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2ND ANNUAL
ENERGY & INNOVATION
CONFERENCE

Applications of Optimization to Industrial Problems

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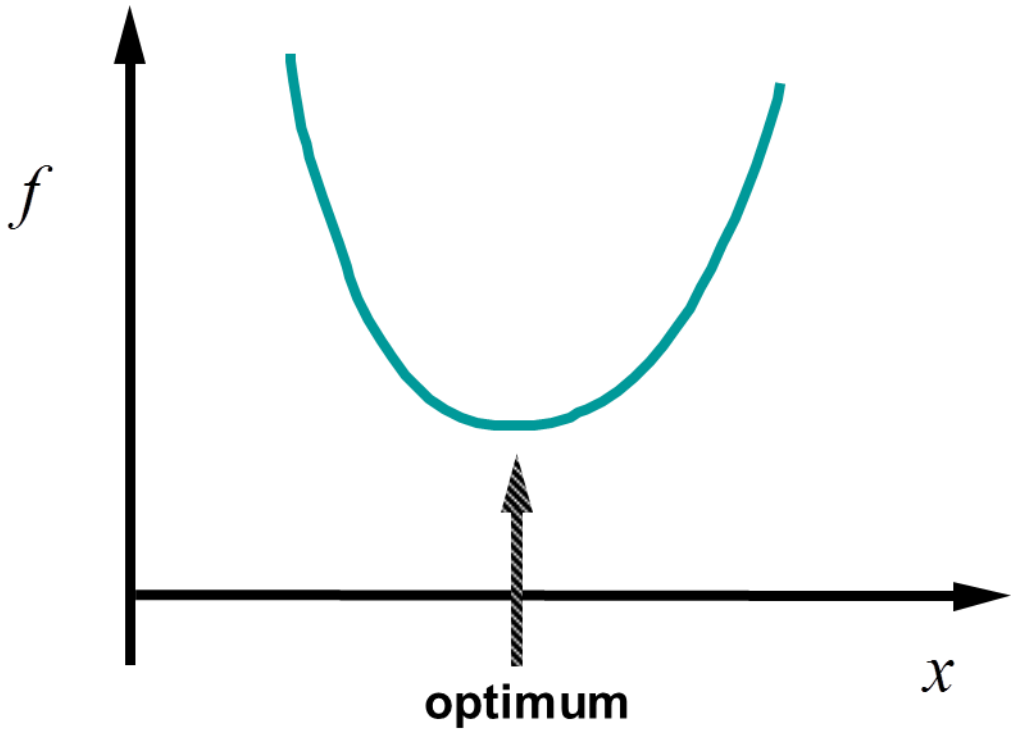
Optimization in 30 seconds

