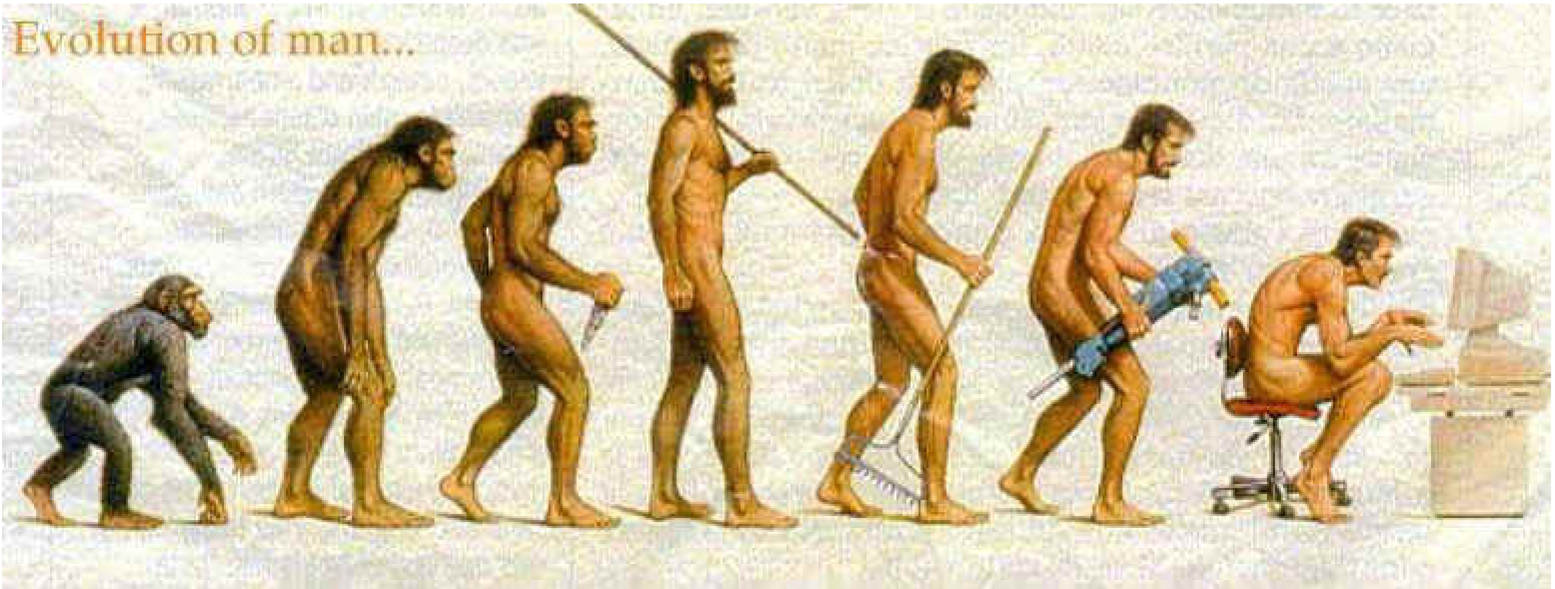
IN SEARCH OF TRUTH (ON THE DEEP WEB)

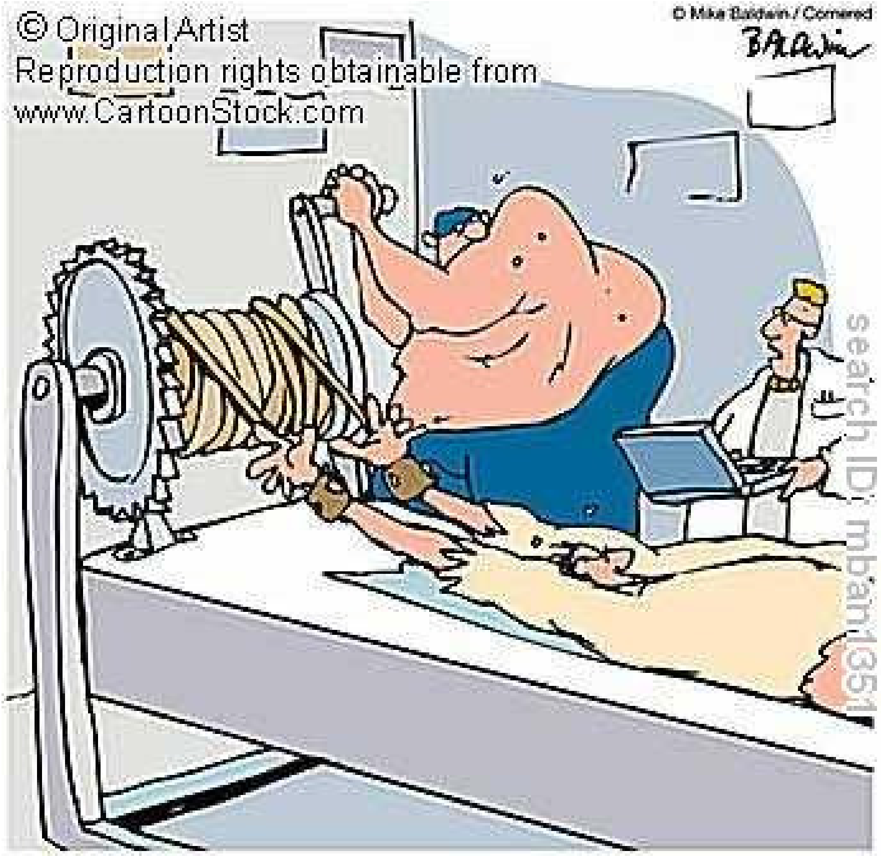
Divesh Srivastava

AT&T Labs-Research

The Web is Great

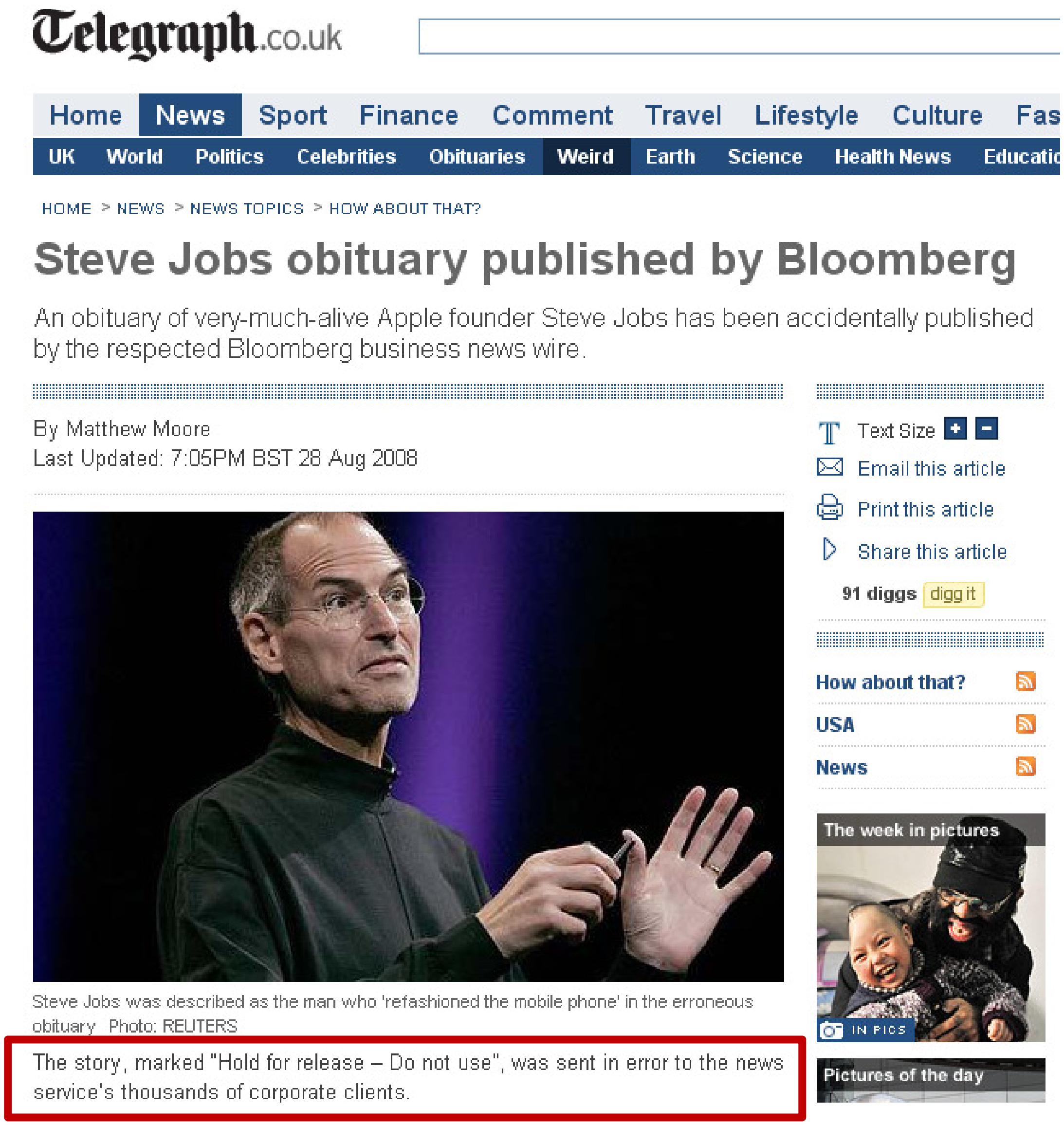


A Lot of Information on the Web


© Original Artist
Reproduction rights obtainable from
www.CartoonStock.com
© Mike Baldwin / Cornered
search ID: mban1351

"Come to think of it, he doesn't need to give us the information. I can just look it up on the Internet."

Information Can Be Erroneous



Steve Jobs obituary published by Bloomberg

An obituary of very-much-alive Apple founder Steve Jobs has been accidentally published by the respected Bloomberg business news wire.

By Matthew Moore
Last Updated: 7:05PM BST 28 Aug 2008

Steve Jobs was described as the man who 'refashioned the mobile phone' in the erroneous obituary Photo: REUTERS

The story, marked "Hold for release – Do not use", was sent in error to the news service's thousands of corporate clients.

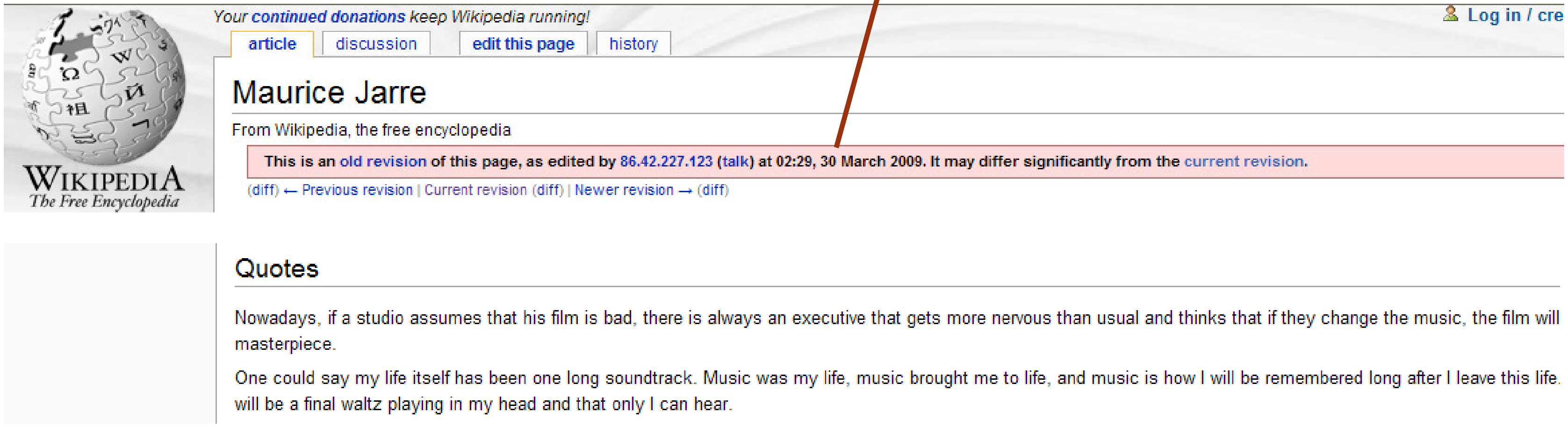
The story, marked "Hold for release – Do not use", was sent in error to the news service's thousands of corporate clients.

Information Can Be Erroneous

Maurice Jarre (1924-2009) French Conductor and Composer

"One could say my life itself has been one long soundtrack. Music was my life, music brought me to life, and music is how I will be remembered long after I leave this life. When I die there will be a final waltz playing in my head and that only I can hear."

2:29, 30 March 2009



Your continued donations keep Wikipedia running!

Maurice Jarre

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by 86.42.227.123 (talk) at 02:29, 30 March 2009. It may differ significantly from the current revision.

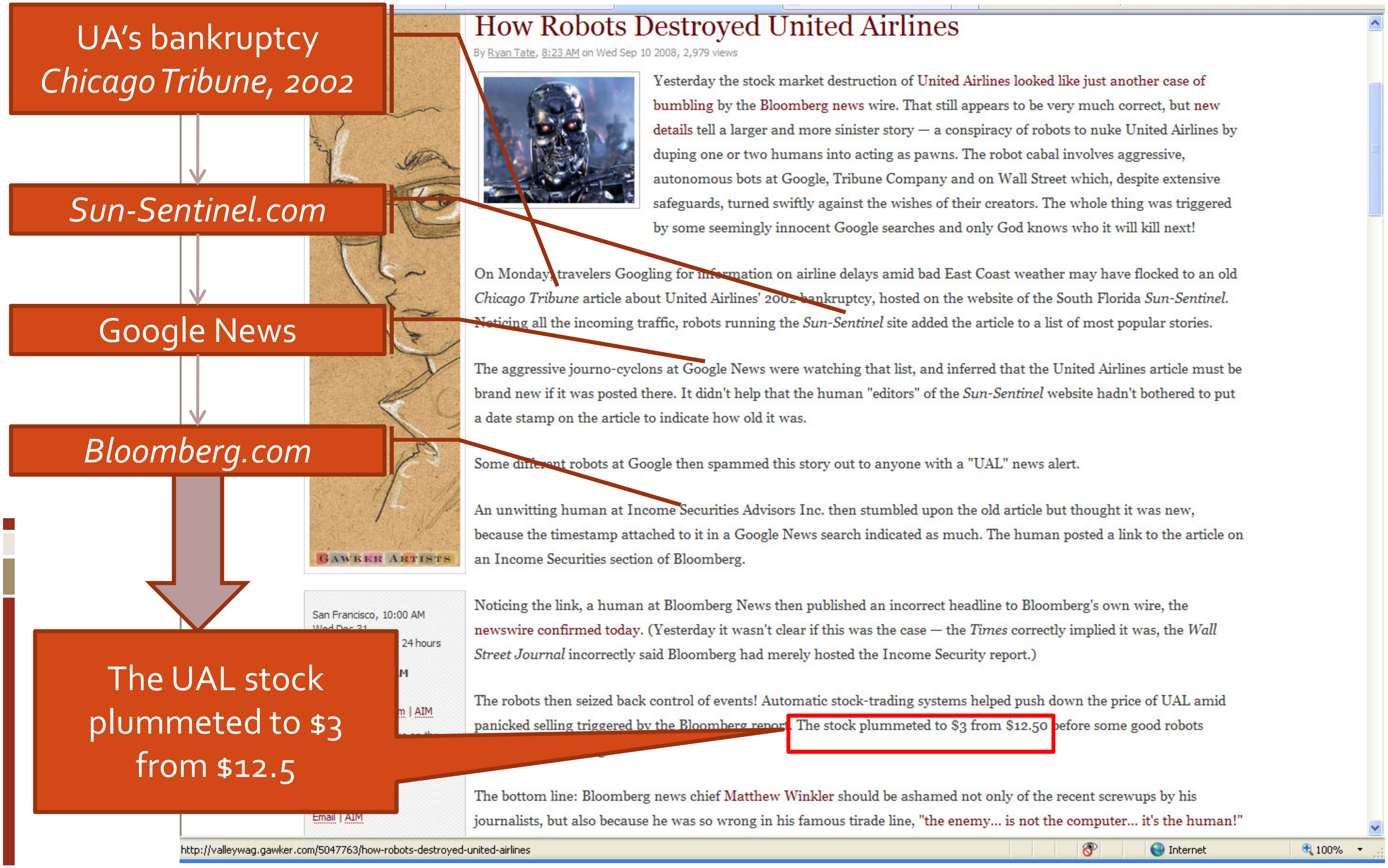
(diff) ← Previous revision | Current revision (diff) | Newer revision → (diff)

Quotes

Nowadays, if a studio assumes that his film is bad, there is always an executive that gets more nervous than usual and thinks that if they change the music, the film will masterpiece.

One could say my life itself has been one long soundtrack. Music was my life, music brought me to life, and music is how I will be remembered long after I leave this life. will be a final waltz playing in my head and that only I can hear.

False Information Can Be Propagated



UA's bankruptcy
Chicago Tribune, 2002

Sun-Sentinel.com

Google News

Bloomberg.com

The UAL stock plummeted to $3 from $12.5

How Robots Destroyed United Airlines

By Ryan Tate, 8:23 AM on Wed Sep 10 2008, 2,979 views

Yesterday the stock market destruction of United Airlines looked like just another case of bumbling by the Bloomberg news wire. That still appears to be very much correct, but new details tell a larger and more sinister story — a conspiracy of robots to nuke United Airlines by duping one or two humans into acting as pawns. The robot cabal involves aggressive, autonomous bots at Google, Tribune Company and on Wall Street which, despite extensive safeguards, turned swiftly against the wishes of their creators. The whole thing was triggered by some seemingly innocent Google searches and only God knows who it will kill next!

