Building Multimodal Search and Recommender Systems at Scale

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About Me

THE HOME DEPOT

UNIVERSITY OF GEORGIA

Southern Data Science Conference

Georgia State University

KENNESAW STATE UNIVERSITY

ATLytiCS
Atlanta Analytics for Community Service

CAREER BUILDER™

THE HOME DEPOT

Multimodality in E-commerce

Bath Event

FLOW

Motion Activated Single-Handle Pull-Down Sprayer Kitchen Faucet in Brushed Nickel

Dimensions

Connection size (in.)	3/8 In.	Extended Hose Length (in.)	12
Faucet Height (in.)	15.5	Spout Height (in.)	15.5

Details

Cartridge Valve Type	Cartridge Faucets	Color Family	Nickel
Color/Finish	Brushed Nickel	Commercial / Residential	Residential
Deckplate Included	Deckplate Included	Faucet Hole Fit	1,3
Faucet Hole Spacing (in.)	No Spacing - Single Hole	Faucet Type	Pull Down
Features	Advanced Spray,Pull Out Spray Wand,Secure Docking	Finish Family	Brushed Nickel
Flow rate (gallons per minute)	1.8	Hub Required	No hub connection available
Included Components	All Mounting Hardware,Faucet Adaptor,Fittings,Supply Lines	Material	Nickel
Mount Location	Deck Mount	Number of Faucet Handles	Single Handle
Power Options	Plug-in	Remote Access	No Remote Access
Requires Hub?	No Hub Required	Returnable	90-Day
Sensor Activation	Touchless	Smart Home Protocol	Proprietary Protocol
Spout Reach (in.)	8.5 in	Spout Swivel Type	180 Degree Spout Swivel
Style	Coastal,Transitional	Valve material	Ceramic
Voice Control Hub Required	No Voice Control	Works With	No additional compatibility

Warranty / Certifications

Certifications and Listings	IAPMO Certified,NSF Certified,NSF Listed	Manufacturer Warranty	5 Year

★★★★★ (8705)

Color/Finish: **Chrome**

★★★★★ Feb 21, 2022

Magic Faucet

That's the name given by my grandkids.It was easy to install, a nice clean look, and its motion activated. It's powered by 4 AA batteries. I will highly recommend the Flow Motion Activated Faucet to anyone in the market for a new kitchen faucet. There is also a manuel override to the motion sensor.

by Tata

Helpful

★★★★★ Feb 19, 2022

Love it

This faucet looks sleek and beautiful in our kitchen, and the motion sensor is much more intuitive than I was expecting, which I'm happy about since it's my first motion activated faucet. Very happy! I installed all myself, so that means anyone can!

by Sara

Helpful

★★★★★ Feb 15, 2022

Easy upgrade

Easy install and looks great

by Boomer

Helpful

★★★★★ Feb 5, 2022

excellent product

excellent product, easy installation and looks very nice in the kitchen

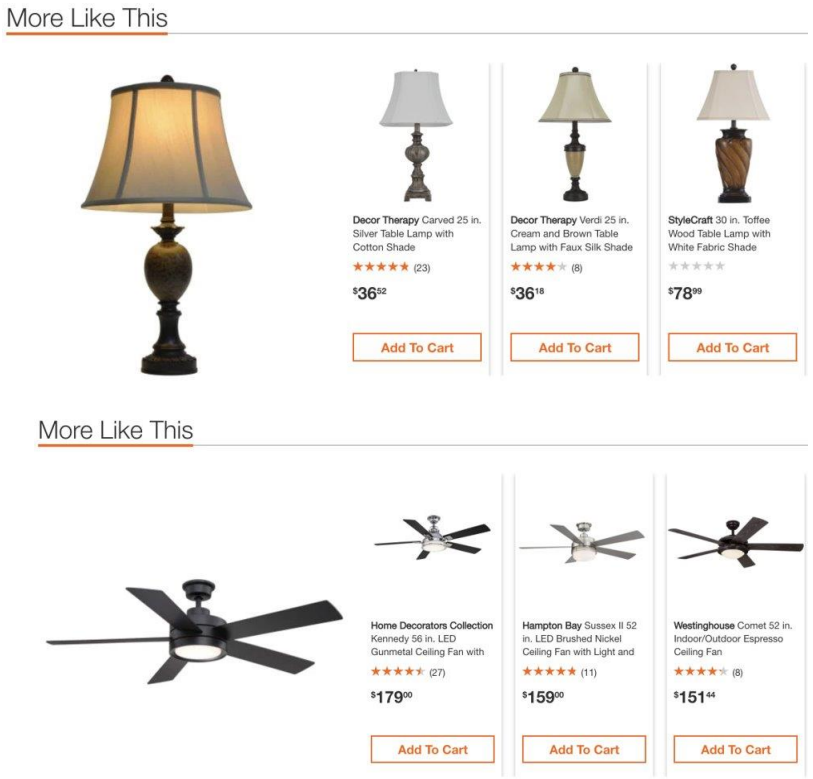
by A1914

Helpful

Visual-based Recommendations

Why

Help customers explore aesthetically similar products. It solves the cold start problem for new products and promotes visual-based exploration of the catalog.



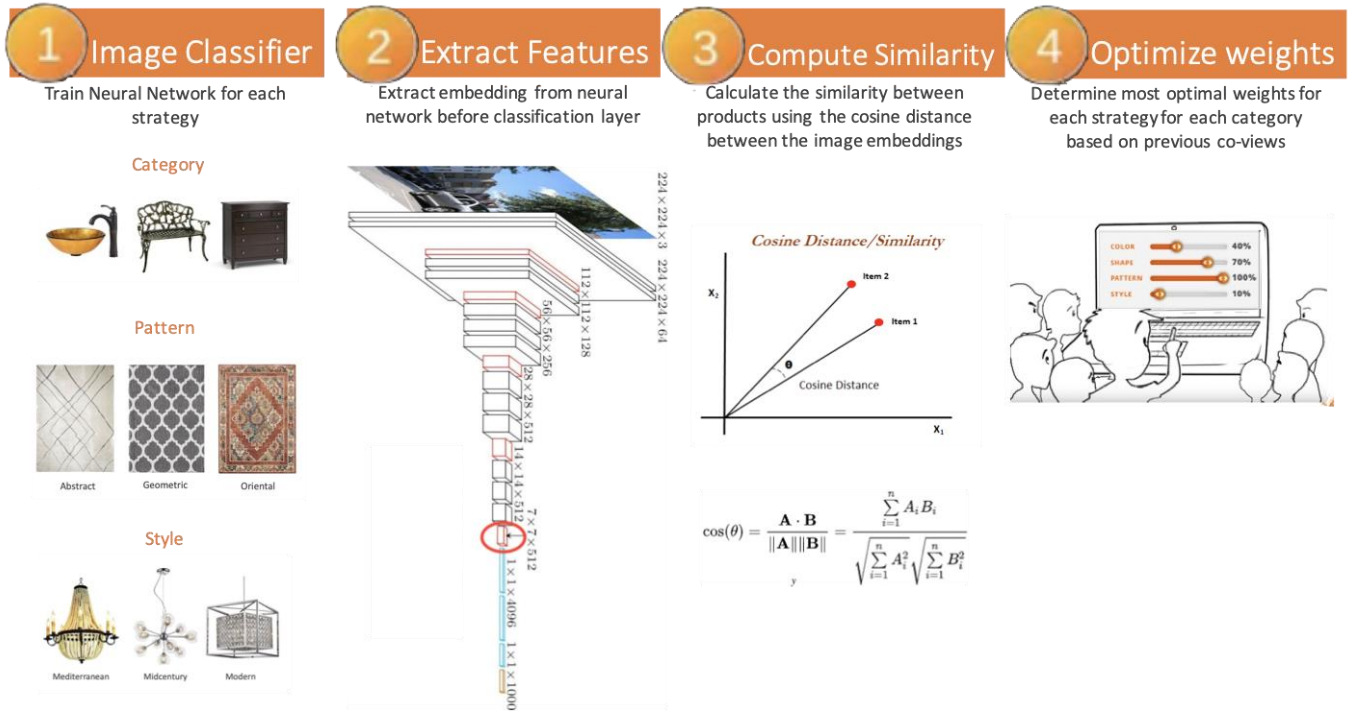
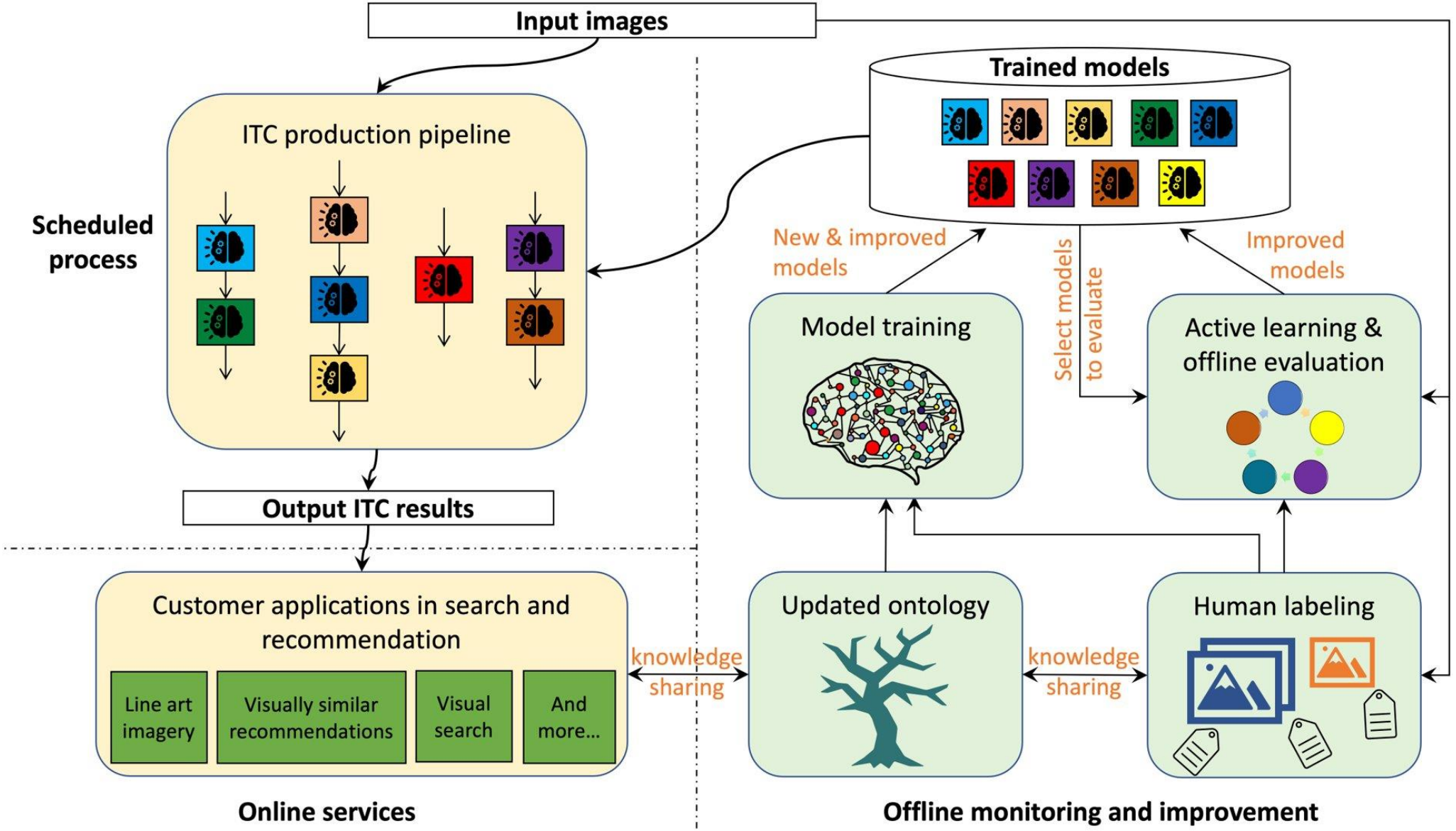
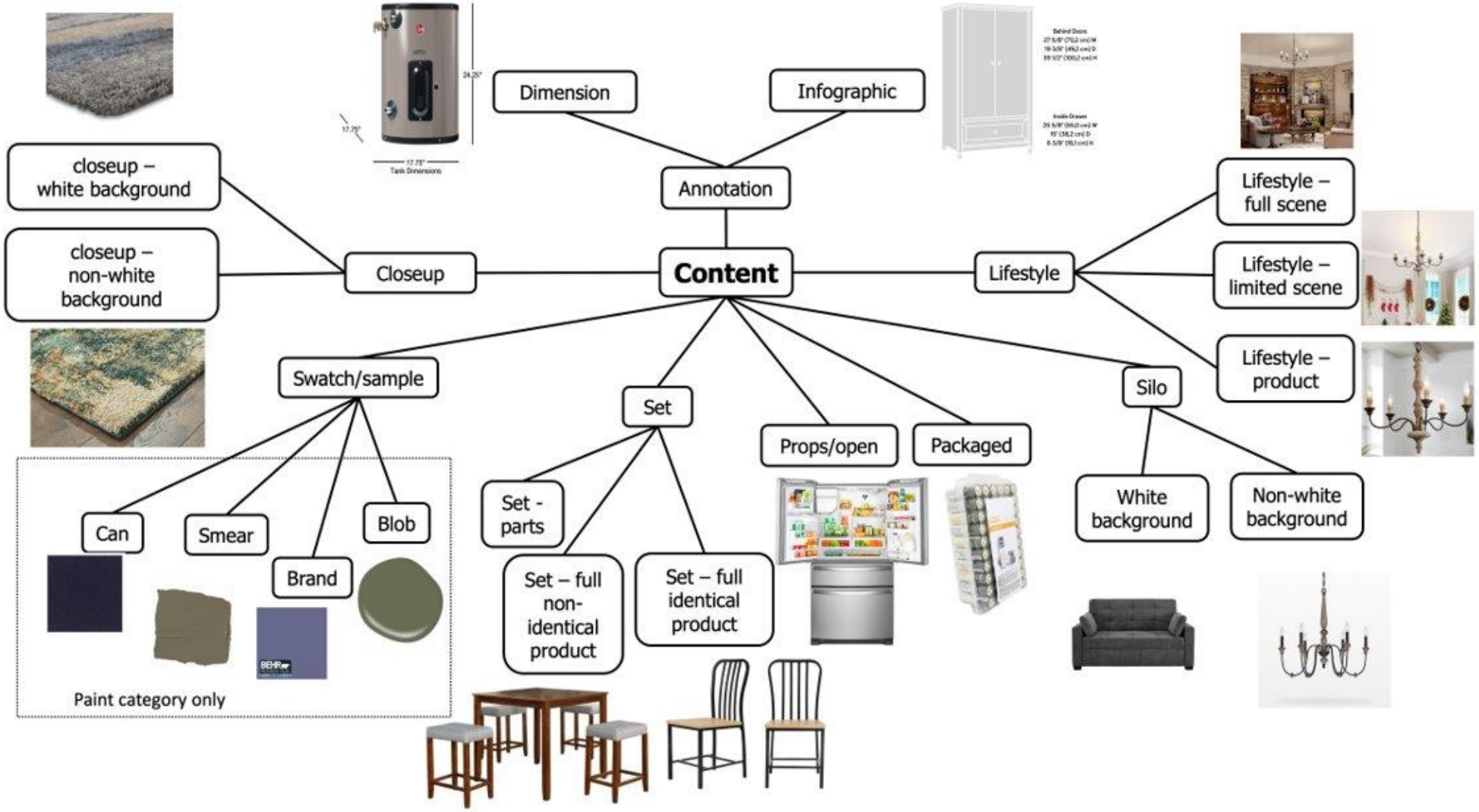


