Xpress-Kalis

A CP Solver integrated in the FICO Xpress Optimization Suite

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## FICO Snapshot

| **Profile** | The leader in predictive analytics for decision management  
| | Founded: 1956  
| | NYSE: FICO  
| | Revenues: $676 million (fiscal 2012) |
| **Products and Services** | Scores and related analytic models  
| | Analytic applications for risk management, fraud, marketing, mobility  
| | Tools for decision management |
| **Clients and Markets** | 5,000+ clients in 80 countries  
| | Industry focus: Banking, insurance, retail, health care |
| **Recent Rankings** | #1 in services operations analytics (IDC)  
| | #6 in worldwide analytics analytics software (IDC)  
| | #7 in Business Intelligence, CPM and Analytic Applications (Gartner)  
| | #26 in the FinTech 100 (American Banker) |
| **Offices** | 20+ offices worldwide, HQ in San Jose, California, USA  
| | 2,400 employees  
| | Regional Hubs: San Rafael (CA); San Diego (CA); New York; Roseville, MN; London; Birmingham (UK); Istanbul; Madrid; Munich; Sao Paulo; Bangalore; Beijing; and Singapore. |
# FICO Product Portfolio

## For Specific Decision Processes

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<th>Collections and Recovery</th>
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<tr>
<td>FICO® Customer Dialogue Manager</td>
<td>FICO® Customer Origination Manager</td>
<td>FICO® TRIAD® Customer Manager</td>
<td>FICO® Debt Manager™</td>
<td>FICO® Falcon® Fraud Manager</td>
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## For Any Decision Process

<table>
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<tr>
<th>Scores</th>
<th>B2B: FICO® Score • FICO® Credit Capacity Index™ • FICO® Insurance Risk Scores myFICO®</th>
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<td>B2C:</td>
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<th>Tools</th>
<th>Business Rules Management: FICO® Blaze Advisor® Predictive Analytics: FICO® Model Builder • FICO® Model Central Optimization: FICO® Xpress Optimization Suite • FICO® Decision Optimizer</th>
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<th>Professional Services</th>
<th>Custom Analytics Operational Best Practices Strategy Design and Optimization</th>
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XPRESS-KALIS

More than a CP solver!
GUI (development/deployment)

- Xpress-Insight: Application Deployment

Problem description facilities

- Xpress-Mosel: Modeling and programming language

Solvers

- Xpress-Optimizer
  - Simplex Optimizer
  - Barrier Optimizer
  - MIP Optimizer
  - LP
  - MIP
  - QP
  - MIQP
  - QCQP
  - MIQCQP

- Xpress-Kalis: CP/MIP
- Xpress-NonLinear
  - QP
  - QCQP
  - SOCP
  - NLP

FICO XPRESS OPTIMIZATION SUITE

Xpress-Kalis: A CP solver integrated in the FICO Xpress Optimization Suite

16 Septembre 2013
Developed by Artelys since 2001

- Object-oriented environment to model and solve complex problems using constraints programming (CP) and mixed-integer programming (MIP) techniques
- C++ libraries
- Many applications successfully deployed and in use
EXAMPLE OF APPLICATIONS

A WIDE RANGE OF APPLICATIONS

ENERGY/ENVIRONMENT
- Production planning and scheduling
- Maintenance planning

MANUFACTURING
- Production scheduling
- Hoist scheduling
- Vehicle Routing

TRANSPORT
- Resource allocation
- Maintenance Planning

HUMAN RESOURCES
- Crew rostering/rotation
- Timetabling

NETWORK/TELECOMS
- Network design
- Frequency assignment

Xpress-Kalis: A CP solver integrated in the FICO Xpress Optimization Suite
A flexible framework for constraint optimization, result of joint efforts between Artelys and FICO (Xpress Team)

Eases the experimentation with alternative model formulations and simulation of different data scenarios: quick prototyping

Seamless integration within the FICO Xpress Optimization Suite
A Mosel module: implement and solve CP problems using the Mosel language

- user-friendly modeling of complex situations, not reserved to software specialists
- from formulation to implementation in a short lapse of time
- small performance overhead
- use standard Mosel facilities for data handling, model analysis, debugging, ...
- possibility to interact with other solvers (Optimizer and NonLinear)
- possibility to implement advanced solution strategies and heuristics
! Default variable bounds
setparam("default_lb", 1); setparam("default_ub", 9)
declarations
XS = {'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I'} ! Columns
YS = 1..9 ! Rows
v: array(XS,YS) of cpvar ! Number assigned to cell (x,y)
end-declarations

v('A',1)=8; v('F',1)=3; v('B',2)=5; v('G',2)=4;
v('A',3)=2; v('E',3)=7; v('H',3)=6; v('D',4)=1;
v('I',4)=5; v('C',5)=3; v('G',5)=9; v('A',6)=6;
v('F',6)=4; v('B',7)=7; v('E',7)=2; v('I',7)=3;
v('C',8)=4; v('H',8)=1; v('D',9)=9; v('I',9)=8;

! All-different values in rows
forall(y in YS) all_different(union(x in XS) {v(x,y)})
! All-different values in columns
forall(x in XS) all_different(union(y in YS) {v(x,y)})
! All-different values in 3x3 squares
forall(i in 0..2) do
  all_different(union(x in {'A','B','C'}, y in {1+3*i,2+3*i,3+3*i}) {v(x,y)})
  all_different(union(x in {'D','E','F'}, y in {1+3*i,2+3*i,3+3*i}) {v(x,y)})
  all_different(union(x in {'G','H','I'}, y in {1+3*i,2+3*i,3+3*i}) {v(x,y)})
end-do

