

Principles Of Information Visualization

What is information visualization

Tufte's guidelines

Visual variables for representing information

The principle of small multiples for displaying information

How metaphors can be used and misused

Direct manipulation and direct engagement

James Tam

Representations

Good representations

- Captures essential elements of the event / world
- Deliberately leaves out / mutes the irrelevant
- Appropriate for the person and their interpretation
- Appropriate for the task, enhancing judgment ability

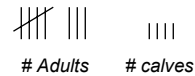
How many buffalo?



Buffalo



Buffalo

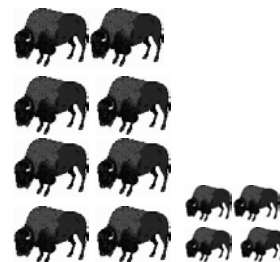


Adults

calves

8

4



James Tam

Representation

A representation is

- A formal system or mapping by which the information can be specified (D. Marr)
- A sign system in that it stands for something other than its self (unknown source)
- A method of encoding information (my description)

For example: the number thirty-four *or* the buffalo example

Decimal: 34, (the most familiar number base)
Binary: 100010, (most closely parallels machine architecture)
Roman: XXXIV (counting)

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Presentation

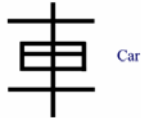
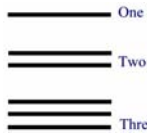
Not the same as representation!

The presentation of information deals with how the representation is placed or organized on the screen

5, 5,
IV, IV

James Tam

Chinese...Sort Of



This method of representation makes it easier to remember the symbols

James Tam

Characteristics Of Good Representations

1. The representation makes it easier to find the relevant information.

- Solving a problem simply means representing it so as to make the solution transparent ... (*Simon, 1981*)

2. (Once the information has been found) good representations makes it easier to make use of the information.

- Allow people to *compute* desired conclusions
- Trying to make use of the information may be a difficult process or “for free” depending on the representation chosen

James Tam

Representations: The Information Is Present But Hard To Find

Symbol	Company	Price	Change	Volume	High	Low	Close	Open
100	Apple	170.00	+0.50	1,200,000	170.50	169.50	170.00	169.50
100	Microsoft	120.00	+1.00	800,000	121.00	119.00	120.00	119.50
100	Amazon	300.00	+2.00	500,000	302.00	298.00	300.00	299.00
100	Google	250.00	+1.50	700,000	251.50	248.50	250.00	249.50
100	Facebook	180.00	+0.80	600,000	180.80	179.20	180.00	179.50
100	Twitter	50.00	+0.50	400,000	50.50	49.50	50.00	49.80
100	LinkedIn	200.00	+1.00	300,000	201.00	199.00	200.00	199.50
100	Slack	150.00	+0.80	200,000	150.80	149.20	150.00	149.50
100	Zoom	100.00	+1.20	1,500,000	101.20	99.80	100.00	99.50
100	Dropbox	80.00	+0.40	1,000,000	80.40	79.60	80.00	79.80
100	Box	60.00	+0.30	800,000	60.30	59.70	60.00	59.80
100	Atlassian	400.00	+2.00	100,000	402.00	398.00	400.00	399.00
100	Okta	300.00	+1.50	150,000	301.50	298.50	300.00	299.50
100	Auth0	200.00	+1.00	100,000	201.00	199.00	200.00	199.50
100	Twilio	150.00	+0.80	700,000	150.80	149.20	150.00	149.50
100	SendGrid	100.00	+0.50	500,000	100.50	99.50	100.00	99.80
100	MailChimp	80.00	+0.40	400,000	80.40	79.60	80.00	79.80
100	HubSpot	120.00	+0.60	300,000	120.60	119.40	120.00	119.80
100	Marketo	90.00	+0.45	200,000	90.45	89.55	90.00	89.75
100	Pardot	70.00	+0.35	150,000	70.35	69.65	70.00	69.85
100	Eloqua	60.00	+0.30	100,000	60.30	59.70	60.00	59.80
100	Braze	50.00	+0.25	80,000	50.25	49.75	50.00	49.85
100	Iterable	40.00	+0.20	60,000	40.20	39.80	40.00	39.90
100	Optimizely	30.00	+0.15	40,000	30.15	29.85	30.00	29.95
100	Unbounce	20.00	+0.10	30,000	20.10	19.90	20.00	19.95
100	Leadpages	15.00	+0.08	20,000	15.08	14.92	15.00	14.95
100	ClickFunnels	10.00	+0.05	15,000	10.05	9.95	10.00	9.98
100	SumoMe	8.00	+0.04	10,000	8.04	7.96	8.00	7.98
100	ConvertKit	6.00	+0.03	8,000	6.03	5.97	6.00	5.99
100	Mailmodo	5.00	+0.02	6,000	5.02	4.98	5.00	4.99
100	GetResponse	4.00	+0.02	5,000	4.02	3.98	4.00	3.99
100	Audible	3.00	+0.01	4,000	3.01	2.99	3.00	2.99
100	Kindle	2.00	+0.01	3,000	2.01	1.99	2.00	1.99
100	Amazon Music	1.50	+0.01	2,000	1.51	1.49	1.50	1.49
100	Amazon Prime	1.00	+0.01	1,500	1.01	0.99	1.00	0.99
100	Amazon Video	0.50	+0.01	1,000	0.51	0.49	0.50	0.49
100	Amazon Kindle	0.25	+0.01	500,000	0.26	0.24	0.25	0.24
100	Amazon Fire	0.10	+0.01	2,000,000	0.11	0.09	0.10	0.09
100	Amazon Echo	0.05	+0.01	3,000,000	0.06	0.04	0.05	0.04
100	Amazon Alexa	0.02	+0.01	4,000,000	0.03	0.01	0.02	0.01
100	Amazon Web Services	0.01	+0.01	5,000,000	0.02	0.00	0.01	0.00
100	Amazon S3	0.005	+0.01	6,000,000	0.006	0.004	0.005	0.004
100	Amazon EC2	0.002	+0.01	7,000,000	0.003	0.001	0.002	0.001
100	Amazon Lambda	0.001	+0.01	8,000,000	0.002	0.000	0.001	0.000
100	Amazon IAM	0.0005	+0.01	9,000,000	0.0006	0.0004	0.0005	0.0004
100	Amazon CloudFront	0.0002	+0.01	10,000,000	0.0003	0.0001	0.0002	0.0001
100	Amazon CloudWatch	0.0001	+0.01	11,000,000	0.0002	0.0000	0.0001	0.0000
100	Amazon ElastiCache	0.00005	+0.01	12,000,000	0.00006	0.00004	0.00005	0.00004
100	Amazon EMR	0.00002	+0.01	13,000,000	0.00003	0.00001	0.00002	0.00001
100	Amazon Redshift	0.00001	+0.01	14,000,000	0.00002	0.00000	0.00001	0.00000
100	Amazon Athena	0.000005	+0.01	15,000,000	0.000006	0.000004	0.000005	0.000004
100	Amazon Kinesis	0.000002	+0.01	16,000,000	0.000003	0.000001	0.000002	0.000001
100	Amazon Kinesis Data Analytics	0.000001	+0.01	17,000,000	0.000002	0.000000	0.000001	0.000000
100	Amazon Kinesis Data Firehose	0.0000005	+0.01	18,000,000	0.0000006	0.0000004	0.0000005	0.0000004
100	Amazon Kinesis Data Streams	0.0000002	+0.01	19,000,000	0.0000003	0.0000001	0.0000002	0.0000001
100	Amazon Kinesis Data Retention	0.0000001	+0.01	20,000,000	0.0000002	0.0000000	0.0000001	0.0000000
100	Amazon Kinesis Data Analytics on Amazon EMR	0.00000005	+0.01	21,000,000	0.00000006	0.00000004	0.00000005	0.00000004
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless	0.00000002	+0.01	22,000,000	0.00000003	0.00000001	0.00000002	0.00000001
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on AWS Glue	0.00000001	+0.01	23,000,000	0.00000002	0.00000000	0.00000001	0.00000000
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker	0.000000005	+0.01	24,000,000	0.000000006	0.000000004	0.000000005	0.000000004
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio	0.000000002	+0.01	25,000,000	0.000000003	0.000000001	0.000000002	0.000000001
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio Classic	0.000000001	+0.01	26,000,000	0.000000002	0.000000000	0.000000001	0.000000000
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio Classic on Amazon SageMaker	0.0000000005	+0.01	27,000,000	0.0000000006	0.0000000004	0.0000000005	0.0000000004
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio Classic on Amazon SageMaker Studio Classic	0.0000000002	+0.01	28,000,000	0.0000000003	0.0000000001	0.0000000002	0.0000000001
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio Classic on Amazon SageMaker Studio Classic on Amazon SageMaker	0.0000000001	+0.01	29,000,000	0.0000000002	0.0000000000	0.0000000001	0.0000000000
100	Amazon Kinesis Data Analytics on Amazon EMR Serverless on Amazon SageMaker Studio Classic on Amazon SageMaker Studio Classic on Amazon SageMaker Studio Classic	0.00000000005	+0.01	30,000,000	0.00000000006	0.00000000004	0.00000000005	0.00000000004

