Key Issues in Performance Evaluation for Document Analysis Systems*

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** Copies of these slides will be available on my website next week.*

Outline

- Motivation / quick overview of document image analysis.
- A simple example of performance evaluation gone awry.
- How do we know when a problem is solved?
- Counting votes – replicating human interpretation.
- A Turing Test-inspired viewpoint.
- Realistic attack models for behavioral biometrics.
- Concluding observations.

Motivation

Isn't performance evaluation easy?

- We all know accuracy, precision/recall, F-measure, etc.
- Standard datasets and competitions are now common.

What are the concerns I hear?

- Everyone believes his/her own problem is unique.
- Disconnect between problems and real-world tasks.
- Desperate need to generate publications.
- As a community, we may be too polite.

Why is it so important to do performance evaluation well?

- Measure progress ⇒ prevent wasted effort.
- Scientific respectability.

Motivation

Typical view of a pattern recognition problem:

From an advisor or the research literature

The real world where our solutions must ultimately live:

Motivation

Pattern recognition techniques are not used in isolation, but rather to solve tasks of interest:

- demands on the degree of automation that is required,
- the minimum acceptable accuracy level,
- and the kinds of errors that can be tolerated.

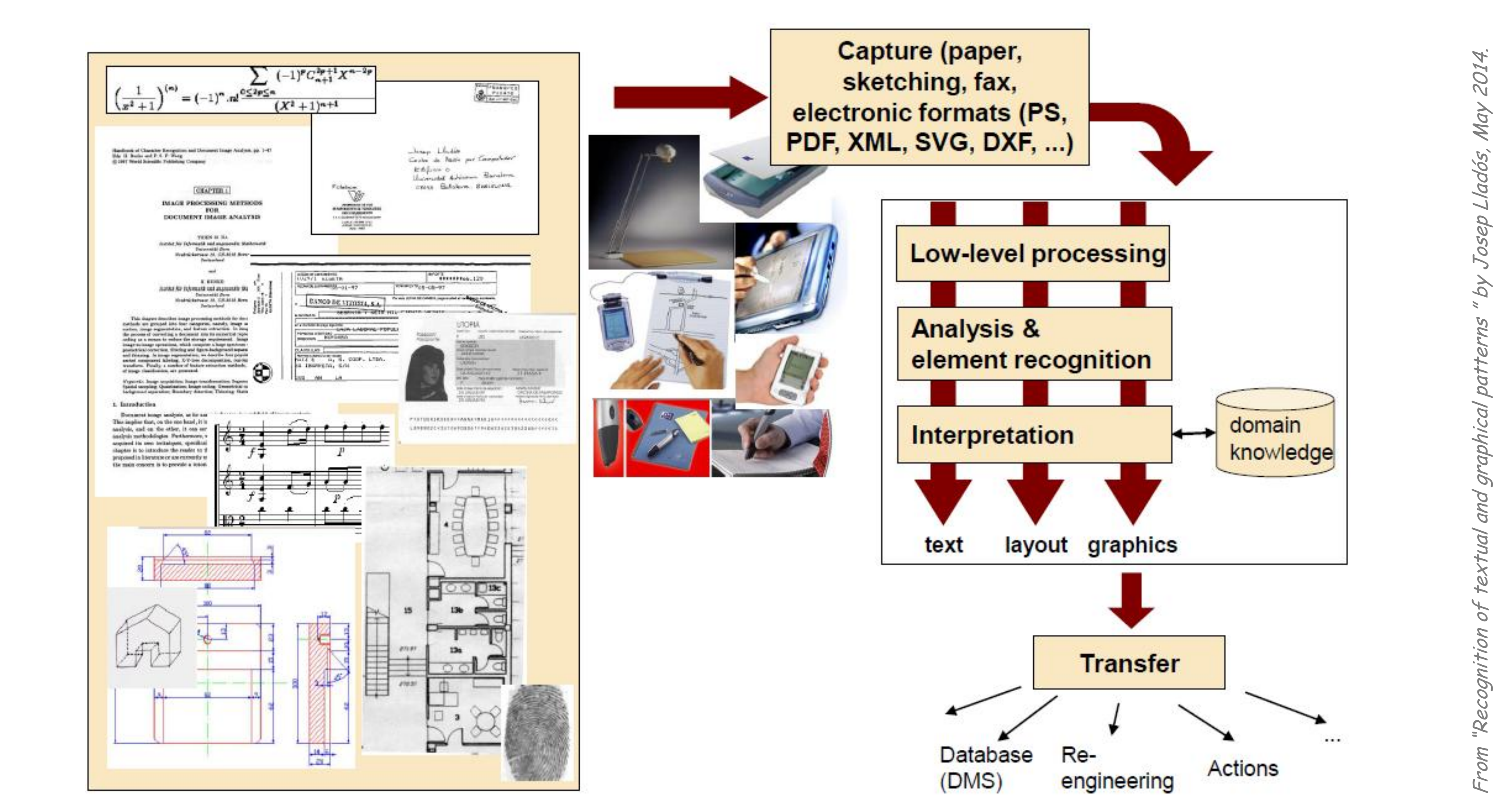
Important implications for:

- performance evaluation,
- and, ultimately, the success of the system.

A Quick Overview of Document Image Analysis (DIA) and Optical Character Recognition (OCR)

Many examples I cite draw from this field which presents a rich range of research opportunities. On the other hand, many observations I make will (I hope) generalize.

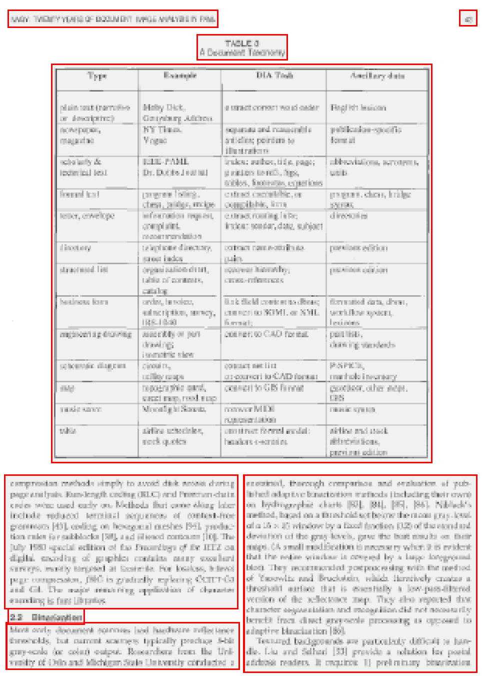
Typical DIA Workflow



From "Recognition of textual and graphical patterns " by Josep Lladós, May 2014.

Document Layout Analysis

Detection of the document logical structure (lines, paragraphs, columns) from the physical structure (image blocks).



NAGY: TWENTY YEARS OF DOCUMENT IMAGE ANALYSIS IN PAMI

TABLE 3
A Document Taxonomy

Type	Example	DIA Task	Ancillary data
plain text (narrative or descriptive)	Moby Dick, Gettysburg Address	extract correct word order	English lexicon
newspaper, magazine	NY Times, Vogue	separate and reassemble articles; pointers to illustrations	publication-specific format
scholarly & technical text	IEEE-PAMI, Dr. Dobbs Journal	index: author, title, page; pointers to refs., figs, tables, footnotes, captions	abbreviations, acronyms, units
formal text	program listing, chess, bridge, recipe	extract executable, or compilable, form	program, chess, bridge syntax
letter, envelope	information request, complaint, recommendation	extract routing info; index: sender, date, subject	directories
directory	telephone directory, street index	extract name-attribute pairs	previous edition
structured list	organization chart, table of contents, catalog	recover hierarchy, cross-references	previous edition
business form	order, invoice, subscription, survey, IRS-1040	link field contents to fillers; convert to SGML or XML format;	formatted data, dbms, workflow system, lexicons
engineering drawing	assembly or part drawing, isometric view	convert to CAD format	part lists, drawing standards
schematic diagram	circuits, utility maps	extract net list or convert to CAD format	PSPICE, symbols inventory
map	topographic quad, street map, road map	convert to GIS format	gazetteer, other maps, GIS
music score	Moonlight Sonata	convert MIDI representation	music syntax
table	airline schedules, stock quotes	construct formal model: headers entries	airline and stock abbreviations, previous edition

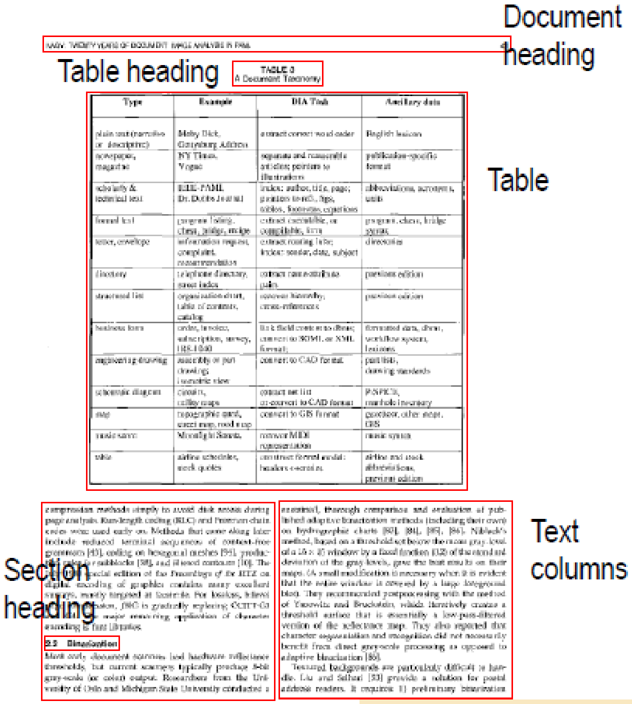
compression methods simply to avoid disk access during page analysis. Run-length coding (RLC) and Freeman chain codes were used early on. Methods that came along later include reduced terminal sequences of context-free grammars [43], coding on hexagonal meshes [91], production rules for subblocks [38], and filtered contours [10]. The July 1980 special edition of the Proceedings of the IEEE on digital encoding of graphics contains many excellent surveys, mostly targeted at facsimile. For binary, lossless page compression, JBIG is gradually replacing CCITT-G3 and G4. The major remaining application of character encoding is font libraries.

2.2 Binarization

Most early document scanners had hardware brilliance thresholds, but current scanners typically produce 8-bit gray-scale (or color) output. Researchers from the University of Oslo and Michigan State University conducted an unbiased, thorough comparison and evaluation of published adaptive binarization methods (including their own) on hydrographic charts [83], [84], [85], [86]. Niblack's method, based on a threshold set below the mean gray level of a 15 × 15 window by a fixed fraction (0.2) of the standard deviation of the gray levels, gave the best results on their maps. (A small modification is necessary when it is evident that the entire window is covered by a large foreground blob.) They recommend postprocessing with the method of Yanowitz and Bruckstein, which iteratively creates a threshold surface that is essentially a low-pass-filtered version of the reflectance map. They also reported that character segmentation and recognition did not necessarily benefit from direct grayscale processing as opposed to adaptive binarization [85].

Textured backgrounds are particularly difficult to handle. Liu and Srihari [53] provide a solution for postal address readers. It requires 1) preliminary binarization

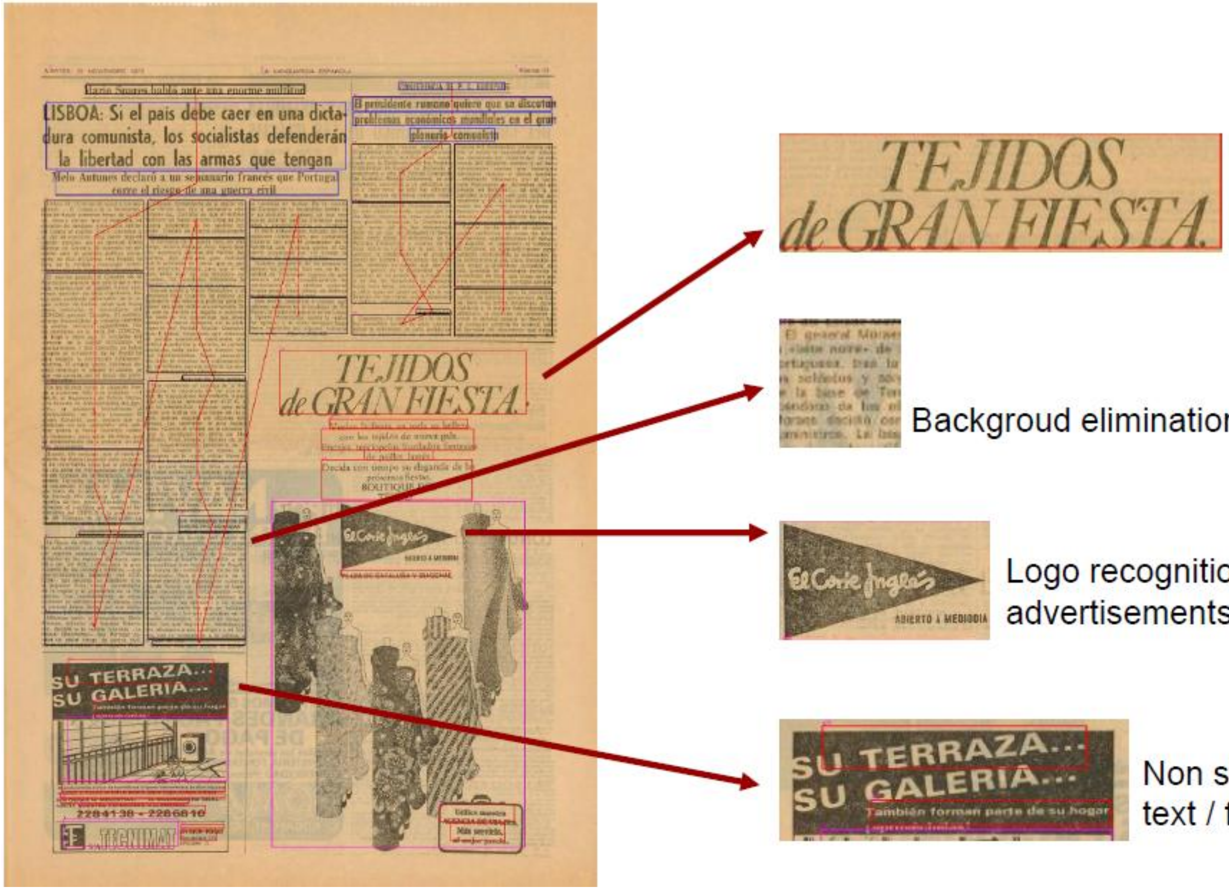
Physical Structure



Logical Structure

From "Recognition of textual and graphical patterns " by Josep Lladós, May 2014.

Challenges in Layout Analysis



LISBOA: Si el país debe caer en una dictadura comunista, los socialistas defenderán la libertad con las armas que tengan
TEJIDOS de GRAN FIESTA
El Corte Inglés
ABIERTO A MEDIODIA
SU TERRAZA... SU GALERIA...
También forman parte de su hogar

Big fonts

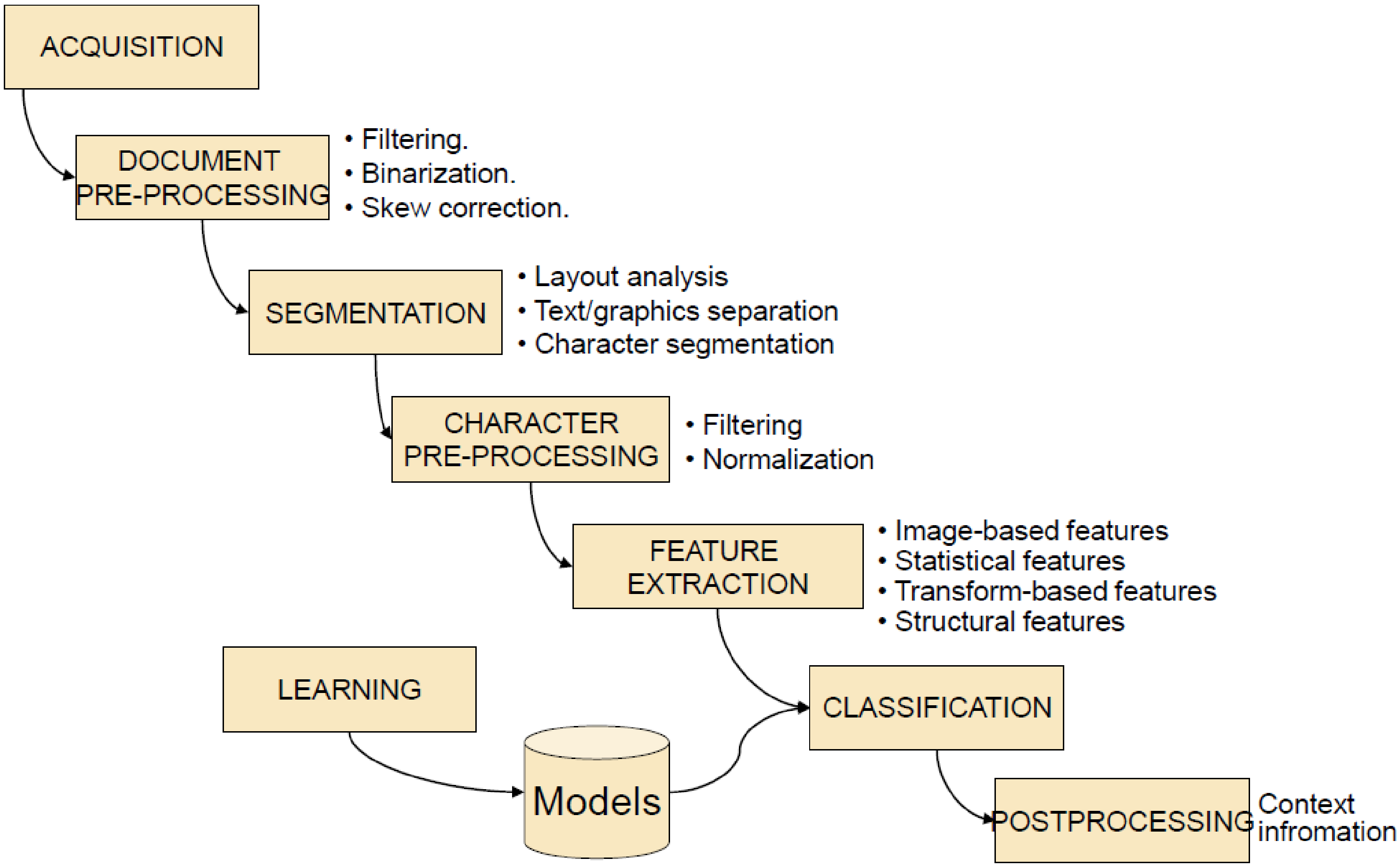
Backgroud elimination

Logo recognition / advertisements

Non standard text / fonts

From "Recognition of textual and graphical patterns " by Josep Lladós, May 2014.

Components in an OCR Workflow



ACQUISITION

DOCUMENT PRE-PROCESSING
- Filtering.
- Binarization.
- Skew correction.

SEGMENTATION
- Layout analysis
- Text/graphics separation
- Character segmentation

CHARACTER PRE-PROCESSING
- Filtering
- Normalization

FEATURE EXTRACTION
- Image-based features
- Statistical features
- Transform-based features
- Structural features

LEARNING

Models

CLASSIFICATION

POSTPROCESSING

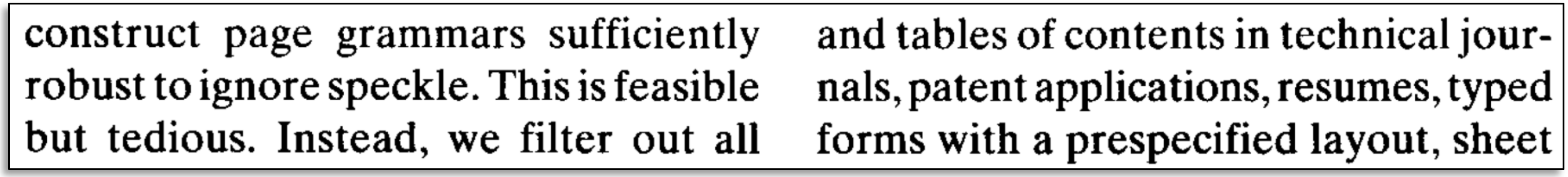
Context infromation

From "Recognition of textual and graphical patterns " by Josep Lladós, May 2014.

Measuring Performance Appropriately: A Simple Worst-Case Example

It's instructive to consider what can go wrong when a standard technique used for performance evaluation is applied without considering the ultimate application.

Measuring DIA Performance



construct page grammars sufficiently robust to ignore speckle. This is feasible but tedious. Instead, we filter out all

and tables of contents in technical journals, patent applications, resumes, typed forms with a prespecified layout, sheet

For the above input, which DIA result is better?

(a) construct page grammors sufficiently robust to ignore spcckle. This is feasible but tedious. Instead, we filter out all …

… and tobles of contents in technical journals, patent appllcations, resumes, typed fonns with a prespecified 1ayout, sheet …

OCR errors

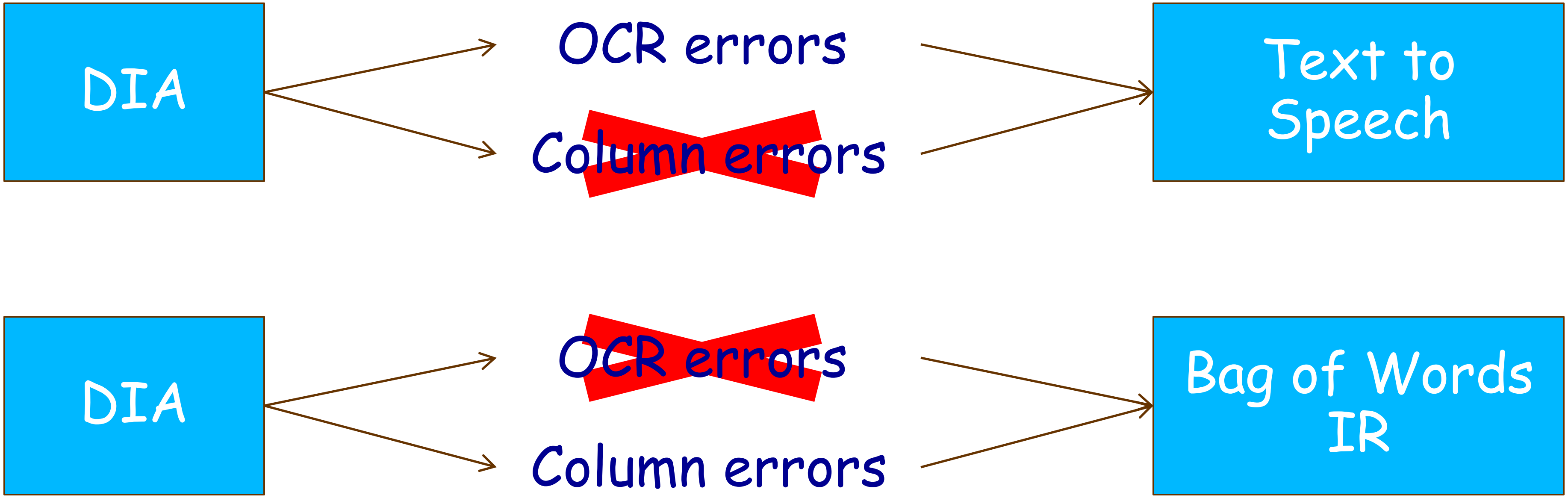
(b) construct page grammars sufficiently and tables of contents in technical jour- robust to ignore speckle. This is feasible nals, patent applications, resumes, typed but tedious. Instead, we filter out all forms with a prespecified layout, sheet …

Missed columns

Measuring DIA Performance

Which DIA result is better?

It depends on the application!



