Foreground and Shadow Segmentation based on a Homography-correspondence pair

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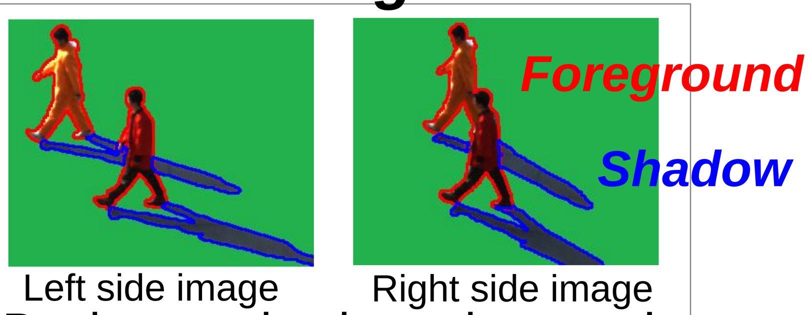
Introduction

◆Background

- A binocular system is widely used
  - Surveillance, Sports visualization, Traffic monitoring
- Foreground extraction is important in these applications
  - Background subtraction is major technique but often suffers from shadow

How to segment?

Input of a binocular system



Background subtraction result

◆Objective

- Assign one of the following labels to each pixel

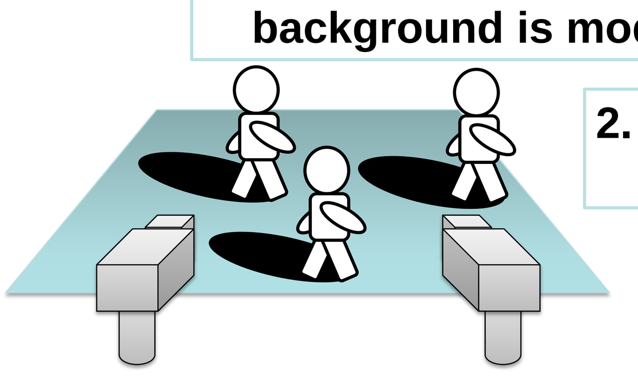
"*F*"(Foreground) or **"*S*"(Shadow)** or **"*B*"(Background)**

◆Related work

- Color-based approach [Horprasert et al. 2000]
  - It fails if foreground region with the color like shadow
- Disparity-based approach [Gordon et al. 1999]
  - It suffers from miss-correspondence problem
- Homography-based approach [Jeong et al. 2005]
  - It fails at occlusion region

