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Offline Signature Verification via Structural Methods: Graph Edit Distance and Inkball Models

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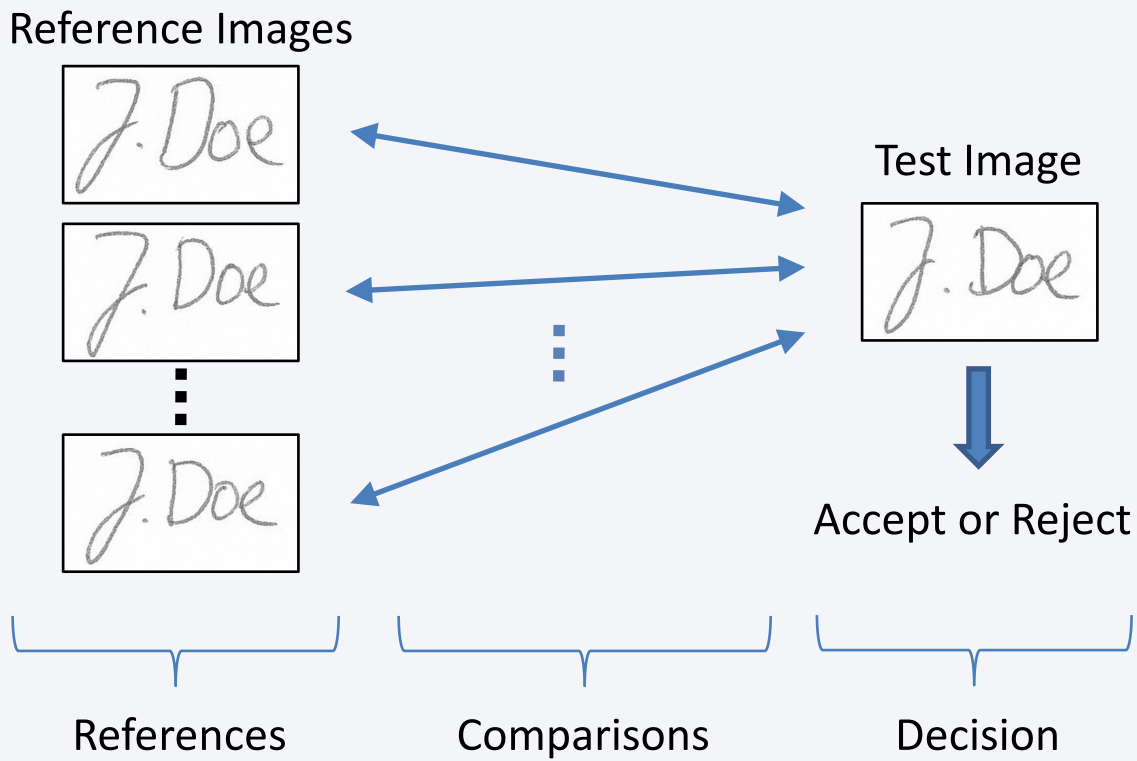
Offline Signature Verification



Statistical vs. Structural Approach

$(x_1, \ldots, x_n)$

Statistical – Feature vectors

+ large number of mathematical methods available

– fixed-size representation

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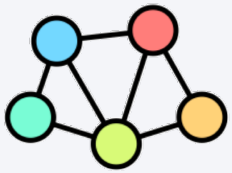
Our Approaches



Structural – Graphs

\+ flexible representation

\+ binary relations

– high computational complexity

Two recent structural approaches

Graph-based Signature Verification Framework

- Introduced by Maergner et al. at ICDAR 2017
- Bipartite approximation of graph edit distance
- Keypoint graphs

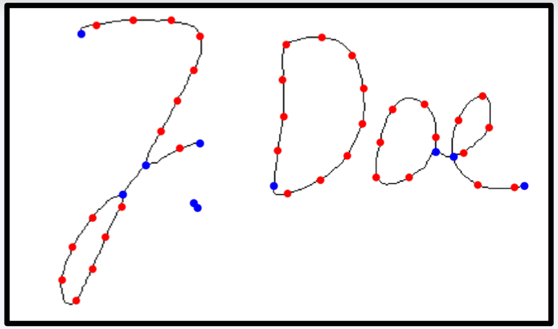
Inkball Models

- Introduced by Howe at ICDAR 2013
- Rooted tree and efficient matching algorithm
- Never been applied to Signature Verification

