Gecode

an open constraint solving library

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Gecode

- Generic Constraint Development Environment
  - open source
  - C++ library
  - constraint propagation + complete (parallel) search
  - finite domain and finite set constraints
  - complete documentation (reference, tutorial, papers)
  - thousands of users

Overview

- History and facts
  - use cases
- Modeling (interfacing) & programming
- Openness

History

- 2002
  - development started
- 1.0.0
  - Dec 6, 2005
- 2.0.0
  - Nov 14, 2007
- 3.0.0
  - Mar 13, 2009
- 3.7.3 (current)
  - Mar 23, 2012

31 releases

43 kloc, 21 klod

77 kloc, 41 klod

81 kloc, 41 klod

134 kloc, 56 klod

- … 4.0.0 at end of 2012

History

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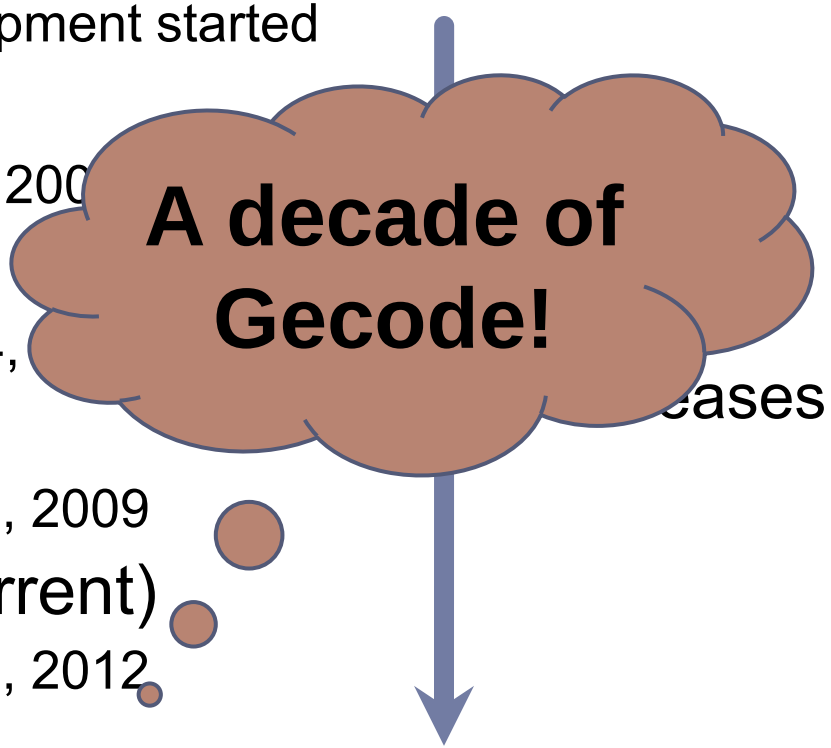

