



Sensometrics 2012
Rennes, France



Finding Best Product-bundles of Sparkling Fruit-juice Beverages using Graph Theoretic Analysis (GTA)

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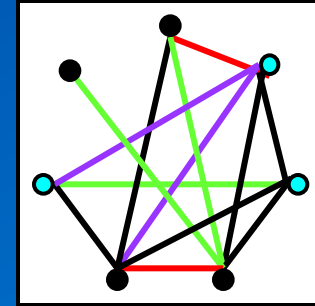
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A Case Study

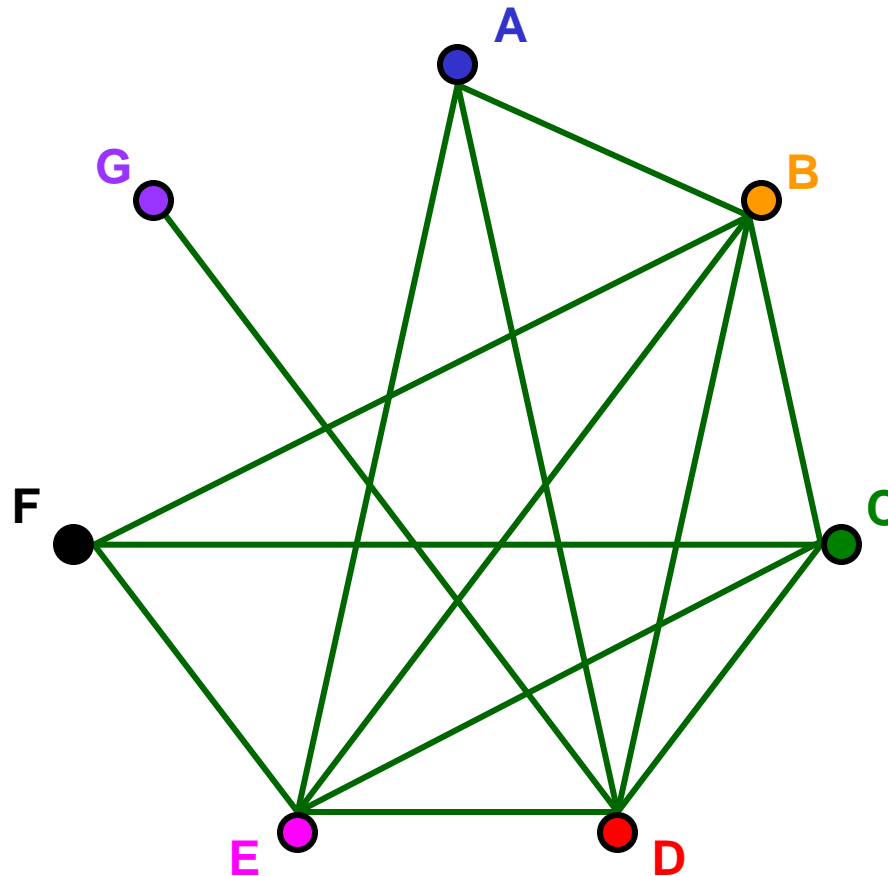
- A soft drink company wishes to launch a line of carbonated fruit juice beverages
- Each beverage will contain a combination of fruit juice flavors
 - ❖ **15 possible juice flavors**
- Each beverage will be marketed with a combination of benefits and imagery
 - ❖ **22 benefits**
 - ❖ **23 imageries**
- 60 possible elements to combine
- Can combine elements within and across categories
- More than 1,000,000,000,000,000,000 possible product bundles
- Want 5 product bundles that work well together



