Precimonious & HiFPTuner

Tuning Assistant for Floating-Point Precision

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http://fpanalysistools.org/

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Floating-Point Precision Tuning

- Floating-point (FP) arithmetic used in variety of domains

- Reasoning about FP programs is difficult
  - Large variety of numerical problems
  - Most programmers are not experts in FP

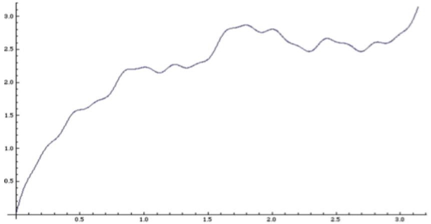
- Common practice: use highest available precision
  - Disadvantage: more expensive!

- Goal: automated techniques to assist in tuning floating-point precision

Example: Arc Length

- Consider the problem of finding the arc length of the function

$$g(x) = x + \sum_{0 \le k \le 5} 2^{-k} \sin(2^k x)$$



- Summing for $x_k \in (0, \pi)$ into n subintervals

$$\sum_{k=0}^{n-1} \sqrt{h^2 + (g(x_{k+1}) - g(x_k))^2}$$ with $h = \pi / n$ and $x_k = kh$

	Precision	Slowdown	Result	
1	double-double	20X	5.795776322412856	✓
2	double	1X	5.795776322413031	✗
3	mixed precision	< 2X	5.795776322412856	✓

Example: Arc Length

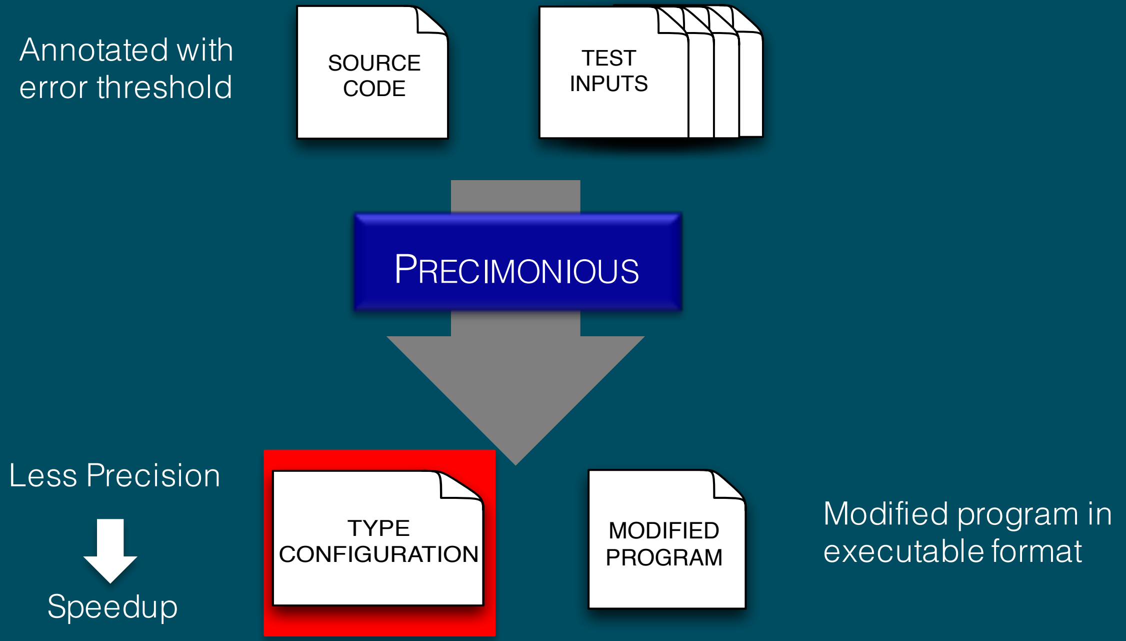
```
long double g(long double x) {
  int k, n = 5;
  long double t1 = x;
  long double d1 = 1.0L;

  for(k = 1; k <= n; k++) {
     ...
  }
  return t1;
}

int main() {
  int i, n = 1000000;
  long double h, t1, t2, dppi;
  long double s1;
  ...
  for(i = 1; i <= n; i++) {
    t2 = g(i * h);
    s1 = s1 + sqrt(h*h + (t2 - t1)*(t2 - t1));
    t1 = t2;
  }
  // final answer stored in variable s1
  return 0;
}
```

Mixed Precision Program

Precimonious

"Parsimonious or Frugal with Precision"