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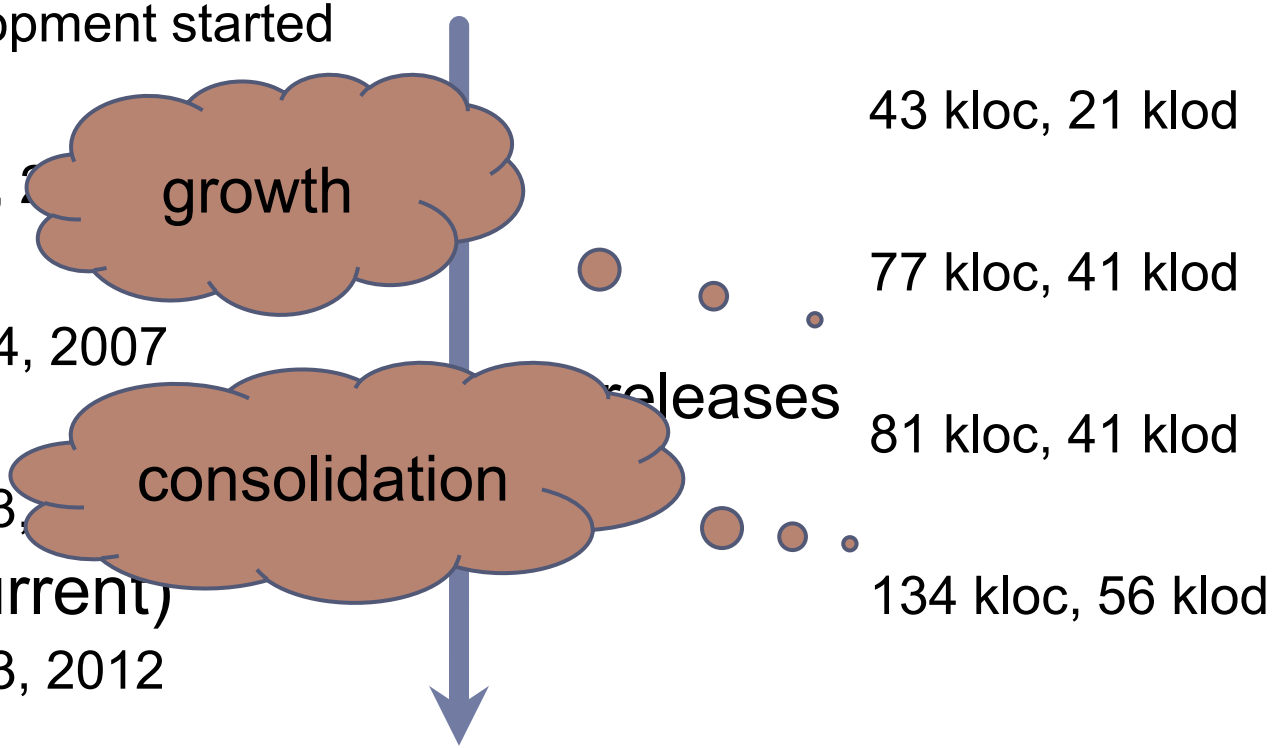

History: Tutorial Documentation

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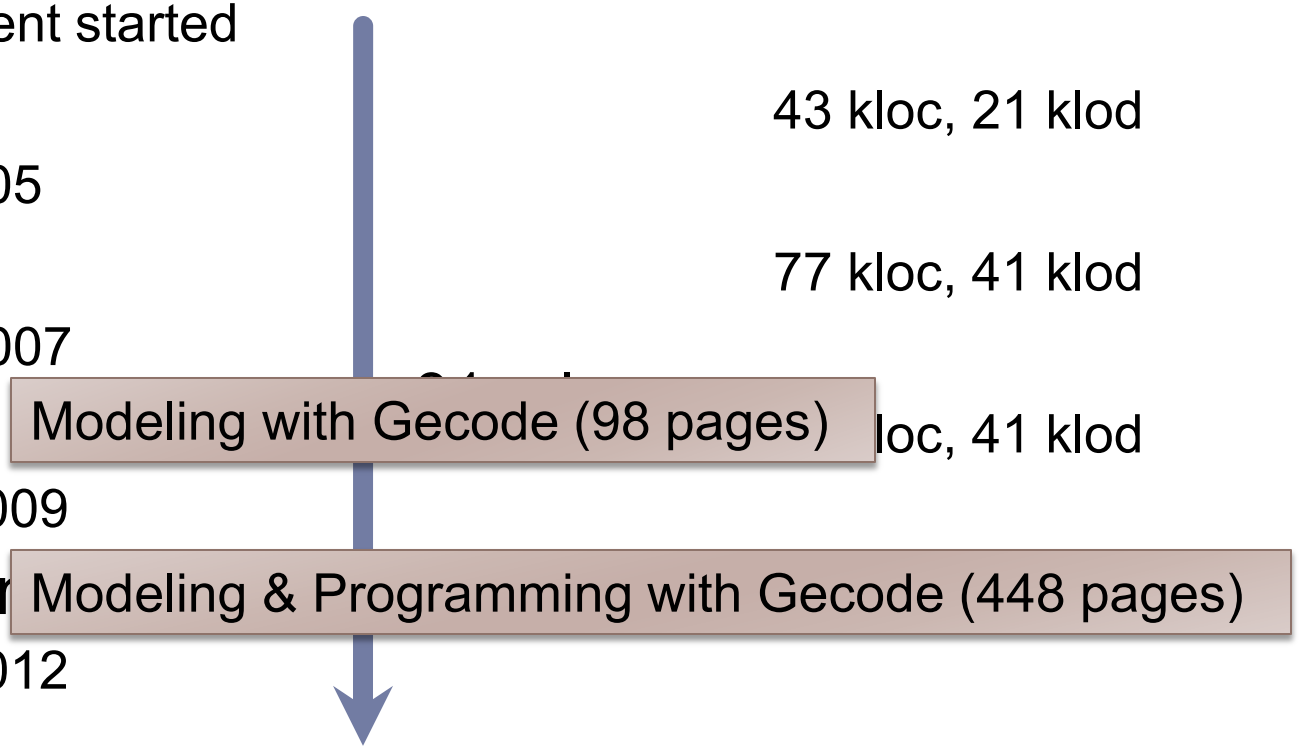


