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Mining End-Of-Life Materials Suitable For Material Resynthesis And Discovering New Application Domains

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PRESENTATION OVERVIEW

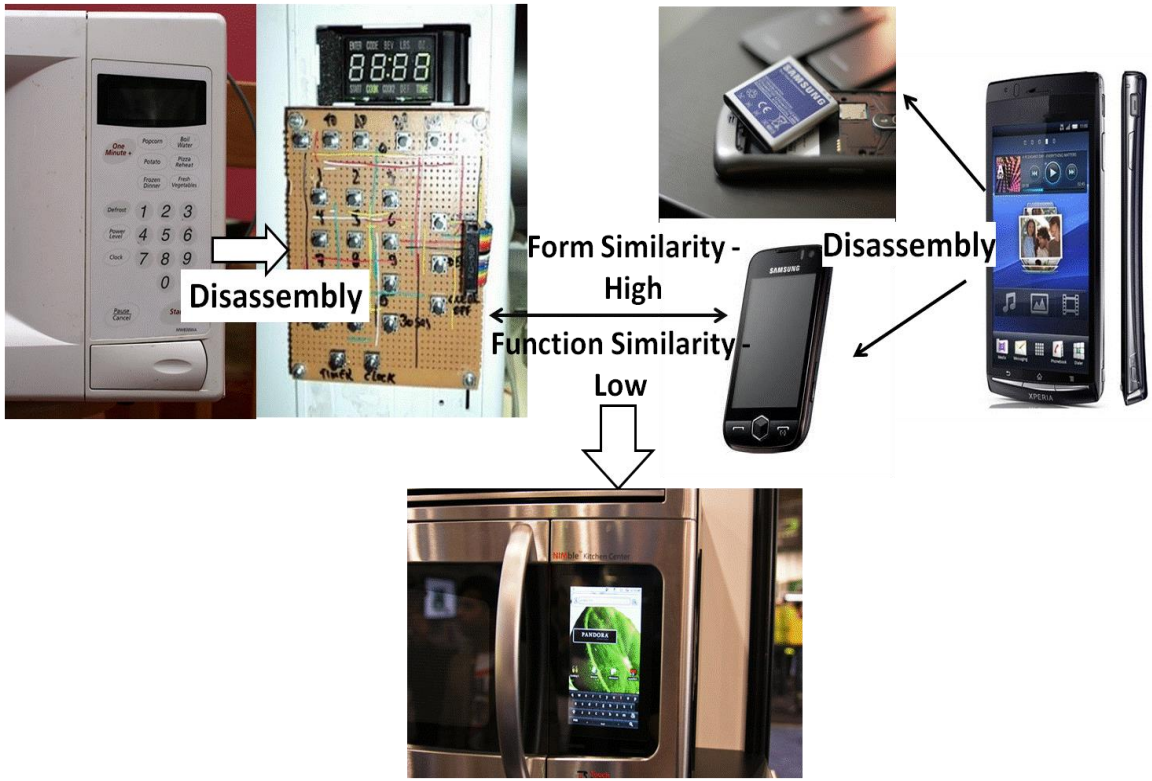
- Research Motivation
- Research Objectives
- Literature Review
- Methodology
- Results
- Path Forward

Research Motivation

- Over 2 million tons of electronic devices were discarded in the U.S in 2009 (also a global problem)
- Only 15-20% of electronic component based waste is treated with EOL decision-making, with the remainder of these electronics going directly to landfills and incinerators

Product Resynthesis

Utilizes existing waste from EOL products from diverse domains to create a new product distinct from its parent assemblies



Resynthesis as an EOL Strategy

Operation	Decision				
	Dispose	Reuse	Remanufacture	Recycle	Resynthesize
Collection	X	X	X	X	X
Transportation to disposal centers	X				
Dismantling	X		X	X	X
Refining	X			X	X
Machining			X		X
Disposal of waste	X				
Assembling					X

Relevant Literature

Product Resynthesis
New products from EOL Products
Kang et al. (2014), Sane and Tucker (2013)

Properties of New Material?

