Simulating Human Saccadic Scanpaths on Natural Images

. [1,3], C . C [1], . . [1,2]
. . . [1,2], F . F . [2,4], . [2],
[1]N E . . Ʊ . , [2] . M P M E , P . U
[3] . U , C A S , ⁄ . 1 4 , C
[4]D P . , P . U , ⁄ . 1 1, C
S M S , P . U , ⁄ . 1 1, C
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Abstract

Human saccade is a dynamic process of information pursuit. Based on the principle of information maximi ation, we propose a computational model to simulate human saccadic scanpaths on natural images. he model integrates three related factors as driven forces to guide eye movements se uentially reference sensory responses, fovea-periphery resolution discrepancy, and visual working memory. For each eye movement, we compute three multi-band filter response maps as a coherent representation for the three factors. he three filter response maps are combined into multi-band residual filter response maps, on which we compute residual perceptual information (RPI) at each location. he RPI map is a dynamic saliency map varying along with eye movements. he next fixation is selected as the location with the maximal RPI value. On a natural image dataset, we compare the saccadic scanpaths generated by the proposed model and several other visual saliency-based models against human eye movement data. Experimental results demonstrate that the proposed model achieves the best prediction accuracy on both static fixation locations and dynamic scanpaths.

1. Introduction

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Proposed method

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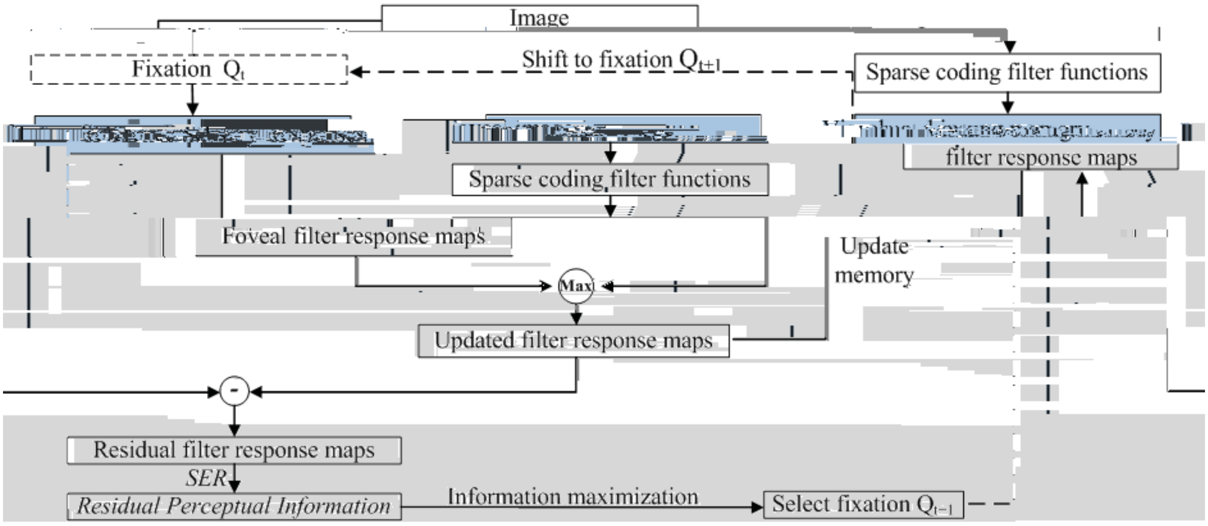
Image
Fixation Q_t
Shift to fixation Q_{t+1}
Sparse coding filter functions
filter response maps
Sparse coding filter functions
Foveal filter response maps
Update memory
Max
Updated filter response maps
-
Residual filter response maps
SER
Residual Perceptual Information
Information maximization
Select fixation Q_{t+1}

F. . 1.

fi fi ϵ $0 \leq \epsilon \leq 1$. fi fi fi fi *so far*

fi fi . C

Site Entropy Rate 2 fi *residual perceptual information (RPI)*. RPI

. I

SER fi Q_{t+1},

A *multi-band filter response maps*

1.1. Related work

I fi . I *et al.* 1 1 *et al.* 1 . I fi . C *et al.* *self-information* . H *et al.* 1 M *et al.* 13 1 , H *et al.* 1 . A *et al.* 1 . I *et al.* 2 fi fi

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2. Our Approach

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2.1. Coherent representation of three factors

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2.1.1 Sparse coding filters

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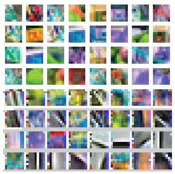

F . 2. 4 .

2.1.2 Foveal imaging

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F . 3. A . . O .
F . fi .

2.1.3 Visual working memory

O , fi . , , . , , , . fi . I fi .

Simulating the forgetting properties. I , fi ϵ $0 \leq \epsilon \leq 1$. I $\epsilon = 1$, $\epsilon = 0$, . I S 3.4, ϵ.

