### Counting Votes and the Attempt to Replicate Human Interpretation

### LABELNOISE'2017 December 1, 2017



Professor Daniel Lopresti Computer Science and Engineering Lehigh University Bethlehem, PA, USA

Counting Votes and the Attempt to Replicate Human Interpretation



# Motivation

Attempt to interest you in an noisy label application area:

- Counting votes replicating human interpretation
   Also, if there's time:
- Turing Test-inspired view of performance evaluation

### Key features:

- Vitally important application, drawn from real life
- Valuable lessons to learn that can be applied elsewhere
- Wonderful opportunity to apply our talents
- Work still needed to frame problem, outline next steps

# How did US get where we are today?

#### 5-> AL CORF PERSIDENT (SOCIALIST) JOE LIEBERMAN - VICE PRESIDENT 0 -6 DAVID MCREYNOLDS PRESIDENT (LIBERTARIAN) MARY CAL HOLLIS . VICE PRESIDENT HARRY BROWNE PRESIDENT 7-> (CONSTITUTION) ART OLIVIER . VICE PRESIDENT - 8 HOWARD PHILLIPS -PRESIDENT J. CURTIS FRAZIER . VICE PRESIDEN (GREEN) te for the candidates will be a vote for their elector 9> RALPH NADER PRESIDENT (WORKERS WORLD) WINONA LADUKE VICE PRESIDENT MONICA MOOREHEAD PRESIDE election. ISOCIALIST WORKERS GLORIA La RIVA ...... 11> IAMES HARRIS PRESIDENT MARGARET TROWE VICE PRESIDENT WRITE-IN CANDIDATE To vote for a write-in candidate, follow the directions on the long stub of your ballot card (NATURAL LAW) 13-JOHN HAGELIN PRESIDENT NAT GOLDHABER . VICE PRESIDENT WITH THE LATEST RESULTS The Palm Beach Po WEDNESDAY, NOVEMBER 8, 2000 **FINAL EDITION** Florida's votes close enough for recount IT'S NOT OVER

OFFICIAL BALLOT, GENERAL ELECTION PALM BEACH COUNTY, FLORIDA NOVEMBER 7, 2000

(REFORM)

PAT BUCHANAN PRESIDENT

EZOLA FOSTER VICE PRESIDENT

The infamous butterfly ballot from the 2000 Presidential



### Bush v. Gore.

DFFICIAL BALLOT, GENERAL ELECTION PALM BEACH COUNTY, FLORIDA NOVEMBER 7, 2000

ELECTORS FOR PRESIDENT AND VICE PRESIDENT

ate for Group

DICK CHENEY . VICE PRESIDENT

(REPUBLICAN) GEORGE W. BUSH PRESIDENT

(DEMOCRATIC)

3->

2 -4

Counting Votes and the Attempt to **Replicate Human Interpretation** 

# Hanging Chads and Voter Intent





Votomatic technology used in Florida was prone to paper jams. This led to hanging and dimpled chads, making it hard to determine voter intent.



http://www.cs.uiowa.edu/~jones/cards/chad.html http://www.pushback.com/justice/votefraud/DimpledChadPictures.html



# Next Big Step ... Backward



Counting Votes and the Attempt to Replicate Human Interpretation

# Voting in the News: Take 3

### The Voting Technology We Really Need? Paper

Software-independent backup systems are more important than ever.

LAWRENCE NORDEN | MAY 10, 2017 | TECHNOLOGY

Tweet

f Share



In January, America's main intelligence agencies issued a report concluding that Russia interfered in the 2016 election, using a combination of cyber-intrusion, espionage, and propaganda. In addition to the details provided in this account, media outlets have since reported that several election databases were hacked before and after the election. While the Department of Homeland Security found no evidence any of these efforts manipulated vote tallies, the assaults have left many Americans asking: Just how safe are voting machines from cyberattack?

The answer is not reassuring.



### Russian hacking fuels return to paper ballots

By Jenni Bergal Oct 03, 2017

This article originally appeared in Stateline, an initiative of the Pew Charitable Trusts.

After the "hanging chad" fiasco during the 2000 presidential recount, many states and counties switched to electronic-only voting machines to modernize their systems.

