

Numerical Facet Range Partition: Evaluation Metric and Methods

Xueqing Liu¹, Chengxiang Zhai¹,
Wei Han², Onur Gungor²



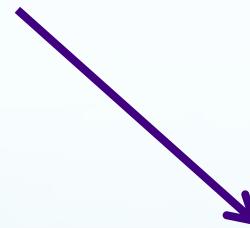
¹Department of CS,
University of Illinois

²Walmart Labs
@WalmartLabs

Faceted Search System

Query:
“laptop”

Facets



Google laptop

All Images Maps Shopping More ▾

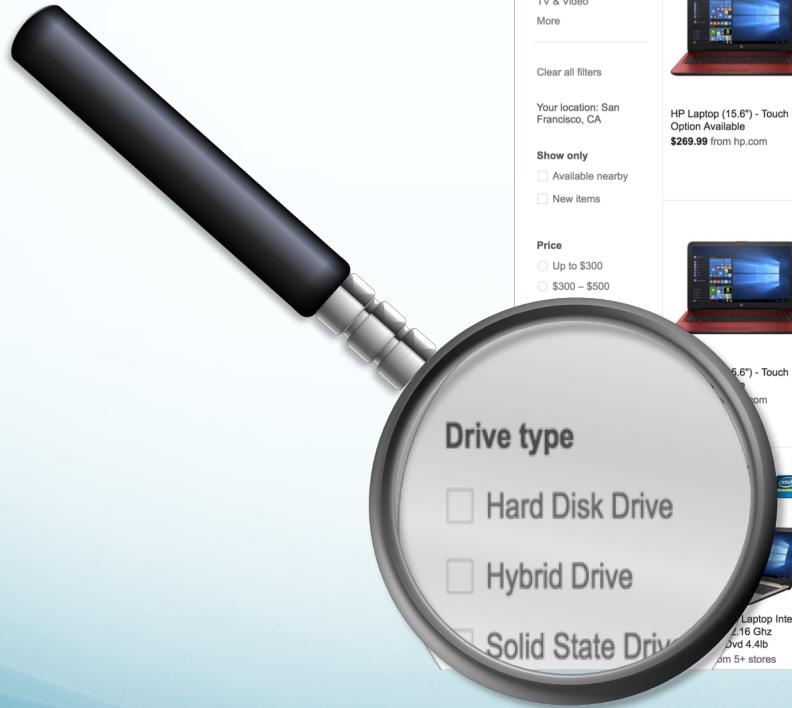
Laptops

Sort: Default View: Grid My Shortlist (0) Merchant links are sponsored

Product Image	Product Name	Price	Rating	More Options
	HP Laptop (15.6") - Touch Option Available \$269.99 from hp.com	\$269.99	★★★★★ (656)	
	Dell Latitude D810 15.4" Laptop (2.26ghz, 1gb, 80gb Hdd, Win Xp) \$139.99 refurbished from 3 stores	\$139.99	★★★★★ (656)	
	Dell Inspiron 11 3162 11.6" Laptop - Celeron N3050 1.6 GHz - 2 GB ... \$183.00 from 5+ stores	\$183.00	★★★★★ (656)	More options
	Acer 15.6" Chromebook Laptop 2GB 16GB CB5-571-C9DH \$207.89 from 4 stores	\$207.89	★★★★★ (656)	
	Dell 15.6" Touch Windows 10 Laptop - QuadCore 2.20 GHz - 6 GB RAM ... \$309.99 from 2 stores	\$309.99	★★★★★ (78)	
	Dell Inspiron i3558-9136BLK 15.6" Touch-Screen Laptop (Intel Core ... \$429.90 from 5+ stores	\$429.90	★★★★★ (1,339)	
	HP Laptop (15.6") - Touch Option Available \$359.99 from hp.com	\$359.99	★★★★★ (692)	
	Dell - Inspiron 14" Laptop - Intel Celeron - 2GB Memory - 32GB ... \$229.99 from 5+ stores	\$229.99	★★★★★ (692)	
	Toshiba Satellite PSCMLU-09L0KU C55-B5277 Laptop PC - Intel ... \$264.97 from 5+ stores	\$264.97	★★★★★ (1)	
	Mini Portable 10.1 Inch Computer Notebook Laptop Wifi Camera Bluetooth \$76.99 from eBay - cozyzonecs2	\$76.99	★★★★★ (1)	
	Toshiba -4517800 Satellite Touch-Screen Laptop \$499.99 from 2 stores	\$499.99	★★★★★ (1,143)	
	Laptop Computer \$185.00 used from Poshmark	\$185.00		
	Asus 15.6 Inch Laptop Intel N3050 Up To 2.16 Ghz 4gb/500gb/ Dvd 4.4lb \$269.99 from 5+ stores	\$269.99	★★★★★ (692)	
	HP 15-af131dx 15.6" Laptop (AMD A6-Series, 4GB Memory, 500GB Hard ... \$329.99 from 5+ stores	\$329.99	★★★★★ (692)	
	2016 Newest Hp Pavilion 15.6" Premium High Performance Laptop Pc, Amd \$344.40 from eBay - icelyinne	\$344.40	★★★★★ (692)	
