Deformable 3D Reconstruction with an Object Database

Pablo F. Alcantarilla and **Adrien Bartoli**

ISIT-UMR 6284 CNRS, Université d'Auvergne, Clermont Ferrand, France

BMVC 2012, Guildford, UK

Outline

1 Introduction

2 Related Work

3 Building the Object Database

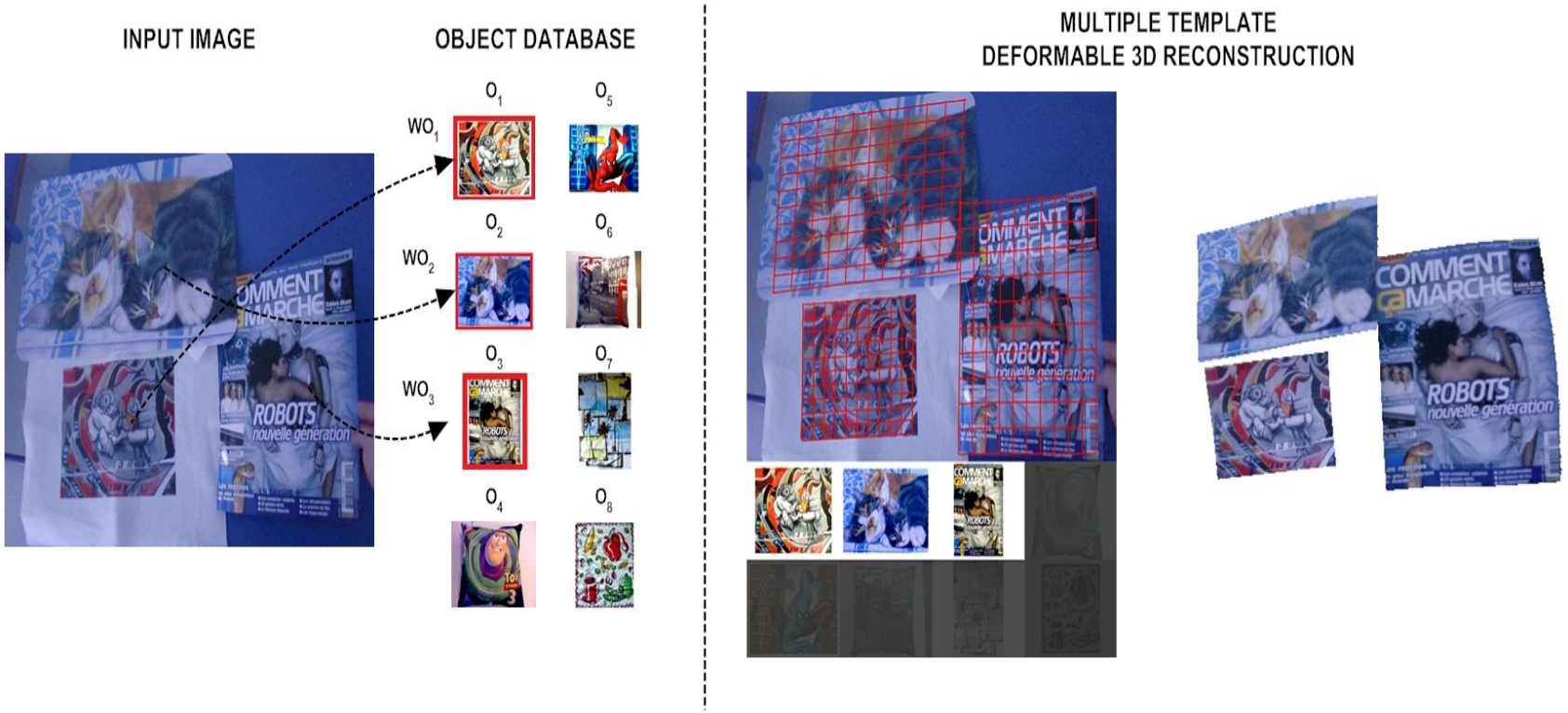
4 Deformable 3D Reconstruction with Multiple Objects