Gecode 4.*

- Dynamic symmetry breaking (LDSB)
  - [Mears, de la Banda, Wallace: On implementing symmetry detection. Constraints 2009]
- Floating point variables and constraints
  - together with Vincent Barichard
- Activity-based search
  - [Michel, Van Hentenryck, CP AI OR 2012]
- Half-reification
  - [Feydy, Somogyi, Stuckey, CP 2011]
- Abstractions for LNS and Restarts
- Propagator groups
  - [Lagerkvist, Schulte, CP 2009]
- New and improved constraints
  - cumulative [Kameugne ea, CP 2011]
  - …
- MiniZinc 2.0
- …

People

- Core team
  - Christian Schulte — KTH – Royal Institute of Technology, Sweden
  - Guido Tack — K.U. Leuven, Belgium
  - Mikael Z. Lagerkvist

- Code
  - contributions: David Rijsman, Denys Duchier, Filip Konvicka, Gabor Szokoli, Gregory Crosswhite, Håkan Kjellerstrand, Patrick Pekczynski, Raphael Reischuk, Tias Guns.
  - fixes: Alexander Samoilov, David Rijsman, Geoffrey Chu, Grégoire Dooms, Gustavo Gutierrez, Olof Sivertsson.
- Documentation
  - Seyed Hosein Attarzadeh Niaki, Vincent Barichard, Felix Brandt, Markus Böhm, Roberto Castañeda, Gregory Crosswhite, Pierre Flener, Gustavo Gutierrez, Gabriel Hjort Blindell, Sverker Janson, Andreas Karlsson, Håkan Kjellerstrand, Chris Mears, Flutra Osmani, Dan Scott, Kish Shen.

Goals

- Research
  - architecture of constraint programming systems
  - propagation algorithms, search, modeling languages, ...
- Efficiency
  - competitive (winner MiniZinc challenges 2008-2011, all categories)
  - proving architecture right
- Education
  - state-of-the-art, free platform for teaching

Users

- Research
  - own papers
  - papers by others: experiments and comparison
  - Google scholar: some 650 references to Gecode
- Education: teaching
  - KTH, Uppsala U, U Freiburg, UC Louvain, Saarland U, American U Cairo, U Waterloo, U Javeriana-Cali, …
- Industry
  - several companies have integrated Gecode into products (part of hybrid solvers)

Use Case: Education

- Courses feasible that include
  - modeling
  - principles

  but also
  - programming search heuristics (branchers)
  - programming constraints (propagators)

- Essential for programming
  - accessible documentation…
  - …including many examples

Use Cases: Interfacing

- Quintiq integrates Gecode as CP component
  - in their modeling language
  - Quintiq: fast growing company in advanced planning and scheduling, example: truck scheduling for Walmart US
- Cologne: A Declarative Distributed Constraint Optimization Platform
  - U Penn, AT&T Labs, Raytheon
  - Datalog + constraints in distributed setup
  - [Liu ea, VLDB 2012]
- Whatever language: Java, Prolog (> 1), Lisp (> 1), Ruby, Python (> 1), Haskell, MiniZinc, …