James Tam

Representations: The Information Is Present But Making Sense Of It Requires Much Effort

Quarterly Income Statements		in millions, except earnings per share								
		Q2-01*	Q3-01*	Q4-01*	Q1-02	Q2-02	Q3-02	Q4-02	Q1-03	€
Revenue		\$ 6,550	\$ 6,403	\$ 6,577	\$ 6,126	\$ 7,741	\$ 7,245	\$ 7,253	\$ 7,746	\$
Operating expenses:										
Cost of revenue		864	899	867	978	1,691	1,567	1,463	1,344	
Research and development		990	1,069	1,364	1,398	1,595	1,474	1,832	1,707	
Acquired in-process technology										
Sales and marketing		1,290	1,198	1,359	1,457	1,676	1,449	1,670	1,415	
General and administrative		212	239	236	286	885	343	329	252	
Other expenses										
Total operating expenses		3,356	3,405	3,826	4,119	5,847	4,833	5,294	4,718	
Operating income		3,194	2,998	2,751	2,007	1,894	2,412	1,959	3,028	
Losses on equity investees and other		(28)	(46)	(33)	(30)	(37)	(11)	(14)	(22)	
Investment income		751	706	(2,620)	(980)	553	739	(617)	41	
Noncontinuing items										
Income before income taxes		3,917	3,658	98	997	2,410	3,140	1,328	3,047	
Provision for income taxes		1,293	1,207	33	319	771	1,005	425	1,006	
Income before accounting change		2,624	2,451	65	678	1,639	2,135	903	2,041	
Accumulative effect of accounting change		-	-	-	-	-	-	-	-	
Net income		\$ 2,624	\$ 2,451	\$ 65	\$ 678	\$ 1,639	\$ 2,135	\$ 903	\$ 2,041	\$
Preferred stock dividends										
Net income available for common shareholders		\$ 2,624	\$ 2,451	\$ 65	\$ 678	\$ 1,639	\$ 2,135	\$ 903	\$ 2,041	\$
Basic EPS before accounting change		\$0.25	\$0.23	\$0.01	\$0.06	\$0.15	\$0.20	\$0.08	\$0.19	
Diluted EPS before accounting change		\$0.24	\$0.22	\$0.01	\$0.06	\$0.15	\$0.19	\$0.08	\$0.19	

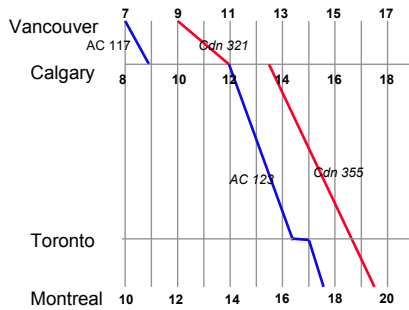
James Tam

Example One: Which Is The Best Flight?

Length, stop-overs, switches...

		<i>Depart</i>	<i>Arrive</i>
AC 117	Vancouver - Calgary	7:00	9:00
Cdn 321	Vancouver - Calgary	9:00	12:00
Cdn 355	Calgary - Montreal	13:30	19:30
AC 123	Calgary - Toronto	12:30	16:30
AC 123	Toronto - Montreal	16:45	17:30

*time zone: +1 van-cal, +2 cal-tor, mtl



James Tam

Example Two: When Do I Take My Drugs? (From “Things That Make Us Smart” By Don Norman)

Note: 10 - 30% error rate in taking pills, same for pillbox organizers

- Inderal - 1 tablet 3 times a day
- Lanoxin - 1 tablet every a.m.
- Carafate - 1 tablet before meals and at bedtime
- Zantac - 1 tablet every 12 hours (twice a day)
- Quinag - 1 tablet 4 times a day
- Couma - 1 tablet a day

	Breakfast	Lunch	Dinner	Bedtime		Breakfast	Lunch	Dinner	Bedtime
Lanoxin	O				Lanoxin				
Inderal	O	O	O		Inderal	Inderal			
Quinag	O	O	O	O	Quinag	Quinag	Quinag		Quinag
Carafate	O	O	O	O	Carafate	Carafate	Carafate		Carafate
Zantac		O		O	Zantac				Zantac
Couma				O	Couma				Couma

Organized by both time of day and by drug

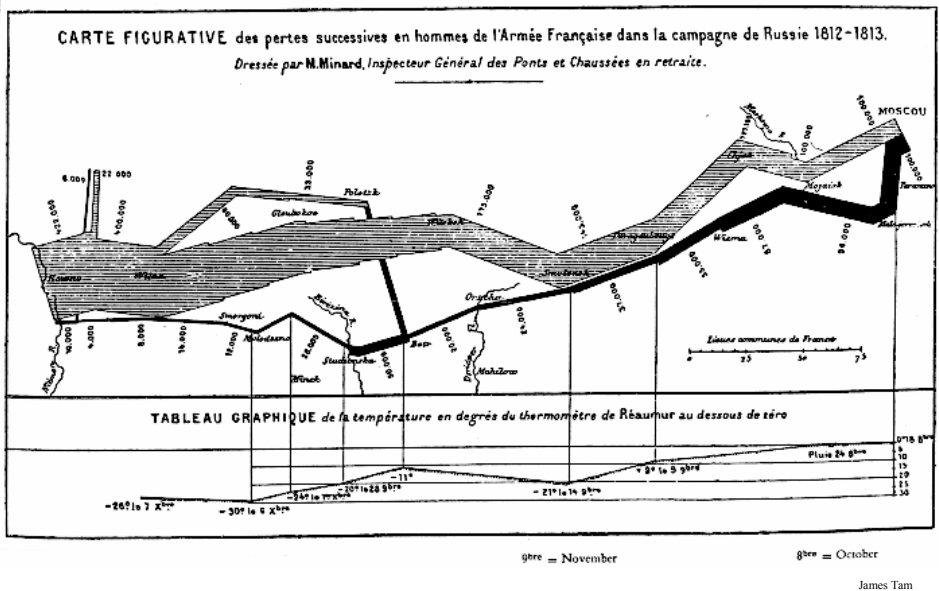
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Example Three: Napoleon's March To Moscow by Charles Minard



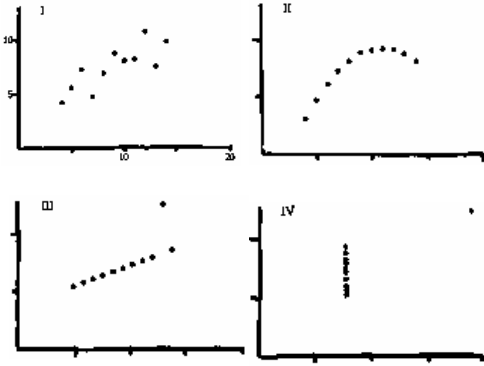
James Tam

Example Three: Napoleon's March To Moscow by Charles Minard



Example Four: Anscombe's Quartet

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.99

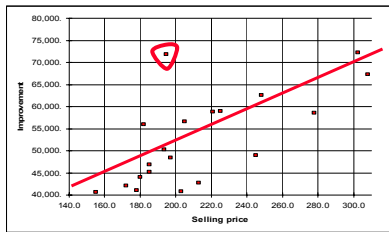
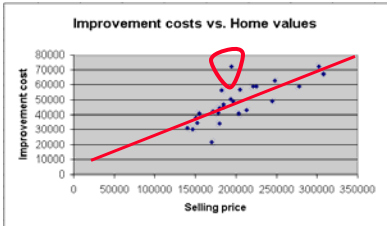


N: 11.0
 mean X's : 9.0
 mean Y's : 7.5
 standard error of slope estimate: 0.1
 sum of squares: 110.0
 regression sum of squares: 27.5
 residual sum of squares of Y: 13.8
 correlation coefficient: 0.8
 r squared: 0.7
 regression line: $Y=3+0.5X$

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Example Five: Do I Deserve A Tax Break

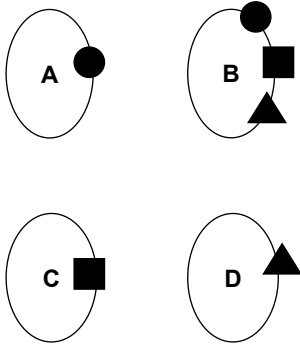
	A	B
1	Market value (\$)	Improvement cost (\$)
2	140000	31120
3	147000	29980
4	151000	38120
5	152000	34360
6	155000	40710
7	170000	21620
8	172000	42100
9	178000	41070
10	180000	34210
11	180000	44090
12	182000	55960
13	185000	45170
14	185000	46820
15	193400	50200
16	194500	71860
17	197000	48460
18	203000	40720
19	205000	56600
20	213000	42780
21	221000	58770
22	225000	58960
23	245000	48910
24	248000	62620
25	278000	58580
26	302500	72200
27	308000	67320



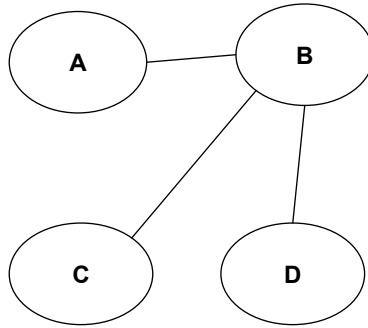
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Not All Diagrammatic Representations Are Equally Effective

First representation



Second representation



From Information Visualization: Perception for Design by Colin Ware.

