Automatic Discovery and Generation of Visual Design Characteristics

Application to Visual Conjoint

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Visual (or aesthetic) design matters across many product categories . . .

Cars

Visual (or aesthetic) design matters across many product categories . . .

Cars

Fashion

Visual (or aesthetic) design matters across many product categories . . .

Cars

Fashion

Furniture

. . . even for mundane categories like yogurt

"We worked hard to *get the packaging right* *. . . American yogurt has always been sold in containers with relatively narrow openings. In Europe yogurt containers are* *wider and squatter**, and that's what I wanted for Chobani."*

—Hamdi Ulukaya, Founder & CEO, Chobani

Visual design matters

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"Exterior look/design is the top reason shoppers avoid a particular vehicle (30%), followed by cost (17%)."

—JD Power Avoider Study 2015

What this paper seeks to do

Research Goals

Our research aims to obtain interpretable visual characteristics directly from unstructured product images

- *automatically discover* (extract) characteristics

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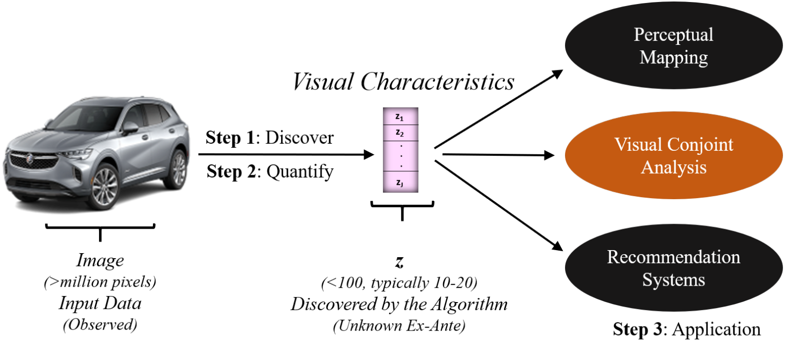
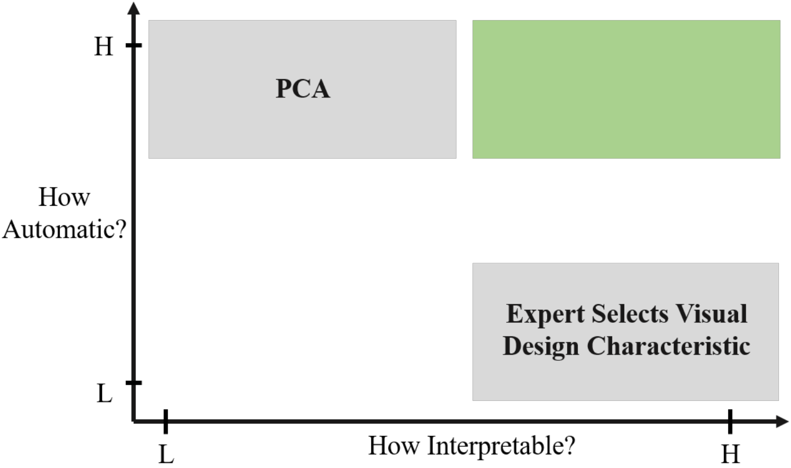
Our research aims to obtain interpretable visual characteristics directly from unstructured product images

- *automatically discover* (extract) characteristics
- *quantify* these characteristics
- *generate* visual design that span the space of visual characteristics

Research Goals



Modeling Visual Characteristics: A comparison of methods



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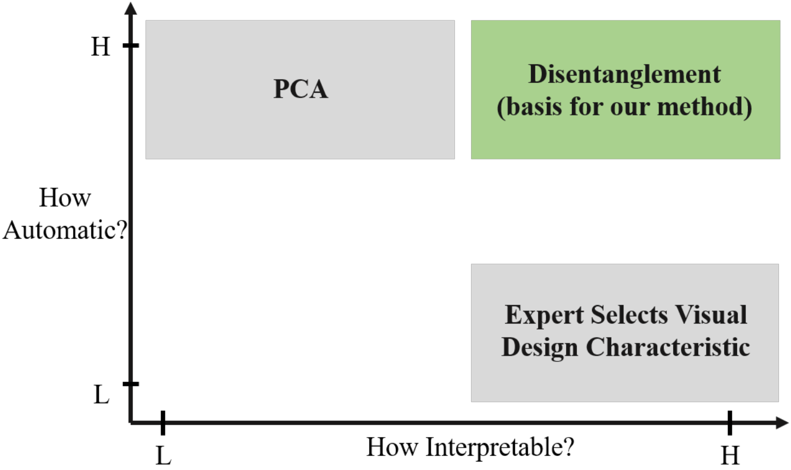