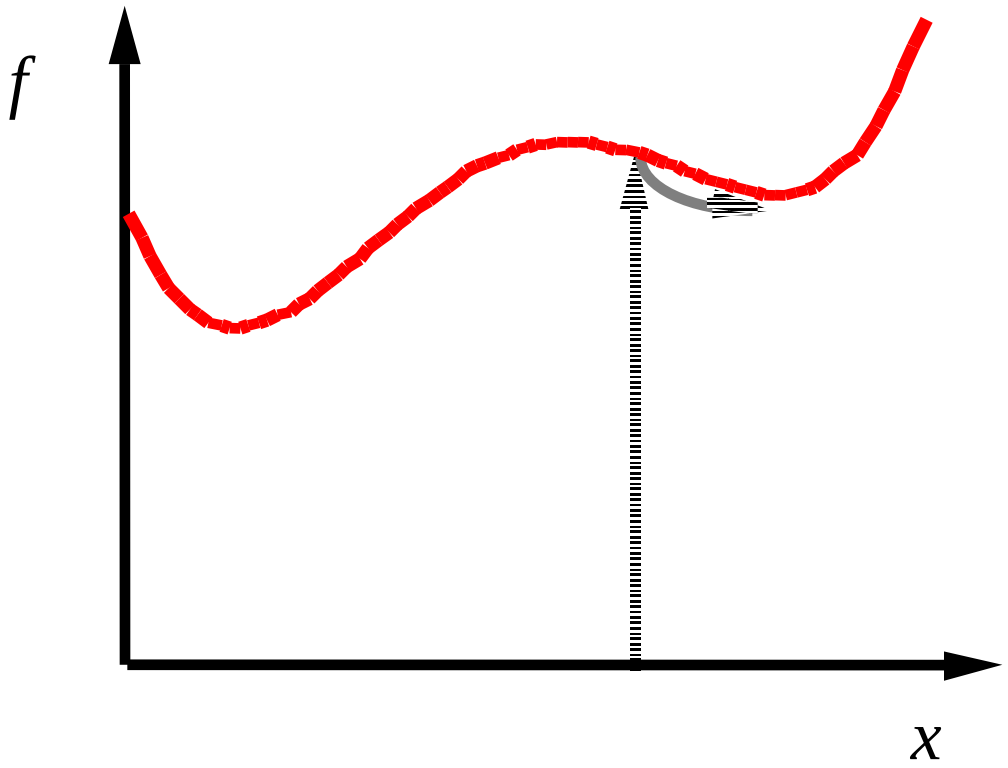


- The optimum is where the gradient of the function is zero

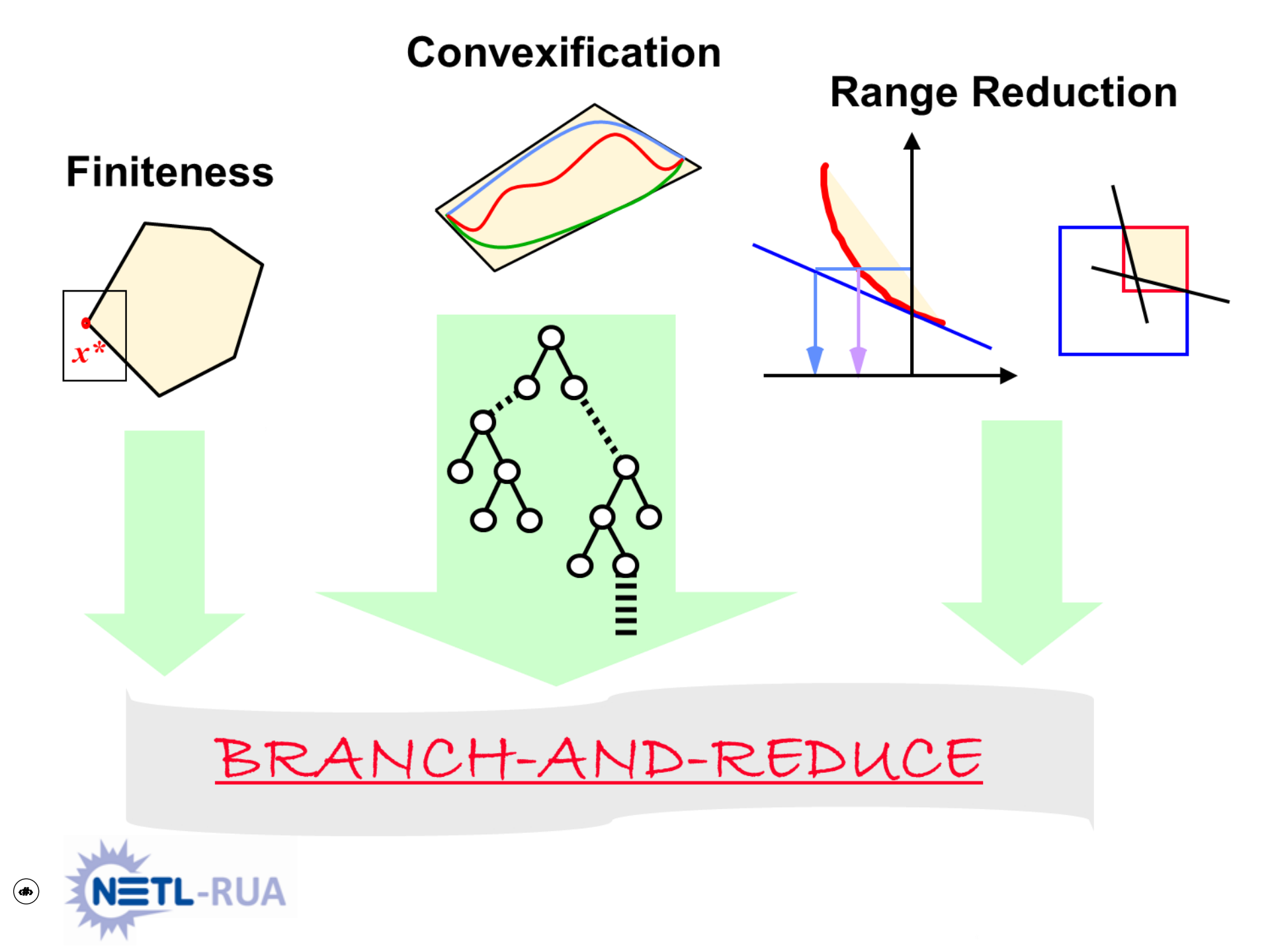
Historical Developments in Optimization

- 300 B.C: Shortest distance from a point to a line (Euclid)
- 1600s: Calculus (Leibniz/Newton)
- 1801: Least squares (Gauss)
- 1875: Minimum free energy principle (Gibbs)
- Late 40's: Linear optimization
  - Army operations; Linear objective function and constraints
- Late 50's: Nonlinear optimization
  - Chemical process industries; Nonlinear functions
- 60's: Integer optimization
  - Discrete manufacturing; Integer variables to model discrete decisions and economies of scale
- Today: Mixed-integer nonlinear optimization—MINLP

The Multiple Local Minima Challenge



- Classical optimization algorithms provide a local minimum “closest” to the starting point used


Convexification
Range Reduction
Finiteness
x*
BRANCH-AND-REDUCE
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BARON Software

- First commercial software to offer deterministic guarantee of global optimality for multi-extremal nonlinear optimization problems
- Two-pronged approach to technology transfer
  - Commercial
    - Under the modeling languages GAMS and AIMMS
  - Free
    - Under the NEOS server for optimization