Hybrid Materials
A + B + shape + scale
Effective Properties
Ashby et al. (2013)

Appropriate Material?

Viable Application?

Materials Selection
Screening and Ranking, Kasaei et al. (2014), Chatterjee (2011)

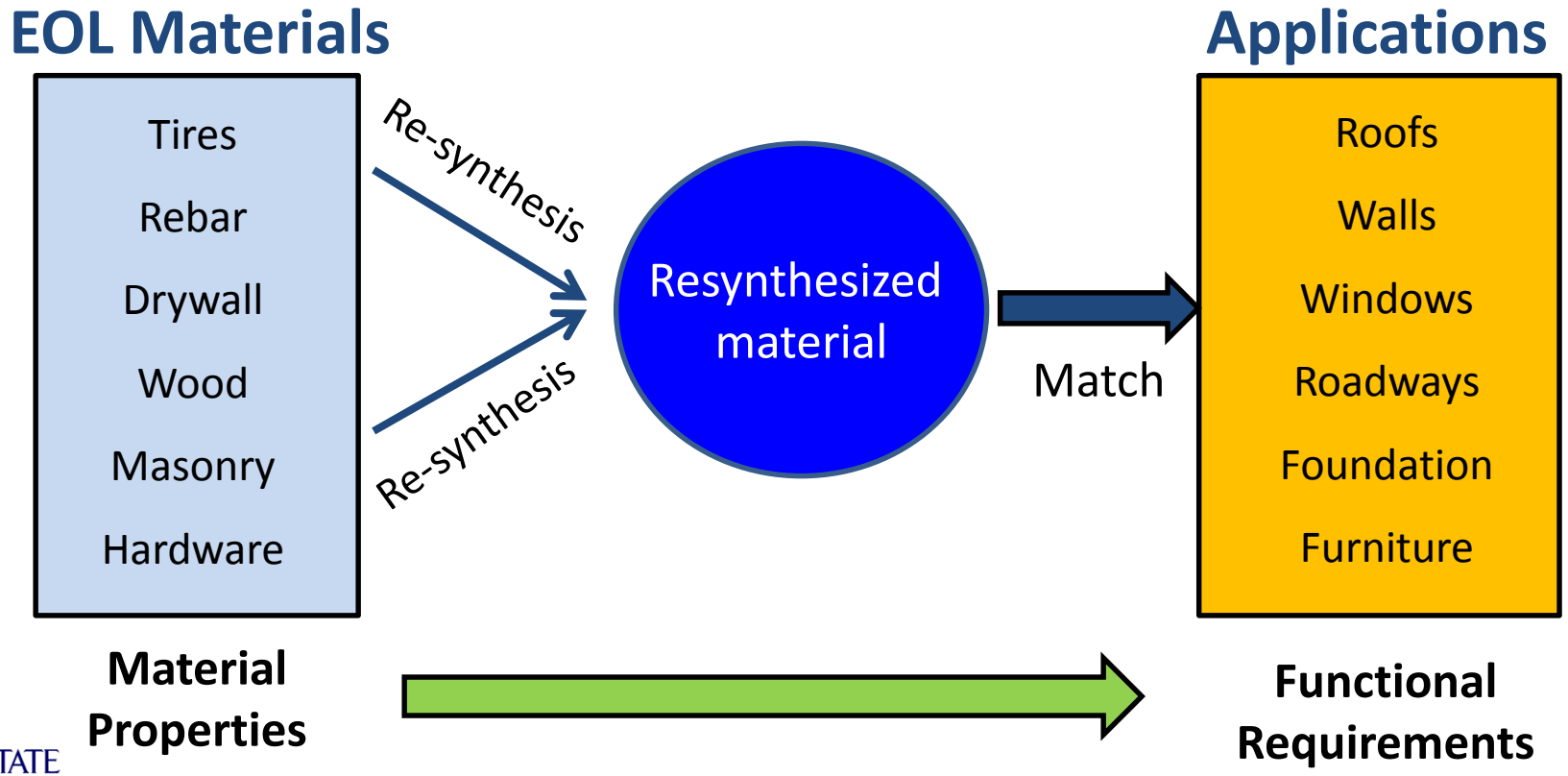
Application Selection
Search through Function
Substitution Matching Requirements
Smith et al (2012)

