

⋮ dash optimization

# The evolution of optimization technologies

Dash Optimization, Alkis Vazacopoulos

INFORMS New York Metro Club

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# ● ● ● Agenda

- Optimization Applications
  - Companies that offer optimization
  - Companies that use optimization
- Development priorities past and now
- Development priorities – Future
- Case Studies

# ● ● Companies that Offer Optimization

- Modeling and Optimization
  - Dash Optimization \*\*\*\*
  - AIMMS
  - Ilog \*\*\*\*
  - Maximal
  - GAMS
  - AMPL
  - \*\*\*\* develop State of the Art solvers

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- Companies – complete solutions

- SAP (Supply Chain) \*\*\* ERP
- Oracle (Retail, Supply Chain) \*\*\* ERP
- Combinenet (procurement)
- Carmen Systems (airlines )
- i2 (supply chain )
- Smartops (inventory Optimization)
- Fair Isaac (Banks, Marketing Optimization)

# ● ● ● Customers that use Optimization

- NFL (Scheduling) (Current Schedule)
- Baseball League (Scheduling)
- Frito-Lay (Production Planning )
- American Airlines (Training Pilots)
- Wachovia (Financial)
- Siemens (process scheduling)
- Toyota (discrete planning and scheduling)

# • • • Verticals

- Process Industry
- Airlines
- Energy
- Retail
- Financial Applications
- Pharma

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- # Process industry problems

- Refinery Scheduling
- Vehicle Routing Problems
- Refinery Expansion/sizing



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- Airlines

- Crew rostering and scheduling
- Pricing (revenue Management)
- Capacity Planning (size of fleet)
- Service maintenance
- Parts inventory

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- Energy

- Unit commitment problems
- Capacity Planning
- Pricing based on Uncertain Demand
- Project selection

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- # Retail

- Markdown Optimization
- Replenishment of Inventory (inventory Optimization)
- Warehouse Management

# Financial Applications

- Security valuation and selection
  - Mortgage backed securities
- Bond Trading
- Crossing
- Index tracking
  - Track sector indices at minimum cost
- Portfolio tracking
  - Track performance at minimum cost

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- Pharma

- Sales promotions
- Assign sales reps to physicians

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- Edelman Award

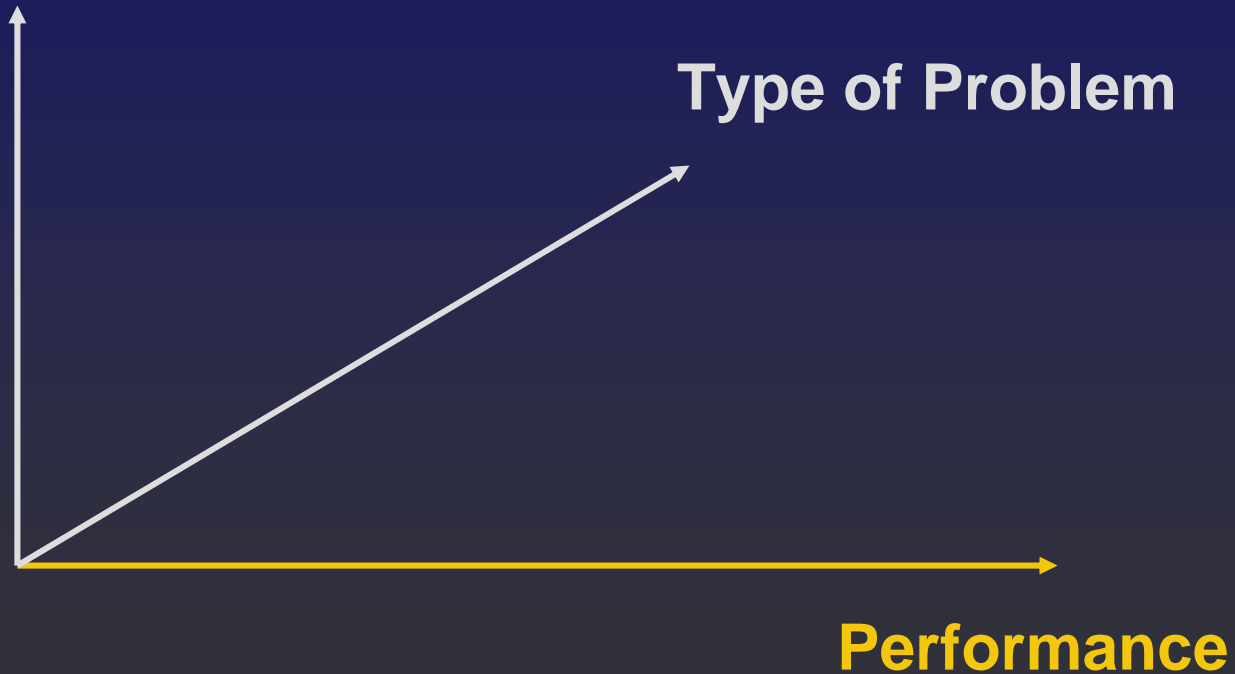
- UPS
- NBC
- Procter & Gamble
- Aspentech (last year)