Selected BARON Users

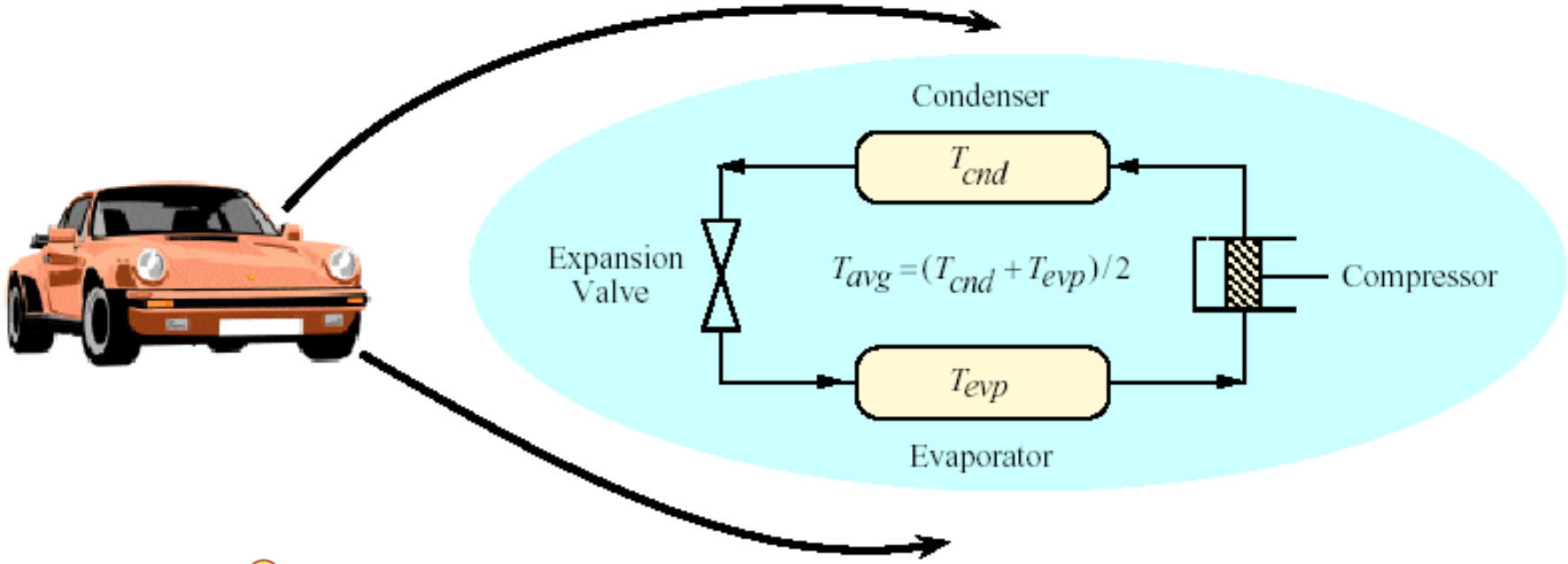
Academic institutions

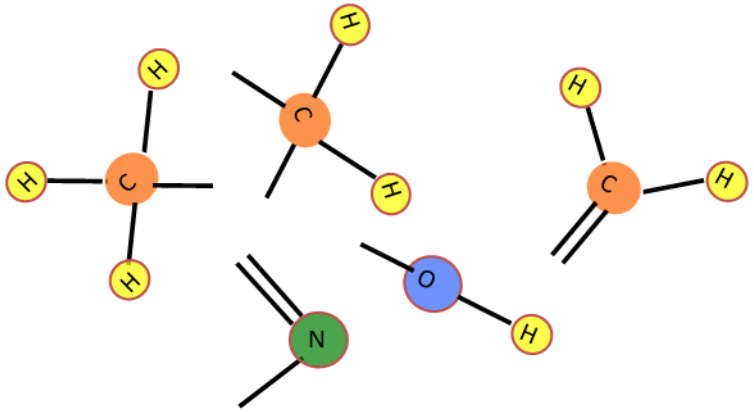
- MIT
- Pennsylvania State University
- RPI
- Lamar University
- Purdue University
- University of Oklahoma
- McMaster University
- Technical Univ. of Darmstadt
- Norwegian Univ. of Technology
- Middle East Technical University
- Australian National University
- IIT Delhi
- Amsterdam University
- Budapest University
- National Univ. of Singapore

Companies

- Pfizer
- ExxonMobil
- ISO New England
- Energy Greece
- Beijing Research
- Tokyo Gas
- China National Water
- Fort S Houston
- Danmarks Stat
- ABN AMRO Asset Management
- Countrywide
- Unilever
- Ecopetrol
- NEC Info Sys
- Comsoft Direct BV
- Shell Global Solutions

Automotive Refrigerant Design





- Higher enthalpy of vaporization (ΔH_{ve}) reduces the amount of refrigerant
- Lower liquid heat capacity (C_{pla}) reduces amount of vapor generated in expansion valve
- Maximize ΔH_{ve}/ C_{pla}