→ **Use both methods individually and combined**

Keypoint graphs
vs.
Inkball models

Keypoint graphs vs. Inkball models



Both Models – Similar Nodes

- End-/Junction points + additional points

Keypoint graphs – Edges

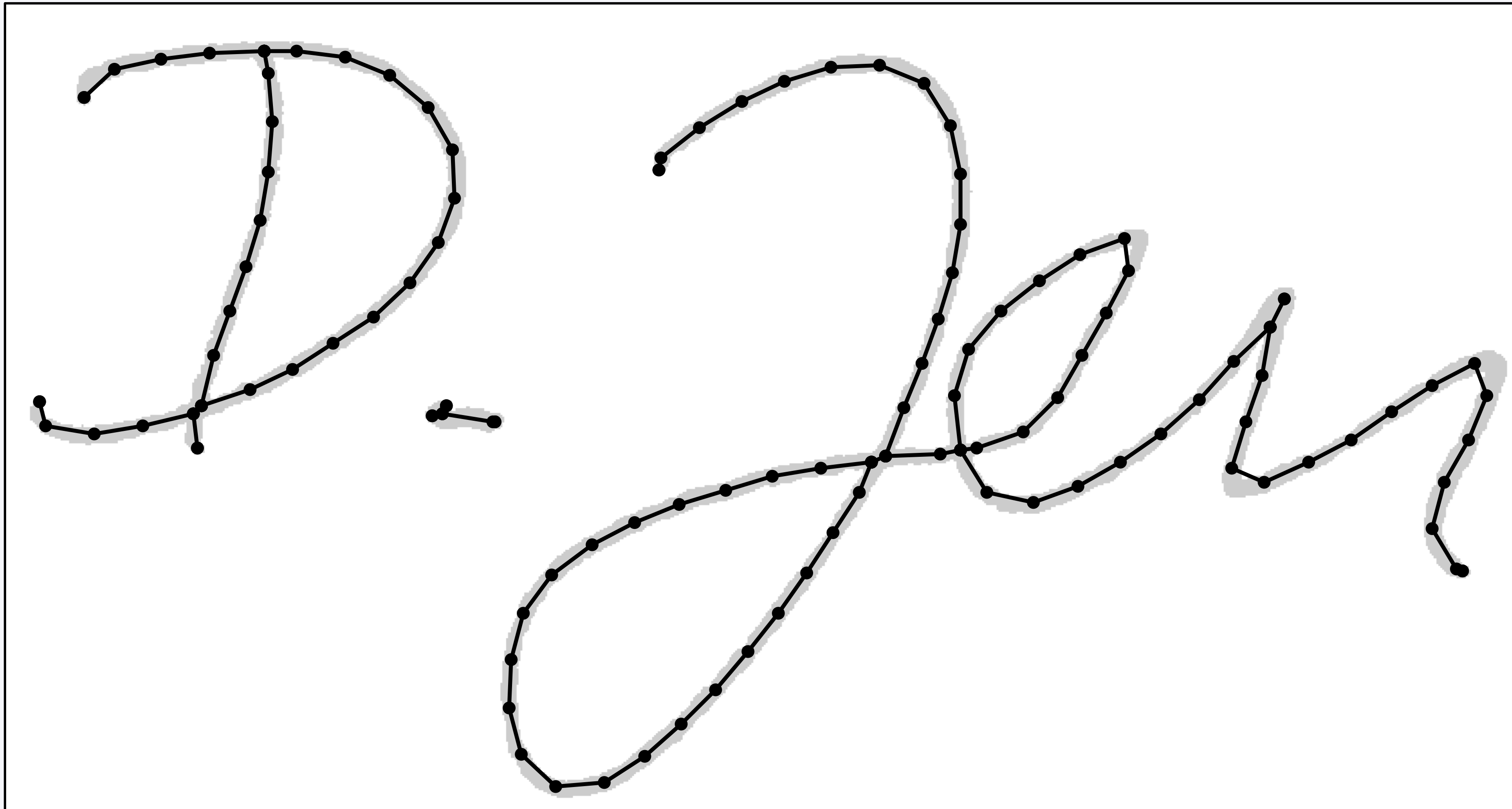
- Edges connect neighboring points on the skeleton
- Not all parts of the graph are connected, contains circles

