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JSR-331
Constraint Programming API
Early Draft Review

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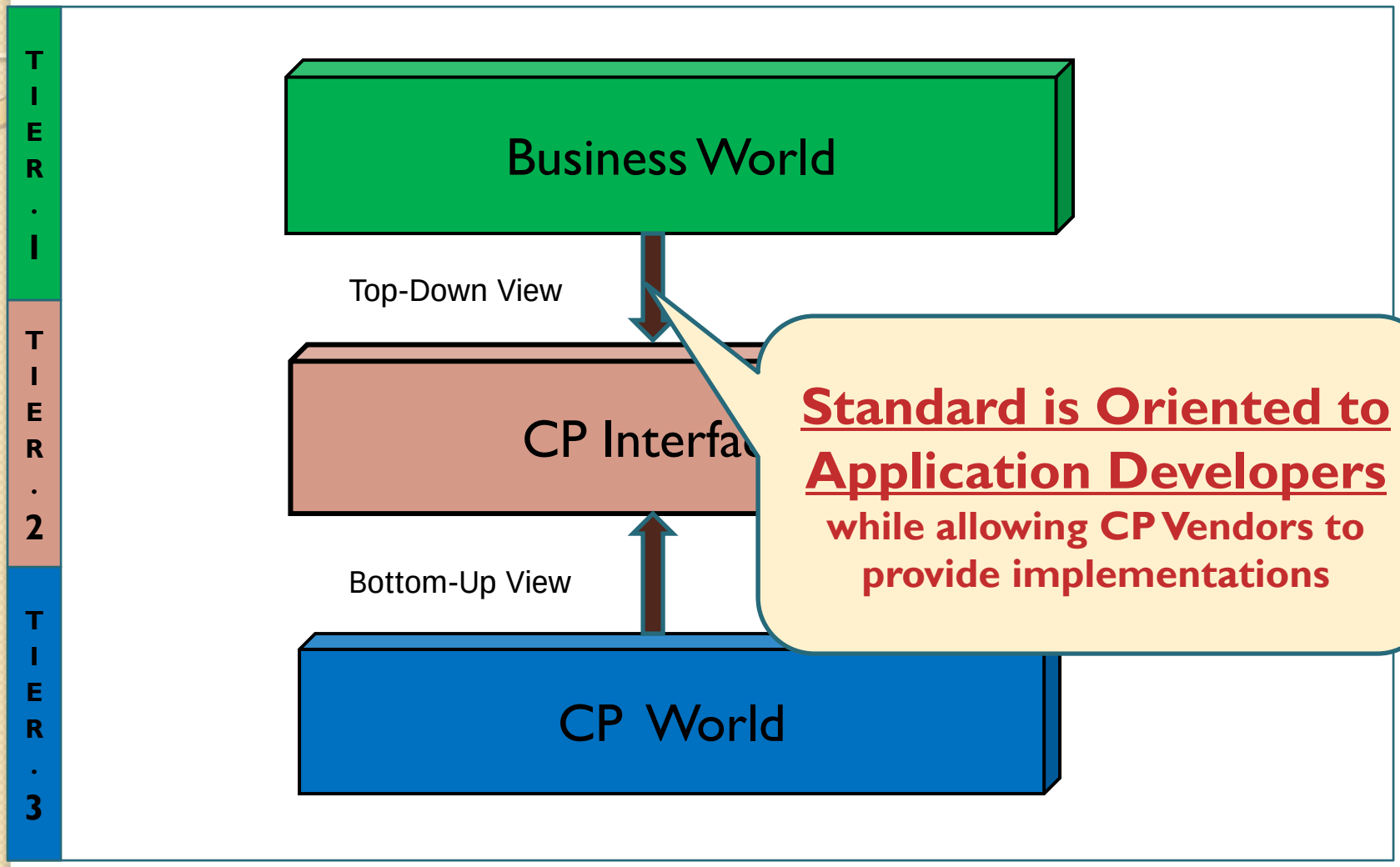
JSR-331 – Java Specification Request

- Java Constraint Programming API under the roof of the Java Community Process (JCP) www.jcp.org
- We present key concepts and design decisions related to the proposed standard for representation and resolution of constraint satisfaction and optimization problems
- JSR-331Early Draft is now available for public review at www.cpstandards.org
- Everybody comments are welcome

