

Machine Learning and Data Science at Etsy

Liangjie Hong
Head of Data Science

Liangjie Hong

- Head of Data Science at Etsy.
- Senior Manager of Research at Yahoo Research in Sunnyvale, CA
Leading science efforts for personalization and search sciences.
- Published papers in SIGIR, WWW, KDD, CIKM, AAI, WSDM, RecSys and ICML (2000+ citations)
- WWW 2011 Best Poster Paper Award
WSDM 2013 Best Paper Nominated
RecSys 2014 Best Paper Award
- Program committee members in KDD, WWW, SIGIR, WSDM, AAI, EMNLP, ICWSM, ACL, CIKM, IJCAI and various journal reviewers
- PhD in Machine Learning from Lehigh University

Etsy



Etsy – A Global Marketplace



Artifact Bags
Omaha, NE

Photo by: Dana Damewood and Jackie Sterba



Clap Clap
Los Angeles, CA

Photo by: Bert Youn and Mimi Kim



redravenstudios
Pittsburgh, PA

Photo by: Janelle Bendycki



Little Hero Capes
Somerset, MA

Photo by: Rich Vintage Photography



Cattails Woodwork
Hermitage, PE, Canada

Photo by: Cattails Woodwork



Room for Emptiness
Berlin, Germany

Photo by: Room for Emptiness



sukrachand
Brooklyn, NY

Photo by: sukrachand



Nicole Porter Design
Saint Paul, MN

Photo by: Nicole Porter Design



noemiah
Montreal, QC, Canada

Photo by: noemiah



Lorgie
Fremantle, WA, Australia

Photo by: Lorgie



Jeremiah Collection
San Francisco, CA

Photo by: Matthew Reamer



Docksmith
Brunswick, ME

Photo by: Docksmith



purlBKnit
Brooklyn, NY

Photo by: purlBKnit



Julia Astreou
Nicosia, Cyprus

Photo by: Panagiotis Mina



Moira K. Lime
Omaha, NE

Photo by: Moira K. Lime



Nested Yellow
Portland, OR

Photo by: Jessica Dremov and Nested Yellow



Habitables
Madrid, Spain

Photo by: Habitables



Woodstorming
Kaunas, Lithuania

Photo by: Iлона & Martynas from Instudija



karoArt
Dublin, Ireland

Photo by: Christine Burns



ADIKILAV
Jerusalem, Israel

Photo by: Shlomit Koslowe



My A La Mode Boutique
Ecuador

Photo by: My A La Mode Boutique

By The Numbers

1.6M
active sellers
AS OF MARCH 31, 2016

25M
active buyers
AS OF MARCH 31, 2016

\$2.39B
annual GMS
IN 2015

35+M
items for sale
AS OF MARCH 31, 2016



Work and Culture

852

employees around
the world

AS OF MARCH 31, 2016

9

offices in 7 countries

AS OF MARCH 31, 2016

54%

female employees

46%

male employees

AS OF DECEMBER 31, 2015



Photo by Emily Andrews

Work and Culture

1.6M
active sellers
AS OF MARCH 31, 2016

86%
of sellers
are women
2014 ETSY SELLER SURVEY

95%
of sellers run
their Etsy shop
from home
2014 ETSY SELLER SURVEY

76%
consider their shop
a business
2014 ETSY SELLER SURVEY



Photo by Moira K. Lime

Passionate and Loyal Business Owners

30%

focus on their
creative businesses as
their sole occupation

2014 ETSY SELLER SURVEY

65%

started their Etsy
shop as a way to
supplement income

2014 ETSY SELLER SURVEY

79%

started their Etsy
shop as an outlet for
creativity

2014 ETSY SELLER SURVEY



Photo by Panagiotis Mina

Engaged and Thoughtful Buyer Base

25M

active buyers

AS OF MARCH 31, 2016

87%

of Etsy buyers
are women

2014 ETSY BUYER SURVEY

92%

of buyers agree Etsy
offers products they can't
find elsewhere

2014 ETSY BUYER SURVEY



Photo by Jean-Michael Seminaro

AI in E-commerce

AI Challenges

For Buyers

- How to choose unique and satisfied products among millions?
How to lead and guide buyers to discover products that they wouldn't buy at the first place?
How to recommend appropriate products for different occasions?

For Sellers

- How to reach larger audience and potential buyers?
How to run advertising campaign more effectively?
How to communicate with buyers through different channels?

For Platform

- How to build a healthy platform?
How to speed-up buyer and seller communication?



AI in E-commerce

AI Challenges

- **Search and Discovery**
 - Query Modeling
 - User Intent Modeling
 - Learning to Rank
- **Personalization and Recommendation**
 - User Profiling
 - Item Modeling
 - Recommender Ranking
- **Computational Advertising**
 - Click-Through Rate Modeling
 - Conversion Rate Modeling
 - Bid Optimization



AI in E-commerce

AI in E-commerce at Etsy

- Multi-modal Deep-learning based Search Solution (KDD 2016)
- Probabilistic Graphical Model based Personalization Recommendation (KDD 2014)
- Ensemble Learning based CTR Prediction Solution (AdKDD 2017/KDD 2017)



Etsy – Search and Discovery

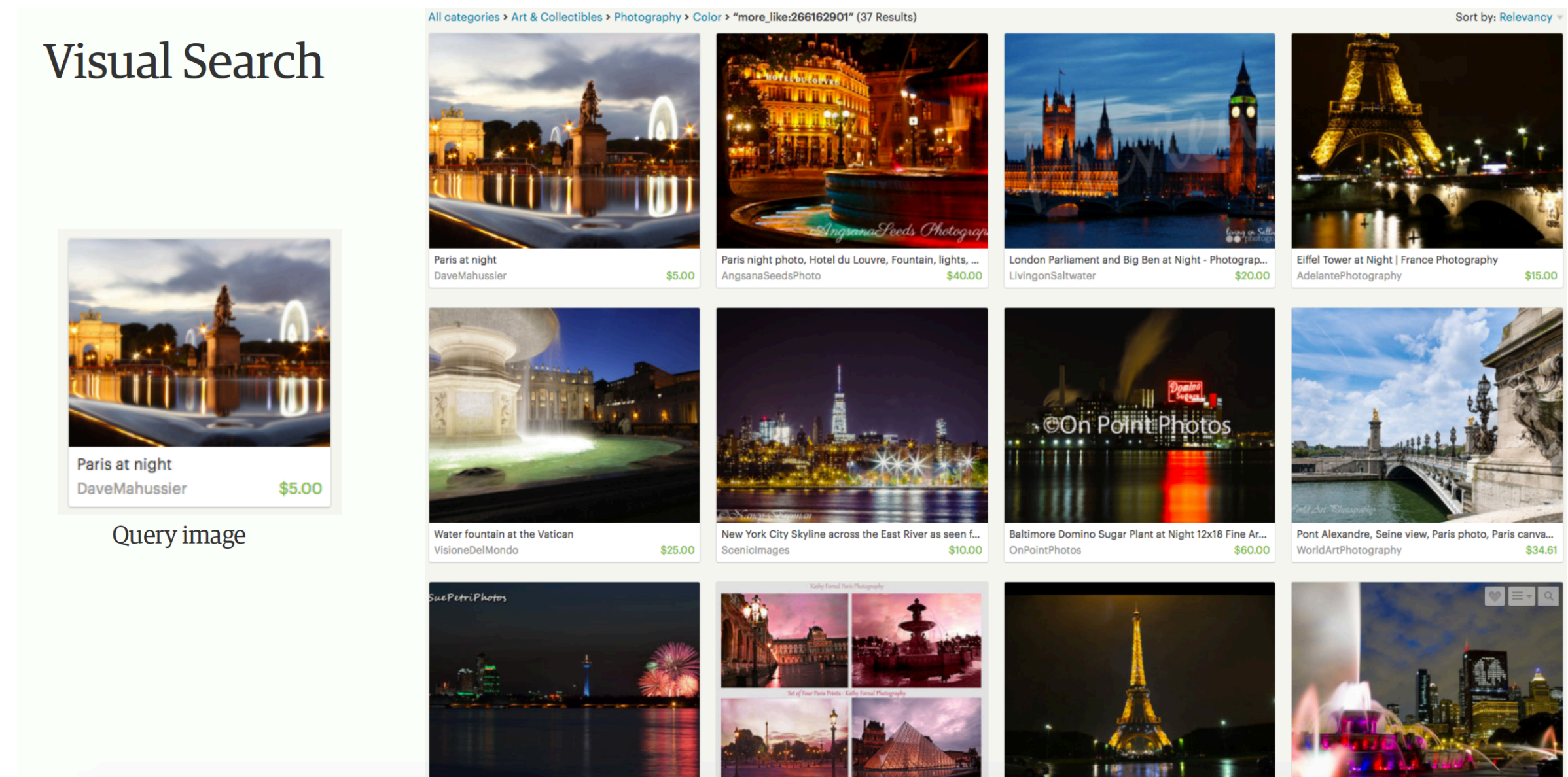
The desktop screenshot shows the Etsy search results for 'wedding dress'. The top navigation bar includes the Etsy logo, a search bar with 'wedding dress' and a 'Search' button, and links for 'Sell on Etsy', 'Register', 'Sign in', and 'Cart'. Below the navigation bar, there are category filters: 'July 4th', 'Clothing & Accessories', 'Jewelry', 'Craft Supplies & Tools', 'Weddings', 'Entertainment', 'Home & Living', 'Kids & Baby', and 'Vintage'. A left sidebar lists 'All categories' such as Clothing, Weddings, Jewelry, etc., and 'Shop location' options: 'Anywhere', 'China', and 'Custom'. The main content area displays 'All categories > "wedding dress" (232,752 Results)' and 'Sort by: Relevancy'. It features a grid of product listings with images, titles, and prices. The first row includes: 'Audrey Hepburn Retro Tea Length Weddi...' for \$299.95, 'Sexy Open Back Wedding Dress, Lace W...' for \$314.00, 'Wedding Suspender. Brown Leather Susp...' for \$23.00, and 'Rush Order ROSE GOLD Wedding Hange...' for \$26.00. The second row includes: 'Detachable lace skirt for wedding dress, ...' for \$119.00, 'Dress FW14-15 | Wedding dress Boho we...' for \$280.00, 'Boho wedding dress "Moonlight"' for \$330.00, and 'Exquisite Lace Wedding Dress V Shape L...' for \$259.00.

The mobile screenshot shows the Etsy search results for 'wedding gift'. The top status bar displays '中国联通 LTE', '10:01', and '99%' battery. The search bar contains 'wedding gift' and a 'Filter' button. Below the search bar, it indicates '1,719,287 items'. The main content area displays a grid of product listings with images, titles, and prices. The first row includes: 'Groomsmen Gift Box, ...' for \$35.00 and 'Navy and Gold Weddi...' for \$70.00. The second row includes: 'Unique wedding gift -...' for \$45.00 and 'Wedding Gift, Gift for...' for \$43.50. The third row includes: a heart-shaped map gift and a wooden tree gift. The bottom navigation bar features icons for 'Home', 'Favorites', 'Search', 'You', and 'Cart'.

Etsy – Search and Discovery

Deep Learning based Multi-modal Learning to Rank

- Corey Lynch, Kamelia Aryafar, and Josh Attenberg. **Images Don't Lie: Transferring Deep Visual Semantic Features to Large-Scale Multimodal Learning to Rank**. In Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (**KDD '16**). ACM, New York, NY, USA, 541-548.



Etsy – Search and Discovery

- >142M images
- Important complementary information to text
- Potential only information



“Red Short dress, Prom Dress, **wedding dress**, dress, ...”

