Jie Zhou, Zheng-xing Sun, Ke-wei Yang, 2014. A controllable stitch layout strategy for random needle embroidery. *Journal of Zhejiang University-SCIENCE C (Computers & Electronics),* **15**(9):729-743. [doi:10.1631/jzus.C1400099]

A controllable stitch layout strategy for random needle embroidery

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Key words: Random needle embroidery, Stitch style, Stitch layout, Stitch neighborhood graph, Reaction diffusion

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Motivation

- Random needle embroidery (RNE): an art combining western oil painting theories and Chinese embroidery skills.
- Modelling various stitching styles is the basic and core issue for research on RNE.
- Existing embroidery software tools are not suitable due to the difference in stitching styles.
- Our previous work firstly confirmed the feasibility about its machine embroidery, but did not allow users to conveniently control the global stitch layout style.

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Features of our approach (I)

- Stitch layout model

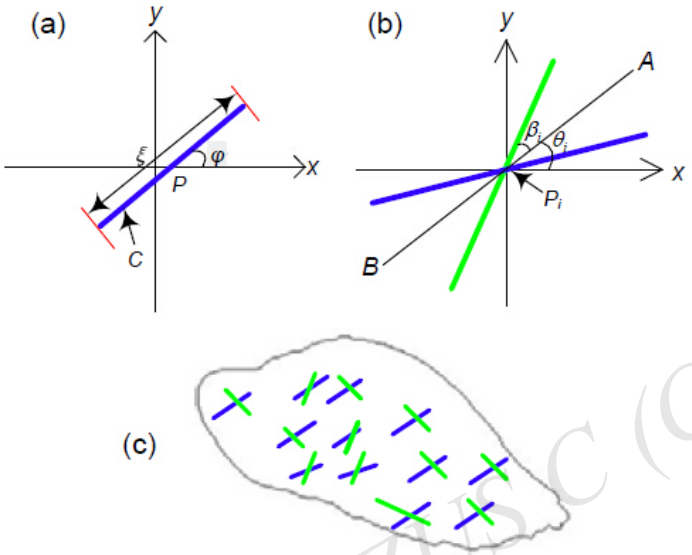


Fig. 1 Stitch layout model for the random needle embroidery (RNE)

(a) A stitch with center coordinate P, length ξ, orientation φ, and color C; (b) An intersecting-stitch with center coordinate P_i, intersection orientation θ_i, and intersection angle β_i; (c) Global layout of intersecting stitches. Each intersecting-stitch (b) includes two stitches (a). The global layout (c) is a combination of various intersecting-stitches

- Stitch neighborhood graph

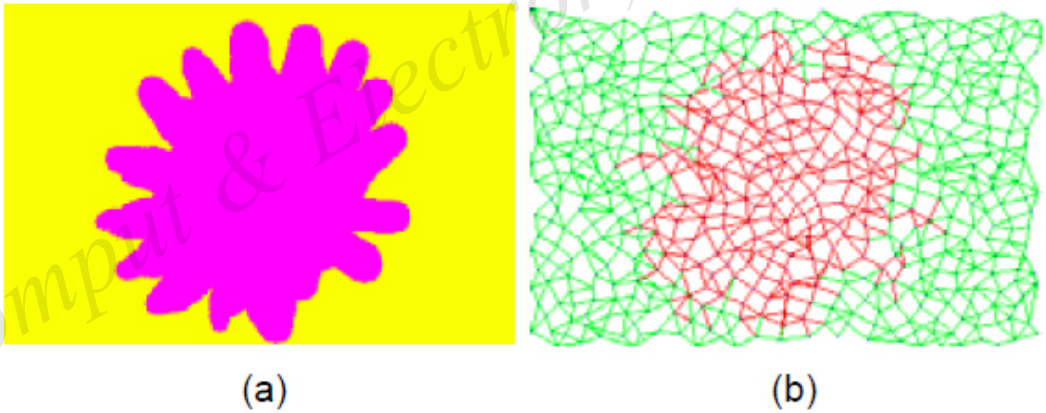


Fig. 4 Stitch neighborhood graph

Two graphs (b) are built for two regions (a) separately

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Features of our approach (II)