Homography correspondence pair-based segmentation

◆Assumption

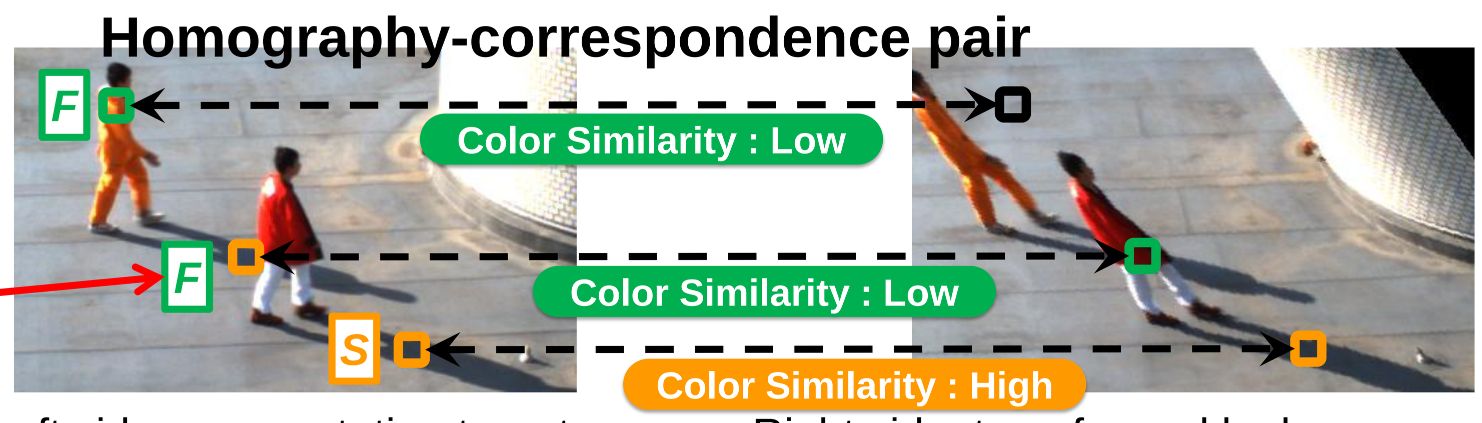


1. A scene is captured by a static binocular camera and the background is modeled as pixel-wise Gaussian model
2. Object stands on the ground plane and shadow appears on the ground plane
3. A homography correspondence between two cameras is calibrated

◆Existing asymmetric approach

Label is decided based on the color similarity

Miss-labeling : occluded shadow



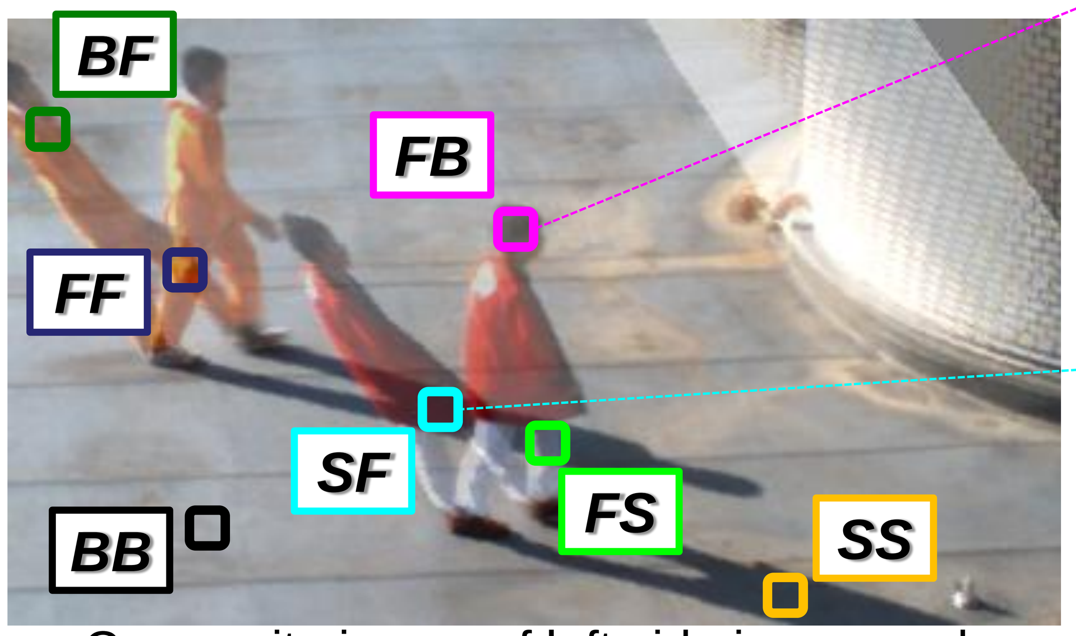
Left side: segmentation target   Right side: transformed by homography

◆Proposed symmetric approach

- **Pair-wise label is assigned to a homography-correspondence pair**

Pair-wise label set : **L**		Right side label F	Right side label S	Right side label B
Left side label	F	FF	SF	BF
Left side label	S	FS	SS	-
Left side label	B	FB	-	BB

Prohibited by homography constraint



Composite image of left side image and homography-transformed right side image

Foreground with the color like shadow

- ■Color-based : ✕ — Left side : S Right side : B — Miss-labeling
- ■Proposed : ○ — Pair-wise label: FB (Prohibited: SB)

Occlusion

- ■Existing homography-based : ✕ — Left side : F Right side : F — Miss-labeling
- ■Proposed : ○ — Pair-wise label: SF