Use Cases: Research

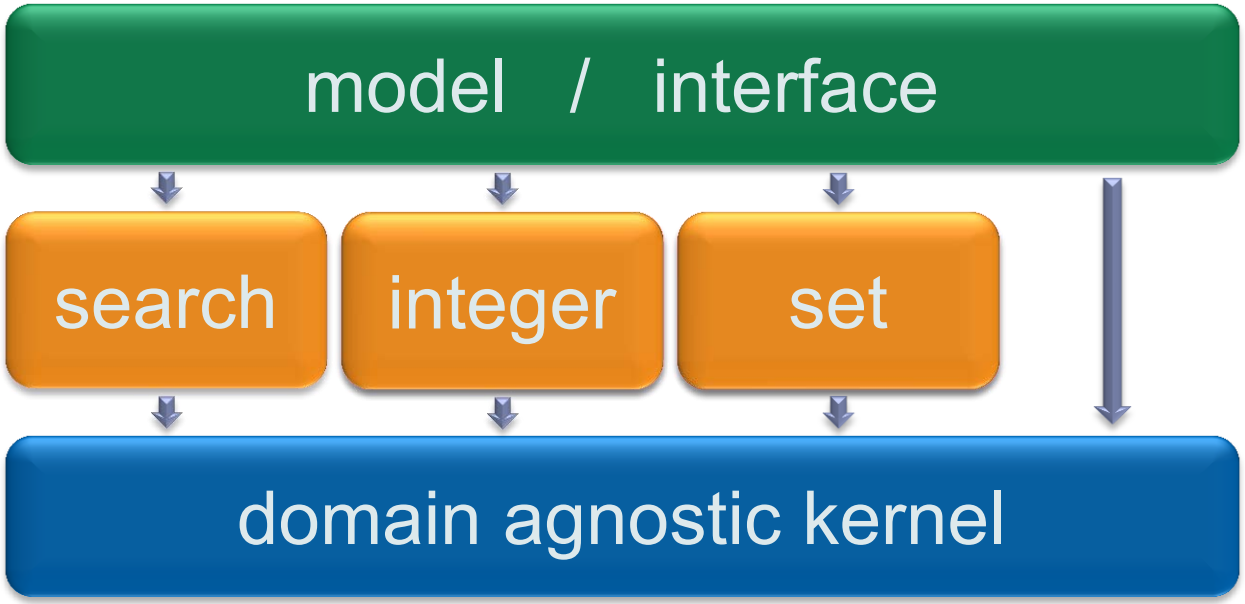
- Benchmarking platform for models
  - lots of people (majority?)
- Benchmarking platform for implementations
  - lots of people
  - requires open source (improve what Gecode implements itself)
- Gecode models as reference
  - Castineiras, De Cauwer, O'Sullivan, Weibull-based Benchmarks for *Bin Packing*. CP 2012.
- Base system for extensions
  - Qecode: quantified constraints (Benedetti, Lalouet, Vautard)
  - Gelato: hybrid of propagation and local search (Cipriano, Di Gaspero, Dovier)
  - Gecode interfaces powerful enough: no extension required