Graph Theoretic Analysis

Graph Theory

- A graph is a collection of objects together with **connections**

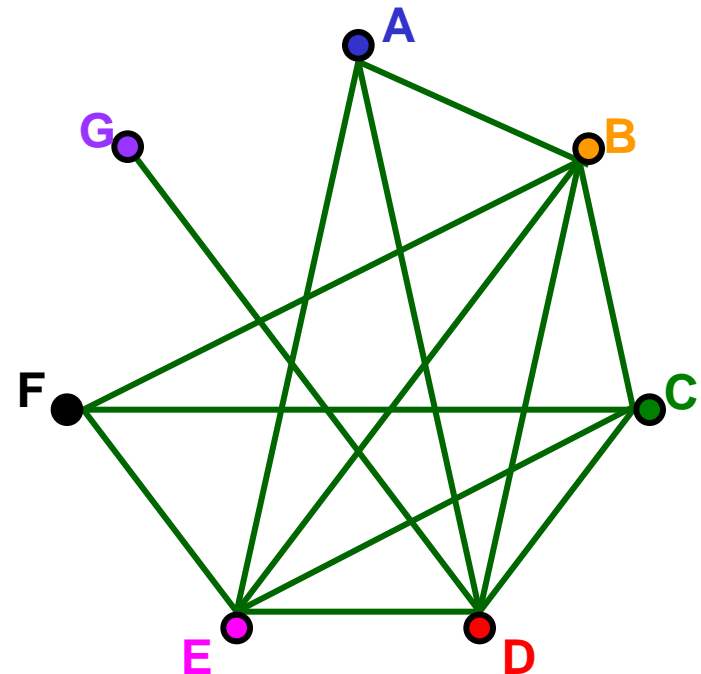
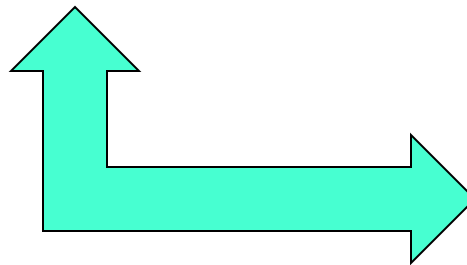


- Graph theory is the study of **connections**

Connectivity Matrices

- ❖ Connectivity information can be stored in a matrix

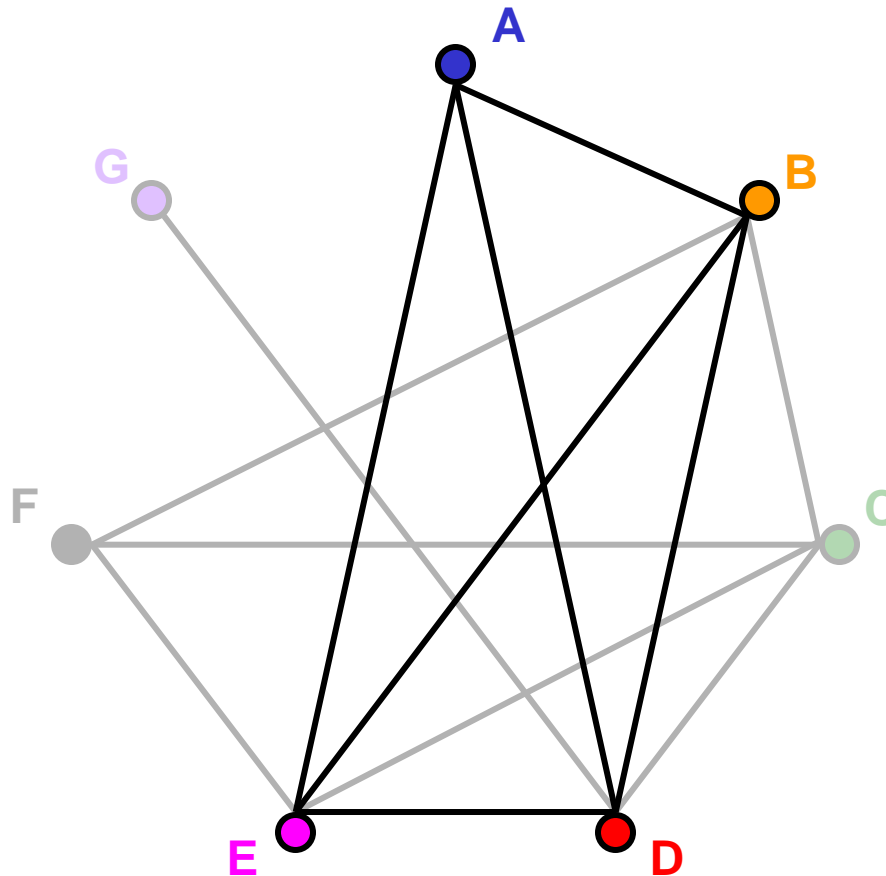
	A	B	C	D	E	F	G
A		1	0	1	1	0	0
B	1		1	1	1	1	0
C	0	1		1	1	1	0
D	1	1	1		1	0	1
E	1	1	1	1		1	0
F	0	1	1	0	1		0
G	0	0	0	1	0	0	