Limitations of Product Resynthesis

- Only explored combinations of components of EOL products (form and function)
- Potential material combinations, acquired from the processing of EOL components are not explored
- Limited exploration of application domains suitable for resynthesized material

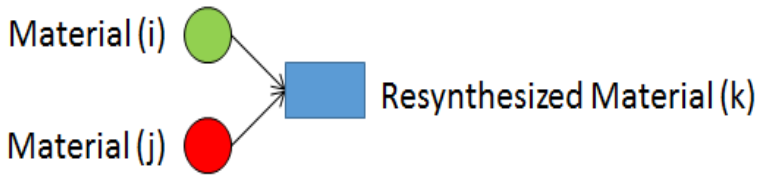
Research Objective

Identify materials suitable for <u>material resynthesis</u> that have the performance characteristics needed for certain application domains



Research Methodology

3.1: Resynthesized Material Generation

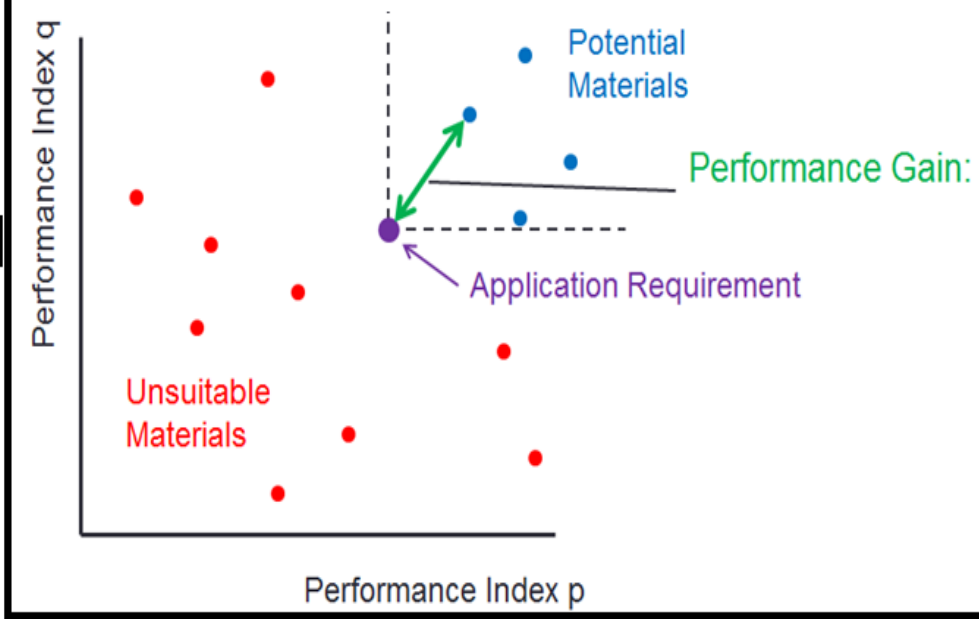


3.2: Evaluation of Resynthesized Material

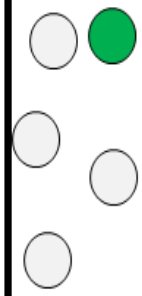
Resynthesized Material (k)

$$\rho_e = \rho_1(1 - VF) + \rho_2(VF)$$

3.3-3.4: Resynthesized Material-Domain Matching



3.5: Final Application Selection (LSA)



	Strength	Stiffness	...
Material (i)			
Material (j)			
Material (k)			

Product Database

Object	Image	3D Cad Image (*Form* data)	*Function* data
Screwdriver			Screw, shank, handle, rotate, pry lever
Calculator			Mathematical computation, add, subtract, multiply, divide, numbers