Image Type Classifier

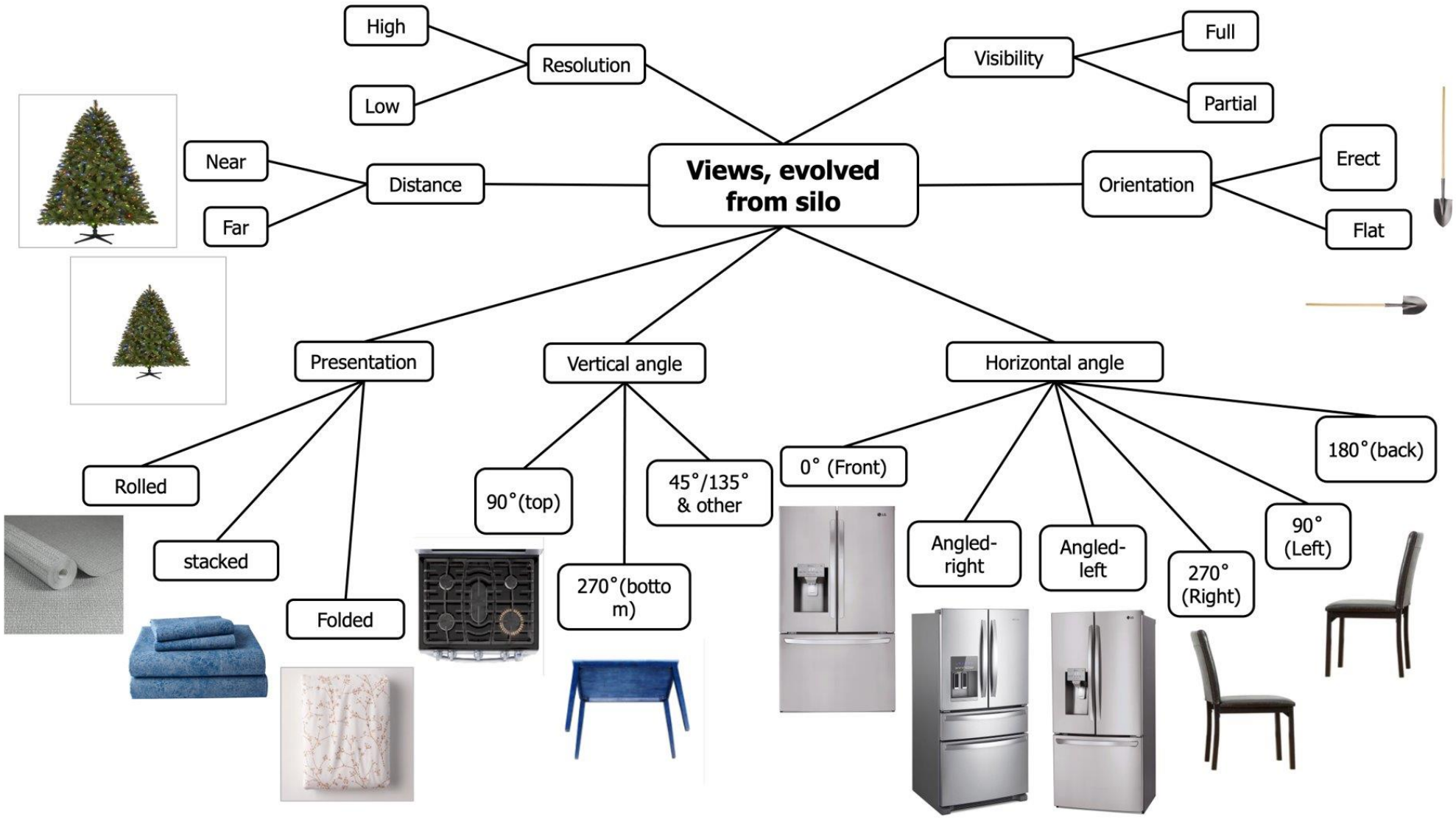


*A Scalable Framework for Product Image Classification applied to Home Improvement E-commerce, KDD'21

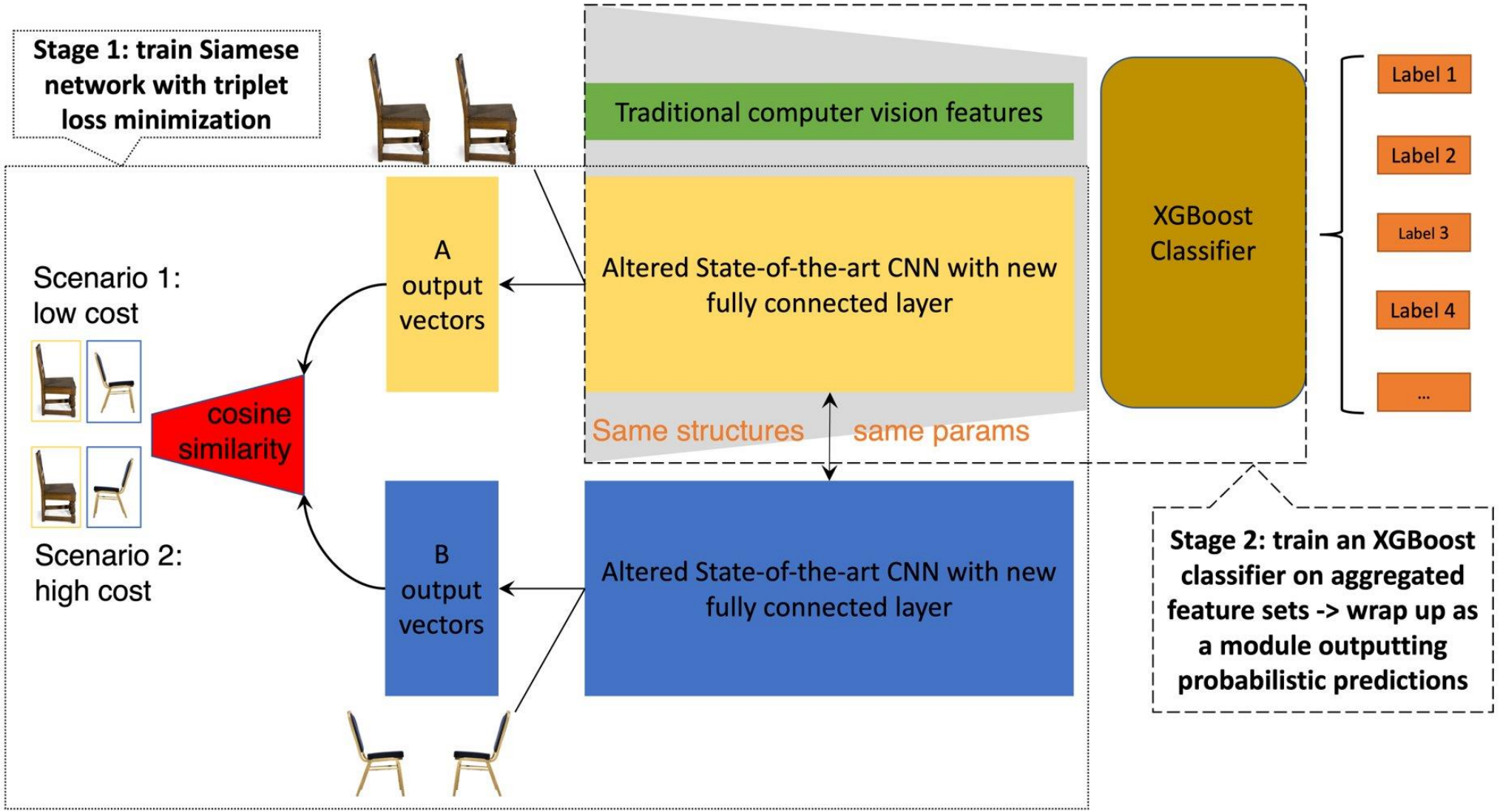
Content Ontology



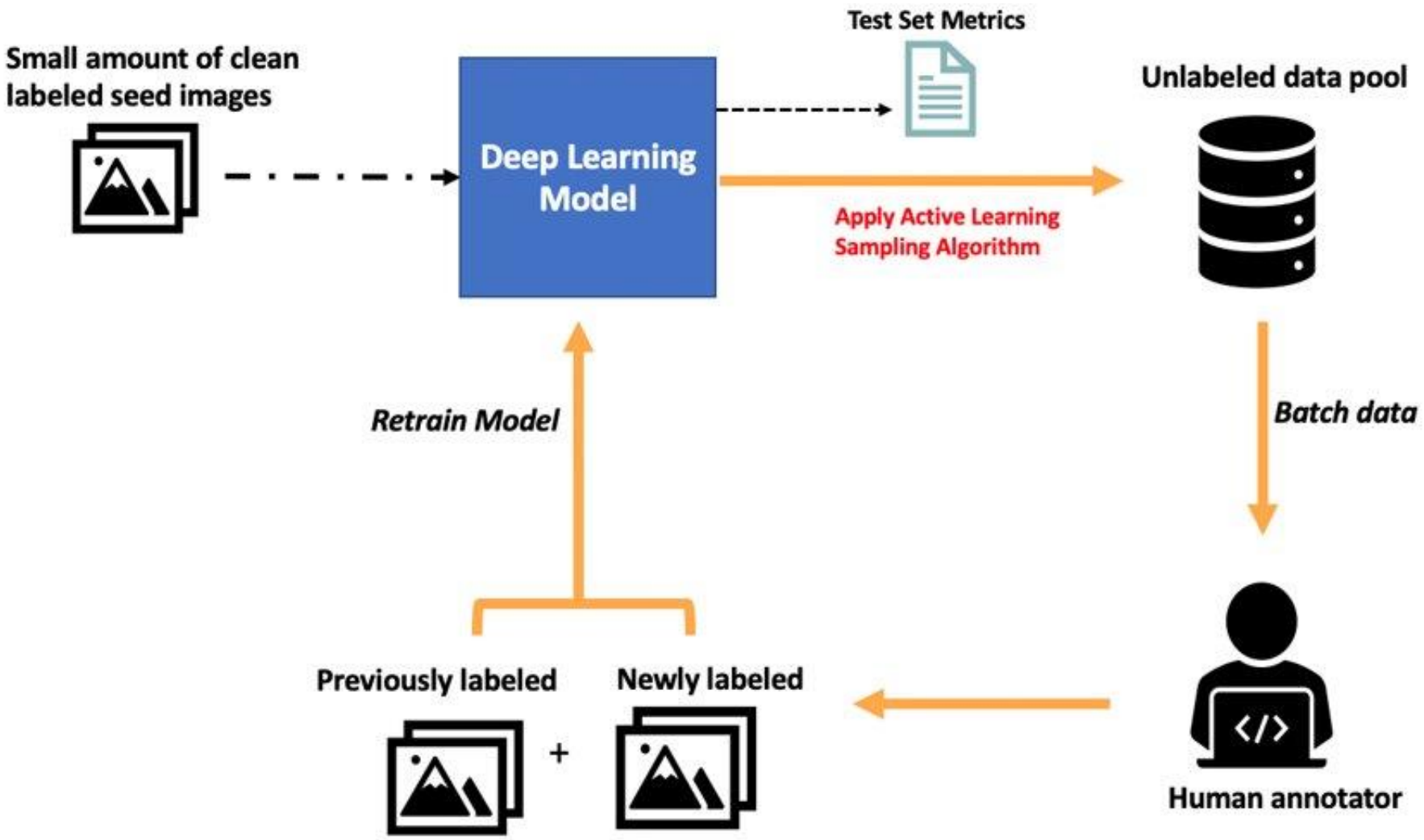
Views


Views, evolved from silo
Resolution
High
Low
Visibility
Full
Partial
Distance
Near
Far
Orientation
Erect
Flat
Presentation
Rolled
stacked
Folded
Vertical angle
90°(top)
270°(botto m)
45°/135° & other
Horizontal angle
0° (Front)
Angled-right
Angled-left
270° (Right)
90° (Left)
180°(back)