Dynamic Analysis for Floating-Point Precision Tuning



Annotated with error threshold

SOURCE CODE

TEST INPUTS

PRECIMONIOUS

Less Precision

Speedup

TYPE CONFIGURATION

MODIFIED PROGRAM

Modified program in executable format

http://fpanalysistools.org/

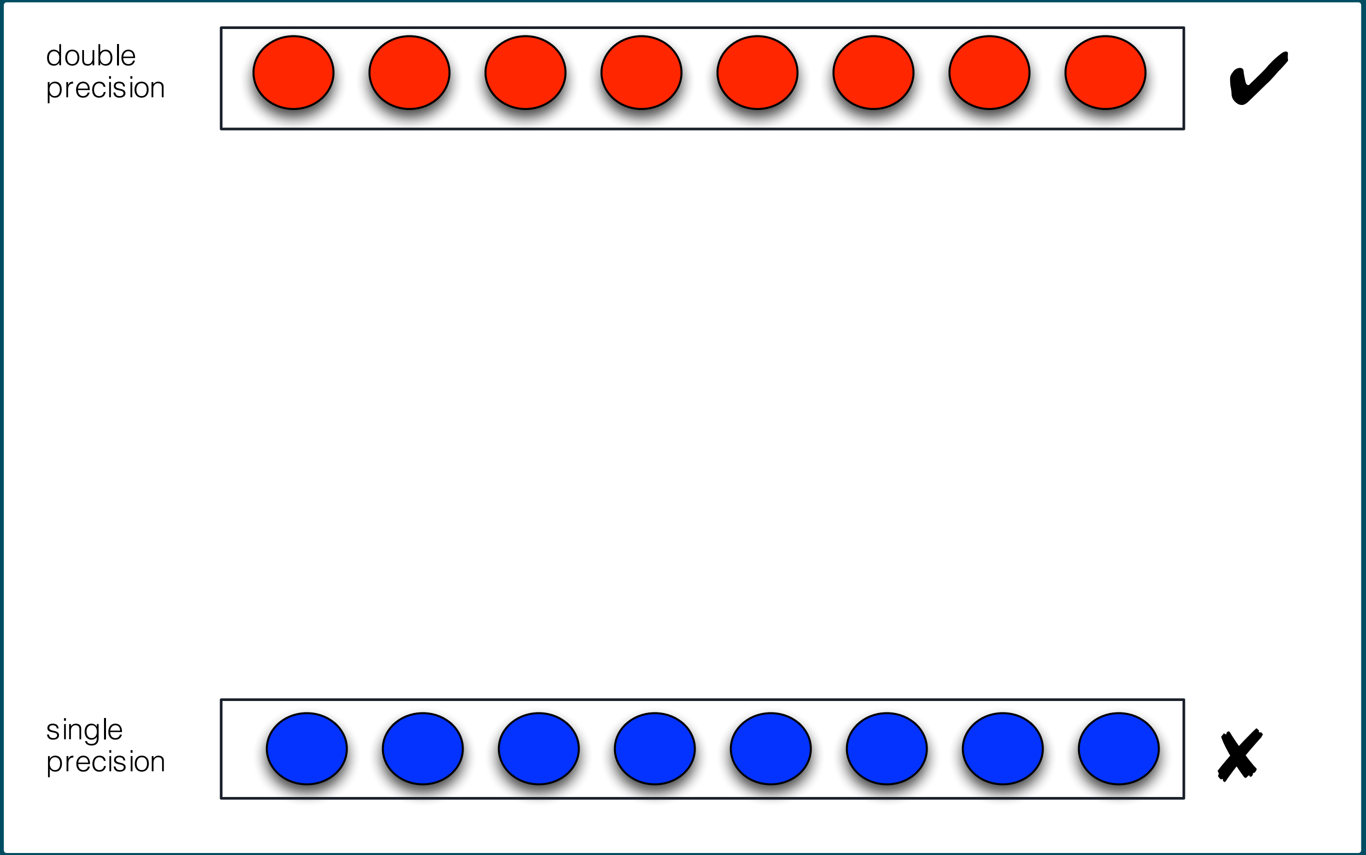
Challenges for Precision Tuning

- Searching efficiently over variable types and function implementations
  - Naïve approach -> exponential time
  - 19,683 configurations for arclength program (3^9)
  - 11 hours 5 minutes
  - Global minimum vs. Local minimum
- Evaluating type configurations
  - Less precision not necessarily faster
  - Based on runtime, energy consumption, etc.
- Determining accuracy constraints
  - How accurate must the final result be?
  - What error threshold to use?