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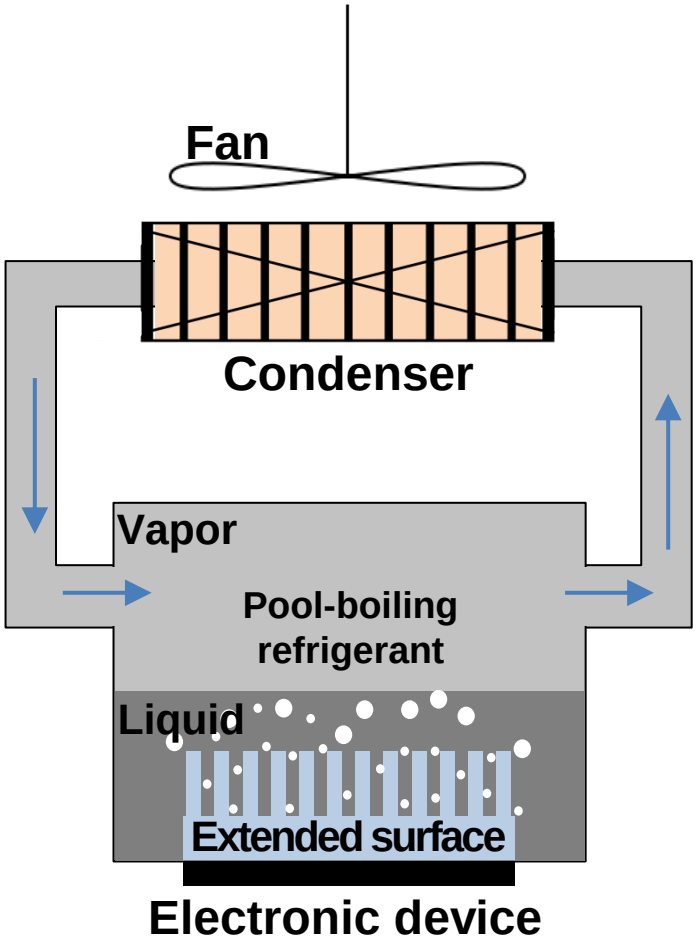
Electronics Cooling



- Continuous increase in circuit density
- Heat flux expected to exceed 1000 W cm^{-2}
- Industry wide accepted limit of 85^{o}C
- Current fluids show poor thermal properties

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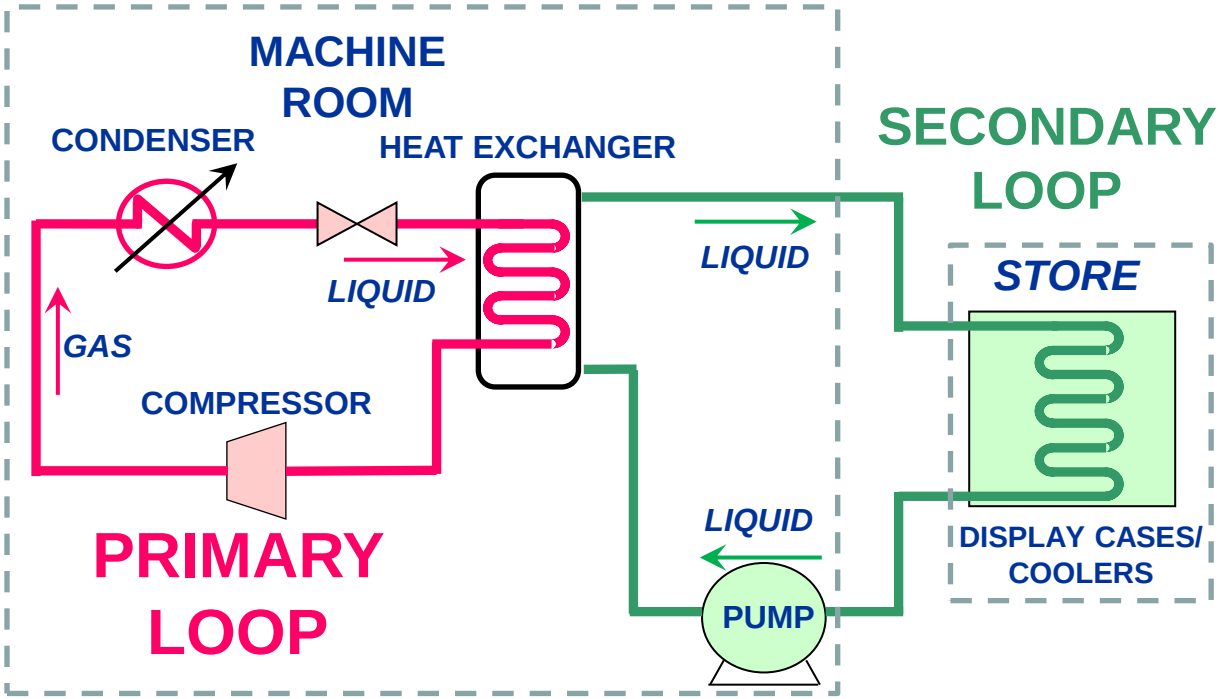
Heat Transfer Fluid Design