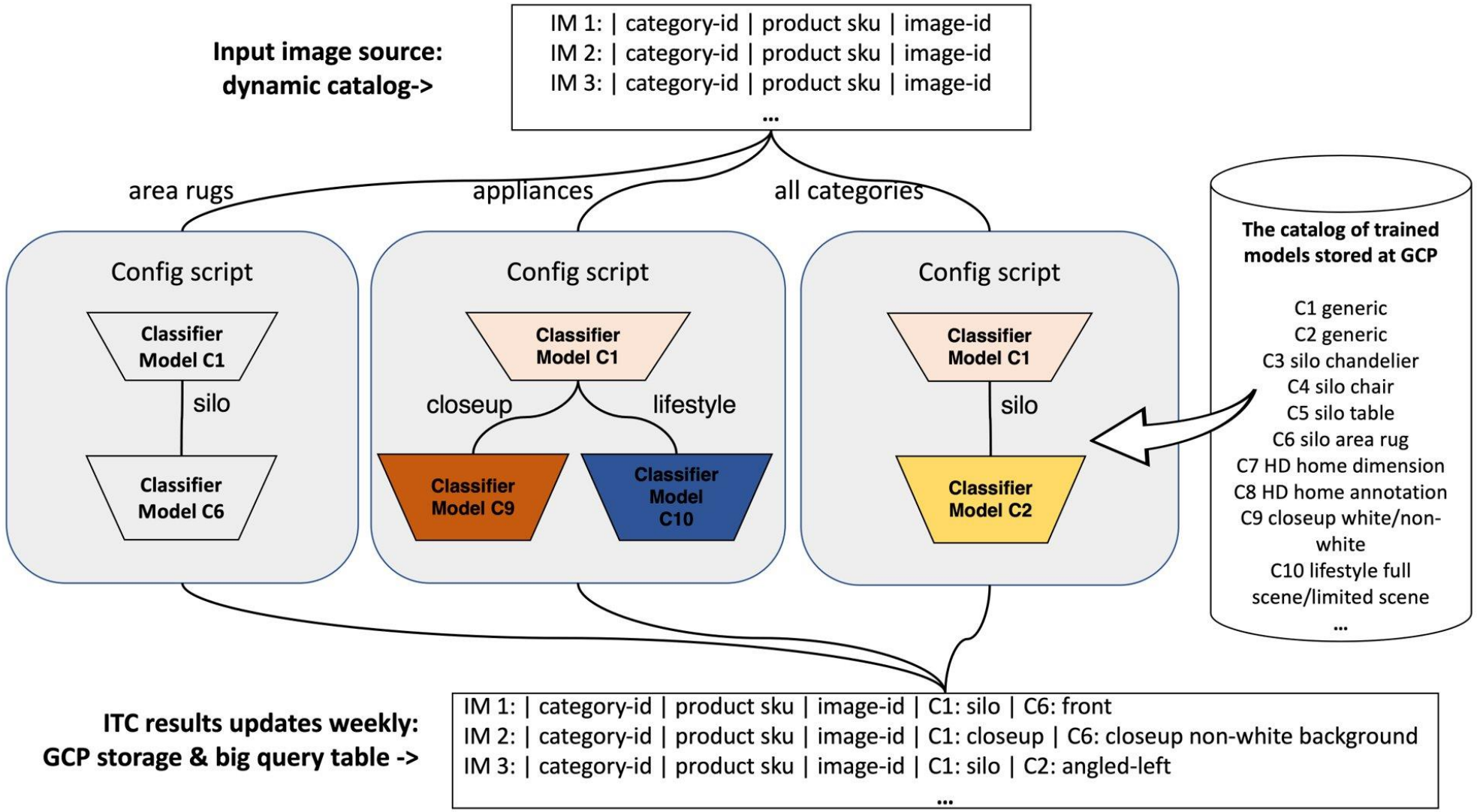
Methodology



Active Learning

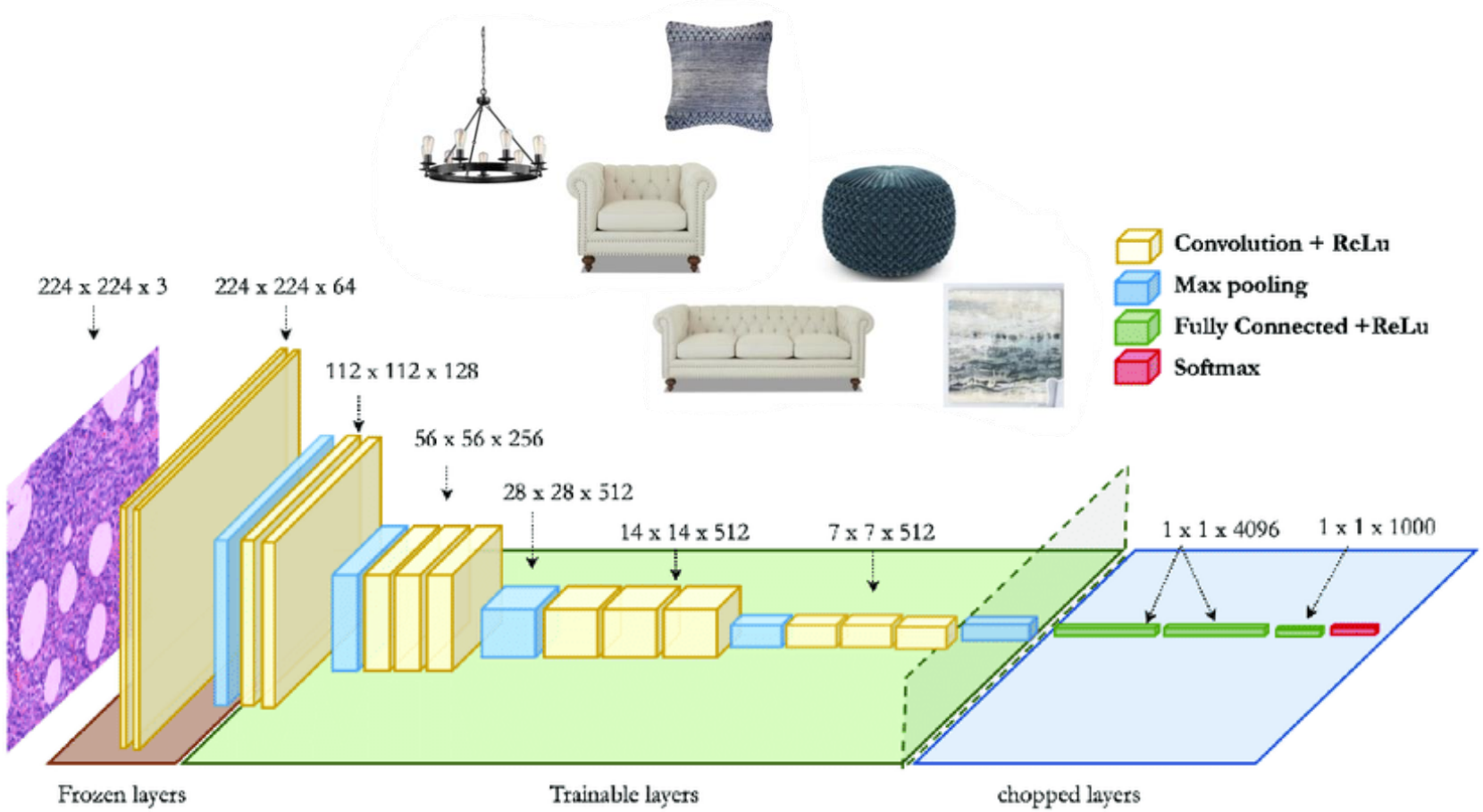


Production Pipeline



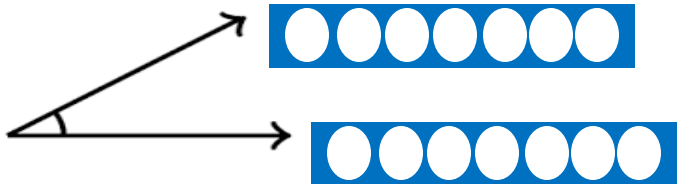
Extract Features

Fine tune a convolutional network with our own product images and freeze and chop layers to build a visual similarity model



Scaling Visually Similar - Approximate Nearest Neighbor

- The output of the CNN model is an embedding vector for each product image
- To find the best matching products, the cosine similarity is computed between embedding vectors – a k nearest neighbor search problem
- Home Depot has Millions online products - requires matching M x M products – trillion pairwise comparisons
- Instead we use an **approximate** KNN search algorithm that sacrifices some accuracy for speed
- We evaluated 3 different approximate KNN libraries:
  - FAIS - https://github.com/facebookresearch/faiss
  - ANNOY - https://github.com/spotify/annoy
  - NMSLIB - https://github.com/nmslib/nmslib
- We found NMSLIB to produce the best accuracy – speed tradeoff, over 2X the speed of ANNOY, and up to 50X faster than brute force
- Using NMSLIB we can generate recommendations for Millions products within a couple of hours



Collection Recommendations*

Problem

- Customers needs a more convenient way to find products that form a collection
- Manual process is error-prone and not scalable

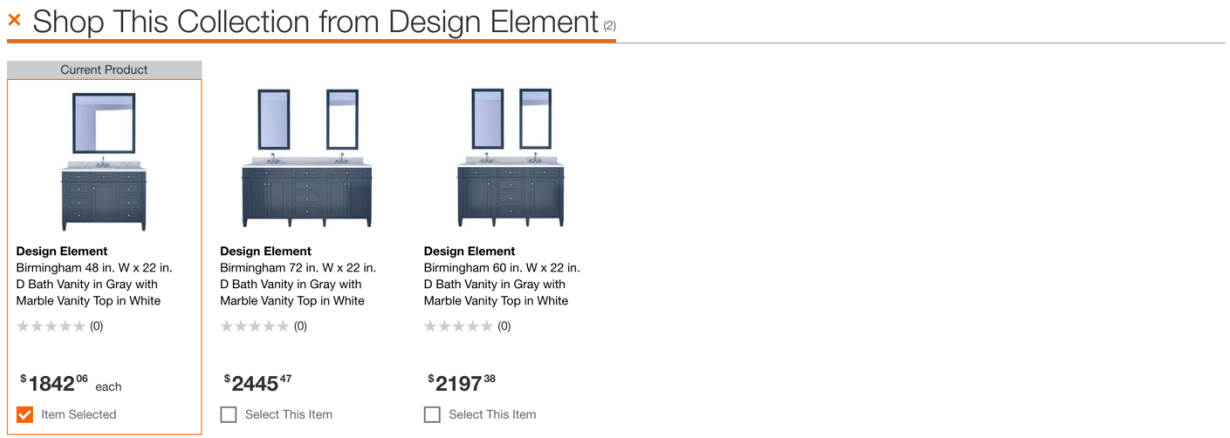
Goal

- To automatically discover ***relevant*** products that form a collection with a given anchor

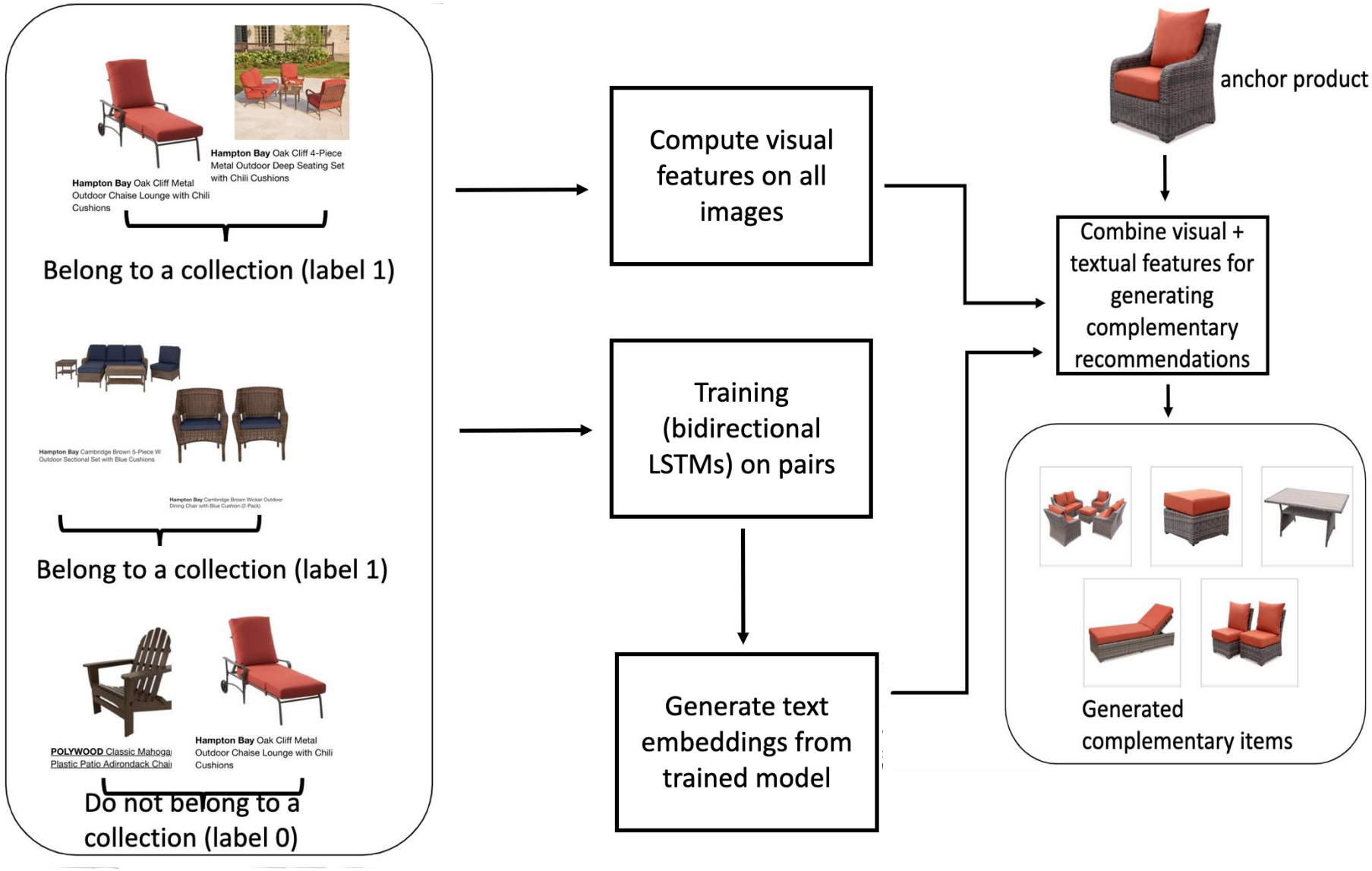
*Product collection recommendation in online retail, ACM Recsys'19

