

Ballot Mark Detection

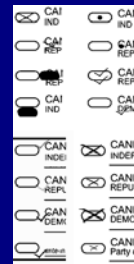
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Paper, in the form of hand- or machine-marked ballots, can play a fundamental role in guaranteeing safe and secure elections. The processing of such records raises its own set of issues, however, which span broad technical and social boundaries. Our work is aimed at making paper less of a nuisance and more of an integral component in election systems.

Sample Ballots

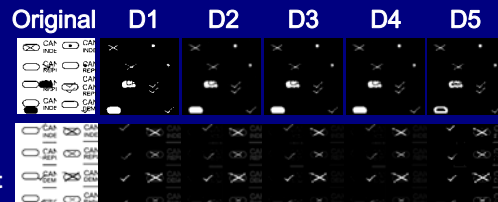
A blank sample ballot was filled with sample marks using the PERFECT Ballot Generator software [1]. Mark shape, position, size and color can be varied.



[1] D. Lopresti, G. Nagy, and E. H. Barney Smith, "A Document Analysis System for Supporting Electronic Voting Research," Proc. Document Analysis Systems, Nara, Japan, September 2006, pp. 167-174.

Differencing Approach

- Apply Differencing method D1-D5
- Median Filter
- Remove components 2x2 or smaller
- Morphological closing with a radius 10 disk structuring element



"Form Removal"

Five different differencing techniques were evaluated for Form Removal.

D1: The absolute value of the difference between the raw images.

D2: The absolute value of the difference between the raw images, smoothed by a 3x3 uniform kernel.

D3: The absolute value of the difference between 3x3 smoothed images.

D4: The absolute value of the difference between 3x3 smoothed images, smoothed by a 3x3 uniform kernel.

D5: The absolute difference of smoothed adaptively binarized images.

Detection rates by mark gray level

Mark Gray Level	0	36	80	132	191
D1	99.5	100.0	100.0	100.0	63.6
D2	100.0	100.0	100.0	66.7	45.4
D3	99.5	100.0	100.0	100.0	45.5
D4	99.5	100.0	100.0	58.3	45.4
D5	99.5	100.0	100.0	100.0	100.0

Detection rates by mark shape over entire data set of 232 marks.

	# FA	% Detected				
		Total	X	✓	●	•
D1	3	97.4	97.0	95.8	100.0	98.1
D2	4	95.7	94.0	94.4	100.0	96.2
D3	7	96.6	97.0	94.4	100.0	96.2
D4	5	94.4	97.0	88.7	97.6	96.2
D5	31	99.1	100.0	97.2	100.0	100.0

Any marking is potentially a valid vote. We are analyzing how mark shapes, sizes, and intensities affect the ability of automated systems to locate and identify marks as votes.

Creation of a public database of ballots (marked, classified, ground-truthed) is an essential part of our infrastructure effort.

FROM A LEGAL STANDPOINT, VOTER INTENT IS KEY!