	Buy a 2-in-1 Laptop Value Bundle with Printer, Case and Flash ... \$296.57 from Walmart	\$296.57	★★★★★ (692)	
	Dell Inspiron i3542-5000BK 15.6-Inch Touchscreen Laptop \$369.90 from 5+ stores	\$369.90	★★★★★ (9)	
	L75-b2720 Refurbished Toshiba Satellite 17.3-inch Laptop \$319.18 from 10+ stores	\$319.18	★★★★★ (9)	

Faceted Search System

Query:
“laptop”



Google Shopping search results for "laptop". The results are filtered under the "Laptops" category. The interface includes a sidebar with filters for Electronics, Audio, Computers & Devices, Photo & Optics, TV & Video, More, Clear all filters, Your location: San Francisco, CA, Show only (Available nearby, New items), and Price (Up to \$300, \$300 - \$500). The main area displays a grid of laptop products with their names, prices, and ratings.

Product	Price	Rating
HP Laptop (15.6") - Touch Option Available	\$269.99	4.5★ (656)
Dell Latitude D810 15.4" Laptop (2.2GHz, 1gb, 80gb Hdd, Win Xp)	\$139.99	refurbished from 3 stores
Dell Inspiron 11 3162 11.6" Laptop - Celeron N3050 1.6 GHz - 2 GB ...	\$183.00	from 5+ stores
Acer 15.6" Chromebook Laptop 2GB 16GB CB5-571-C9DH	\$207.89	from 4 stores
Dell 15.6" Touch Windows 10 Laptop - QuadCore 2.20 GHz - 6 GB RAM ...	\$309.99	from 2 stores
Dell Inspiron i3558-9136BLK 15.6" Touch-Screen Laptop (Intel Core ...	\$429.90	from 5+ stores
Dell - Inspiron 14" Laptop - Intel Celeron - 2GB Memory - 32GB ...	\$229.99	from 5+ stores
Toshiba Satellite PSCMLU-09L0KU C55-B5277 Laptop	\$264.97	from 5+ stores
Mini Portable 10.1 Inch Computer Notebook Laptop Wifi Camera Bluetooth	\$76.99	from eBay - cozyzonecs2
Toshiba -4517800 Satellite Touch-Screen Laptop	\$499.99	from 2 stores
Laptop Computer	\$185.00	used from Poshmark
HP 15-af131dx 15.6" Laptop Intel A6-Series, 4GB Memory, 500GB Hard ...	\$329.99	from 5+ stores
2016 Newest Hp Pavilion 15.6" Premium High Performance Laptop Pc, Amd	\$344.40	from eBay - icelynnne
Buy a 2-in-1 Laptop Value Bundle with Printer, Case and Flash ...	\$296.57	from Walmart
Dell Inspiron i3542-5000BK 15.6-inch Touchscreen Laptop	\$369.90	from 5+ stores
L75-b7270 Refurbished Toshiba Satellite 17.3-inch Laptop	\$319.18	from 10+ stores