Deployment & Distribution

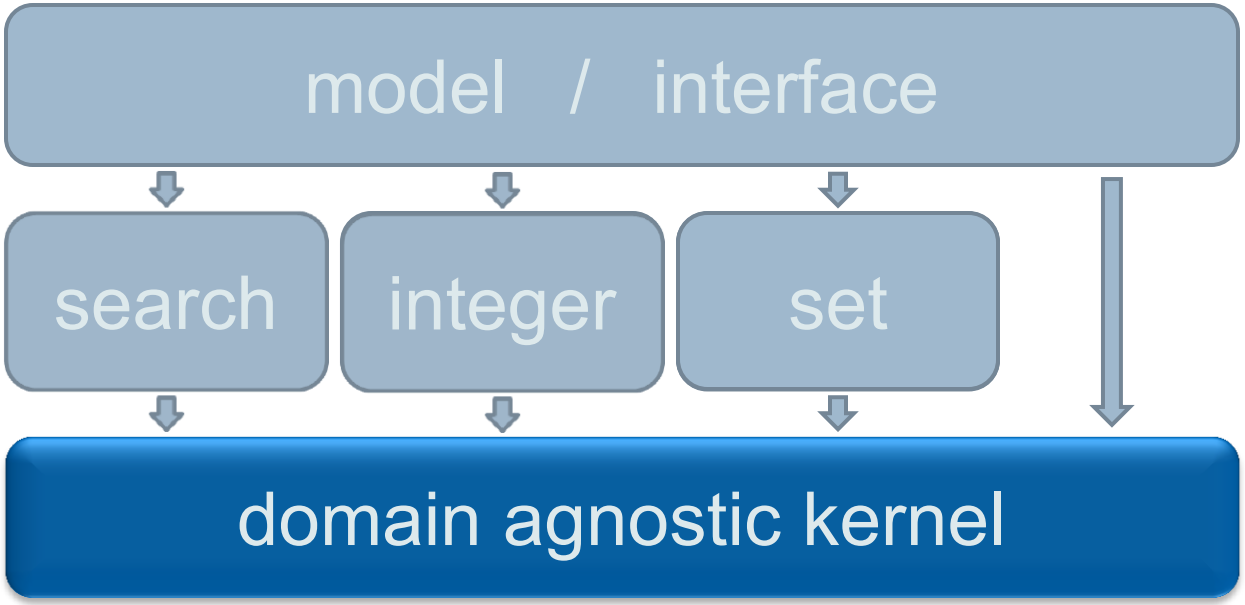
- Open source ≠ Linux only
  - Gecode is native citizen of: Linux, Mac, Windows
- High-quality
  - extensive test infrastructure (around 16% of code base)
  - you have just one shot!
- Downloads from Gecode webpage
  - software: between 25 to 125 per day
  - documentation: between 50 to 300 per day
- Included in
  - Debian, Ubuntu, FreeBSD, …

