An Introduction to the COIN-OR Optimization Suite:

Open Source Tools for Building and Solving Optimization Models

TED RALPHS
ISE Department
COR@L Lab
Lehigh University
ted@lehigh.edu

Optimization Days, Montreal, May 7, 2013

About the Tutorial

- I'll touch on a lot of things and can drill down if there's interest.
- There is an inevitable bias towards things that I work on.
- I'm going to talk about the work of lots of different people and will inevitably miss some attributions.
- The talk proceeds from general high level tools down to lower level tools, feel free to leave when you've seen enough.
- I'll try to focus on the "not-so-obvious" bits.
- Please ask questions! I may or may not be able to answer them.

Let's Go!

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Brief History of COIN-OR

- The Common Optimization Interface for Operations Research Initiative was an initiative launched by IBM at ISMP in 2000.
- IBM seeded an open source repository with four initial projects and created a Web site.
- The goal was to develop the project and then hand it over to the community.
- The project has now grown to be self-sustaining and was spun off as a nonprofit educational foundation in the U.S. several years ago.
- The name was also changed to the Computational Infrastructure for Operations Research to reflect a broader mission.

What is COIN-OR Today?

The COIN-OR Foundation

- A non-profit foundation promoting the development and use of interoperable, open-source software for operations research.
- A consortium of researchers in both industry and academia dedicated to improving the state of computational research in OR.
- A venue for developing and maintaining standards.
- A forum for discussion and interaction between practitioners and researchers.

The COIN-OR Repository

- A collection of interoperable software tools for building optimization codes, as well as a few stand alone packages.
- A venue for peer review of OR software tools.
- A development platform for open source projects, including a wide range of project management tools.

The COIN Boards

The COIN-OR Foundation is governed by two boards.

Strategic Leadership Board

- Matt Saltzman (President)
- Lou Hafer (Secretary)
- Randy Kiefer (Treasurer)
- Ted Ralphs (TLC Rep)
- Bill Hart
- Kevin Furman
- Alan King

Technical Leadership Council

- Ted Ralphs (Chair)
- Kipp Martin
- Stefan Vigerske
- John Siirola
- Matthew Galati
- Haroldo Santos

- The SLB sets the overall strategic direction and manages the business operations: budgeting, fund-raising, legal, etc.
- The TLC focuses on technical issues: build system, versioning system, bug reporting, interoperability, etc.

PayPal

You received a payment

May 2, 2013 06:02:42 PDT
Transaction ID: [illegible]

Hello COIN-OR Foundation, Inc,

You received a payment from [illegible] for Donation

Customer details

Customer name:	[illegible]
Customer email:	[illegible]
Profile ID:	[illegible]
Profile status:	Active

Subscription details

Amount received:	$0.01 USD
For:	Donation
Amount paid each time:	$0.01 USD
Maximum amount you can bill:	$0.01 USD
Billing cycle:	Monthly
Next payment due:	Jun 2, 2013

What's Happening at COIN

- Development efforts have been moving up the stack.
- Core tools are still evolving but emphasis has shifted to maintenance, documentation, improvements to usability, development of the ecosystem.

Current priorities

- Re-launching Web site with many new features
  - Forums
  - Social integration, single sign-on (OpenID)
  - Support for git
  - Individual project Web sites
- Installers
- RPMs and .debs
- Modeling tools
- Python support
- New versions of most tools ⇐ due out imminently!
- And more...

What You Can Do With COIN: Low-level Tools

- We currently have 50+ projects and more are being added all the time.
- Most projects are now licensed under the EPL (very permissive).
- COIN has solvers for most common optimization problem classes.
  - Linear programming
  - Nonlinear programming
  - Mixed integer linear programming
  - Mixed integer nonlinear programming (convex and nonconvex)
  - Stochastic linear programming
  - Semidefinite programming
  - Graph problems
  - Combinatorial problems (VRP, TSP, SPP, etc.)
- COIN has various utilities for reading/building/manipulating/preprocessing optimization models and getting them into solvers.
- COIN has overarching frameworks that support implementation of broad algorithm classes.
  - Parallel search
  - Branch and cut (and price)
  - Decomposition-based algorithms

What You Can Do With COIN: High-level Tools

One of the most exciting developments of recent years is the number of is the wide range of high-level tools available to access COIN solvers.

- Python-based modeling languages
- Spreadsheet modeling (!)
- Commercial modeling languages
- Matlab
- R
- Sage (?)
- Julia
- ...

COIN isn't just for breakfast anymore!

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

COIN-OR Projects Overview: Linear Optimization

- Clp: COIN LP Solver

  Project Manager: Julian Hall

- DyLP: An implementation of the dynamic simplex method

  Project Manager: Lou Hafer

- Cbc: COIN Branch and Cut

  Project Manager: Ted Ralphs

- SYMPHONY: a flexible integer programming package that supports shared and distributed memory parallel processing, biobjective optimization, warm starting, sensitivity analysis, application development, etc.

  Project Manager: Ted Ralphs

- BLIS: Parallel IP solver built to test the scalability of the CHiPPS framework.

  Project Manager: Ted Ralphs

- Cgl: A library of cut generators

  Project Manager: Robin Lougee

COIN-OR Projects Overview: Nonlinear Optimization

- Ipopt: Interior Point OPTimizer implements interior point methods for solving nonlinear optimization problems.

  Project Manager: Andreas Wächter
- DFO: An algorithm for derivative free optimization.

  Project Manager: Katya Scheinberg
- CSDP: A solver for semi-definite programs

  Project Manager: Brian Borchers
- OBOE: Oracle based optimization engine

  Project Manager: Nidhi Sawhney
- FilterSD: Package for solving linearly constrained non-linear optimization problems.

  Project Manager: Frank Curtis
- OptiML: Optimization for Machine learning, interior point, active set method and parametric solvers for support vector machines, solver for the sparse inverse covariance problem.

  Project Manager: Katya Scheinberg

COIN-OR Projects Overview: Mixed Integer Nonlinear Optimization

- Bonmin: Basic Open-source Nonlinear Mixed INteger programming is for (convex) nonlinear integer programming.

  Project Manager: Pierre Bonami

- Couenne: Solver for nonconvex nonlinear integer programming problems.

  Project Manager: Pietro Belotti

- LaGO: Lagrangian Global Optimizer, for the global optimization of nonconvex mixed-integer nonlinear programs.

  Project Manager: Stefan Vigerske

COIN-OR Projects Overview: Modeling

- FLOPC++: An open-source modeling system.

  Project Manager: Tim Hultberg
- COOPR: A repository of python-based modeling tools.

  Project Manager: Bill Hart
- PuLP: Another python-based modeling language.

  Project Manager: Stu Mitchell
- DipPy: A python-based modeling language for decomposition-based solvers.

  Project Manager: Mike O'Sullivan
- CMPL: An algebraic modeling language

  Project Manager: Mike Stieglich
- SMI: Stochastic Modeling Interface, for optimization under uncertainty.

  Project Manager: Alan King

COIN-OR Projects Overview: Interfaces and Solver Links

- Osi: Open solver interface is a generic API for linear and mixed integer linear programs.

  Project Manager: Matthew Saltzman
- GAMSlinks: Allows you to use the GAMS algebraic modeling language and call COIN-OR solvers.

  Project Manager: Stefan Vigerske
- AIMMSlinks: Allows you to use the AIMMS modeling system and call COIN-OR solvers.

  Project Manager: Marcel Hunting
- MSFlinks: Allows you to call COIN-OR solvers through Microsoft Solver Foundation.

  Project Manager: Lou Hafer
- CoinMP: A callable library that wraps around CLP and CBC, providing an API similar to CPLEX, XPRESS, Gurobi, etc.

  Project Manager: Bjarni Kristjansson
- Optimization Services: A framework defining data interchange formats and providing tools for calling solvers locally and remotely through Web services.

  Project Managers: Jun Ma, Gus Gassmann, and Kipp Martin

COIN-OR Projects Overview: Frameworks

- Bcp: A generic framework for implementing branch, cut, and price algorithms.

  Project Manager: Laci Ladanyi

- CHiPPS: A framework for developing parallel tree search algorithms.

  Project Manager: Ted Ralphs

- DIP: A framework for implementing decomposition-based algorithms for integer programming, including Dantzig-Wolfe, Lagrangian relaxation, cutting plane, and combinations.