Now, amid security concerns over Russian hackers targeting state voting systems in last year's election, there's a renewed focus on shifting to paper ballots.

In Virginia, election officials decided last month to stop using paperless touch-screen machines, in an effort to safeguard against unauthorized access to the equipment and improve the security of the state's voting system.

In Georgia, which uses electronic voting machines

with no paper record, legislators are discussing

getting rid of their aging equipment and using

#### MORE INFO

Virginia considers decertifying touchscreen voting machines The state could accelerate the move to systems that provide a paper trail for election audits. Read more.

https://www.theatlantic.com/technology/archive/2017/05/the-voting-technology-we-really-need-paper/524820/ https://gcn.com/articles/2017/10/03/return-paper-ballots.aspx

# Voting in the News: Take 3



https://www.washingtonpost.com/local/virginia-politics/paper-ballots-make-a-comeback-in-virginia-this-fall/2017/10/07/ https://www.theatlantic.com/magazine/archive/2017/12/guardian-of-the-vote/544155/



### 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

To vote, cor	INSTRUCTIONS TO VOTERS	ice(s) like this:			
FEDERAL OFFICES	STATE OFFICES	COUNTY OFFICES			
UNITED STATES SENATOR VOTE FOR ONE	SECRETARY OF STATE	COUNTY ADDITOR VOTE FOR ONE			
	CANDIDATE INDEPENDENCE				
		within, fary			
		COUNTY TREASURER VOTE FOR ONE			
	STATE AUDITOR				
UNITED STATES REPRESENTATIVE	VOTE FOR ONE				
DISTRICT [NUMBER] VOTE FOR ONE					
		VOTE FOR ONE			
CANDIDATE REPUBLICAN	CANDIDATE DEMOCRATIC-FARMER-LABOR				
CANDIDATE DEMOCRATIC-FARMER-LABOR	write-in, Fary				
witeis, if any	ATTORNEY GENERAL VOTE FOR ONE				
STATE OFFICES	CANDIDATE	VOTE FOR ONE			
UNITE OFFICES					
STATE SENATOR DISTRICT [NUMBER]	CANDIDATE				
	DEMOCRATIC-FARMER-LABOR				
CANDIDATE	AMENDMENT	CANDIDATE CANDIDATE CANDIDATE COUNTY SURVEYOR VOTE FOR ONE			
DEMOCRATIC-FARMER LABOR	Failure to vote on a constitutional amendment, will have				
STATE REPRESENTATIVE DISTRICT [NUMBER]	<ul> <li>the same effect as voting no for the amendment.</li> <li>To vote for a proposed constitutional amendment, completely fill in the oval next to the word "YES" for that</li> </ul>				
	question. To vote against a proposed constitutional amendment, completely fill in the oval next to the word "NO" for that quistion.				
CANDIDATE	CONSTITUTIONAL AMENDMENT TITLE				
DEMOCRATIC-FARMER-LABOR	[Body of question printed in upper and lower case letters.]	[CITY NAME OPTIONAL]			
GOVERNOR AND		COUNCIL MEMBER			
LIEUTENANT GOVERNOR VOTE FOR ONE TEAM		VOTE FOR UP TO TWO			
CANDIDATE AND CANDIDATE					
CANDIDATE AND	COUNTY COMMISSIONER DISTRICT [NUMBER]				
	CANDIDATE	and a state of the			
CANDIDATE DEMOCRATIC FARMER-LABOR					
ativia, fazy	setteris, fany				

#### **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.

Counting Votes and the Attempt to Replicate Human Interpretation

# 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:



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

Note: this does <u>not</u> 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.

#### Counting Votes and the Attempt to Replicate Human Interpretation

# Whole-Ballot Recognition



### 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



"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



"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%				
			Cla	assifier						
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.