# • • • Characteristics

- Size of Problems
  - 100000 variables
- CPU Time
  - A few seconds

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- # Development Directions

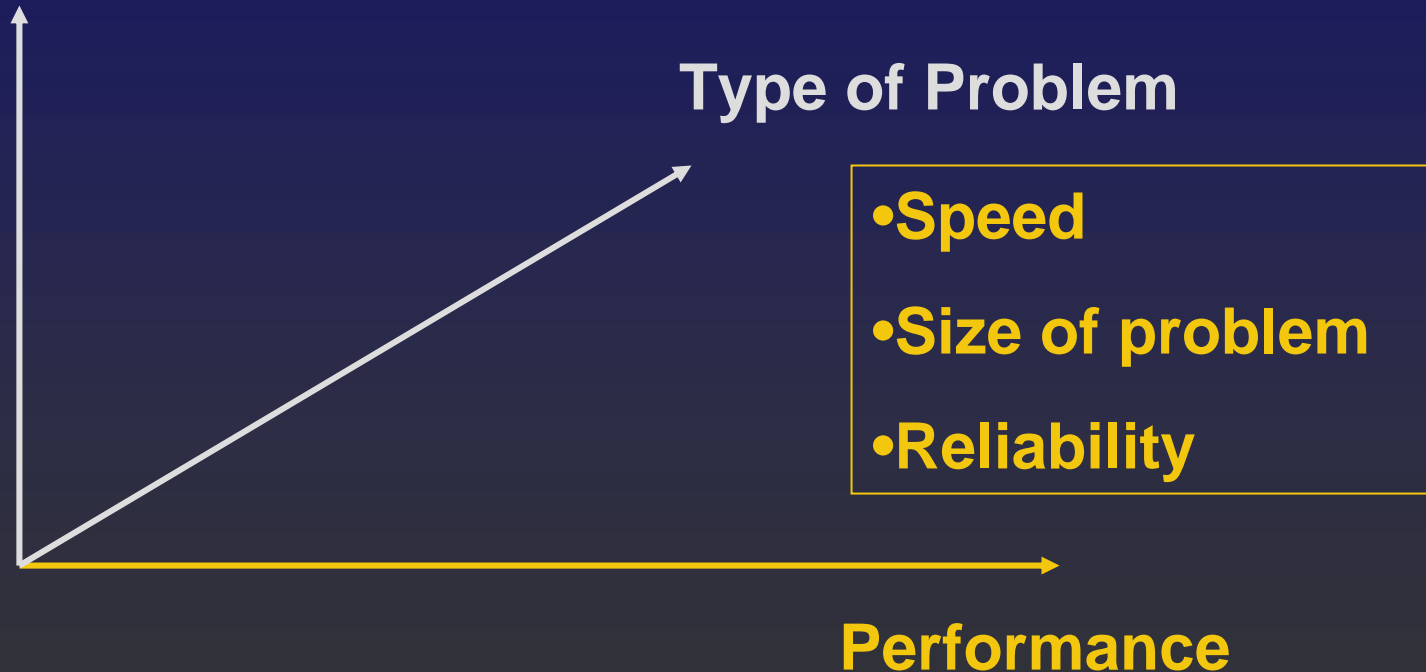
Ease of use





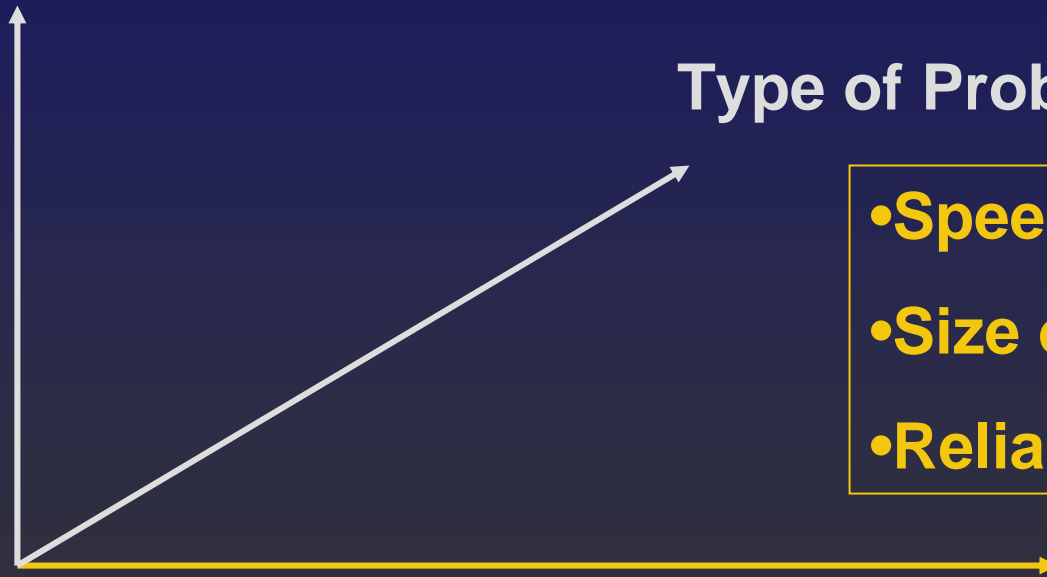
# Development Directions

Ease of use



# ● ● ● Development Directions

Ease of use



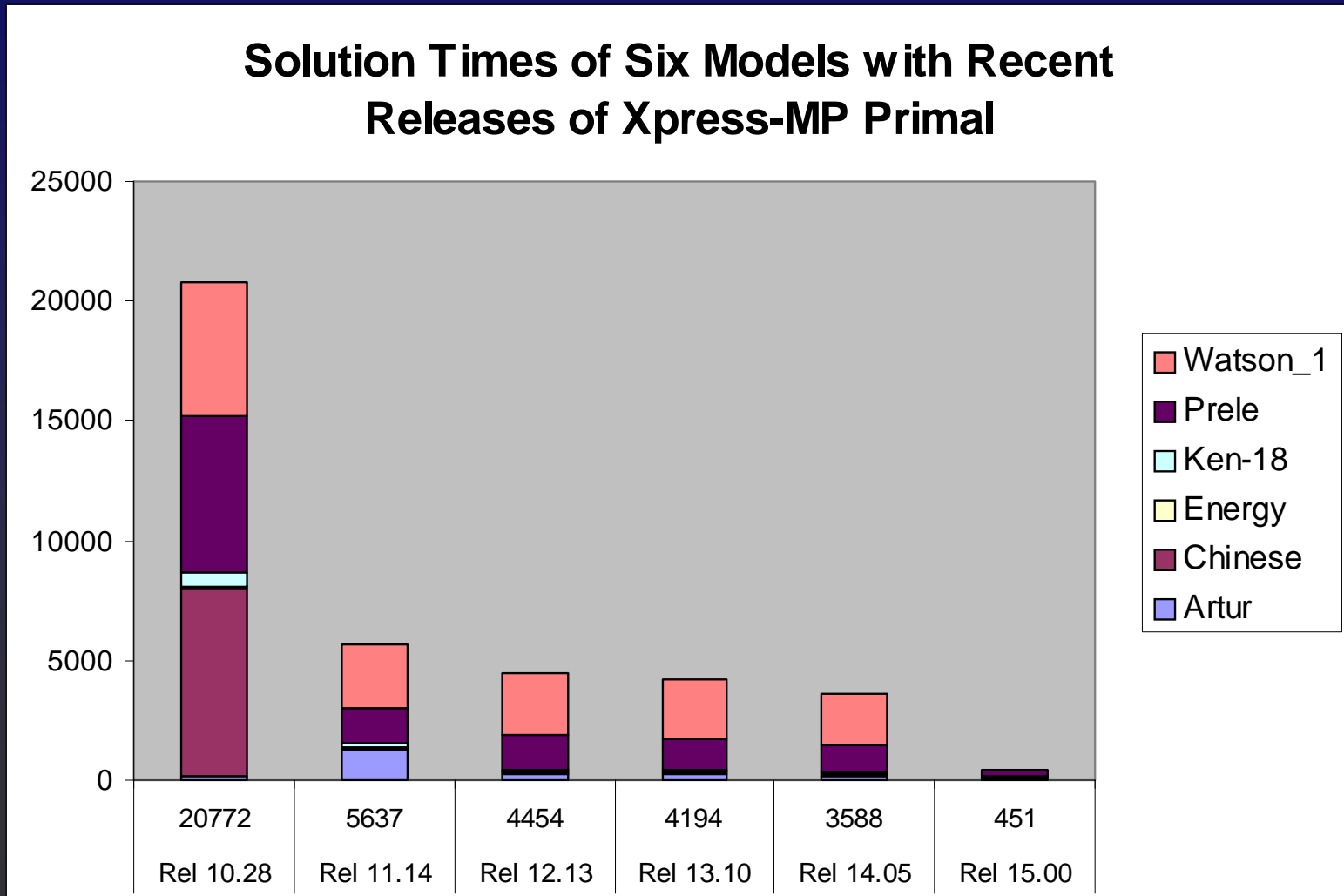
Type of Problem

- Speed
- Size of problem
- Reliability

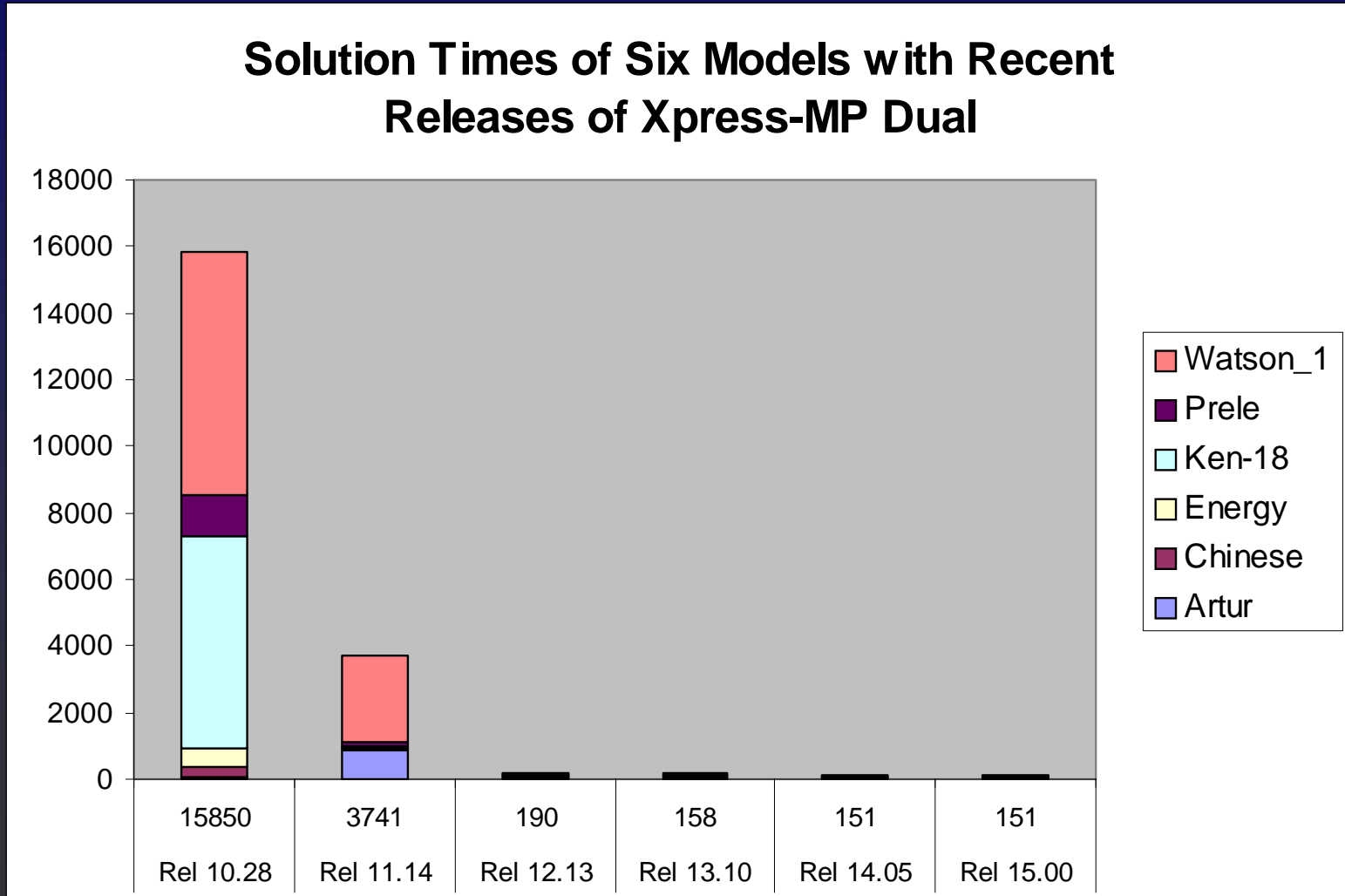
Performance

Out-of-the-box

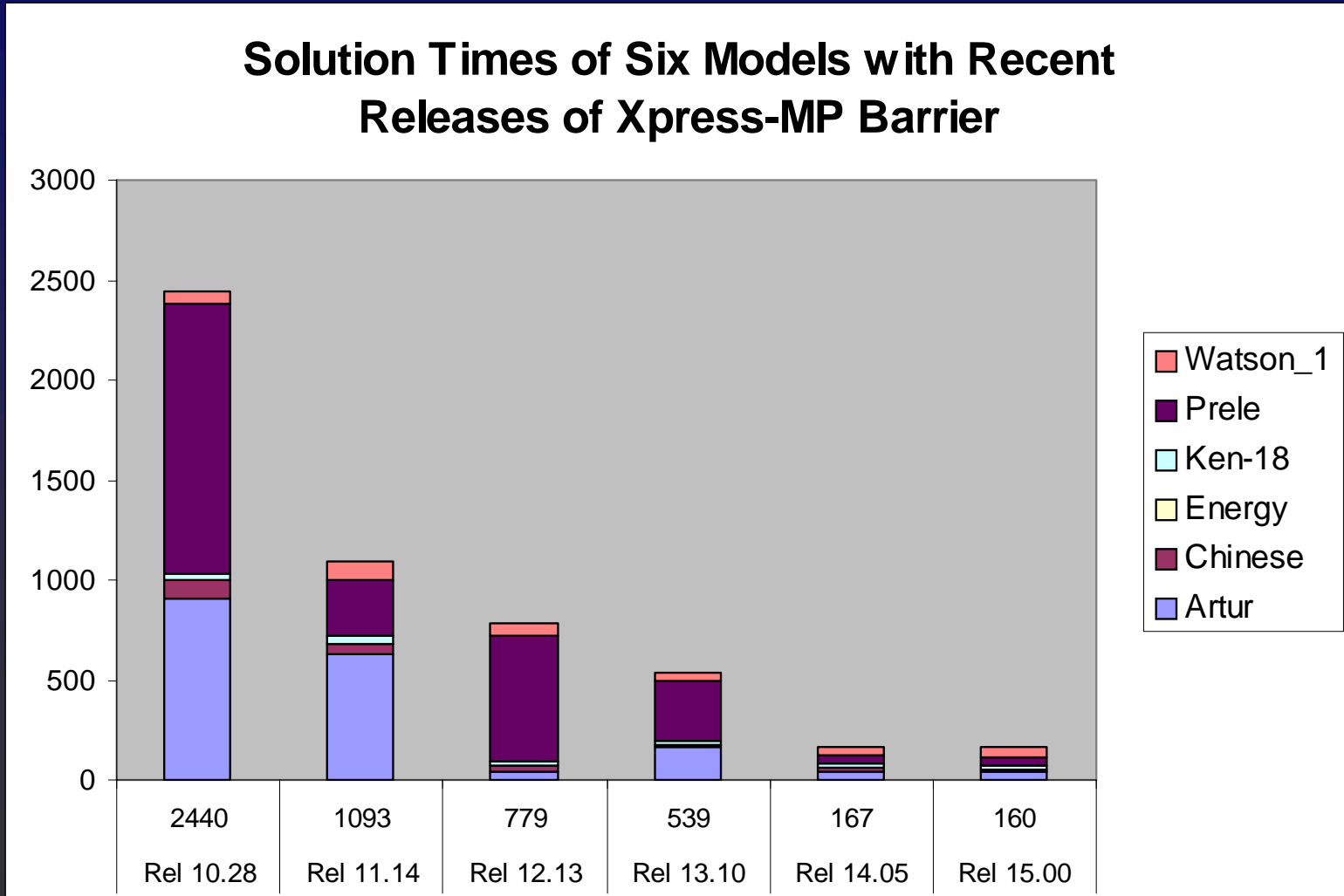
# Primal Simplex



# Dual Simplex



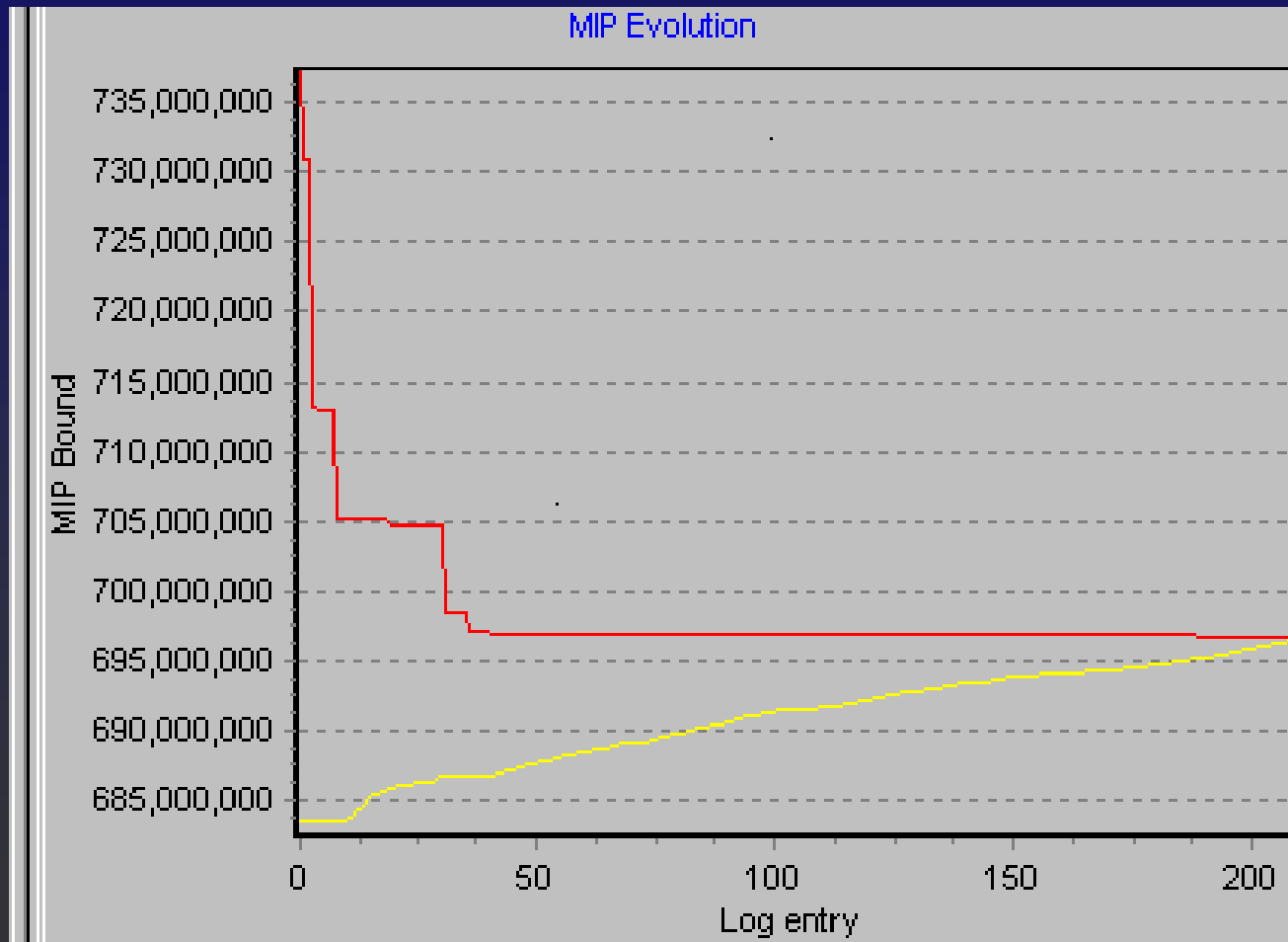
# Barrier Method (Interior Point)



# • • • Optimizer Speed

- Last Ten Years
  - 30 times faster
  - 100 times hardware
  - 3,000 times overall
  - Year on year gains of 125%
- Expectation
  - 60% per annum from hardware
  - 30% per annum from software

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- MIP Good Solutions - Fast



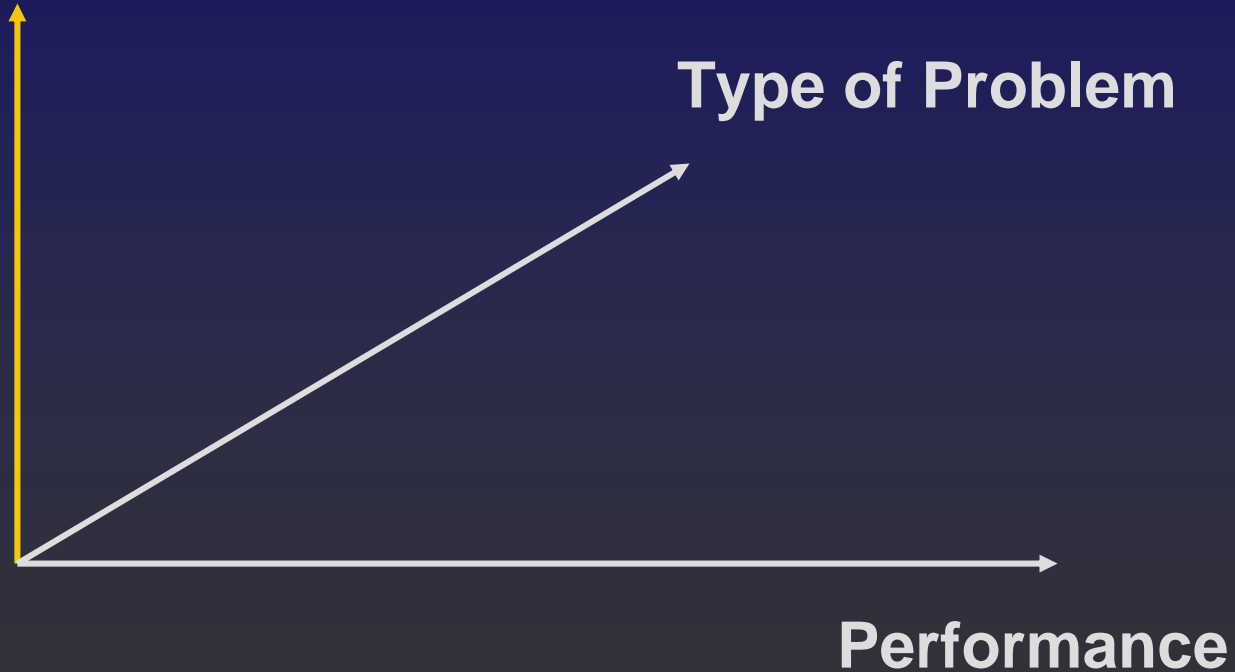
# MIP Performance

|        | <b>XPR 14.10</b> | <b>XPR 15.00</b> |
|--------|------------------|------------------|
| neos1  | >10000           | 4                |
| neos2  | 4412             | 6                |
| neos3  | >10000           | 29               |
| neos13 | >10000           | 1242             |