- ❖ Each connectivity matrix corresponds to exactly one graph

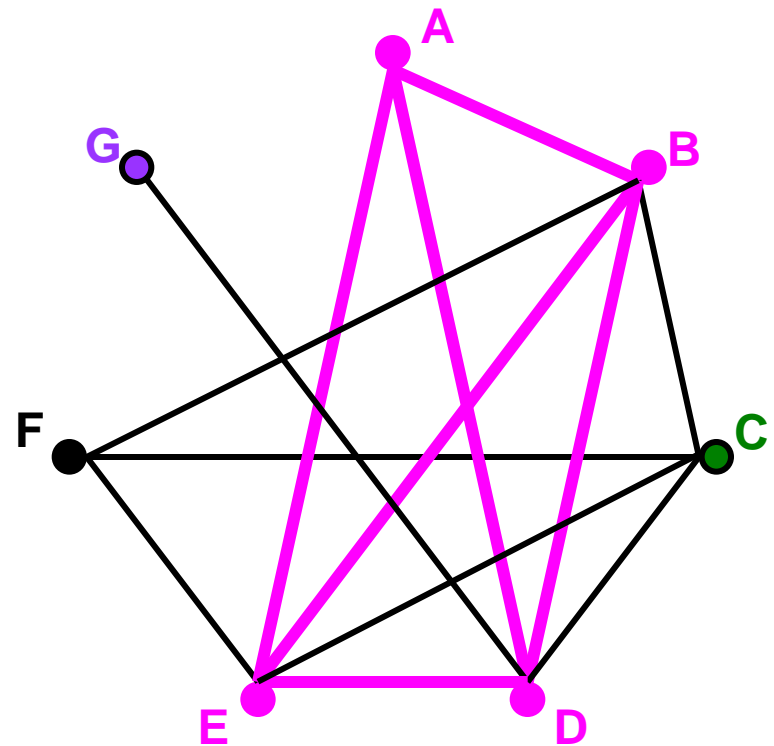
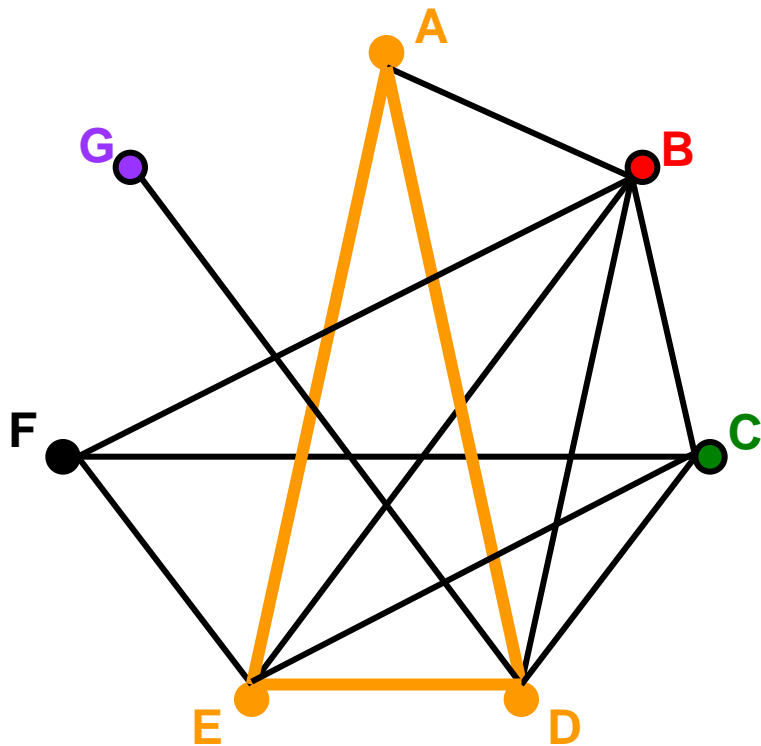
Cliques

- A **clique** is a collection of objects that is fully connected



Cliques (cont.)

