Ada as a Foundation Programming Language: 
Starting Off on the Right Foot

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What’s a Foundation Programming Language?

- Introduced in first or second course in undergrad curriculum (“CS1” or “CS2”, in educator shorthand)
- (Usually) the first language students learn
- Introduced early enough to serve as a foundation for the rest of the curriculum
- A good foundation language helps student “start off on the right foot”
Why Ada as the Foundation Language?

- the disciplined control and data structures of Pascal
- modeling of scalar data (scalar subtypes)
- system composition structures (private types, packages, exceptions, generics, concurrency) derived from Simula, Clu, CSP
- classification structures in Ada 95 are an easily understood extension of the existing type and package structures
- a standard that is taken seriously—provides portability, and sets a good example of professionalism and maturity in the software field
- GNAT is a very friendly compiler!
How Does the Foundation Language Get Chosen?

- Faculties usually *vote* on curriculum decisions.
- There are always fads, bandwagons, factions, speculations, etc., just like any other political process.
- Smaller departments are easier to work with, simply because fewer “yes” votes are required to pass something.
- As in Congress, in a faculty it is difficult to make something happen but easy to make it *not* happen.
Ada as a Foundation Programming Language

Number of Institutions Introducing Ada First in CS1-type Course

Number of Institutions Introducing Ada First in CS2/7-type Course
Continuing Innovation in Ada Foundation Courses

- AdaGIDE and GRASP GUIs both contain “beginner-friendly” features.
- University of Northern Iowa: switched from C++ to Ada. Local industry really likes the recent graduates, even for C++ projects.
- British Columbia Institute of Technology adopted Ada this year as foundation language.
- U.S. Air Force Academy is starting to use Ada in all-freshmen course to program LEGO Mindstorm robots.
- George Washington University research in introducing concurrent programming into a CS1-level course. (2 doctoral dissertations so far.)
BEGIN -- Drunken_Spider
    Spider.Start;
    LOOP -- keep going forever
        Spider.Face(WhichWay => Spider.RandomDirection);
        Spider.ChangeColor(NewColor => Spider.RandomColor);
        -- Spider will count steps correctly
        -- but might change direction
        FOR Count IN 1..Spider.RandomStep LOOP
            IF Spider.AtWall THEN
                Spider.TurnRight;
                Spider.TurnRight;
                END IF;
                Spider.Step;
            END LOOP;
        Spider.TurnRight;
    END LOOP;
    END Drunken_Spider;
BEGIN -- Drunken_Spider
   Spider.Start;

   LOOP -- keep going forever
      Spider.Face(WhichWay => Spider.RandomDirection);
      -- Spider will count steps correctly
      -- but might change direction
      FOR Count IN 1..Spider.RandomStep LOOP
         IF Spider.AtWall THEN
            --
            Spider.TurnRight;
            Spider.TurnRight;
            END IF;
         Spider.Step;
      END LOOP;
   END LOOP;

END Drunken_Spider;
LEGO Mindstorms at U.S. Air Force Academy
GW Computer Science Education Research:
Should We Teach Concurrency in Intro Courses?

- Language sophistication is making it possible to do—concurrency primitives are no longer “low level” and OS-dependent
- Some educators opine that because the world is concurrent, concurrency is not hard for beginners to understand
- Some opine that if students learn concurrency early, they won’t be stuck in a sequential “von Neumann bottleneck”
- A possible downside: “conservation of curriculum”; i.e., making room for concurrency means we may have to give less attention to other introductory subjects
- Caution and controlled experimentation is called for, to try to ensure that introducing a major new subject does not degrade student learning of traditional subjects
GW’s Introductory Software Development Course for CS Majors

http://www.seas.gwu.edu/~csci51

- Csci 51, Introduction to Software Development
- Catalog Description:
  Introduction to the solution of problems on a digital computer using Ada. Structured programming concepts; proper documentation techniques; efficiency of programs; design of test data. Writing, debugging, and running programs in an interactive computing environment.
- 3 credits: 2.5 clock hours lecture; 1.5 clock hours laboratory per week
CSci 51 Demographics, Spring 2000

• Number of students: 79
  Students claiming previous programming experience: 31 (39%)
• Students indicating they were CS majors: 51 (64%)
  CS majors claiming previous programming experience: 22 (43%)
• Number of females: 19 (25% of population)
  Females with previous experience: 9 (47% of females)
  Female CS majors: 12 (23% of CS majors)
  Female CS majors with previous experience: 4 (33%)
• In most semesters, a student’s position on the final grade curve is essentially independent of major or previous experience
• In most semesters, the withdrawal rate is no more than about 25% (this is low for typical CS1 courses)
GW’s Introductory Software Development Course for CS Majors

- Course was taught with Pascal 1980-92, Ada 83 1992-95, Ada 95 1995-present
- Students complete a small lab exercise in each lab
- Students complete (typically) 8 software development projects, 1-2 weeks each
- “Spider”—simple turtle-graphics-type algorithm animation—used at start of course to teach algorithms, control structures, and exception handling
- GNU Ada 95 (GNAT) compiler used; default platform is Solaris but students can install on Mac, Linux, Windows
- Default Spider is simple 24 x 80 monochrome, but high-resolution color provided for Windows, Mac
WITH Spider;
PROCEDURE Spiral IS
BEGIN -- Spiral
   Spider.Start;
   Spider.Face(WhichWay => Spider.RandomDirection);

