

A Combined Neural Price-Aware Collaborative Filtering and Clustering Approach for User Segmentation Based on Willingness to Pay

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Building on belief

Objective

- User segmentation can benefit in increasing business revenue by providing users with the right offers, improving user satisfaction by making marketing efforts segment-oriented, etc.
- While user segmentation considers a wide range of factors such as geographic, demographic, psychological, and behavioral, user segmentation based on willingness to pay (WTP) focuses exclusively on the price sensitivity aspect of user behavior.
- User segmentation based on WTP is crucial in developing a successful pricing and revenue strategy for a product or service.
- *The paper aims to propose a novel approach for user segmentation based on their WTP using user purchase data.*



<https://emglobalgroup.com/marketing-segmentation/>

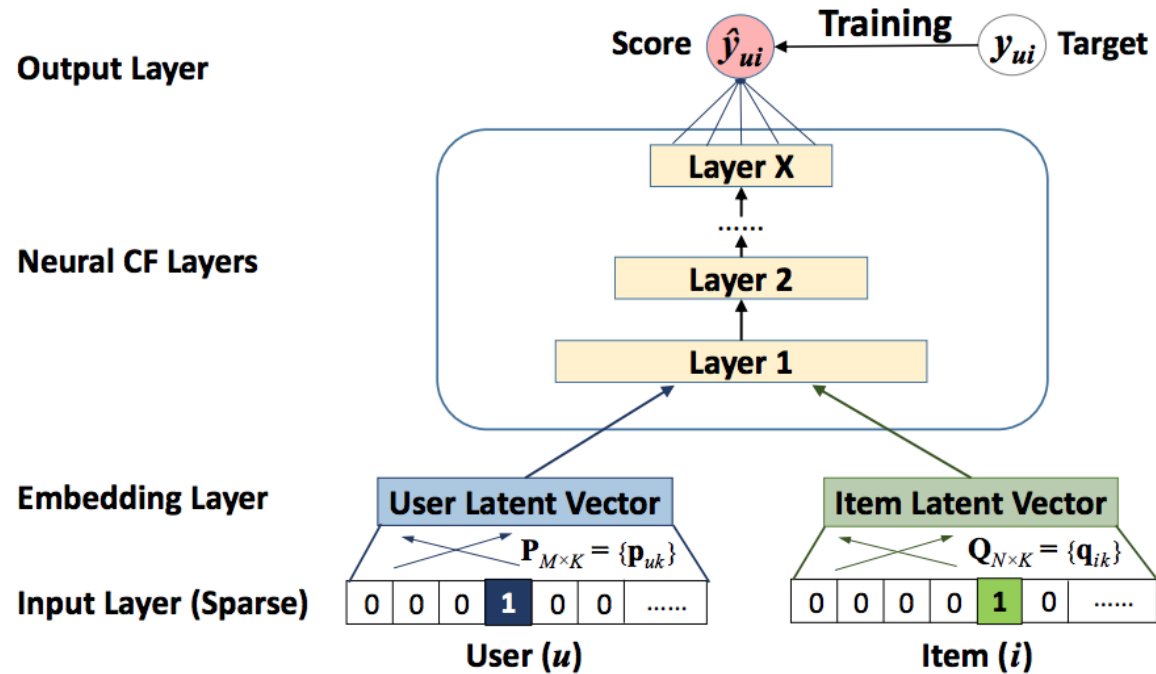
Introduction

User segmentation based on WTP		
Method	Stated preference	Revealed preference
	<ul style="list-style-type: none">➤ Involve directly asking individuals about their preferences through surveys, interviews, or hypothetical scenarios.➤ Data is self-reported and hypothetical, based on what individuals say they would do or prefer.	<ul style="list-style-type: none">➤ Infer preferences based on observed choices made by individuals in real-world situations.➤ Data is based on actual choices made by individuals in real situations, providing more concrete and observable information.
Limitations	<ul style="list-style-type: none">➤ Does not necessarily require respondents to purchase the product, and thus can deviate from the user's actual WTP➤ Do not consider user's joint purchase decision on multiple item	<ul style="list-style-type: none">➤ Need well-defined item and user attributes, which might sometimes be difficult to gather due to security and privacy issues.➤ Do not consider user's joint purchase decision on multiple item

Proposed approach addresses the limitations:

- *Uses user purchase data that correspond to revealed preference data*
- *Consider joint purchasing decisions/behavior on multiple items when segmenting.*
- *Uses the collaborative filtering technique that does not require well-defined item and user attributes.*