CP Standardization Perspective

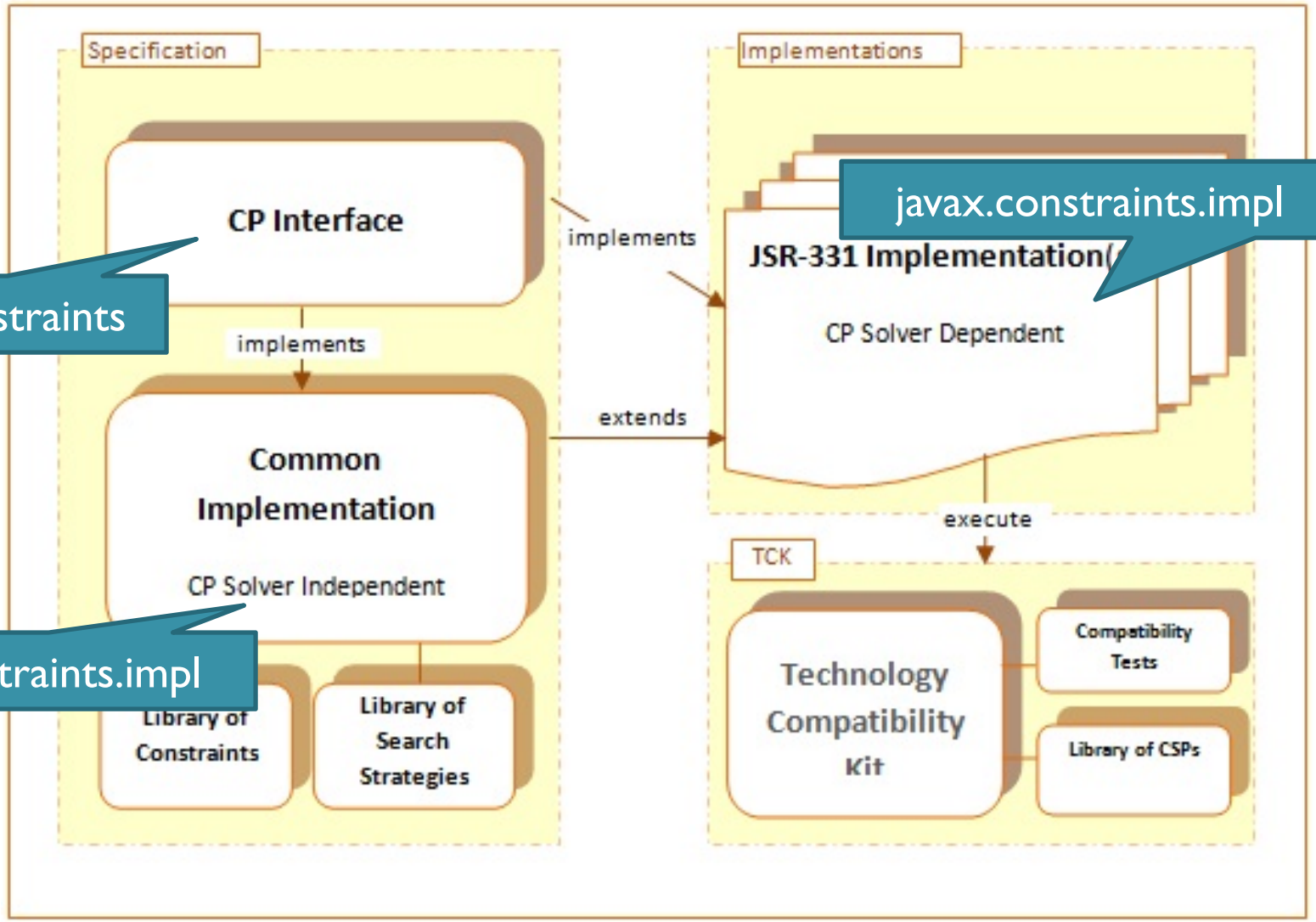


Key Objectives

- Make CP more accessible for business software developers
- Allow a Java business application developer to easily switch between different solver implementations without any changes in the application code
- Assist CP vendors in creating practical and efficient JSR-331 implementations