  Project Manager: Ted Ralphs

COIN-OR Projects Overview: Automatic Differentiation

- ADOL-C: Package for the automatic differentiation of C and C++ programs.

  Project Manager: Andrea Walther

- CppAD: A tool for differentiation of C++ functions.

  Project Manager: Brad Bell

COIN-OR Projects Overview: Graphs

- GiMPy and GrUMPy: Python packages for visualizing algorithms

  Project Manager: Ted Ralphs

- Cgc: Coin graph class utilities, etc.

  Project Manager: Phil Walton

- LEMON: Library of Efficient Models and Optimization in Networks

  Project Manager: Alpar Juttner

COIN-OR Projects Overview: Miscellaneous

- Djinni: C++ framework with Python bindings for heuristic search

  Project Manager: Justin Goodson
- METSlib: An object oriented metaheuristics optimization framework and toolkit in C++

  Project Manager: Mirko Maischberger
- CoinBazaar: A collection of examples, application codes, utilities, etc.

  Project Manager: Bill Hart
- PFunc: Parallel Functions, a lightweight and portable library that provides C and C++ APIs to express task parallelism

  Project Manager: Prabhanjan Kambadur
- ROSE: Reformulation-Optimization Software Engine, software for performing symbolic reformulations to Mathematical Programs (MP)

  Project Manager: David Savourey
- MOCHA: Matroid Optimization: Combinatorial Heuristics and Algorithms, heuristics and algorithms for multicriteria matroid optimization

  Project Manager: David Hawes

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

How It's Organized: CoinAll and BuildTools

- Many of the tools mentioned interoperate by using the configuration and build utilities provided by the BuildTools project.
- The interoperable suite of tools for optimization will be the focus of the remainder of the tutorial.
- The BuildTools project provides build infrastructure for
  - MS Windows (CYGWIN, MINGW, and Visual Studio)
  - Linux
  - Mac OS X
- The BuildTools provides autoconf macros and scripts to allow the modular use of code across multiple projects.
- If you work with multiple COIN projects, you may end up maintaining many (possibly incompatible) copies of COIN libraries and binaries.
- The CoinAll project is an über-project that includes compatible version of all mutually interoperable projects.
- The easiest way to use multiple COIN projects is simply download and install the latest version of CoinAll (1.7 is due out imminently).
- The TestTools project is the focal point for testing of COIN code.

Getting Pre-built Libraries and Binaries

- You can download `CoinAll` binaries here:

  `http://www.coin-or.org/download/binary/CoinAll`
- About version numbers
  - COIN numbers versions by a standard *major*, *minor*, *release* scheme.
  - All version within a *major.minor* series are compatible.
  - All versions within a *major* series are backwards compatible.
- The `CoinBinary` project is a long-term effort to provide pre-built binaries for popular platforms.
  - We now have (beta) cross-platform installers built with the open source InstallJammer.
  - We are in the process of being approved for inclusion in the Fedora distribution (RPM).
  - COIN can already be installed with `apt-get` on Ubuntu, but these versions are quite old now.
- Other ways of obtaining COIN include downloading it through a number of modeling language front-ends (more on this later).

Installing from Source

- Why download and build COIN yourself?
  - There are many options for building COIN codes and the distributed binaries are built with just one set of options.
  - We cannot distribute binaries linked to libraries licensed under the GPL, so you must build yourself if you want GMPL, command completion, command history, Haskell libraries, etc.
  - Other advanced options that require specific hardware/software my also not be supported in distributed binaries (parallel builds, MPI)
  - Once you understand how to get and build source, it is *much* faster to get bug fixes.
- You can download `CoinAll` source tarballs and zip archives here:

  `http://www.coin-or.org/download/source/CoinAll`
- The recommended way to get source is to use `subversion`.
- With subversion, it is easy to stay up-to-date with the latest sources and to get bug fixes.

  `http://www.coin-or.org/svn/CoinBinary/CoinAll`

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Documentation

- Documentation on using the full optimization suite

  http://projects.coin-or.org/CoinHelp
  http://projects.coin-or.org/CoinEasy

- User's manuals and documentation for individual projects

  http://projects.coin-or.org/ProjName
  http://www.coin-or.org/ProjName

- Source code documentation

  http://www.coin-or.org/Doxygen

Support

- Support is available primarily through mailing lists and bug reports.

  http://list.coin-or.org/mailman/listinfo/ProjName
  http://projects.coin-or.org/ProjName

- Keep in mind that the appropriate place to submit your question or bug report may be different from the project you are actually using.
- Make sure to report all information required to reproduce the bug (platform, version number, arguments, parameters, input files, etc.)
- Also, please keep in mind that support is an all-volunteer effort.
- In the near future, we will be moving away from mailing lists and towards support forums.

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Using COIN with a Modeling Language

- Commercial
  - GAMS ships with COIN solvers included,
  - MPL ships with CoinMP (wrapper around Clp and Cbc),
  - AMPL works with OSAmplClient (as well as several other projects directly),
  - AIMMS can be connected via the `AIMMSLinks` project.
- Python-based Open Source Modeling Languages and Interfaces
  - Coopr (Pyomo, PySP, SUCASA)
  - PuLP/Dippy (Decomposition-based modeling)
  - CyLP (provides API-level interface)
  - yaposib (OSI bindings)
- Other
  - FLOPC++ (algebraic modeling in C++)
  - CMPL (modeling language with GUI interface)
  - MathProg.jl (modeling language built in Julia)
  - GMPL (open-source AMPL clone)
  - ZMPL (stand-alone parser)
  - OpenSolver (spreadsheet plug-in)
  - R (RSymphony Plug-in)
  - Matlab (OPTI)

Optimization Services (OS)

Optimization Services (OS) integrates numerous COIN-OR projects and is a good starting point for many use cases. The OS project provides:

- A set of XML based standards for representing optimization instances (`OSiL`), optimization results (`OSrL`), and optimization solver options (`OSoL`).
- A uniform API for constructing optimization problems (linear, nonlinear, discrete) and passing them to solvers.
- A command line executable `OSSolverService` for reading problem instances in several formats and calling a solver either locally or remotely.
- Utilities that convert files in AMPL nl, MPS, and LP format to OSiL.
- Client side software for creating Web Services SOAP packages with OSiL instances and contact a server for solution.
- Standards that facilitate the communication between clients and solvers using Web Services.
- Server software that works with Apache Tomcat.
- *Developers*: Kipp Martin, Gus Gassmann, and Jun Ma

Using AMPL with OS

To use OS to call solvers in AMPL, you specify the `OSAmplClient` as the solver.

```
model hs71.mod;
# tell AMPL that the solver is OSAmplClient
option solver OSAmplClient;

# now tell OSAmplClient to use Ipopt
option OSAmplClient_options "solver ipopt";

# now solve the problem
solve;
```

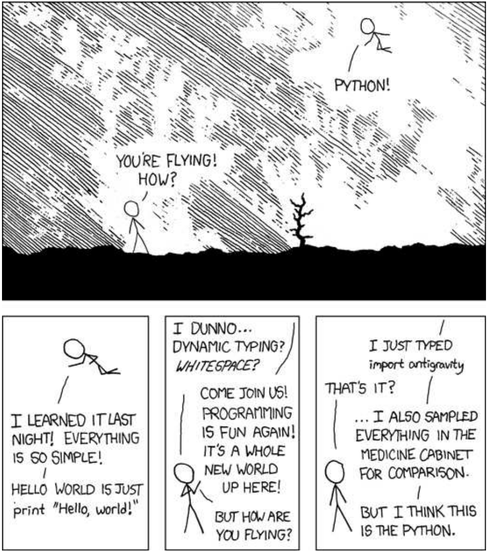
In order to call a remote solver service, set the solver `service` option to the address of the remote solver service.

```
option ipopt_options
  "service http://74.94.100.129:8080/OSServer/services/OSSolverService";
```

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Drinking the Python Kool-Aid



Why Python?

Singing the Praises

- As with many high-level languages, development is quick and painless (relative to C++!)
- Python is popular in many disciplines and there is a dizzying array of packages available.
- Python's syntax is very clean and naturally adaptable to expressing mathematical programming models.
- Python has the primary data structures necessary to build and manipulate models built in.