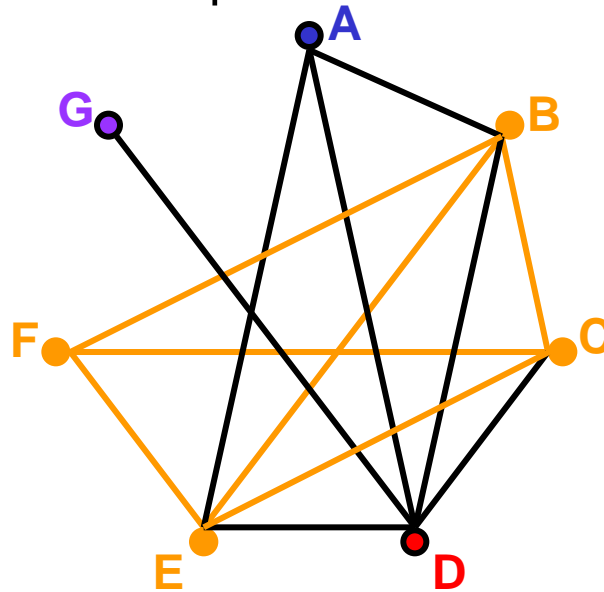
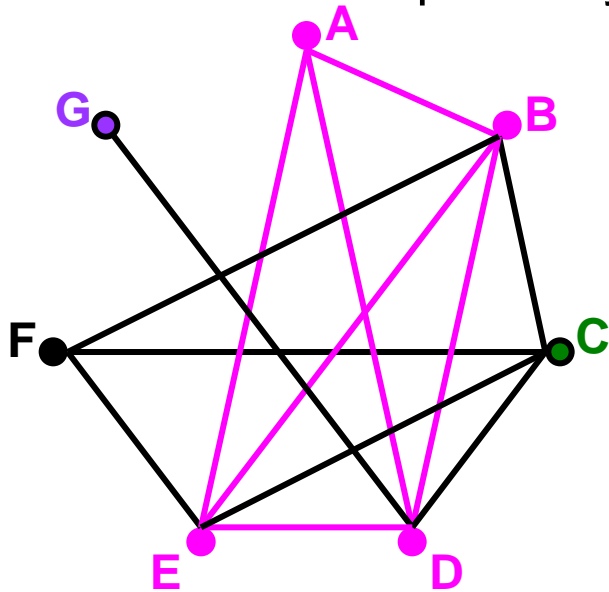
- Cliques can be found within larger cliques



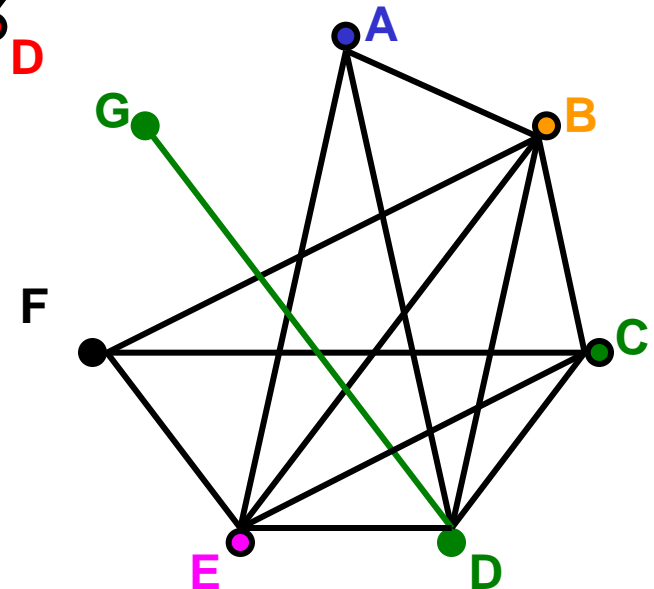
- A **maximal clique** is not contained in any larger clique

Maximal Cliques

- Maximal cliques may not be unique



- Maximal cliques can be different sizes





Return to Case Study

Lists of Flavors, Benefits and Imagery

➤ **Possible flavors**

Apple, Blackberry, Blueberry, Cherry, Grape, Grapefruit, Lemon-Lime, Mango, Orange, Peach, Pineapple, Pomegranate, Raspberry, Strawberry

➤ **Possible benefits**

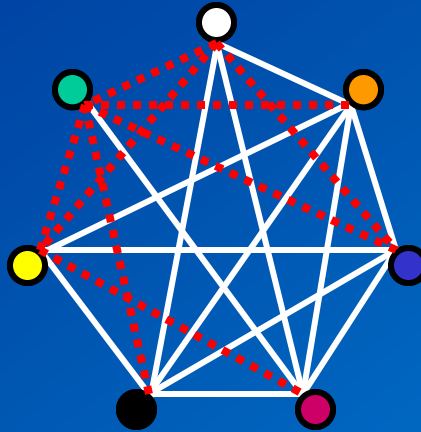
All-natural, Becoming popular, Clean-tasting, Delicious, Energizing, Fizzy, Goes down easy, Good when hanging out, Good-tasting, Invigorating, Low-carb, Refreshing, Relaxing, Reviving, Rewarding, Satisfying, Social, Stimulating, Thirst-quenching, Uplifting, No harsh taste, Would recommend

