UNIVERSITY OF MARYLAND

How Designs Differ: Non-linear Embeddings Illuminate Intrinsic Design Complexity

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August 22, 2016

Motivation

Fully **unsupervised** method to construct low dimensional **semantic spaces** from high dimensional design spaces

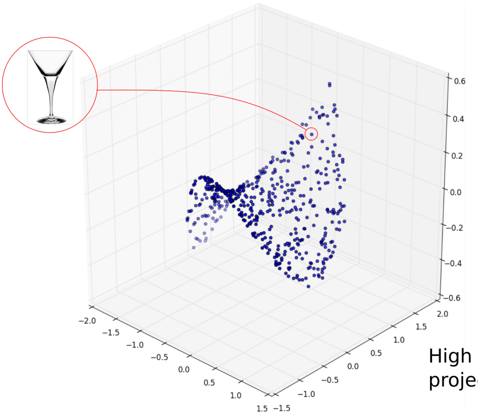
Continuous generation of new **valid** designs by exploring the semantic space

Valid vs Invalid Design

Design representation using Bezier curves:
dimensionality / degrees of freedom?

Manifold Assumption

High dimensional design parameters actually lie on a lower-dimensional manifold (semantic space)



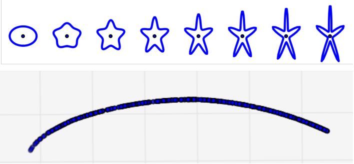
High dimensional design space projected to 3D by PCA

Experiment samples

Synthetic example: superformula

$$(x, y) = superformula(a, b, m_1, m_2, n_1, n_2, n_3)$$

Linear: vary aspect ratio



Nonlinear: vary n_2 and n_3

Multiple categories: vary m_1 or m_2

Experiment samples

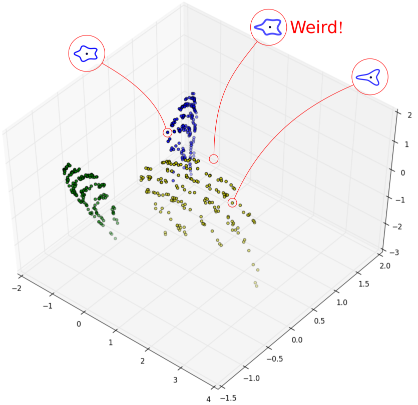
Real-world example: glassware

Design Space Properties

Start by learning the properties of design spaces.

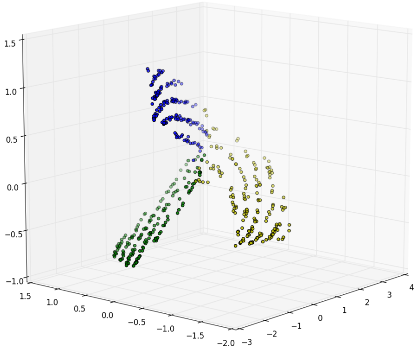
Why?

Design Space Properties



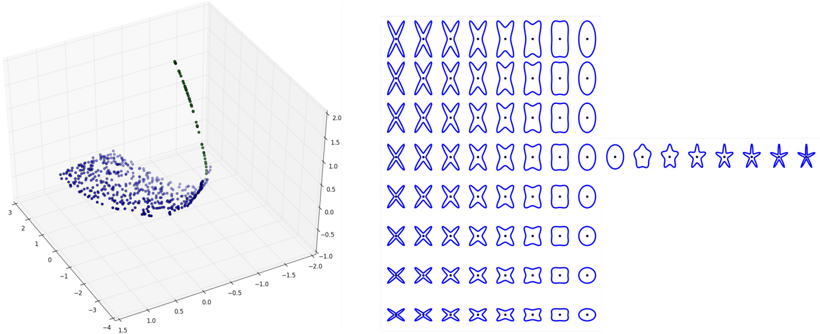
Multiple manifolds

Design Space Properties



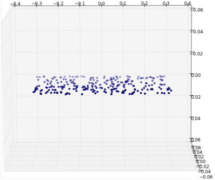
Multiple manifolds with intersection

Design Space Properties

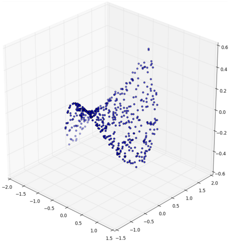


Multiple manifolds with different intrinsic dimensionality

Design Space Properties



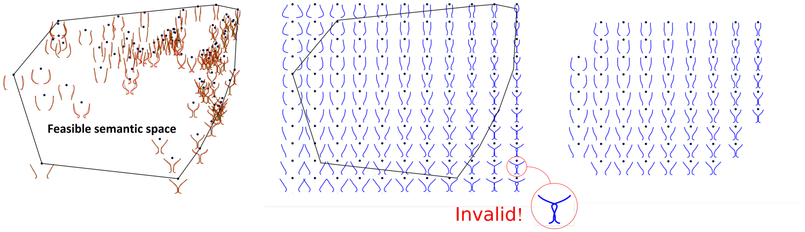
Linear: PCA



Nonlinear: kernel PCA, autoencoder, ...