# 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!





## 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





### Who gets vote? Public opinion:

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



🕹 Challenged Ballots: You be the Ju	ıdge   Ca	impaign 2008   Minnesota Pul	blic Radio NewsQ	- Mozilla F 🗖 🗖 💌			U.S. SENATOR VOTE FOR ONE	<u>write-i</u>
File Edit View Higtory Bookma	arks <u>T</u> o htt	ols <u>H</u> elp p://minnesota.publicradio.org	j/feature ☆ ・	🚼 • is: You be thi 🔎 🔒		0	DEAN BARKLEY Independence	SOIL AND W
Challenged Ballots: You be the Ballot #5: The Yes	Judge .	•• ÷			*	0	NORM COLEMAN Republican	v
View the whole ballot (PDF 2 ope The Coleman campaign challenge to have written the word 'yes' insi	<i>ns in net</i> ed this B de the o	w window) enton County ballot becaus val next to Al Franken's na	e of "unusual ma me. (Secretary o	arks." The voter appears f State's Office)	-	T2	AL FRANKEN Democratic-Farmer-Labor	🕬 WAD
	0	U.S. SENATOR VOTE FOR ONE DEAN BARKLEY Independence NORM COLEMAN	SOIL AND DIS1			0	CHARLES ALDRICH Libertarian	write-i
-	) <b>\$</b>	Republican AL FRANKEN Democratic-Farmer-Labor CHARLES ALDRICH Libertarian				0	JAMES NIEMACKL Constitution	SOIL AND W
	0 0	JAMES NIEMACKL Constitution write-in, if any	SOIL AND DIST	Ξ		0	write-in, if any	v
		oes Al Franken get the vote	9?			U	S. REPRESENTATIVE	🗩 BER
	○Ye ○No <sup>View</sup>	S. ). Results vo	te		V	'ote f	or Franken? Pub	lic opinion:
۲ Done				Þ	·	Yes	: 96% (11,250 vo	tes)

No: 4% (452 votes)