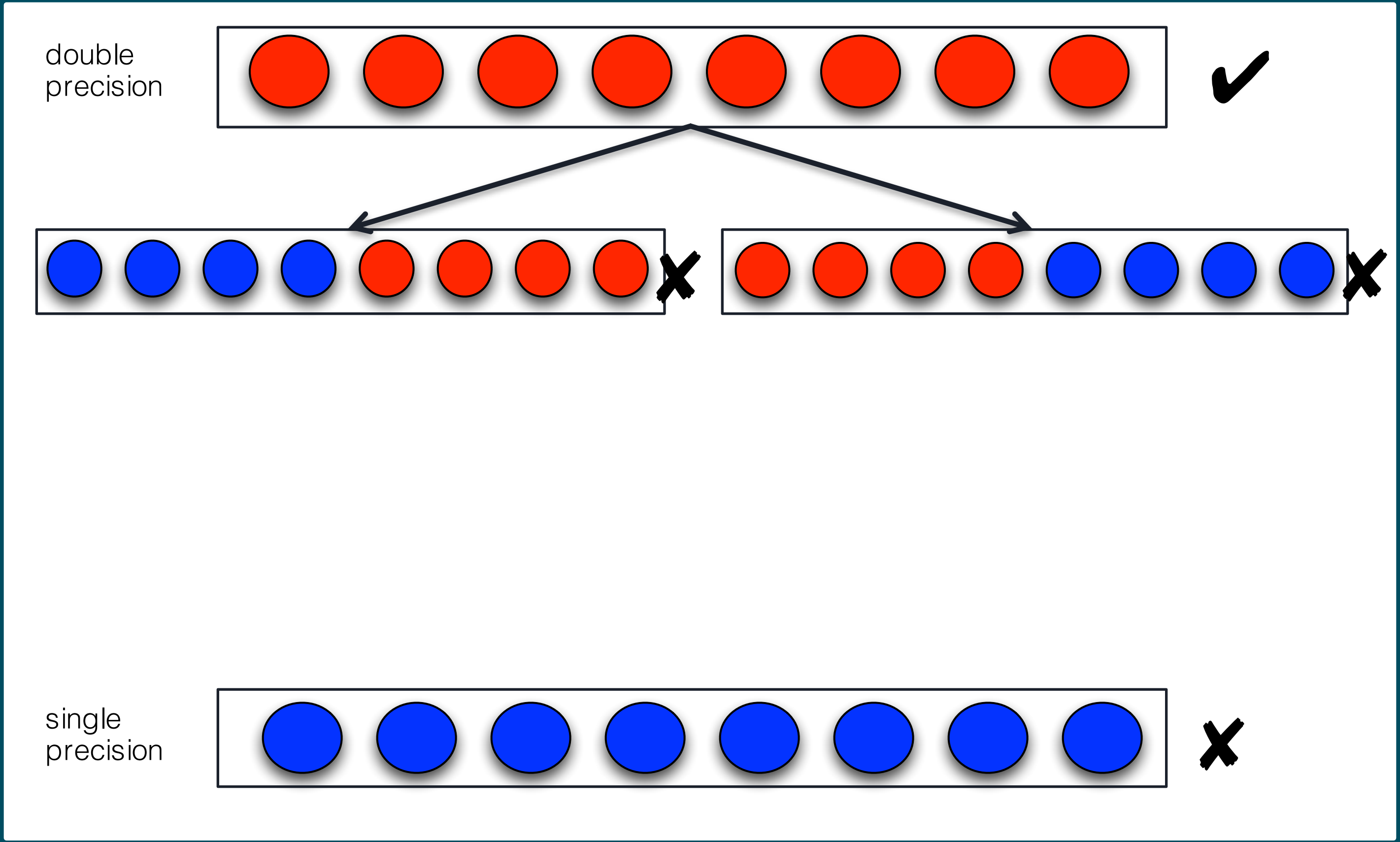
Automated

Specified by the user

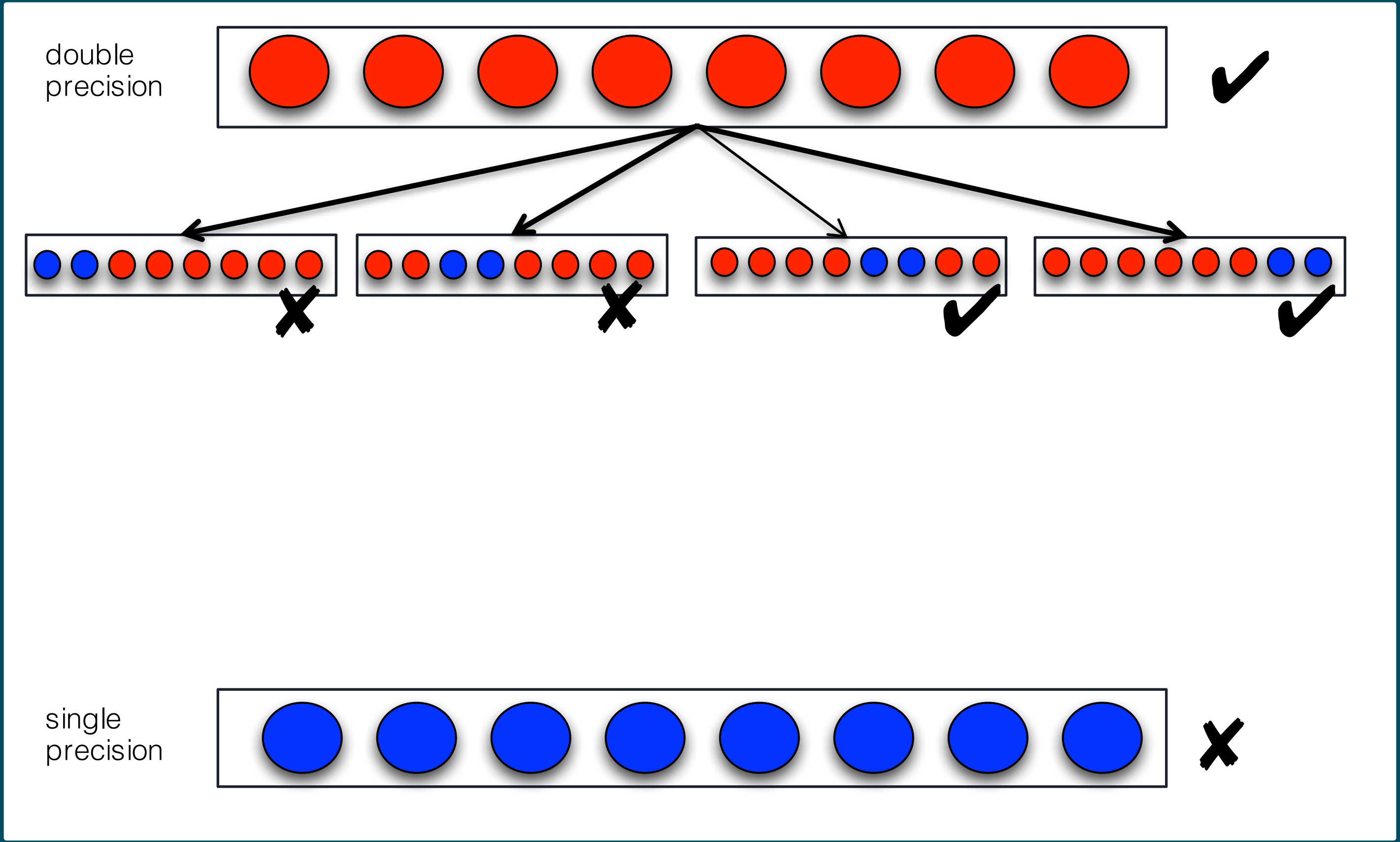
Searching for Type Configuration



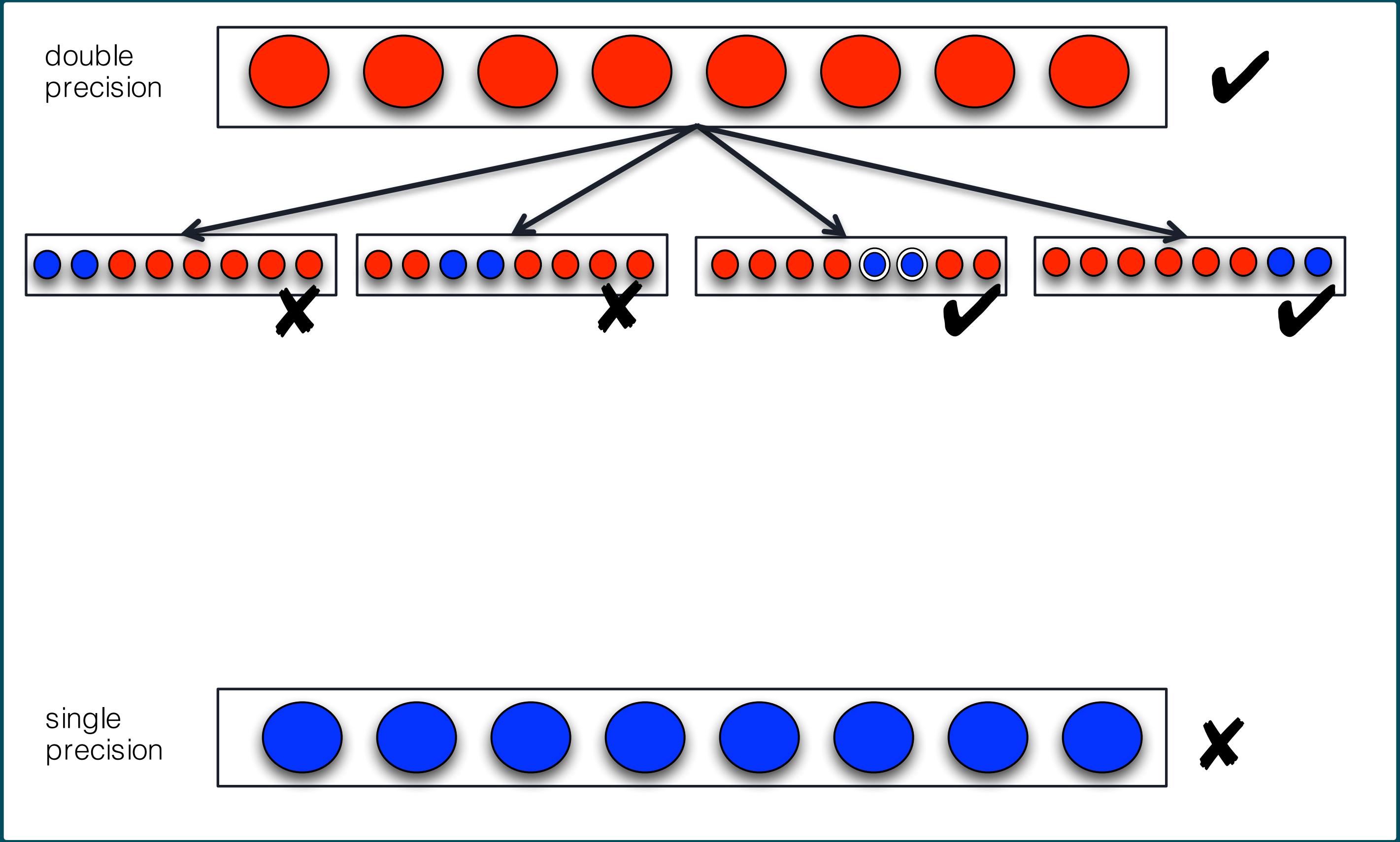