DIA

OCR errors

~~Column errors~~

Text to Speech

DIA

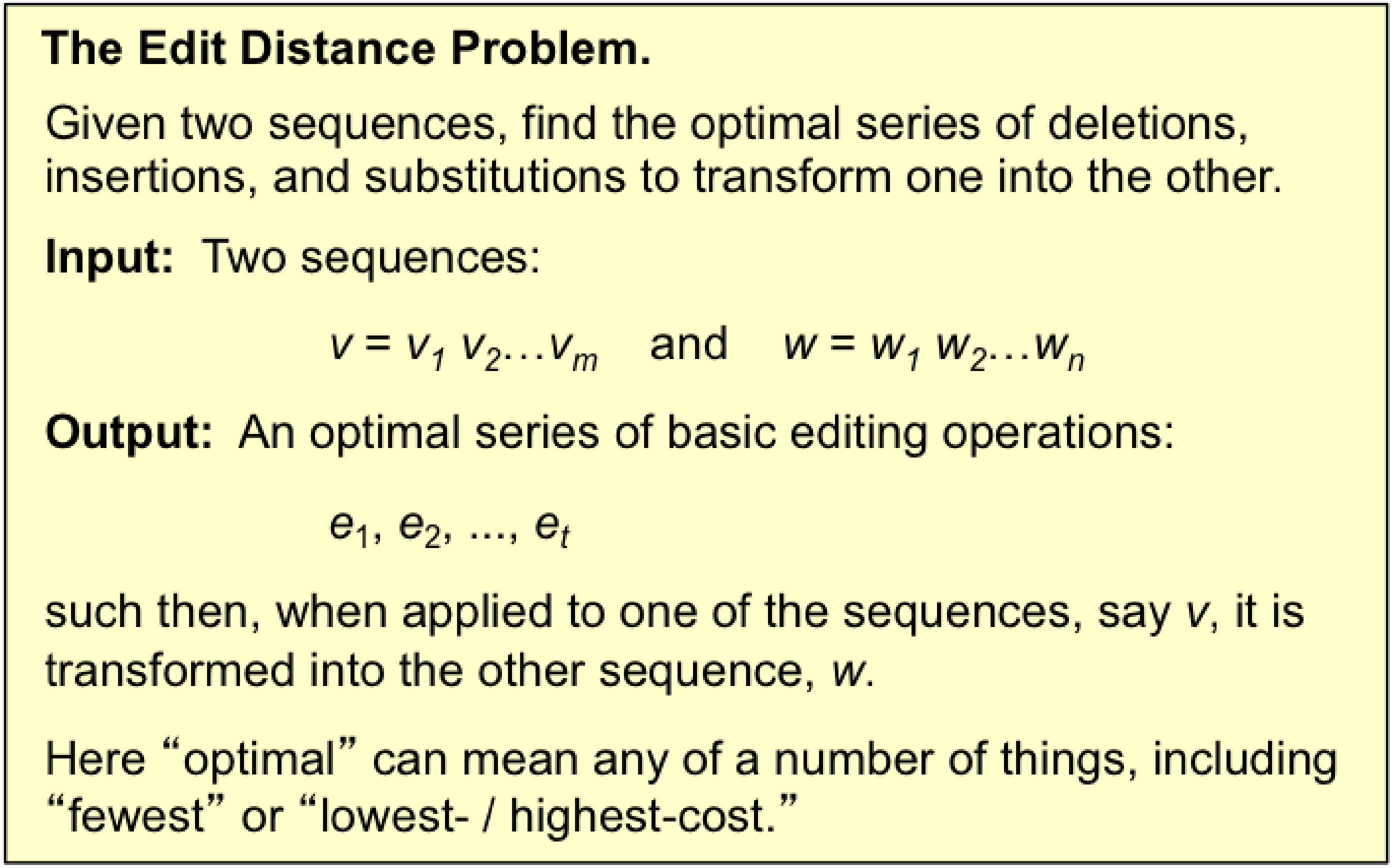
~~OCR errors~~

Column errors

Bag of Words IR

String Edit Distance

Edit distance is standard measure used for OCR accuracy.



The Edit Distance Problem.

Given two sequences, find the optimal series of deletions, insertions, and substitutions to transform one into the other.

Input: Two sequences:

$$v = v_1\, v_2 \ldots v_m \quad \text{and} \quad w = w_1\, w_2 \ldots w_n$$

Output: An optimal series of basic editing operations:

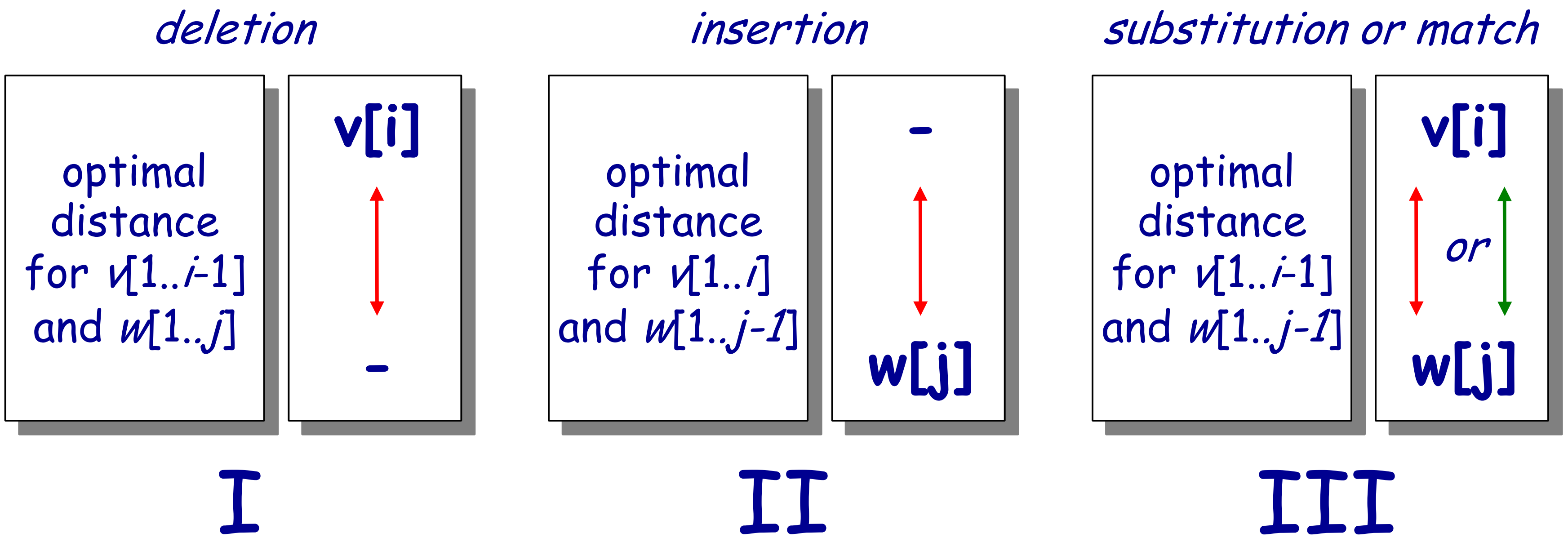
$$e_1,\ e_2,\ \ldots,\ e_t$$

such then, when applied to one of the sequences, say *v*, it is transformed into the other sequence, *w*.

Here "optimal" can mean any of a number of things, including "fewest" or "lowest- / highest-cost."

String Edit Distance

Given two sequences v and w, consider what is required to compute optimal distance between prefixes $v[1..i]$ and $w[1..j]$. There are three possible cases:



deletion

optimal distance for $v[1..i-1]$ and $w[1..j]$

v[i]

-

I

insertion

optimal distance for $v[1..i]$ and $w[1..j-1]$

-

w[j]

II

substitution or match

optimal distance for $v[1..i-1]$ and $w[1..j-1]$

v[i]

or

w[j]

III

If we already have solutions for all shorter prefixes, we can compute the distance for $v[1..i]$ and $w[1..j]$.

String Edit Distance

Conceptually, this might look something like this:

optimal distance at
v[1..*i*] and *w*[1..*j*]

= min

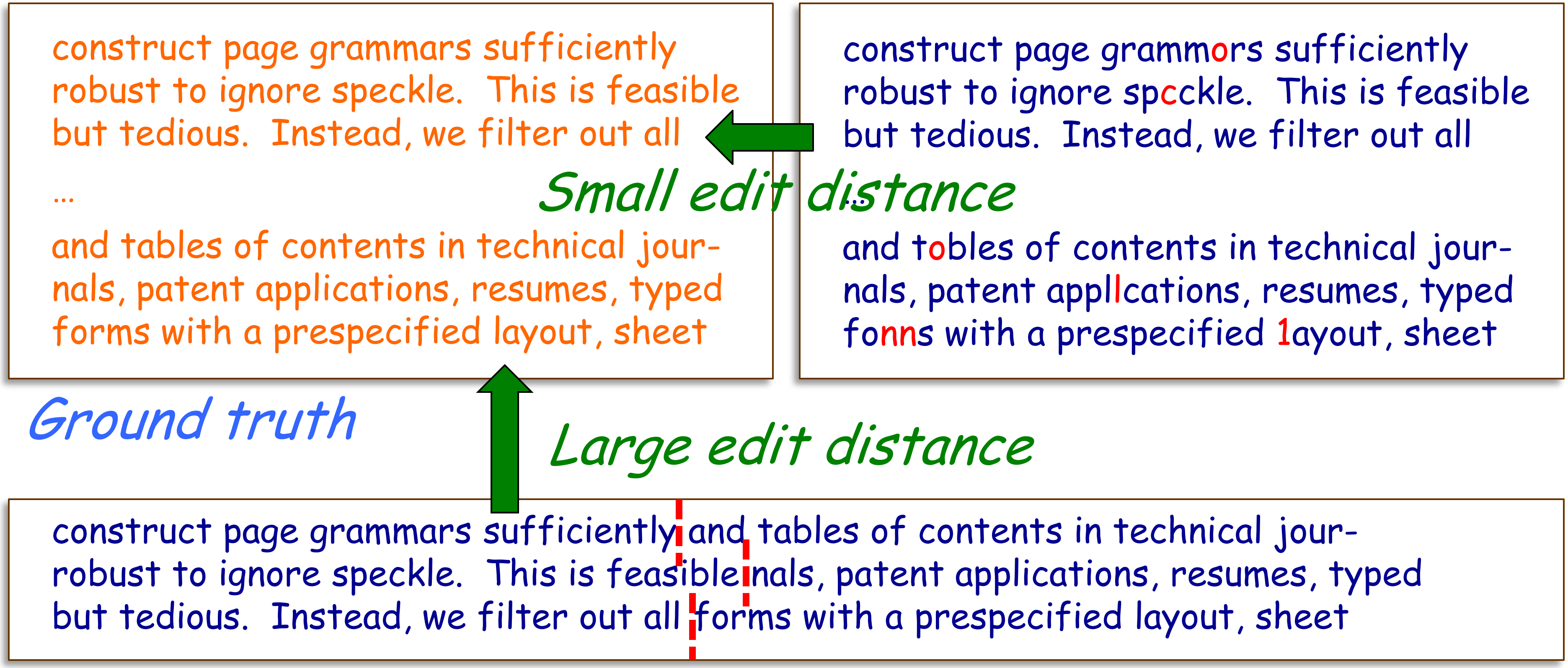
optimal distance at
v[1..*i*-*1*] and *w*[1..*j*]
+
cost of deleting *v*[*i*]

optimal distance at
v[1..*i*] and *w*[1..*j*-*1*]
+
cost of inserting *w*[*j*]

optimal distance at
v[1..*i*-*1*] and *w*[1..*j*-*1*]
+
cost of matching *v*[*i*] and *w*[*j*]

We assume deletions, insertions, and mismatches have positive cost, while matches have zero or negative cost.

Measuring DIA Performance



construct page grammars sufficiently robust to ignore speckle. This is feasible but tedious. Instead, we filter out all

…

and tables of contents in technical journals, patent applications, resumes, typed forms with a prespecified layout, sheet

Ground truth

construct page grammors sufficiently robust to ignore spcckle. This is feasible but tedious. Instead, we filter out all

…

and tobles of contents in technical journals, patent appllcations, resumes, typed fonns with a prespecified 1ayout, sheet

Small edit distance

Large edit distance

construct page grammars sufficiently and tables of contents in technical jour-
robust to ignore speckle. This is feasible nals, patent applications, resumes, typed
but tedious. Instead, we filter out all forms with a prespecified layout, sheet

It is vital to match your performance measure to your target application.

Just now “in the weeds.”

Turn to 30,000 foot view.

Specific details of performance evaluation
➔ When is a problem solved?

Performance evaluation confirms when we have advanced state of the art and, ultimately, when a problem is solved.

What's the challenge?

We define our open problems as automating a task: this is quite different from math, physics, theoretical CS, etc.

Some ways of measuring success:

- Accuracy of new algorithm (vs. previous methods).
- Current degree of community interest (publishability).
- Economic considerations (net payoff for using method).
- Distinguishability of algorithm from human result.

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

What’s the challenge?

When is a problem solved?

This seems like a simple, basic question.

It also seems like an important question.

But it’s not clear we know how to answer it ...

“When is a Problem Solved?,” D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Viewpoint #1

The endless pursuit of perfection:

> "A problem is solved if there is a method which has been widely publicized and documented and freely available to the community which achieves 100% accuracy on within-spec inputs it receives."

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Viewpoint #2

As good as it gets:

> “A problem is solved if there is a method which has been widely publicized and documented and freely available to the community which performs better than any other method, and which cannot be further improved without investing excessive resources.”

“When is a Problem Solved?,” D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Viewpoint #3

Good enough to get the job done:

> "A problem is solved if there is a method which has been widely publicized and documented and freely available to the community which cannot be replaced with any other method to improve the end-to-end performance of a specific application of interest."

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Viewpoint #4

Pure pragmatism:

> "A problem is solved when it is no longer possible to get a paper published on the topic (or, alternatively, to raise research funding to study the question)."

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Viewpoint #5

The Turing Test:

> "A problem is solved if there is a method which has been widely publicized and documented and freely available to the community which generates output for a given input that a human judge cannot reliably distinguish from the output of a human expert."

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Show of Hands

Which viewpoint(s) do you agree with?

- The endless pursuit of perfection.
- As good as it gets.
- Good enough to get the job done.
- Pure pragmatism.
- The Turing Test.

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

Key Considerations

Let's also keep in mind the following important points:

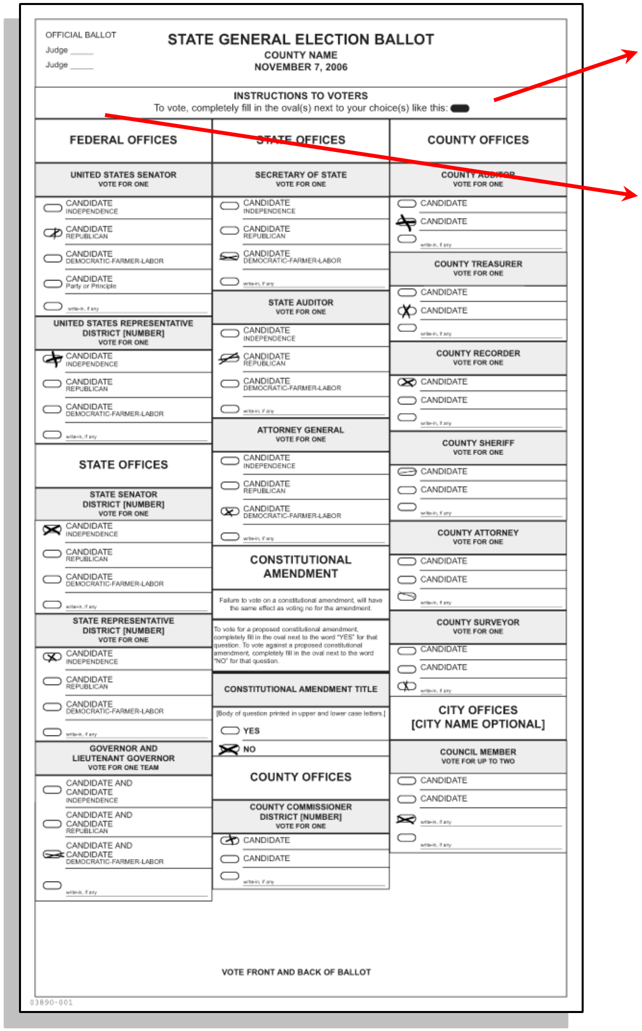
- Populations vs. samples: performance figures like error, reject, or retrieval rates are of interest only with regard to populations rather than specific samples.
- Algorithms, heuristics, and implementations: most of pattern recognition is built on heuristics rather than algorithms, although the latter term is applied to both. To be a solution, an algorithm must be implementable.
- Desirable criteria: solutions should be invariant to 90° rotation, modest differences in resolution, remapping RGB/gray values, jitters in threshold settings, etc.

"When is a Problem Solved?," D. Lopresti and G. Nagy, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 32-36.

A Simple Yet Vexing Case Study: Counting Votes Recorded on Paper

Topic of current interest where the legal need to respect voter intent transforms a seemingly trivial pattern recognition problem into much more complex task.

Counting Votes Not So Easy



OFFICIAL BALLOT
Judge _____
Judge _____

STATE GENERAL ELECTION BALLOT
COUNTY NAME
NOVEMBER 7, 2006

INSTRUCTIONS TO VOTERS
To vote, completely fill in the oval(s) next to your choice(s) like this: ●

FEDERAL OFFICES

UNITED STATES SENATOR
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ⊗ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ CANDIDATE Party or Principle
- ○ write-in, if any

UNITED STATES REPRESENTATIVE DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE OFFICES

STATE SENATOR DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE REPRESENTATIVE DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

GOVERNOR AND LIEUTENANT GOVERNOR
VOTE FOR ONE TEAM

- ○ CANDIDATE AND CANDIDATE INDEPENDENCE
- ○ CANDIDATE AND CANDIDATE REPUBLICAN
- ⊗ CANDIDATE AND CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE OFFICES

SECRETARY OF STATE
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ⊗ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE AUDITOR
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ⊗ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

ATTORNEY GENERAL
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ⊗ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

CONSTITUTIONAL AMENDMENT

Failure to vote on a constitutional amendment, will have the same effect as voting no for the amendment.

To vote for a proposed constitutional amendment, completely fill in the oval next to the word "YES" for that question. To vote against a proposed constitutional amendment, completely fill in the oval next to the word "NO" for that question.

CONSTITUTIONAL AMENDMENT TITLE

[Body of question printed in upper and lower case letters.]

- ○ YES
- ⊗ NO

COUNTY OFFICES

COUNTY COMMISSIONER DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY OFFICES

COUNTY AUDITOR
VOTE FOR ONE

- ○ CANDIDATE
- ⊗ CANDIDATE
- ○ write-in, if any

COUNTY TREASURER
VOTE FOR ONE

- ○ CANDIDATE
- ⊗ CANDIDATE
- ○ write-in, if any

COUNTY RECORDER
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY SHERIFF
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY ATTORNEY
VOTE FOR ONE

- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any

COUNTY SURVEYOR
VOTE FOR ONE

- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any

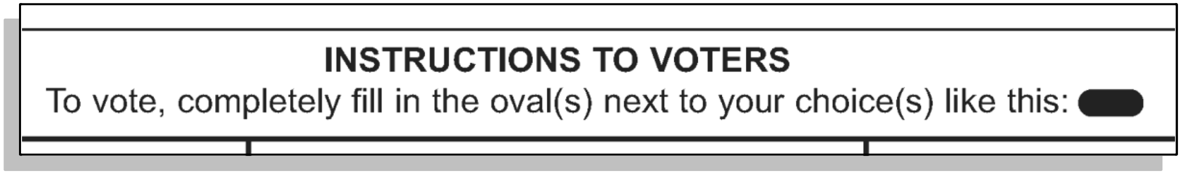
CITY OFFICES
[CITY NAME OPTIONAL]

COUNCIL MEMBER
VOTE FOR UP TO TWO

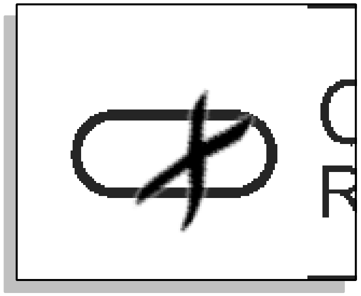
- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any
- ○ write-in, if any

VOTE FRONT AND BACK OF BALLOT

03890-001



INSTRUCTIONS TO VOTERS
To vote, completely fill in the oval(s) next to your choice(s) like this: ●



Is this a legal vote?

- Courts would probably say so …
- … but op-scan readers might not count it.

Increasing demands that machine's interpretation match a human's.

Research Questions

Issues that arise from using paper ballots in elections:

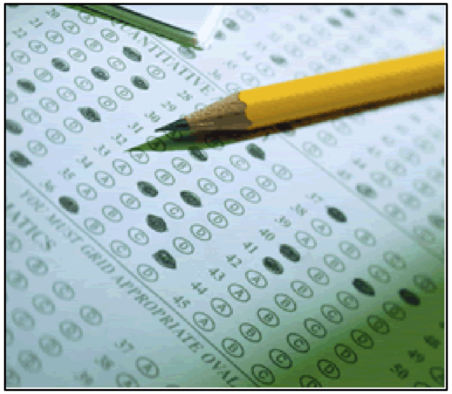
- Accurate interpretation of marginal markings.
- Human cost, error rate, and bias in performing manual recounts.
- Failure modes in ballot imaging (e.g., paper jams).
- Systematic errors due to ballot layout (one candidate may be disadvantaged over another based on physical location on page).

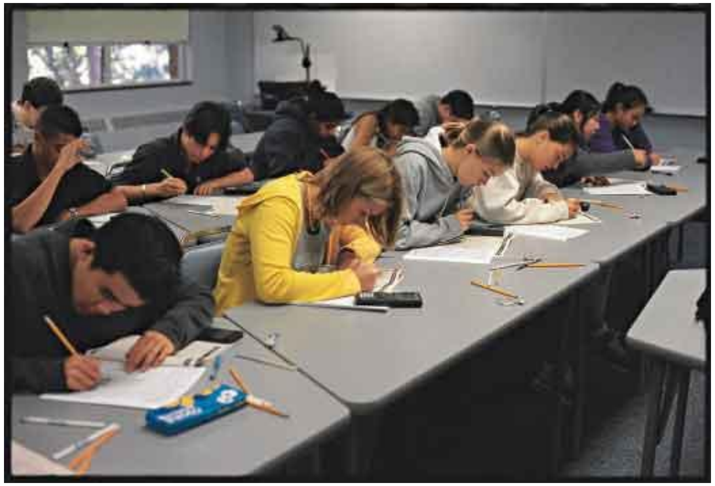
Also keep in mind:

- U.S. elections can be complex (10’s to 100’s of choices).
- Impact of “voter error” (e.g., improper markings, erasures).
- Potential for traditional ballot-box stuffing.
- Computer hackers attempting to manipulate the vote.

Why isn't this a solved problem?

Students have been taking standardized tests using op-scan answer sheets for decades …





- While accuracy rates are very high, problems do occur.
- Compared to voters, students are a much more homogeneous (and well-educated) population.
- Standardized testing is NOT anonymous. Students can (and do) complain when they receive a lower score than they expect.

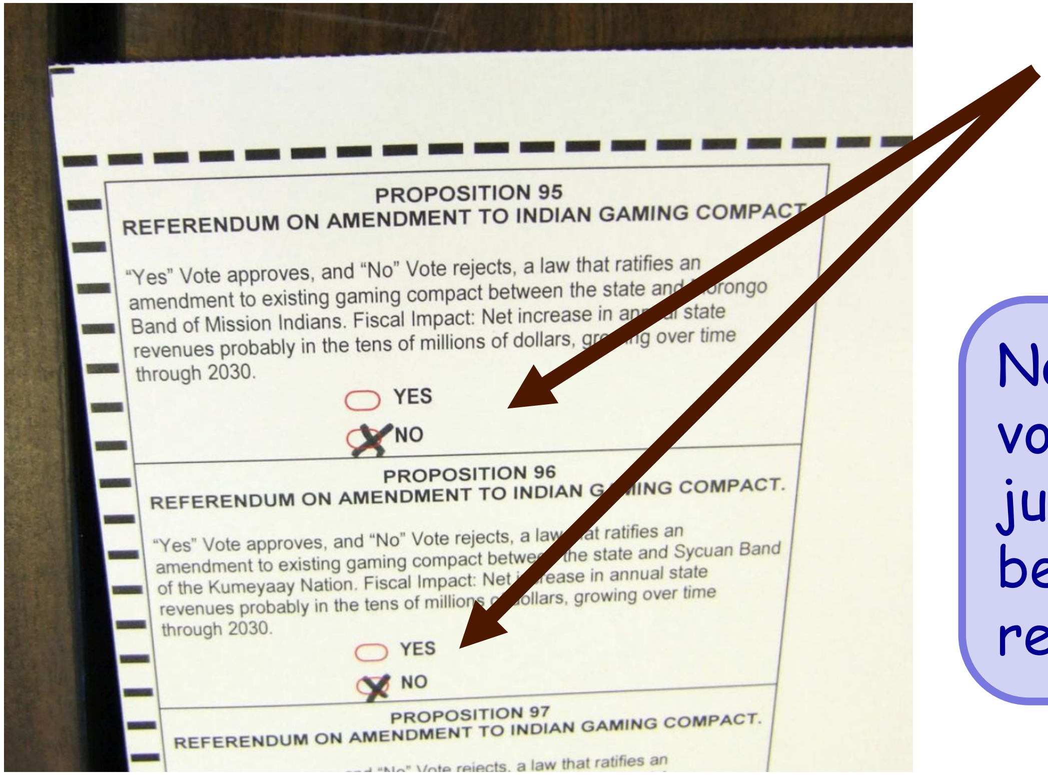
Connection to Forms Processing

Similarities to forms processing, but also some key differences:

- Much broader range of users (education level, literacy, etc.) than for traditional forms applications.
- Ballots must preserve a voter's anonymity.
- Demand to count votes and report results quickly.
- Elections are held infrequently, so voting equipment sits unused for long periods in storage.
- Poll workers often lack technical expertise.
- Maintaining chain-of-custody is a critical security requirement.
- No *financial* interest in making sure votes are counted accurately, but there is tremendous *public* interest.

Counting Votes Not So Easy

Real ballot from an election in California:



PROPOSITION 95
REFERENDUM ON AMENDMENT TO INDIAN GAMING COMPACT

"Yes" Vote approves, and "No" Vote rejects, a law that ratifies an amendment to existing gaming compact between the state and Morongo Band of Mission Indians. Fiscal Impact: Net increase in annual state revenues probably in the tens of millions of dollars, growing over time through 2030.

○ YES
☒ NO

PROPOSITION 96
REFERENDUM ON AMENDMENT TO INDIAN GAMING COMPACT.