Faceted Search System

Query:
“laptop”



Google laptop

All Images Maps Shopping More ▾

Sort: Default View: Grid My Shortlist (0) Merchant links are sponsored

Electronics		Laptops					
Audio							
Computers & Devices		HP Laptop (15.6") - Touch Option Available \$269.99 from hp.com	Dell Latitude D810 15.4" Laptop (2.26ghz, 1gb, 80gb Hdd, Win Xp) \$139.99 refurbished from 3 stores	Dell Inspiron 11 3162 11.6" Laptop - Celeron N3050 1.6 Ghz - 2 GB ... \$183.00 from 5+ stores ★★★★★ (656) More options	Acer 15.6" Chromebook Laptop 2GB 16GB CB5-571-C9DH \$207.89 from 4 stores	Dell 15.6" Touch Windows 10 Laptop - QuadCore 2.20 GHz - 6 GB RAM ... \$309.99 from 2 stores ★★★★★ (78)	Dell Inspiron i3558-9136BLK 15.6" Touch-Screen Laptop (Intel Core ... \$429.90 from 5+ stores ★★★★★ (1,339)
Photo & Optics							
TV & Video							
More							
Clear all filters							
Your location: San Francisco, CA							
Show only							
<input type="checkbox"/> Available nearby							
<input type="checkbox"/> New items							
Sort: Default View: Grid My Shortlist (0) Merchant links are sponsored							
Price		<input type="radio"/> Up to \$300	<input type="radio"/> \$300 – \$500	<input type="radio"/> Over \$500	\$ <input type="text"/> to <input type="text"/>	<input type="button" value="Go"/>	
		<input type="checkbox"/> Hybrid Drive	<input type="checkbox"/> Solid State Drive				
		Asus 15.6 Inch Laptop Intel N3050 Up To 2.16 Ghz 4gb/500gb/ Dvd 4.4lb \$269.99 from 5+ stores	HP 15-af131dx 15.6" Laptop (AMD A6-Series, 4GB Memory, 500GB Hard ... \$329.99 from 5+ stores	2016 Newest Hp Pavilion 15.6" Premium High Performance Laptop Pc, Amd \$344.40 from eBay - icelynnne	Buy a 2-in-1 Laptop Value Bundle with Printer, Case and Flash ... \$296.57 from Walmart	Dell Inspiron i3542-5000BK 15.6-inch Touchscreen Laptop \$369.90 from 5+ stores ★★★★★ (9)	L75-b7270 Refurbished Toshiba Satellite 17.3-inch Laptop \$319.18 from 10+ stores

Problem Definition

How to suggest k query-adaptable numerical ranges?



Is This Topic Too Narrow?

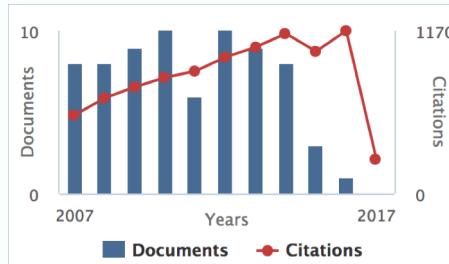


Is This Topic Too Narrow? No!



Perth, Australia Travel Guide - Must-See...
BookingHunterTV
3 years ago · 216K vie...

