A Suite of Tools for Pragmatic Program Analysis of C and C++

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- Build Interceptor
- Elsa/Oink
- Delta

Acknowledgments

- Alex Aiken and David Wagner funded and supported the project
- Scott McPeak wrote Elsa, extended Delta, collaborated extensively on thinking, debugging, learning/“puzzling out” C++
- Jeff Foster and Rob Johnson provided Cqual
- Build Interceptor extends work by Ben Liblit and Hao Chen and Geoff Morrison
- Ben helped substantially with C++ also
- Many others helped with ideas, testing, a little implementation, etc.

Helped with Talk

- Matt Harren
- Simon Goldsmith
- Adam Chlipala
- Tachio Terauchi
- Scott McPeak

Analyzing Code In the Wild

- Much real code is C/C++
- Messy/unique build process
- Hard to isolate failure-inducing part of large inputs (Kernel, Mozilla)
- Want to re-use the front-end
- Want analyses to compose
  - Poor-man's flow-sensitive cqual: run control-flow, then data-flow (repeat?)

Outline of process

- Build as usual; use **Build Interceptor** to get .i files (post-preprocessed files)
- Use **Elsa/Oink** to parse and typecheck C/C++
- Debug minimizing large inputs with **Delta**
- Ship your analysis with Oink so others can re-use it.

Where we are

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Build Interceptor: features

- Captures .i files generated during build
  - and linking info for whole-program analysis
- No need to modify build process!
  - Scales to hundreds of projects
- 4th generation, builds on work done in Hao Chen's and Ben Liblit's projects
  - 92.5% of Red Hat 7.3 projects *
  - Being improved further for Debian

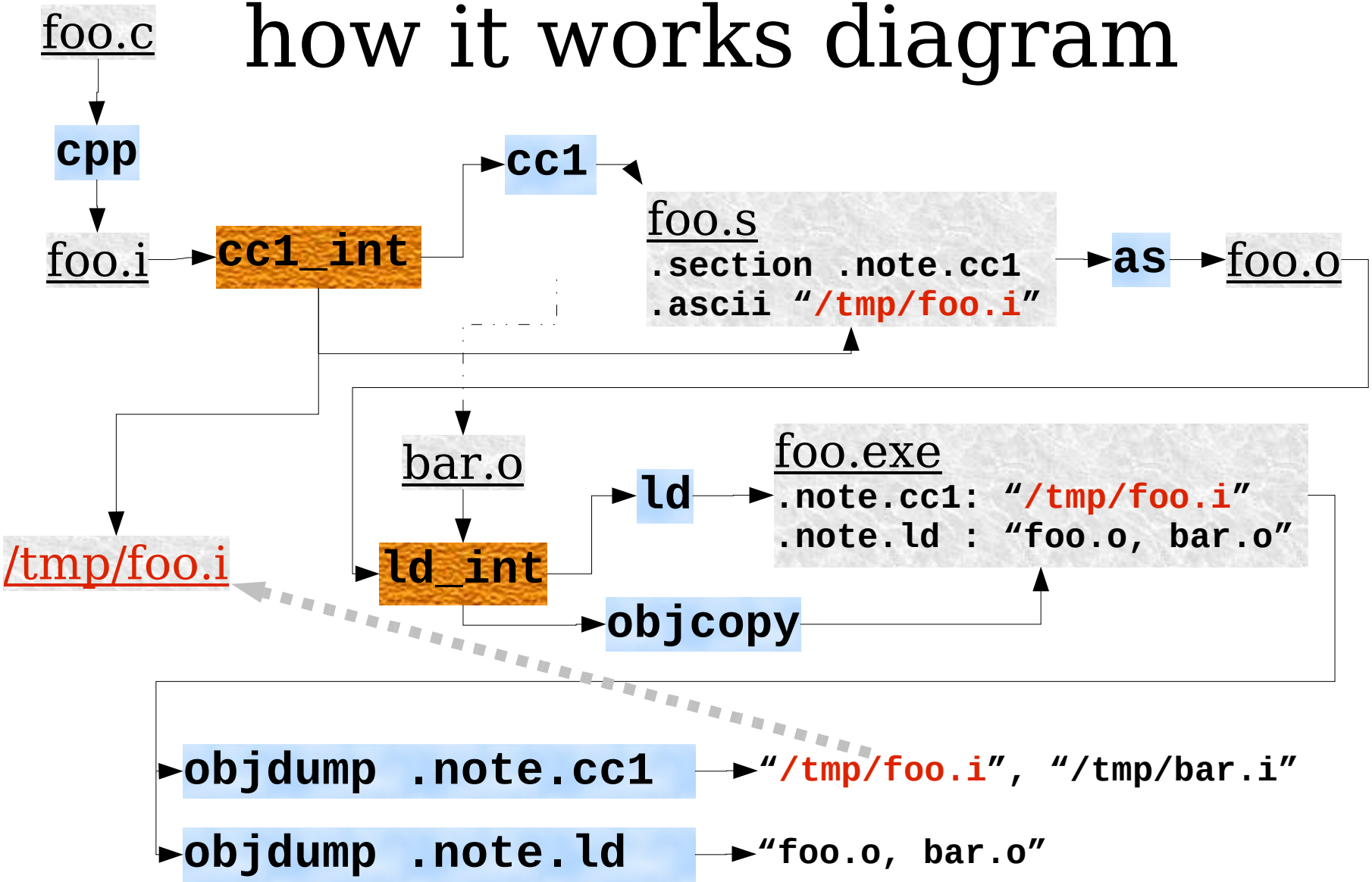
Build Interceptor, p.2: usage

- Works by replacing system tools
  - You must have root
  - Prevents stupid mistakes with checks and helpful on/off make targets
- Result is
  - a .i file for every compile
  - a .ld file for every link
    - The list of .i files that went into the ELF
- To get whole-program analysis just pass the .ld file to Oink with a flag.