- **Formulation : Multi-labeling problem**

$$E(\mathbf{X}) = w_g \sum_{\mathbf{v}\in\mathbf{V}} \mathbf{g}(\mathbf{x}_\mathbf{v}) + w_h \sum_{(\mathbf{u},\mathbf{v})\in\mathbf{E}} \mathbf{h}(\mathbf{x}_\mathbf{u}, \mathbf{x}_\mathbf{v})$$

Data term   Smoothness term

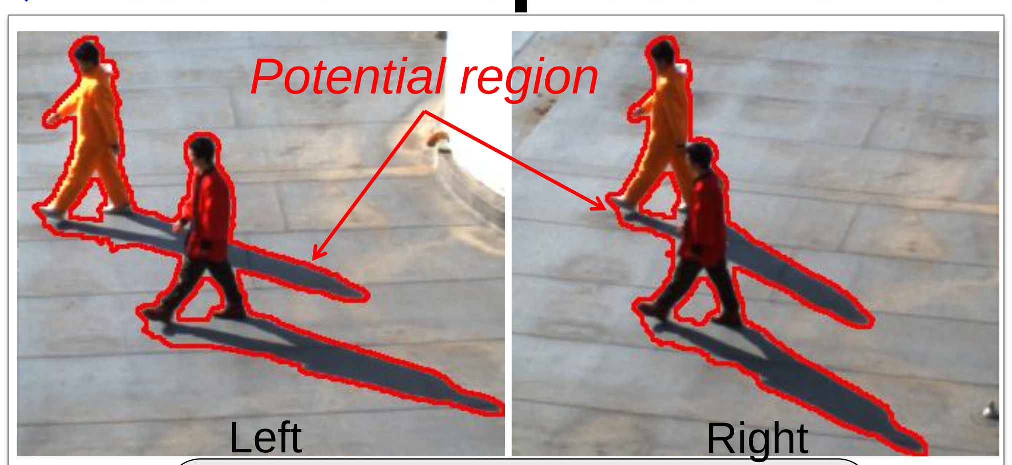
$\mathbf{v} = (\mathbf{p}^l_\mathbf{v}, \mathbf{p}^r_\mathbf{v})$: homography-correspondence pair $\mathbf{x}_\mathbf{v} \in \mathbf{L}$: label

$\mathbf{X}$: label assignment $\mathbf{V}$: a set of all sites $\mathbf{E}$: a set of all combinations of neighborhood sites

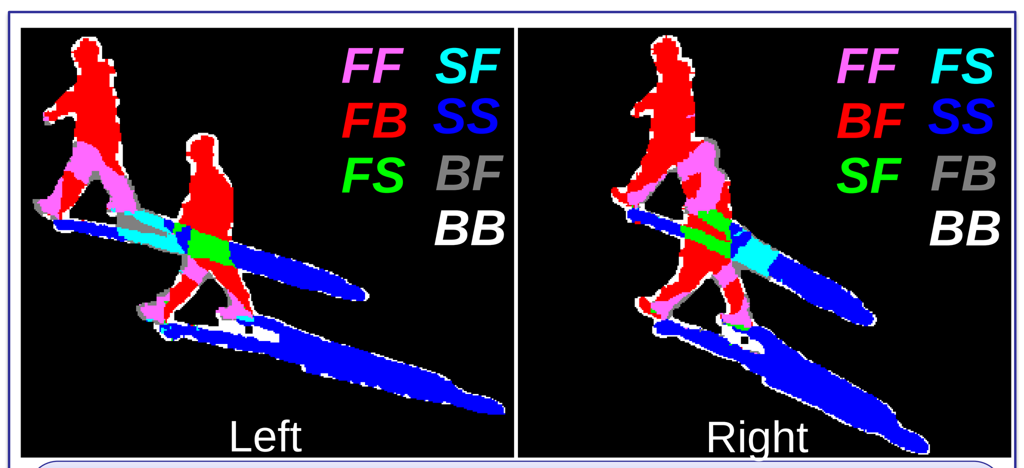
w_g : weight of data term w_h : weight of smoothness term