Reduce pumping costs	Low viscosity
High heat transfer rates	High thermal conductivity
Reduce refrigerant charge	High heat capacity

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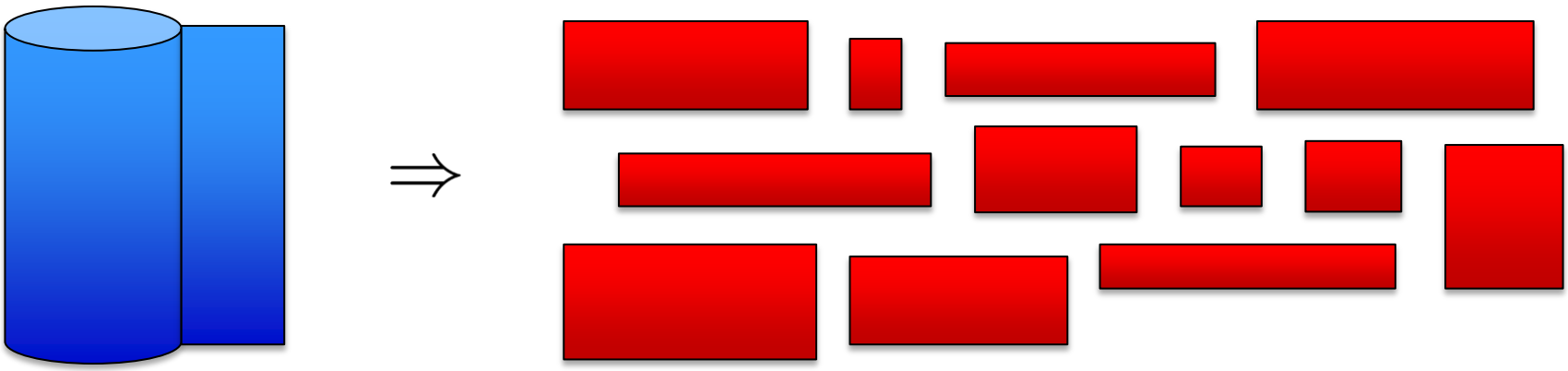
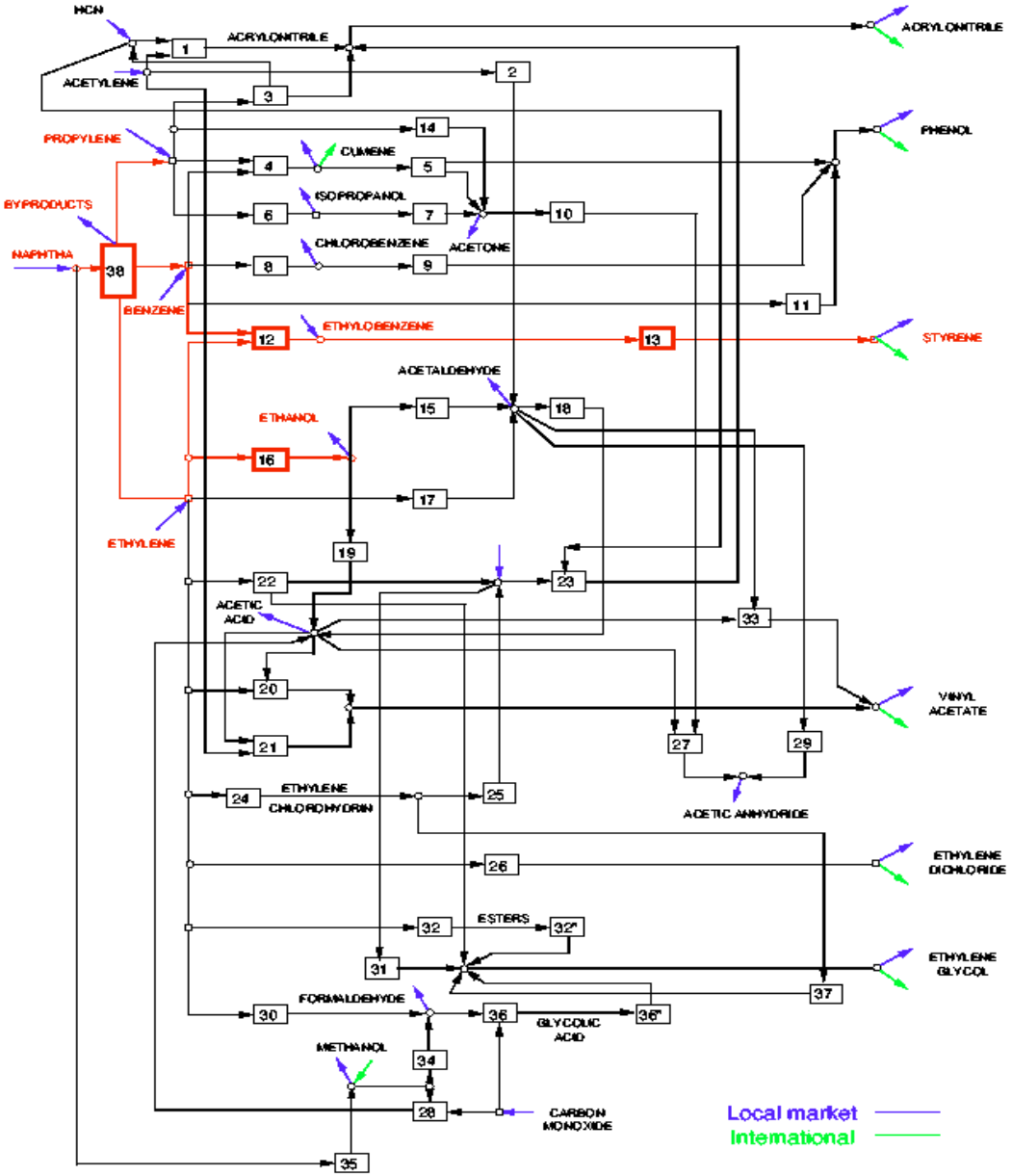
Trim Loss Minimization



