

Visual Comparison of Complex Sets of Quantifiable Forensic Data

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by

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David Sorensen, P.E., BSME, MSMET, RPE in CA, ID & UT, member SME, IEEE & ASME (IEEE Com. Chair), Patents w GE & Bunker Ramo, Dir. Engr at INL w staff of 600+, Started EG&G Services, grew to \$5 million in 2 yrs w 90% ROI & staff of 125, Bid against Lockheed, Rockwell & Boeing for the NASA Ops Contrate & won (10 yr \$1 billion). Exec VP at Eyring, Founder of RPR Ctr at BYU, Exec Dir of NIST MEP in UT for 15 yrs. Creating over 32,000 jobs in Utah alone.

**Data Retrieval is what Google is all about.
... but why do people want to access data**

**Data Analysis and
Decision Making
is what HSG is all about.**

**What process and approach
do people really use?**

Decision Making

- ◆ A **decision** involves making a choice between several options.
- ◆ Each **option** has a set of attributes.
- ◆ **Attributes** are generally quantifiable.
- ◆ Variation in the attributes distinguishes each option from all other options.
- ◆ The **correlation** between attributes is an important part of overall decisions.
- ◆ Several options, each with quantifiable attributes, are compiled into a spreadsheet.

Spreadsheet Data

(Cost of Living Attributes, various cities)

	Groceries	Housing	Utilities	Transportation	Health
US Avg	100	100	100	100	100
Sacramento	104.8	120.3	111.5	111.9	122.8
San Diego	106.4	200.8	78.1	127	125.2
Denver	95.5	117.9	89.9	101.4	113.8
Boise	89.8	101.9	73.7	99.3	87.2
Missoula	103.7	86.4	97.7	100.7	110
Reno	99.1	114.1	97.8	99.5	109.5
Albuquerque	98.1	108.8	99	103	105.1
Seattle	111.2	115.9	63	117	139.7
SLC	94.8	86.9	89.8	101.1	100

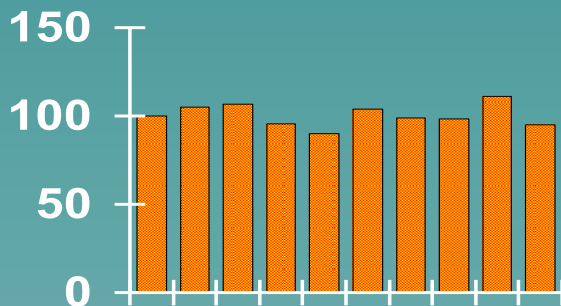
Columns and Rows



1 Variable

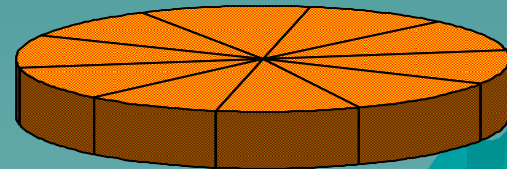
	Groceries	Housing	Utilities	Transportation	Health
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Sacramento	104.8	120.3	111.5	111.9	122.8
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Albuquerque	98.1	108.8	99	103	105.1
Seattle	111.2	115.9	63	117	139.7
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Bar Chart

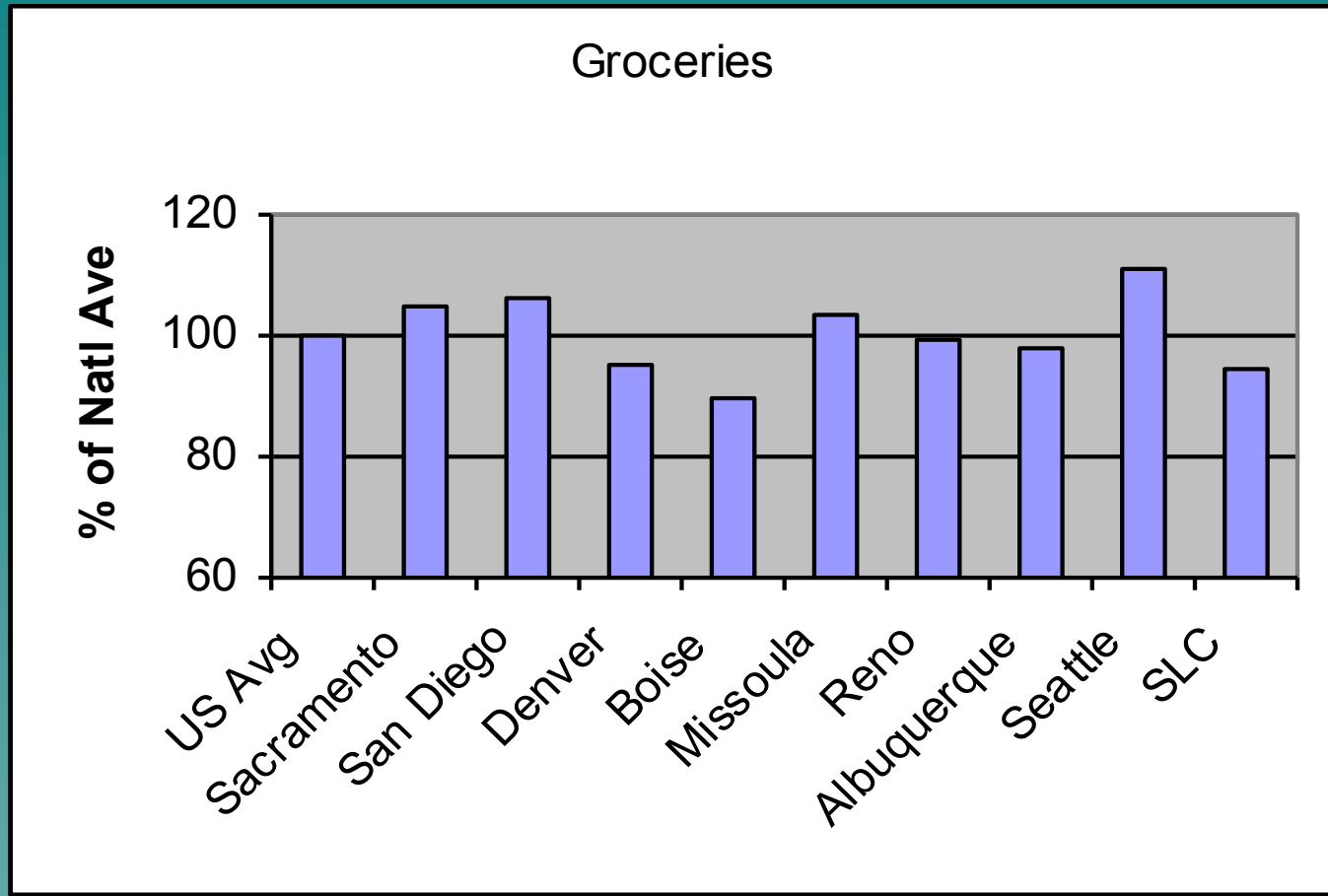


Or

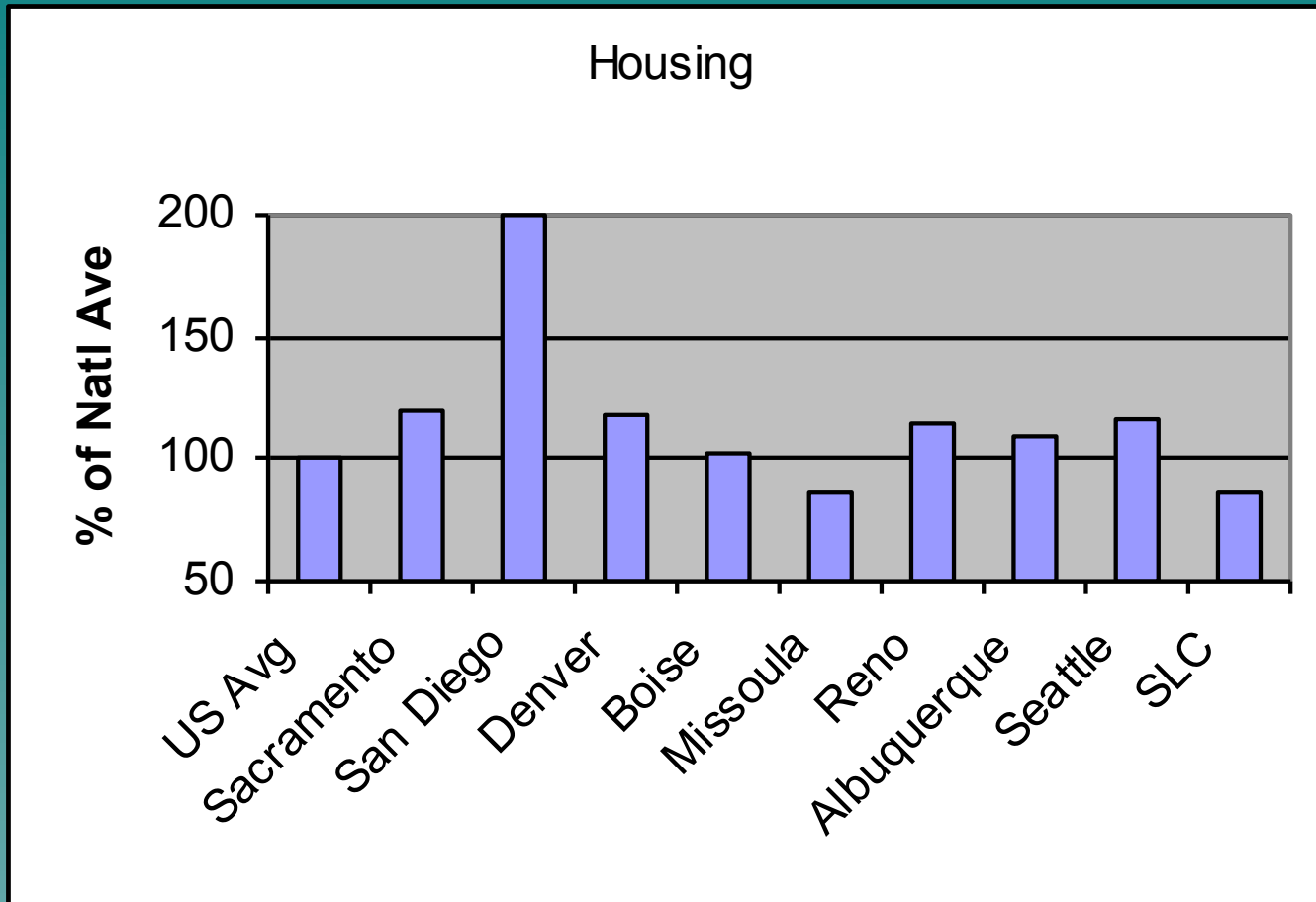
Pie Chart



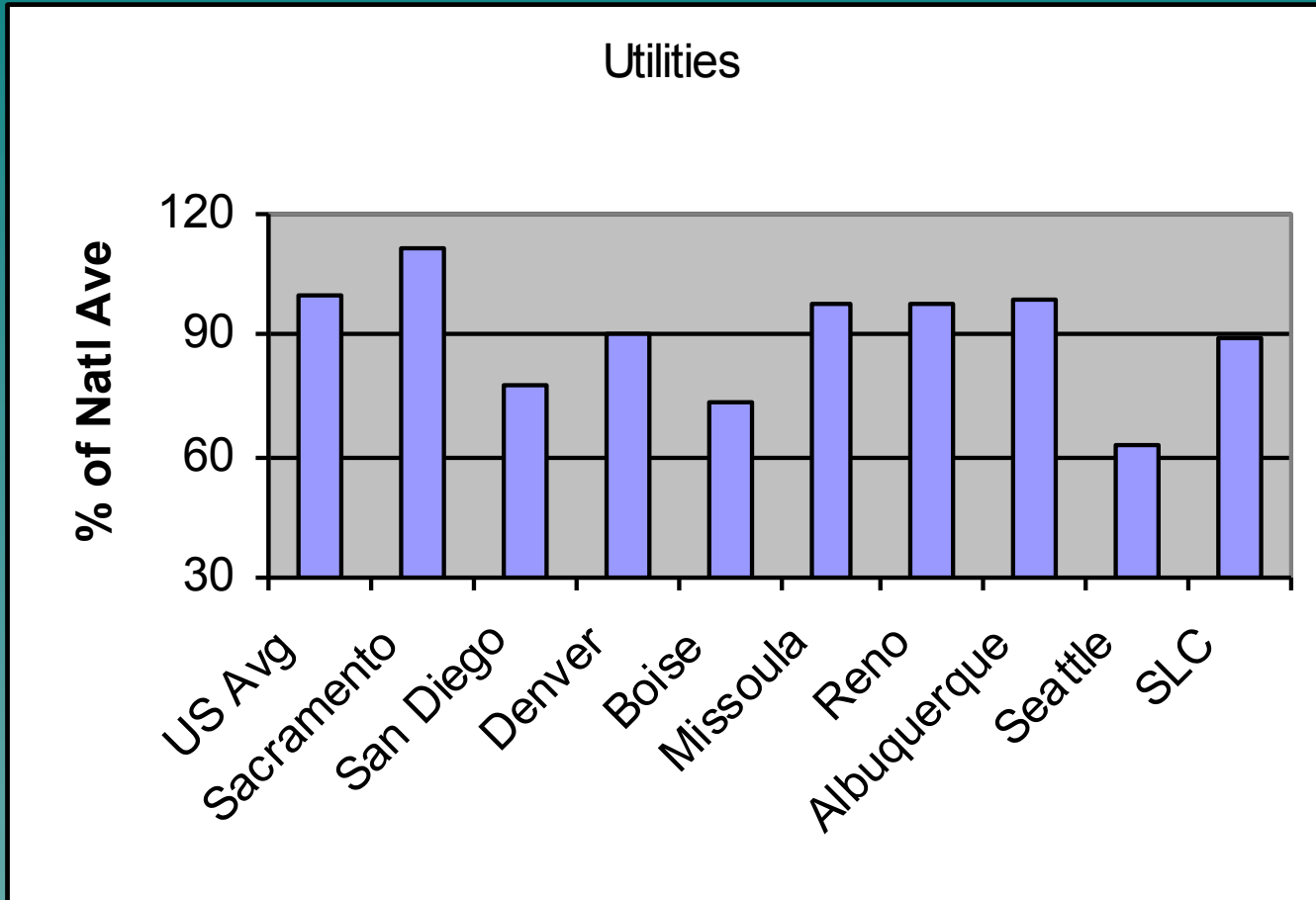
Groceries



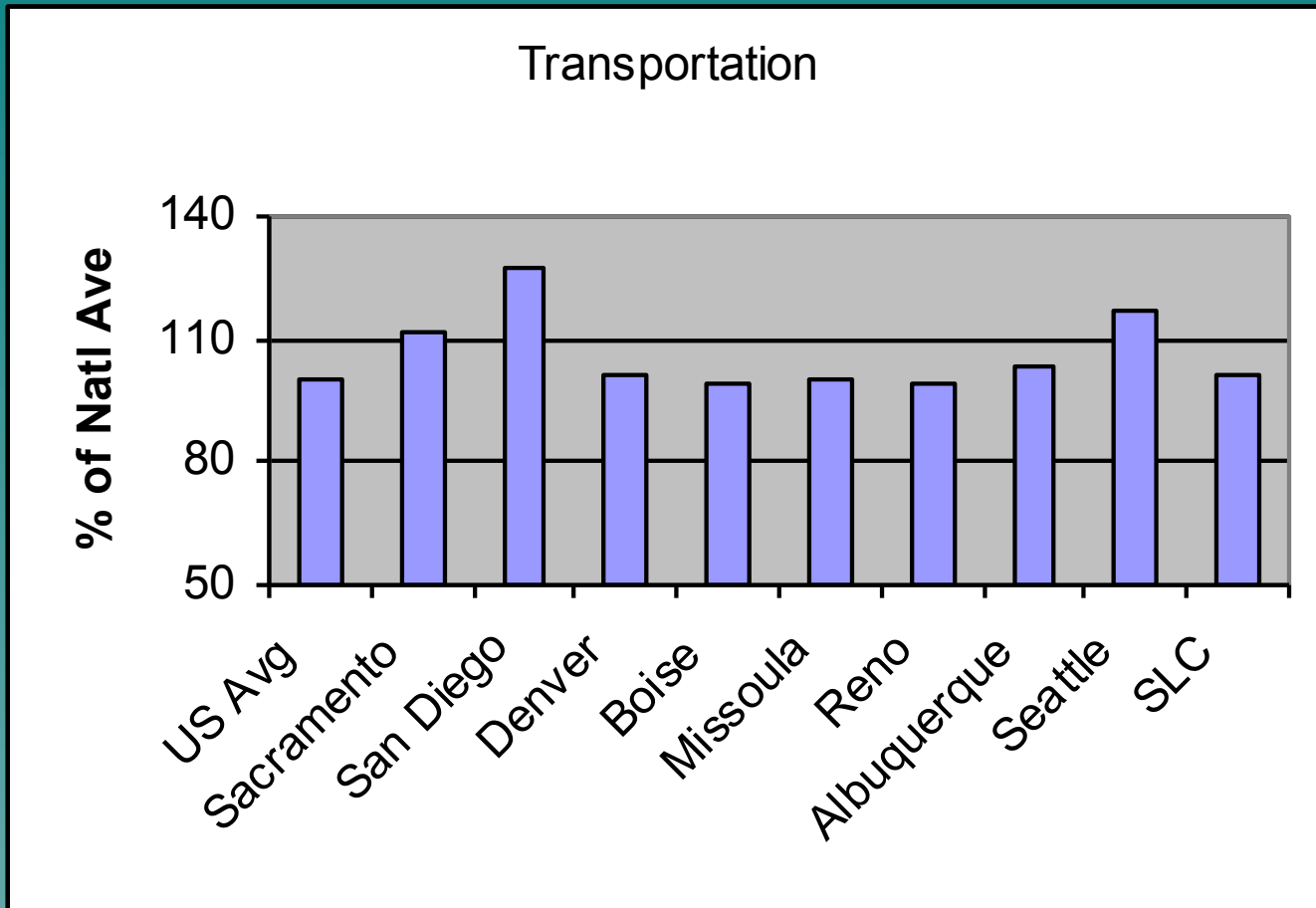
Housing



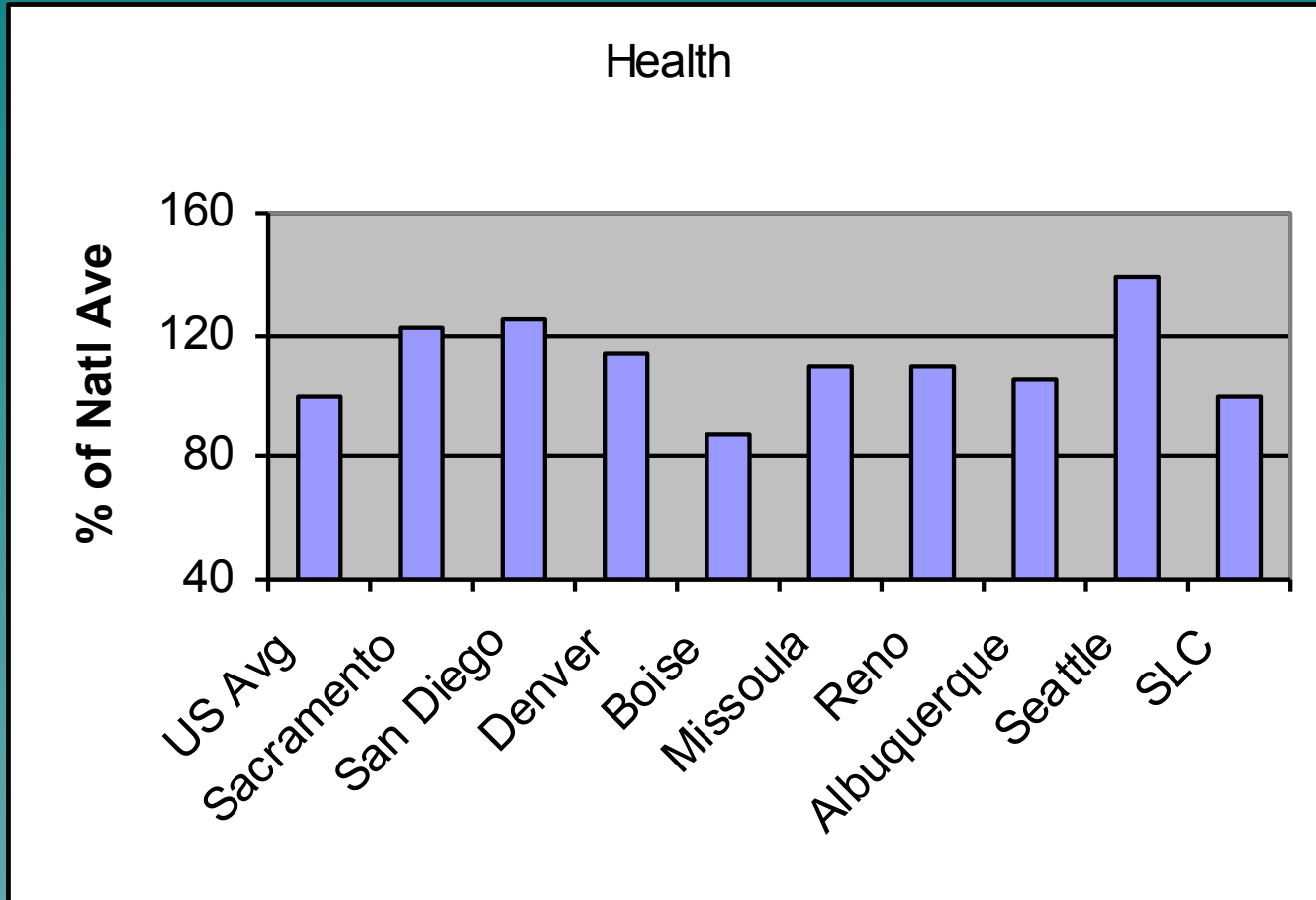
Utilities



Transportation



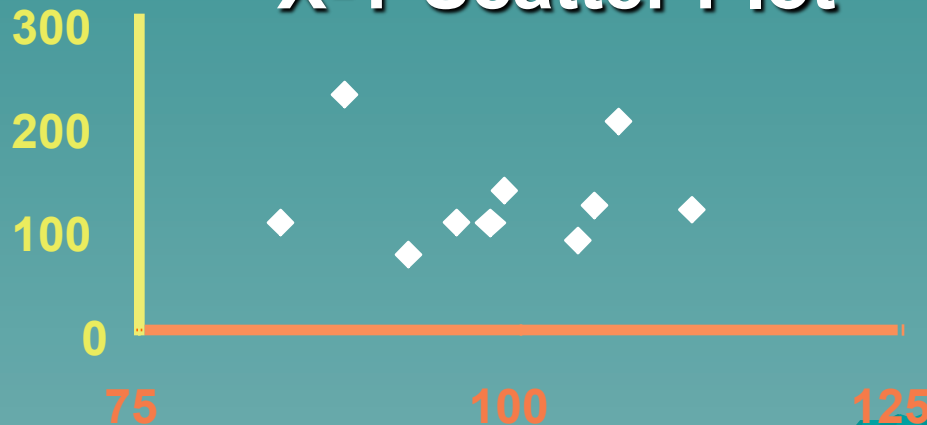
Health Care



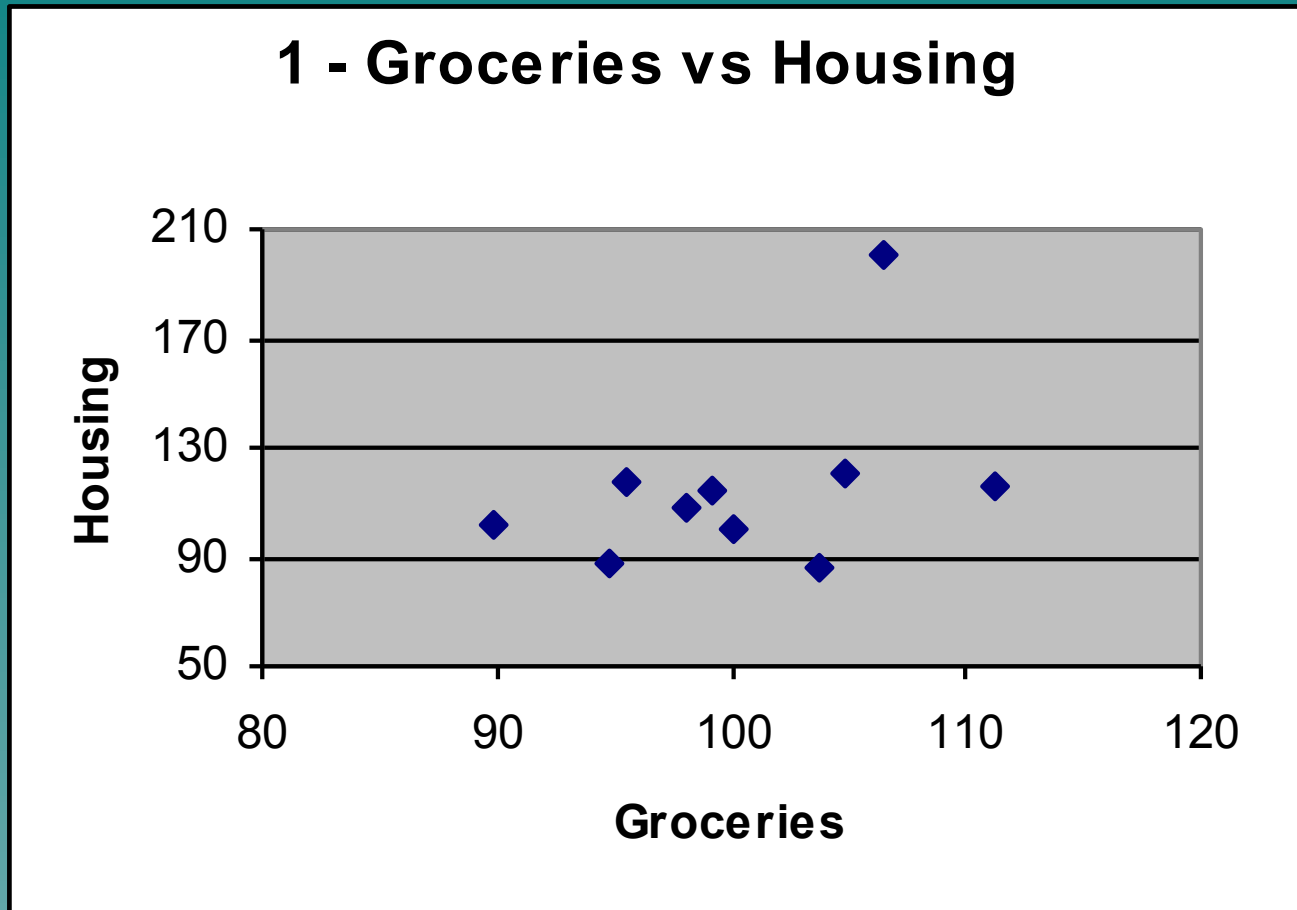
2 Variables

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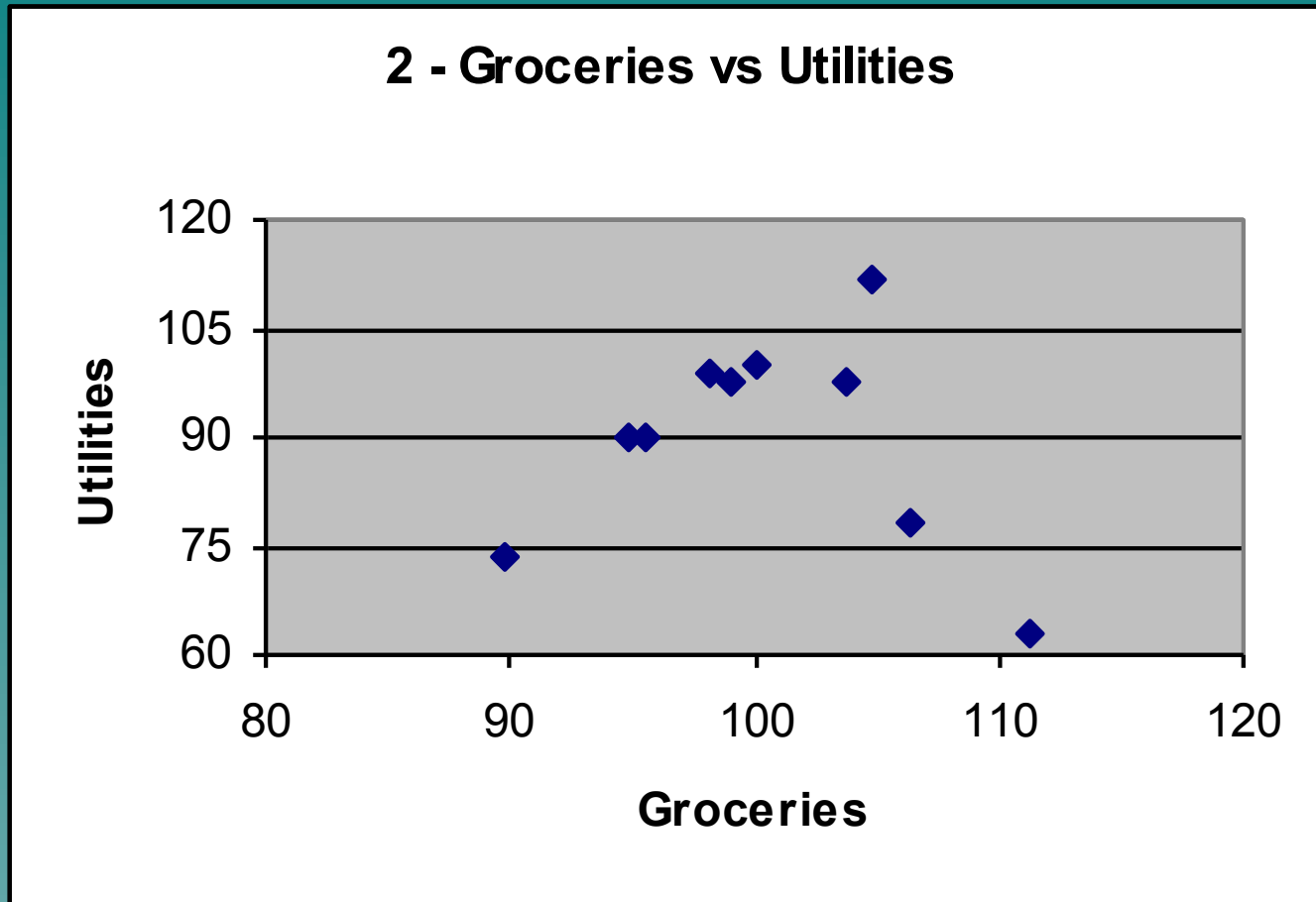
X-Y Scatter Plot