James Tam

Tufte's Principles Of Information Visualization₁

Graphics should reveal the data

- Show the data
- Not get in the way of the message
- Avoid distortion
- Present many numbers in a small space
- Make large data sets coherent
- Encourage comparison between data
- Supply both a broad overview and fine detail
- Serve a clear purpose

1 "Visual Display of Quantitative Information" by E. Tufte

Note: Some of the visual examples on the following slides are taken from Tufte's books

James Tam

Show The Data



Buffalo

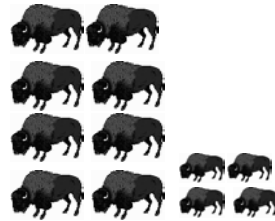


Buffalo



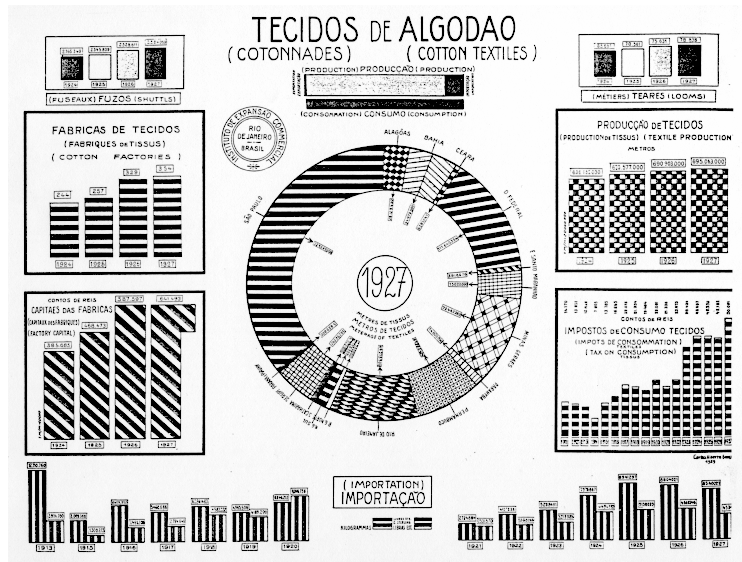
Adults

calves



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Not Get In The Way Of The Message

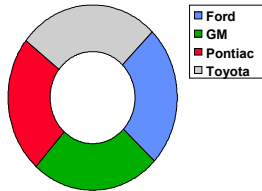
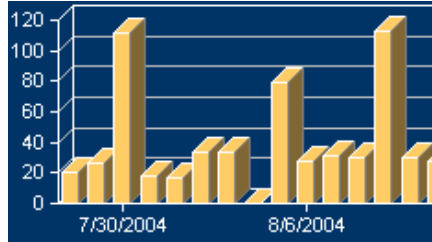
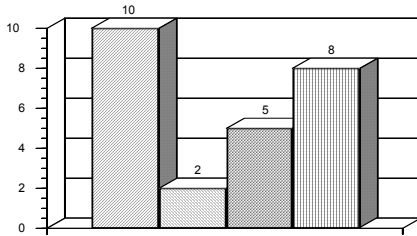


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Chart Junk: A Common Error (The Representation Getting In The Way Of The Message)

Information display is not just pretty graphics

- Graphical re-design by amateurs on computers gives us
 - Overly complicated or even deceptive representations

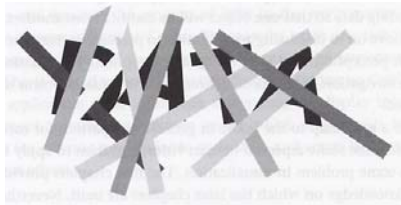


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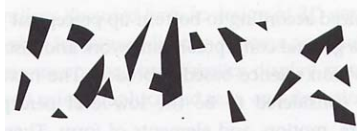
The Representation Should Not Get In The Way Of The Message

But it's not just as simple as removing "irrelevant" information.

Extra clutter?



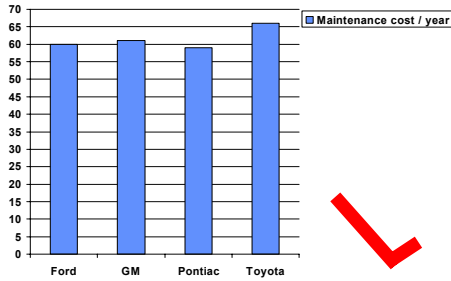
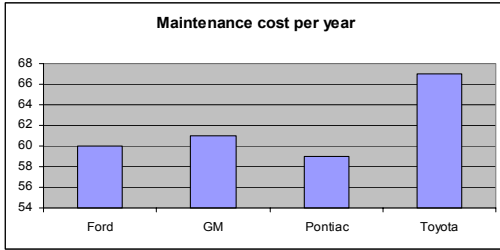
Is the message clearer?



From "Information Visualization: Perception for Design" by Colin Ware

James Tam

Avoid Distortion: The Representation Alters The Message

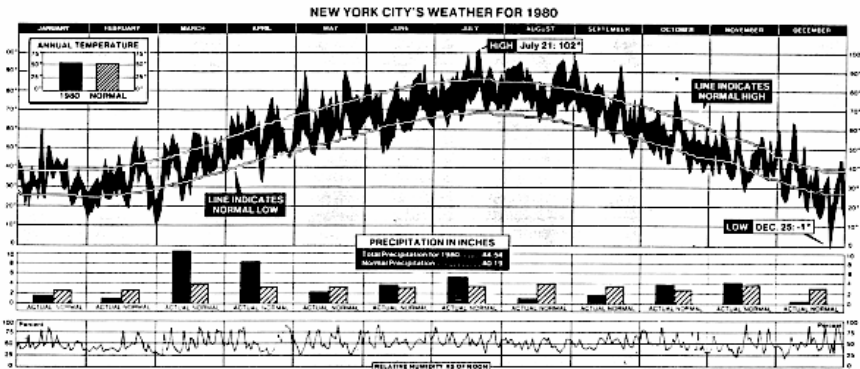


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Present Many Numbers In A Small Space, Make Large Data Sets Coherent

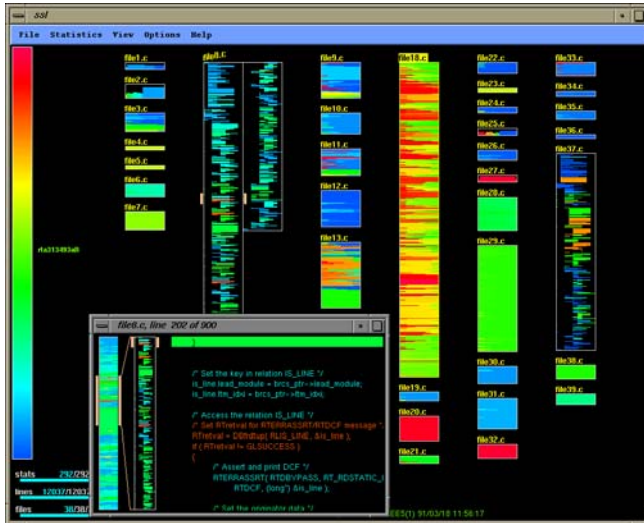
New York Weather History

- 181 numbers/sq inch



James Tam

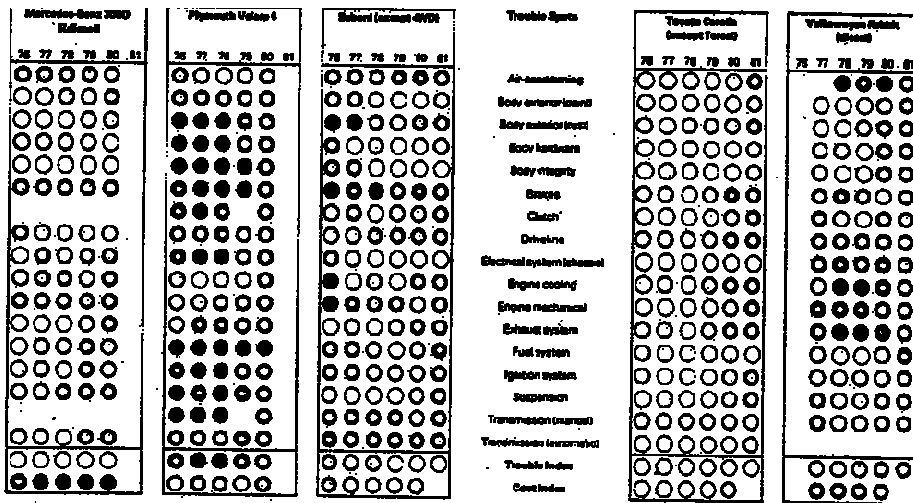
Encourage Comparison Between The Data



1) "Seesoft—A Tool for Visualizing Line Oriented Software Statistics", Eick S.G., Steffen J.L. and Sumner E.E

