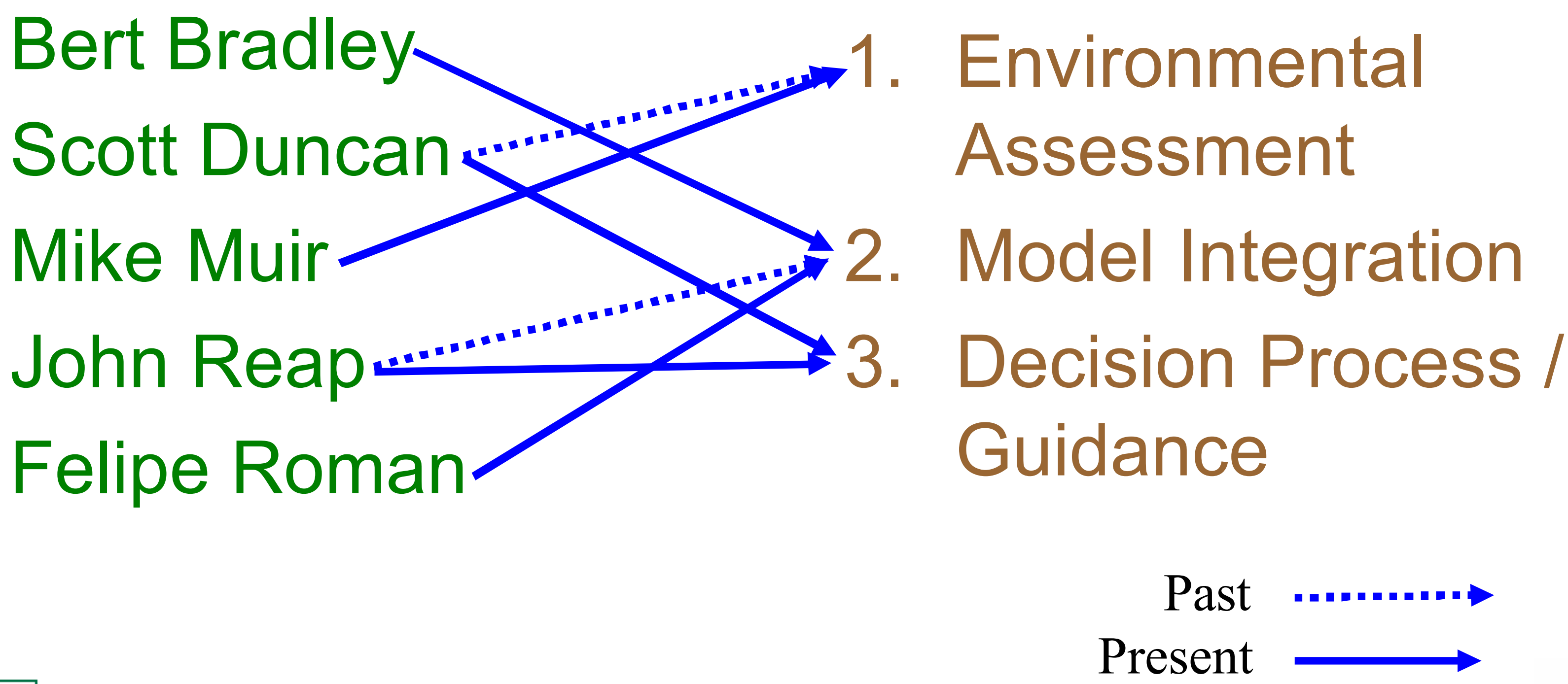
Environmentally Conscious Design & Manufacturing Group

Research Overview to SRL

ECDM Mission

- "Researchers in the ECDM program will develop methodologies and decision support tools that integrate the best business practices with those that produce superior environmental and social performance. Our research products will enable corporations to recognize, pursue and embrace triple bottom line goals."

