Shape Modeling 1

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Introduction

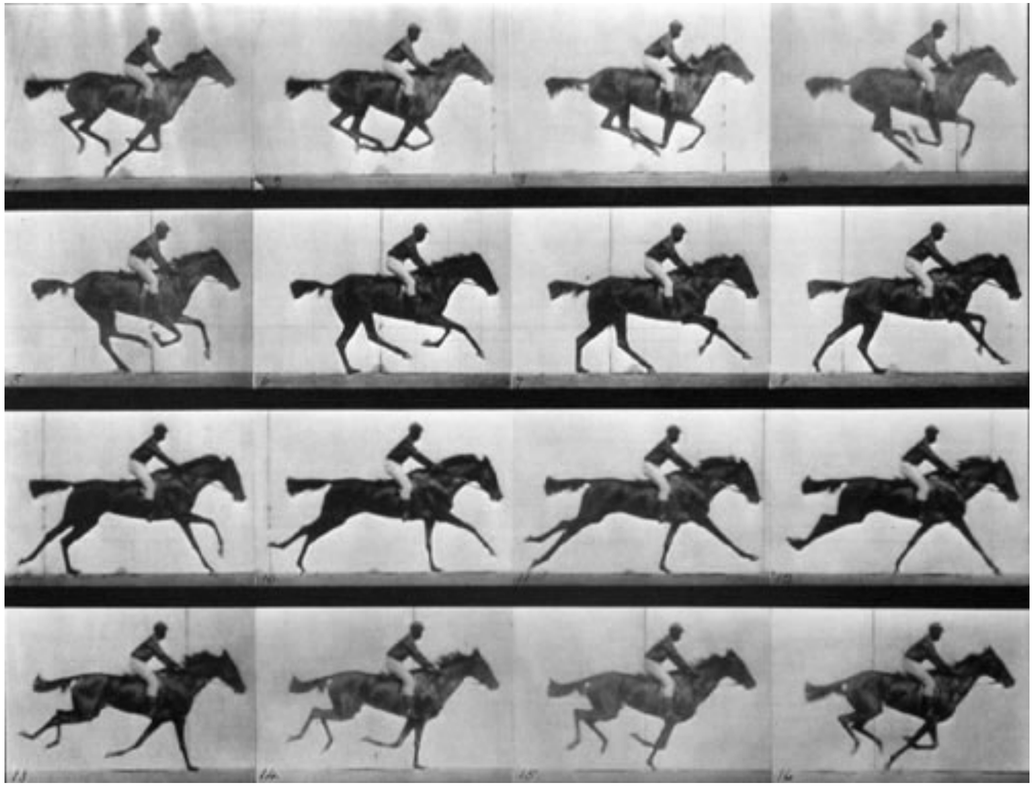
- [Computer] Vision: Using visual cues to infer information on the real environment.

- 4D Scene Modeling: analysis of 3D scenes composed of real objects, possibly moving and deforming
  1. Shape Modeling: Static->3D, dynamic->4D (3D+t).
  2. Motion Modeling.
  3. Motion Semantic Modeling (e.g. modeling actions, activities).

- Applications :
  Contents Production: TV3D, Virtual/Augmented Reality, Interactions.
  Intelligent Environments: smart rooms,
  Surveillance. Medical applications. Etc.

Introduction

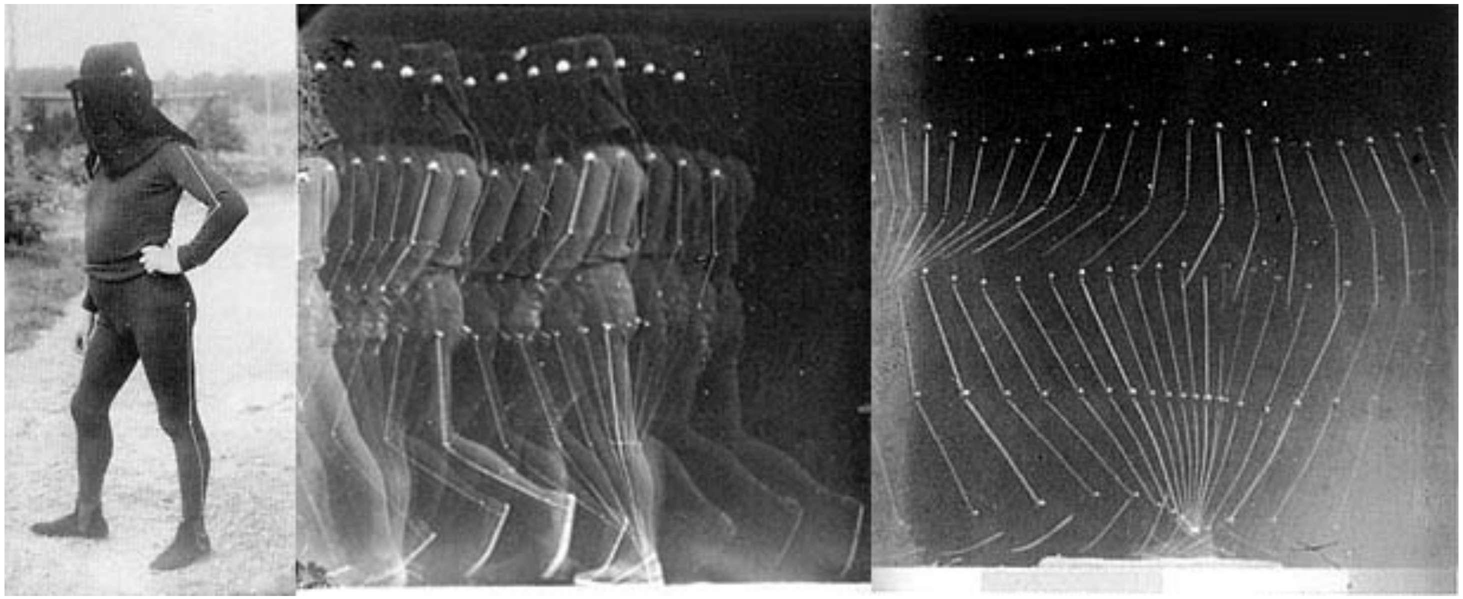
Early use of images to infer information on moving shapes



Eadweard Muybridge (1878): *Animal locomotion.*

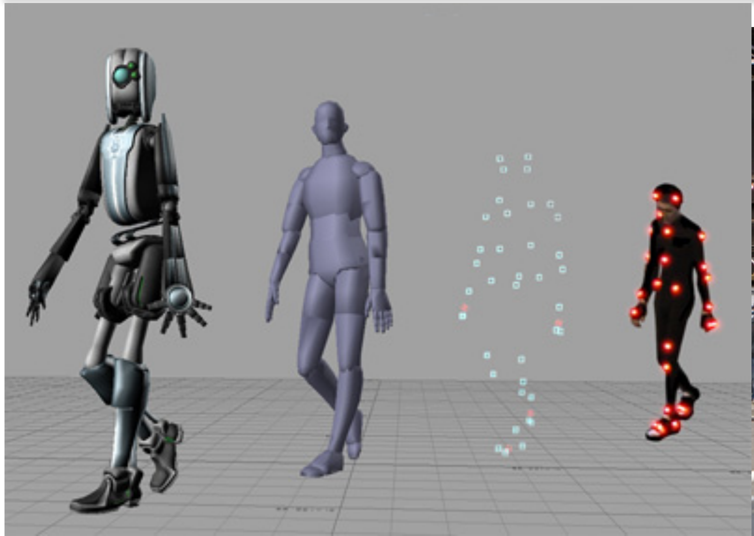
Introduction

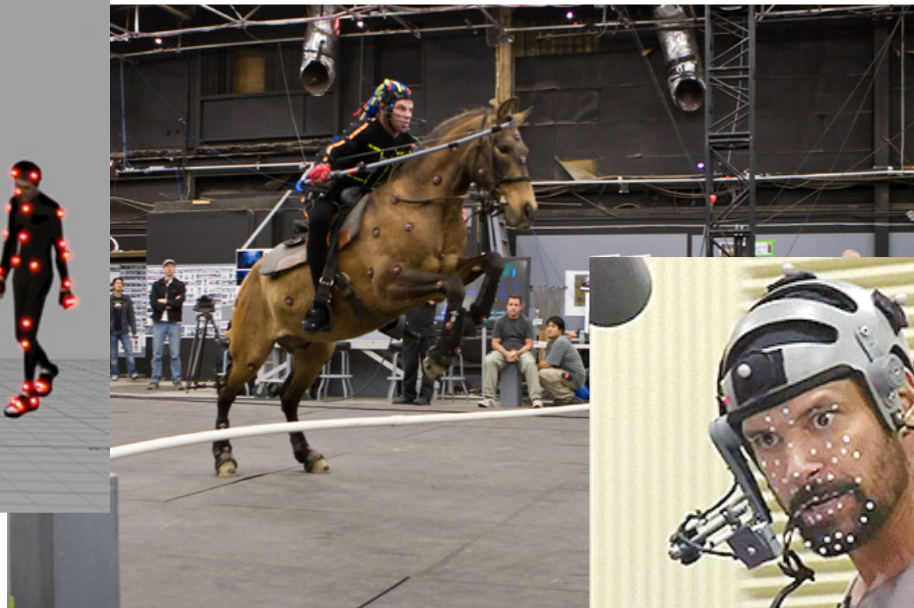
Early use of images to infer information on moving shapes



Etienne Jules Marey (1883): *Chronophotographie géométrique, man locomotion.*

Introduction



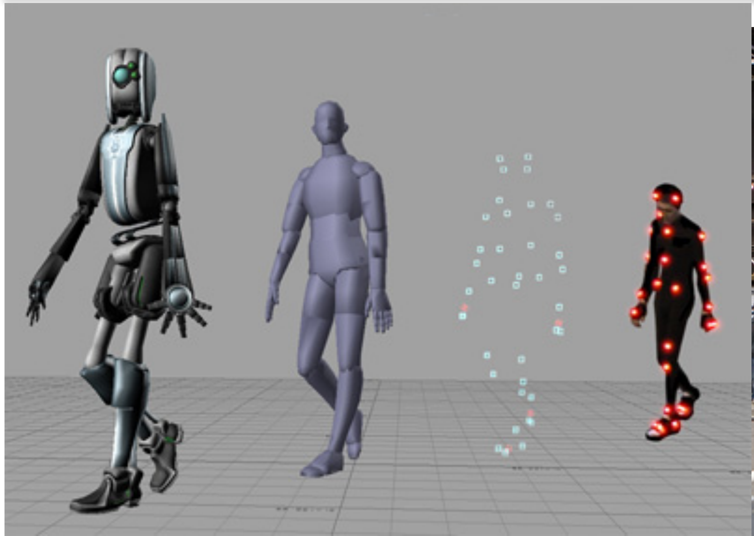


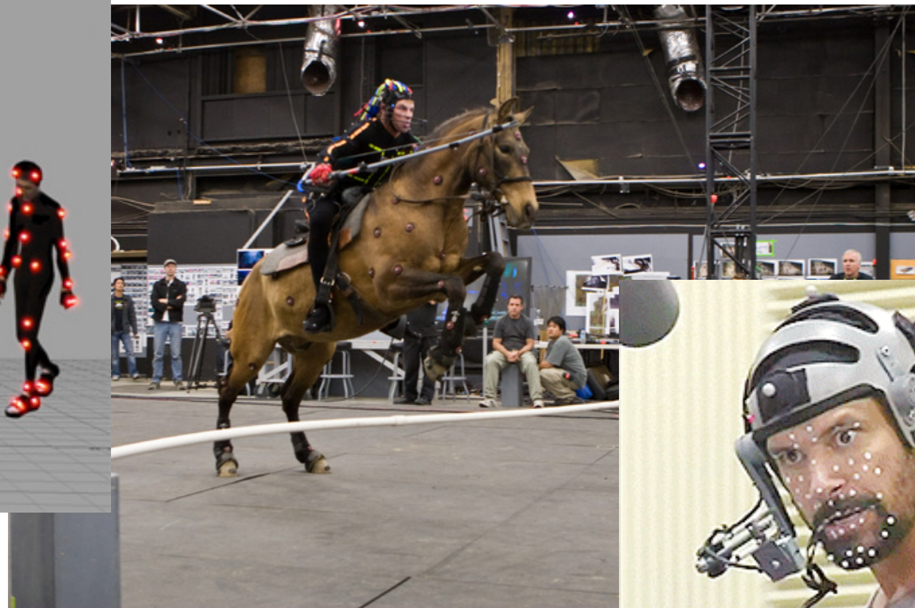
Avatar

The Hobbit

Motion Capture systems using markers:

Introduction





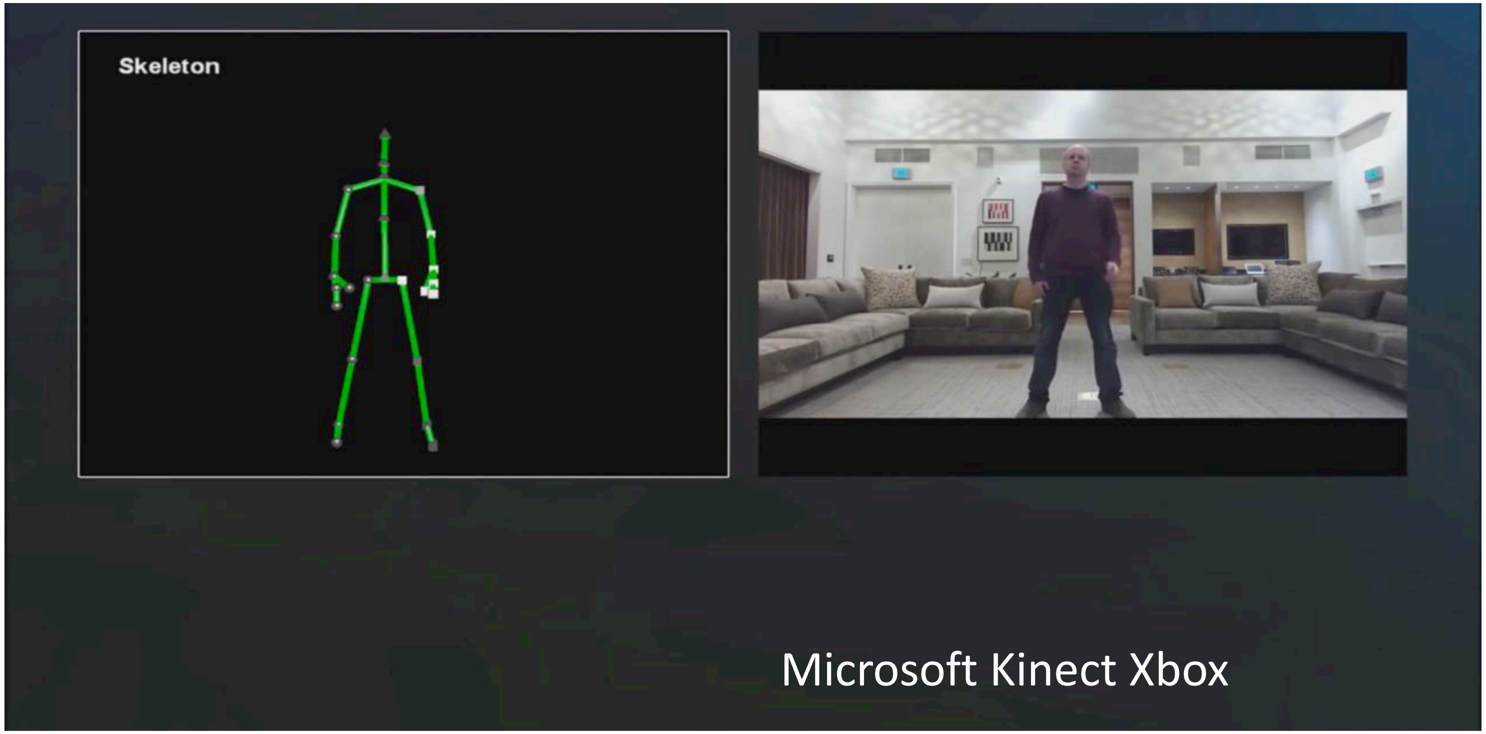
Avatar

The Hobbit

Motion Capture systems using markers:

- Markers provide sparse motion information;
- No information on shapes or their appearances.

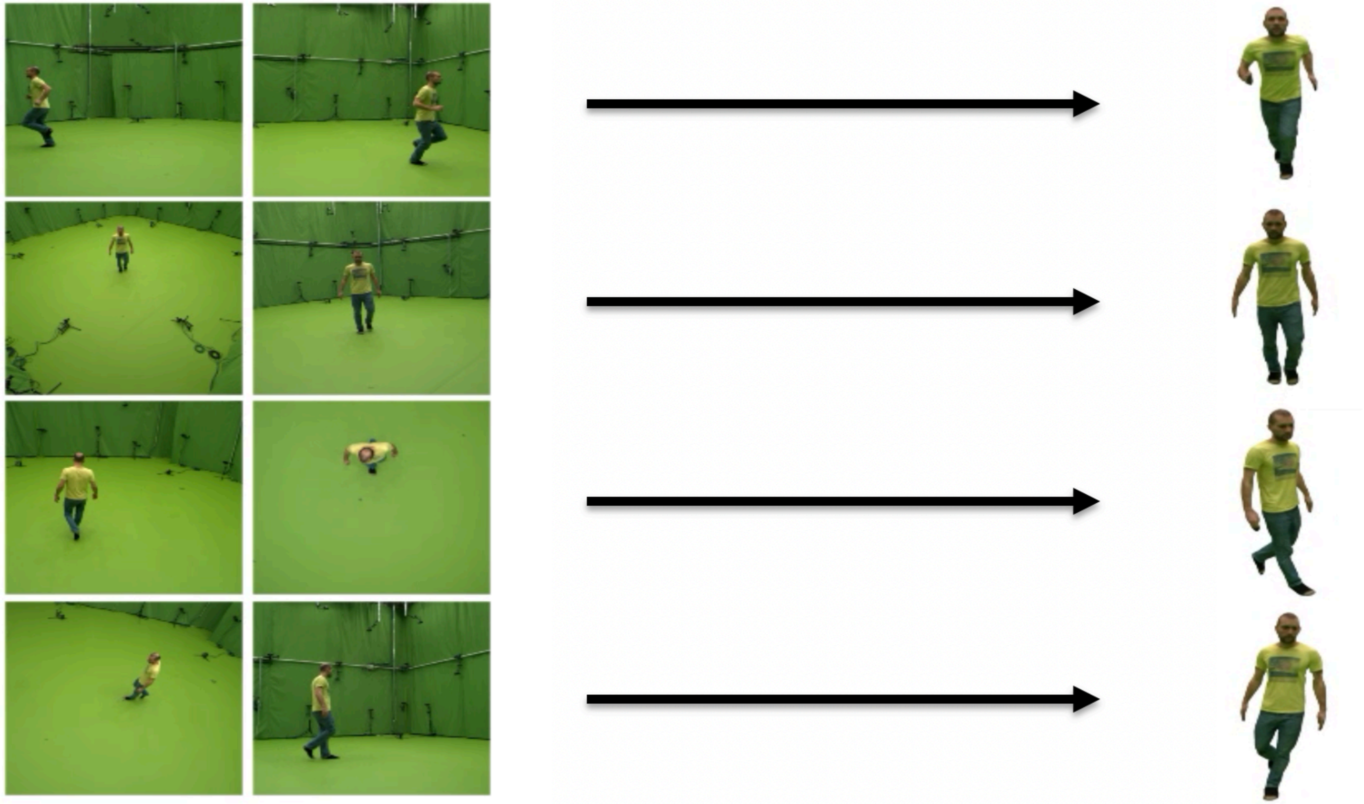
Introduction



- Observations: depth fields;
- Outputs: skeleton poses, orientations, etc.

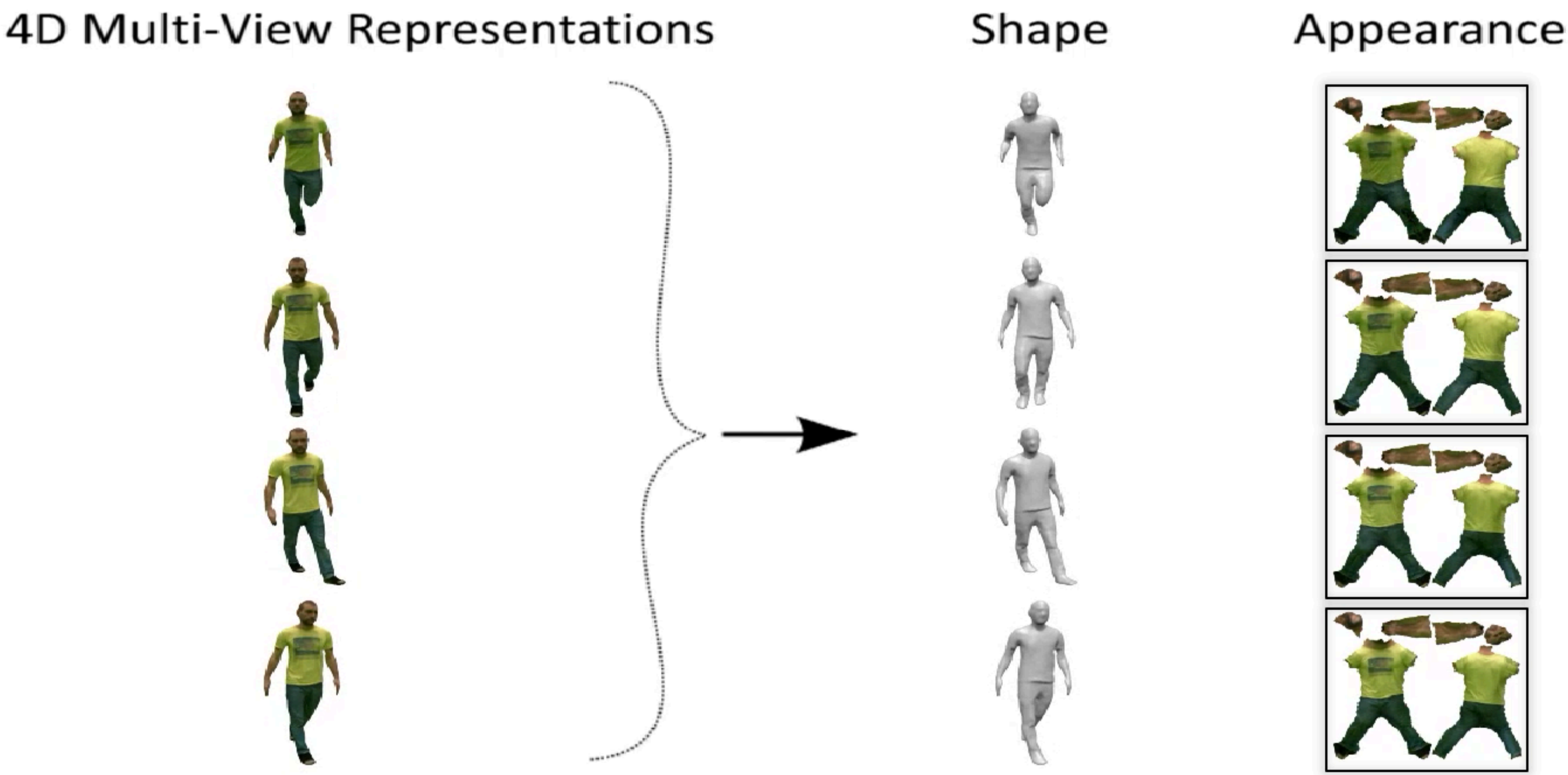
Introduction

Input: Multi-View Videos **Output:** 4D Multi-View Representations



Instead of sparse marker locations or depth fields, multi-view systems can consider full color image information to produce 4D models.