| neos10 | 261              | 126              |
|        | <b>XPR 14.10</b> | <b>XPR 15.00</b> |



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- # Development Directions

Ease of use

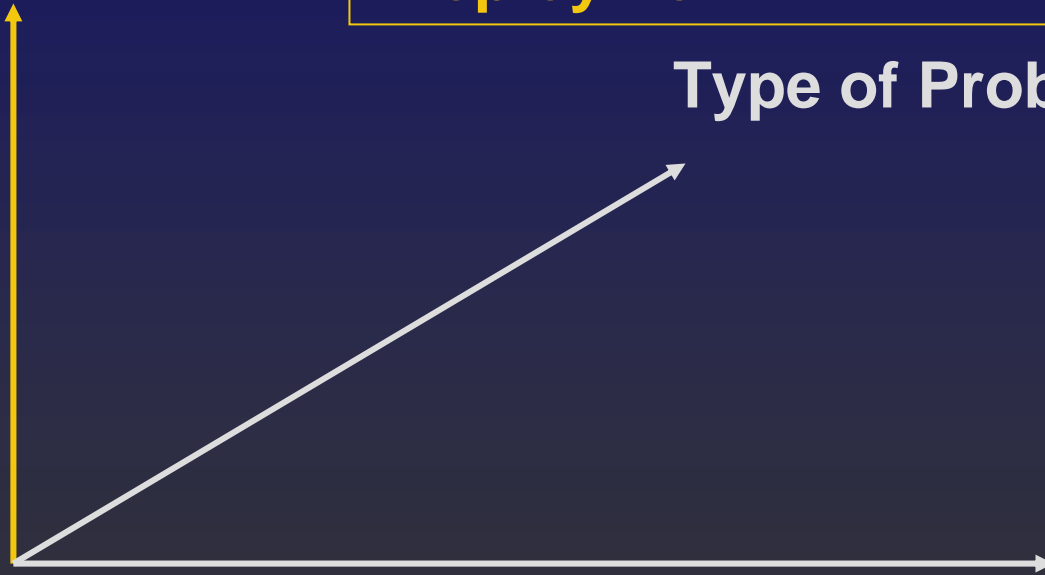


# ● ● ● Development Directions

Ease of use

- Building Applications
- Deployment

Type of Problem



Performance

# Modeling Environment

**Xpress-IVE - [markowitz.mos]**

File Edit View Project Build Deploy Modules Window Help

markowitz.mos

markowitz.mos (D:\pr

```

// Portfolio management using Markowitz model
// =====
// Code generated using Xpress-IVE Markowitz wizard
// =====
model Markowitz
options noimplicit
uses "mmxprs", "mmquad"
uses "mmodbc",
uses "mmive"
parameters
ENABLE_LIMITS = true !enforce weight limits or
ENABLE_CARDINALITY = false !true !enforce portfolio s
ENABLE_ROUNDLOTS = false !true !enforce round lots
ENABLE_GRAPHS = true !draw graphs
STEPS = 30 !process for 20 step intervals
MININCLUDED = 10 !minimum number of securities in p
MAXINCLUDED = 15 !maximum number of securities in p
MIPGAP = 0.01 !optimality stopping criterion
end-parameters
forward procedure DisplayPortfolio
setparam("SQLVERBOSE", true)
setparam("XPRS_LOADNAMES", true)
setparam("XPRS_MIPRELSTOP", MIPGAP) ! Set an acceptable op
! The model does not make sense with less than 1 step.
if STEPS<1 then writeln("Minimum 1 step required!"); exit(