"Yes" Vote approves, and "No" Vote rejects, a law that ratifies an amendment to existing gaming compact between the state and Sycuan Band of the Kumeyaay Nation. Fiscal Impact: Net increase in annual state revenues probably in the tens of millions of dollars, growing over time through 2030.

○ YES
☒ NO

PROPOSITION 97
REFERENDUM ON AMENDMENT TO INDIAN GAMING COMPACT.

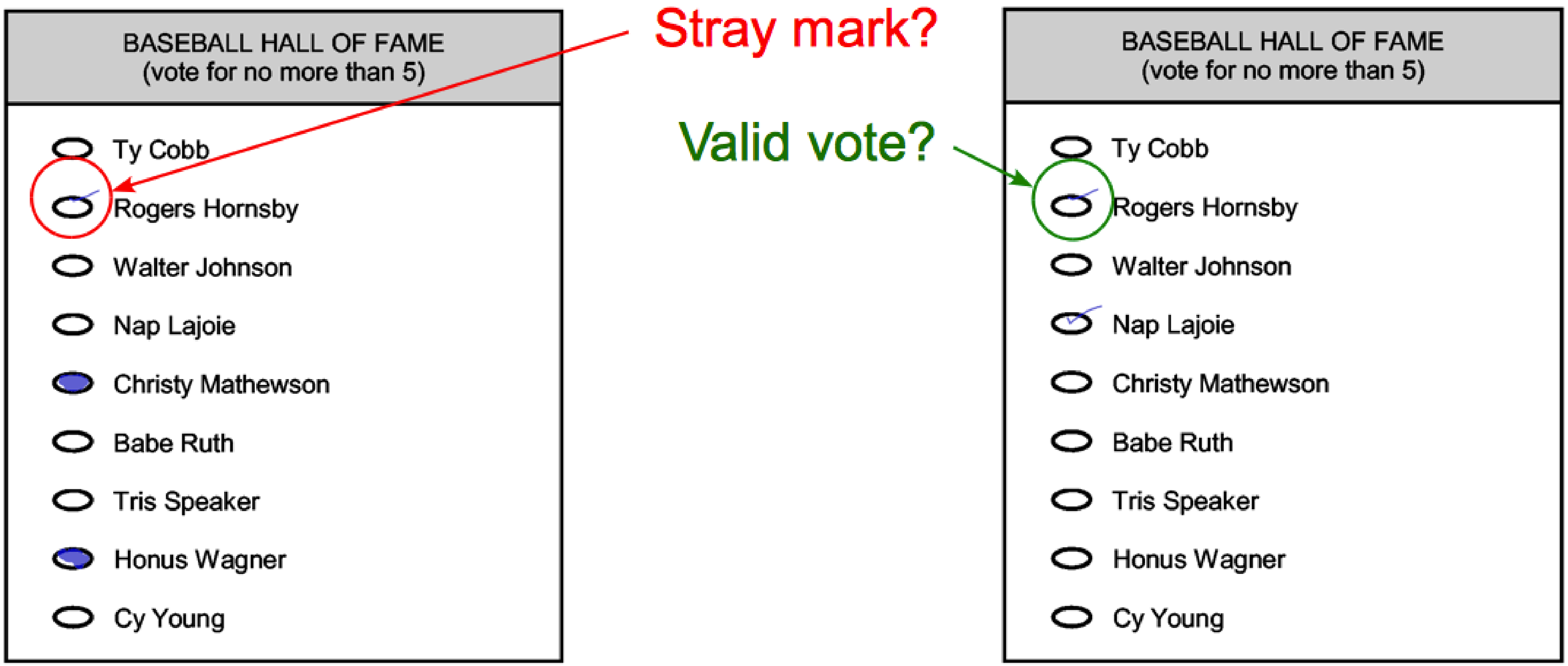
"No" Vote rejects, a law that ratifies an

One of these votes was counted correctly by the op-scan equipment, the other was not.

Note: this does not mean voting on paper ballots is bad, just (1) manual audits should be mandatory, and (2) more research is needed.

"Improving California's 1% Manual Tally Procedure," Joseph Lorenzo Hall, UC Berkeley School of Information, EVT Workshop 2008.

Whole-Ballot Recognition



BASEBALL HALL OF FAME
(vote for no more than 5)

- ○ Ty Cobb
- ✓ Rogers Hornsby
- ○ Walter Johnson
- ○ Nap Lajoie
- ● Christy Mathewson
- ○ Babe Ruth
- ○ Tris Speaker
- ● Honus Wagner
- ○ Cy Young

Stray mark?

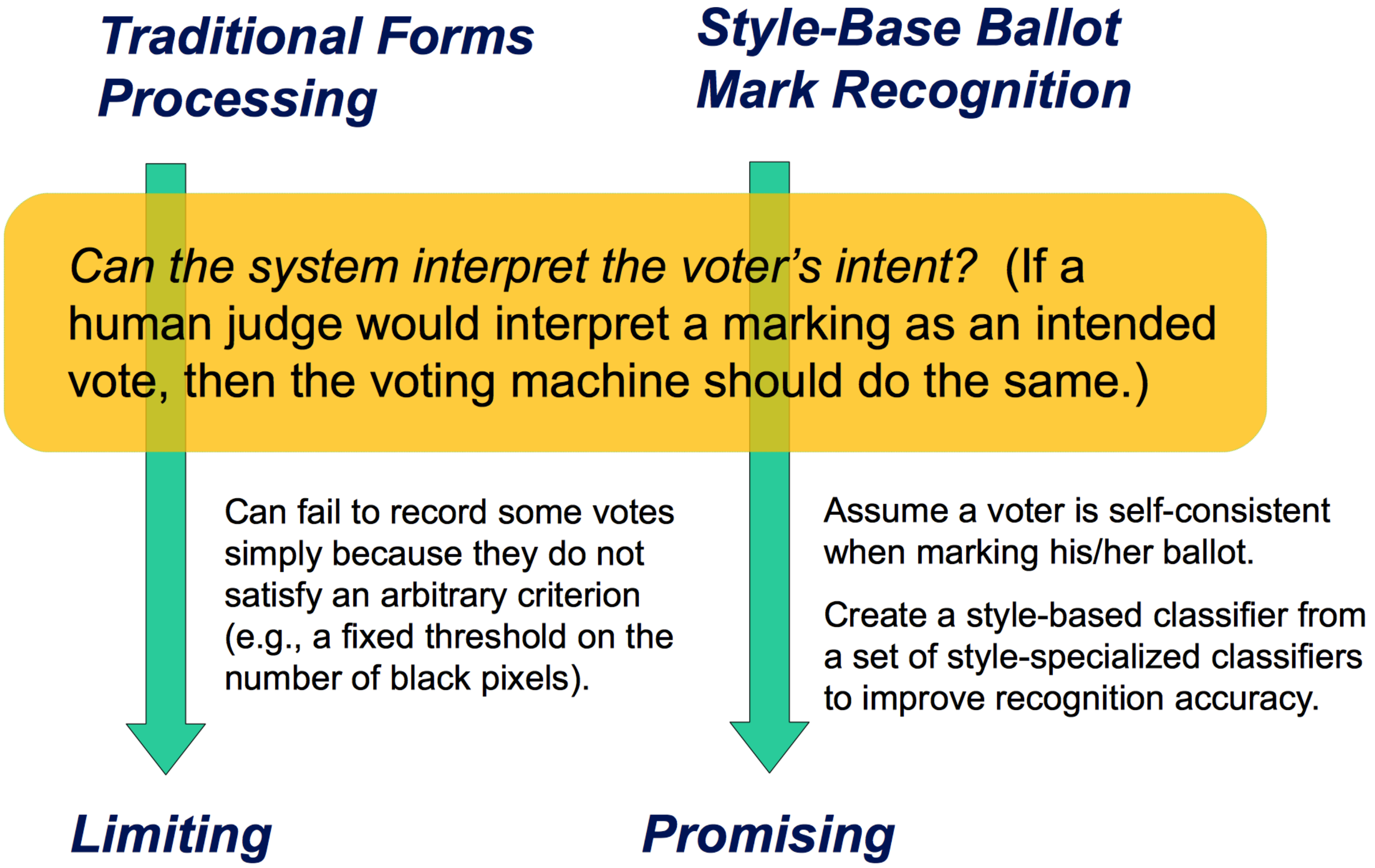
Valid vote?

BASEBALL HALL OF FAME
(vote for no more than 5)

- ○ Ty Cobb
- ✓ Rogers Hornsby
- ○ Walter Johnson
- ✓ Nap Lajoie
- ○ Christy Mathewson
- ○ Babe Ruth
- ○ Tris Speaker
- ○ Honus Wagner
- ○ Cy Young

Can we capture voter intent via style-based techniques?

Style-Based Mark Recognition



Traditional Forms Processing

Style-Base Ballot Mark Recognition

Can the system interpret the voter's intent? (If a human judge would interpret a marking as an intended vote, then the voting machine should do the same.)

Can fail to record some votes simply because they do not satisfy an arbitrary criterion (e.g., a fixed threshold on the number of black pixels).

Assume a voter is self-consistent when marking his/her ballot.

Create a style-based classifier from a set of style-specialized classifiers to improve recognition accuracy.

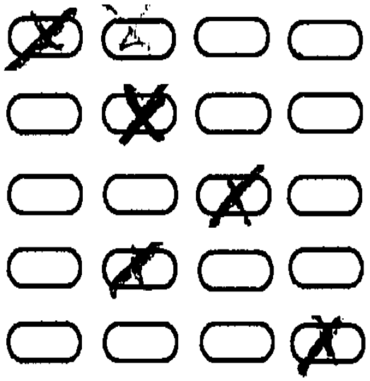
Limiting

Promising

"Style-Based Ballot Mark Recognition," P. Xiu, D. Lopresti, H. Baird, G. Nagy, and E. Barney Smith, *Proceedings of the Tenth International Conference on Document Analysis and Recognition*, July 2009, Barcelona, Spain, pp. 216-220.

Challenging Cases

A Style-Consistent Field

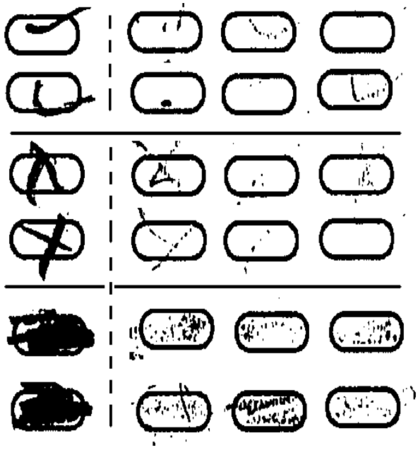


Human Interpretation

VNNN,NVNN,NNVN,NVNN,NNNV

(V for Vote, N for Non-vote)

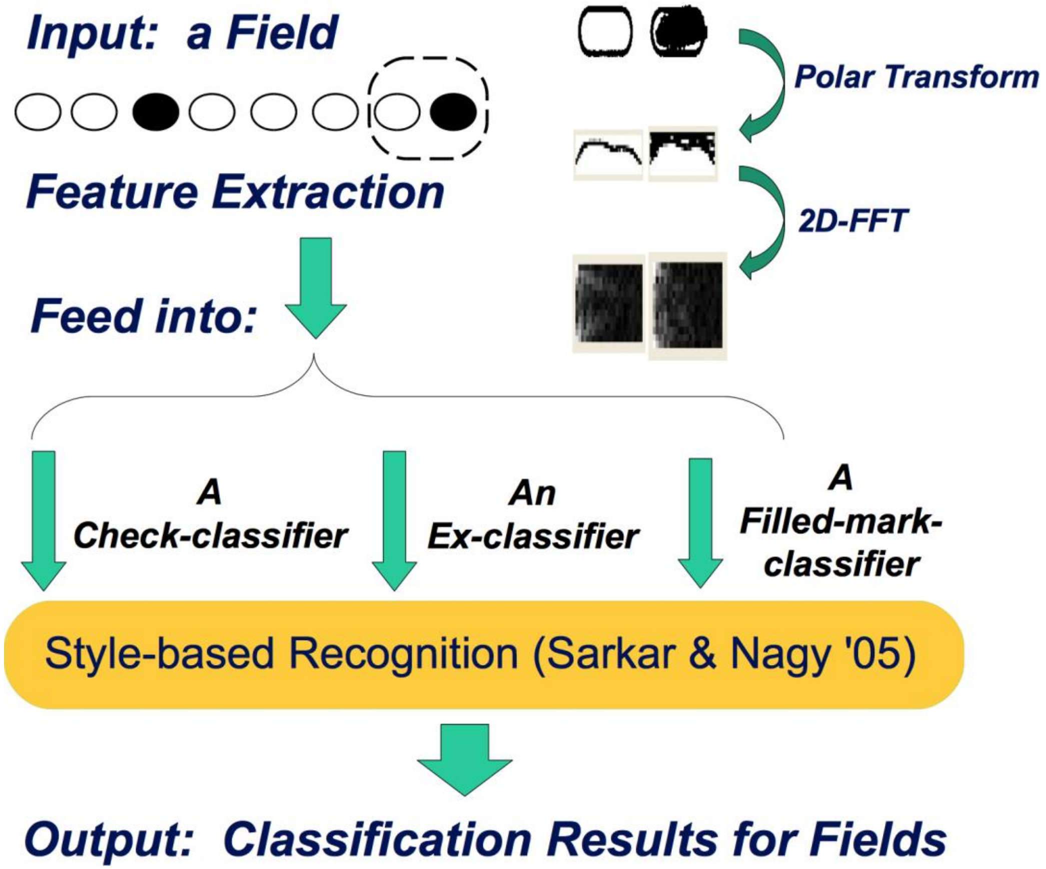
Variations in Marking Style



Check, ex, and filled marks (left) vs. noisy non-votes (right)

"Style-Based Ballot Mark Recognition," P. Xiu, D. Lopresti, H. Baird, G. Nagy, and E. Barney Smith, *Proceedings of the Tenth International Conference on Document Analysis and Recognition*, July 2009, Barcelona, Spain, pp. 216-220.

System Design



Input: a Field

Feature Extraction

Polar Transform

2D-FFT

Feed into:

A Check-classifier

An Ex-classifier

A Filled-mark-classifier

Style-based Recognition (Sarkar & Nagy '05)

Output: Classification Results for Fields

“Style-Based Ballot Mark Recognition,” P. Xiu, D. Lopresti, H. Baird, G. Nagy, and E. Barney Smith, *Proceedings of the Tenth International Conference on Document Analysis and Recognition*, July 2009, Barcelona, Spain, pp. 216-220.

Style-Based Performance

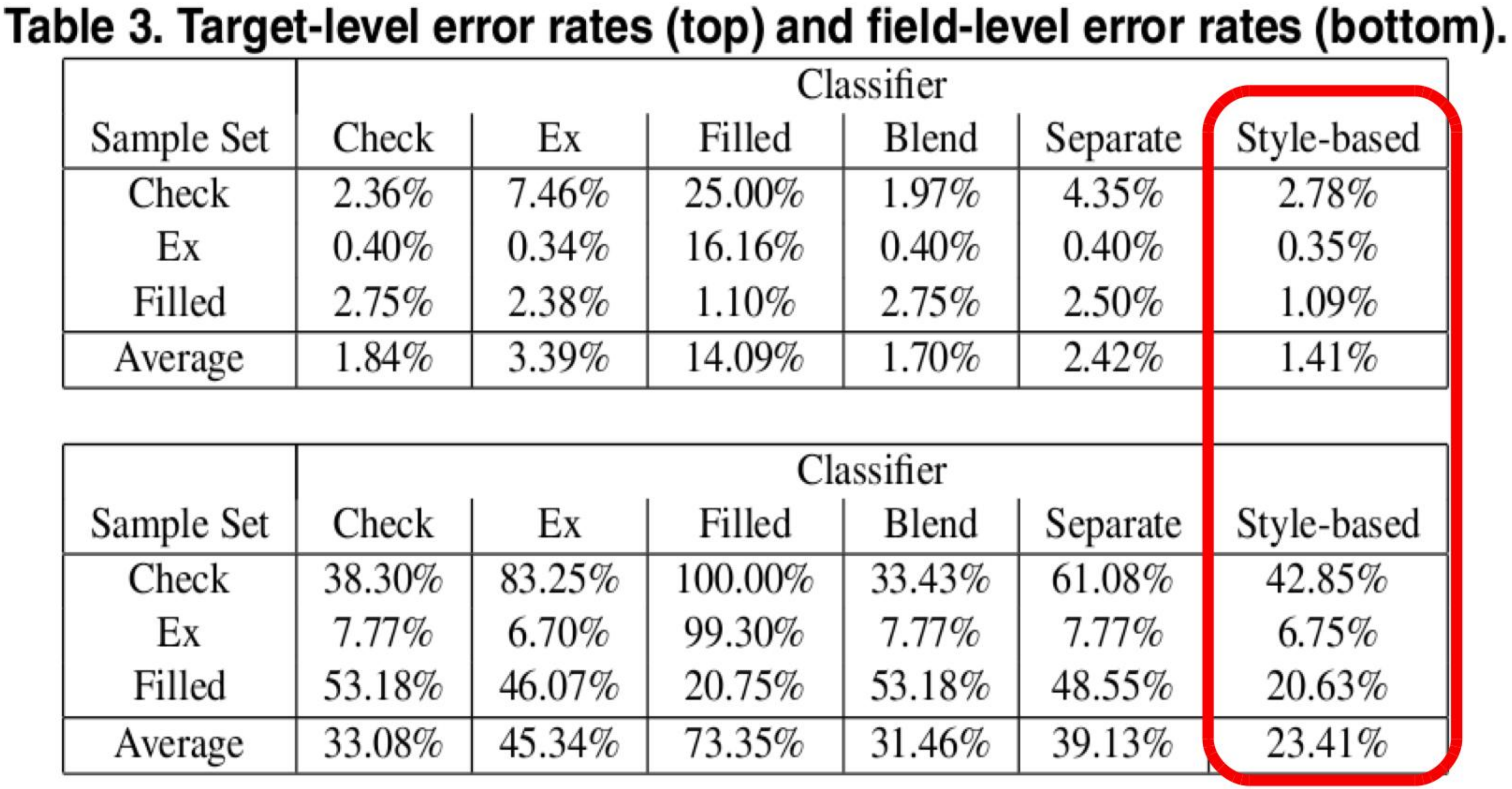


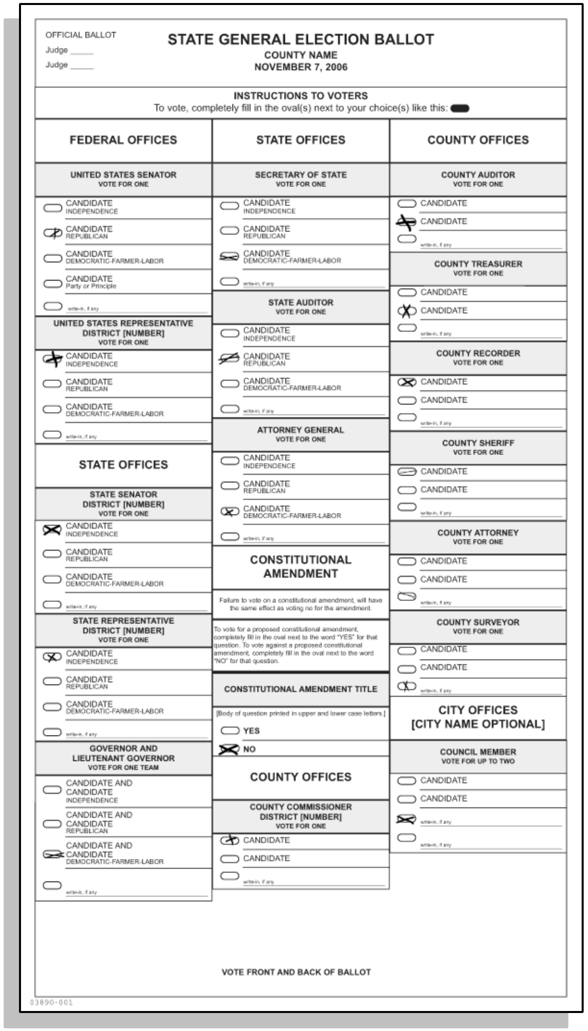
Table 3. Target-level error rates (top) and field-level error rates (bottom).

	Classifier					
Sample Set	Check	Ex	Filled	Blend	Separate	Style-based
Check	2.36%	7.46%	25.00%	1.97%	4.35%	2.78%
Ex	0.40%	0.34%	16.16%	0.40%	0.40%	0.35%
Filled	2.75%	2.38%	1.10%	2.75%	2.50%	1.09%
Average	1.84%	3.39%	14.09%	1.70%	2.42%	1.41%

	Classifier					
Sample Set	Check	Ex	Filled	Blend	Separate	Style-based
Check	38.30%	83.25%	100.00%	33.43%	61.08%	42.85%
Ex	7.77%	6.70%	99.30%	7.77%	7.77%	6.75%
Filled	53.18%	46.07%	20.75%	53.18%	48.55%	20.63%
Average	33.08%	45.34%	73.35%	31.46%	39.13%	23.41%

"Style-Based Ballot Mark Recognition," P. Xiu, D. Lopresti, H. Baird, G. Nagy, and E. Barney Smith, *Proceedings of the Tenth International Conference on Document Analysis and Recognition*, July 2009, Barcelona, Spain, pp. 216-220.

BallotGen Mark Synthesis



OFFICIAL BALLOT
Judge ______
Judge ______

STATE GENERAL ELECTION BALLOT
COUNTY NAME
NOVEMBER 7, 2006

INSTRUCTIONS TO VOTERS
To vote, completely fill in the oval(s) next to your choice(s) like this: ●

FEDERAL OFFICES

UNITED STATES SENATOR
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ⊗ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ CANDIDATE Party or Principle
- ○ write-in, if any

UNITED STATES REPRESENTATIVE
DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE OFFICES

STATE SENATOR
DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE REPRESENTATIVE
DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

GOVERNOR AND
LIEUTENANT GOVERNOR
VOTE FOR ONE TEAM

- ○ CANDIDATE AND CANDIDATE INDEPENDENCE
- ○ CANDIDATE AND CANDIDATE REPUBLICAN
- ⊗ CANDIDATE AND CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE OFFICES

SECRETARY OF STATE
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ⊗ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

STATE AUDITOR
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ⊗ CANDIDATE REPUBLICAN
- ○ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

ATTORNEY GENERAL
VOTE FOR ONE

- ○ CANDIDATE INDEPENDENCE
- ○ CANDIDATE REPUBLICAN
- ⊗ CANDIDATE DEMOCRATIC-FARMER-LABOR
- ○ write-in, if any

CONSTITUTIONAL AMENDMENT

Failure to vote on a constitutional amendment, will have the same effect as voting no for the amendment.

To vote for a proposed constitutional amendment, completely fill in the oval next to the word "YES" for that question. To vote against a proposed constitutional amendment, completely fill in the oval next to the word "NO" for that question.

CONSTITUTIONAL AMENDMENT TITLE

[Body of question printed in upper and lower case letters.]