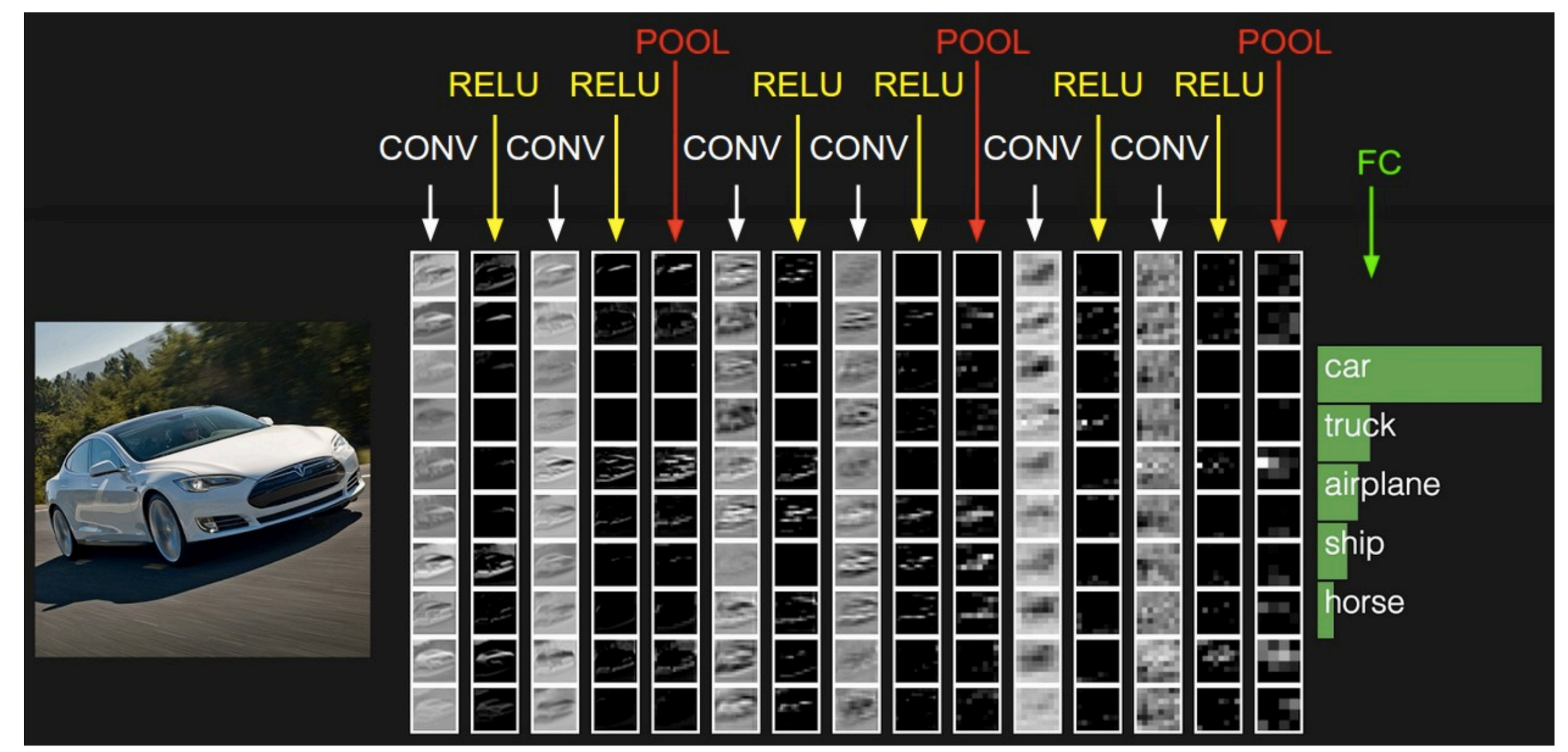
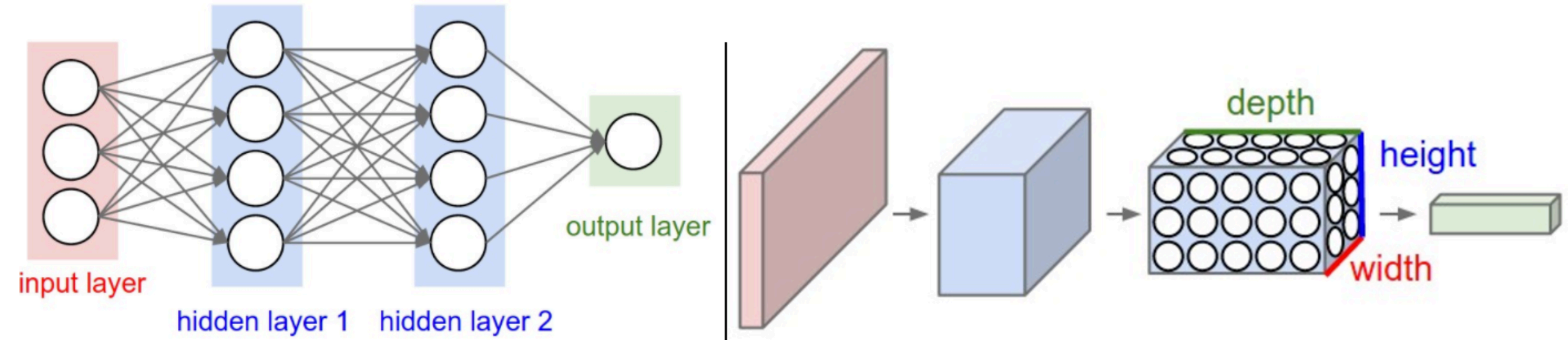


“Pocket Knife wedding shower ideas **wedding dresses**, beach ...”



“Yellow dress. Retro dress **Wedding dress**. Flared skirt...”

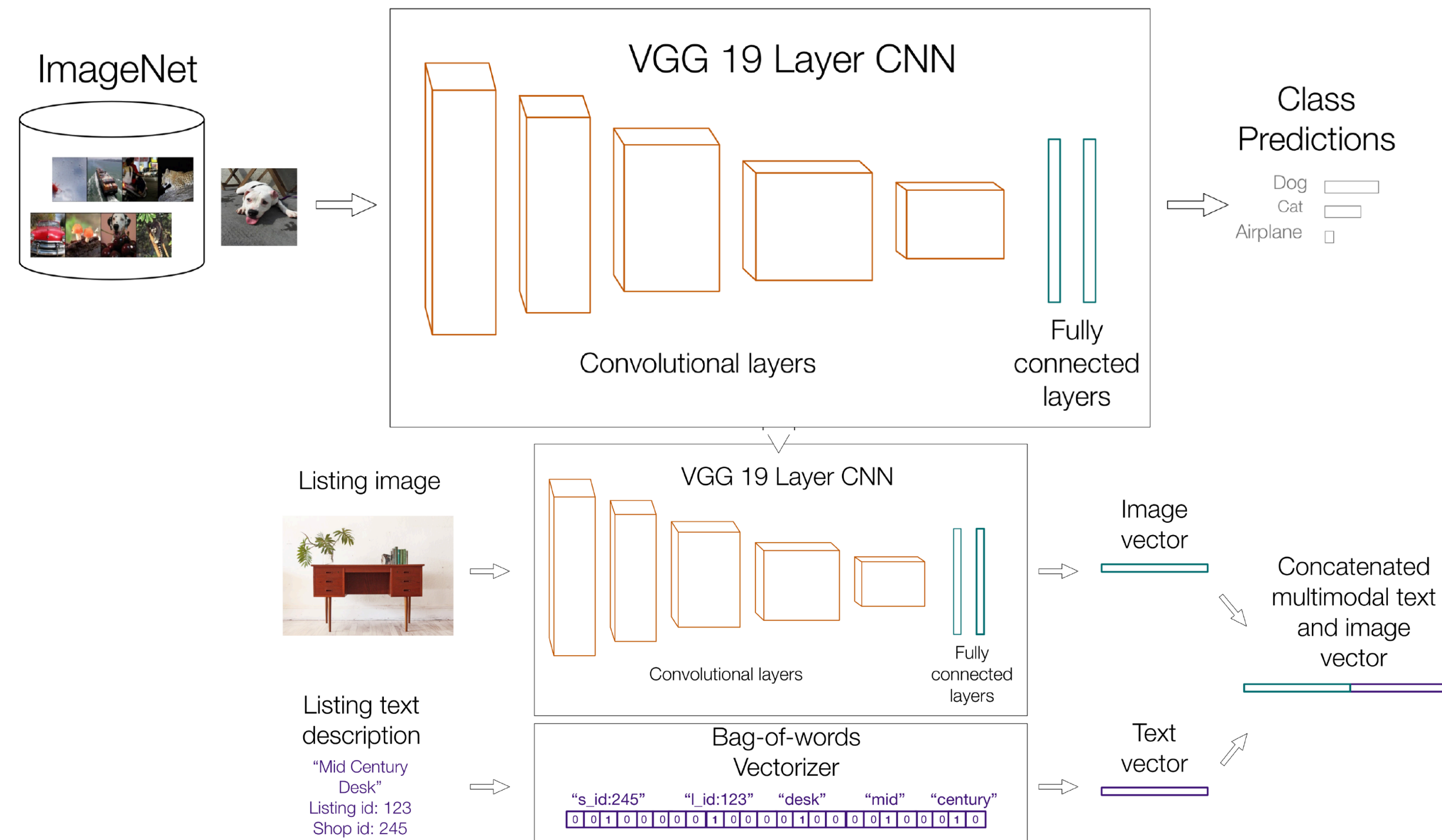
Etsy – Search and Discovery



Etsy – Search and Discovery

Deep Learning-based Feature Extraction + Transfer Learning

- Learn CNN model from ImageNet
- Extract CNN's parameters
- Apply Model on Etsy's data and combine with text info



Etsy – Search and Discovery

Multi-modal Learning to rank

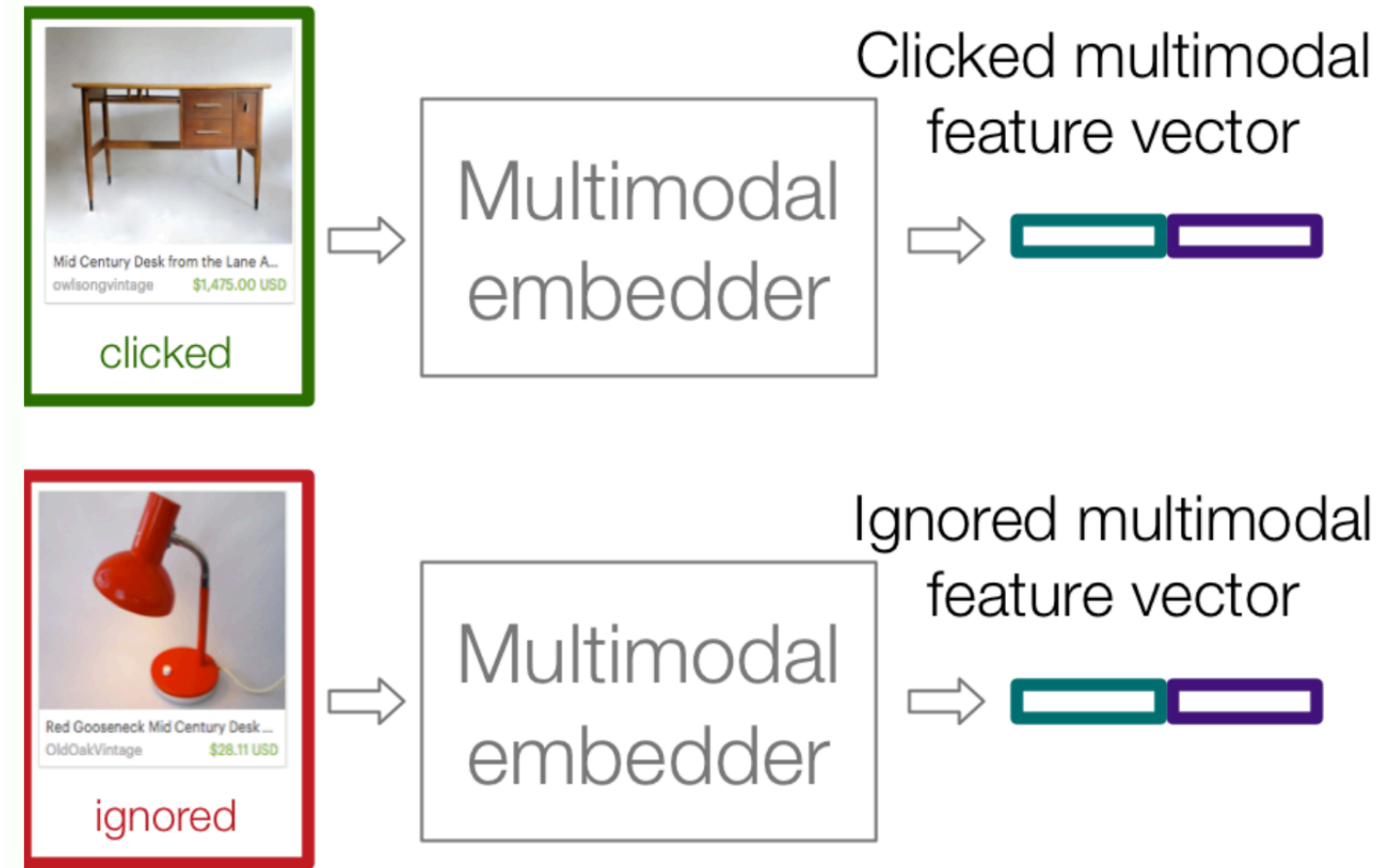
The image illustrates a search and discovery process on Etsy. It starts with a search for "mid century desk" which returns a grid of six items:

- Mid Century Desk / Entryway Table (OrWaDesigns, \$475.00 USD)
- Mid Century Desk 48" or 60" Minim... (FlintAlleyFurniture, \$565.00 USD)
- French vintage mid century desk t... (lestrictmaximum, \$55.09 USD)
- mid century modern secretary des... (dsartereno, \$799.00 USD)
- Red Gooseneck Mid Century Desk ... (OldOakVintage, \$28.11 USD)
- Mid Century Desk from the Lane A... (owlsongvintage, \$1,475.00 USD)

A blue arrow points to a zoomed-in view of two items:

- Red Gooseneck Mid Century Desk ... (OldOakVintage, \$28.11 USD) - labeled "ignored" in red text.
- Mid Century Desk from the Lane A... (owlsongvintage, \$1,475.00 USD) - labeled "clicked" in green text.