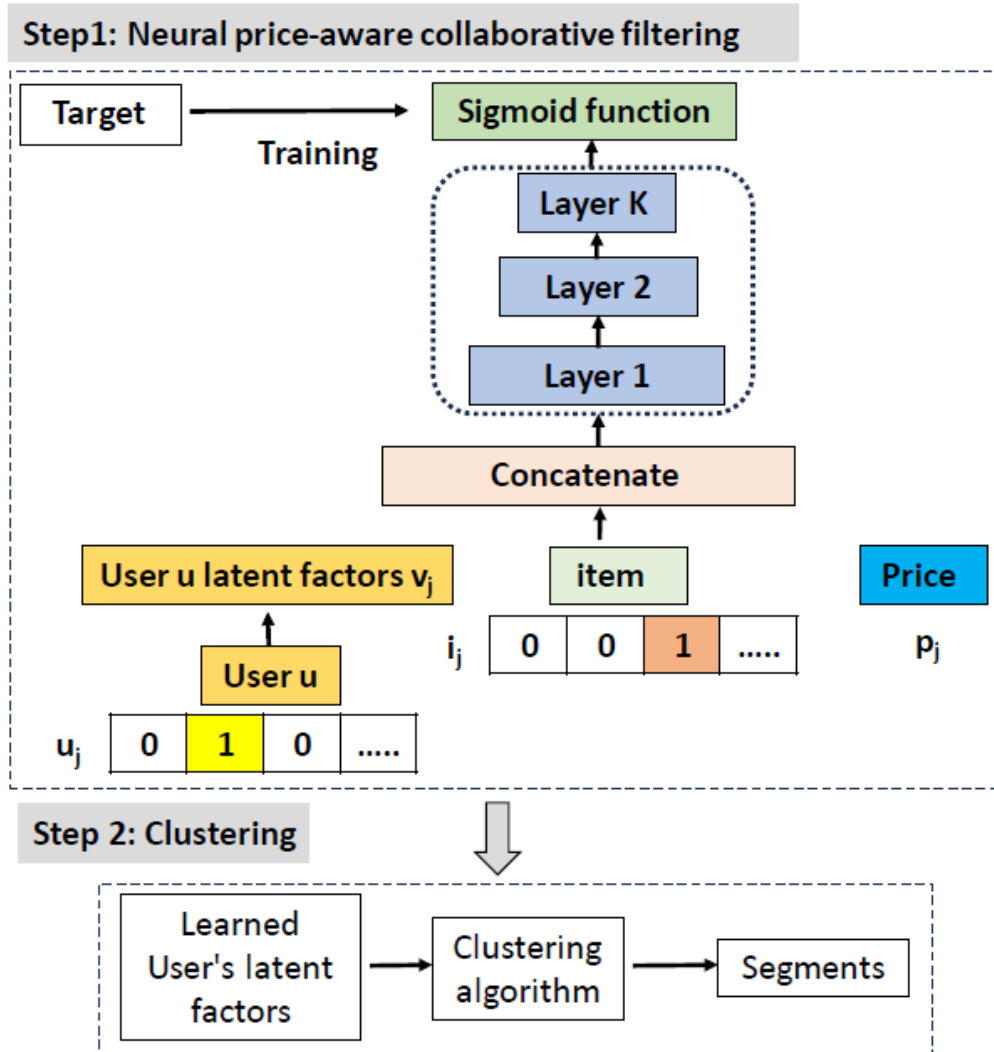
Neural collaborative filtering(2017)



- Neural Collaborative Filtering (NCF) uses neural networks to model complex interactions between users and items for recommendation systems.
- NCF is generic and can express and generalize matrix factorization under its framework.
- NCF is scalable, making it suitable for large-scale recommendation systems with millions of users and items

He, Xiangnan, Lizi Liao, Hanwang Zhang, Liqiang Nie, Xia Hu, and Tat-Seng Chua. "Neural collaborative filtering." In Proceedings of the 26th international conference on world wide web, pp. 173-182. 2017.

Proposed approach



Step1: Neural price-aware collaborative filtering

$$v_j = P^T u_j$$
$$x_j = [v_j \ i_j \ p_j]$$
$$c_1 = a_1(W_1^T x_j + b_1)$$
$$c_2 = a_2(W_2^T c_1 + b_2)$$
$$\dots\dots\dots$$
$$\hat{y}_j = a_k(W_k^T c_{(k-1)} + b_k)$$

- Extension to Neural collaborative filtering to consider price
- \hat{y}_j represents the predicted purchase probability of item i at a particular price p by a user u for the j -th sample.
- When training, the model learns the latent factors for the users to best explain their purchase behavior. Consequently, latent factors of users with similar purchase behavior will be close together.

Step 2: Clustering

- Users are clustered using the learned latent factors. These clusters refer to the segments formed comprising users having similar WTP

Data generation

- We **consider two scenario** and 3 items i.e., item 0, item 1, and item 2.
 - In *scenario 1*, we consider item 0 and around 1000 users
 - In *scenario 2* we consider three items i.e., item 0, item 1, and item 2, and around 1000 users.
- **To generate data :**
 - A given user is shown an item/items (as per scenario) at a given offer price,
 - Each user WTP for an item/items is sampled from the Figure 1. distributions for items
 - Based on the user's WTP, the user decides to purchase it or not.