- ○ YES
- ⊗ NO

COUNTY OFFICES

COUNTY COMMISSIONER
DISTRICT [NUMBER]
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY OFFICES

COUNTY AUDITOR
VOTE FOR ONE

- ○ CANDIDATE
- ⊗ CANDIDATE
- ○ write-in, if any

COUNTY TREASURER
VOTE FOR ONE

- ○ CANDIDATE
- ⊗ CANDIDATE
- ○ write-in, if any

COUNTY RECORDER
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY SHERIFF
VOTE FOR ONE

- ⊗ CANDIDATE
- ○ CANDIDATE
- ○ write-in, if any

COUNTY ATTORNEY
VOTE FOR ONE

- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any

COUNTY SURVEYOR
VOTE FOR ONE

- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any

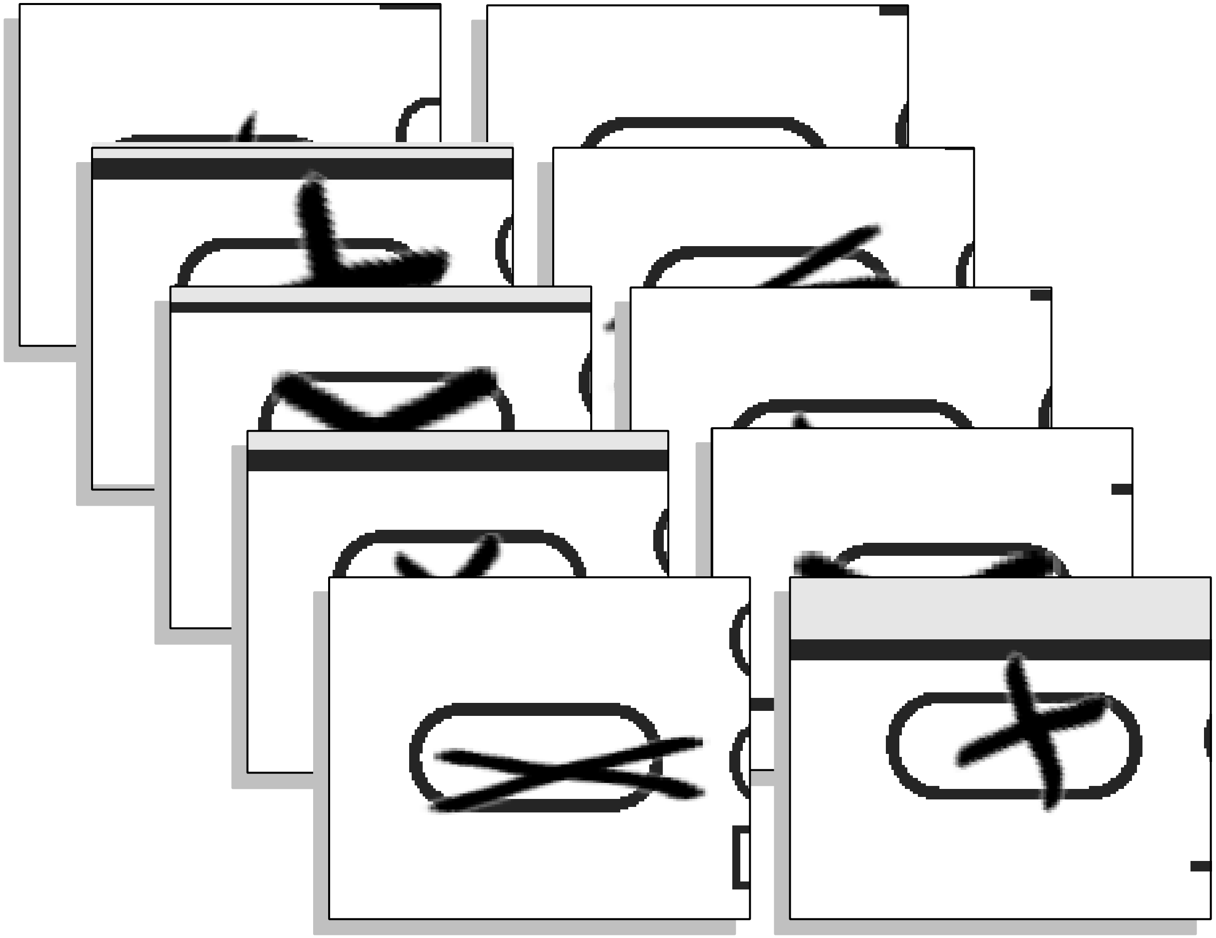
CITY OFFICES
[CITY NAME OPTIONAL]

COUNCIL MEMBER
VOTE FOR UP TO TWO

- ○ CANDIDATE
- ○ CANDIDATE
- ⊗ write-in, if any
- ○ write-in, if any

VOTE FRONT AND BACK OF BALLOT

03890-001



A Bit of Good Luck

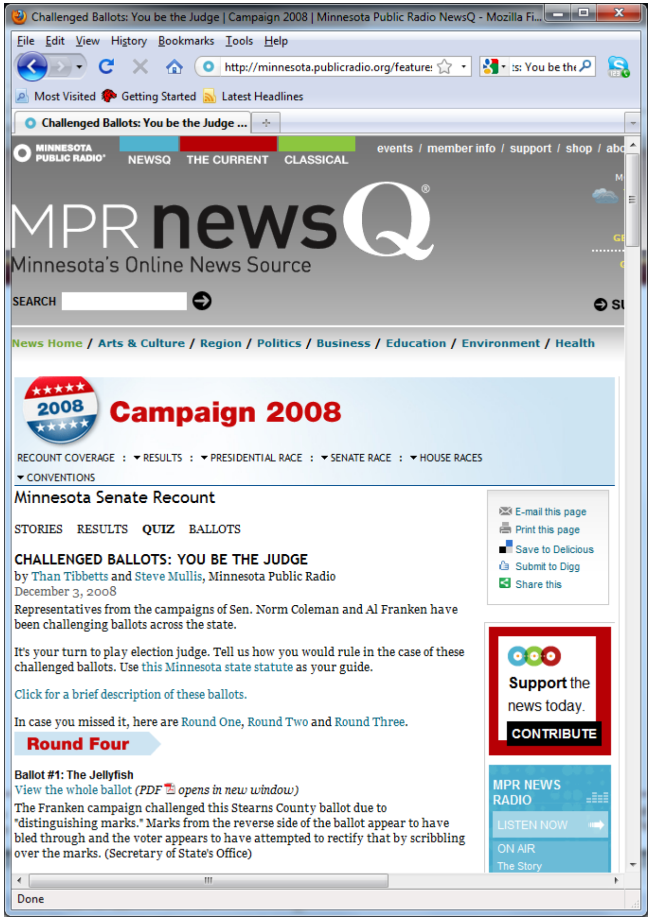
But what we'd like to have is ballots from a real election. Even better, the ballots would be from an important election where the voter markings present serious pattern recognition challenges.

Extremely close U.S. Senate race in State of Minnesota: six days after election, unofficial results showed Republican Norm Coleman leading Democratic challenger Al Franken by 206 votes out of nearly 3 million cast, a difference of less than 0.01%.

"Document Analysis Issues in Reading Optical Scan Ballots," D. Lopresti, G. Nagy, and E. Barney Smith, *Proceedings of the Ninth IAPR International Workshop on Document Analysis Systems*, June 2010, Boston, MA, pp. 105-112.

A Bit of Good Luck

- Minnesota uses op-scan ballots.
- Closeness of election triggers a manual recount.
- Both sides are allowed to challenge validity of "questionable" ballots.
- Openness laws make challenged ballots a matter of public record.
- Ballot images made available on MN public radio website.
- PDF files contain 300 dpi TIF images!


Challenged Ballots: You be the Judge | Campaign 2008 | Minnesota Public Radio NewsQ - Mozilla Fi...
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http://minnesota.publicradio.org/feature:
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events / member info / support / shop / abo
MPR newsQ
Minnesota's Online News Source
SEARCH
News Home / Arts & Culture / Region / Politics / Business / Education / Environment / Health
2008
Campaign 2008
RECOUNT COVERAGE : RESULTS : PRESIDENTIAL RACE : SENATE RACE : HOUSE RACES
CONVENTIONS
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Print this page
Save to Delicious
Submit to Digg
Share this
Support the news today.
CONTRIBUTE
MPR NEWS RADIO
LISTEN NOW
ON AIR
The Story
Done

Minnesota Senate Recount

STORIES RESULTS QUIZ BALLOTS

CHALLENGED BALLOTS: YOU BE THE JUDGE

by Than Tibbetts and Steve Mullis, Minnesota Public Radio

December 3, 2008

Representatives from the campaigns of Sen. Norm Coleman and Al Franken have been challenging ballots across the state.

It's your turn to play election judge. Tell us how you would rule in the case of these challenged ballots. Use this Minnesota state statute as your guide.

Click for a brief description of these ballots.

In case you missed it, here are Round One, Round Two and Round Three.

Round Four

Ballot #1: The Jellyfish

View the whole ballot *(PDF opens in new window)*

The Franken campaign challenged this Stearns County ballot due to "distinguishing marks." Marks from the reverse side of the ballot appear to have bled through and the voter appears to have attempted to rectify that by scribbling over the marks. (Secretary of State's Office)

http://minnesota.publicradio.org/features/2008/11/19_challenged_ballots/

Minnesota Statutes

Remember that the guiding principle is *voter intent*. Here are a few key points to keep in mind when interpreting ballot markings:

- "A ballot shall not be rejected for a technical error that does not make it impossible to determine the voter's intent."
- "If a mark (X) is made out of its proper place, but so near a name or space as to indicate clearly the voter's intent, the vote shall be counted."
- "Misspelling or abbreviations of the names of write-in candidates shall be disregarded if the individual for whom the vote was intended can be clearly ascertained from the ballot."

https://www.revisor.mn.gov/statutes/?id=204C.22

Minnesota Statutes

… and …

- "If a voter uniformly uses a mark other than (X) which clearly indicates an intent to mark a name or to mark yes or no on a question, and the voter does not use (X) anywhere else on the ballot, a vote shall be counted for each candidate or response to a question marked.
- If a voter uses two or more distinct marks, such as (X) and some other mark, a vote shall be counted for each candidate or response to a question marked, unless the ballot is marked by distinguishing characteristics that make the entire ballot defective …"

https://www.revisor.mn.gov/statutes/?id=204C.22

Minnesota Statutes

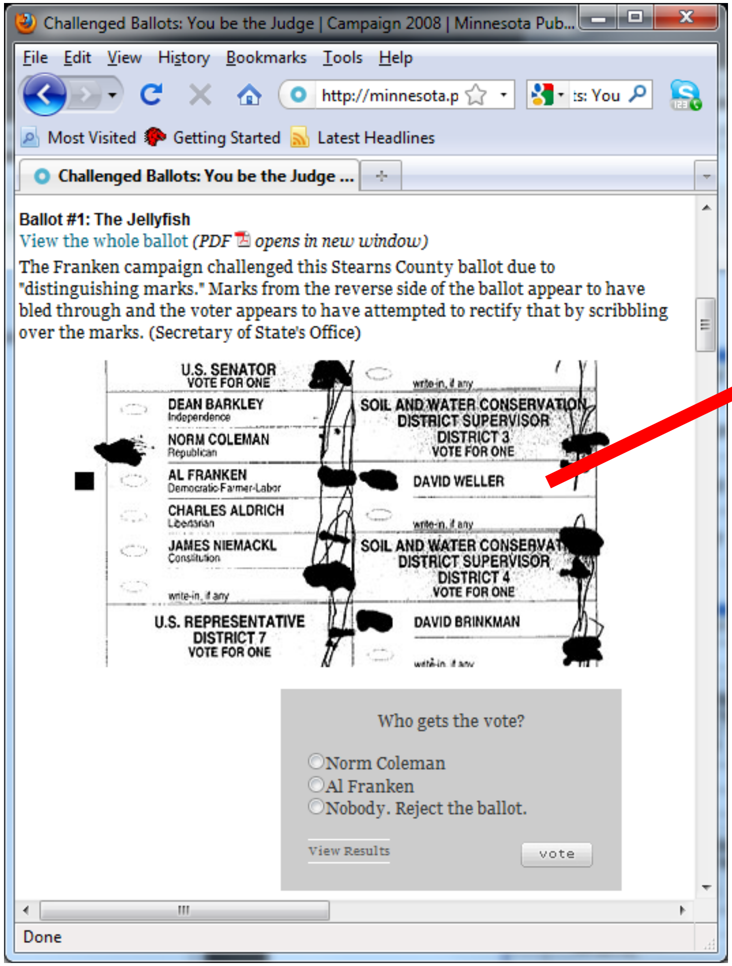
… and …

- "If the names of two candidates have been marked, and an attempt has been made to erase or obliterate one of the marks, a vote shall be counted for the remaining marked candidate."
- "A ballot shall not be rejected merely because it is slightly soiled or defaced."
- "If a ballot is marked by distinguishing characteristics in a manner making it evident that the voter intended to identify the ballot, the entire ballot is defective."

Goal here is to prevent coercion or vote selling.

https://www.revisor.mn.gov/statutes/?id=204C.22

Challenge: you be the judge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Ballot #1: The Jellyfish

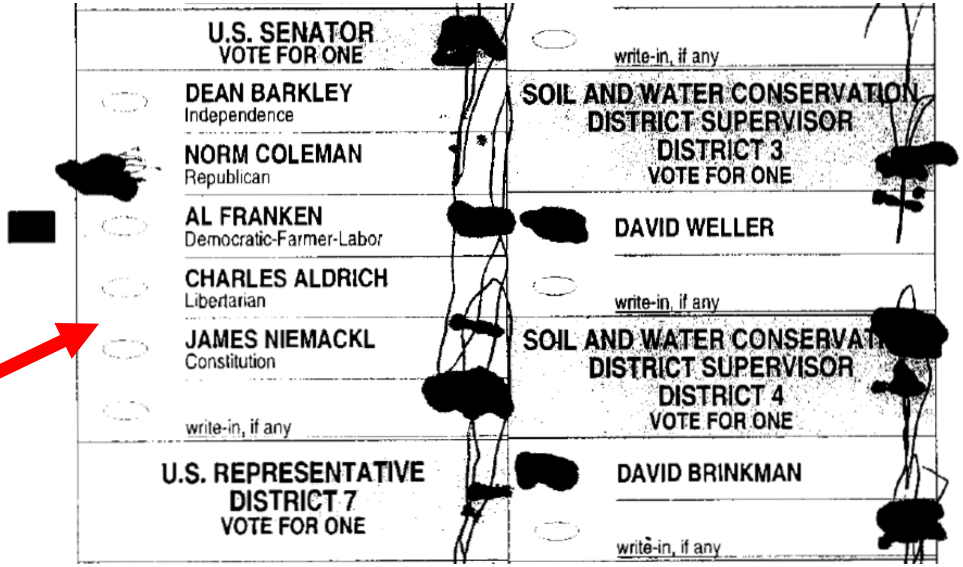
View the whole ballot *(PDF opens in new window)*

The Franken campaign challenged this Stearns County ballot due to "distinguishing marks." Marks from the reverse side of the ballot appear to have bled through and the voter appears to have attempted to rectify that by scribbling over the marks. (Secretary of State's Office)

Who gets the vote?

○ Norm Coleman
○ Al Franken
○ Nobody. Reject the ballot.

View Results   vote



U.S. SENATOR
VOTE FOR ONE

DEAN BARKLEY
Independence

NORM COLEMAN
Republican

AL FRANKEN
Democratic-Farmer-Labor

CHARLES ALDRICH
Libertarian

JAMES NIEMACKL
Constitution

write-in, if any

U.S. REPRESENTATIVE
DISTRICT 7
VOTE FOR ONE

write-in, if any

SOIL AND WATER CONSERVATION
DISTRICT SUPERVISOR
DISTRICT 3
VOTE FOR ONE

DAVID WELLER

write-in, if any

SOIL AND WATER CONSERVAT
DISTRICT SUPERVISOR
DISTRICT 4
VOTE FOR ONE

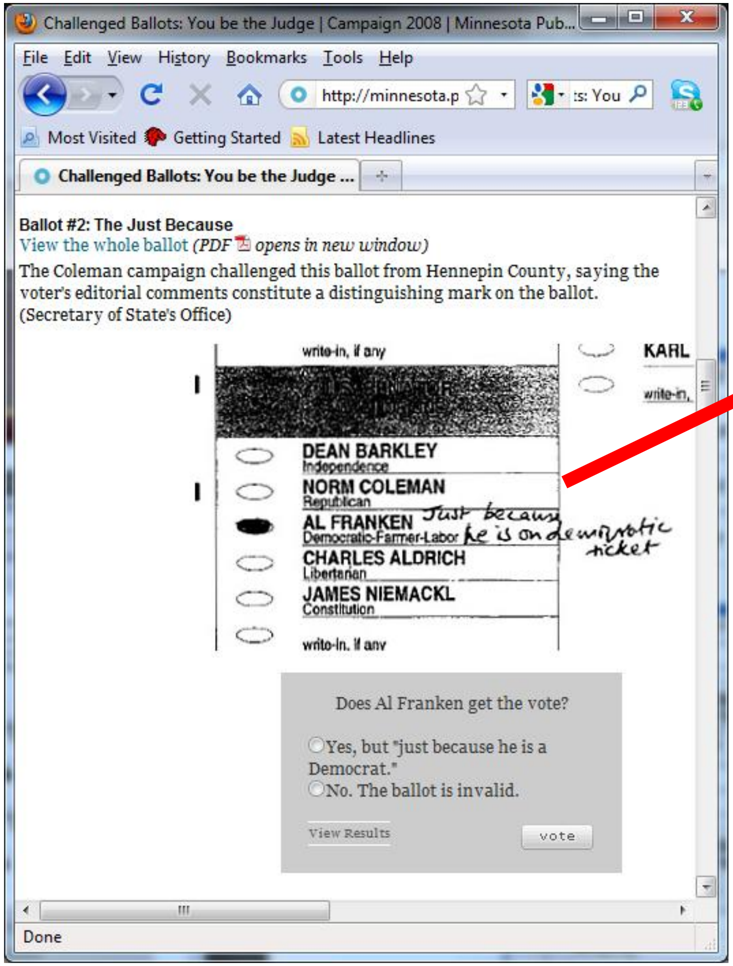
DAVID BRINKMAN

write-in, if any

Who gets vote? Public opinion:

- Norm Coleman: 63% (7,626 votes)
- Al Franken: 4% (474 votes)
- Nobody: 33% (4,050 votes)

Challenge: you be the judge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Ballot #2: The Just Because

View the whole ballot (PDF opens in new window)

The Coleman campaign challenged this ballot from Hennepin County, saying the voter's editorial comments constitute a distinguishing mark on the ballot. (Secretary of State's Office)

write-in, if any

○ KARL

○ write-in,

○ DEAN BARKLEY Independence

○ NORM COLEMAN Republican

● AL FRANKEN Democratic-Farmer-Labor Just because he is on democratic ticket

○ CHARLES ALDRICH Libertarian

○ JAMES NIEMACKL Constitution

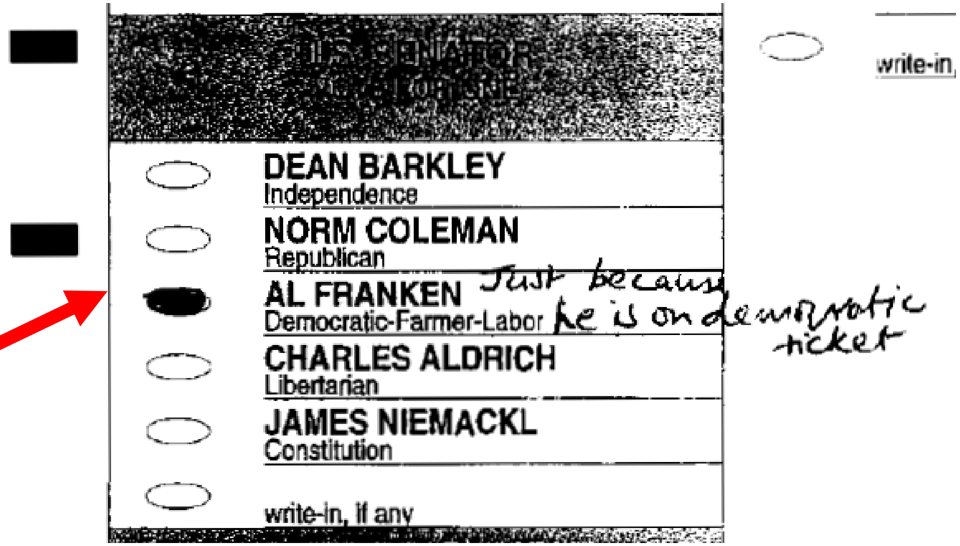
○ write-in, if any

Does Al Franken get the vote?

○ Yes, but "just because he is a Democrat."

○ No. The ballot is invalid.

View Results   vote



○ write-in,

U.S. SENATOR VOTE FOR ONE

○ DEAN BARKLEY Independence

○ NORM COLEMAN Republican

● AL FRANKEN Democratic-Farmer-Labor Just because he is on democratic ticket

○ CHARLES ALDRICH Libertarian

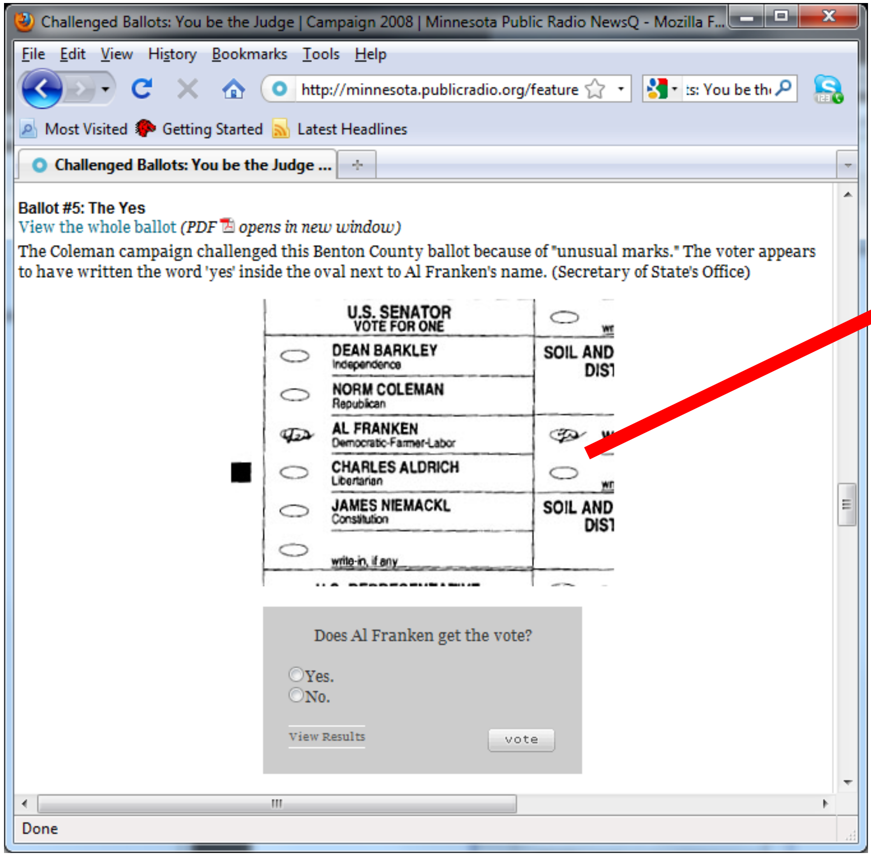
○ JAMES NIEMACKL Constitution

○ write-in, if any

Vote for Franken? Public opinion:

- Yes: 92% (11,069 votes)
- No: 8% (1,012 votes)

Challenge: you be the judge



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Ballot #5: The Yes

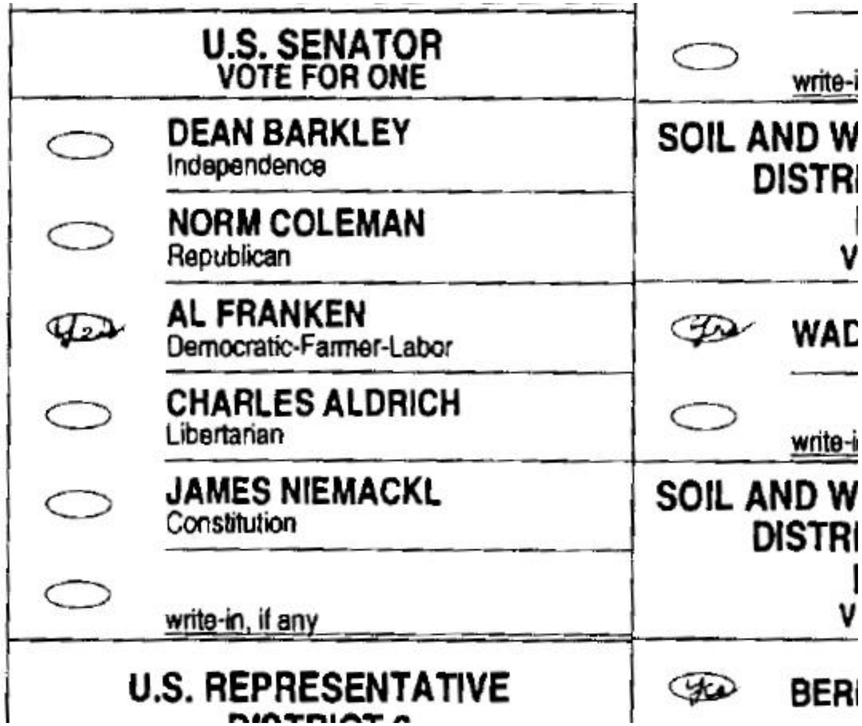
View the whole ballot *(PDF opens in new window)*

The Coleman campaign challenged this Benton County ballot because of "unusual marks." The voter appears to have written the word 'yes' inside the oval next to Al Franken's name. (Secretary of State's Office)

Does Al Franken get the vote?

○ Yes.
○ No.