Coordinating: Relevant and Complementary

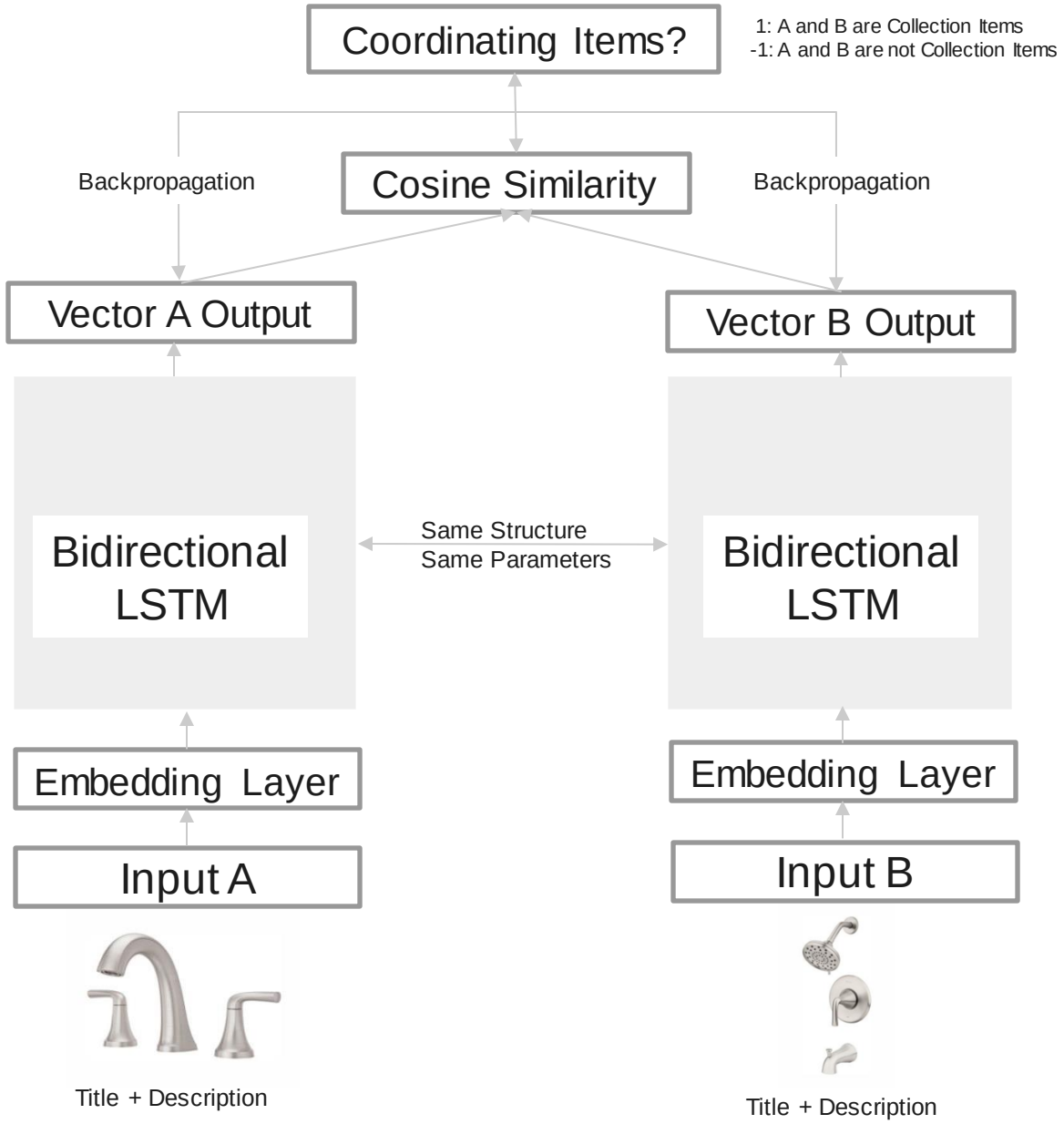
- Collection = textual relevance and visual similarity
- For a bath faucet, all recommended items must be:
  - Relevant to bath
  - Visually coordinated (color, style etc.)
  - Diverse!
- How to supervise such a model?
  - Manual Collections!



Approach for Generating Collection Recs



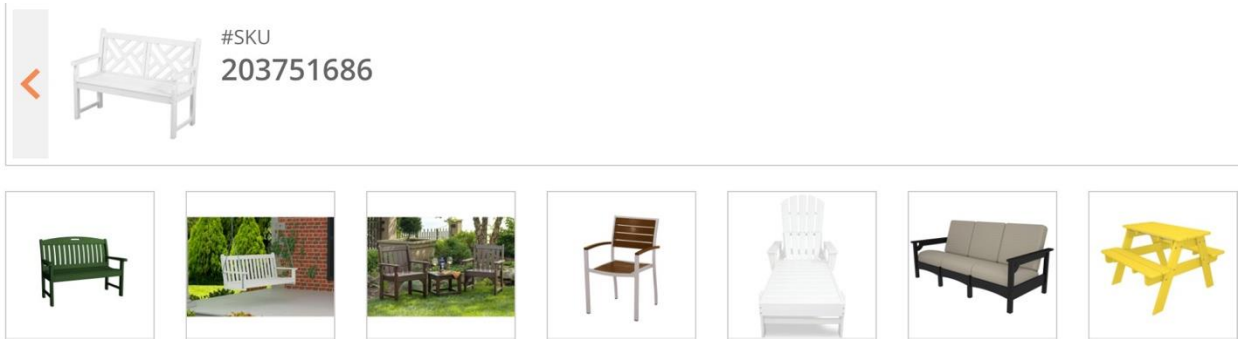
Siamese Deep Learning Network for Coordinating Items



Siamese **Network**

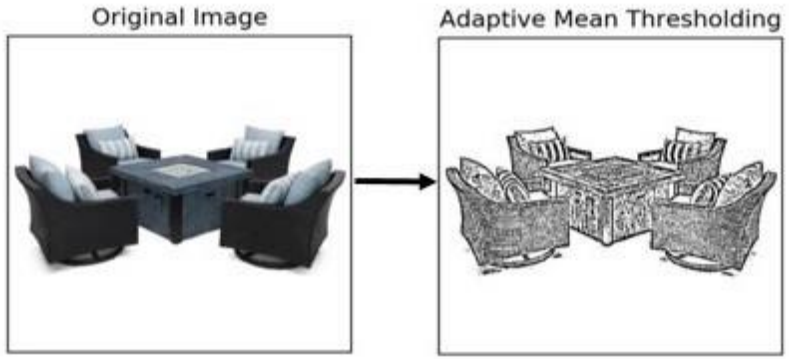
Visual Features: Color Histograms

- Color Histograms
  - Binned pixel intensity values for Red, Green, Blue (RGB) channels
- Why color histograms?

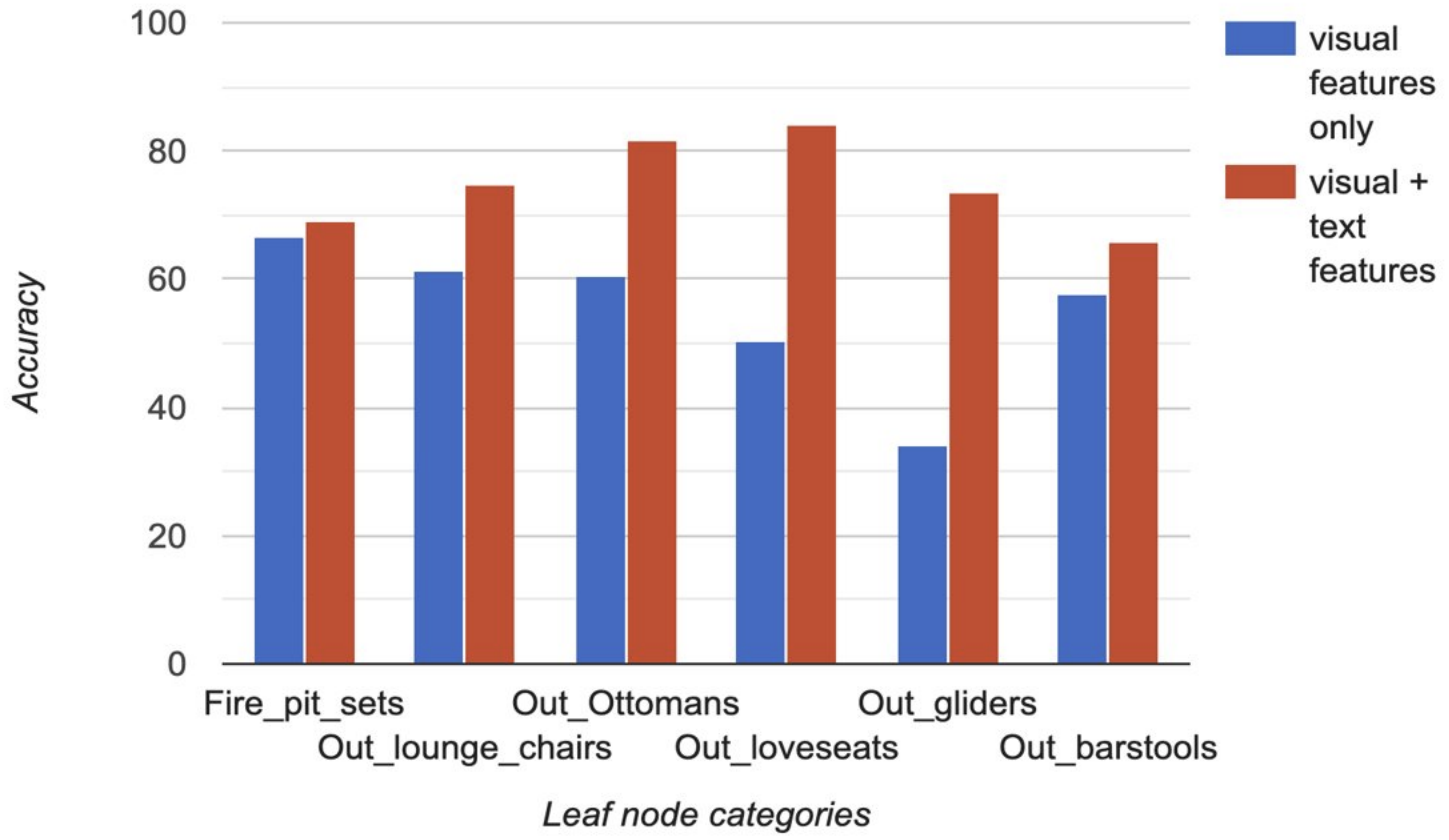


Result from state of the art deep network pretrained on ImageNet

- What to do about background?
- Mean Adaptive Threshold
  - Thresholds an image and extracts only the foreground
  - We compute color histograms on the foreground only