On Monday, travelers Googling for information on airline delays amid bad East Coast weather may have flocked to an old *Chicago Tribune* article about United Airlines' 2002 bankruptcy, hosted on the website of the South Florida *Sun-Sentinel*. Noticing all the incoming traffic, robots running the *Sun-Sentinel* site added the article to a list of most popular stories.

The aggressive journo-cyclons at Google News were watching that list, and inferred that the United Airlines article must be brand new if it was posted there. It didn't help that the human "editors" of the *Sun-Sentinel* website hadn't bothered to put a date stamp on the article to indicate how old it was.

Some different robots at Google then spammed this story out to anyone with a "UAL" news alert.

An unwitting human at Income Securities Advisors Inc. then stumbled upon the old article but thought it was new, because the timestamp attached to it in a Google News search indicated as much. The human posted a link to the article on an Income Securities section of Bloomberg.

Noticing the link, a human at Bloomberg News then published an incorrect headline to Bloomberg's own wire, the newswire confirmed today. (Yesterday it wasn't clear if this was the case — the *Times* correctly implied it was, the *Wall Street Journal* incorrectly said Bloomberg had merely hosted the Income Security report.)

The robots then seized back control of events! Automatic stock-trading systems helped push down the price of UAL amid panicked selling triggered by the Bloomberg report. The stock plummeted to $3 from $12.50 before some good robots

The bottom line: Bloomberg news chief Matthew Winkler should be ashamed not only of the recent screwups by his journalists, but also because he was so wrong in his famous tirade line, "the enemy... is not the computer... it's the human!"

IS DEEP-WEB DATA CONSISTENT & RELIABLE?

Study on Two Domains

	#Sources	Period	#Objects	#Local-attrs	#Global-attrs	Considered items
Stock	55	7/2011	1000*20	333	153	16000*20
Flight	38	12/2011	1200*31	43	15	7200*31

- Belief of clean data
- Poor data quality can have big impact

Study on Two Domains

	#Sources	Period	#Objects	#Local-attrs	#Global-attrs	Considered items
Stock	55	7/2011	1000*20	333	153	16000*20

❑ Stock

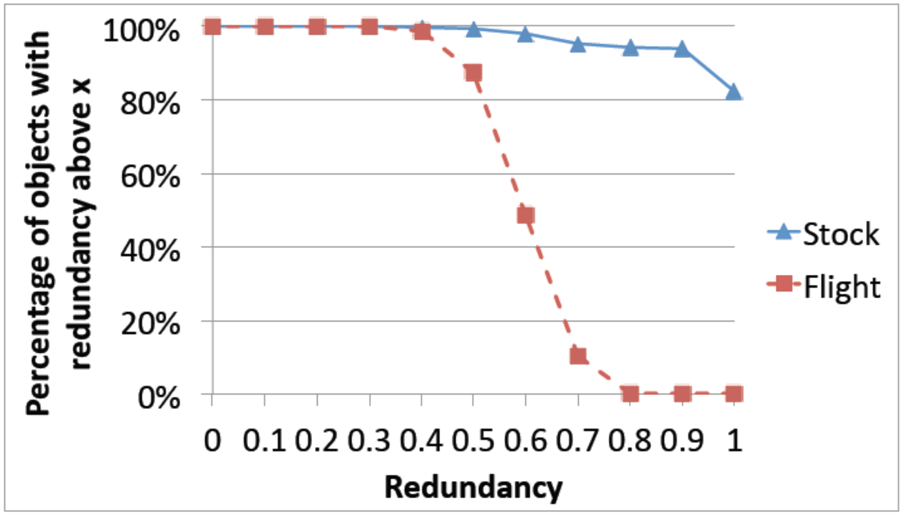
- ❑ Search “stock price quotes”
- ❑ Sources: 200 (search results)→89 (deep web)→76 (GET method) →55 (no JavaScript)
- ❑ 1000 “Objects”: a stock with a particular symbol on a particular day
  - ❑ 30 from Dow Jones Index
  - ❑ 100 from NASDAQ100 (3 overlaps)
  - ❑ 873 from Russell 3000
- ❑ Attributes: 333 (local) → 153 (global) → 21 (provided by > 1/3 sources) → 16 (no change after market close)

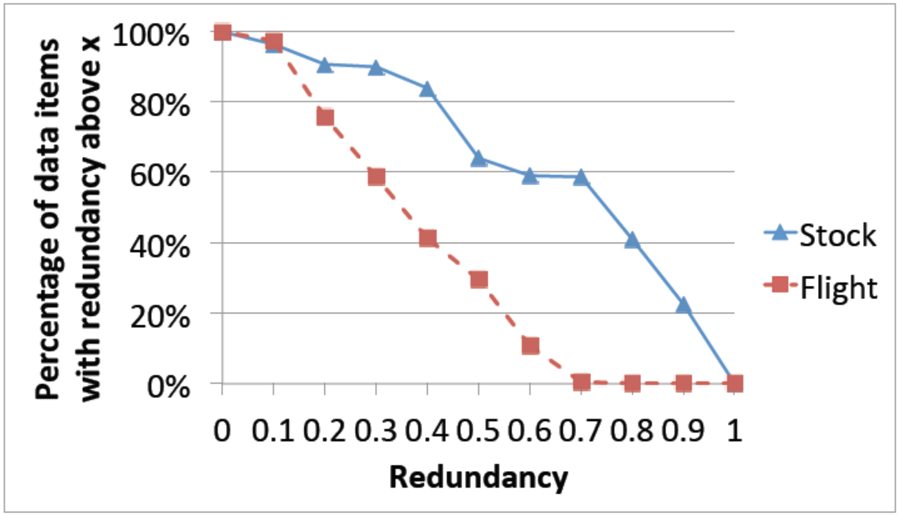
Study on Two Domains

	#Sources	Period	#Objects	#Local-attrs	#Global-attrs	Considered items
Flight	38	12/2011	1200*31	43	15	7200*31

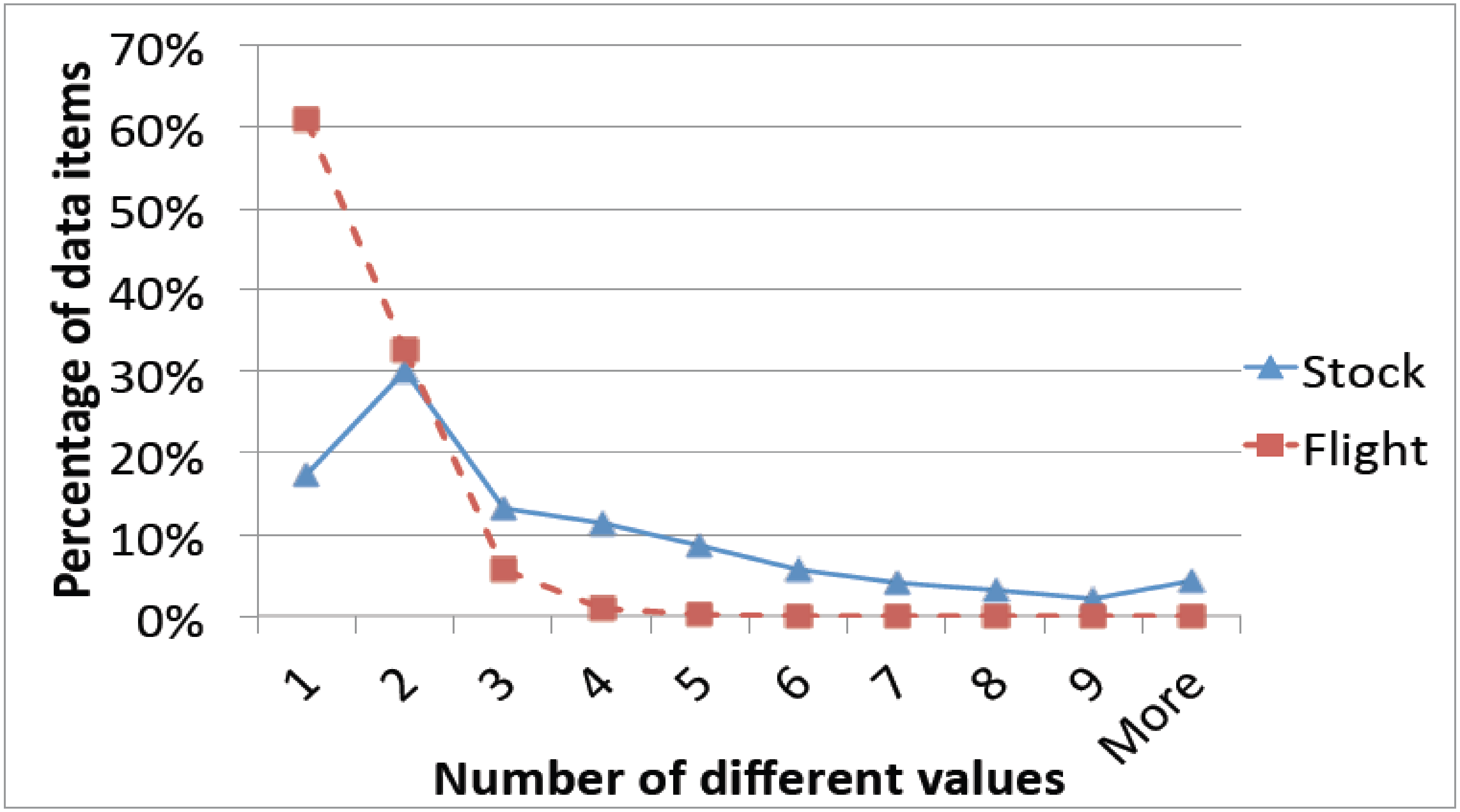
- ❑Flight
  - ❑ Search "flight status"
  - ❑ Sources: 38
    - ❑ 3 airline websites (AA, UA, Continental)
    - ❑ 8 airport websites (SFO, DEN, etc.)
    - ❑ 27 third-party websites (Orbitz, Travelocity, etc.)
  - ❑ 1200 "Objects": a flight with a particular flight number on a particular day from a particular departure city
    - ❑ Departing or arriving at the hub airports of AA/UA/Continental
  - ❑ Attributes: 43 (local) → 15 (global) → 6 (provided by > 1/3 sources)
    - ❑ scheduled dept/arr time, actual dept/arr time, dept/arr gate

Q1. Is There a Lot of Redundant Data? ✓



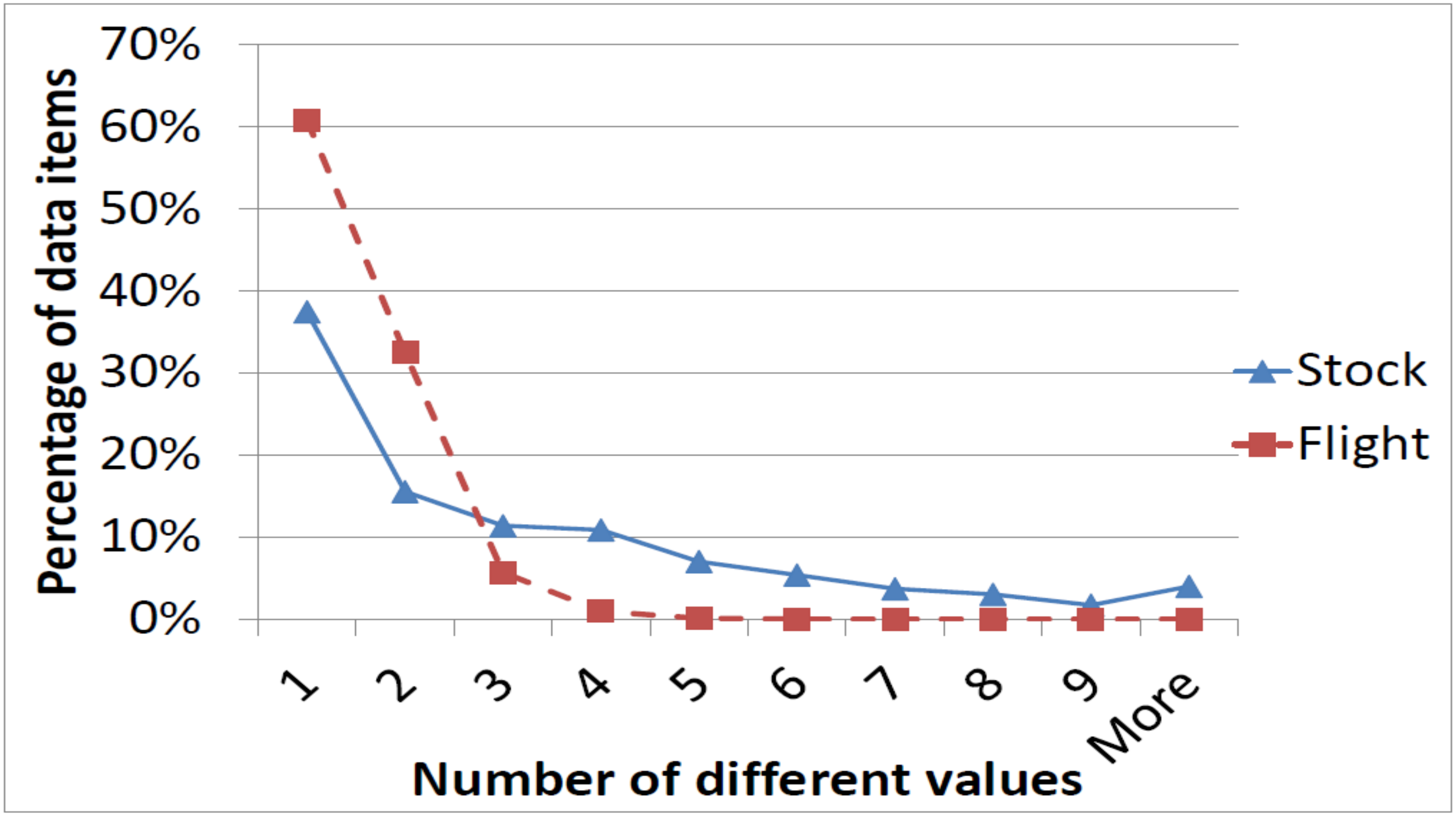


Q2. Is the Data Consistent? ✗



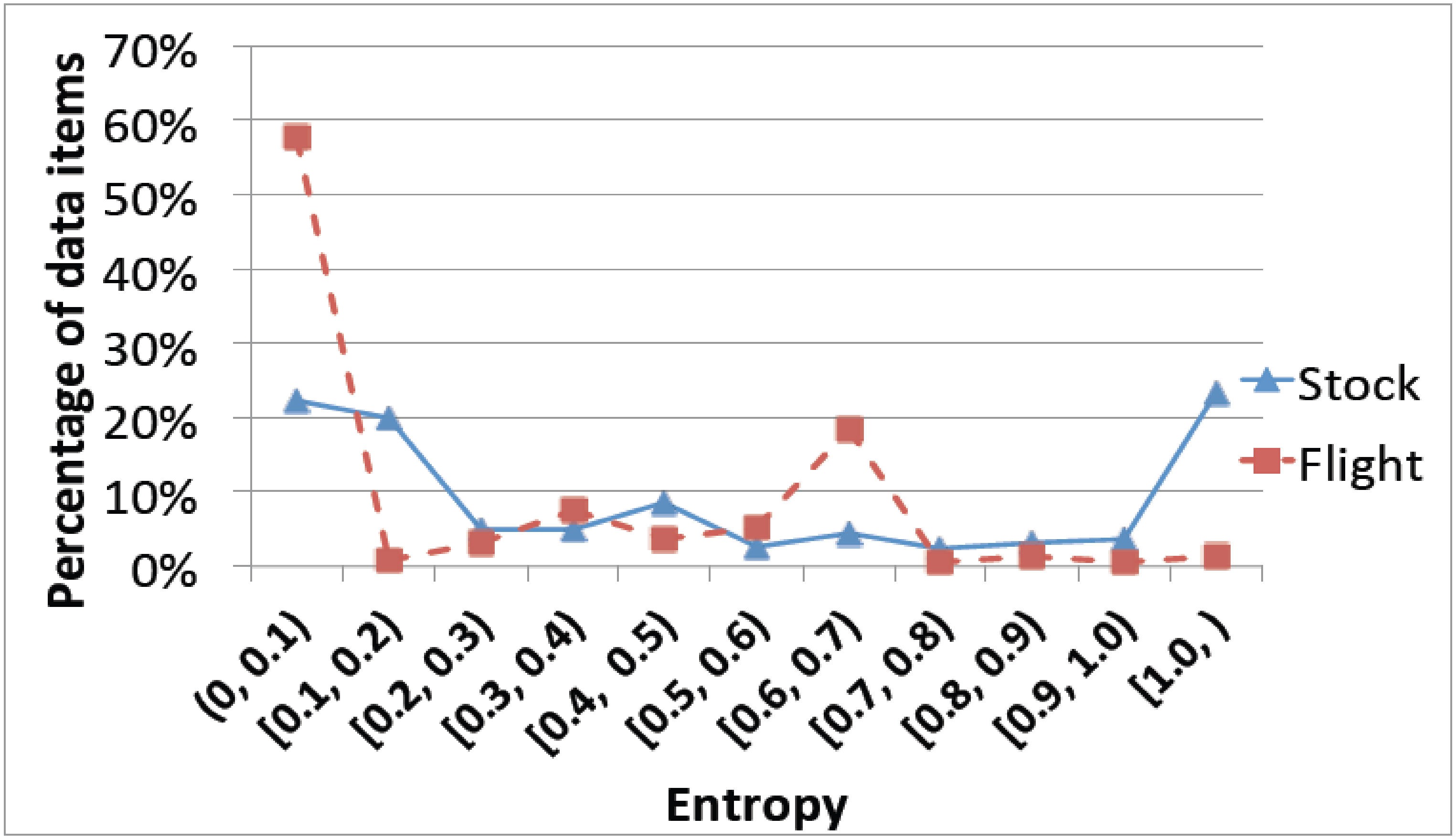
❑Tolerance to 1% value difference

Q2. Is the Data Consistent? ✗



- ❑Tolerance to 1% value difference
- ❑Inconsistency on 50% items after removing *StockSmart*

