A new, modular dependency solver for `cabal-install`

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Why?

- Error messages are suboptimal.
- We want the solver to be more configurable.
- Solver is difficult to extend (current design is rather ad-hoc).

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Status

- New solver is implemented.
- “At least as good” as the old solver
  – when used with `ghc-7.*`
- Ready for experimentation.
- Some new features prepared, but not yet implemented.

Talk overview

- Dependencies in Cabal
- Architecture of the new solver
- Private dependencies
- Error messages
- Remaining work

Dependencies in Cabal

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Independent sanity check makes it relatively easy to trust the new solver.

Terminology

Index	database of information about packages (can be built from many indices)
Location	an index location (such as Hackage, or your installed packages)
Package **Name**	a name such as `mtl` or `threadscope`
Version	a version such as `1.1.0.2`
Instance	a triple of a name, version and location
Instance **Constraint**	restrictions on version and location
Dependency	a pair of a name and a constraint

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- In other words: installed instances have **fixed** dependencies, new instances have **flexible** dependencies.
- In general, one application cannot use multiple instances of the same package.
- With `ghc-pkg`, we can install many instances of one package, but only one instance per package version.

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Conservative approach

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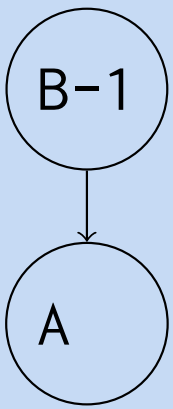
Furthermore:

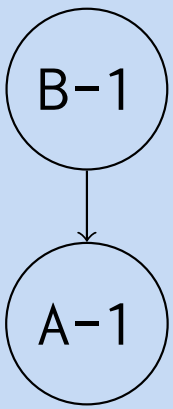
- Never backtracks (but looks ahead a bit).
- Exclude packages that can't be configured (relatively new).
- Flag resolution tied to package selection.
- Maintains hardly any information about the order in which packages are resolved.

Cabal can break your system



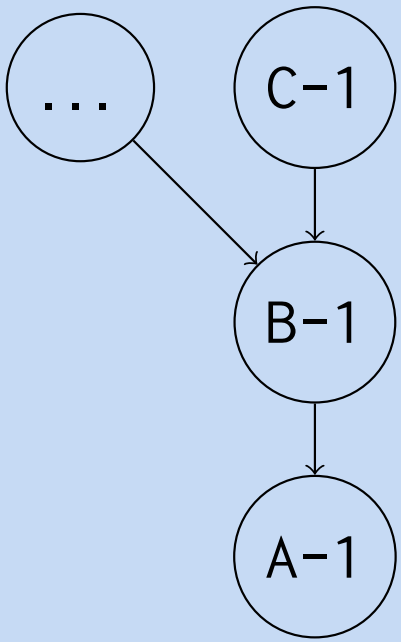
Assume `B-1` depends on any version of `A`.

Cabal can break your system



You install `B-1` on your system, fixing the dependency to `A-1`.

Cabal can break your system



Many other packages that depend on `B-1` are installed later.

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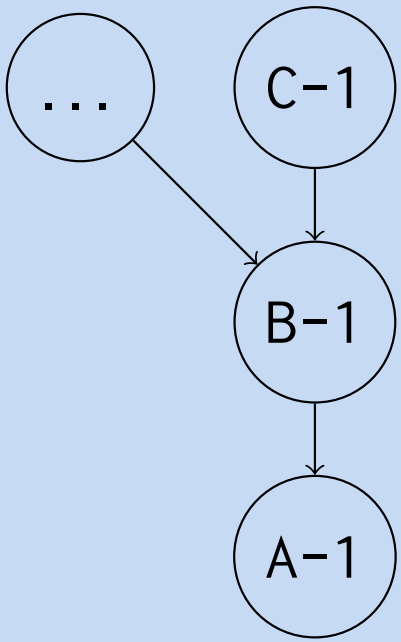

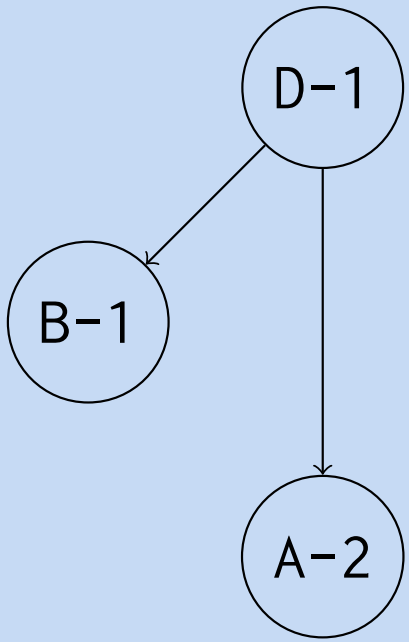

Now we want to install `D` which depends on `A-2` (!) and `B`.