Searching for Type Configuration



Searching for Type Configuration

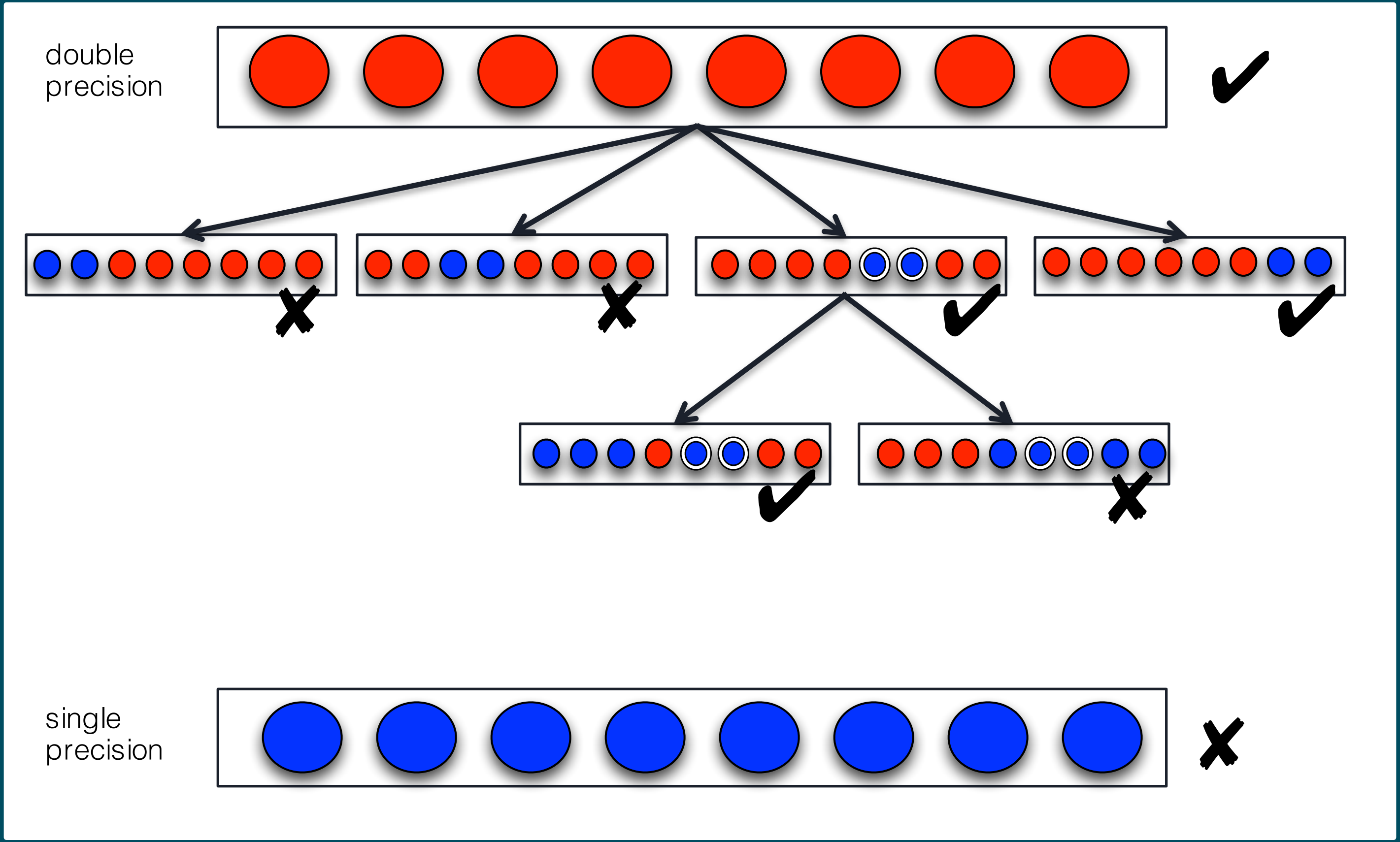


Searching for Type Configuration



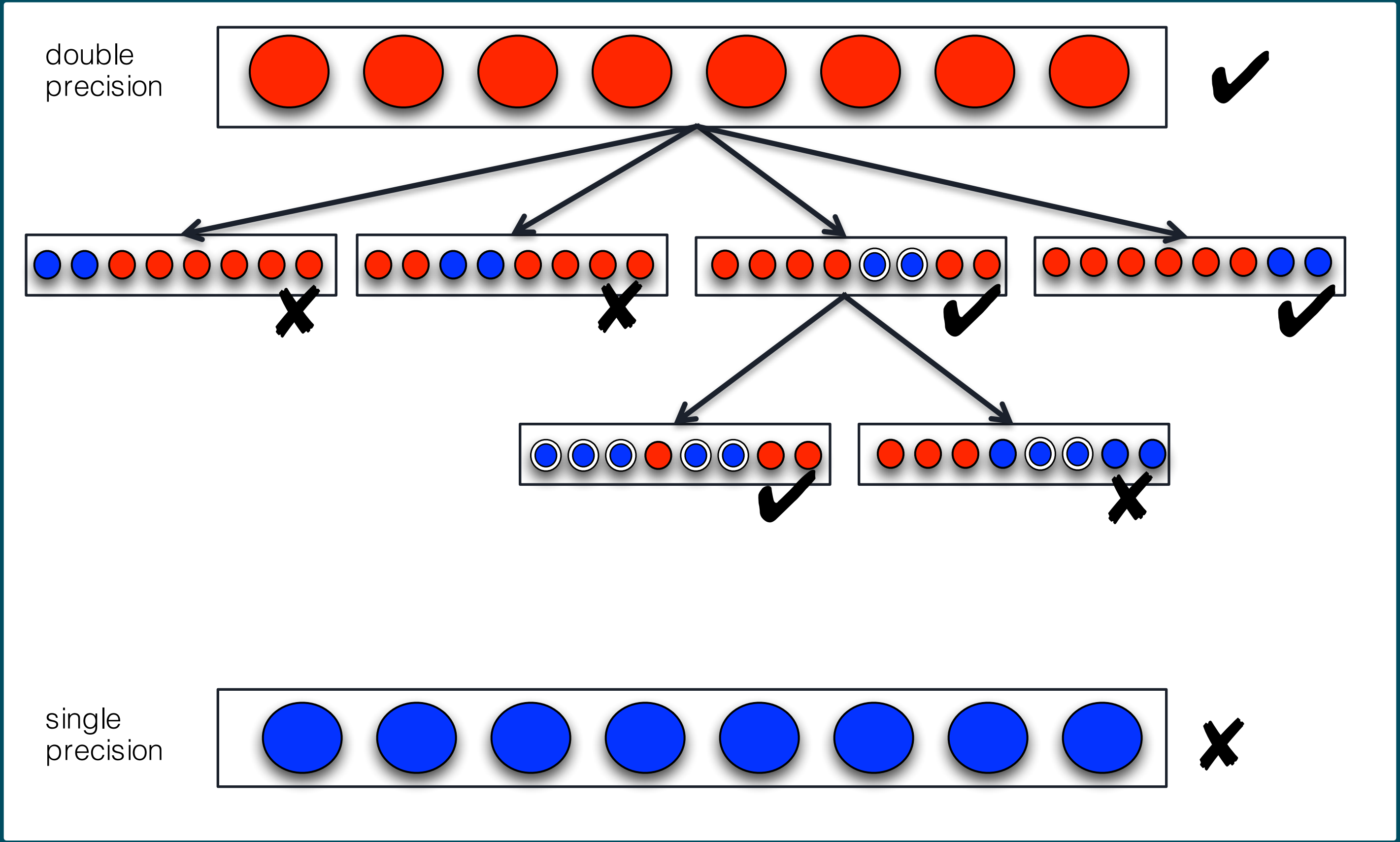