➤ **Possible imageries**

Abundance, Admire, Appeals to me, Aromatic, Authentic, Breezy, Classic, Crisp, Desperate, Different, Distinctive taste, Fresh, Healthy, Let loose, Light, Masculine, Patriotic, Quality, Robust, Smooth, Sophisticated, Strong, Strong heritage

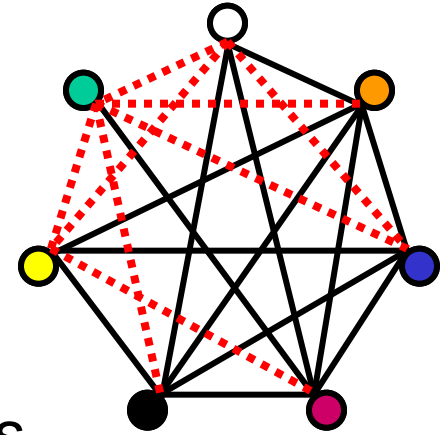
Step 1: Reducing the Problem Size

- 60 possible elements gives 1770 possible pairs
- Respondents can evaluate about 300 in a session
- Choices
 - 1) Gather incomplete information from 6 respondents to give full information about pairs
 - 2) Reduce problem size so there are 300 pairs total, then ask for full information from every respondent
- If we care most about global information, (1) could be a good option
- If we want to find segmentation, (2) is needed
- In our case, there is much redundancy in the elements
 - ❖ Invigorating \approx Energizing
 - ❖ Strong \approx Masculine
- We use “independent sets” to remove redundancy
- We then use cliques to find best bundles



