibility



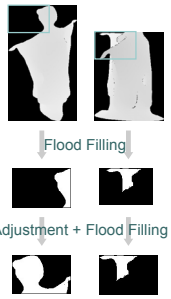
Assignment scheme

- Constraints
  - Visibility
  - Accessibility
  - Connectivity
  - Distance : from the camera
  - Field of view
  - 3D reconstruction : At least 2 views toward each point



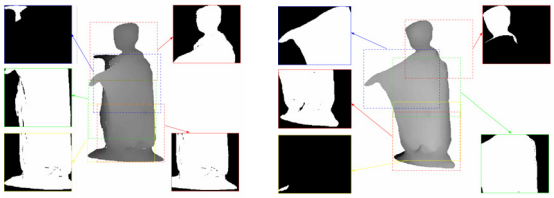
Assignment scheme

- Windowing scheme
  - **Goal :**
    - To define for one camera the set of possible orientations.
    - To select for one orientation the set of facets to be involved in the visibility evaluation is selected.
  - **How:**
    - Gradually splitting the panoramic image into several windows based on the segmentation of depth image.



Assignment scheme

- Windowing scheme



Assignment scheme

- Visibility quantification
  - Facet-wise level
  - Local level
  - Global visibility

$V(f,c)=|\vec{f}.\vec{n}|=|\cos(\alpha)|;\ \vec{f},\vec{n}$ normalized

(Facet f, Camera c)

$$L(c,w)=\frac{\bar{D}(c,w)}{\bar{S}(c,w)}\cdot\sum_{f\in Vp(c,w)}\frac{V(c,f).S(f)}{D(c,f)}$$

$$\bar{D}(c,w)=\frac{\sum_{f\in Vp(c,w)}(D(c,f))}{cpt_{c,w}}$$

$$\bar{S}(c,w)=\frac{\sum_{f\in Vp(c,w)}(S(f))}{cpt_{c,w}}$$

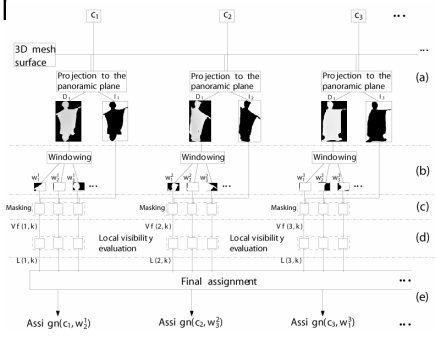
S (f) : The surface area of facet f
V p(c, w) (resp. , cpt(c, w)): The set (resp. the count) of facets visible from c and corresponding to the window w
D(f, c) : The mean distance of the facet i from j.

$$G=\sum_{c,w}L(c,w)$$

Assignment scheme

- Assignment algorithm
  - **Goal:**
    - Assign each camera to one of its respective windows so as to achieve a high global visibility.
  - **How:**
    - First, the camera and its window having the highest visibility are sought among all cameras and their respective windows.
    - After assigning the camera to the window, the facets that have been selected twice are deleted from the 3D surface, and the visibility of all couples (camera, window) comprising the deleted facets are updated accordingly.
    - This procedure is continued until all facets have been visited.

Assignment scheme



System initialization

- Goal:
  - Given a target position, set the initial camera set-up.
  - Thereafter, the assignment scheme can be processed.
- How:
  - Model based camera planning using the Multiple camera assignment scheme.

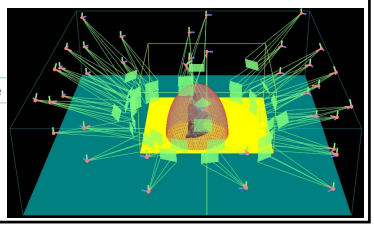
Get object position

↓

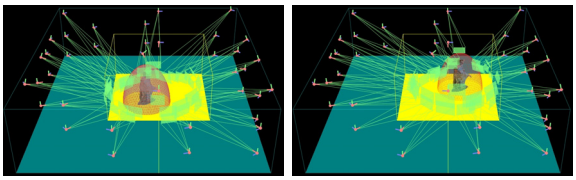
Generate a semi-spherical surface

↓

Apply the assignment scheme

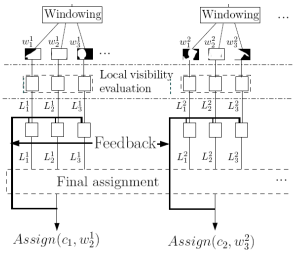


System initialization



Temporal extension

- Goal:
  - The presented assignment scheme is executed at each frame independently.
  - Temporally extend this scheme while optimizing the camera movement
- How:
  - Infer the assignment by the last state of the camera system.
  - The local visibility for each camera is updated using the last camera orientation.



$$L'(c,w) = \lambda \cdot L(c,w)$$

Temporal extension

$$\lambda = 1 - \beta(1 - \left|\overrightarrow{R_{c,w}} \cdot \overrightarrow{O_c^{t-1}}\right|)$$

$$L'(c,w) = L(c,w) * \lambda = L(c,w) * (1 - \beta(1 - \left|\overrightarrow{R_{c,w}} \cdot \overrightarrow{O_c^{t-1}}\right|))$$

β : Expresses the importance given by a user to the camera movement optimization

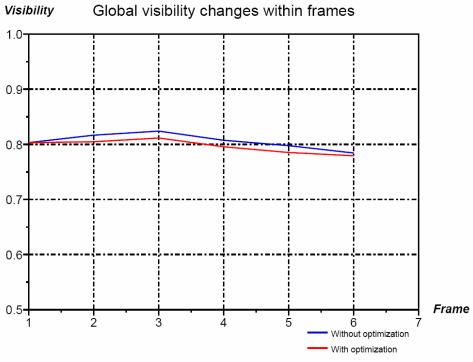
$\beta = 0 \Rightarrow L'(c,w) = L(c,w)$: Optimization is ignored

$\beta = 1 \Rightarrow L'(c,w) = L(c,w) * (\left|\overrightarrow{R_{c,w}} \cdot \overrightarrow{O_c^{t-1}}\right|)$: Optimization is given the highest importance

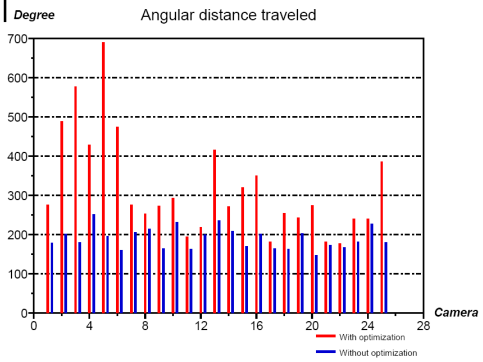
Experimental results

- Environment:
  - 25 cameras
  - Reconstruction: PPP scheme [Matsuyama et al. 2004]
  - Mesh surface
- Considerations
  - The same environment
  - Longer focal lengths
- we applied the assignment process with and without camera movement optimization on a sequence of 6 frames.

Experimental results



Experimental results



Experimental results

	Mean travelled angular distance (º)	Mean global visibility
λ =0	319.172	0.805
λ =1	190.805	0.796
Difference	-128.367=-40,22%	-0.009=-1.12%

A clear optimization of the camera movement has been obtained at the price of a minor loss of visibility.

Conclusion and perspectives

- Conclusion
  - The initialization of the assignment scheme has been presented
  - For a temporal extension, the assignment in inferred by the last state of the camera system.
- Future works
  - Real time implementation