```

**Current optimization statistics.**  Auto Hide

| Matrix:                | Presolved:   |
|------------------------|--------------|
| Rows(constraints): 123 | Rows(const   |
| Columns(variables): 61 | Columns(va   |
| Nonzero elements: 272  | Nonzero ele  |
| Global entities: 30    | Global entit |
| Sets: 0                | Sets:        |
| Set members: 0         | Set member   |

Overall status: **Finished LP relaxation.**

| LP relaxation:                   | Global  |
|----------------------------------|---------|
| <b>Algorithm:</b> Newton Barrier | Current |
| Iterations: 10                   | Depth   |
| Primal objective: 55.3999        | Active  |
| Dual objective: 3.3166e+006      | Best t  |
| Time: 3.9s                       | Best s  |
|                                  | Gap:    |
|                                  | Status: |
|                                  | Time:   |

**Time overheads:**

|                  |      |
|------------------|------|
| Progress graphs: | 0.7s |
| Writing output:  | 1.3s |
| Pausing:         | 0.0s |
| Updating status: | 0.0s |

Output/Input Stats Matrix  
Objective MIP search BB tree User graph

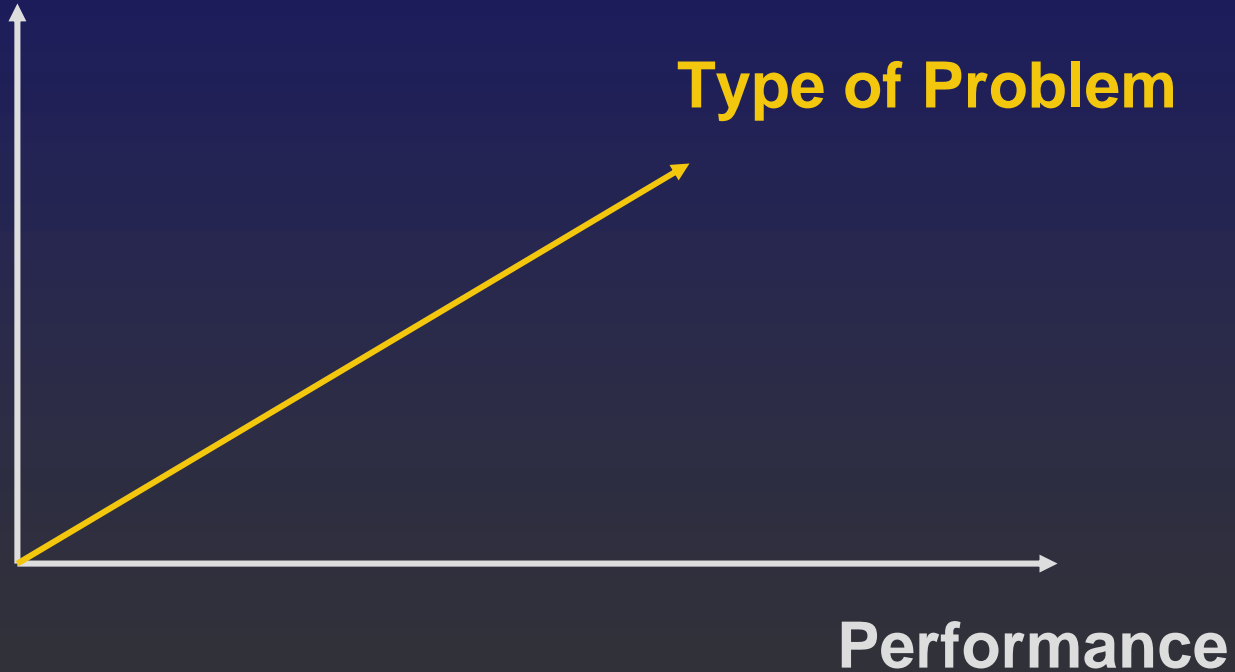
Mosel version: 1.2.2  
Module(s) in use: mmodbc version 1.2.0, mmquad version 1.0.2, mmxprs version 1.2.2, mmive version 1.14.10.  
Started running D:\projects\Informs May 2003\Demo\markowitz\markowitz  
Xpress-IVE: Model run complete

Build Search Copy to clipboard

Ready Line: 1/200 Col: 0

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- # Development Directions

Ease of use



# ● ● ● Type of problem - Technologies

- Network design
- Capacity Planning
- Pricing
- Strategic Sourcing
- Scheduling
- LP
- MIP
- QP
- MIQP
- Constraint Programming
- Nonlinear
- Heuristics