- Minimize costs (cutting patterns and pattern changes)
- Satisfy customer demands
- What patterns to use?
- How many times should each pattern repeat?

Supply Chain Design and Operations

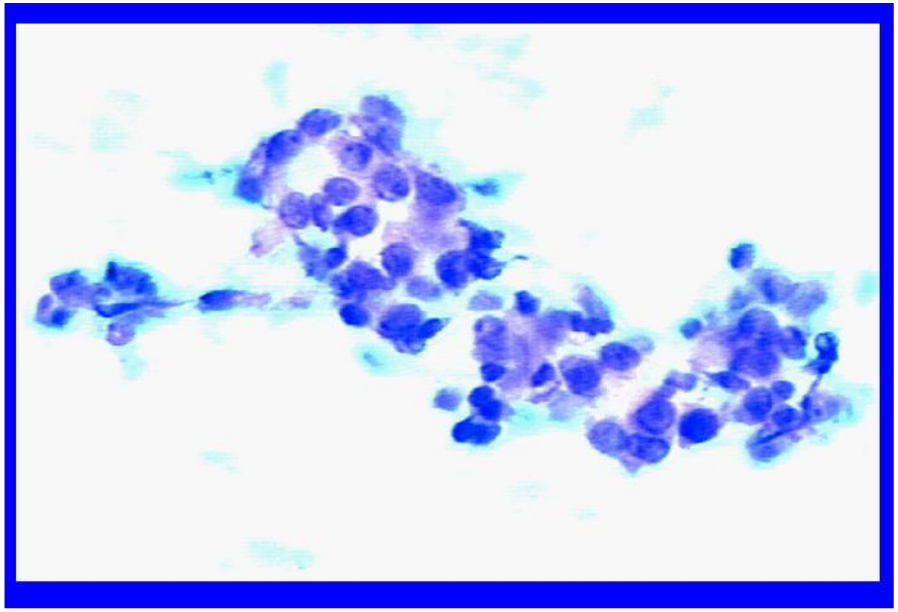
- Technology selection
- Facility location
- Capacity expansion
- Blending and pooling
- Uncertainty
- Portfolio optimization
- Very large-scale decision making problems