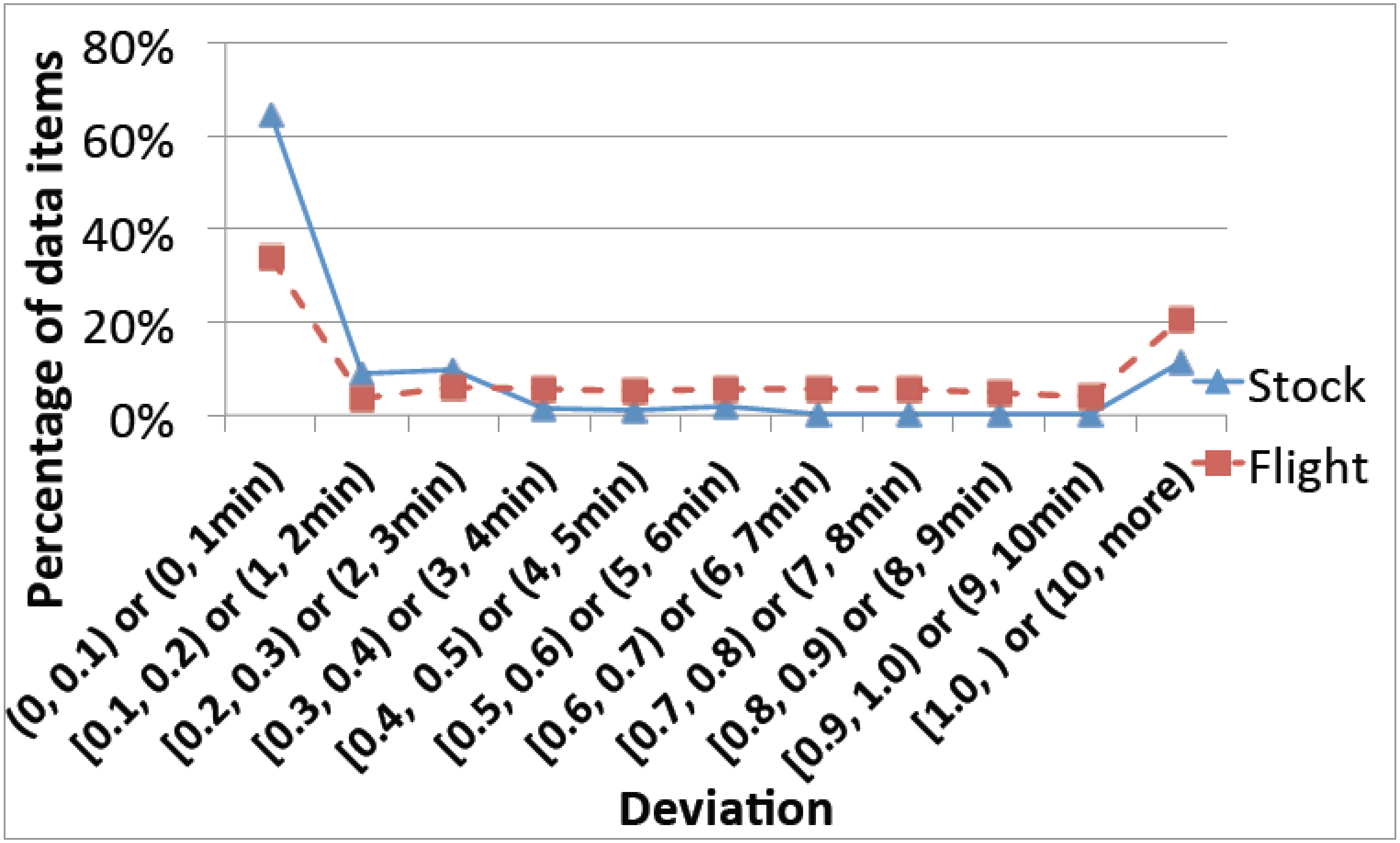
Q2. Is the Data Consistent? (II)



❑Entropy measures distribution of different values

❑Quite low entropy: one value provided more often than others

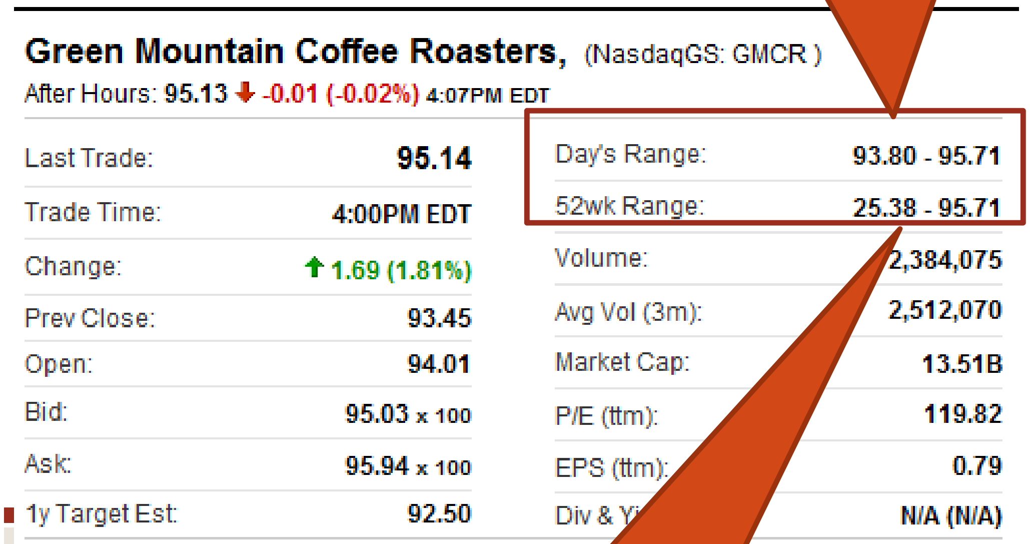
Q2. Is the Data Consistent? (III)



- ❑Deviation measures difference of numerical values
- ❑High deviation: 13.4 for Stock, 13.1 min for Flight

Why Such Inconsistency?
— I. Semantic Ambiguity

Yahoo! Finance



Green Mountain Coffee Roasters, (NasdaqGS: GMCR)

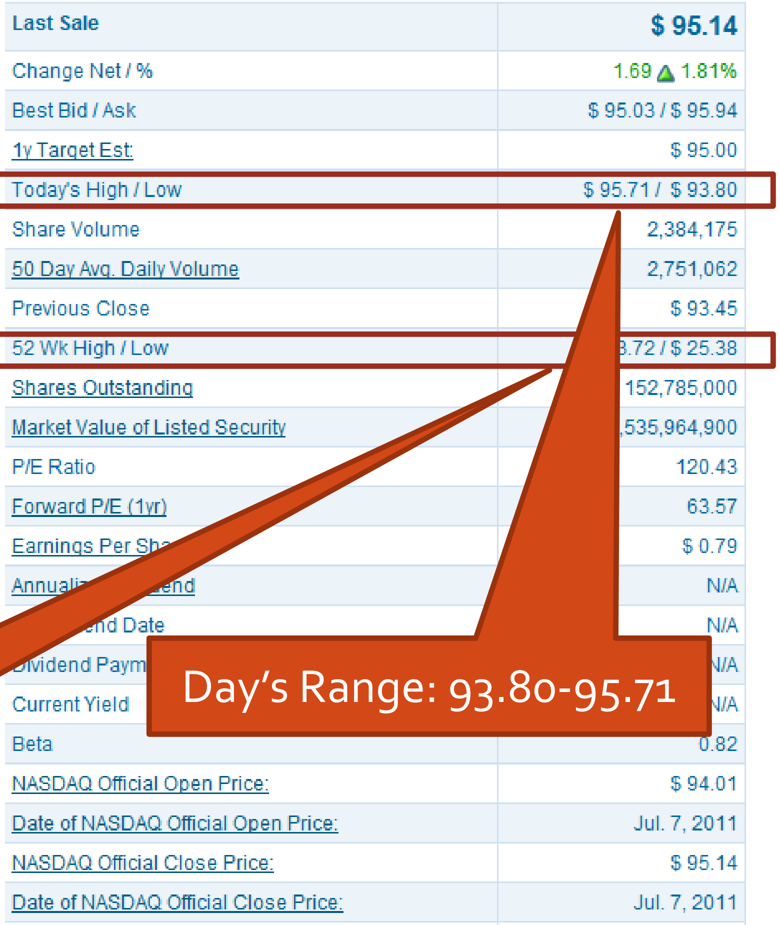
After Hours: **95.13** ↓ -0.01 (-0.02%) 4:07PM EDT

Last Trade:	**95.14**	Day's Range:	**93.80 - 95.71**
Trade Time:	**4:00PM EDT**	52wk Range:	**25.38 - 95.71**
Change:	↑ **1.69 (1.81%)**	Volume:	**2,384,075**
Prev Close:	**93.45**	Avg Vol (3m):	**2,512,070**
Open:	**94.01**	Market Cap:	**13.51B**
Bid:	**95.03 x 100**	P/E (ttm):	**119.82**
Ask:	**95.94 x 100**	EPS (ttm):	**0.79**
1y Target Est:	**92.50**	Div & Yi	**N/A (N/A)**

Day's Range: 93.80-95.71

52wk Range: 25.38-95.71

Nasdaq

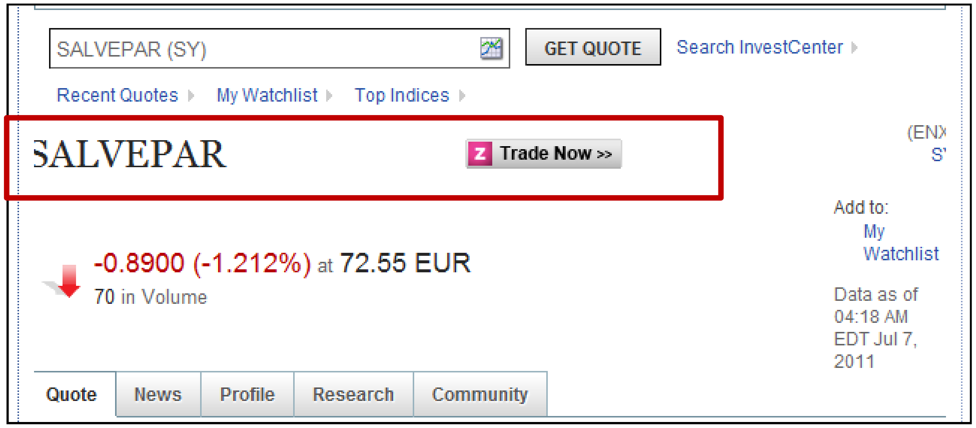


Last Sale	**$ 95.14**
Change Net / %	1.69 ▲ 1.81%
Best Bid / Ask	$ 95.03 / $ 95.94
1y Target Est:	$ 95.00
Today's High / Low	$ 95.71 / $ 93.80
Share Volume	2,384,175
50 Day Avg. Daily Volume	2,751,062
Previous Close	$ 93.45
52 Wk High / Low	3.72 / $ 25.38
Shares Outstanding	152,785,000
Market Value of Listed Security	,535,964,900
P/E Ratio	120.43
Forward P/E (1yr)	63.57
Earnings Per Sh	$ 0.79
Annuali end	N/A
nd Date	N/A
Dividend Paym	N/A
Current Yield	N/A
Beta	0.82
NASDAQ Official Open Price:	$ 94.01
Date of NASDAQ Official Open Price:	Jul. 7, 2011
NASDAQ Official Close Price:	$ 95.14
Date of NASDAQ Official Close Price:	Jul. 7, 2011

52 Wk: 25.38-93.72

Day's Range: 93.80-95.71

Why Such Inconsistency?
— II. Instance Ambiguity



SALVEPAR (SY)

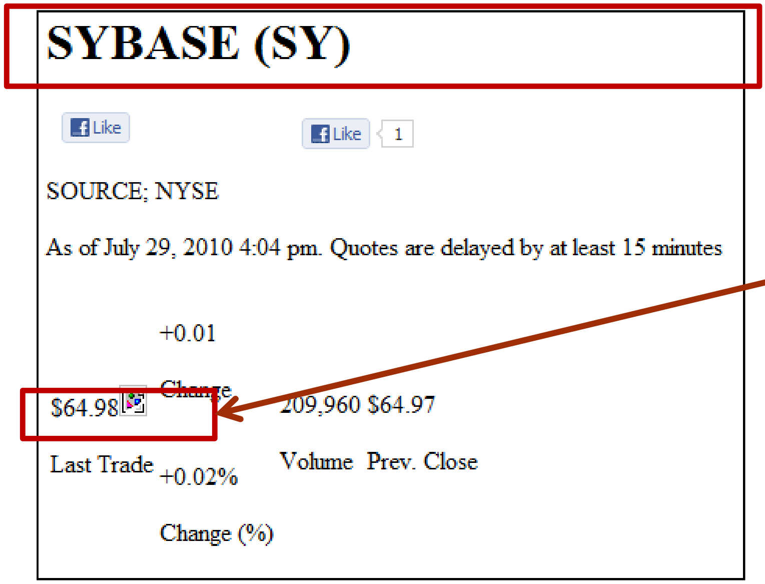
SALVEPAR

(ENX
S

Add to:
My Watchlist

-0.8900 (-1.212%) at 72.55 EUR
70 in Volume

Data as of 04:18 AM EDT Jul 7, 2011



SYBASE (SY)

SOURCE; NYSE

As of July 29, 2010 4:04 pm. Quotes are delayed by at least 15 minutes

+0.01

$64.98

Change

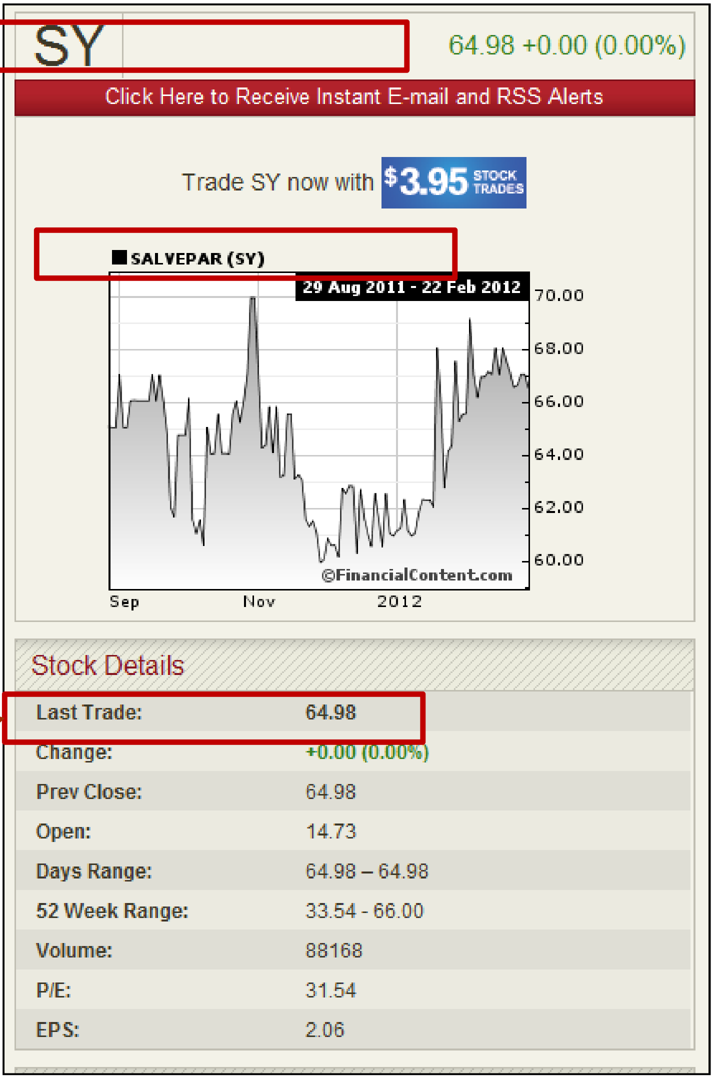
209,960 $64.97

Last Trade

+0.02%

Volume Prev. Close

Change (%)



SY

64.98 +0.00 (0.00%)