Challenged Ballotz You be the Judge Campage 2001 [Menesota Public Radio New? - Mozile F		, , , , , , , , , , , , , , , , , , , ,	
C       Image: http://minescia.public/adio.org/feature       Image: http:/minescia.public/adio.org/feature       Image: http:/mi	Challenged Ballots: You be the Judge   Campaign 2008   Minnesota Public Radio NewsQ - Mozilla F	U.S. SENATOR VOTE FOR ONE	, <u>write-in, if a</u> ny
Challenged Balots: You be the Judge *       NORM & COLEMAN       MORA & COLEMAN         Ballot #7: The Write-out       AL FRANKEN       Ballot (2015)       AL FRANKEN         Discontant - Farmer, Labor       CHARLES ALDRICH       Ballot (2015)       Ballot (2015)         View the voide ballot (2015)       Challenged Balots: You be does not neu window)       The Franken campaign challenged this Hennepin county ballot, isaying the ballot for U.S. Senate is an undervote and not a vote for Norm Coleman. (Secretary of States Office)       View the voide ballot (2015)       View the voide ballot (2015)         U.S. SEPATOR       NORM COLEMAN       exec. ##W       U.S. REPRESENTATIVE       District 5 voide Gor Note         Demogradie - Bander - Norm Coleman get the vote?       NORM COLEMAN       NORM COLEMAN       NORM COLEMAN         Write-in, fany       U.S. REPRESENTATIVE       District - Sense Labor       Bill MCGAUGHEY         Moder Coleman get the vote?       Norm Coleman get the vote?       Bill MCGAUGHEY       Norm Coleman get the vote?         Write-in, fany       Vote foor Coleman?       Public opinion:         Write-in, fany       Vote foor Coleman?       Public opinion:	Image: Constraint of the second state of the second sta	DEAN BARKLEY	
Bailet #7: The Write-out View the whole bailet (#7: The Write-out View the whole bailet (#7: The Write-out Uses Senare is an undervote and not a vote for Norm Coleman. (Secretary of States Office) U.S. SENATOR U.S. SENATOR U.S. SENATOR U.S. SENATOR U.S. REPRESENTATIVE DEAN BARKLEY Independence Write-in, if any U.S. The Voters Intent is clear. No. The bailot is an undervote. View Senite Dean Coleman get the vote? View Senite U.S. The Voters Intent is clear. No. The bailot is an undervote. View Senite U.S. SENATOR View Senite U.S. REPRESENTATIVE DISTRICT 5 Write-in, if any Vote for Coleman? Public opinion: Yes: 54% (66,080 votes)	● Challenged Ballots: You be the Judge +		NORM COLEMAN
View the whole failor (PDF <sup>28</sup> ) opens in neu window) The Franken campaign challenged this Hanneph County ballet, raying the ballot for U.S. Senate is an undervote and not a vote for Norm Coleman. (Secretary of States Office) U.S. SENATOR U.S. SENATOR U.S. SENATOR U.S. SENATOR Dean BarkLEY NORM & CHARLES ALBRCH NORM & CHARLES ALBRCH NORM & CHARLES ALBRCH Definition U.S. REPRESENTATIVE DISTRICT 5 VOTE FOR ONE BILL MCGAUGHEY Independance BARB DAVIS WHITE Republica Write-in, if any Vote for Coleman? Public opinion: Vers : 54% (6,080 votes)	Ballot #7: The Write-out	AL FRANKEN Democratic-Farmer-Labor	
undervote and not a vote for Norm Coleman. (Secretary of States Office) U.S. SENATOR VOTE FOR ONE DEAN BARKLEY Constitution DEAN BARKLEY Constitution Desmocratic farmer Labor Withen tay Dees Norm Coleman get the vote? Vote States and mice vote? Vote States intent is clear. No. The ballot is an undervote. Vote States of Coleman? Public opinion: Vote for Coleman? Public opinion: Vote States 54% (6,080 votes)	View the whole ballot (PDF 🖆 opens in new window) The Franken campaign challenged this Hennenin County ballot, saying the ballot for U.S. Senate is an	CHARLES ALDRICH	
U.S. SENATOR VOTE FOR ONE DEAN BARKLEY DEAN BARKLEY DEAN BARKLEY DEAN BARKLEY DEAN BARKLEY DEAN BARKLEY DEAN BARKLEY DEAN BARKEN DEAN BARK	undervote and not a vote for Norm Coleman. (Scretary of State's Office)	JAMES NIEMACKL Constitution	
DEAN BARKLEY         Independence         NORM COLEMAN         Begabere         AL FRANKEN         Charantes         Charantes         Charantes         James         Versentes         Versentes      <	U.S. SENATOR VOTE FOR ONE write-in, if any	write-in, if any	
AL FRANKEN         Charles ALDRICH         Charles ALDRICH         JAMES NIEMACKL         Constituon         Write-in, if any         Does Norm Coleman get the vote?         Verse The voter's intent is clear.         No. The ballot is an undervote.         View Results         Vote         Forme         Vote         Vote         Set 54% (6,080 votes)	DEAN BARKLEY Independence NORM COLEMAN Republicar NORM COLEMAN	U.S. REPRESENTATIVE DISTRICT 5 VOTE FOR ONE	
Des Norm Coleman get the vote?       View Results     vote       View Results     vote         View Results     vote   Vote for Coleman? Public opinion:        Ves: 54% (6,080 votes)	CHARLES AL DOLCU	BILL MCGAUGHEY	
write-in, if any         Does Norm Coleman get the vote?         View Results         vote         One         KEITH ELLISON         Democriatic-Farmer-Labor         write-in, if any         Vote for Coleman?         Public opinion:         Yes: 54% (6,080 votes)	JAMES NIEMACKL Constitution	BARB DAVIS WHITE Republican	_
Does Norm Coleman get the vote? View Results Vote Vote Vote Vote Vote Vote Vote for Coleman? Public opinion: Vote for Star (6,080 votes)	write-in, if any	Semiconal Semico	
View Results vote View Results vote View Results vote View Results vote View Results vote Vote for Coleman? Public opinion: Vote 54% (6,080 votes)	Does Norm Coleman get the vote?	write-in, if any	
Vote for Coleman? Public opinion: • Yes: 54% (6,080 votes)	○Yes. The voter's intent is clear. ○No. The ballot is an undervote.		
• Yes: 54% (6,080 votes)	View Results vote	/ote for Coleman?	Public opinion:
• yes; 54% (0,080 votes)			
		yes; 04% (0,00	ou votesj