http://fpanalysistools.org/

Searching for Type Configuration

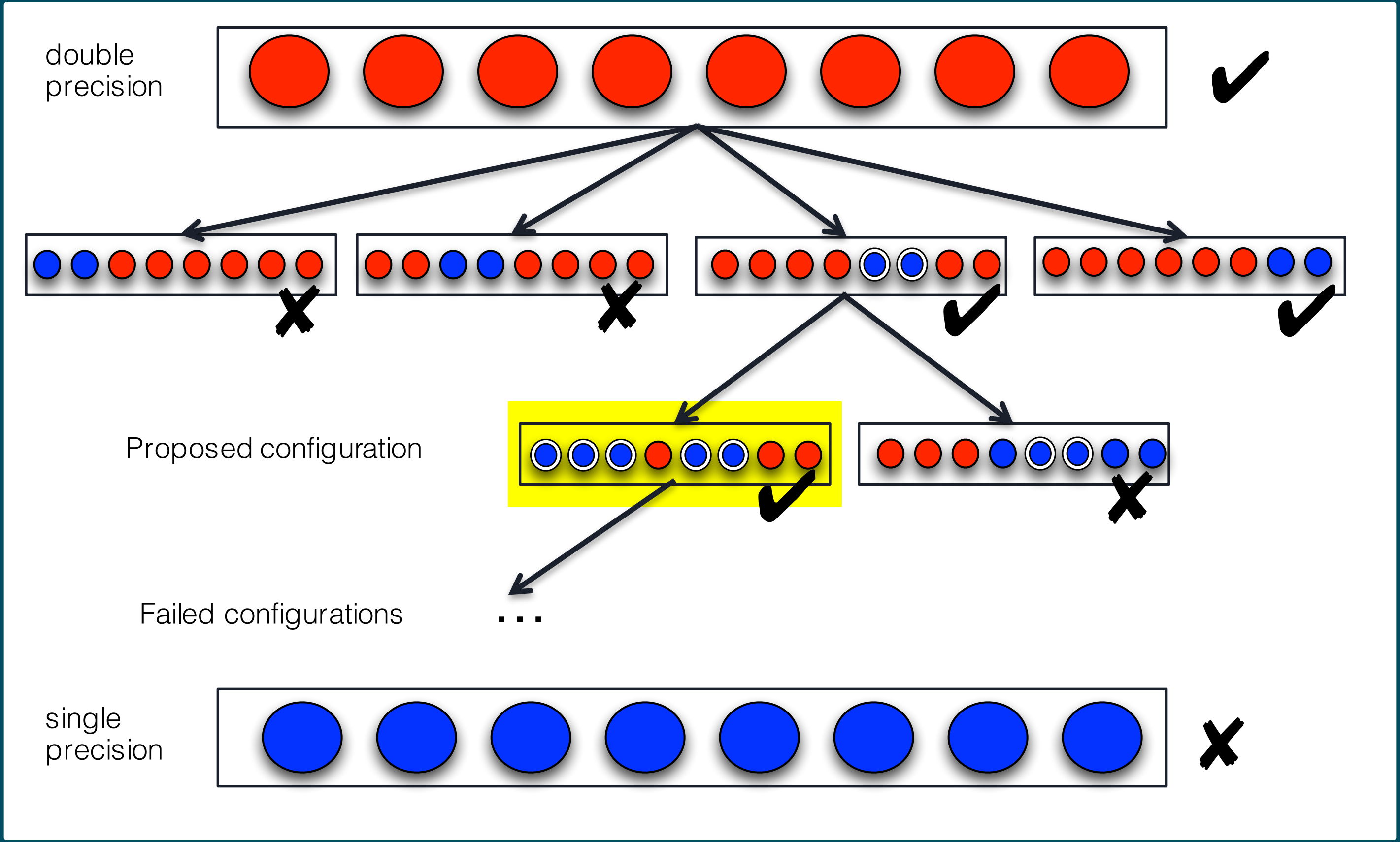


http://fpanalysistools.org/

Searching for Type Configuration



Searching for Type Configuration



double precision

Proposed configuration

Failed configurations

...

single precision

Source code available:
https://github.com/plse/precimonious

Questions?