Modeling & Programming

Architecture

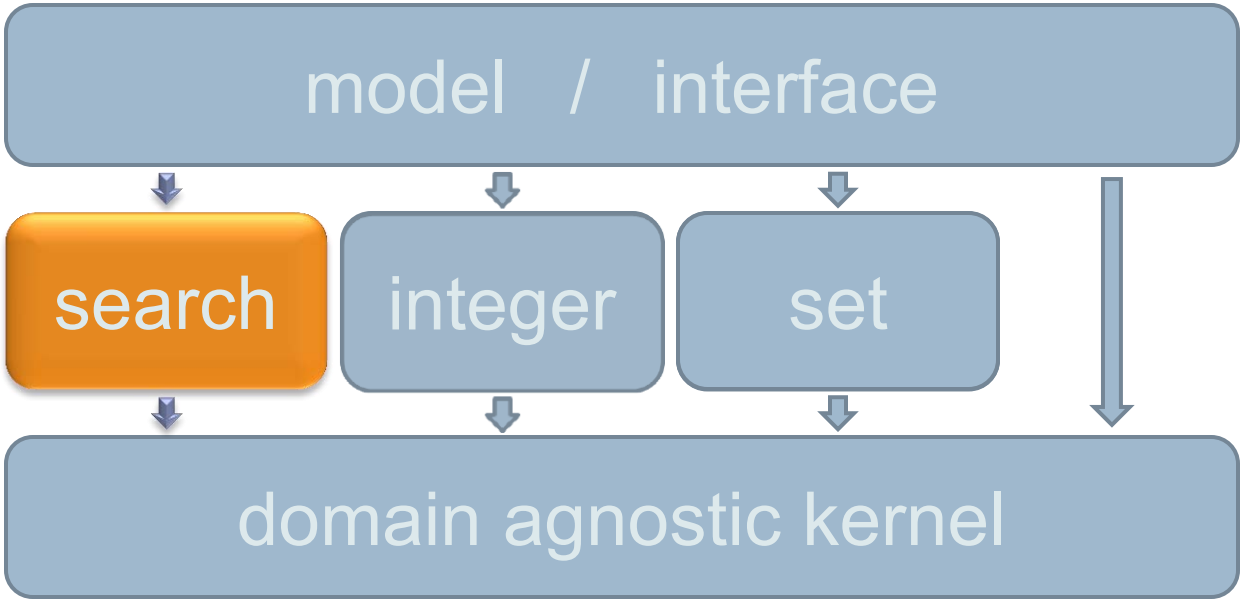


Architecture



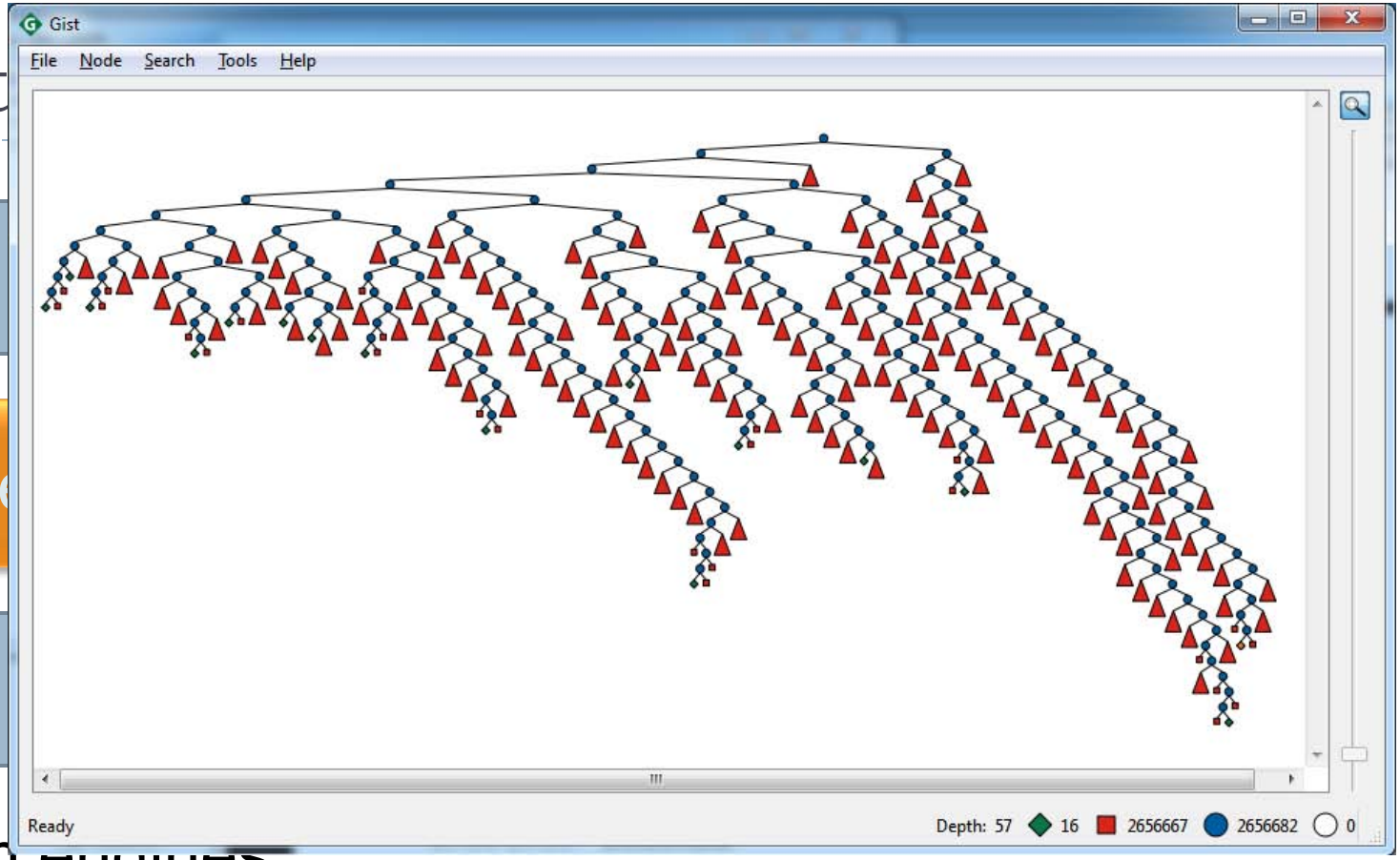
- propagation loop
- backtracking for search
- memory management