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- # Supply Chain

Network  
Design  
LP, MIP

Capacity  
Planning,  
LP, MIP

Supply Chain

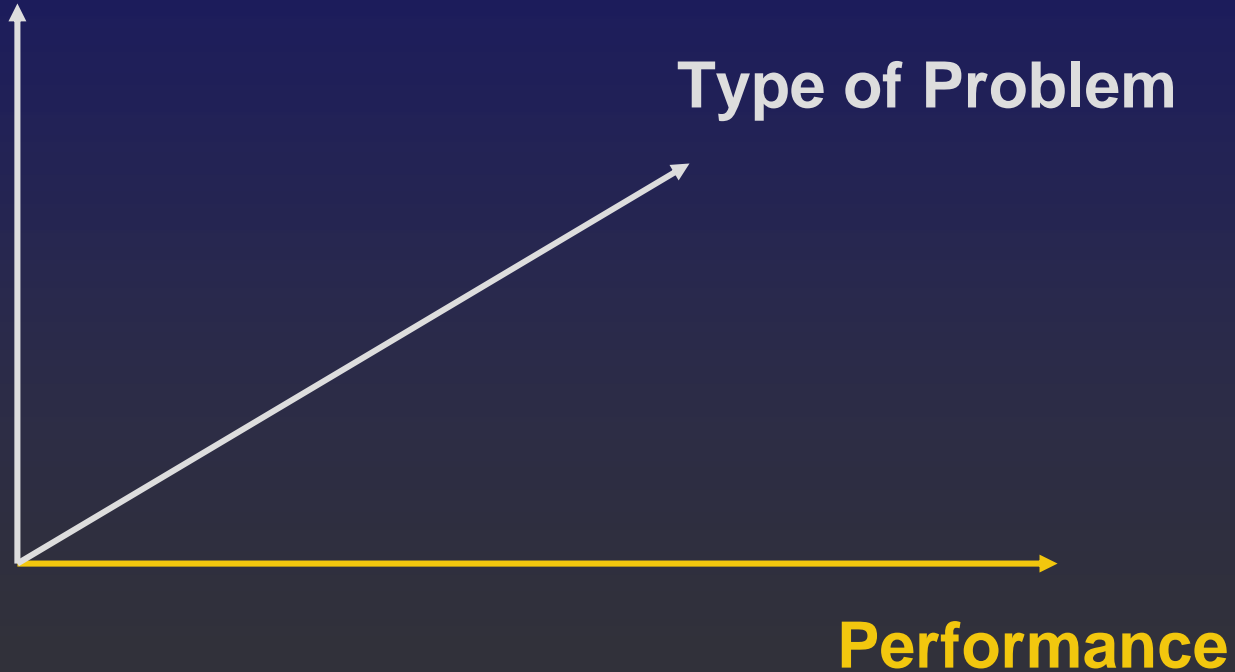
Scheduling,  
LP, MIP, CP,  
Heuristics

Pricing,  
LP,  
Nonlinear

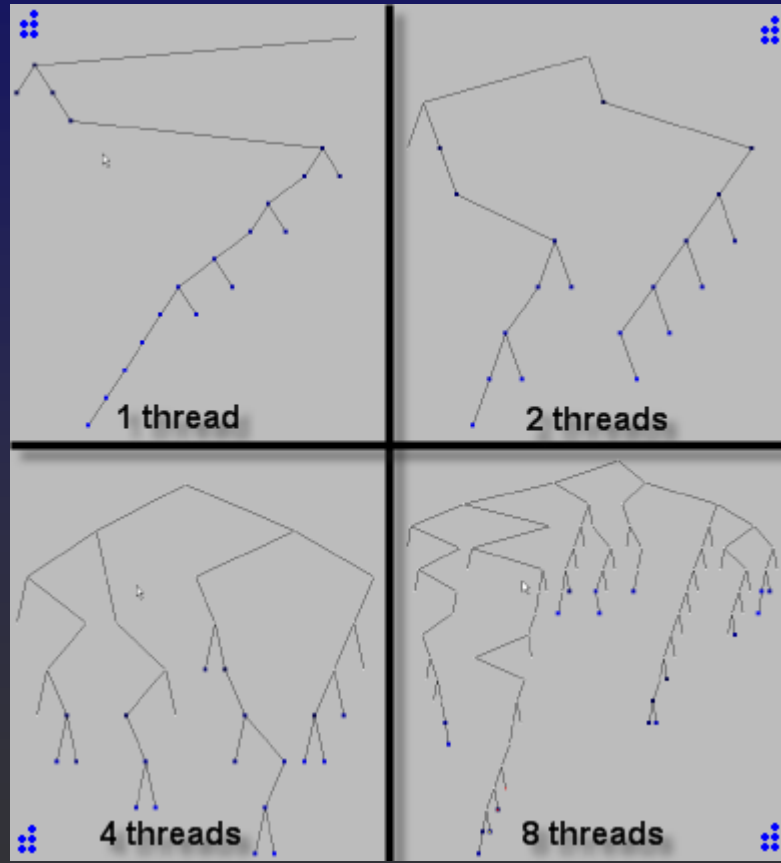
Strategic  
Sourcing,  
LP, MIP, MIQP

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- # Development Directions

Ease of use



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- 64 bit & Parallel





# ● ● ● Future

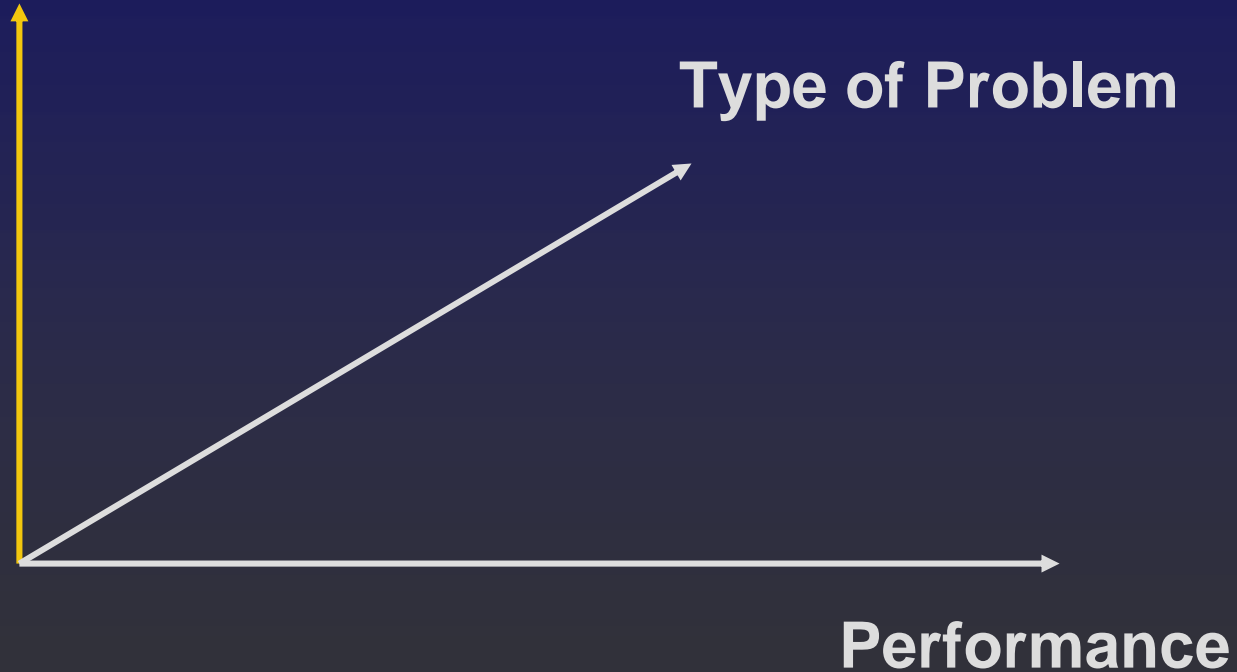
- Grid computing
  - Solve millions of small scale lps and mips or nlps in seconds
  - Examples – Pricing for Airlines-Hotels-Cars

# ● ● ● Large Scale Programs

- Solve large scale optimization problems
- Decompose them
- Use different processors to calculate upper bounds (find feasible solutions and lower bounds – optimality)
  - Example – pricing for energy in a large scale (pricing gas in a specific time)
  - Example (deploy resources after a catastrophic event – terrorism etc...)

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- **Development Directions**

**Ease of use**



# ● ● ● Clever Modeling Languages

- Solve Models in Parallel
- Profiling models
- Wizard – model development
- Development of Clever algorithms
  - Expert systems – Artificial intelligence

# Wizard – decision variables

Mosel assistant / scratch pad

Hide window

1.Name & Type  
2.Parameters  
3.Data Input  
4.Variables  
5.Objective  
6.Constraints  
7.Results & tuning  
8.Text Output  
9.Graphing  
10.Programming etc.  
11.Debugging  
12.Complete models

4.Variables

Existing decision variables

alloc : array (DISTRICT,CONTRACT) of mpvar  
quant : array (DISTRICT,CONTRACT) of mpvar

Declare new decision variable(s)

Identifier: alloc

Type

Free (allow negative values)

Continuous  Semicontinuous  
 Binary  Partial integer  
 Integer  Semicontinuous integer

Click to add sets to declaration

CONTRACT  
DISTRICT

alloc : array(DISTRICT, CONTRACT) of mpvar

^ Clear index sets

Mosel preview:  
Insert at cursor

This preview is independent of the model open in the editor. Select and drag or copy/paste as needed.

```
declarations
  alloc : array(DISTRICT, CONTRACT) of mpvar
end-declarations

!make variable(s) binary
forall(i1 in DISTRICT,i2 in CONTRACT)
  alloc(i1,i2) is_binary
```

# Xpress-Application Developer

**A simple window**

Monday Tuesday Wednesday Thursday Friday Saturday Sunday

Text  
The text object may contain any text.

Zoom In  
Zoom Out

Longer text editor:  
type, cut, copy, paste, etc.

Enable month selection

Operation progress

A group of other objects

Months  
January  
February  
March  
April  
May  
June

Histogram

Histogram buckets: 25

Run  
Exit

Multi-dim arrays

| Cities      | Cities      | Distance |
|-------------|-------------|----------|
| New York    | Miami       | 1294     |
| Los Angeles | New York    | 2843     |
| Los Angeles | Los Angeles | 0        |
| Los Angeles | Miami       | 2768     |
| Miami       | New York    | 1294     |
| Miami       | Los Angeles | 2768     |
| Miami       | Miami       | 0        |

One  
 Two  
Many

**Canvas experiments**

Demonstration canvas

Pick one

Shade  
Network  
Lines  
Rectangles  
Fractal  
Images

All written in Mosell

Exit

**Investment example**

Asset returns

|        | 1    | 2       |
|--------|------|---------|
| Stocks | 1.15 | 0.88666 |
| Bonds  | 1.1  | 0.94    |
| Cash   | 1.05 | 0.98    |

Inputs

Initial amount: 55  
Goal amount: 80

Solution type

Recourse  
 Expected value with recourse

Parsing

Nodes  
 Scenarios

Solve

Portfolio evolution

Y1 Y2 Y3 Y4 Y5 Y6 Y7 Y8

Scenario: 68

Goal

Initial

Scenarios

51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69

**Power management in a hydro-thermal system under uncertainty**

Production timeline choices and results

1. Click on a stage number: 1 2 3 4 5

2. Place the stage number on a time block: OK

Time: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Stage: 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 5 5 5 5 5