Inkball models – Edges

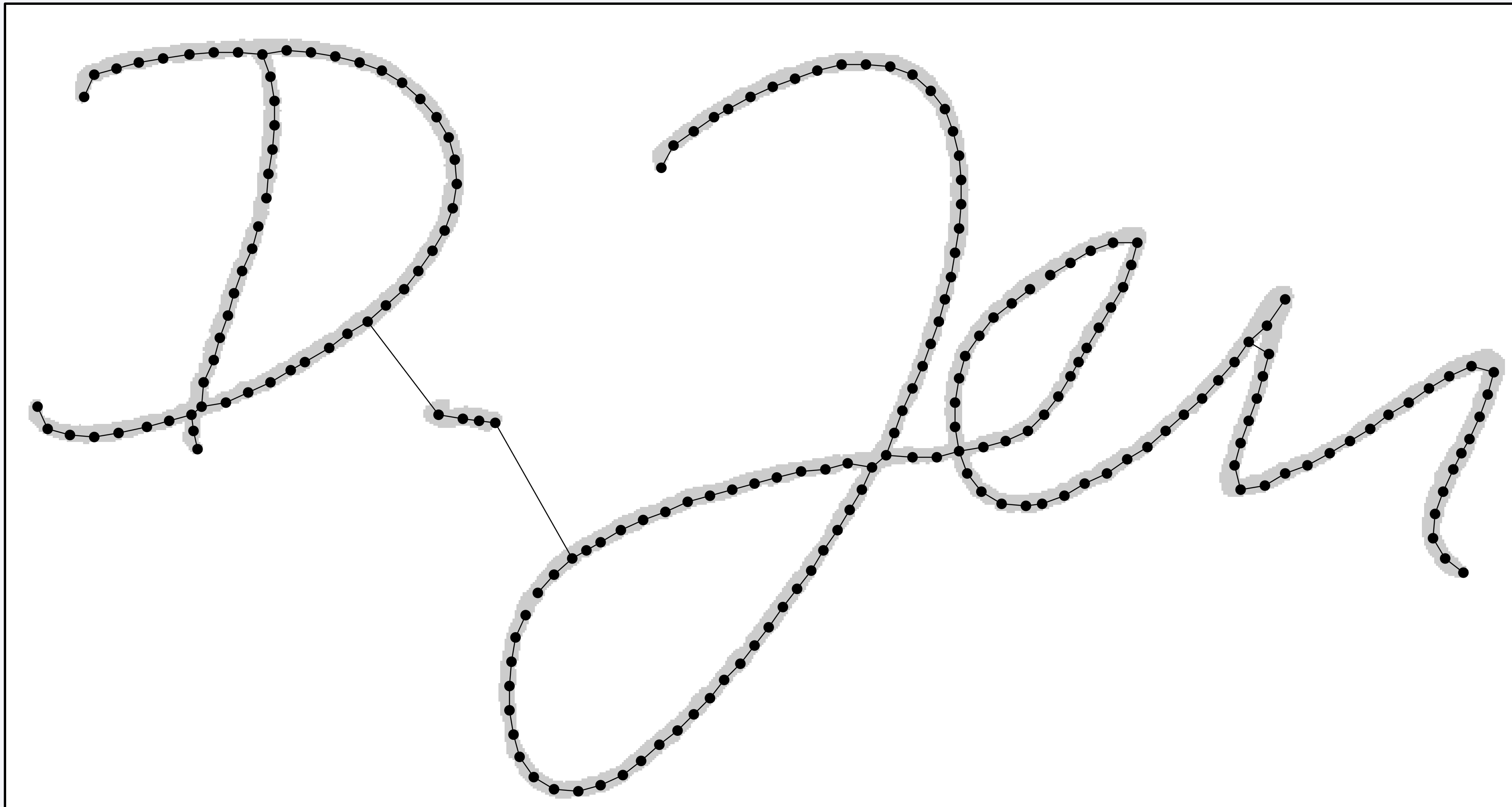
- Rooted tree (no circles, all parts are connected)
- Nodes are greedily connected to the nearest nodes