Product i

$\sum$ **Aggregate Material**

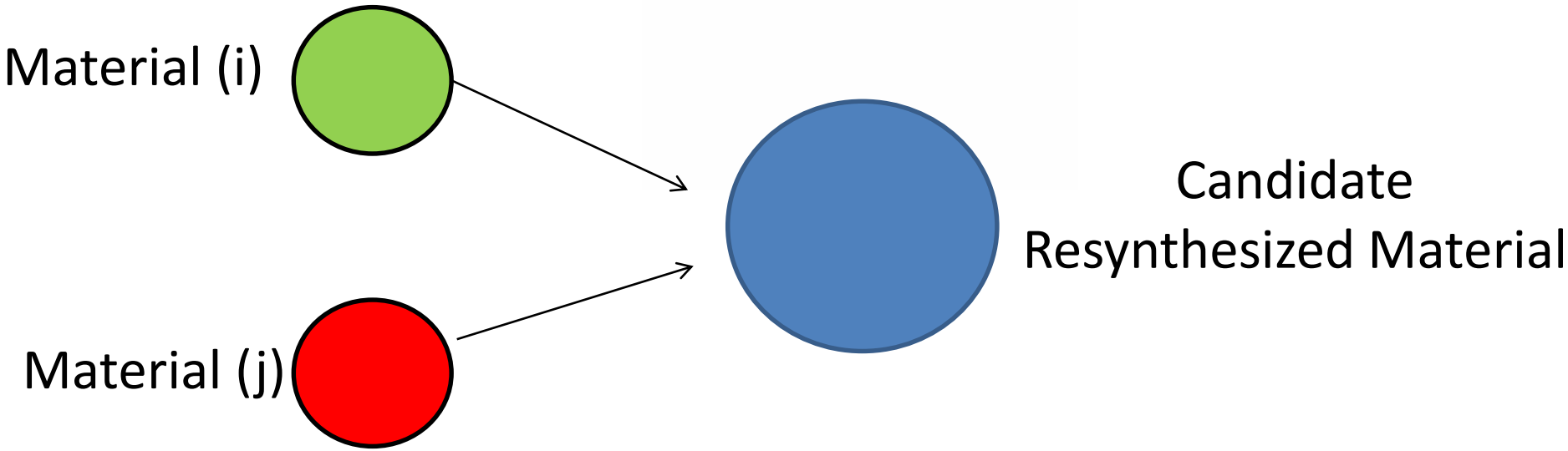
materials that can be easily ground into fine particles

e.g., wood

$\sum$ **Binder Material**

materials that can be converted into a liquid or semi-solid with the introduction of common solvents or heat

e.g., Thermoplastics



- Δthermal expansion coefficients of the materials <ε
- Melting or decomposition temperature of the aggregate < processing temperature of the binder.

Predicting properties of hybrid or composite material (Ashby and Bréchet (2000))

$$\rho_e = \rho_1(VF_1) + \rho_2(VF_2) + \rho_3(VF_3) \quad (1)$$

Where,

ρ_i is the density of material i

VF_i is its volume fraction

$VF_1 + VF_2 + VF_3 = 1$

Performance indices (PIs) for evaluating the effectiveness of material resynthesis

Function	PI
Lightweight Strong Axial Support	σ / ρ
Lightweight Stiff Beam	$E^{1/3} / \rho$
Thermal insulator	$1/k$