5 Experimental Results

6 Conclusions and Future Work

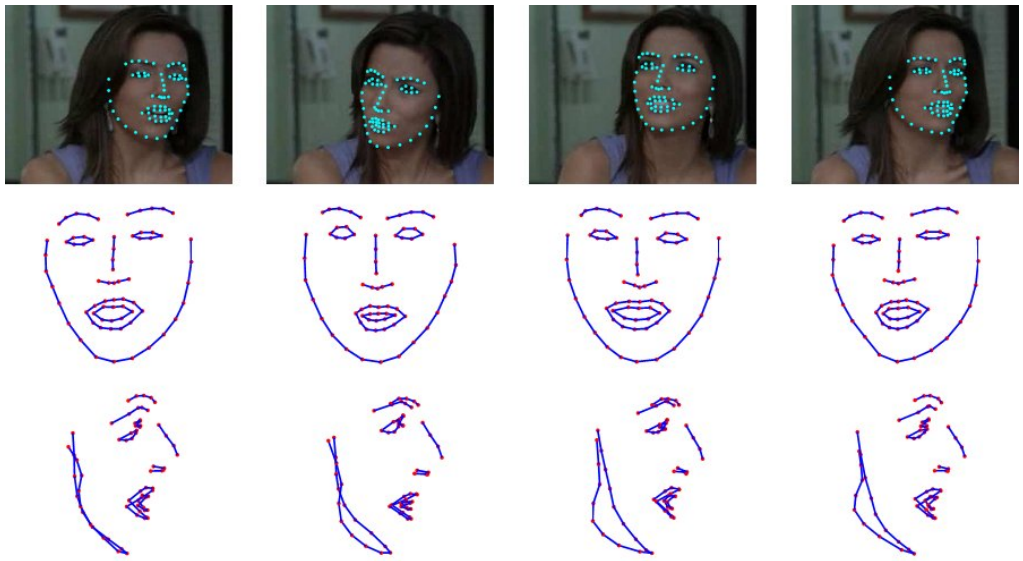
Introduction

- **Goal**: **Deformable 3D reconstruction** from a **single image** and for **multiple objects**



Deformable 3D Reconstruction from 2D images

- **Template-free** methods:
  - **Multiple images**
  - **Feature tracks** with enough baseline between images
  - Spatio temporal **smoothness priors** to constrain the problem
  - Example from: Paladini et al. [2010], *Sequential non-rigid structure from motion with the 3D-implicit low rank shape model*



Frame 31 Frame 48 Frame 84 Frame 102

Deformable 3D Reconstruction from 2D images

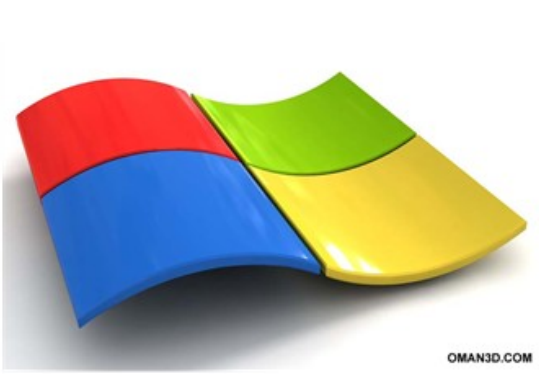
- **Template-based** methods:
  - **Single image**
  - Requires a **3D template** of the **object at rest**
  - Example from: Salzmann and Fua [2009], *Reconstructing sharply folding surfaces: A convex formulation*

Augmented Reality

- **Object detection** and **augmentation** with a **large-scale object database** is standard in **augmented reality**
- Most of the approaches consider **planar rigid objects**
- Example from: Pilet and Saito [2010], *Virtually Augmenting Hundreds of Real Pictures: An Approach based on Learning, Retrieval, and Tracking*

Contributions

- **Template-free** and **template-based** methods can handle only **one single object** at each time
- Our approach is the first one to propose **multiple template-based deformable 3D reconstruction** from a **single image**
- We improve **augmented reality** frameworks by **detecting deformable objects** and computing the **3D surface**
- Our approach can deal with both **developable** and **non-developable objects**
  - Developable objects can be flattened onto a plane without any distortion such as stretching or compression, i.e. isometric to the plane