View Results | vote



U.S. SENATOR
VOTE FOR ONE

○ DEAN BARKLEY
Independence

○ NORM COLEMAN
Republican

Yes AL FRANKEN
Democratic-Farmer-Labor

○ CHARLES ALDRICH
Libertarian

○ JAMES NIEMACKL
Constitution

○ write-in, if any

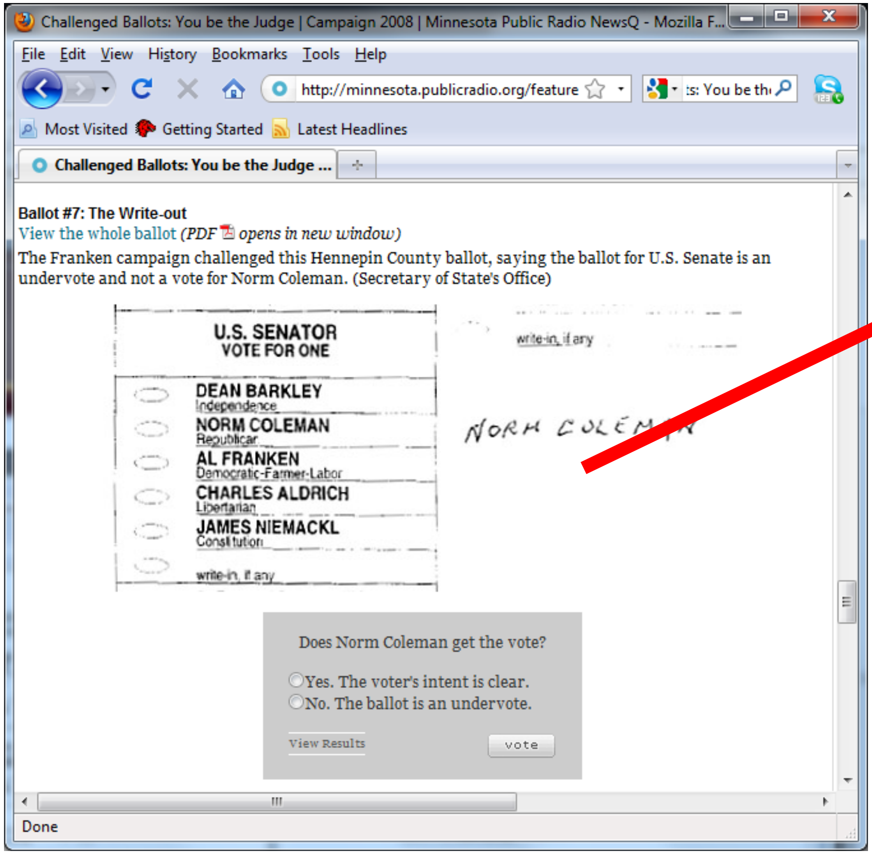
U.S. REPRESENTATIVE

write-i
SOIL AND W
DISTRI
WAD
BER

Vote for Franken? Public opinion:

- Yes: 96% (11,250 votes)
- No: 4% (452 votes)

Challenge: you be the judge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Done

Ballot #7: The Write-out

View the whole ballot *(PDF opens in new window)*

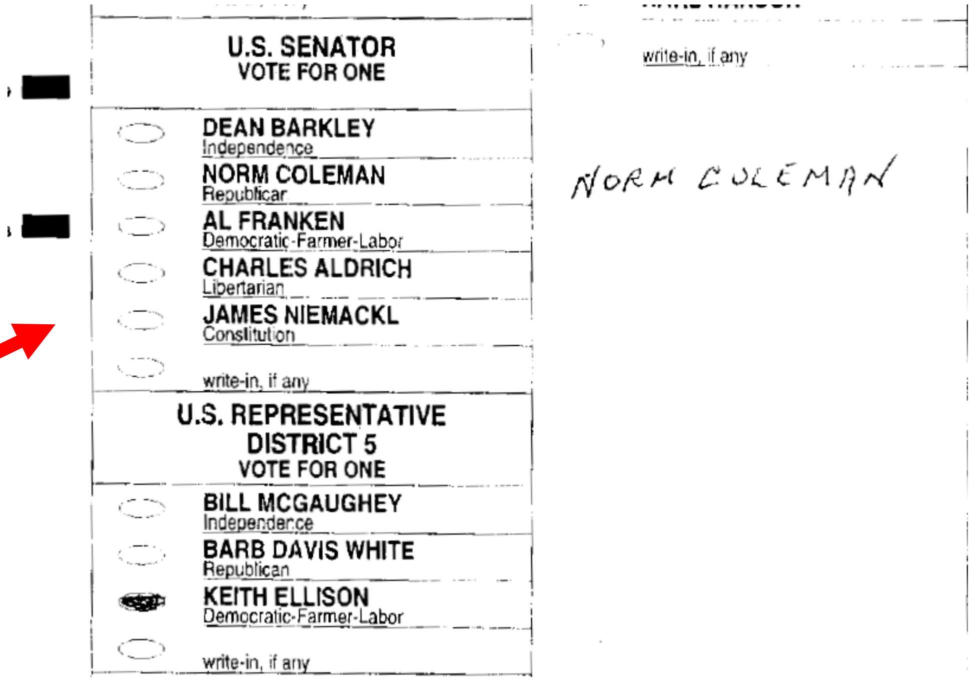
The Franken campaign challenged this Hennepin County ballot, saying the ballot for U.S. Senate is an undervote and not a vote for Norm Coleman. (Secretary of State's Office)

Does Norm Coleman get the vote?

○ Yes. The voter's intent is clear.

○ No. The ballot is an undervote.

View Results | vote



[redacted]

[redacted]

U.S. SENATOR
VOTE FOR ONE

○ DEAN BARKLEY Independence

○ NORM COLEMAN Republican

○ AL FRANKEN Democratic-Farmer-Labor

○ CHARLES ALDRICH Libertarian

○ JAMES NIEMACKL Constitution

○ write-in, if any

U.S. REPRESENTATIVE
DISTRICT 5
VOTE FOR ONE

○ BILL MCGAUGHEY Independence

○ BARB DAVIS WHITE Republican

● KEITH ELLISON Democratic-Farmer-Labor

○ write-in, if any

write-in, if any

NORM COLEMAN

Vote for Coleman? Public opinion:

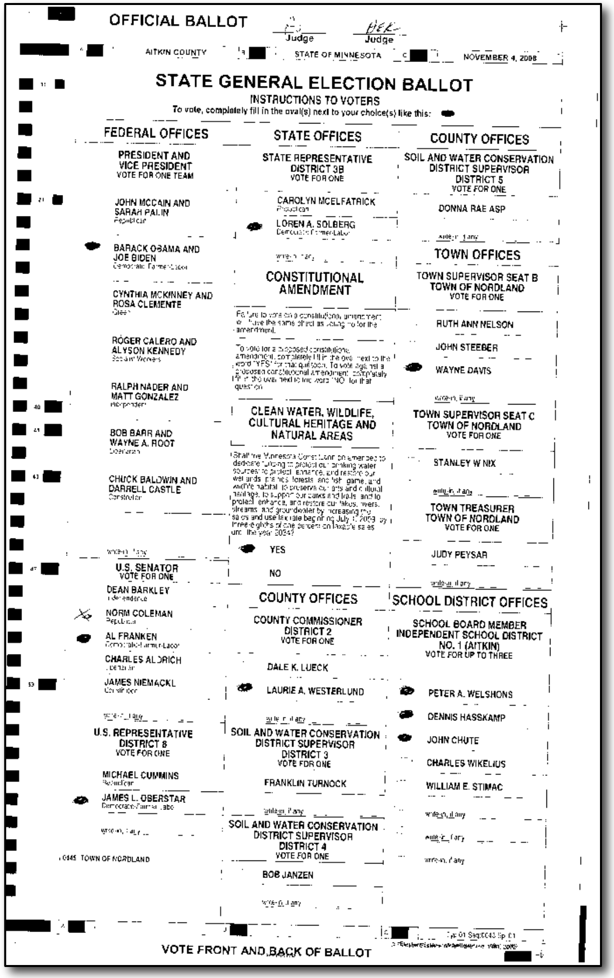
- Yes: 54% (6,080 votes)
- No: 46% (5,203 votes)

MN Challenged Ballot Collection

How the ballot collection was generated and harvested:

- Ballots photocopied and originals stored in a secure location.
- Copies scanned to PDF using auto-feeder flatbed scanner.
- Ballot was two-sided, with both sides scanned simultaneously.
- I wrote a simple web "crawler" that automatically downloaded all the files and extracted TIF images from PDF.
- A total of 6,737 ballots in the set.
- Examination of the TIF suggests that ballots were scanned at 300 dpi bitonal, and that lossy compression was never used.
- Hence, they form an ideal dataset for research purposes.

Minnesota Ballot Front and Back



OFFICIAL BALLOT

HEK

Judge　Judge

AITKIN COUNTY　STATE OF MINNESOTA　NOVEMBER 4, 2008

STATE GENERAL ELECTION BALLOT

INSTRUCTIONS TO VOTERS

To vote, completely fill in the oval(s) next to your choice(s) like this: ●

FEDERAL OFFICES

PRESIDENT AND VICE PRESIDENT
VOTE FOR ONE TEAM

JOHN MCCAIN AND SARAH PALIN
Republican

● BARACK OBAMA AND JOE BIDEN
Democratic-Farmer-Labor

CYNTHIA MCKINNEY AND ROSA CLEMENTE
Green

ROGER CALERO AND ALYSON KENNEDY
Socialist Workers

RALPH NADER AND MATT GONZALEZ
Independent

BOB BARR AND WAYNE A. ROOT
Libertarian

CHUCK BALDWIN AND DARRELL CASTLE
Constitution

write-in, if any

U.S. SENATOR
VOTE FOR ONE

DEAN BARKLEY
Independence

✗ NORM COLEMAN
Republican

● AL FRANKEN
Democratic-Farmer-Labor

CHARLES ALDRICH
Libertarian

JAMES NIEMACKL
Constitution

write-in, if any

U.S. REPRESENTATIVE
DISTRICT 8
VOTE FOR ONE

MICHAEL CUMMINS
Republican

● JAMES L. OBERSTAR
Democratic-Farmer-Labor

write-in, if any

0145 TOWN OF NORDLAND

STATE OFFICES

STATE REPRESENTATIVE
DISTRICT 3B
VOTE FOR ONE

CAROLYN MCELFATRICK
Republican

● LOREN A. SOLBERG
Democratic-Farmer-Labor

write-in, if any

CONSTITUTIONAL AMENDMENT

Failure to vote on a constitutional amendment will have the same effect as voting no for the amendment.

To vote for a proposed constitutional amendment, completely fill in the oval next to the word "YES" for that question. To vote against a proposed constitutional amendment, completely fill in the oval next to the word "NO" for that question.

CLEAN WATER, WILDLIFE, CULTURAL HERITAGE AND NATURAL AREAS

Shall the Minnesota Constitution be amended to dedicate funding to protect our drinking water sources; to protect, enhance, and restore our wetlands, prairies, forests, and fish, game, and wildlife habitat; to preserve our arts and cultural heritage; to support our parks and trails; and to protect, enhance, and restore our lakes, rivers, streams, and groundwater by increasing the sales and use tax rate beginning July 1, 2009, by three-eighths of one percent on taxable sales until the year 2034?

● YES

NO

COUNTY OFFICES

COUNTY COMMISSIONER
DISTRICT 2
VOTE FOR ONE

DALE K. LUECK

● LAURIE A. WESTERLUND

write-in, if any

SOIL AND WATER CONSERVATION DISTRICT SUPERVISOR
DISTRICT 3
VOTE FOR ONE

FRANKLIN TURNOCK

write-in, if any

SOIL AND WATER CONSERVATION DISTRICT SUPERVISOR
DISTRICT 4
VOTE FOR ONE

BOB JANZEN

write-in, if any

COUNTY OFFICES

SOIL AND WATER CONSERVATION DISTRICT SUPERVISOR
DISTRICT 5
VOTE FOR ONE

DONNA RAE ASP

write-in, if any

TOWN OFFICES

TOWN SUPERVISOR SEAT B
TOWN OF NORDLAND
VOTE FOR ONE

RUTH ANN NELSON

JOHN STEEBER

● WAYNE DAVIS

write-in, if any

TOWN SUPERVISOR SEAT C
TOWN OF NORDLAND
VOTE FOR ONE

STANLEY W NIX

write-in, if any

TOWN TREASURER
TOWN OF NORDLAND
VOTE FOR ONE

JUDY PEYSAR

write-in, if any

SCHOOL DISTRICT OFFICES

SCHOOL BOARD MEMBER
INDEPENDENT SCHOOL DISTRICT
NO. 1 (AITKIN)
VOTE FOR UP TO THREE

● PETER A. WELSHONS

● DENNIS HASSKAMP

● JOHN CHUTE

CHARLES WIKELIUS

WILLIAM E. STIMAC

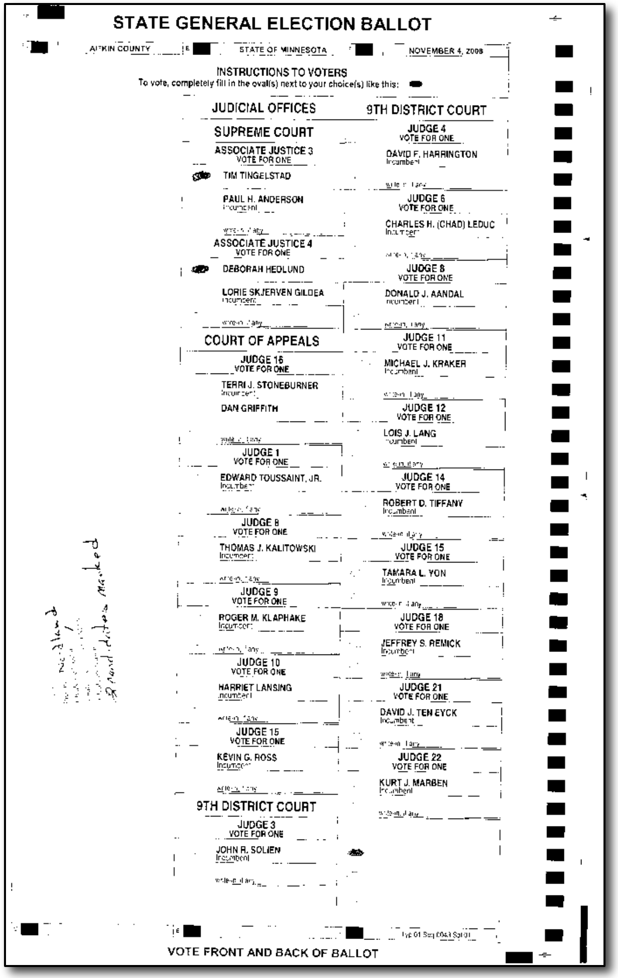
write-in, if any

write-in, if any

write-in, if any

Typ:01 Seq:0043 Spl:01

VOTE FRONT AND BACK OF BALLOT



STATE GENERAL ELECTION BALLOT

AITKIN COUNTY　STATE OF MINNESOTA　NOVEMBER 4, 2008

INSTRUCTIONS TO VOTERS

To vote, completely fill in the oval(s) next to your choice(s) like this: ●

JUDICIAL OFFICES

SUPREME COURT

ASSOCIATE JUSTICE 3
VOTE FOR ONE

● TIM TINGELSTAD

PAUL H. ANDERSON
Incumbent

write-in, if any

ASSOCIATE JUSTICE 4
VOTE FOR ONE

● DEBORAH HEDLUND

LORIE SKJERVEN GILDEA
Incumbent

write-in, if any

COURT OF APPEALS

JUDGE 16
VOTE FOR ONE

TERRI J. STONEBURNER
Incumbent

DAN GRIFFITH

write-in, if any

JUDGE 1
VOTE FOR ONE

EDWARD TOUSSAINT, JR.
Incumbent

write-in, if any

JUDGE 8
VOTE FOR ONE

THOMAS J. KALITOWSKI
Incumbent

write-in, if any

JUDGE 9
VOTE FOR ONE

ROGER M. KLAPHAKE
Incumbent

write-in, if any

JUDGE 10
VOTE FOR ONE

HARRIET LANSING
Incumbent

write-in, if any

JUDGE 15
VOTE FOR ONE

KEVIN G. ROSS
Incumbent

write-in, if any

9TH DISTRICT COURT

JUDGE 3
VOTE FOR ONE

JOHN R. SOLIEN
Incumbent

write-in, if any

9TH DISTRICT COURT

JUDGE 4
VOTE FOR ONE

DAVID F. HARRINGTON
Incumbent

write-in, if any

JUDGE 6
VOTE FOR ONE

CHARLES H. (CHAD) LEDUC
Incumbent

write-in, if any

JUDGE 8
VOTE FOR ONE

DONALD J. AANDAL
Incumbent

write-in, if any

JUDGE 11
VOTE FOR ONE

MICHAEL J. KRAKER
Incumbent

write-in, if any

JUDGE 12
VOTE FOR ONE

LOIS J. LANG
Incumbent

write-in, if any

JUDGE 14
VOTE FOR ONE

ROBERT D. TIFFANY
Incumbent

write-in, if any

JUDGE 15
VOTE FOR ONE

TAMARA L. YON
Incumbent

write-in, if any

JUDGE 18
VOTE FOR ONE

JEFFREY S. REMICK
Incumbent

write-in, if any

JUDGE 21
VOTE FOR ONE

DAVID J. TEN EYCK
Incumbent

write-in, if any

JUDGE 22
VOTE FOR ONE

KURT J. MARBEN
Incumbent

write-in, if any

Nordland /
2 nd Judges marked

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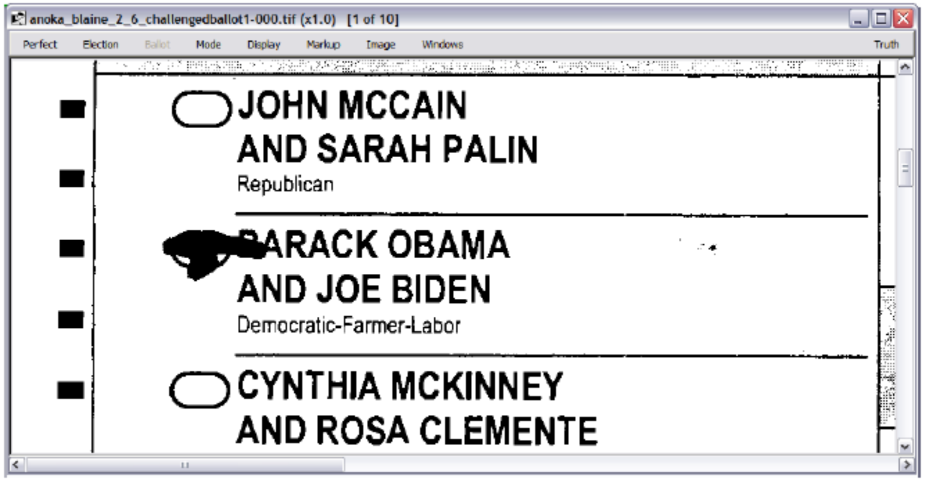
VOTE FRONT AND BACK OF BALLOT

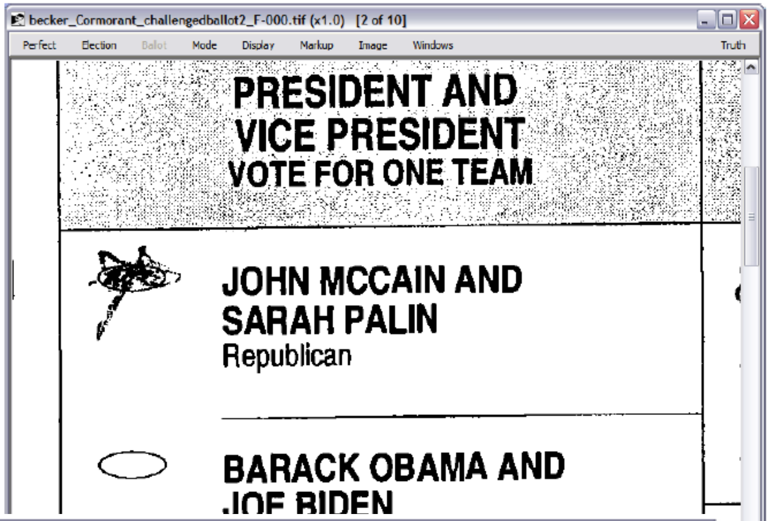
Sloppy-But-Valid Marks



○ JOHN MCCAIN
AND SARAH PALIN
Republican

[✓ BARACK OBAMA
AND JOE BIDEN
Democratic-Farmer-Labor]

○ CYNTHIA MCKINNEY
AND ROSA CLEMENTE


becker_Cormorant_challengedballot2_F-000.tif (x1.0) [2 of 10]
Perfect
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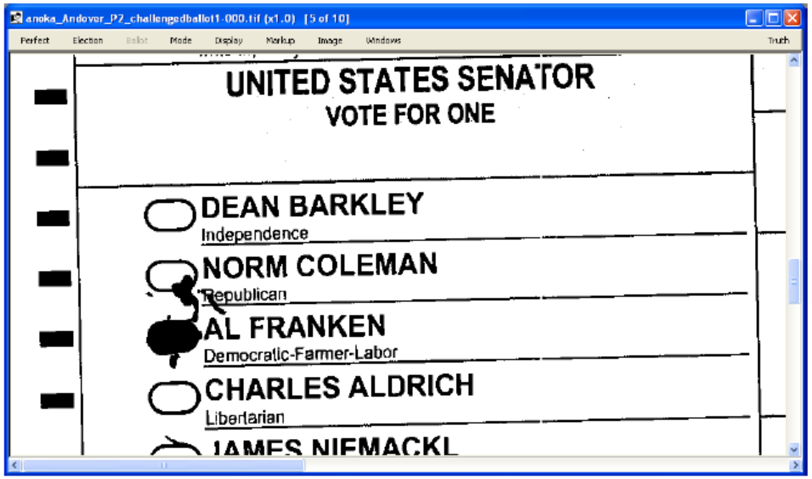
Windows
Truth

PRESIDENT AND
VICE PRESIDENT
VOTE FOR ONE TEAM

[✓ JOHN MCCAIN AND
SARAH PALIN
Republican]

○ BARACK OBAMA AND
JOE BIDEN



UNITED STATES SENATOR
VOTE FOR ONE

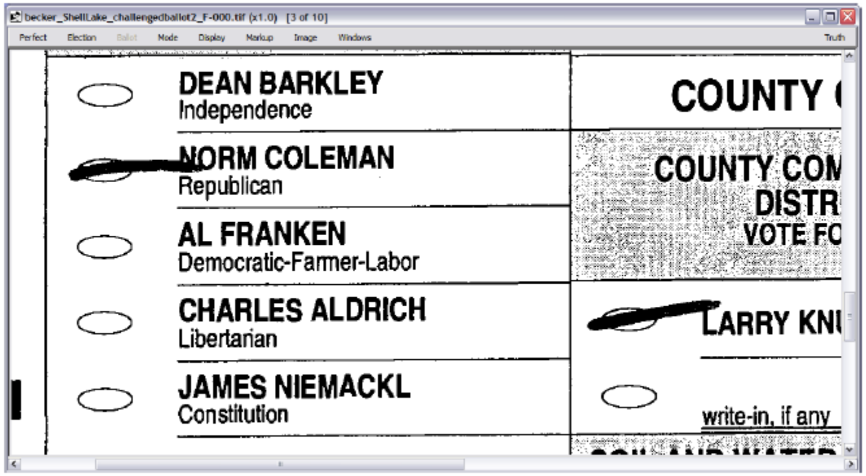
○ DEAN BARKLEY
Independence

○ NORM COLEMAN
Republican

[✓ AL FRANKEN
Democratic-Farmer-Labor]

○ CHARLES ALDRICH
Libertarian

JAMES NIEMACKL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Perfect
Election
Ballot
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Image
Windows
Truth

○ DEAN BARKLEY
Independence

[✓ NORM COLEMAN
Republican]

○ AL FRANKEN
Democratic-Farmer-Labor

○ CHARLES ALDRICH
Libertarian

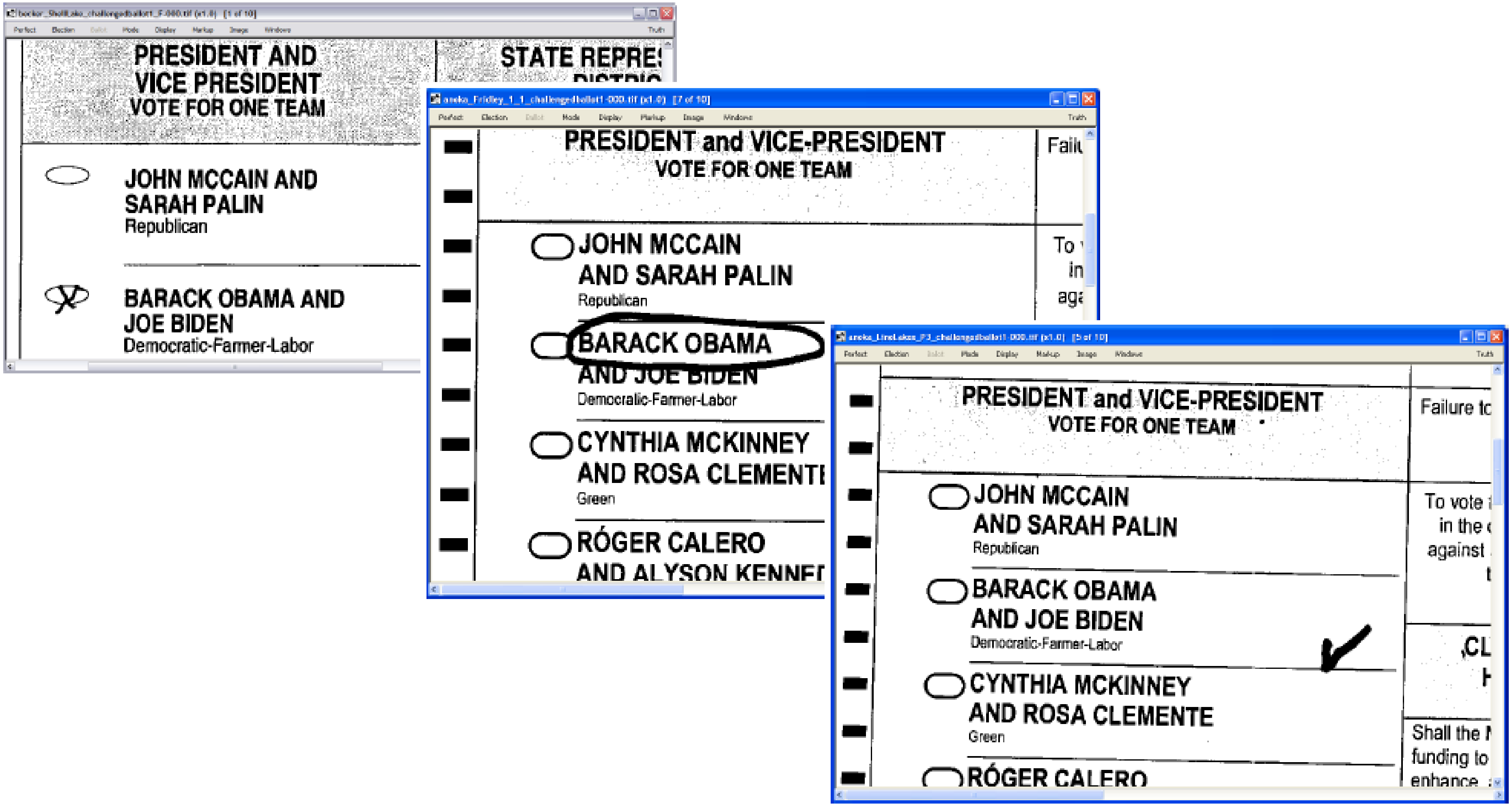
○ JAMES NIEMACKL
Constitution

COUNTY C
COUNTY COM
DISTR
VOTE FO

[✓ LARRY KN]