- There has been a very strong movement in recent years toward the adoption of Python as the high-level language of choice for (discrete) optimizers.
- For these reasons and more, Sage is quickly emerging as a very capable open-source alternative to Matlab.
- Python does have one major downside: it can be very slow.
- One solution is to write extensions in C/C++: COIN!
- Go and Julia are faster alternatives that retain many of Python's advantages.

Two-minute Python Primer

- Python is dynamically typed.
- No memory allocation or freeing, no variable declarations
- Indentation has a syntactic meaning: no curly braces and good formatting is required!
- Code is usually easy to read "in English" (keywords like `is`, `not`, and `in`).
- Everything is a pointer to an object: functions, classes, variables,...
- Everything can be "printed."
- Built-in data structures:
    - Lists (dynamic arrays)
    - Dictionaries (hash tables)
    - Sets
- Easy to define new data types via classes and re-definition of basic operators (magic methods).
- Light-weight inheritance mechanism for customizing classes.
- Extremely flexible mechanism for passing function arguments.

PuLP (Stu Mitchell)

- A modeling language for expressing linear models in Python.
- Similar to other algebraic modeling languages but with the power of Python.
- Let's see an example.

Example: Facility Location Problem

- We have n locations and m customers to be served from those locations.
- There is a fixed cost c_j and a capacity W_j associated with facility j.
- There is a cost d_{ij} and demand w_{ij} for serving customer i from facility j.
- We have two sets of binary variables.
  - y_j is 1 if facility j is opened, 0 otherwise.
  - x_{ij} is 1 if customer i is served by facility j, 0 otherwise.

Capacitated Facility Location Problem

$$
\begin{array}{lll}
\min & \displaystyle\sum_{j=1}^{n} c_j y_j + \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij} x_{ij} & \\
\text{s.t.} & \displaystyle\sum_{j=1}^{n} x_{ij} = 1 & \forall i \\
& \displaystyle\sum_{i=1}^{m} w_{ij} x_{ij} \leq W_j & \forall j \\
& x_{ij} \leq y_j & \forall i, j \\
& x_{ij}, y_j \in \{0, 1\} & \forall i, j
\end{array}
$$

PuLP Basics: Facility Location Example

```
from products   import REQUIREMENT, PRODUCTS
from facilities import FIXED_CHARGE, LOCATIONS, CAPACITY

prob = LpProblem("Facility_Location")

ASSIGNMENTS = [(i, j) for i in LOCATIONS for j in PRODUCTS]
assign_vars = LpVariable.dicts("x", ASSIGNMENTS, 0, 1, LpBinary)
use_vars    = LpVariable.dicts("y", LOCATIONS, 0, 1, LpBinary)

prob += lpSum(use_vars[i] * FIXED_COST[i] for i in LOCATIONS)

for j in PRODUCTS:
    prob += lpSum(assign_vars[(i, j)] for i in LOCATIONS) == 1

for i in LOCATIONS:
    prob += lpSum(assign_vars[(i, j)] * REQUIREMENT[j]
                  for j in PRODUCTS) <= CAPACITY * use_vars[i]

prob.solve()
```

PuLP Basics: Facility Location Example

```
# The requirements for the products
REQUIREMENT = {
    1 : 7,
    2 : 5,
    3 : 3,
    4 : 2,
    5 : 2,
}

# Set of all products
PRODUCTS = REQUIREMENT.keys()
PRODUCTS.sort()

# Costs of the facilities
FIXED_COST = {
    1 : 10,
    2 : 20,
    3 : 16,
    4 : 1,
    5 : 2,
```

DipPy: Modeling Decomposition (Mike O'Sullivan)

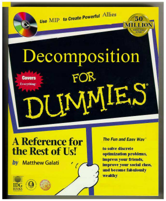
DIP Framework

DIP is a software framework and stand-alone solver for implementation and use of a variety of decomposition-based algorithms.

- Decomposition-based algorithms have traditionally been extremely difficult to implement and compare.
- DIP abstracts the common, generic elements of these methods.
  - Key: API is in terms of the compact formulation.
  - The framework takes care of reformulation and implementation.
  - DIP is now a *fully generic* decomposition-based parallel MILP solver.

Methods

- Column generation (Dantzig-Wolfe)
- Cutting plane method
- Lagrangian relaxation (not complete)
- Hybrid methods



$\Leftarrow$ *Joke*!

DipPy Basics: Facility Location Example

```
from products   import REQUIREMENT, PRODUCTS
from facilities import FIXED_CHARGE, LOCATIONS, CAPACITY

prob = dippy.DipProblem("Facility_Location")

ASSIGNMENTS = [(i, j) for i in LOCATIONS for j in PRODUCTS]
assign_vars = LpVariable.dicts("x", ASSIGNMENTS, 0, 1, LpBinary)
use_vars    = LpVariable.dicts("y", LOCATIONS, 0, 1, LpBinary)

prob += lpSum(use_vars[i] * FIXED_COST[i] for i in LOCATIONS)

for j in PRODUCTS:
    prob += lpSum(assign_vars[(i, j)] for i in LOCATIONS) == 1

for i in LOCATIONS:
    prob.relaxation[i] += lpSum(assign_vars[(i, j)] * REQUIREMENT[
                                for j in PRODUCTS) <= CAPACITY * use_vars[

dippy.Solve(prob, {doPriceCut:1})
```

SolverStudio (Andrew Mason)

- Spreadsheet optimization has had a (deservedly) bad reputation for many years.
- SolverStudio will change your mind about that!
- SolverStudio provides a full-blown modeling environment inside a spreadsheet.
  - Edit and run the model.
  - Populate the model from the spreadsheet.

Coopr and Pyomo

- An algebraic modeling language in Python similar to PuLP.
- More powerful, includes support for nonlinear modeling.
- Coopr also include PySP for stochastic Programming.
- *Developers*: Bill Hart, David Woodruff, John Siirola, and others at Sandia National Labs.

CyLP: Low-level API for Cbc/Clp

- A lower-level modeling language for accessing details of the algorithms and low-level parts of the API.
- Clp
  - Pivot-level control of algorithm in Clp.
  - Access to fine-grained results of solve.
- Cbc
  - Python class for cut generators
- *Developers*: Mehdi Towhidi and Dominique Orban

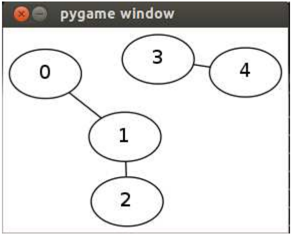
CyLP: Accessing the Tableaux

```
lp = CyClpSimplex()
x = lp.addVariable('x', numVars)
lp += x_u >= x >= 0

lp += (A * x <= b if cons_sense == '<=' else A * x >= b)

lp.objective = -c * x if obj_sense == 'Max' else c * x
lp.primal(startFinishOptions = 1)
numCons = len(b)
print 'Current solution is', lp.primalVariableSolution['x']
numAllVars = len(lp.primalVariableSolutionAll)

tableaux = np.zeros(shape = (numAllVars, numCons))
for i in range(numAllVars):
    lp.getBInvACol(i, tableaux[i,:])
tableaux = tableaux.transpose()
rhs = tableaux[:,numVars:]*np.matrix(b).transpose()
```

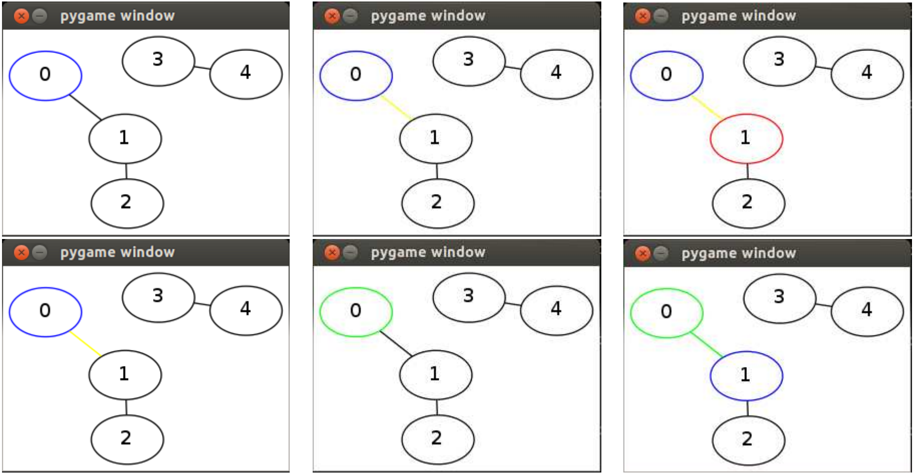
GiMPy (with Aykut Bulut)

- A graph class for Python 2.$*$.
- Builds, displays, and saves graphs (many options)
- Focus is on *visualization* of well-known graph algorithms.
  - Priority in implementation is on *clarity* of the algorithms.
  - Efficiency is *not* the goal (though we try to be as efficient as we can).

