Stochastic Computational Methods for Designing Complex and Emerging Systems

IDEAL
Integrated DEsign Automation Laboratory

Dr. Wei Chen, Wilson-Cook Professor in Engineering Design, Mechanical Engineering, Northwestern University

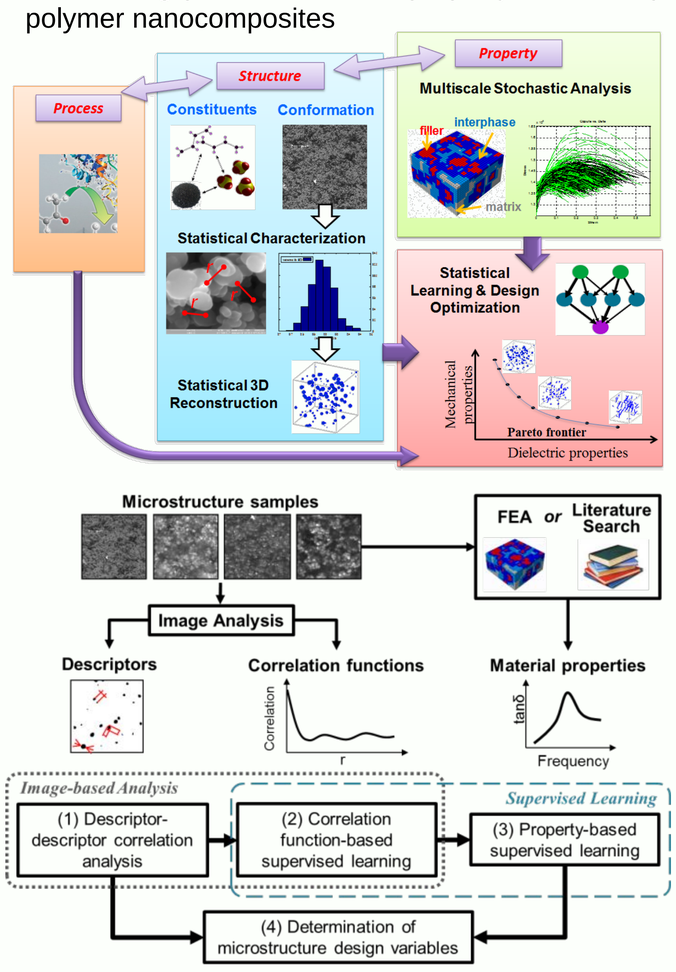
GRANTS

Nanostructured Materials System (NMS)	Complex Customer-Product Networks	Multifidelity and Multidisciplinary Optimization under Epistemic Uncertainty
DEMS-1334929 Engineering Polymer Nanodielectric Systems Using a Descriptor-Based Design Methodology (PI: W. Chen, Co-PIs: C. Brinson and L.Schadler). EDI-1130640 Robust Design to Account for Geometric Imperfections in Small-Scale Structures (PI: W. Chen, Co-PI: C. Sun)	ESD-1436658 Multidimensional Network Analysis for Analyzing and Predicting Complex Customer-Product Relations in Engineering Design (PI: W. Chen, Co-PI: N. Contractor, Ford Motor Company)	ESD-1537641 Model-Based Multidisciplinary Dynamic Decisions in Design (PI: B. German, D. Apley; Co-PI: W. Chen)

METHODS & RESULTS

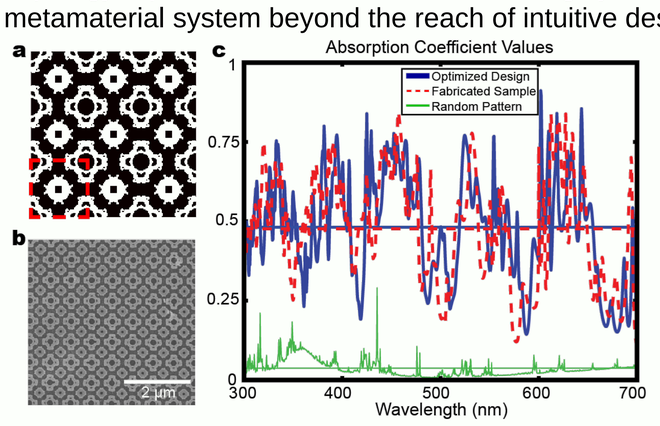
Heterogeneous Polymer Nanocomposites

❖ Descriptor based computational design framework for establishing process-structure-property relationship of polymer nanocomposites