Demand

Hydro units

Hy 1  
Hy 2

Thermal units

Th 1  
Th 2  
Th 3

Overall generation and demand

Select scenario to view figures: 1 2 3 4 5 6 7 8 9 10

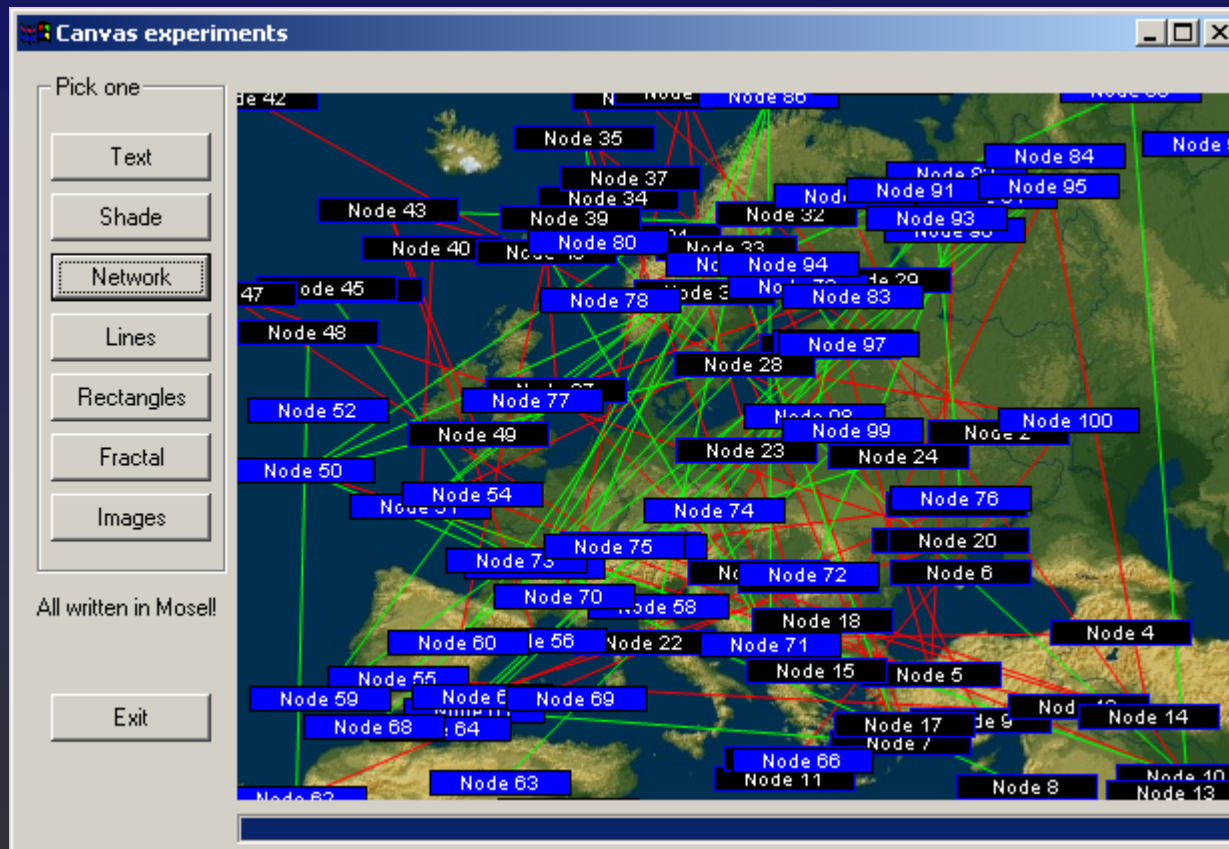
Scenarios: 10

Solution type

Recourse  
 Expected value with recourse

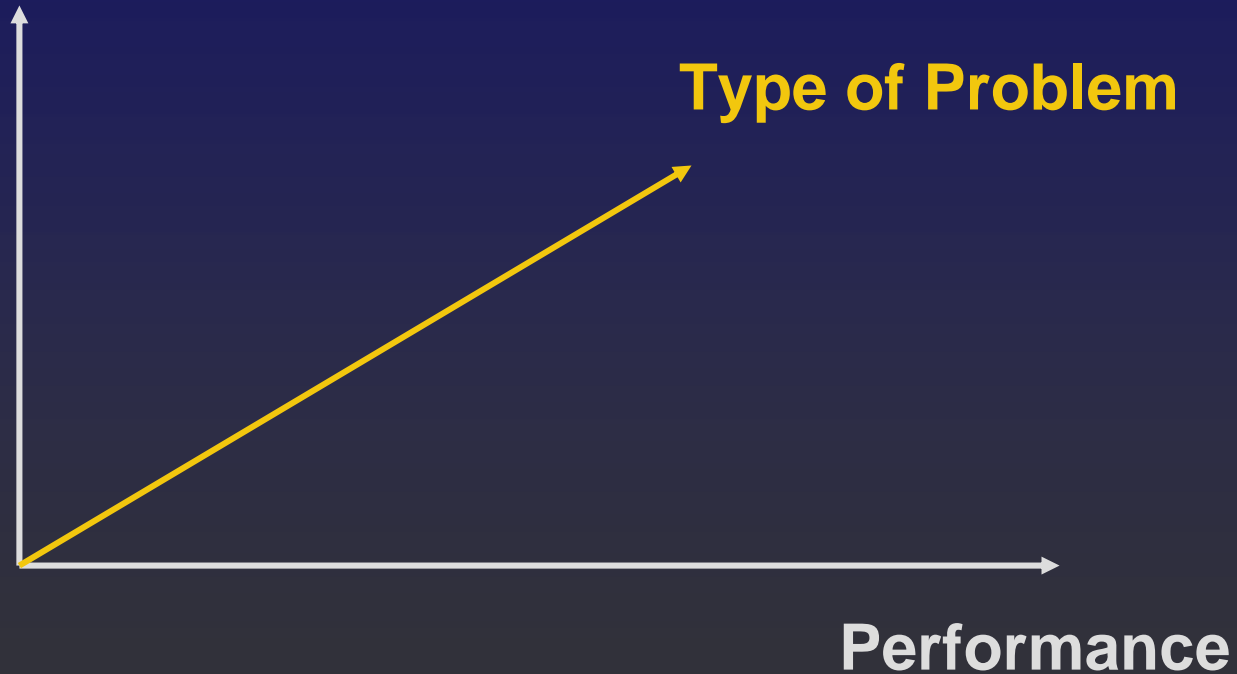
Solve

# • Screenshots of XAD apps



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- **Development Directions**

**Ease of use**





# ● ● ● Xpress-SLP

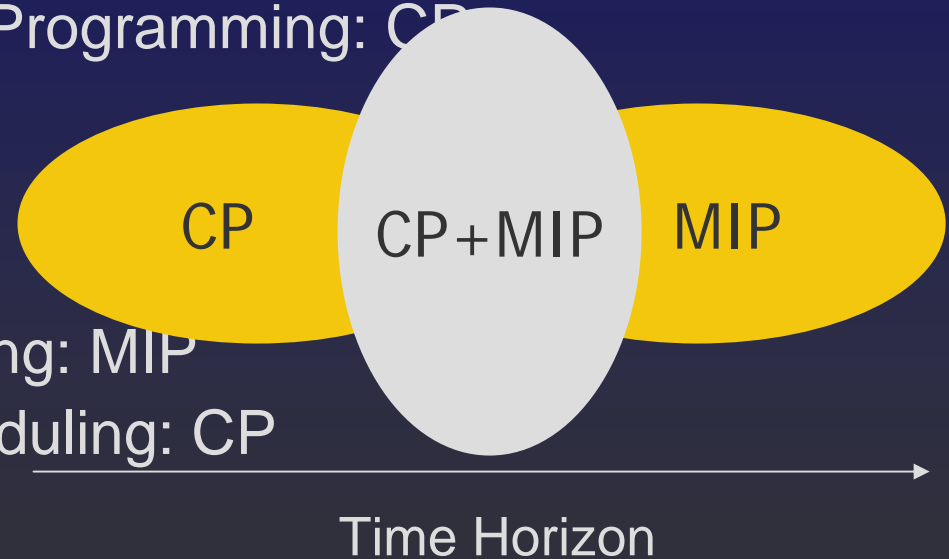
- Non-Linear
- MINLP Option
- Large scale
- Applications:
  - Process Industry
  - Pricing
  - Energy

# CP, MIP and their combination

- Optimization Technologies
  - Mixed Integer Programming: MIP
  - Finite Domain Constraint Programming: CP

- Planning & Scheduling

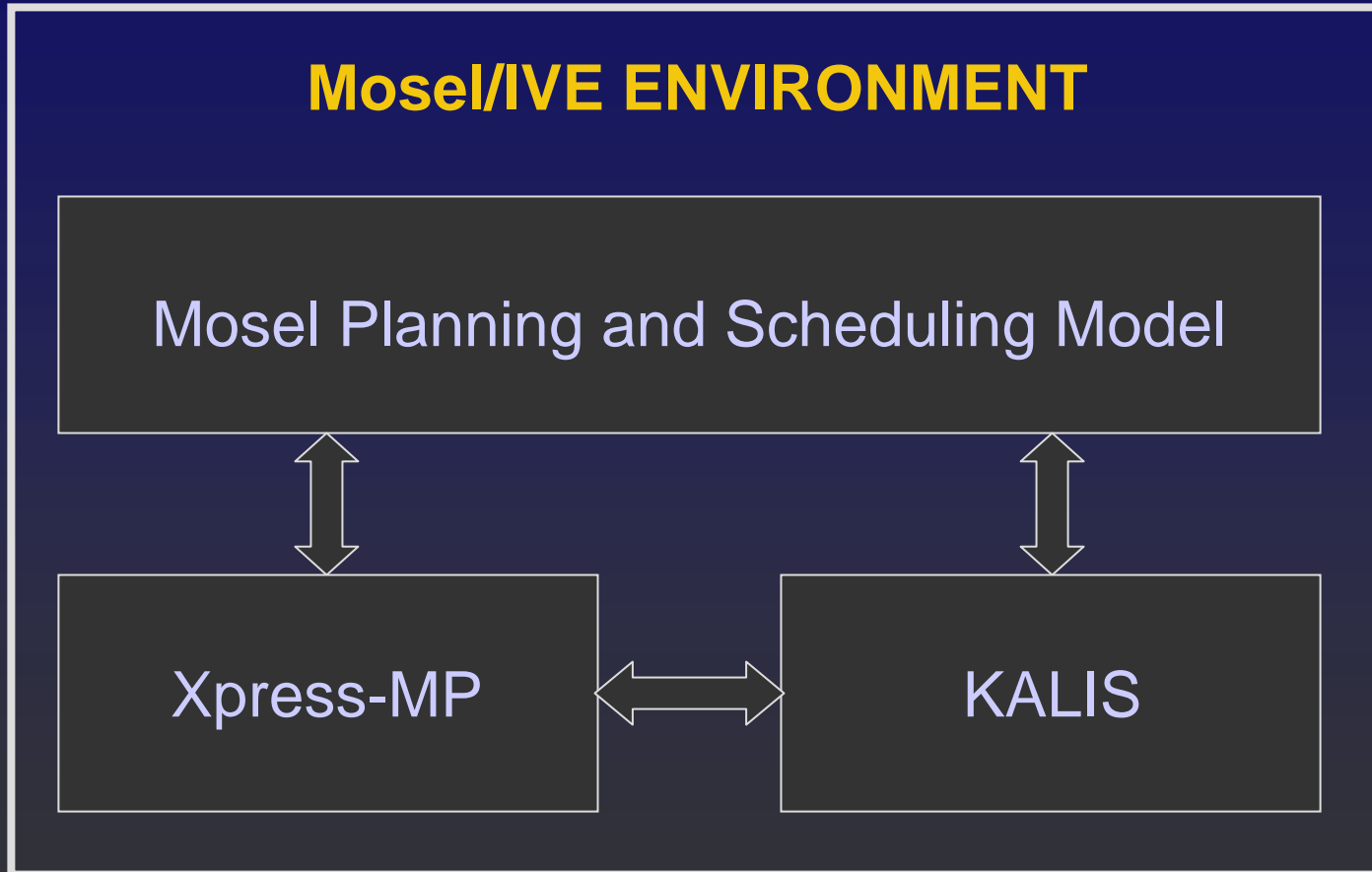
- Long and mid-term planning: MIP
- Short-term planning, scheduling: CP



Supply chain optimization

Requires MIP, CP, and their combination

- Xpress-CP Architecture
- (cooperative solver approach)