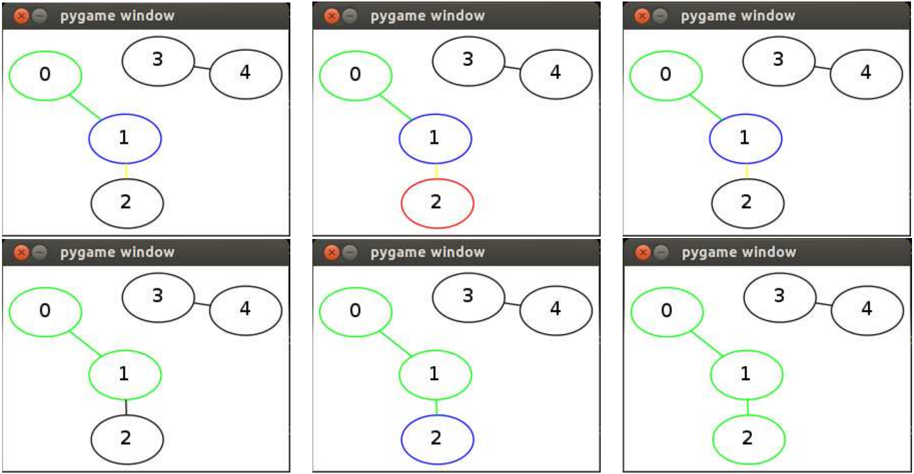
```
from gimpy import Graph
if __name__=='__main__':
  g = Graph(display='pygame')
  g.add_edge(0,1)
  g.add_edge(1,2)
  g.add_edge(3,4)
  g.display()
  g.search(0)
```



GIMPy Example



GiMPy Example



GiMPy Algorithm Visualization

The following problem/algorithm pairs with similar visualization options exist.

- Graph Search:
  - BFS
  - DFS
  - Prim's
  - Component Labeling,
  - Dijkstra's
  - Topological Sort
- Shortest path: Dijkstra's, Label Correcting
- Maximum flow: Augmenting Path, Preflow Push
- Minimum spanning tree: Prim's Algorithm, Kruskal Algorithm
- Minimum Cost Flow: Network Simplex, Cycle Canceling
- Data structures: Union-Find (quick union, quick find), Binary Search Tree, Heap

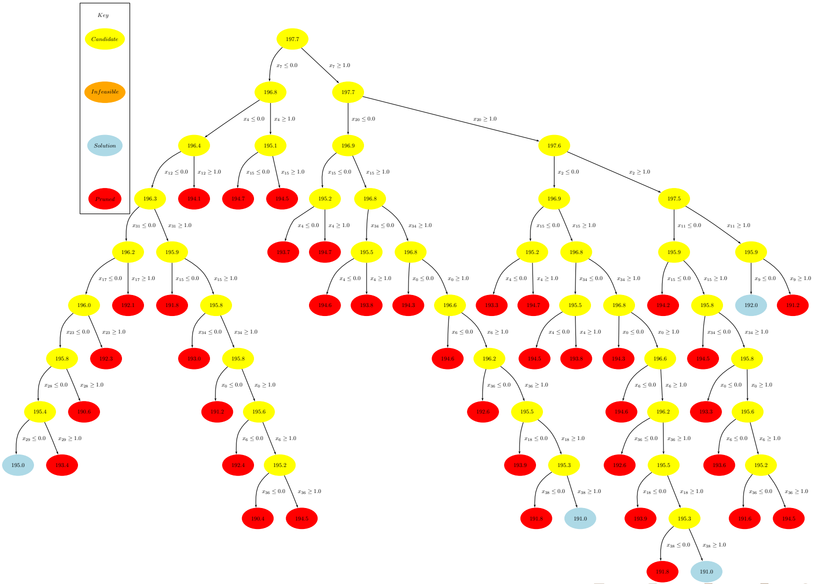
GiMPy Tree

- `Tree` class derived from `Graph` class.
- `BinaryTree` class derived from `Tree` class.
- Has binary tree specific API and attributes.

GrUMPy Overview

- Visualizations for solution methods for linear models.
  - Branch and bound
  - Cutting plane method
- `BBTree` derived from GiMPy `Tree`.
  - Reads branch-and-bound data either dynamically or statically.
  - Builds dynamic visualizations of solution process.
  - Includes a pure Python branch and bound implementation.
- `Polyhedron2D` derived from `pypolyhedron`.
  - Can construct 2D polyhedra defined by generators or inequalities.
  - Displays convex hull of integer points.
  - Can produce animations of the cutting plane method.
- GrUMPy is an expansion and continuation of the BAK project (Brady Hunsaker and Osman Ozaltin).

GrUMPy: `BBTree` Branch and Bound Implementation

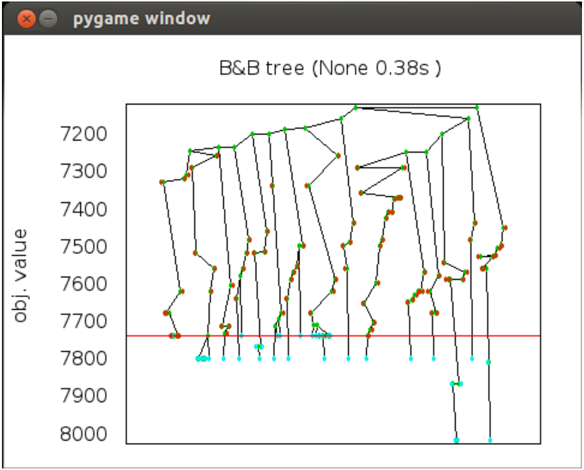


GrUMPy: Dynamic Branch and Bound Visualizations

- GrUMPy provides four visualizations of the branch and bound process.
- Can be used dynamically or statically with any instrumented solver.
  - BB tree
  - Histogram
  - Scatter plot
  - Incumbent path