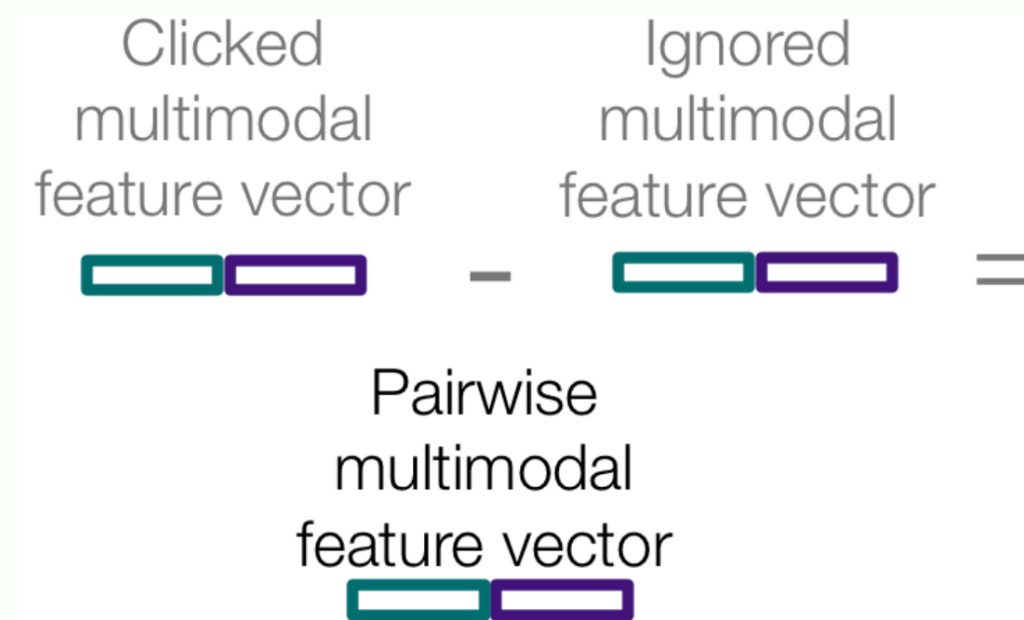
Etsy – Search and Discovery



Algorithm 1 Multimodal Embedding of Listings

```

1: procedure EMBEDMULTIMODAL( $\mathbf{d}_i$ )
2:    $\mathbf{d}_{T_i} \leftarrow \mathbf{BoW}(text)$ 
3:    $\mathbf{d}_{I_i} \leftarrow \mathbf{VGG}(image)$ 
4:    $\mathbf{d}_{MM_i} \leftarrow [\mathbf{d}_{T_i}, \mathbf{d}_{I_i}]$ 
5:   return  $\mathbf{d}_{MM_i}$ 
  
```



Algorithm 2 Generate Pairwise Classification Instances











```

1: procedure GETPAIRWISEINSTANCES( $\{\langle \mathbf{d}_i^+, \mathbf{d}_i^- \rangle\}$ )
2:    $L \leftarrow \{\}$ 
3:   for  $i = 1 \dots |P|$  do  $\triangleright |P|$  labeled tuples
4:      $\mathbf{d}_{MM_i}^+ \leftarrow \mathbf{EmbedMultimodal}(\mathbf{d}_i^+)$ 
5:      $\mathbf{d}_{MM_i}^- \leftarrow \mathbf{EmbedMultimodal}(\mathbf{d}_i^-)$ 
6:     Draw  $r$  uniformly at random from  $[0, 1)$ 
7:     if  $r > 0.5$  then
8:        $x_i \leftarrow \mathbf{d}_{MM_i}^+ - \mathbf{d}_{MM_i}^-$ 
9:        $y_i \leftarrow +1$ 
10:    else
11:       $x_i \leftarrow \mathbf{d}_{MM_i}^- - \mathbf{d}_{MM_i}^+$ 
12:       $y_i \leftarrow -1$ 
13:     $L = L.append(\langle x_i, y_i \rangle)$ 
14:    return  $L$   $\triangleright$  The list of classification instances.
  
```

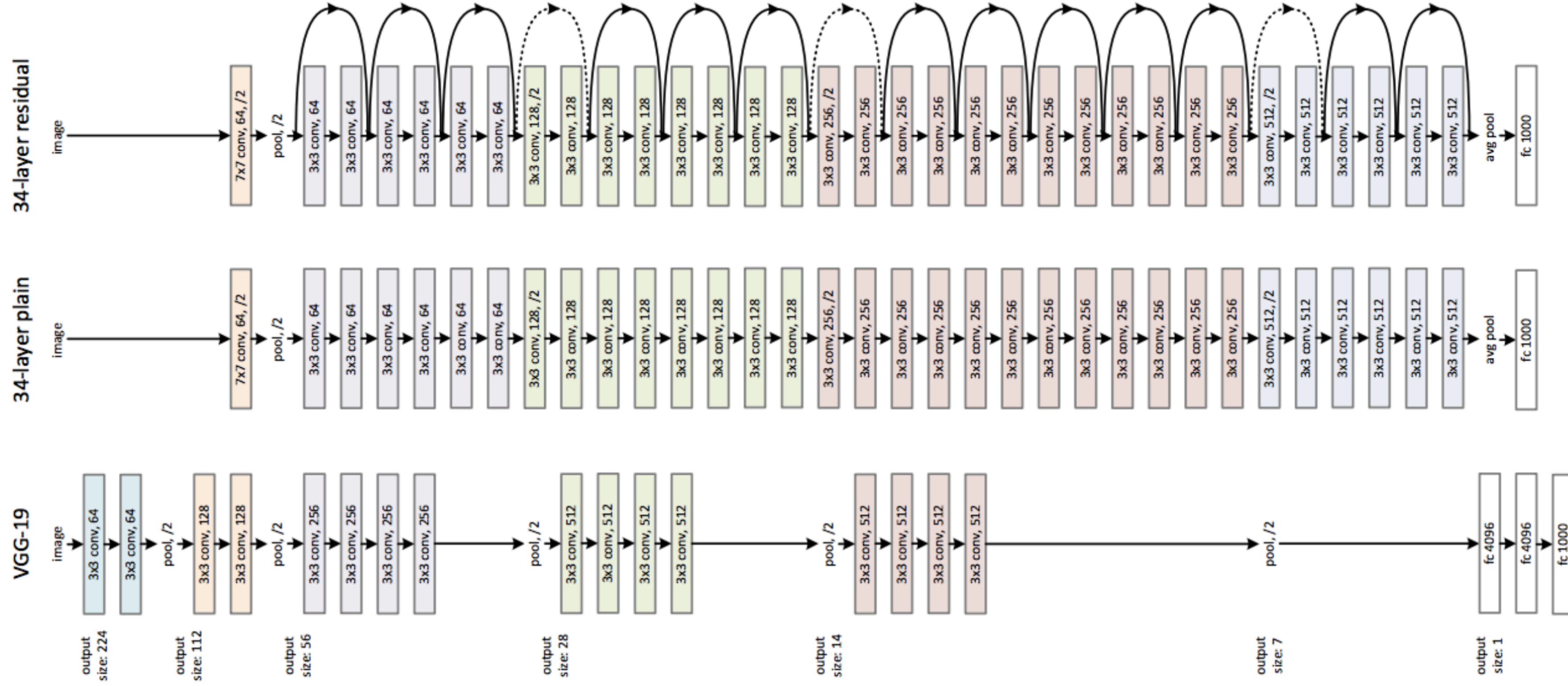
Etsy – Search and Discovery

Text-only ranking for
“bar necklace”

Multimodal ranking for
“bar necklace”

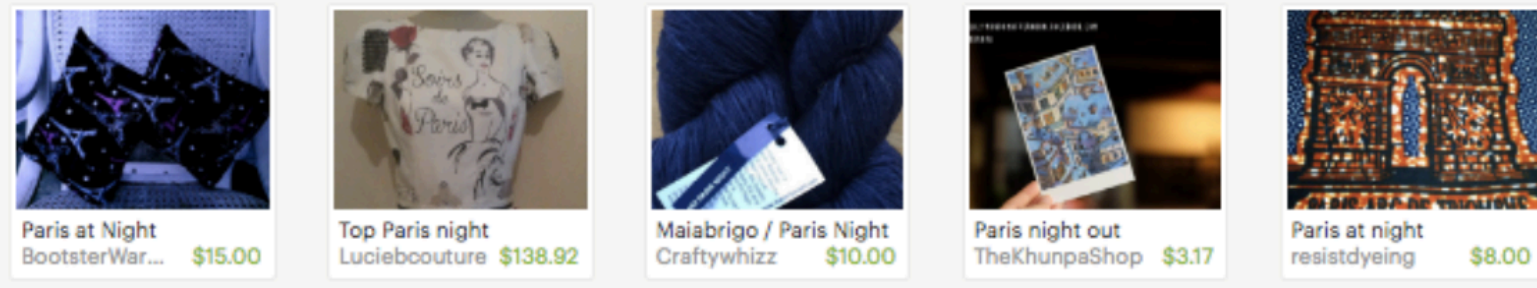
| | | | |
|-----------------|--|---|---|
| 90th percentile |  | → |  |
| 80th percentile |  | → |  |
| 70th percentile |  | → |  |
| 60th percentile |  | → |  |
| 50th percentile |  | → |  |

Etsy – Search and Discovery



Etsy – Search and Discovery

Similar Items [Shop More](#)




Paris at Night \$15.00
Top Paris night \$138.92
Maiabrigo / Paris Night \$10.00
Paris night out \$3.17
Paris at night resistdyeing \$8.00

DaveMahussier
Favorite shop
5 items

Like this item?
Add it to your favorites to revisit it later.

Instant download



Item details Shop policies

Taken outside of the Louvre in Paris, France.

Paris at night
\$5.00 [Ask a question](#)

Overview

- Handmade item
- Instant Digital Download: 1 JPG included
- Made to order
- Favorited by: 1 person

This shop accepts Etsy gift cards

[Add to cart](#)

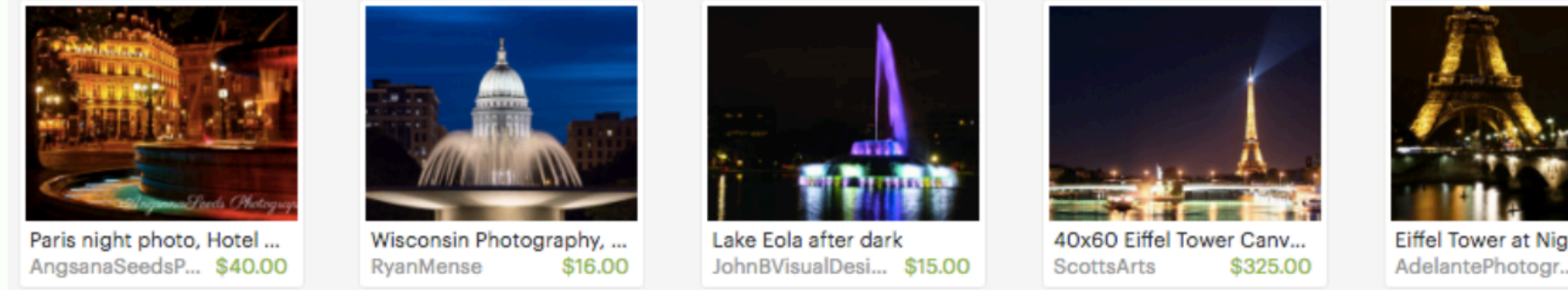
Favorite Add to -

Tweet Pin it tumblr. + Like 0

DaveMahussier
in United States

Control


Similar Items [Shop More](#)



Paris night photo, Hotel ... \$40.00
Wisconsin Photography, ... \$16.00
Lake Eola after dark \$15.00
40x60 Eiffel Tower Canv... \$325.00
Eiffel Tower at Night

DaveMahussier
Favorite shop

Instant download



Item details Shop policies

Paris at night
\$5.00 [Ask a question](#)

Overview

- Handmade item
- Instant Digital Download: 1 JPG included
- Made to order
- Favorited by: 1 person

This shop accepts Etsy gift cards

[Add to cart](#)


Favorite Add to -

Tweet Pin it tumblr. + Like 0

Variant

61

Etsy – Personalization and Recommendation

 Curated by Etsy, Based on [Your History](#).

Our Picks for You



Portrait Art of French Composer Ge...
ArtyMargit **\$26.34**



Map of Far E...
HunnapPrint



SALE: Violin Fine Art Photography M...
KEenzPhotography **\$20.00**



Original 189...
BooksMapsa



zoom

Item details

★★★★★ (53)

Shipping & Policies

Hand-drawn print of French composer Georges Bizet. Signed and dated.

Click on the photo to see others in this series: Brahms, Pachelbel and Vivaldi....

This limited edition print is printed on fine art 280gsm paper. Makes the perfect present for young or old. I take every care to package my artwork securely, to ensure it arrives in perfect condition.

