Content-Aware Stereo Image/Video Retargeting

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Outline

- Introduction
- Problems in Image/Video Retargeting
- Region-Based Stereo Image Retargeting
- Temporally Coherent Stereo Video Retargeting
- Summary & Discussions
Motivation

Various Displays

Various Layouts

Interactions
Artifacts due to Image Resizing

• Problems with existing resizing schemes

Letter Boxing
Waste of Resolution

Cropping
Information Loss

Uniform Scaling
Shape Deformation
Artifacts due to Image Resizing

• Traditional Techniques: Uniform Scaling & Cropping
  – 3D Image & Video

Cropping -> “window violation”

Scaling changes the depth
Problems in Stereo Image/Video Retargeting

- Retargeting a stereo image/video will change the perceived depth of 3D scene, depending on the viewing distance and display size.

How to adapt a stereo image/video to various displays to enrich the 3D viewing experience?
Video Retargeting for Display Adaptation

Uniform scaling

“Retargeting”
Video Retargeting for Display Adaptation

Original Video

Uniform Scaling

Proposed Method

16:9
HDTV

4:3
SDTV
Content-Aware Image Retargeting

- Image retargeting: content-aware image resizing
- Image retargeting usually consists of two steps:
Image Retargeting Methods

• Two kinds of schemes: discrete & continuous methods
• Discrete methods: Iteratively remove/inserts pixels

implies Seam Carving [Avidan et al. 2007]

• Pros & Cons:
  – Pros: high flexibility, suitable for image editing applications
  – Cons: discontinuous distortions
Image Retargeting Methods

• Continuous Methods: Deriving continuous warping functions to transform an image

Warping [Wang et al. 2008]

• Pros & Cons:
  – Pros: smoother and continuous resizing
  – Cons: non-uniform deformation of an object
The same object in neighboring frames should be resized coherently.
Temporal Coherence in Video Retargeting

Original video

Wolf et al.

Seam Carving
Content-Aware Retargeting

- Content-Aware Image/Video Retargeting

**Content Analysis**
- Saliency detection
- Disparity Est.
- ...

**Content Processing**
- Geometric Trans. Optimization
- ...

**Content Presentation**
- Quality Assessment Coding
- ...

**Research Topics**
- Machine Learning
- Image Processing
- Signal Processing
- Computer Vision
- Multimedia
- Numerical An.
- IC Design
- Signal Processing
- Graphics
- Psychology
- HCI
- Aesthetics

**Journals**
- IJCV, PAMI, TIP, TCSVT, TMM, TOG

**Conferences**
- ICCV, ECCV, CVPR, Siggraph, Eurographics, MM
Region-Based Stereo Image Retargeting

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Background

- 3D is popular
Background

• We can view a stereo image pair on many devices

Displays with various sizes call for an efficient stereo image retargeting method to fit a stereo image to a screen
Background

• The simplest method: uniform scaling
  – Distorting the shapes of objects,
  – Distorting the depth of the 3D scene
Background

- The simplest method: uniform scaling
  - Change the depth of a 3D scene

Left image

Right image

Original size

Target size

Disparity

Screen

Depth
Related Work

• Content aware stereo image retargeting
  – Aim: shape preservation, disparity preservation
  – Stereo seam carving: [Utsugi et al. 2010], [Basha et al. 2013]
    • Inserting or removing pixels

Noticeable shape distortion

Spatial Coherence Constraints

• **Region-based methods** [Chang et al. 2011], [Lee et al. 2012], [Yoo et al. 2013]

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Do not explicitly consider the effect of resizing regions on the disparity/depth


Our Approach

• Analyze the effect of resizing different regions on the depth of 3D scene.
  – key finding: the scaling of various kinds of regions leads to different effects on the depth construction of 3D scene.
  – region classification: isolated region, occluded regions, paired regions.
  – Depth preservation constraints: considering the resizing effect of different regions on depth