Build Interceptor, p.3: how it works

- When gcc runs cc1, gets our script instead, which
  - copies .i file input
  - Runs real cc1
  - Appends assembly data string in an unused ELF section containing name of copied .i file
- This section concatenates during linking and survives stripping

Build Interceptor, p.4: how it works diagram



Build Interceptor, p.5: you can really control build

- We also intercept `collect2/ld`
  - With -t, get list of .o files as they are linked
  - These are stored into ELF file using objcopy to insert an unused ELF section
  - This trick due to Hao Chen and Ben Liblit
- Intercept `make` to turn off -j
- Intercept `cpp` to turn off -P
- Provide our own `gcc` spec file, etc.

Build Interceptor, p.6: already run for you

- Red Hat 7.3 .i files are available if you want to avoid this for now
  - We also give list of the subset of those that Elsa/Oink can parse
  - On those, any bugs are yours, not Elsa/Oink
  - We forgot to include .so files in whole-program lists
    - Oops
    - We'll fix that

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Scott McPeak's Elsa

- Parses, typechecks C
- & simplifies C++
  - Result is simplified down to “Java with Multiple inheritance”
  - Pretty clean design internally
- Red Hat 7.3
  - >99% C files go through
  - >50% C++ files go through with old headers
- Kernel, Mozilla and Qt go through

Elsa, p.2: “Java”-semantic output

- Instantiates templates
- Turns operator overloading into function calls
- Inserts implicit function calls: ctors, dtors.
- Writes implicit code: default ctor, dtor, operator =()
- Looks up all variables for you

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Oink

- Client of Elsa
  - Which provides intra-procedural control-flow for Oink
- Generic flow-insensitive data-flow analysis
  - Client: Jeff Foster's monomorphic Cqual
  - Rob Johnson's polymorphic in the works
- Linker imitator
  - Order of linking probably right by default

Oink, p.2: compose analyses

- Designed to allow analyses to collaborate/compose if they
  - Step 1: annotate types and AST (using the generic annotation mechanism)
  - Step 2: then make conclusions
- Can run step 1 for many analyses before running a custom step 2
- Can ship your analyses with Oink
  - Can also ship combo analyses built from others

Oink, p.3: projects using it

- “Scrash”, Matt, Naveen et. al.: “eliminate sensitive information ... [in] crash report”
  - Annotated with $tainted, flowed qualifiers, Pretty printed back out
- Umesh: “Find sensitive data that is live at the time of `fork()`”
  - Combo data/control -flow analysis
  - Simply added usual function call edges to intra-procedural control-flow
  - Something like 1 month to get it to work with lots of help from me

Oink, p.4: work in progress

- Karl Chen and I working on verifying Debian C code has no format-string bugs
  - Goal: become part of Debian vetting process
  - adding other analyses would then have low marginal cost
- Hao started porting MOPS to Oink, but became a professor; said student is doing it
- Zhendong & Alex said wanted it for something
- Could add Wes Weimer's Java parser
  - Typecheck into C++ AST and Types
  - Any C++ analysis is **also** a Java analysis

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Delta

- Minimizes interesting files
  - Such as those that crash your program
- Just provide a test of interestingness
  - Such as: `grep 'error'`
- Used on quarter-million line inputs
  - Seems to always stop at a page or two
- Implementation of “Delta Debugging” algorithm from Saarland University
  - My code is easier to read than the paper

Delta, p.2: how it works

- Simulated annealing
- For i going down (temperature)
  - For each group of 2^i lines
    - Remove group and run test
    - Deletion permanent if test passes
- Original algorithm also tries negative: deleting “all but this group”
  - this is a waste of time
- “Dumb as hell but goes like 60”
  - Feynman

Delta, p.3: using language structure

- Guesses much better if we use the language structure somehow
- Filter `topformflat` added by Scott
  - Omits newlines > a given nesting depth
  - Depth=0 means one line=whole function
  - Minimize at each depth with Delta, with depth increasing from 0
- Result: Delta “understands” C-like syntax nesting

Delta, p.4: results

- Don't know if Elsa/Oink possible without it
- Alex: “I used it for one assignment where the students were given something that we knew would minimize pretty well. They all liked it.”
- User Ed Avis: “successfully used delta to track down . . . perl bugs”
- Works on configuration files, etc.

Summary

- Use the tools to analyze real programs
- Write analyses with Oink and they will all compose together!
  - Saves duplicated effort on front-ends
  - Makes composite analyses possible
- If Elsa/Oink achieves critical mass, all analyses for C/C++ will be written in it and will compose with one another
- Take over the analysis universe.
- Feel free to talk to me about using any of these tools for a demo/lesson.