DEVELOPABLE

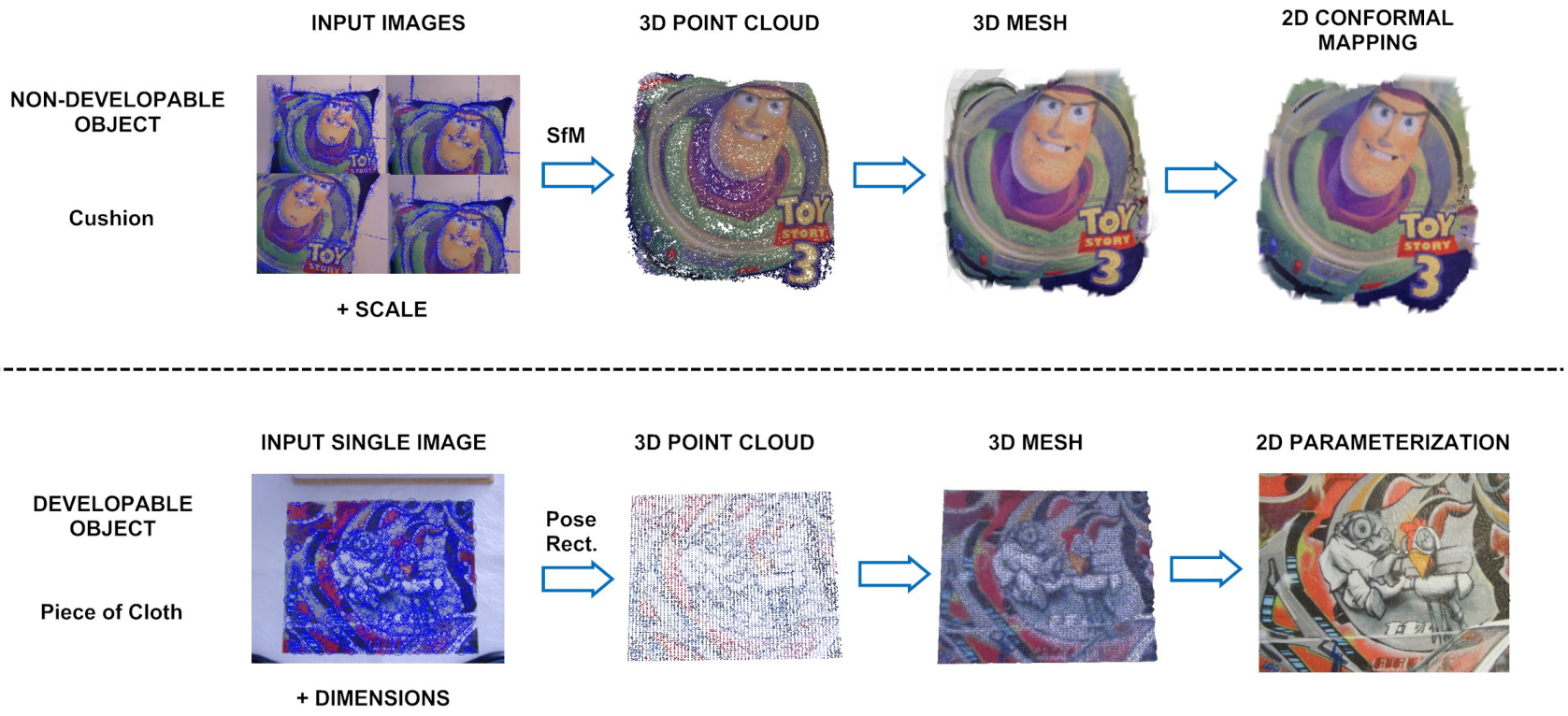
NON-DEVELOPABLE

Building the Object Database

- The **object database** comprises of **developable** and **non-developable** objects
- Each object O_i is composed of:
  - **Appearance descriptors**: $d_{O_i} = \left\{ d_1 \ldots d_{N_i} \right\}$
  - **3D Template**: $T_{O_i} = \left\{ (x_1, y_1, z_1) \ldots \left(x_{N_i}, y_{N_i}, z_{N_i} \right) \right\}$
  - **2D Parameterization**: $P_{O_i} = \left\{ (u_1, v_1) \ldots \left(u_{N_i}, v_{N_i} \right) \right\}$

Building the Object Database

- **Two different approaches** for building the 3D and 2D templates
  - **Non-developable** objects
  - **Developable** objects