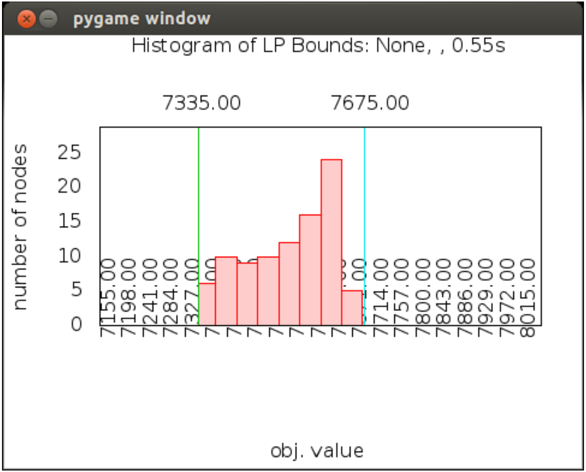
GrUMPy Branch and Bound Tree

Figure: BB tree generated by GrUMPy



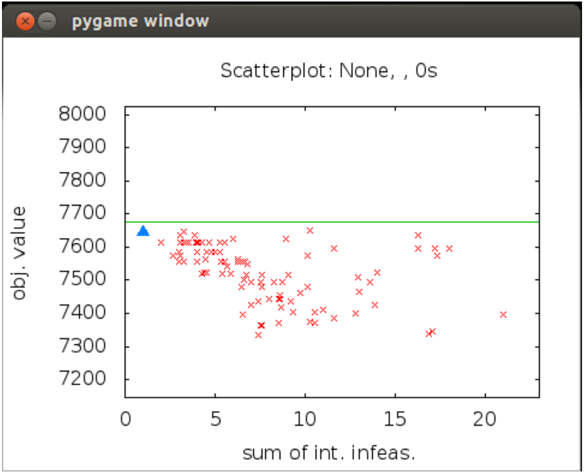
GrUMPy Histogram

Figure: BB histogram generated by GrUMPy



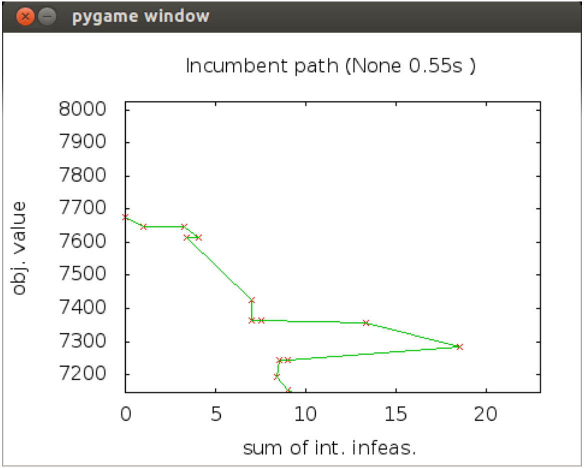
GrUMPy Scatter Plot

Figure: Scatter plot generated by GrUMPy



GrUMPy Incumbent Path

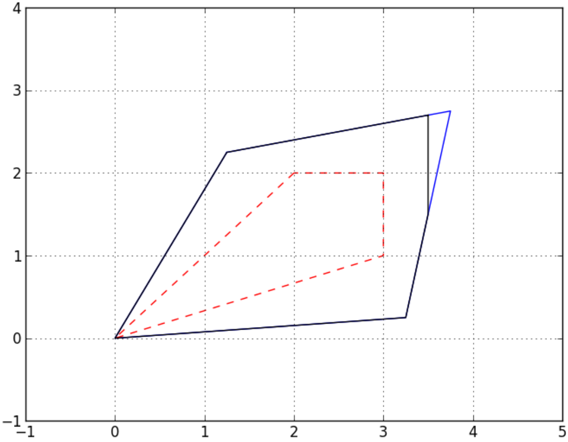
Figure: Incumbent path generated by GrUMPy



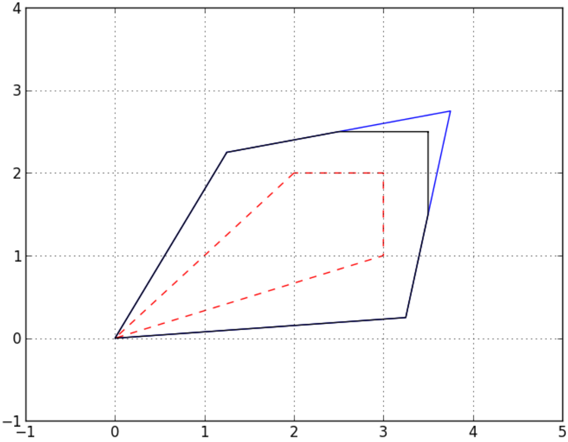
GrUMPy: Polyhedron2D

```
fig = plt.figure()
ax = fig.add_subplot(111)
ax.grid()
if points is not None:
    p = Polyhedron2D(points = points, rays = rays)
else:
    p = Polyhedron2D(A = A, b = b)
p.draw(ax, color = 'blue', linestyle = 'solid')
ax.set_xlim(p.plot_min[0], p.plot_max[0])
ax.set_ylim(p.plot_min[1], p.plot_max[1])
pI = p.make_integer_hull()
pI.draw(ax, color = 'red', linestyle = 'dashed')
if c is not None:
    add_line(ax, c, obj_val, p.plot_max - [0.2, 0.2], p.plot_min +
                  linestyle = 'dashed')
plt.show()
```

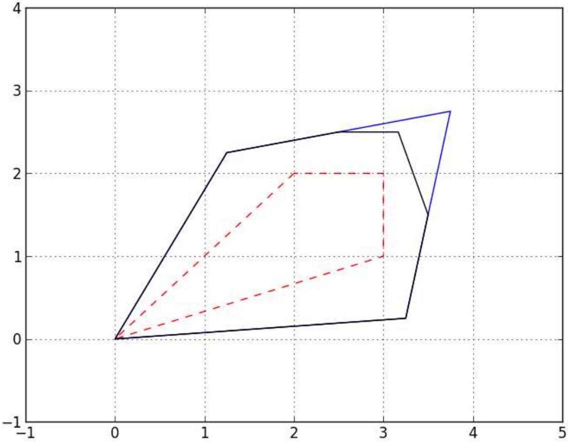
GrUMPy: Polyhedron2D



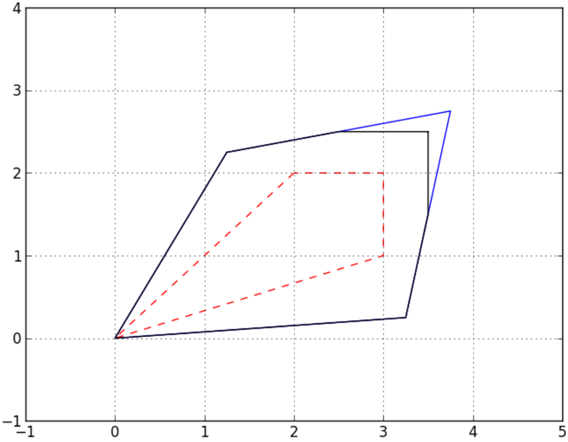
GrUMPy: `Polyhedron2D`



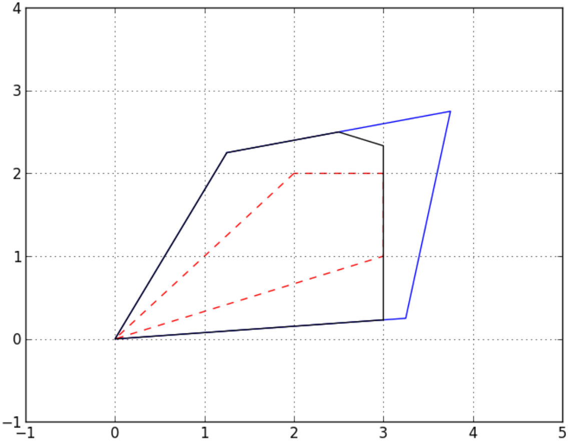
GrUMPy: Polyhedron2D



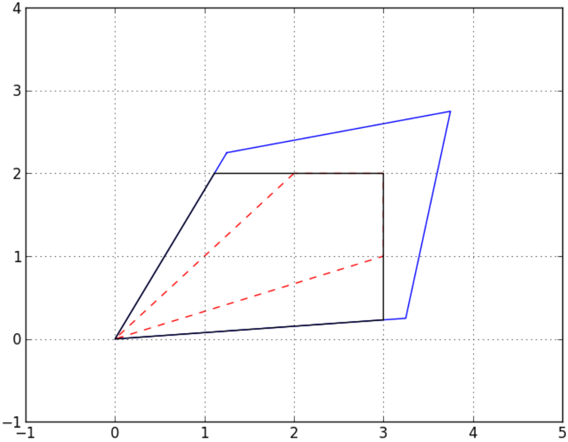
GrUMPy: Polyhedron2D



GrUMPy: `Polyhedron2D`



GrUMPy: `Polyhedron2D`



Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Interactive Shells

A number of projects provide interactive shells (SYMPHONY, CLP, Cbc, OS)

```
~/COIN/trunk/build/bin > ./symphony
==  Welcome to the SYMPHONY MILP Solver
==  Copyright 2000-2011 Ted Ralphs and others
==  All Rights Reserved.
==  Distributed under the Eclipse Public License 1.0
==  Version: Trunk (unstable)
==  Build Date: Mar 16 2013
==  Revision Number: 2068

***** WELCOME TO SYMPHONY INTERACTIVE MIP SOLVER ******

Please type 'help'/'?' to see the main commands!

SYMPHONY:
```

To invoke, type command with no arguments in the `bin` directory (or click in incon).
Note that shells are more capable when `readline` and `history` are available.