Title: "Bizet" #0776

Size: A4 (21 x 30cm)

Comes unframed

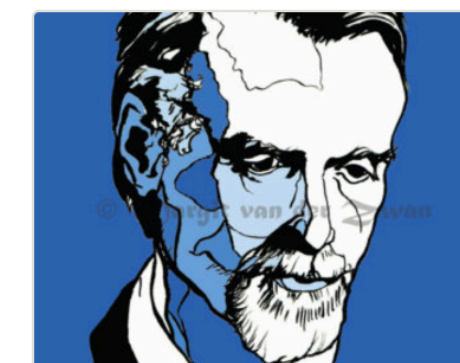
limited edition: 100 prints

The copyright symbol and letters are for each business sale and will not



ArtyMargit

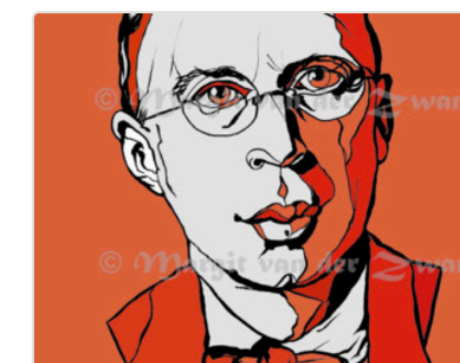
in Manchester, United Kingdom



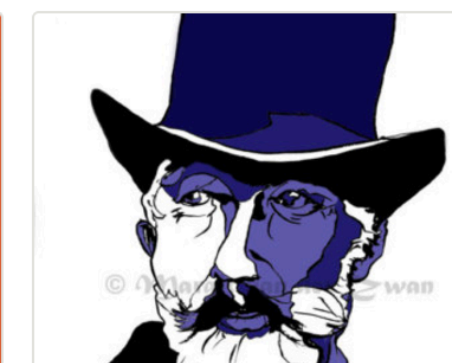
Limited edition Print of Zolta...
\$26.34



Khachaturian Composer port...
\$26.34



Prokofiev Portrait Print Limite...
\$26.34

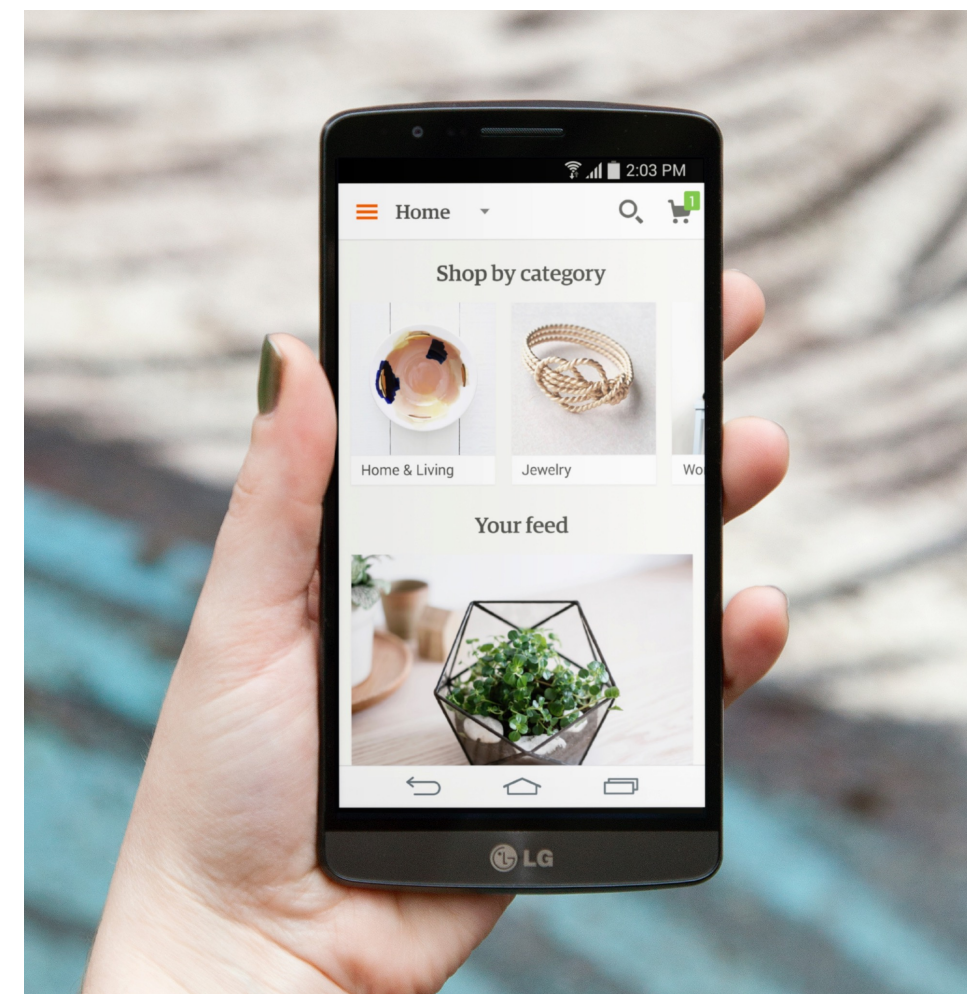


Music Art Print of Composer ...
\$26.34

Etsy – Personalization and Recommendation

Probabilistic Graphical Model based Personalization Recommendation

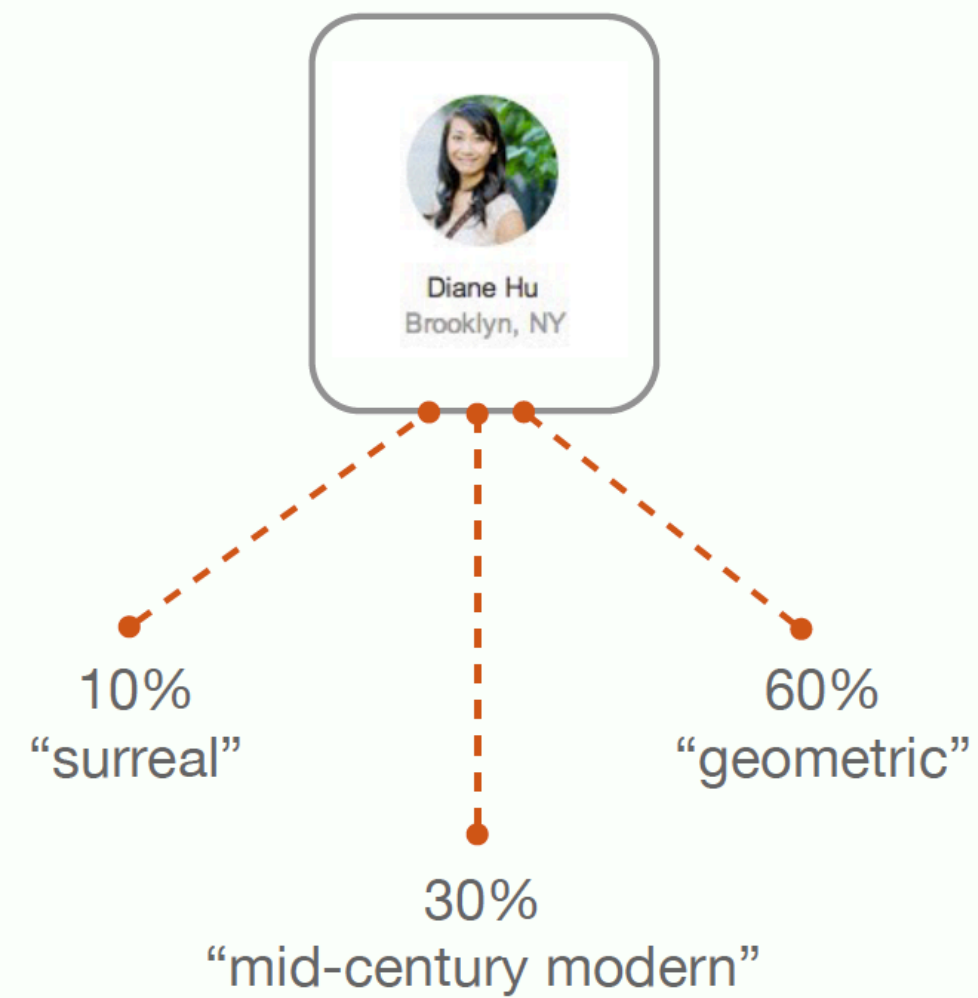
- Diane J. Hu, Rob Hall, and Josh Attenberg. **Style in the long tail: Discovering Unique Interests with Latent Variable Models in Large Scale Social E-Commerce**. In Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining (**KDD '14**). ACM, New York, NY, USA, 1640-1649.
- **KDD 2014 Industrial Best Paper**



Etsy – Personalization and Recommendation

Latent Dirichlet Allocation

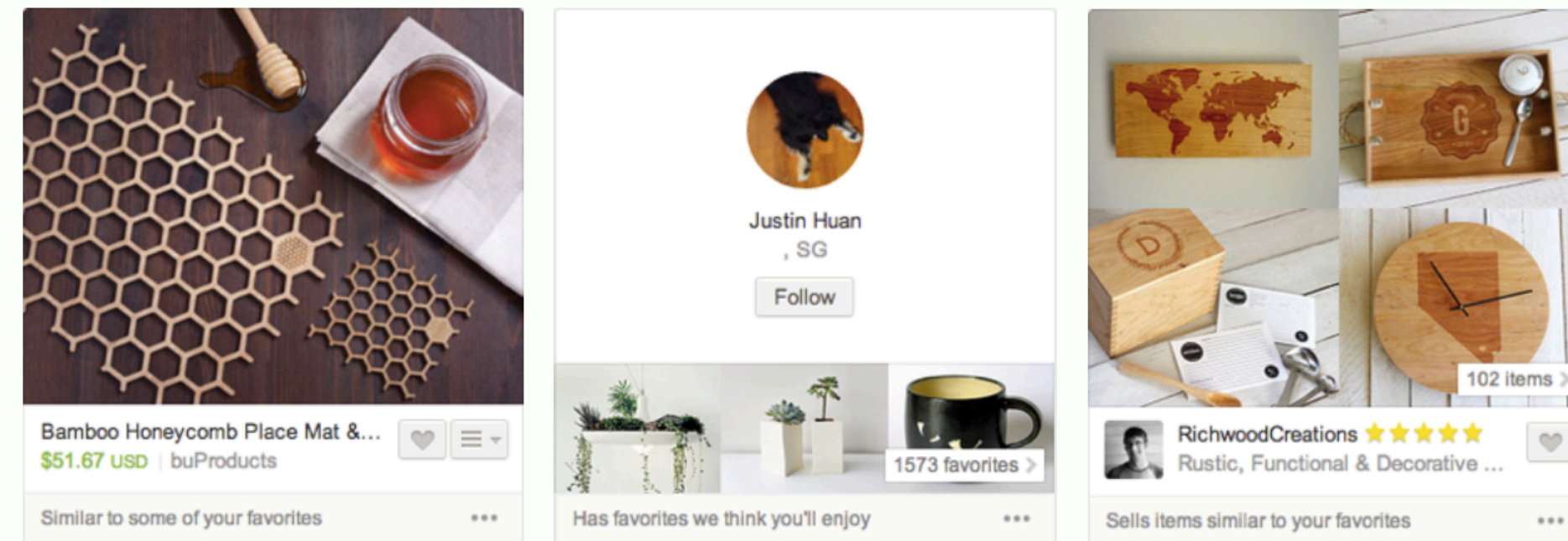
Learn **style profiles** for each user using LDA