Non-Developable Objects

- **Toy Story Cushion**

Developable Objects

- **Graffiti Paper**

Deformable 3D Reconstruction with Multiple Objects

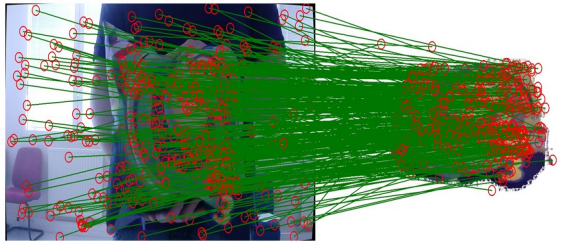
1. **Object Recognition**
   - **Hierarchical vocabulary tree** to select a set of M_1 potential objects present in the image; Nistér and Stewénius [2006]
2. **Feature-Based Deformable Surface Detection**
   - **Wide-baseline matching** with **outlier rejection** based on **local surface smoothness**; Pizarro and Bartoli [2012]
   - **Image Deformation Model**: **Thin Plate Spline (TPS) warp** between the selected **templates** and the **target objects** in the image; Bartoli et al. [2010]
3. **Deformable 3D Reconstruction**
   - Assumption that the **surfaces** deform **isometrically**
   - Closed-form solution for the isometric case that depends on the **image warp**, set of **first and second order warp derivatives** and **known camera intrinsics**; Bartoli et al. [2012]

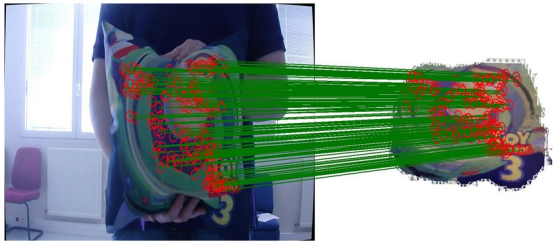
Feature-Based Deformable Surface Detection