→ **Similar Representations**

Keypoint Graph

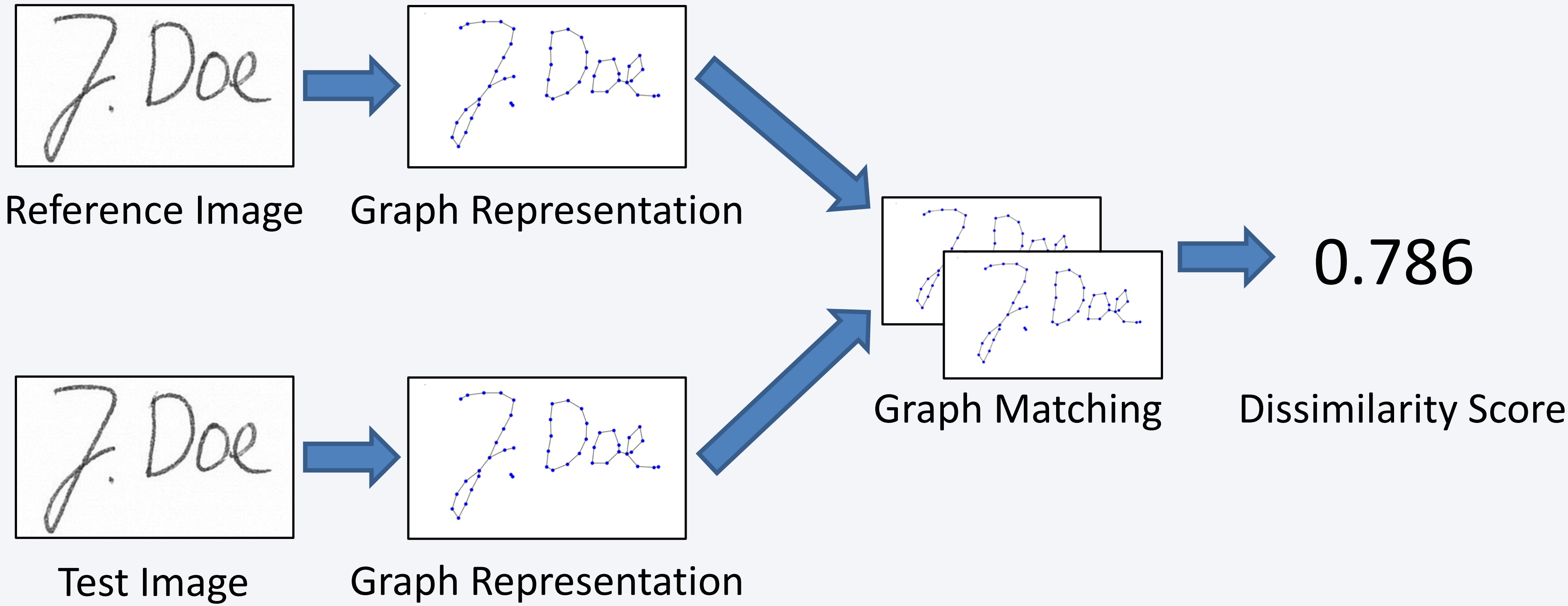


Inkball Model



Matching

Graph Edit Distance Approach: Overview

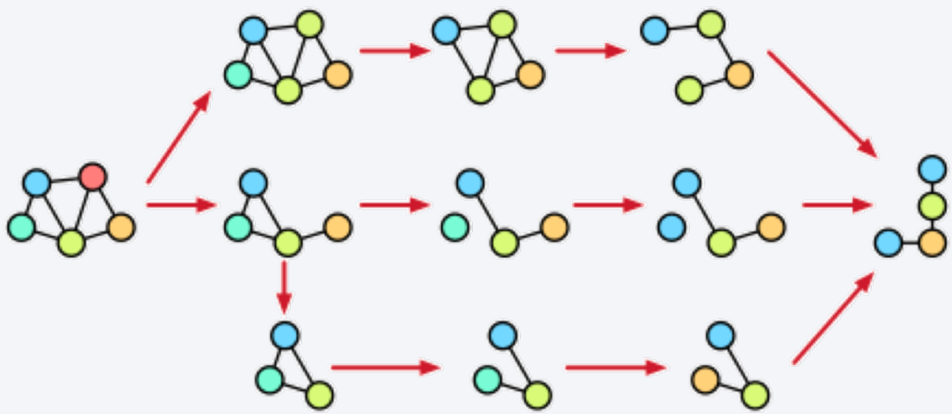


Graph Edit Distance (GED)