People & Research Domains



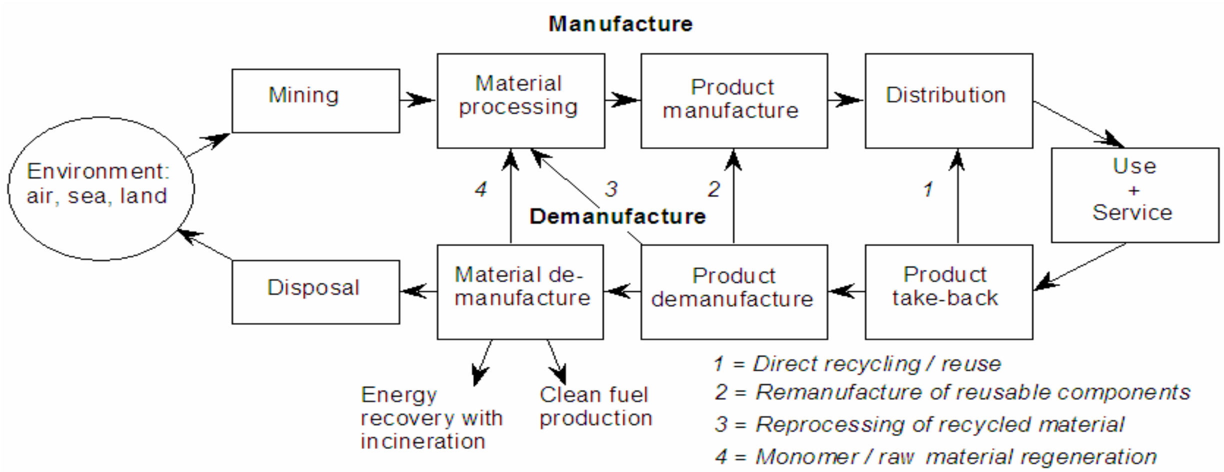
Michael Muir

LCA for Product Service System Design

Consumer Imaging Systems

Industry Case Study: Eastman Kodak Company

LCA for Product Service System Design



Life Cycle of a Product (Bras 1997)

Life Cycle Perspective

LCA Structure:

Life Cycle Assessment

1) ISO 14040: Goal & Scope Definition
2) ISO 14041 Inventory Analysis
3) ISO 14042 Impact Assessment
4) ISO 14043 Improvement Assessment

Biomimicry for Environmentally Benign Engineering

By:

John Reap

For:

Systems Realization Laboratory

July 26, 2005

Motivation & Objectives

Motivation

- Current ECDM / EBE tools ad-hoc and retrospective
  - Not based on guiding principles or theory
  - Find errors after commission in design / manufacturing
- Biomimicry Limited to Technical Innovation
  - Reductive

Objectives

- Propose and Define Holistic Biomimicry
- Integrate EBE with Holistic Biomimicry
- Evaluate life's characteristics as an instantiation of Holistic Biomimicry

Approach

- Verify reductive biomimicry's lack of utility for EBE
  - Comparative environmental assessments
- Compare EBE guidance with life's characteristics
  - Qualitative research using literature
- Apply and evaluate life's characteristics in (re)design scenarios
  - (Re)design scenarios
  - Environmental Impact assessment

Preliminary Results

Products	Upstream Activities (Pt)	Distribution (Pt)	End of Life (Pt)	Total Impact (Pt)
Stomata-Mimic	2.44×10^{-5}	4.33x1[illegible]	[illegible]	**2.50×10^{-5}**
P. Polychl.	$2.27\text{-}7.95 \times 10^{-5}$	$4.03\text{-}14.1 \times 10^{-7}$	$1.55\text{-}5.41 \times 10^{-7}$	**$2.33\text{-}8.14 \times 10^{-5}$**
Porous Nylon Sheet	5.14×10^{-6}	4.93x1[illegible]	[illegible]	**5.21×10^{-6}**
Polyethyl. Sheet	3.53×10^{-6}	1.34×10^{-7}	3.14×10^{-8}	**3.70×10^{-6}**
Barbed Wire Fence	3.51	0.06[illegible]	[illegible]	**3.58**
Post and Rail Fence	7.30	0.16	0.00	**7.46**