1 Define what each style looks like



2 Use style profiles to generate personalized content



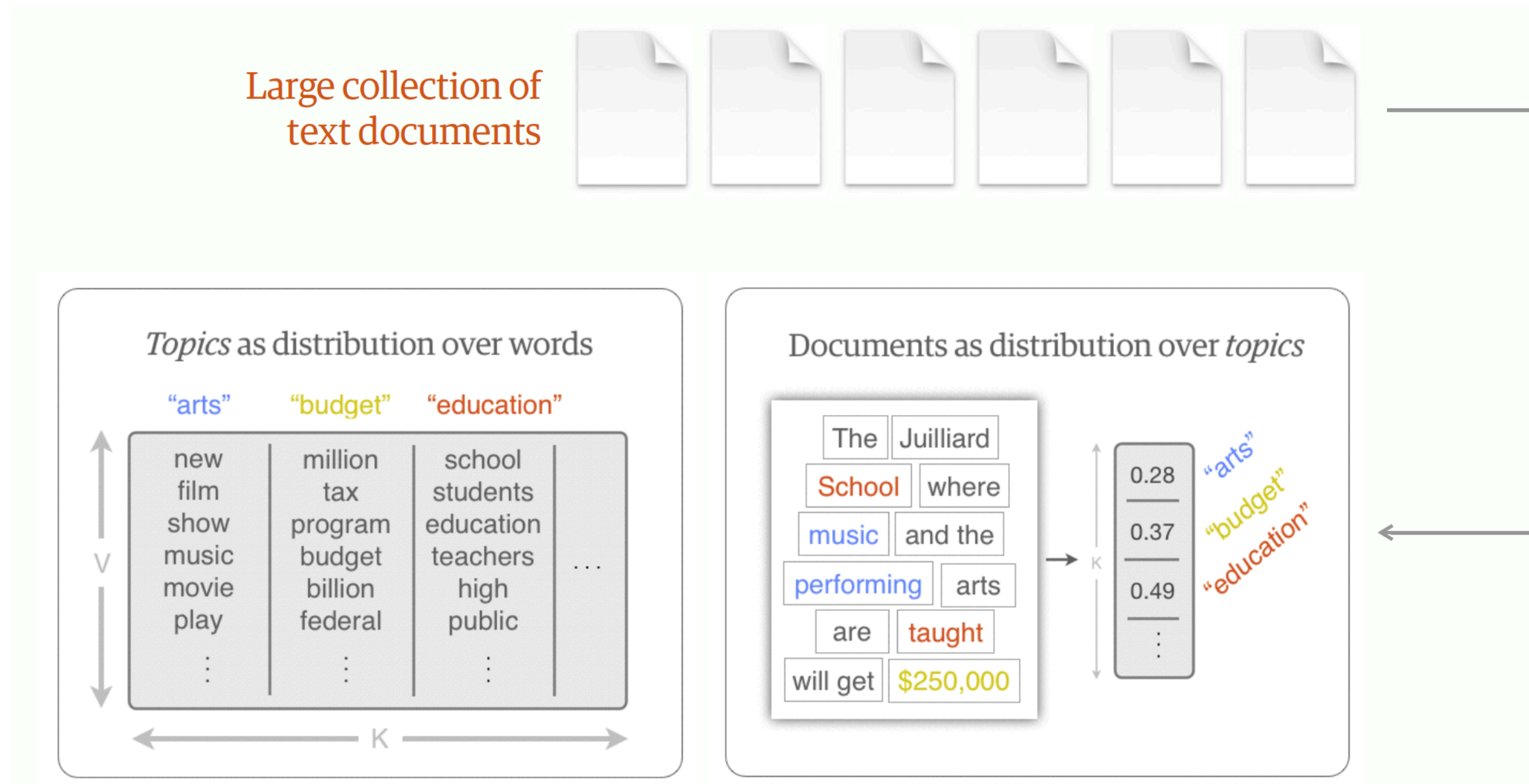
ITEM RECS

USER REC

SHOP REC

Etsy – Personalization and Recommendation

Latent Dirichlet Allocation



Etsy – Personalization and Recommendation

Latent Dirichlet Allocation

Article
about Juilliard

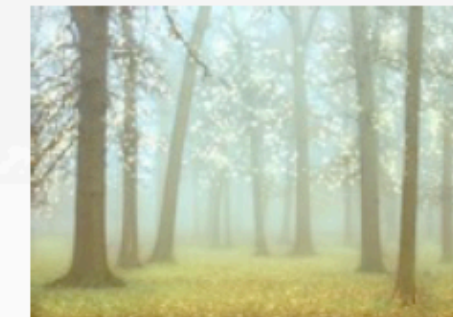
The
Juilliard School
where music and
the performing
arts are taught
will get \$250,000



Diane's
favorited items



#101975185



#63876344



#100109163

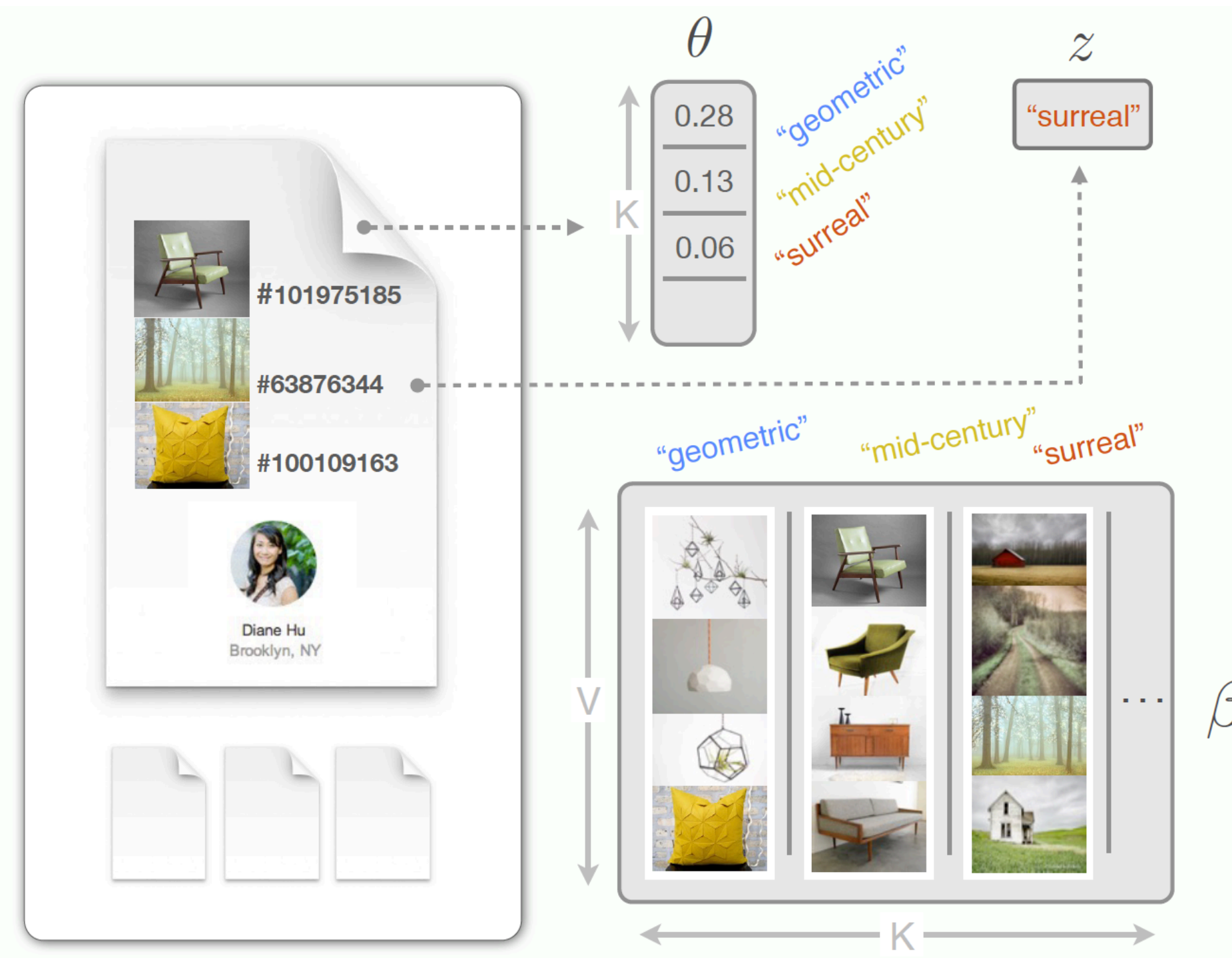
Etsy – Personalization and Recommendation

Latent Dirichlet Allocation

Assume: Each user's favorited items are generated by this process:

For each user u ,

1. Draw a style profile:
 $\theta \sim \text{Dirichlet}(\alpha)$
2. For each item, x_n that user u has favorited,
 - (a) Draw a style:
 $z_n \sim \text{Multinomial}(\theta)$
 - (b) Draw an item:
 $x_n \sim \text{Multinomial}(\beta_{z_n})$



Etsy – Personalization and Recommendation

Latent Dirichlet Allocation

1) Inference:

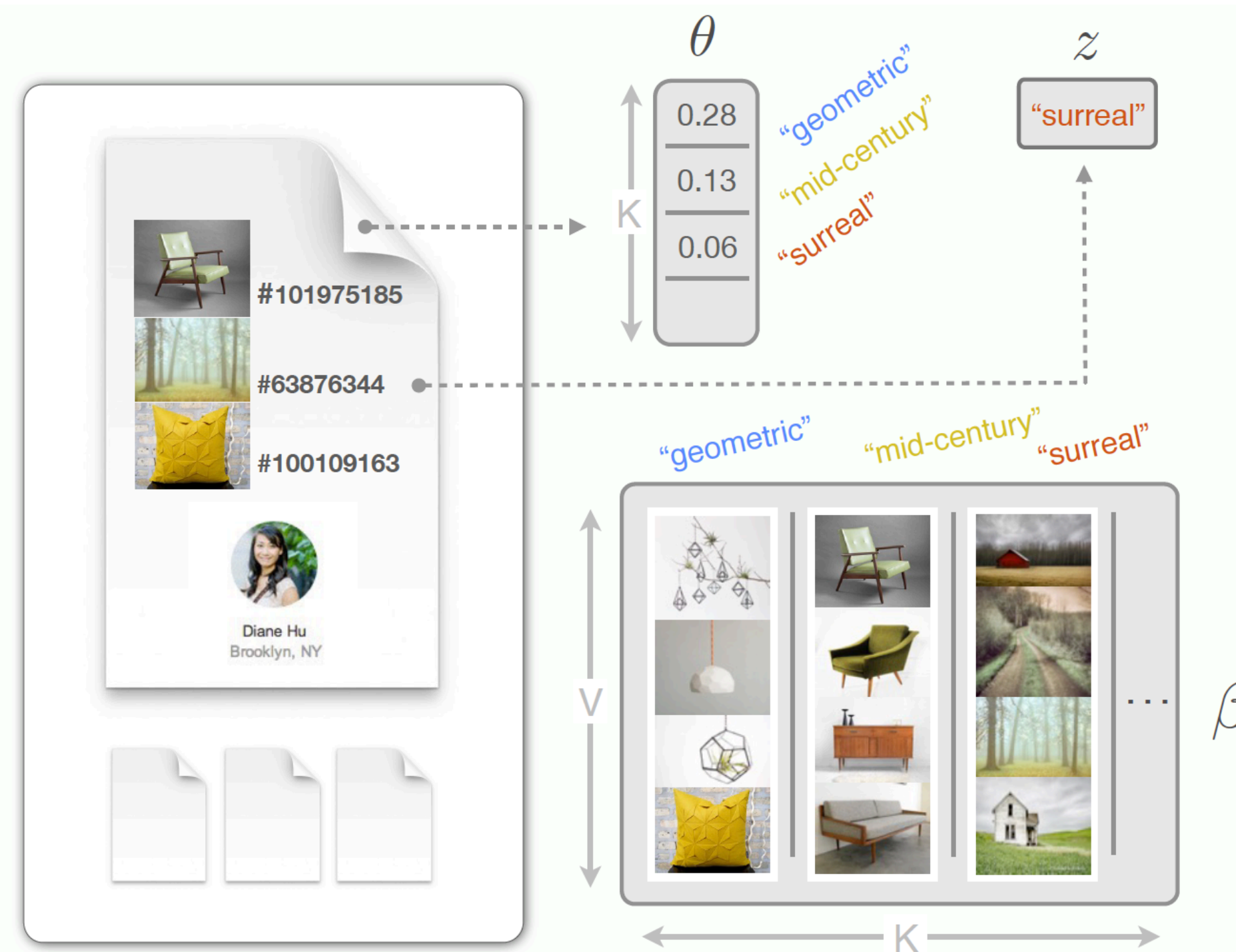
Determine posterior distribution:

$$p(\theta, \mathbf{z} | \mathbf{w}, \alpha, \beta) = \frac{p(\theta, \mathbf{z}, \mathbf{w} | \alpha, \beta)}{p(\mathbf{w} | \alpha, \beta)}$$

2) Estimation:

Choose α and β that maximize the log-likelihood of all user's data:

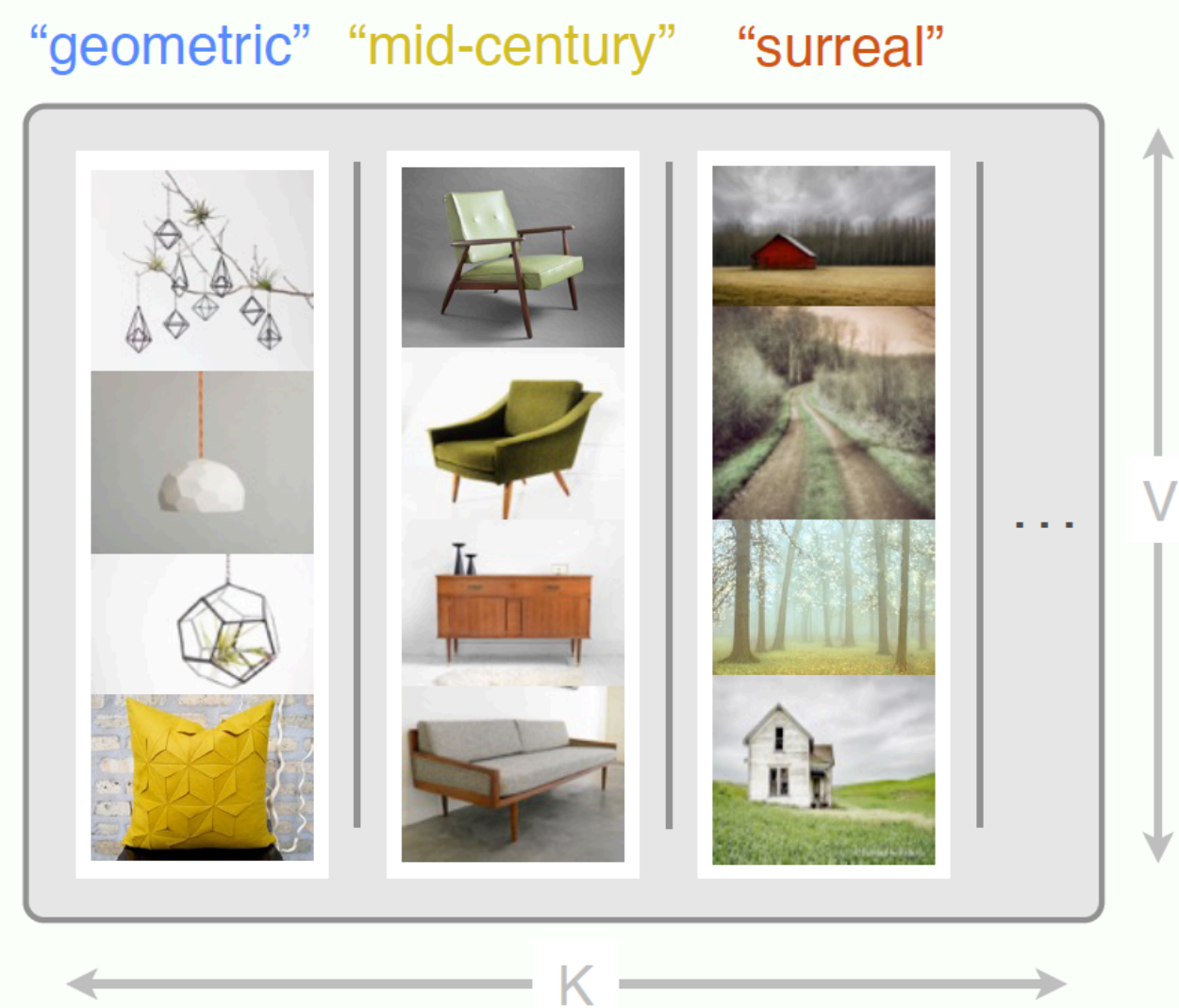
$$\mathcal{L}(\alpha, \beta) = \sum_{m=1}^M \log p(\mathbf{w} | \alpha, \beta)$$