Breast Cancer Diagnosis

- 200,000 cases diagnosed in the U.S. a year
- 40,000 deaths a year
- Most breast cancers are first diagnosed by the patient as a lump in the breast
- Majority of breast lumps are benign
- Available diagnosis methods:
  - Mammography (68% to 79% correct)
  - Surgical biopsy (100% correct but invasive and costly)
  - Fine needle aspirate (FNA)
    - With visual inspection: 65% to 98% correct
    - Automated diagnosis: 95% correct
    - Linear programming techniques
    - Mangasarian and Wolberg in 1990s

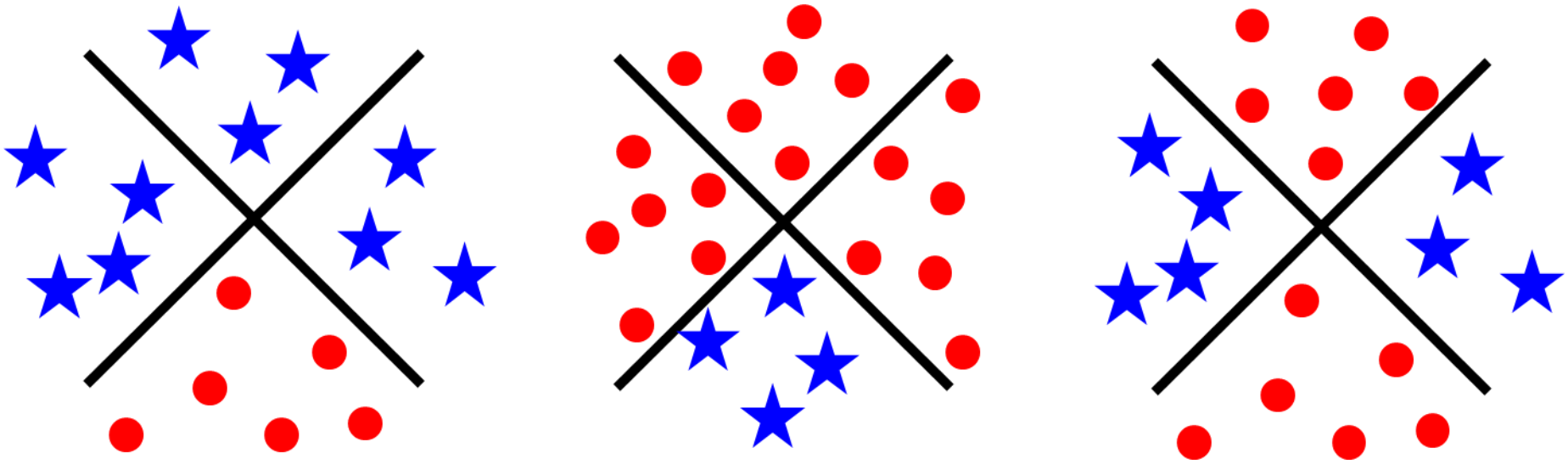
Wisconsin Diagnostic Breast Cancer Database



From Wolberg, Street, & Mangasarian, 1993

- 653 patients
- 9 cytological characteristics:
  - Clump thickness
  - Uniformity of cell size
  - Uniformity of cell shape
  - Marginal adhesion
  - Single epithelial cell size
  - Bare nuclei
  - Bland chromatin
  - Normal nucleoli
  - Mitoses
- Biopsy classified these 653 patients in two classes:
  - Benign
  - Malignant

Bilinear Separability of Two Sets in R^n



- Requires the solution of three nonlinear optimization problems with multiple local optima—solved with BARON
- 99% accuracy on testing set

Partnership Opportunities

- Optimization is essential technology in applications in
  - Chemistry, biology, medicine
  - Automated manufacturing
  - Engineering design
  - Business management
- Center for Advanced Process Decision-making
  - Optimizers: Biegler-Grossmann-Sahinidis
  - International visitors and self-funded students
  - 25 member companies
  - Research contracts
  - http://capd.cheme.cmu.edu/index.html

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