Sometimes

No

Yes / No

Summary

1. Reductive biomimicry lacks utility for EBE
2. Test development NOT proving straightforward

SRL Connection

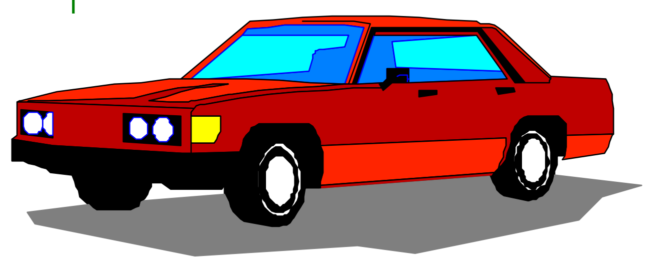
Tools

1. MATLAB
   - Others better
2. Spatial Modeling Environment (SME)
   - Barely
   - Patuxent Ecosystem Landscape Model
3. Fanuc Robot
   - Can make it go
4. Life Cycle Assessment
5. ABCEM
   - Nodding acquaintance

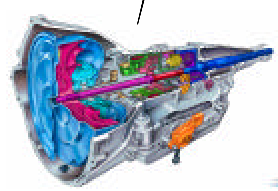
Mutual Interests

- Modeling
- Previous Case Studies
  - Compiling a list
- DSPs
  - Maybe

Environmentally Conscious Design: Automotive Life Cycle



Use phase, end-of-life focus:
- **Scott Duncan**

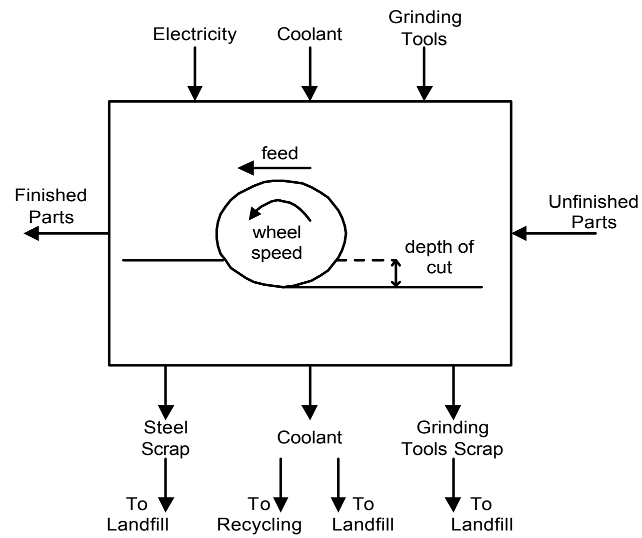


Manuf. Focus:
- **Bert Bradley**
- **Felipe Roman**

Bert Bradley

Development of Total Cost Models for Transmission Gear Design

- Goals
  - Develop Predictive Cost Models
    - Value stream mapping
  - Reduce Total Costs through Design



- Summer: Gather Info on Major Process Steps
  - Hobbing - Chamfering - Heat Treat
  - Grinding - Honing - Washing

Felipe Roman-Morales

Environmentally Conscious Machine-based Computer Aided Process Planning

Motivation & Objectives

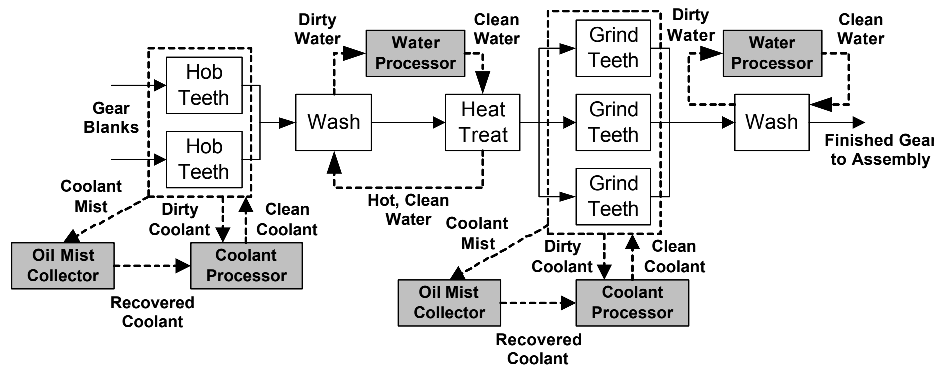
- Motivation
  - Previous attempts to conduct environmentally conscious process planning (ECPP) have:
    - Focused on feature-based CAPP approaches only
    - Not considered the whole machine or auxiliary processes
    - Focused on some machining operations, not the whole line or cleaning operations
- Objectives
  - Develop simple machine-centered environmental models to support ECPP
  - Develop framework for integrating models into various CAPP approaches