Video search



Academic search



When is Easter 2017, what are the school holiday dates and why ...
The Sun · 3 hours ago



News search



12. Adina Apartment Hotel Perth
 4 Reviews
33 Mounts Bay Rd, Perth City Hotels

.4 mi
\$\$\$

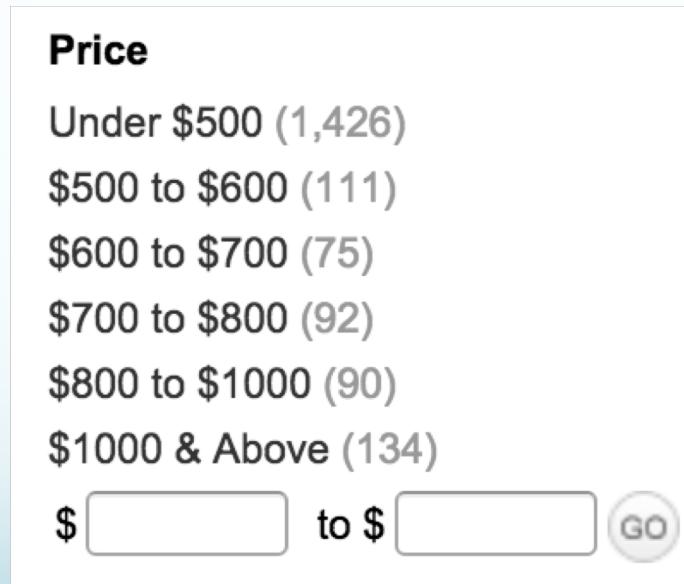
Location search

Why Unhappy with Current Websites?

Why Unhappy with Current Websites?

- Highly skewed distribution!

Query: “refurbished laptop”



What Makes a Good Partition?

What Makes a Good Partition?

- One that saves user's browsing cost!

Price

Under \$500 (1,426)
\$500 to \$600 (111)
\$600 to \$700 (75)
\$700 to \$800 (92)
\$800 to \$1000 (90)
\$1000 & Above (134)