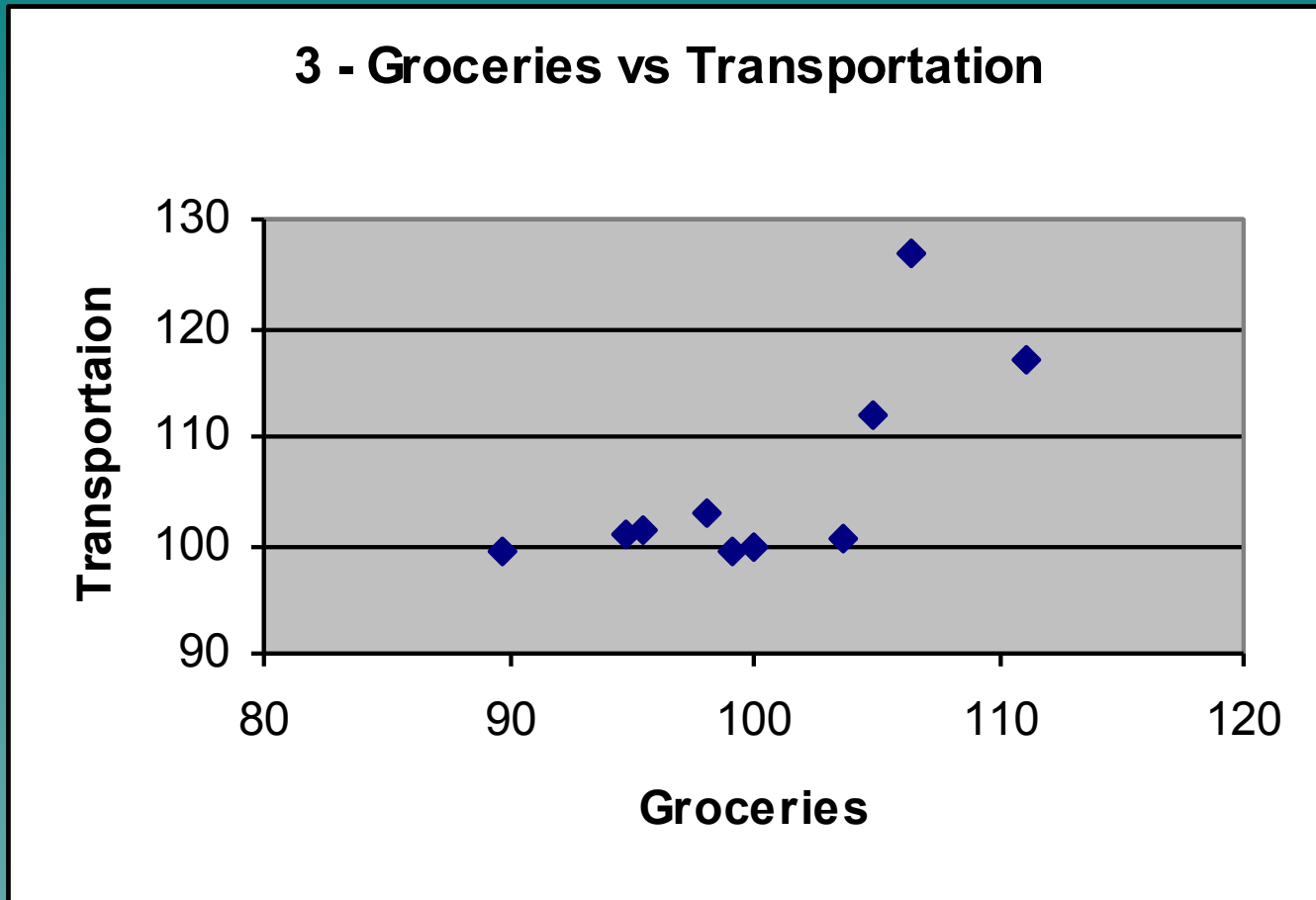
1 - Groceries vs Housing



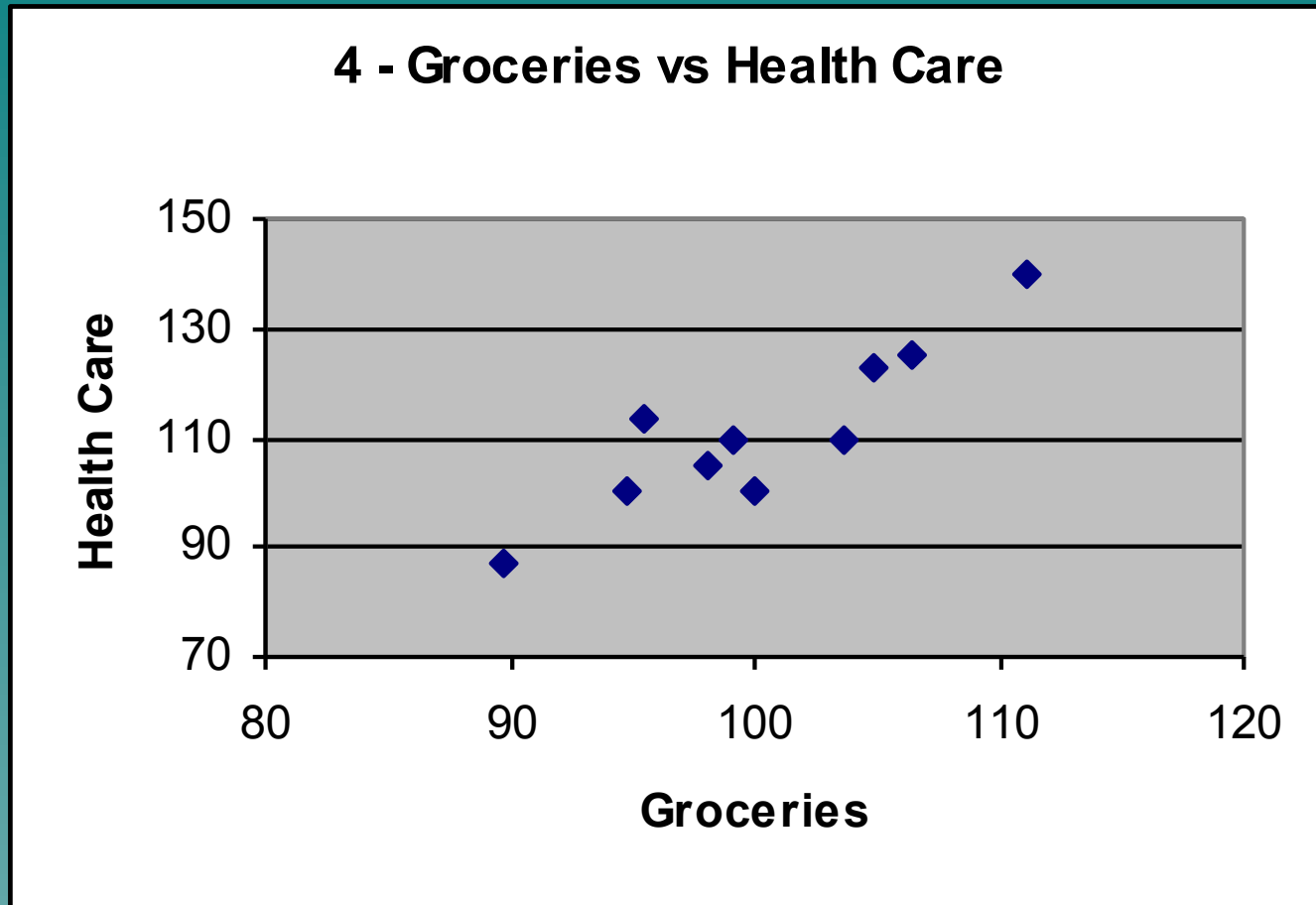
2 - Groceries vs Utilities



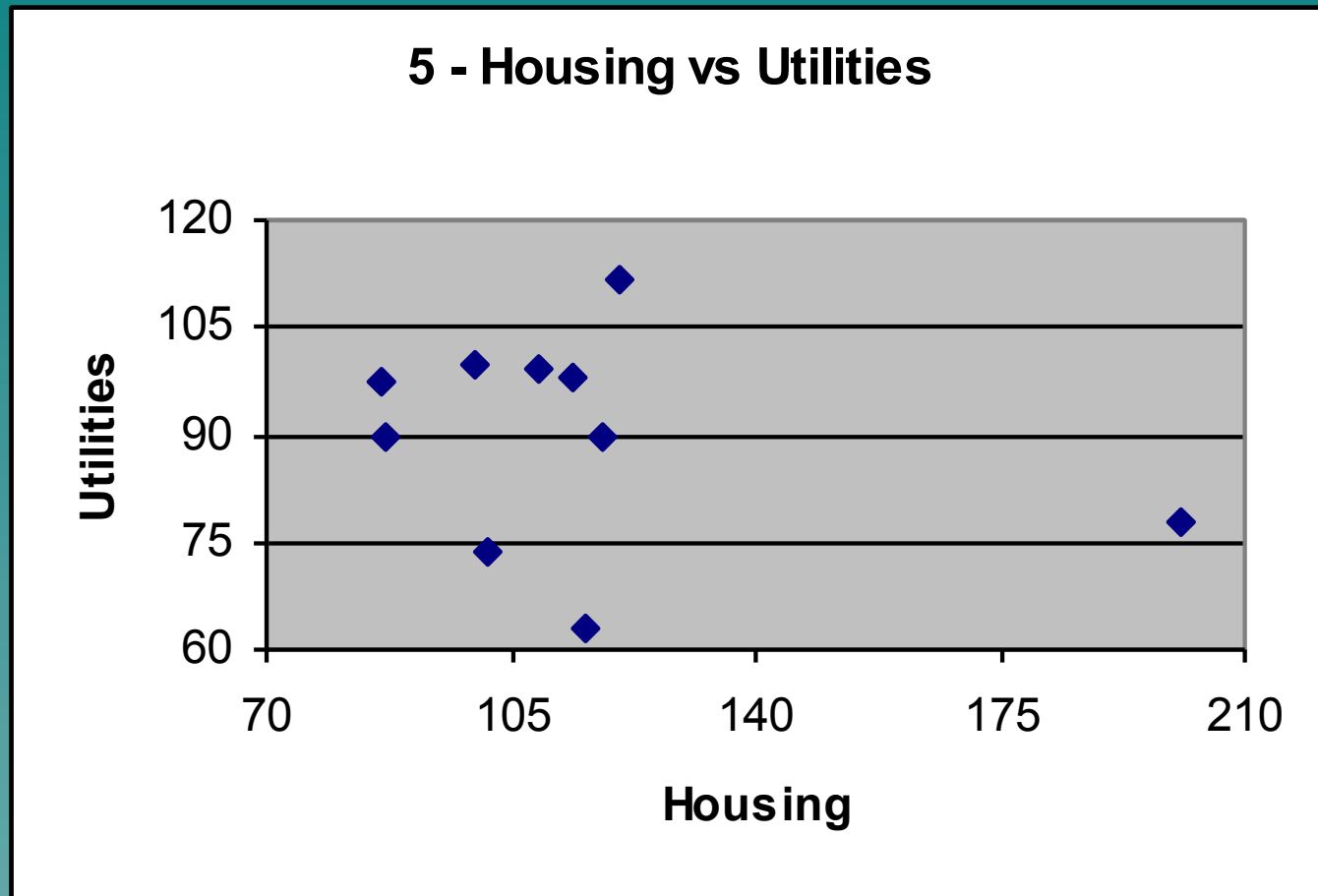
3 - Groceries vs Transportation



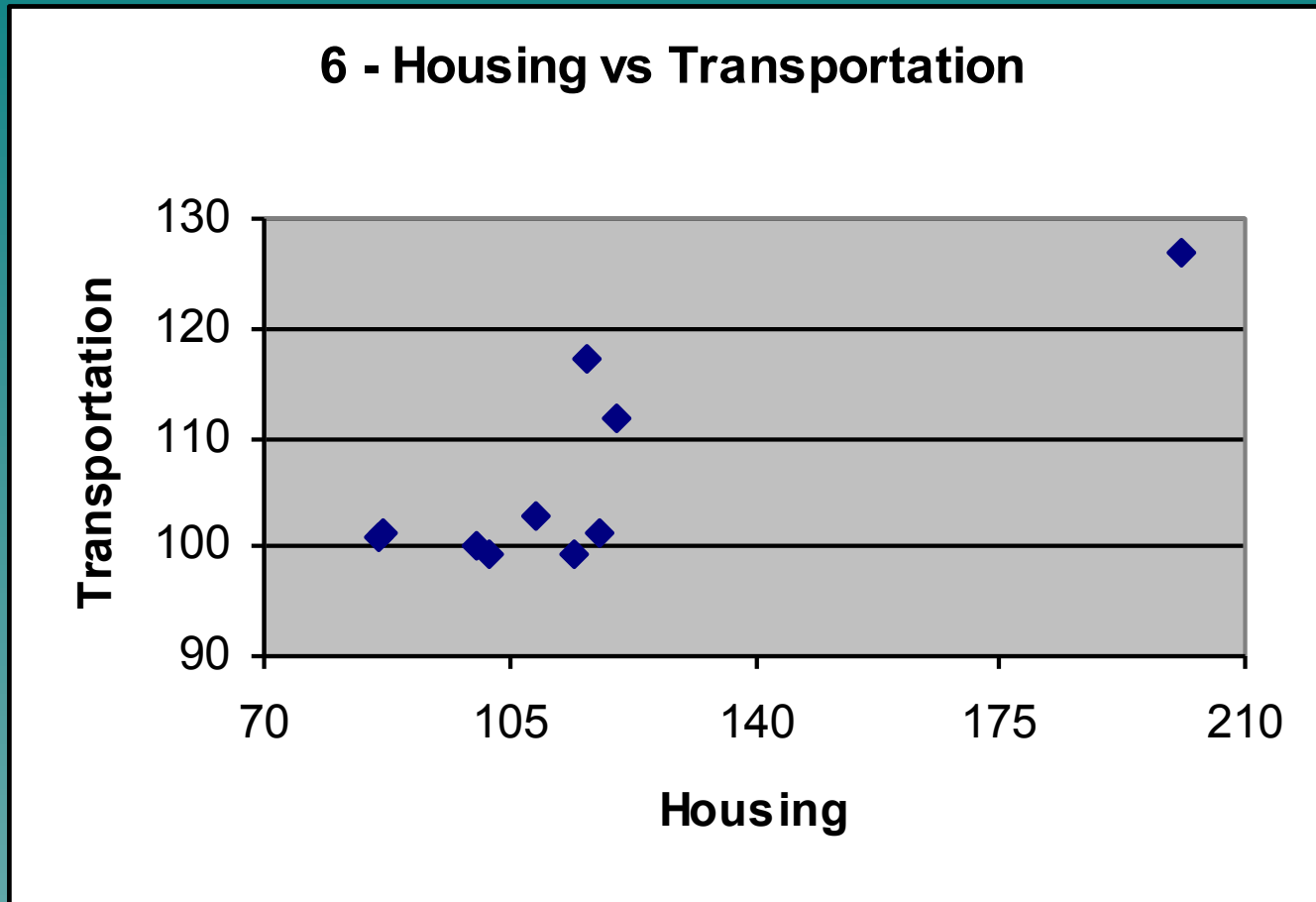
4 - Groceries vs Health Care



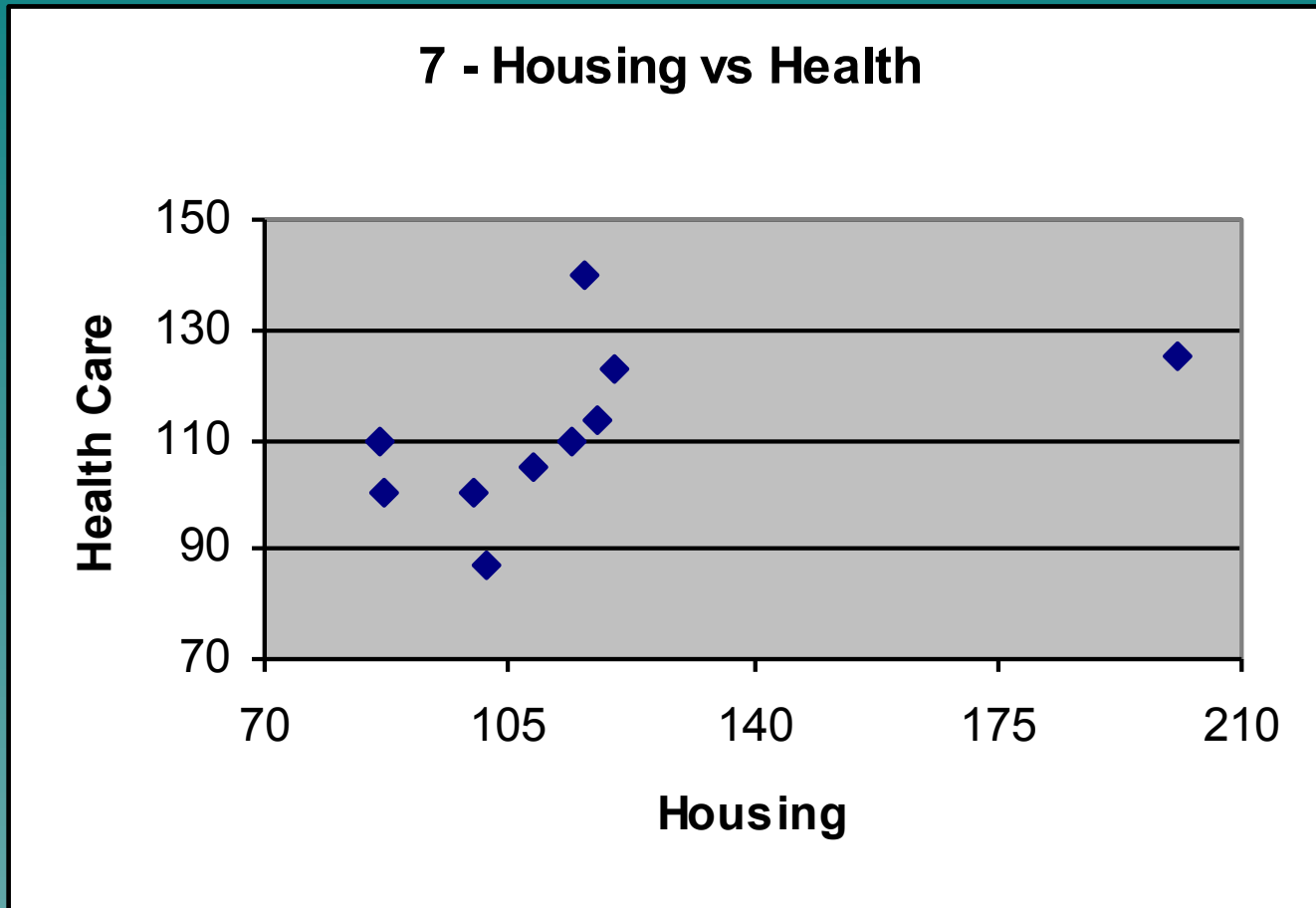
5 - Housing vs Utilities



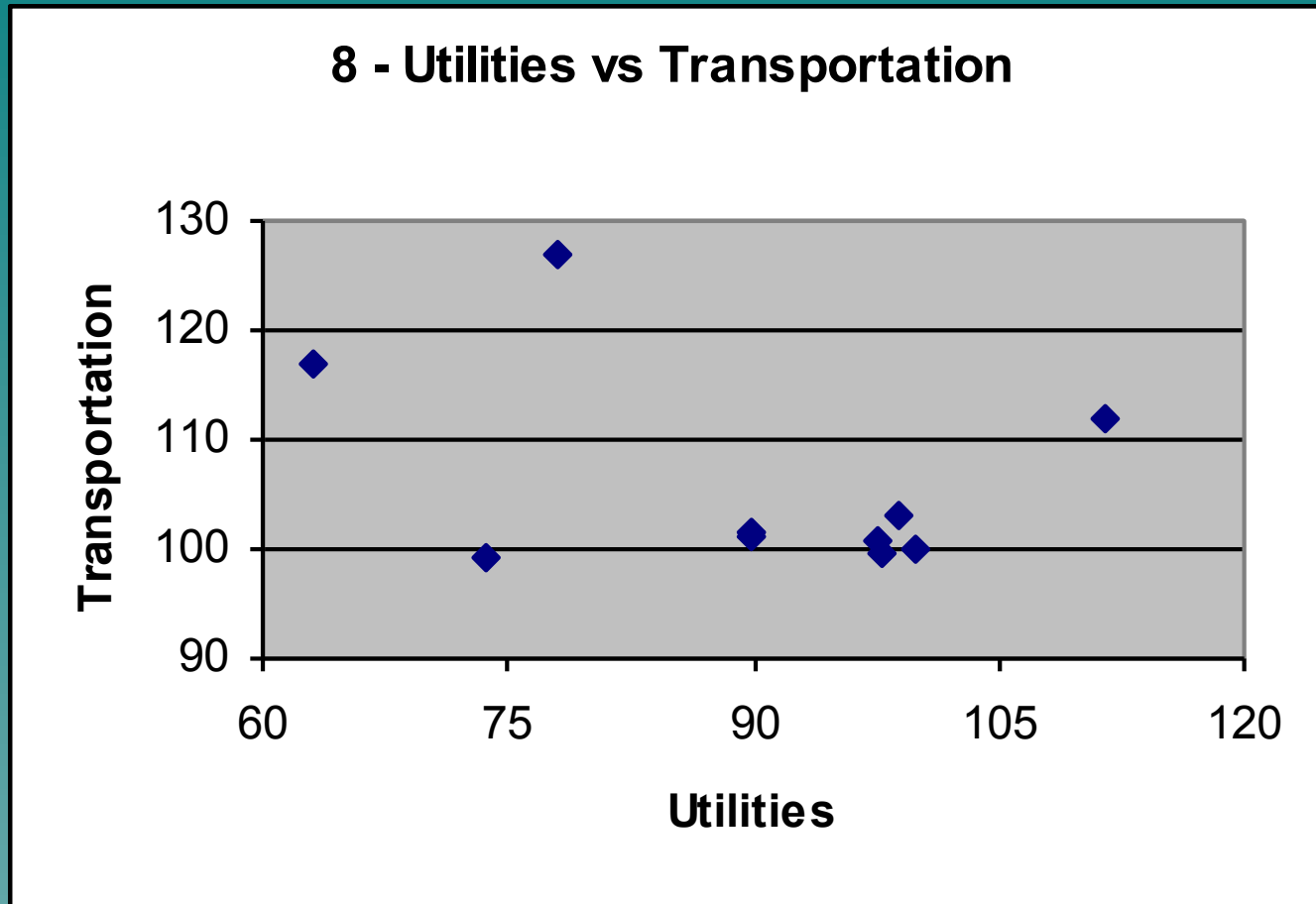
6 - Housing vs Transportation



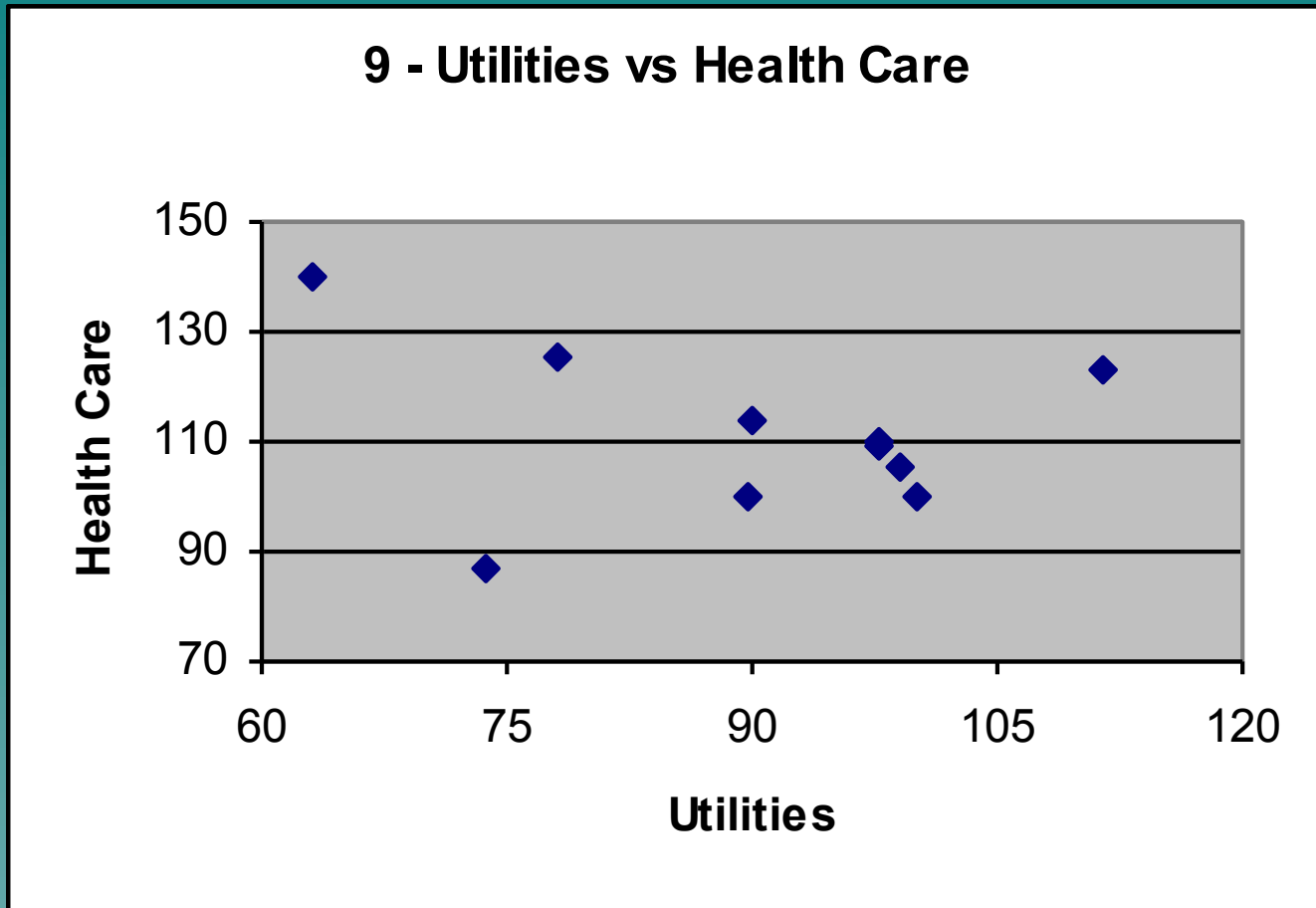
7 - Housing vs Health Care



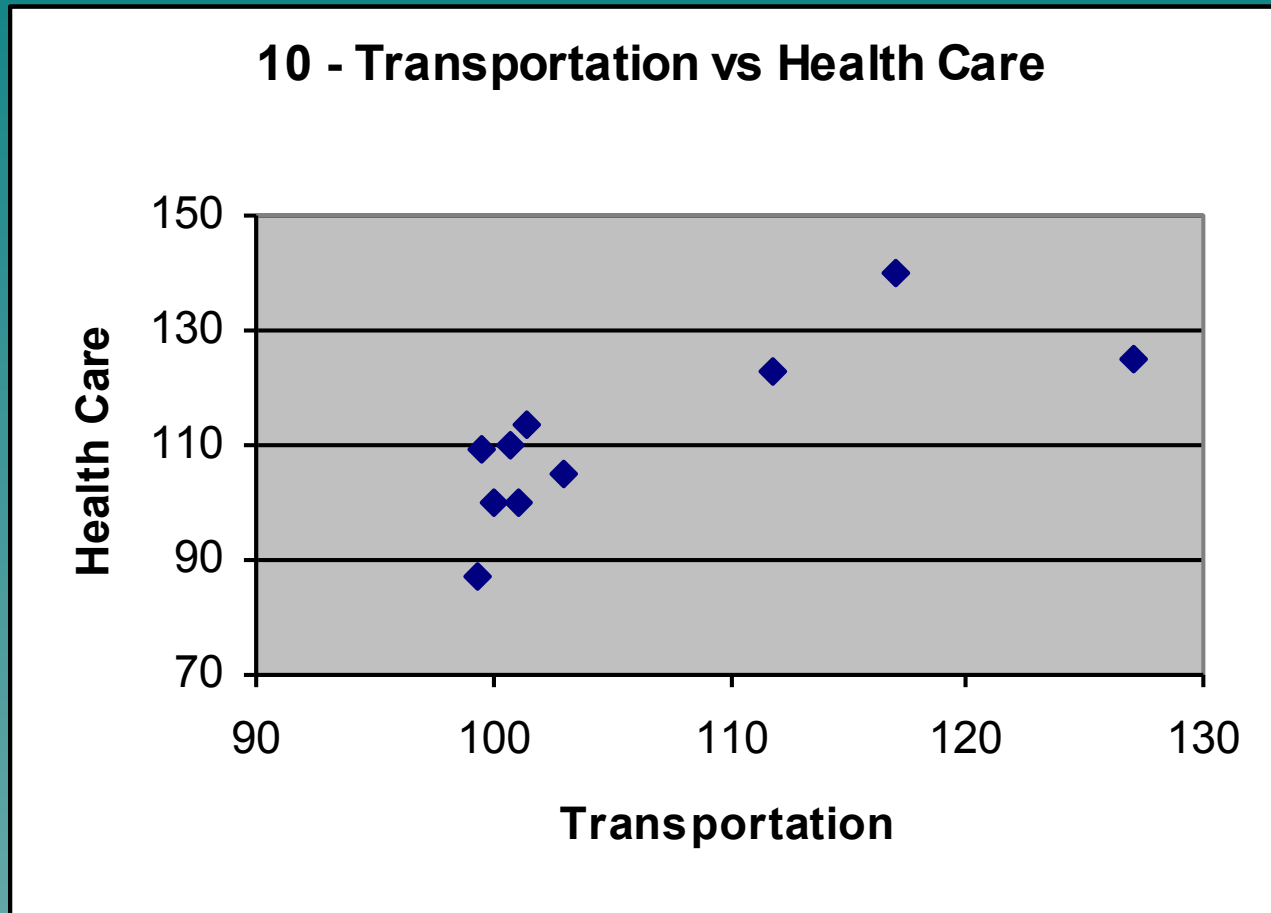
8 - Utilities vs Transportation



9 - Utilities vs Health Care



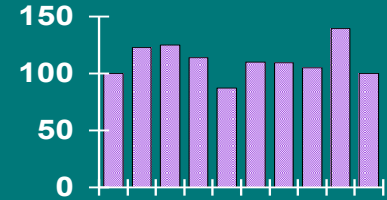
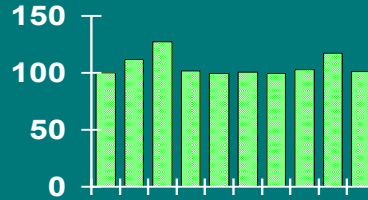
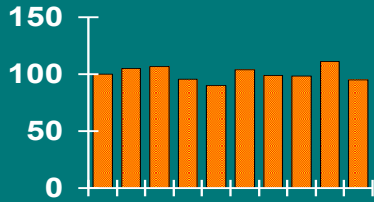
10 - Transportation vs Health Care



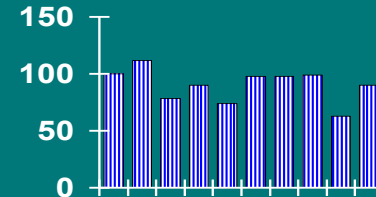
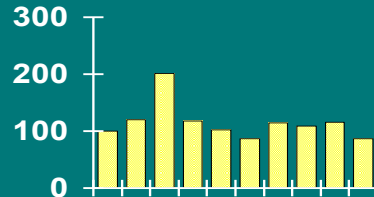
5 Variables, 10 Cities...

