Ada Code Analysis:

Technology, Experience, and Issues

C. Daniel Cooper

cdaniel.cooper@boeing.com

The Boeing Company

Ada Code Analysis

1: Technology

- capability, applicability, limitations

2: Experience

- examples: problems found, useful reports
- challenges: underleveraged technology

3: Issues

- vision of how things could be
- overcoming barriers to adoption

4: Summary

1: Code Analysis Technology

- Capability
  - current realities
  - technology enablers
- Applicability
  - usage categories
  - beneficiaries
- Limitations

Capability: Current Realities

- Traditionally minimal expectations
  - only call trees, cross-reference tables, metrics
  - home-grown, ad hoc tools: full language not supported
- Analysis feedback is typically missing
- But for some problem classes, analysis is:
  - the earliest, cheapest means of detection
  - possibly the ***only*** means of detection
- Analysis technology is now mature
  - available: industrial strength tools
  - scalable: thousands of files, MSLOCs

Capability: Technology Enablers

- Ada Semantic Interface Specification (ASIS)
  - binding for ARM-based query language
  - ISO Standard 15291
- Compiler provides the analysis database
  - analysis tools only query the compilation data
  - certified full language support
- Other analysis technologies also available
- Results displayed textually or graphically

Applicability: Usage Categories

- Descriptive Use: as-built information
  - code comprehension and review
  - architectural dependencies (inter-unit, inter-layer)
  - document generation
- Prescriptive Use: assessment
  - inefficiency and error discovery
  - architectural enforcement, complexity reduction
  - style and standards compliance
  - portability and reuse, dead code elimination
  - maintainability and quality improvement
- Corrective Use: repair and refactoring

Applicability: Beneficiaries

- Back end of life-cycle (as soon as code exists)
- Individual developers: daily “hygiene”
- Code reviews
  - unbiased, automated
  - issue-based versus reviewer-based
- Formal releases, quality assurance
- Range of domains
  - high-integrity, safety-critical applications
  - less emphasis where time-to-market dominates

Technology Limitations

- Code analysis is static, not dynamic
  - capitalizes on structural/semantic information
  - path-based but not dynamic run-time behavior
- Analyzed code must be compilable
- Computationally intensive
  - high-end hardware needed
- Under/over-reporting of analysis results
  - may miss some cases of interest
  - may report “potential” cases (false positives)

2: Code Analysis Experience

- Examples
  - problems found
  - useful reports
- Challenges
  - underleveraged technology

Experience: Problems Found

Typographical errors:

```
function Convert is new Unchecked_Conversion
    (Source => System.Address,
     Target => State_Table);
```

Type-cast of 32 bits into 2048 bits! Should be:

```
function Convert is new Unchecked_Conversion
    (Source => System.Address,
     Target => State_Table_Access);
```

Experience: Problems Found

Broken, but seems okay (not WYSIWYG):

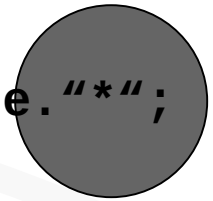
```
   Fahrenheit : Temperature.Value;
   Centigrade : Temperature.Value;
begin
   Fahrenheit := …something…
   Centigrade := (Fahrenheit - 32.0) * 5.0 / 9.0;
```

Grossly miscalculates conversion… can stare at this for hours… maybe a compiler bug?

Experience: Problems Found

```
   function “+“ (Left, Right : Temperature.Value)
       return Temperature.Value renames Temperature.“+“;
   function “-“ (Left, Right : Temperature.Value)
       return Temperature.Value renames Temperature.“-“;
   function “*“ (Left, Right : Temperature.Value)
       return Temperature.Value renames Temperature.“*“;
   function “/“ (Left, Right : Temperature.Value)
       return Temperature.Value renames Temperature.“*“;

   Fahrenheit : Temperature.Value;
   Centigrade : Temperature.Value;
begin
   Fahrenheit := …something…
   Centigrade := (Fahrenheit - 32.0) * 5.0 / 9.0;
```



Experience: Problems Found

Okay, but seems broken:

```
   type Fail_Type is (Overrun, RAM_Error, HW_Error,
       Hard_Failure, RTC_Failure, Watchdog_Timer);

   subtype Hard_Fail_Type is Fail_Type range
       Hard_Failure .. Watchdog_Timer;

   Error: Hard_Fail_Type;
begin
   Error := Overrun;
```

Should raise Constraint_Error, but…

Experience: Problems Found

Missing code:

```
function Convert (Color : Colors) return Integer is
begin
    case Color is
          when Blue   => return 6;
          when Green  => return 17;
          when Red    => return 23;
          when others => null;
    end case;
end Convert;
```

Should raise Program_Error, but…

Experience: Problems Found

Extraneous dead code: four granularities

- unWITHed units
- uncalled subprograms
- infeasible execution paths (unreachable statements)
- unneeded declarations or clauses

Dead code includes “weak dependencies” e.g.:

- a representation clause for an unused type
- a pragma for an uncalled subprogram
- a WITH clause supporting only an unneeded USE
- the chain of weak dependencies can be long

Experience: Problems Found

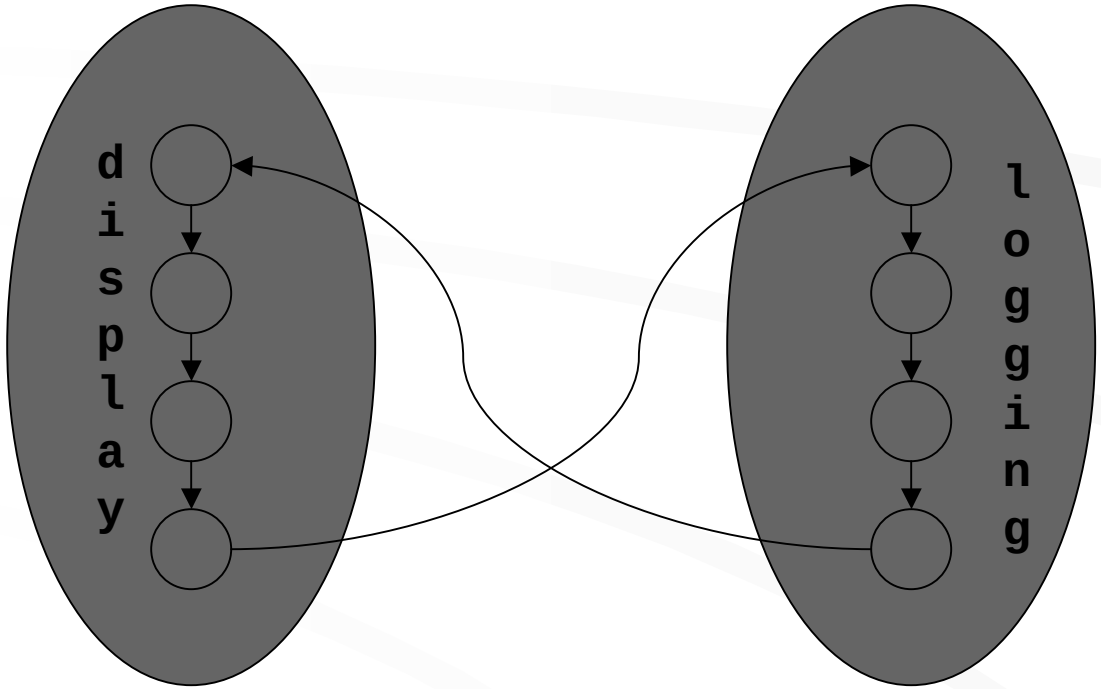
Questionable oddities:

```
-- single-literal enum versus a constant
type Foo is (Bar);
for Foo use (Bar => 23);

-- unnecessary redundant rep spec (Ada95)
type Foo is (A, B, C, D);
for Foo use (A => 0,
             B => 1,
             C => 2,
             D => 3);
```

Experience: Problems Found

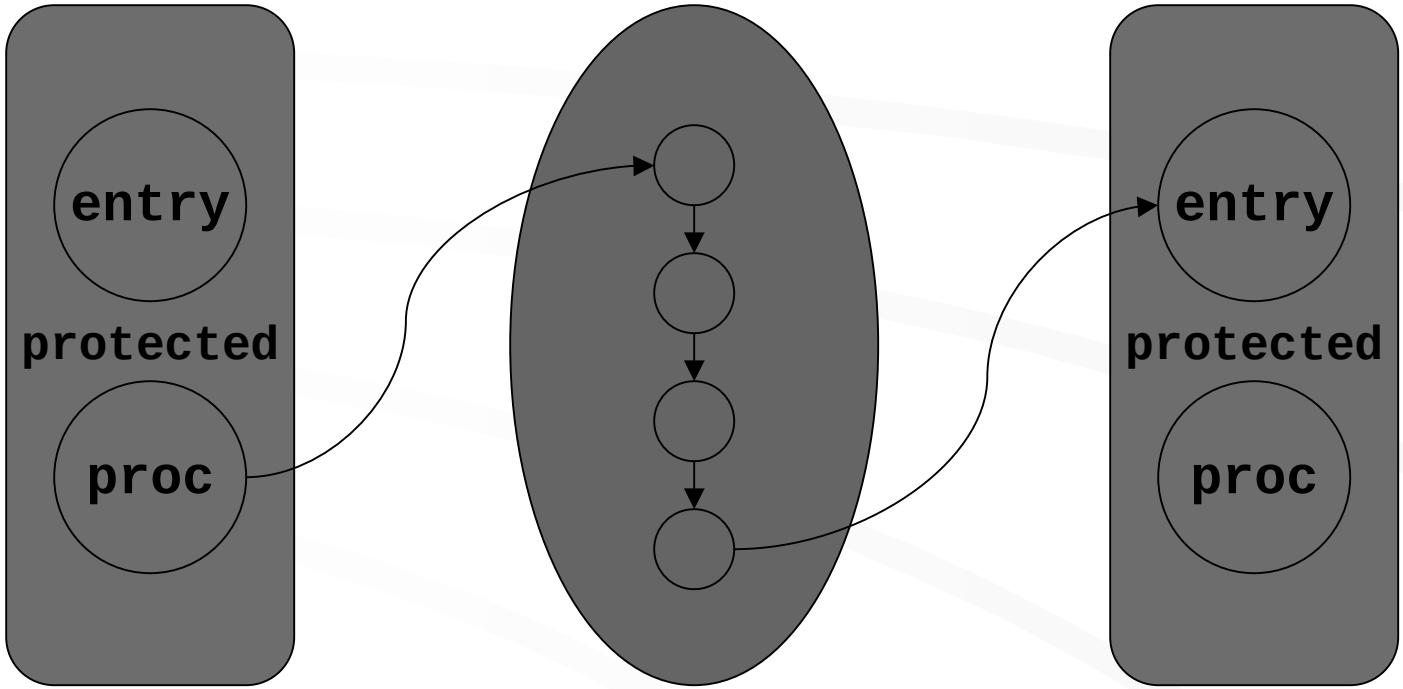
Local cohesion, global coupling:



unintended indirect recursion

Experience: Problems Found

(More) local cohesion, global coupling:



protected action (eventually) calls blocking op

Experience: Useful Reports

Architectural Issues

- unneeded WITH clauses
- over-scoped WITH clauses
- excessive WITHing (or trend)
- variables declared in package spec
- one-way IN OUT parameters
- exception propagation
- potentially redundant record types
- candidate subunits

Experience: Useful Reports

Performance Issues

- potential race conditions
- run-time expensive types
- dynamic instantiations
- elaboration impacts
- variables set twice before use
- candidate InLine subprograms
- candidate short-circuit operators
- unneeded IF to assign Booleans

Experience: Useful Reports

Programming Issues

- variables used before set
- potential division by zero
- equality operators for reals
- inevitable constraint violations
- inconsistent representation clauses
- side-effects in functions
- unneeded type conversions
- redeclared predefined names

Experience: Challenges

- Appallingly underleveraged technology!
  - non-technical reasons
  - unrecognized benefits, values not shared
  - schedule and time-to-market pressures
- Disruption of the status quo
  - developers: analysis results are job interruption
  - testers: easier workload, but it's not their job
- Tyranny of the functional
  - build the house, but leave the trash
  - "It ain't broke, so don't fix it!"
  - "*Better* is the enemy of *Good Enough*."

3: Code Analysis Issues

- Vision of how things could be
  - improved code quality
  - improved tool usage
- Overcoming barriers to adoption
  - management barriers
  - environment barriers
  - cultural barriers

Vision of Improved Code Quality

- Enhanced coding standards
  - enabled by automation
  - living, evolving: not frozen at project start
- Deeper code assessment
  - expose hard-to-find problems
  - for some problems, may be the *only* recourse
  - easy for users to perform ad hoc analyses
  - greater code consistency
- Continuous, real quality improvement
  - refactoring: code evolution, anti-entropy

Vision of Improved Tool Usage

- Traditional approach:

```
while Code_Not_Working loop
      Edit; Compile; Link; Test;
end loop;
```

- Visionary approach:

```
while Code_Not_Working loop
      while Code_Not_Clean loop
            Edit; Compile; Analyze;
      end loop;
      Link; Test;
end loop;
```

Overcoming Management Barriers

- Support
  - quality improvement must be a shared value
- Benefit versus Cost
  - reduce cost of testing, downstream maintenance
  - bigger cost is engineering time, not tool licenses
  - history confirms cost of low quality
- Planning
  - must be part of the infrastructure, institutionalized
- Time-to-Market Pressures
  - different needs: embedded versus office products

Overcoming Environment Barriers

- Recognized Process
  - analysis results need somewhere to go
  - must be overt part of the development process
- Integrated Environment
  - assure easy access, non-obtrusive
  - include industrial-strength tools
  - support alternate approaches, tech-transfer
- Evangelism
  - capability/resources must be public knowledge
  - software architect should be strongest proponent

Overcoming Cultural Barriers

- Analysis results can be overwhelming
  - need strategy to prioritize, filter
- User-friendliness
  - analysis must be usable as well as useful
  - users may need special training
- “It ain’t broke, so don’t fix it.”
  - more kinds of “broke” than just functional
  - “so what” attitude: must understand the issues
  - pride in high-quality code
- Quality is everyone’s job

4: Code Analysis Summary

- Addresses significant problems
- On real platforms
  - mature, industrial strength, ASIS-based
- Reducing the cost
  - earlier detection = cheaper to fix
  - improved quality = cheaper to maintain
- Non-obtrusively
  - incorporated into development process
  - integrated with development environment

Go forth and do great things!