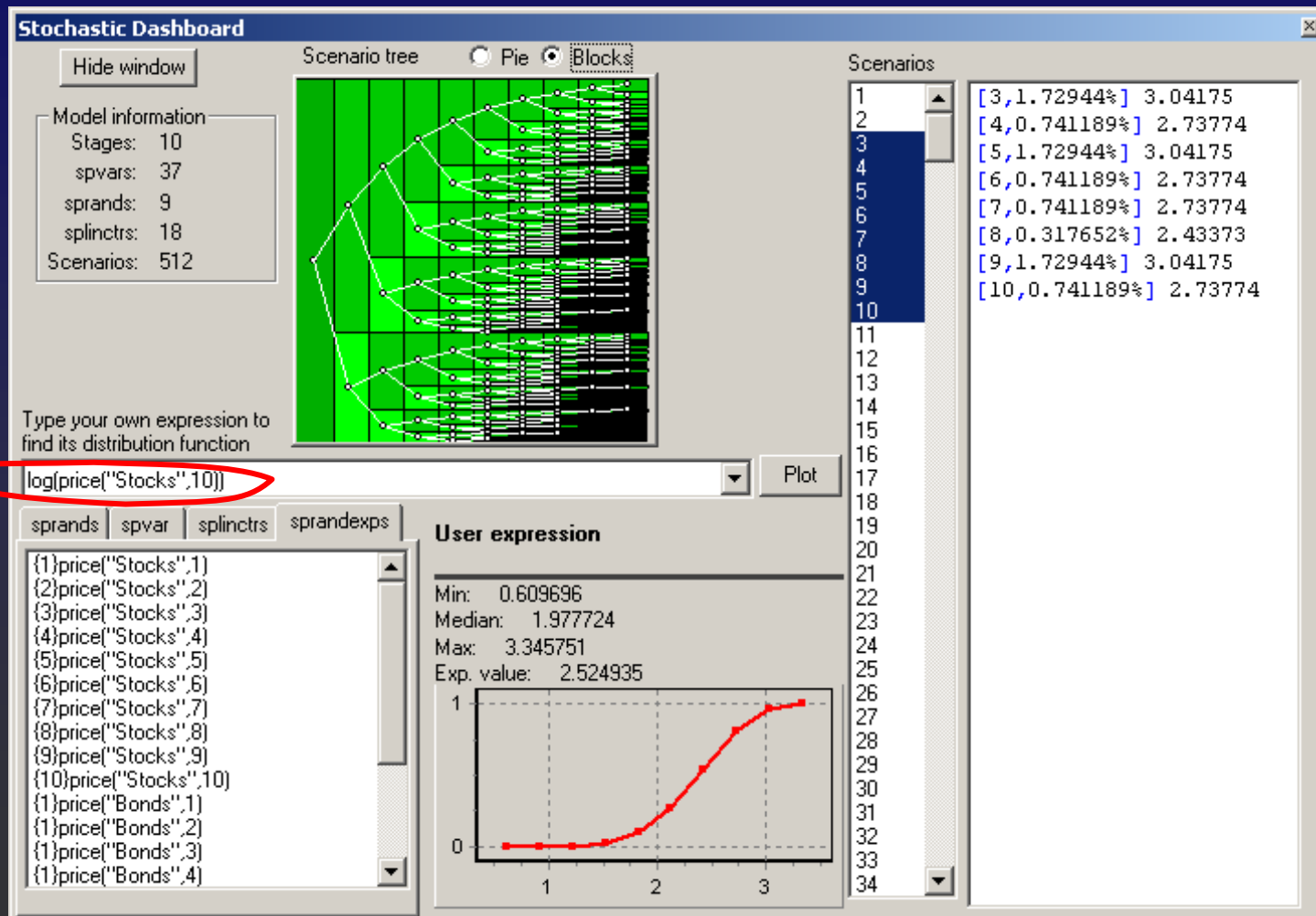
- 
- 
- Xpress-CP Adopters

- BASF
  - Chemicals
- Peugeot
  - Cars
- Procter and Gamble
  - Discrete products

# ● ● ● Stochastic Programming

- Basis
  - Represent uncertainty
  - Build problem efficiently
  - Manage scenarios
- Applications
  - Planning
  - Supply chain
  - Interaction with forecasting

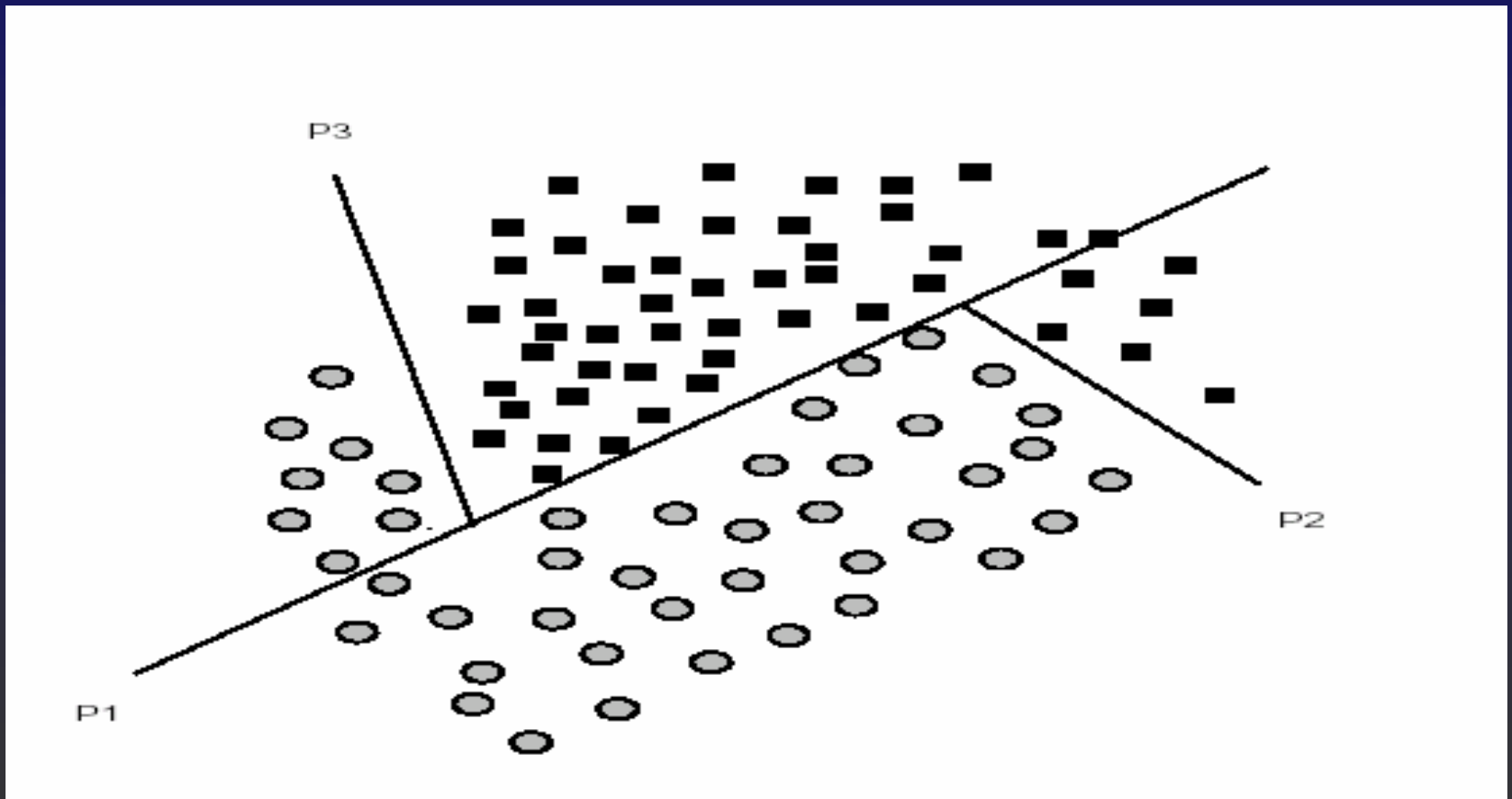
# Stochastic Programming



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- Future

- Data mining
- Robust Optimization

- Classification Problems:
- example





- **Classification Problems:**
- **Application Examples**

- **Cancer Diagnosis**

(Mangasarian *et al*, 1995 –  
linear separating surfaces)

- **Classification of Credit Card Applications,  
Bonds Rating**

(Bugera *et al*, 2002, 2003 –  
quadratic separating surfaces)

# ● ● Problems

There are two major biomedical data mining problems associated with microarray data:

- **Classification:** Determine classes of the test samples.
- **Gene detection:** For each of the classes, select a subset of genes responsible for creating the condition corresponding to the class.

Usual noisiness of microarray data complicates solution of these problems.

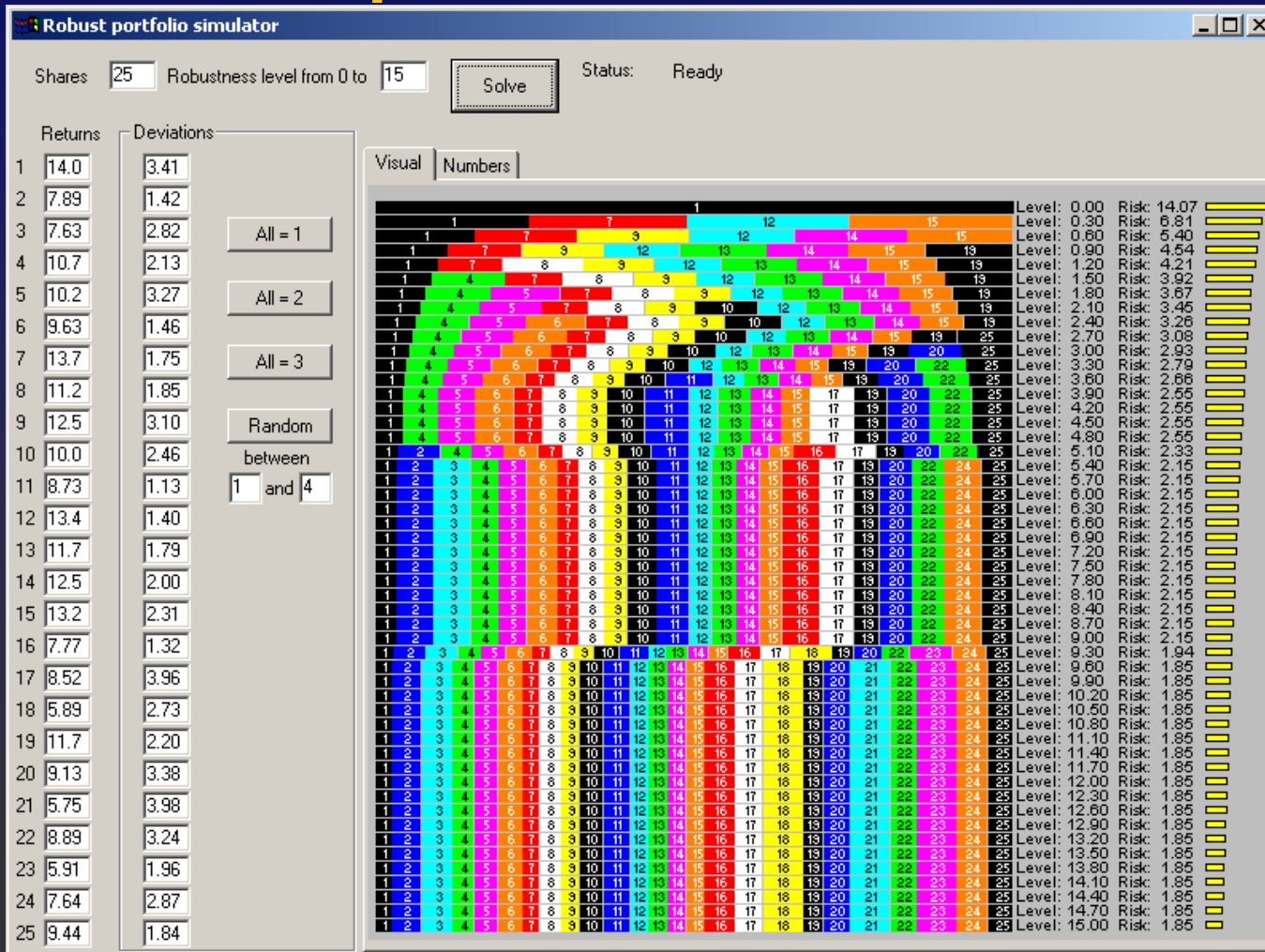
- 
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- Credit Rating