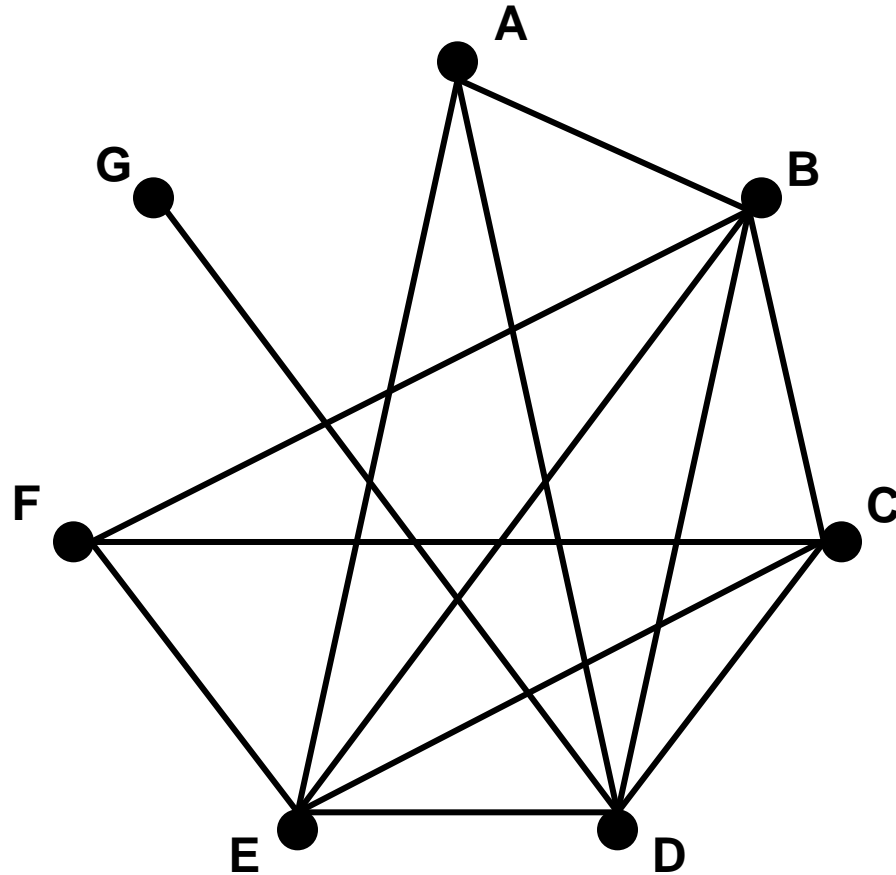
Independent Sets

Independent Sets



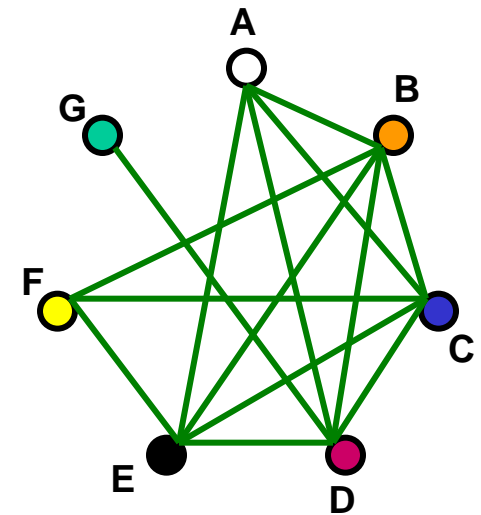
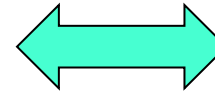
- Cliques are maximally connected sets
- Sometimes we want maximally *distinct* sets
 - ❖ Selecting products for a category appraisal
 - ❖ Selecting factories for monitoring
 - ❖ ...
- Such collections are called **independent sets**
- Independent sets are the opposite of cliques
 - ❖ Cliques are fully connected
 - ❖ Independent sets are fully disconnected

Independent Sets

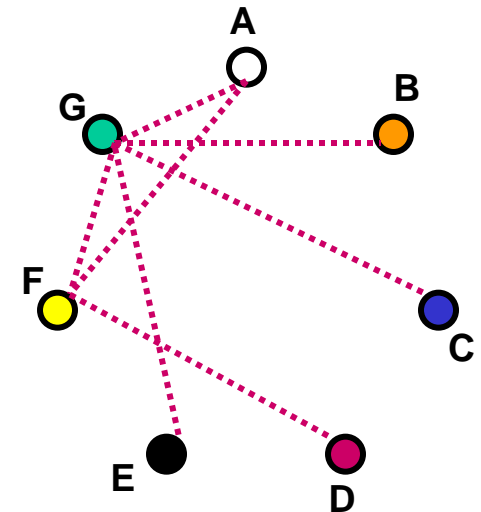
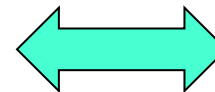


Complement Graphs

	Item A	Item B	Item C	Item D	Item E	Item F	Item G
Item A		1	0	1	1	0	0
Item B	1		1	1	1	1	0
Item C	0	1		1	1	1	0
Item D	1	1	1		1	0	1
Item E	1	1	1	1		1	0
Item F	0	1	1	0	1		0
Item G	0	0	0	1	0	0	