Architecture



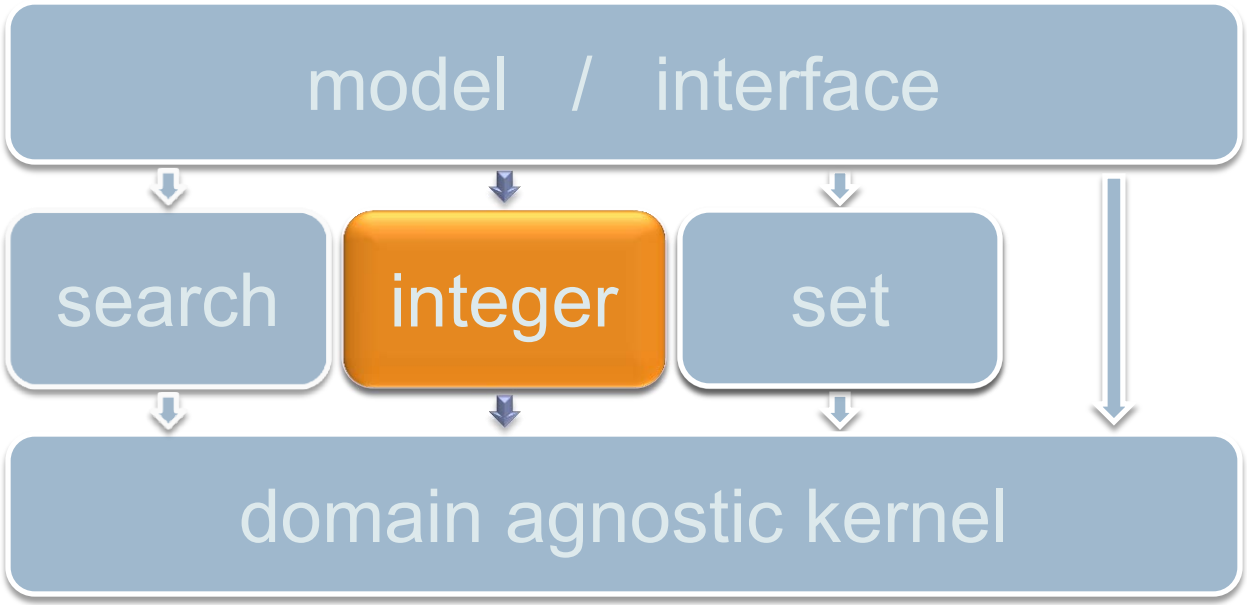
- search engines
  - depth-first (DFS) and branch-and-bound (BAB)
  - parallel search
  - whatever you fancy: program yourself

Archit



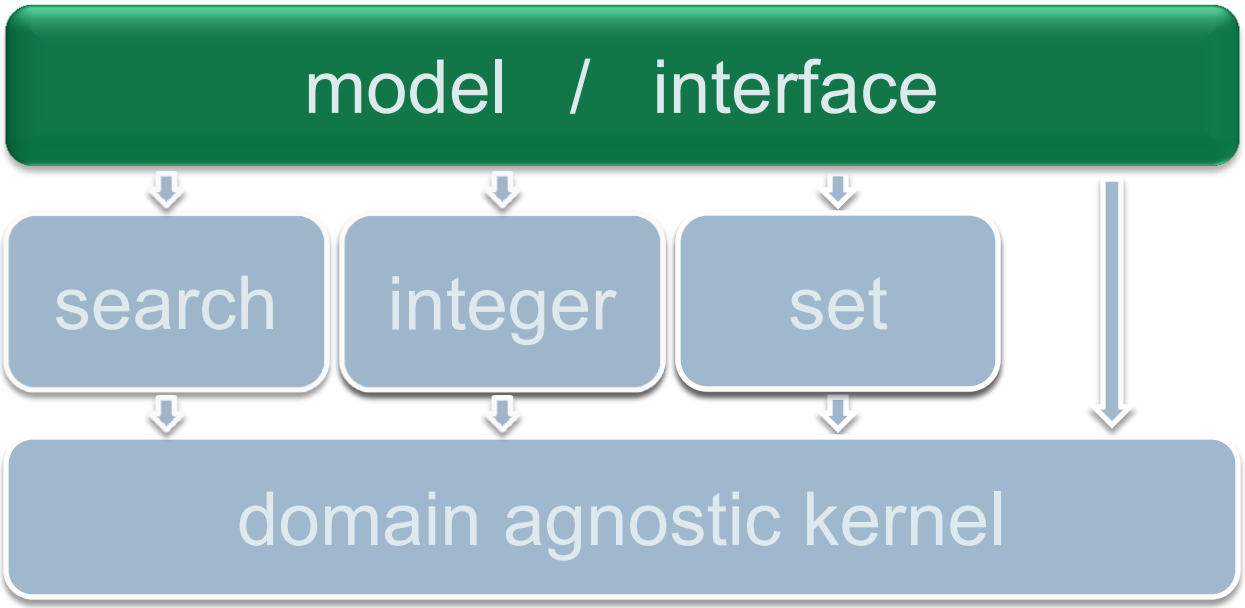
- search engines
  - depth-first (DFS) and branch-and-bound (BAB)
  - parallel search
- search tool: Gist (millions of nodes)