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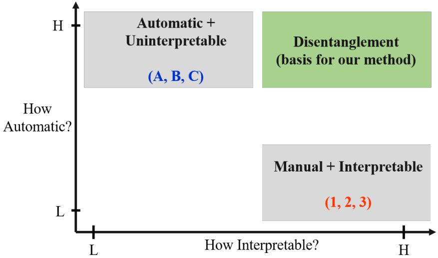

Automatic + Uninterpretable

- A - Bajari, P. L. et al. (2021) : Hedonic prices and quality adjusted price indices powered by AI, *CENMAP working paper*
- B - Law, S., et al. (2019) : Take a look around: using street view and satellite images to estimate house prices. *ACM Transactions on Intelligent Systems and Technology (TIST)*
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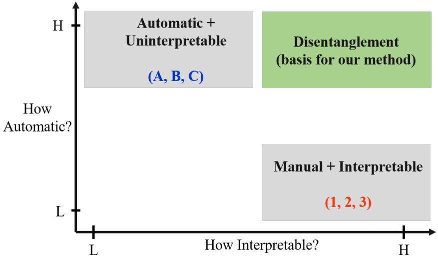

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Manual + Interpretable

- 1 - Zhang, M. et al. (2022) : Can consumer-posted photos serve as a leading indicator of restaurant survival? Evidence from yelp. *Management Science*
- 2 - Liu, Y., et al. (2017) : The effects of products' aesthetic design on demand and marketing-mix effectiveness: The role of segment prototypicality and brand consistency. *Journal of Marketing*
- 3 - Zhang, S., et al. (2021) : What makes a good image? Airbnb demand analytics leveraging interpretable image features. *Management Science*

What is disentanglement?

Bengio et al (2013)

"A disentangled representation can be defined as one where **single latent units** *are sensitive to changes in single generative factors, while being relatively invariant to changes in other factors"*

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"A disentangled representation can be defined as one where **single latent units** *are sensitive to changes in single generative factors, while being relatively invariant to changes in other factors"*

- Latent Units ($\mathbf{v}$): Dimensions in the model's latent space
- Generative factors ($\mathbf{c}$): Human-interpretable true characteristics

Is Interpretability always necessary?

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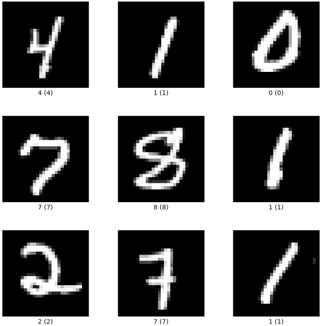
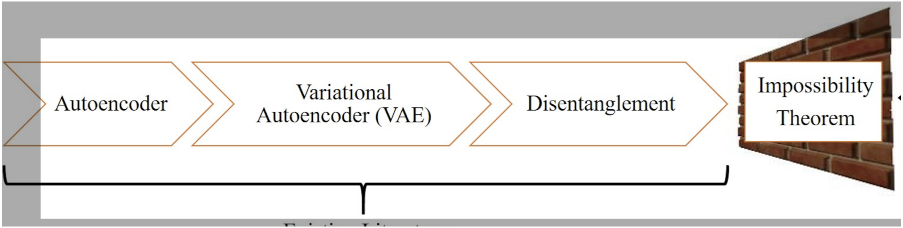


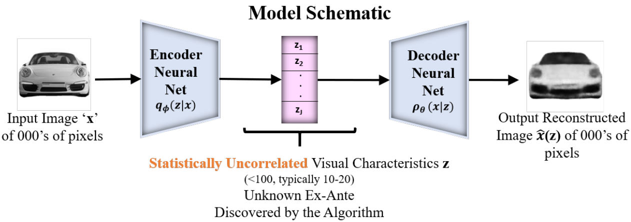
Roadmap of Our Approach



Contribution

We aim to overcome this impossibility theorem with a simple approach of using structured product characteristics.