Joint Approach Outperforms Visual Only Approach



Patio Dataset

Combining Visual and Textual Features with Weights

- Given an anchor text embedding:
  - Compute a large list of candidate recs based on textual cosine similarity
  - Keep the cosine similarity scores (let's call each score $score_text$)
  - Given the same anchor's color feature vector
    - Compute the cosine similarities with all the recs within candidate set
    - Keep the cosine similarity scores (let's call each score $score_color$)
  - Combine the scores using weights and sort:

$$combined_score = w_1 \times score_text + w_2 \times score_color$$

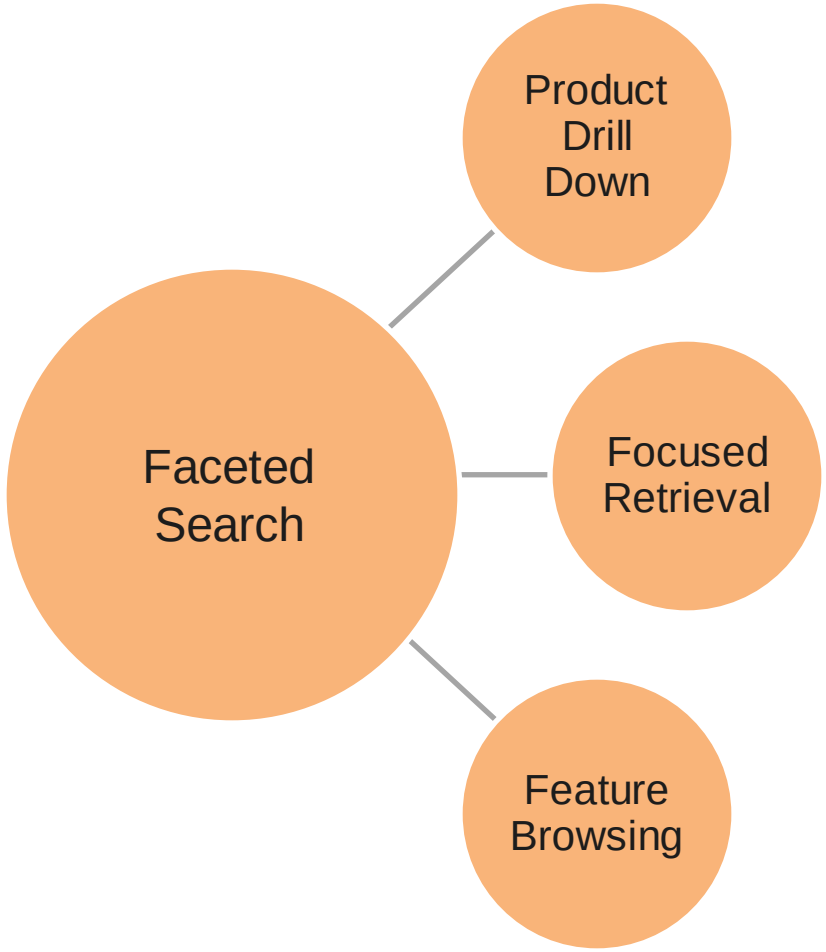
  - Pick the top "m" as final recs

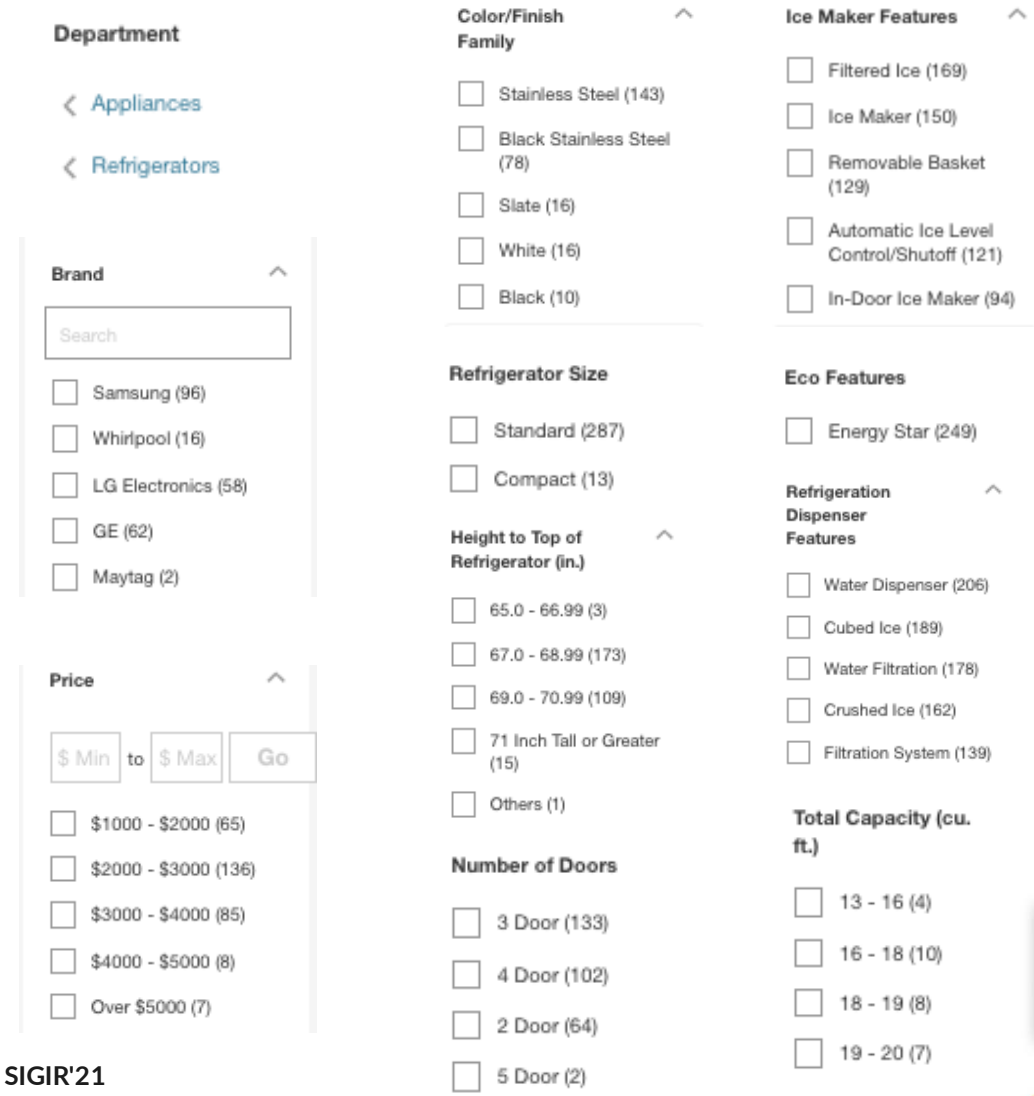
Sample Results

#SKU
309307649

SKU#	SKU#	SKU#	SKU#	SKU#	SKU#	SKU#	SKU#	SKU#	SKU#
306191402	202828732	305973955	301003403	202636864	309305696	308824923	303262307	202780841	206203027
Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.	Enter comments.
Description	Description	Description	Description	Description	Description	Description	Description	Description	Description
Monaco 36.5 in. W x 22 in. D Vanity in Gold with Solid Oak Wood Vanity Top in Chrome with Gold Basin	Alina Art Vessel Sink in Green Reflections	SoHo 29 in. W x 35 in. H Framed Wall Mirror in Gold	Retro Wave Collection 18 in. Two Tiered Glass Shelf with Integrated Towel Bar in Polished Brass	6-Light Honey Oak Vanity Light	Legacy 3-Handle Bidet Faucet in Polished Brass	1-Light Pyrite Sconce	65.5 in. x 30.5 in. Rustic Light Walnut Beveled Vanity Wall Mirror	30 in. x 60 in. x 60 in. 5-Piece Easy Up Adhesive Tub Wall in Barley	Roman Selection Raw Ginger Lantern 9-3/4 in. x 10-1/2 in. x 8 mm Glass Mosaic Tile

Smart Facet*





*Featured Keywords: Enabling Product Discovery in E-Commerce Through Unstructured Product Attributes, SIGIR'21

Faceted Search- Challenges

- Key-Value style presentation limits scope

Dimensions

Maximum Cut Depth @ 90 Deg.	0 in	Product Depth (in.)	25.98 in
Product Height (in.)	12.57 in	Product Width (in.)	7.64 in

Details

Batteries Included	Yes	Battery Amp Hours	12 Ah
Battery Power Type	Lithium Ion	Battery Size	Lithium Ion
Battery/Charger	2 Batteries & Charger Included	Battery/Charger	(2) 12 Ah Batteries & Charger Included
Bevel Capacity	0	Blade Diameter (in.)	9 in
Blade Location	Centered	Charger Included	Charger Included
Color Family	Red	Condition	New
Construction Material	Plastic	Cordless Tool Type	Circular Saw
Cordless/ Corded	Cordless	Included	No Additional Items Included
Included Accessories	Blade(s),Charger	Maximum Cut Depth @ 45 Deg.	0 in
Maximum Speed (rpm)	6600	Motor Type	Brushless
Number of Total Batteries Included	2	Power Tool Features	Electric Brake,Keyed Blade Change,Mobile App Integrated
Product Weight (lb.)	10.41 lb	Returnable	90-Day
Saw Drive Type	Sidewinder	Tools Product Type	Power Tool
Voltage (volts)	18		

Warranty / Certifications

Certifications and Listings	UL Listed	Manufacturer Warranty	5 Year Warranty & 3 Year Battery Warranty

Brand

Search

- RYOBI (13)
- Makita (91)
- DEWALT (71)
- Milwaukee (67)
- Genesis (5)

+ See All

Cordless/ Corded

- Cordless (245)
- Corded (85)

Blade Diameter (in.)

- 7-1/4 in (126)
- 6-1/2 in (73)
- 4-1/2 in (18)
- 5-1/2 in (14)
- 3 in (12)

+ See All

Battery Platform

- Milwaukee M12 (20)
- Ryobi 18v ONE+ (9)
- Dewalt Flexvolt Advantage (2)
- Milwaukee M18 (41)
- Dewalt 60v MAX Flexvolt (13)

+ See All

Battery Amp Hours

- No Battery (86)
- 5 Ah (47)
- 4 Ah (31)
- 2 Ah (17)
- 3 Ah (8)

+ See All

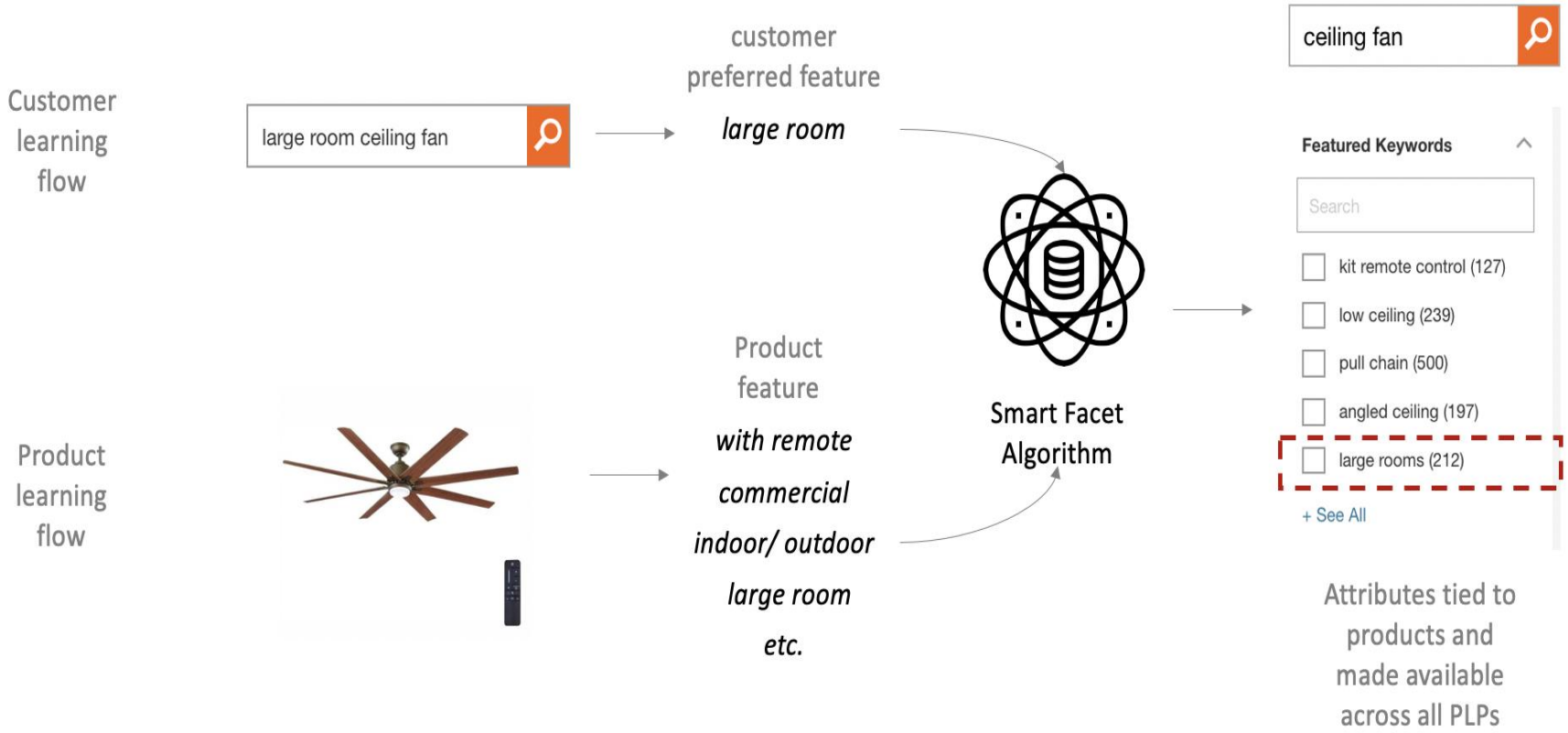
Motor Type

- Brushless (175)
- Brushed (71)