James Tam

Broad Overview And Fine Detail



James Tam

Applying Visual Representations To A Common Task: Browsing A Large Dataset

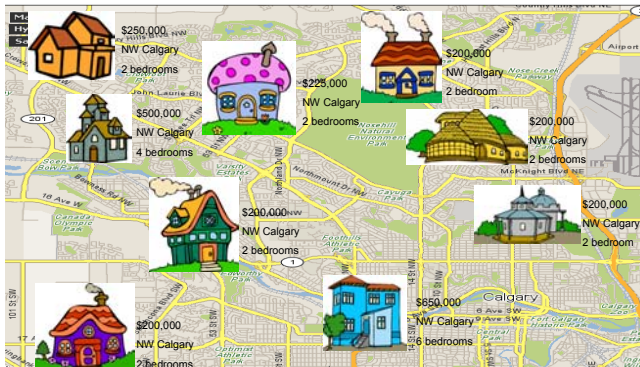
Example: Browsing for a house



James Tam

A Model Of Perceptual Processing¹

- The set of information is large to show all at once.
- Example search results:



- To help assist the person in this type of situation, take advantage of how people process visual information.

¹ From "Information Visualization: Perception for Design" by Colin Ware

James Tam

Stage 1: Parallel Processing To Extract Low Level Properties Of The Visual Scene

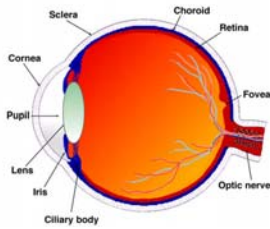
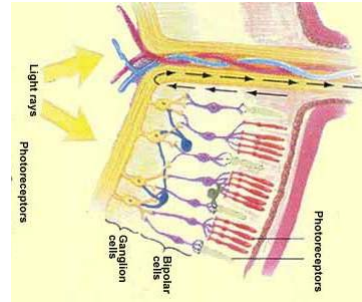


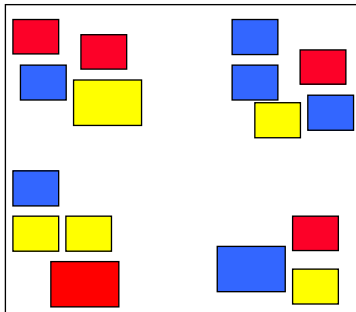
Diagram of the human eye from The John Moran Eye Center



The Brain from top to bottom

James Tam

Stage 1: Parallel Processing To Extract Low Level Properties Of The Visual Scene (2)



A Diagram

- Different properties of diagram are processed by the neurons in the retinal.
- This processing automatically occurs.
- The processing is done in parallel

Color

Size

Position



James Tam



Stage 1: Parallel Processing To Extract Low Level Properties Of The Visual Scene (3)

Characteristics of visual information that can be automatically processed:

1. Processing cannot be inhibited
2. Information is rapidly processed
3. Information can be processed in parallel
4. Can be understood without training

Communicate information by relying on perceptual powers of the brain without learning.

Examples:

- Color 
- Size 
- Many more to come...

James Tam

Applying Stage 1 Processing To The Problem Of Browsing A Large Dataset

Representing information in a manner that can be automatically processed can help the person browse a large data set.

85689726984689762689764358922659865986554897689269898
02462996874026557627986789045679232769285460986772098
90834579802790759047098279085790847729087590827908754
98709856749068975786259845690243790472190790709811450
85689726984689762689764458922659865986554897689269898

Vs.

85689726984689762689764358922659865986554897689269898
02462996874026557627986789045679232769285460986772098
90834579802790759047098279085790847729087590827908754
98709856749068975786259845690243790472190790709811450
85689726984689762689764458922659865986554897689269898

James Tam

Stage 2: Sequential Goal-Directed Processing

The focus now shifts from gathering perceptual information about large quantities of information to getting details about a single object.

At this stage information can be represented in a fashion that requires controlled processing (not automatic).

Characteristics of representations that require controlled processing:

1. Requires conscious effort
2. Slow serial processing
3. Hard to learn
4. Easy to forget
5. Formally powerful

Example of a representation that require controlled processing:

- Written language

James Tam

Automatic Vs. Controlled Processing Of Information



Controlled

For this question you are to write a function that will take as input a string and return an integer value that is the length of the string. The end of the string will always...

Automatic



James Tam

Visual Variables

Position

- Changes in the x, y, z location



Size

- Changes in length, area or repetition



Shape

- Changes in form



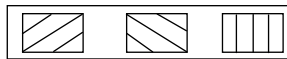
Value

- Changes in brightness



Orientation

- Changes in alignment



Colour

- Changes in hue



James Tam

Visual Variables (2)

Texture

- Variations in pattern



Motion



www.st-duffer.com

James Tam

Visual Variables (3)

Characteristics of visual variables

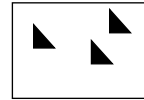
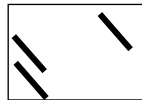
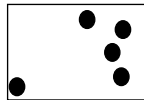
- **Selective**
Is a change in this variable enough to allow us to select it *from a group*?
- **Associative**
Is a change in this variable enough to allow us to perceive them *as a group*?
- **Quantitative**
Is there a numerical reading obtainable from changes in this variable?
- **Order**
Do changes in the visual variable indicate some sort of ranking?
- **Length¹**
Across how many changes in this variable are distinctly perceptible?

¹ Think of it as variation

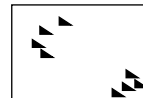
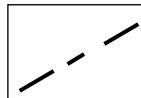
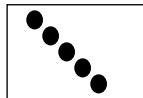
James Tam

Visual Variable: Position

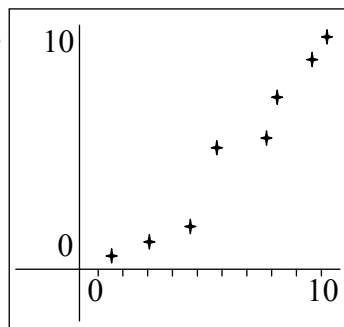
✓ Selective



✓ Associative



✓ Quantitative



✓ Order

✓ Length

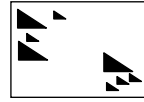
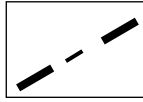
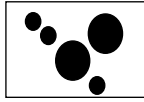
James Tam

Visual Variable: Size

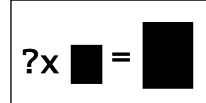
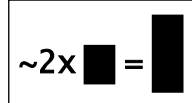
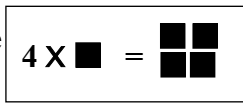
✓ Selective



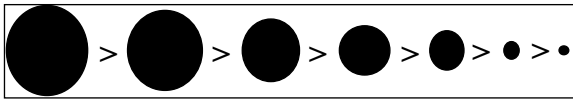
✓ Associative



≈ Quantitative



✓ Order



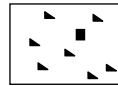
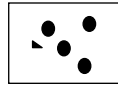
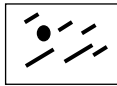
✓ Length

Theoretically infinite but practically limited

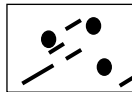
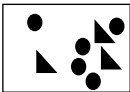
James Tam

Visual Variable: Shape

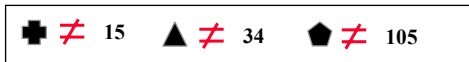
≈ Selective



≈ Associative



≠ Quantitative



≠ Order

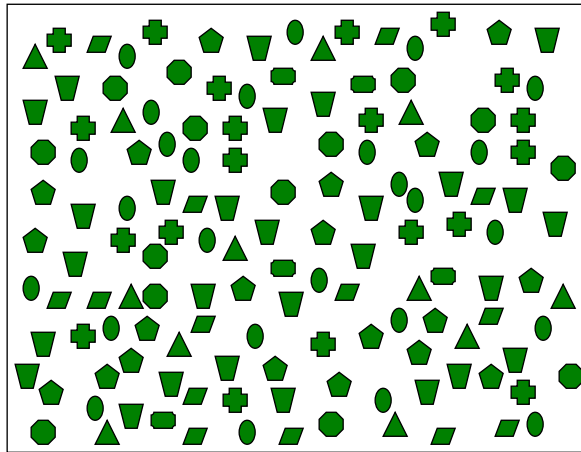


✓ Length



James Tam

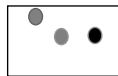
Shape



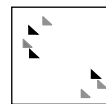
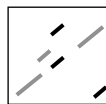
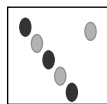
James Tam

