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Dense Labeling with User Interaction: an Example for Depth-Of-Field Simulation

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Introduction

- Many problems in Computer Vision can be formulated as a dense labeling problem.
- Common dense labeling techniques require a high computational cost for interactive applications.
- Besides, adding user knowledge in automatic systems can produce better solutions: interactive feedback.

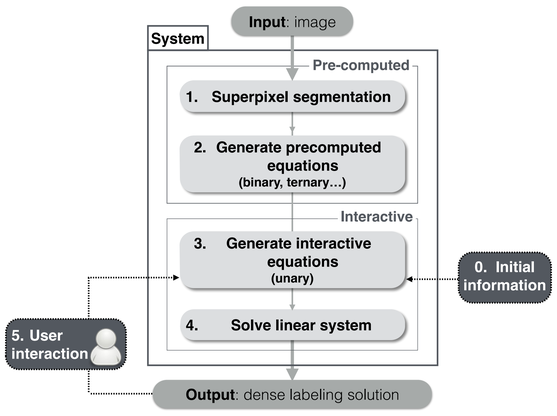
Related Work

Markov Random Fields (MRF):
- discrete labels
- high execution time for interactive app

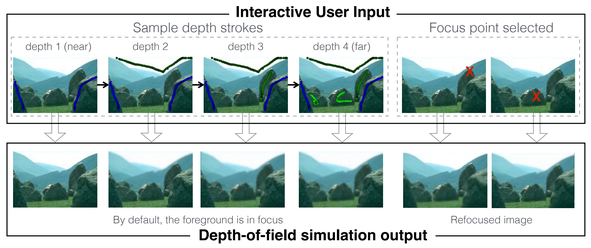
Random Walks:
- one linear system per label
- discrete labels with seeds

Contributions

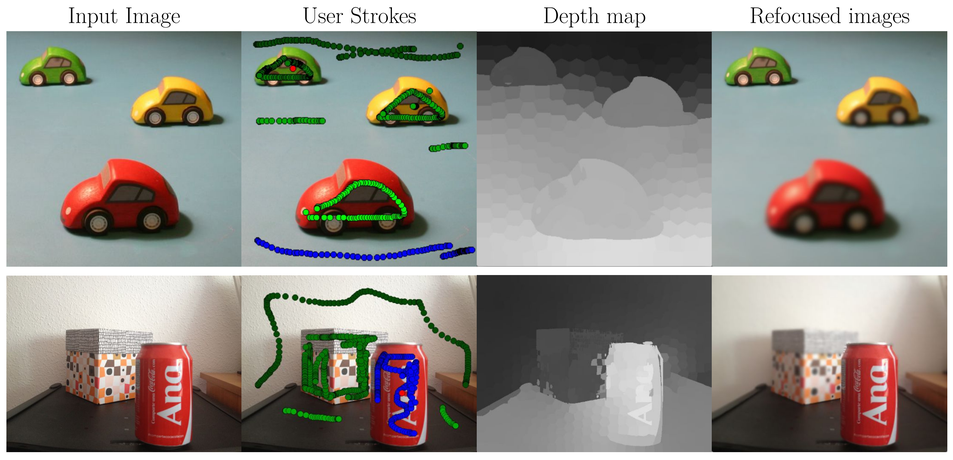
- Efficient dense labeling approach



- Interactive application for D-o-F simulation



Results



Formulation

- Model the image as a graph:
  - nodes N: SLIC superpixels [1]
  - edges E: relationships between superpixels.
- Continuous set of labels: real numbers in [0,1].
- Linear system of equations: $\begin{pmatrix} A_p \\ A_i \end{pmatrix} \cdot x = \begin{pmatrix} b_p \\ b_i \end{pmatrix}$

Binary equations: $w_b(l_p - l_q) = 0$

$$w_b = \begin{cases} w_c & \text{if } d_{pq} \leq D_{MAX} \\ 1 - w_c & \text{otherwise} \end{cases}$$

$$d_{pq} = \sqrt{(B^L_{pq} - B^L_{qp})^2 + (B^a_{pq} - B^a_{qp})^2 + (B^b_{pq} - B^b_{qp})^2}$$

Unary equations: $l_p = z_i$

More Information

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Code: https://github.com/anacambra/app_lensblur
Video

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Evaluation

Automatic dense input

Method	Tsukuba (384x288) #Labels=16		Venus (434x383) #Labels=20		Teddy (450x375) #Labels=60	
	time	err	time	err	time	err
Pixel-based						
ICM [2]	0.520	0.12	0.460	0.10	1.900	0.13
Expansion [3]	2.220	0.02	6.940	0.02	19.90	0.05
Swap [3]	2.250	0.02	7.010	0.02	12.60	0.05
TRW−S [4]	8.840	0.02	115.0	0.02	158.0	0.05
BP−S [5]	1.370	0.02	8.690	0.03	21.20	0.05
BP−M [5]	13.30	0.02	–	–	193.0	0.05
BCD [6]	0.920	0.09	1.500	0.17	2.760	0.08
RW [7]	0.200*	0.12	0.400*	0.20	0.600*	0.16
Superpixel-based						
Expansion	3.090	0.06	6.320	0.10	6.210	0.08
Ours	**0.002**	0.06	**0.005**	0.10	**0.005**	0.09

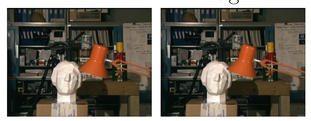
–: the method did not converge to a solution
*: execution time is measured in Matlab.

Sparse user input

Method	Tsukuba (384x288) #Labels=5		Venus (434x383) #Labels=5		Teddy (450x375) #Labels=5	
	time	err	time	err	time	err
Pixel-based						
ICM [2]	N/A	N/A	N/A	N/A	N/A	N/A
Expansion [3]	N/A	N/A	N/A	N/A	N/A	N/A
Swap [3]	N/A	N/A	N/A	N/A	N/A	N/A
TRW−S [4]	N/A	N/A	N/A	N/A	N/A	N/A
BP−S [5]	N/A	N/A	N/A	N/A	N/A	N/A
BP−M [5]	24.40	0.14	34.20	0.09	35.10	0.18
BCD [6]	–	–	–	–	–	–
RW [7]	0.500*	0.13	0.600*	0.20	0.700*	0.09
Superpixel-based						
Expansion	4.170	0.06	6.370	0.14	7.960	0.09
Ours	**0.002**	0.06	**0.005**	0.15	**0.005**	0.06

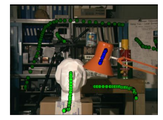
–: can't provide to available implementation.
*: execution time is measured in Matlab.

Left Right



Dense automatic input

User strokes



Superpixel affected by user strokes

Conclusion

- Our approach is the **fastest** to obtain a solution while keeping comparable quality in the results.
- The dense labeling pipeline has great flexibility to model this problem and has the advantage of providing an **interactive solver**.
- We believe that our approach will inspire future research for interactive editing applications based on dense labeling.

References

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