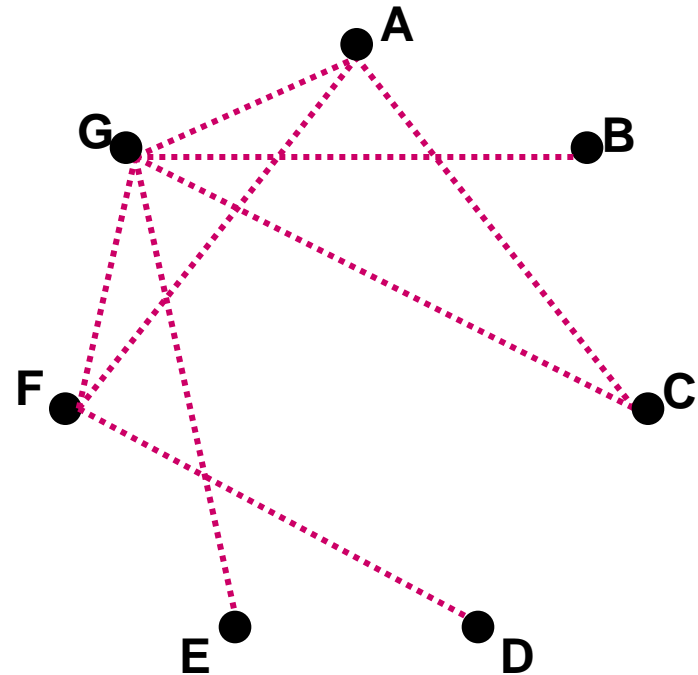
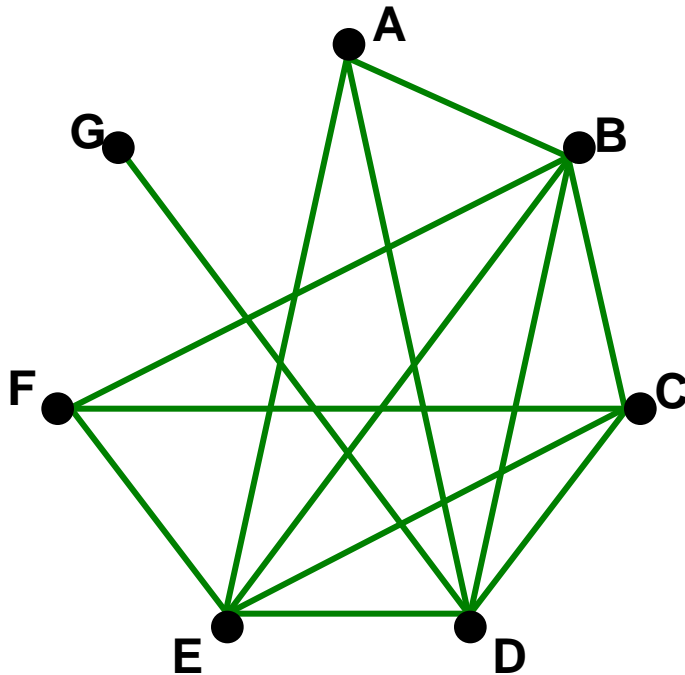


0	Item A	Item B	Item C	Item D	Item E	Item F	Item G
Item A		0	1	0	0	1	1
Item B	0		0	0	0	0	1
Item C	1	0		0	0	0	1
Item D	0	0	0		0	1	0
Item E	0	0	0	0		0	1
Item F	1	0	0	1			1
Item G	1	1	1	0	1	1	



Independent Sets and Cliques

- **Independent sets** are **cliques** in the complement

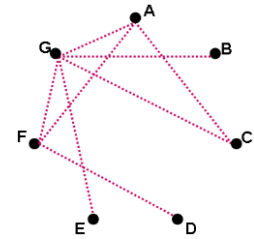


- Clique finding techniques also find independent sets



Return to Case Study

Using Independent Sets



- Preliminary experiment, conducted internally
- For each category, degree of difference ratings between pairs
 - ❖ 105 pairs of **flavors**
 - ❖ 231 pairs of **benefits**
 - ❖ 253 pairs of **imageries**
- Data from internal respondents aggregated to give similarity between each pair of **flavors**, each pair of **benefits**, and each pair of **imagery**
- We have 3 similarity matrices: one for each of **flavors**, **benefits**, and **imageries**
- We analyzed each matrix using GTA to find independent sets

Independent Sets of Flavors, Benefits and Imageries

- We use GTA to find the following independent sets
- **Flavors**
 - ❖ Apple, Blueberry, Cherry, Lime, Orange, Mango, Peach, Pineapple, Pomegranate
- **Benefits**
 - ❖ All-natural, Fizzy, Goes down easy, Low-carb, Relaxing, Reviving, Satisfying, Social
- **Imageries**
 - ❖ Abundance, Authentic, Breezy, Classic, Crisp, Healthy, Let loose, Smooth
- There are now only 33,227,775 possible bundles
- We have 25 items total, which gives 300 pairs for consumers
- We collect pair-wise information, then use GTA to eliminate more bundles

Step 2: Large Scale Consumer Study

- 1000 consumers nationwide participate in internet-based study
- Each consumer evaluates all 300 pairs for compatibility
- Randomized design used
- Consumers asked

“In thinking about sparkling fruit juice beverages, which of the following pairs of items do you think go well together? Please select each pair that applies”
- Consumer data tells us overall compatibility between items
- We seek product bundles with at least one **flavor**, at least one **benefit** and at least one **imagery**
- We want compatible product bundles with no more than 6 items