Models in Existing Literature



Model	Goal
Autoencoder (AE)	Reconstruction accuracy
Variational Autoencoder (VAE)	…+ structured latent space
Disentanglement	…+ …+ statistically independent latent space

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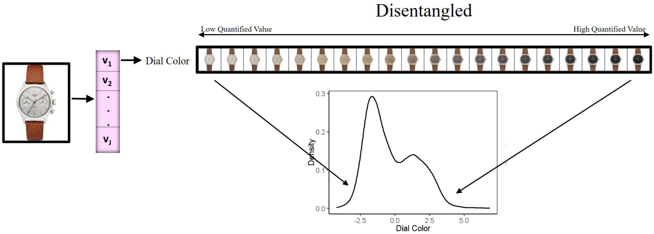
Disentangled v Entangled Representation



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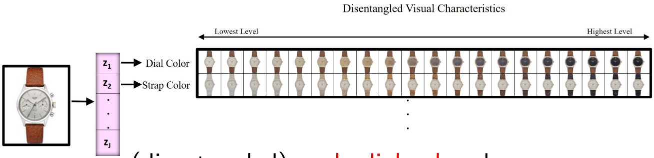

v_1 (disentangled): only dial color changes

v_2 (disentangled): only strap color changes

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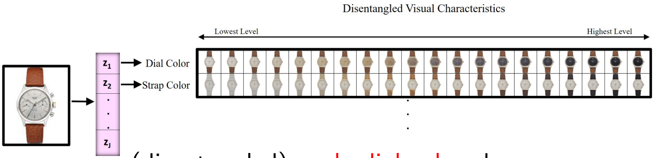

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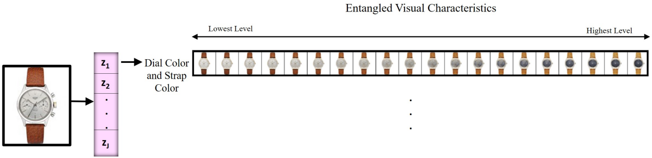

v_1 (entangled): both dial color and strap color changes

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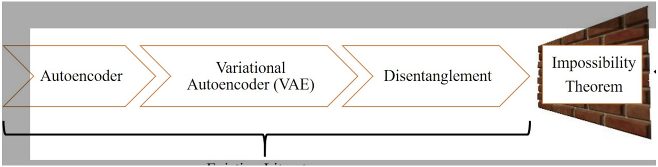
Impossibility Theorem

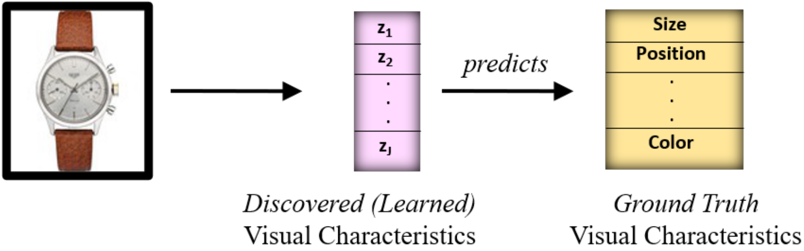


Impossibility Theorem

Unsupervised (*i.e. only images*) learning of disentangled representations is *fundamentally impossible* except under certain restrictive conditions.

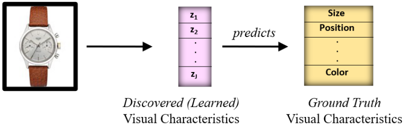
Implication: Every disentangled representation can have other equivalent entangled representations.

Overcoming Impossibility Theorem



Overcoming Impossibility Theorem

Common approach to ground truth in ML is to get humans to label[1]



What's the Problem?

- Ground truth on visual characteristics is unknown. In fact, these are precisely what we want to find.

[1] Locatello, Francesco, et al. "Disentangling factors of variation using few labels." ICLR. 2020.
Gyawali, Prashnna K. et al. "Learning to disentangle inter-subject anatomical variations in electrocardiographic data." IEEE Transactions on Biomedical Engineering. 2021.

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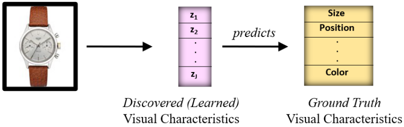

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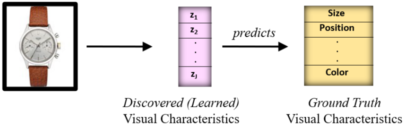

What's the Problem?