Directory Structure

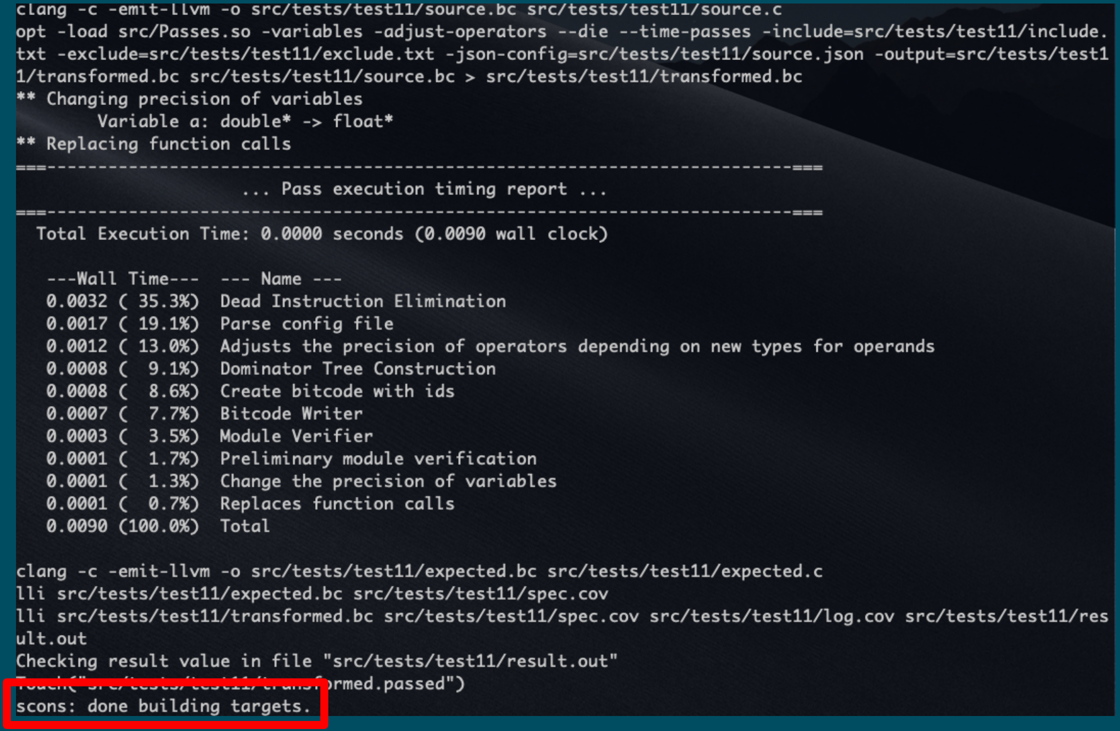
```
/$HOME

  |--/Module-Precimonious
       |---/exercise
       |---/exercise-2

  |--/Module-HiFPTuner
       |---/exercise
       |---/exercise-2
```

Exercise

```
$ cd Module-Precimonious
```

Step 1: Build Precimonious

- Open setup.sh file
- Precimonious uses LLVM and is built using scons
- Execute :
  - $ ./setup.sh



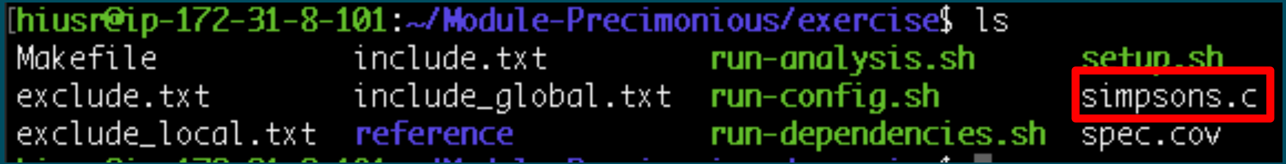
```
clang -c -emit-llvm -o src/tests/test11/source.bc src/tests/test11/source.c
opt -load src/Passes.so -variables -adjust-operators --die --time-passes -include=src/tests/test11/include.
txt -exclude=src/tests/test11/exclude.txt -json-config=src/tests/test11/source.json -output=src/tests/test1
1/transformed.bc src/tests/test11/source.bc > src/tests/test11/transformed.bc
** Changing precision of variables
        Variable a: double* -> float*
** Replacing function calls
===-------------------------------------------------------------------------===
                      ... Pass execution timing report ...
===-------------------------------------------------------------------------===
  Total Execution Time: 0.0000 seconds (0.0090 wall clock)

   ---Wall Time---  --- Name ---
   0.0032 ( 35.3%)  Dead Instruction Elimination
   0.0017 ( 19.1%)  Parse config file
   0.0012 ( 13.0%)  Adjusts the precision of operators depending on new types for operands
   0.0008 (  9.1%)  Dominator Tree Construction
   0.0008 (  8.6%)  Create bitcode with ids
   0.0007 (  7.7%)  Bitcode Writer
   0.0003 (  3.5%)  Module Verifier
   0.0001 (  1.7%)  Preliminary module verification
   0.0001 (  1.3%)  Change the precision of variables
   0.0001 (  0.7%)  Replaces function calls
   0.0090 (100.0%)  Total

clang -c -emit-llvm -o src/tests/test11/expected.bc src/tests/test11/expected.c
lli src/tests/test11/expected.bc src/tests/test11/spec.cov
lli src/tests/test11/transformed.bc src/tests/test11/spec.cov src/tests/test11/log.cov src/tests/test11/res
ult.out
Checking result value in file "src/tests/test11/result.out"
Touch("src/tests/test11/transformed.passed")
scons: done building targets.
```