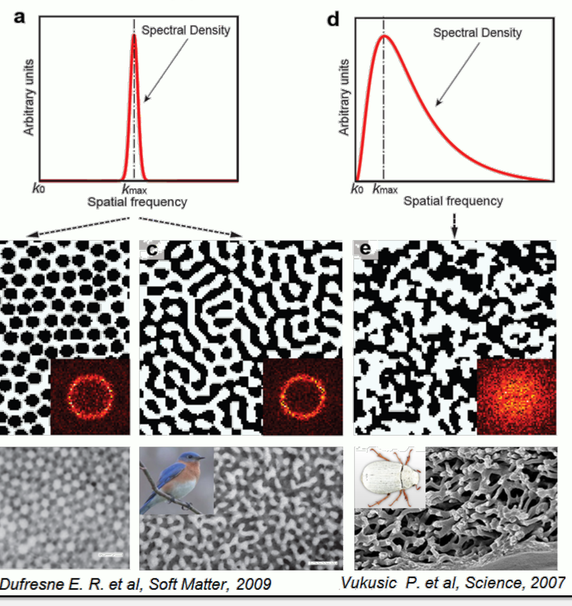
Metamaterials Design of Solar Cell

❖ Topology optimization method achieves highly efficient metamaterial system beyond the reach of intuitive design.



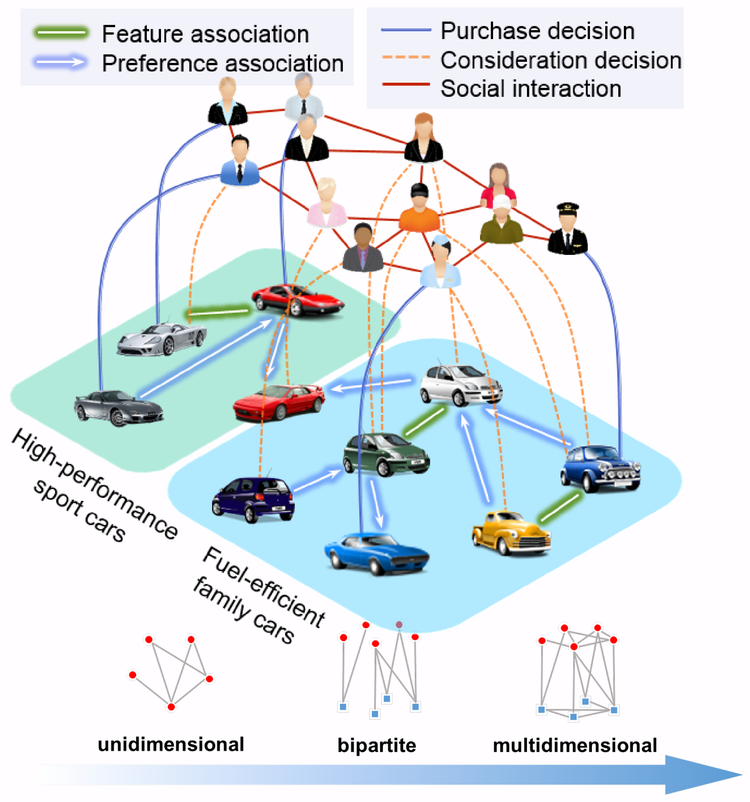
Quasi-Random Nanophotonics Design

❖ Bio-inspired non-deterministc design strategy to achieve high-performance quasi-random NMS for scalable manufacturing processes.



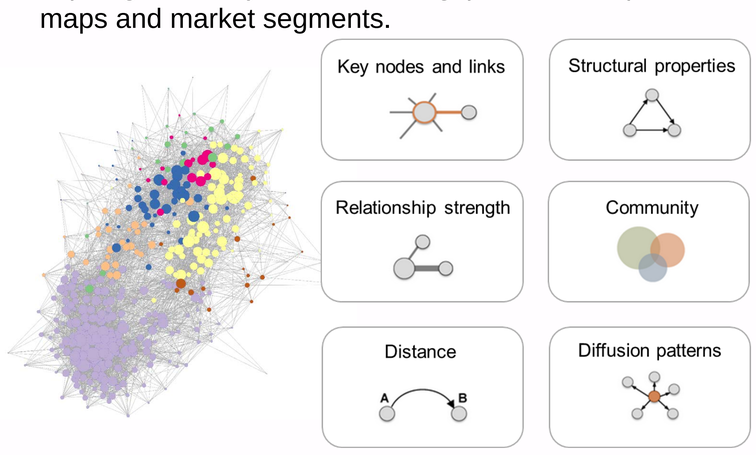
Dufresne E. R. et al, Soft Matter, 2009 *Vukusic P. et al, Science, 2007*