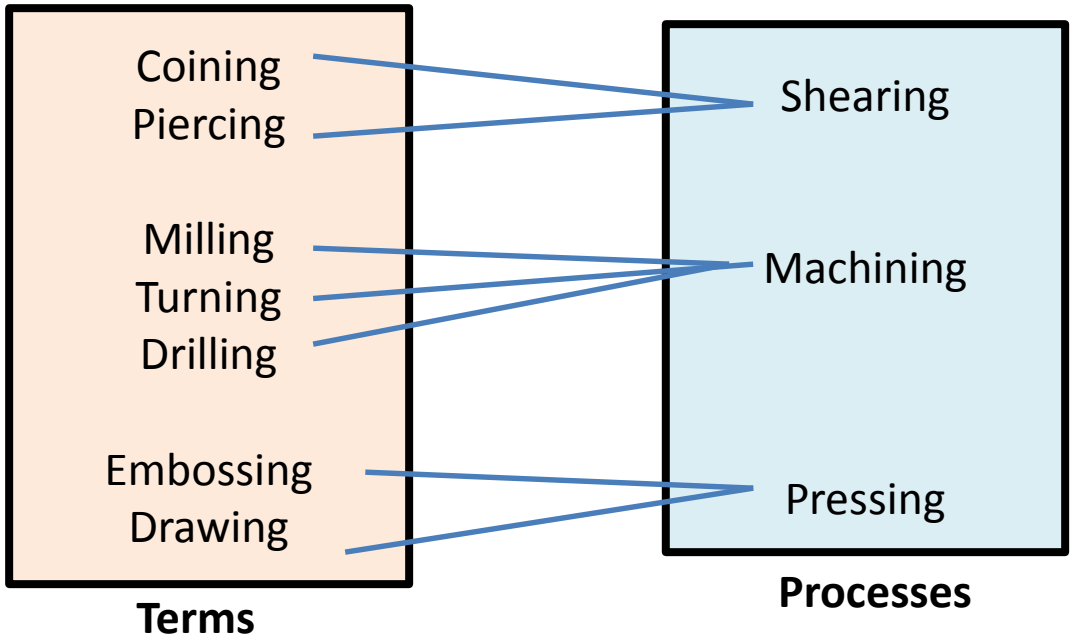
Quantifying Material-Application

		Textual Data Base of Materials and Applications			
		Material (i)	Material (j)	..	Application (k)
Functional Descriptive Terms	Term 1	$C_{1,1}$	$C_{1,2}$	..	$C_{1,n}$
	Term 2	$C_{2,1}$	$C_{2,2}$	..	$C_{2,n}$
	.	.	.	..	.
	.	.	.	..	.
	Term M	$C_{m,1}$	$C_{m,2}$	..	$C_{m,n}$

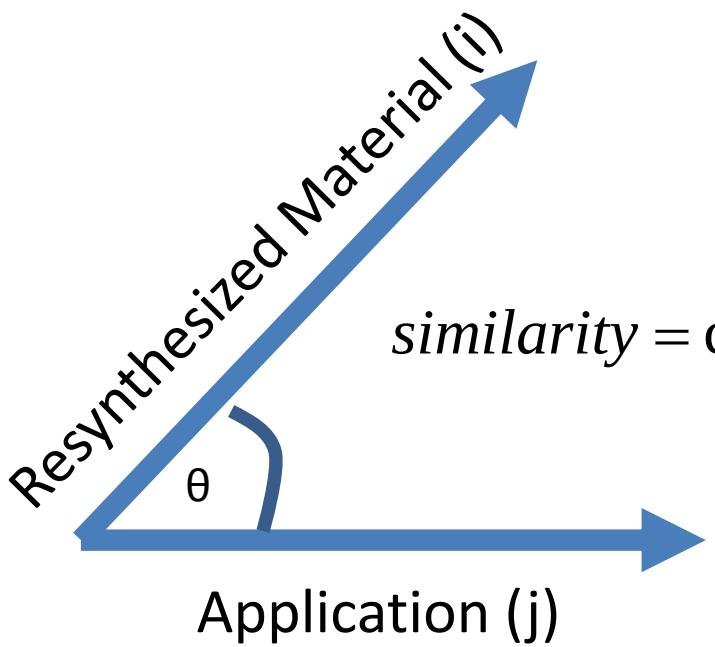
Latent Semantic Analysis

- Data Mining Algorithm for quantifying relationships between textual documents

Example of synonymy:



Quantifying Resynthesized Material-Application Compatibility

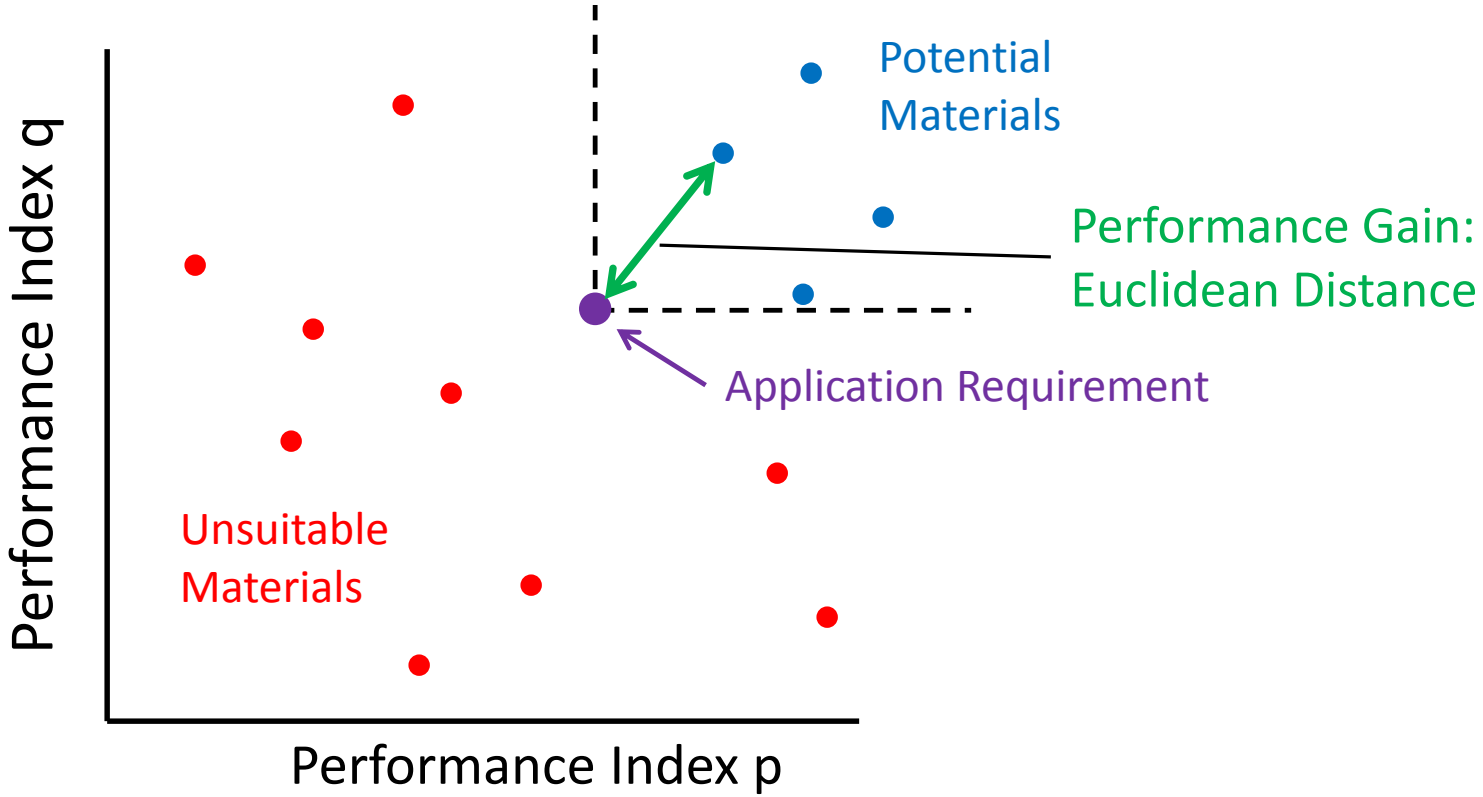


$$similarity = \cos(\theta) = \frac{D_i \cdot D_j}{\|D_i\|\|D_j\|} = \frac{\sum_{q=1}^{Q} D_{q,i} D_{q,j}}{\sqrt{\sum_{q=1}^{Q} (D_{q,i})^2}\sqrt{\sum_{q=1}^{Q} (D_{q,j})^2}}$$

* David M. Blei, Andrew Y. Ng, and Michael I. Jordan. Latent dirichlet allocation. J. Mach. Learn. Res., 3:993–1022, March 2003.