Introduction



Outline

1. 3D perception, holograms and 4D models.
2. Applications.
3. Multi-View platforms.
4. Shape recovery: basics.

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3D Perception

- Our environment is 3D.
- Visual perception uses 2D projections of 3D scenes, either on the retina or in images.
- These 2D projections differ with respect to the viewpoint.

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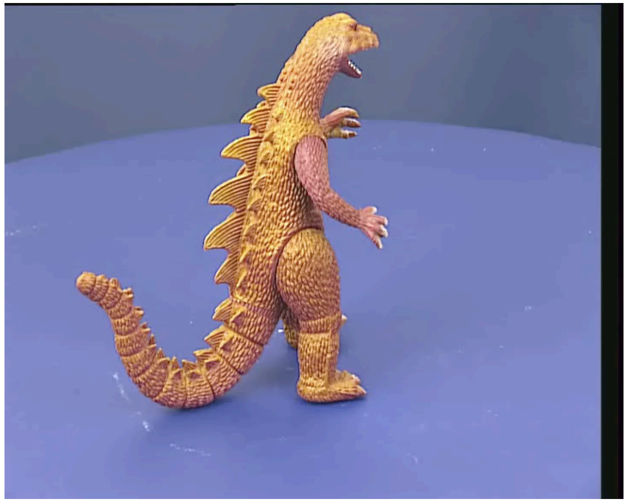
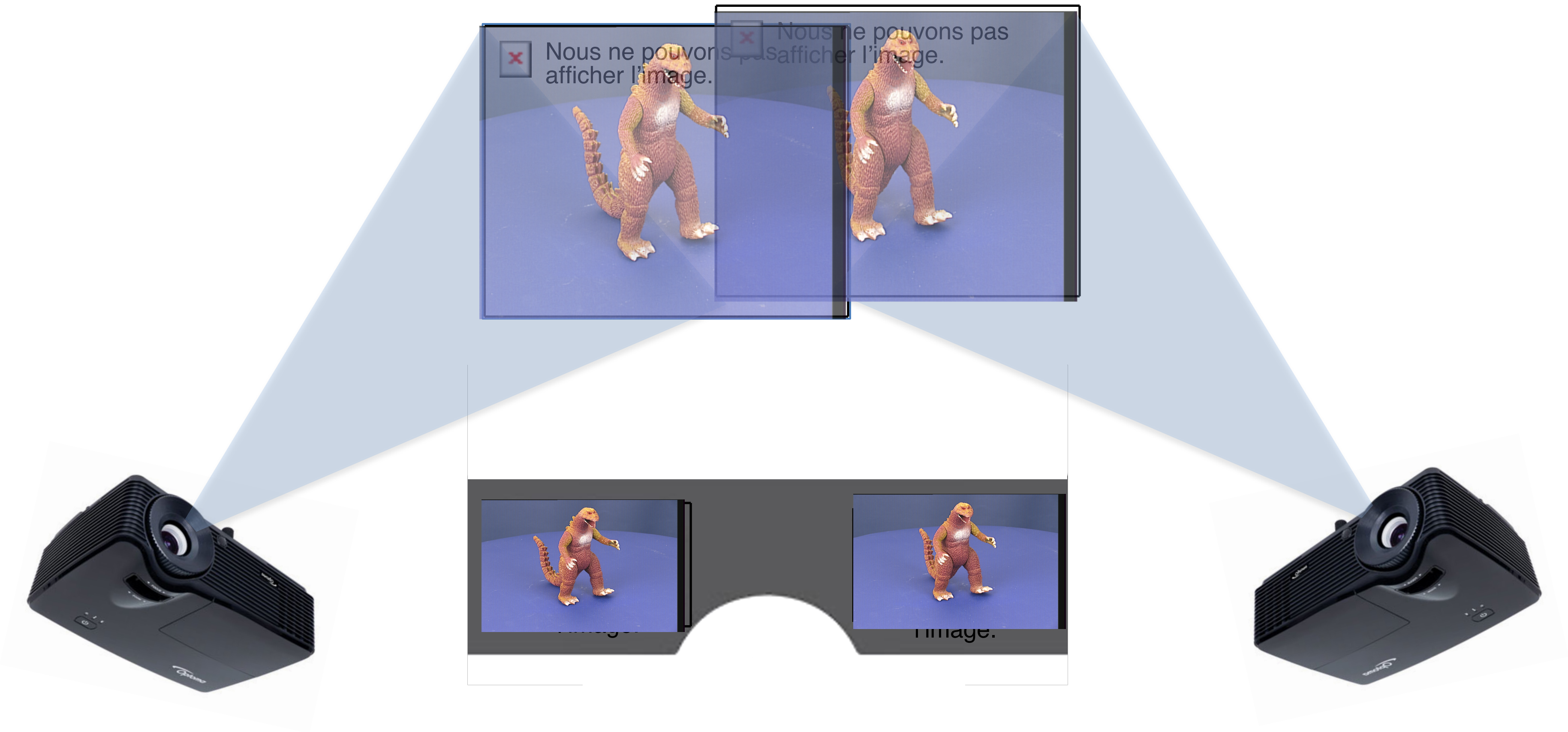


3D Perception

- Our environment is 3D.
- Visual perception uses 2D projections of 3D scenes, either on the retina or in images.
- These 2D projections differ with respect to the viewpoint.

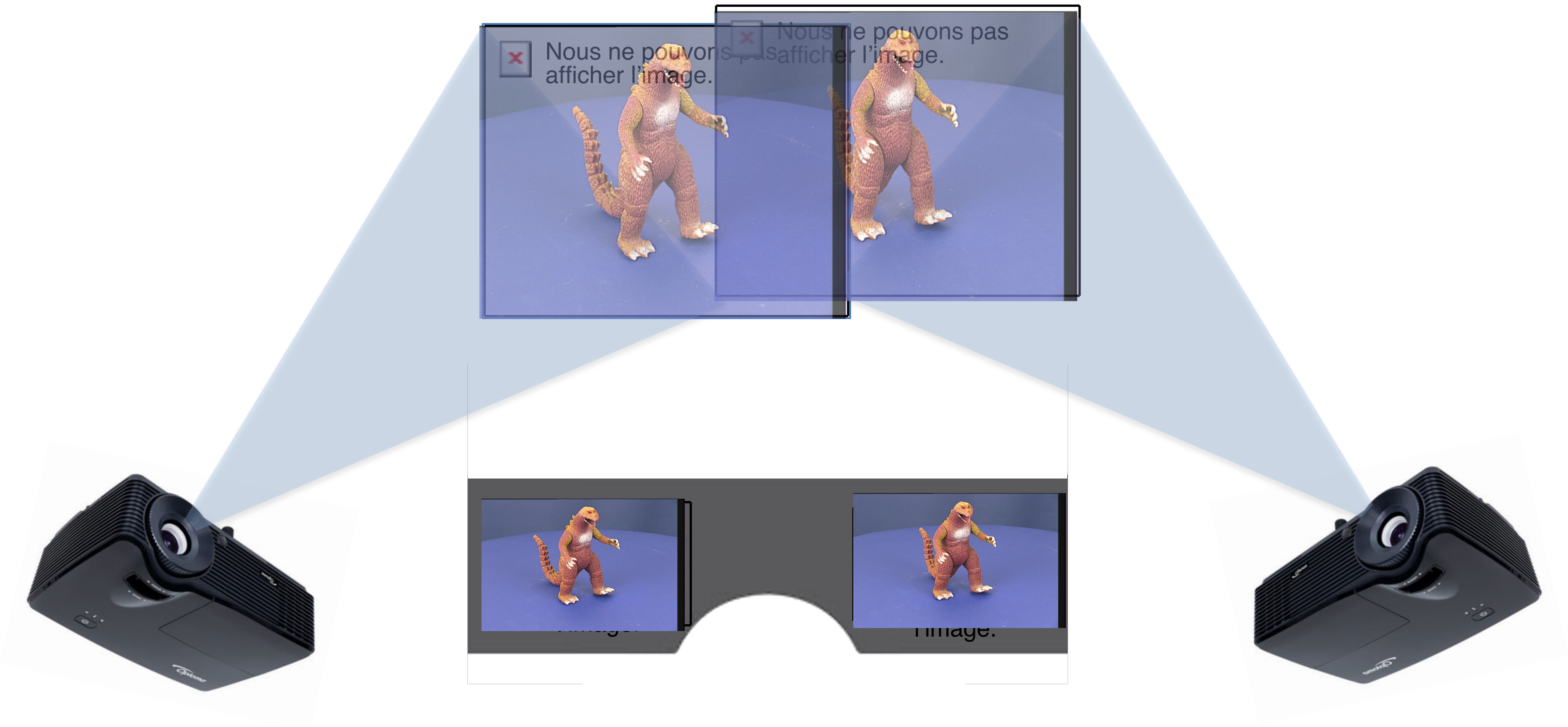
- We “build” 3D using these 2D differences (parallax).

Relief Perception



Relief Perception : 2 closed viewpoints.

Relief Perception



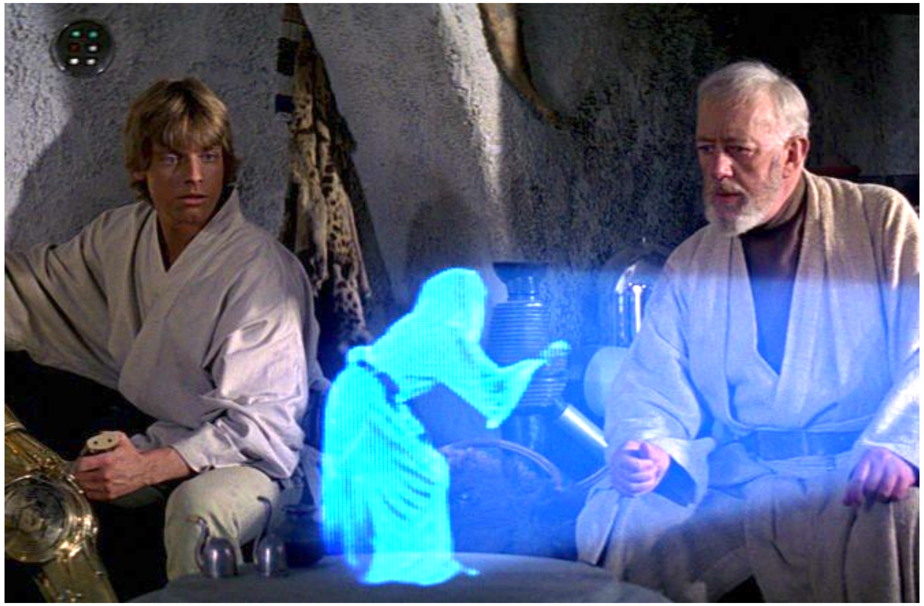
This is a partial 3D perception, i.e. with a fixed position.

And holograms ?

Hologram-production.org

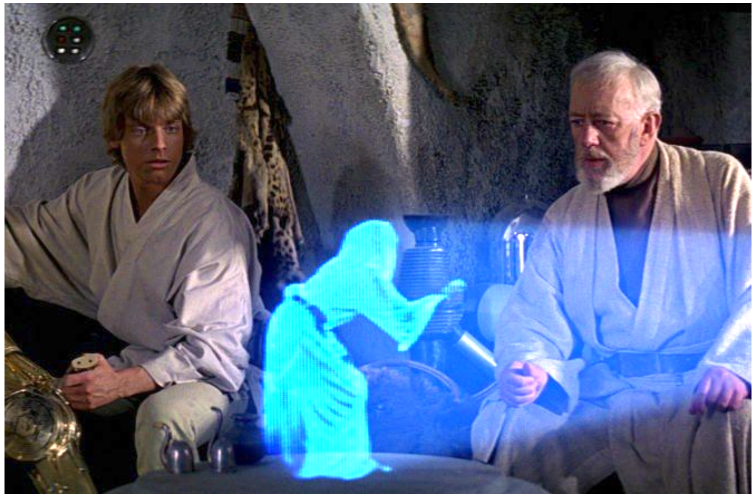
Historically (in the 60s) it is a relief image.

And holograms ?



The term has been extended to 3D video projections, following startreck and starwars in the 70s.

And holograms ?

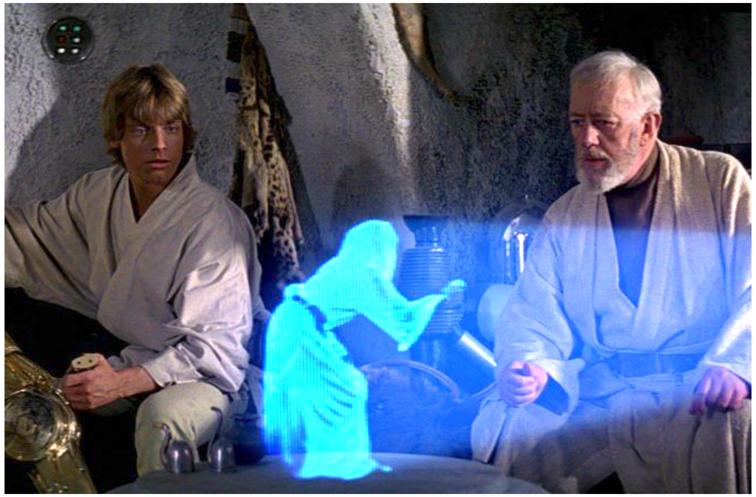


The term has been extended to 3D video projections, following startreck and starwars in the 70s

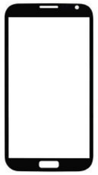
A 3D video can be observed from any viewpoint (free viewpoint ability).

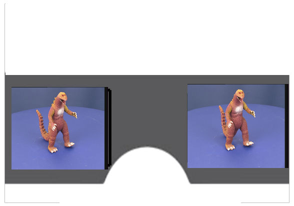
The 3D video is the **content**, we say volumetric video or 4D model.

And holograms ?



Visualisation (by projection) of a 4D model can be performed in:

2D: 

Relief (stereo or more) :  

3D :  

Outline

1. 3D perception, holograms and 4D models.
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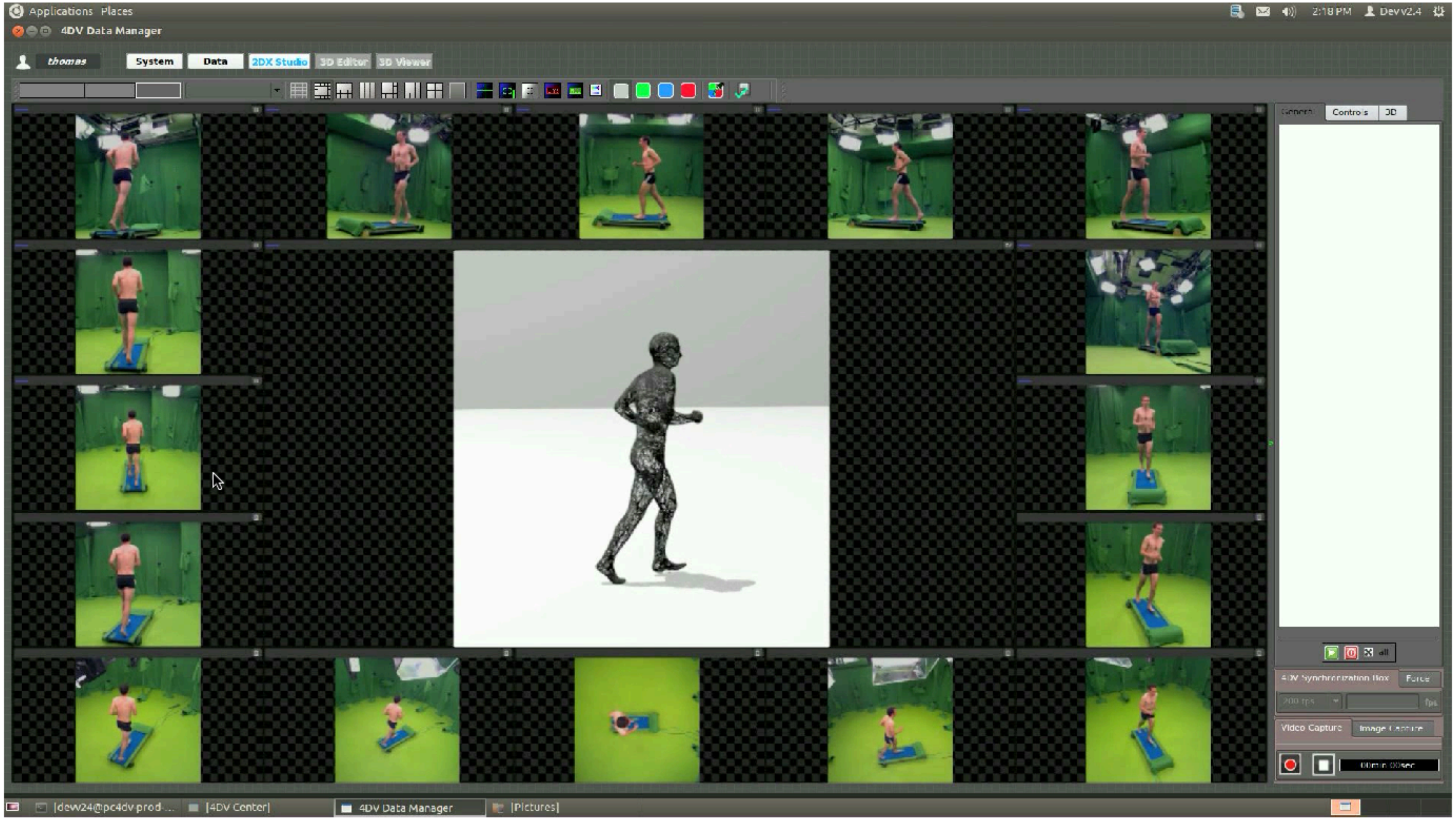
4. Shape recovery: basics.
5. Shape recovery: inside shapes.

Applications

4D Modeling Applications:

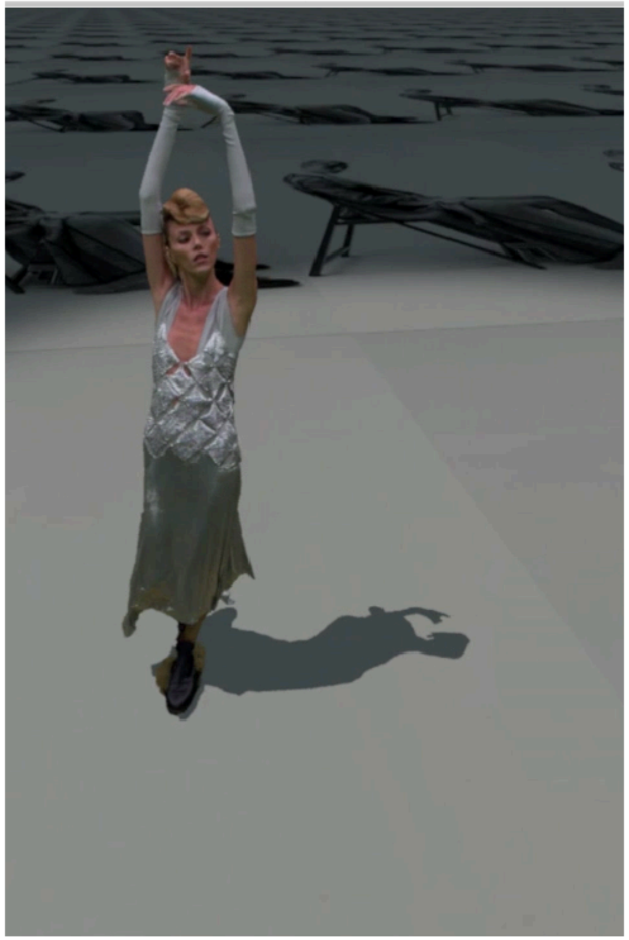
- Media contents.
- Motion Analysis:
  - Sport analysis;
  - Diagnostics in medical applications.
- Interactive and Immersive environments:
  - Gesture interfaces;
  - Games.