OS: Solving a Problem on the Command Line

- The OS project provides an single executable `OSSolverService` that can be used to call most COIN solvers.
- To solve a problem in MPS format

```
OSSolverService -mps parinc.mps
```

- The solver also accepts AMPL nl and OSiL formats.
- You can display the results in raw XML, but it's better to print to a file to be parsed.

```
OSSolverService -osil parincLinear.osil -osrl result.xml
```

- You can then view in a browser using XSLT.
  - Copy the style sheets to your output directory.
  - Open in your browser

OS: Remote Solves

The OSSolverService can be invoked to make remote solve calls.

```
./OSSolverService osol remoteSolve2.osol serviceLocation
      http://74.94.100.129:8080/OSServer/services/OSSolverService
```

Note that in this case, even the instance file is stored remotely.

```
<osol xmlns="os.optimizationservices.org">
<general>

<instanceLocation locationType="http">
http://www.coin-or.org/OS/p0033.osil
</instanceLocation>
<solverToInvoke>symphony</solverToInvoke>
</general>

</osol>
```

OS: Specifying a Solver

```
OSSolverService -osil ../../data/osilFiles/p0033.osil
      -solver cbc
```

To solve a **linear program** set the solver options to:

- `clp`
- `dylp`

To solve a **mixed-integer linear program** set the solver options to:

- `cbc`
- `symphony`

To solve a **continuous nonlinear program** set the solver options to:

- `ipopt`

To solve a **mixed-integer nonlinear program** set the solver options to:

- `bonmin`
- `couenne`

OS: File formats

- What is the point of the OSiL format?
  - Provides a single interchange standard for all classes of mathematical programs.
  - Makes it easy to use existing tools for defining Web services, etc.
  - Generally, however, one would not build an OSiL file directly.
  -
- To construct an OSiL file, there are several routes.
  - Use a modeling language—AMPL, GAMS, and MPL work with COIN-OR solvers.
  - Use FlopC++.
  - Build the instance in memory using COIN-OR utilities.
- There are also result and options languages for specifying options to a solver and getting results back.
- XML makes it easy to display the results in a standard templated format.

Outline

1 Introduction to COIN
- COIN-OR Foundation
- Overview of Projects

2 Overview of Optimization Suite
- Installing the COIN Optimization Suite
- Documentation and Support

3 Entry Points
- Modeling Systems
- Python Tools
- Command-line Tools
- Building Applications

4 Advanced Development
- SYMPHONY
- DIP
- CHiPPS
- Working with Source

Building Applications

- After mastering black box solvers, the next step is to try building a custom applications.
- There are two basic routes
  - Calling the library as a black box through the API.
  - Customizing the library through callbacks and customization classes.

Building Applications: APIs

Using SYMPHONY API

```
#include "symphony.h"

int main(int argc, char **argv)
{
   sym_environment *env = sym_open_environment();

   sym_parse_command_line(env, argc, argv);

   sym_load_problem(env);

   sym_solve(env);

   sym_close_environment(env);

   return(0);
}
```

Linking to COIN Libraries: Distribution

- `bin`
- `lib`
  - `python2.*/site-packages`
  - `pkg-config`
- `share/coin`
  - `doc`
  - `Data`
- `include/coin`

Linking to COIN Libraries: Using pkg-config

- pkg-config is a utility available on most *nix systems.
- It helps automatically determine how to build against installed libraries.
- To determine the libraries that need to be linked against, the command is

```
pkg-config --libs cbc
```

- To determine the flags that should be given to the compiler, the command is

```
pkg-config --cflags cbc
```

- Note that the user doesn't need to know what any of the downstream dependencies are.
- Depending on the install location, may need to set the environment variable PKG_CONFIG_PATH.
- The .pc files are installed in

```
/path/to/install/location/lib/pkgconfig
```

Linking to COIN Libraries: `pkg-config` in a Makefile

- The `pkg-config` command can be used to vastly simplify the Makefiles used to build project that link with COIN.

```
LIBS = ‘PKG_CONFIG_PATH=/path/to/pc-files pkg-config --libs os‘
CFLAGS = ‘PKG_CONFIG_PATH=/path/to/pc-files pkg-config --cflags os‘

.cpp.o:
        $(CXX) \$(CFLAGS) -c -o file.cpp
$(EXE):
        $(CXX) \$(CFLAGS) -o app.exe $(OBJS) \$(LIBS)
```

- Note that the auto tools will automatically produce Makefiles that utilize pkg-config.

Libtool Versioning (Shared Libraries)

- Libtools versioning allows smooth upgrading without breaking existing builds.
- The libtool version number indicates backward compatibility.
- Versions of the same library can be installed side-by-side (version number is encoded in the name).
- When a new version of a library is installed, codes built against the older library are automatically linked to the new version (if it is backward compatible).
- Based on concepts of *age*, *current*, and *revision*.

A Note About Configuration Headers

- One of the most recent enhancements to the build system is better handling of configuration header files.
- These are the files that contain settings specific to a platform or individual user's set-up.
- In all cases, the header file to include to get these settings is called `ConfigXxx.h`. From this file, the proper additional file will be included.
- For each project, the defined symbols are now divided into public and private sets, with a generated and default header for each set.
  - `config.h` (private)
  - `config_default.h` (private)
  - `config_xxx.h` (public)
  - `config_xxx_default.h` (public)
- Which header to include is controlled by whether the symbol `XXX_BUILD` is defined or not.

Finding Code Snippets and Examples

- Many projects have a directory with examples that show how to link to the library.
- The examples typically reside in the `examples/` directory of the project's source tree.
- In the near future, they will be installed as part of the binary distribution.
- If you build from source on a *nix platform, custom Makefiles are produced that allow easy linking to installed libraries.
- Visual Studio project files are also available for many examples.

CoinBazaar and Application Templates

- CoinBazaar is a collection of examples, utilities, and light-weight applications built using COIN-OR.
- Application Templates is a project within CoinBazaar that provides templates for different kinds of projects.
- In CoinAll, it's in the `examples` directory.
- Otherwise, get it with

```
svn co
https://projects.coin-or.org/svn/CoinBazaar/projects/ApplicationTemplates/releases/1.2.2
```

- Examples
  - Branch-cut-price
  - Algorithmic differentiation
  - Adding Cgl cuts
  - ...

Building Blocks: Open Solver Interface

- Uniform API for a variety of solvers: CBC, CLP, CPLEX, DyLP, FortMP, GLPK, Mosek, OSL, Soplex, SYMPHONY, the Volume Algorithm, XPRESS-MP supported to varying degrees.
- Read input from MPS or CPLEX LP files or construct instances using COIN-OR data structures.
- Manipulate instances and output to MPS or LP file.
- Set solver parameters.
- Calls LP solver for LP or MIP LP relaxation.
- Manages interaction with dynamic cut and column generators.
- Calls MIP solver.
- Returns solution and status information.

Building Blocks: Open Solver Interface

- Uniform API for a variety of solvers: CBC, CLP, CPLEX, DyLP, FortMP, GLPK, Mosek, OSL, Soplex, SYMPHONY, the Volume Algorithm, XPRESS-MP supported to varying degrees.
- Read input from MPS or CPLEX LP files or construct instances using COIN-OR data structures.
- Manipulate instances and output to MPS or LP file.
- Set solver parameters.
- Calls LP solver for LP or MIP LP relaxation.
- Manages interaction with dynamic cut and column generators.
- Calls MIP solver.
- Returns solution and status information.

Building Blocks: Cut Generator Library

- A collection of cutting-plane generators and management utilities.
- Interacts with OSI to inspect problem instance and solution information and get violated cuts.
- Cuts include:
  - Combinatorial cuts: AllDifferent, Clique, KnapsackCover, OddHole
  - Flow cover cuts
  - Lift-and-project cuts
  - Mixed integer rounding cuts
  - General strengthening: DuplicateRows, Preprocessing, Probing, SimpleRounding

Building Blocks: Calling a Solver with OS

Step 1: Construct an instance in a solver-independent format using the OS API.
Step 2: Create a solver object

```
CoinSolver *solver = new CoinSolver();
solver->sSolverName = "clp";
```

Step 3: Feed the solver object the instance created in Step 1.

```
solver->osinstance = osinstance;
```

Step 4: Build solver-specific model instance

```
solver->buildSolverInstance();
```

Step 5: Solve the problem.

```
solver->solve();
```

Building an OS Instance

The `OSInstance` class provides an API for constructing models and getting those models into solvers.