Visual Variable: Value

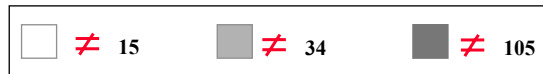
✓ Selective



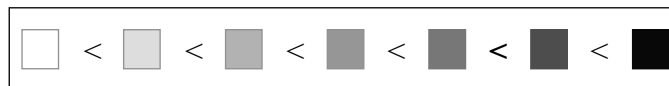
✓ Associative



✗ Quantitative



✓ Order



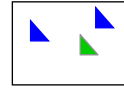
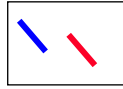
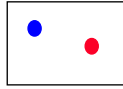
✓ Length

- Theoretically infinite but practically limited
- Association ~ < 7 and selection ~ 10

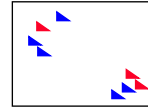
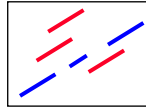
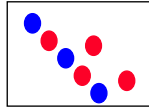
James Tam

Visual Variable: Color

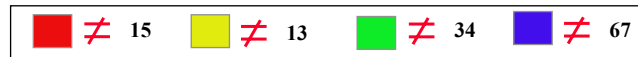
✓ **Selective**



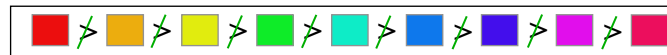
✓ **Associative**



≠ **Quantitative**



≠ **Order**

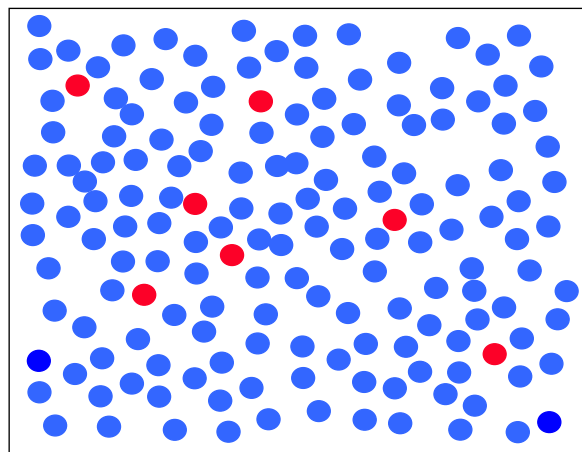


✓ **Length**

- Theoretically infinite but practically limited
- Association $\sim < 7$ and selection ~ 20

James Tam

Color

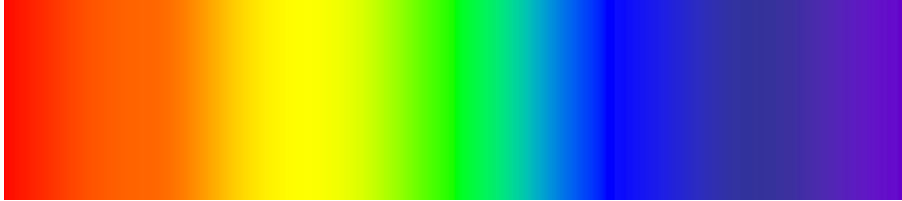


James Tam

Color Encoding

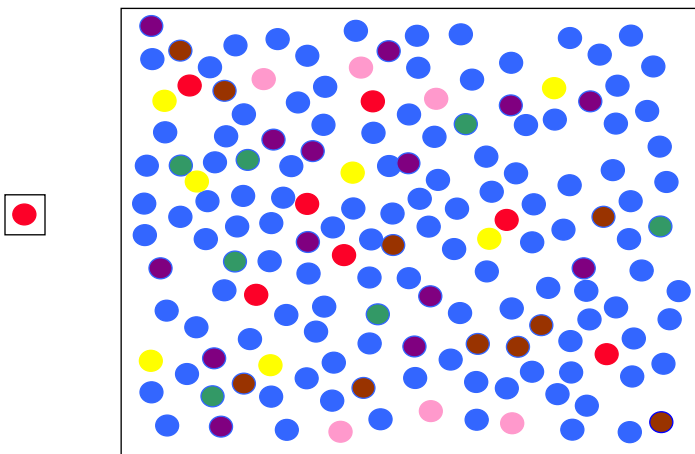
Common advice says use a rainbow scale

- Marcus, Murch, Healey
- There are problems with rainbows

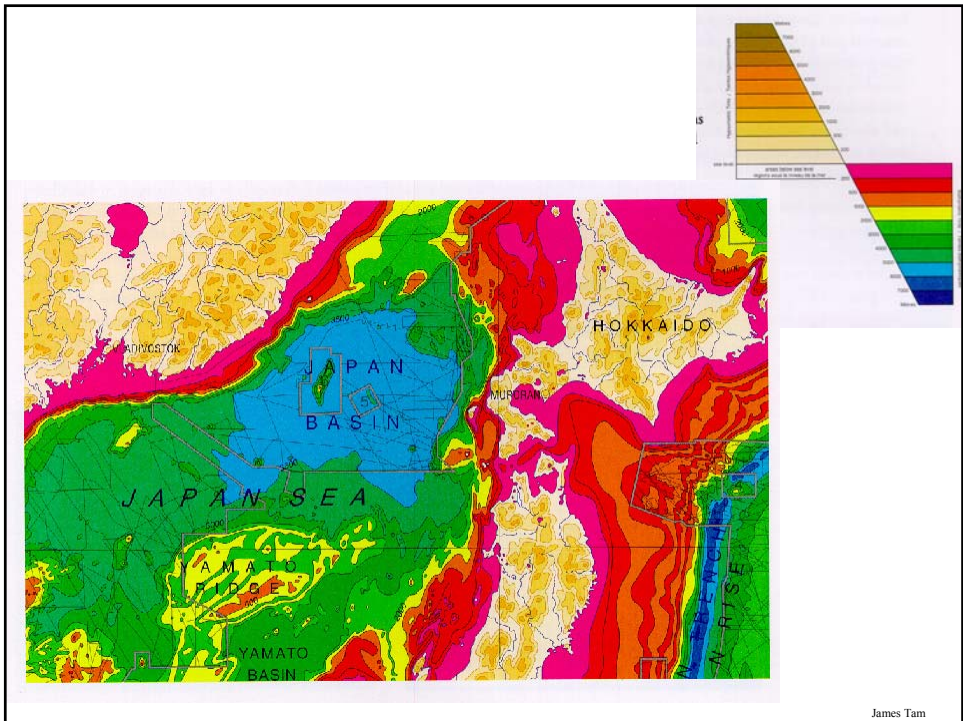
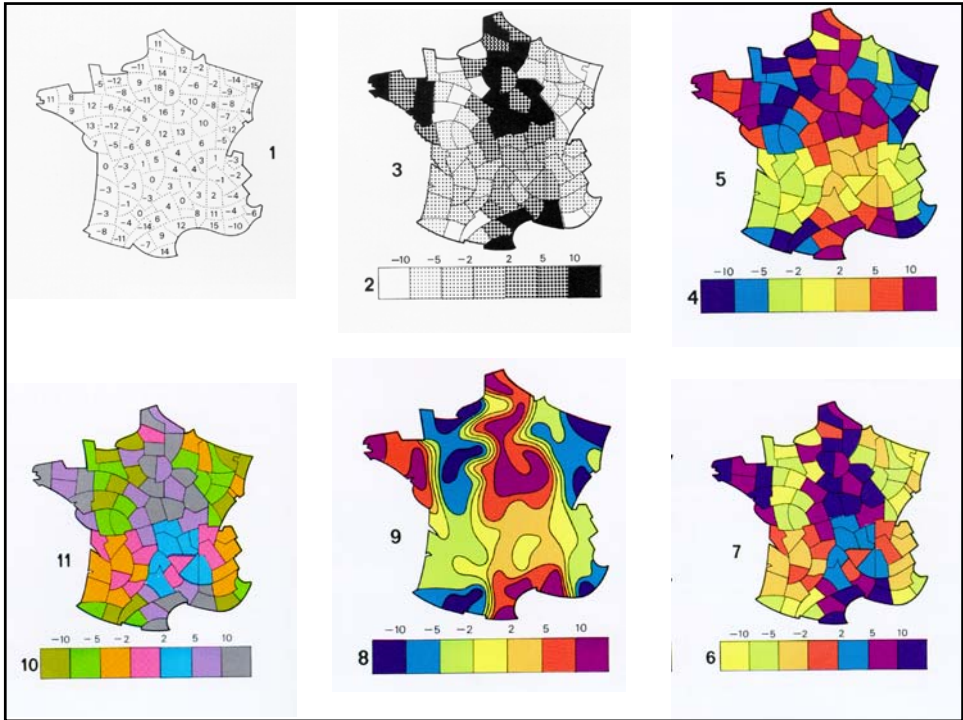