Applications



4D Modeling Applications: Media content production (4D View Solutions - startup INRIA)

Applications



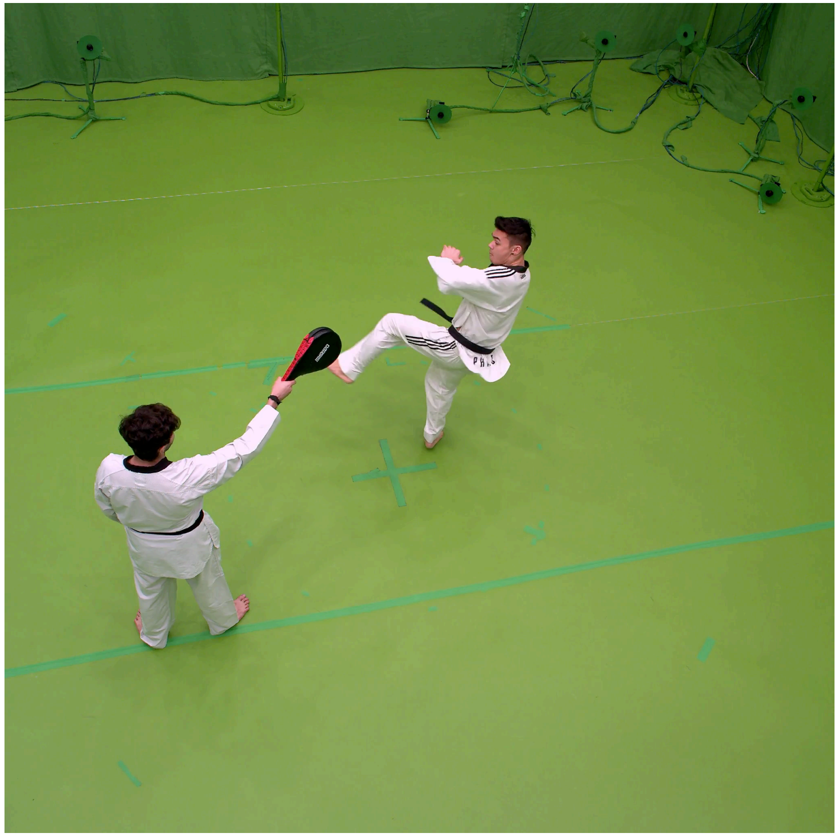
4D Modeling Applications: VR and AR contents (Holooh@Paris)

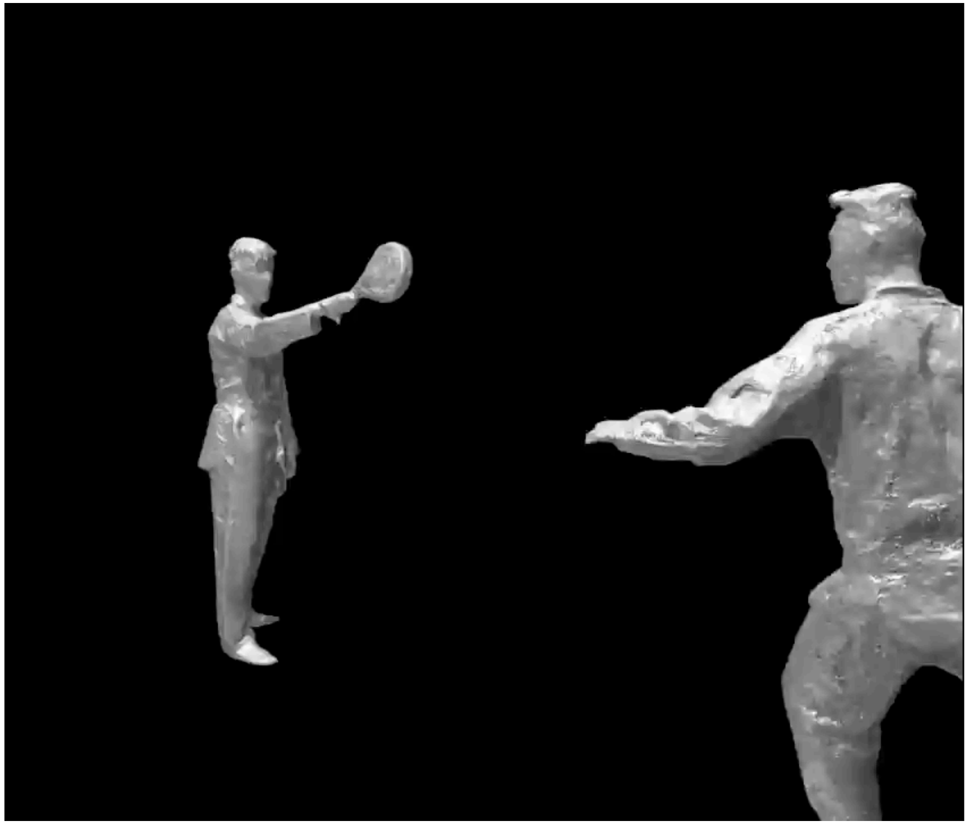
Applications

[INRIA DEMO SIGGRAPH 2009]

4D Modeling Applications: Interactive and Immersive environments.

Applications





Challenges

Some 4D modeling issues:

- Modeling both shapes and appearances of complex scenes:
  - Acquisition issues: camera with different modalities, segmentation;
  - Shapes and appearances: learning over time;
- Recovering robust motion information.
- Modeling and analyzing motions/gaits.
- Animation Synthesis.

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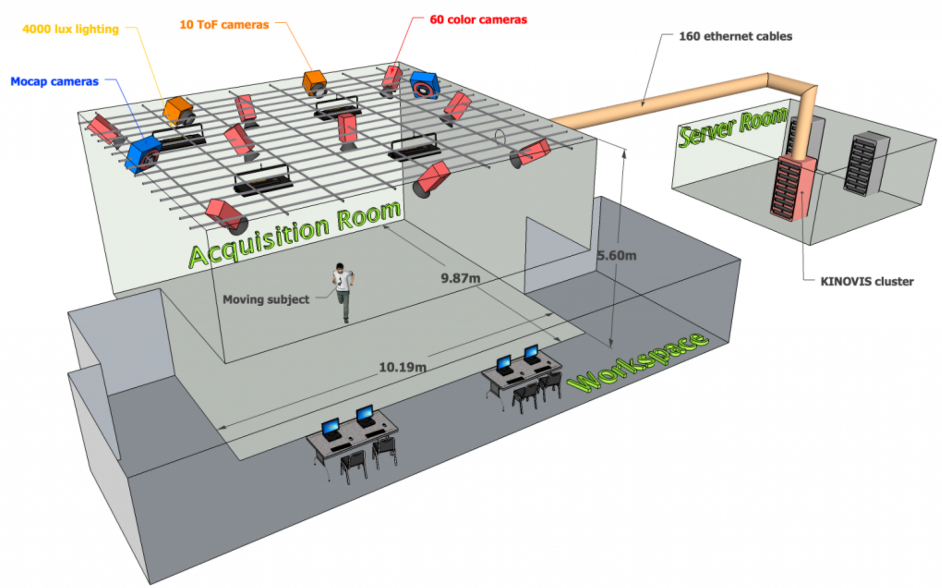
Multi-View Platforms

MPI Tubingen 4D Scanner [Siggraph’15]:

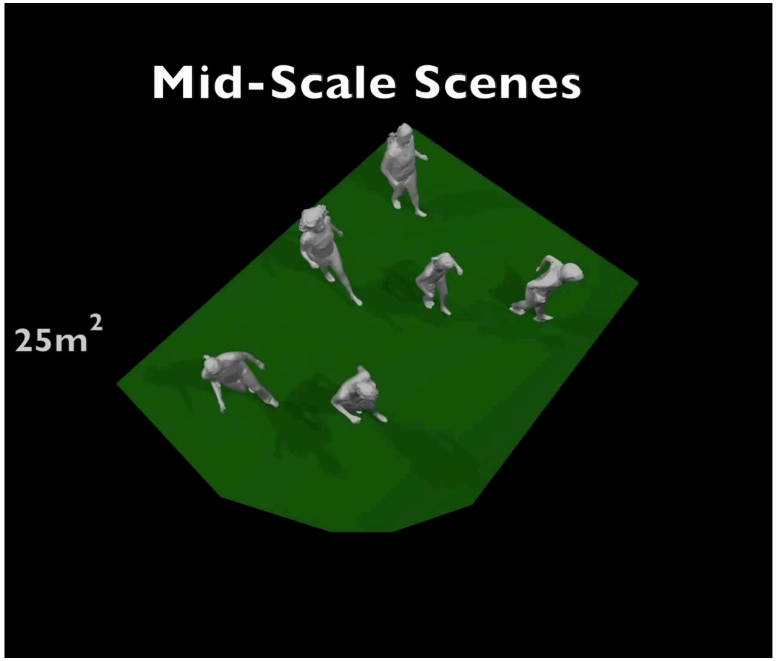
Multi-View Platforms

Multi-View Platforms



Kinovis platform at INRIA Grenoble

Multi-View Platforms



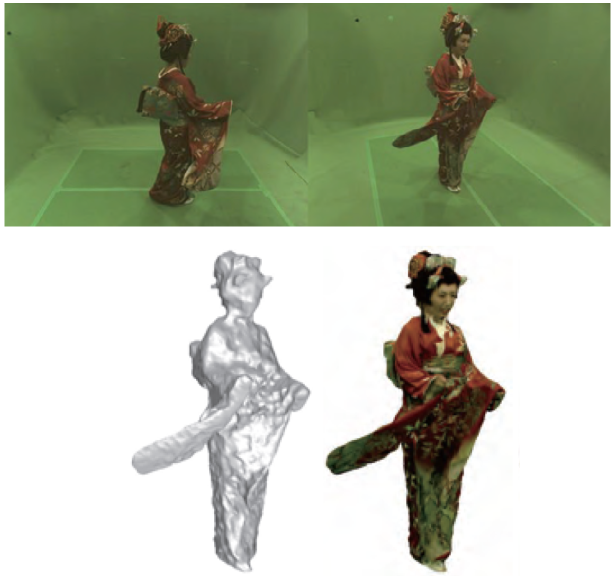
Kinovis platform@inria (64 cameras)

Multi-View Platforms

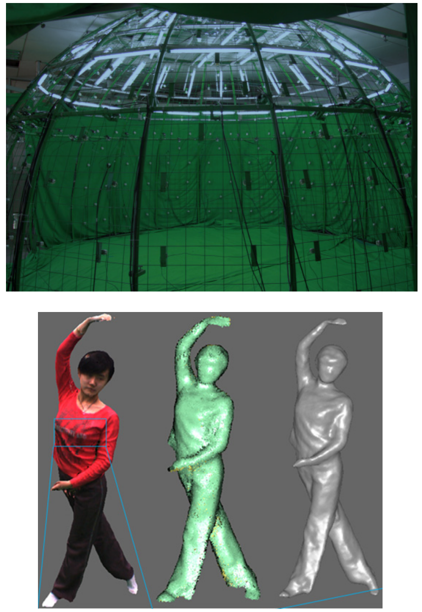
@Microsoft, High-Quality Streamable Free-Viewpoint Video, Siggraph'15
Combined passive and active system

Multi-View Platforms

University of Surrey



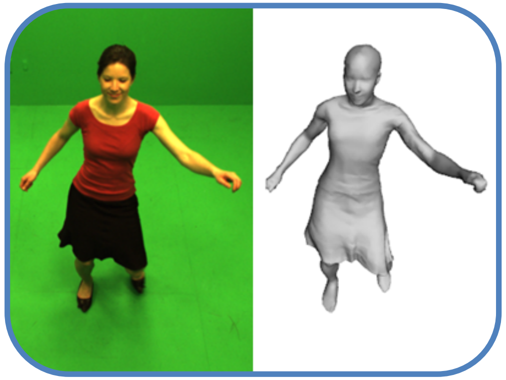
University of Kyoto



University of Tsinghua

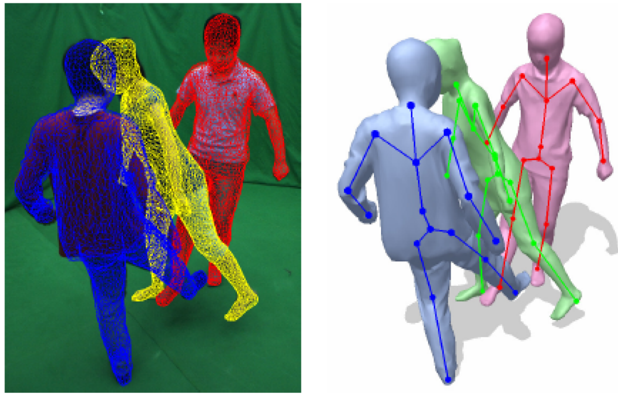
Model free shape estimation

Multi-View Platforms



MIT

MPI Tubingen



MPI Sarrebrucken

Model based shape estimation

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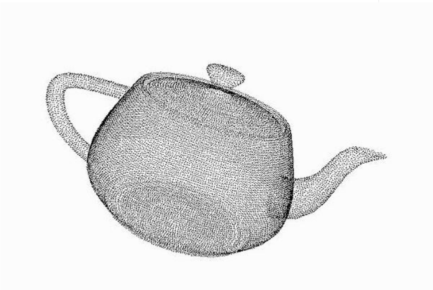
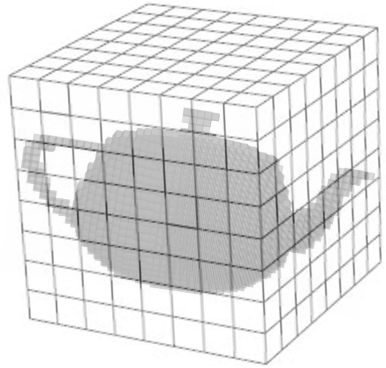
Shape Recovery: Basics

Shape representations: Geometric Models



Point clouds



Voxels

3D Meshes

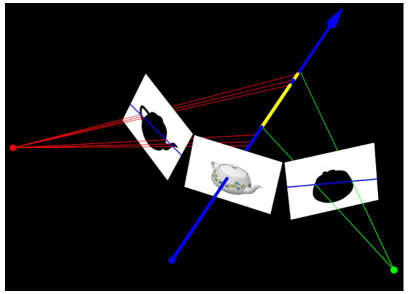
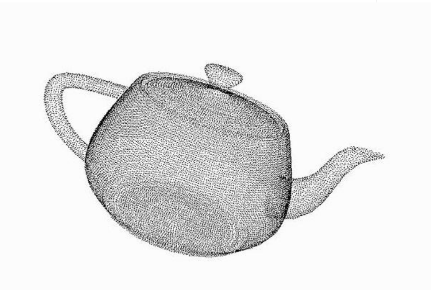


Image Based

Shape Recovery: Basics

Shape representations: Geometric Models



Point clouds

Voxels

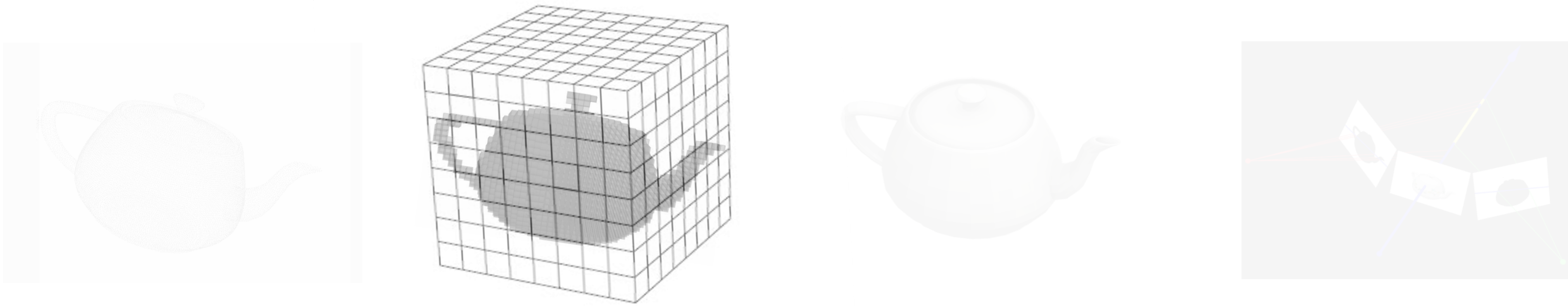
3D Meshes

Image Based

- Simplest representation which is the output of most sensing devices (depth, stereo, etc.)
- Independent point do not encode local or global shape properties, unless equipped with normal information, connectivities, etc.
- Require a point2surface step to get a surface model (usually Poisson based) over which appearances (normals, etc.) can be defined.

Shape Recovery: Basics

Shape representations: Geometric Models



Point clouds | Voxels | 3D Meshes | Image Based

- Model occupancy in 3D -> Volumetric model.
- Simplified representation: easy to manipulate in algorithms.
- Discretization attached to surrounding space not shape: High complexity.
- Require a volume2surface step to get a surface model (usually marching cubes) over which appearances (normals, etc.) can be defined.

Shape Recovery: Basics

Shape representations: Geometric Models

Point clouds | Voxels | 3D Meshes | Image Based

- Surface model, highly standard (handled by most 3D engines).
- Appearance easy to model: e.g. textures.
- Discretization attached to shape: complexity attached to shape as well.
- Irregular Data Grid: a mesh is a graph with nodes (vertices), edges (between neighboring vertices), and faces (often triangles).

Shape Recovery: Basics

Shape representations: Geometric Models

Point clouds

Voxels

3D Meshes

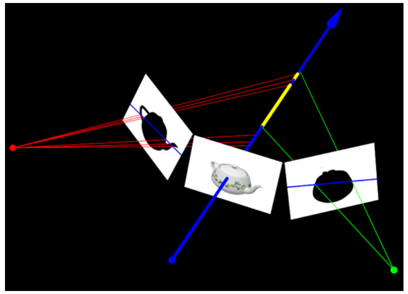
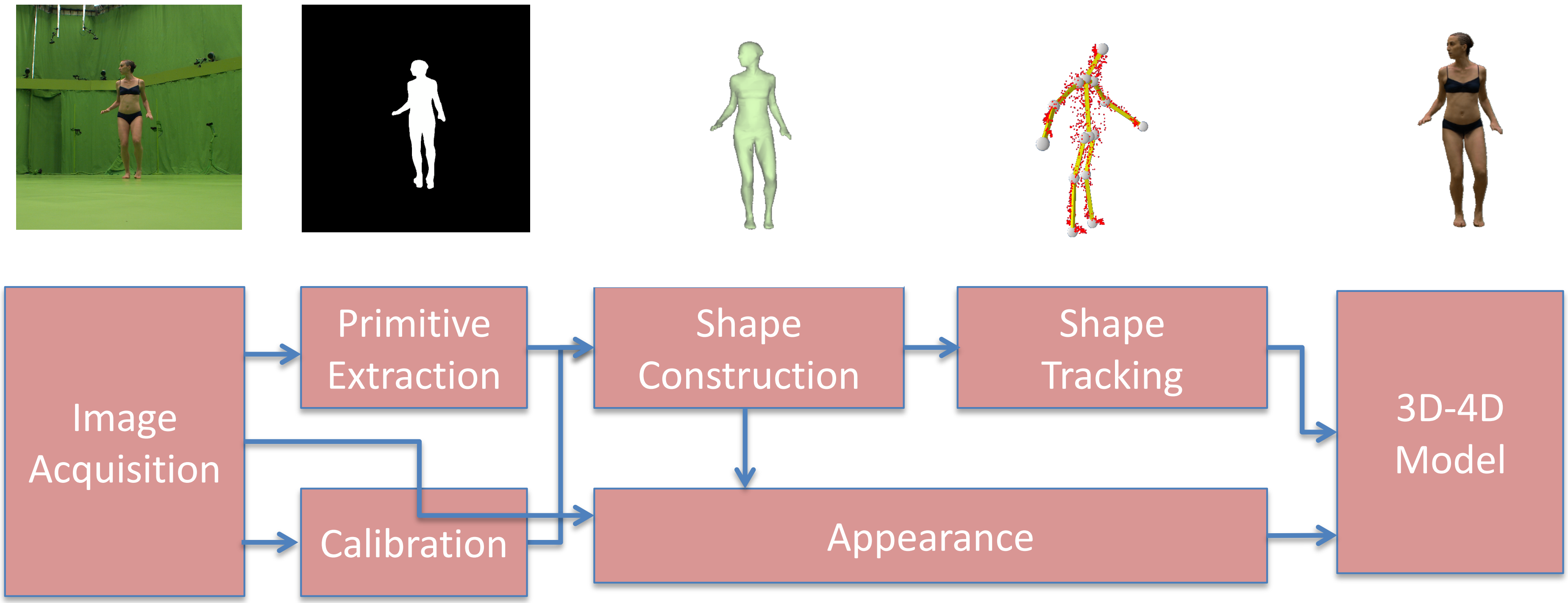


Image Based

- Image Based Rendering (IBR): No explicit 3D model. The model is composed of a set of images (calibrated) from which any new image is directly generated.
- Appearance implicitly handled by the model.
- Discretization attached to images.
- Parallax (Self) occlusions difficult to handle without going to 3D.

Shape Recovery: Basics



Traditional generative 3D-4D modeling pipeline: no prior model

Shape Recovery: Basics

2D Primitives

- Regions (silhouettes) -> surfaces, volumes
- Points (image features) -> 3D point clouds

Shape Recovery: Basics

2D Primitives

- **Regions (silhouettes) -> surfaces, volumes**
- Points (image features) -> 3D point clouds

Shape Recovery: Basics

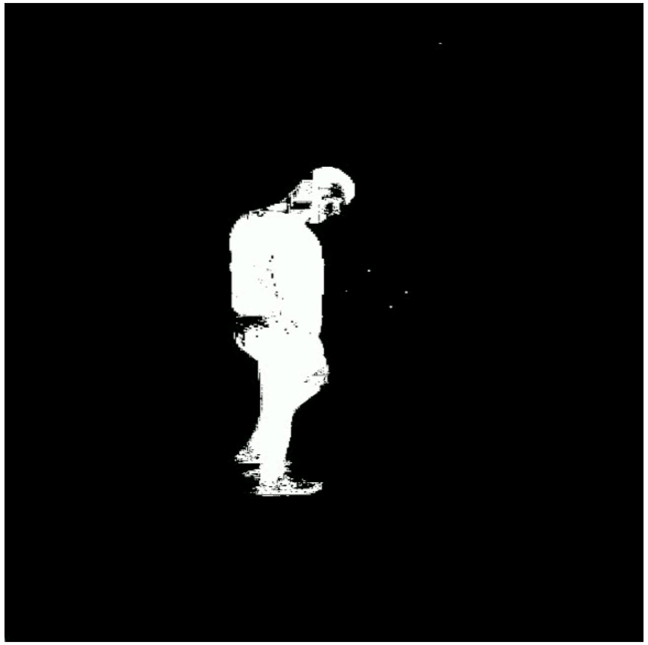
Silhouette

- Silhouettes are regions in the images where object of interest project.
- Silhouettes are estimated using low-level processes.
- Silhouettes give information on the observed surfaces.
- Extraction:
    - Chroma keying (blue or green background != skin color)
    - Background subtraction (static background)

Shape Recovery: Basics

Silhouette Segmentation

- Background subtraction:
  - Statistical background model
    - Gaussian
    - Gausian mixtures
    - Non parametric: e.g. histograms.
- Issues:
  - Image digitalization (noise);
  - Color ambiguities between background and foregroud objects;
  - Luminosities changes, etc.