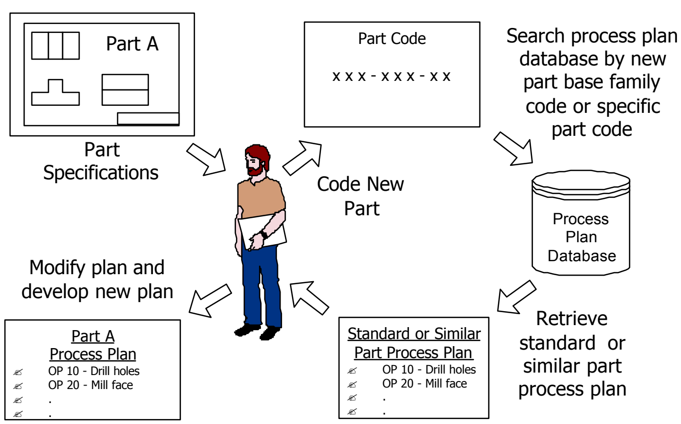
Approach

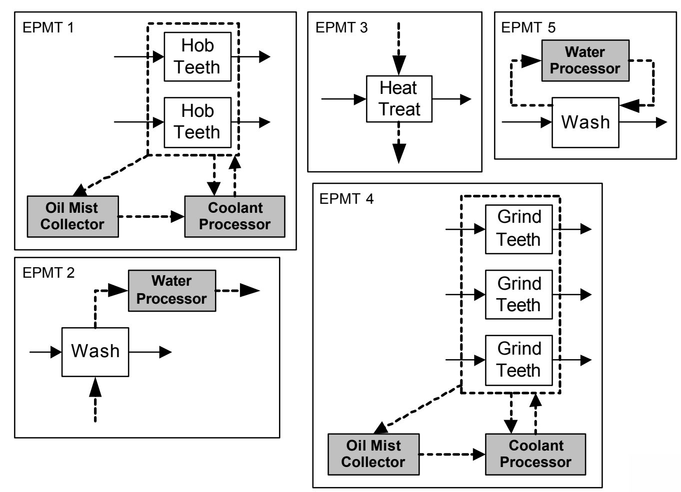
- Verify feature-based environmental analysis do not properly support ECPP
  - Conduct simple manufacturing examples
- Develop simple machine-based environmental models to support ECPP approach
  - Use mass and energy balance models
- Compare feature-based ECPP approach to machine-based approach
  - Show superiority of machine-based approaches for ECPP
- Develop & Apply machine-based integration framework into different CAPP approaches
  - Conceptually show how to integrate models into Variant, Generative & Hybrid CAPP

Example: Variant CAPP

- Variant CAPP automates process planning by using a base process plan for part families
  - Develop environmental process model templates





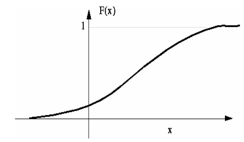


Scott Duncan

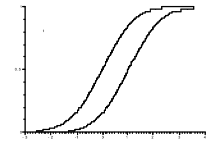
Design for Robustness to Severe Uncertainty in the Product Life Cycle using Info-Gap Decision Theory (IGDT)

Motivation

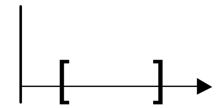
Uncertainty information



- Distribution params, μ, s (frequentist, Bayesian)
- Bounds within which distributions lie (P-box)



- Known bounds on the uncertainty (interval)



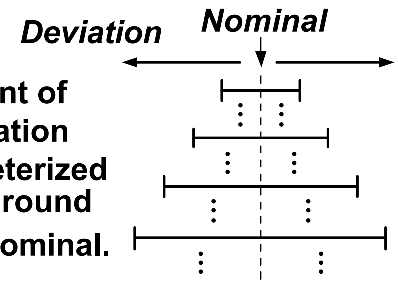
- **Severe uncertainty**
  - Size of bounds on deviation is unknown

When does use of traditional models require unsafe assumptions?