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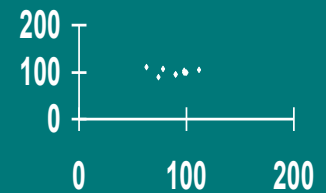
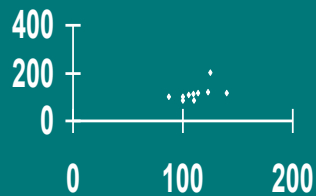
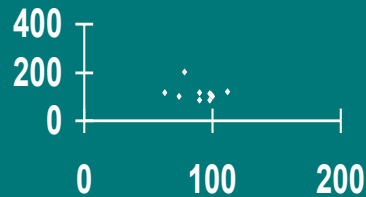
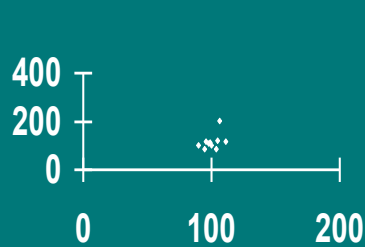
...Results in 5 Bar Charts...



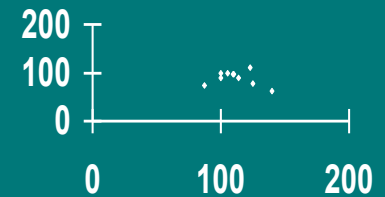
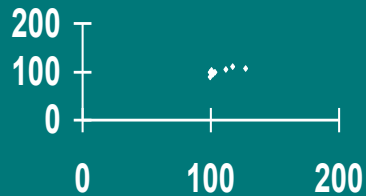
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Seattle	111.2	115.9	63	117	139.7
SLC	94.8	86.9	89.8	101.1	100



...and 10 X-Y Scatter Plots

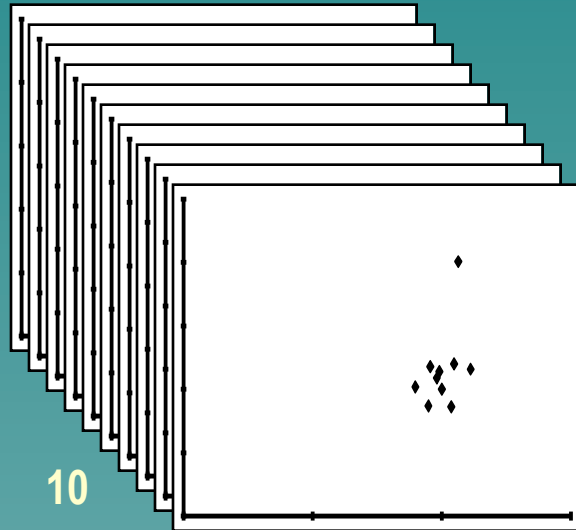
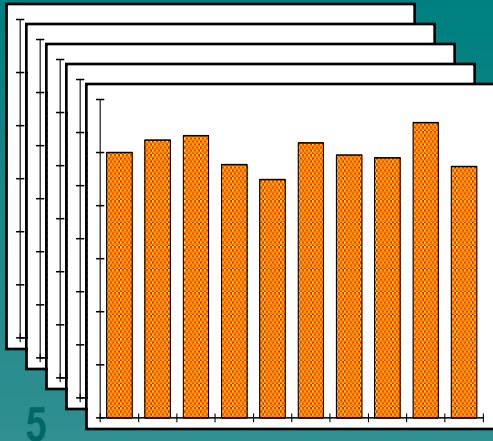


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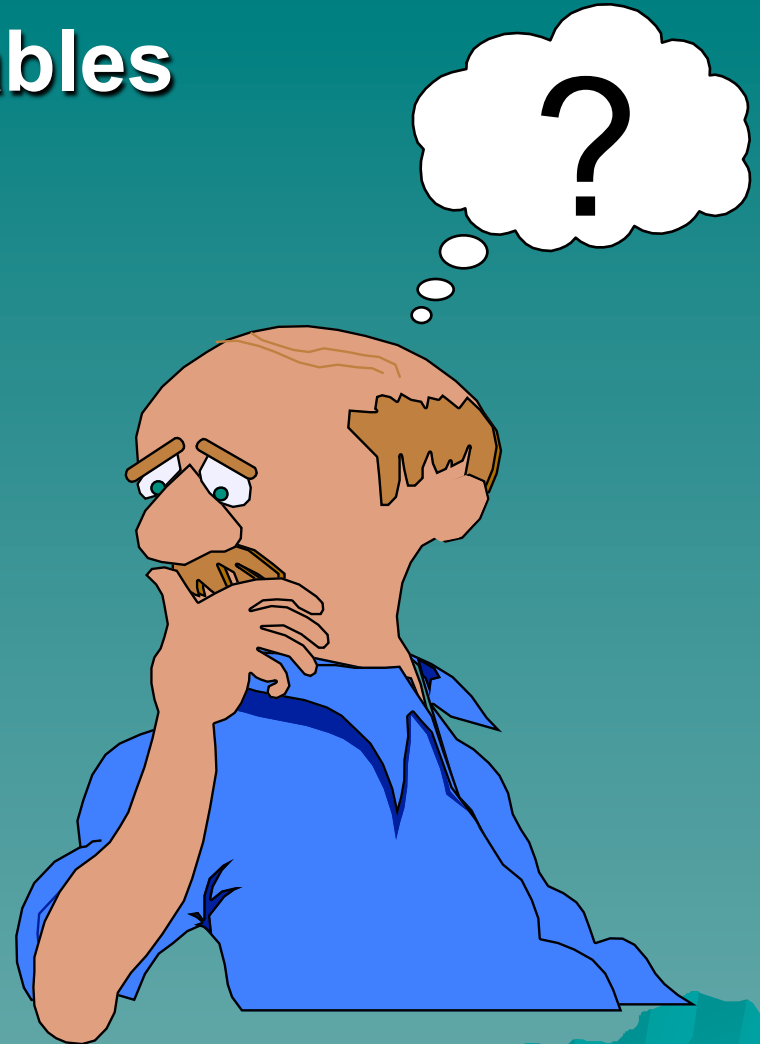


Traditional Graphics

5 Variables



15 Charts and Graphs



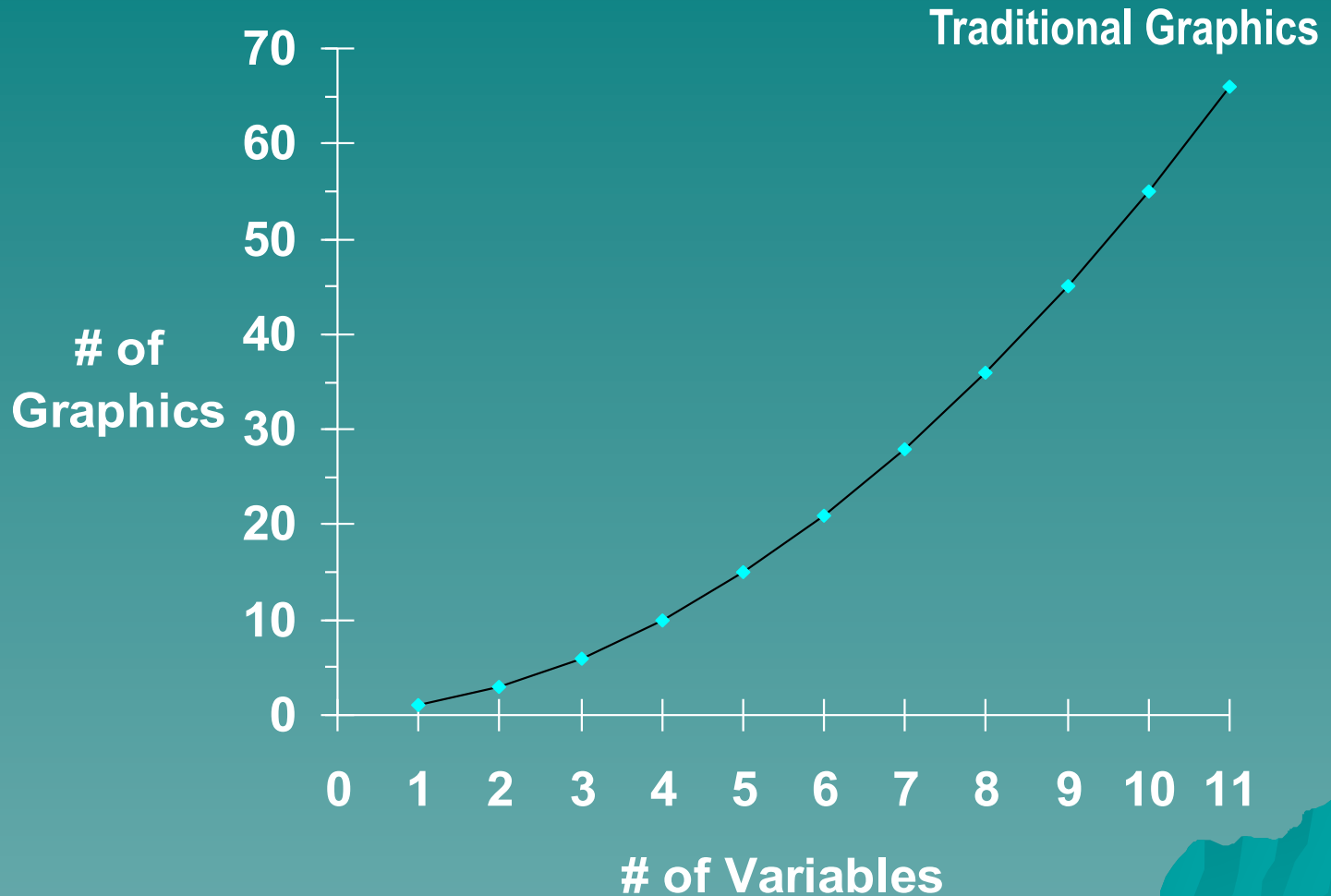
Handling More Complex Data

The previous data was from some actual U. S. cities; **10 different cities**, compared against **5 decision attributes**.

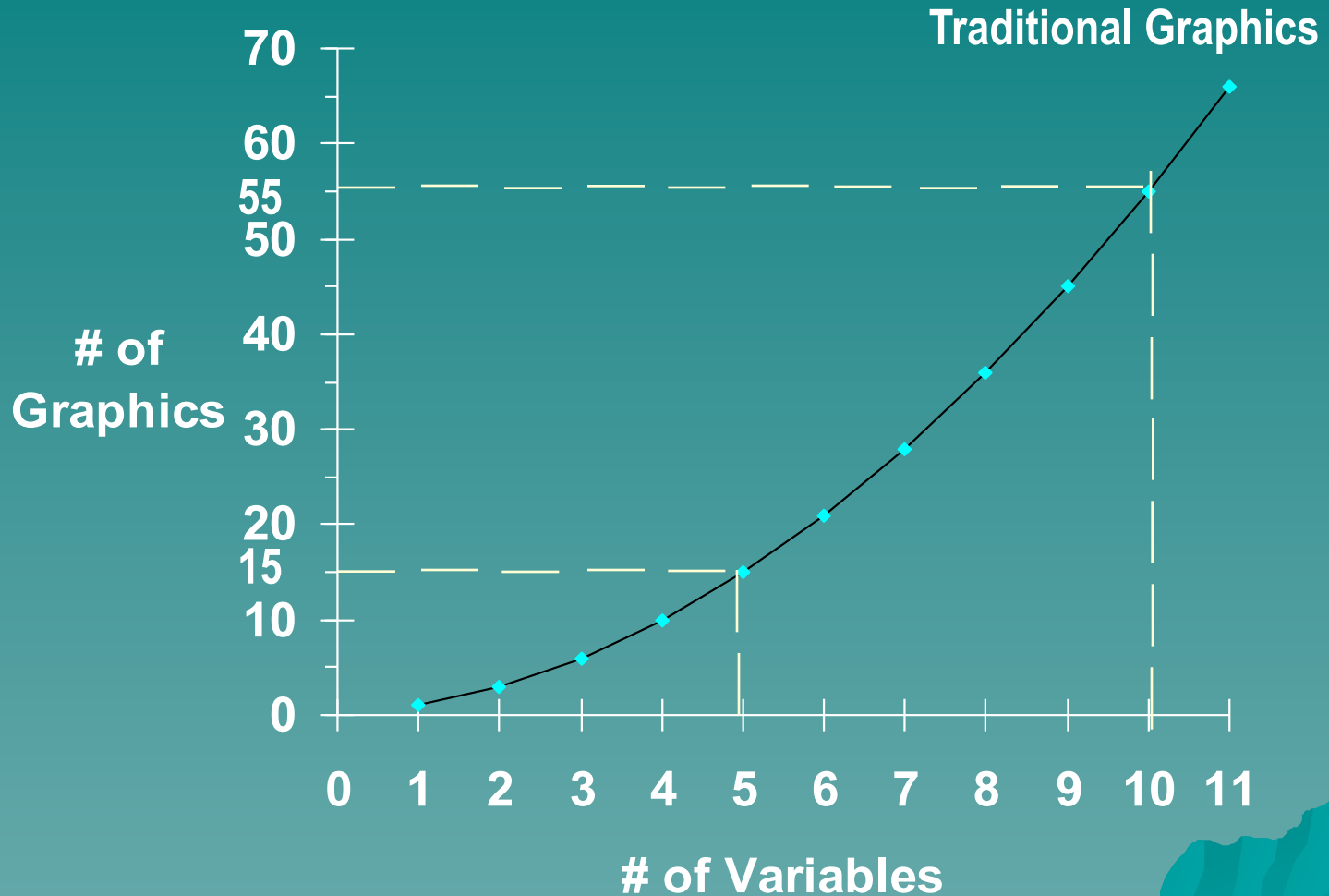
Using traditional graphics, a total of 5 bar charts are required to present comparative information, and 10 more X-Y scatter plots are also required.

<u>#Variables</u>	<u>#Bar Charts</u>	<u>#X-Y Scatter Plots</u>	<u>#</u>
<u>Paper Charts</u>	1	0	1
2	2	1	3
3	3	3	6
4	4	6	10
5	5	10	15
6	6	15	21
7	7	21	28
8	8	28	36
9	9	36	45
10	10	45	55

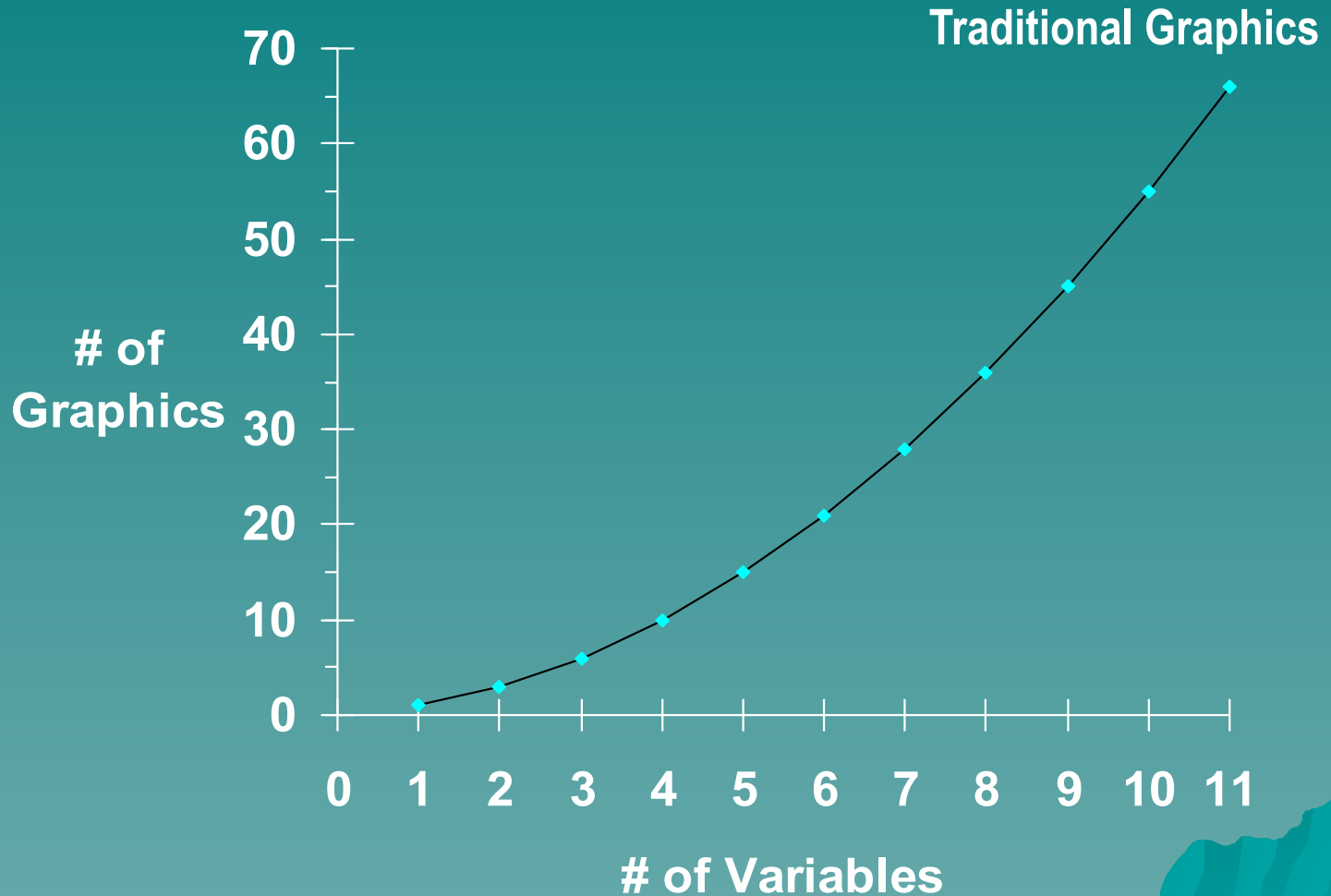
Many Graphics



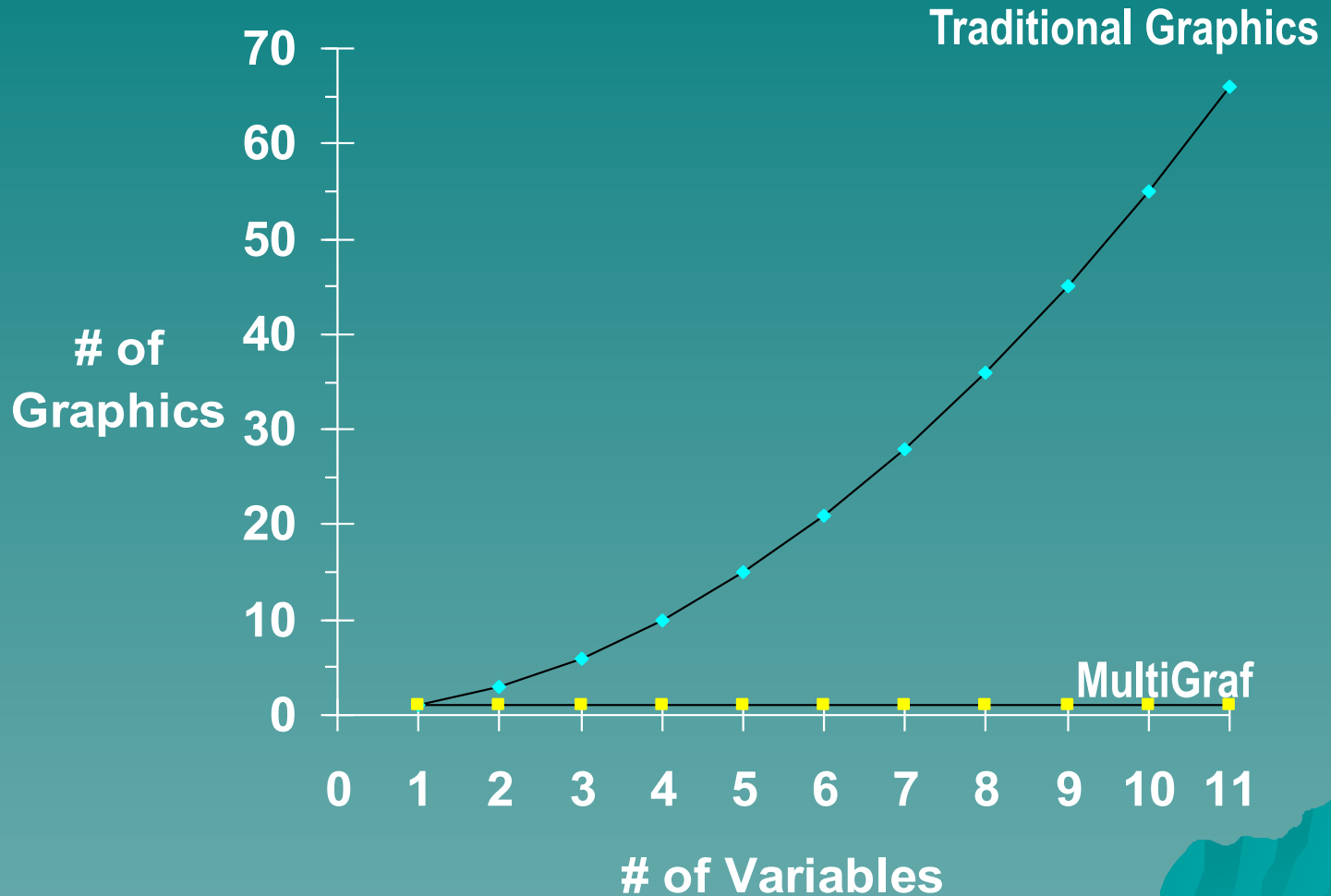
Many Graphics



One MultiGraf



One MultiGraf

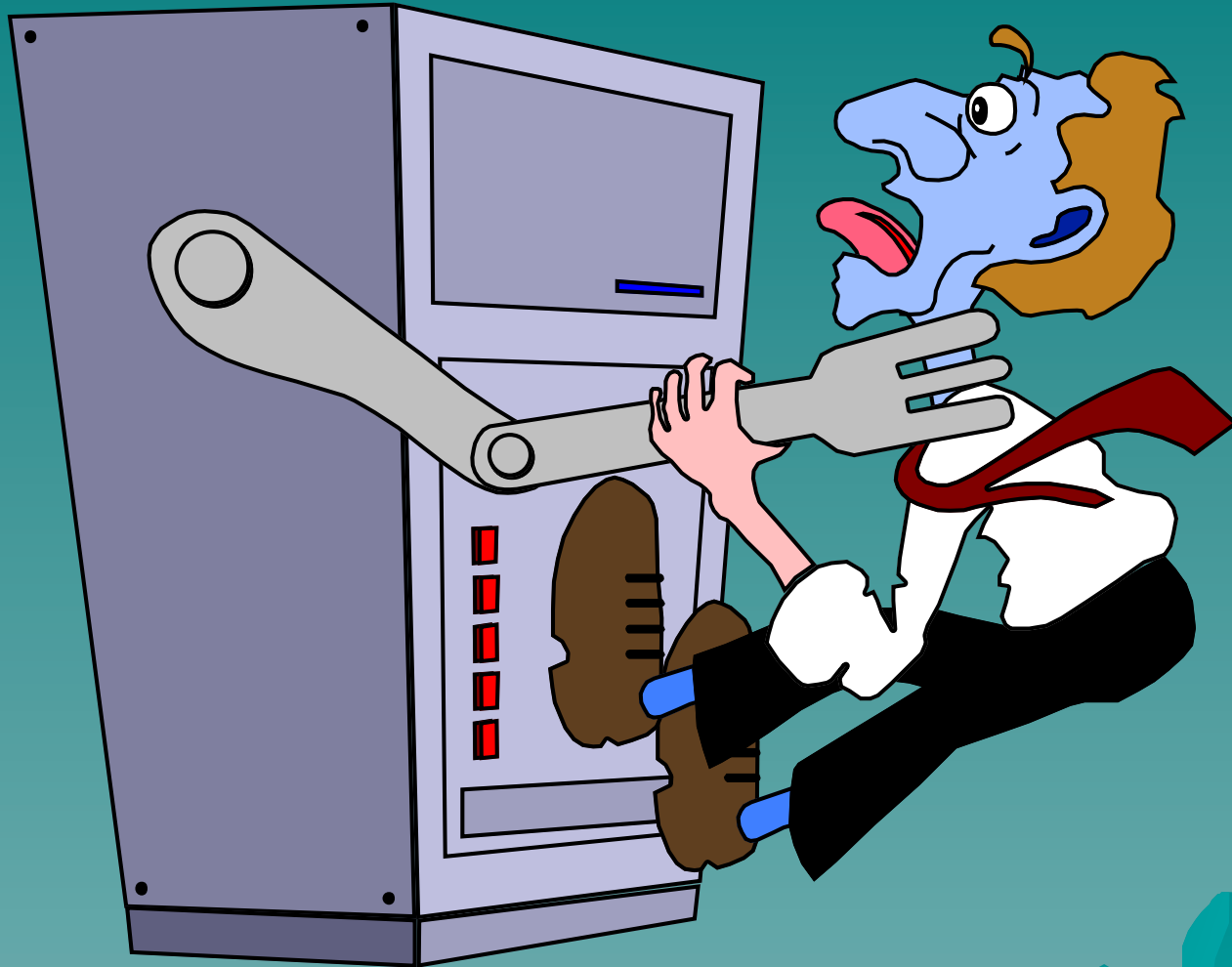


The Problem


Each **decision maker** must mentally merge a large number of graphics without correlation data to make a decision, which introduces significant error.

- ◆ TODAY, **decision making** is where **data retrieval** was BEFORE.

Today we're choking on
the data.



Traditional Problem (Separate Graphics)

- **Subjective**
 - **Inaccurate**
 - **Tedious**
- 

Traditional Problem (Separate Graphics)

- **Subjective**
- **Inaccurate**
- **Tedious**

HSG Solution (Combined Graphics)

- **Objective**
 - **Accurate**
 - **Immediate**
- 

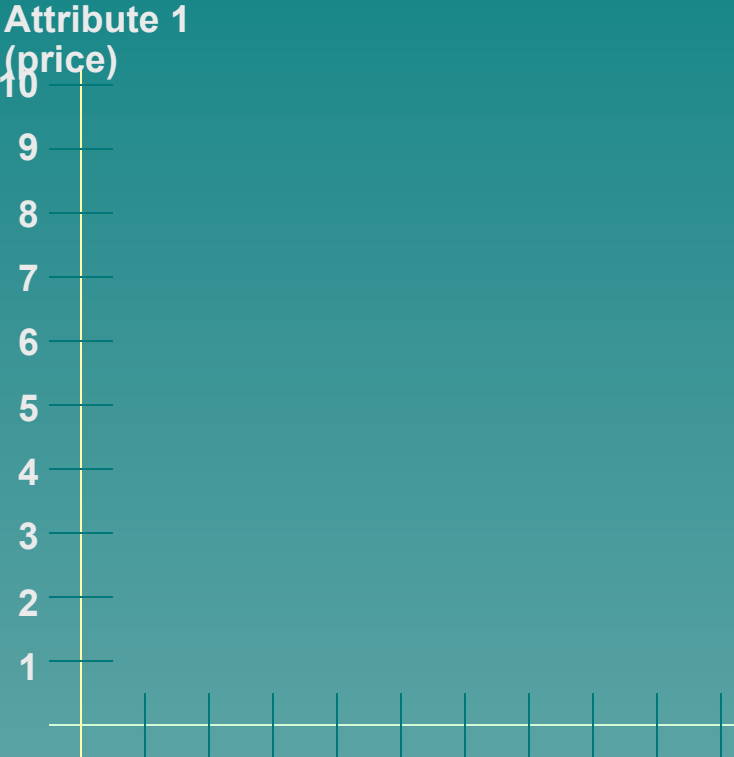
Summary of HSG's Single Graphic Data Display Features

- ◆ Multiple data points (objects) are shown together.
- ◆ Each object is represented by only one data point.
- ◆ Multiple or all axes (attributes) are shown.
- ◆ All data points are referenced to each axis.
- ◆ The axes are positioned in the center of the graphic.
- ◆ The average for each attribute is graphically shown.