Start with Java and surrounding languages (Scala, Groovy, Clojure,…)

JSR-331 Architecture



JSR-331 interfaces "javax.constraints"

- Only 6 major CP concepts:
  - Problem
    - ConstrainedVariable
    - Constraint
  - Solver
    - SearchStrategy
    - Solution

Simple Example (Problem Definition)

```
public static void main(String[] args) {
       //==== PROBLEM DEFINITION ==============================
      Problem p = new Problem("Test");
      //======= Define variables
      Var x = p.var("X",1,10);
      Var y = p.var("Y",1,10);
      Var z = p.var("Z",1,10);
      Var r = p.var("R",1,10);
      Var[] vars   = { x, y, z, r };
      //======= Define and post constraints
      try {       // X < Y
                  x.lt(y).post();

                  // X + Y = Z
                  x.add(y).eq(z).post();
                  // or p.linear(new Var[]{x,y}, Oper.EQ, z).post();

                  p.allDifferent(vars).post();

                  // 3x + 4y -7z + 2r > 0
                  int[] coef1 = { 3, 4, -7, 2 };
                  p.linear(coef1,vars, Oper.GT, 0).post();

                  // x + y + z + r >= 15
                  p.linear(vars, Oper.GE, 15).post();

                  // 2x - 4y + 5z - r > x*y
                  int[] coef2 = { 2, -4, 5, -1 };
                  p.linear(coef2,vars, Oper.GT, x.mul(y)).post();

      } catch (Exception e) {
                  p.log("Error posting constraints: " + e);
                  System.exit(-1);
      }
```

Simple Example (Problem Resolution)

```
//=== PROBLEM RESOLUTION ===============

p.log("=== Find One Solution:");
Solver solver = p.getSolver();
Solution solution = solver.findSolution();
if (solution != null)
        solution.log();
else
        p.log("No Solution");
solver.logStats();
```

```
=== Find One Solution:
Solution #1: X[2] Y[3] Z[5] R[9]
*** Execution Profile ***
Number of Choice Points: 5
Number of Failures: 3
Occupied memory: 683448
Execution time: 31 msec
```

Problem Definition

- Problem – a factory and a placeholder for all other objects
- ConstrainedVariable – a base class for:
  - Var
  - VarBool
  - VarReal
  - VarSet
  - Common associated concepts:
    - name, impl, business object, #of constraints,…
- Constraint

Var – constrained integer variables

- Getters: getMin(), getMax(), getValue(),..
- But no setters, instead:
  - var.le(25).post();
- Creation:

```
Var x = problem.var("X",1,10);
int[] domain = new int[] {1,2,4,7,9};
Var var = problem.var("A", domain);
Var[] vars = problem.varArray("A", 0, 10, 100);
```

- Domain type

```
public enum DomainType {
    DOMAIN_SMALL,
    DOMAIN_MIN_MAX,
    DOMAIN_SPARSE,
     DOMAIN_OTHER
}
```

Constraint: common methods

- Constraint **and**(Constraint c)
- Constraint **or**(Constraint c)
- Constraint **negation**()
- Constraint **implies**(Constraint c)
- VarBool a
- void **pos**
- void **pos**

```
// green bin can contain plastic, wood, copper
c1 = pb.linear(type, Oper.EQ, green);
c2 = pb.linear(counts[glass], Oper.EQ, 0);
c3 = pb.linear(counts[steel], Oper.EQ, 0);
c1.implies( c2.and(c3) ).post();
```

Constraints: examples

```
try {
        x.lt(y).post();
        p.allDifferent(vars).post();
        int[] coef1 = { 3, 4, -7, 2 };
        p.linear(coef1,vars, Oper.GT, 0).post();

} catch (Exception e) {
        p.log("Error posting constraint: " + e);
}
```

Constraints

- Currently Included:
  - All Basic
  - Linear
  - AllDifferent
  - Element
  - Cardinality
  - GlobalCardinality
- Under Consideration:
  - “regular”, “diffn”, “cumulative”, …

User-Defined Constraints

- Combinations of predefined constraints
- New sub-classes of Constraintl
- Controversial Concepts (postponed):
  - Propagators
  - PropagationEvent