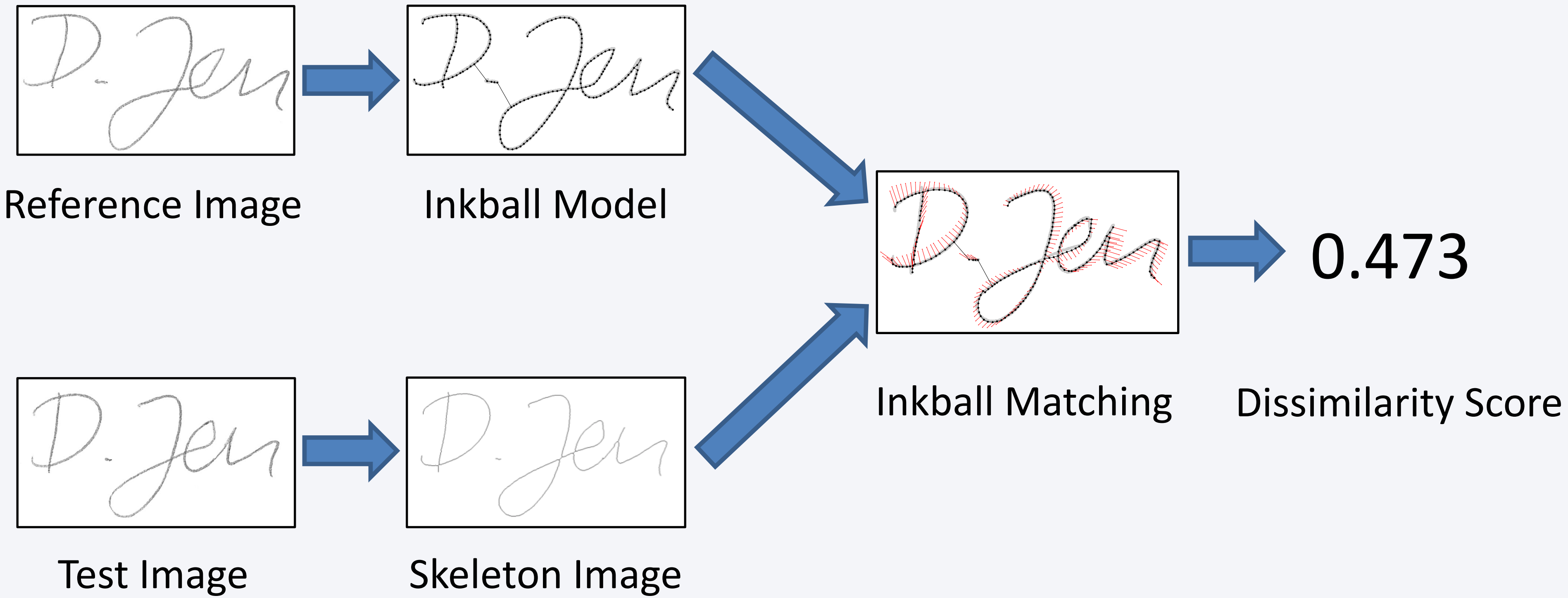
GED between g_1 and g_2

$$d(g_1, g_2) = \min_{(e_1,\ldots,e_k)\in\Upsilon(g_1,g_2)} \sum_{i=1}^{k} c(e_i)$$