- <u>Goal</u>: support decisions in product life cycle design when lack of information creates *severe uncertainty*, e.g., in:
  - Material recovery value or demand
  - Customer behaviors
  - Force and thermal loads
  - Environmental impact of burdens
- How much robustness to *severe* uncertainty can/should designs achieve?

Foundations

To the designer's limited knowledge, input deviation could be any of a large range of sizes.



Extent of deviation parameterized by ? around some nominal.

Info Gap Decision Theory (Ben-Haim)

- Model
  - Parameterized uncertainty bounds around a nominal
- Philosophy
  - Determine how wrong you can be in the nominal estimate of input uncertainty and still guarantee some level of performance.
  - Sometimes better design to *guarantee* less performance than promise maximum performance at risk.
- IGDT Approach

When is employing info-gap too conservative?

  - Settle for some satisficed (not optimized) performance.
  - Over the design space, *maximize robustness* to uncertainty of unknown size while still guaranteeing that performance.
  - Investigate tradeoffs between performance and uncertainty.

Objectives

- Proposal: Apply IGDT to design that includes environm'l life-cycle performance with severely limited input info.
- Gaps in Knowledge
  - Undefined limits of IGDT applicability for archetype ECDM scenarios.
  - Inadequate integration of IGDT into multi-criteria design process.
- Research Hypotheses
  1. Results from experimental characterizations can be formulated into guidelines of when to use IGDT for different information availability & decision implications in ECDM problems.
  2. Concepts from existing multicriteria optimization methods can be used to make IGDT preference elicitation and tradeoff techniques compatible with multi-criteria design.

Approach

- RQ1: Range of IGDT applicability
  – Classify instances of severe uncertainty in ECDM
  – Solve design problems with IGDT& other robust design approaches
  – Compare performance to design found using complete information
  – Repeat tests for a range of conditions
    • Information availability
    • Implications of failure
- RQ2: Evaluating performance and preferences
  ✍ Identify possible solution principles from “classical” multicriteria (optimization) techniques for normalizing/balancing tradeoff preferences.
  ✍ Develop computational methods to enable design exploration
  ✍ Operationalize the tradeoff-curve evaluation processes
    ✍ Inducing preferences
    • Requirements for designer interaction
  ✍ Validate with multi-dimensional case studies

SRL Connections

Legacy

- Identification of applicability range of IGDT in design, bounded to environmentally conscious design examples.
- New decision support schemes for exploring tradeoffs and eliciting robustness preferences amidst *severe uncertainty*
  - Incorporation of robustness maximizing approach into multicriteria design.

Relation to other SRL work

- 266 Group (Uncertainty, Imprecision)
- Tech Square ME/ISyE Students
- Hae-Jin Choi (Uncertainty)