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

		STATE OF MINNESOTA	NOVEMBER 4, 2008
	STATE	GENERAL ELECTION	N BALLOT
	To vote, com	INSTRUCTIONS TO VOTERS plately fill in the aval(s) next to your choicer	s) like this: 🖝
·	FEDERAL OFFICES	STATE OFFICES	COUNTY OFFICES
	PRESIDENT AND VICE PRESIDENT VOTE FOR ONE TEAM	STATE REPRESENTATIVE DISTRICT 3B VOTE FOR ONE	SOIL AND WATER CONSERVATIO DISTRICT SUPERVISOR DISTRICT 5 VOTE FOR DWE
•	JOHN MCCAIN AND SARAH PALIN Featlan	CAROLYN MCELFATRICK	DONNA RAE ASP
		Demousts former Labor	Ante r jany
•	BARACK OBAMA AND JOE BIDEN	auf	TOWN OFFICES
	CYNTHIA MCKINNEY AND	CONSTITUTIONAL AMENDMENT	TOWN SUPERVISOR SEAT B TOWN OF NORDLAND VOTE FOR ONE
	Geen	Fighting to vote on a constitutional amendment on there the same direct as using no for the arrentment.	RUTH ANN NELSON
	ROGER CALERO AND ALYSON KENNEDY	To vold for a proposed constitutions	JOHN STEEBER
	Rái DH NADER AND	<ul> <li>And the set of the s</li></ul>	WAYNE DAVIS
<b>_</b>	MATT GONZALEZ		<u>aren</u> , ian
	BOB BARR AND WAYNE A. ROOT	CLEAN WATER, WILDLIFE, CULTURAL HERITAGE AND NATURAL AREAS	TOWN SUPERVISOR SEAT C TOWN OF NORDLAND VOTE FOR ONE
i i	CHUCK BALOWIN AND	Bhail my Munesota Constituant on eventees to dedicate function to protect our territory safet sources to protect lensance, and resolve our weburds, praines sources and the game, and	STANLEY W NEX
	DARRELL CASTLE	where factual is preserve our arts and o tipuol protect support our cancers and loads and to protect enhance, and returns our block metric streams and grant dealer by increasing the streams and use leving to again in guily 1, 2019, ay interfer global streams our heads's as as with the very 2004?	TOWN TREASURER TOWN OF NORDLAND VOTE FOR ONE
,	waan 'ay	Tes Yes	JUDY PEYSAR
	U.S. SENATOR VOTE FOR DNE	I NO	· · · · · · · · · · · · · · · · · · ·
	DEAN BARKLEY	COUNTY OFFICES	
×.	NORM COLEMAN	COUNTY COMMISSIONER DISTRICT 2	SCHOOL BOARD MEMBER
	CHARLES AL DRICH	VOTE FOR ONE	NO. 1 (Artkin) VOTE FOR UP TO THREE
	JAMES NIEMACKL	LAURIE A, WESTERLUND	PETER A. WELSHONS
	978-7_14L9	· · · · · · · · ·	DENNIS HASSKAND
	U.S. REPRESENTATIVE	SOIL AND WATER CONSERVATION	<ul> <li>JOHN CHUTE</li> </ul>
	VOTE FOR ONE	DISTRICT 3 VOTE FOR ONE	CHARLES WIKELIUS
-	MICHAEL CUMMINS	FRANKLIN TURNOCK	WILLIAM E. STIMAC
-	Democrato/Jama .abo		with the second
	ψτα-m, : 4 <u>1</u> f	SOIL AND WATER CONSERVATION . DISTRICT SUPERVISOR DISTRICT 4	* <u>##_*_</u> fory
- 0445 TOW	N OF NORDLAND	BOB JANZEN	···· wr/s-w, / any
			i
	1	10.010 · · · ·	



Counting Votes and the Attempt to Replicate Human Interpretation

# Sloppy-But-Valid Marks



Counting Votes and the Attempt to Replicate Human Interpretation

# Non-Conforming Marking Styles



# Attempts to Cancel a Vote



# Votes that Look Cancelled





# Stray Marks and Bleedthrough



Counting Votes and the Attempt to Replicate Human Interpretation

# Invalidating Markings



Counting Votes and the Attempt to Replicate Human Interpretation

# Another Example of Recent Interest



### See Dealing with doubtful paper ballots in GB:

http://www.electoralcommission.org.uk/\_\_data/assets/pdf\_file/0012/87699/UKPE-doubtfuls-booklet.pdf

Counting Votes and the Attempt to Replicate Human Interpretation



# 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

- Interpretations collected from 8 test subjects, 980 ballot sides.
- All 6,737 ballots now online on DAE server (see URL for more details on server and its capabilities: joint work with Bart).
- Approach is a bit traditional, so far ...