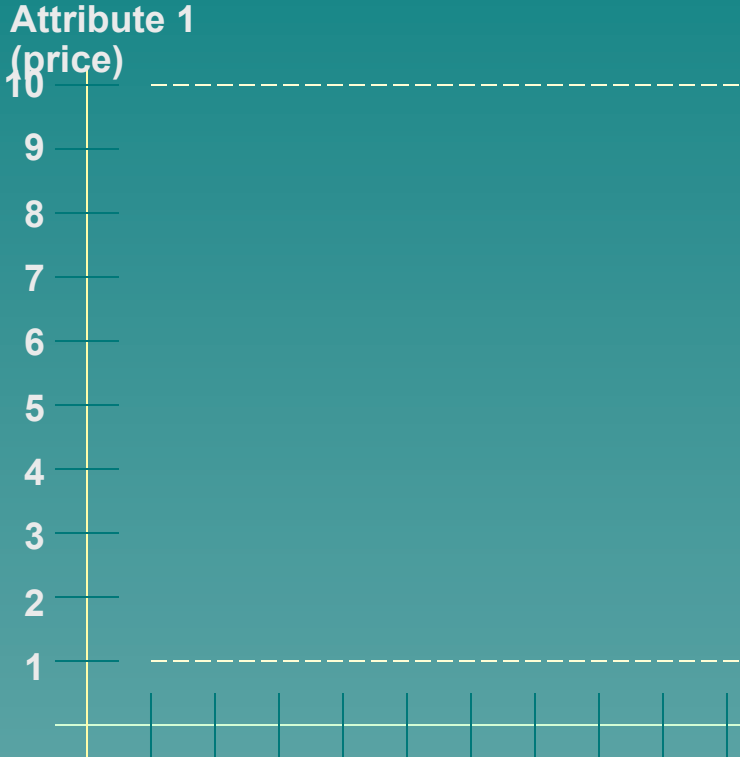
Summary of Features (CONT.)

- ◆ The comparative relationship between each attribute and all attributes is graphically displayed.
- ◆ The relative correlation between each attribute and all other attributes is accurately maintained.

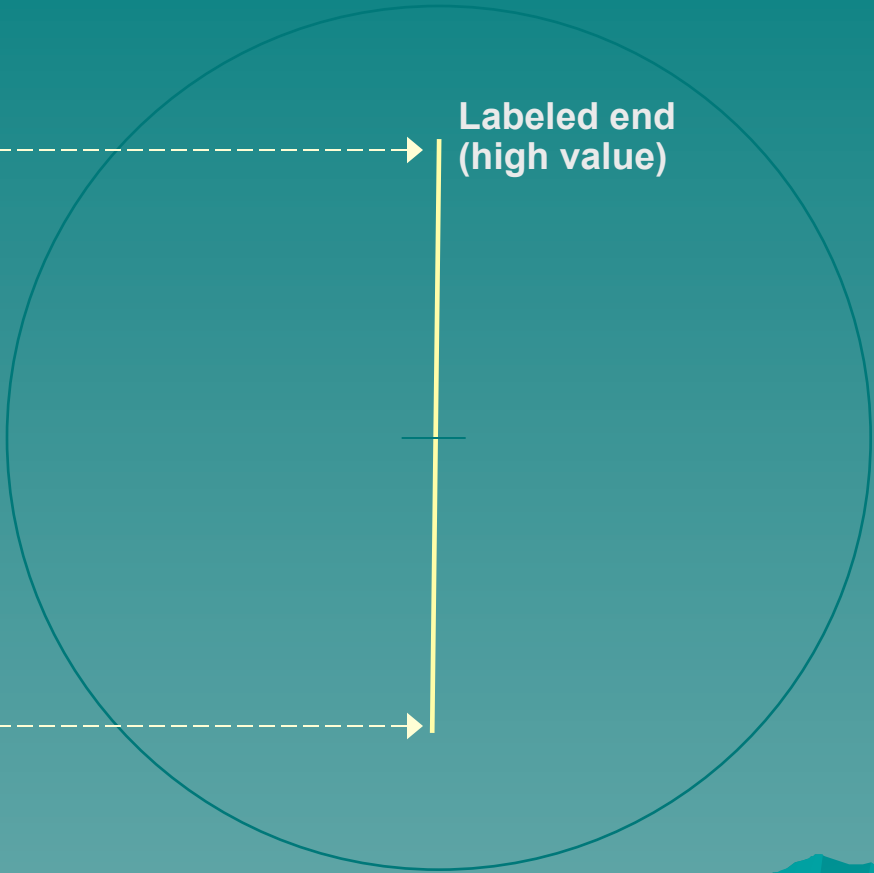
Standard 2D x-y scatter plot



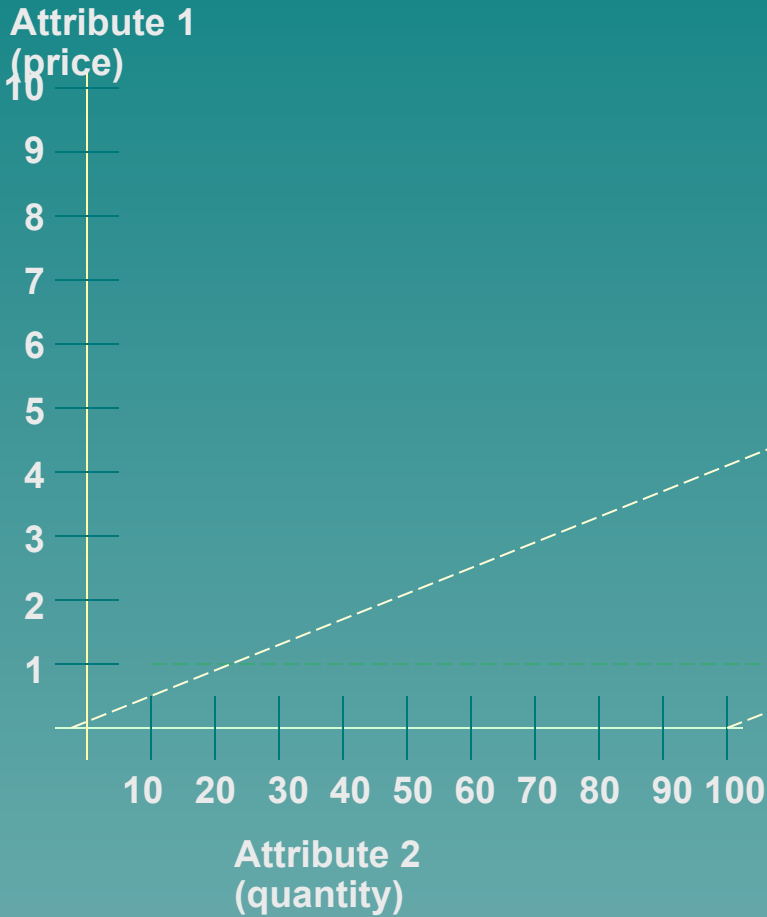
Standard 2D x-y scatter plot



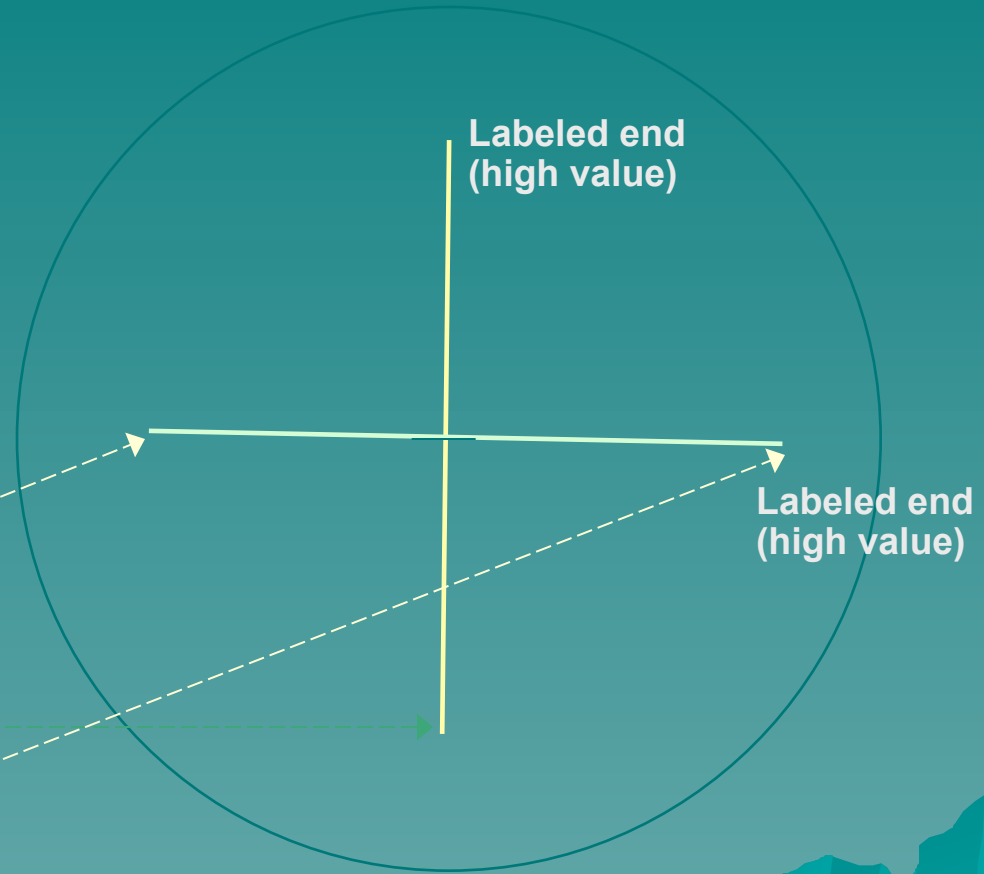
Multigraf



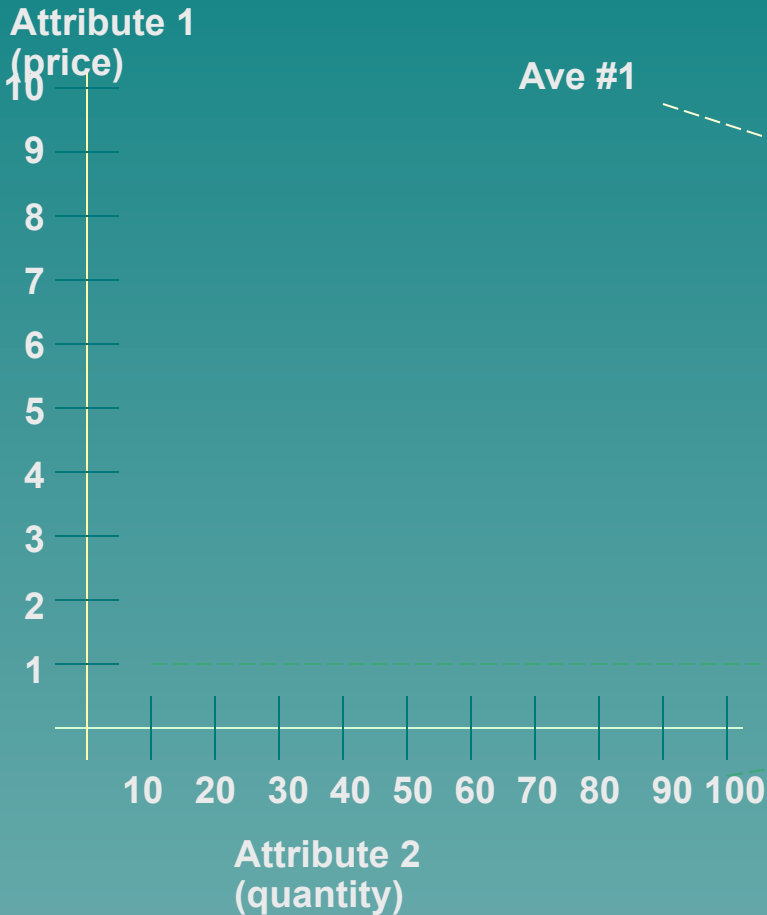
Standard 2D x-y scatter plot



Multigraf

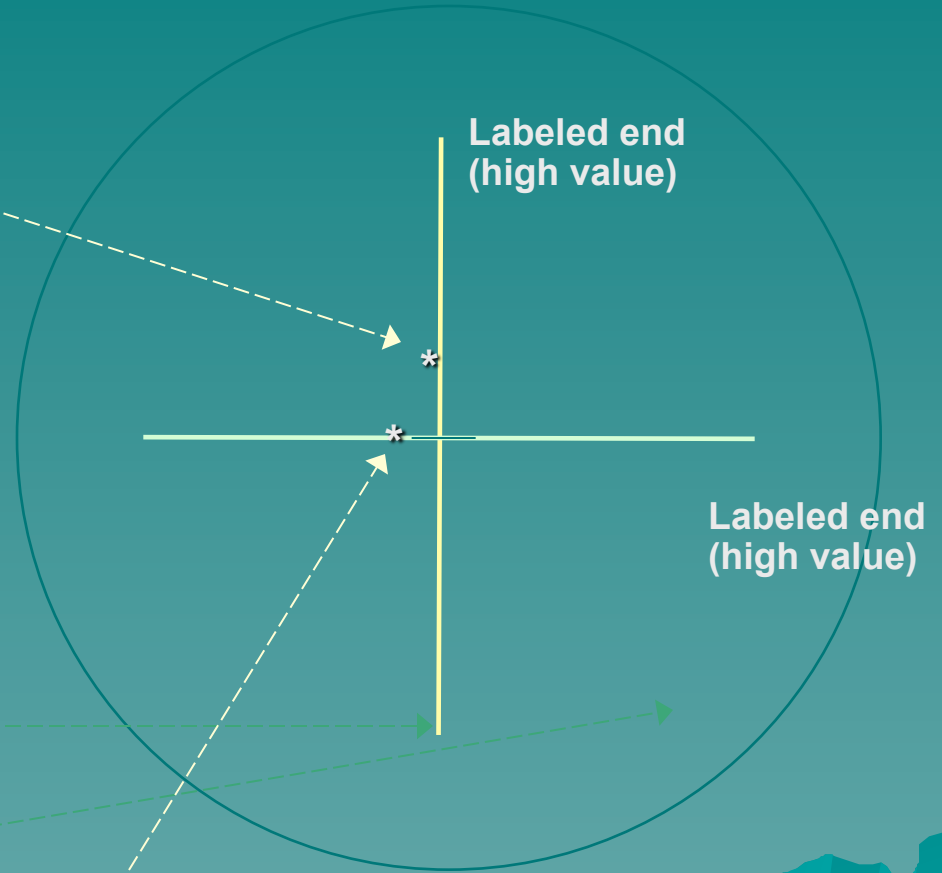


Standard 2D x-y scatter plot

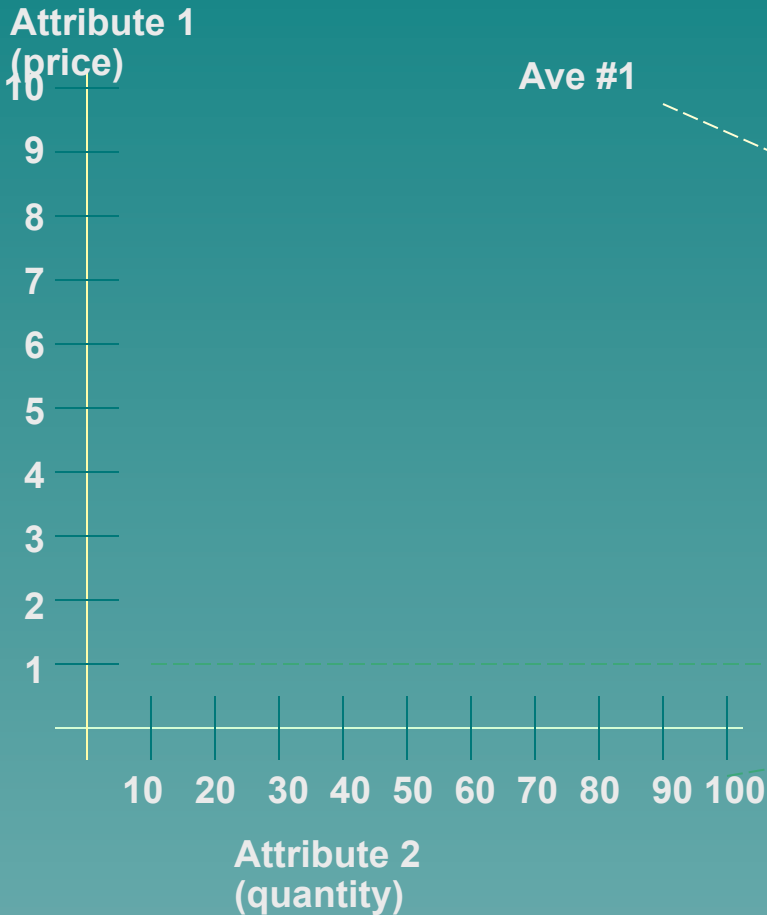


Multigraf

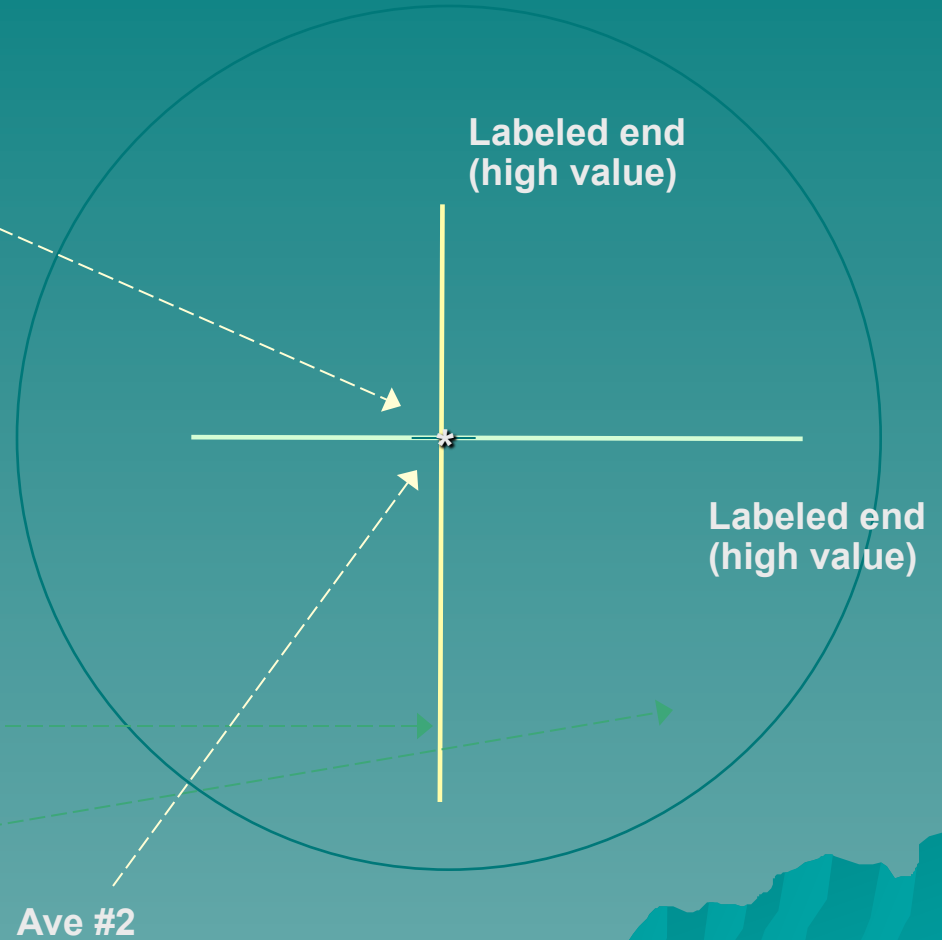
Ave #1



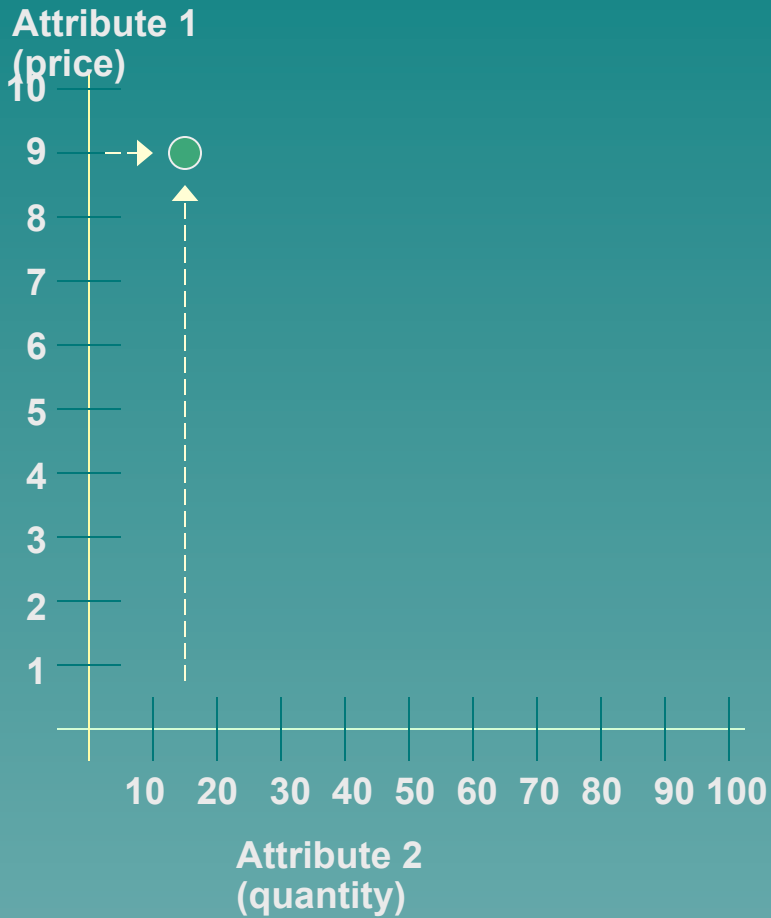
Standard 2D x-y scatter plot



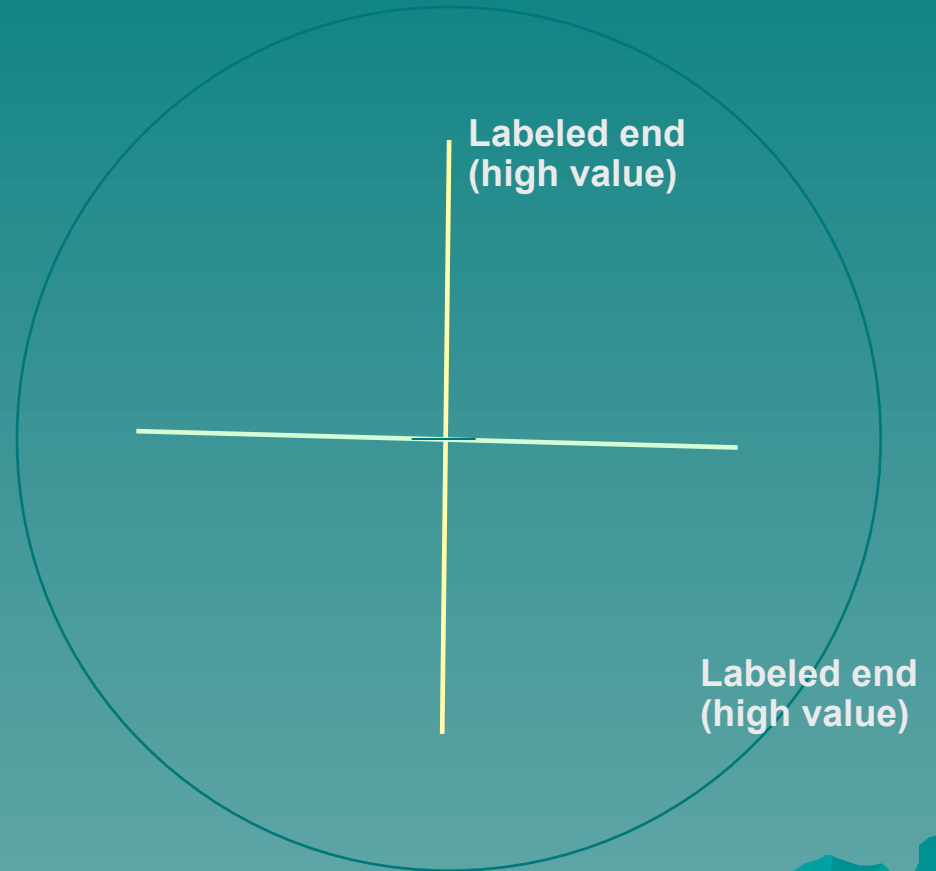
Multigraf



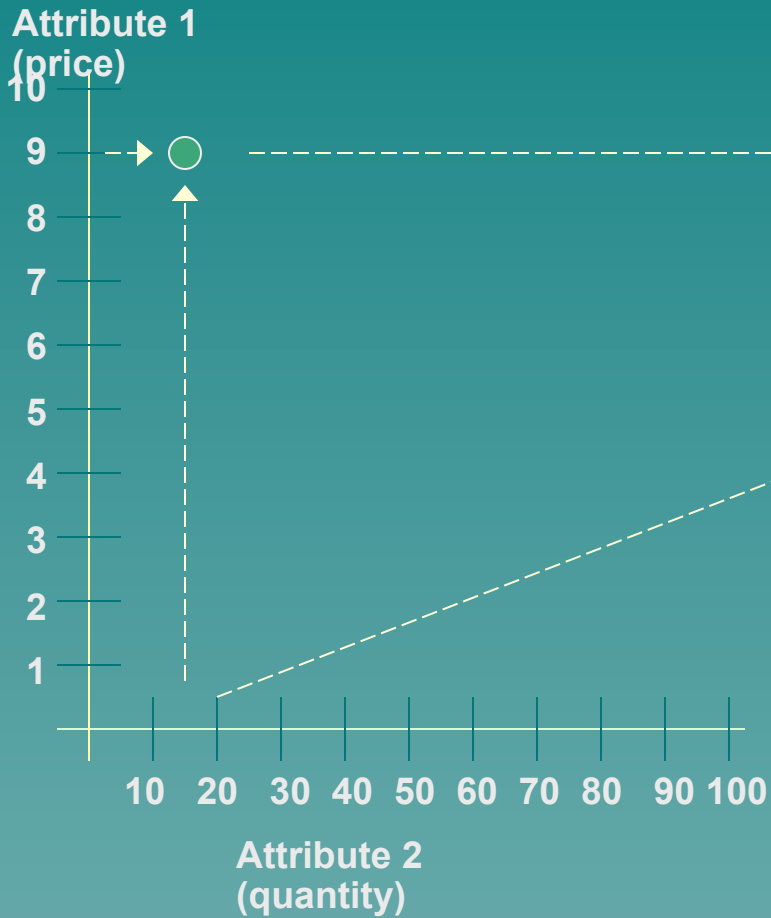
Standard 2D x-y scatter plot



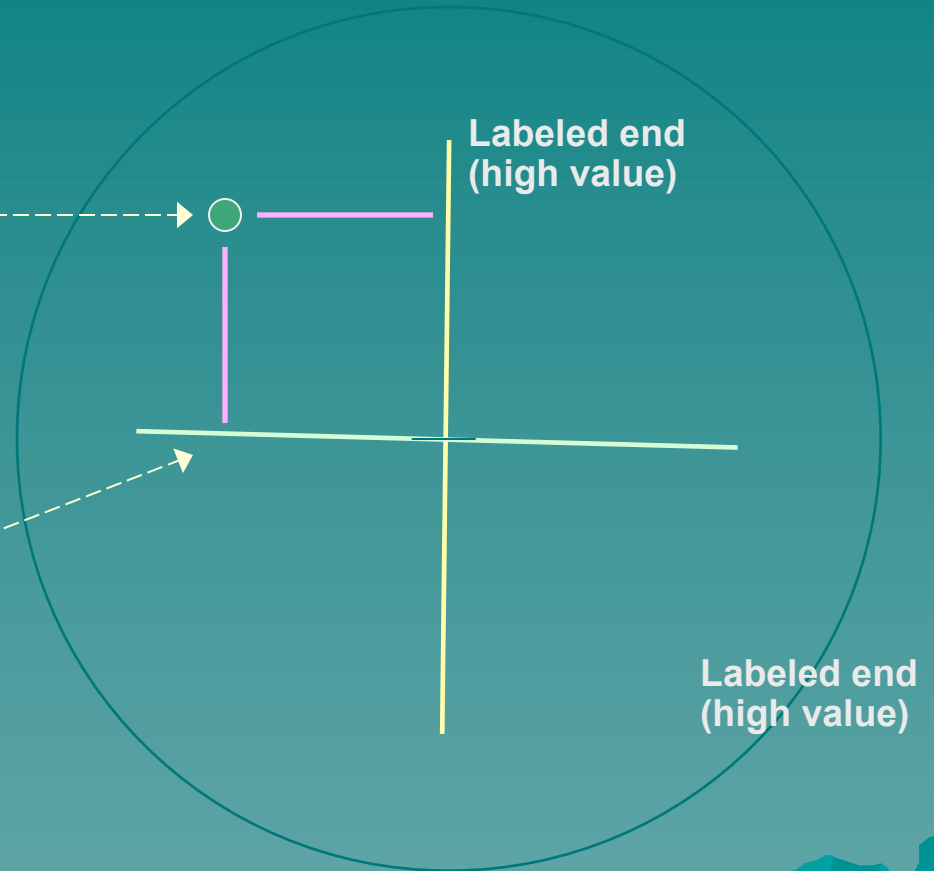
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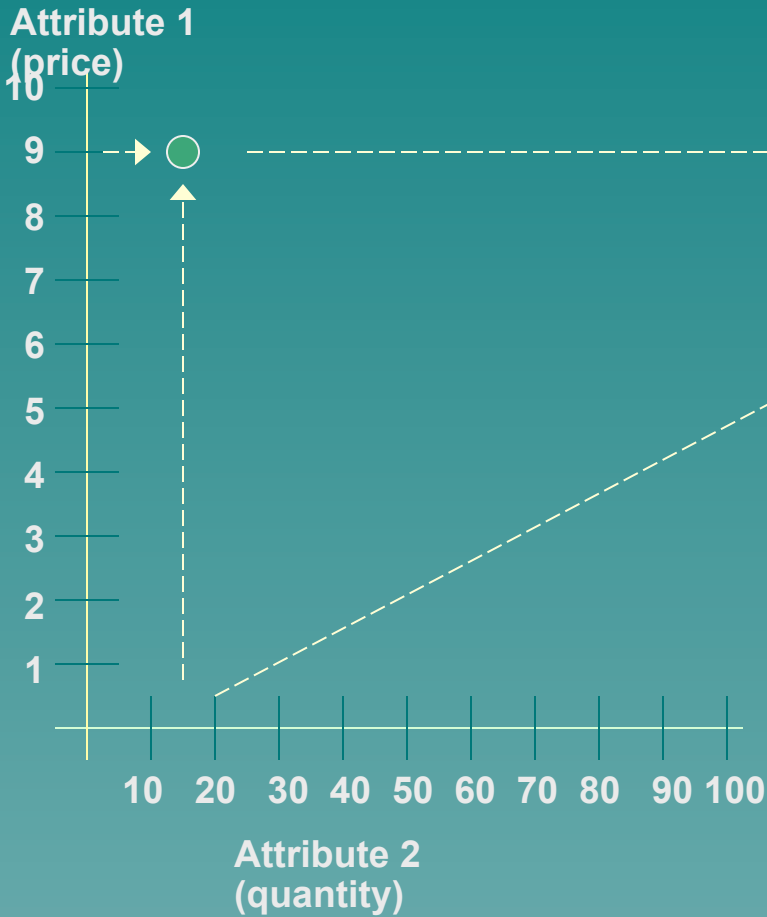
Standard 2D x-y scatter plot