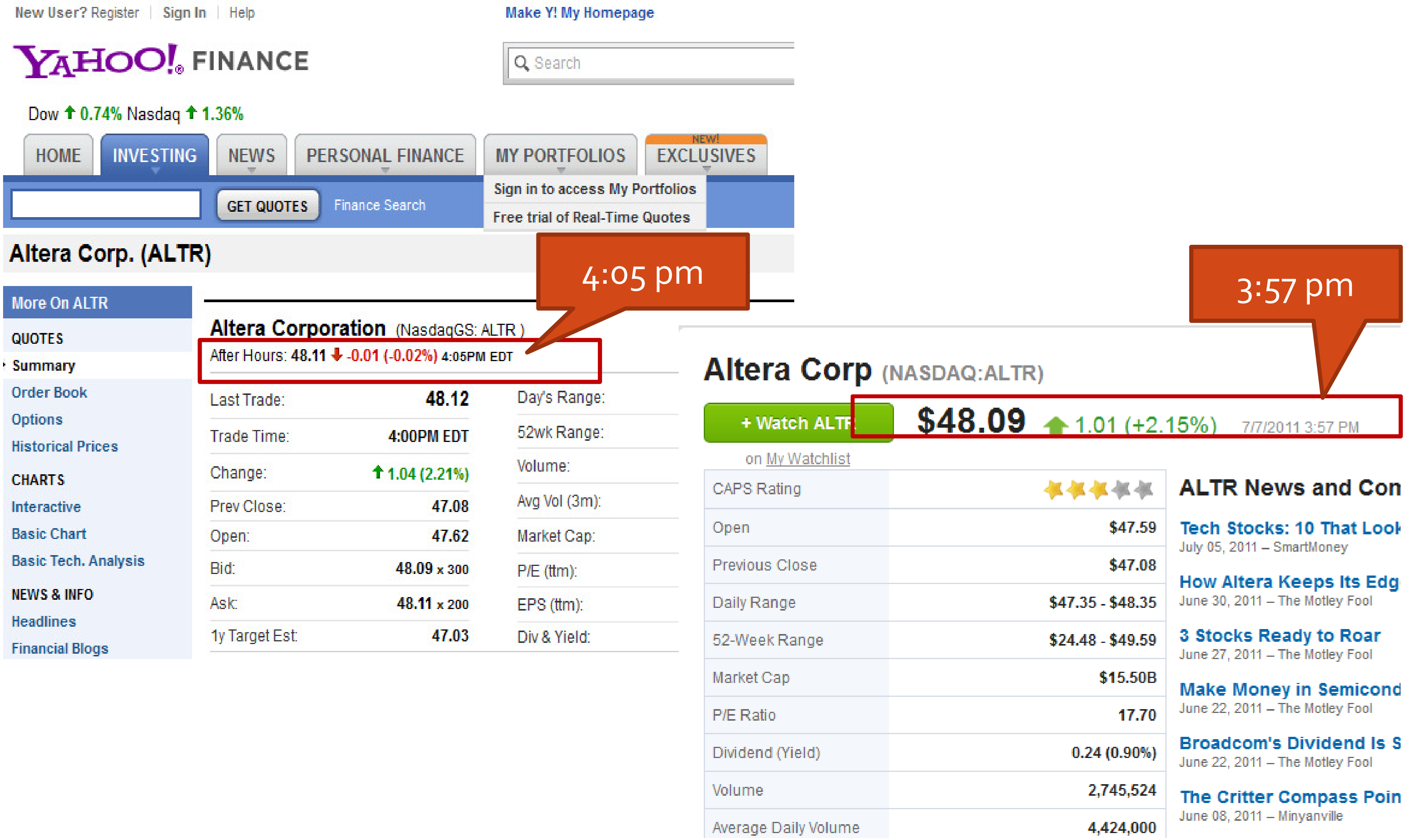
Click Here to Receive Instant E-mail and RSS Alerts

Trade SY now with $3.95 STOCK TRADES

Stock Details

Last Trade:	64.98
Change:	+0.00 (0.00%)
Prev Close:	64.98
Open:	14.73
Days Range:	64.98 – 64.98
52 Week Range:	33.54 - 66.00
Volume:	88168
P/E:	31.54
EPS:	2.06

Why Such Inconsistency?
— III. Out-of-Date Data



New User? Register | Sign In | Help

Make Y! My Homepage

Altera Corp. (ALTR)

4:05 pm

Altera Corporation (NasdaqGS: ALTR)

After Hours: 48.11 ↓ -0.01 (-0.02%) 4:05PM EDT

Last Trade:	48.12	Day's Range:
Trade Time:	4:00PM EDT	52wk Range:
Change:	↑ 1.04 (2.21%)	Volume:
Prev Close:	47.08	Avg Vol (3m):
Open:	47.62	Market Cap:
Bid:	48.09 x 300	P/E (ttm):
Ask:	48.11 x 200	EPS (ttm):
1y Target Est:	47.03	Div & Yield:

3:57 pm

Altera Corp (NASDAQ:ALTR)

+ Watch ALTR on My Watchlist

$48.09 ↑ 1.01 (+2.15%) 7/7/2011 3:57 PM

CAPS Rating	★★★☆☆
Open	$47.59
Previous Close	$47.08
Daily Range	$47.35 - $48.35
52-Week Range	$24.48 - $49.59
Market Cap	$15.50B
P/E Ratio	17.70
Dividend (Yield)	0.24 (0.90%)
Volume	2,745,524
Average Daily Volume	4,424,000

ALTR News and Con

Tech Stocks: 10 That Look
July 05, 2011 – SmartMoney

How Altera Keeps Its Edg
June 30, 2011 – The Motley Fool

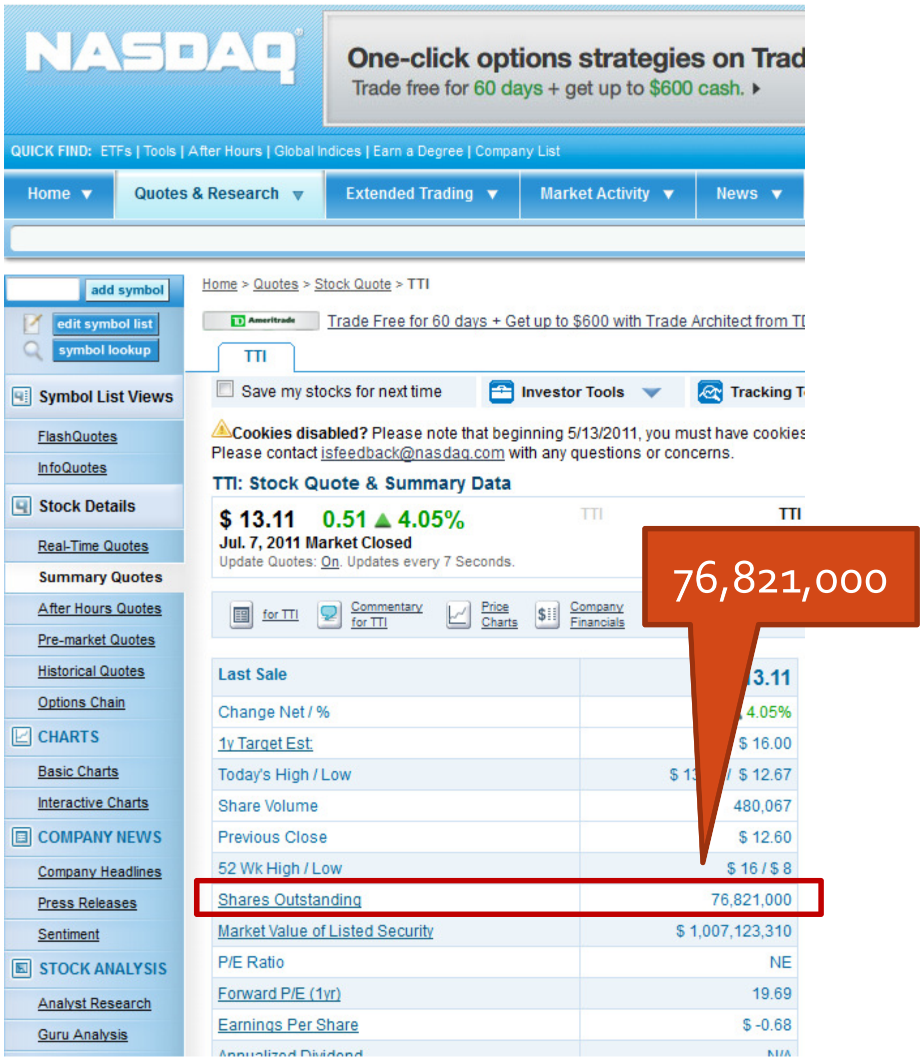
3 Stocks Ready to Roar
June 27, 2011 – The Motley Fool

Make Money in Semicond
June 22, 2011 – The Motley Fool

Broadcom's Dividend Is S
June 22, 2011 – The Motley Fool

The Critter Compass Poin
June 08, 2011 – Minyanville

Why Such Inconsistency? — IV. Unit Error



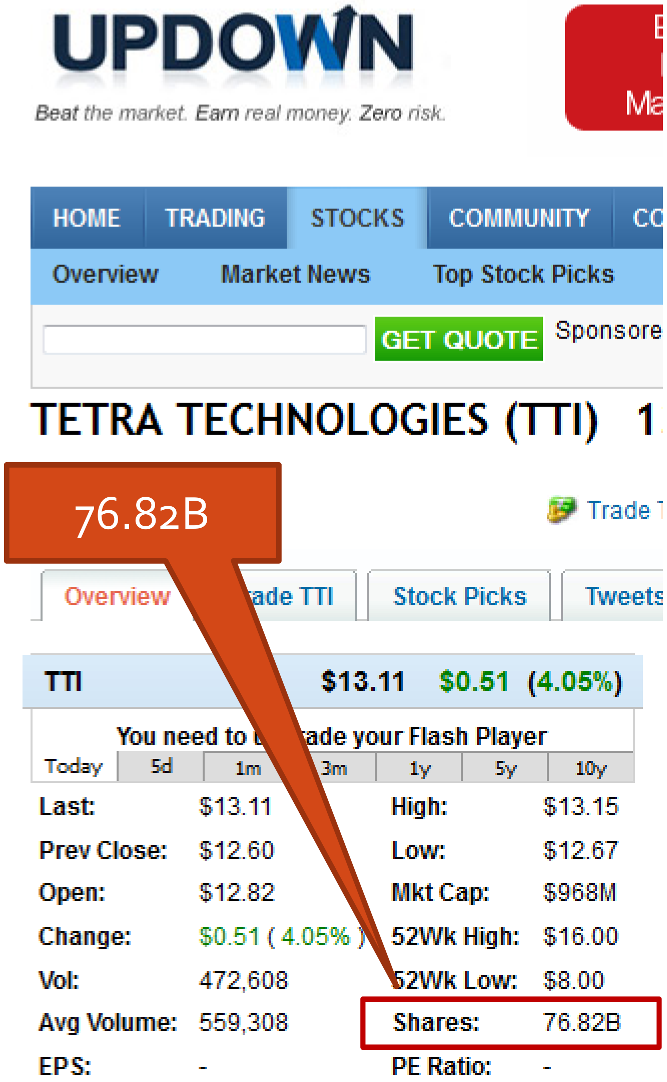
⚠Cookies disabled? Please note that beginning 5/13/2011, you must have cookies
Please contact isfeedback@nasdaq.com with any questions or concerns.

TTI: Stock Quote & Summary Data

$ 13.11 0.51 ▲ 4.05%
Jul. 7, 2011 Market Closed
Update Quotes: On. Updates every 7 Seconds.

Last Sale	3.11
Change Net / %	4.05%
1y Target Est:	$ 16.00
Today's High / Low	$ 13 / $ 12.67
Share Volume	480,067
Previous Close	$ 12.60
52 Wk High / Low	$ 16 / $ 8
Shares Outstanding	76,821,000
Market Value of Listed Security	$ 1,007,123,310
P/E Ratio	NE
Forward P/E (1yr)	19.69
Earnings Per Share	$ -0.68
Annualized Dividend	N/A

76,821,000



TETRA TECHNOLOGIES (TTI) 1

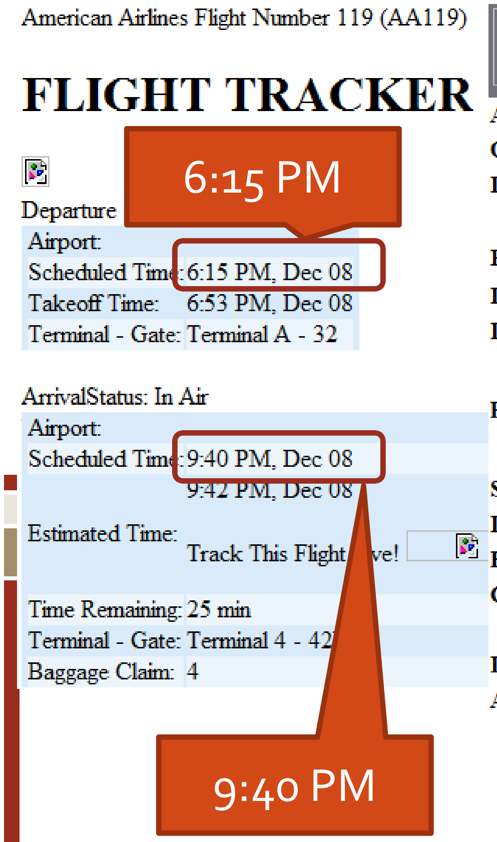
TTI $13.11 $0.51 (4.05%)

Last:	$13.11	High:	$13.15
Prev Close:	$12.60	Low:	$12.67
Open:	$12.82	Mkt Cap:	$968M
Change:	$0.51 (4.05%)	52Wk High:	$16.00
Vol:	472,608	52Wk Low:	$8.00
Avg Volume:	559,308	Shares:	76.82B
EPS:	-	PE Ratio:	-

76.82B

Why Such Inconsistency? —V. Pure Error

FlightView



American Airlines Flight Number 119 (AA119)

FLIGHT TRACKER

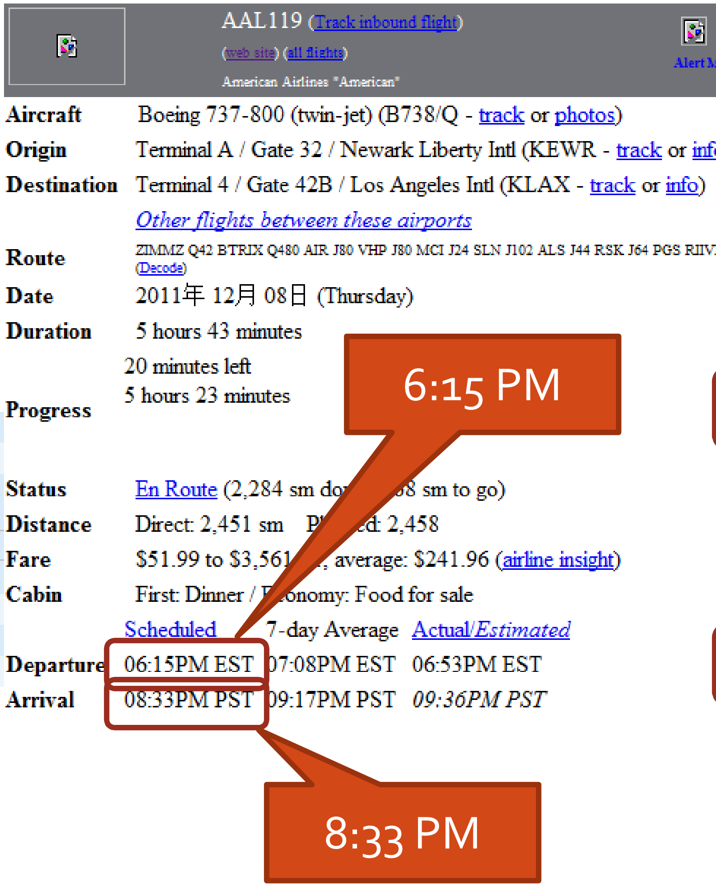
Departure

Airport:	
Scheduled Time:	6:15 PM, Dec 08
Takeoff Time:	6:53 PM, Dec 08
Terminal - Gate:	Terminal A - 32

ArrivalStatus: In Air

Airport:	
Scheduled Time:	9:40 PM, Dec 08
	9:42 PM, Dec 08
Estimated Time:	Track This Flight ve!
Time Remaining:	25 min
Terminal - Gate:	Terminal 4 - 42
Baggage Claim:	4

FlightAware



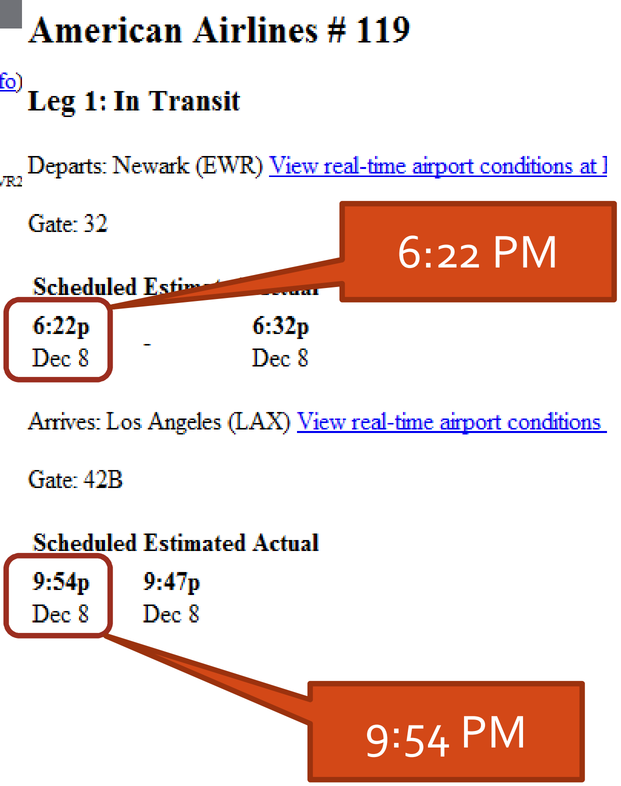
AAL119 (Track inbound flight)
(web site) (all flights)
American Airlines "American"

Alert Me

Aircraft	Boeing 737-800 (twin-jet) (B738/Q - track or photos)
Origin	Terminal A / Gate 32 / Newark Liberty Intl (KEWR - track or info)
Destination	Terminal 4 / Gate 42B / Los Angeles Intl (KLAX - track or info)
	Other flights between these airports
Route	ZIMMZ Q42 BTRIX Q480 AIR J80 VHP J80 MCI J24 SLN J102 ALS J44 RSK J64 PGS RIIVR2 (Decode)
Date	2011年 12月 08日 (Thursday)
Duration	5 hours 43 minutes
Progress	20 minutes left 5 hours 23 minutes
Status	En Route (2,284 sm do 8 sm to go)
Distance	Direct: 2,451 sm Pl ed: 2,458
Fare	$51.99 to $3,561 , average: $241.96 (airline insight)
Cabin	First: Dinner / onomy: Food for sale

	Scheduled	7-day Average	*Actual/Estimated*
Departure	06:15PM EST	07:08PM EST	06:53PM EST
Arrival	08:33PM PST	09:17PM PST	*09:36PM PST*