Screening by Performance Indices

N Relevant Performance Metrics → N Dimensional Space



Case Study: Material Resynthesis

Product Database

EOL Car

EOL Steering Wheel

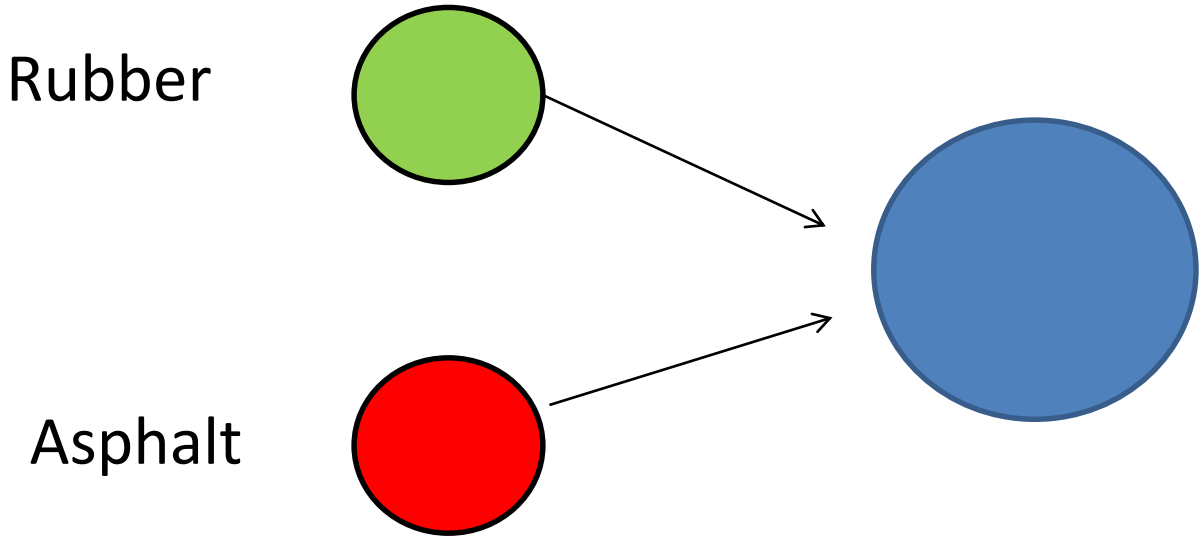
EOL Tires

EOL Engine

Product Database

Object	Image	3D Cad Image (*Form* data)	*Function* data
Screwdriver			covers the wheel's rim to protect it..
Calculator			Mathematical computation, add, subtract, multiply, divide, numbers

Data Acquisition → **Resynthesized Material Generation** → Resynthesized Material Evaluation → Resynthesized Material-Application Matching



Candidate Resynthesized Material =Rubberized Asphalt

Data Acquisition → Resynthesized Material Generation → Resynthesized Material Evaluation → Resynthesized Material-Application Matching