- Logical Analysis of Data
- Credit scoring of Countries
- Credit scoring of Companies

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- # Medical Applications

- Different types of Cancer
- Obesity

# Robust Optimization



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- Other examples

- Robust Portfolio Optimization
- Robust Inventory policies



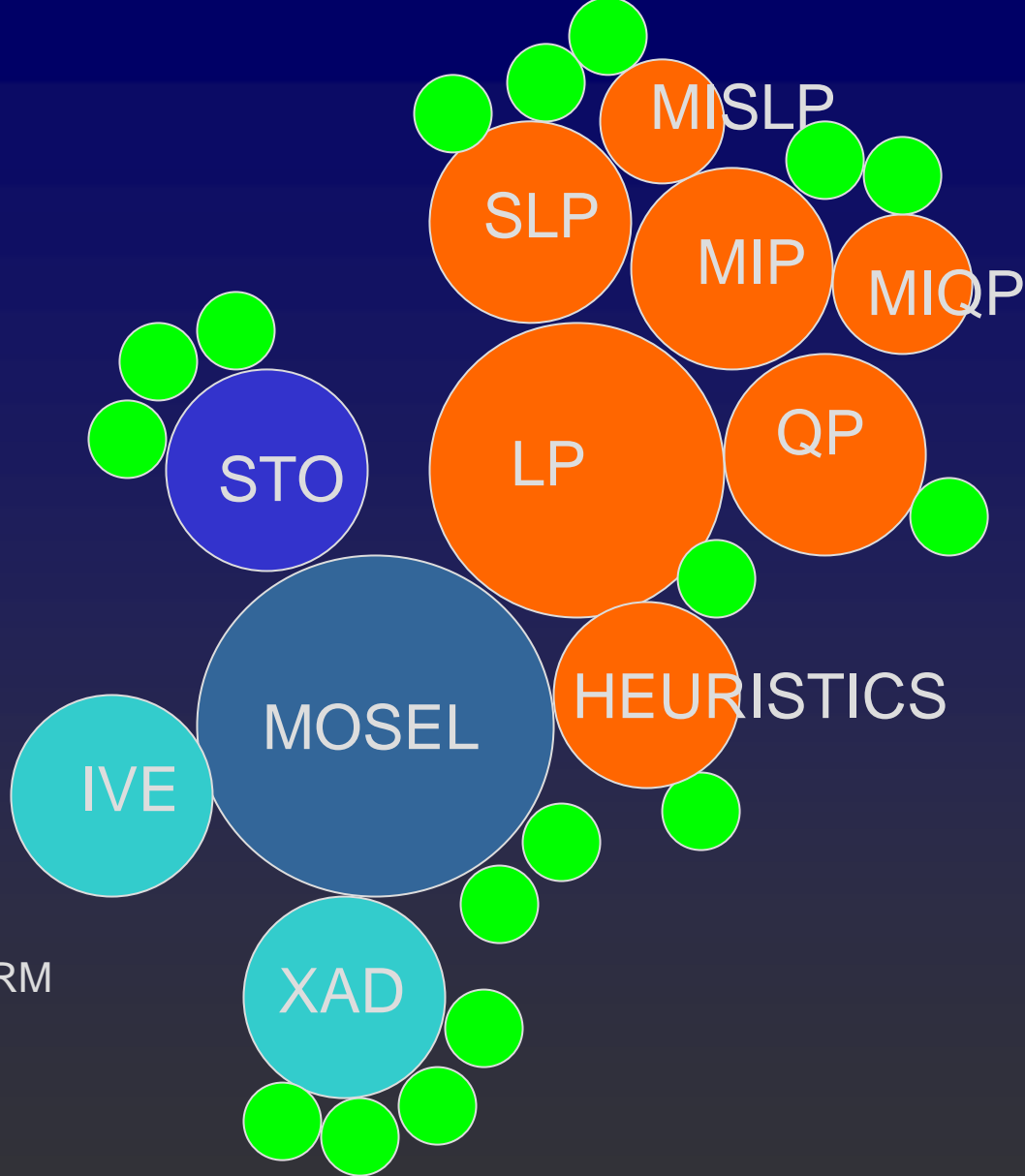
VERTICAL APP.

GUI / STUDIO

EXTENSIONS/NAT

SOLVERS

MODELING PLATFORM



# ● ● ● Some Trends

- Profitable-to-Promise
- Very large problems
- Time of the essence
- Custom driven supply chains
- Flexibility/lifecycle
- Analytics & Forecasting /  
Data Mining
- Out-of-box performance
- Non-expert users

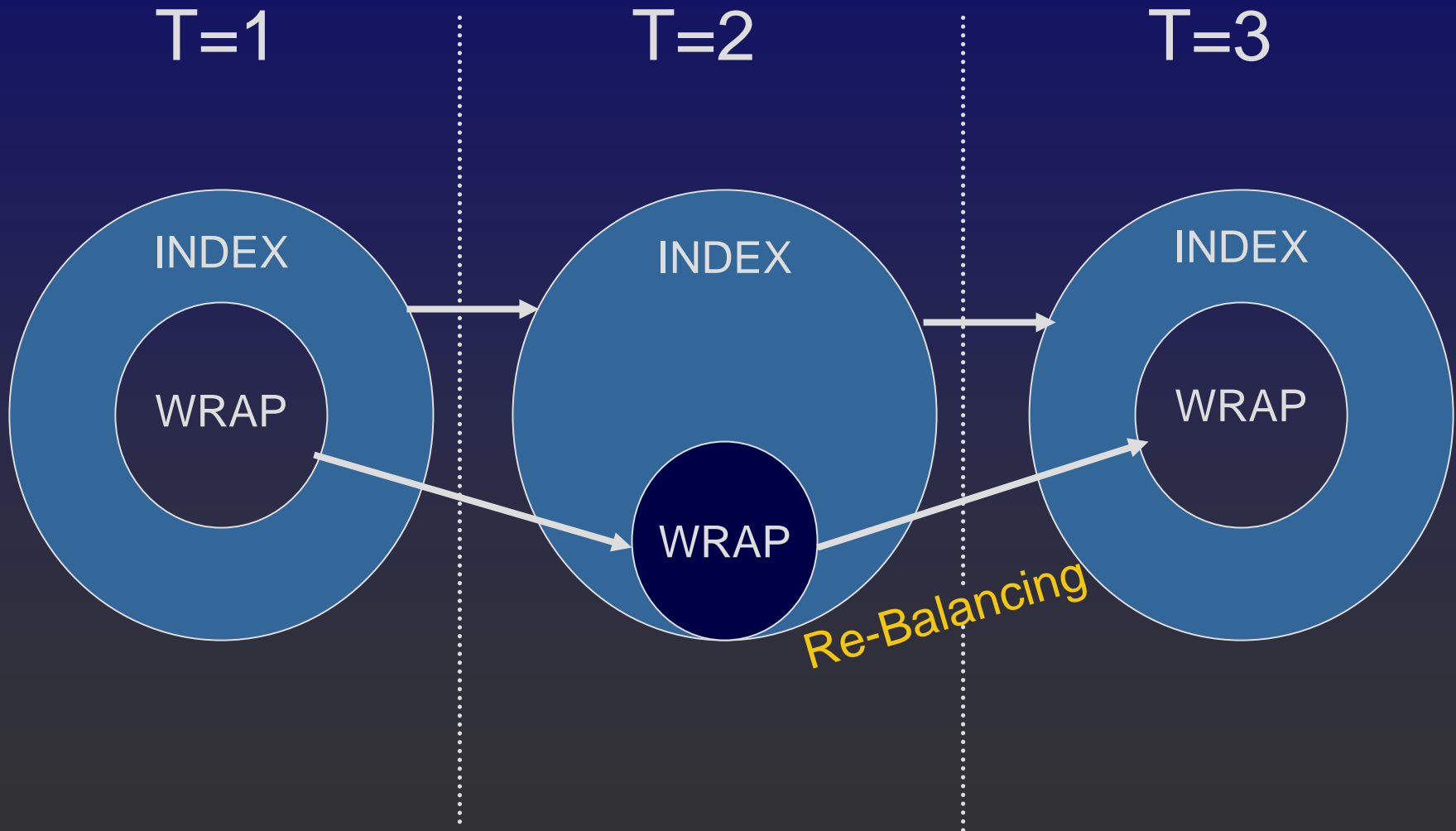


# ● ● ● Portfolio Management

- Wrap Portfolio
  - Tracks another index / actively managed portfolio
  - Realigns periodically to match risks and returns
  - Provides similar performance at lower management costs



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- WRAP Portfolio



# ● ● ● Portfolio Management

## Challenges

- How to realign with minimum trading costs
- How closely to track sector, country.. exposures
- When and how frequently to re-align
- How to automate the complete process



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- # Portfolio Management

- Optimization
  - Determine trades to re-align with minimum costs
- Business rules
  - Determine when to re-align
  - Generate test cases to determine
    - How closely to track
    - How frequently to re-align



# ● ● ● Portfolio Management



Want to automate the complete process

- Need to combine
  - Business Rules
  - Optimizationin a *'single'* application

# ● ● ● Portfolio Management



- Real Time Management
  - Rules engine monitors tracked index and portfolio movement
  - Calls and runs optimization engine when index and portfolio deviates beyond acceptable limits
  - Rules engine evaluates and executes trades

# ● ● ● Portfolio Management

Customization – one step further

- Determines acceptable deviation limits for risk-return combinations
  - Rules generate scenarios
  - Optimization engine determines action
  - Enables to predict returns for risk levels



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- # Benefits

- Lower monitoring and management costs
- Lower execution costs
- Assured compliance





# • • • Other Applications

- Marketing
  - State Farm
- Process Industries
  - AspenTech
- Transport
  - Schneider

# ● ● ● Simple Concept

- Business rules monitor and determine when to re-optimize
- Optimization determines best action
- Business rules evaluate and execute actions to achieve desired effect

# ● ● ● Conclusion

## Combine

- Flexibility of business rules and
- Robustness of optimization



## Next Generation

## Intelligent

## Applications

- Automation
- Testing
- Determining rules ?

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- # Workshop

- October 21-22<sup>nd</sup>
- New York University

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- Informs San Francisco

- Preconference Workshop
- 1 Tutorial
- 2 talks
- Exhibit

⋮ dash optimization