- Ground truth on visual characteristics is unknown. In fact, these are precisely what we want to find.
- Researcher needs to determine what are the true characteristics to focus on
- Need to ensure humans understand what these labels are and how to quantify them for each image

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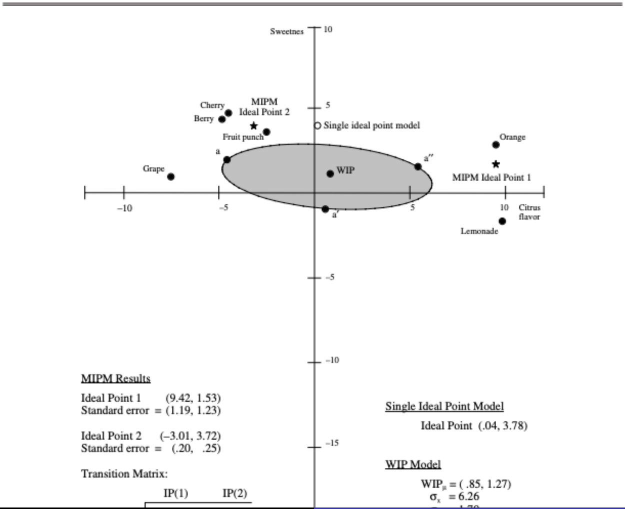
Ideal Point

Fruit Punch: Example from Lee, Sudhir and Steckel (2002)

Figure 2
MIPM RESULTS FOR HOUSEHOLD 057



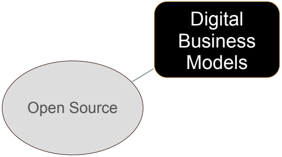
Research Overview – Substantive

Digital Business Models

Research Overview – Substantive

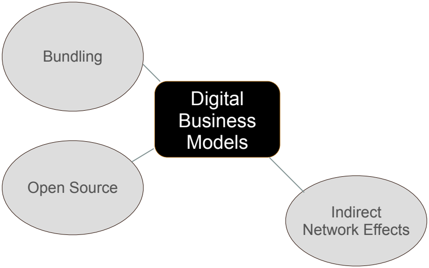
Competitive Product Strategy for Open Source Software, *with B. Gordon and K. Srinivasan*

Marketing Science, 30(6)



Research Overview – Substantive

The Dynamic Effects of Bundling as a Product Strategy, *with T. Derdenger*
Marketing Science, 32(6)



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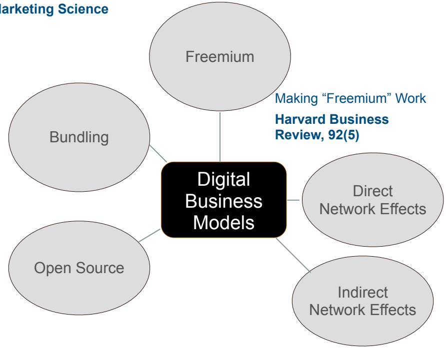
Designing Freemium: Strategic Balancing of Growth and Monetization, *with C. Lee and S. Gupta*

Revision at **Marketing Science**

Designing Plans on Digital Platforms, *with I. Weaver and S. Jonnalagedda* ***(Working Paper)***

Making “Freemium” Work

Harvard Business Review, 92(5)



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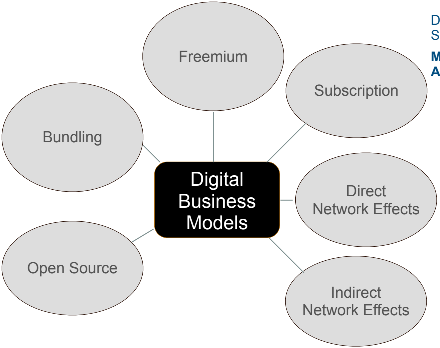

Demand Estimation for Subscriptions, *with C. Chou*

Marketing Science (Cond. Accepted)

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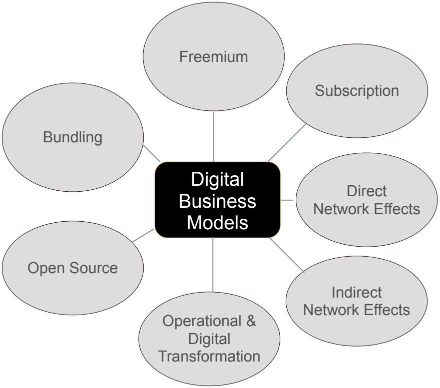

Designing Pricing Strategy for Operational and Technological Transformation, *with Y. Sun*

Management Science, 66(6)