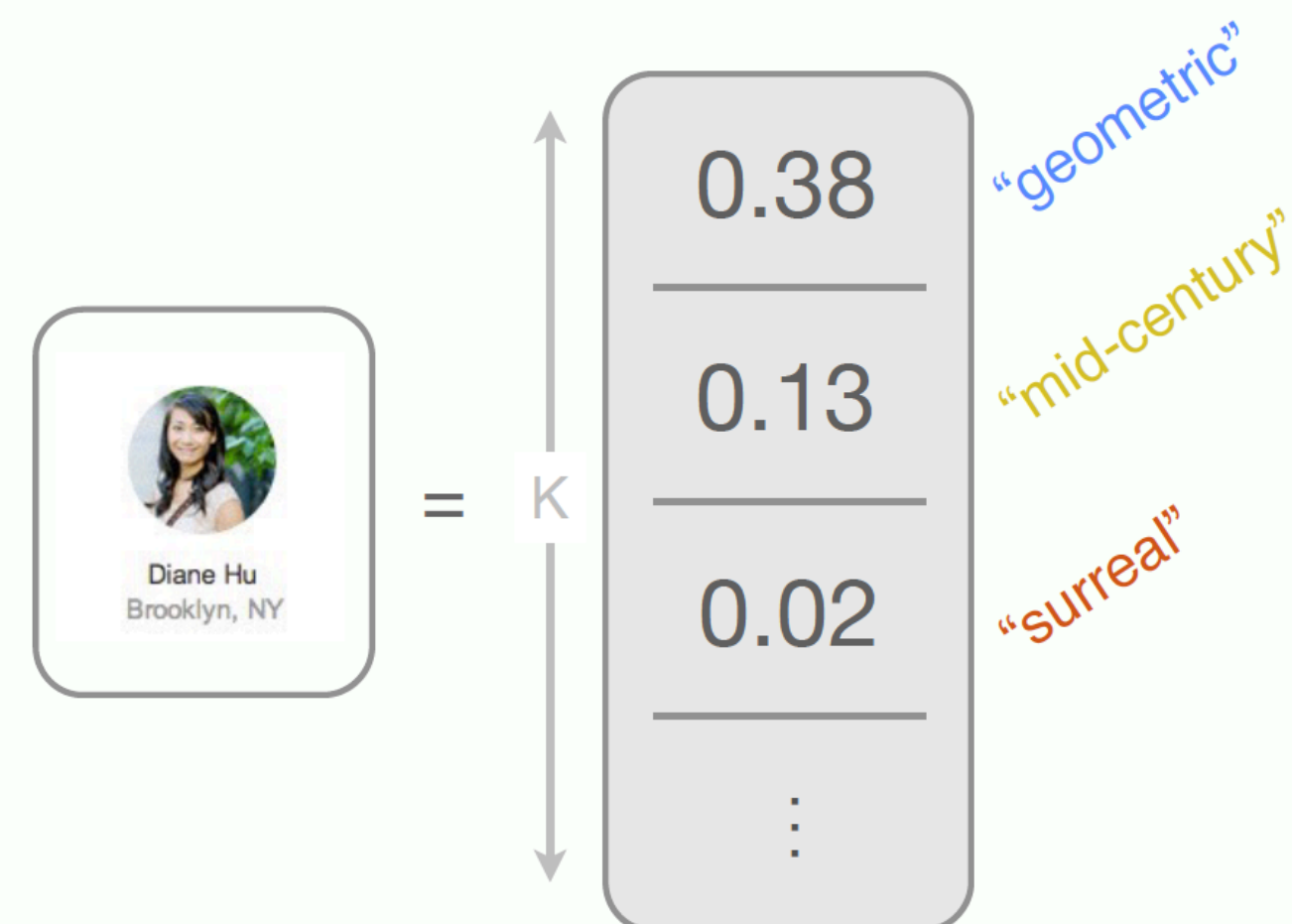
Etsy – Personalization and Recommendation

Latent Dirichlet Allocation

Discover popular styles on Etsy as a distribution over items

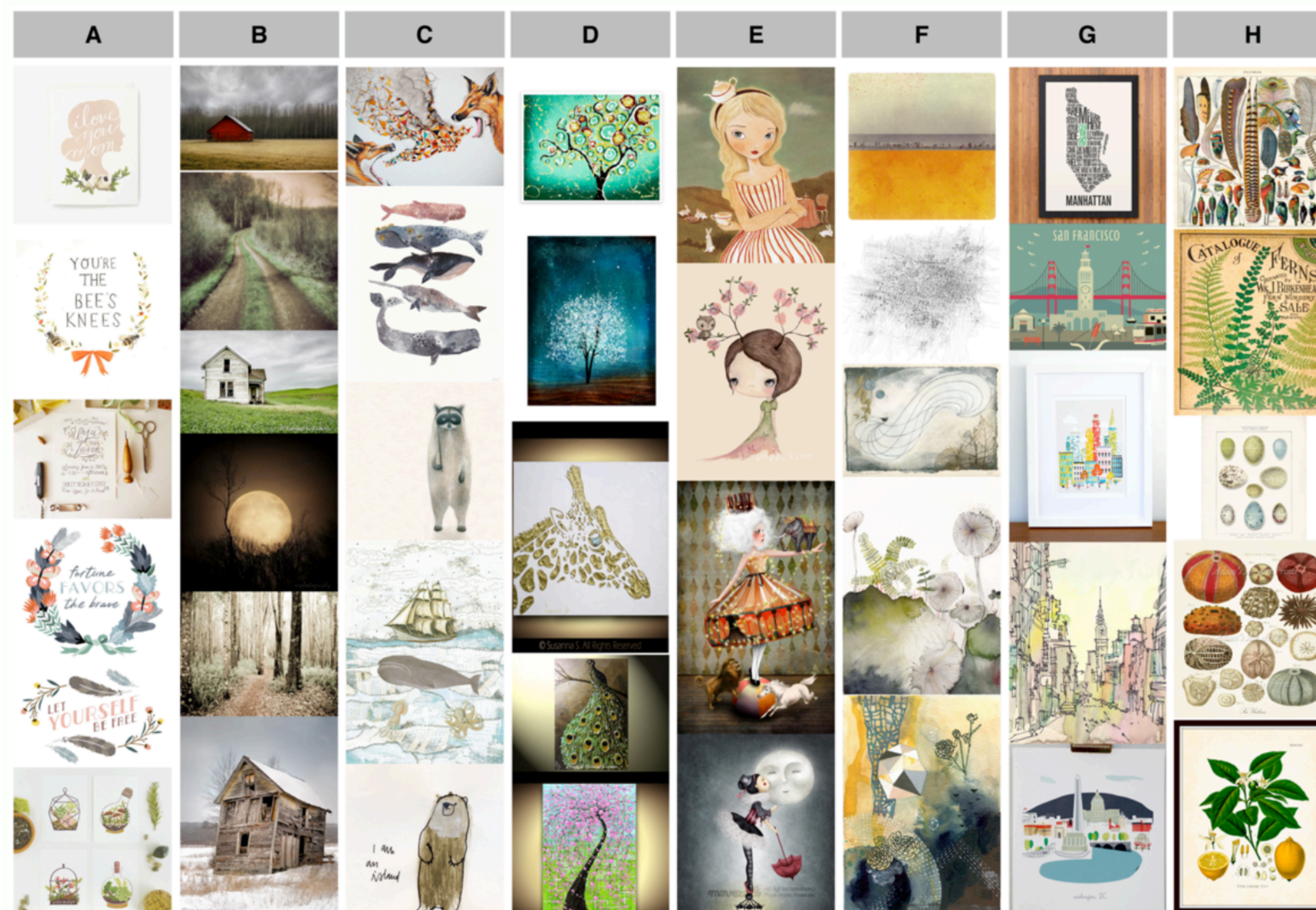


Represent each user as a distribution over popular styles, i.e. “style profile”



Etsy – Personalization and Recommendation

Learned Styles from LDA



Example of learned styles that contain art prints:

A = Botanical

B = Surreal landscapes

C = Whimsical

D = Acrylic/Abstract

E = French Dolls

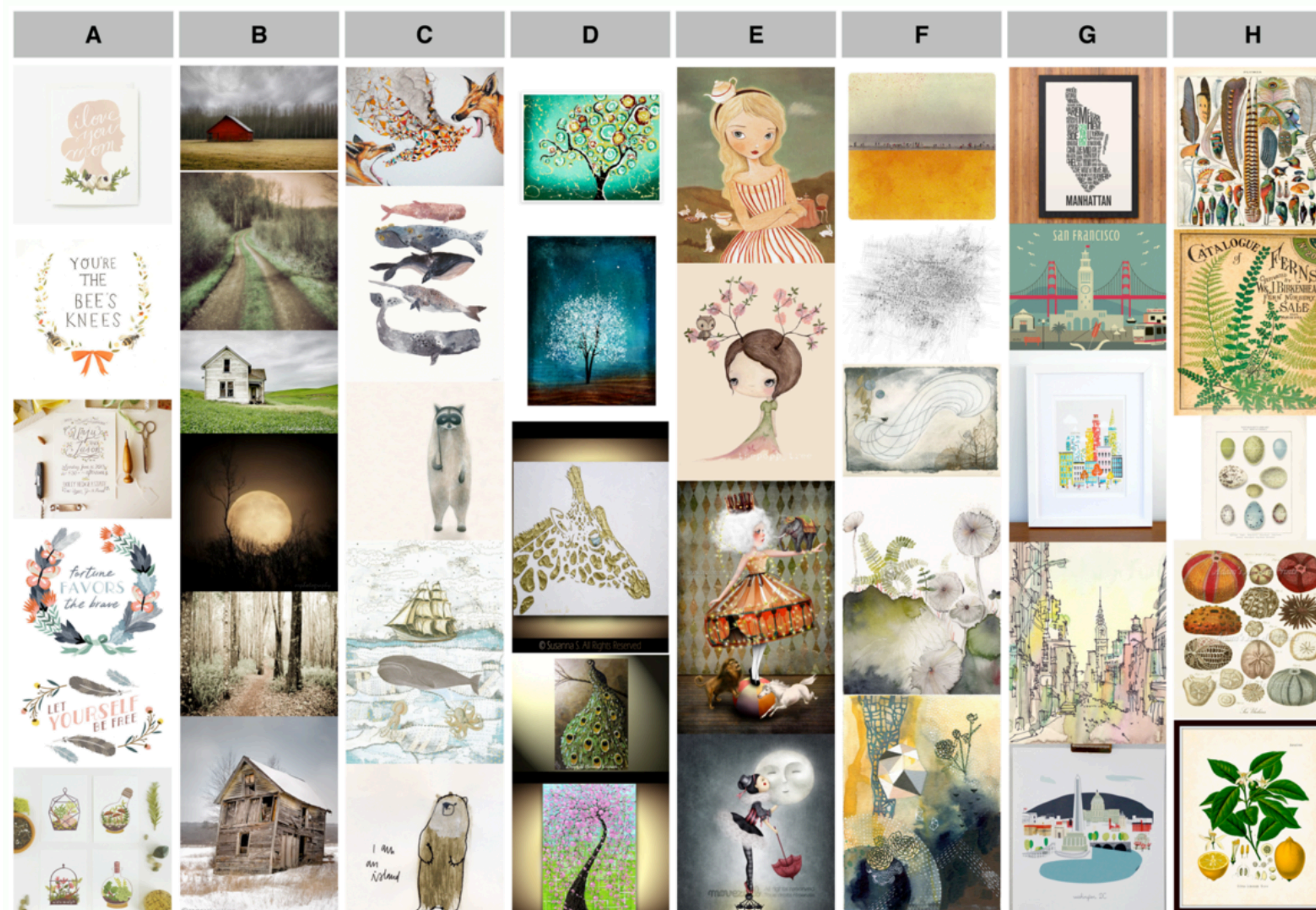
F = Whimsical/Abstract

G = Cities

H = Vintage

Etsy – Personalization and Recommendation

Learned Styles from LDA



Example of learned styles that contain art prints:

A = Botanical

B = Surreal landscapes

C = Whimsical

D = Acrylic/Abstract

E = French Dolls

F = Whimsical/Abstract

G = Cities

H = Vintage

Etsy – Personalization and Recommendation

Given that each user has an style profile:

Recommend N listings from most highly weighted styles

MY FAVORITES



STYLE #428



STYLE #54



STYLE #655



STYLE #87



Etsy – Personalization and Recommendation

Given that each user has an style profile:

USER RECOMMENDATION

- Use LSH on MapReduce to do fast, approximate KNN
- Get top N users with most similar interest profiles
- *Recommend these top N users*

LISTING RECOMMENDATION

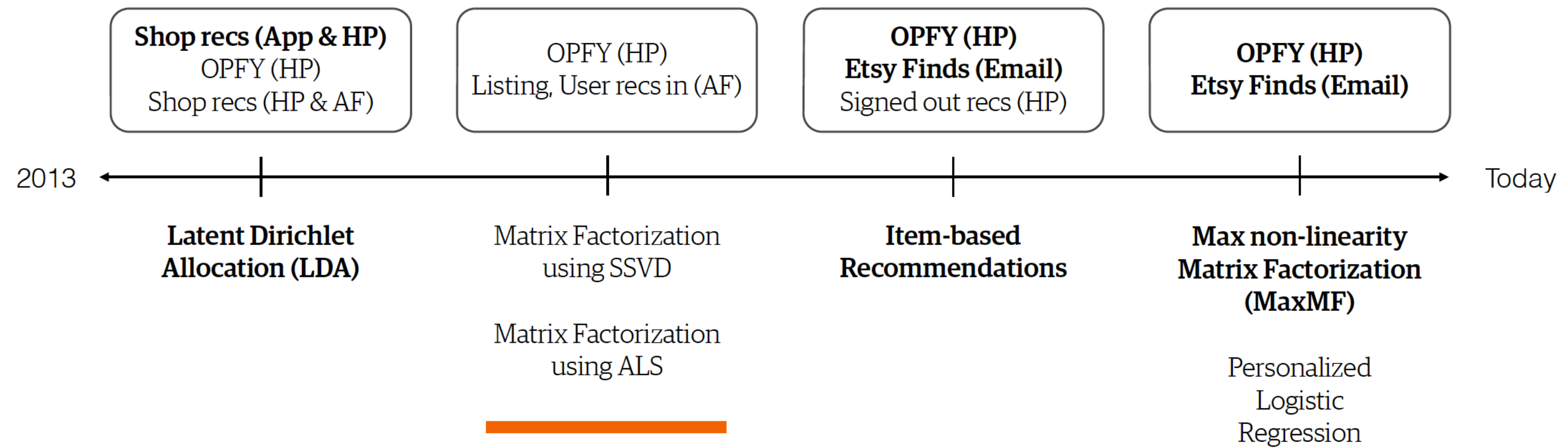
- Multiply user style profile by topic-item matrix
- Return list of ranked items for each user
- *Recommend top N listings*

SHOP RECOMMENDATION


- Rebuild topic model replacing items with corresponding shop
- Get list of ranked shops, as in item recommendations
- *Recommend top N shops*

Etsy – Personalization and Recommendation

A Brief History



Etsy – Computational Advertising

Etsy [Sell on Etsy](#) [Register](#) 

[Clothing & Accessories](#) [Jewelry](#) [Craft Supplies & Tools](#) [Weddings](#) [Entertainment](#) [Home & Living](#) [Kids & Baby](#) [Vintage](#)

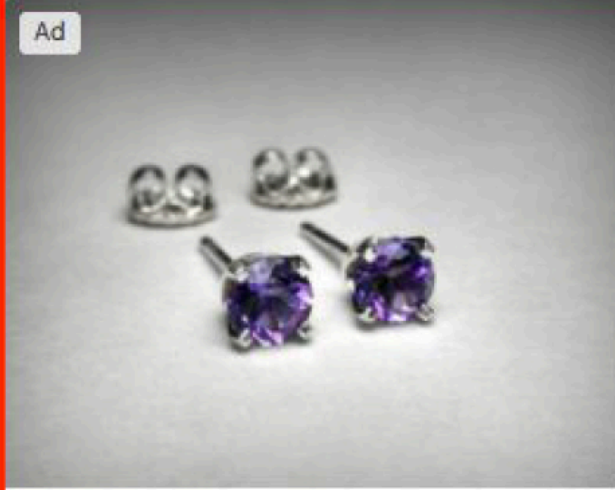
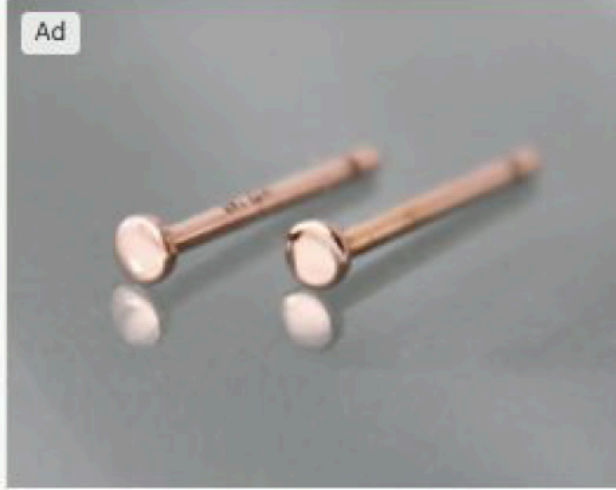
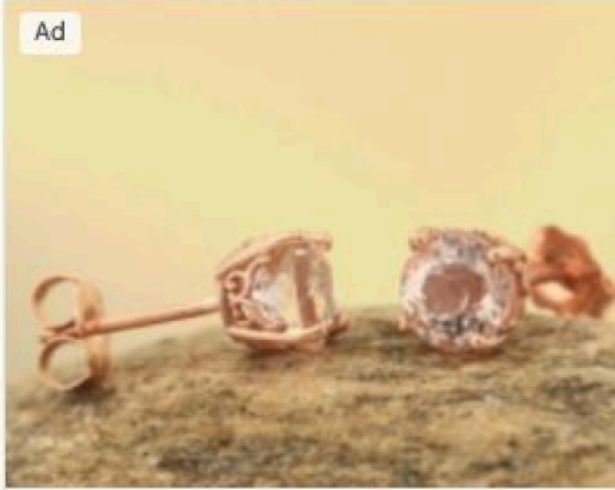
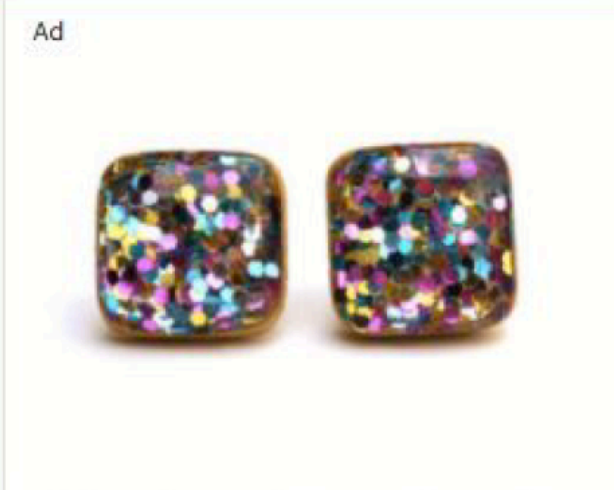



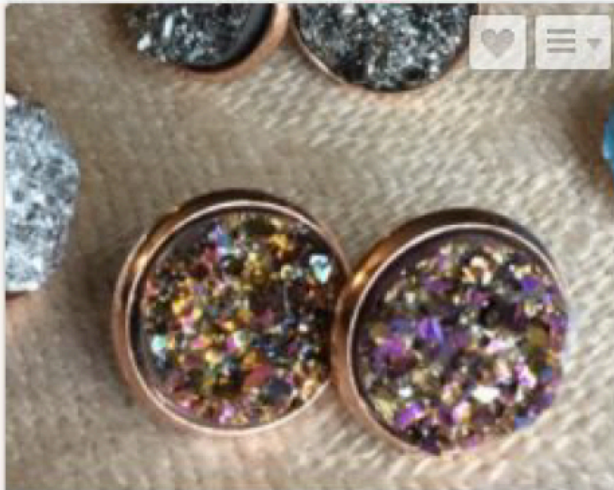
Show results for: [All categories](#) > "stud earrings" (363,150 Results) Sort by: Relevancy ▾

All categories

- Jewelry
- Craft Supplies & Tools
- Weddings
- Accessories
- Home & Living
- Paper & Party Supplies
- Bath & Beauty
- Art & Collectibles
- Toys & Games
- Bags & Purses
- Clothing
- Pet Supplies
- Electronics & Accessories
- Shoes
- Books, Movies & Music

Refine your search

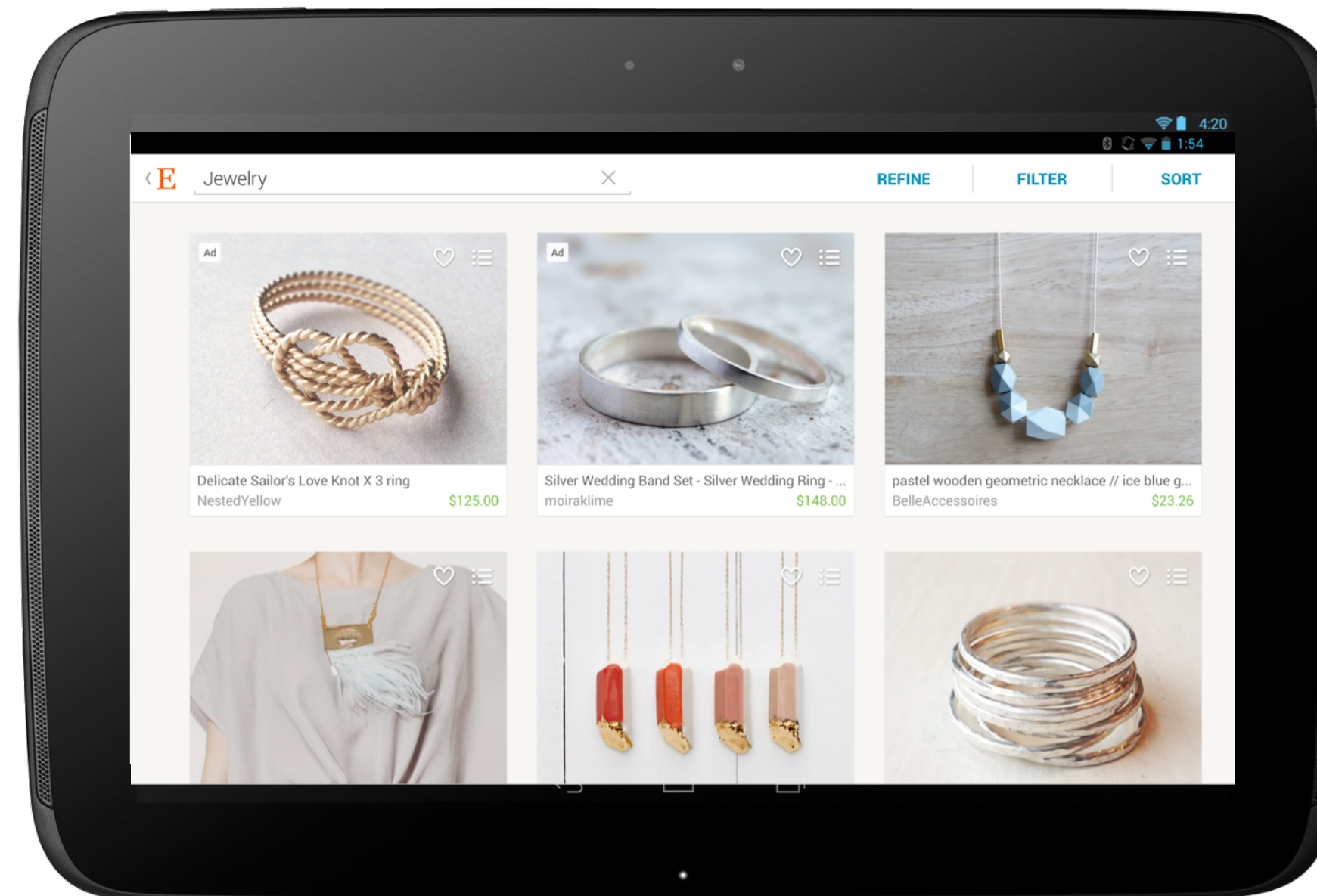
Shop location

| | | | |
|---|---|--|--|
|  <p>Ad</p> <p>14K Amethyst Earrings Genuine AAA Amet... PristinityJewelry \$99.00</p> |  <p>Ad</p> <p>SINGLE 2mm 14k SOLID Rose Gold Stud E... tinysparklestudio \$37.50</p> |  <p>Ad</p> <p>AAA Morganite Earring, Fancy Scroll Earrin... GNGJewel \$185.00</p> |  <p>Ad</p> <p>Rainbow glitter studs mom wife wood stu... starlightwoods \$27.75</p> |
|  <p>Small Earring Set of Three Mix and Match...</p> |  <p>Mint Succulent Earrings. Gift. Polymer cla...</p> |  <p>Hook Stud Earrings, Sterling Silver, Gold P...</p> |  <p>Rose gold Druzy earrings, Faux Druzy stud...</p> |

Etsy – Computational Advertising

Large-scale Ads CTR Prediction System

- Kamelia Aryafar, Devin Guillory and Liangjie Hong. **An Ensemble-based Approach to Click-Through Rate Prediction for Promoted Listings at Etsy**. To appear in the proceedings of **AdKDD & TargetAd 2017** workshop, held in conjunction with the 23rd SIGKDD Conference on Knowledge Discovery and Data Mining (**KDD 2017**), Halifax, Nova Scotia, August, 2017.