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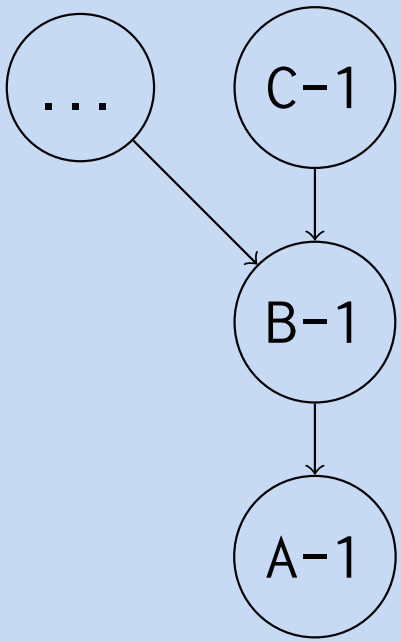
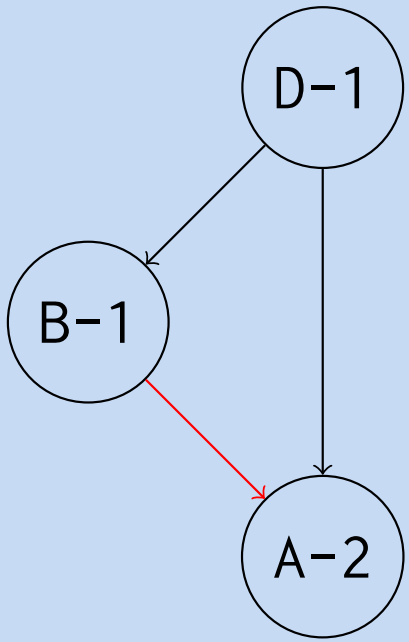
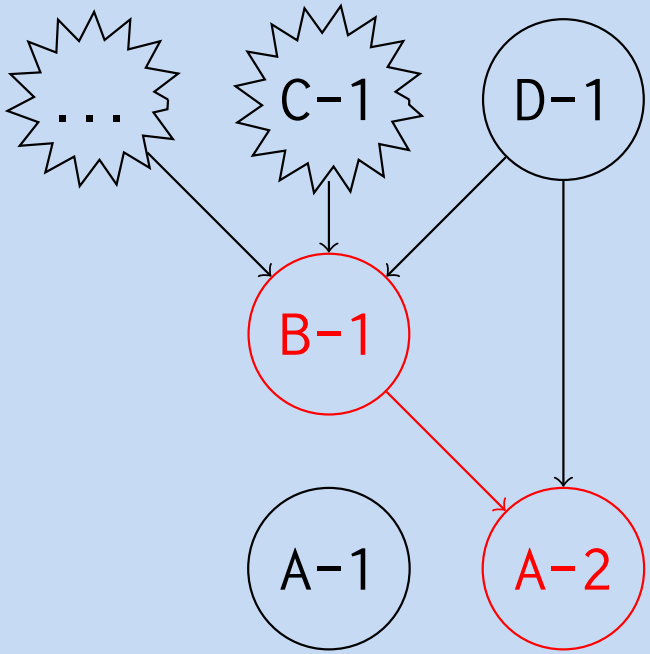




Since `B` still depends on `A`, the install plan selects `A-2`.

Cabal can break your system



Upon actual installation, the old B-1 is destructively updated . . .

About destructive updates

Proper solution

NixOS-style package database – no destructive updates, ever.

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Other options

- warn explicitly about destructive updates
- discourage or prevent destructive updates in the solver options

The new solver

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Inspired by . . .

Thomas Nordin and Andrew Tolmach, Modular Lazy Search for Constraint Satisfaction Problems, JFP, 2001

The algorithm

```
solve cfg idx userPrefs userConstraints userGoals =
  explorePhase       $
  heuristicsPhase    $
  preferencesPhase   $
  validationPhase    $
  prunePhase         $
  buildPhase
  where
    buildPhase    :: Tree ...
    prunePhase    :: Tree ... → Tree ...
    ...
    explorePhase  :: Tree ... → Log (Assignment, RevDepMap)
```

The search tree

```
data Tree a =
    PChoice     QPN a        (PSQ I           (Tree a))
  | FChoice     QFN a Bool   (PSQ Bool        (Tree a))
  | GoalChoice               (PSQ OpenGoal    (Tree a))
  | Done        RevDepMap
  | Fail        (ConflictSet QPN) FailReason
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- Nodes represent goals / choices.
- Edges represent assignments.
- The search tree is **not** the dependency tree.

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All nodes are equipped with additional info.

Note that goal-choice nodes have a different semantics from single-goal nodes.

Building the tree

Keep track of current goals:

- build goal choice node
- build goal-specific nodes
- add new goals depending on choice if needed
- if no goals left, end with a success node

Validating the tree

Keep track of constraints:

- use constraints to remove choices
- but keep disabled choices around (for error messages)
- add new constraints corresponding to the choices while moving down

After validation, the tree contains just correct solutions.

Reorderings

- exploration will in essence proceed depth-first, left-to-right
- the order of subtrees in the choice nodes is relevant
- we can thus express preferences by reordering

Typical preferences

- Prefer later versions over older versions.
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```
packageOrderFor :: (PN → Bool) →
                   (PN → I → I → Ordering) →
                   Tree a → Tree a
packageOrderFor p cmp = trav go
  where
    go (PChoiceF v@(Q _ pn) r cs)
      | p pn       = PChoiceF v r
                              (sortByKeys (flip (cmp pn)) cs)
      | otherwise = PChoiceF v r                          cs
    go x           = x
```

Goal heuristics

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Because it does never make sense to backtrack in goal-choice nodes, we actually leave only the first goal choice after applying goal heuristics.