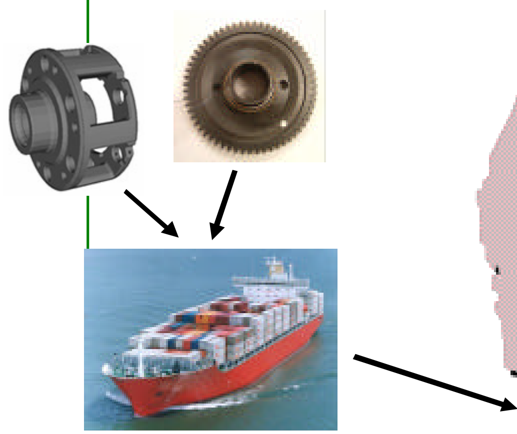
Expertise

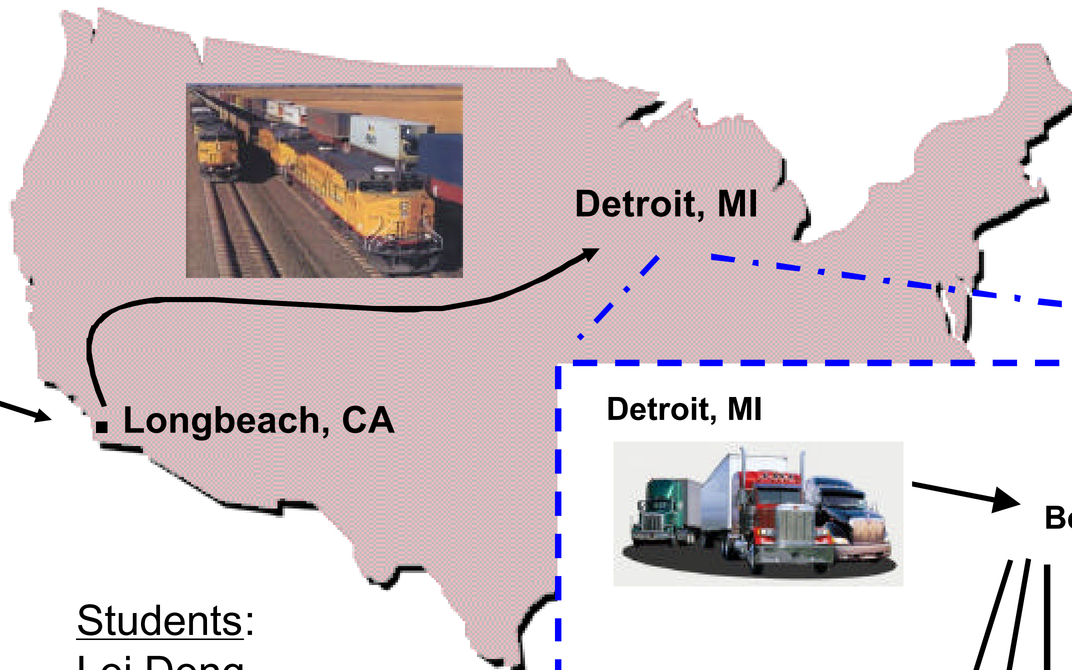
- Life Cycle Assessment for design concepts
- Optimization techniques
- Activity-Based Cost and Environmental Management (ABCEM)
- Off-the-shelf sensor selection and implementation
- Dealing with suppliers and contractors
- Tools
  - MATLAB (not a Pro, though)
  - RiskCalc (the basics)
  - SQLServer (storage of streaming data)
  - @Risk (the basics)

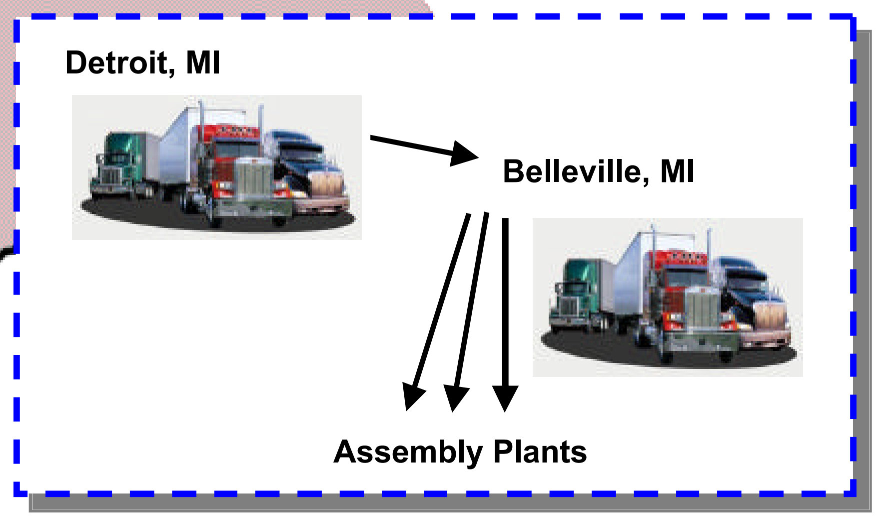
Work by ECDM Colleagues

Sustainable Packaging for International Logistics

Comparative Life Cycle Analysis: Waste, Energy, $







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Thanks

- Any questions?