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



"An Open Architecture for End-to-End Document Analysis Benchmarking," B. Lamiroy and D. Lopresti, Proceedings of the Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011), September 2011, Beijing, China, pp. 42-47.

# Very Close Indeed

### That's all well and good. But what <u>really</u> happened in Minnesota?

Date	Description	Votes for Coleman	Votes for Franken
11/18/08	Initial State Canvassing Board meeting.	1,211,590	1,211,375
12/5/08	After hand recount, not including challenged ballots.	1,209,240	1,209,228
12/20/08	After review of challenged ballots by State Canvassing Board.	1,211,901	1,211,950
1/5/09	After counting of improperly rejected absentee ballots by order of Minnesota Supreme Court. This total was certified by State Canvassing Board.	1,212,206	1,212,431
4/13/09	After counting of improperly rejected absentee ballots by order of three-judge panel during the election contest.	1,212,317	1,212,629

http://www.sos.state.mn.us/elections-voting/2008-general-election-results/2008-state-recounts/

# FAQ for Official Recount

#### WHEN DID THE RECOUNT BEGIN?

WHO SITS ON THE STATE CANVASSING BOARD?

HOW WILL THE RECOUNT WORK?

Every single vote cast for the U.S. Senate candidates will be recounted by hand.

The official recount is being conducted in approximately 110 locations throughout the state, generally in every county courthouse and in the city halls of major cities. In some locations more than one recount "station" will be used depending on the size of the jurisdiction.

The people doing the recounting are county election officials and election judges. Teams of recounters will examine each ballot and record the vote.

As many as four, perhaps even more, observers have been present as each ballot is recounted -- the election judge doing the recounting, representatives from each candidate's campaign, and any other interested parties. The recounts and canvassing board meetings are all open to the public.

https://www.mprnews.org/story/2008/11/06/recount\_faq

#### WHAT ARE THE RECOUNT OFFICIALS LOOKING FOR?

The recounters are trying to determine the intent of the voter when they encounter problem ballots.

Most voters fill in the circle next to the candidate they choose. But sometimes an individual will put a check mark or an X next to a name. Others will circle a name. Ballots marked in that way cannot be scanned by the voting machines, so they wouldn't have been counted the first time around.

If a voter's intentions aren't clear by looking at a ballot, or if there is any objection to the decision being made by the election official by either one or both of the candidates' representatives, the ballots in dispute become "challenged" ballots that will go to the State Canvassing Board for review.

HOW LONG WILL THIS PROCESS TAKE? HOW MUCH WILL THIS COST? COULD THIS END UP BEING TAKEN TO COURT? HOW WOULD THE CASE PROCEED? WHY WOULD A CANDIDATE CHOOSE THIS PROCESS INSTEAD OF GOING WITH THE SECRETARY OF

STATE'S RECOUNT?

# More Details on Official Recount

#### **POLITICS & POLICY**

### Judges' 'three votes' give Al Franken convincing win in Senate recount trial

By Jay Weiner I 04/13/09

🖂 Email 📑 Share 🍑 Tweet 🖶 Print

When this 2008 U.S. Senate race is finally over, when all the appeals are exhausted, when its history is written – based on what we know today -- it will be said that Al Franken won the election and the seat of the junior senator from Minnesota by 312 votes.

But that will not be exactly correct.

After Monday's long-awaited final legal ruling (PDF), add three more votes to Franken's tally: those of Judges Elizabeth Hayden, Kurt Marben and Denise Reilly.

Technically, the three-judge panel that oversaw a seven-week-long trial that generated 19,181 pages of legal filings "voted" against Norm Coleman in their unanimous 56-page opinion, with another 12 pages of exhibits.