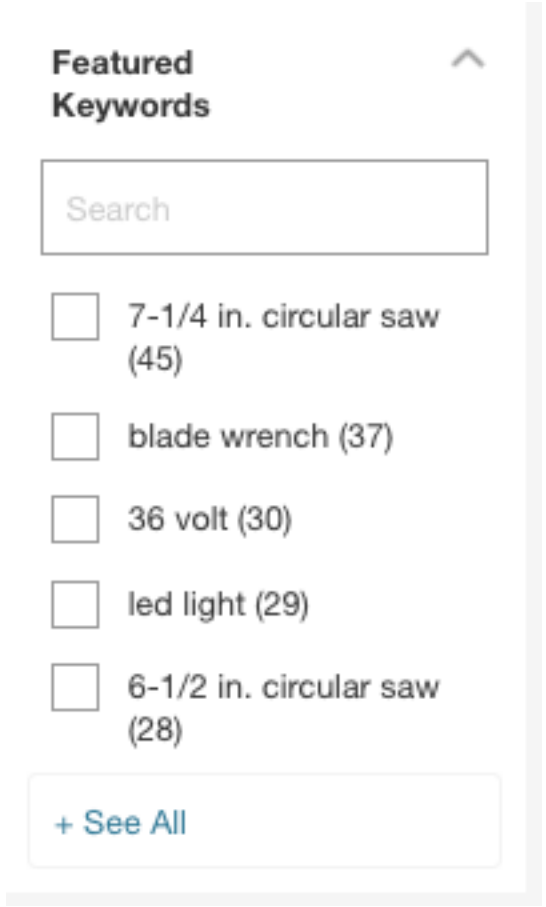
Number of Total Batteries Included

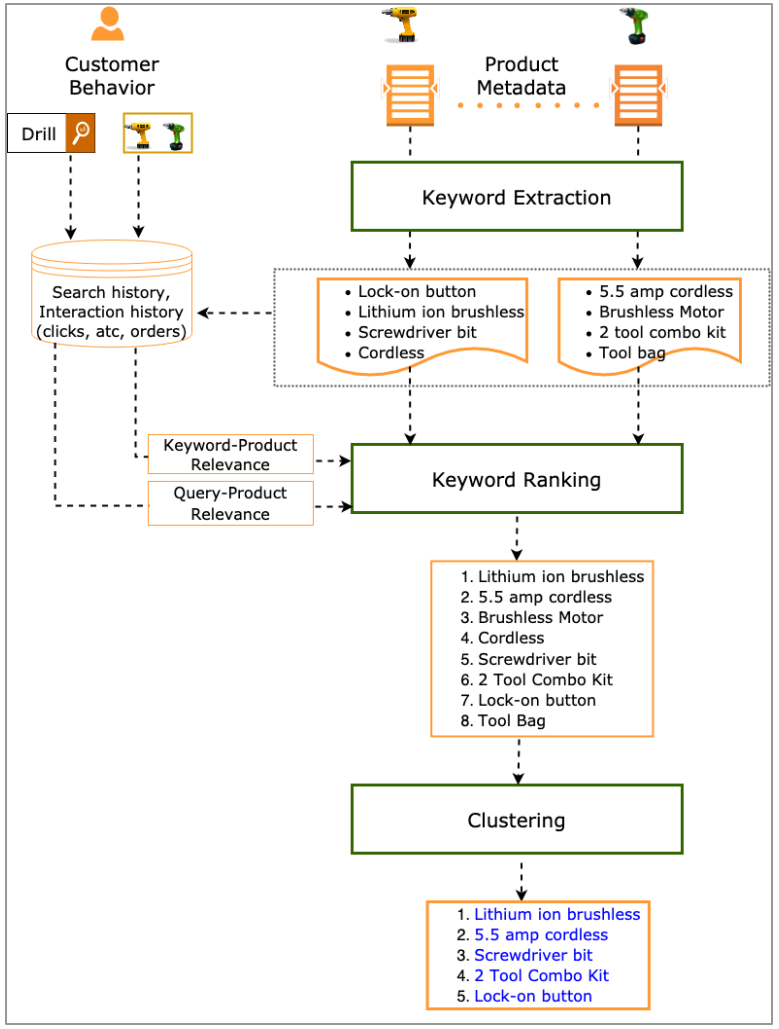
- 0 (98)
- 1 (87)
- 2 (52)
- 3 (5)
- 4 (4)

Smart Facet Overview



System Design





Extract facets from unstructured product attributes

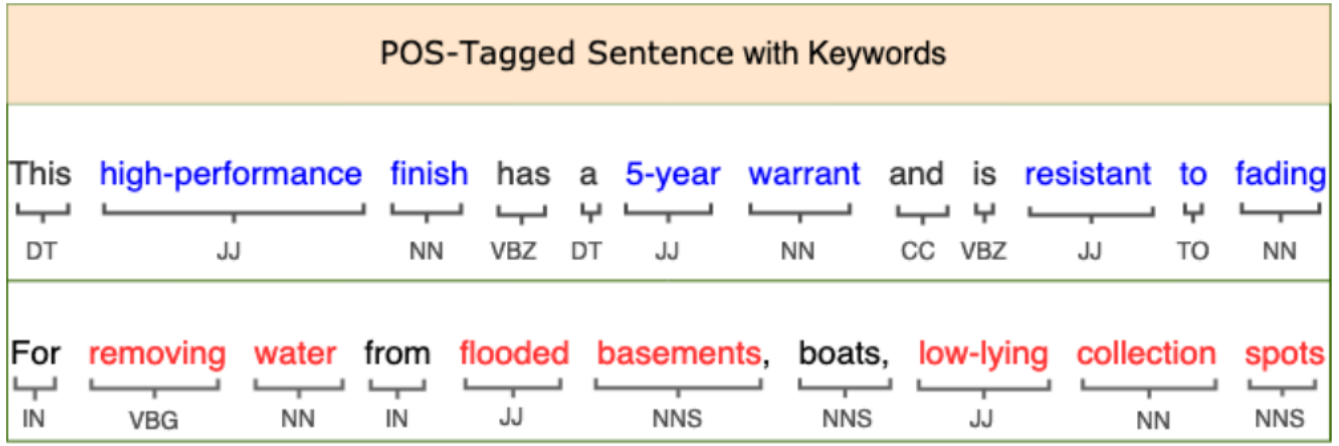
Incorporate customer search trends

One-stop free-form searchable filter across several dimensions

Keyword Extraction

- Extract keywords from product meta data
  - Title, Description, Highlights, Bullets
  - Define POS patterns of interest

POS Patterns
(<JJ.?>|<NN.?>)? <VB[^Z]>+ <NN.?>+ (extracts adjective, noun and verb combinations)
<NN[^S]?>? <JJ.?>+ <NN[^S]?>* <NN.?> (extracts noun and adjective combinations)



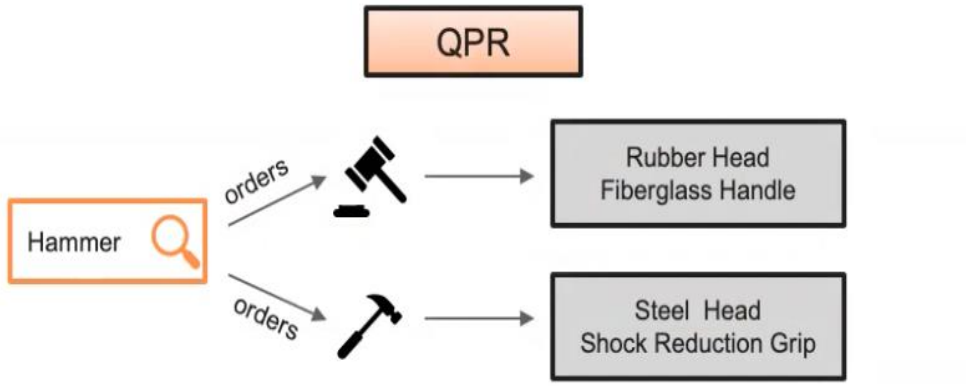
- Keyword cleaning
  - TF-IDF – remove insignificant keywords
  - Limit keyword length between 2 and 5
  - Light deduplication

Methodology

- Filter and Rank keywords for each search term
  - Aggregate all keywords from all products for a search term
  - Use customer search behavior to filter and rank keywords

- Query – Product Relevance

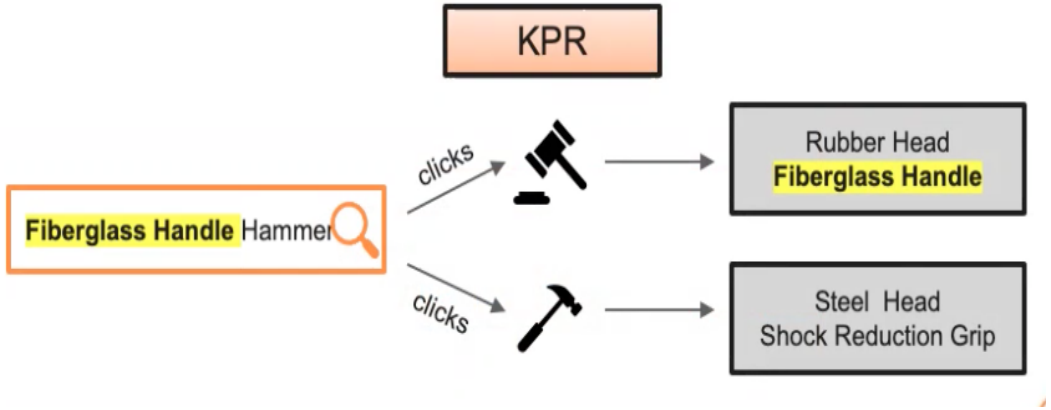
$$QPR(Q,P) = \frac{Orders(Q,P)}{\max(\{Orders(Q,P_i) : \forall P_i \in P_i^Q\})}$$



Methodology

- Keyword – Product Relevance
  - Hypothesis: **Customers would often include the key product feature they are looking for, right within their search query**

$$KPR(K,P) = \frac{Clicks(Q^K, P)}{\max(\{Clicks(Q^{K_i}, P) : \forall K_i \in F_P\})}$$



- Final Score $rank(K,P,Q) = \alpha \cdot KPR(Q,P) + (1-\alpha) \cdot QPR(K,P)$

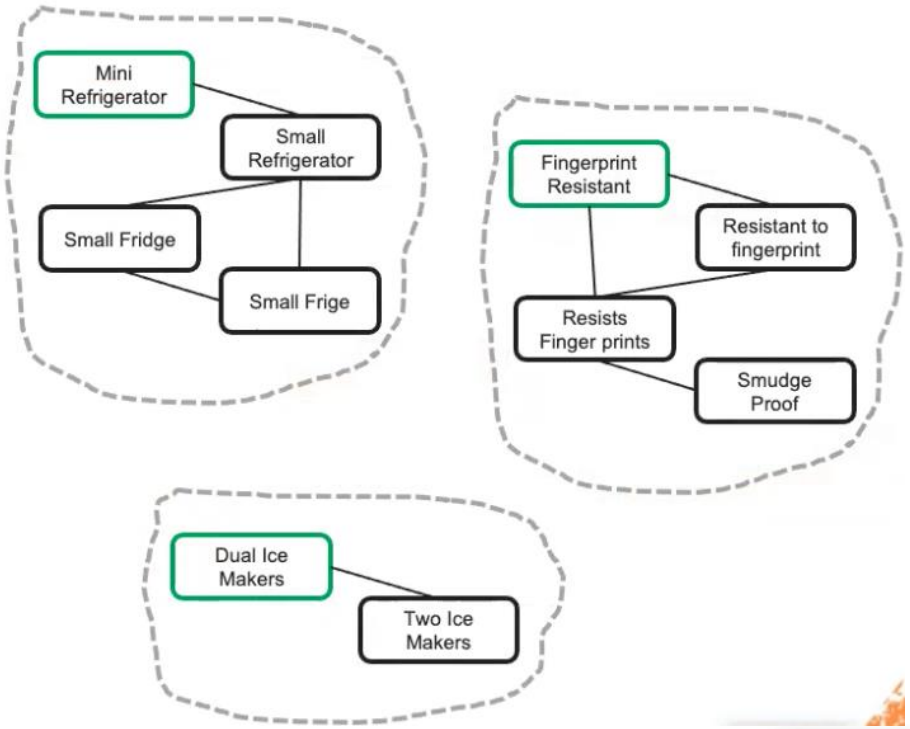
Methodology

- Remove Duplicates
  - Define pairwise-similarity for top-k keywords per search term

$$Sim_{lexical}(K_i, K_j) = \frac{|Tokens(K_i) \cap Tokens(K_j)|}{|Tokens(K_i) \cup Tokens(K_i)|}$$

$$Sim_{semantic}(K_i, K_j) = Cosine_Sim(V(K_i), V(K_j))$$

$$Sim(K_i, K_j) = \beta \cdot Sim_{lexical}(K_i, K_j) + (1 - \beta) \cdot Sim_{semantic}(K_i, K_j)$$



  - Connected Components to form clusters
  - Choose keyword with min(rank) as cluster representative

Experiment and Results

- Conducted A/B test for 2 weeks
- Metrics measured

$$Engagement = \frac{Number\ of\ sessions\ with\ a\ click\ on\ the\ facets}{Total\ number\ of\ sessions}$$