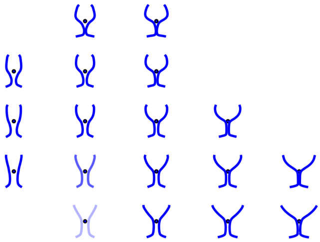
Design Embedding and Reconstruction

Embedding: $f : \mathcal{X} \rightarrow \mathcal{F}$
Reconstruction: $g : \mathcal{F} \rightarrow \mathcal{X}$
Choose valid designs in a semantic space



Design Embedding and Reconstruction

How glassware designs differ?



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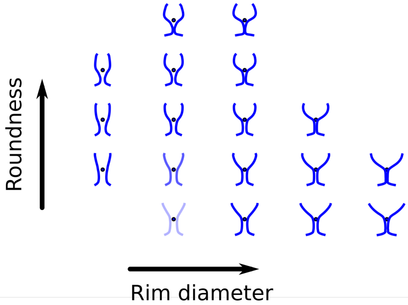

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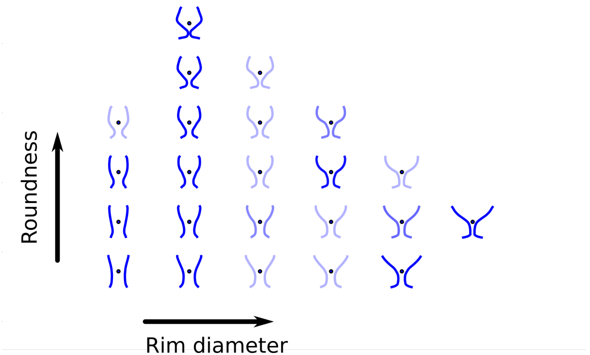

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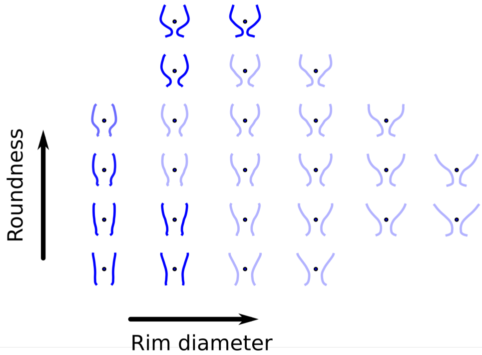

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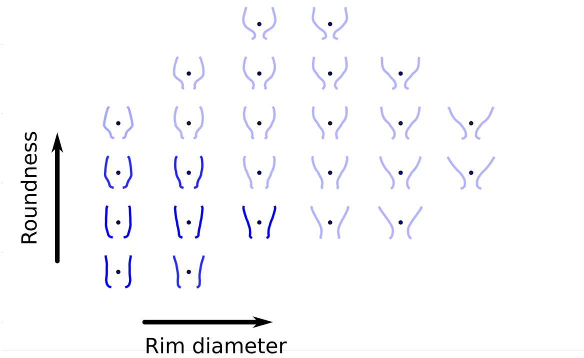

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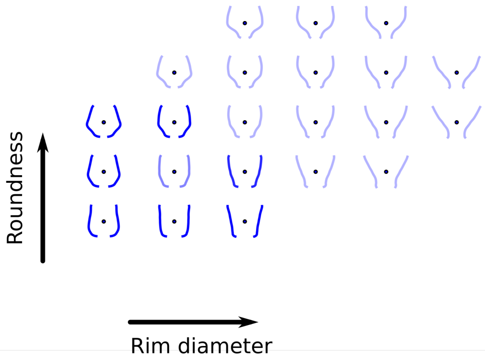

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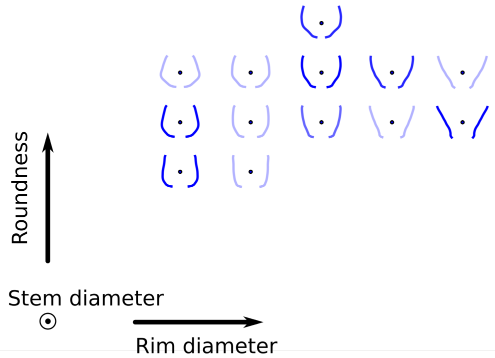

Application Examples

Design optimization: $\mathcal{X} \in \mathbb{R}^{\mathrm{D}} \to \mathcal{F} \in \mathbb{R}^{\mathrm{d}}$, continuous

Semantic-based design automation: $\mathcal{F} \to \mathcal{X}$

Thank you

Get code+data:
`github.com/IDEALLab/design_embeddings_idetc_2016`

Get paper:
`ideal.umd.edu/publications.html`

Get in touch:
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