Multidimensional Customer-Product Network Framework



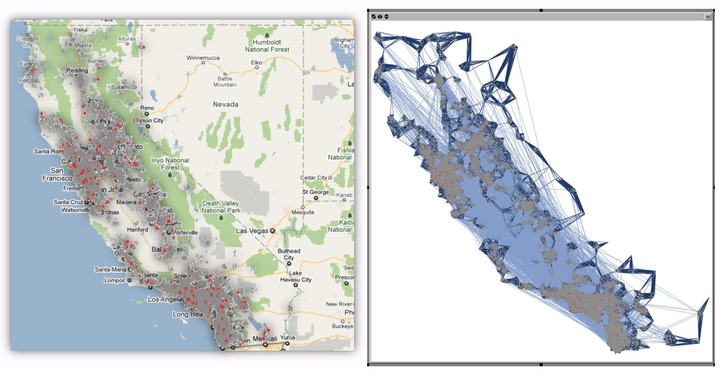
Product Network Structure Analysis

❖ Topological analysis for deriving product competition maps and market segments.



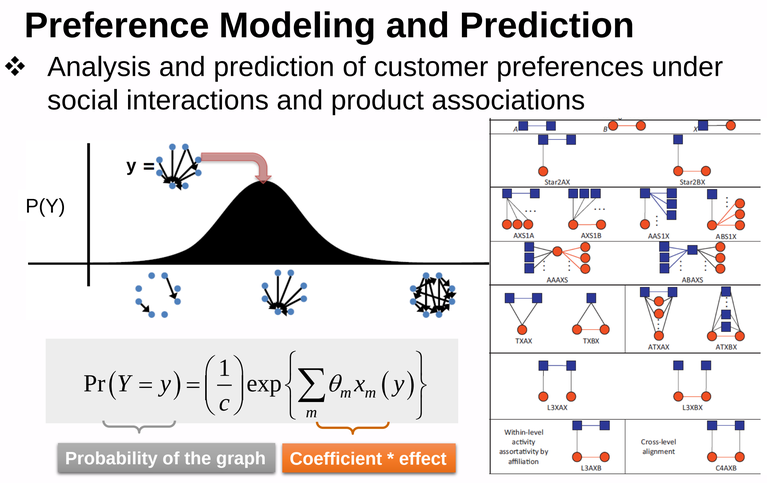
Social Network Simulation

❖ Simulation of customer social interactions based on small word model and social distance theories.



Preference Modeling and Prediction

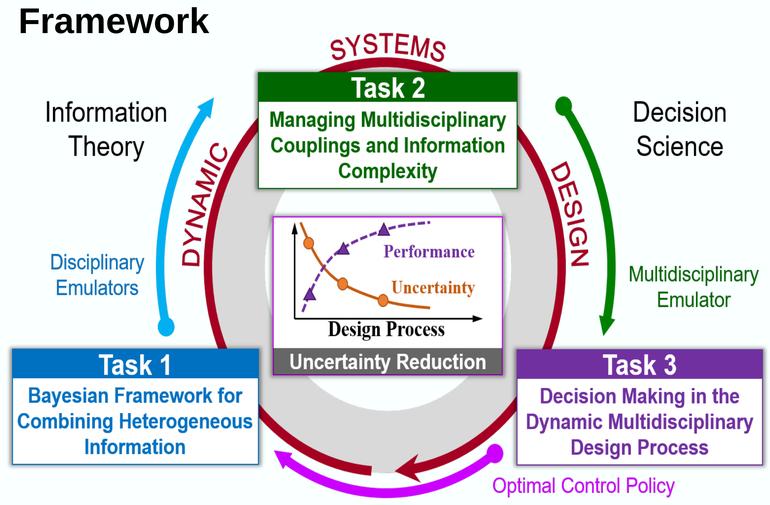
❖ Analysis and prediction of customer preferences under social interactions and product associations