Orbitz



American Airlines # 119

Leg 1: In Transit

Departs: Newark (EWR) View real-time airport conditions at

Gate: 32

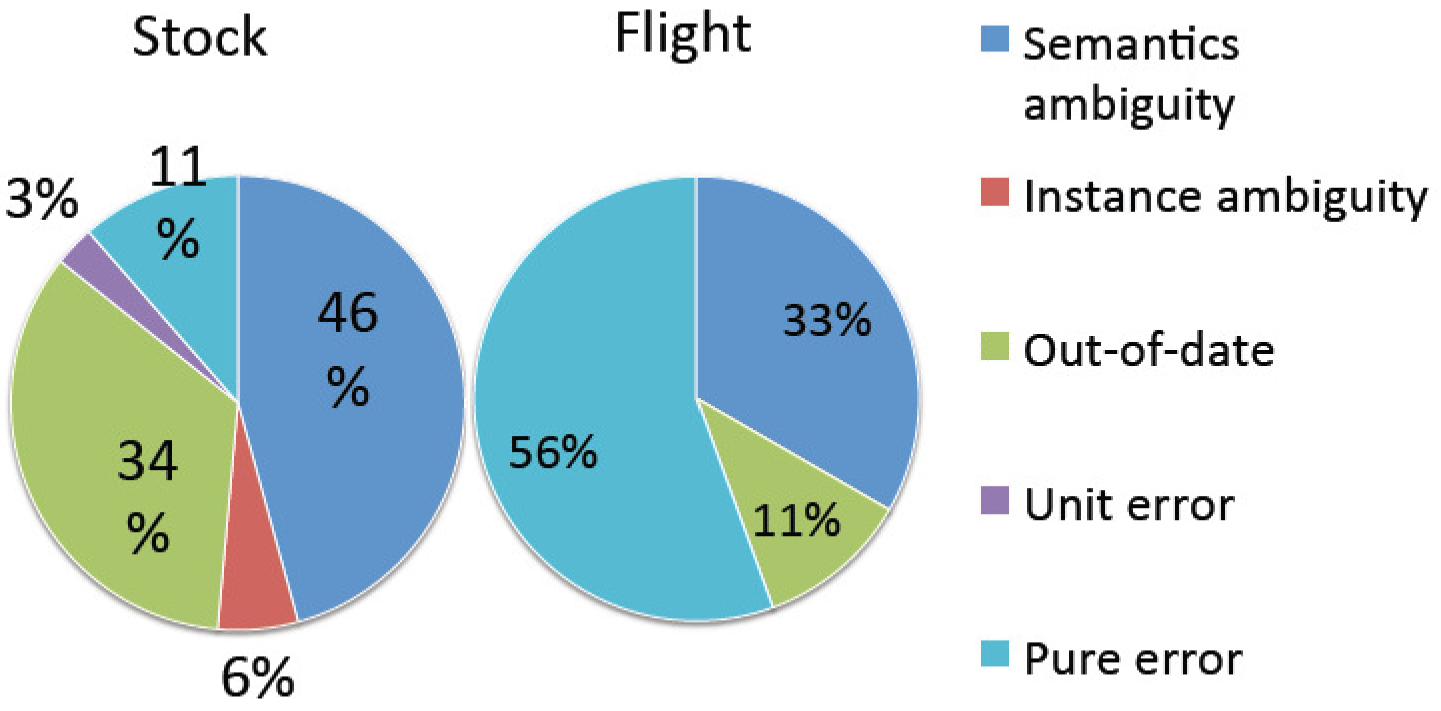
Scheduled	Estim	Actual
6:22p Dec 8	-	**6:32p** Dec 8

Arrives: Los Angeles (LAX) View real-time airport conditions

Gate: 42B

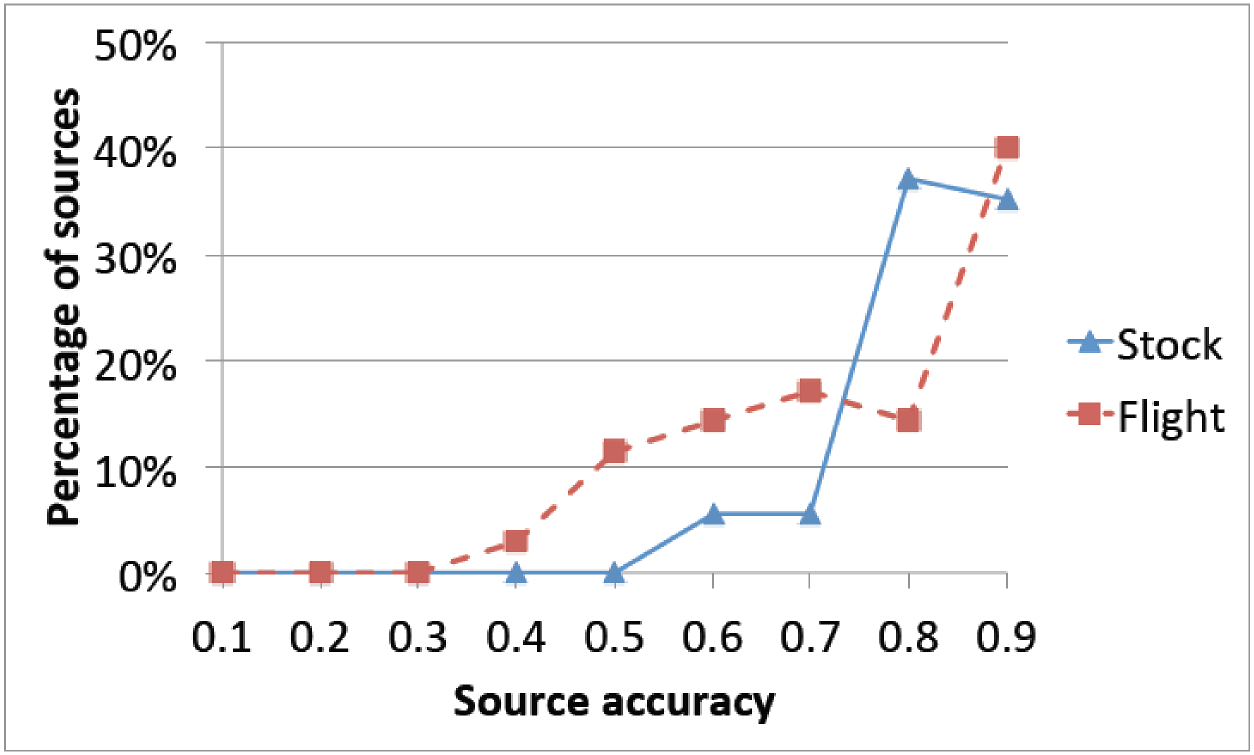
Scheduled	Estimated	Actual
9:54p Dec 8	**9:47p** Dec 8	

Why Such Inconsistency?



❑Random sample of 20 data items and 5 items with the largest # of values in each domain

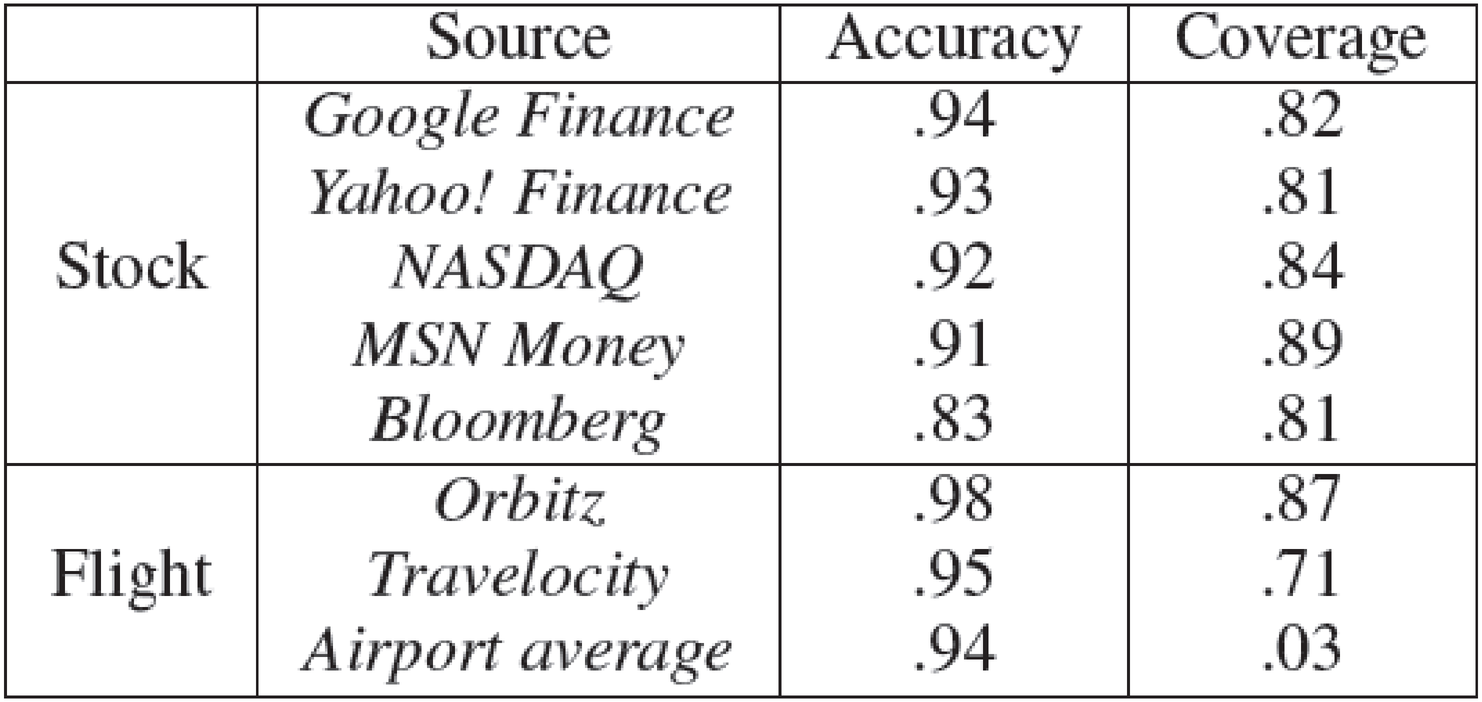
Q3. Do Sources Have High Accuracy? ✘



- ❑Not high on average: .86 for Stock and .8 for Flight
- ❑Gold standard
  - ❑ Stock: vote on data from *Google Finance, Yahoo! Finance, MSN Money, NASDAQ, Bloomberg*
  - ❑ Flight: from airline websites

Q3-2. What About Authoritative Sources?

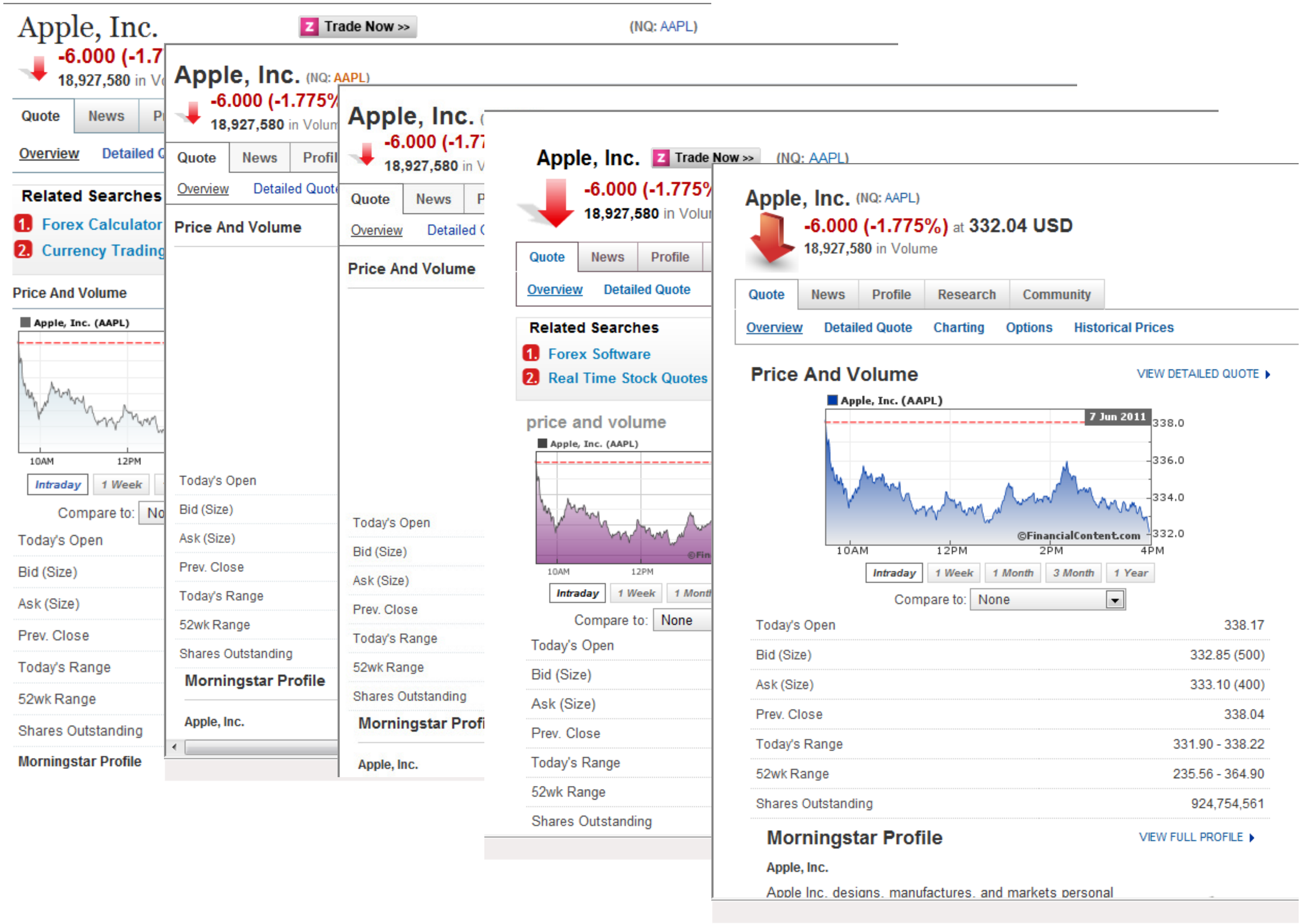
✘



	Source	Accuracy	Coverage
Stock	*Google Finance*	.94	.82
	Yahoo! Finance	.93	.81
	NASDAQ	.92	.84
	MSN Money	.91	.89
	Bloomberg	.83	.81
Flight	*Orbitz*	.98	.87
	Travelocity	.95	.71
	Airport average	.94	.03

- □Reasonable but not so high accuracy
- □Medium coverage

Q4. Is There Copying or Data Sharing Between Deep-Web Sources? ✓



Apple, Inc. Trade Now >> (NQ: AAPL)
-6.000 (-1.7
18,927,580 in Vo
Quote | News | P
Overview | Detailed Q
Related Searches
1. Forex Calculator
2. Currency Trading
Price And Volume
Today's Open
Bid (Size)
Ask (Size)
Prev. Close
Today's Range
52wk Range
Shares Outstanding
Morningstar Profile

Apple, Inc. (NQ: AAPL)
-6.000 (-1.775%
18,927,580 in Volum
Quote | News | Profil
Overview | Detailed Quote
Price And Volume
Today's Open
Bid (Size)
Ask (Size)
Prev. Close
Today's Range
52wk Range
Shares Outstanding
Morningstar Profile
Apple, Inc.

Apple, Inc.
-6.000 (-1.77
18,927,580 in V
Quote | News | P
Overview | Detailed
Price And Volume
Today's Open
Bid (Size)
Ask (Size)
Prev. Close
Today's Range
52wk Range
Shares Outstanding
Morningstar Profi
Apple, Inc.