Problem Resolution

- Solver – a factory and a placeholder for search related objects
- Search Methods
  - Find One Solution
  - Find Optimal Solution
  - Iterate through solutions within user-defined limits
- SearchStrategy
  - The default strategy and implementation strategies
  - Variable and Value Selectors
- Solution

Search Strategies

- For now only one search strategy is required:

```
SearchStrategy strategy = solver.getSearchStrategy();
strategy.setVarSelectorType( VarSelectorType.MIN_DOMAIN_MIN_VALUE);
```

- Solver-specific strategies are listed (but not required):
  - RestartSearchStrategy(RestartFunction)
  - BoundedBacktrackingSearchStrategy(Steps)
  - LimitedDiscrepancySearchStrategy(Disc)
  - CreditBasedSearchStrategy(InitialCredit,CreditFunction,Steps)
  - DepthBoundedSearchStrategy(Level,Steps)
  - Other

```
SearchStrategy strategy = new BoundBacktrackingSearchStrategy(100); //steps
solver.setSearchStrategy(strategy);
```

Common Implementation Package "javax.constraints.impl.search"

- Provides default implementations for:
  - solutionIterator()
  - findSolution(…)
  - findOptimalSolution(…)
  - findAllSolutions(…)
  - Most Variable and Value Selectors
  - The only abstract method is:

abstract public Solution **findSolution**(ProblemState restoreOrNot);

Queens Example (definition)

```
public static void main(String[] args) {
  //========= Problem Representation ==================
  Problem problem = new Problem("Queens");
  String arg = (args.length < 1) ? "1000" : args[0];
  int size = Integer.parseInt(arg);
  problem.log("Queens " + size);
  // create 3 arrays of variables
  Var[] x = problem.varArray("x",0, size-1, size);
  Var[] x1 = new Var[size];
  Var[] x2 = new Var[size];
  for (int i = 0; i < size; i++) {
          x1[i] = x[i].add(i);
          x2[i] = x[i].sub(i);
  }
  // post "all different" constraints
  problem.allDifferent(x).post();
  problem.allDifferent(x1).post();
  problem.allDifferent(x2).post();
```

Queens Example (resolution)

```
//========== Problem Resolution ====================
        // Find a solution
        Solver solver = problem.getSolver();
        solver.setTimeLimit(600000); // milliseconds
        SearchStrategy strategy = solver.getSearchStrategy();
        strategy.setVars(x);
        strategy.setVarSelectorType(VarSelectorType.MIN_DOMAIN_MIN_VALUE);
        strategy.setValueSelectorType(ValueSelectorType.MIN);
        Solution solution = solver.findSolution();
        if (solution == null)
                problem.log("no solutions found");
        else {
                solution.log();
        }
        solver.logStats();
    }
}
```

```
Queens 1000
Solution #1: x-0[0] x-1[555] x-2[1] x-3[502] x-4[2] x-5[507] ...
*** Execution Profile ***
Number of Choice Points: 996
Number of Failures: 8
Execution time: 1093 msec
```

TCK – Technology Compatibility Kit

- **org.jcp.jsr331.tests**
  - JUnit tests Unit tests with asserts for expected results
- **org.jcp.jsr331.samples**
  - A library of well-known CSPs implemented using a pure JSR-331 API

JSR-331 Implementations

- CP Vendors
  - Support
  - Compromises
- Initial Implementations with open source CP Solvers:
  - Constrainer – available in beta
  - Choco – available in alpha
  - JaCoP – under development
  - Others are welcome

CP Community Support

- Thanks to all contributors!
  - Especially: H.Simonis, M.Z.Lagerkvist, P.Stucky, R.Szymanek, …
- To do:
  - Add Real and Set variables implementations
  - More global constraints
  - TCK Implementation
  - Integration:
    - LP/MIP tools
    - Vizualizer
  - Adding verticals (e.g. Scheduler, Router,…)
  - Discuss controversial concepts:
    - New custom constraints
    - New custom search strategies (goals)

Appeal

- CP Vendors:
  - Contact us to get an SVN access and start your own JSR-331 implementation
- CP Practitioners:
  - Contact us to get a working JSR-331 implementation and start using it for your own problems!
  - Testers are needed
  - Need more constructive critique – comment at www.cpstandards.org Discussion Forum
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