Compatibility Matrix

	All-natural	Fizzy	Goes down easy	Low-carb	Relaxing	Reviving	Satisfying	Social	...
All-natural	---	0.257	0.394	0.328	0.440	0.399	0.478	0.239	...
Fizzy		---	0.212	0.195	0.225	0.330	0.327	0.248	...
Goes down easy			---	0.220	0.417	0.269	0.429	0.247	...
Low-carb				---	0.222	0.216	0.250	0.174	...
Relaxing					---	0.282	0.454	0.291	...
Reviving						---	0.372	0.229	...
Satisfying							---	0.277	...
Social								---	...
⋮									---

Compatible Product Bundles

- A threshold of 0.363 gives cliques of size 6 but none of size 7
- Any smaller threshold gives cliques of size 7
- There are 37 maximal cliques total
- There are 27 maximal cliques that have at least one item from each category, i.e. 27 maximal product bundles:

All-natural
Goes down easy
Relaxing
Satisfying
Smooth
Peach

All-natural
Satisfying
Classic
Smooth
Apple
Cherry

All-natural
Satisfying
Healthy
Smooth
Orange
Mango

...

An Observation: “All-Natural”

- “**All-Natural**” appears in every maximal product bundle
 - ❖ “**All-Natural**” is a highly relevant benefit for this category and should be used in all consumer communications
- With this insight, we re-run the analyses without “**All-Natural**”
- Without “**All-Natural**,” we find a threshold of 0.35
- There are 33 maximal cliques of size 6 or smaller
- There are 25 maximal product bundles:

Goes down easy
Relaxing
Satisfying
Smooth
Apple
Cherry

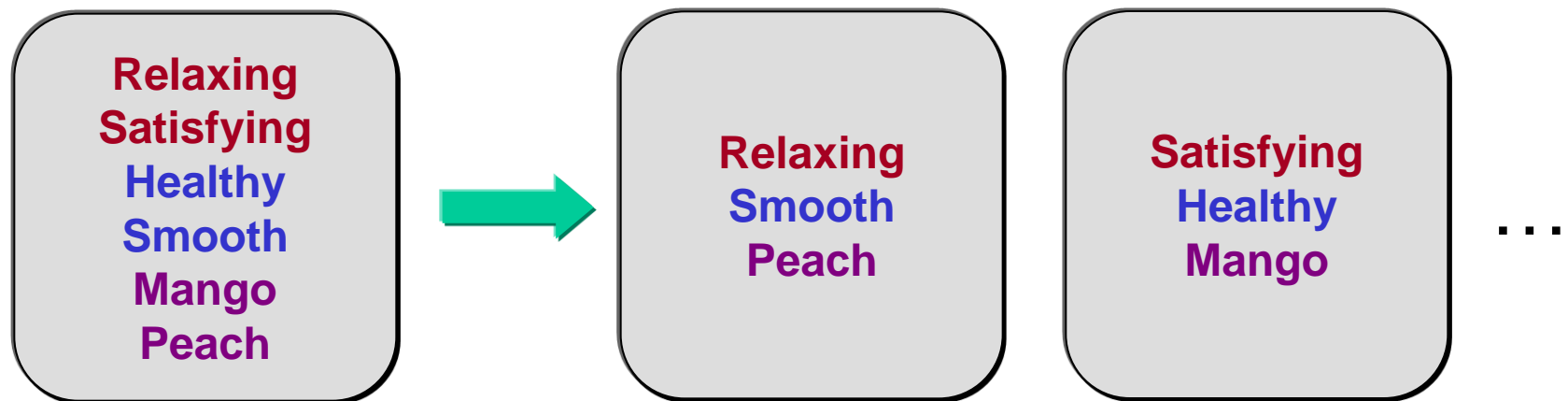
Reviving
Crisp
Cherry
Lime

Relaxing
Satisfying
Healthy
Smooth
Mango
Peach

...

Step 3: Finding an Optimal Portfolio

- We want to recommend 5 product bundles
- There are 25 maximal product bundles but many more (270) product bundles overall



- For each product bundle we can predict acceptance for individuals
- We now use TURF to find best portfolios of product bundles

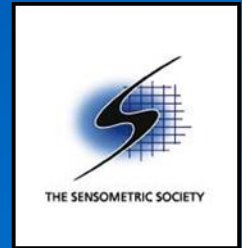
Recommended Portfolio

- For optimization we focus on bundles of size 3
- There are 59 such bundles
 - ❖ 685 consumers reached by at least one bundle
- Best portfolio of 5 bundles reaches 460 consumers (68%)





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