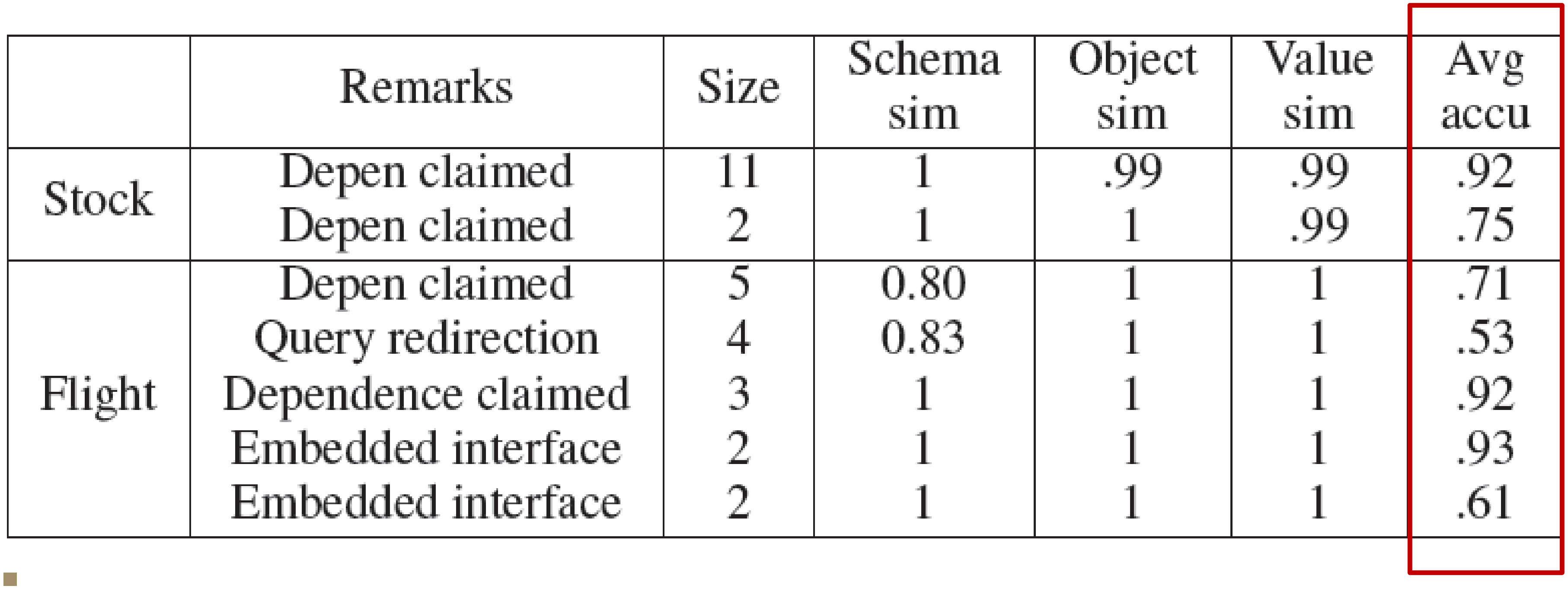
Apple, Inc. Trade Now >> (NQ: AAPL)
-6.000 (-1.775%
18,927,580 in Volu
Quote | News | Profile
Overview | Detailed Quote
Related Searches
1. Forex Software
2. Real Time Stock Quotes
price and volume
Compare to: None
Today's Open
Bid (Size)
Ask (Size)
Prev. Close
Today's Range
52wk Range
Shares Outstanding

Apple, Inc. (NQ: AAPL)
-6.000 (-1.775%) at 332.04 USD
18,927,580 in Volume
Quote | News | Profile | Research | Community
Overview | Detailed Quote | Charting | Options | Historical Prices
Price And Volume VIEW DETAILED QUOTE
Compare to: None

Today's Open	338.17
Bid (Size)	332.85 (500)
Ask (Size)	333.10 (400)
Prev. Close	338.04
Today's Range	331.90 - 338.22
52wk Range	235.56 - 364.90
Shares Outstanding	924,754,561

Morningstar Profile VIEW FULL PROFILE
Apple, Inc.
Apple Inc. designs, manufactures, and markets personal

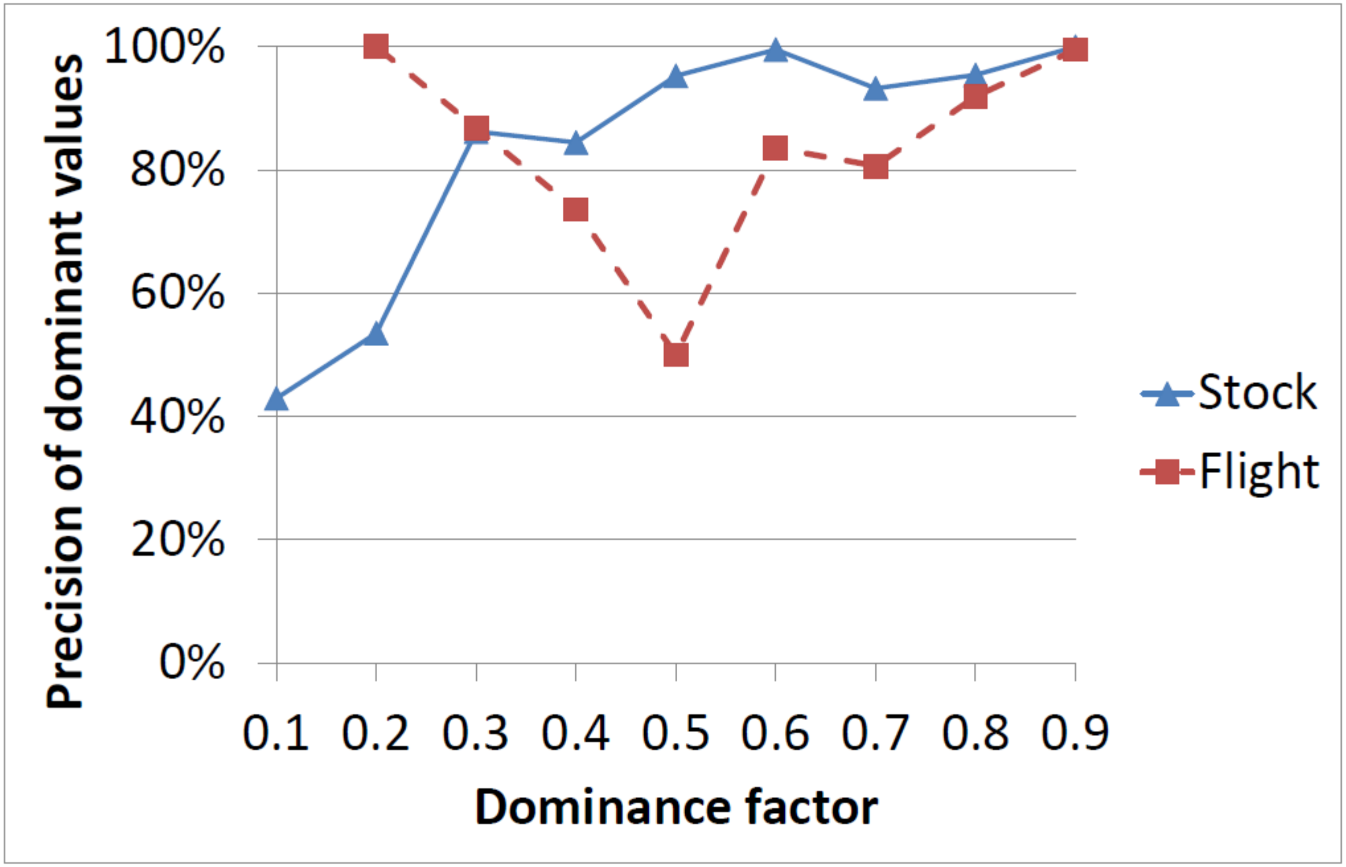
Q4-2. Is Copying or Data Sharing Mainly on Accurate Data? ✘



	Remarks	Size	Schema sim	Object sim	Value sim	Avg accu
Stock	Depen claimed	11	1	.99	.99	.92
	Depen claimed	2	1	1	.99	.75
Flight	Depen claimed	5	0.80	1	1	.71
	Query redirection	4	0.83	1	1	.53
	Dependence claimed	3	1	1	1	.92
	Embedded interface	2	1	1	1	.93
	Embedded interface	2	1	1	1	.61

HOW TO RESOLVE INCONSISTENCY (*DATA FUSION*)?

Basic Solution: Voting



- ❑Only 70% correct values are provided by over half of the sources
  - ❑ .908 voting precision for Stock; i.e., wrong values for 1500 data items
  - ❑ .864 voting precision for Flight; i.e., wrong values for 1000 data items

Improvement I. Using Source Accuracy

	S1	S2	S3
Flight 1	7:02PM	6:40PM	7:02PM
Flight 2	5:43PM	5:43PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM

Improvement I. Using Source Accuracy

	S1	S2	S3
Flight 1	7:02PM	6:40PM	7:02PM
Flight 2	5:43PM	5:43PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM

Higher accuracy;
More trustable

Naïve voting obtains an accuracy of 80%

Improvement I. Using Source Accuracy

	S1	S2	S3
Flight 1	7:02PM	6:40PM	7:02PM
Flight 2	5:43PM	5:43PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM

Higher accuracy;
More trustable

Challenges:

1. How to decide source accuracy?
2. How to leverage accuracy in voting?

Considering accuracy obtains an accuracy of 100%

Source Accuracy: Bayesian Analysis

- Goal: $\Pr(v_i(D) \text{ true} \mid \Phi_D(\mathbf{S}))$, for each D, $v_i(D)$

- According to Bayes Rule, we need to know
  - $\Pr(\Phi_D(\mathbf{S}) \mid v_i(D) \text{ true})$, $\Pr(v_i(D) \text{ true})$, for each $v_i(D)$
- $\Pr(\Phi_D(\mathbf{S}) \mid v_i(D) \text{ true})$ can be computed as:
  - $\prod_{S \in \mathbf{S}(v_i(D))}(A(S)) * \prod_{S \in \mathbf{S} \setminus \mathbf{S}(v_i(D))}((1 - A(S))/n)$
- $\Pr(v_i(D) \text{ true} \mid \Phi_D(\mathbf{S})) = e^{Conf(v_i(D))}/(\sum_{v_0(D)} e^{Conf(v_0(D))})$
  - $Conf(v_i(D)) = \sum_{S \in \mathbf{S}(v_i(D))} \ln(nA(S)/(1 - A(S)))$

- $A(S) = \text{Avg}_{\ v_i(D) \in S} \Pr(v_i(D) \text{ true} \mid \Phi_D(\mathbf{S}))$

Computing Source Accuracy

- Source accuracy A(S)

$$A(S) = \text{Avg}_{v_i(D) \in S} \Pr(v_i(D) \text{ true} \mid \Phi)$$

  - $v_i(D) \in S$: S provides value v_i on data item D
  - Φ : observations on all data items by sources **S**
  - $\Pr(v_i(D) \text{ true} \mid \Phi)$: probability of $v_i(D)$ being true

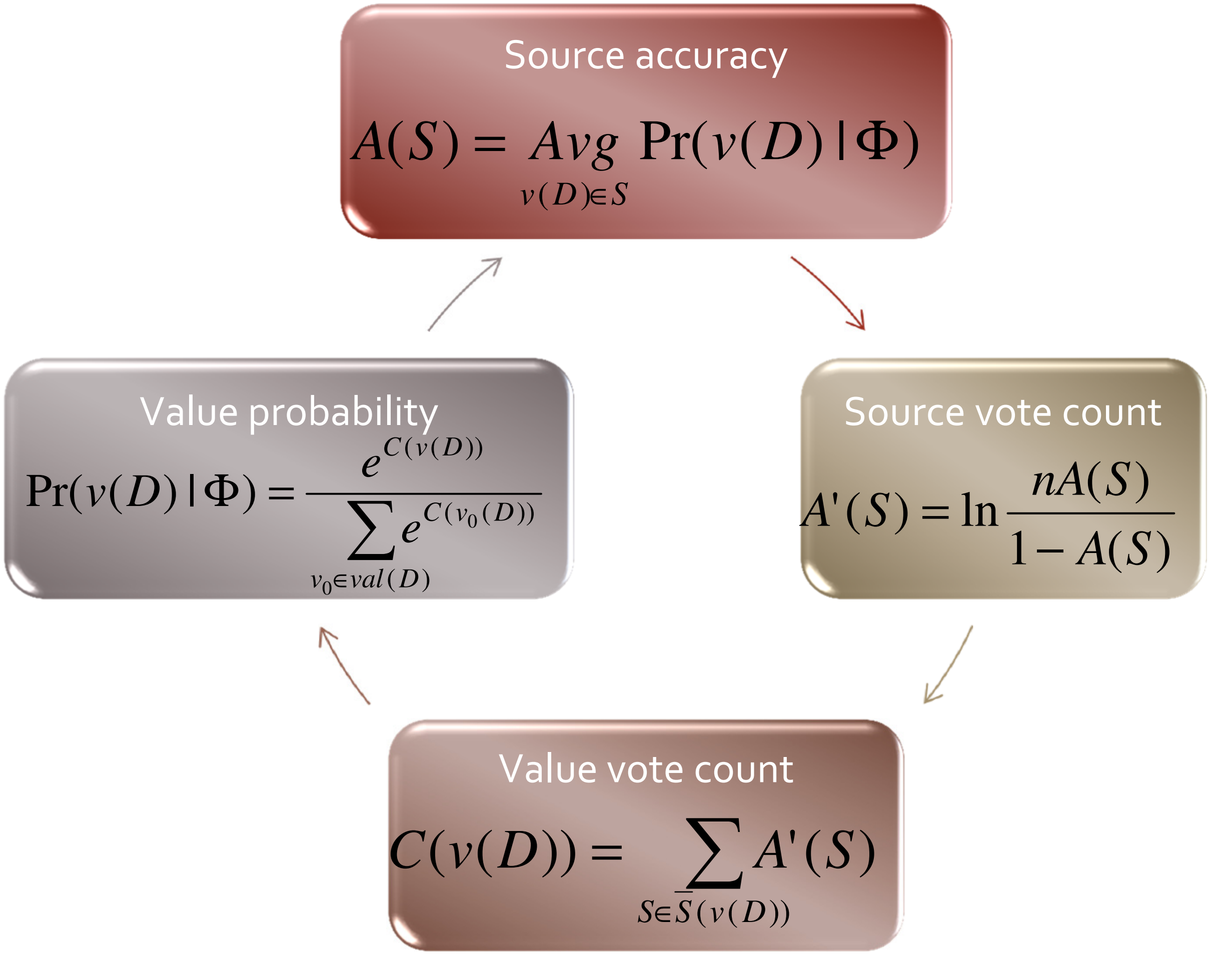
How to compute $\Pr(v_i(D) \text{ true} \mid \Phi)$?

Using Source Accuracy in Data Fusion

- ❑Input: data item D, val(D) = $\{v_0, v_1, \ldots, v_n\}$, Φ
- ❑Output: Pr(v_i(D) true | Φ), for i=0,…, n (sum=1)
- ❑Based on Bayes Rule, need Pr(Φ | v_i(D) true)
- ❑Under independence, need Pr(Φ_D(S)|v_i(D) true)
  - ❑If S provides v_i : Pr(Φ_D(S) |v_i(D) true) = A(S)
  - ❑If S does not : Pr(Φ_D(S) |v_i(D) true) =(1-A(S))/n

Challenge: How to handle inter-dependence between source accuracy and value probability?

Data Fusion Using Source Accuracy



Source accuracy

$$A(S) = \underset{v(D)\in S}{Avg} \Pr(v(D) \mid \Phi)$$

Source vote count

$$A'(S) = \ln \frac{nA(S)}{1 - A(S)}$$

Value vote count

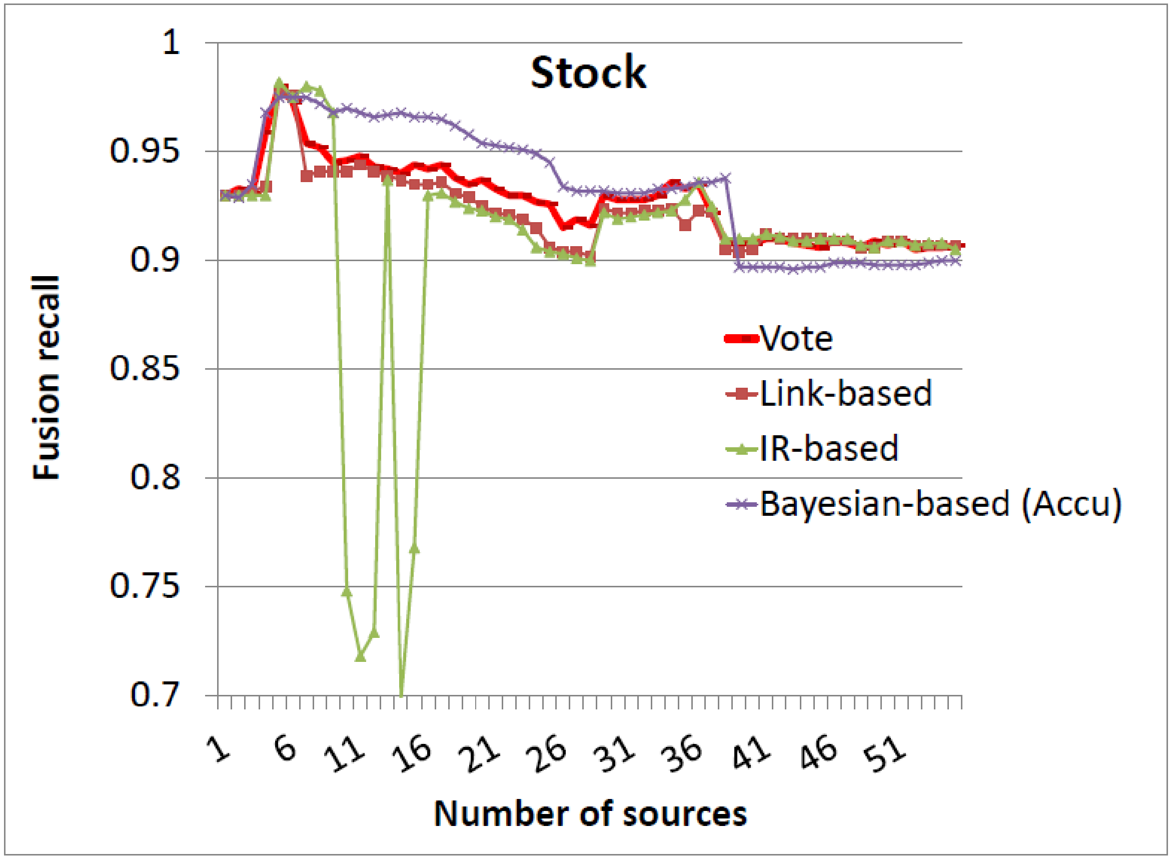
$$C(v(D)) = \sum_{S \in \bar{S}(v(D))} A'(S)$$

Value probability

$$\Pr(v(D) \mid \Phi) = \frac{e^{C(v(D))}}{\sum_{v_0 \in val(D)} e^{C(v_0(D))}}$$