Figure 1. Distribution of the price of an item

Item	1 st peak	2 nd peak
Item 0	$\mathcal{N}(40, 5)$	$\mathcal{N}(60, 5)$
Item 1	$\mathcal{N}(80, 5)$	$\mathcal{N}(100, 5)$
Item 2	$\mathcal{N}(100, 5)$	$\mathcal{N}(120, 5)$

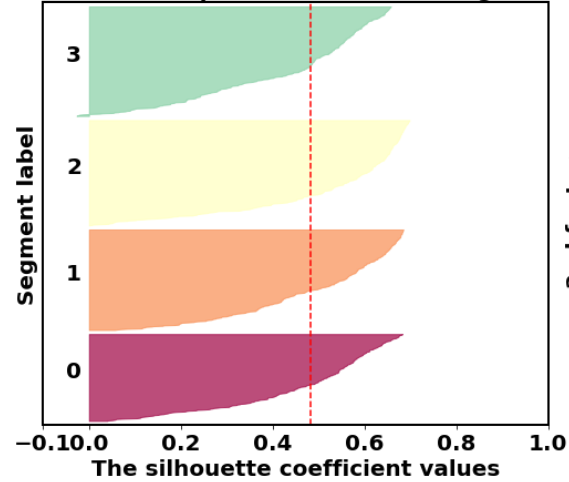
Figure 2. Sample data

Scenario 1				Scenario 2			
User	Item Shown	Offer price	Purchase decision	User	Item Shown	Offer price	Purchase decision
User 0	Item 0	35.55	1	User 0	Item 0	31.02	1
User 0	Item 0	67.87	0	User 0	Item 1	78.36	0
User 1	Item 0	68.88	0	User 0	Item 2	89.79	1
User 1	Item 0	31.51	1	User 1	Item 0	73.87	0
...	...	...	...	User 1	Item 1	66.12	1
...	...	...	...	User 1	Item 2	113.06	1
...

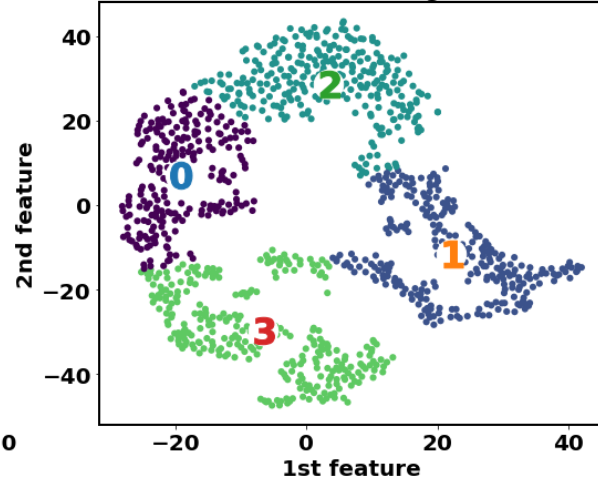
Result: Quality of the segments formed

Scenario 1: Silhouette score is 0.48 with 4 segments

The silhouette plot for the various segments.

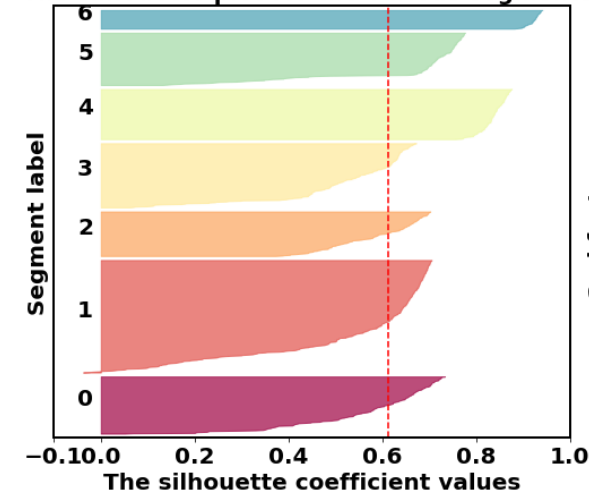


The visualization of the segmented data.