○ write-in, if any

Non-Conforming Marking Styles



becker_ShellLake_challengedballot1_F-000.tif (x1.0) [1 of 10]

PRESIDENT AND VICE PRESIDENT
VOTE FOR ONE TEAM

STATE REPRE

JOHN MCCAIN AND SARAH PALIN
Republican

BARACK OBAMA AND JOE BIDEN
Democratic-Farmer-Labor

anoka_Fridley_1_1_challengedballot1-000.tif (x1.0) [7 of 10]

PRESIDENT and VICE-PRESIDENT
VOTE FOR ONE TEAM

Failu

JOHN MCCAIN AND SARAH PALIN
Republican

To v
in
aga

BARACK OBAMA AND JOE BIDEN
Democratic-Farmer-Labor

CYNTHIA MCKINNEY AND ROSA CLEMENTE
Green

RÓGER CALERO AND ALYSON KENNEI

anoka_LinoLakes_P3_challengedballot1-000.tif (x1.0) [5 of 10]

PRESIDENT and VICE-PRESIDENT
VOTE FOR ONE TEAM

Failure to

JOHN MCCAIN AND SARAH PALIN
Republican

To vote
in the
against

BARACK OBAMA AND JOE BIDEN
Democratic-Farmer-Labor

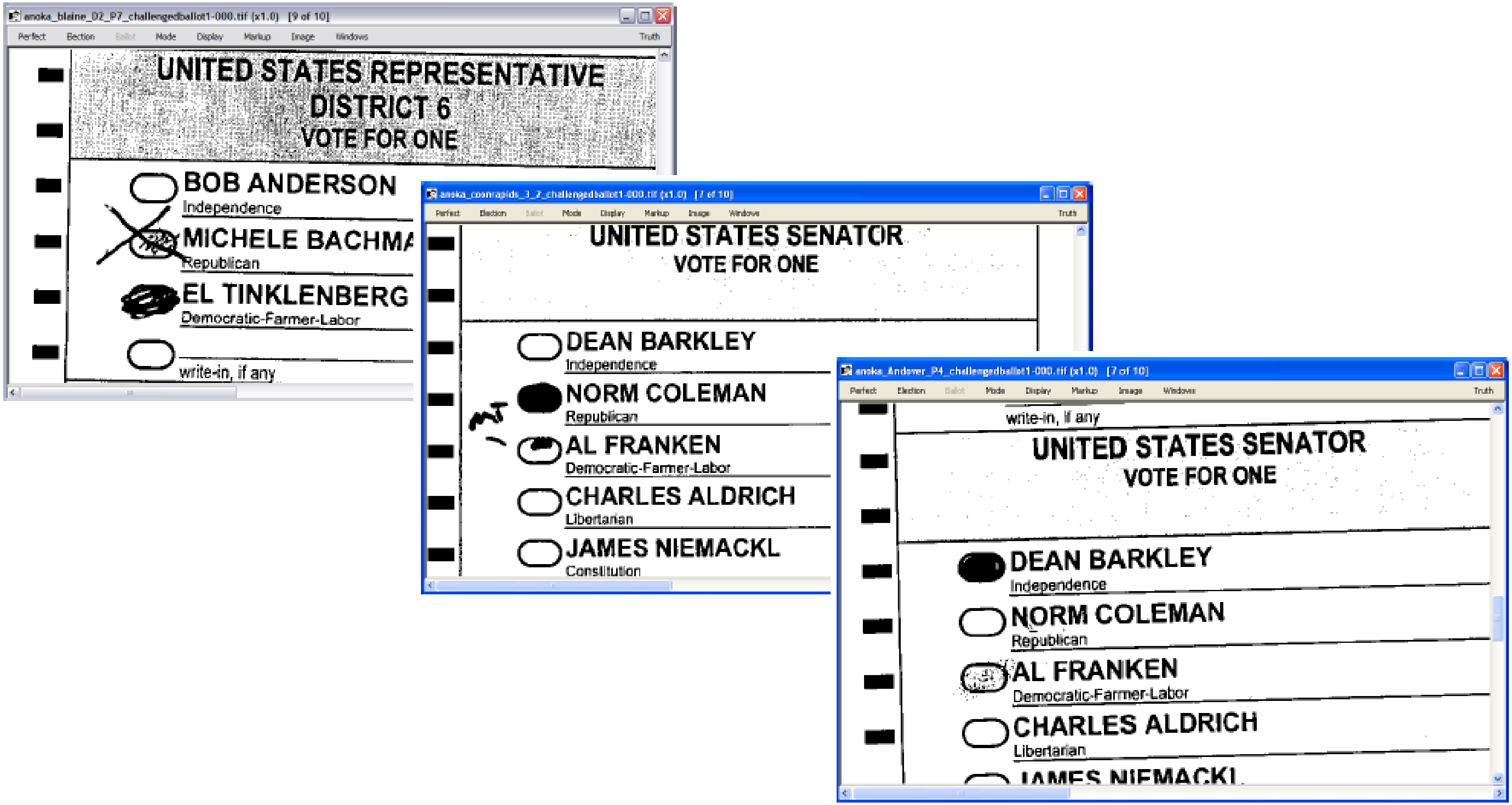
CYNTHIA MCKINNEY AND ROSA CLEMENTE
Green

RÓGER CALERO

CL
H

Shall the
funding to
enhance

Attempts to Cancel a Vote



anoka_blaine_D2_P7_challengedballot1-000.tif (x1.0) [9 of 10]

UNITED STATES REPRESENTATIVE
DISTRICT 6
VOTE FOR ONE

○ BOB ANDERSON
Independence

○ MICHELE BACHMA
Republican

● EL TINKLENBERG
Democratic-Farmer-Labor

○ ____________
write-in, if any

anoka_coonrapids_3_2_challengedballot1-000.tif (x1.0) [7 of 10]

UNITED STATES SENATOR
VOTE FOR ONE

○ DEAN BARKLEY
Independence

● NORM COLEMAN
Republican

○ AL FRANKEN
Democratic-Farmer-Labor

○ CHARLES ALDRICH
Libertarian

○ JAMES NIEMACKL
Constitution

anoka_Andover_P4_challengedballot1-000.tif (x1.0) [7 of 10]

write-in, if any

UNITED STATES SENATOR
VOTE FOR ONE

● DEAN BARKLEY
Independence

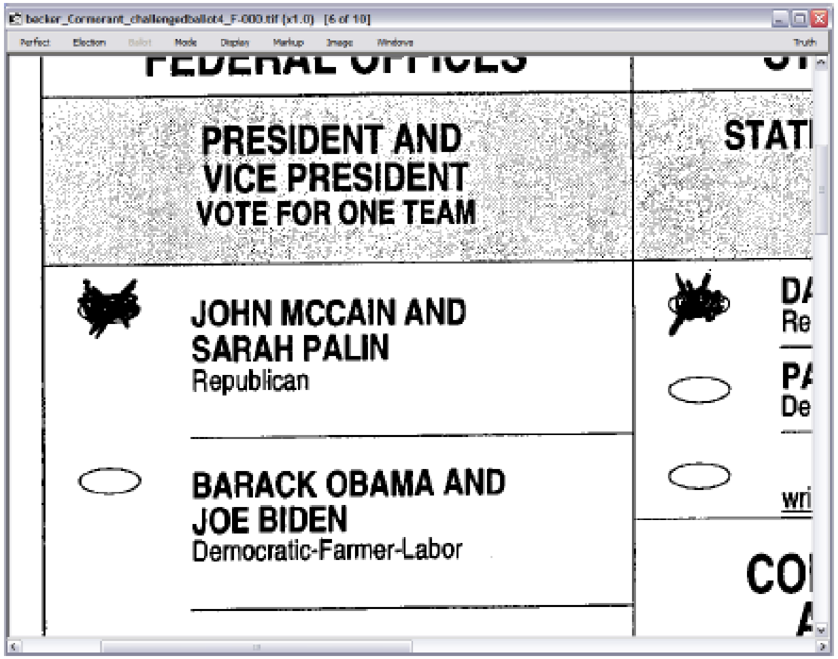
○ NORM COLEMAN
Republican

○ AL FRANKEN
Democratic-Farmer-Labor

○ CHARLES ALDRICH
Libertarian

○ JAMES NIEMACKL

Votes that Look Cancelled



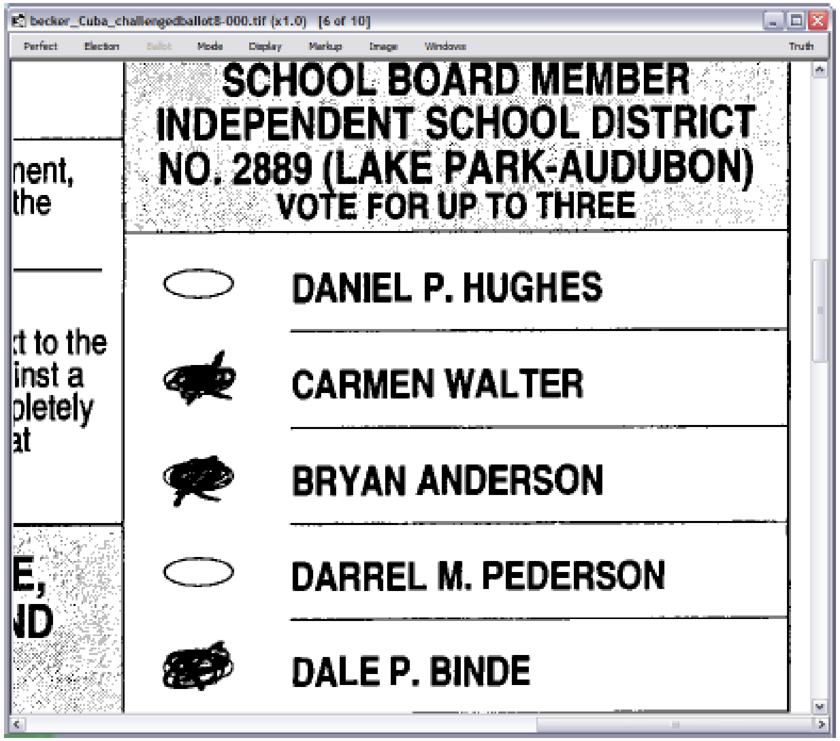
becker_Cormorant_challengedballot4_F-000.tif (x1.0) [6 of 10]

FEDERAL OFFICES

PRESIDENT AND VICE PRESIDENT
VOTE FOR ONE TEAM

● JOHN MCCAIN AND SARAH PALIN
Republican

○ BARACK OBAMA AND JOE BIDEN
Democratic-Farmer-Labor



becker_Cuba_challengedballot8-000.tif (x1.0) [6 of 10]

SCHOOL BOARD MEMBER
INDEPENDENT SCHOOL DISTRICT
NO. 2889 (LAKE PARK-AUDUBON)
VOTE FOR UP TO THREE

○ DANIEL P. HUGHES

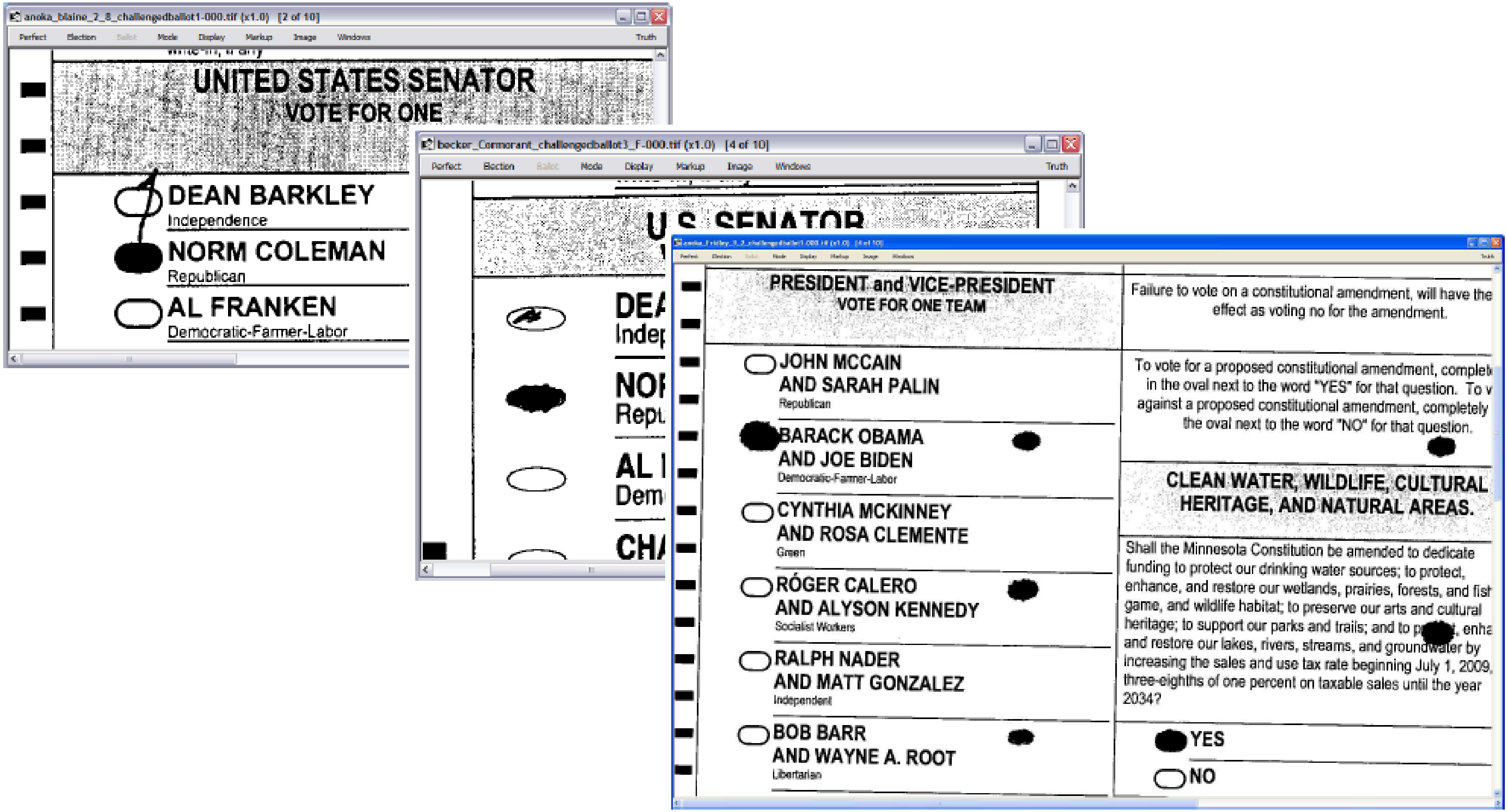
● CARMEN WALTER

● BRYAN ANDERSON

○ DARREL M. PEDERSON

● DALE P. BINDE

Stray Marks and Bleedthrough


anoka_blaine_2_8_challengedballot1-000.tif (x1.0) [2 of 10]
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UNITED STATES SENATOR
VOTE FOR ONE

○ DEAN BARKLEY
Independence

● NORM COLEMAN
Republican

○ AL FRANKEN
Democratic-Farmer-Labor

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Truth

PRESIDENT and VICE-PRESIDENT
VOTE FOR ONE TEAM

○ JOHN MCCAIN
AND SARAH PALIN
Republican

● BARACK OBAMA
AND JOE BIDEN
Democratic-Farmer-Labor

○ CYNTHIA MCKINNEY
AND ROSA CLEMENTE
Green

○ RÓGER CALERO
AND ALYSON KENNEDY
Socialist Workers

○ RALPH NADER
AND MATT GONZALEZ
Independent

○ BOB BARR
AND WAYNE A. ROOT
Libertarian

Failure to vote on a constitutional amendment, will have the effect as voting no for the amendment.

To vote for a proposed constitutional amendment, complete the oval next to the word "YES" for that question. To v against a proposed constitutional amendment, completely the oval next to the word "NO" for that question.

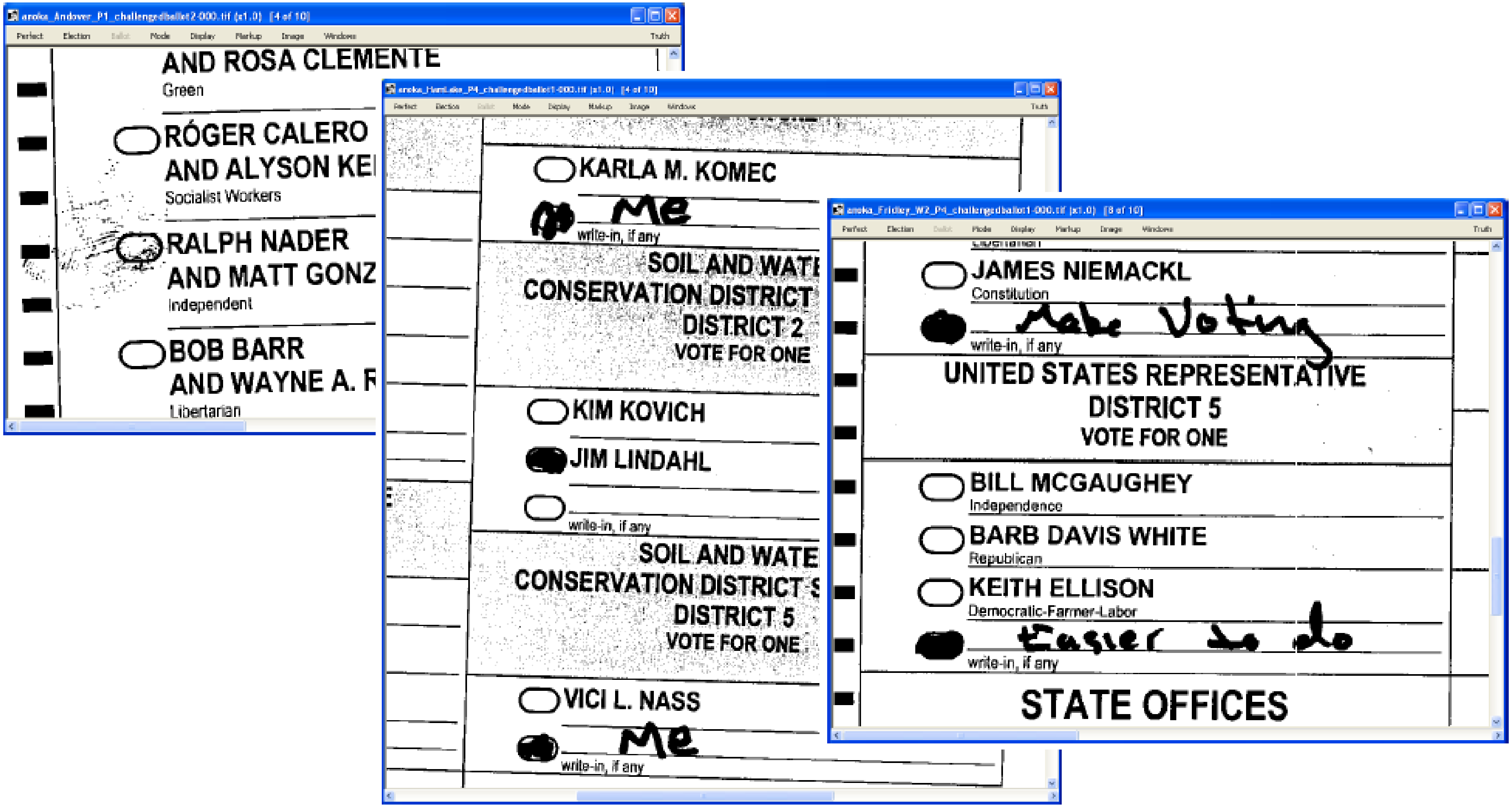
CLEAN WATER, WILDLIFE, CULTURAL HERITAGE, AND NATURAL AREAS.

Shall the Minnesota Constitution be amended to dedicate funding to protect our drinking water sources; to protect, enhance, and restore our wetlands, prairies, forests, and fish game, and wildlife habitat; to preserve our arts and cultural heritage; to support our parks and trails; and to p, enha and restore our lakes, rivers, streams, and groundwater by increasing the sales and use tax rate beginning July 1, 2009, three-eighths of one percent on taxable sales until the year 2034?

● YES

○ NO

Invalidating Markings



anoka_Andover_P1_challengedballot2-000.tif (x1.0) [4 of 10]

AND ROSA CLEMENTE
Green

○ RÓGER CALERO
AND ALYSON KE
Socialist Workers

○ RALPH NADER
AND MATT GONZ
Independent

○ BOB BARR
AND WAYNE A. R
Libertarian

anoka_HamLake_P4_challengedballot1-000.tif (x1.0) [4 of 10]

○ KARLA M. KOMEC

● Me
write-in, if any

SOIL AND WATE
CONSERVATION DISTRICT
DISTRICT 2
VOTE FOR ONE

○ KIM KOVICH

● JIM LINDAHL

○
write-in, if any

SOIL AND WATE
CONSERVATION DISTRICT S
DISTRICT 5
VOTE FOR ONE

○ VICI L. NASS

● Me
write-in, if any

anoka_Fridley_W2_P4_challengedballot1-000.tif (x1.0) [8 of 10]

○ JAMES NIEMACKL
Constitution

● Make Voting
write-in, if any

UNITED STATES REPRESENTATIVE
DISTRICT 5
VOTE FOR ONE

○ BILL MCGAUGHEY
Independence

○ BARB DAVIS WHITE
Republican

○ KEITH ELLISON
Democratic-Farmer-Labor

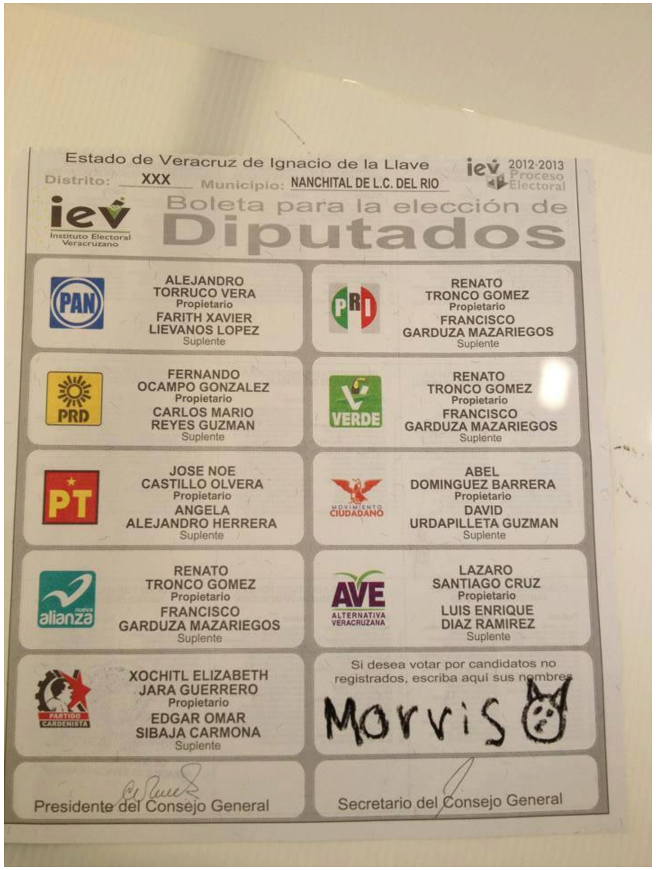
● Easier to do
write-in, if any

STATE OFFICES

An Example from Mexico

And such issues are not limited to U.S. elections …

2014-2017
MORRIS



Estado de Veracruz de Ignacio de la Llave

iev 2012-2013 Proceso Electoral

Distrito: XXX Municipio: NANCHITAL DE L.C. DEL RIO

iev Instituto Electoral Veracruzano

Boleta para la elección de Diputados

PAN ALEJANDRO TORRUCO VERA Propietario FARITH XAVIER LIEVANOS LOPEZ Suplente	PRI RENATO TRONCO GOMEZ Propietario FRANCISCO GARDUZA MAZARIEGOS Suplente
PRD FERNANDO OCAMPO GONZALEZ Propietario CARLOS MARIO REYES GUZMAN Suplente	VERDE RENATO TRONCO GOMEZ Propietario FRANCISCO GARDUZA MAZARIEGOS Suplente
PT JOSE NOE CASTILLO OLVERA Propietario ANGELA ALEJANDRO HERRERA Suplente	MOVIMIENTO CIUDADANO ABEL DOMINGUEZ BARRERA Propietario DAVID URDAPILLETA GUZMAN Suplente
nueva alianza RENATO TRONCO GOMEZ Propietario FRANCISCO GARDUZA MAZARIEGOS Suplente	AVE ALTERNATIVA VERACRUZANA LAZARO SANTIAGO CRUZ Propietario LUIS ENRIQUE DIAZ RAMIREZ Suplente
PARTIDO CARDENISTA XOCHITL ELIZABETH JARA GUERRERO Propietario EDGAR OMAR SIBAJA CARMONA Suplente	Si desea votar por candidatos no registrados, escriba aquí sus nombres Morris
Presidente del Consejo General	Secretario del Consejo General

Why isn't this an easy problem?