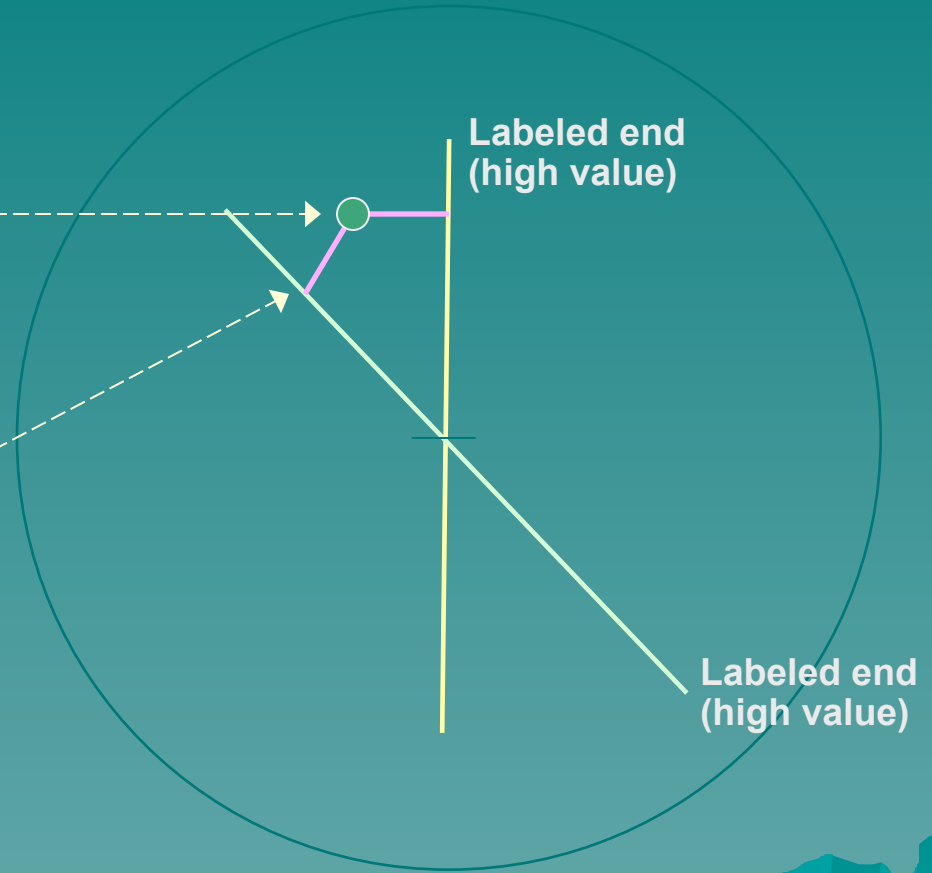
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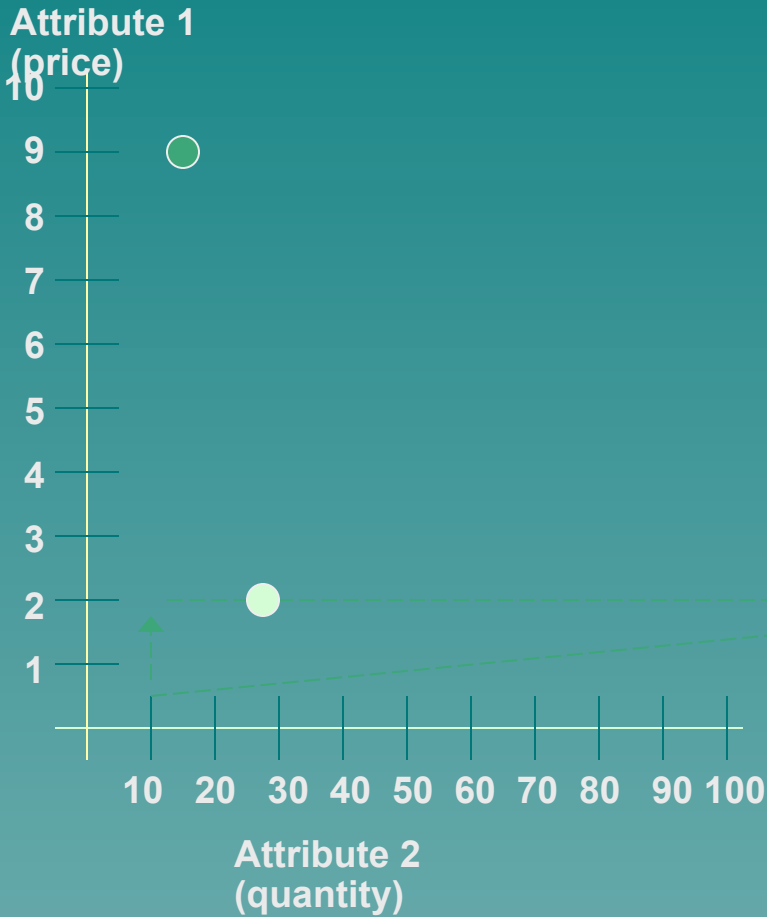
Standard 2D x-y scatter plot



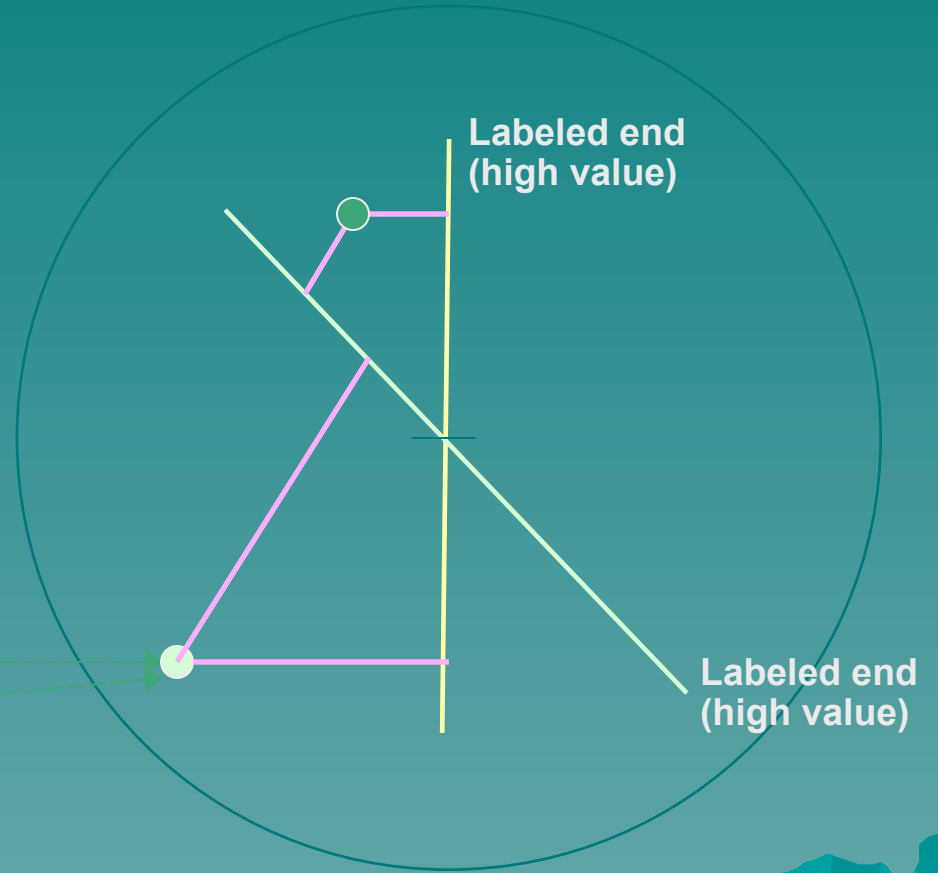
Multigraf



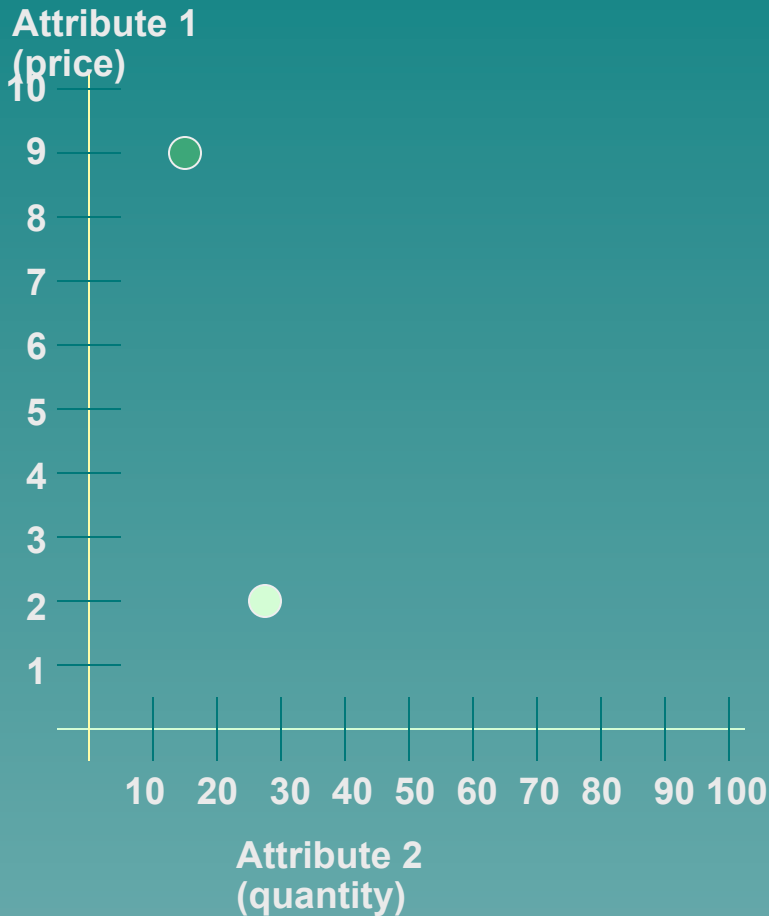
Standard 2D x-y scatter plot



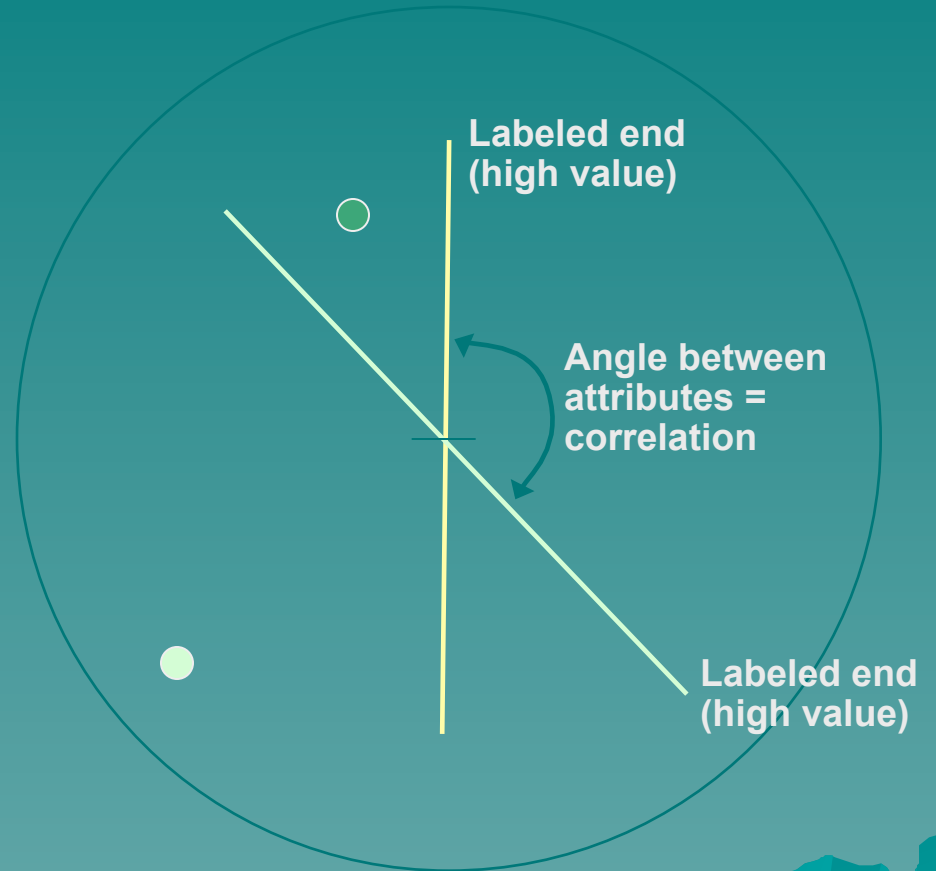
3D Multigraf



Standard 2D x-y scatter plot



3D Multigraf



Tabular Data

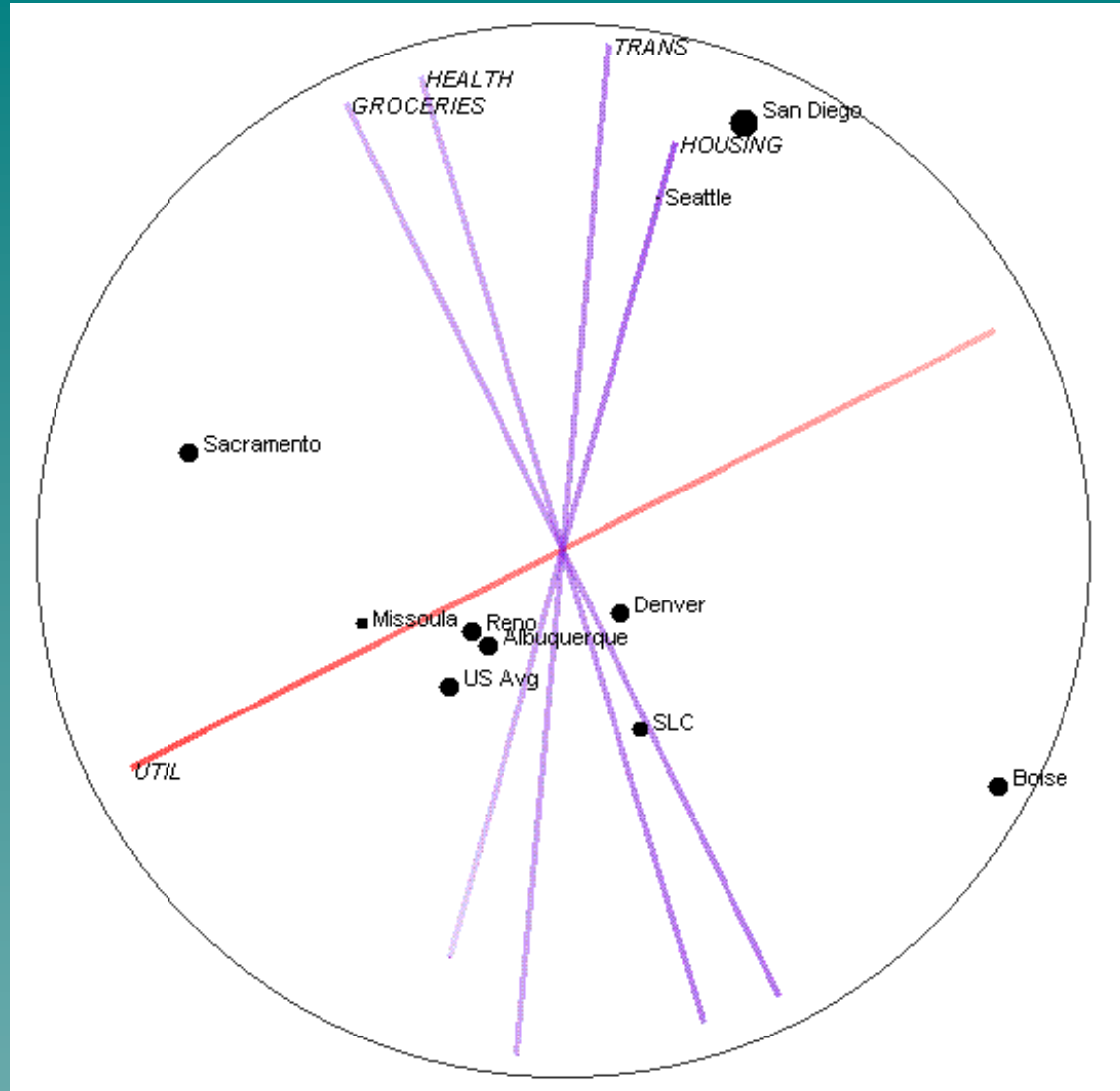
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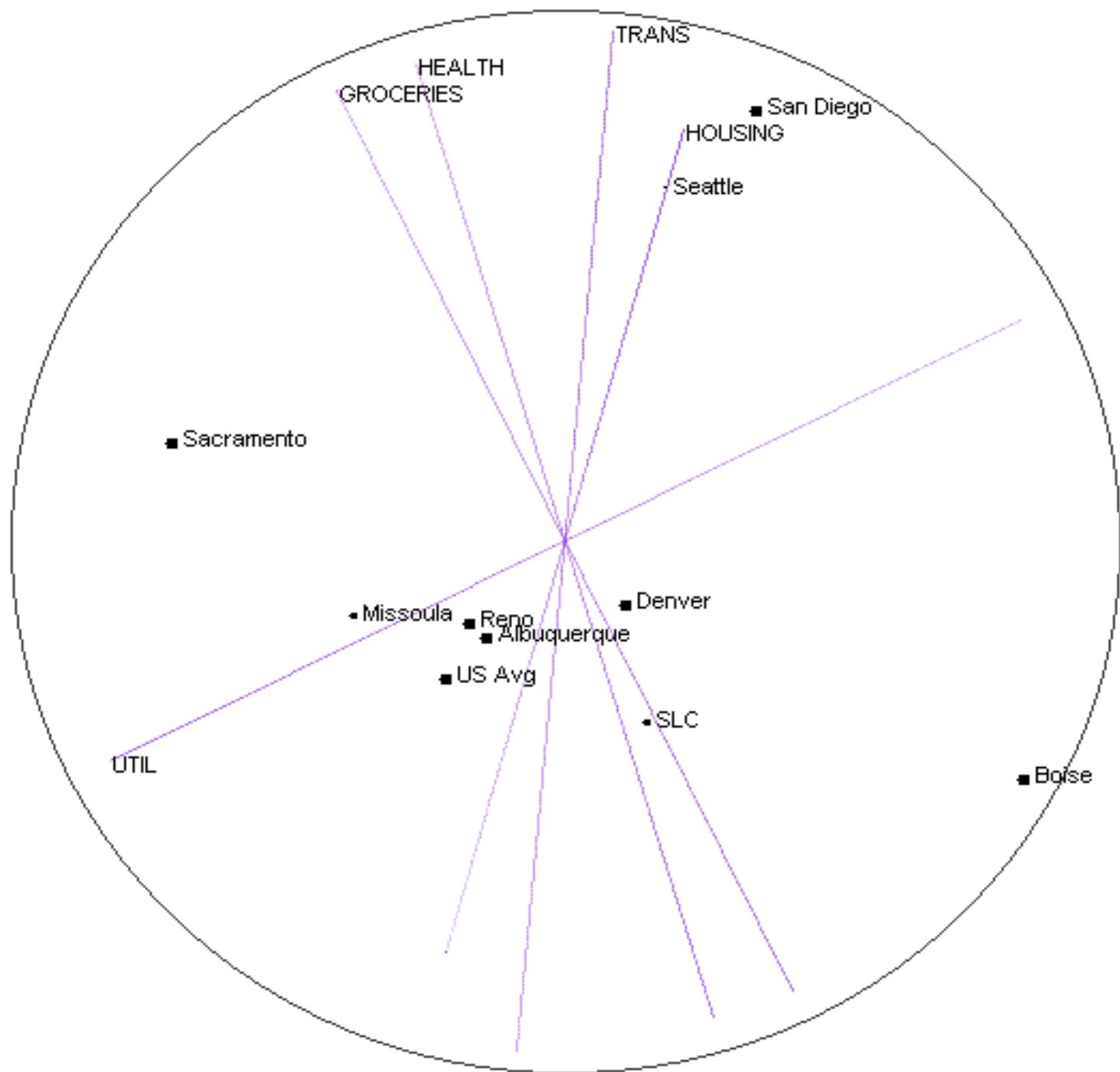
Columns and Rows

HSG's MultiGraf for 10 cities data

- ✚ The labeled end of each attribute has the highest numeric value
- ✚ The angle between two attributes represents their correlation value
- Objects are placed in 3D relative to all attributes
- Native view (as shown) is “flatest” possible view for all variables displayed

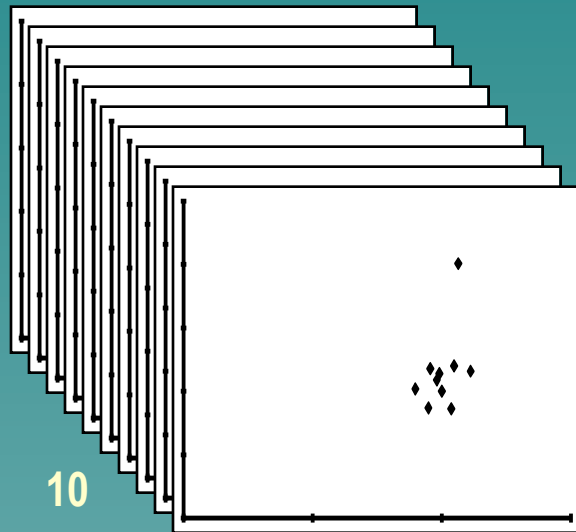
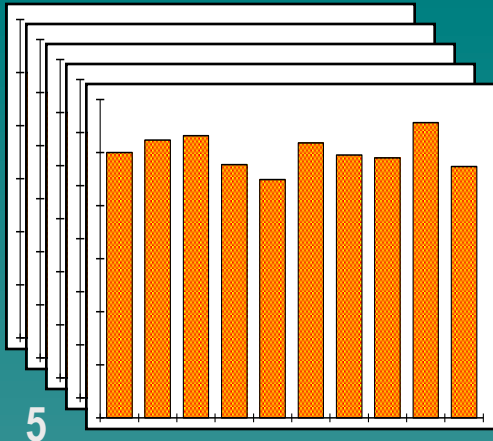
MultiGraf





Traditional Graphics

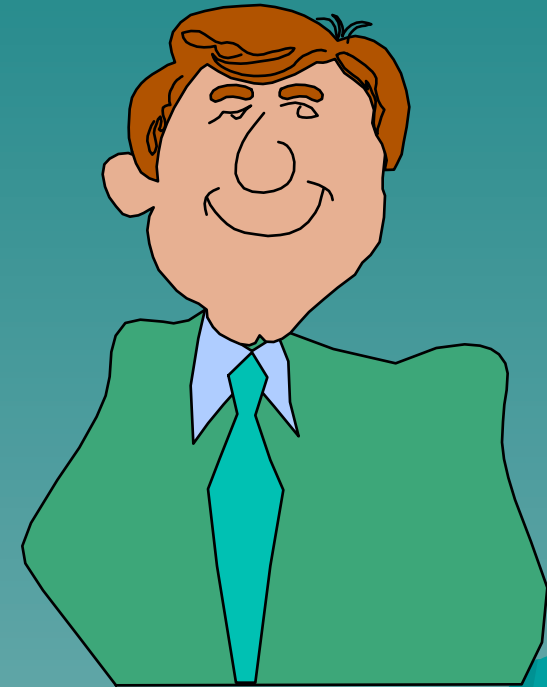
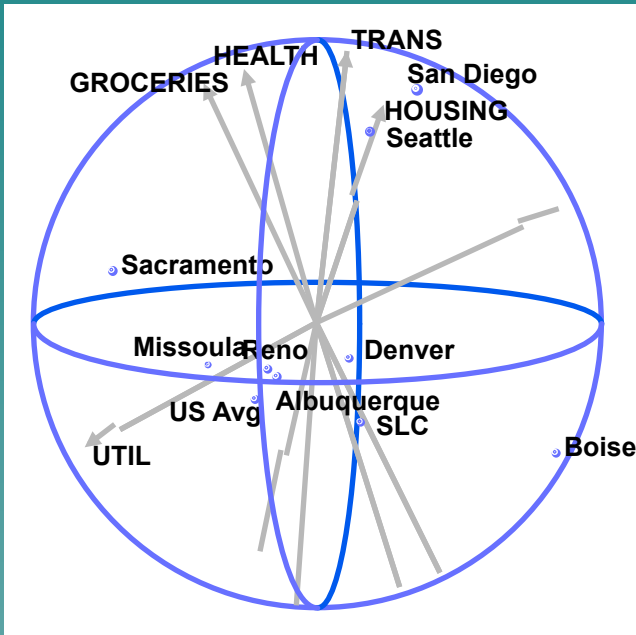
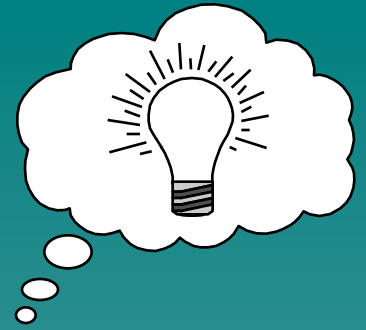
5 Variables



15 Charts and Graphs

HSG Graphics

5 Variables



1 MultiGraf

Unique HSG Features

- ◆ The entire data set is **displayed objectively**.
- ◆ **No conclusions** are required before graphically representing the data.
- ◆ The entire data set is **analyzed without segmentation**.
- ◆ **Attribute correlations** are graphically displayed.
- ◆ **Relevant data elements** are easier to subsequently identify, eliminate and/or explore.
- ◆ Numerous traditional **graphs are combined** into a single MultiGraf.
- ◆ **Data input is a simple spreadsheet format**.

Handling More Complex Data

Following are some actual Consumer Reports' data on **3 different data sets** of batteries, compared against **3 decision attributes**.

Using **traditional bar charts**, a total of 9 bar charts are used to present comparative information, and 36 X-Y scatter plot could also be generated.