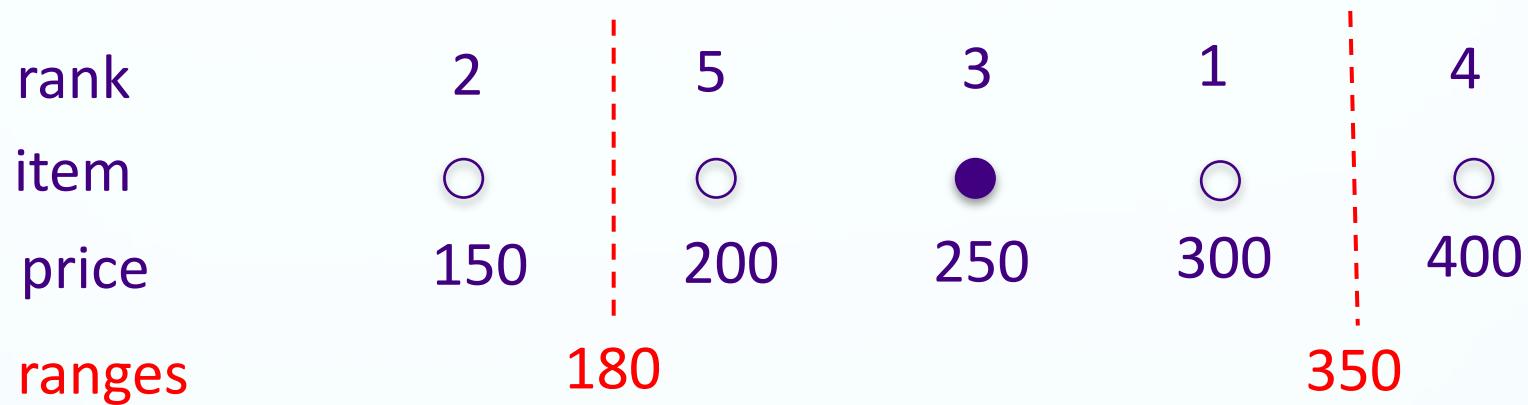
\$ to \$

Browsing Cost under Partition

rank	2	5	3	1	4
item	○	○	●	○	○
price	150	200	250	300	400

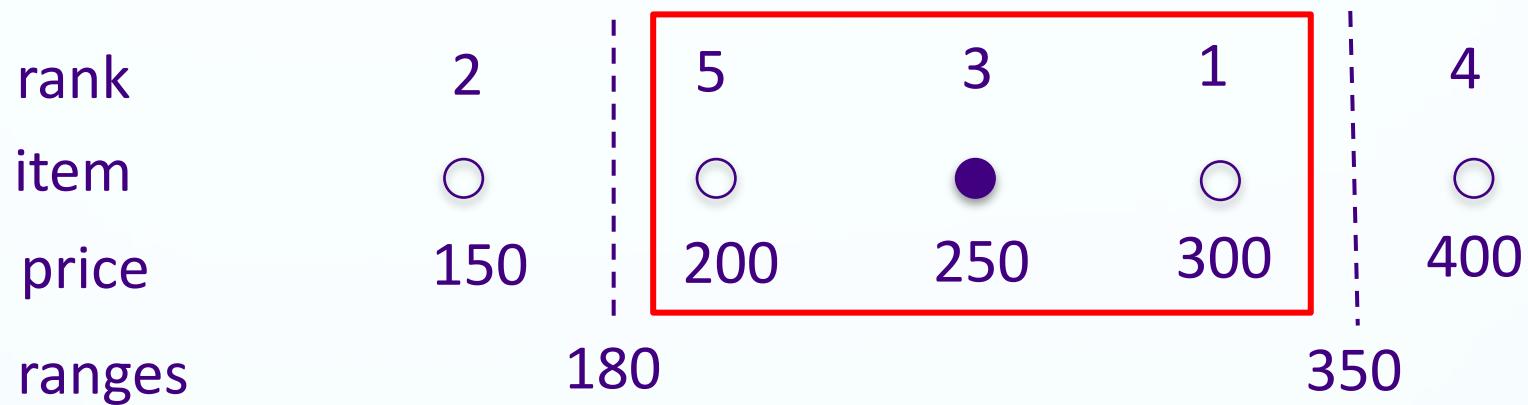
- relevant (clicked) item
- irrelevant (not clicked) item

Browsing Cost under Partition



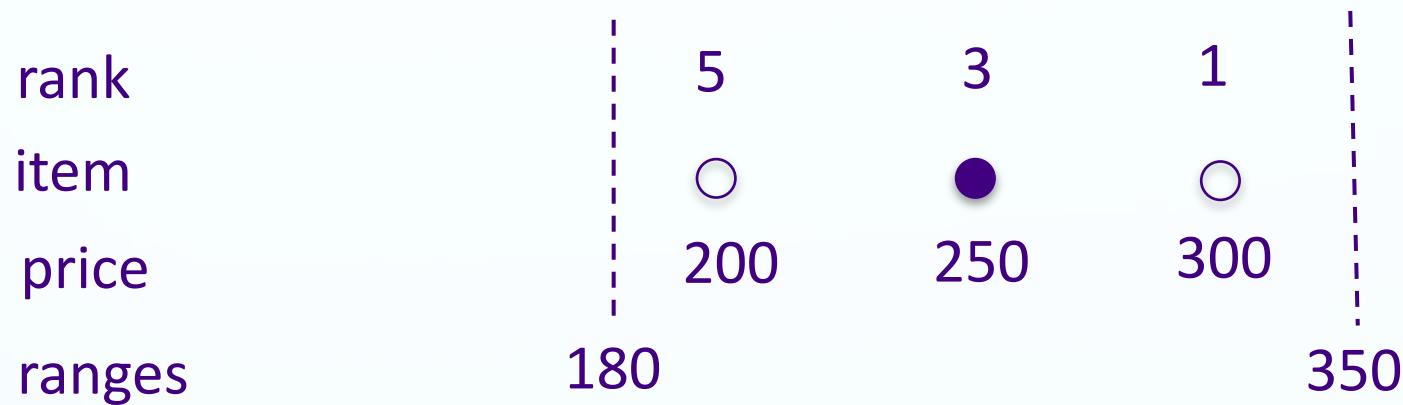
e.g., $[0, 180)$, $[180, 350)$, $[350, \infty)$