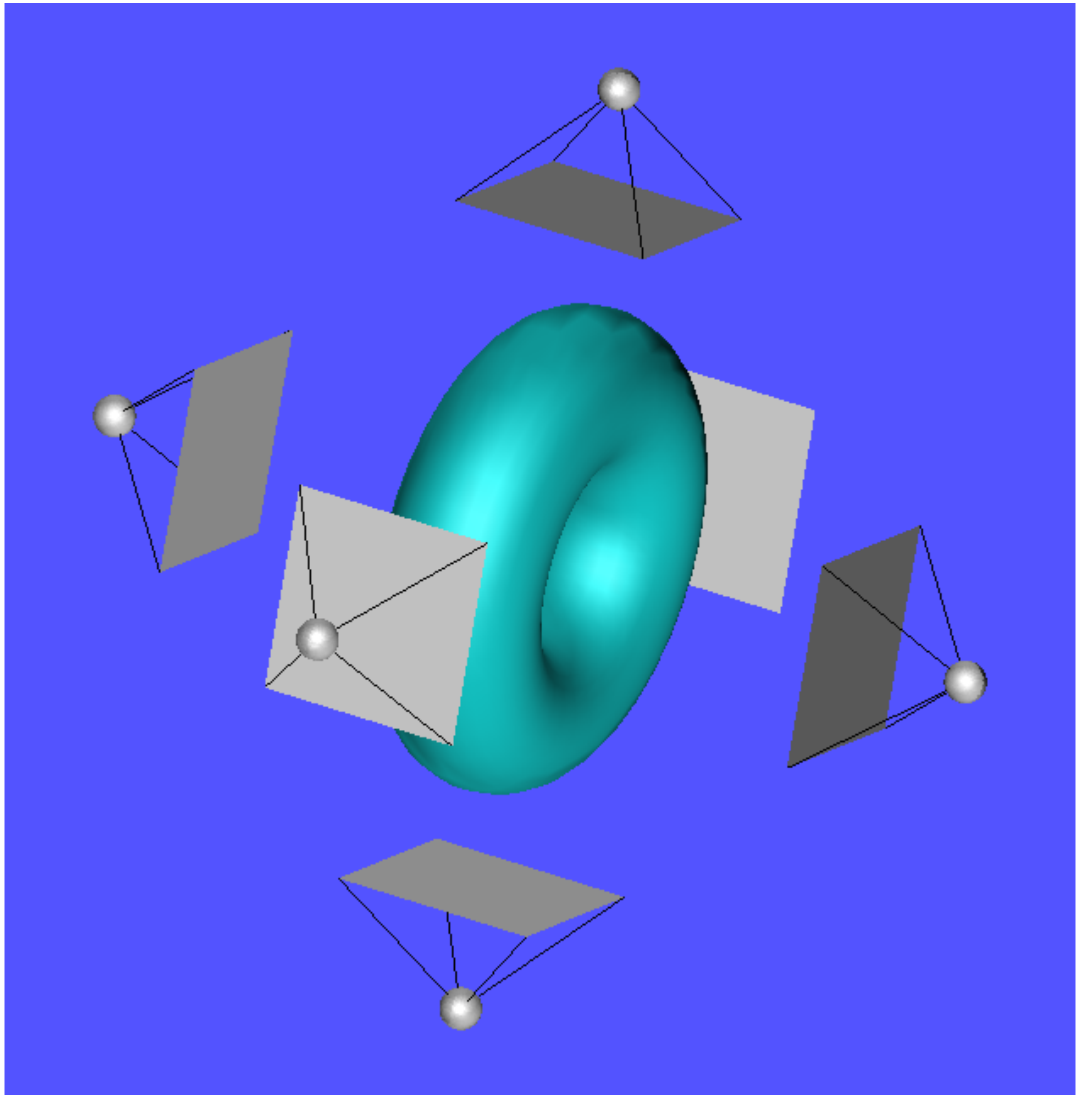


Shape Recovery: Basics

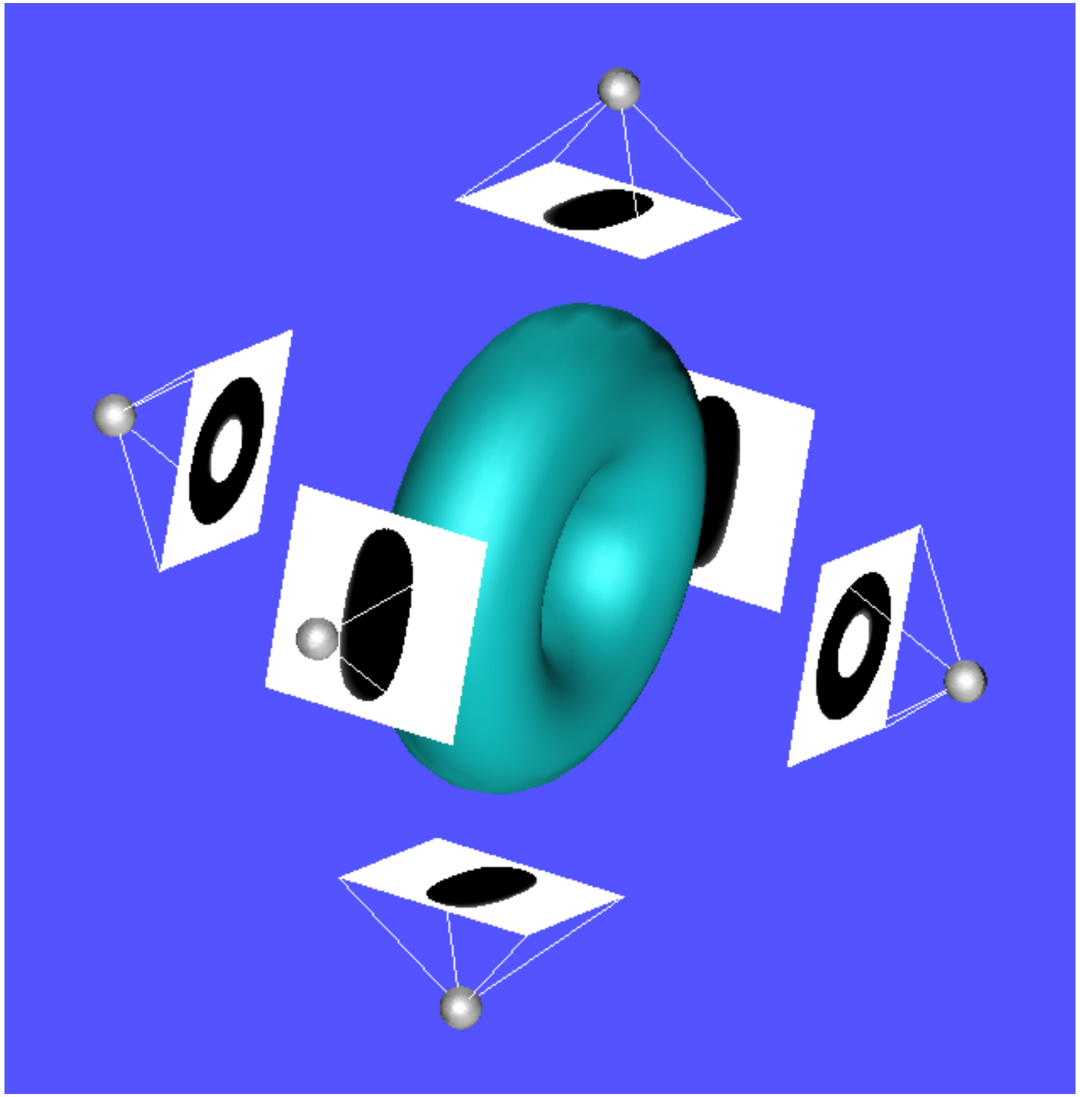
From silhouettes to shapes:

2D silhouettes define a volume in 3D called the **visual hull**. It is the maximal volume compatible with a set of silhouettes.

Shape Recovery: Basics



Shape Recovery: Basics



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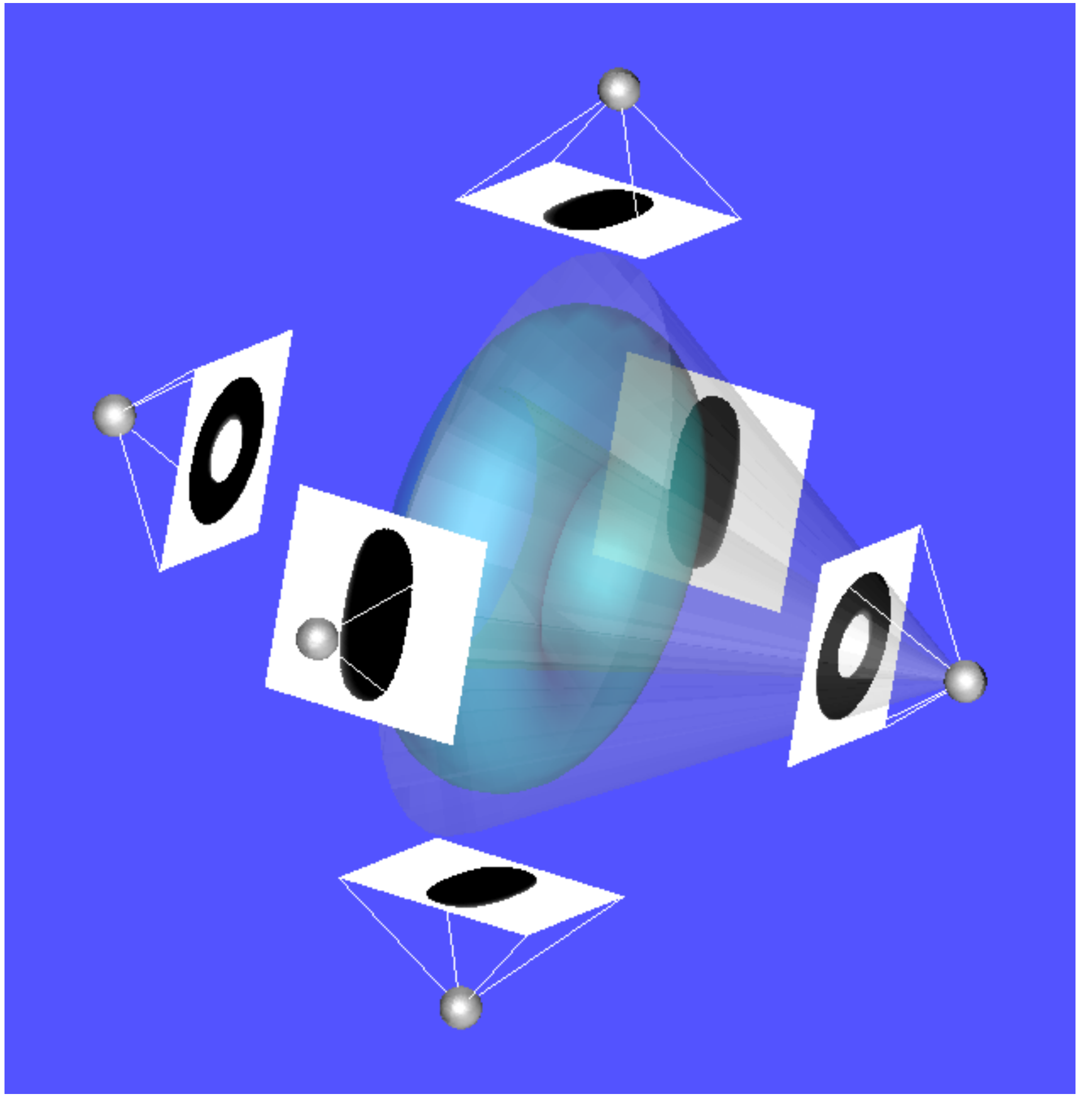
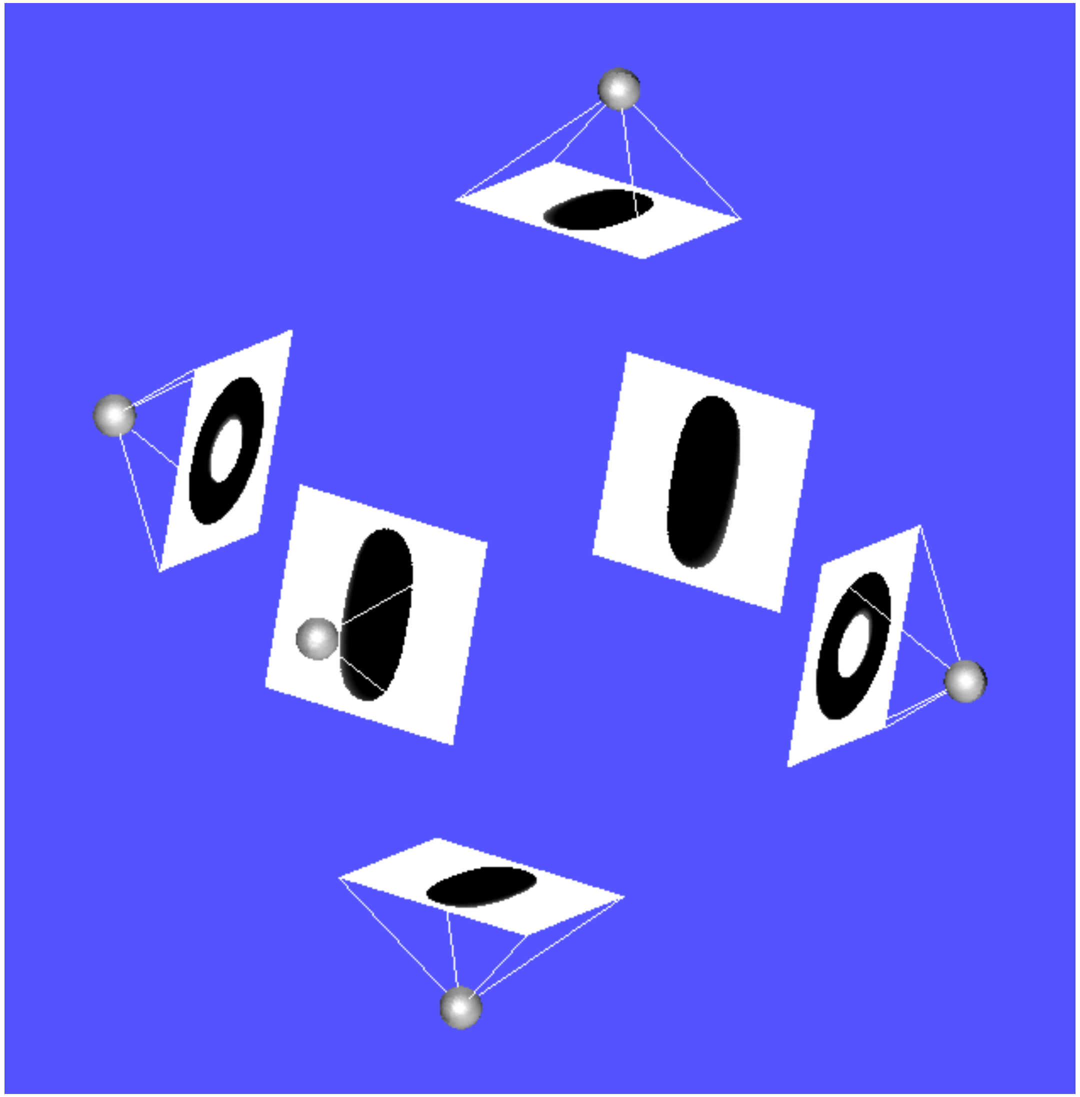
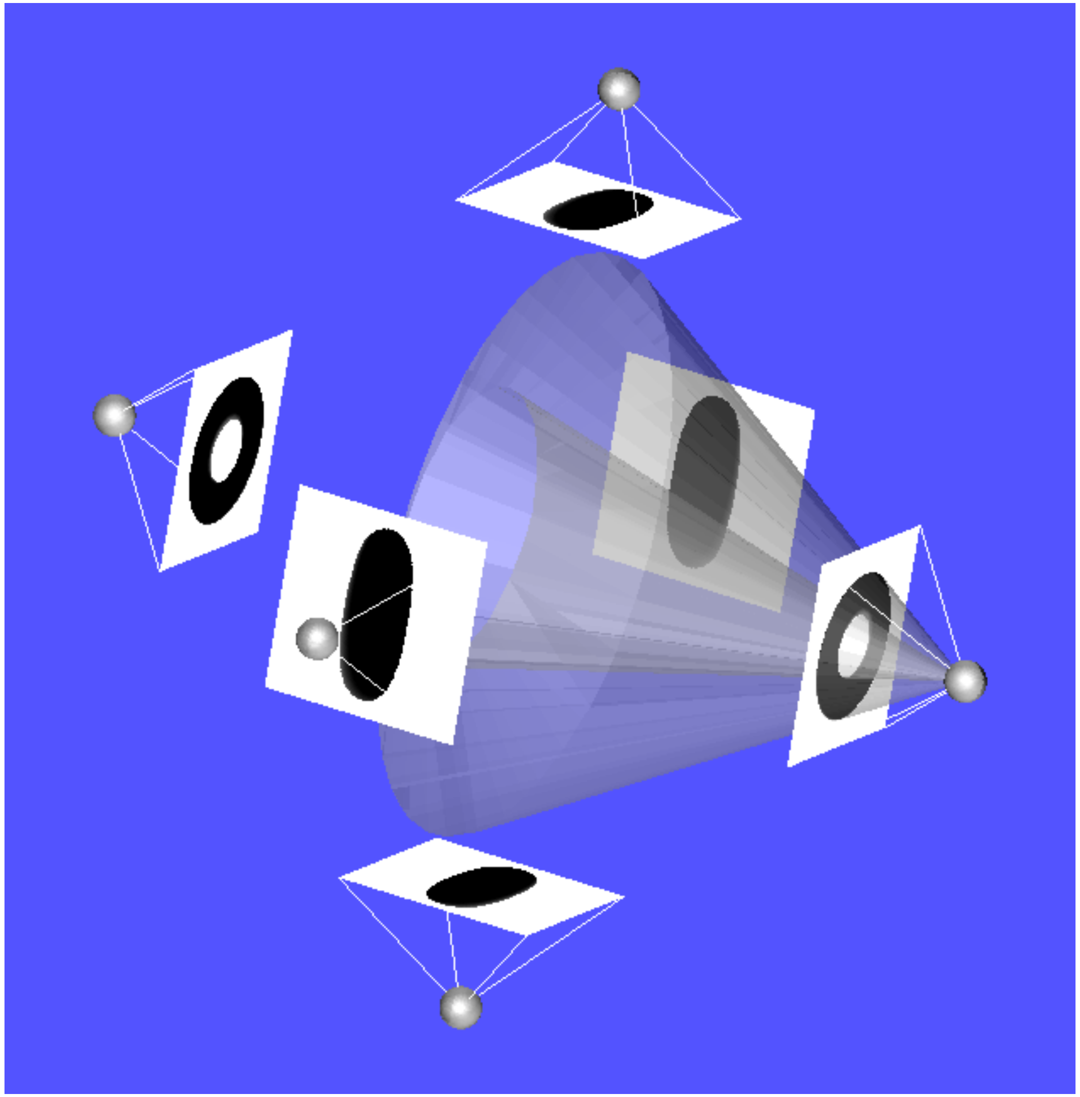