After all, ballots are just a simple type of form. We must read votes correctly, but we aren't expected to recognize write-ins.

Can't we just push up reject rate until accuracy reaches 100%?

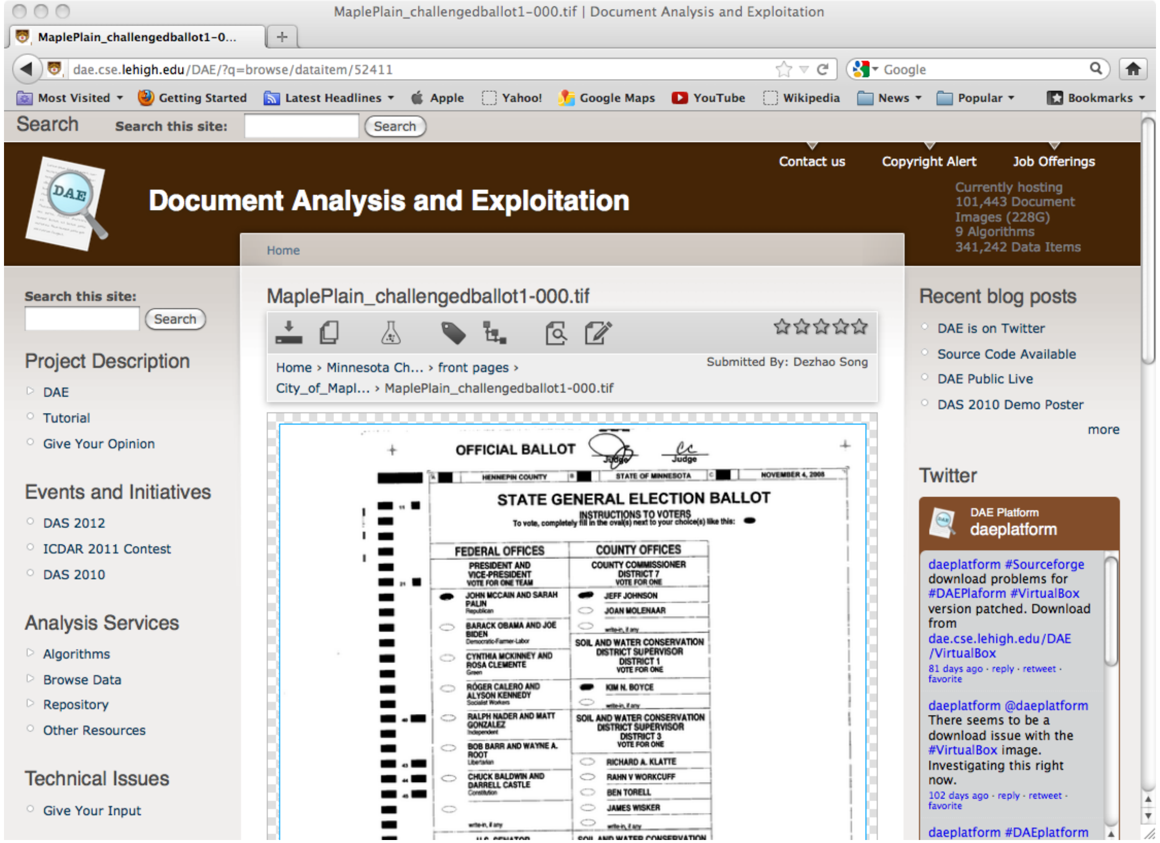
Remember, we can't change rules in ways that violate the law. VOTER INTENT is the definition we must always follow.

To do this right, we must be prepared to:

- Reject any ballot that may contain "identifying marks."
- Recognize intent when mark is atypical or far from target.
- Accurately identify when a vote has been cancelled.

Status

- Ground truth collected from 8 test subjects, 980 ballot sides.
- All 6,737 ballots now online on DAE server (see URL below for more details on the server and its capabilities).


MaplePlain_challengedballot1-000.tif | Document Analysis and Exploitation
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dae.cse.lehigh.edu/DAE/?q=browse/dataitem/52411
Google
Most Visited
Getting Started
Latest Headlines
Apple
Yahoo!
Google Maps
YouTube
Wikipedia
News
Popular
Bookmarks
Search
Search this site:
Search

Contact us | Copyright Alert | Job Offerings

Document Analysis and Exploitation

Currently hosting 101,443 Document Images (228G) 9 Algorithms 341,242 Data Items

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Project Description
- DAE
- Tutorial
- Give Your Opinion

Events and Initiatives
- DAS 2012
- ICDAR 2011 Contest
- DAS 2010

Analysis Services
- Algorithms
- Browse Data
- Repository
- Other Resources

Technical Issues
- Give Your Input

MaplePlain_challengedballot1-000.tif

Home › Minnesota Ch... › front pages › City_of_Mapl... › MaplePlain_challengedballot1-000.tif

Submitted By: Dezhao Song

OFFICIAL BALLOT Judge Judge

HENNEPIN COUNTY | STATE OF MINNESOTA | NOVEMBER 4, 2008

STATE GENERAL ELECTION BALLOT

INSTRUCTIONS TO VOTERS

To vote, completely fill in the oval(s) next to your choice(s) like this: ●

FEDERAL OFFICES	COUNTY OFFICES
PRESIDENT AND VICE-PRESIDENT VOTE FOR ONE TEAM	COUNTY COMMISSIONER DISTRICT 7 VOTE FOR ONE
● JOHN MCCAIN AND SARAH PALIN Republican	● JEFF JOHNSON
○ BARACK OBAMA AND JOE BIDEN Democratic-Farmer-Labor	○ JOAN MOLENAAR
	○ write-in, if any
○ CYNTHIA MCKINNEY AND ROSA CLEMENTE Green	SOIL AND WATER CONSERVATION DISTRICT SUPERVISOR DISTRICT 1 VOTE FOR ONE
○ ROGER CALERO AND ALYSON KENNEDY Socialist Workers	● KIM N. BOYCE
	○ write-in, if any
○ RALPH NADER AND MATT GONZALEZ Independent	SOIL AND WATER CONSERVATION DISTRICT SUPERVISOR DISTRICT 3 VOTE FOR ONE
○ BOB BARR AND WAYNE A. ROOT Libertarian	○ RICHARD A. KLATTE
○ CHUCK BALDWIN AND DARRELL CASTLE Constitution	○ RAHN V WORKCUFF
	○ BEN TORELL
○	○ JAMES WISKER
write-in, if any	○ write-in, if any
U.S. SENATOR	SOIL AND WATER CONSERVATION

Recent blog posts
- DAE is on Twitter
- Source Code Available
- DAE Public Live
- DAS 2010 Demo Poster

more

Twitter

DAE Platform
daeplatform

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81 days ago · reply · retweet · favorite

daeplatform @daeplatform There seems to be a download issue with the #VirtualBox image. Investigating this right now.
102 days ago · reply · retweet · favorite

daeplatform #DAEplatform

http://dae.cse.lehigh.edu/DAE/

Adapting the Turing Test for Declaring a Problem Solved

An interesting thought experiment, given the demand for algorithms that can perform at human levels when users are free to act in ways that confound the system.

Recall from Earlier …

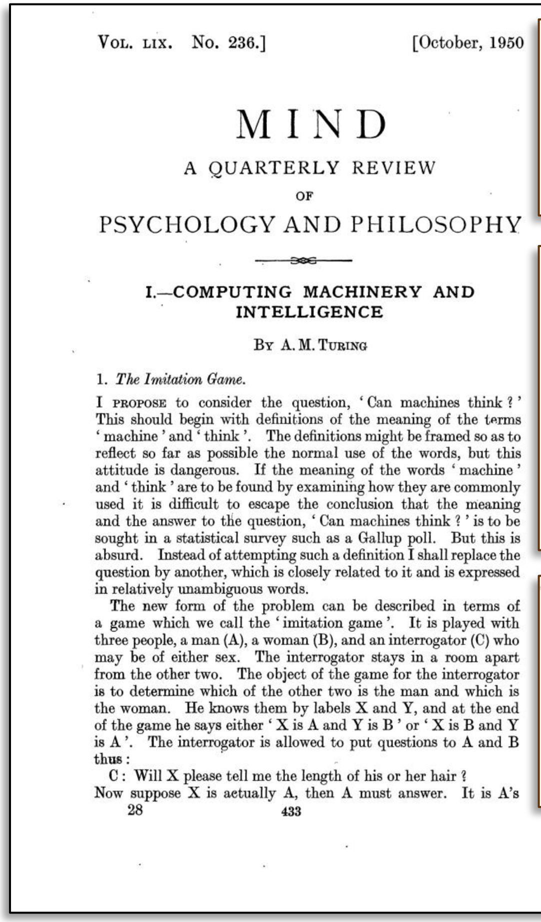
The Turing Test:

> “A problem is solved if there is a method which has been widely publicized and documented and freely available to the community which generates output for a given input that a human judge cannot reliably distinguish from the output of a human expert.”

Differs significantly from employing ground-truth provided by a human expert in advance.

“Adapting the Turing Test for Declaring Document Analysis Problems Solved,” D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

The Imitation Game



Vol. lix. No. 236.] [October, 1950

MIND

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. *The Imitation Game.*

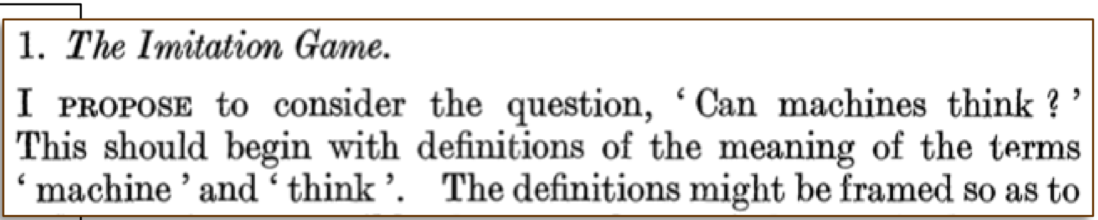
I propose to consider the question, 'Can machines think ?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think ?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either 'X is A and Y is B' or 'X is B and Y is A'. The interrogator is allowed to put questions to A and B thus:

C: Will X please tell me the length of his or her hair ?

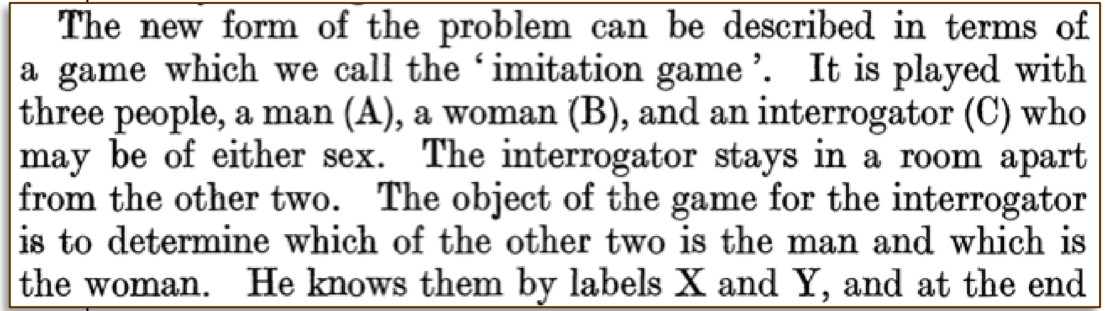
Now suppose X is actually A, then A must answer. It is A's

28 433

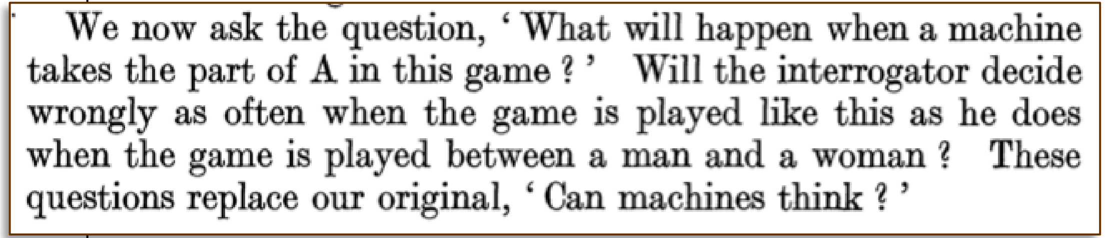


1. *The Imitation Game.*

I propose to consider the question, 'Can machines think ?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to



The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end

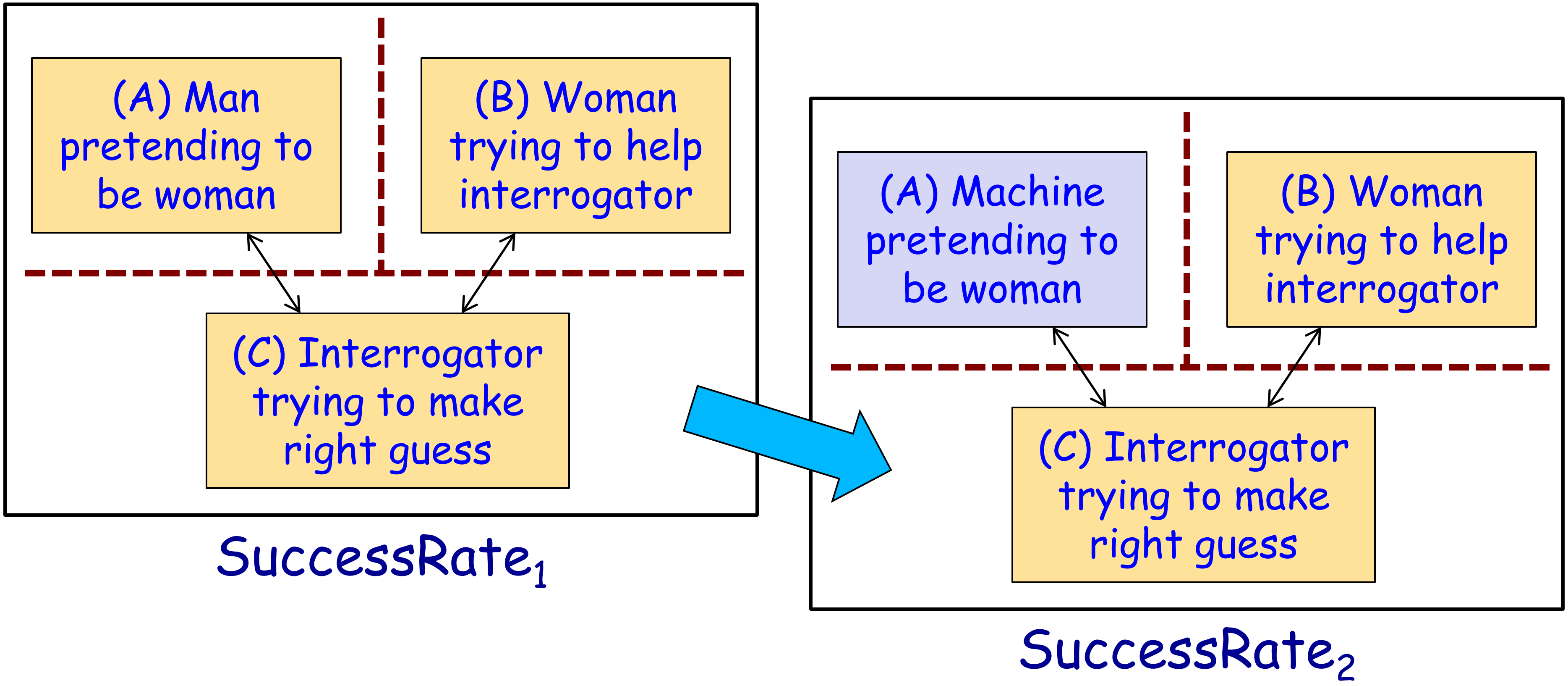


We now ask the question, 'What will happen when a machine takes the part of A in this game ?' Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman ? These questions replace our original, 'Can machines think ?'

A. M. Turing, "Computing Machinery and Intelligence," *Mind*, vol. 59, no. 236, October 1950, pp. 433-460.

"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

The Turing Test

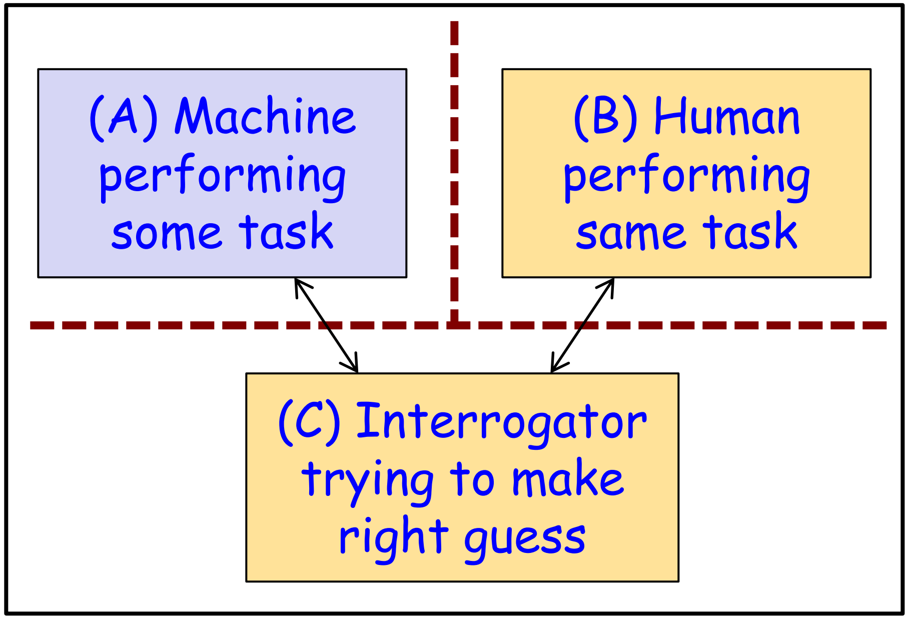

(A) Man pretending to be woman
(B) Woman trying to help interrogator
(C) Interrogator trying to make right guess
SuccessRate₁
(A) Machine pretending to be woman
(B) Woman trying to help interrogator
(C) Interrogator trying to make right guess
SuccessRate₂

Is $\text{SuccessRate}_2 \approx \text{SuccessRate}_1$?

"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

The Turing Test

The Turing Test is an elegantly simple idea, so it should be simple to implement, right?

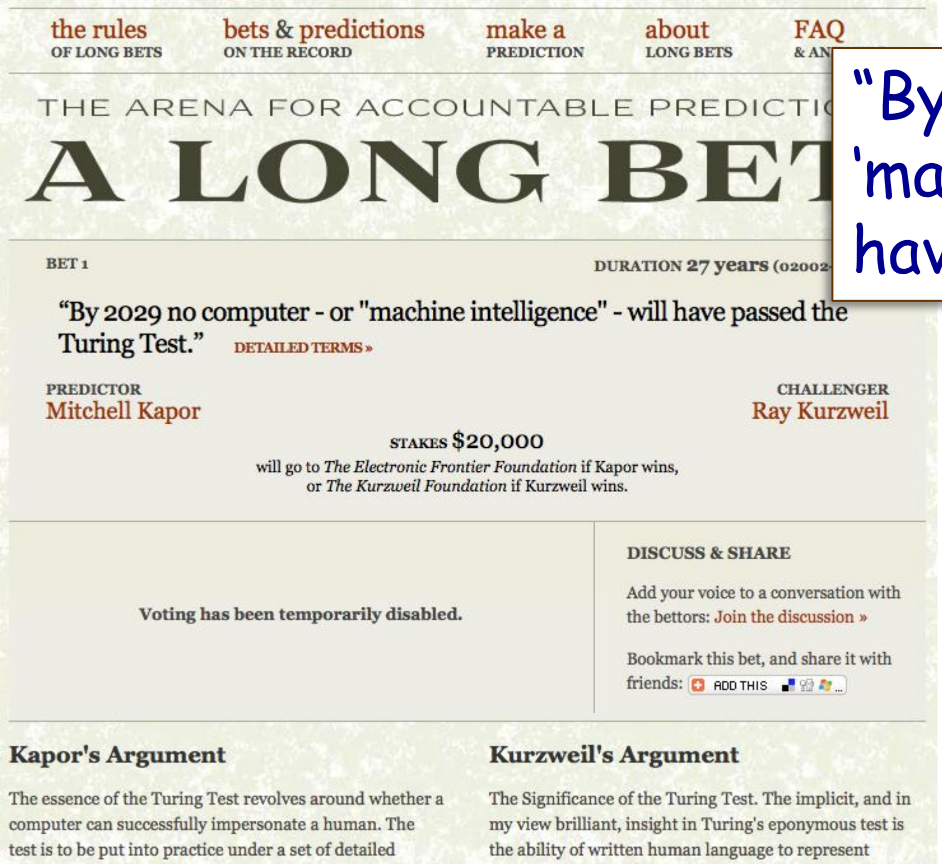

(A) Machine performing some task
(B) Human performing same task
(C) Interrogator trying to make right guess

Is SuccessRate no better than random chance ?

- Note this differs from Turing's original formulation.
- When considering a real implementation, other, more serious complications arise.

"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

Long Bet*



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THE ARENA FOR ACCOUNTABLE PREDICTI

A LONG BET

BET 1

DURATION 27 years (02002-

"By 2029 no computer - or "machine intelligence" - will have passed the Turing Test." DETAILED TERMS »

PREDICTOR
Mitchell Kapor

CHALLENGER
Ray Kurzweil

STAKES $20,000
will go to *The Electronic Frontier Foundation* if Kapor wins,
or *The Kurzweil Foundation* if Kurzweil wins.

Voting has been temporarily disabled.

DISCUSS & SHARE

Add your voice to a conversation with the bettors: Join the discussion »

Bookmark this bet, and share it with friends: ADD THIS

Kapor's Argument

The essence of the Turing Test revolves around whether a computer can successfully impersonate a human. The test is to be put into practice under a set of detailed

Kurzweil's Argument

The Significance of the Turing Test. The implicit, and in my view brilliant, insight in Turing's eponymous test is the ability of written human language to represent

"By 2029 no computer – or 'machine intelligence' – will have passed the Turing Test."

PREDICTOR:
  Mitchell Kapor
CHALLENGER:
  Ray Kurzweil
STAKES: $20,000

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Long Bet Rules

Turing was nonspecific about how to administer his Test, but concreteness is needed when $20,000 is at stake.

- Each of three Turing Test judges is to conduct an online interview ("chat") with each of four human players as well as the machine for two hours.
- At the end of these interviews, the judges indicate whether or not each candidate is human and also rank them from "least human" to "most human."
- The machine is said to pass the Turing Test if it fools two or more judges and if its median rank is equal to or greater than at least two of the human players.

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Adapting the Turing Test

The Long Bet is a one-time event with a significant amount of prize money involved. As a result, it makes sense to employ a heavy-weight protocol for the test.

How can the Turing Test be applied in document analysis?

- What are the essential qualities to preserve?
- What can be dispensed with, or at least simplified?
- When implemented, how would the test "look"?
- When might such a test be appropriate?

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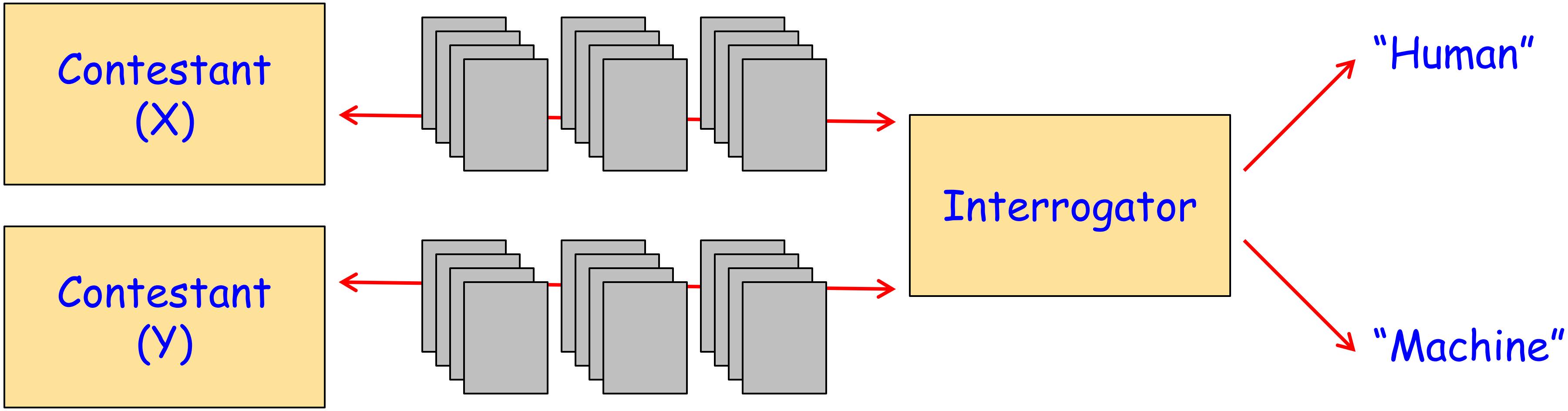
Properties to Preserve #1

Human judgment is applied to determine a simple machine/human distinction and nothing more complex than this. Automated evaluation (i.e., a computation to determine how "similar" a machine output is to some predefined human "ground truth") is ruled out.