+ 2%

$$Average\ Order\ Value = \frac{Total\ Revenue}{Total\ number\ of\ orders}$$

+ 2.9%

$$Revenue\ Per\ Visit = \frac{Total\ Revenue}{Total\ number\ of\ sessions}$$

+ 3.6%

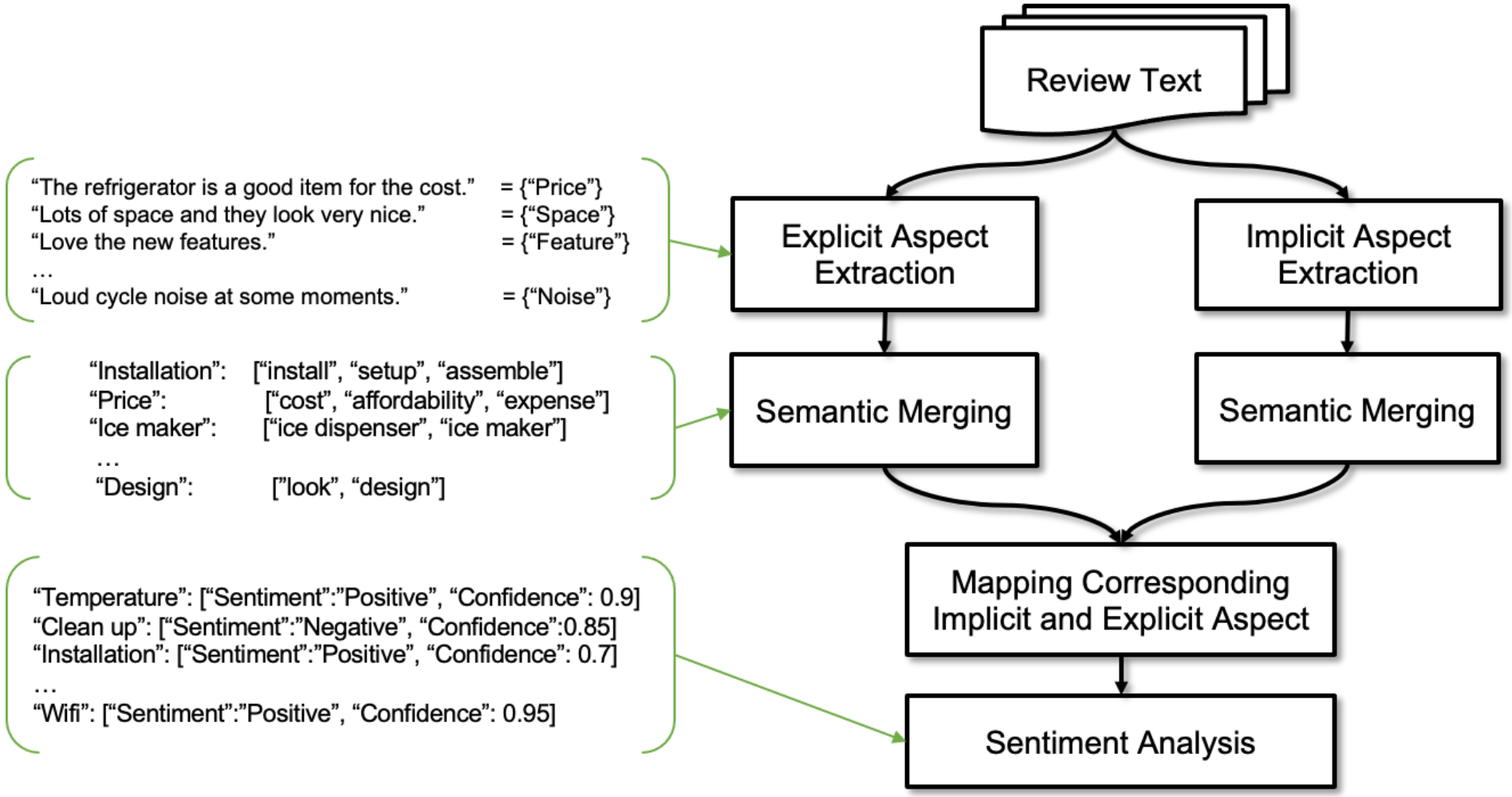
Product Review Summarization

- Improve readability of reviews which accumulate to an enormous amount.
- Identify key themes in our product reviews that we can extract and surface to the customers.

Category Name	Reviews	Sentences
Small Kitchen Appliances	1,636,426	6,027,097
Refrigerators	978,155	3,696,724
Ranges	549,428	1,924,709
Appliance Parts	133,689	312,650
Range Hoods	117,169	353,236
Washers & Dryers	614,060	2,254,625
Floor Care	213,196	980,699
Dishwashers	631,137	2,394,990
Microwaves	443,042	1,416,400
Cooktops	54,304	187,607
Wall Ovens	85,631	314,265
Beverage Coolers	18,008	72,389
Mini Fridges	31,990	95,348
Freezers & Ice Makers	65,875	214,683
Household Appliances	11,795	52,594
Garbage Disposals	103,198	332,585
Trash Compactors	3,613	12,468
Total	5,690,716	20,643,069

*A Pipeline of Aspect Detection and Sentiment Analysis for E-Commerce Customer Reviews, SIGIR'20

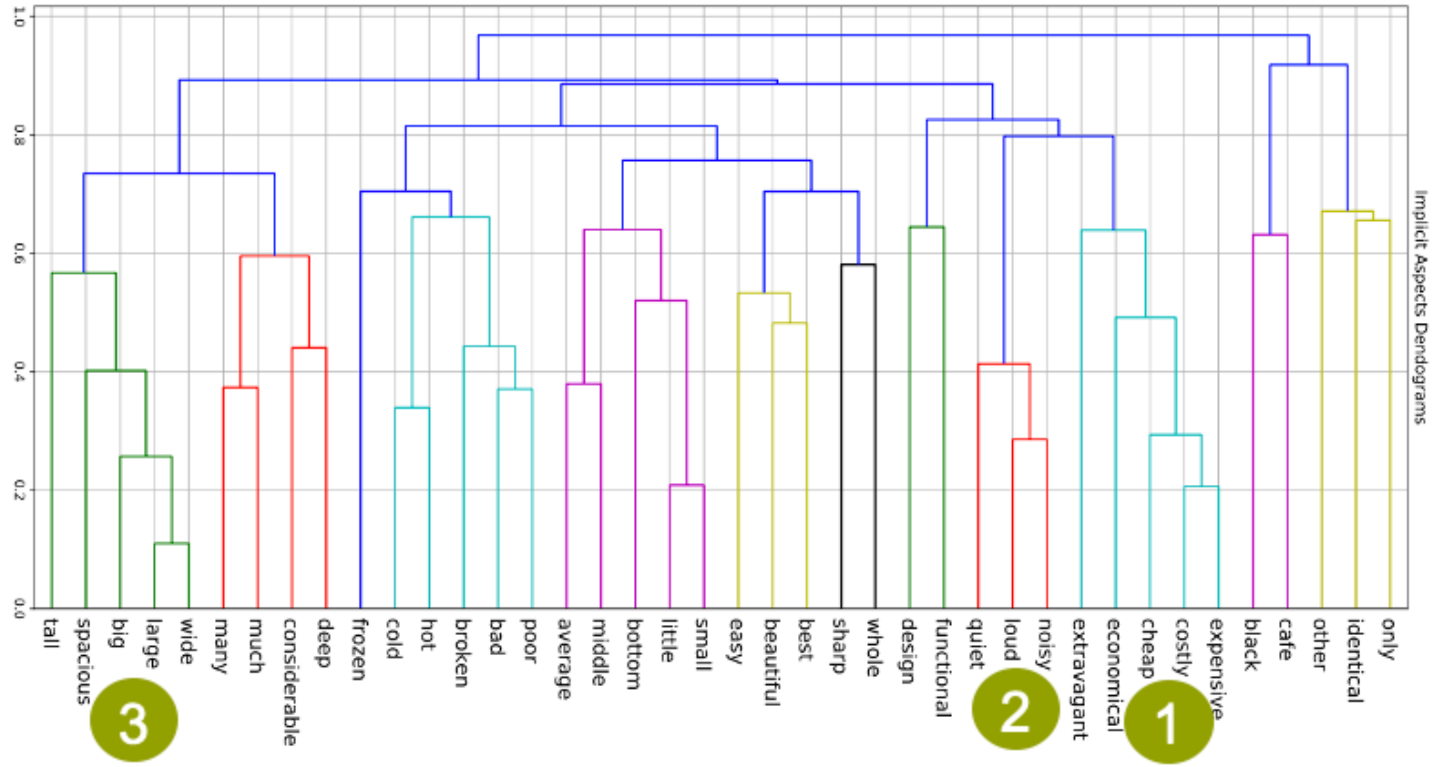
Aspect Extraction



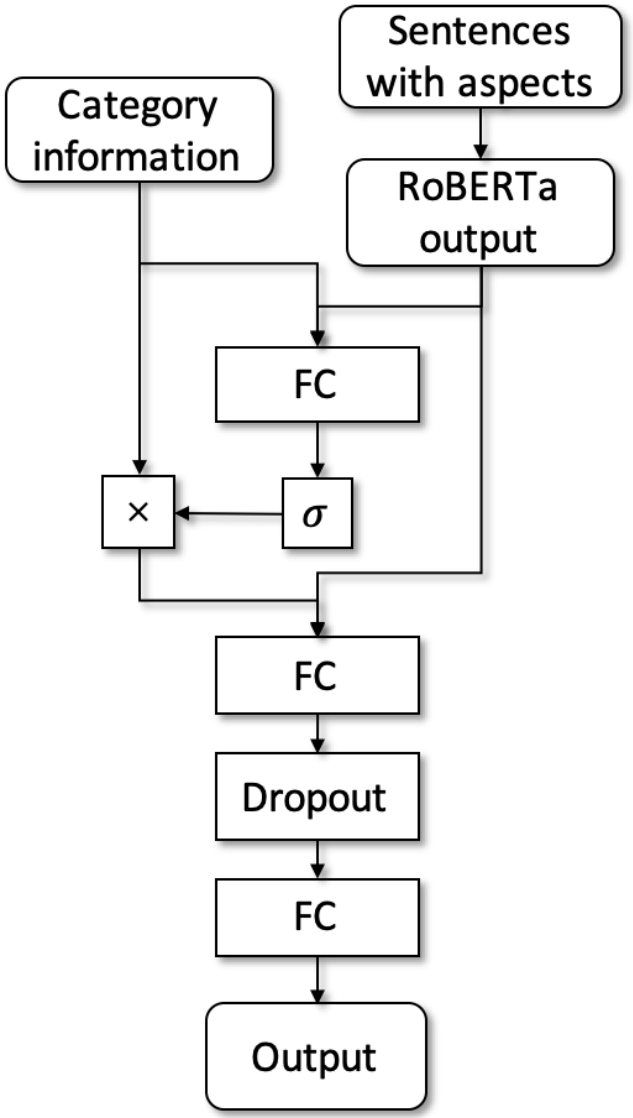
Aspect Merging

- Semantic clustering using Universal Sentence Encoder
- Explicit aspect mapping using WordNet

1. “Price”: "expensive", "costly", "cheap", "economical",
2. “Noise”: "noisy", "loud", "quiet",
3. “Space”: "wide", "large", "big", "spacious"

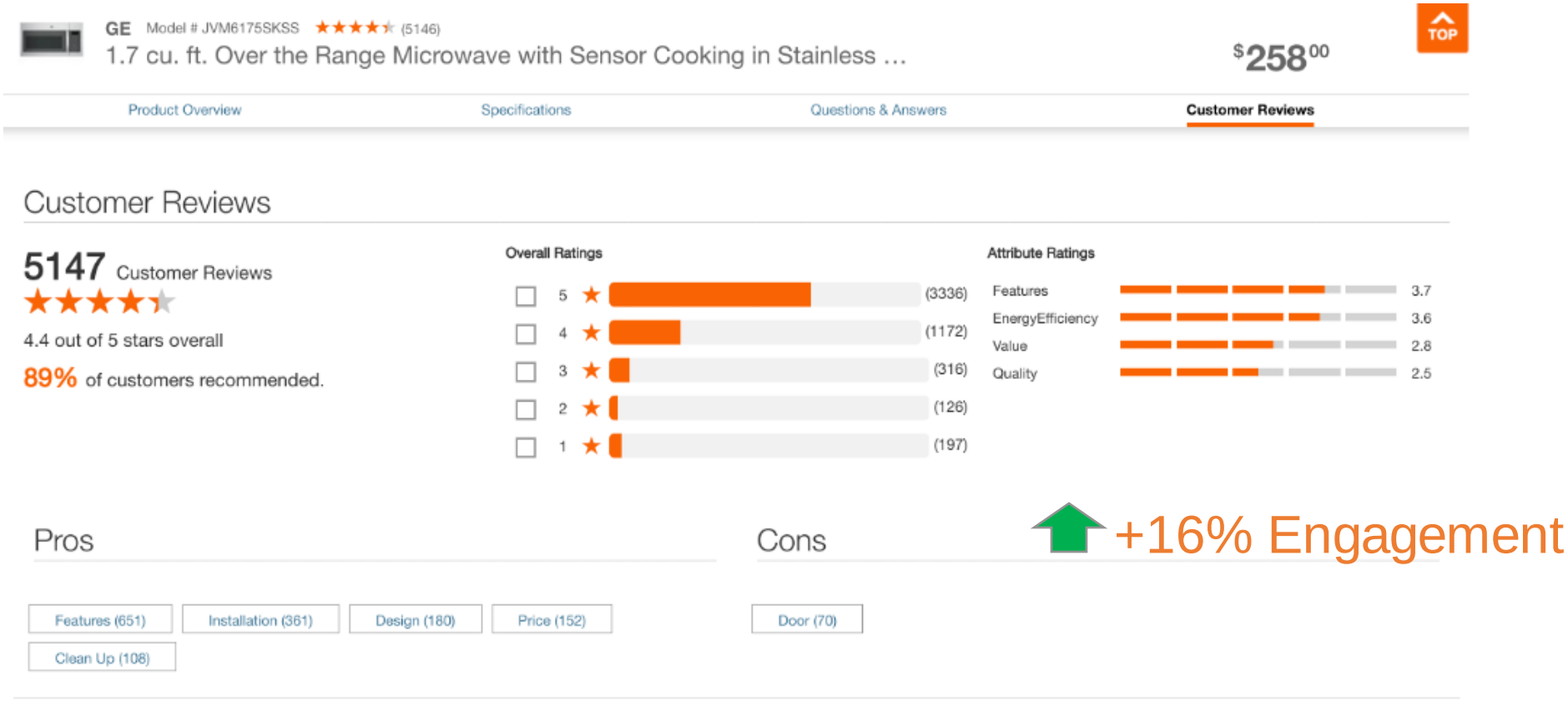


Sentiment Analysis



Models	Accuracy	MCC	Kappa
Conv+LSTM	0.666448	0.476716	0.472205
RoBERTa trained seperately	0.8997	0.857224	0.856966
RoBERTa trained together	0.898005	0.841215	0.840983
Gated RoBERTa	**0.916382**	**0.870304**	**0.870078**