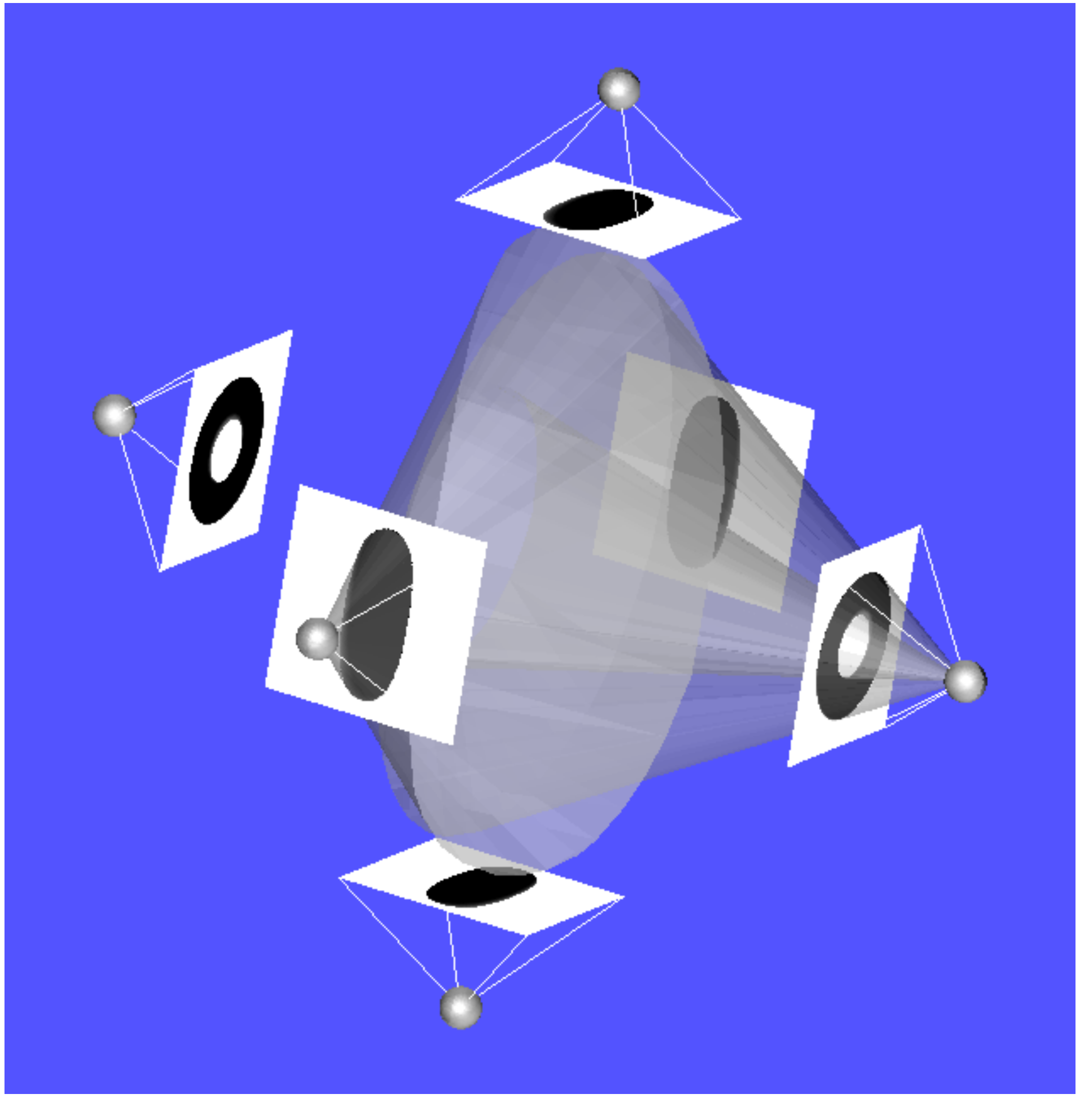
Shape Recovery: Basics



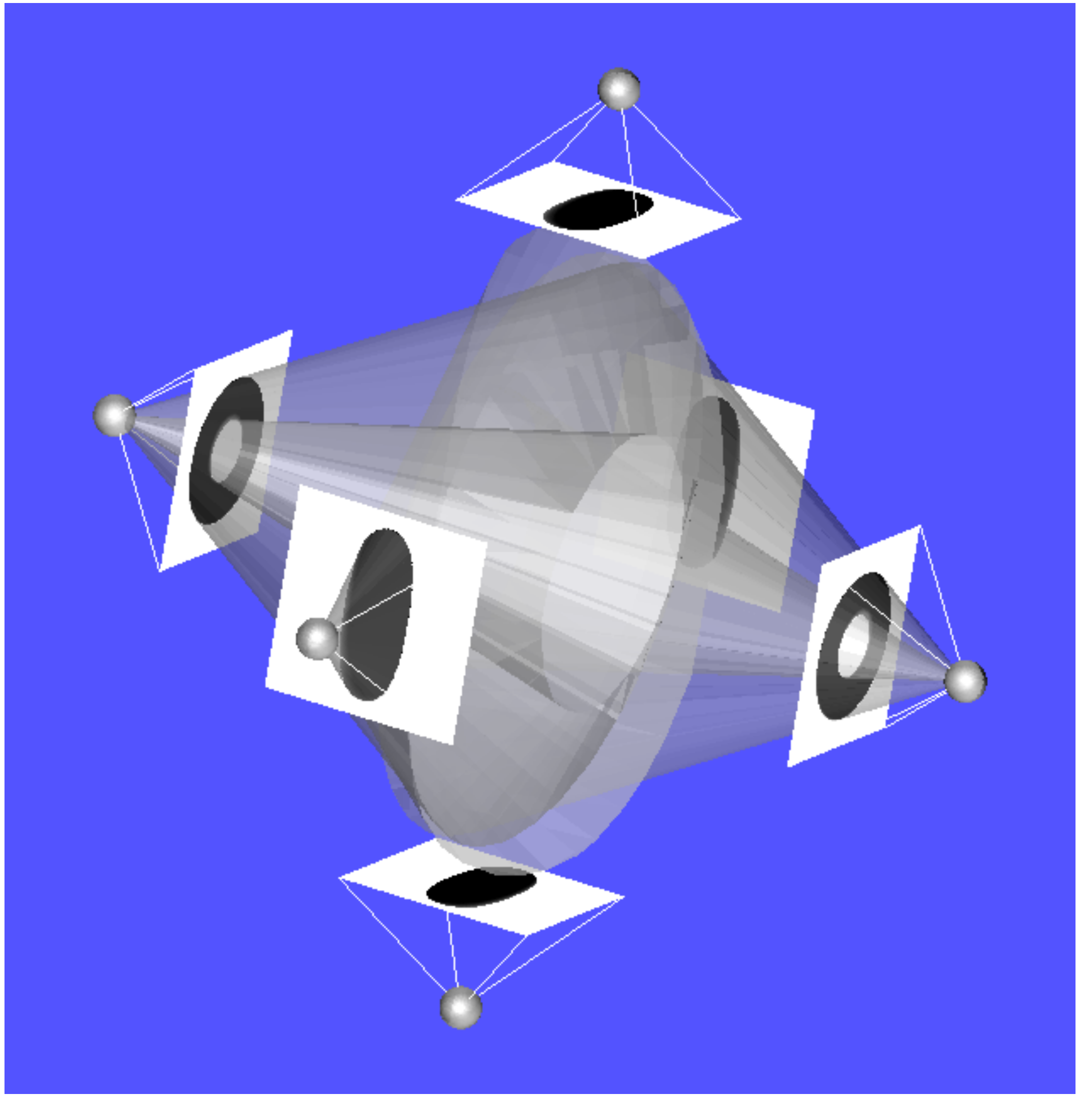
Shape Recovery: Basics



Shape Recovery: Basics



Shape Recovery: Basics



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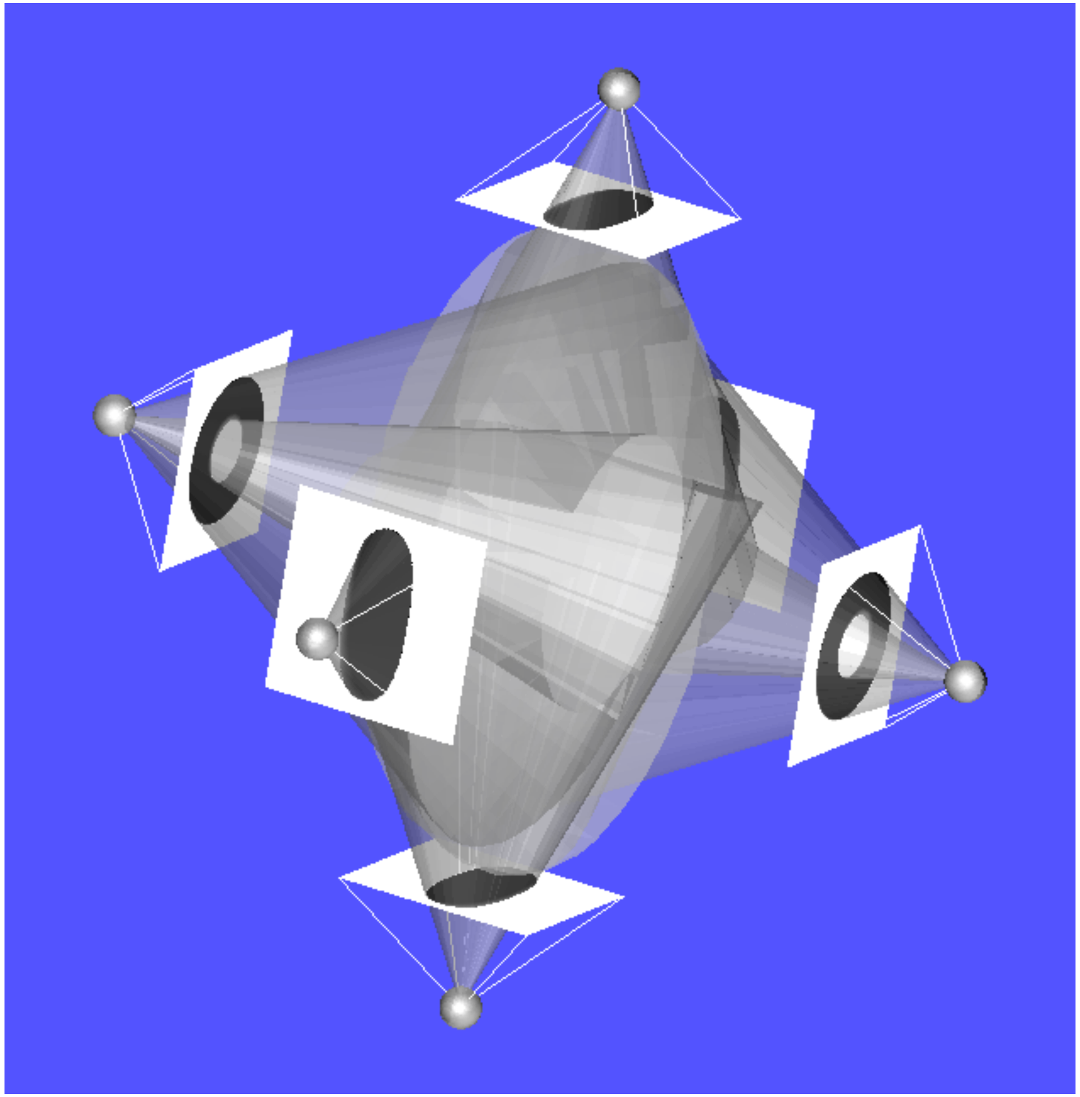

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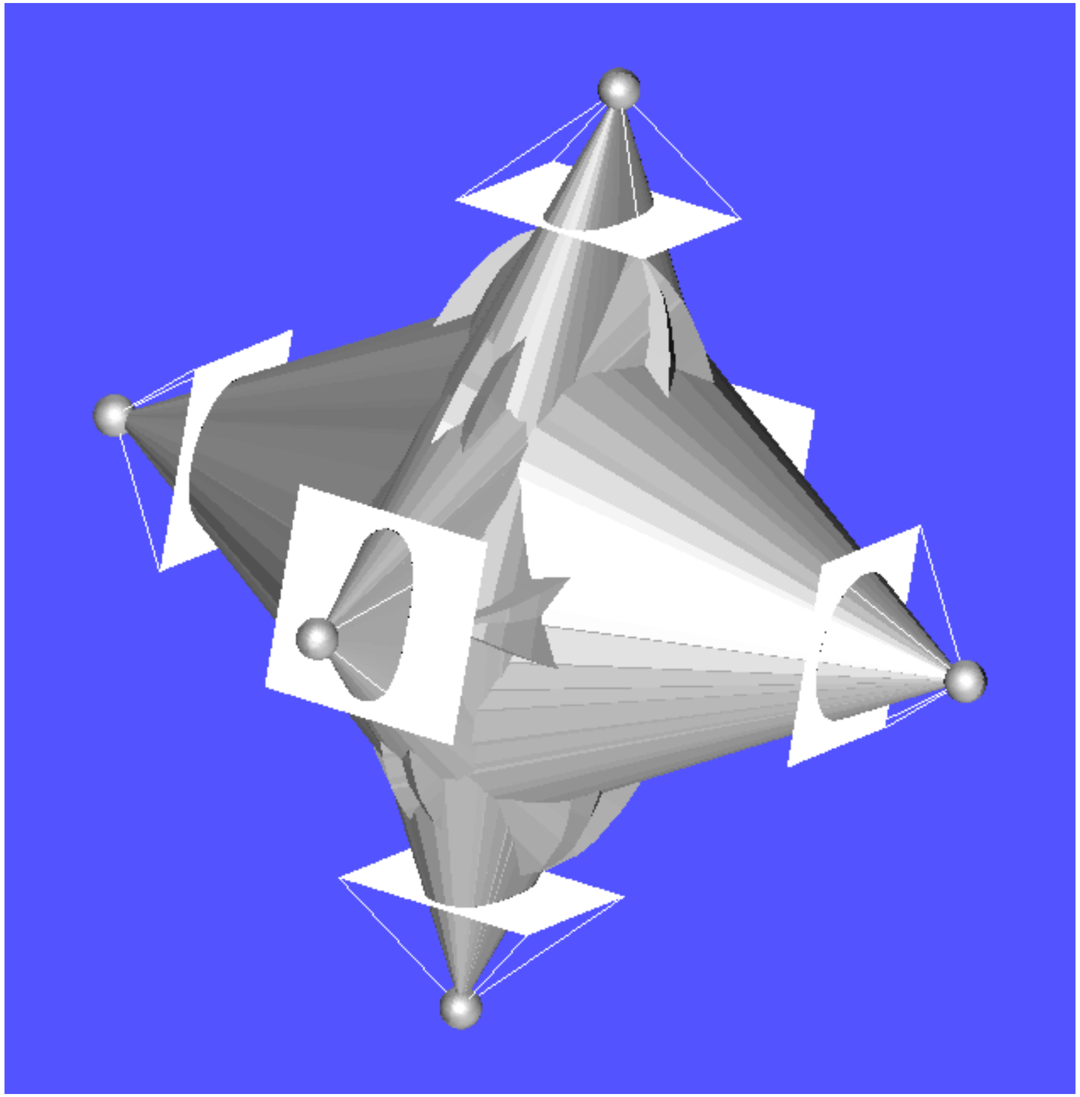

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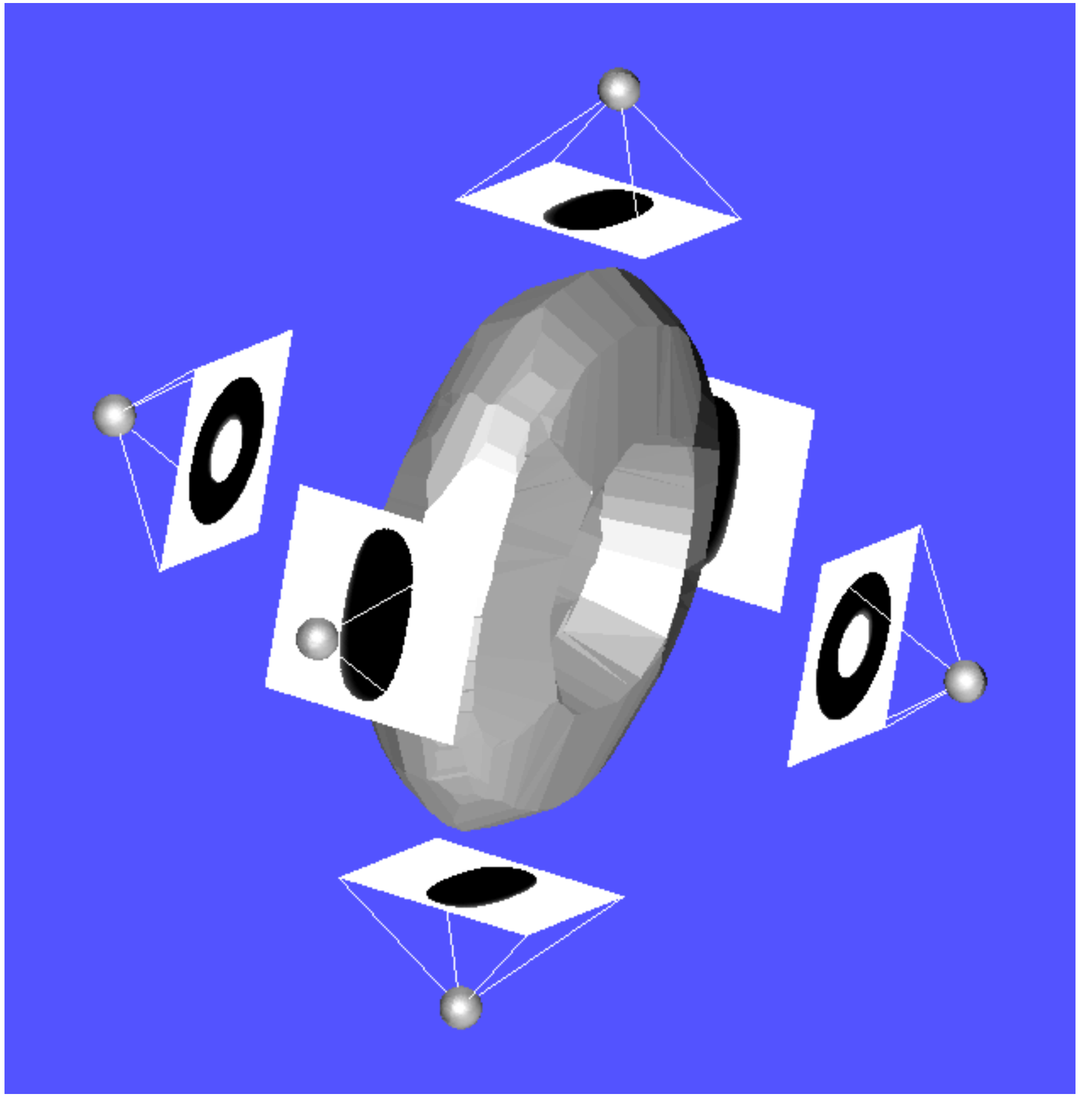
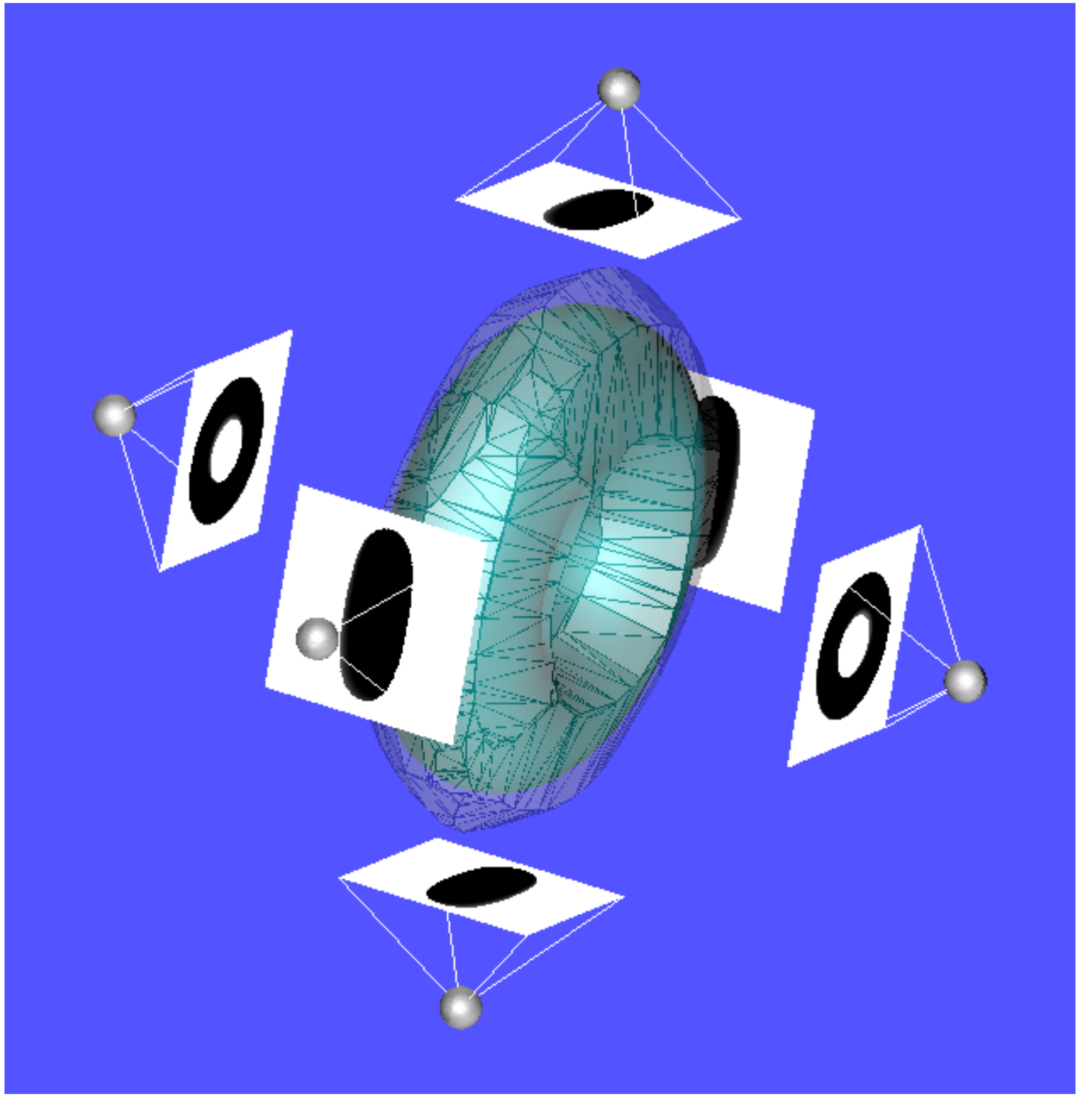


Shape Recovery: Basics



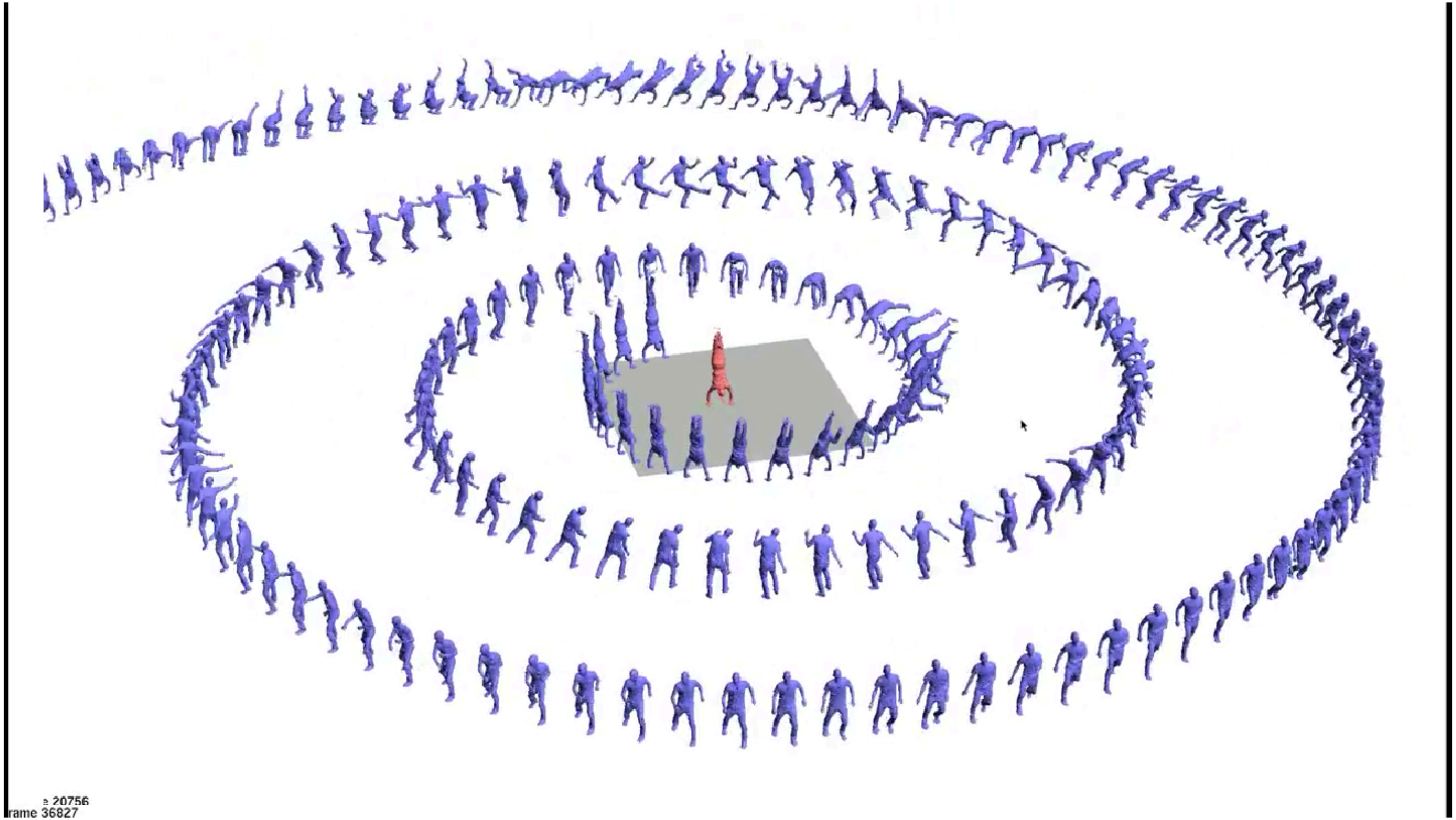
Shape Recovery: Basics

Visual Hull: Voxel Based Algorithm

```
Input: Image Silhouettes S{1..N}; Grid G of size LxLxL; Projection Matrices P{1..N}
#Initialization
For each voxel in G
    voxel = 0;  # Empty
End for
# Main Loop
For each voxel in G
    count = 0
    For i in [1..N]
        if(projection(voxel, Pi ) in Si
            count += 1
        else break
        End if
    End for
    if (count == N)
        voxel = 1  # Occupied
    End if
End for
```

Shape Recovery: Basics

Real time Visual hulls with 67 cameras



Shape Recovery: Basics

Primitive Extraction

- Regions (silhouettes) -> surfaces, volumes
- **Points (image features) -> 3D point clouds**

Shape Recovery: Basics

Getting 3D points

- Depth cameras (active system)
- Multi-view stereo with color cameras (passive system)

Shape Recovery: Basics

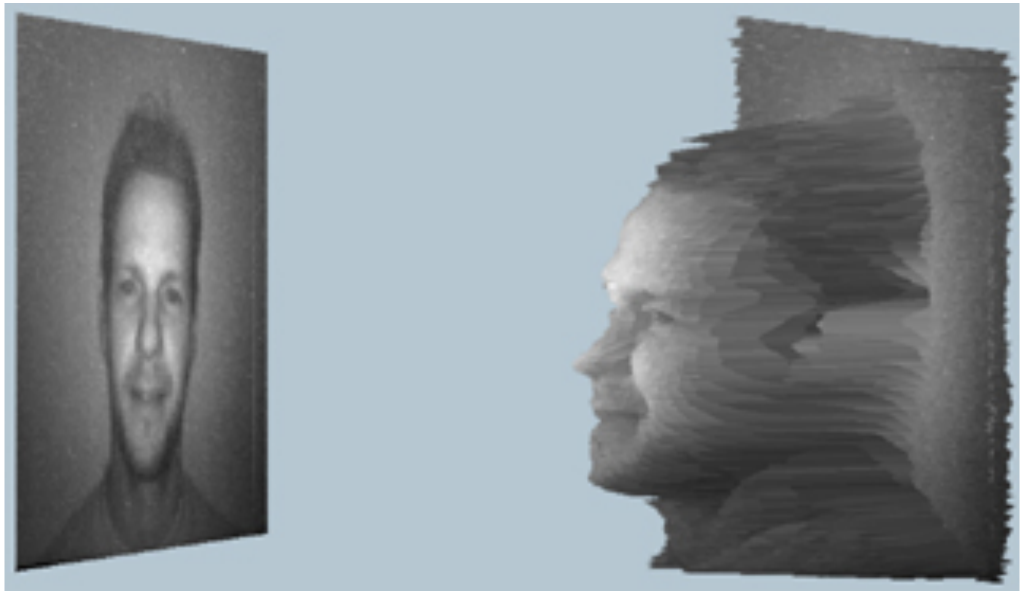
Getting 3D points

- Depth cameras (active system)
- Multi-view stereo with color cameras (passive system)

- Some platforms (e.g. Microsoft) are using both.
- While directly providing 3D information, active system have inherently more limitations than passive ones (e.g. scale, illumination).