Updating visual working memory. fi . I , fi fi fi . A *Max* 4. . fi , $f_k^v(x,y,t)$ $f_k^w(x,y,t)$ k fi t (x,y) .

$$f_k^w(x,y,t) \leftarrow \max\left(f_k^v(x,y,t), \epsilon \cdot f_k^w(x,y,t-1)\right). \quad 1$$

Computing residual filter response maps. fi fi F . 1 . P fi . A , fi . fi $r_k = |f_k^o - f_k^w|$, f_k^o k .

2.2. Measuring residual perceptual information

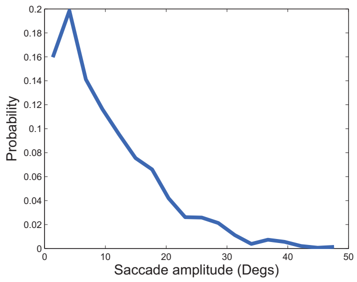
F , fi fi . . I , *Site Entropy Rate* SER 2 fi . *Site Entropy Rate* fi . R . . I , fi SER . SER , SER i

$$S_i = \sum_k SER_{ki} = -\sum_k \left(\pi_{ki} \sum_j P_{kij} \log P_{kij}\right) \quad 2$$

π_{ki} i k fi , P_{kij} i j k fi . A 2 , SER , . P 2 SER . SER . F , SER fi . M , fi , *e.g.*, , . S , SER . , . .

2.3. Saccadic amplitude

U , F . 4. I 90% 20° . fi . , , fi Q_{t+1} fi Q_t. F , $Z \times Z$ fi Q_t , $Z/2$ 4 20° . SER .



F . . 4. . . .

Q_{t+1}. N , Q_{t+1} . $p(z \leq Z/2)$, .

F . . 4. A fi Q_{t+1}, . . .

3. Experimental Results

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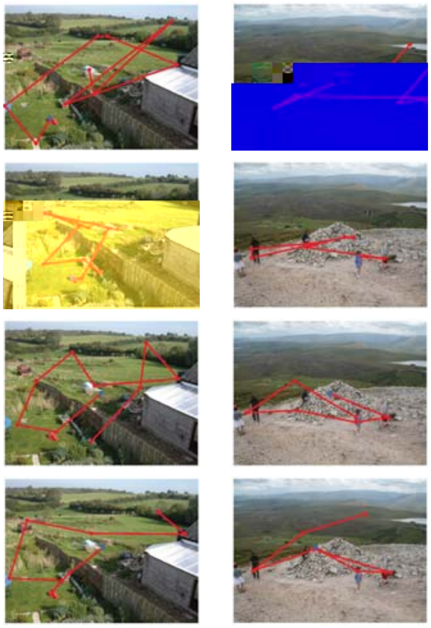
3.1. Dataset and eye movement data collection

2 . I . . . , . . , . , . 24 . . . . SMI H . . S. . 3 21 CR . . , 3 1 . A . . fi fi . . . .

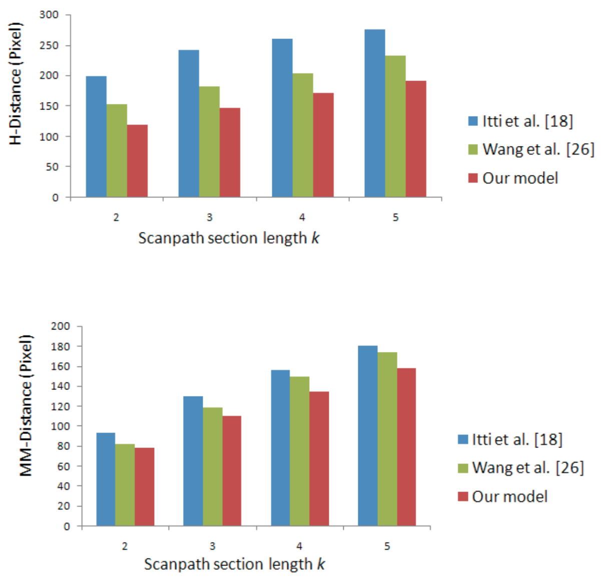
3.2. Evaluation of fixation order

. . . A , . 1 . . . . . , R . et al. 22. . , , . . N , I et al. 1 . .



F . . . C . . . 1 . , 2 . , . , . , . . . fi .

A . I R . . . . . , . . H , . I et al. . M , . . . , ... 1 . . 2 . , . . . A I R . . 1 . , . . . 1 . . . , . fi . . fi . . , fi . . . . . 8 ∼ 10 fi . , . fi . . . . . , . , I et al. 1 . . . . 2 . , . R . , . . . S. . , ... A F . . , . . .