Browsing Cost under Partition

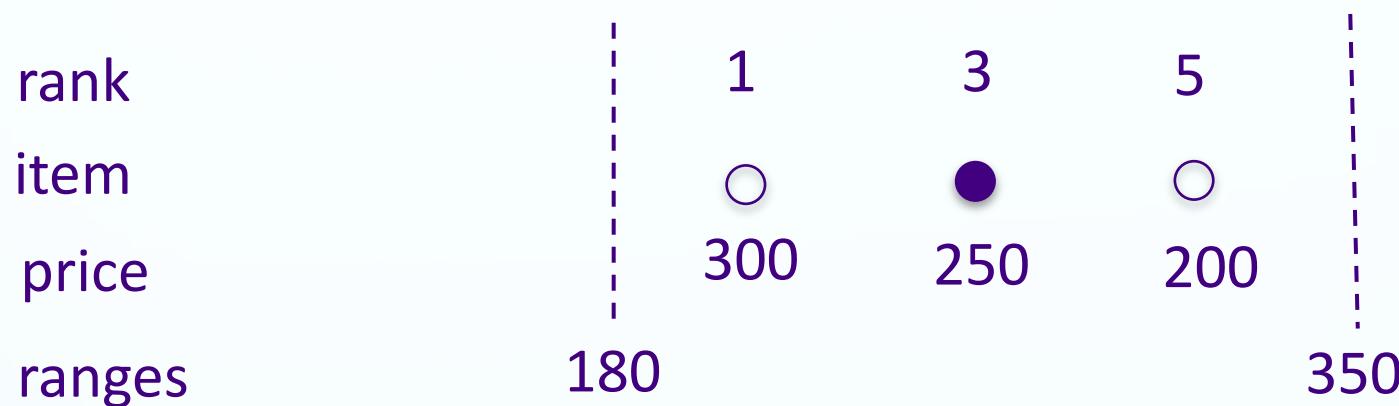


Assumption 1: user will select the unique range containing the relevant item

Browsing Cost under Partition

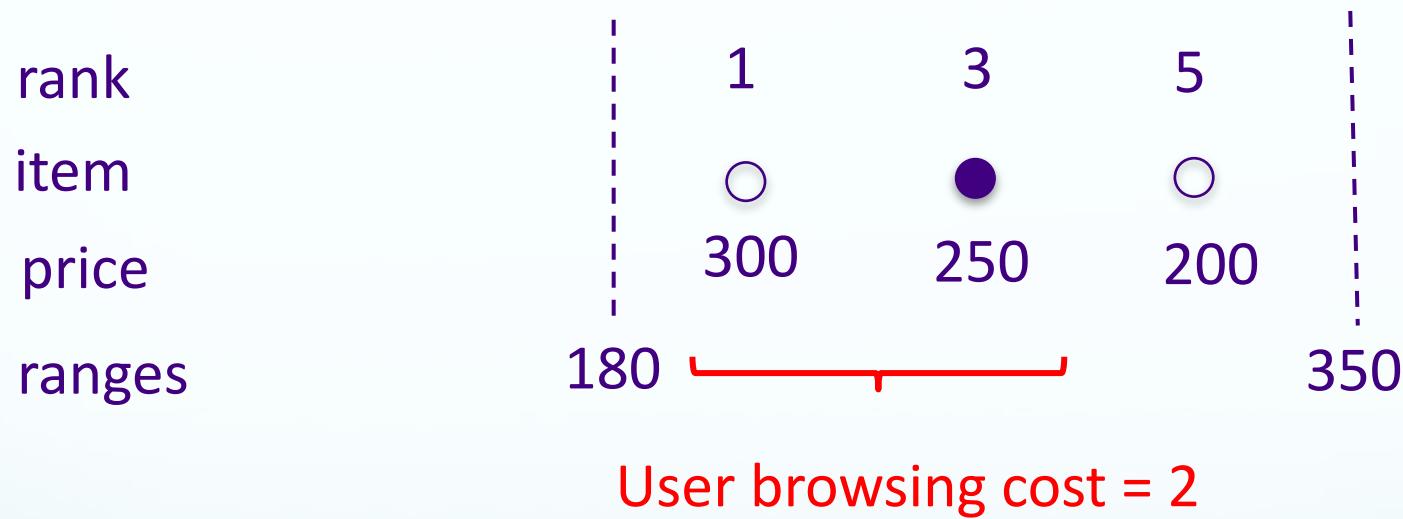


Browsing Cost under Partition



Assumption 2: after selecting the unique range, user will sequentially browse until finding the relevant item

Browsing Cost under Partition



Evaluation Metric

- User log contains n queries:

q_1, q_2, \dots, q_n

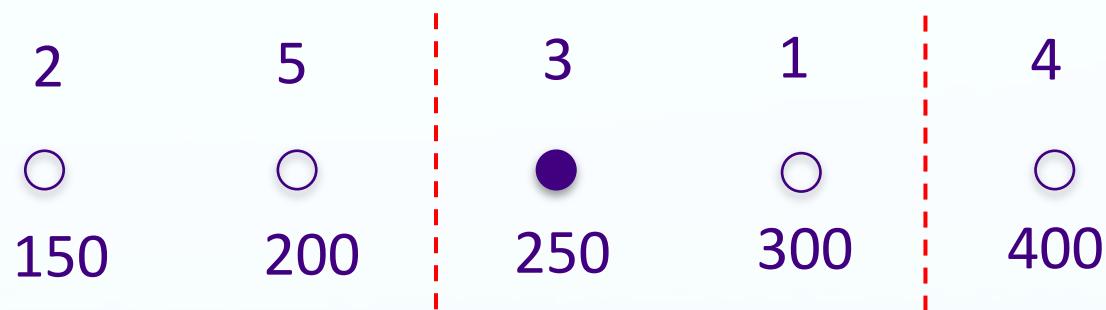
- For each query q_i :