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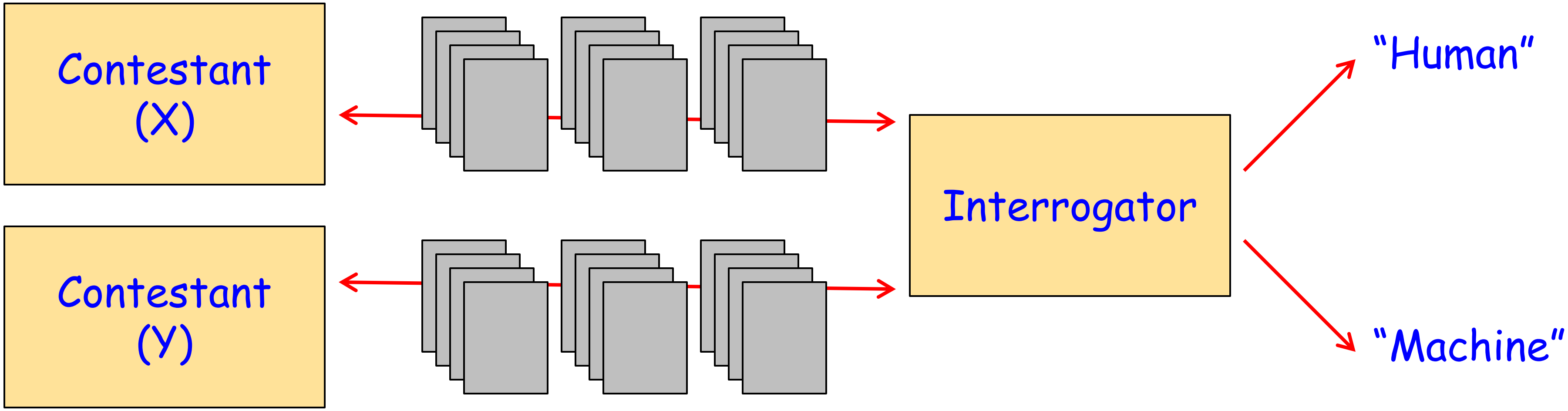
Properties to Preserve #2

A judge may ask any number of questions before making a determination. A "question" here is a challenge that requires a response from the player. For document analysis applications, this will normally consist of a page image to be processed in some way.



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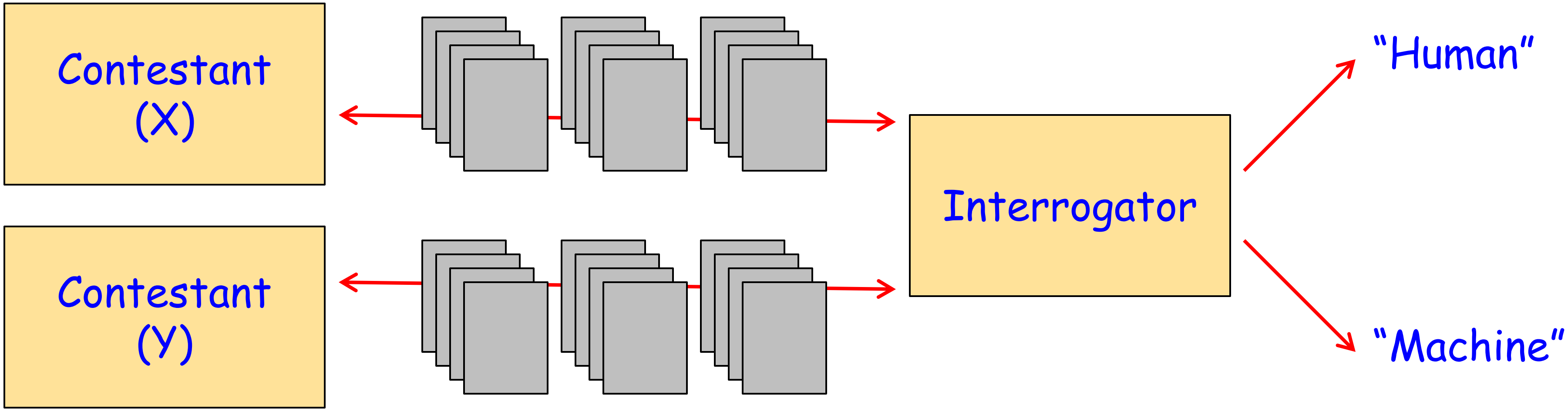
Properties to Preserve #3

The judge decides which questions to use, and is free to conduct the questioning of the players without constraint on the choice, sequence, and number of questions.



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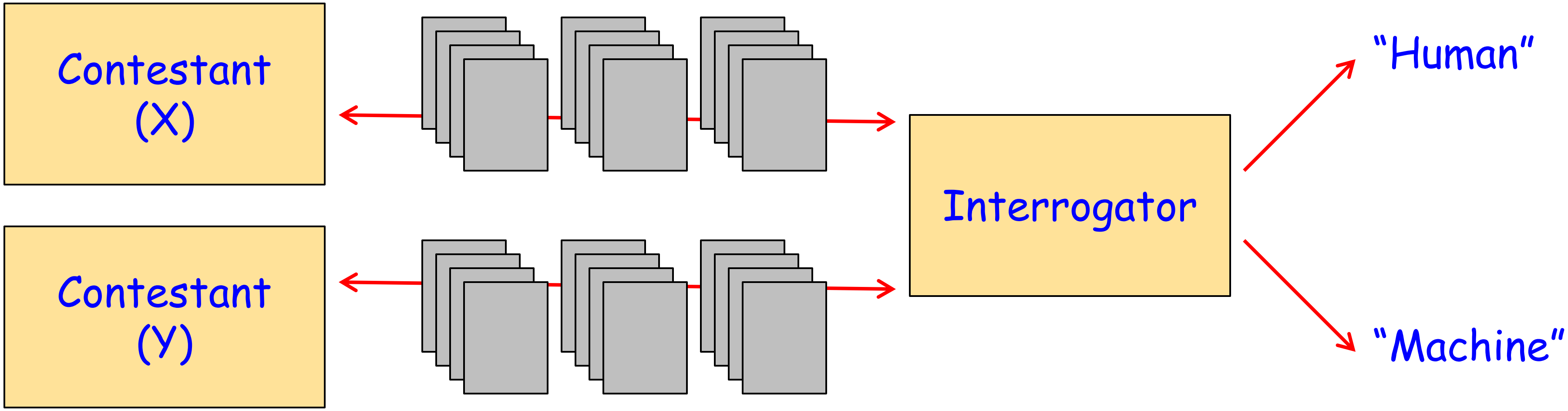
Properties to Preserve #4

A series of such evaluations, with anyone being allowed to volunteer to serve as judge or as the human player, is conducted before declaring a problem "solved" (if/when the success rates of the best-performing judges are statistically no better than random).



"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

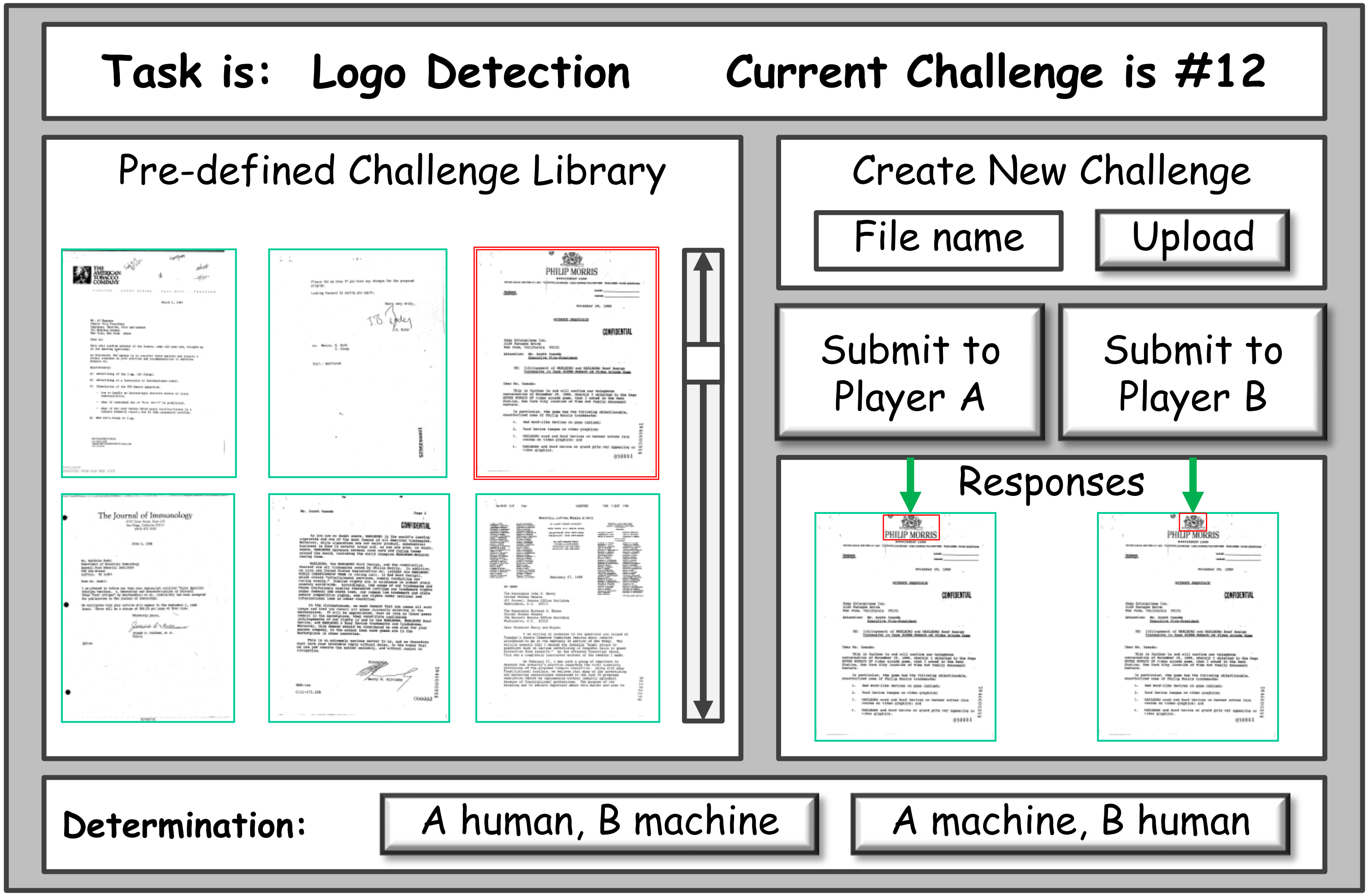
Properties to Adapt

Some aspects of Turing's original Test must be updated:

- The judge and players do not interact via a natural language question-and-answer process. Instead, they employ a graphical user interface which supports the upload of image files and visual inspection of results.
- The domain of discourse is no longer open-ended. Note that this replaces Turing's original question "Can machines think?" with our "Is this problem solved?"

"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

GUI from Judge's Perspective



Task is: Logo Detection Current Challenge is #12

Determination:

"Adapting the Turing Test for Declaring Document Analysis Problems Solved," D. Lopresti and G. Nagy, Proceedings of the Tenth IAPR International Workshop on Document Analysis Systems (DAS 2012), March 2012, Gold Coast, Australia, 5 pages.

Other Considerations

Additional details to be addressed, some easy, some hard:

- Anyone should be permitted to volunteer at any point in time to serve as the judge or the human player.
- The need to pair a judge with a human player can be addressed through crowdsourcing (e.g., using micro-payments to recruit subjects like Mechanical Turk).
- How can we eliminate out-of-scope querying / collusion?
- Which problems are appropriate to test this way? (Avoid tedious tasks where machines are "too good.")
- How can learning (by human, by machine) be included?

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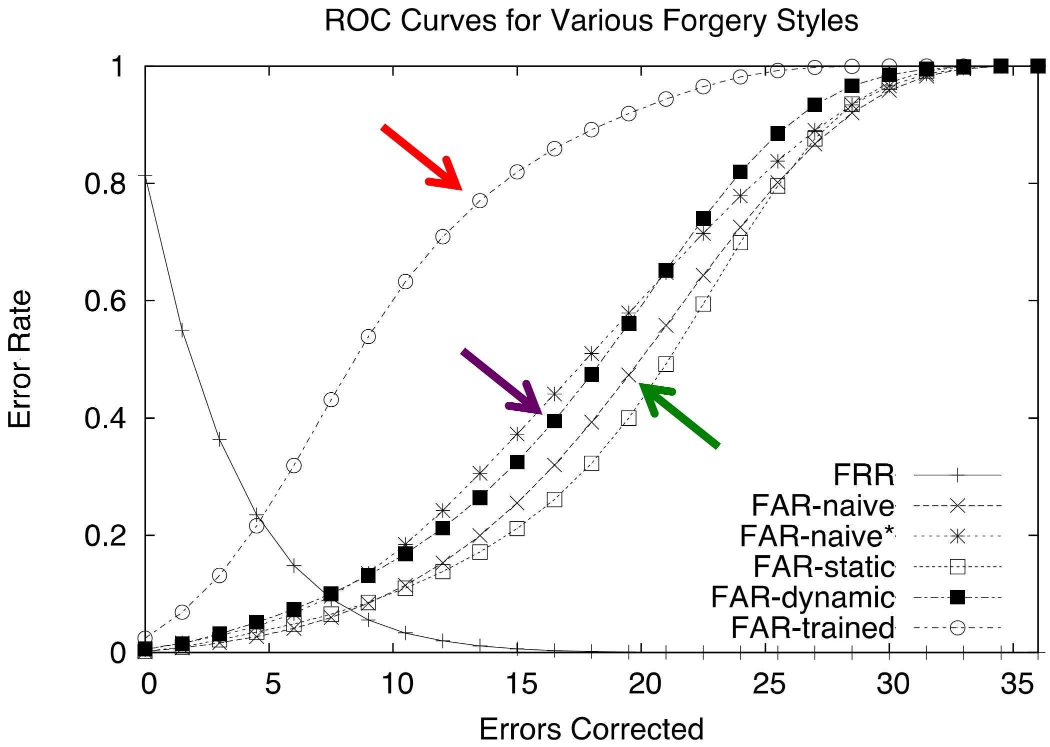
Attack Models for Biometrics

My interests in rigorous, real-world performance evaluation have included research on attack models for behavioral biometrics, including online handwriting.

Trained, talented forgers are far more effective than "naïve" forgers, who are even bested by an automated synthesis technique.



"Forgery Quality and Its Implications for Behavioral Biometric Security," L. Ballard, D. Lopresti, and F. Monrose, IEEE Transactions on Systems, Man, and Cybernetics Part B, vol. 37, no. 5, October 2007, pp. 1107-1118.

Concluding Observations

- Play close attention to performance evaluation – it's important and not as straightforward as it may seem.
- Simply following common practice is not always enough.
- In most cases, ultimate goal is to replicate human interpretation for a pattern recognition task of interest.
- Recent developments – including new and better classifier technologies as well as the era of "big data" have led to tremendous breakthroughs and useful systems – but this doesn't diminish importance of performance evaluation.
- My thinking developed through collaborations with my students and colleagues, including Prof. George Nagy.

Thank you!

¡Gracias!

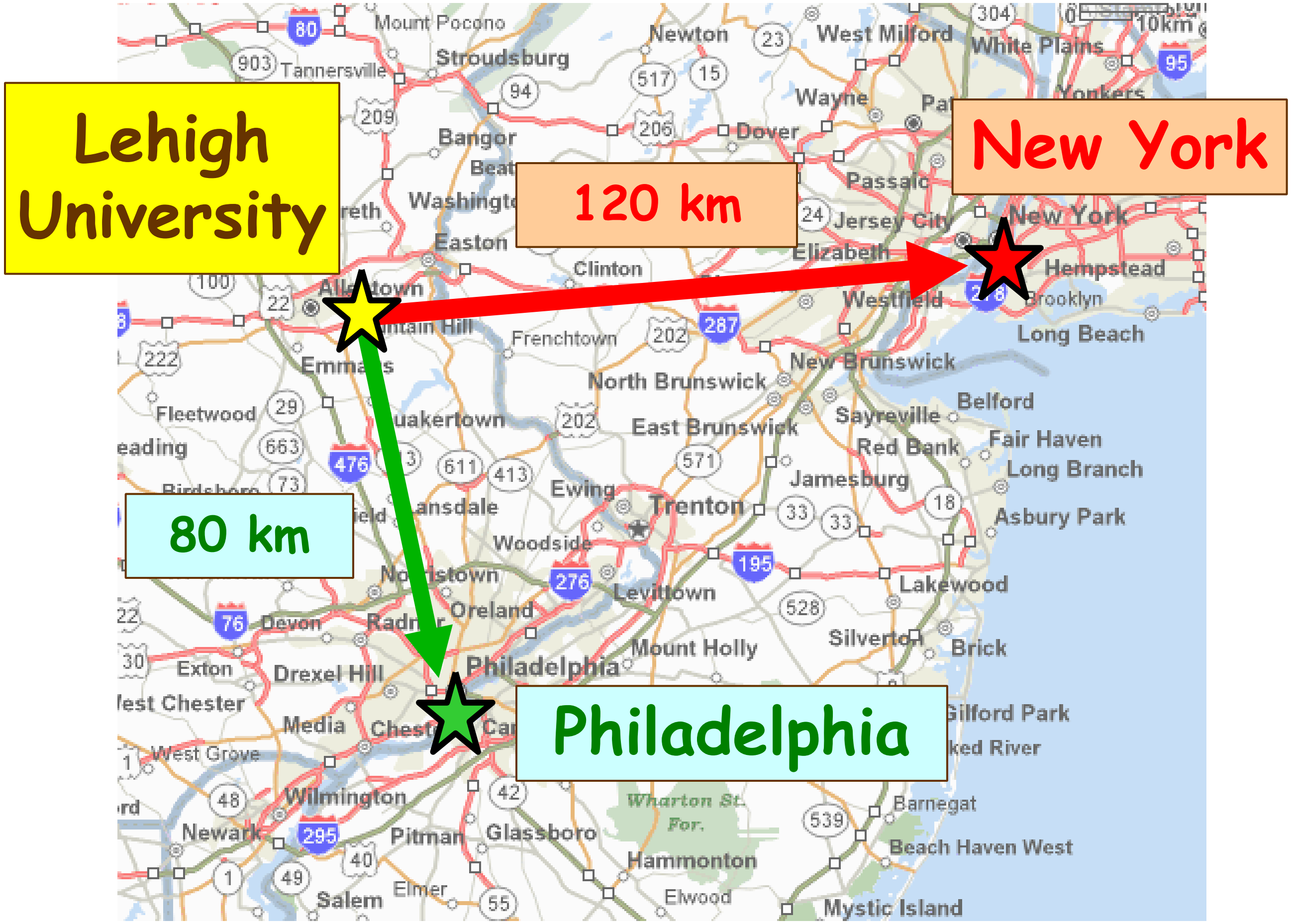
A Few Words About My University

Lehigh University

Packard Lab: Home of Computer Science & Engineering

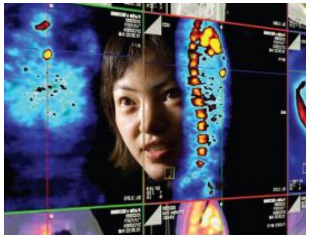
- Private research university (1865)
- Four colleges: Engineering, Arts & Sciences, Business, Education
- 441 full-time faculty members
- 4,577 undergrads, 2,064 grad students
- Three campuses, over 1,600 acres (side and top of mountain, heavily wooded)
- Located about 1.5 hours from NYC and Philadelphia, 3 hours from Washington
- Ranked in top 15% of U.S. national universities
- Ranked in top 20% of U.S. PhD-granting schools for engineering

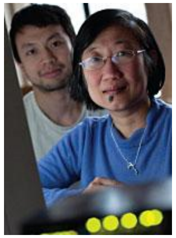
Lehigh University



Please pay me a visit if you're in the area!

CSE Department





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- Biomedical Image Analysis
- Data Mining
- Database Systems
- Document Analysis
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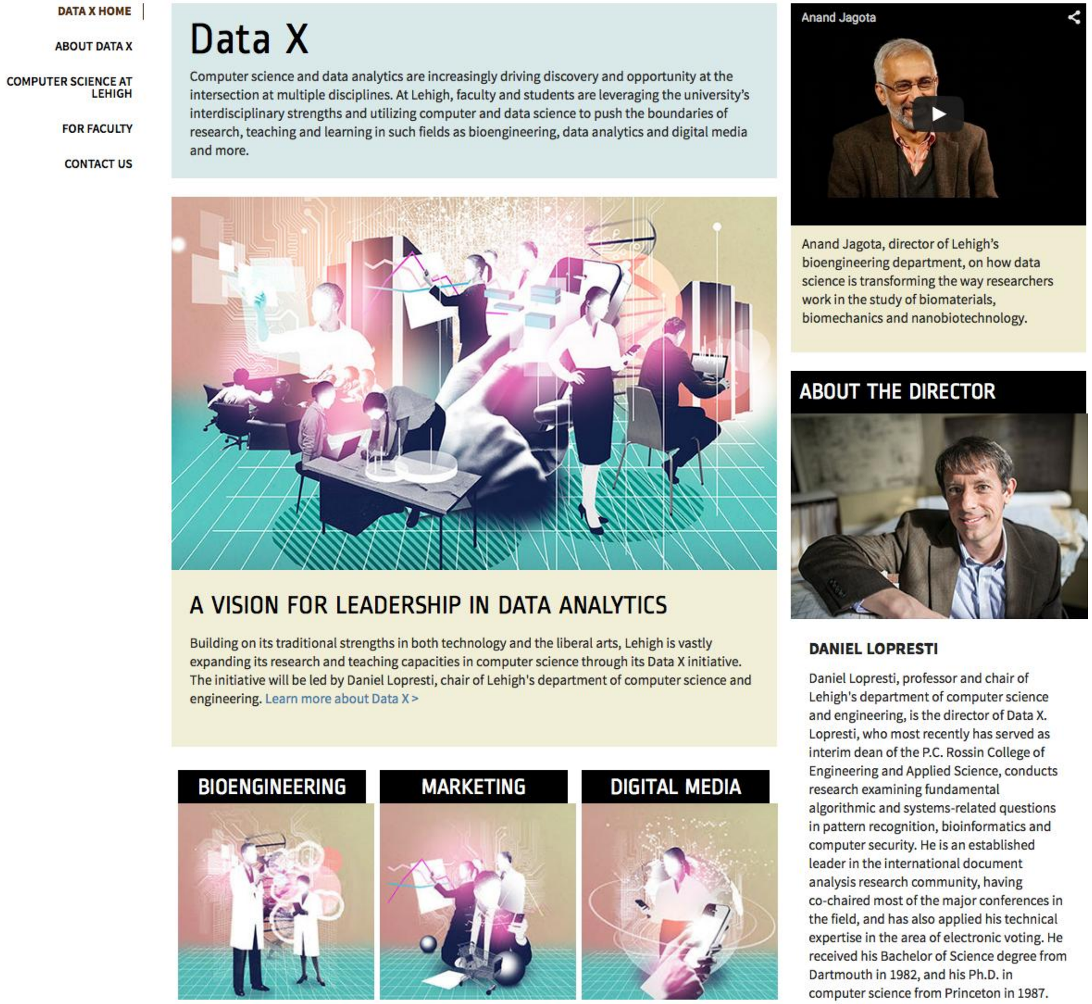
- Parallel Processing
- Programming Languages
- Computer Security
- Semantic Web
- Social Networking
- Web Search / Systems

Data X Strategic Initiative



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Computer science and data analytics are increasingly driving discovery and opportunity at the intersection at multiple disciplines. At Lehigh, faculty and students are leveraging the university's interdisciplinary strengths and utilizing computer and data science to push the boundaries of research, teaching and learning in such fields as bioengineering, data analytics and digital media and more.

Anand Jagota

Anand Jagota, director of Lehigh's bioengineering department, on how data science is transforming the way researchers work in the study of biomaterials, biomechanics and nanobiotechnology.

A VISION FOR LEADERSHIP IN DATA ANALYTICS

Building on its traditional strengths in both technology and the liberal arts, Lehigh is vastly expanding its research and teaching capacities in computer science through its Data X initiative. The initiative will be led by Daniel Lopresti, chair of Lehigh's department of computer science and engineering. Learn more about Data X >

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ABOUT THE DIRECTOR

DANIEL LOPRESTI

Daniel Lopresti, professor and chair of Lehigh's department of computer science and engineering, is the director of Data X. Lopresti, who most recently has served as interim dean of the P.C. Rossin College of Engineering and Applied Science, conducts research examining fundamental algorithmic and systems-related questions in pattern recognition, bioinformatics and computer security. He is an established leader in the international document analysis research community, having co-chaired most of the major conferences in the field, and has also applied his technical expertise in the area of electronic voting. He received his Bachelor of Science degree from Dartmouth in 1982, and his Ph.D. in computer science from Princeton in 1987.

http://www.lehigh.edu/datax