Shape Recovery: Basics

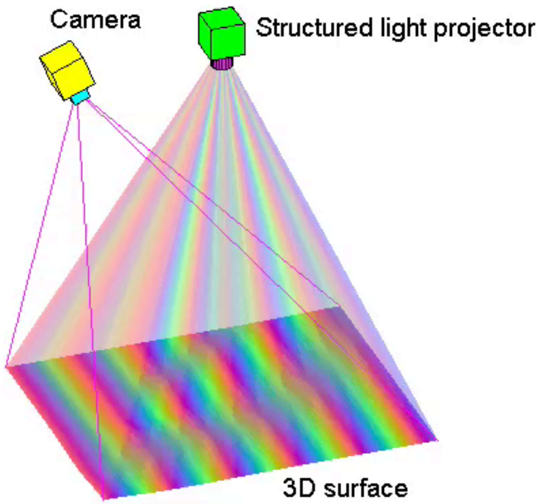
Depth cameras



Time of flight cameras

Shape Recovery: Basics

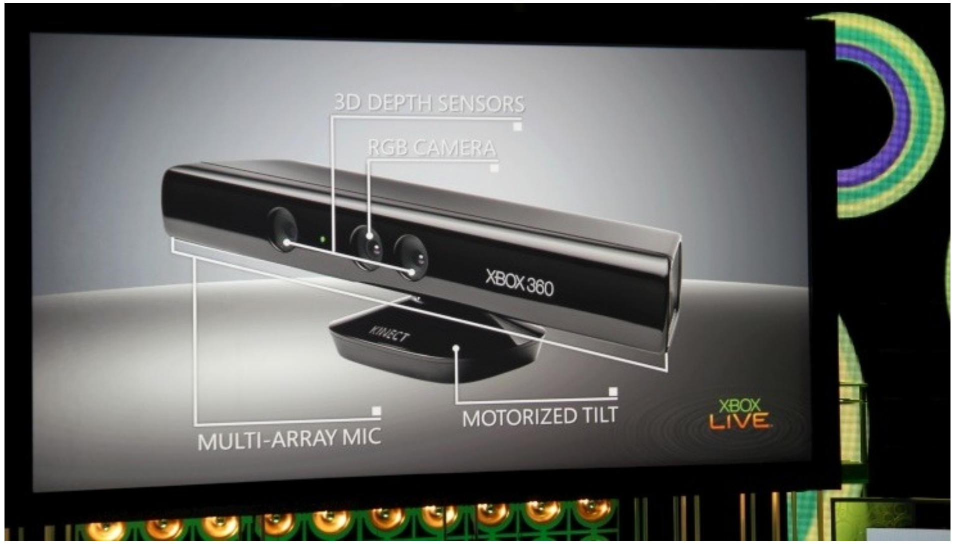
Depth cameras



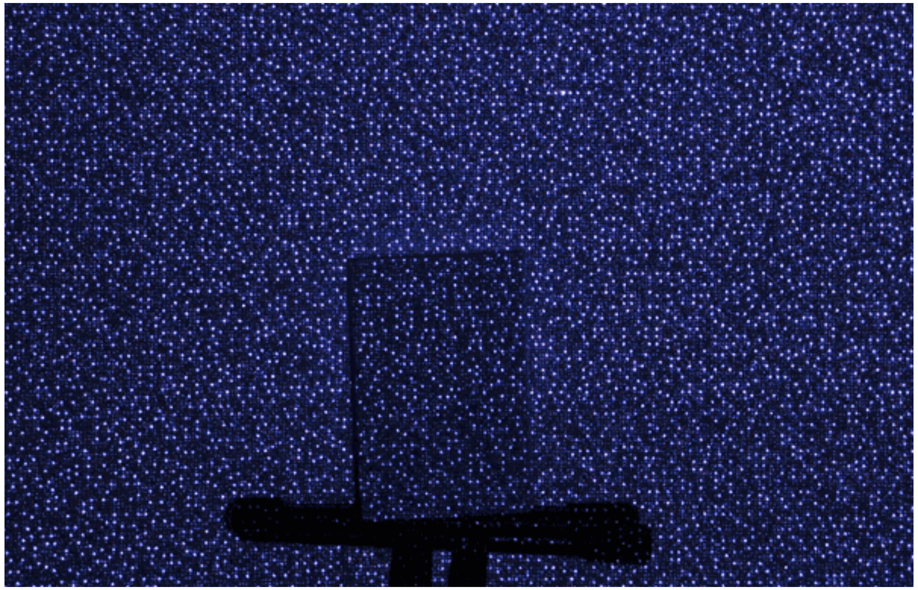
Structured light systems

Shape Recovery: Basics

Depth cameras



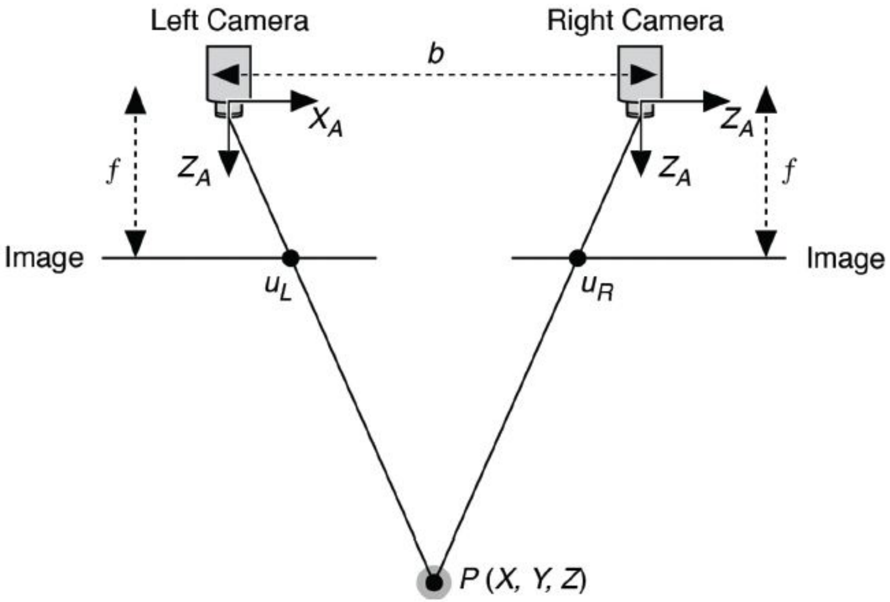
Microsoft Kinect 1 (Primesense)



Infrared pseudorandom pattern
(©PrimeSense)
with a book in front.

Shape Recovery: Basics

Depth cameras

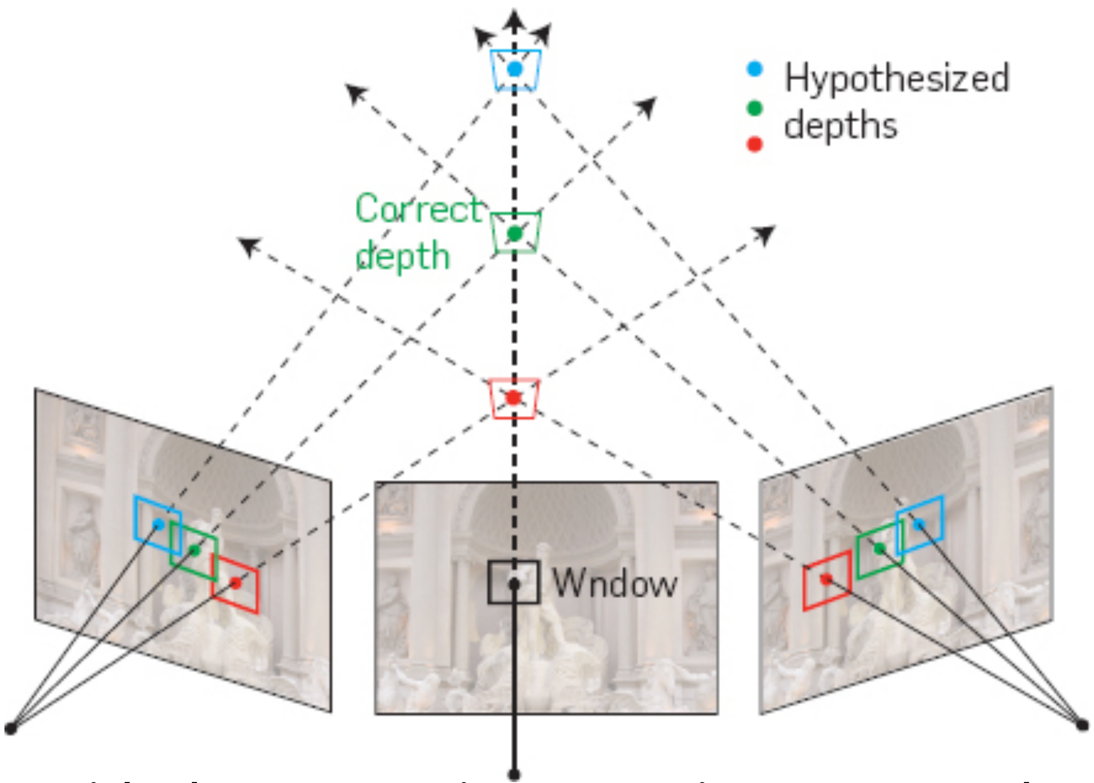


Bumblebee camera @FLIR

Stereovision cameras: point must be matched in the 2 images

Shape Recovery: Basics

Multi-view Stereo



[Building Rome in a Day
ICCV 2009]

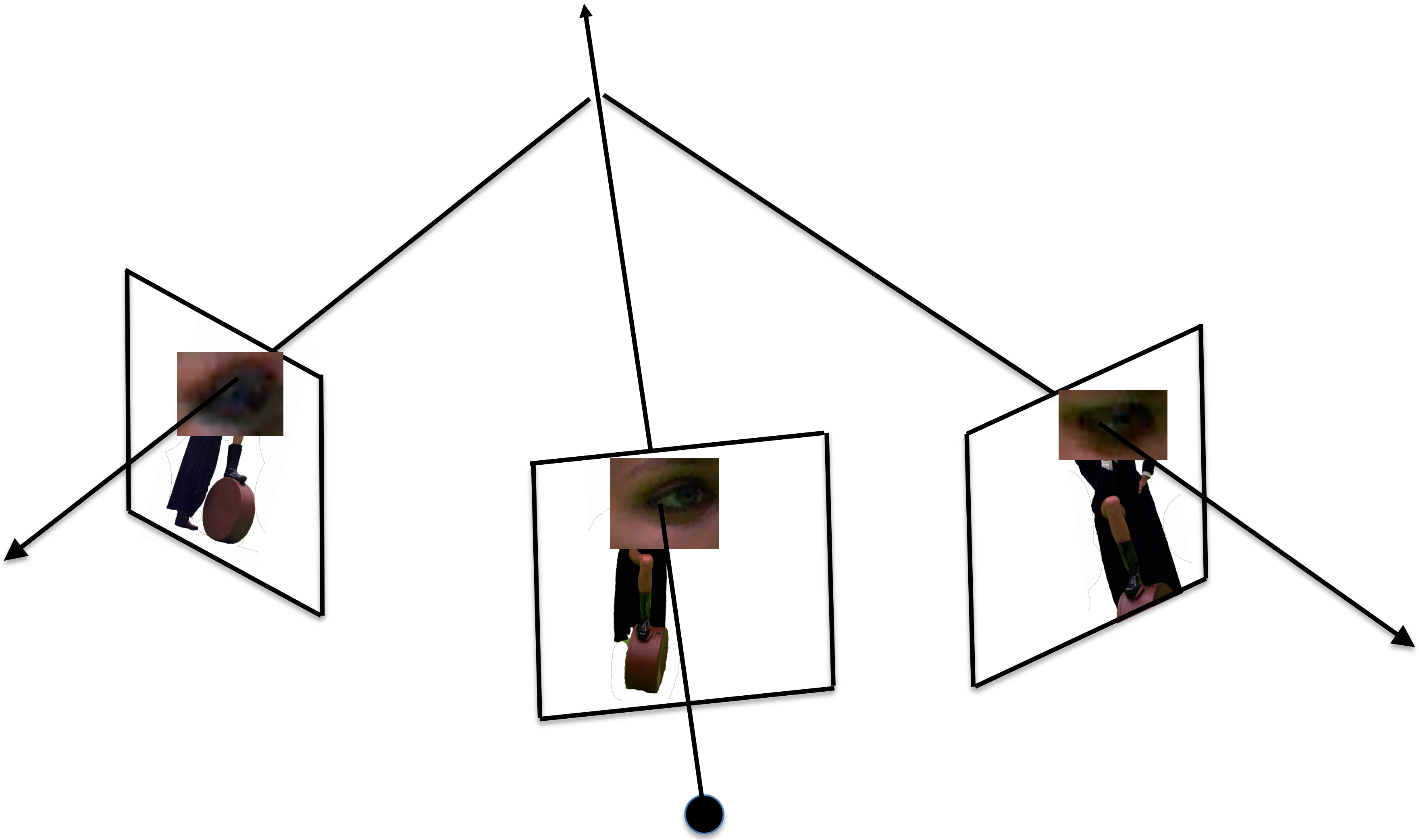
As with the stereo, image points are matched but more than 2 images are considered.

Shape Recovery: Basics

[Leroy, Franco, Boyer, ECCV 2018]

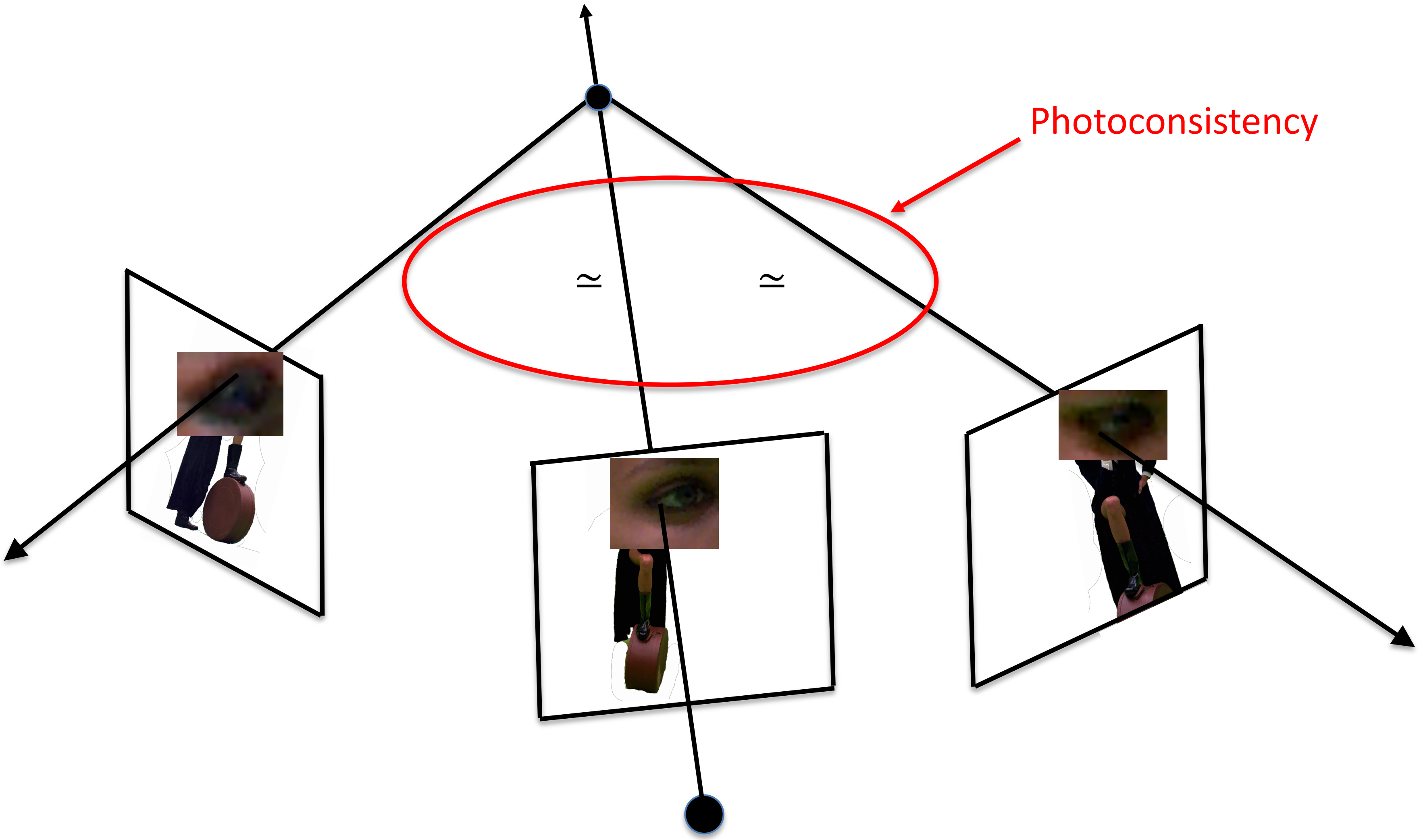
Multi View Stereo: Photoconsistency

Shape Recovery: Basics



Multi View Stereo: Photoconsistency

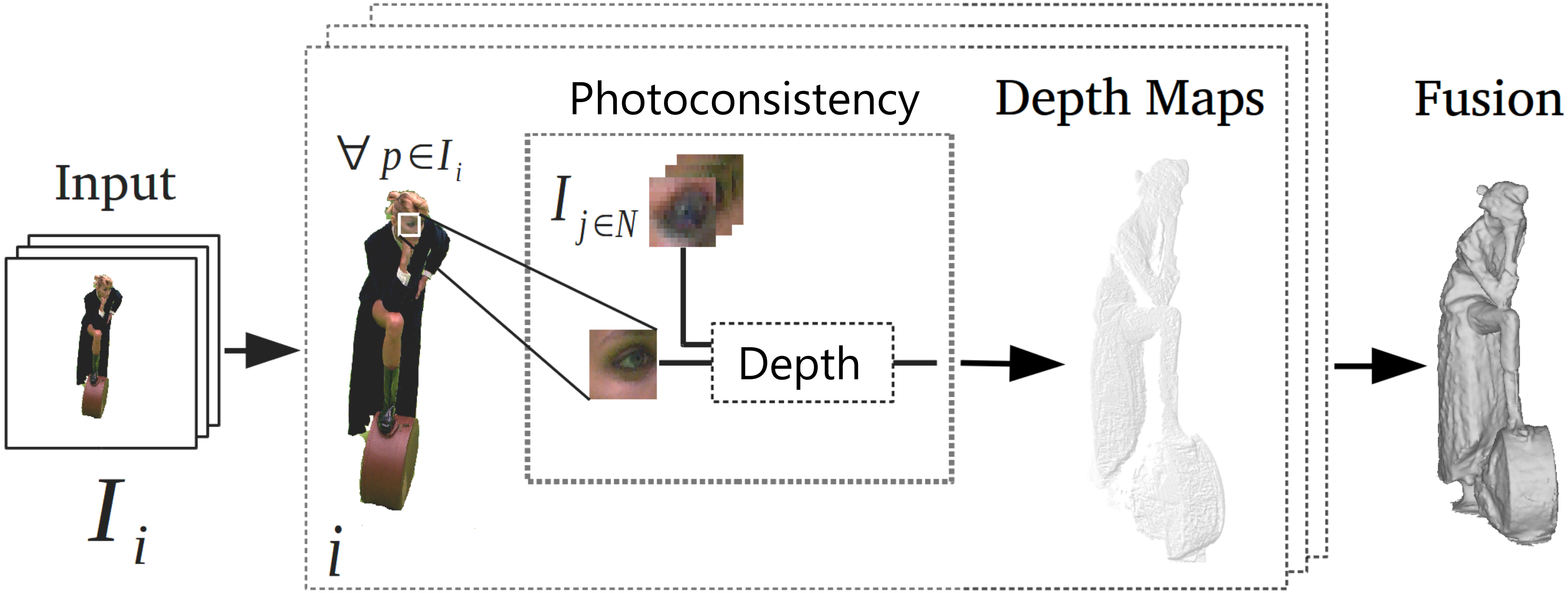
Shape Recovery: Basics



Multi View Stereo: Photoconsistency

Shape Recovery: Basics

Multi View Stereo: General Framework

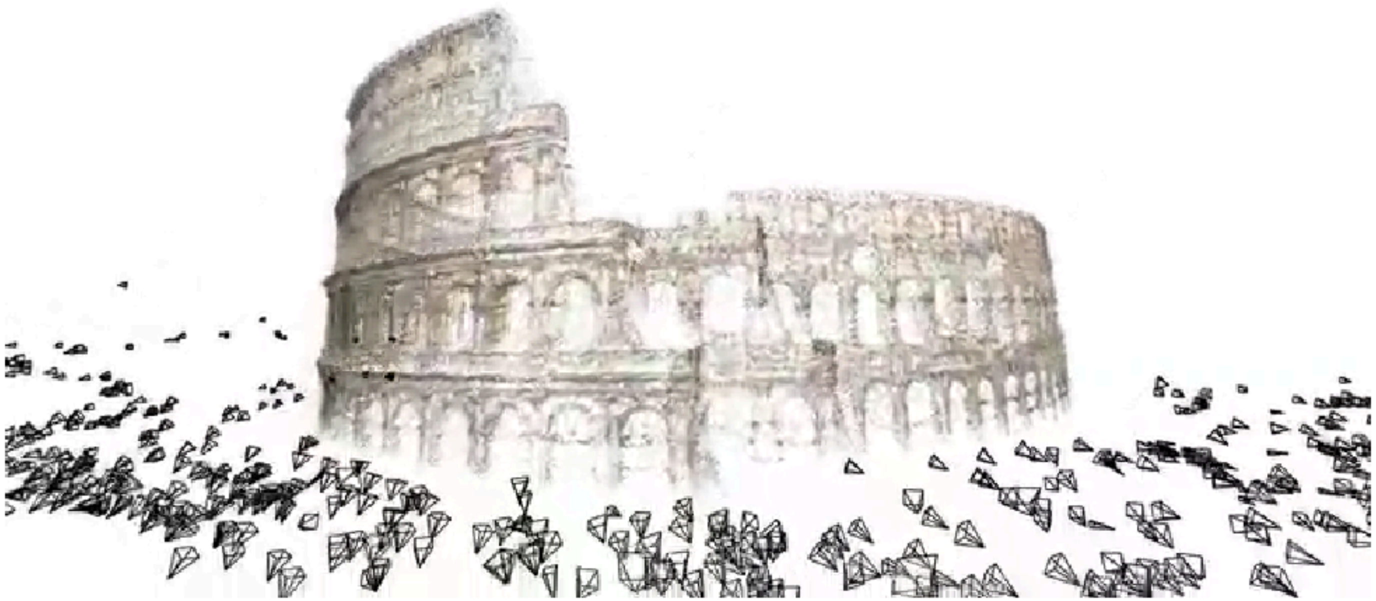


Multi-View Stereo (MVS) dominant strategy:

- Depth map from each viewpoint using photoconsistency.
- Spatial depth map integration with TSDF.
- Surface reconstruction (Poisson, CVT, …).