Cost (i) = rank of relevant item in its unique range

$$\text{AvgCost} = 1/n \sum_i \text{Cost}(i)$$

A Simple Baseline

- Quantile method: making each range contain same number of items



Learning to Partition

- Parameter: r_i = proportion of items in range i
- Quantile method: $r_i = 1/k$, $i=1,2,\dots,k$

$$r_1^*, \dots, r_k^* = \arg \min_{r_1, \dots, r_k} AvgCost$$

$$s.t. \sum_{i=1}^k r_i = 1$$

Learning to Partition

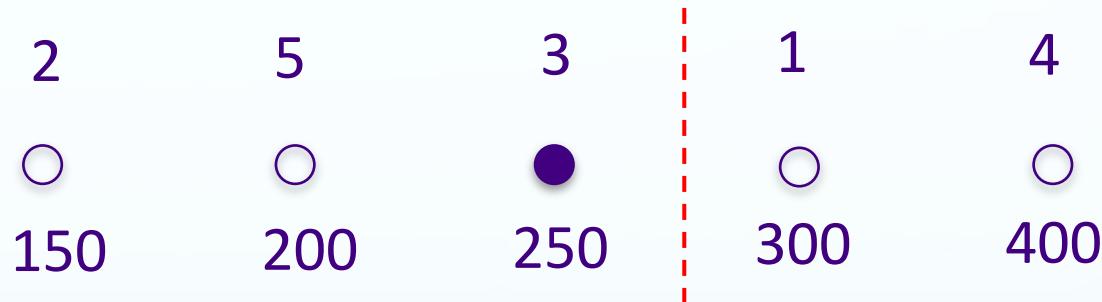
- AvgCost is Non-smooth!
- e.g., $r_1, r_2 = [0.8, 0.2]$