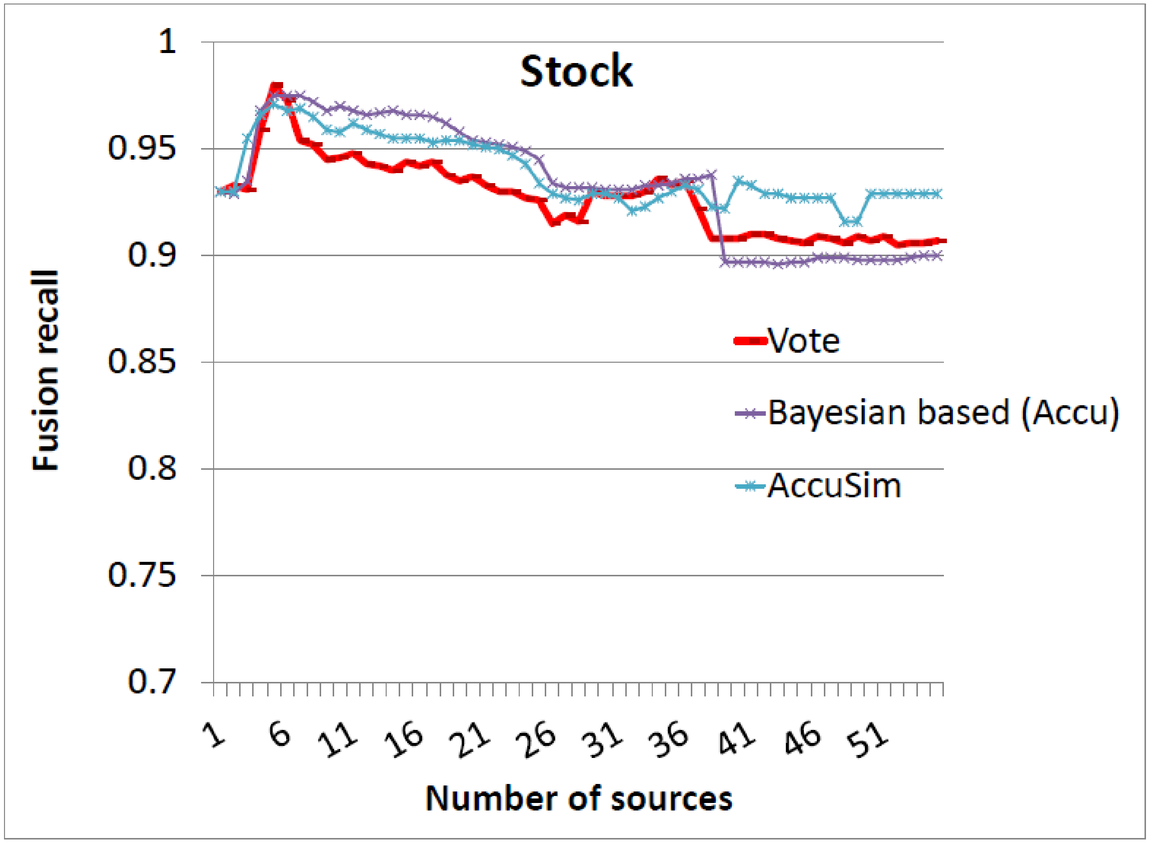
- ❑Continue until source accuracy converges

Results on Stock Data (I)



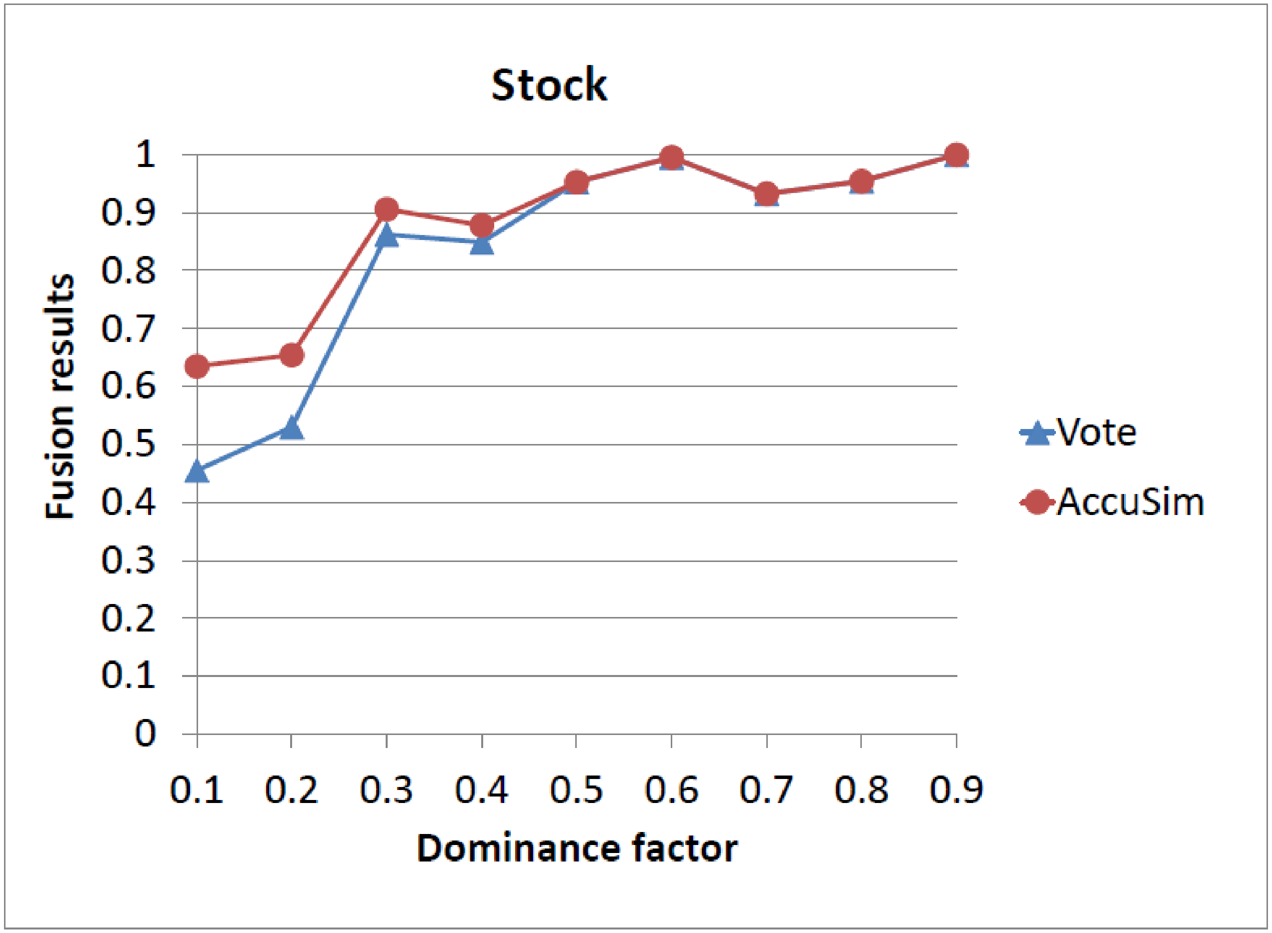
- ❑Sources ordered by recall (coverage * accuracy)
- ❑Among various methods, the Bayesian-based method (Accu) performs best at the beginning, but in the end obtains a final precision (=recall) of .900, worse than Vote (.908)

Results on Stock Data (II)

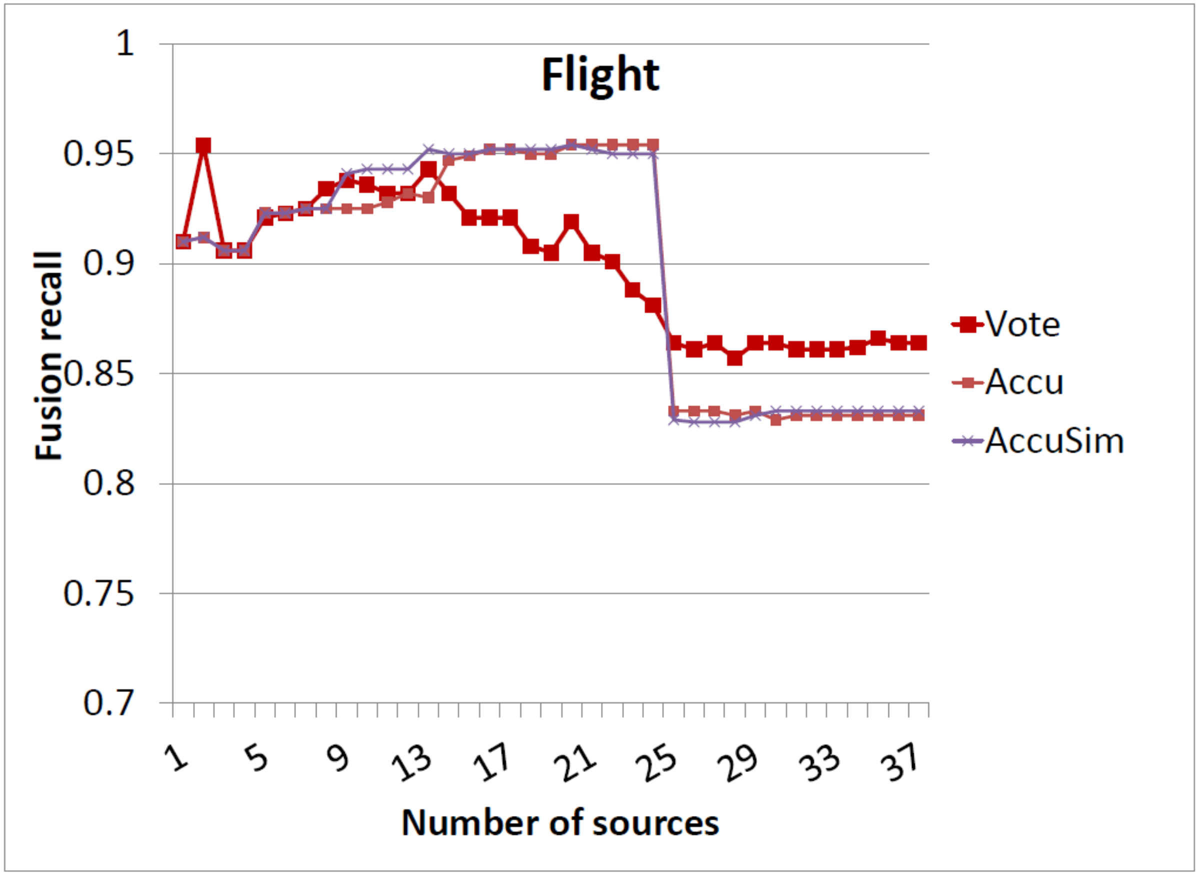


- ❑AccuSim obtains a final precision of .929, higher than Vote and any other method (around .908)
  - ❑ This translates to 350 more correct values

Results on Stock Data (III)



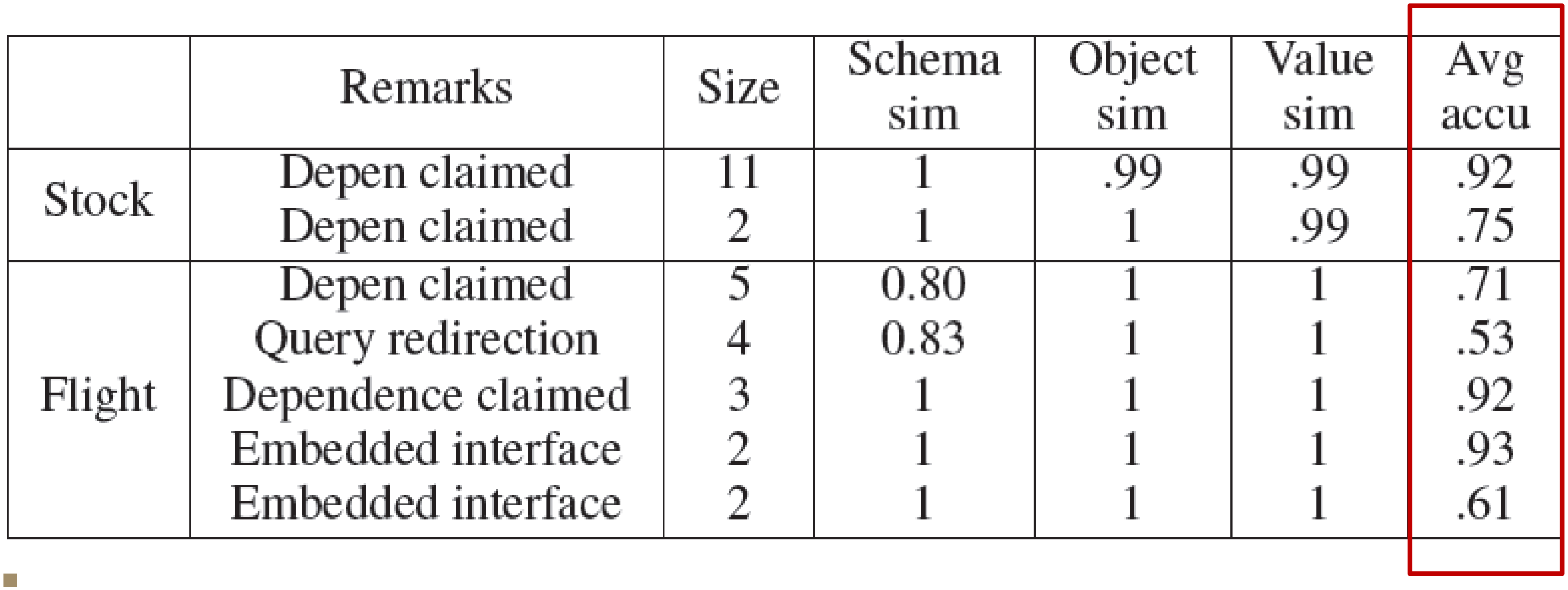
Results on Flight Data



❑Accu/AccuSim obtain final precision of .831/.833, both lower than Vote (.857)

❑WHY??? What is that magic source?

Copying on Erroneous Data



	Remarks	Size	Schema sim	Object sim	Value sim	Avg accu
Stock	Depen claimed	11	1	.99	.99	.92
	Depen claimed	2	1	1	.99	.75
Flight	Depen claimed	5	0.80	1	1	.71
	Query redirection	4	0.83	1	1	.53
	Dependence claimed	3	1	1	1	.92
	Embedded interface	2	1	1	1	.93
	Embedded interface	2	1	1	1	.61

Copying on Erroneous Data

	S1	S2	S3	S4	S5
Flight 1	7:02PM	6:40PM	7:02PM	7:02PM	8:02PM
Flight 2	5:43PM	5:43PM	5:50PM	5:50PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM	8:33PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM	6:22PM	6:22PM

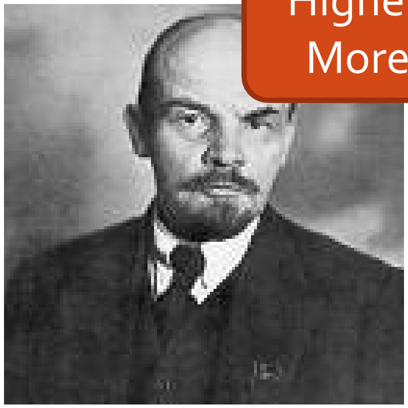
A lie told often enough becomes the truth.
—*Vladimir Lenin*

Copying on Erroneous Data

	S1	S2	S3	S4	S5
Flight 1	7:02PM	6:40PM	7:02PM	7:02PM	8:02PM
Flight 2	5:43PM	5:43PM	5:50PM	5:50PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM	8:33PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM	6:22PM	[illegible]PM

Higher accuracy;
More trustable

A lie told often enough becomes the truth.
—*Vladimir Lenin*



Considering source accuracy can be worse when there is copying

Improvement II. Ignoring Copied Data

	S1	S2	S3	S4	S5
Flight 1	7:02PM	6:40PM	7:02PM	7:02PM	8:02PM
Flight 2	5:43PM	5:43PM	5:50PM	5:50PM	5:50PM
Flight 3	9:20AM	9:20AM	9:20AM	9:20AM	9:20AM
Flight 4	9:40PM	9:52PM	8:33PM	8:33PM	8:33PM
Flight 5	6:15PM	6:15PM	6:22PM	6:22PM	6:22PM

Challenges:

1. How to detect copying?
2. How to leverage copying in voting?

It is important to detect copying and ignore copied values in fusion

Copying?