Shape Recovery: Basics

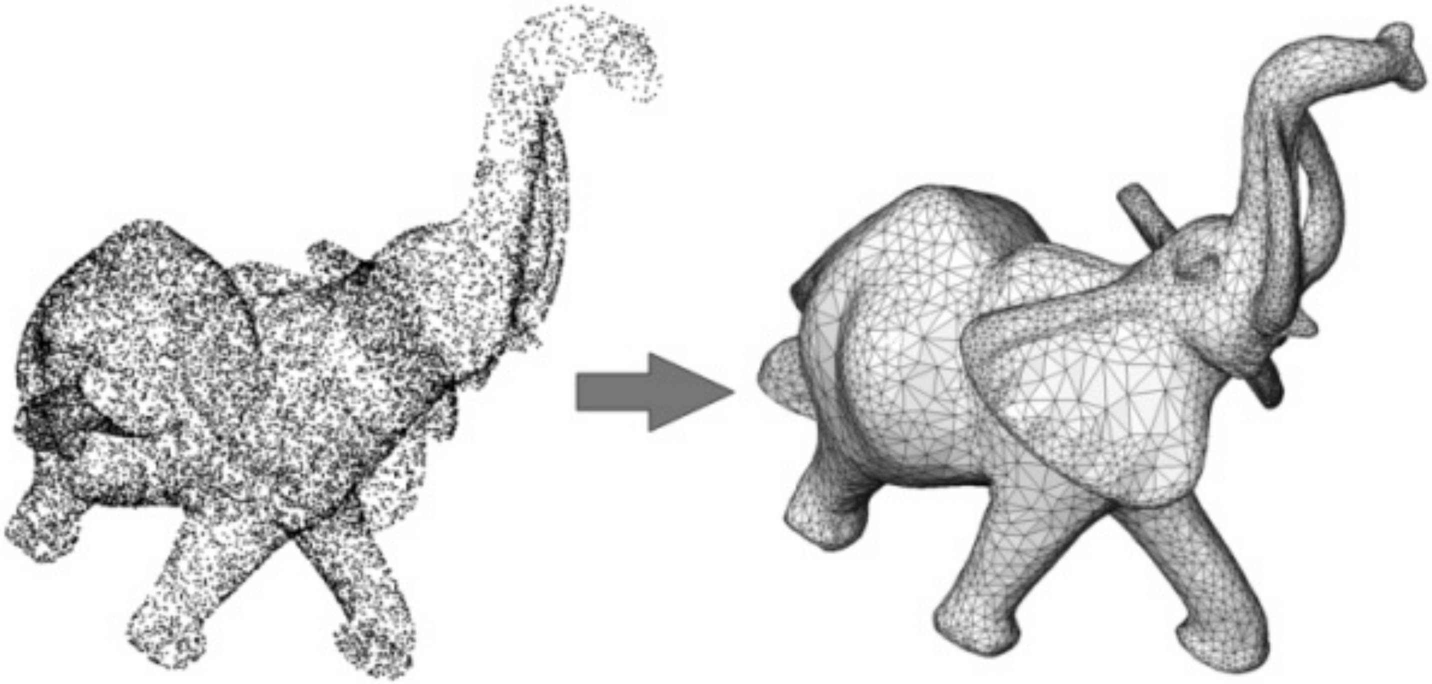
Multi-view Stereo



Building Rome in a Day, ICCV 2009
Agarwal, Furukawa, Snavely, Simon, Curless, Seitz, Szeliski.

Shape Recovery: Basics

From 3D points to Shapes

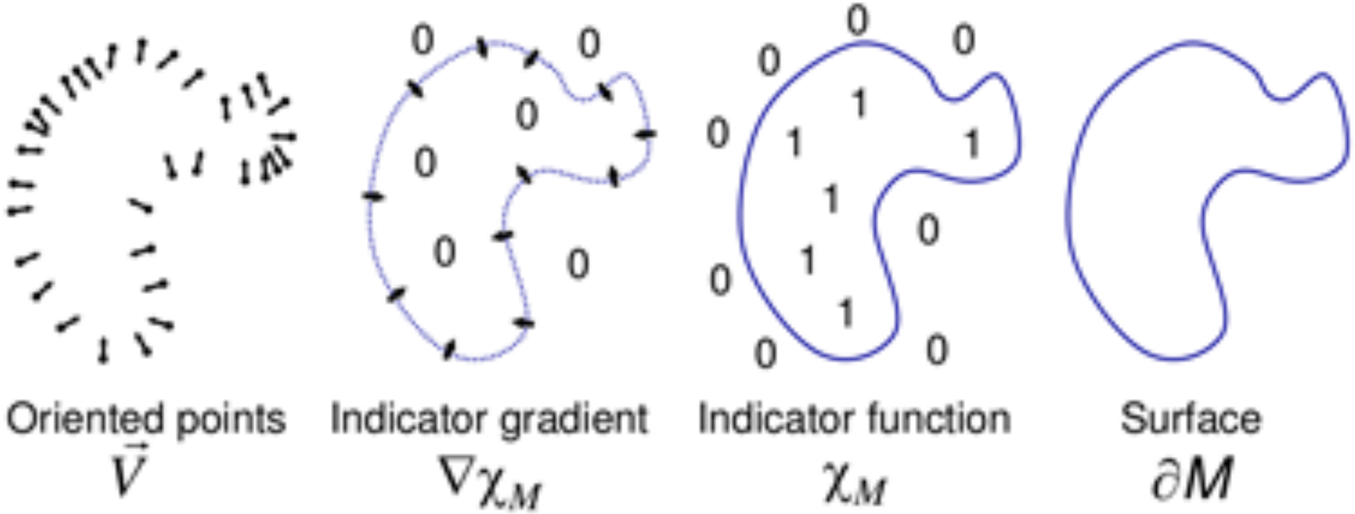


Example with: Poisson Surface Reconstruction, SGP 2006
M. Kazhdan, M Bolitho & H Hoppe

.

Shape Recovery: Basics

From 3D points to Shapes



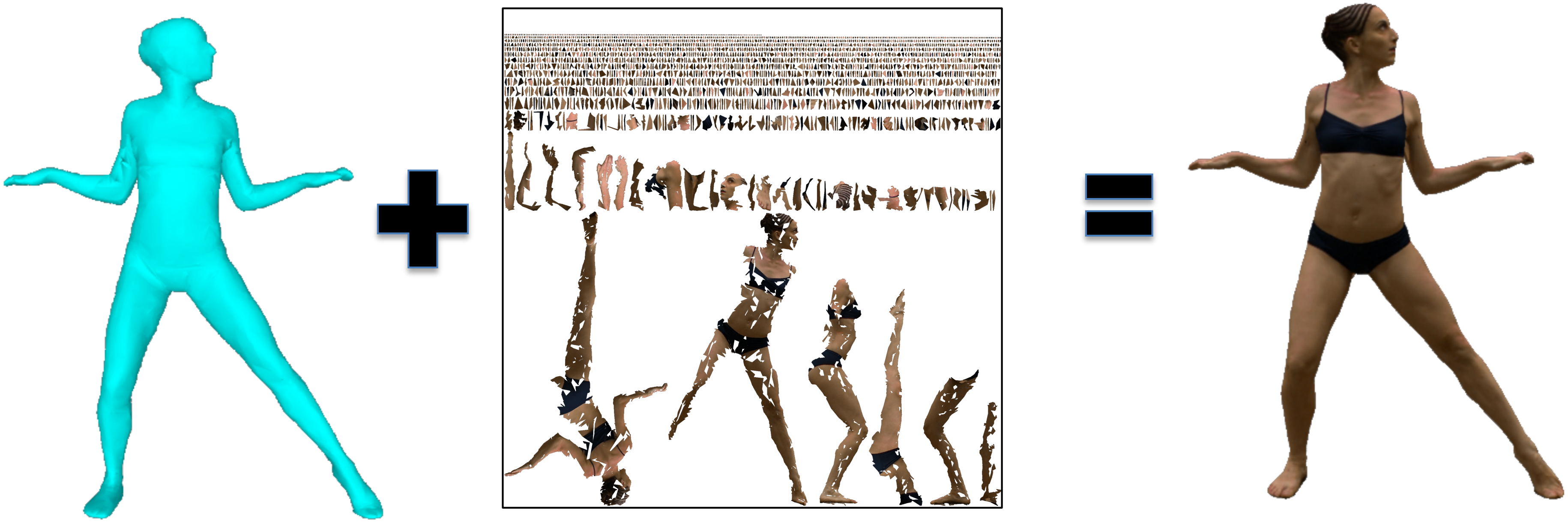
Poisson Surface Reconstruction, SGP 2006
M. Kazhdan, M Bolitho & H Hoppe
.