   -- draw ten lines, starting in a random direction
   FOR Line IN 1..10 LOOP
      Spider.ChangeColor(NewColor => Spider.RandomColor);
   END LOOP;
   Spider.TurnRight;
END LOOP;
Spider.Quit;
END Spiral;
WITH Spider_Hires; USE Spider_Hires;
PROCEDURE Polystars IS
  PROCEDURE Polystar(Length: IN Steps; Sides: IN Positive) IS
  BEGIN
    FOR Side IN 1..Sides LOOP
      Step(HowMany => Length);
      TurnRight(HowFar => 180.0 - 180.0/Float(Sides));
    END LOOP;
  END Polystar;
END Polystars;
BEGIN -- Polystars
  SetSpeed(Slow);
  FOR Count IN 3 .. 25 LOOP
    IF Count REM 2 = 1 THEN
      Start;
      Polystar(Length => 100, Sides => Count);
      Wait;
    END IF;
  END LOOP;
  Quit;
END Polystars;
High Resolution Polystars
WITH Spider;
PROCEDURE Drunken_Spider IS
BEGIN -- Drunken_Spider
    Spider.Start;
    LOOP -- keep going forever
        Spider.Face(WhichWay => Spider.RandomDirection);
        Spider.ChangeColor(NewColor => Spider.RandomColor);
        -- Spider will count steps correctly
        -- but might change direction
        FOR Count IN 1..Spider.RandomStep LOOP
            IF Spider.AtWall THEN
                Spider.TurnRight;
                Spider.TurnRight;
            END IF;
            Spider.Step;
        END LOOP;
        Spider.TurnRight;
    END LOOP;
END Drunken_Spider;
Drunken Spider
Drunken Spider, High Resolution
Research Studies on Concurrent Programming in Intro Courses


- METHOD: non-credit GW summer course with voluntary students; soldiers at U.S. Army IT training school

- RESULT: Bachus showed that students without much programming experience can understand some fairly sophisticated examples of concurrency
Research Studies on Concurrent Programming in Intro Courses

• Lund, D.Sc. Dissertation 1999. Can we introduce concurrency into a CS1-level course? Will we lose anything by doing so?

• METHOD:
  teach Csci 51 with no concurrency content
  teach it again (twice) with unchanged original content but add concurrency
  measure student outcomes (projects, exams) on both nonconcurrency and concurrency content

• RESULT: Lund showed that we can introduce concurrency with no substantial degradation of outcomes
Typical Final Projects Using Concurrency in Csci 51 (and Csci 131, Algorithms and Data Structures I)

- Simulation of Highway Speed Monitor
- Multiple Drunken Spiders
- Dining Philosophers
- Simulation of a Bank in Operation
Highway Speed Monitor Simulation

- Pseudo-Random (std library)
- Big Digit Package (earlier project)
- Calendar (std library)
- Simulated Radar Unit
- Time of Day Formatter
- Display Device
Drunken Spiders Family
Dijkstra’s Famous Dining Philosophers (1971)

- plate
- chopstick (titanium)

Ichbiah

Dijkstra

Kung Pao Chicken (Infinite Supply)

Taft

Stroustrup

Anderson
## Dining Philosophers

<table>
<thead>
<tr>
<th>Edsger Dijkstra</th>
<th>Jean Ichbiah</th>
<th>Bjarne Stroustrup</th>
<th>Tucker Taft</th>
<th>Chris Anderson</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 13 Meal 1, 5 seconds.</td>
<td>T = 14 First chopstick 3</td>
<td>T = 19 Meal 1, 9 seconds.</td>
<td>T = 19 Yum-yum (burp)</td>
<td>T = 18 First chopstick 2</td>
</tr>
<tr>
<td>T = 18 Yum-yum (burp)</td>
<td>T = 19 Second chopstick 4</td>
<td>T = 18 First chopstick 1</td>
<td>T = 19 Thinking 4 seconds.</td>
<td>T = 13 Yum-yum (burp)</td>
</tr>
<tr>
<td>T = 18 Thinking 8 seconds.</td>
<td>T = 19 Meal 2, 10 seconds.</td>
<td>T = 19 Second chopstick 5</td>
<td>T = 9 Meal 2, 10 seconds.</td>
<td>T = 13 Thinking 4 seconds.</td>
</tr>
</tbody>
</table>
Module Dependencies for Dining Philosophers

- Main
- Society
- Room
- Chopsticks
- Philosophers
- Random
Bank Simulation

T = 5    Teller B: Transaction will take 4 sec
T = 7    Teller A: Acct 2 - Balance is 0
T = 7    Teller A: Transaction will take 3 sec
T = 7    Account 2 alive.
T = 7    Account 2 will return after 3 sec
T = 9    Teller B: Acct 1 - Balance is 266
T = 10   Account 1 will return after 5 sec
T = 10   Teller A: Acct 3 - Balance is 0
T = 10   Teller A: Transaction will take 4 sec
T = 10   Account 3 alive.
T = 10   Account 3 will return after 3 sec
T = 10   Account 2 depositing 266 with Teller B
T = 10   Teller B: Transaction will take 1 sec
T = 11   Teller B: Acct 2 - Balance is 266
T = 12   Account 2 will return after 5 sec
T = 13   Account 3 depositing 266 with Teller B
Conclusions

• Material in foundation courses must be handled with care; students must complete the course well-prepared for the rest of the courses in their program

• GW seniors study Ada, Java, C, C++, and lots of other stuff in their four years. They tell us they are glad they began their program with Ada.

• The jury is still out on concurrency in intro courses but we are starting to understand the issues

• Computer Science Education research is challenging but rewarding