- **Outlier rejection for image matching in deformable surfaces**

NON-DEVELOPABLE OBJECT

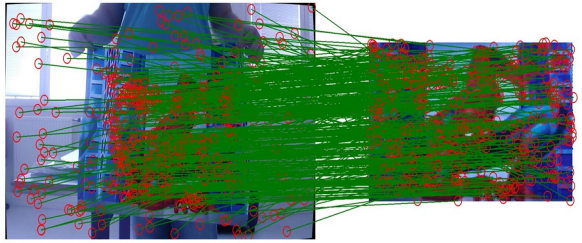
Cushion

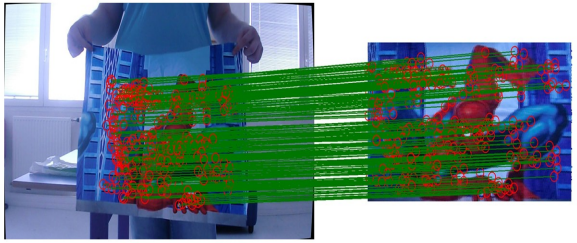




DEVELOPABLE OBJECT

Piece of Cloth



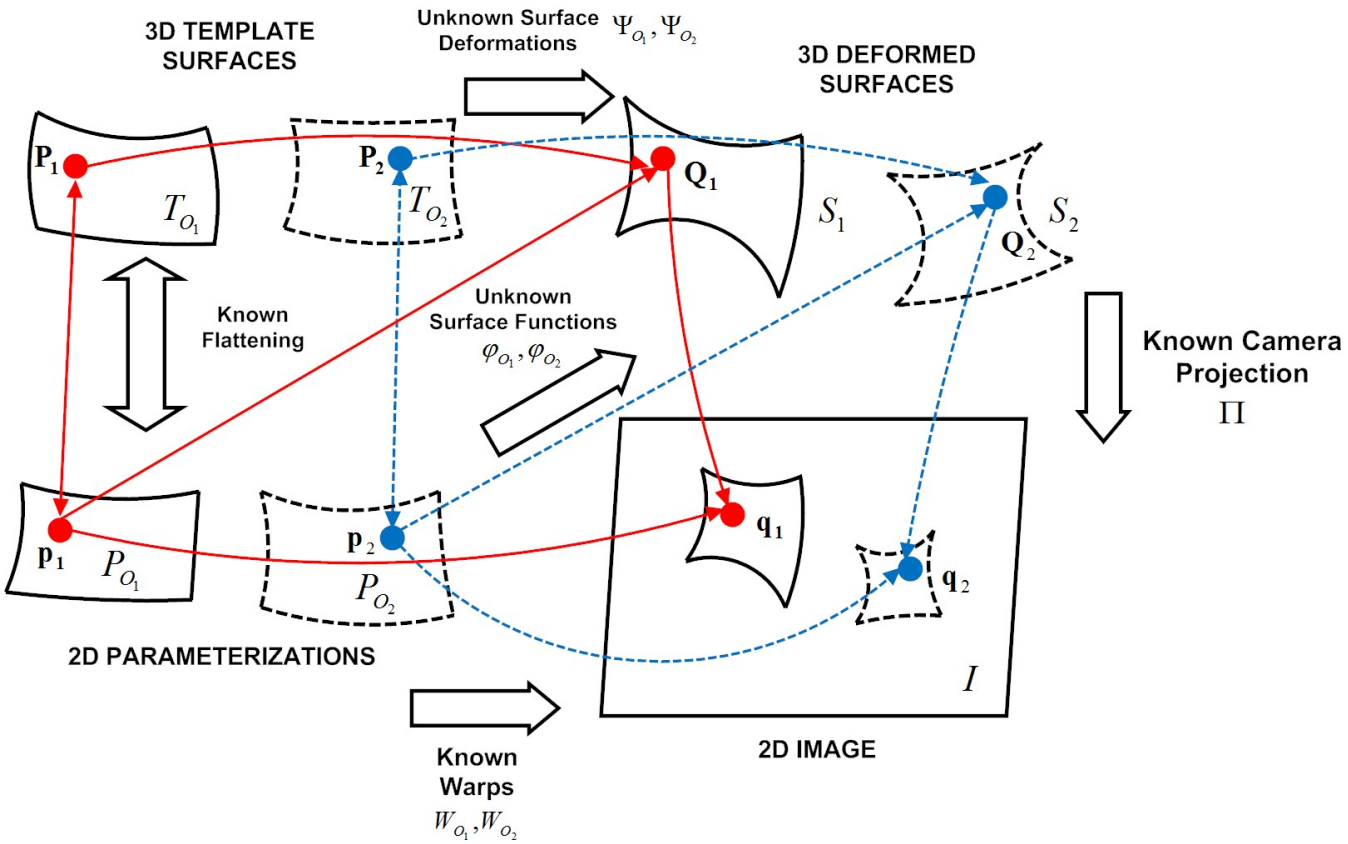


SET OF CORRESPONDENCES

SET OF CLEAN-UP MATCHES

Deformable 3D Reconstruction

- The **analytical solution** is obtained by solving a system of **PDEs**
- The solution depends only on the **2D warp** W_{Oi}, the set of **first** and **second order derivatives** and **camera intrinsics**