It was Coleman's case to prove, and now he'll get another chance when he appeals today's ruling to the Minnesota Supreme Court within 10 days.

https://www.minnpost.com/politics-policy/2009/04/judges%E2%80%99-%E2%80%98 three-votes%E2%80%99-give-al-franken-convincing-win-senate-recount-trial three-win-senate-recount-trial th

# Deciphering Official Recount Results

4	A	B	C	D	E	F	G	Н		J	K	L	M	N	0	P	Q	R	S	Т	U
1	County Name	County Number	Precinct Number	Precinct Name	Nov. 4, 2008	Nov. 4, 2008			RECOUNT			Ballot D for CO	isposition LEMAN	Ballot Di for FR	sposition ANKEN	Ballot Di for C	sposition Other	Change in Ballots Counted	Change in Ballots Counted	Final Recount Totals	Final Recount Totals
					Votes Counted for COLEMA N	Votes Counted for FRANKEN	Number of Ballots for COLEMA N (as recounte	Number of Ballots for FRANKE N (as recounte	Number of All Other Ballots (as recounte	COLEMA N and Other Ballots Challeng ed by	FRANKE N and Other Ballots Challeng ed by	w	СВ	w	СВ	w	СВ	for COLEMA N	for FRANKEN	for COLEMA N	for FRANKE N
2							d)	d)	a)	FRANKEN	N N										
144	ANOKA	2	4810	FRIDLEY V	407	547	407	547	206	0	0	0	0	0	0	0	0	0	0	407	547
145	ANOKA	2	4820	FRIDLEY V	575	710	574	709	292	2	1	1	0	1	0	1	0	0	0	575	710
146	ANOKA	2	4830	FRIDLEY V	231	416	231	417	153	1	0	0	0	0	0	1	0	0	1	231	417
147	ANOKA	2	4840	FRIDLEY V	297	498	297	497	186	0	1	0	0	1	0	0	0	0	0	297	498
148	ANOKA	2	5010	HAM LAKE	541	344	539	344	187	3	0	0	2	0	0	0	1	0	0	541	344
149	ANOKA	2	5020	HAM LAKE	850	396	849	396	252	1	0	1	0	0	0	0	0	0	0	850	396
150	ANOKA	2	5030	HAM LAKE	606	360	606	360	242	0	0	0	0	0	0	0	0	0	0	606	360
151	ANOKA	2	5040	HAM LAKE	904	488	902	488	283	2	1	2	0	0	1	0	0	0	1	904	489
152	ANOKA	2	5050	HAM LAKE	1029	531	1025	531	320	4	1	4	0	0	0	0	1	0	0	1029	531
153	ANOKA	2	5060	HAM LAKE	895	436	895	436	296	0		0	0	1	0	0	0	0	1	895	437
154	ANOKA	2	5210	HILLIOP P	6/	189	0/	188	69	0	1	0	0	1	0	0	0	0	0	250	189
155	ANOKA	2	5610	LEXINGTO	511	308	540	401	210	3	2	1	1	2	0			0	0	511	308
157	ANOKA	2	5620	LINOLAKE	821	598	822	598	243	1	2	1	0	2	0	0		2	0	823	588
158	ANOKA	2	5630	LINOLAKE	647	504	647	505	299	1	0		0	0	0	0	0	1	1	648	505
159	ANOKA	2	5640	LINO LAKE	1177	548	1174	548	310	3	0	3	0	ő	ő	ő	0		0	1177	548
160	ANOKA	2	5650	LINO LAKE	487	383	485	383	204	3	Ő	1	1	Ő	Ő	Ĭ	0	0	0	487	383
161	ANOKA	2	5660	LINO LAKE	1025	444	1023	442	275	2	2	2	0	Ĭ	1	0	0	0	Ő	1025	444
162	ANOKA	2	5670	LINO LAKE	1007	545	1005	544	297	1	1	1	0	0	0	0	1	-1	-1	1006	544
163	ANOKA	2	5810	LINWOOD	1460	983	1455	981	606	4	5	3	2	2	0	1	1	0	0	1460	983
164	ANOKA	2	5910	NOWTHEN	1452	677	1448	672	479	4	5	4	0	2	2	0	1	0	-1	1452	676
165	ALC: YA	0	Po40	0.11/ 000	000	E04	004	500	0.47	0								- A	•	000	504