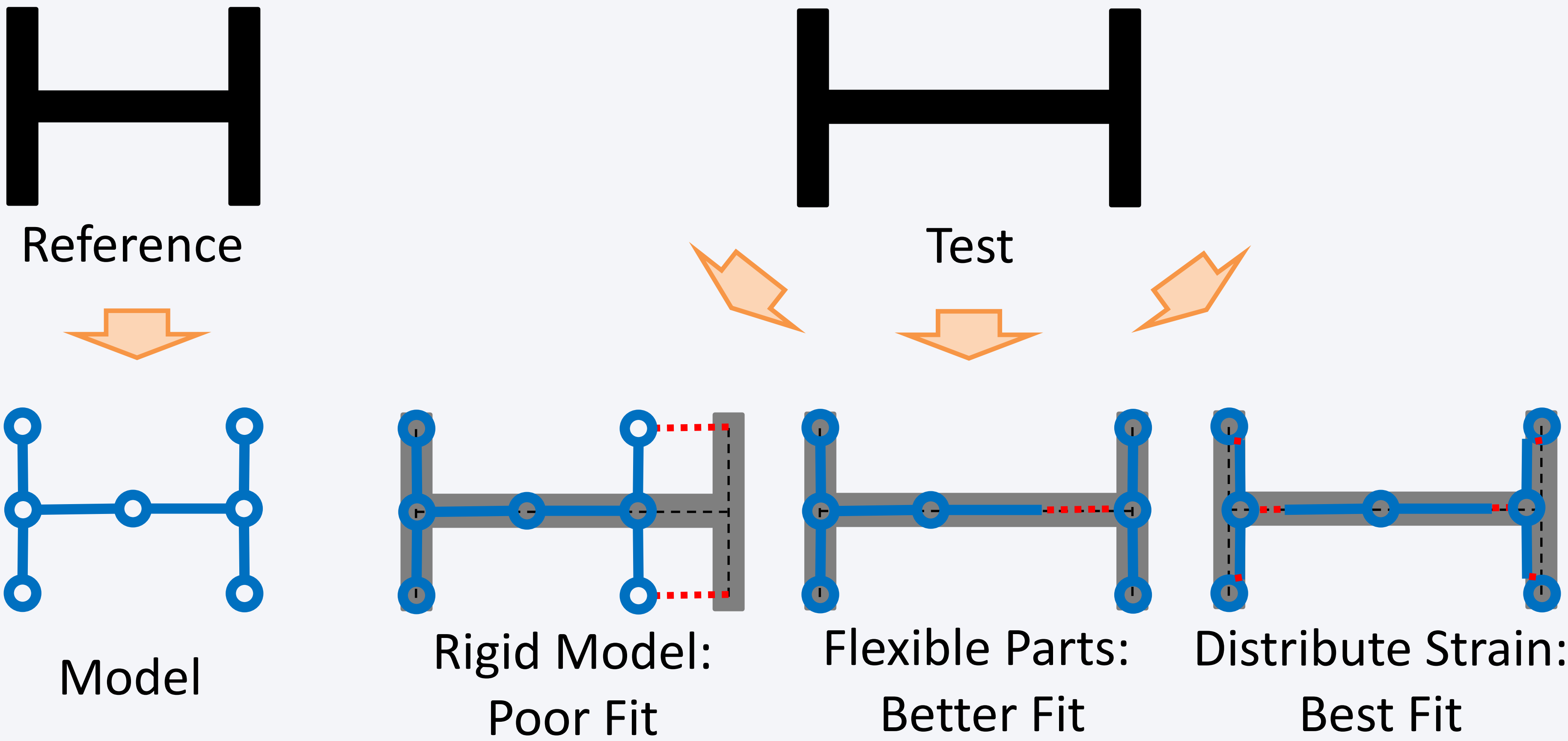
$\Upsilon(g_1, g_2)$	Set of edit paths
$c(e_i)$	Cost of edit operation e_i
Edit operations	Substitution/deletion/insertion of nodes and edges



Inkball Model Approach: Overview



Inkball matching



Signature Verification Score

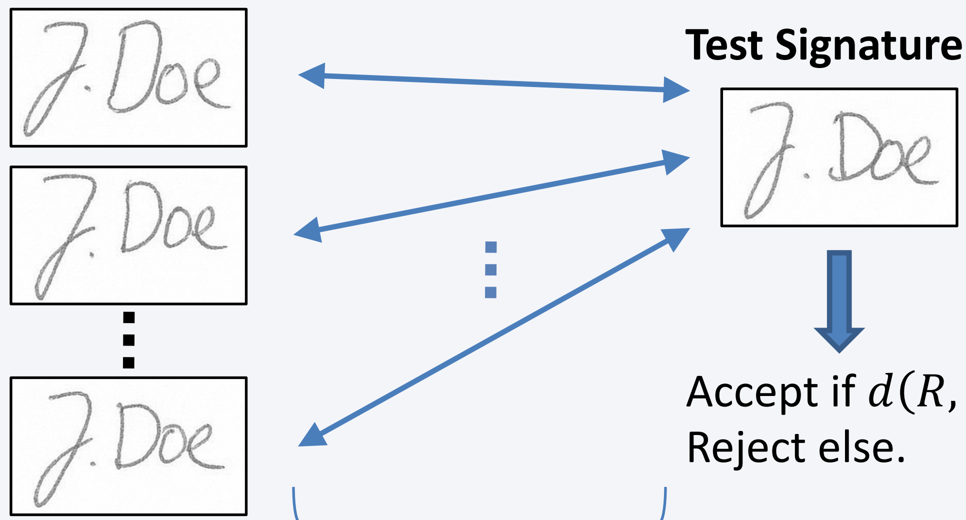
Dissimilarity Score $d(R, g)$

Reference Signatures R

Normalization:

Intra-User Variability

$$\delta(R) = \frac{1}{|R|}\sum_{r\in R}\min_{s\in R\setminus r} d(r, s)$$



Test Signature t

Accept if $d(R, t) < T$,
Reject else.