One Single Object in the Image

One Single Object in the Image

- **T-Shirt Video**

One Single Object in the Image

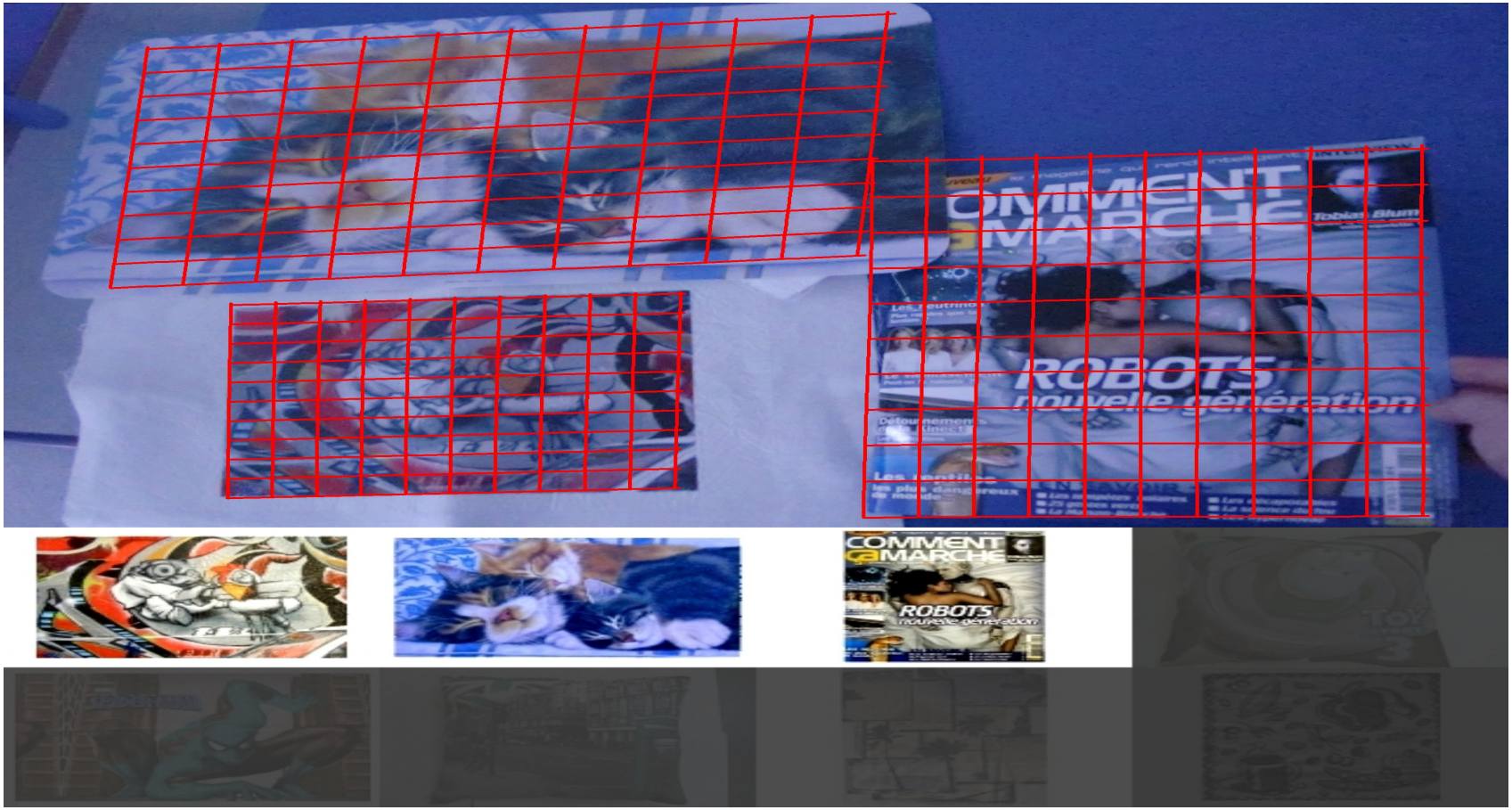
- **London Cushion Video**

Two Objects in the Image

Two Objects in the Image. Not Simultaneously.

- **Spiderman and T-Shirt Video**

Three Objects in the Image



Conclusions and Future Work

- **Conclusions**
  - **First deformable 3D reconstruction** approach using an **object database**
  - **Deformable 3D reconstruction** from only **one image** and for **multiple objects**
  - It works with both **developable** and **non-developable** objects
  - **New area of approaches** that can benefit from using **strong priors** encoded in a versatile **object database**
- **Future Work**
  - **New deformation models** such as **conformal** or **quadratic local models**
  - Incorporate **material properties** in the **object database**
  - **Large-scale object database** with new types of objects and classes of detectors
  - Deal with **texture-less** objects
  - **Tracking** of **deformable objects**
  - **Augmentation for deformable surfaces**

Thanks for your time!!

- ***The Amazing Deformable Spiderman Flag*!!**

Bibliography

Bartoli, A., Gérard, Y., Chadebecq, F., and Collins, T. (2012). On template-based reconstruction from a single view: Analytical solutions and proofs of well-posedness for developable, isometric and conformal surfaces. In IEEE Conf. on Computer Vision and Pattern Recognition (CVPR), Providence, Rhode Island, USA.

Bartoli, A., Perriollat, M., and Chambon, S. (2010). Generalized thin-plate spline warps. Intl. J. of Computer Vision, 88(1):85–110.

Nistér, D. and Stewénius, H. (2006). Scalable recognition with a vocabulary tree. In IEEE Conf. on Computer Vision and Pattern Recognition (CVPR).

Paladini, M., Bartoli, A., and Agapito, L. (2010). Sequential non-rigid structure from motion with the 3D-implicit low rank shape model. In Eur. Conf. on Computer Vision (ECCV), Crete, Greece.

Pilet, J. and Saito, H. (2010). Virtually augmenting hundreds of real pictures: An approach based on learning, retrieval, and tracking. In IEEE Virtual Reality (VR), Waltham, MA, USA.

Pizarro, D. and Bartoli, A. (2012). Feature-based deformable surface detection with self-occlusion reasoning. Intl. J. of Computer Vision, 97(1):54–70.

Salzmann, M. and Fua, P. (2009). Reconstructing sharply folding surfaces: A convex formulation. In IEEE Conf. on Computer Vision and Pattern Recognition (CVPR), Miami, USA.