Are Source 1 and Source 2 dependent? Not necessarily

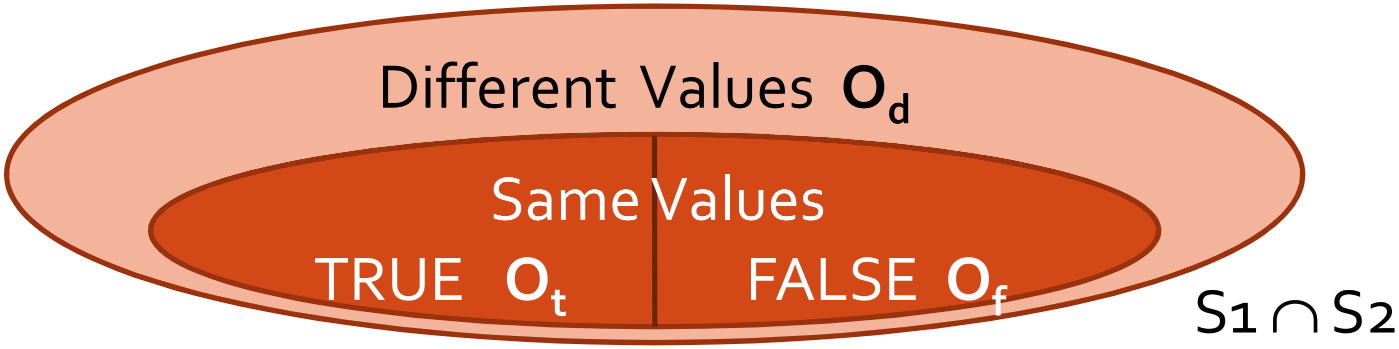
Source 1 on USA Presidents:	Source 2 on USA Presidents:	
1st : George Washington	1st : George Washington	✓
2nd : John Adams	2nd : John Adams	✓
3rd : Thomas Jefferson	3rd : Thomas Jefferson	✓
4th : James Madison	4th : James Madison	✓
…	…	
41st : George H.W. Bush	41st : George H.W. Bush	✓
42nd : William J. Clinton	42nd : William J. Clinton	✓
43rd : George W. Bush	43rd : George W. Bush	✓
44th: Barack Obama	44th: Barack Obama	✓

Copying? — Common Errors

Are Source 1 and Source 2 dependent? Very likely

Source 1 on USA Presidents:	Source 2 on USA Presidents:	
1st : George Washington	1st : George Washington	✓
2nd : Benjamin Franklin	2nd : Benjamin Franklin	✗
3rd : John F. Kennedy	3rd : John F. Kennedy	✗
4th : Abraham Lincoln	4th : Abraham Lincoln	✗
…	…	
41st : George W. Bush	41st : George W. Bush	✗
42nd : Hillary Clinton	42nd : Hillary Clinton	✗
43rd : Dick Cheney	43rd : Dick Cheney	✗
44th: Barack Obama	44th: John McCain	

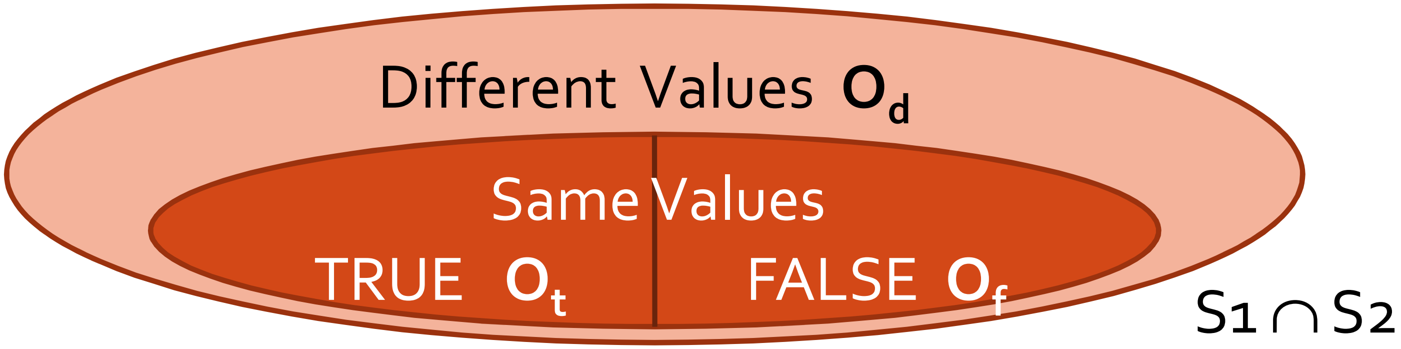
Copying Detection: Bayesian Analysis



- ❑Goal: Pr(S1⊥S2| Φ), Pr(S1~S2| Φ) (sum = 1)

- ❑According to Bayes Rule, we need to know
  - ❑Pr(Φ|S1⊥S2), Pr(Φ|S1~S2)
- ❑Key: compute Pr(Φ_D|S1⊥S2), Pr(Φ_D|S1~S2)
  - ❑For each D ∈ S1 ∩ S2

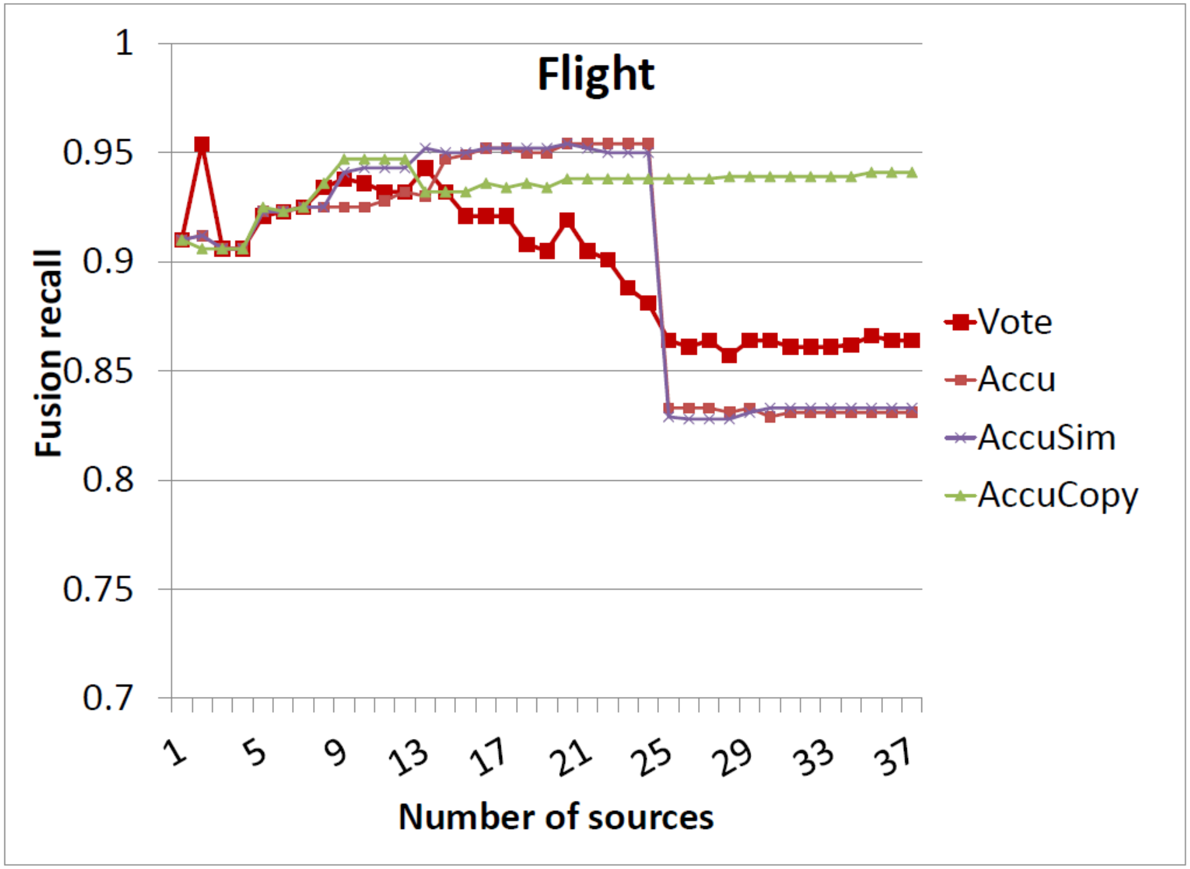
Copying Detection: Bayesian Analysis



Pr	Independence		Copying
O_t	A^2	$<$	$A \bullet c + A^2(1-c)$
O_f	$\frac{(1-A)^2}{n}$	$\ll$	$(1-A) \bullet c + \frac{(1-A)^2}{n}(1-c)$
O_d	$P_d = 1 - A^2 - \frac{(1-A)^2}{n}$	$>$	$P_d(1-c)$

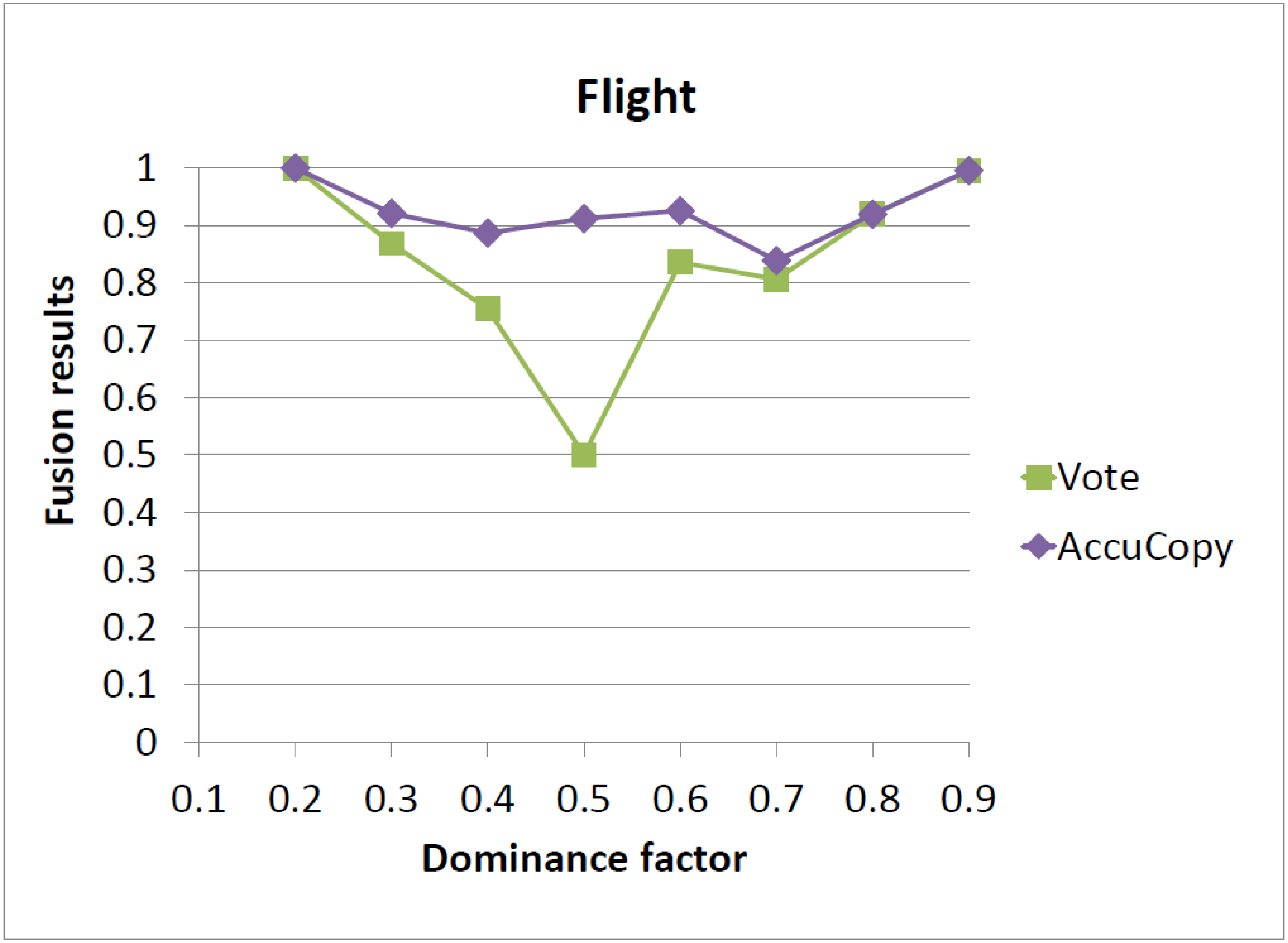
A-source accuracy; n-#wrong-values; c-copy rate

Results on Flight Data



- ❑AccuCopy obtains a final precision of .943, much higher than Vote (.864)
  - ❑ This translates to 570 more correct values

Results on Flight Data (II)

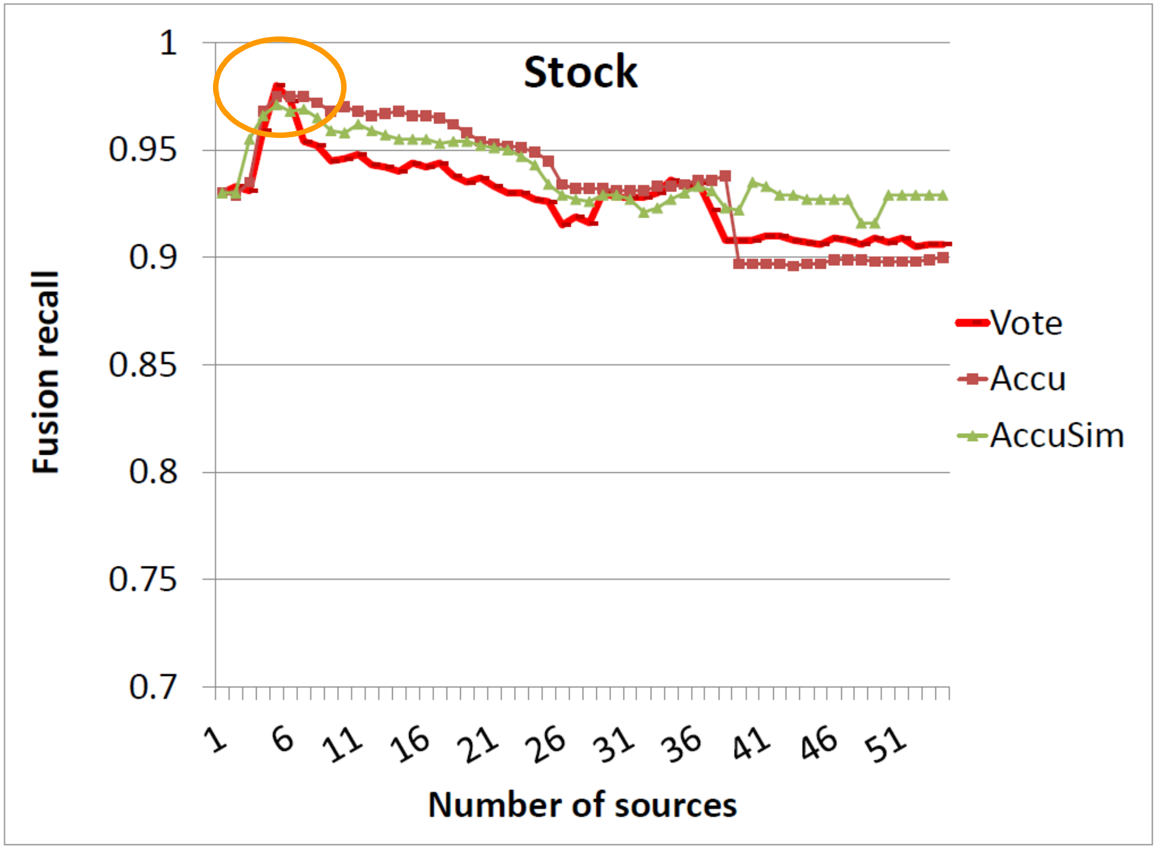


Take-Aways

- Deep Web data is not fully trustable
  - Deep Web sources have different accuracies
  - Copying is common

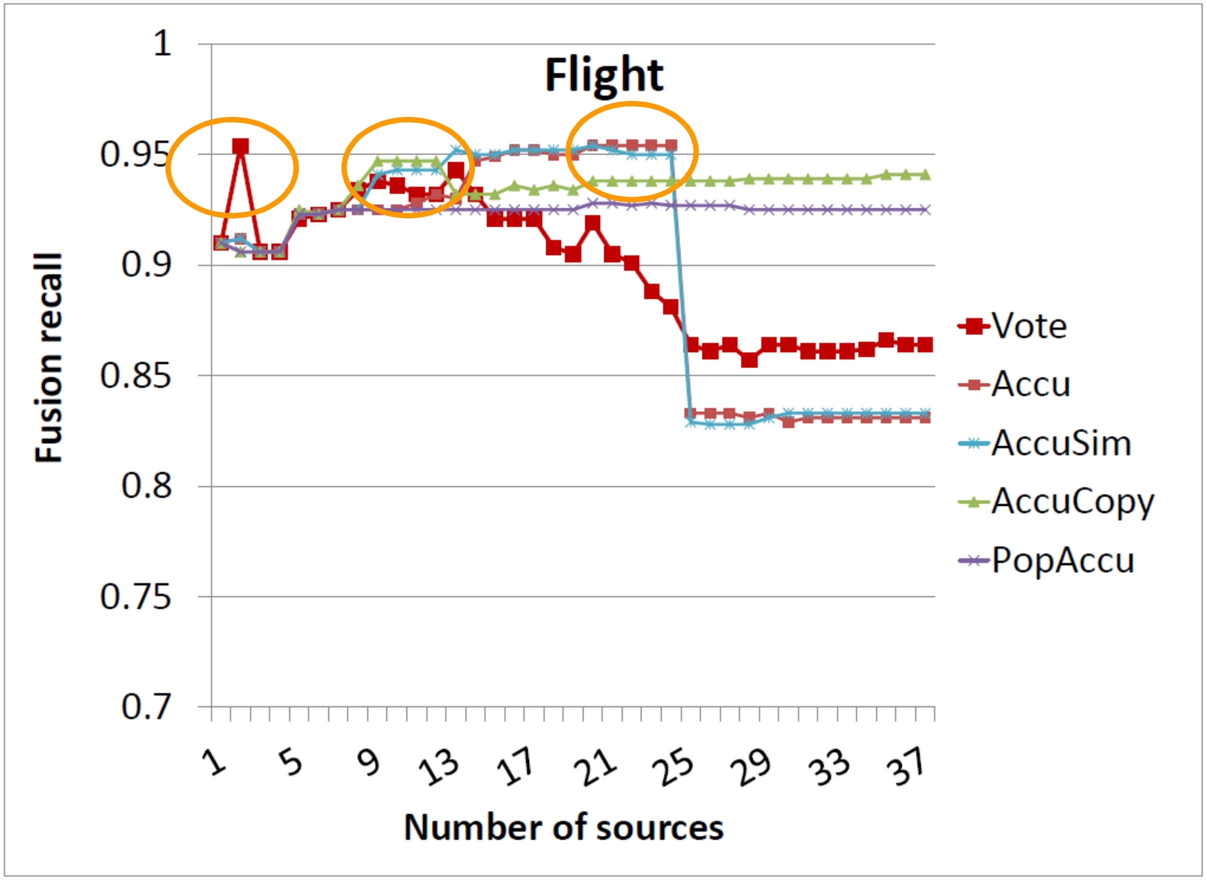
- Truth finding on the Deep Web can leverage
  - source accuracy
  - copying relationships, and
  - value similarity

Important Direction: Source Selection



- ❑Peaks happen before integrating all sources
- ❑How to find the best set of sources while balancing quality gain and integration cost?

Important Direction: Source Selection



❑Peaks happen before integrating all sources

❑How to find the best set of sources while balancing quality gain and integration cost?

Acknowledgements

- Joint work with:
  - Xin Luna Dong (Google Inc.)
  - Yifan Hu, Ken Lyons (AT&T)
  - Laure Berti-Equille (IRD)
  - Xian Li, Weiyi Meng (SUNY-Binghamton)
- Selected research papers:
  - Truth Finding on the Deep Web: Is the Problem Solved? PVLDB 2013
  - Global detection of complex copying relationships between sources. PVLDB 2010.
  - Integrating conflicting data: the role of source dependence. PVLDB 2009.

THANK YOU