! Solve the problem
solct:= 0
while (cp_find_next_sol) do
  solct:=solct+1 print_solution(solct)
end-do
writeln("Number of solutions: ", solct)
writeln("Time spent in enumeration: ", getparam("COMPUTATION_TIME"), " sec")
writeln("Number of nodes: ", getparam("NODES"))
Xpress-IVE: solver-specific features for Xpress-Kalis

- visualization of CP search tree
- search statistics
- built-in scheduling representation with Gantt chart and resource usage diagram
- use standard IVE facilities for working with models, defining user graphs, debugging, etc.
FEATURES

Specialized for your problems…
Decision Variables
- Discrete (set or range of integers)
- Continuous (floating-point interval)

Constraints
- Linear / Nonlinear
  - sum, power, product, divide, exponential, ...
- Logical
  - (A or B), (A and B), (A ⇔ B), (A => B)
- Symbolic
  - all_different, abs, distance, element (1D/2D), occurrence, distribute, implies, equiv, cycle, etc.
- User-defined constraints
Search

- find one / all / best (according to some optimization criterion) solution(s)
- Configurable pre-defined strategies
  - Search with restart, dichotomic objective search, ...
- Customizable choice of branching schemes
  - Enumeration of values, domain splitting, branching on disjunctions, ...
- User-defined search heuristics
Scheduling

- High-level modeling objects for scheduling (tasks / resources)
- Cumulative and disjunctive, renewable / non-renewable resources constraints
- Setup times, resource idle times, resource usage profiles
- Scheduling oriented search process

Example: job-shop scheduling

- Schedule the production of a set of jobs on a set of machines.
- Every job is produced by a sequence of tasks, each of these tasks is processed on a different machine.
- A machine processes at most one job at a time.
Scheduling model

- using tasks and unary resource objects
- default scheduling search

```
declarations
JOBS = 1..NJ  ! Set of jobs
MACH = 1..NM  ! Set of resources
RES: array(JOBS,MACH) of integer ! Resource use of tasks
DUR: array(JOBS,MACH) of integer  ! Durations of tasks
res: array(MACH) of cpresource    ! Resources
task: array(JOBS,MACH) of cptask    ! Tasks
end-declarations

... ! Initialize the data
```
EXAMPLE: JOBSHOP SCHEDULING

HORIZON := sum(j in JOBS, m in MACH) DUR(j,m)
forall(j in JOBS) getend(task(j,NM)) <= HORIZON

! Setting up the resources (capacity 1)
forall(m in MACH)
    set_resource_attributes(res(m), KALIS_UNARY_RESOURCE, 1)

! Setting up the tasks (durations, resource used)
forall(j in JOBS, m in MACH)
    set_task_attributes(task(j,m), DUR(j,m), res(RES(j,m)))

! Precedence constraints between the tasks of every job
forall (j in JOBS, m in 1..NM-1)
    setsuccessors(task(j,m), {task(j,m+1)})

! Solve the problem & print solution
if cp_schedule(getmakespan)<>0 then
    writeln("Total completion time: ", getsol(getmakespan))
end-if
**Xpress-IVE**: automated display (Gantt chart, resource diagrams) of results for scheduling problems

**EXAMPLE: JOBSHOP SCHEDULING**

**Gantt chart:**

**Detailed task information:**
Integration of CP and MIP algorithms

CP
- Inference methods
- Concise modelling
- Exploits local constraint structure

MIP
- Relaxation methods
- Duality theory
- Exploits global matrix structure

MIP and CP have complementary strengths
Automatic linear relaxations generated by Kalis

- available for linear constraints, all-different, occurrence, distribute, minimum/maximum, absolute value, distance, element, cycle, logical (implies, or, and, equiv)

Possibility to display and extend the linear relaxations generated by Kalis (or else define your own)

Linear relaxations solved by Xpress-Optimizer

Fully automatic, configurable or even user-defined interaction

Can be used to solve min max problems found in game theory
APPLICATION EXAMPLE

Nuclear Power Plant Preventive Maintenance Planning
Schedule nuclear power plant preventive maintenances

- 8 year period for 58 nuclear reactors

Different kinds of maintenance stops:

- Every year / 5 years / 10 years (5/8/14 weeks)
- Maximum distance in time between two stops

Subject to cumulative resource constraints:

- Specific tool needed to remove and replace the reactor cover for 10 years maintenance
- Highly specialized maintenance operators and engineers are needed for these complex operations

Enough active power plants to satisfy demand
Scheduling subproblem

1 year

5 years

10 years

C1-P1 → C1-S1 → C1-P2
C2-P1 → C2-S1 → C2-P2
C3-P1 → C3-S1 → C3-P2

TIMELINE: 2008 → 2009 → 2010 → 2011 → 2012
Combined subproblem

PREVENTIVE MAINTENANCE PLANNING
Main difficulty:

- Production and maintenance tasks must be scheduled on a daily basis
- Production power and demand data are to be dealt with on a monthly basis

Need for a problem-specific constraints that links production tasks with production power variables

Task projection constraints
Task projection constraints

PREVENTIVE MAINTENANCE PLANNING
Solution display in IVE

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ANY QUESTIONS?

Thank you for your attention