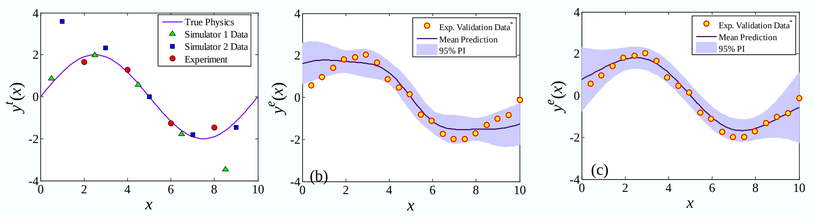
$$\Pr(Y=y)=\left(\frac{1}{c}\right)\exp\left\{\sum_m \theta_m x_m(y)\right\}$$

Probability of the graph | Coefficient * effect

Multidisciplinary Uncertainty Reduction Framework



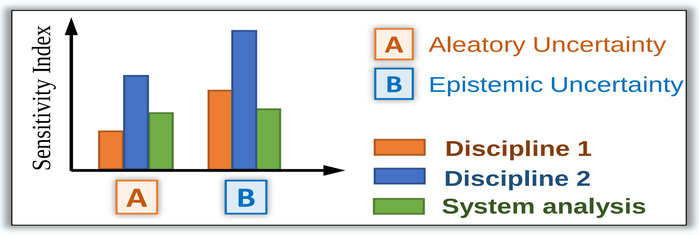
Non-hierarchical Multi- Model Fusion



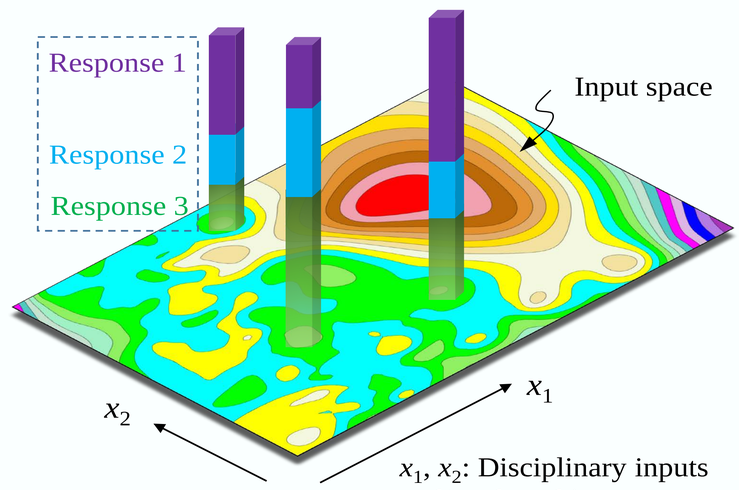
Weighted Sum $y^t(\mathbf{x}) = y^e(\mathbf{x}) - \varepsilon = \sum_i \rho^{\{i\}} y^{m\{i\}}(\mathbf{x}) + \delta(\mathbf{x})$

Parallel Combination $y^t(\mathbf{x}) = y^e(\mathbf{x}) - \varepsilon = y^{m\{i\}}(\mathbf{x}) + \delta^{\{i\}}(\mathbf{x})$

Multidisciplinary Global Sensitivity Analysis (MSSA)



Resource Allocation for Reducing Epistemic Uncertainty



- **Where** in the input space of a multidisciplinary system shall we allocate more resources?
- To **what** disciplinary response(s) shall we allocate more resources?
- **Which** type of resource shall we allocate, experiments or simulations?

Determine *near-optimal paths of information seeking actions* by maximizing decision-centric measures of information.

Key Publications

Xu, H., et al. "A Descriptor-based Design Methodology for Developing Heterogeneous Microstructural Materials System", *Journal of Mechanical Design* 2014. **Best Paper Award** in 2014 ASME IDETC/CIE-DAC.
Wang, C., et al., "Highly Efficient Light-Trapping Structure Design Inspired By Natural Evolution", ***Scientific Reports***, 2013.
Wang, M., et al. "A Multidimensional Network Approach for Modeling Customer-product Relations in Engineering Design", ASME IDETC2015-47302, 2015.
Jiang, Z. et al. "Resource Allocation for Reduction of Epistemic Uncertainty in Simulation-based Multidisciplinary Design", IDETC2015-47473, 2015.