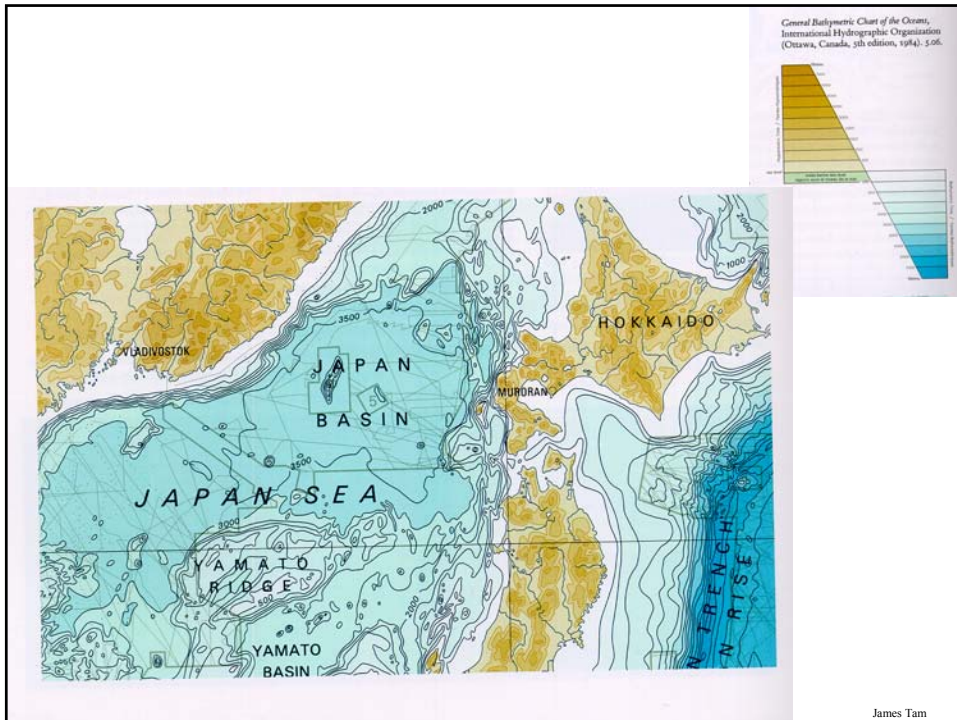
James Tam

Color



James Tam





Additional Issues Associated With Color

Color blindness:

- The majority of people who are color blind are red-green color blind so these colors should be avoided when communicating information.

Field size

- The larger the area to be color coded, the more easily that colors can be distinguished.
- When objects are small and color is used to distinguish the colors use highly saturated colors.

Additional Issues Associated With Color (2)

Field Size (continued)

- When large color coded regions are used (e.g., maps) use colors with low saturation (reduces interference with detailed information e.g., text)

```

import java.applet.Applet;
import java.awt.Graphics;
import java.awt.Color;

public class ColorText extends Applet
{
    public void init ()
    {
        red = 100;
        green = 255;
        blue = 20;
    }

    public void paint (Graphics g)
    {
        G.setColor (new Color (red, green, blue));
        G.drawString ("Colored Text", 30,50);
    }

    private int red;
    private int green;
    private int blue;
}
    
```

Conventions

- “Commonly accepted” conventions can vary widely by culture and their use should be carefully considered e.g., white is associated with purity in some Western cultures and death with some Eastern cultures.

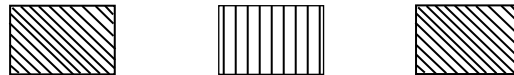
James Tam

Visual Variable: Orientation

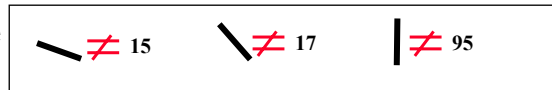
✓ Selective



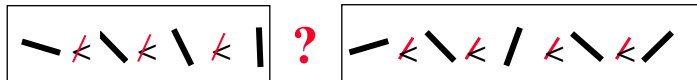
✓ Associative



≠ Quantitative



≠ Order



✓ Length

~5 in 2D

? in 3D

James Tam

Visual Variable: Texture

✓ Selective



✓ Associative



≠ Quantitative



≠ Order



✓ Length

- Theoretically infinite

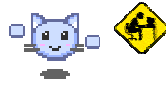
James Tam

Visual Variable: Motion

✓ Selective - motion is one of our most powerful attention grabbers



✓ Associative – objects moving in unison groups them effectively



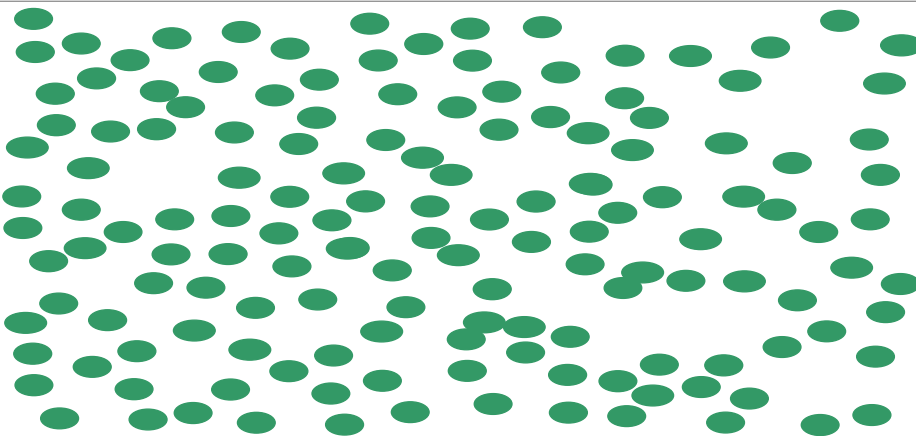
≠ Quantitative - subjective perception

≠ Order

? Length - distinguishable types of motion?