Consumer Reports'

Heavy Duty Battery Test Results

Heavy Duty Battery	Toy Test
Eveready - H	1.2
Mallory - H	1.2
Radio Shack - H	1.0
Rayovac - H	1.2
Sears - H	1.2

Heavy Duty Battery	Stereo Test
Eveready - H	4.5
Mallory - H	4.8
Radio Shack - H	5.5
Rayovac - H	4.6
Sears - H	4.2

Heavy Duty Battery	Price
Eveready - H	\$0.57
Mallory - H	\$0.49
Radio Shack - H	\$0.37
Rayovac - H	\$0.56
Sears - H	\$0.44

Consumer Reports' Alkaline Battery Test Results

Alkaline Battery	Toy Test
Duracell - A	6.2
Eveready - A	5.3
Kodak - A	5.5
Panasonic - A	5.7
Radio Shack - A	5.1
Rayovac - A	4.5
Sears - A	5.7

Alkaline Battery	Stereo Test
Duracell - A	14.2
Eveready - A	14.1
Kodak - A	13.5
Panasonic - A	14.1
Radio Shack - A	13.5
Rayovac - A	11.2
Sears - A	14.0

Alkaline Battery	Price
Duracell - A	\$1.08
Eveready - A	\$0.92
Kodak - A	\$0.99
Panasonic - A	\$0.88
Radio Shack - A	\$0.72
Rayovac - A	\$0.98
Sears - A	\$0.70

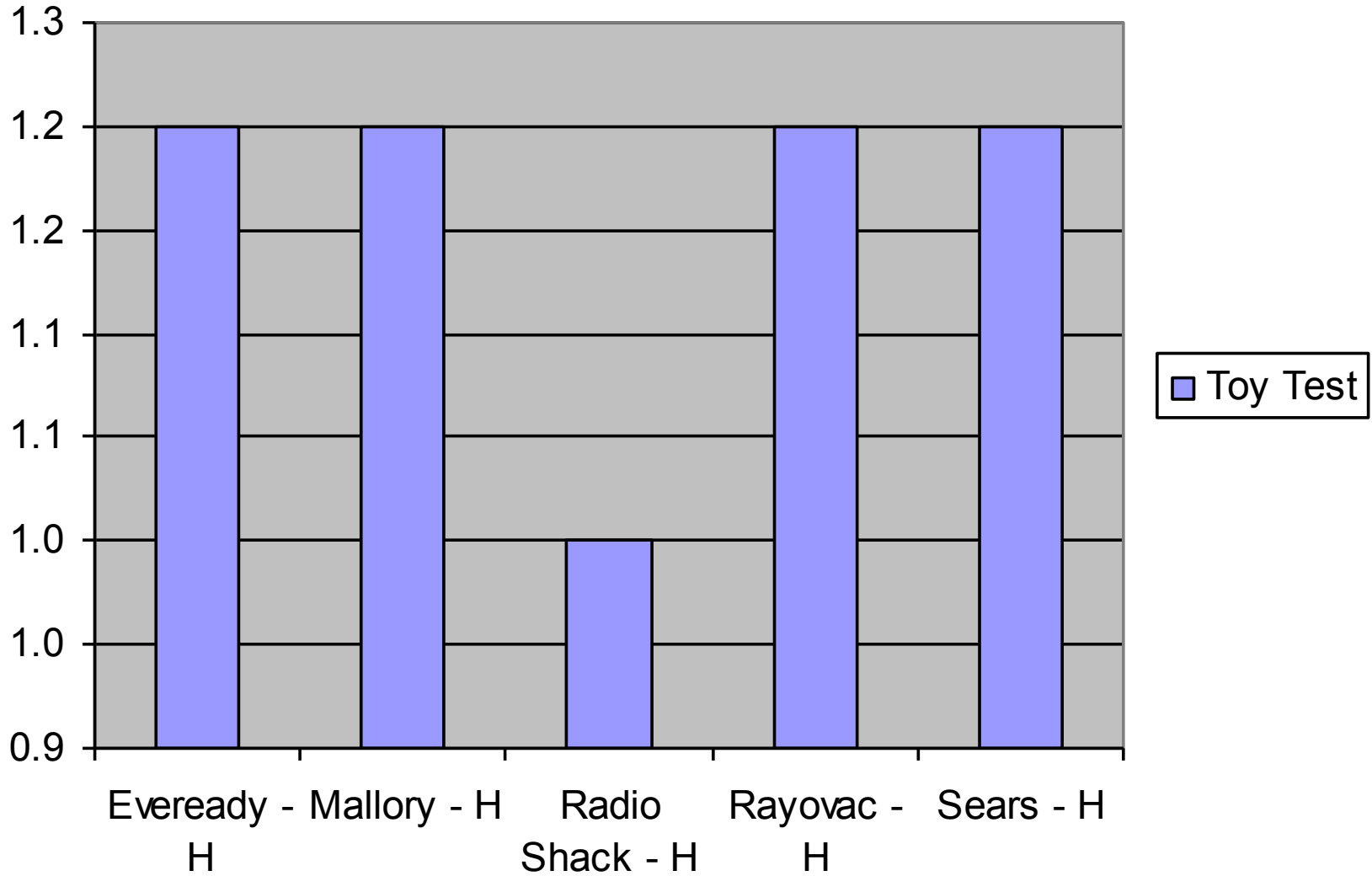
Consumer Reports' Rechargeable Battery Test Results

Rechargeable Battery	Toy Test
Eveready - R	1.6
GE - R	2.2
Millenium - R	1.7
Radio Shack - R	2.2

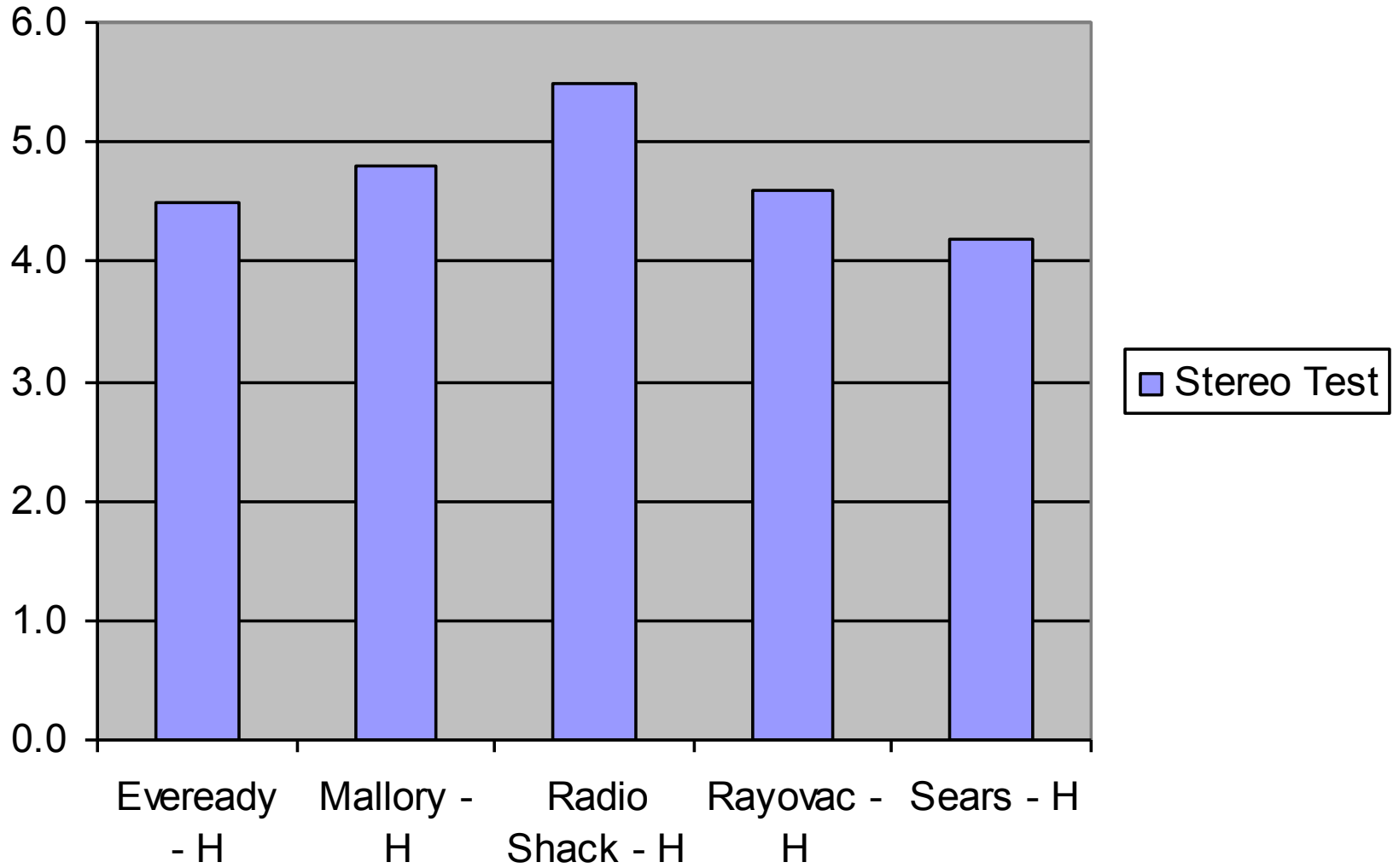
Rechargeable Battery	Stereo Test
Eveready - R	3.5
GE - R	5.5
Millenium - R	4.7
Radio Shack - R	3.9

Rechargeable Battery	Price
Eveready - R	\$3.95
GE - R	\$3.85
Millenium - R	\$2.99
Radio Shack - R	\$2.35

