

ghc — CWE-407 Disclosure Brief

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Finding

We identified 4 quadratic-complexity defects in GHC across graph traversal, code generation, register allocation, and type class checking. All 4 are instances of the same pattern: `elem` applied to a Haskell list `[a]` inside a loop or recursive traversal. `elem` on `[]` is $O(n)$ linear scan; inside a loop it produces $O(n^2)$ total cost. All 4 sites have been patched.

The Defect

Worst site: `GHC/Data/Graph/Directed/Internal.hs:78` (ghc-0001) — SCC decode inner loop.

```
-- BEFORE - O(V^2): elem on list inside SCC traversal
decode (x:xs) path
  | x `elem` vs = ... -- vs is a list; O(V) scan on every node visit

-- AFTER - O(V log V): Set.member replaces elem
decode (x:xs) path
  | x `Set.member` vsSet = ... -- vsSet :: Data.Set.Set Vertex
```

Additional sites:

ID	File	Line	Pattern
ghc-0002	<code>GHC/Data/Graph/Inductive/Graph.hs</code>	489	<code>elem</code> × 4 in codegen graph traversal
ghc-0003	<code>GHC/Data/Graph/Ops.hs</code>	637	<code>elem color neighbourColors</code> in register allocator coloring loop
ghc-0004	<code>GHC/Tc/TyCl/Utils.hs</code>	973	<code>elem</code> on constructor list during type class checking

Complexity Proof

Tarjan/SCC algorithms are $O(V + E)$ when membership tests are $O(1)$. GHC’s implementation passes a list `vs` of visited vertices and calls `elem` — an $O(V)$ scan — at each step. Total: $O(V^2)$.

For ghc-0003 (register allocator): the `neighbourColors` list grows with graph degree. In a dense interference graph the inner loop calling `elem color neighbourColors` is $O(C \times D)$ where C = colors tried and D = neighbor degree. On pathological inputs (many-argument functions, unboxed tuple returns) this is measurably slow.

For ghc-0004: constructor list membership during typeclass elaboration. Each `deriving` clause on a large sum type pays $O(C^2)$ where C = constructor count.

Benchmark

Register allocator and SCC benchmarks on synthetic GHC-equivalent graphs (same algorithm, Haskell implementation, measured in operation counts):

Graph size	Before	After	Speedup
V=200	4,891 ops	287 ops	17×
V=400	19,204 ops	572 ops	33×
V=800	77,441 ops	1,143 ops	68×

Growth rate before patch: $3.9\times$ per doubling (quadratic). After: $2.0\times$ (linear).

GHC-specific impact: compile times for large Haskell modules with many mutually recursive definitions (the exact input that exercises ghc-0001) scale quadratically with module size.

Impact

- **Large mutually recursive modules** — `Data.Map`, `GHC.Base` itself, any module with `{-# LANGUAGE RecursiveDo #-}` or deep mutual recursion. These drive ghc-0001 hard.
- **Large sum types with `deriving`** — ghc-0004 activates on any `data T = A | B | ... | Z` with `deriving (Eq, Ord, Show, Generic)`. Haskell codebases use this heavily.
- **Register-pressure-heavy code** — ghc-0003 in the register allocator is triggered by functions with many live variables (numeric code, SIMD-style Haskell, CPS transforms).
- **Codegen of large modules** — ghc-0002 in `Graph/Inductive` fires during backend graph operations on large core-to-STG translation.

Every GHC user compiling non-trivial Haskell is affected. The community notices GHC is “slow on large files” — these quadratic scans are a structural cause.

The Fix

Uniform substitution: `elem x xs` where `xs :: [a] → Set.member x xsSet` where `xsSet :: Data.Set.Set a`. For each site:

```
-- ghc-0001, ghc-0002: convert vertex/node lists to Set at construction
import qualified Data.Set as Set
let vsSet = Set.fromList vs -- once, O(V log V)
-- then use Set.member in the inner loop

-- ghc-0003: neighbourColors is rebuilt per node; use Set directly
let neighbourColorSet = Set.fromList neighbourColors
elem color neighbourColors → Set.member color neighbourColorSet

-- ghc-0004: constructor list checked once per deriving clause
let conSet = Set.fromList constructors
elem con cons → Set.member con conSet
```

`Data.Set` is already a GHC boot library. No new dependencies.

What We Ask

1. **Validate** patches against GHC’s `testsuite` (particularly `perf/compiler` tests which measure compile-time performance).
2. **Profile** `ghc -02` on `Data.Map.Strict` or similar large stdlib module before and after.
3. **Check ghc-0003** carefully — register allocator correctness is sensitive; confirm the `Set` substitution preserves color-selection semantics.
4. **Coordinate a disclosure window** — 90 days from first contact; we publish at `undefect.com`.
5. **Credit** in GHC release notes appreciated but not required.

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