$$\text{Cost}(i) = 3$$

Learning to Partition

- AvgCost is Non-smooth!
- e.g., $r_1, r_2 = [0.8-\varepsilon, 0.2+\varepsilon]$



$$\text{Cost}(i) = 2$$

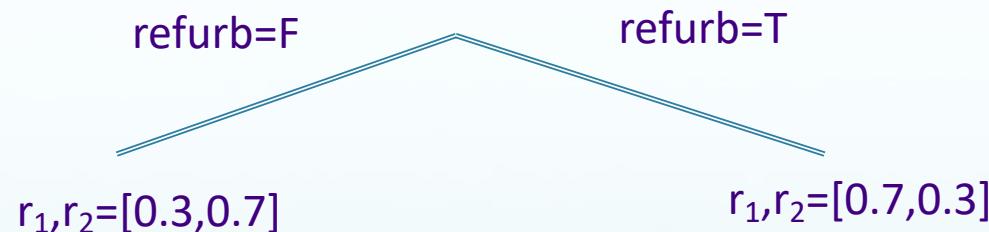
Learning to Partition

- **AvgCost is Non-smooth!**
- Non-smooth optimization of AvgCost is time-consuming
- Introducing surrogate function:

$$O(N_{\text{eval}} mn \log m) \longrightarrow O(mn \log m + N_{\text{eval}} k \log m)$$

Partition by Different Parameters

- So far, we have been using the same parameters on different queries
- What if different queries have different parameters?
- Decision tree



AvgCost

		quant.	dp	powell	tree
Laptop	$k = 2$	33.27	30.15	31.63	28.00
	$k = 3$	22.07	21.22	19.95	17.62
	$k = 4$	16.76	16.47	15.28	13.29
	$k = 5$	13.55	13.43	11.94	10.72
	$k = 6$	11.33	11.03	10.15	9.03
TV	$k = 2$	31.85	30.99	31.73	30.78
	$k = 3$	21.30	20.88	21.43	20.75
	$k = 4$	16.19	15.95	16.30	15.57
	$k = 5$	13.08	12.83	13.18	12.62
	$k = 6$	10.95	10.64	10.98	10.48

quant.: quantile method

powell: same parameter

dp: dynamic programming

tree: different parameter

Example Ranges

60 inch tv	40 inch tv	tv mount
0\$-450\$	0\$-165\$	0\$-20\$
450\$-660\$	165\$-260\$	20\$-25\$
660\$-950\$	260\$-355\$	25\$-40\$
950\$-1200\$	355\$-540\$	40\$-75\$
1200\$+	540\$+	75\$+

Example Ranges

60 inch tv	40 inch tv	17 inch laptop	tablet
0-55 "	0-30 "	0-13.5 "	0-7.5 "
55-56 "	30-40 "	13.5-15.5 "	7.5-8.5 "
56-61 "	40-42 "	15.5-16 "	8.5-10 "
61-68 "	42-47 "	16-17.5 "	10-10.5 "
68+ "	47+ "	17.5+ "	10.5+ "

Conclusion

- Propose a new research problem
- Propose two algorithms
- Especially helpful for diverse inventory, e.g., eBay

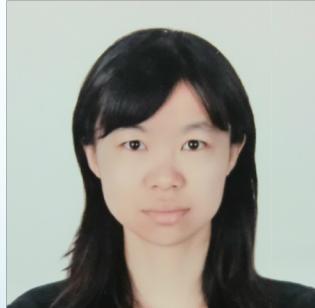
Future Work

- Generating ranges based on user feedback

Q & A

- xliu93@illinois.edu

Xueqing Liu



Chengxiang Zhai



Wei Han



Onur Gungor