- `set()` and `add()` methods for creating models.
- `get()` methods for getting information about a problem.
- `calculate()` methods for finding gradient and Hessians using algorithmic differentiation.

Building an OS Instance (cont.)

- Create an `OSInstance` object.

```
OSInstance *osinstance =  new OSInstance();
```

- Put some variables in

```
osinstance->setVariableNumber( 2);
osinstance->addVariable(0, "x0", 0, OSDBL_MAX, 'C', OSNAN, "");
osinstance->addVariable(1, "x1", 0, OSDBL_MAX, 'C', OSNAN, "");
```

- There are methods for constructing
  - the objective function
  - constraints with all linear terms
  - quadratic constraints
  - constraints with general nonlinear terms

Building Linear Models

- `CoinUtils` has a number of utilities for constructing instances.
  - `PackedMatrix` and `PackedVector` classes.
  - `CoinBuild`
  - `CoinModel`
- `Osi` provides an interface for building models and getting them into solvers for linear probes.

Customization through Callbacks and Inheritance

- A number of the solvers can be customized with callbacks for adding such things as
  - Valid inequalities
  - Heuristics
  - Branching
- These include Clp, Cbc, SYMPHONY, Bcp, DIP, and CHiPPS.
- In Dippy, callbacks can be written in Python, providing convenient customization options.
- Most other frameworks require coding in C/C++.
- On the TODO list is to enable Python callbacks in more projects.

Dippy Callbacks

```
def solve_subproblem(prob, index, redCosts, convexDual):
   ...
   return knapsack01(obj, weights, CAPACITY)
def knapsack01(obj, weights, capacity):
    ...
    return solution
def first_fit(prob):
    ...
    return bvs
prob.init_vars = first_fit
def choose_branch(prob, sol):
   ...
   return ([], down_branch_ub, up_branch_lb, [])
def generate_cuts(prob, sol):
    ...
    return new_cuts
def heuristics(prob, xhat, cost):
    ...
    return sols
dippy.Solve(prob, {'doPriceCut': '1'})
```

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

SYMPHONY (with M. Guzelsoy and A. Mahajan)

Using SYMPHONY

- C Library API
- OSI C++ interface
- Interactive shell
- AMPL/GMPL, GAMS, FLOPC++
- Framework for customization

Advanced Features

- Shared and distributed memory parallel MIP (since 1994)
- Biobjective MIP
- Warm starting for MIP
- Sensitivity analysis for MIP

SYMPHONY Applications

- TSP/VRP
- Set Partitioning Problem
- Mixed Postman Problem
- Capacitated Node Routing
- Multicriteria Knapsack

Outline

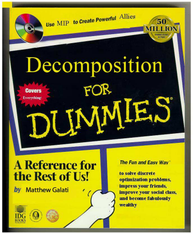
1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

DIP Framework: Motivation

DIP Framework

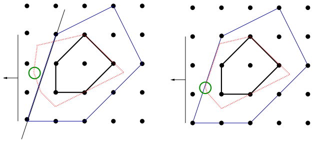
DIP is a software framework that provides a virtual sandbox for testing and comparing various decomposition-based bounding methods.

- It's difficult to compare variants of decomposition-based algorithms.
- The method for separation/optimization over a given relaxation is the primary custom component of any of these algorithms.
- DIP abstracts the common, generic elements of these methods.
  - Key: The user defines methods in the space of the compact formulation.
  - The framework takes care of reformulation and implementation for all variants.



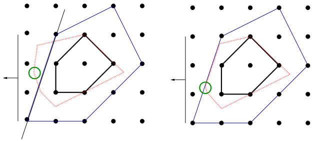
Traditional Decomposition Methods

The Cutting Plane Method (CP) iteratively builds an *outer* approximation of $\mathcal{P}'$ by solving a cutting plane generation subproblem.

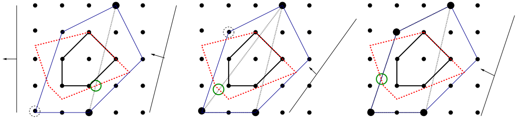


Traditional Decomposition Methods

The Cutting Plane Method (CP) iteratively builds an *outer* approximation of $\mathcal{P}'$ by solving a cutting plane generation subproblem.

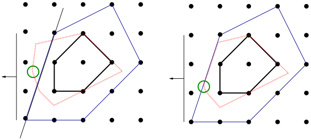


The Dantzig-Wolfe Method (DW) iteratively builds an *inner* approximation of $\mathcal{P}'$ by solving a column generation subproblem.

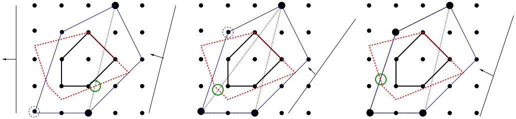


Traditional Decomposition Methods

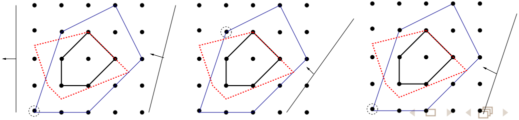
The Cutting Plane Method (CP) iteratively builds an *outer* approximation of $\mathcal{P}'$ by solving a cutting plane generation subproblem.



The Dantzig-Wolfe Method (DW) iteratively builds an *inner* approximation of $\mathcal{P}'$ by solving a column generation subproblem.



The Lagrangian Method (LD) iteratively solves a Lagrangian relaxation subproblem.



Common Threads

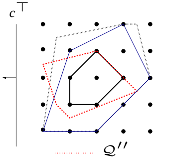
- The LP bound is obtained by optimizing over the intersection of two explicitly defined polyhedra.

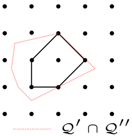
$$z_{LP} = \min_{x \in \mathbb{R}^n} \{c^\top x \mid x \in \mathcal{Q}' \cap \mathcal{Q}''\}$$

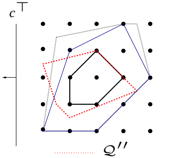
- The decomposition bound is obtained by optimizing over the intersection of one explicitly defined polyhedron and one implicitly defined polyhedron.

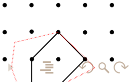
$$z_{CP} = z_{DW} = z_{LD} = z_D = \min_{x \in \mathbb{R}^n} \{c^\top x \mid x \in \mathcal{P}' \cap \mathcal{Q}''\} \geq z_{LP}$$

- Traditional decomposition-based bounding methods contain two primary steps
  - **Master Problem:** Update the primal/dual solution information.
  - **Subproblem:** Update the approximation of $\mathcal{P}'$: $SEP(x, \mathcal{P}')$ or $OPT(c, \mathcal{P}')$.
- Integrated decomposition methods further improve the bound by considering two implicitly defined polyhedra whose descriptions are iteratively refined.
  - Price and Cut (PC)
  - Relax and Cut (RC)
  - Decompose and Cut (DC)









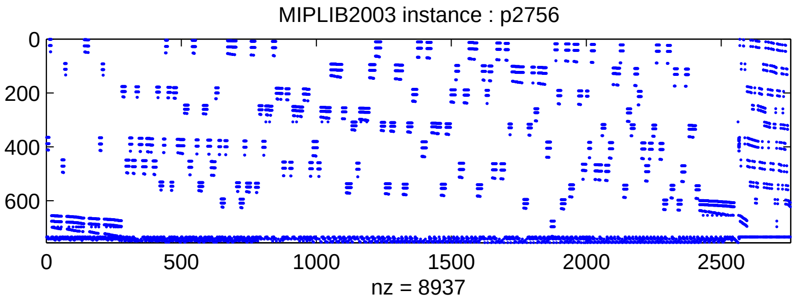
DIP Framework (with Matt Galati)

- The DIP framework, written in C++, is accessed through two user interfaces:
  - Applications Interface: `DecompApp`
  - Algorithms Interface: `DecompAlgo`
- DIP provides the bounding method for branch and bound.
- ALPS (Abstract Library for Parallel Search) provides the framework for parallel tree search.
  - `AlpsDecompModel : public AlpsModel`
    - a wrapper class that calls (data access) methods from `DecompApp`
  - `AlpsDecompTreeNode : public AlpsTreeNode`
    - a wrapper class that calls (algorithmic) methods from `DecompAlgo`

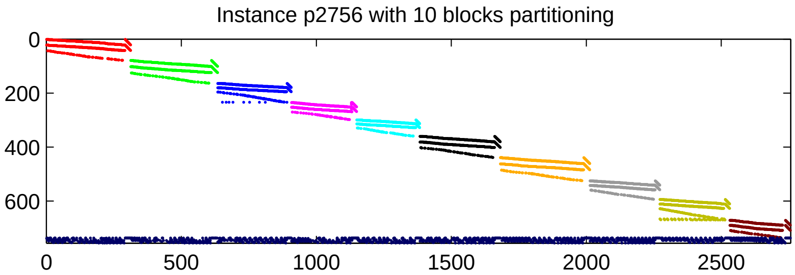
Automatic Structure Detection

- For unstructured problems, block structure may be detected automatically.
- This is done using hypergraph partitioning methods.
- We map each row of the original matrix to a hyperedge and the nonzero elements to nodes in a hypergraph.
- Hypergraph partitioning results in identification of the blocks in a singly-bordered block diagonal matrix.