- Stitch attribute process

Attributes	Diffusion equation & Markov field energy
orientation	$\frac{d\theta}{dt} = R(\theta) + \lambda_\theta D(\theta) + \varepsilon_\theta \,,\; E(\theta) = \sum_i \varphi(\theta_i - \theta_i^*) + \lambda_\theta \sum_i \sum_{j \in N(i)} \omega_{ij} \varphi(\theta_i - \theta_j)$
length	$\frac{d\xi}{dt} = (\xi^* - \xi) + \lambda_\xi \sum_n \omega_n (\xi_n - \xi) + \varepsilon_\xi \,,\; E(\xi) = \sum_i \left\| \xi_i - \xi_i^* \right\|^2 + \lambda_\xi \sum_i \sum_{j \in N(i)} \omega_{ij} \left\| \xi_i - \xi_j \right\|^2$
	$\frac{dh}{dt} = \sin(h^* - h) + \lambda_h \sum_n \omega_n \sin(h_n - h) + \varepsilon_h \,,\; E(h) = \sum_i \varphi(h_i - h_i^*) + \lambda_h \sum_i \sum_{j \in N(i)} \omega_{ij} \varphi(h_i - h_j)$
color	$\frac{ds}{dt} = (s^* - s) + \lambda_s \sum_n \omega_n (s_n - s) + \varepsilon_s \,,\; E(s) = \sum_i \left\| s_i - s_i^* \right\|^2 + \lambda_s \sum_i \sum_{j \in N(i)} \omega_{ij} \left\| s_i - s_j \right\|^2$
	$\frac{dv}{dt} = (v^* - v) + \lambda_v \sum_n \omega_n (v_n - v) + \varepsilon_v \,,\; E(v) = \sum_i \left\| v_i - v_i^* \right\|^2 + \lambda_v \sum_i \sum_{j \in N(i)} \omega_{ij} \left\| v_i - v_j \right\|^2$

- Stitch rendering

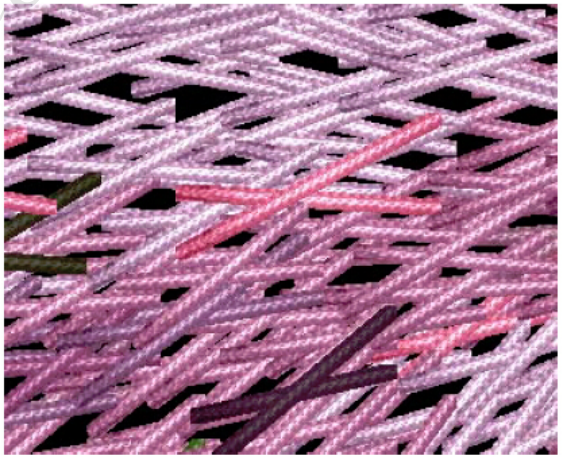


Fig. 7 Stitch rendering detail

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Major results (I)

