Course work

- Based on GCC compiler
- One piece of course work: 25% of course mark
- Set today and due **Thursday 4pm Feb 21st 2019** week 6
- Feedback due **Thursday 4pm Mar 7th 2019** week 8
- Penalties for late submission.
- Plagiarism software used. Do your own work!
Iterative Compilation
Find the best way to compile a program
Goal

- Evaluate different compiler optimisation settings on a set of benchmarks.
- Try to beat -O3
- Write a report about your methodology and your findings.
Program Optimisation in GCC

- GCC supports some simple levels of optimisations: 
  - -01, -02, -03
- At each level, a set of optimisations are enabled 
  (25 for 01, 25+29 for 02 and 19+28+9 for 03)
- At higher levels, more optimisations are enabled which results in potentially\(^1\) faster code, but also slows down the compilation process.
- Rather than using these pre-defined optimisation options, the users can enable individual options themselves, e.g. “-funroll-loops”.
- For more information on optimisation options see http://gcc.gnu.org/onlinedocs/gcc/Optimize-Options.html

\(^1\)Not all optimisations make code better
Methodology: Evaluating Compiler Flags

- Always use `-O3`: Some optimisations won’t work without it
- Randomly choose flags (on/off) and parameter values
- Evaluate 200 randomly chosen configurations
  (i.e. combinations of optimisations)
- Use the same configurations for all benchmarks!
Running Experiments

- **Avoid noise:**
  - Make sure no one else is logged on to the computer (using `who`) and no other applications are running (using `top`).
  - Don't run on top of AFS ⇒ use `/disk/scratch` or `/tmp`.
  - BUT: move the results back to your home-directory and don't leave the data accessible to everyone.

- **Run benchmarks at least 10 times to get stable results.**
  - Determine how many measurements you need to get a stable value.
  - Compute and report *average* runtime.
  - Also report the *variance* and the number of iterations you used.
Use scripting languages to automate the process of evaluating optimisations on the benchmark programs.

Example (pseudo code)

```plaintext
for each b in benchmarks
    for each o in optimisations
        compile b with o
        run b N times and record runtimes
        calculate average runtime and variance
    end
end
```
The Benchmarks

- We use 14 benchmarks from the SPEC CPU2006 and MediaBench II suites.
- CPU intensive benchmarks developed from real user applications.
- Download and extract the programs (use wget) from: https://docs.google.com/file/d/0B5GasMlWJhT0aTdvaFkzUzNobDQ/edit
- Let me know if you need more disk space!
Directory Structure

spec/
  └── 400.perlbench/
      ├── src/
      │    └── Makefile
      └── data/
          └── run.sh
  └── 401.bzip2/
      └── ...

Compiling and Running the Benchmarks

- Compiling a program with certain optimisations enabled and executing it a single time:

  cd 400.perlbench/src/
  make CFLAGS="-funroll-loops -param max-unroll-times=4"
  cd ../
  ./run.sh
Report and Results

- Maximum 5 pages + 2 pages for results
- Explain what you have done.
- Precisely describe the experimental setup.
  - Number of runs per benchmark/configuration
- For every program report performance of:
  - Baseline -O0, -O1, -O2, -O3
  - Best found flags for individual program.
  - Best found single set of flags across all programs.
  - Average across all flag settings (expected random performance).
- Results should be detailed: per-program, average, variance
Store all raw data in a file. For each program:

- First line: program name
- Following lines: flag setting and all runtimes
- Runtimes in milliseconds, without decimal digits

400.perlbench
"-00" 837 833 890 850 813 828 ... 
"-01" 602 620 610 611 650 580 ... 
...

401.bzip2
"-00" 837 833 890 850 813 828 ... 
"-01" 602 620 610 611 650 580 ... 
...

e-mail file to: hleather@inf.ed.ac.uk WITH the subject: copt-results
Report Structure

- Abstract. (Summary of paper) and Introduction
- Evaluation methodology: Selection of flags, etc.
- Experimental setup: Platform. How time was measured. Number of runs.
- Results (for each program)
  - Baseline -O0, -O1, -O2, -O3
  - Best found flags for individual program.
  - Best found single set of flags across all programs.
  - Average across all flag settings (expected random performance).
- Analysis and Discussion of Results. Followed by conclusion.
Submission. Awarding of Marks

- Submit to ITO written report by Thursday 4pm Feb 21st 2019.
- Marks are awarded for clear explanation of experimental methodology and thorough analysis of results.
- Remember wish to see optimisation setting that gives best results per program AND the setting that is best for all the benchmarks.
Final Remarks

- For further questions e-mail me
- Start early!! It takes time to run the experiments!
- Deadline: Thursday 4pm Feb 21st 2019
PPar CDT Advert

The biggest revolution in the technological landscape for fifty years
Now accepting applications!
Find out more and apply at:
pervasiveparallelism.inf.ed.ac.uk

• 4-year programme: MSc by Research + PhD

• Research-focused: Work on your thesis topic from the start

• Collaboration between:
  ▶ University of Edinburgh’s School of Informatics
    ★ Ranked top in the UK by 2014 REF
  ▶ Edinburgh Parallel Computing Centre
    ★ UK’s largest supercomputing centre

• Research topics in software, hardware, theory and application of:
  ▶ Parallelism
  ▶ Concurrency
  ▶ Distribution

• Full funding available

• Industrial engagement programme includes internships at leading companies

The biggest revolution in the technological landscape for fifty years

Now accepting applications!
Find out more and apply at:
pervasiveparallelism.inf.ed.ac.uk

EPSRC Centre for Doctoral Training in Pervasive Parallelism