James Tam

Motion

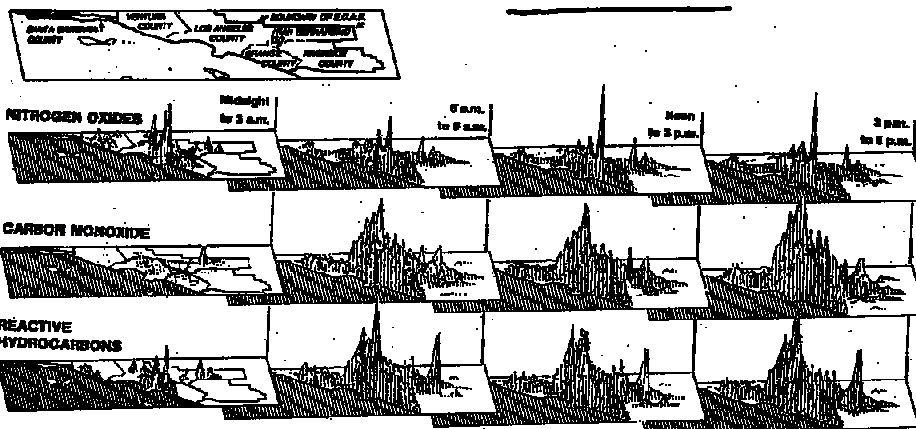


James Tam

Small Multiples: General Principles

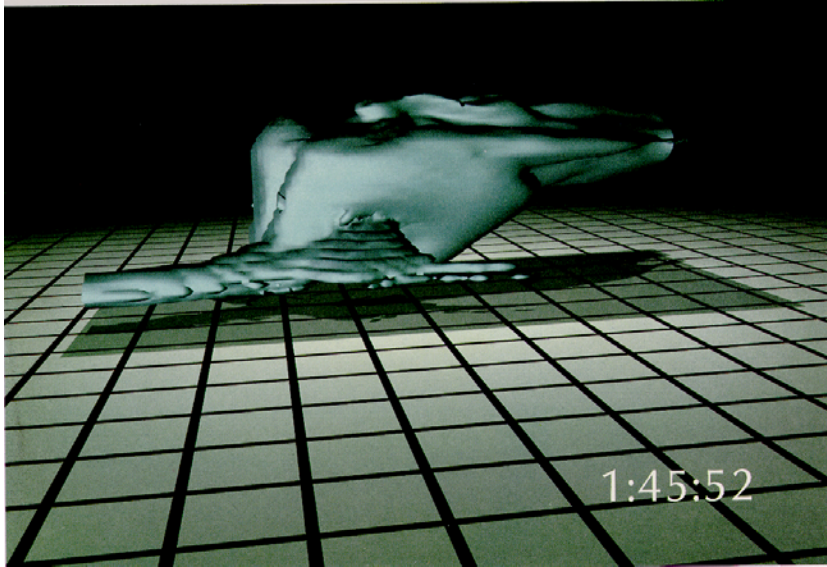
Learn once

Invite comparisons



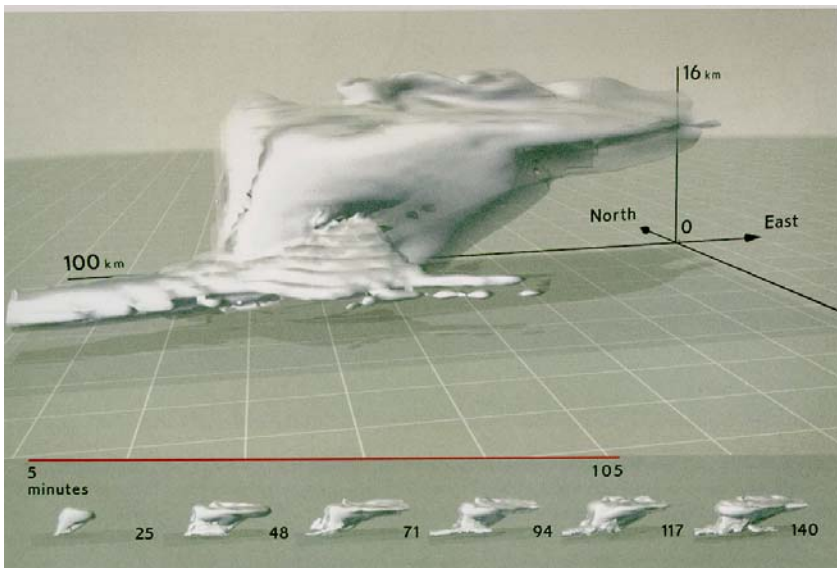
James Tam

Small Multiples: Showing Time And Change



James Tam

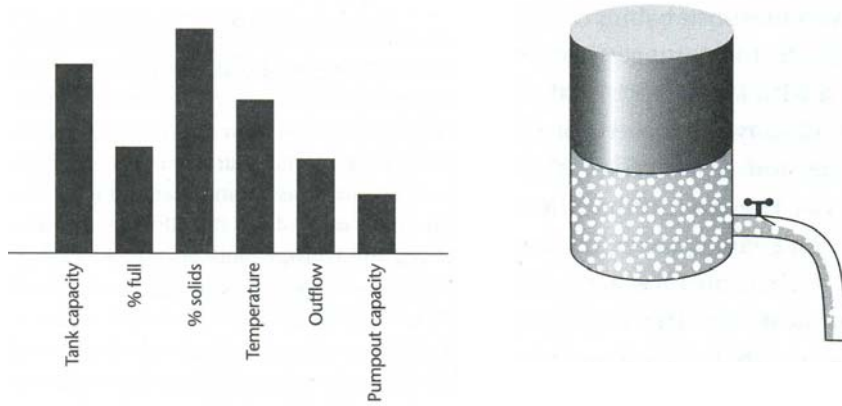
Small Multiples: Showing Time And Change



James Tam

Object Display Employing A Single Contoured Object

It's theorized that mapping many data variables onto a single object will guaranteed that these variables are processed together in parallel.¹



¹ From Engineering Psychology and Human Performance (2nd Edition) by Wickens C.D.

James Tam

Metaphors

Definition of a Metaphor

- One kind of object or idea is used in place of another to suggest a likeness or analogy between them
- Application of name or descriptive term to an object to which it is not literally applicable

James Tam

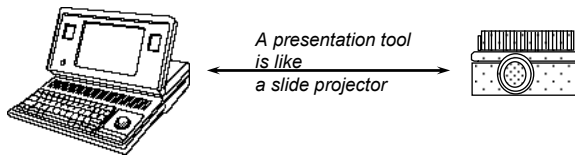
Interface Metaphors

Purpose

- Function as natural models
- Leverages our knowledge of familiar, concrete objects/experiences to understand abstract computer and task concepts

Problem

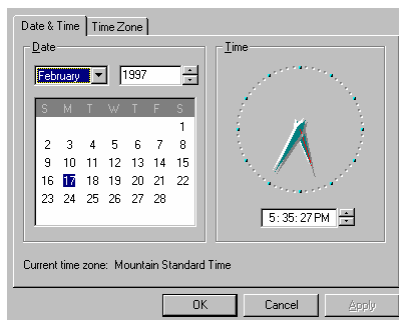
- Metaphor may portray inaccurate or naive conceptual model of the system



James Tam

Interface Metaphors

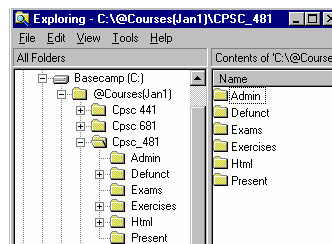
Pervade excellent interfaces



Control Panels with familiar controls

Name: _____
Address: _____
City: _____
Province: _____
Postal Code: _____

Forms



Hierarchical Folders

James Tam

A Real Life Metaphor: Life!



The Sims House Party © Maxis

James Tam

Creating Interface Metaphors

Generating metaphors

- Use metaphors that matches user's conceptual task
 - Desktop metaphor for office workers
 - Paintbrush metaphor for artists...
- Given a choice, choose the metaphor close to the way the system works
- Ensure emotional tone is appropriate to users
 - e.g., file deletion metaphors
 - Trashcan
 - Black hole
 - Paper shredder
 - Pit bull terrier
 - Nuclear disposal unit...

James Tam

Evaluating Metaphors

Potential problems:

- The metaphor has attributes that the system does not have.
- The system has attributes that are not suggested by the metaphor.
- An attribute exists both in the metaphor and in the system but works differently in each.

James Tam

The Metaphor Is More Powerful Than The System

Will the metaphor make people believe that the system can do more than it currently can?

```
West of House          Score: 0/0
ZORK I: The Great Underground Empire
Copyright 1982 by Infocom, Inc.
All rights reserved.
ZORK is a trademark of Infocom, Inc.
Release 30 / Serial number 830330

West of House
You are standing in an open field west
of a white house, with a boarded front
door.
There is a small mailbox here.

>■
```

Zork © Infocom

James Tam

The System Is More Powerful Than The Metaphor Implies

Will the metaphor restrict how people will try to use the system?

- e.g., file folders



James Tam

An Attribute Differs Between The Metaphor And The System

e.g., The trash can



Real trashcan



Desk top trashcan

James Tam

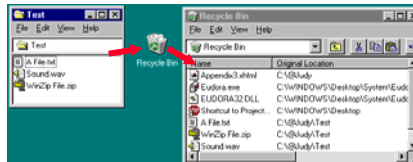
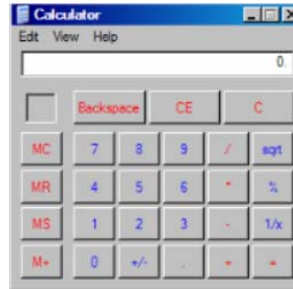
Misuse Of Metaphors

Caveat

- Metaphors can be overdone!

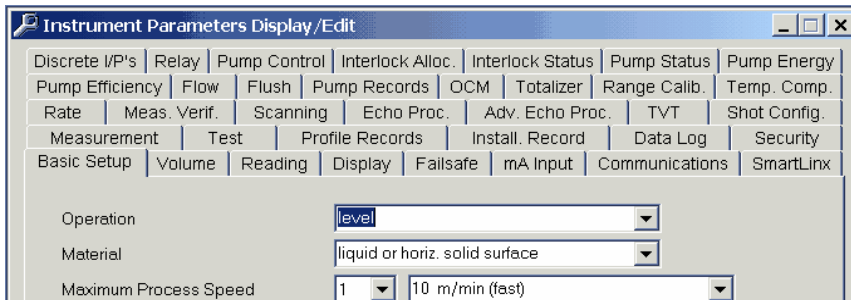
Common pitfalls

- Overly literal
 - Unnecessary fidelity
 - Excessive interactions
- Overly cute
 - Novelty quickly wears off
- Overly restrictive
 - Capabilities suggested by the metaphor don't match the actual capabilities
- Mismatched
 - Does not match user's task and/or thinking



James Tam

Misuse Of Metaphors (2)



Milltronics' *Dolphin Plus* a configuration package for industrial level and flow sensors