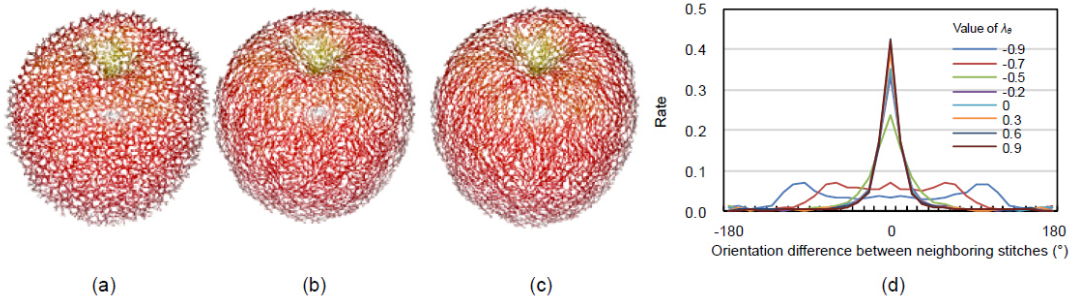


Fig. 12 Effects of λ_θ on stitch orientation

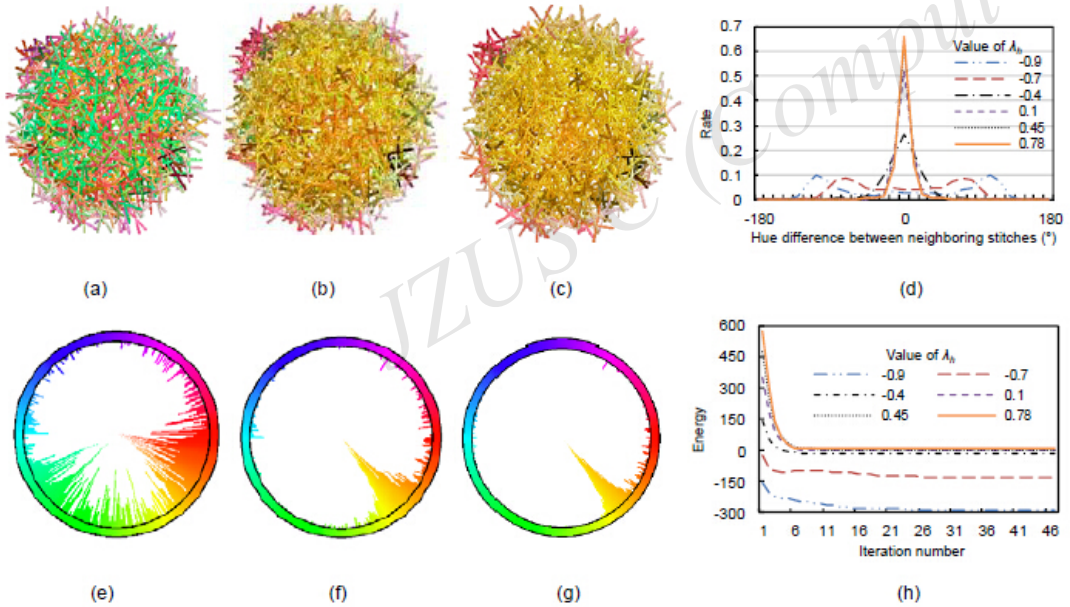


Fig. 14 Effects of λ_h on stitch hue

(a) λ_h=−0.9; (b) λ_h=0.1; (c) λ_h=0.78; (d) Histograms of different λ_h's; (e) λ_h=−0.9; (f) λ_h=0.1; (g) λ_h=0.78; (h) Energy iterations of different λ_h's

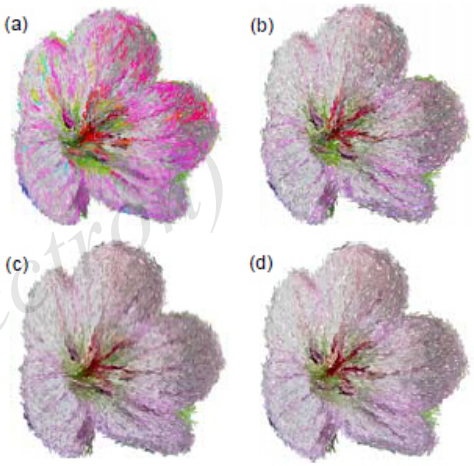


Fig. 15 Effects of λ_s on stitch saturation

(a) λ_s=−0.9; (b) λ_s=−0.6; (c) λ_s=0.35; (d) λ_s=0.64

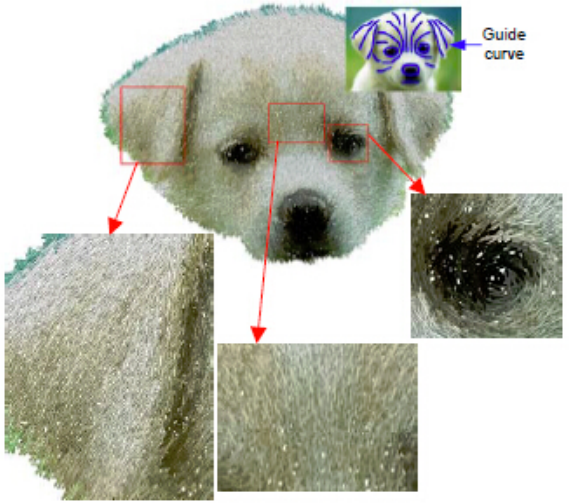


Fig. 18 A user interaction example of guide curves and final results with local details

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Major results (II)

Table 1 General ranges of five layout parameters for RNE

Object	λ_θ	λ_ξ	λ_h	λ_s	λ_v
Animal	0.16–0.52	−0.12–0.43	0.05–0.90	0.45–0.87	−0.05–0.15
Bird	0.02–0.53	−0.07–0.39	0.1–0.6	−0.03–0.71	0.01–0.15
Grass	−0.85–0.50	0.10–0.86	0.8–0.9	0.50–0.86	0.04–0.50
Flower	−0.9–−0.7 or 0.50–0.78	0.40–0.89	−0.87–−0.30 or 0.05–0.50	−0.1–0.3	0.10–0.67
Sky	0.8–0.9	−0.83–−0.41	0.7–0.9	0.00–0.34	−0.4–0.4

λ_θ, λ_ξ, λ_h, λ_s, and λ_v are diffusion factors for orientation, length, hue, saturation, and lightness, respectively



(a) (b) (c) (d)

Fig. 19 Final results of our proposed approach for RNE works of Apple (a), Flower (b), Bird (c), and Dog (d)

Conclusions

Our approach has the following features:

- controllability of reflecting various stitch layout styles via high-level layout parameters and the diffusion-based stitch layout process;
- flexibility of user adjustment and interaction.

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