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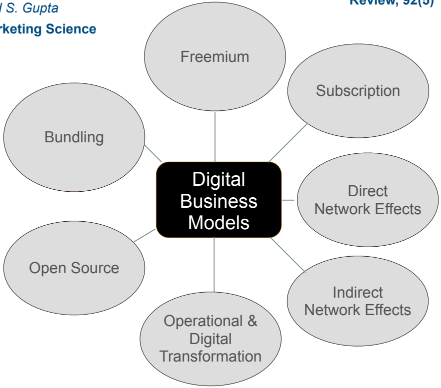

Can Random Friends Seed More Buzz and Adoption? Leveraging the Friendship Paradox, *with K. Sudhir*

Management Science (Accepted)

Competitive Product Strategy for Open Source Software, *with B. Gordon and K. Srinivasan*

Marketing Science, 30(6)

Other:

Match Your Own Price? Self-Matching as a Multichannel Retailer's Pricing Strategy, *with P. Kireyev and E. Ofek*

Marketing Science, 36(6)

Designing Pricing Strategy for Operational and Technological Transformation, *with Y. Sun*

Management Science, 66(6)

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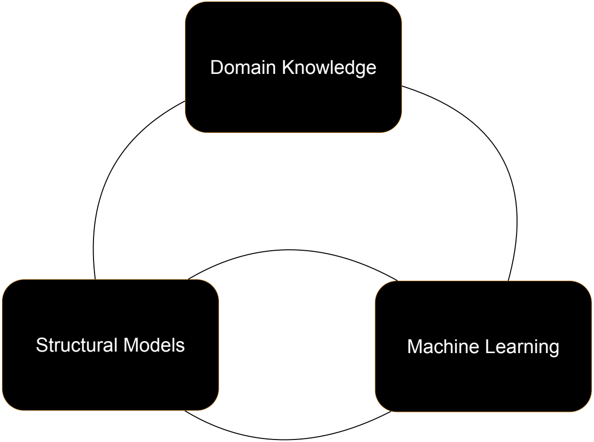
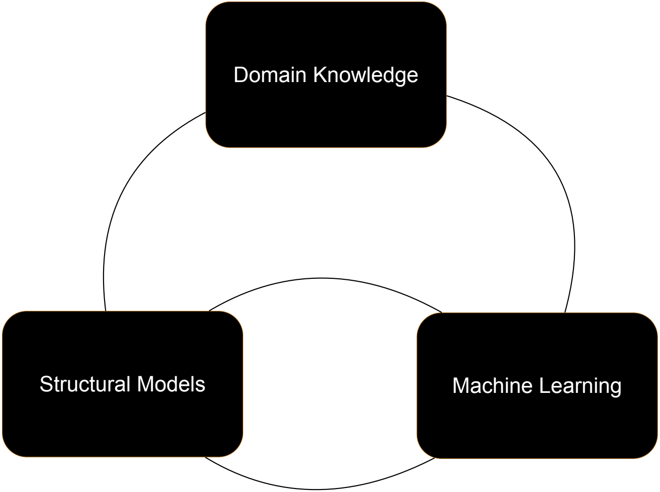


Research Overview – Methodological



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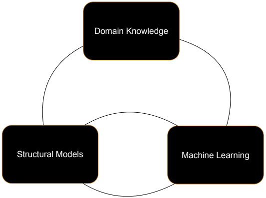
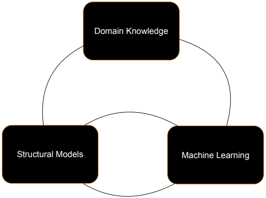


- Structural Models:
  - Linear Estimation of Aggregate Dynamic Discrete Demand for Durable Goods without the Curse of Dimensionality, with C. Chou and T. Derdenger **Marketing Science**
  - Estimating Dynamic Discrete Choice Models with Aggregate Data: Properties of the Inclusive Value Approximation, with T. Derdenger, **Quantitative Marketing and Economics**

Research Overview – Methodological



- Machine Learning:
  - Nonparametric Bandits Leveraging Informational Externalities to Learn the Demand Curve, with I. Weaver, *Major Revision* at **Marketing Science**
  - A Theory-Based Interpretable Deep Learning Architecture for Music Emotion, with H. Fong and K. Sudhir, *Major Revision* at **Marketing Science**
  - Automatically Discovering Unknown Product Attributes Impacting Consumer Preferences, with A. Sisodia and A. Burnap, *Revision* at **Journal of Marketing Research**

The End