Backjumping

We prune the tree by propagating failure information up.

Key observation

Not all the nodes on a path to a conflict actually contribute to that conflict.

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So in many cases we can prune entire failing subtrees quickly.

We also use conflict set info for error messages.

Exploring the tree

Mainly depth-first, left-to-right being used, but with various degrees of debugging info being produced.

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Mainly depth-first, left-to-right being used, but with various degrees of debugging info being produced.

Configurable backtracking: we can impose a limit on the number of backjumps performed – the old solver never backtracks.

Reflections on the implementation

- The approach is reasonably easy to work with in practice, because we can split the algorithm into multiple independent steps.
- We haven't made any effort on clever optimizations, and the new solver has about the same speed in practice as the old one ...
- However, while laziness is the key to modularity here, there are also very subtle laziness constraints that aren't expressible in the type system.

Encapsulations

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The assumption to allow only one instance of a package per application is too conservative:

- The problem arises from exported types that aren't compatible between instances.
- Some libraries are mostly used privately or don't export any types.
- If we could declare such private dependencies, we might get better results.

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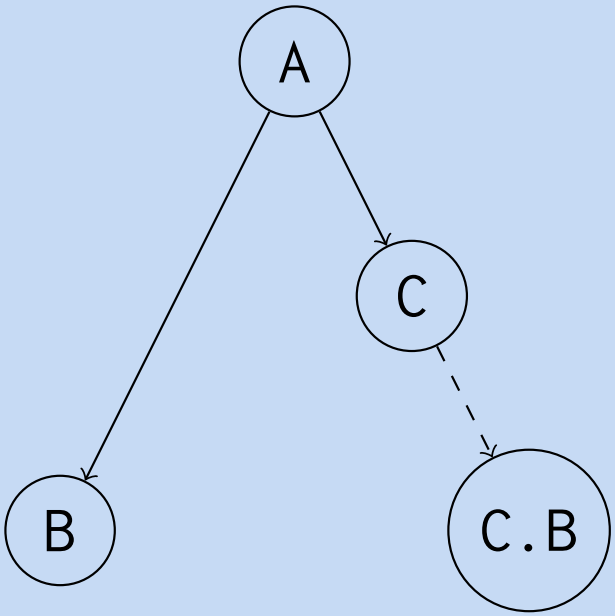
However, encapsulations are subtle . . .

Encapsulation example



Different instances can be chosen for `B` and `C.B`.

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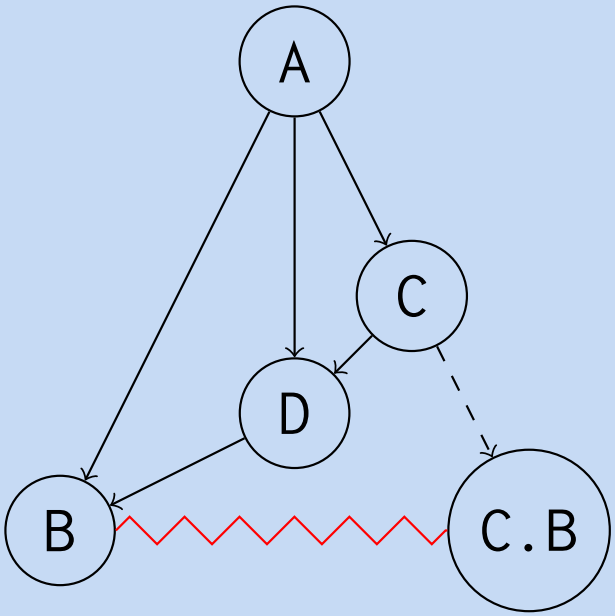

The encapsulation is invalidated by other dependencies. Both `B` and `C.B` must be the same instance.

The plan for encapsulations

- The solver is prepared for scoped goals.
- Scoped goals are introduced when packages declare encapsulations.
- Scoped goals can be invalidated by other dependencies (i.e., forced to be equal to original goals).
- Scoped goals should therefore be resolved as late as possible, to prevent unnecessary backtracking.
- Even if scoped goals can be resolved differently, the preference should still be to select a single instance per package.
- The install plan checker has to be generalized.
- The Cabal library needs to be extended to check private dependencies.

Error messages

Ideas

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Current status

- All the information is there.
- Could be presented in a better/cleaner way.
- There are some choices on how to produce excerpts.

Demo

Future work

- Turn `cabal-install` into a proper library.
- Factor out the solver into a separate package.
- Others can write their own solvers.
- Integrate `cabal-dev`, or make such tools use the library.
- Track external dependencies.
- Allow more configuration options.

Please try it

We appreciate early feedback:

```
darcs get \
  http://darcs.haskell.org/cabal-branches/cabal-modular-solver
cd cabal-modular-solver
cabal install ./cabal ./cabal-install
```