Architecture



- Ingredients:
  - variables
  - propagators (constraints)
  - branchers (search heuristics)
- Whatever you fancy: program yourself!

Architecture



- direct C++ modeling or interfacing
- language interfaces: MiniZinc, Java, JavaScript, Lisp, Ruby, Eclipse Prolog, …

Modeling (interfacing)

- Use modeling layer in C++
  - matrices, operators for arithmetical and logical expressions, …
- Use predefined
  - constraints
  - search heuristics and engines
- Documentation
  - getting started 30 pages
  - concepts and functionality 96 pages
  - case studies 76 pages

Modeling (interfacing)

- Constraint families
  - arithmetics, Boolean, ordering, ….
  - alldifferent, count (global cardinality, …), element, scheduling, table and regular, sorted, sequence, circuit, channel, bin-packing, lex, geometrical packing, nvalue, lex, value precedence, …
- Families
  - different variants and different propagation strength
- “All” global constraints from MiniZinc have native implementation in Gecode

Gecode ⇆ Global Constraint Catalogue

- 74 constraints implemented:

  abs_value, all_equal, alldifferent, alldifferent_cst, among, among_seq, among_var, and, arith, atleast, atmost, bin_packing, bin_packing_capa, circuit, clause_and, clause_or, count, counts, cumulative, cumulatives, decreasing, diffn, disjunctive, domain, domain_constraint, elem, element, element_matrix, eq, eq_set, equivalent, exactly, geq, global_cardinality, gt, imply, in, in_interval, in_intervals, in_relation, in_set, increasing, int_value_precede, int_value_precede_chain, inverse, inverse_offset, leq, lex, lex_greater, lex_greatereq, lex_less, lex_lesseq, link_set_to_booleans, lt, maximum, minimum, nand, neq, nor, not_all_equal, not_in, nvalue, nvalues, or, roots, scalar_product, set_value_precede, sort, sort_permutation, strictly_decreasing, strictly_increasing, sum_ctr, sum_set, xor

Programming

- Interfaces for programming
  - propagators (for constraints)
  - branchers (for search heuristics)
  - variables
  - search engines

Documentation	intro	advanced
propagators	40 pages	58 pages
branchers	22 pages	
variables		44 pages
search engines	12 pages	26 pages

Openness

Open Source

- MIT license
  - permits commercial, closed-source use
  - disclaims all liabilities (as far as possible)
- License motivation
  - public funding
  - focus on research
- Not a reason
  - attitude, politics, dogmatism

Open Architecture

- More than a license
  - **license** restricts what users **may do**
  - **code and documentation** restrict what users **can do**
- Modular, structured, documented, readable
  - complete tutorial and reference documentation
  - ideas based on scientific publications
- Equal rights: clients are first-class citizens
  - you can do what we can do: APIs
  - you can know what we know: documentation
  - on every level of abstraction

Open Development

- We encourage contributions
  - direct, small contributions
    → we take over maintenance and distribution
  - larger modules on top of Gecode
    → you maintain the code, we distribute it

- Prerequisites
  - MIT license
  - compiles and runs on platforms we support

Summary

- Open source libraries require open architecture
  - users need good code to build on
- Open architecture promotes equality
  - client code is first-class citizen
  - encourages code contributions
- Open development fosters research
  - collaboration
  - experiments are reproducible