# Freely available as MS Excel file. But note ambiguity: work is needed to translate this into decisions on a ballot-by-ballot basis.

https://www.sos.state.mn.us/media/1979/2008-final-recount-summary-by-precinct.xls

# What Can Be Learned Here?

Counting ballots not just an <u>abstract</u> pattern recognition problem:

- A real task defined by pre-determined laws and processes.
- Important to society (not just labeling "cute cat" photos).
- Inherently political, but designed to be as fair as possible.
- Expressed in terms of <u>human interpretation</u>.
- Ambiguity is utterly inherent (real world is messy).
- "<u>Noisy labeling</u>" is utterly inherent.
- AI (pattern recognition) <u>can</u> and <u>must</u> do better.

In other words, this is a perfect problem to study for those of us who want our research to have an impact in the real world.

# A Sad Epilogue ...

Google	Al Franken								
	All New	s Images	Videos	Shopping	More		Settings	Tools	
	About 35,200	),000 results (0.3	37 seconds)						
	Al Franken: two more women accuse senator of sexual misconduct The Guardian - 3 hours ago Two more women have come forward to accuse Democratic senator Al Franken of sexual impropriety, according to reports on Thursday. Stephanie Kemplin, an Ohio army veteran, told CNN that Franken groped her breast in 2003, while she was deployed in Kuwait and he was a comedian on a tour of the Al Franken Accused of Groping Army Veteran in 2003 Variety - 7 hours ago New England Elected Official Says Al Franken Tried to Give Her A Highly Cited - Jezebel - 7 hours ago All the Women Who Have Accused Sen. Al Franken of Sexual								
	Top Democrat tells <b>AI Franken</b> to QUIT as more victims come In-Depth - Daily Mail - 46 minutes ago								
	Blog - Slate Magazine (blog) - 4 hours ago								
			Sh.		15 g				
	TIME View all	BBC News	Variety	Daily Mail	AV Club	Deadline			
	are	Bill Clinto Observer - Women wi	on's Accuse 5 hours ago ho accused f	ers Storm Al	Franken'	<b>s</b> Office Dem on of sexual mi	anding His . sconduct storn	ned	

Counting Votes and the Attempt to Replicate Human Interpretation

### 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.

# When is a Problem Solved?

### 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

MIND A QUARTERLY REVIEW or PSYCHOLOGY AND PHILOSOPHI 	Vol. lix. No. 236.] [October, 1950	1. The Imitation Game.
L-COMPUTING MACHINERY AND INTELLIGENCE BY A.M. Turns 1. The Initiation Game. 1. The Initiation Game of the question, 'Can machines think !' The should begin with definitions of the meaning of the varies and 'think.' The definitions might be the transd so as the source of the source of the question, 'Can machines think !' 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 takes the part of A in this game ?' Will the interrogator decide wrongly as often when the game is played like this as he doess when the game is played between a man and a woman ? These questions replace our original, 'Can machines think ?'	M I N D a quarterly review of PSYCHOLOGY AND PHILOSOPHY	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
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 'initiation game'. It is played with the other two. The object of the game for the 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 (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 (C) who may be of either sex. The interrogator is the man and which is the woman. He knows them by labels X and Y, and at the end of the game is played between a man and a woman ? These thus: C: Will X please tell me the length of his or her hair ? Now suppose X is actually A. the A must answer. It is is A's	L-COMPUTING MACHINERY AND INTELLIGENCE     BY A.M.TURING     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, but this     attitude is dangerous. If the meaning of the words, but this     attitude is dangerous. If the meaning 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	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
28 433	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 ( $\Delta$ ), 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	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 ?'

"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.

Mind, vol. 59, no. 236, October 1950, pp. 433-460.

# The Turing Test



### Is SuccessRate<sub>2</sub> $\approx$ SuccessRate<sub>1</sub>?

"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?



# 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.





"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 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.

"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.

# 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?

"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.

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.



"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.

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.



"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 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.



"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.

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



"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?

"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. Hopefully this has given you some points to think about ... if you're interested in collaborating to turn MN ballots into a community resource for exploring interesting and important "noisy labeling" problem, let me know!

# Thank you! Merci!!