• Region-based stereo image retargeting method
  – simultaneously preserving the shape of salient objects and maintaining the depth of 3D scene
Effect of Region Resizing on Scene Depth

- **Paired region**: a region in one image that can find a correspondence in the other image of a stereo pair.
- **Occluded region**: a region in one image that cannot find any correspondence in the other image due to the occlusion by other objects.
- **Isolated region**: a region that lies in the left (right) boundary of the left (right) image, and has no correspondence in the other image.
Effect of Region Resizing on Scene Depth

• Given a correspondence pair \((f^L, f^R)\), the horizontal disparity is calculated by

\[
d = x^R - x^L
\]

• Reformulating the equation in terms of the width of different region classes

\[
d = \sum_{r^L_j, r^R_j \in \gamma_p} (w^R_{y,j} - w^L_{y,j}) - \rho^z \sum_{r^z_j \in \gamma_o} w^z_{y,k} - \sum_{r^L_j \in \gamma_l} w^L_{y,j}
\]

Paired regions    Occluded regions    Isolated regions
Effect of Region Resizing on Scene Depth

• Resizing an occluded region would affect the disparities of all regions to the right of it (local effect).

• Resizing an isolated region would change the disparities of all regions (global effect).

• Resizing a paired region has no effect on the disparity of any other region, provided that both the widths of the region and its correspondence are changed consistently.
Intuition behind our Work

1. Resizing an isolated region

For depth preservation,
- preserve the widths of isolated regions,
- avoid horizontal distortions of occluded regions,
- consistently change the widths of paired regions and that of their corresponding ones.

Global effect

Local effect

Preserving

Right image

- Paired region
- Occluded region
- Isolated region

3. Resizing a paired region and its correspondence
Proposed Framework
Problem Formulation

- Objective:
  - Simultaneously minimizing the overall shape distortions of salient objects and the depth distortions in stereo pairs

\[
\min (1 - \alpha) D^s + \alpha \cdot D^d
\]

- Shape distortion
- Depth distortion
Characterizing Shape Distortion

- The weighted sum of individual grids’ deformations

\[ D^s = \sum_{z \in \{L,R\}} \sum_{i=1}^{z} \sum_{j=1}^{z} (w_{ij}^z \cdot \tilde{h}_{ij}^z - \tilde{w}_{ij}^z \cdot \tilde{h}_{ij}^z)^2 \cdot \eta_{ij}^z \]

- Grid’s aspect ratio changes
- Importance
Characterizing Depth Distortion

• To preserve depth:
  – preserve the widths of isolated regions and occluded regions
  – consistently change the widths of a paired region and its correspondence

\[
D^d = \beta_1 D^l + \beta_2 D^o + \beta_3 D^p = \\
\sum_{g_{ij}^z \in G_l} \beta_1 (w_{ij}^L - \tilde{w}_{ij}^L)^2 + \sum_{g_{ij}^z \in G_o} \beta_2 (w_{ij}^z - \tilde{w}_{ij}^z)^2 + \sum_{g_{ij}^z \in G_p} \sum_{g_{ik}^z \in C_{ij}} \beta_3 (\tilde{w}_{ij}^z - \tilde{w}_{ik}^z)^2
\]

Isolated regions  Occluded regions  Paired regions
Experiments: Depth Distortion

Results of Resizing different classes of regions on Baby1
Experiments: Retargeting Quality

Original | Stereo Seam Carving | Multi-Level Warping | Ours
Experiments: Retargeting Quality

Original  Stereo Seam Carving  Multi-Level Warping  Ours
Summary

❖ Depth-Preserving Stereo Image Retargeting
  ▪ We show that resizing different regions of a stereo image pair leads to different effects on the depth of 3D scene
  ▪ We propose to maintain the depth of 3D scene via imposing different smoothness constraints on different classes of regions

❖ Temporally Coherent Stereo Video Retargeting
  ▪ We propose a framework to achieve shape preservation, depth preservation and temporal coherence in stereo video retargeting