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Large-scale Ads CTR Prediction System

- Data Aggregation
- Feature Engineering
- Learning Algorithm
- Ensemble Learning

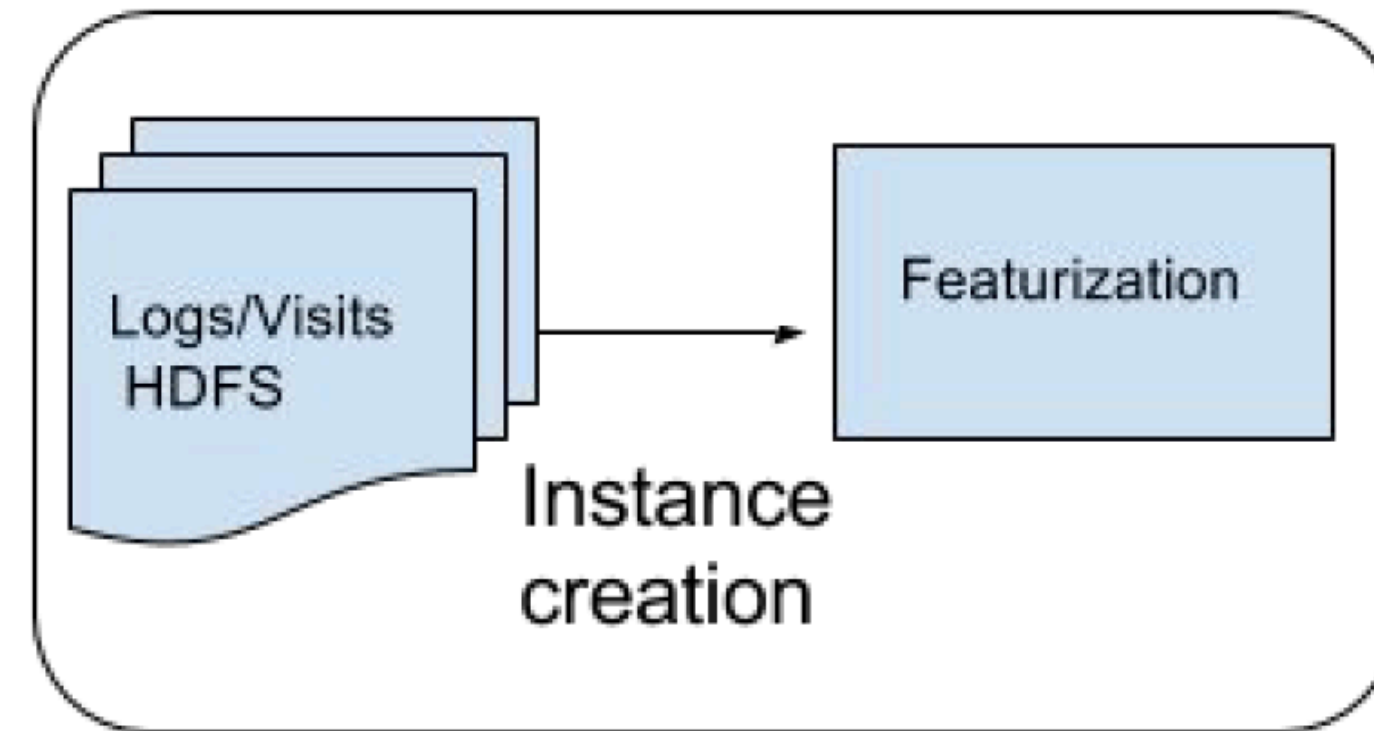


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Training Data: 14 days Organic Search Data or 30 Days Promoted Listings Data

Balanced Sampling

Evaluation Data: Previous Day Promoted Listings Data



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Feature Engineering

- Simple unigram text features
- Seller, ads, user historical information
- Ads information like price, inventory amount
- SVD-based features
- Utilizing feature hashing

The diagram illustrates the SVD decomposition of matrix A_k . It shows four matrices arranged horizontally, separated by an equals sign. The first matrix is A_k , with dimensions $m \times n$ indicated below it. The second matrix is U , with dimensions $m \times r$ indicated below it; its first k columns are shaded black. The third matrix is Σ , with dimensions $r \times r$ indicated below it; its top-left $k \times k$ submatrix is shaded black and contains a diagonal line of dots. The fourth matrix is V^T , with dimensions $r \times n$ indicated below it; its first k rows are shaded black. The labels k , k , and k are placed above the second, third, and fourth matrices respectively. Below the matrices, the equation $A_k = U_k \Sigma_k V_k^T$ is written.

$$A_k = U_k \Sigma_k V_k^T$$

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Logistic Regression with FTRL-Proximal Background

Features: vector $\mathbf{x}_t \in \mathbb{R}^d$;
model parameters \mathbf{w}_t

Prediction = $\sigma(\mathbf{w}_t \cdot \mathbf{x}_t)$ where $\sigma(a) = 1/(1 + \exp(-a))$

we observe the label $y_t \in \{0, 1\}$

$$\ell_t(\mathbf{w}_t) = -y_t \log p_t - (1 - y_t) \log(1 - p_t),$$

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Logistic Regression with FTRL-Proximal

- FTRL-Proximal is equivalent to Online (Stochastic) Gradient Descent when no regularization is used
- The key is re-expressing the gradient descent as simply as possible:

Given a sequence of gradients $\mathbf{g}_t \in \mathbb{R}^d$, OGD performs the update

$$\mathbf{w}_{t+1} = \mathbf{w}_t - \eta_t \mathbf{g}_t,$$

where η_t is a non-increasing learning-rate schedule, e.g., $\eta_t = \frac{1}{\sqrt{t}}$. The FTRL-Proximal algorithm instead uses the update

$$\mathbf{w}_{t+1} = \arg \min_{\mathbf{w}} \left(\mathbf{g}_{1:t} \cdot \mathbf{w} + \frac{1}{2} \sum_{s=1}^t \sigma_s \|\mathbf{w} - \mathbf{w}_s\|_2^2 + \lambda_1 \|\mathbf{w}\|_1 \right),$$

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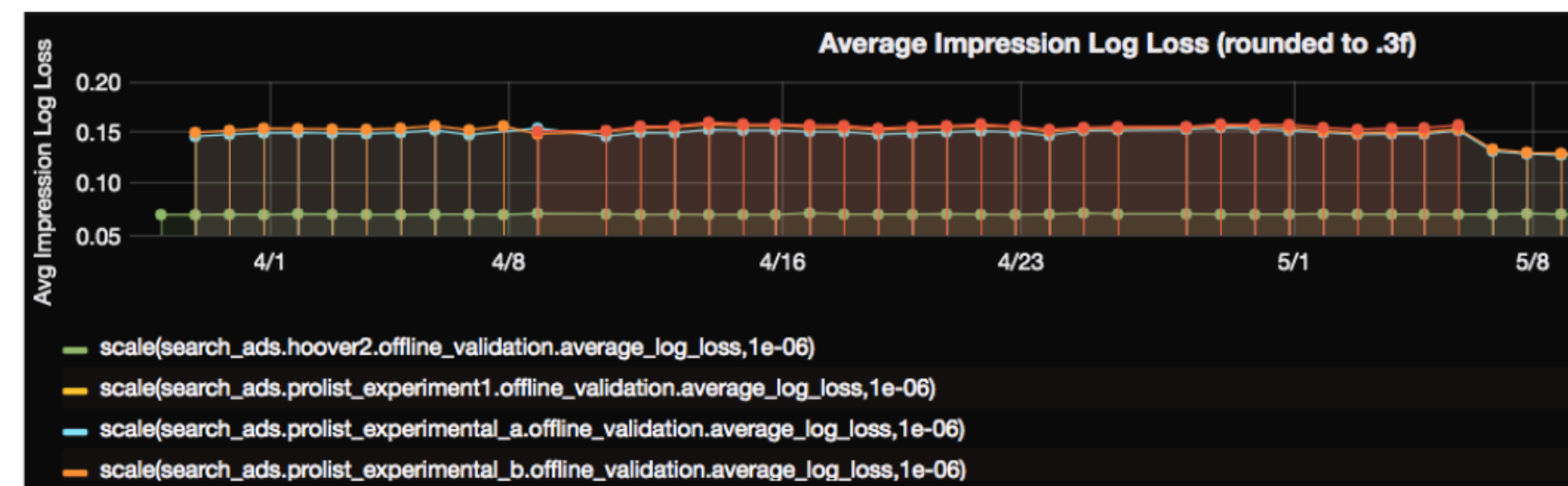
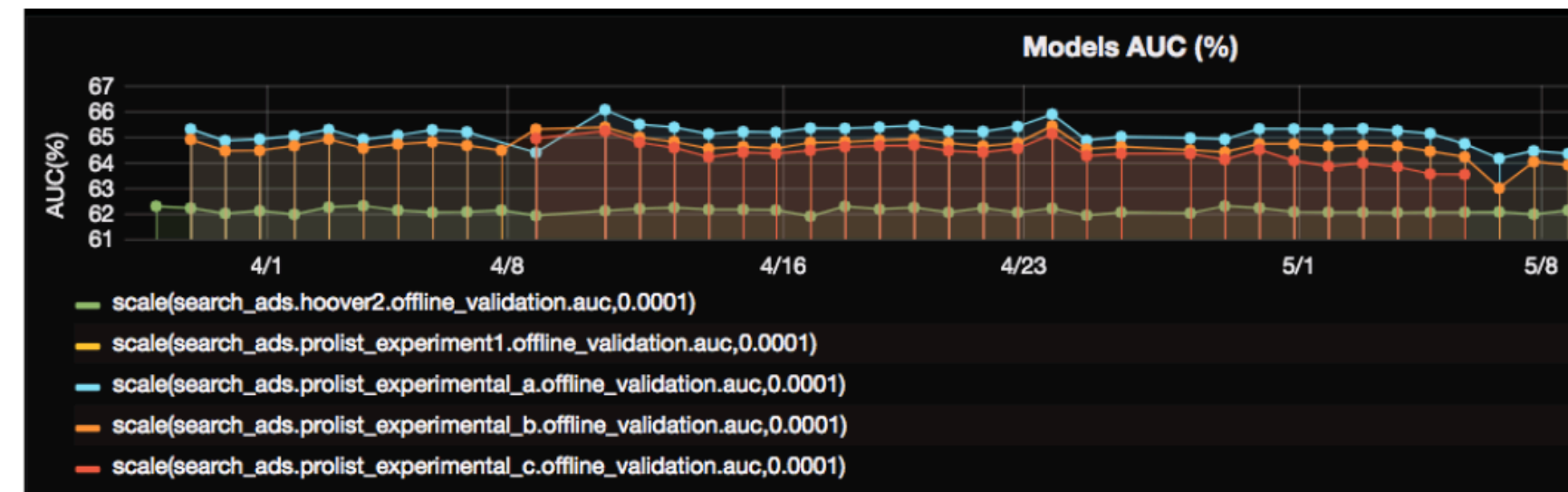
Ensemble Learning

- Cold Start
- Warm Start
- Mix



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| | Historical | | | Content-based | | | Ensemble | | |
|--------------------------------------|------------|--------|--------|---------------|--------|--------|----------|--------|--------|
| | mixed | cold | warm | mixed | cold | warm | mixed | cold | warm |
| AUC (%) | +1.56 | +1.89 | +1.55 | -1.57 | +6.39 | -1.74 | +1.87 | +8.09 | +1.79 |
| Log Loss ($\times 10^3$) | -0.016 | -0.048 | -0.018 | +0.311 | -0.194 | +0.335 | -0.200 | -0.330 | -0.193 |
| Normalized Entropy ($\times 10^3$) | -0.29 | -1.23 | -0.31 | +5.67 | -5.00 | +6.01 | -3.64 | -8.51 | -3.46 |



AI in E-commerce

AI in E-commerce at Etsy

- Multi-modal Deep-learning based Search Solution (KDD 2016)
- Probabilistic Graphical Model based Personalization Recommendation (KDD 2014)
- Ensemble Learning based CTR Prediction Solution (AdKDD 2017/KDD 2017)