Dissimilarity Score:

$$d(R, t) = \min_{r\in R}\frac{d(r, t)}{\delta(R)}$$

Multiple Classifier System (MCS)

- Simply linear combination with weight α
- Dissimilarity scores are z-score normalized based on reference signatures

$$d_{\mathrm{MCS},\alpha}(R,t) = \min_{r \in R}\left(\alpha \cdot \hat{d}^{*}_{\mathrm{GED}}(r,t) + (1-\alpha) \cdot \hat{d}^{*}_{\mathrm{inkball}}(r,t)\right)$$

Evaluation

Evaluation Protocol

Datasets

MCYT-75 and GPDS-75 (GPDSsynthetic-Offline)

Skilled forgeries (SF)

Forgers with access to the genuine signatures

Random forgeries (RF)

Signatures of other users; brute force attack

Two tasks

R5/R10 using 5/10 genuine signatures per user as reference

Evaluation Measure

Equal Error Rate (EER)

Equal Error Rate Results – Test Protocol 1

System	Skilled Forgeries				Random Forgeries			
	GPDS-75		MCYT-75		GPDS-75		MCYT-75	
	R5	R10	R5	R10	R5	R10	R5	R10
Maergner et al. ($\alpha = 1.0$, GED app.)	**11.96**	9.42	20.36	14.40	**4.90**	**3.60**	6.25	**2.92**
Proposed Inkball ($\alpha = 0.0$)	14.09	10.36	**12.98**	**10.49**	7.75	5.51	**5.19**	3.46

Equal Error Rate Results – Test Protocol 1

System	Skilled Forgeries				Random Forgeries			
	GPDS-75		MCYT-75		GPDS-75		MCYT-75	
	R5	R10	R5	R10	R5	R10	R5	R10
Maergner et al. ($\alpha = 1.0$, GED app.)	11.96	9.42	20.36	14.40	4.90	3.60	6.25	2.92
Proposed Inkball ($\alpha = 0.0$)	14.09	10.36	**12.98**	10.49	7.75	5.51	5.19	3.46
Proposed MCS ($\alpha = 0.4$)	**9.42**	**6.84**	13.07	**8.71**	**3.66**	**2.05**	**3.06**	**1.24**

Equal Error Rate Results – Test Protocol 2

Average EER over ten random selections of 10 reference signatures

System	GPDS-75 R10		MCYT-75 R10	
	RF	SF	RF	SF
Ferrer et al.	**0.76***	16.01	**0.35***	11.54
Maergner et al. (GED app.)	2.73	8.29	2.83	12.01
Proposed Inkball ($\alpha = 0.0$)	5.22	10.64	3.13	8.29
Proposed MCS ($\alpha = 0.4$)	1.99	**6.67**	1.88	**7.20**

*: All genuine signatures of other users as RF

Equal Error Rate Results – Test Protocol 3

EER Results with a posteriori user-dependent score normalization

System	MCYT-75 R5		MCYT-75 R10	
	RF	SF	RF	SF
Alonso-Fernandez et al.	9.79*	23.78	7.26*	22.13
Fierrez-Aguilar et al.	2.69**	11.00	1.14**	9.28
Gilperez et al.	2.18*	10.18	1.18*	6.44
Maergner et al. (GED app.)	2.40	14.49	1.89	11.64
Proposed Inkball ($\alpha = 0.0$)	2.88	9.33	2.02	8.53
Proposed MCS ($\alpha = 0.4$)	**0.92**	**9.07**	**0.52**	**5.78**

*: All genuine signatures of other users as RF

**: First 5 genuine signature from each other user as RF

Conclusion

Two structural methods for signature verification

- inkball models used for the first time

Excellent signature verification performance for skilled forgeries on MCYT-75 and GPDS-75

- room for improvement for random forgeries

Combination achieves best results

- two complementary methods

Outlook

Further develop structural representations

- other types of nodes and edges
- improved cost functions

Include stability models

- which parts of the structure are stable?

Make matching visible for human expert

Thank you for your attention!
Questions?