Shape Recovery: Basics

@Microsoft, High-Quality Streamable Free-Viewpoint Video, Siggraph'15

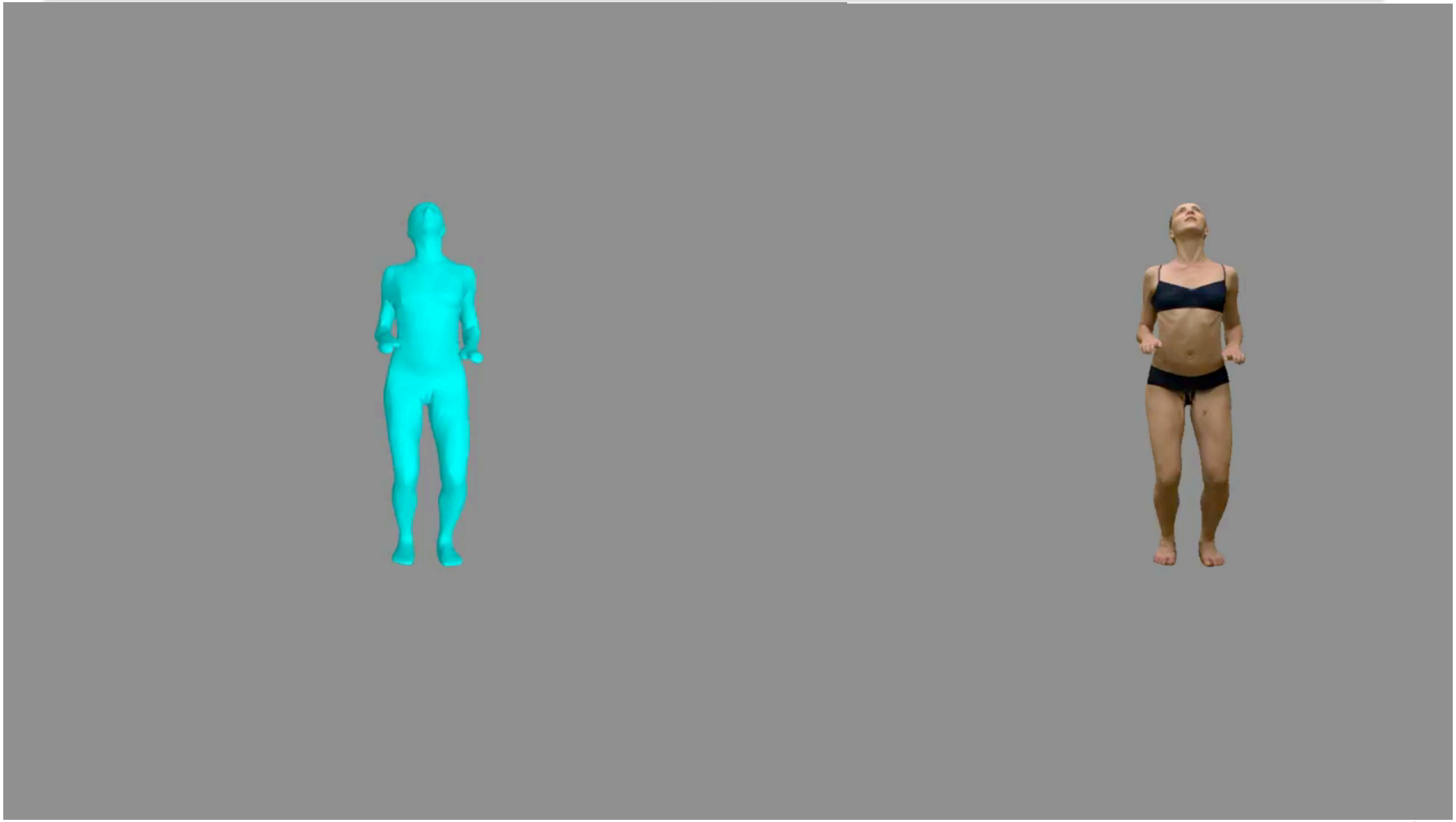
Shape Recovery: Basics

Appearance



INRIA Kinovis

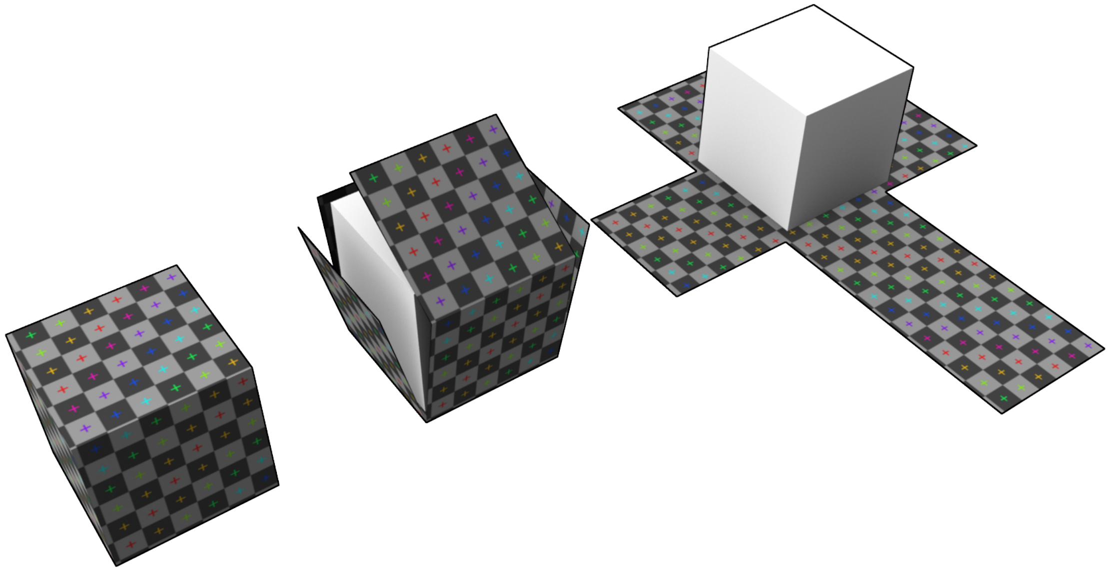
Shape Recovery: Basics



Shape Recovery: Basics

Appearance

1. At each frame, unwrap the mesh to define a 2D atlas where appearance (texels) can be specified.



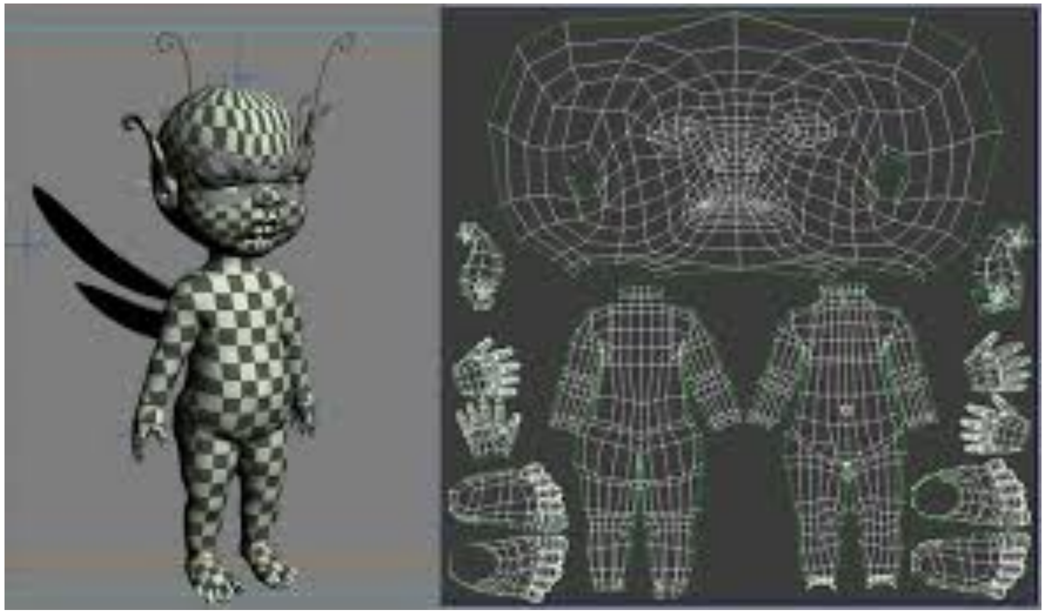
@wikipedia

1. Map the observed images at the given frame onto the UV atlas to define a 2D texture map at each frame.

Shape Recovery: Basics

Appearance

1. At each frame, unwrap the mesh to define a 2D atlas where appearance (texels) can be specified.



@Blender

1. Map the observed images at the given frame onto the UV atlas to define a 2D texture map at each frame.

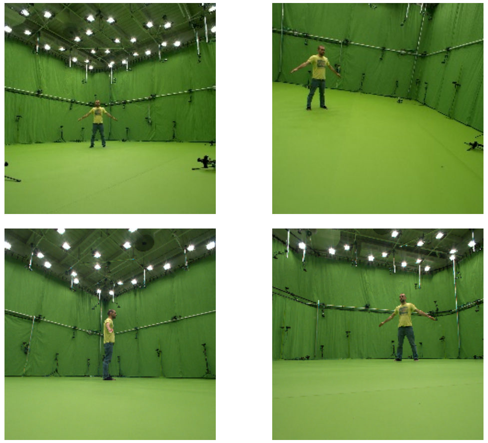
Shape Recovery: Basics

Appearance

Some challenges

- Noisy input images

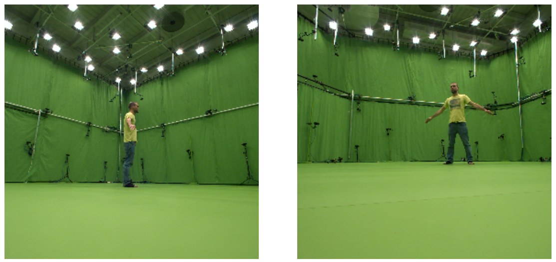
- Visual redundancy over space



- Camera inaccuracies

- Reconstruction inaccuracies

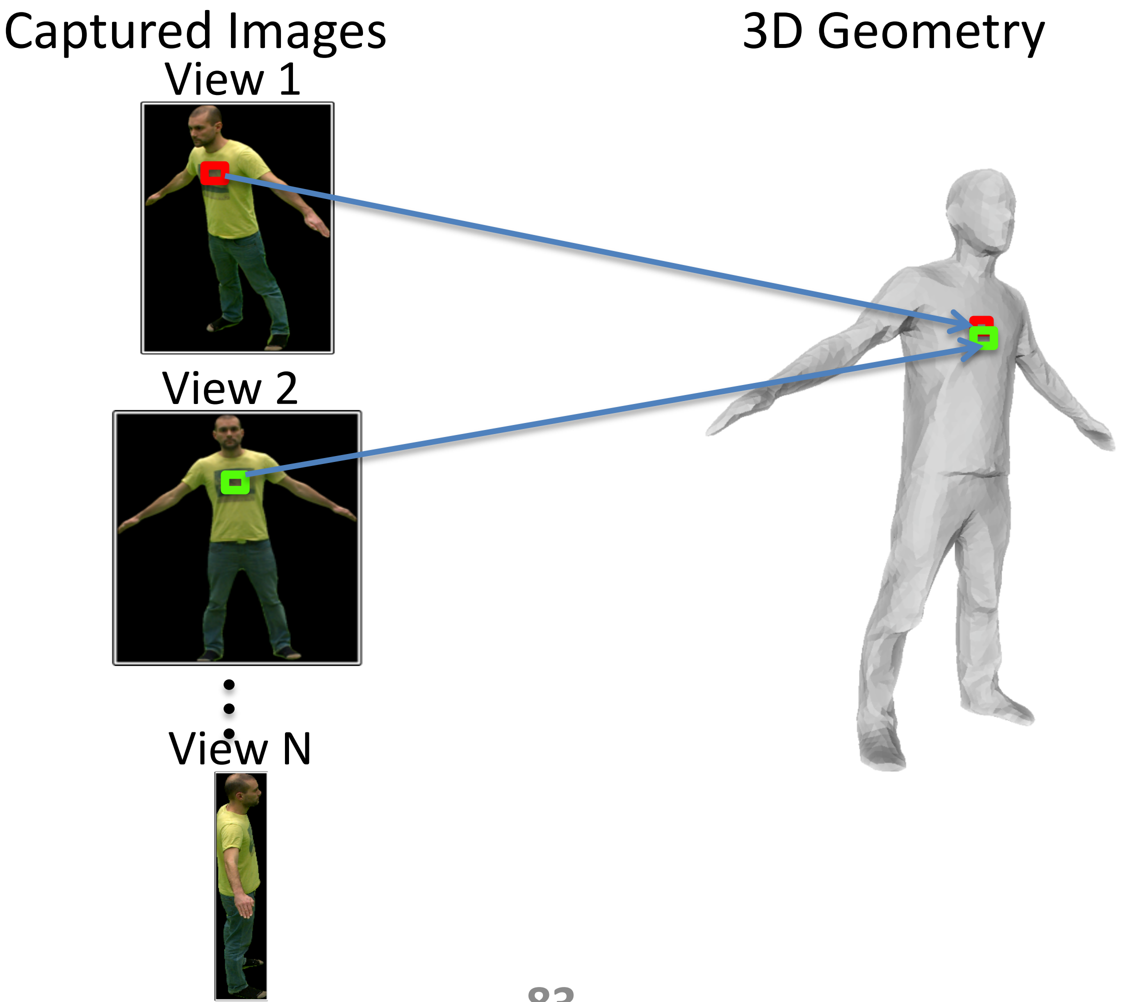
- Occlusions



- Visual redundancy over time

Shape Recovery: Basics

Appearance: Naive Strategy Blending



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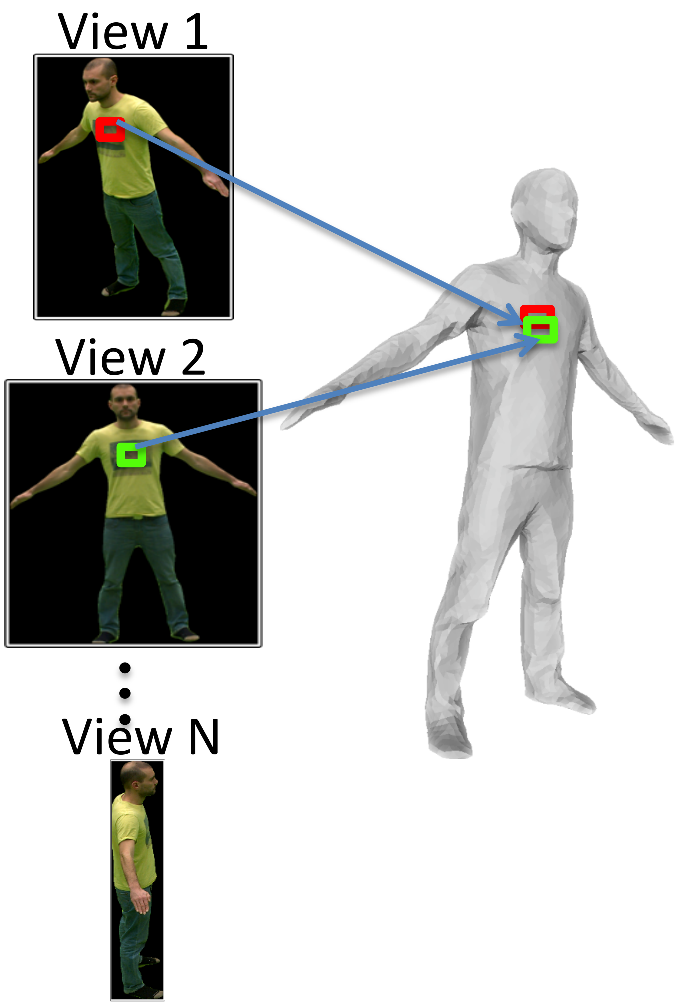
Shape Recovery: Basics

Appearance: Naive Strategy Blending

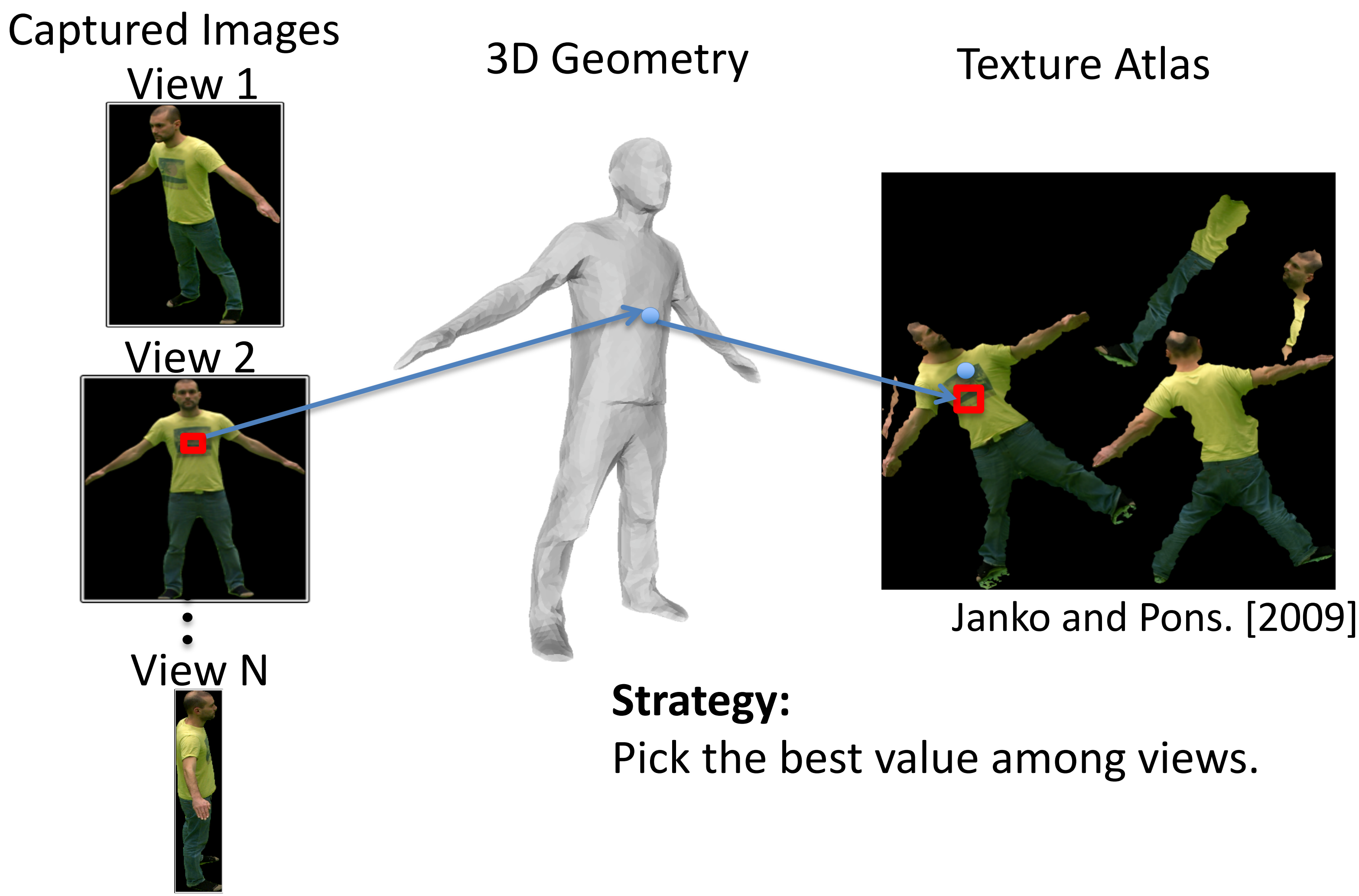


Example

Limitation:
Geometric inaccuracies lead to strong blurring effects.

Shape Recovery: Basics

Appearance: Best value

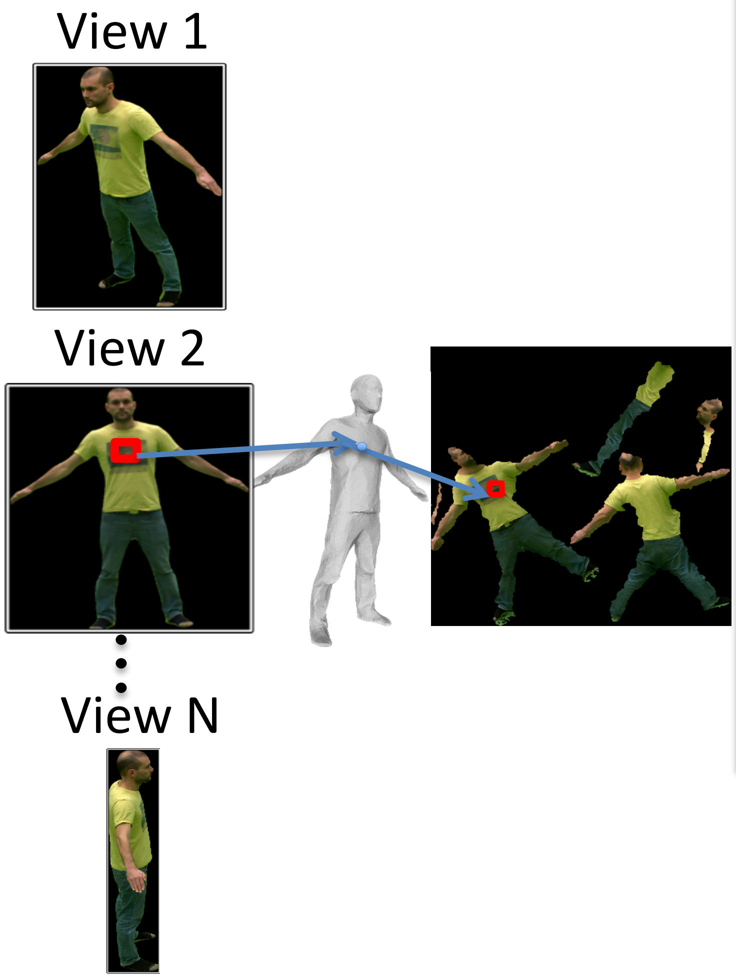


Janko and Pons. [2009]

Strategy:
Pick the best value among views.

Shape Recovery: Basics

Appearance: Best value



Example

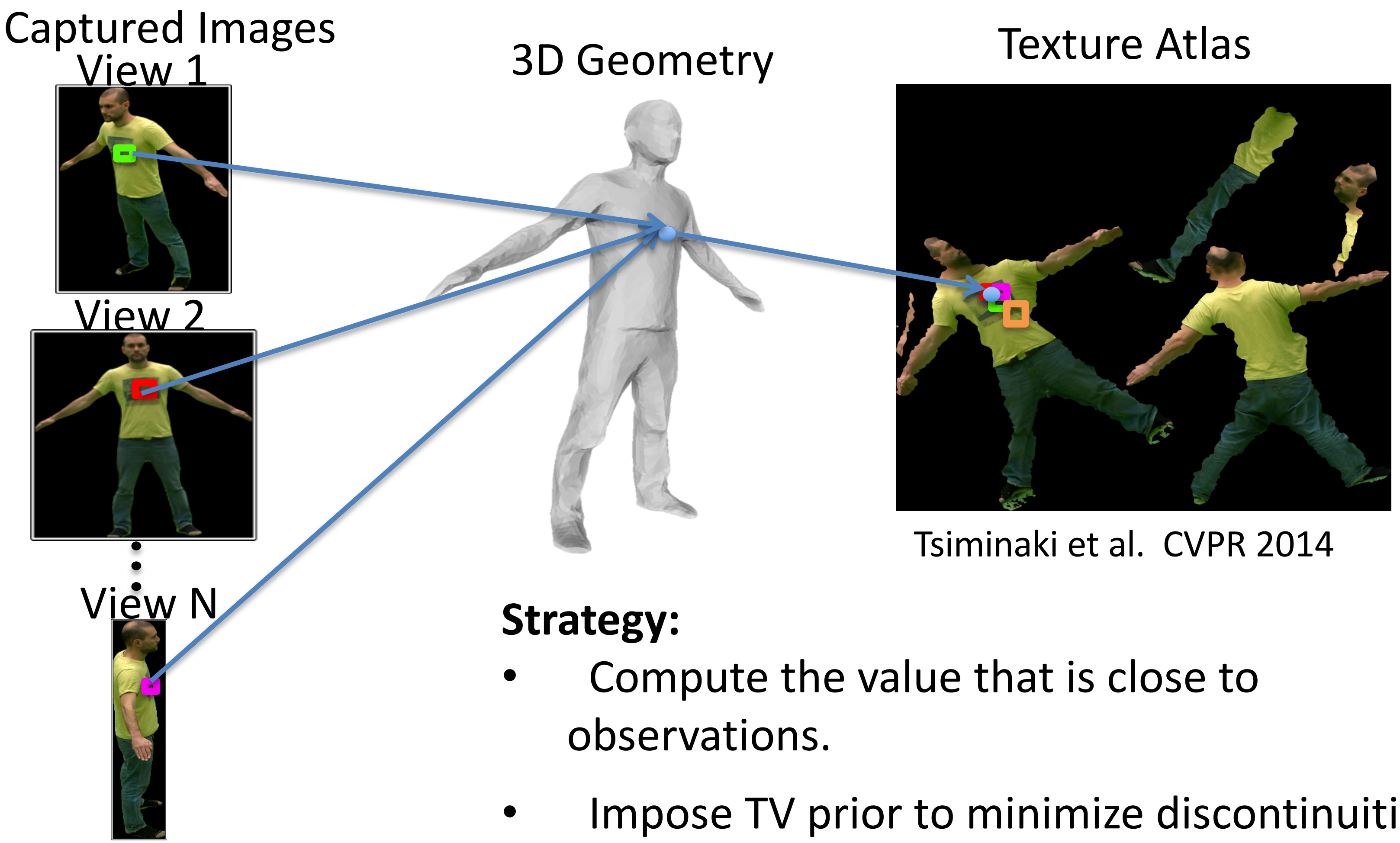
Janko and Pons. [2009]

Limitation:

Visual redundancy is not exploited.

Shape Recovery: Basics

Appearance: Super Resolution Strategy



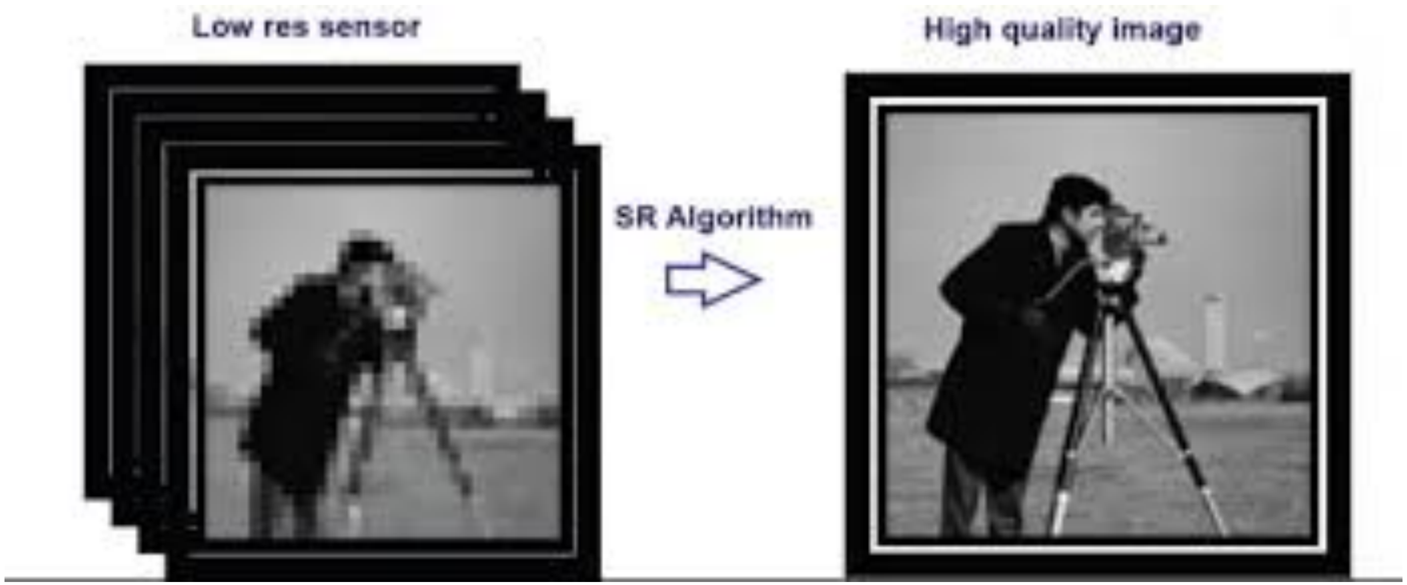
Tsiminaki et al. CVPR 2014

Strategy:

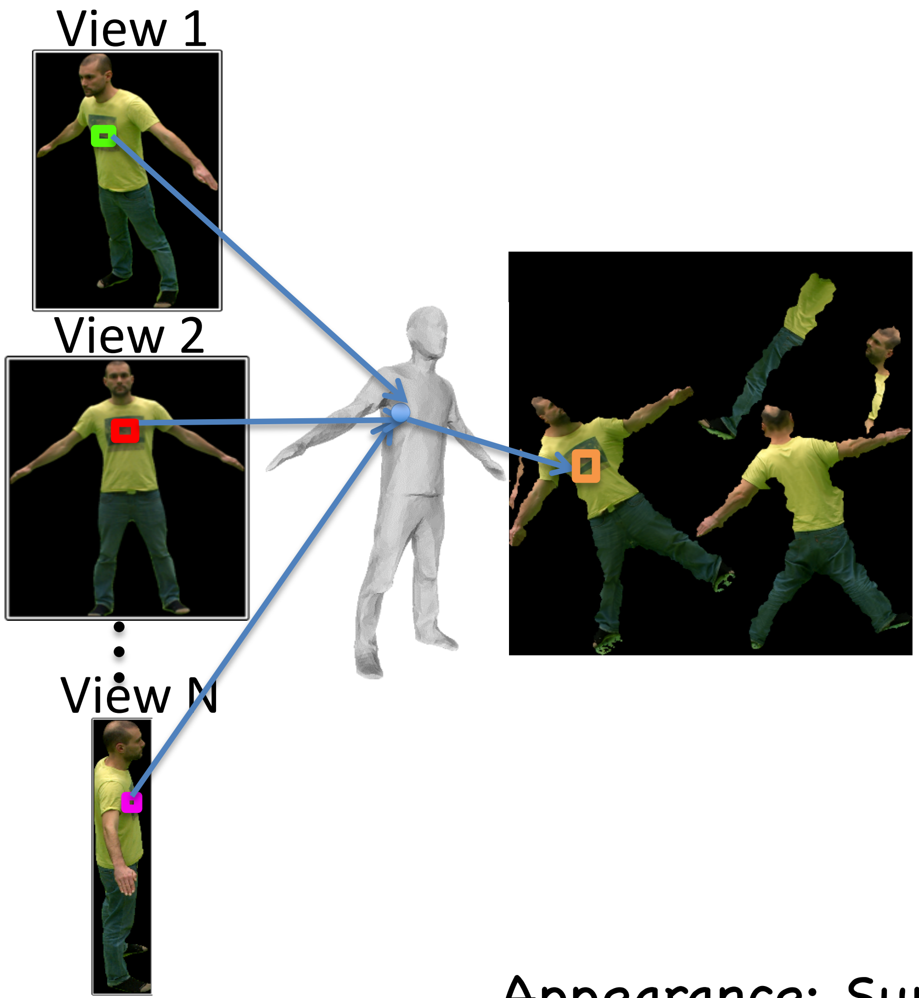
- Compute the value that is close to observations.
- Impose TV prior to minimize discontinuities.

Shape Recovery: Basics

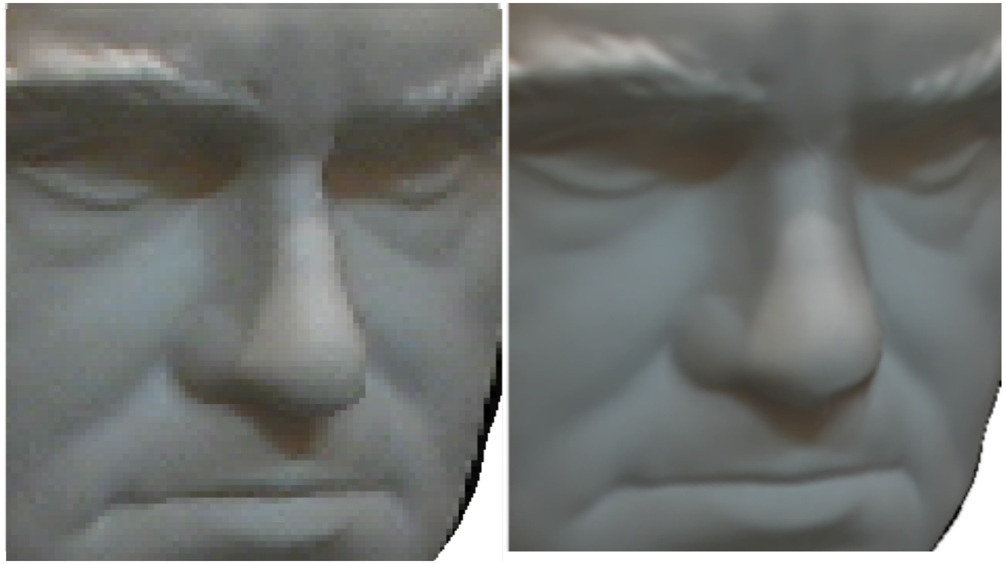
Image Super-resolution



Shape Recovery: Basics



Example: Input Images



Input

Tsiminaki et al. CVPR 2014

Appearance: Super Resolution Strategy

THOMAS
68 viewpoints
resolution 2048 x 2048

Averaging

SR method

Conclusion

Modeling evolving shapes:

- Pretty good models + deformations with simple scenes.
- Some results with the dynamic aspects: information redundancy, statistics for example.

Progress to be made:

- Acquisition: precision, robustness, modalities (X-ray).
- Shape: representation (e.g. clothes), changing appearances,
- Motion: build relevant models, pose spaces and motion spaces; statistical analysis.
- Datasets: benchmarks.

Fundamental issues:

- Shape models that account for material, appearance and anatomical information.
- Fully exploiting the time dimension to build models.
- Learning.

Website: http://morpheo.inrialpes.fr

Acquisition Platform: http://kinovis.inrialpes.f

Shape Tracking

Shape Tracking: More

Combined simulated and captured Shape dynamics