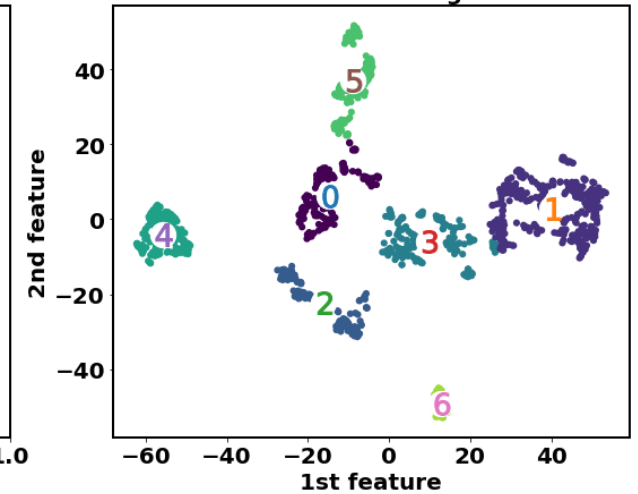


Scenario 2 : Silhouette score is 0.61 with 7 segments

The silhouette plot for the various segments.



The visualization of the segmented data.



Result: Comparing segment-specific WTP (Scenario 1)

- Segments formed have users with different WTPs.
 - WTP for item 0 is different between segments for example in segment 0 the "Mean:P" is 41.22 and in segment 2 the "Mean:P" is 33.33.
- Segmentation is not only based on the price at which the item is purchased by a user but also based on the price at which the item is not purchased by a user.
 - "Mean:P" is nearly the same between segments 1 and 2 i.e. 36.9 and 33.33 respectively, the "Mean: NP" is 52.09 in segment 1 and 68.9 in segment 2.

Segment	Item	Mean:P	Stdev:P	Mean: NP	Stdev: NP
0	0	41.22	2.83	72.87	5
1	0	36.9	4.74	52.09	6.57
2	0	33.33	2.28	68.9	7.24
3	0	52.9	4.86	69.56	6.2

- "Mean:P" : Mean of the prices at which a particular item is purchased within a segment
- "Stdev:P" : Standard deviation(Stdev) of the prices at which a particular item is purchased within a segment
- "Mean:NP" : Mean of the prices at which a particular item is not purchased within a segment
- "Stdev:NP" : Stdev of the prices at which a particular item is not purchased within a segment

Result: Comparing segment-specific WTP(Scenario 2)

- Similar to scenario 1, segmentation in scenario 2 is also not only based on the price at which the item is purchased by a user but also based on the price at which the item is not purchased by a user.
- Segmentation is based on the user's joint purchasing decisions on all items.
 - "Mean:P" for item 0 is nearly the same between segments 0 and 4 i.e. 42.67 and 43.16 respectively, the mean is different for item 1 and item 2.

Segment	Item	Mean:P	Stdev:P	Mean:NP	Stdev:NP
0	0	42.67	9.4	71.95	6.33
0	1	75.65	12.44	97.9	12.62
0	2	101.48	12.84	108.16	4
1	0	64.18	3.57	63.41	10.6
1	1	77.68	11.65	106.1	11.03
1	2	92.08	10.01	122.28	12.11
2	0	35.1	0	53.7	9.93
2	1	80.6	11.34	77.14	0
2	2	100.01	11.3	135.1	3.15
3	0	42.79	9.98	69.93	8.9
3	1	72.67	8.24	99.14	11.49
3	2	99.91	11.95	124.33	11.36
4	0	43.16	9.13	78.21	1.96
4	1	63.37	1.33	103.65	11.83
4	2	0	0	124.35	11.45
5	0	43.33	9.27	0	0
5	1	80.27	10.47	110.74	6.98
5	2	89.09	5.72	119.86	11.54
6	0	42.95	8.77	0	0
6	1	67.15	5.01	0	0
6	2	0	0	130.56	7.47

Result: User's purchase behavior for a given item at a given price within a segment

Scenario 1

	User	Item shown	Offer price	Purchase decision
Similar/ Nearby clustered users	150	0	65.35	1
		0	78.99	0
	427	0	66.36	1
		0	77.98	0
	269	0	73.43	0
		0	58.28	1
	312	0	60.81	1
		0	72.42	0
	141	0	61.31	1
		0	74.95	0

Scenario 2

	User	Item shown	Offer price	Purchase decision
Similar/ Nearby clustered users	92	0	77.96	0
		2	97.14	1
		1	63.67	1
	253	1	62.45	1
		0	75.92	0
		2	94.69	1
	383	2	92.24	1
		1	64.9	1
		0	78.98	0

Nearby clustered users are the ones having similar purchase decisions for a given item at a given offer price.

Conclusion

- Demonstrated a novel approach for user segmentation based on WTP, using a combination of neural price-aware collaborative filtering and clustering techniques.
- Segments are not only formed based on the price at which the item is purchased by a user but the price at which the item is not purchased by a user is also considered.
- In case the user purchase data contains user interaction with multiple items, the user's joint purchasing decisions on all items are considered while segmenting.
- The proposed approach can be used to create user segments based on WTP in various business domains, enabling them to create more personalized pricing and marketing strategies, leading to increased revenue and user satisfaction.

Reference

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Thank you, Any questions ?