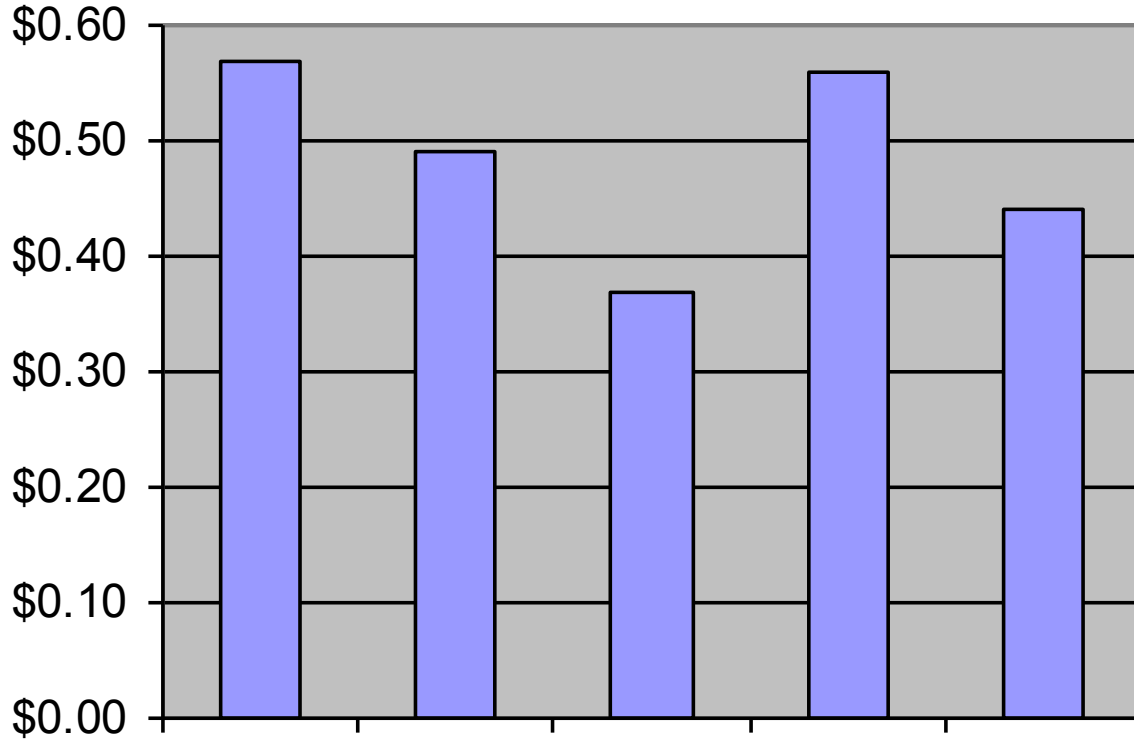
Toy Test



Stereo Test



Heavy Duty Price



■ Heavy Duty Price

Eveready - H

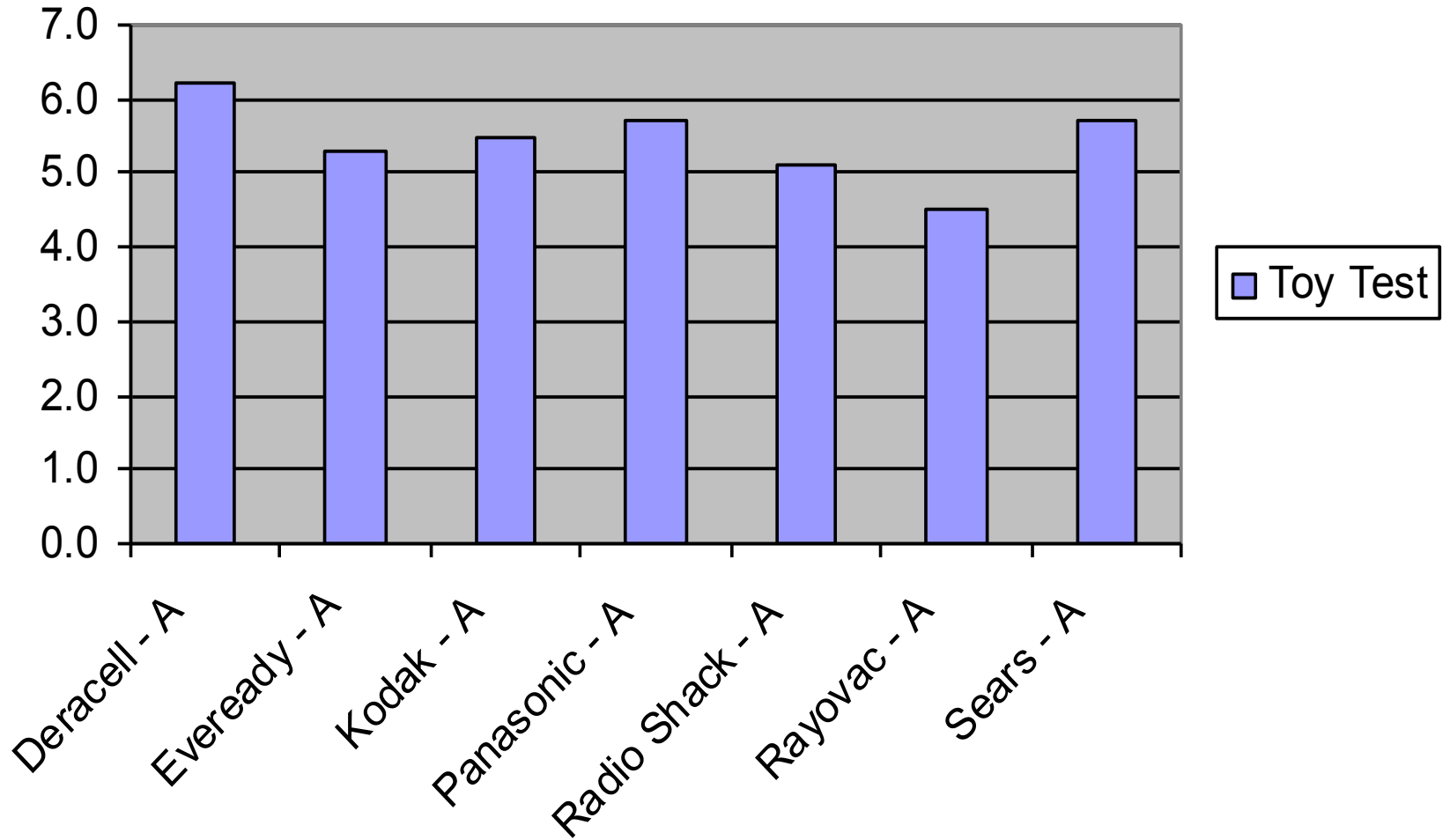
Mallory - H

Radio Shack - H

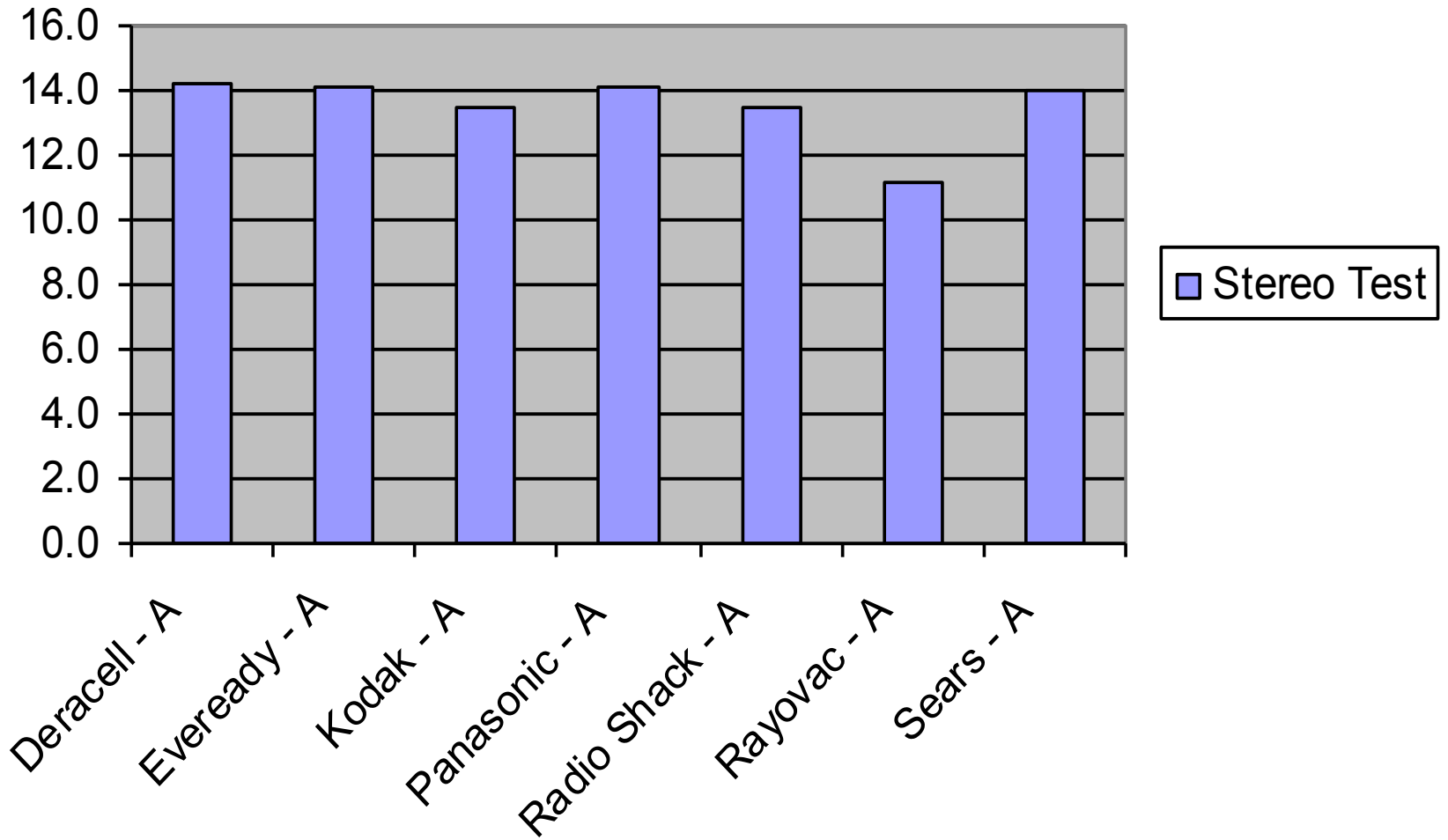
Rayovac - H

Sears - H

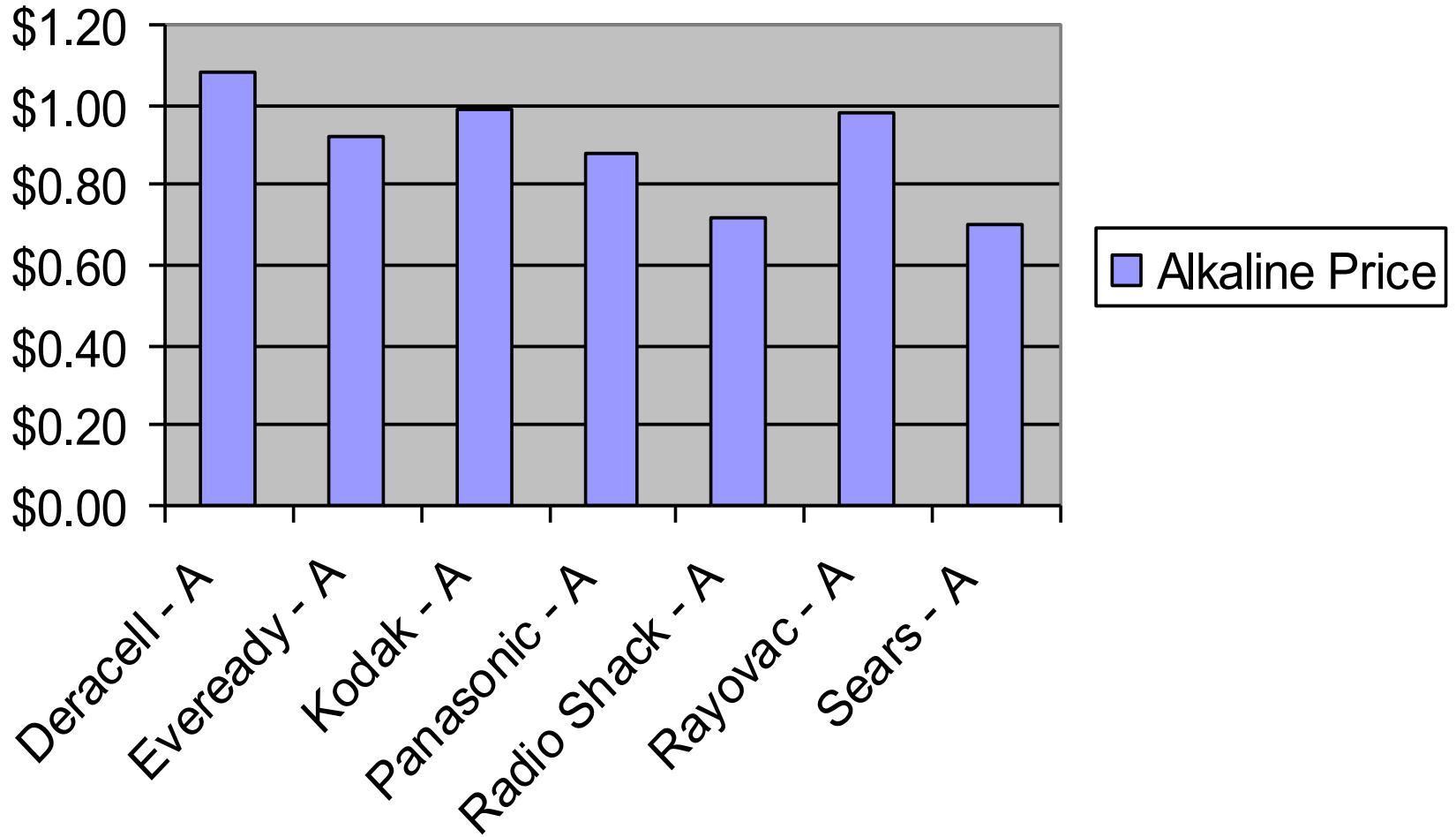
Toy Test



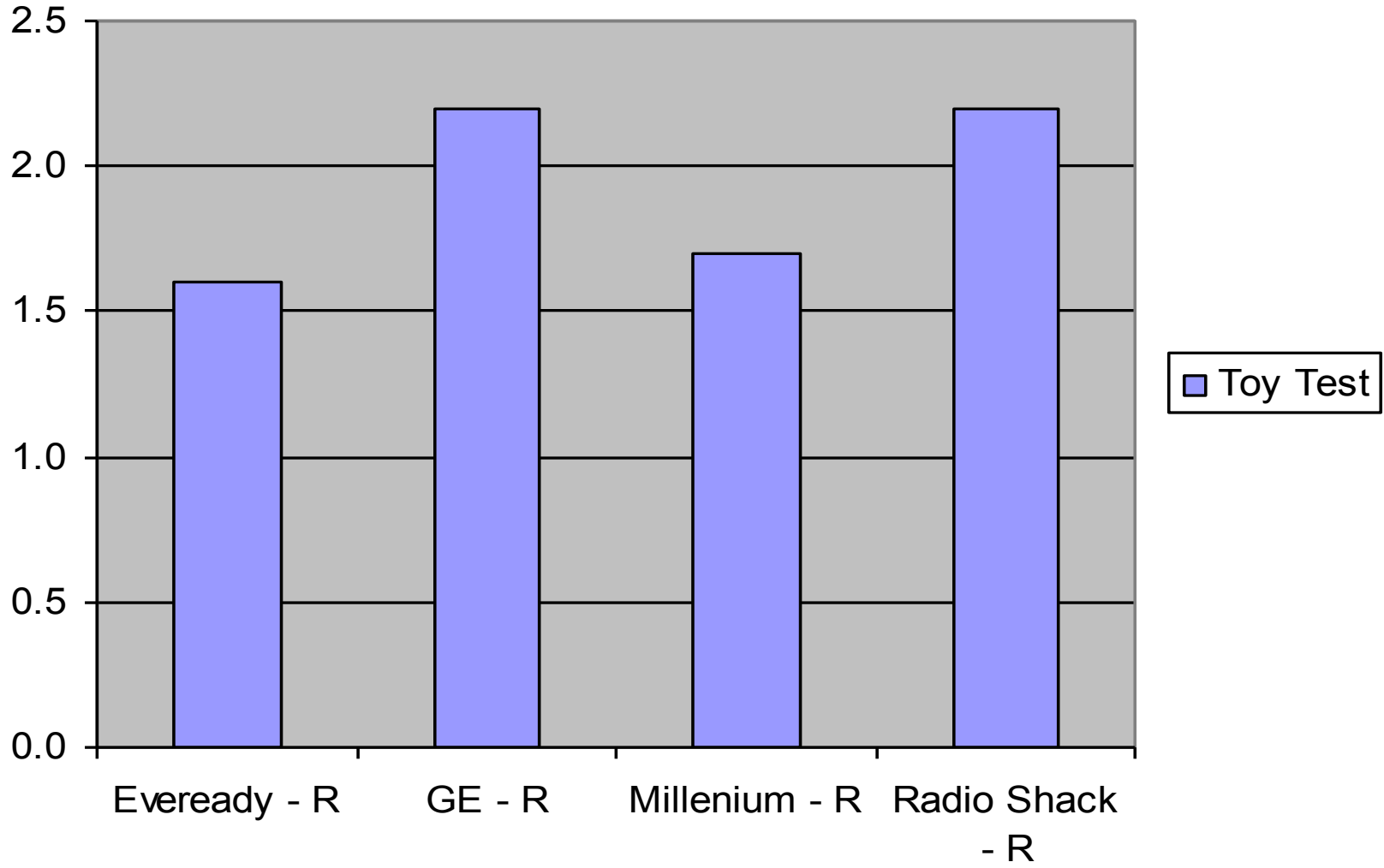
Stereo Test



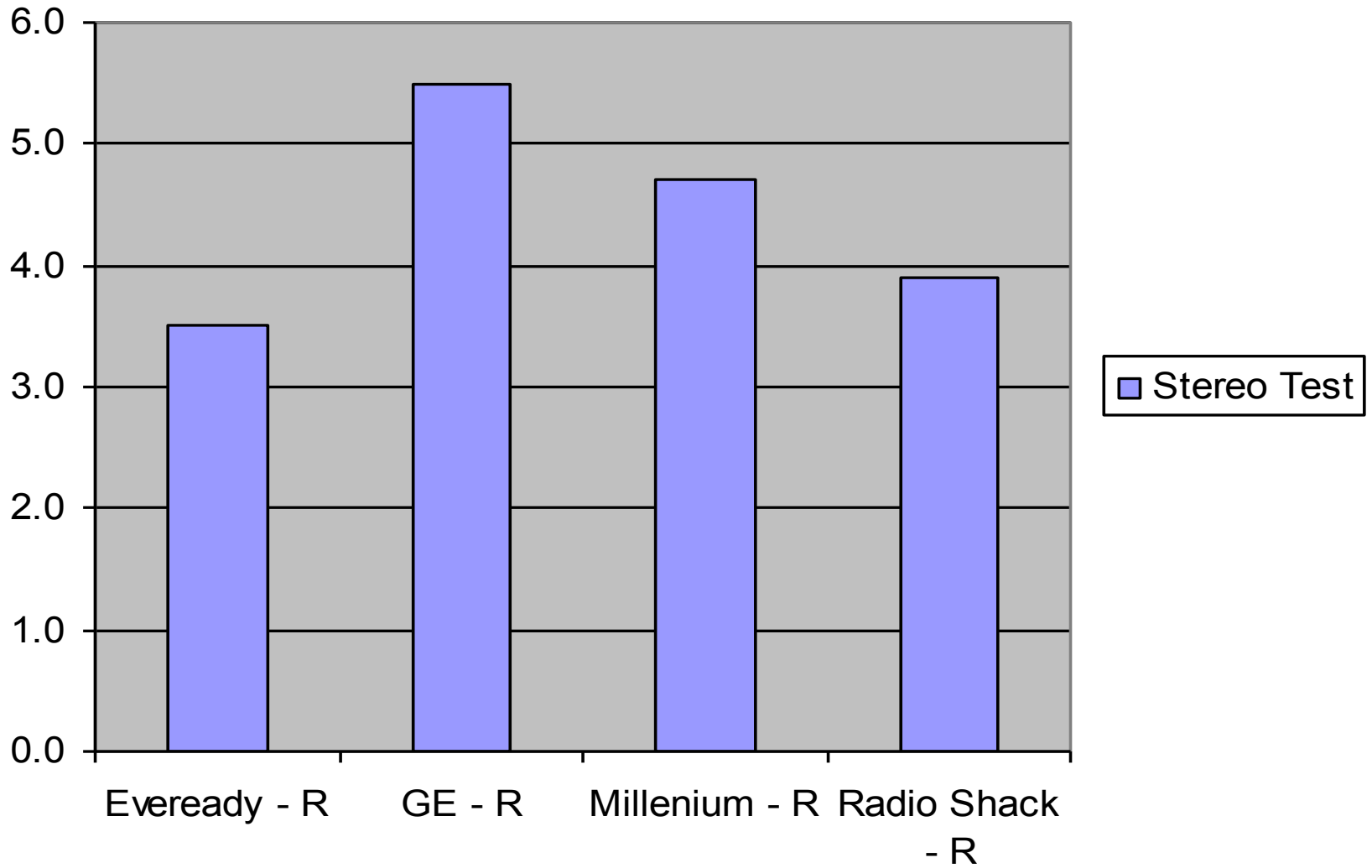
Alkaline Price



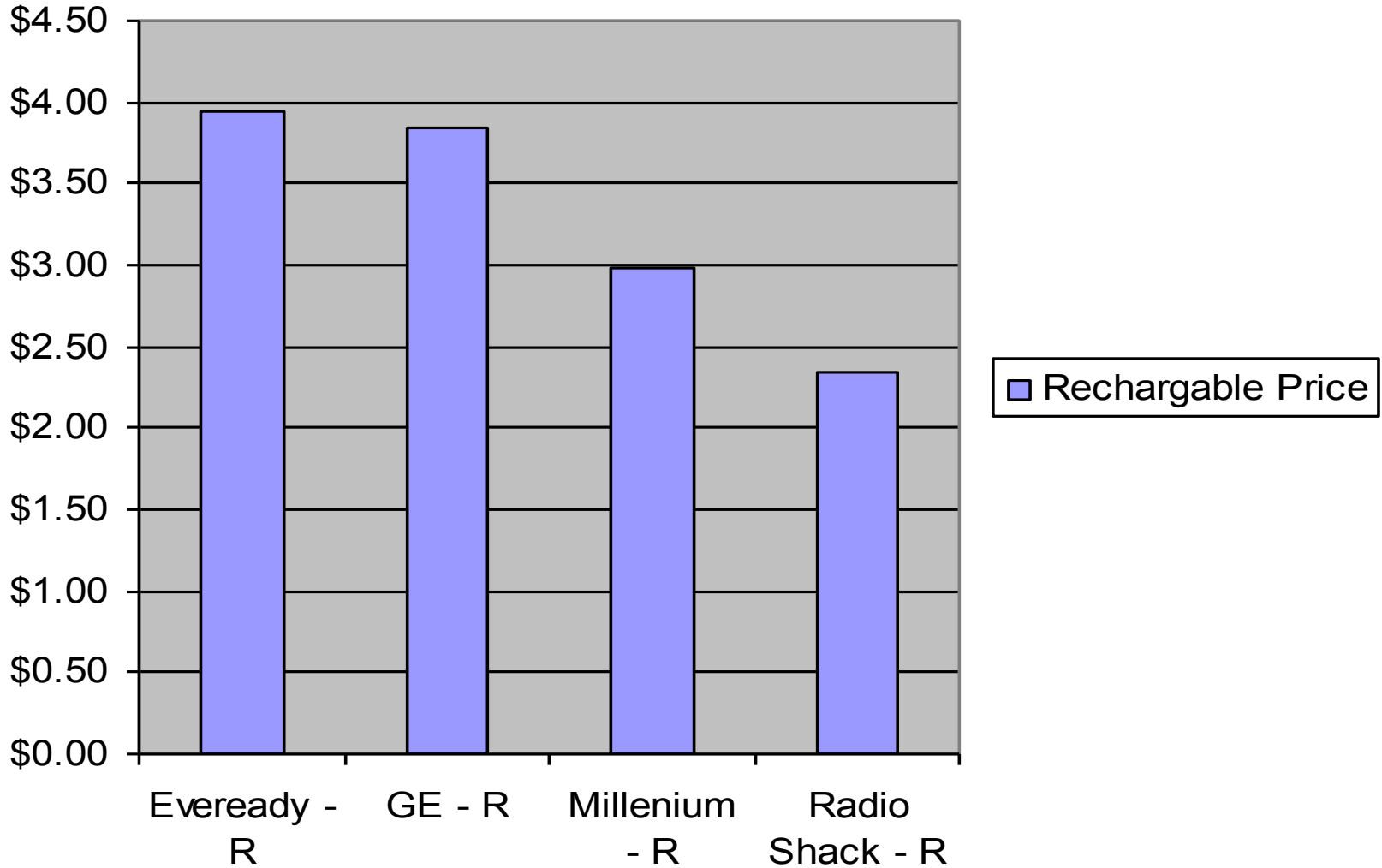
Toy Test



Stereo Test



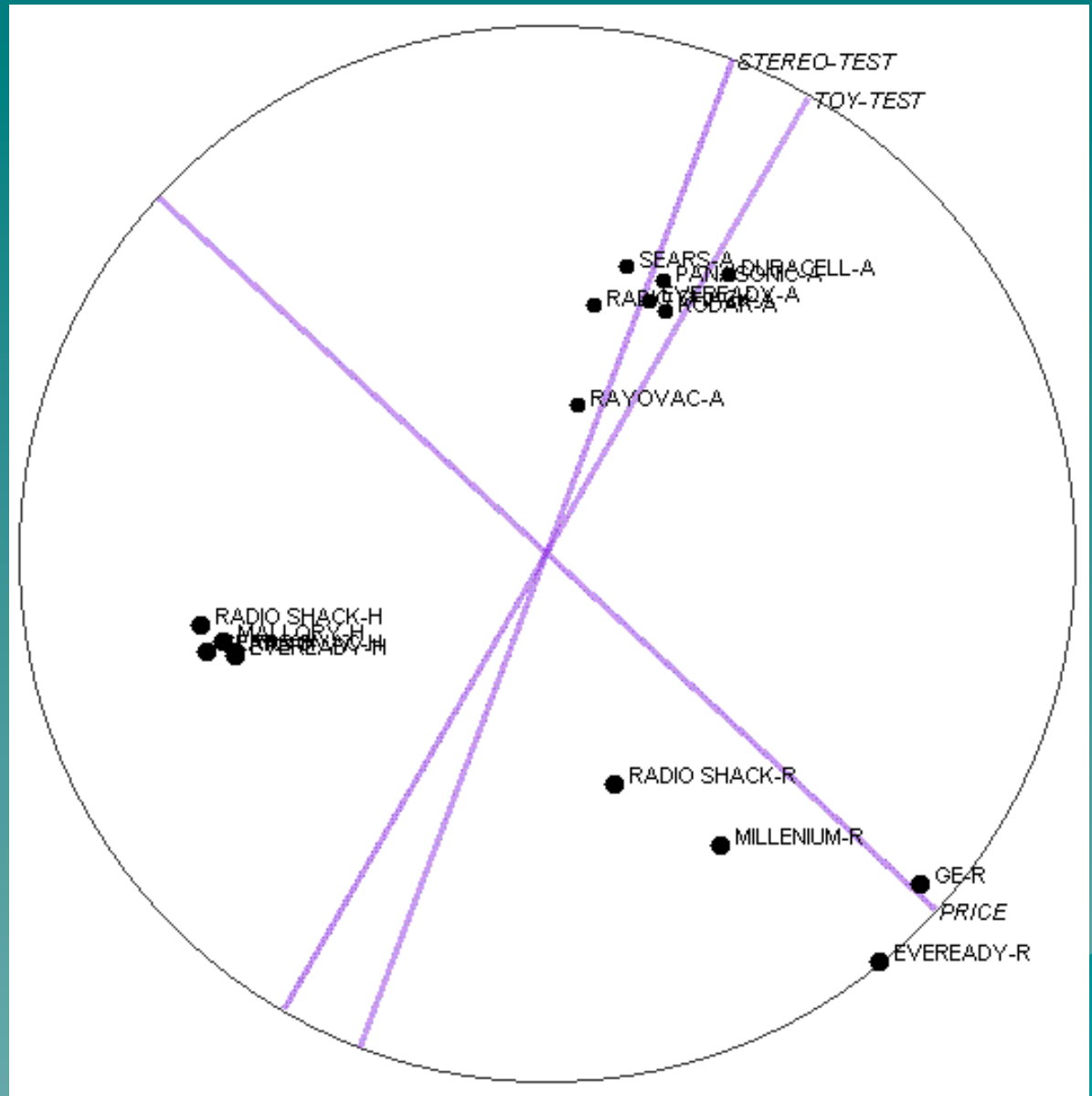
Rechargeable Price



Heavy Duty Battery	Toy Test	Stereo Test	Price
Eveready - H	1.2	4.5	\$0.57
Mallory - H	1.2	4.8	\$0.49
Radio Shack - H	1.0	5.5	\$0.37
Rayovac - H	1.2	4.6	\$0.56
Sears - H	1.2	4.2	\$0.44
Alkaline Battery	Toy Test	Stereo Test	Price
Duracell - A	6.2	14.2	\$1.08
Eveready - A	5.3	14.1	\$0.92
Kodak - A	5.5	13.5	\$0.99
Panasonic - A	5.7	14.1	\$0.88
Radio Shack - A	5.1	13.5	\$0.72
Rayovac - A	4.5	11.2	\$0.98
Sears - A	5.7	14.0	\$0.70
Rechargeable Battery	Toy Test	Stereo Test	Price
Eveready - R	1.6	3.5	\$3.95
GE - R	2.2	5.5	\$3.85
Millenium - R	1.7	4.7	\$2.99
Radio Shack - R	2.2	3.9	\$2.35

All Batteries	Toy Test	Stereo Test	Price
Eveready - H	1.2	4.5	\$0.57
Mallory - H	1.2	4.8	\$0.49
Radio Shack - H	1.0	5.5	\$0.37
Rayovac - H	1.2	4.6	\$0.56
Sears - H	1.2	4.2	\$0.44
Duracell - A	6.2	14.2	\$1.08
Eveready - A	5.3	14.1	\$0.92
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Eveready - R	1.6	3.5	\$3.95
GE - R	2.2	5.5	\$3.85
Millenium - R	1.7	4.7	\$2.99
Radio Shack - R	2.2	3.9	\$2.35

Example #1: MultiGraf of Comparative Battery Data



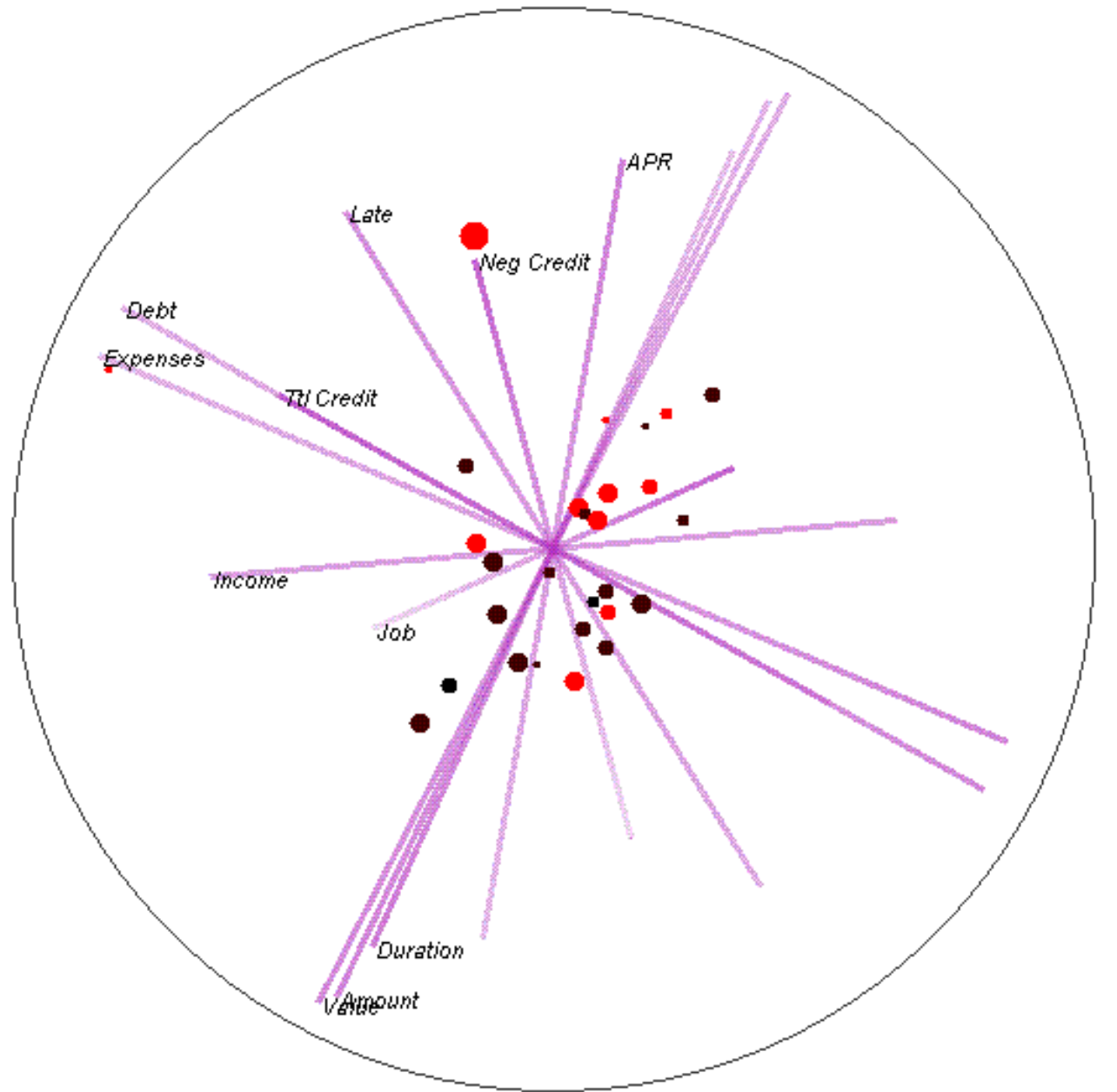
Some Conclusions

From Comparative Battery Data MultiGraf

- ◆ Stereo and toy tests are highly correlated
- ◆ Price is not highly correlated with performance
- ◆ Heavy Duty batteries are a commodity
- ◆ Duracell & Rayovac don't compare in performance
- ◆ Sears alkaline may be the best buy
- ◆ Name brands demand a higher price in new items
- ◆ Buy Duracell, maybe Sears and never Rayovac

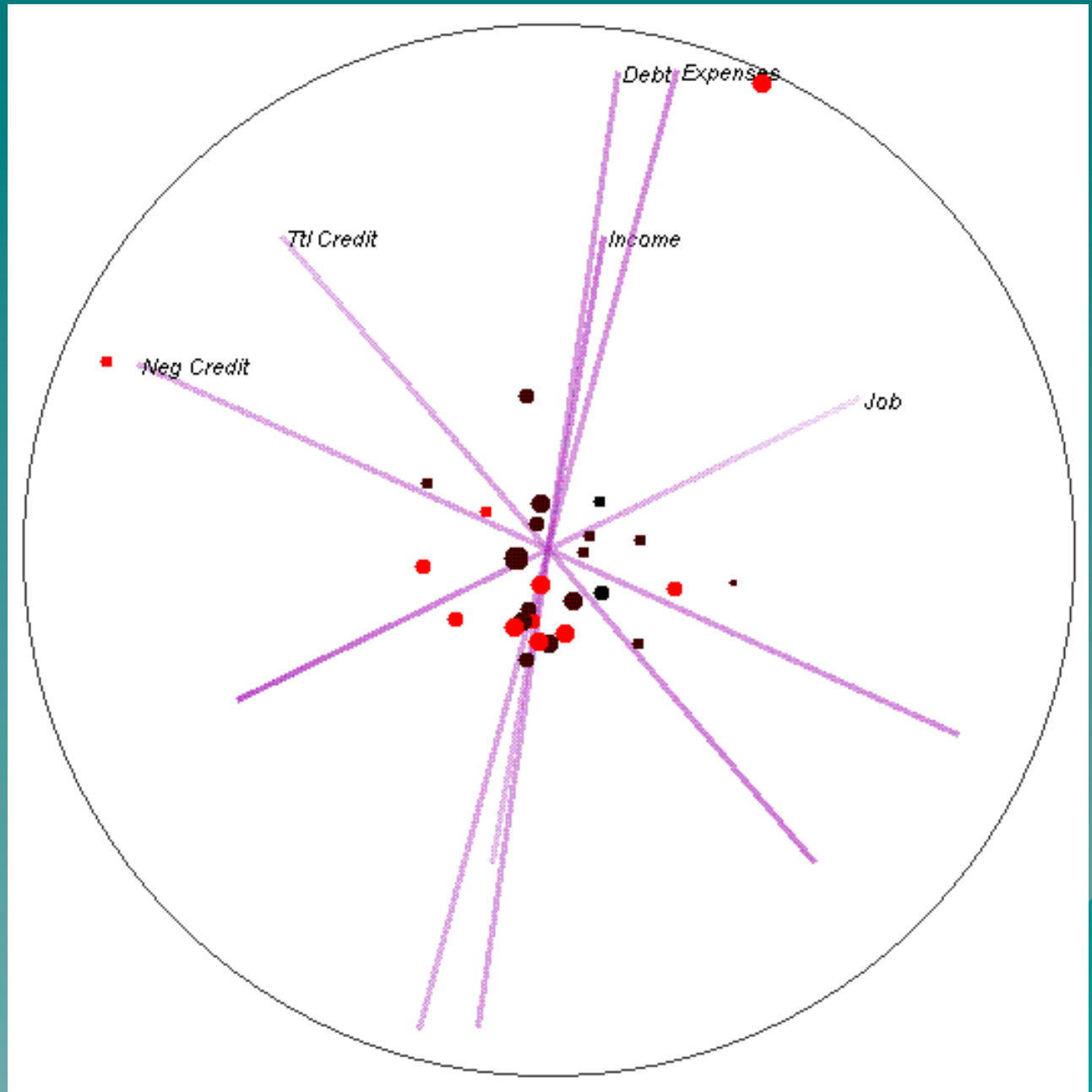
	Amount	Mo	APR	Debt	Income	Expenses	Job	Value	Ttl Credit	Neg Credit	Late
Obj1	\$21,356	60	11.5%	0.245	\$4,435	\$1,086	1	\$21,765	11	0	0
Obj2	\$16,491	60	10.5%	0.217	\$3,000	\$650	13	\$16,800	17	0	0
Obj3	\$9,212	48	9.5%	0.273	\$1,300	\$355	8	\$9,434	6	0	0
Obj4	\$16,491	60	10.5%	0.217	\$3,000	\$650	13	\$16,800	17	0	0
Obj5	\$9,212	48	9.5%	0.273	\$1,300	\$355	8	\$9,434	6	0	0
Obj6	\$8,447	60	14.4%	0.286	\$1,000	\$286	3	\$7,495	13	2	5
Obj7	\$15,359	48	13.2%	0.041	\$1,850	\$76	23	\$16,200	6	0	0
Obj8	\$9,415	48	14.5%	1.765	\$4,250	\$7,500	12	\$11,020	17	0	17
Obj9	\$4,531	30	12.5%	0.017	\$1,800	\$30	2	\$7,347	4	0	0
Obj10	\$10,850	48	12.8%	0.428	\$1,600	\$684	12	\$9,150	8	0	0
Obj11	\$10,748	48	9.9%	0.149	\$2,200	\$327	4	\$12,703	5	0	0
Obj12	\$9,766	48	12.5%	0.000	\$1,600	\$0	6	\$11,000	13	0	0
Obj13	\$5,000	42	12.0%	0.334	\$1,790	\$598	10	\$5,500	13	0	0
Obj14	\$2,502	13	14.0%	0.237	\$1,860	\$441	10	\$2,800	13	0	0
Obj15	\$2,389	25	16.2%	0.258	\$1,850	\$477	2	\$2,500	8	0	2
Obj16	\$10,642	60	13.7%	0.196	\$3,300	\$646	10	\$12,611	12	4	0
Obj17	\$5,504	42	13.8%	0.411	\$4,800	\$1,972	11	\$6,500	11	3	0
Obj18	\$11,806	60	11.0%	0.000	\$5,000	\$0	0	\$15,530	10	0	0
Obj19	\$13,878	60	14.3%	0.311	\$2,694	\$837	4	\$14,531	14	0	0
Obj20	\$3,939	24	18.0%	0.650	\$2,000	\$1,300	0	\$3,909	31	7	14
Obj21	\$12,173	60	14.7%	0.286	\$1,750	\$500	7	\$12,350	25	0	10
Obj22	\$5,651	42	13.5%	0.000	\$800	\$0	2	\$4,895	18	0	5
Obj23	\$3,516	24	14.8%	0.117	\$3,000	\$350	11	\$4,495	0	0	15
Obj24	\$10,203	60	13.9%	0.083	\$600	\$50	1	\$11,649	5	0	0
Obj25	\$11,960	60	11.9%	0.189	\$1,322	\$250	2	\$9,800	2	0	2
Obj26	\$9,533	60	18.5%	0.171	\$1,200	\$205	4	\$7,930	3	1	9
Obj27	\$12,202	60	13.0%	0.122	\$740	\$90	10	\$14,200	1	0	0
Obj28	\$17,703	61	12.8%	0.050	\$2,000	\$100	0	\$15,892	3	0	1
Obj29	\$2,899	18	19.8%	0.119	\$2,100	\$250	1	\$4,064	1	1	0
Obj30	\$10,891	48	15.0%	0.088	\$1,700	\$150	2	\$9,995	3	1	11

Example #2: MultiGraf of Car Loan Data (all attributes)



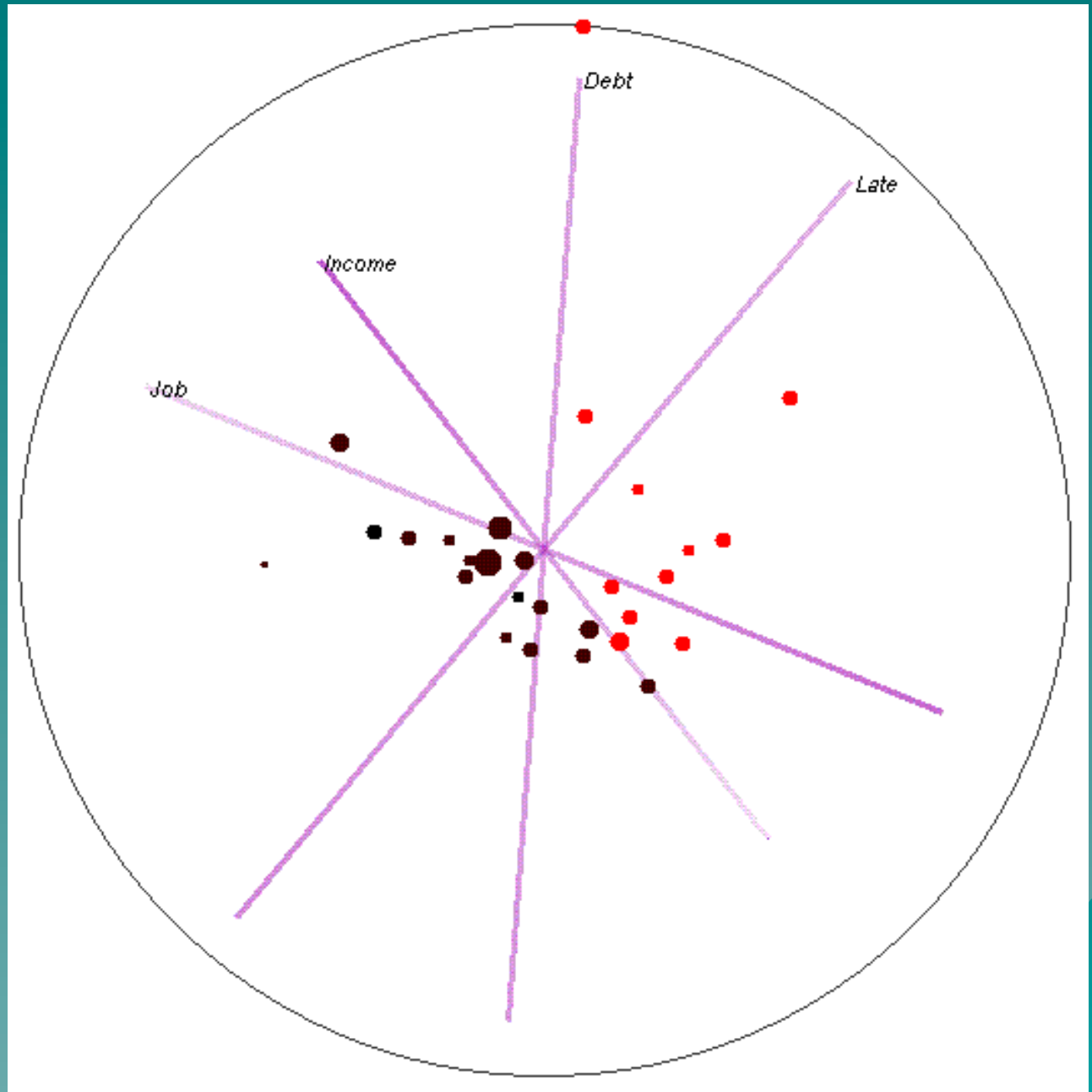
Example #2: MultiGraf of Car Loan Data

(excludes
value,
amount,
duration, late
and APR)



Example #2: MultiGraf of Car Loan Data

(includes only
Job, Income,
Debt & Late)




Some Conclusions

From Car Loan Data MultiGraf

- ◆ Attributes range from high positive to high negative correlation, with 3 attributes highly correlated
- ◆ Defaulted loans appear in wide range of situations
- ◆ Most attributes do not appear to discriminate well on loan repayment predictability
- ◆ Eliminating selected attributes increases clarity of loan repayment performance, predictability

Conclusions (cont.)

- ◆ Job duration and low late payment experience are key
 - ◆ Income level is not a significant factor for making loan
 - ◆ Higher risk loans can be mitigated by requiring higher down payment to lower risk of late payment, etc.
- 

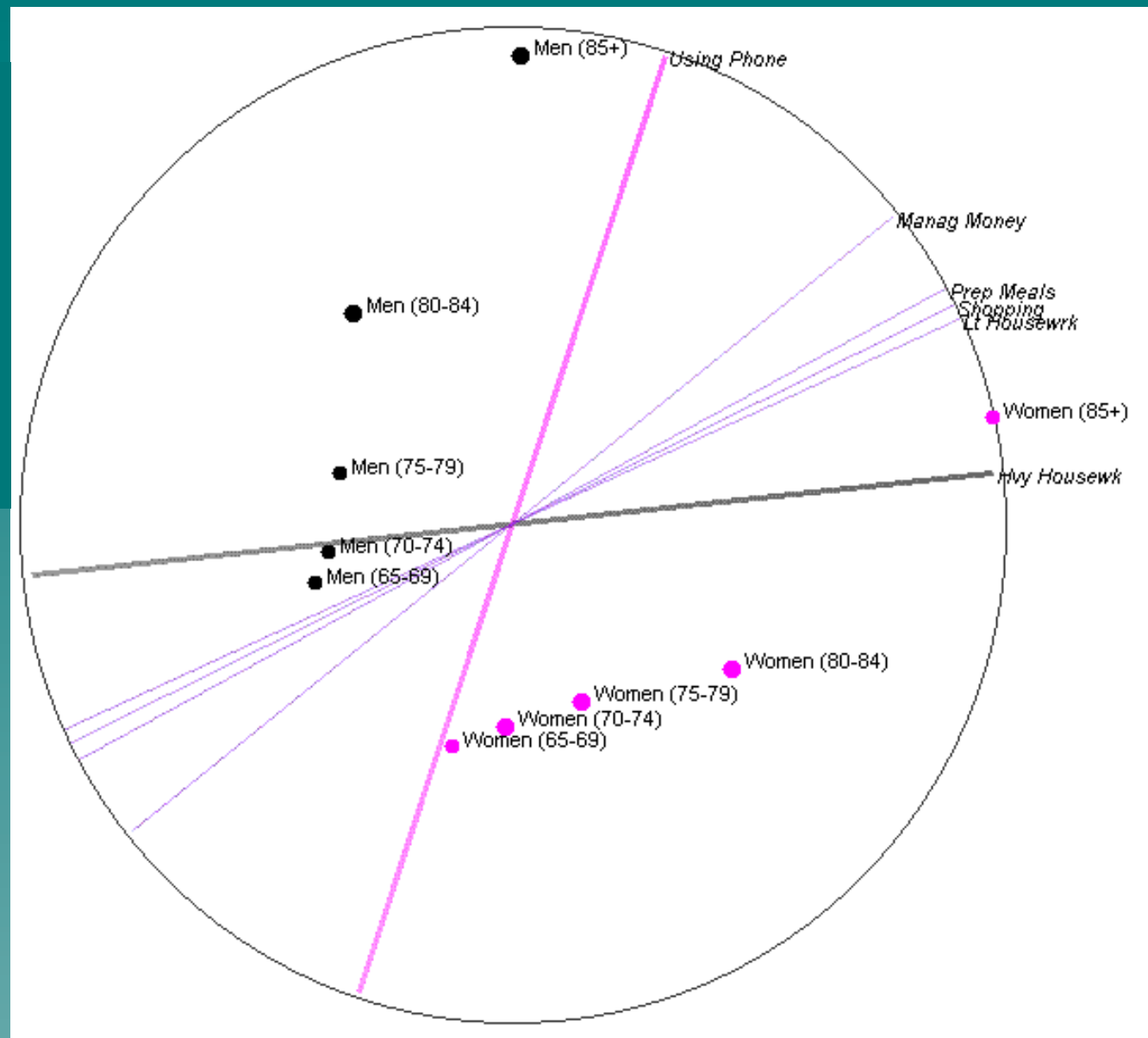
Aging

	Prep Meals	Heavy Housewk	Light Housewrk	Using Phone	Manage Money	Shopping
Men (65-69)	2.6	9.8	3.5	3	2.6	4.1
Men (70-74)	3.6	13	3.4	4.3	3.1	5.3
Men (75-79)	5.1	14.6	5.2	6.3	5.2	7.6
Men (80-84)	7.8	18.9	8.2	11.3	5.8	13.9
Men (85+)	18.5	33.3	15.2	18.4	19	26.8
Women (65-69)	4.2	21.8	4	1.3	1.4	6.4
Women (70-74)	5.5	27.3	6.2	2.8	2.3	9.4
Women (75-79)	8.3	33.2	8.4	4.1	5.2	14.5
Women (80-84)	14	41.7	14	6	9.3	24.7
Women (85+)	29.5	54.2	27.4	12.1	26.2	41.6



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Example #3: MultiGraf of Aging vs. Capabilities Data



Some Conclusions

From Aging vs. Capabilities Data MultiGraf

- ◆ All of the attributes are positively correlated
- ◆ Three attributes are the same (data distortion)
- ◆ Attributes progress from Physical to Social tasks
- ◆ Women have more difficulty with physical tasks
- ◆ Men have more difficulty with social tasks

Secretary Data

	Type Speed	Accuracy	Hourly \$	WP Emp	Tot Emp	Attend	Eng Prof
Ann	60	92	9.90	4	28	98	85
Beth	65	88	10.50	6	24	97	88
Chris	50	94	10.84	9	30	96	90
Don	45	85	7.90	2	14	99	78
Ellen	30	90	8.24	4	16	98	88
Fay	40	98	10.62	7	60	95	93
Gail	78	95	11.90	12	48	97	94
Holly	70	85	9.70	6	12	88	81
Ida	72	91	10.30	22	72	96	97
Jackie	80	97	13.44	30	84	95	98

Some Conclusions

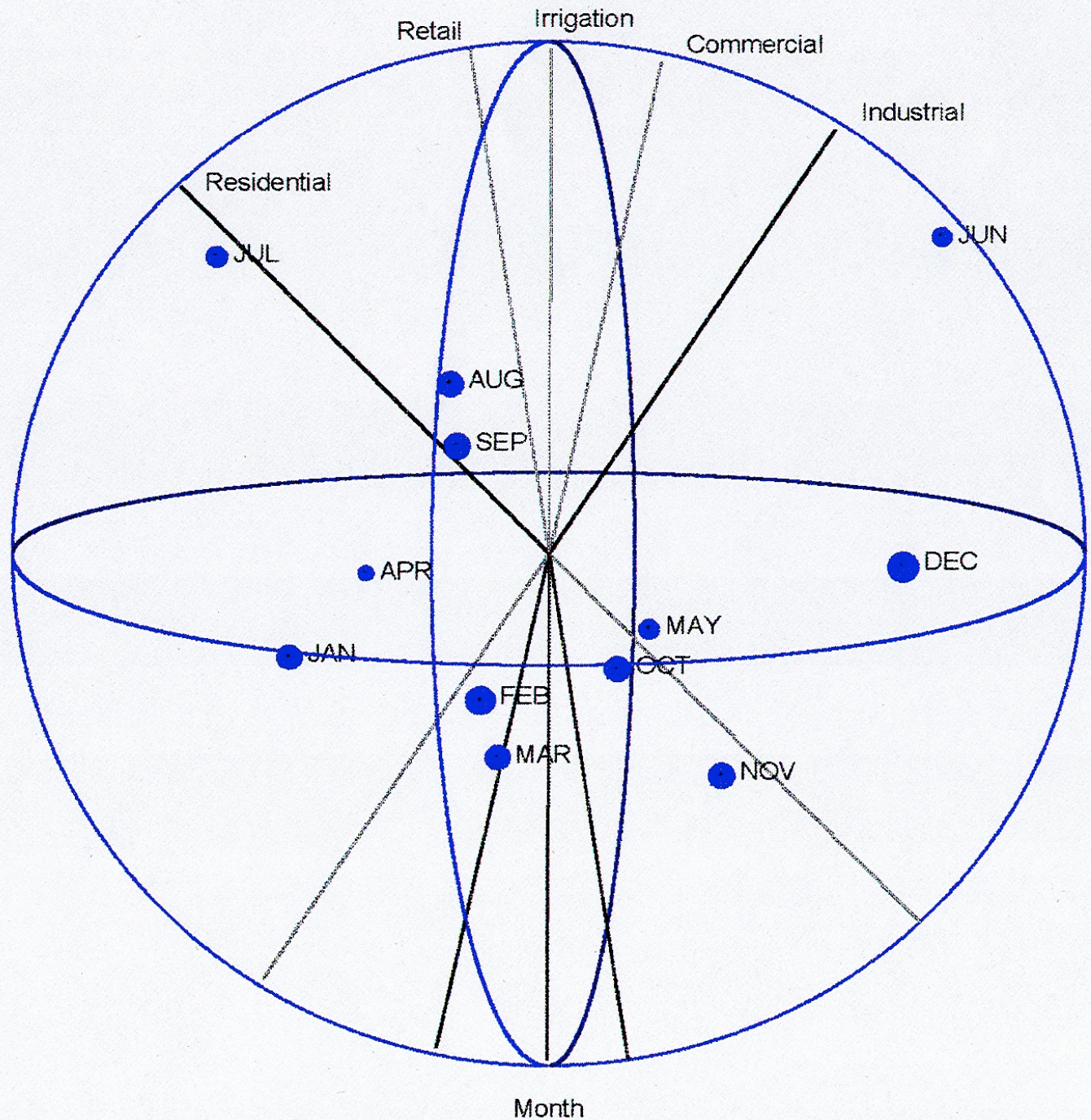
From Applicants vs. Performance Data MultiGraf

- ◆ All applicants can be evaluated simultaneously relative to all other applicants and all attributes.
- ◆ The top candidates can be easily identified.
- ◆ Interviewing process is significantly simplified.
- ◆ Applicants with limited performance in one or more areas are readily identified.
- ◆ Improvement opportunities for training are also readily identified.