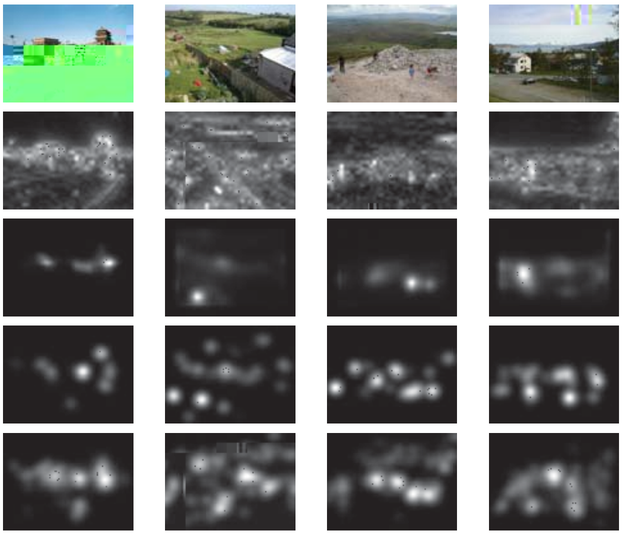


F . . . C . . . , 1 . 2 . . . H . . k.

3.2.1 Distance of scanpaths

I . . , *time-delay embedding*, . . 23. . S fi , . k, . . . $C_m^k(t) =$ $(c_m(t), \cdots c_m(t+k-1))$ k . , . t fi . m. / . t, . k . $X = \{C_m^k(t)\}_t \subseteq \mathbb{R}^k$. S $Y = \{C_h^k(\tau)\}_\tau$ k . . I . $k = 2$, fi . C . . X Y $\mathbb{R}^k$ . .

F . k $x =$ $C_m^k(t) \in X$, fi . $d_k(x,Y) = \min_\tau\{\|x - C_h^k(\tau)\|_2\}/k$. I , . . k . . . , $d_k(x,Y)$ . . x. . , ' . , ... H .



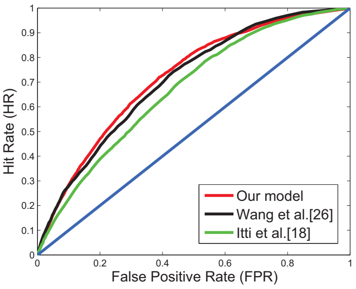
F . . . C . . fi . . . . , 1 . , 2 . , . , . fi , .

H D . . , fi

$$d_H^k = \max_t\{\min_\tau\{\|C_m^k(t) - C_h^k(\tau)\|_2\}\}/k \qquad 3$$

$$= \max_t\{d_k(C_m^k(t), Y)\}. \qquad 4$$

mean minimal distance MM D , , fi $d_M^k = \mathrm{E}_t[d_k(C_m^k(t), Y)]$. I . , . . . $\epsilon = 0.7$, $Z = 800$, . . . 2.3°. F . . . 2 3



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1. ROC

	I *et al.* 1 ,	. *et al.* 2 ,	O.
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3.4. Assessment of the forgetting factor

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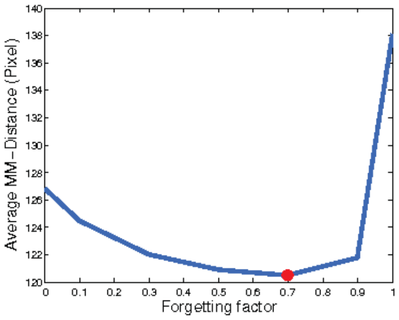

F . .   1 .   .   . k
ϵ. $\epsilon = 0.7$.

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ϵ = 0.7   .   .
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4. Conclusion, Discussion and Future Work

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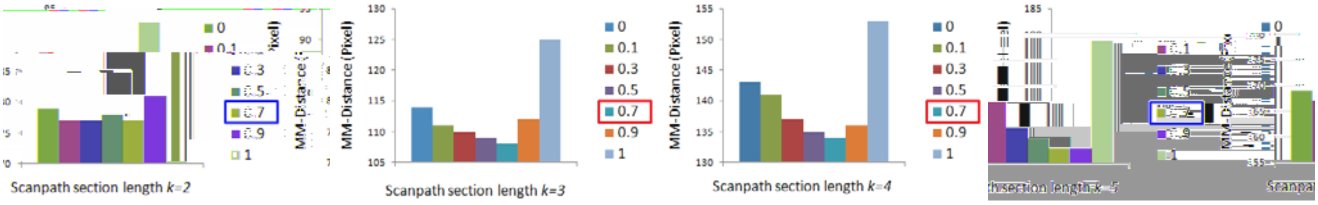

F. . . A . . . . ϵ . .

I . , . *edit distance* . . . . . . , ... I . . . . , ... I . . , ... M , fi . . . I . . . .

Acknowledgments

. N S F . C . . N . 2 12 2 , N ⁄ R _ 3, P . C . . N . 2 C⁄ 32 4.

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21. ⁄ . O . D. F . E . fi . . . *Nature*, 1 .
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2 . . . , . . , . H. . , . . M . . . . *CVPR*, 2 1 .