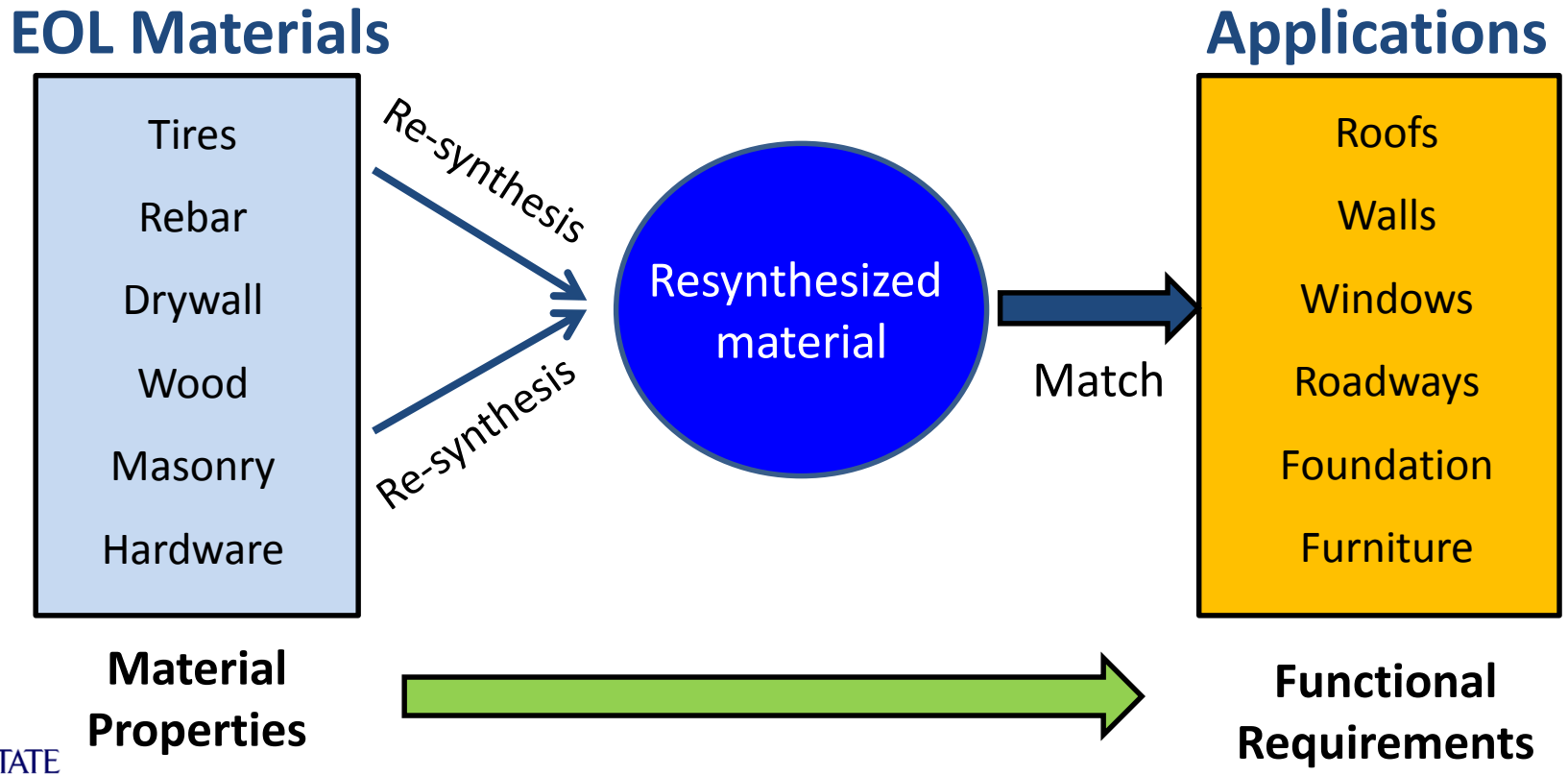
Predicting properties of hybrid or composite material

	E/ρ	UTS/ρ	Ductility
Glass-Asphalt	0.90	0.00	0.43
Glass-PVC	0.93	0.90	0.89
Glass-Concrete	1.00	0.25	0.27
Glass-Rubber	0.94	0.75	0.94
Concrete-Asphalt	0.85	0.07	0.44
Concrete-PVC	0.90	0.35	0.89
Concrete-Rubber	0.90	0.38	0.94
Rubber-Asphalt	0.45	0.11	0.94
Rubber-PVC	0.46	0.86	0.98
Asphalt-PVC	0.53	0.08	0.89

	Polypropylene + Brick	Asphalt + Concrete	Epoxy + Sawdust
Roof	0.30	0.31	0.23
Furniture	0.38	0.48	0.28
LoadBearing Wall	0.31	0.33	0.26
Road Surface	0.62	0.56	0.49
Footpath	0.28	0.38	0.19
Acoustic Board	0.24	0.18	0.19
Thermal Insulation	0.56	0.37	0.51
Window	0.37	0.54	0.28

Conclusion and Path Forward

Identified materials suitable for <u>material resynthesis</u> that have the performance characteristics needed for certain application domains



Acknowledgement & References

Contributors:

- D.A.T.A. Lab: Kristopher Doll, Conrad S.Tucker, Suja John

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Questions