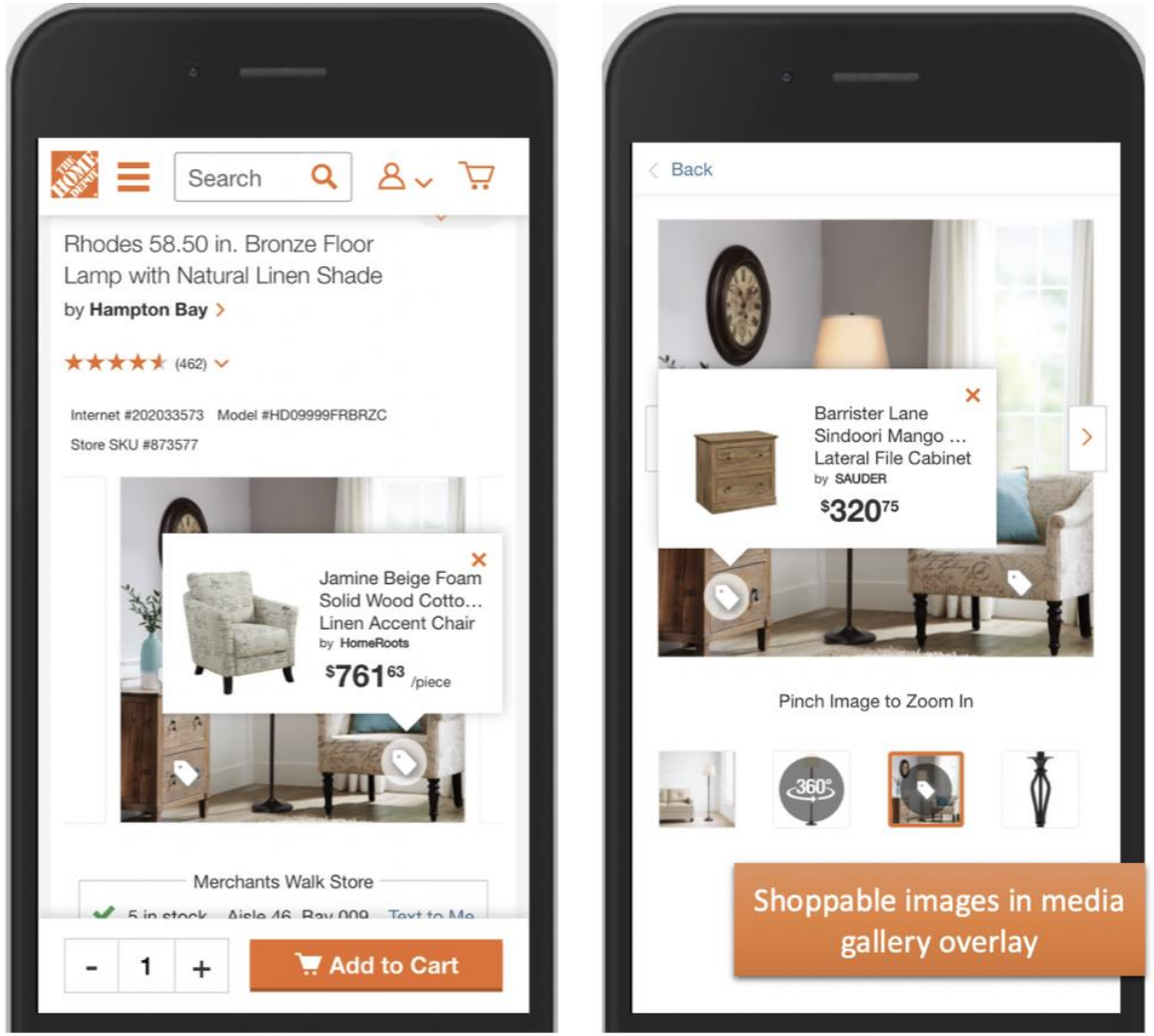
Performance



+16% Engagement

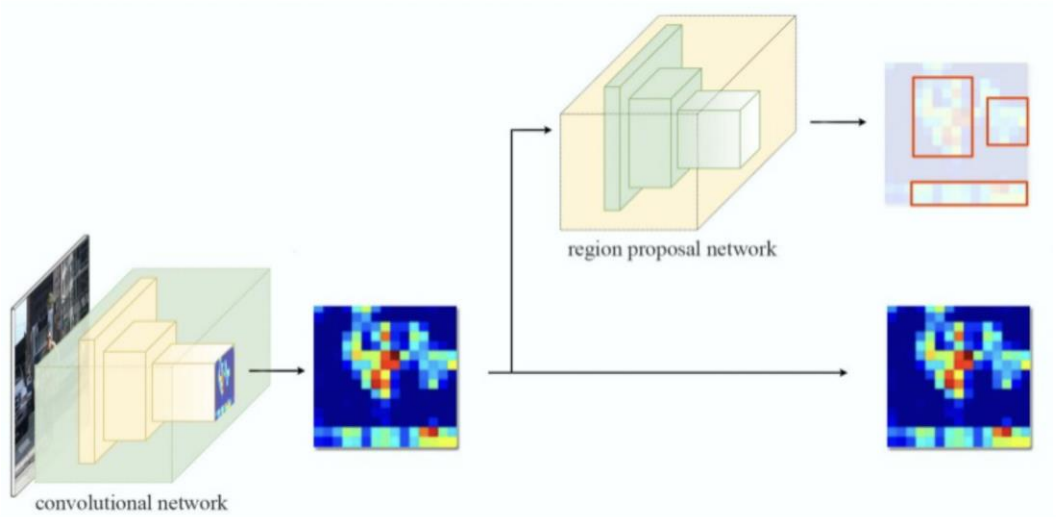
Shoppable Images

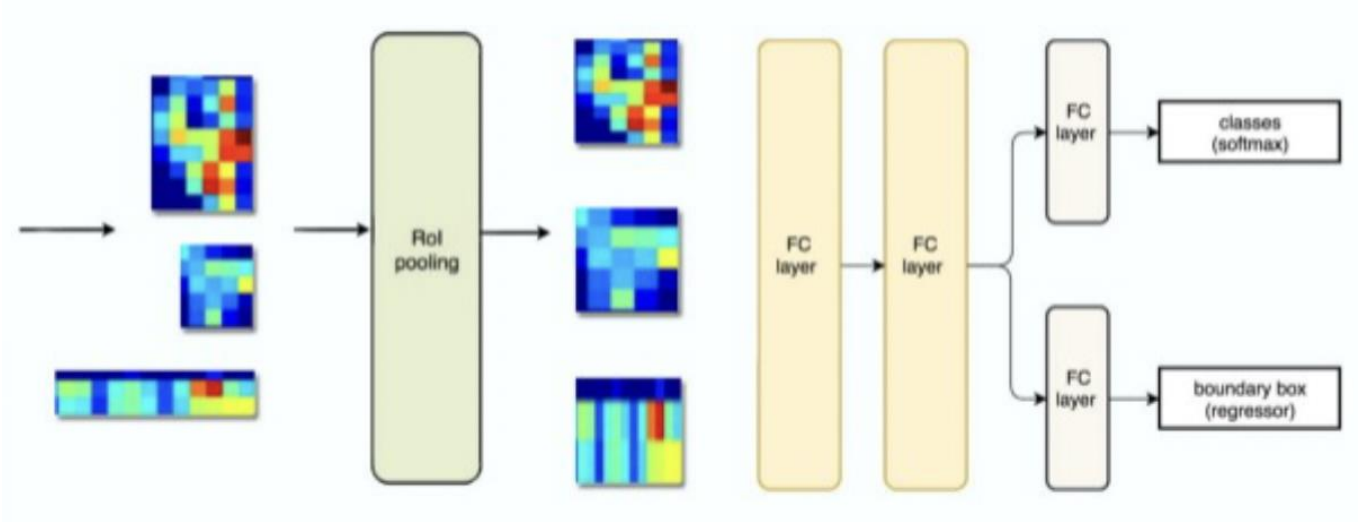
Create more shoppable images by automatically identifying and matching to sellable products from our lifestyle photos.



Object Detection

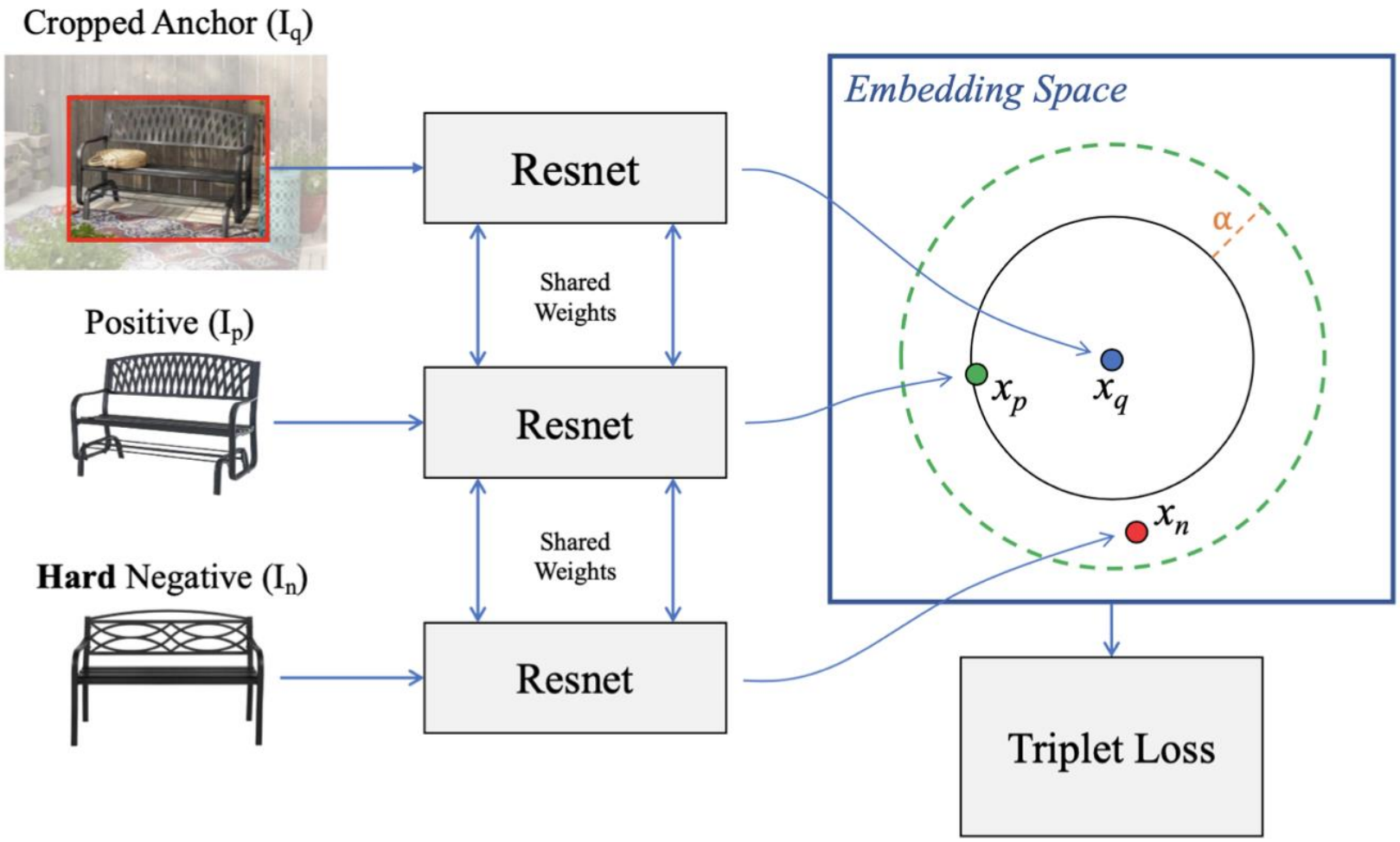
Use a region proposal network and feature extractor backbone to predict bounding boxes and product categories





Visual Search

Visually match cropped products by training a Siamese network with hard triplets of negative and positive pairs

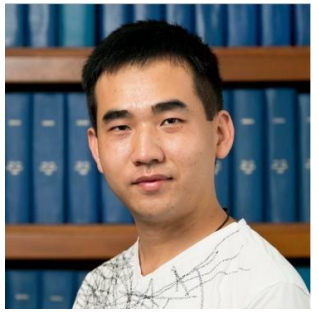


Input/Ouput

Scene Image

Visual Search

Acknowledgement



Questions?

****We are Hiring****

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