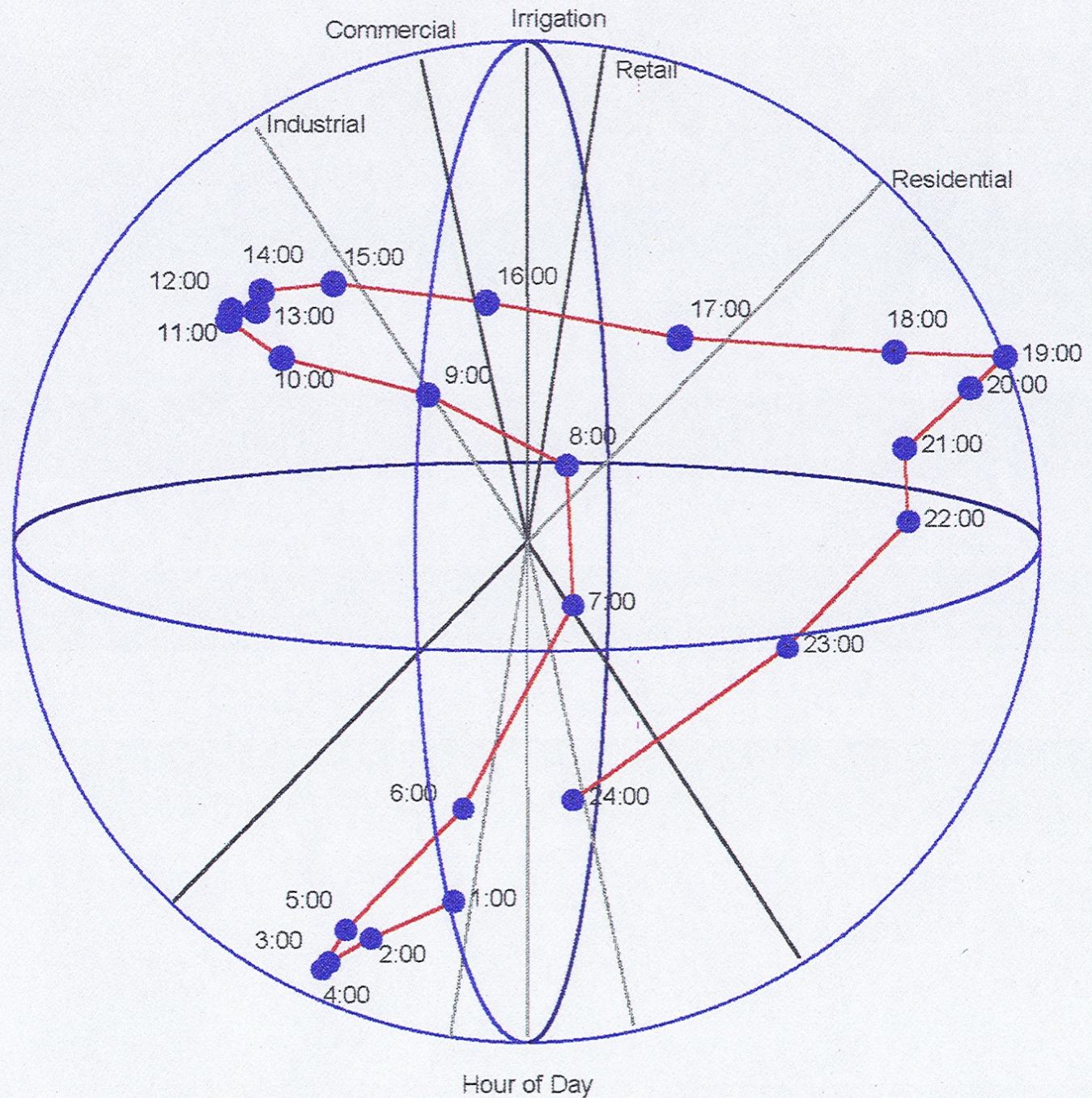
Unique HSG Features

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- ◆ The entire data set is **analyzed without segmentation**.
- ◆ **Attribute correlations** are graphically displayed.
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- ◆ Numerous traditional **graphs are combined** into a single MultiGraf.
- ◆ **Data input is a simple spreadsheet format**.

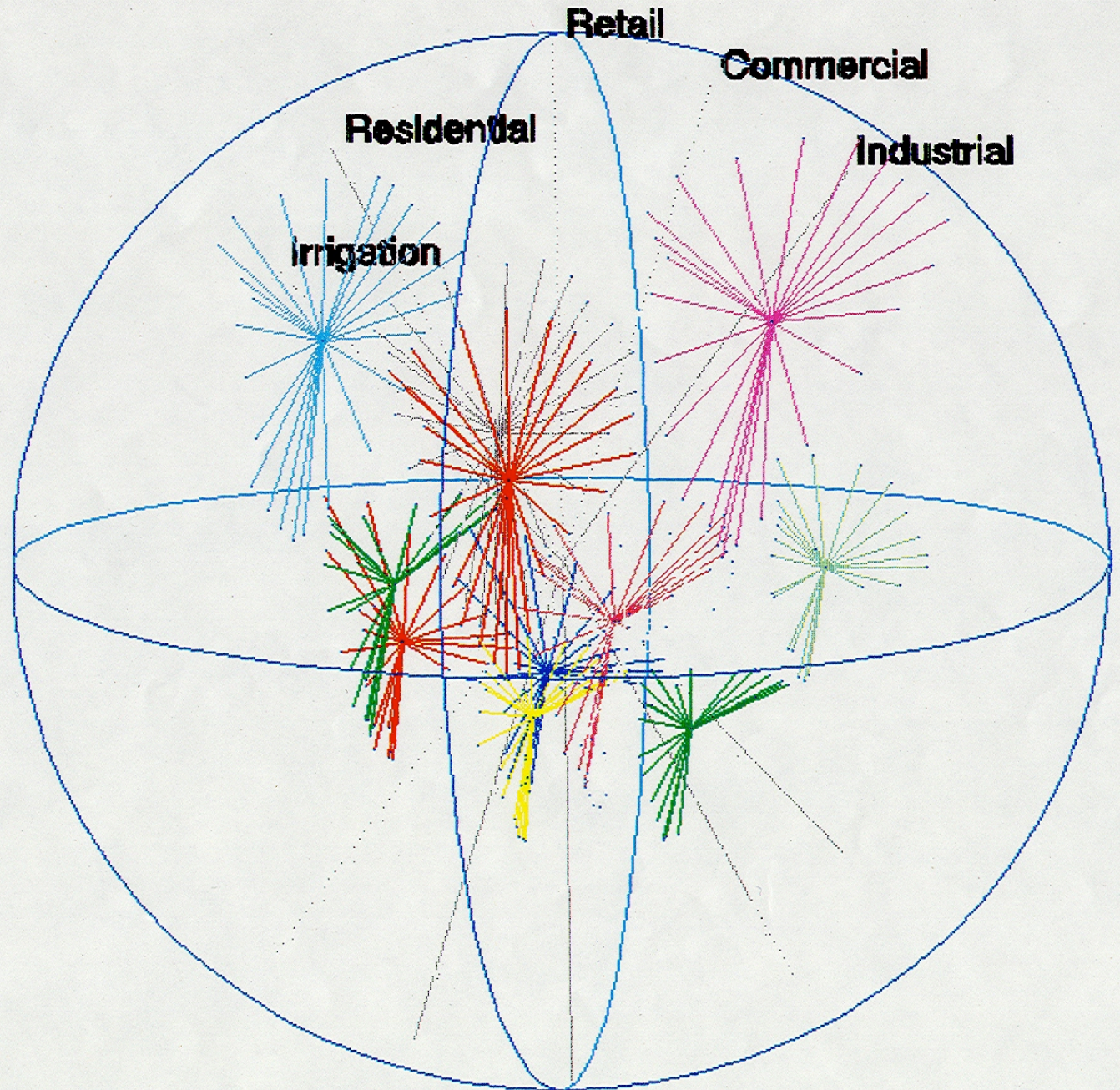
APS Data (Slide 1)



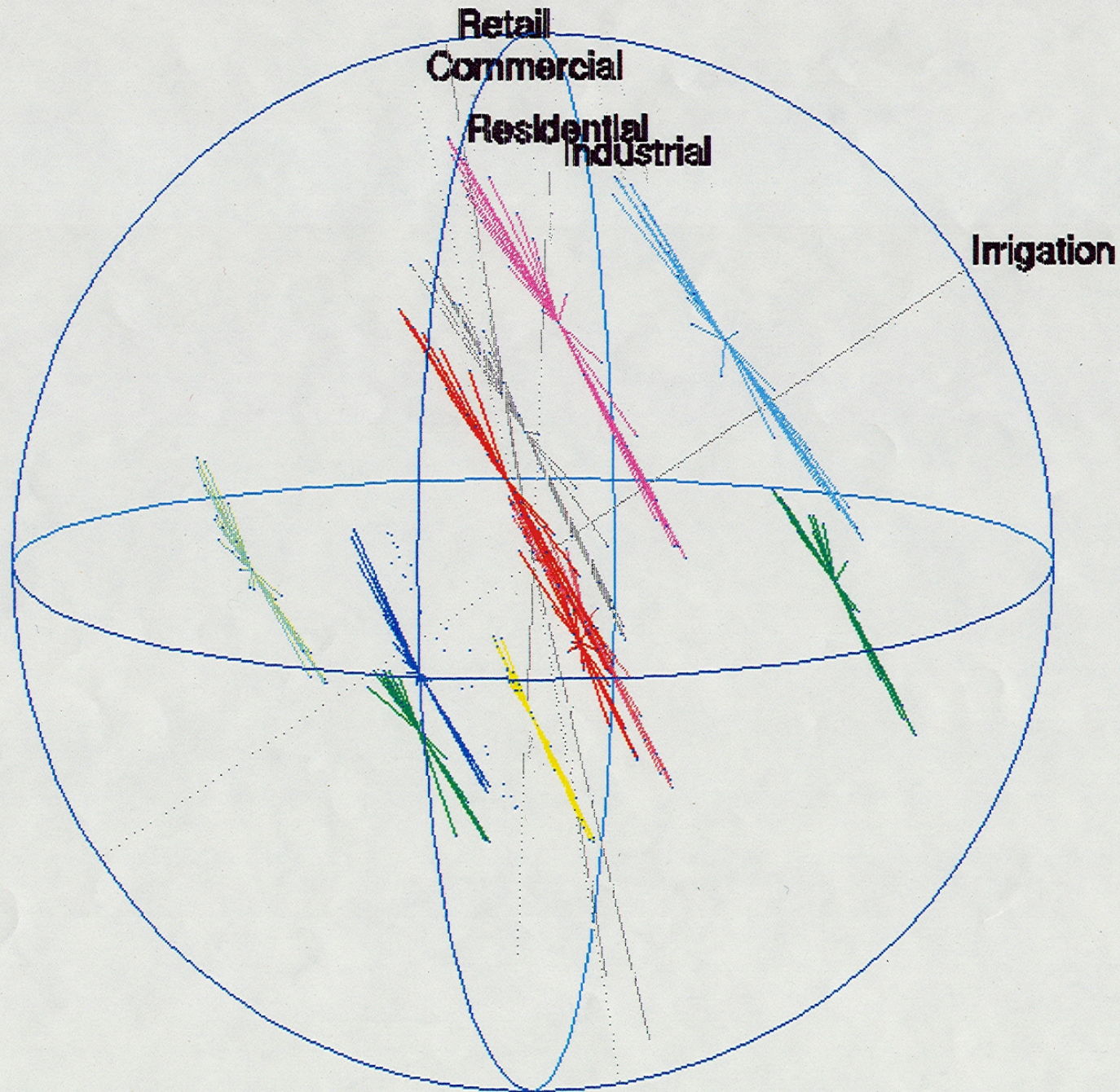
APS Data (Slide 2)



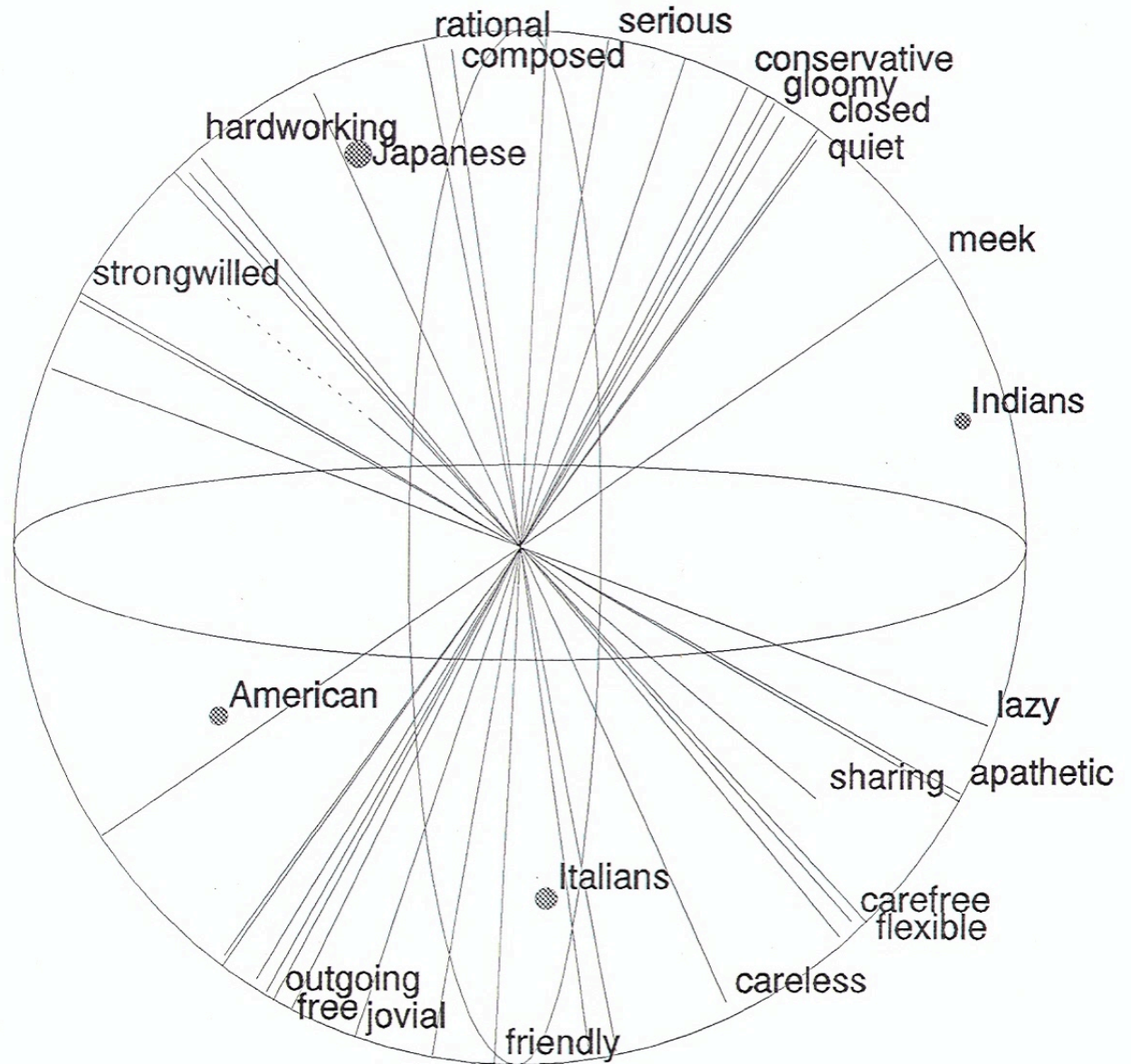
APS Data (Slide 3)



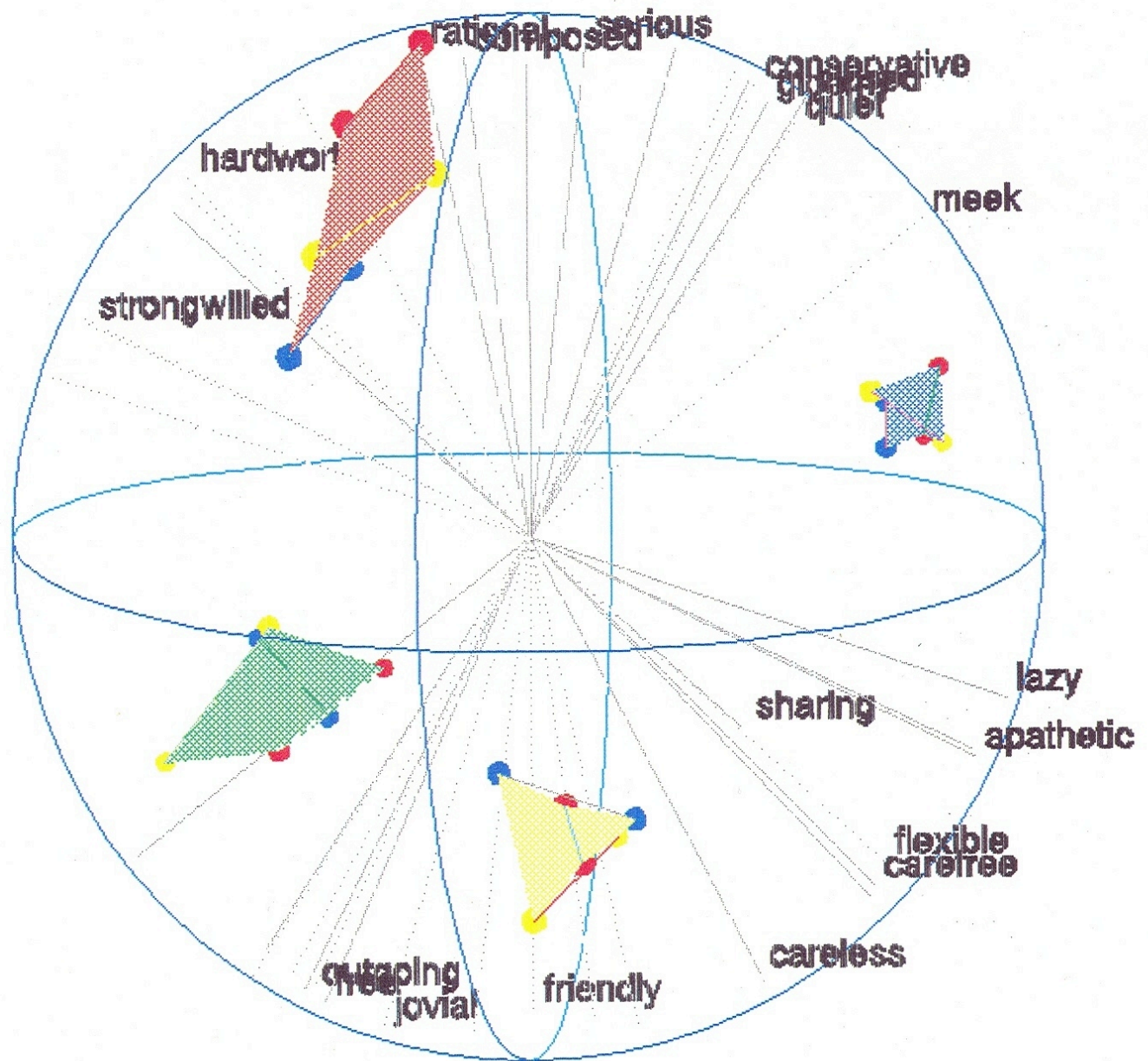
APS Data (Slide 4)



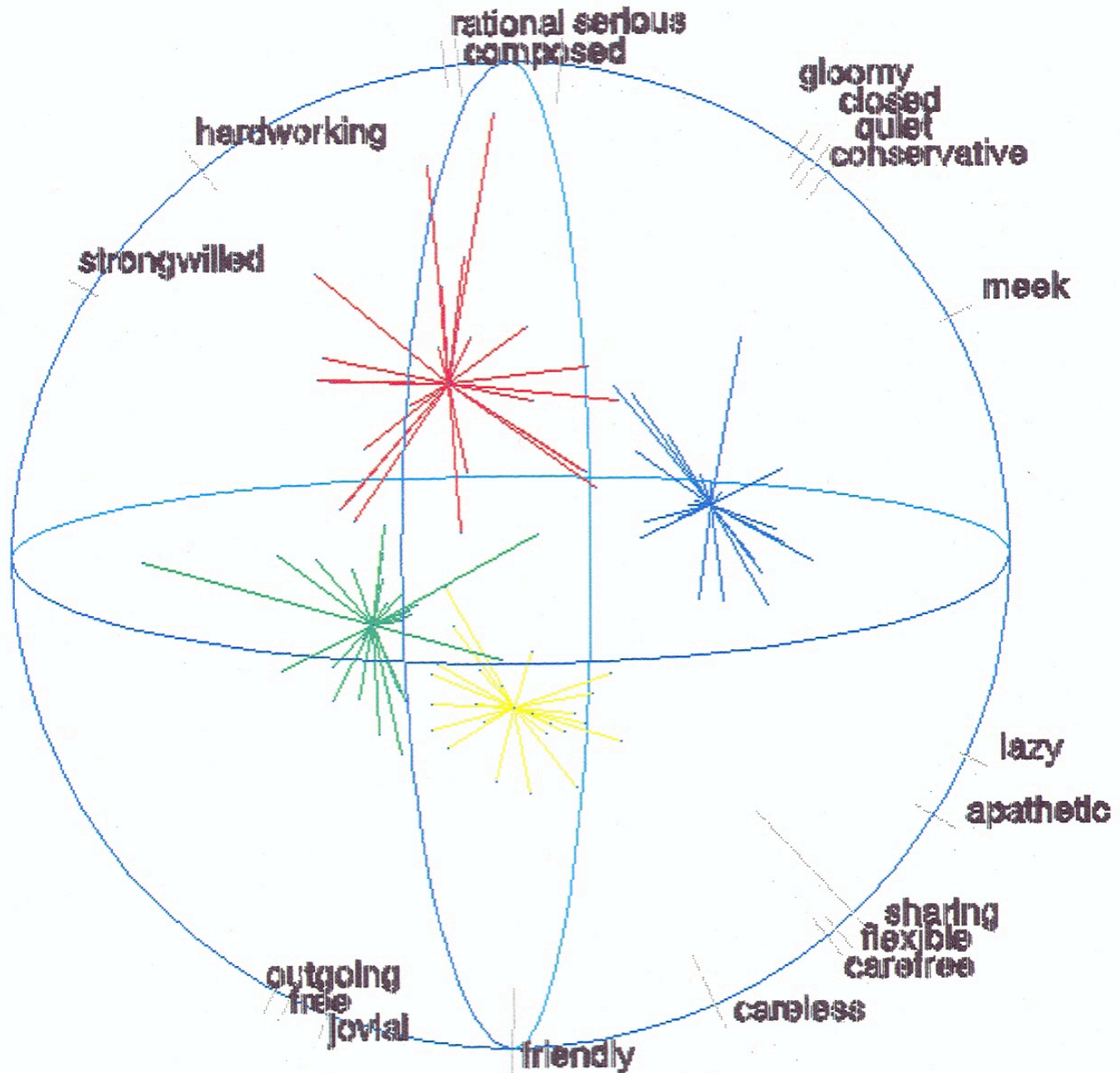
21 Nation Study (slide 1)



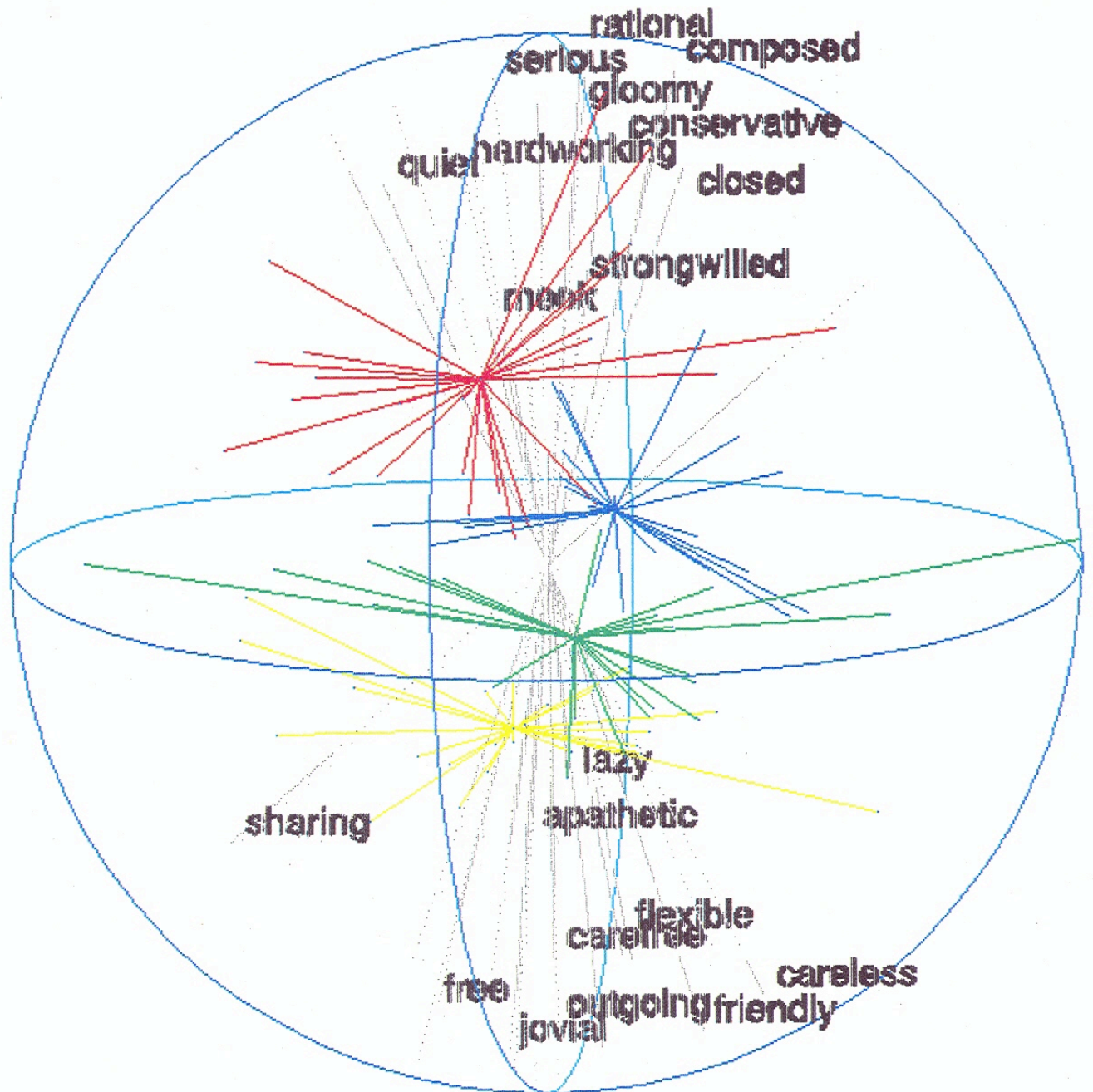
21 Nation Study (slide 2)



21 Nation Study (slide 3)



21 Nation Study (slide 4)



Baseball Data

	Batting	Home				Slugging
	Ave	Runs	Runs	RBIs	Walks	Ave
Aaron	327	47	95	118	71	669
Foxx	364	58	151	169	116	749
Gehrig	373	47	147	175	109	765
Greenberg	315	58	144	146	119	683
Hornsby	403	39	133	143	83	756
Mantle	353	52	132	130	112	705
Maris	269	61	132	142	94	620
Mays	319	51	123	127	79	659
Ruth	378	59	177	171	144	846
Simmons	381	36	152	165	39	708
Williams	406	37	135	120	145	735