James Tam

A Example System That Applies A Metaphor: The Data Mountain



Robertson / Czerwinski / Larson / Robbins / Thiel / van Dantzych
Data Mountain: Using Spatial Memory for Document Management Proc ACM UIST'98

James Tam

A Example System That Applies A Metaphor: The Data Mountain

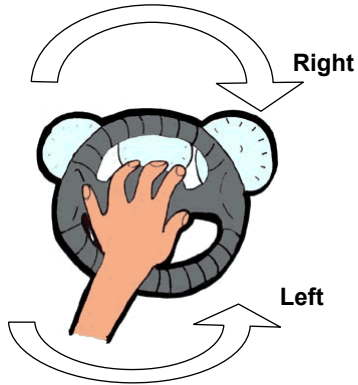


Robertson / Czerwinski / Larson / Robbins / Thiel / van Dantzych
Data Mountain: Using Spatial Memory for Document Management Proc ACM UIST'98

James Tam

Manipulating Real World Objects

Example steering a car:



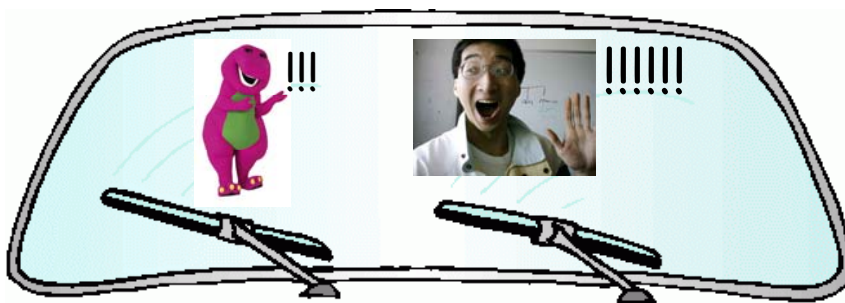
Direct mapping between the driver's actions and how the car reacts.

Objects of interest are visible

- Steering wheel
- The world outside of the car

James Tam

Imagine: Operating A Car In A Indirect Fashion



> Select: steering wheel, rotate left -30d

James Tam

Direct Manipulation

- **An interface that behaves as though the interaction was with a real-world object rather than with an abstract system**
- **Almost always based on a metaphor**
 - Mapped onto some facet of the real world task semantics



Ping was created by Nolan Bushnell

James Tam

Characteristics Of Direct Manipulation

- **Objects of interest are visible**
- **When it is logical: visible objects can be manipulated**
- **Manipulation occurs by pointing and moving**

James Tam

Indirect Interaction: Traditional Approach To Writing Java GUI's



James Tam

Indirect Interaction: Changing The Java Code

```
ContactsTracker.java - WordPad
File Edit View Insert Format Help

private Button add;
private Button remove;
private FileIO f;
private Button load;
private Button save;

public ContactsTracker ()
{
    gbc = new GridBagConstraints ();
    setLayout(gbc);
    list = new List(5);
    addWidget(this, list, 0, 1, 2, 3, GridBagConstraints.BOTH, GridBagConstraints.WEST);
    inputOne = new TextField();
    inputOne.addActionListener(new TextFieldListener());
    emailLabel = new Label ("Enter new email below");
    add = new Button ("<- Add");
    remove = new Button ("Rem ->");
    load = new Button ("Load");
    save = new Button ("Save");
    f = new FileIO();
}

public List getList () { return list; }

public void addWidget(Container container, Component widget,
    int x, int y, int w, int h, int fill, int anchor)
{
    LayoutManager lm = container.getLayout();
    GridBagConstraints gbc = new GridBagConstraints();

    gbc.gridx = x;
    gbc.gridy = y;
    gbc.gridwidth = w;
    gbc.gridheight = h;
    gbc.fill = fill;
    gbc.anchor = anchor;
    gbc.setConstraints(widget,gbc);
    container.add(widget);
}
```

James Tam

Is Direct Manipulation The Way To Go?

Some Disadvantages

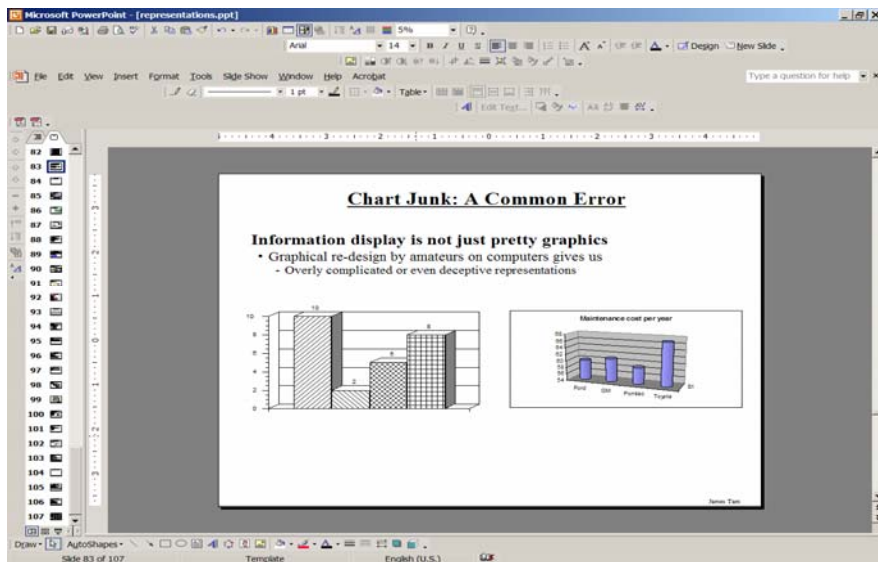
- Ill-suited for abstract operations or for vision impaired users
 - Spell-checker?
- Tedium
 - Manually search large database vs. query
- Metaphor may be misleading:
 - Overly restrictive may limit usage or overly powerful may imply functions that aren't available
- Direct manipulation systems require more screen space

Solution

- Most systems combine direct manipulation and abstractions
 - Word processor:
 - WYSIWYG document (direct manipulation)
 - buttons, menus, dialog boxes (abstractions, but direct manipulation “in the small”)

James Tam

Conventional Applications: A Mix



PowerPoint © Microsoft

James Tam

Direct Engagement

- **The feeling of working directly on the task (as opposed to using a particular tool).**
- **To employ it, you need to consider the user of the system and the tasks that he or she engages in.**
- **Often direct manipulation is an important requirement for direct engagement.**
 - e.g., A drawing program provides tools that are familiar to artists (brushes, palettes etc.)

James Tam

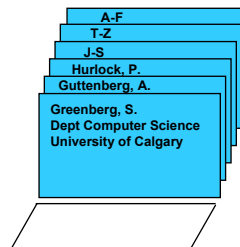
Direct Engagement: A Telephone Database

```
Find "Green"  
>S. Greenberg  
>Dept Computer Science  
>University of Calgary
```

Command system
no direct manipulation

```
Search for: Green  
  
Result: S. Greenberg  
Dept Computer Science  
University of Calgary
```

Form metaphor:
syntactic direct
manipulation



Rolodex metaphor:
full direct manipulation

James Tam

Action-Object

The traditional approach for writing software.

Focus on verbs, actions or functions that the software is capable of.

Often requires learning a complex and arbitrary syntax that varies greatly from system to system and platform to platform:

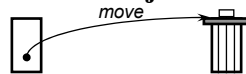
- e.g., Deleting text: <Ctrl>-<h>, <ctrl-g>, <ctrl-d>, <delete>, <backspace> etc.

James Tam

Object-Action

•Focus on nouns, objects which already have meaning in the task domain of the user.

•Select an object which then has a set of allowable actions.



my.doc

•Because the user is already familiar with these objects, previous knowledge can help leverage when learning the new systems:

- e.g., Trash cans for deletion, folders for storing information, inbox for reading new messages, outbox for sending messages

•It requires that the objects of interest have a visual representation (compatible with Direct Manipulation)

James Tam

Advantages Of The Object-Action Approach

- **The syntax is already familiar so the time spent learning the capabilities of the system is reduced.**
- **The new syntax that the user is required to learn is fairly limited e.g., there are only so many ways that a button can be used.**
- **Error messages are rarely needed. Actions that are inappropriate, given the current state of system, can be excluded:**



The Sims House Party © Maxis

James Tam

What You Now Know

Good Representations

- Captures essential elements of the event / world
- Deliberately leaves out / mutes the irrelevant
- Appropriate for the person, their task, and their interpretation

Information Visualization

- Tufte's principles
- Exploits our knowledge of visual variables
- Many techniques now available (illustrated with research and commercial systems)

James Tam

What You Now Know (2)

Metaphors

- Uses our knowledge of the familiar and concrete to represent abstract concepts
- Need not be literal
- Has limitations that must be understood

Direct manipulation

- Visibility of the objects of interest
- Manipulation by pointing and moving

These four components are the foundation of a true Visual Interface

James Tam