Experiments

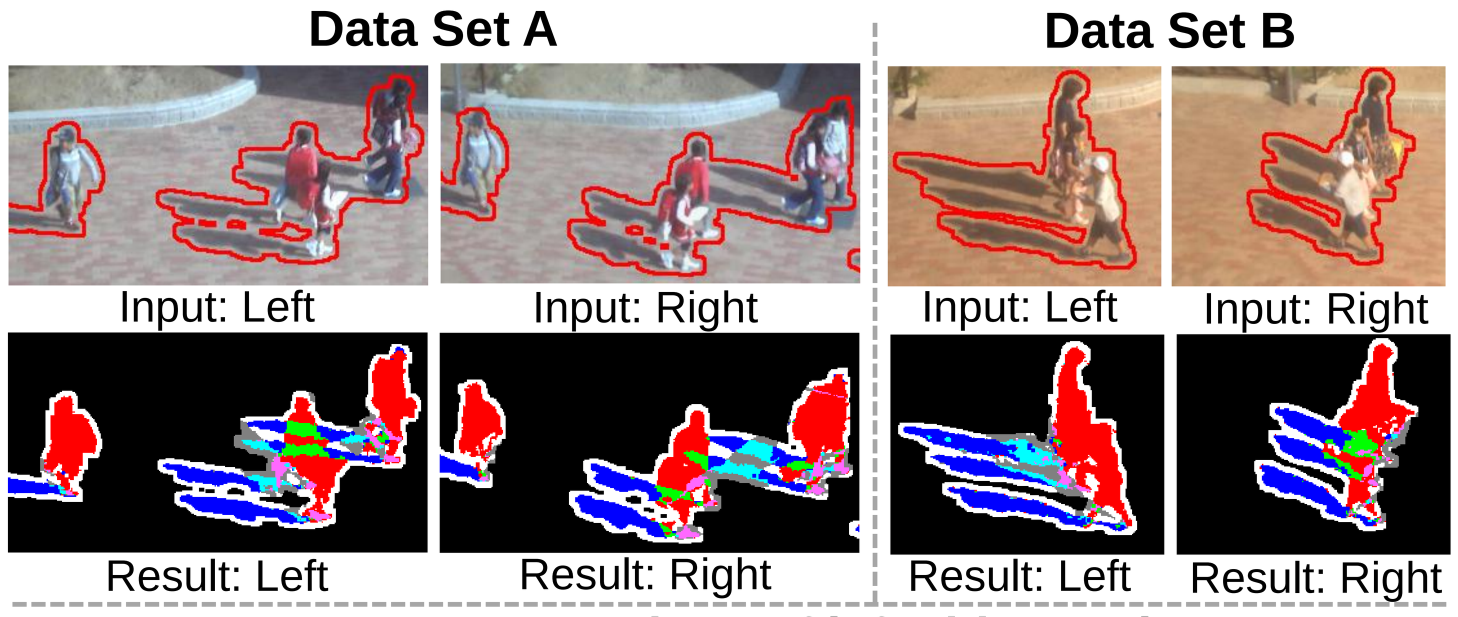
◆Result of Proposed Method



Step1. Background subtraction



Step2. Multi labeling via Energy minimization



◆Comparison Result : F-measure evaluation

$F = \frac{2PR}{P+R}$ F : F-measure, P : precision, R : recall

Method	Feature	Solution	Data Set A Foreground	Data Set A Shadow	Data Set B Foreground	Data Set B Shadow
Horparsert et al. 2000	Color	Threshold processing	0.816	0.516	0.627	0.653
Color	Color	Energy minimization	0.896	0.833	0.817	0.776
Disparity	Disparity	Energy minimization	0.758	0.643	0.822	0.708
Disparity + Color	Disparity + Color	Energy minimization	0.906	0.843	0.897	0.857
Homography	Homography	Energy minimization	0.872	0.779	0.877	0.770
Jeong et al. 2006	Homography + Color	Threshold processing	0.878	0.791	0.868	0.764
Homography + Color (Asymmetric)	Homography + Color	Energy minimization	0.921	0.854	0.874	0.824
Proposed method	Homography + Color	Energy minimization	0.920	0.875	0.899	0.864

Comparison of left side result