Hidden Block Structure



Hidden Block Structure



Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

CHiPPS (with Yan Xu)

- CHiPPS stands for COIN-OR High Performance Parallel Search.
- CHiPPS is a set of C++ class libraries for implementing tree search algorithms for both sequential and parallel environments.

CHiPPS Components (Current)

ALPS (Abstract Library for Parallel Search)

- is the search-handling layer (parallel and sequential).
- provides various search strategies based on node priorities.

BiCePS (Branch, Constrain, and Price Software)

- is the data-handling layer for relaxation-based optimization.
- adds notion of variables and constraints.
- assumes iterative bounding process.

BLIS (BiCePS Linear Integer Solver)

- is a concretization of BiCePS.
- specific to models with linear constraints and objective function.

ALPS: Design Goals

- Intuitive object-oriented class structure.
  - `AlpsModel`
  - `AlpsTreeNode`
  - `AlpsNodeDesc`
  - `AlpsSolution`
  - `AlpsParameterSet`
- Minimal algorithmic assumptions in the base class.
  - Support for a wide range of problem classes and algorithms.
  - Support for constraint programming.
- Easy for user to develop a custom solver.
- Design for *parallel scalability*, but operate effective in a sequential environment.
- Explicit support for *memory compression* techniques (packing/differencing) important for implementing optimization algorithms.

ALPS: Overview of Features

- The design is based on a very general concept of *knowledge*.
- Knowledge is shared asynchronously through *pools* and *brokers*.
- Management overhead is reduced with the *master-hub-worker* paradigm.
- Overhead is decreased using dynamic task granularity.
- Two static load balancing techniques are used.
- Three dynamic load balancing techniques are employed.
- Uses asynchronous messaging to the highest extent possible.
- A scheduler on each process manages tasks like
  - node processing,
  - load balaning,
  - update search states, and
  - termination checking, etc.

BiCePS: Support for Relaxation-based Optimization

- Adds notion of *modeling objects* (variables and constraints).
- Models are built from sets of such objects.
- Bounding is an iterative process that produces new objects.
- A differencing scheme is used to store the difference between the descriptions of a child node and its parent.

```
struct BcpsObjectListMod
{
    int  numRemove;
    int* posRemove;
    int  numAdd;
    BcpsObject **objects;
    BcpsFieldListMod<double> lbHard;
    BcpsFieldListMod<double> ubHard;
    BcpsFieldListMod<double> lbSoft;
    BcpsFieldListMod<double> ubSoft;
};
```

```
template<class T>
struct BcpsFieldListMod
{
    bool relative;
    int  numModify;
    int  *posModify;
    T    *entries;
};
```

BLIS: A Generic Distributed Solver for MILP

MILP

$$\begin{aligned} min \quad & c^T x && (1)\\ s.t. \quad & Ax \leq b && (2)\\ & x_i \in \mathbb{Z} \quad \forall\, i \in I && (3)\end{aligned}$$

where $(A, b) \in \mathbb{R}^{m\times(n+1)}$, $c \in \mathbb{R}^n$.

Basic Algorithmic Components

- Bounding method.
- Branching scheme.
- Object generators.
- Heuristics.

Outline

1. Introduction to COIN
   - COIN-OR Foundation
   - Overview of Projects
2. Overview of Optimization Suite
   - Installing the COIN Optimization Suite
   - Documentation and Support
3. Entry Points
   - Modeling Systems
   - Python Tools
   - Command-line Tools
   - Building Applications
4. Advanced Development
   - SYMPHONY
   - DIP
   - CHiPPS
   - Working with Source

Build Tools

- Build system is based on the GNU auto tools.
  - Build scripts work on any platform
  - Externals can be used to get complete sources (including dependencies).
  - Projects are only loosely coupled and can be installed individually.
  - Scripts available for upgrading to latest releases.
  - Smooth upgrade path.
- Features
  - Libtool library versioning.
  - Support for pkg-config.
  - Build against installed binaries.
  - Wrapper libraries for third party open source projects.

Monolithic Builds from Source (*Nix)

- Suppose you want to check out CoinAll (or any other project) and build all required libraries and binaries from source.

Monolithic Build

```
svn co http://projects.coin-or.org/svn/CoinBinary/CoinAll/stable/1.6 CoinAll-1.
cd CoinAll-1.6
mkdir build
cd build
../configure --enable-gnu-packages -C --prefix=/path/to/install/location
make -j 2
make test
make install
```

- Note that after building, the examples will be installed with Makefiles in project subdirectories.

ThirdParty Projects

- There are a number of open-source projects that COIN projects can link to, but whose source we do not distribute.
- We provide convenient scripts for downloading these projects and a build harness for build them.
- We also produce libraries and pkg-config files.
    - AMPL Solver Library
    - Blas
    - Lapack
    - Glpk
    - Metis
    - MUMPS
    - Soplex
    - SCIP
    - HSL
    - FilterSQP

Parallel Builds

- SYMPHONY, DIP, CHiPPS, and Cbc all include the ability to solve in parallel.
  - CHiPPS uses MPI and is targeted at massive parallelism (it would be possible to develop a hybrid algorithm, however).
  - SYMPHONY and Cbc both have shared memory threaded parallelism.
  - DIP's parallel model is still being implemented but is a hybrid distributed/shared approach.
- To enable shared memory for Cbc, option is `-enable-cbc-parallel`.
- For SYMPHONY, it's `-enable-openmp`
- For CHiPPS, specify the location of MIP with `-with-mpi-incdir` and `-with-mpi-lib`:

```
configure --enable-static
          --disable-shared
          --with-mpi-incdir=/usr/include/mpich2
          --with-mpi-lib="-L/usr/lib  -lmpich"
          MPICC=mpicc
          MPICXX=mpic++
```

Other Configure-time Options

- Over-riding variables: `CC, CXX, F77`
- `-prefix`
- `-enable-debug`
- `-enable-gnu-packages`
- `-C`

Building Individual Projects from Source (*Nix)

- Assuming some libraries are already installed in `/path/to/install/location`

Tweaking a Single Library

```
svn co http://projects.coin-or.org/svn/Cbc/stable/2.6/Cbc Cbc-2.6
cd Cbc-2.6
mkdir build
cd build
../configure --enable-gnu-packages -C --prefix=/path/to/install/location
make -j 2
make test
make install
```

- Note that this checks out Cbc without externals and links against installed libraries.
- “Old style” builds will still work with all dependencies checked out using SVN externals.

Building Individual Projects from Source (Windows)

- Building with either CYGWIN or MinGW compilers is just as on other *nix systems.
- For Visual Studio, it is possible to build with the `cl` compiler using the autotools!
- To build through the IDE, MSVC++ project files provided for most projects.
- Current standard version of the compiler is v10.
- Projects requiring Fortran are a problem with the MSVC++ IDE.
- Keeping settings synced across all projects has always been painful.
  - *Important*: We recently switched to using property sheets to save common settings.
  - Change the settings on the property sheets, not in the individual projects and configurations!!!!
  - It is incredibly easy to slip up on this and the repercussions are always annoyingly difficult to deal with.

COIN needs your help!

- Contribute a project
- Help develop an existing project
- Use projects and report bugs
- Volunteer to review new projects
- Develop documentation
- Develop Web site
- Chair a committee

Questions? & Thank You!