Success building and running tests

Step 2: Annotate Program (already done)

- Execute :
  - $ cd exercise
  - $ ls

The program we will tune:

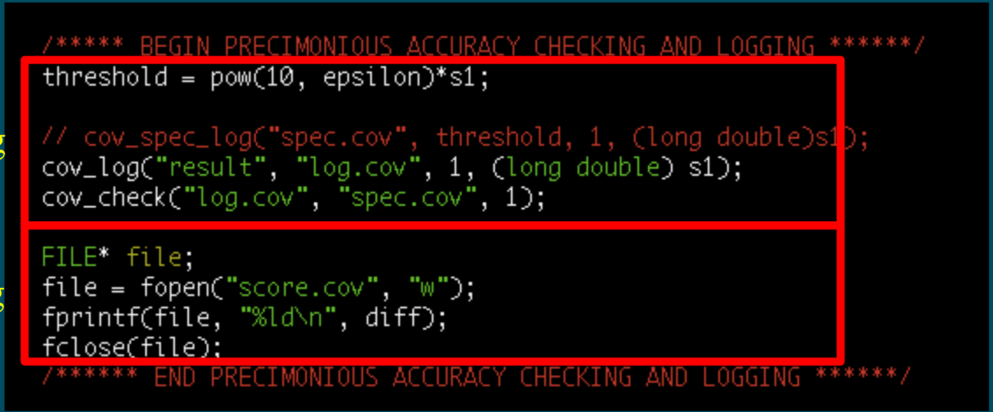


```
[hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise$ ls
Makefile           include.txt          run-analysis.sh      setup.sh
exclude.txt        include_global.txt   run-config.sh        simpsons.c
exclude_local.txt  reference            run-dependencies.sh  spec.cov
```

- Open *simpsons.c* file

Accuracy logging & checking

Performance logging



```
/***** BEGIN PRECIMONIOUS ACCURACY CHECKING AND LOGGING ******/
threshold = pow(10, epsilon)*s1;

// cov_spec_log("spec.cov", threshold, 1, (long double)s1);
cov_log("result", "log.cov", 1, (long double) s1);
cov_check("log.cov", "spec.cov", 1);

FILE* file;
file = fopen("score.cov", "w");
fprintf(file, "%ld\n", diff);
fclose(file);
/****** END PRECIMONIOUS ACCURACY CHECKING AND LOGGING ******/
```

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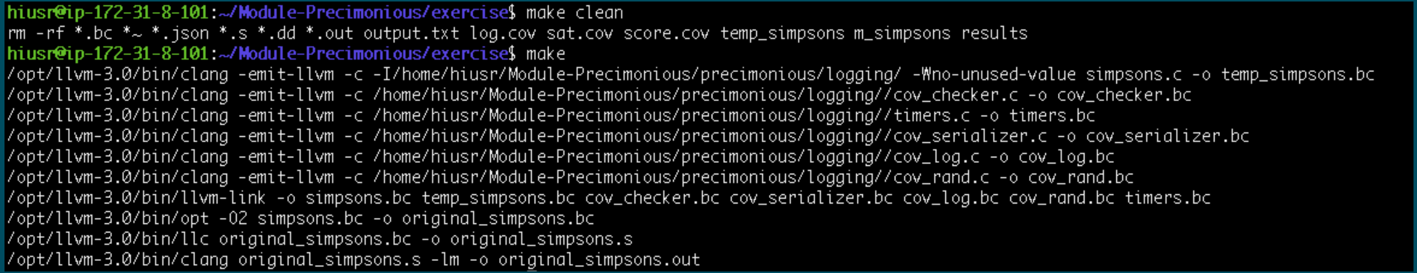
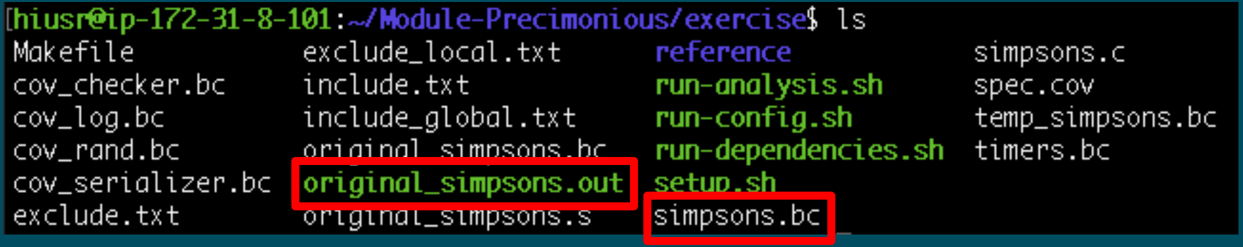
Step 3: Compile Program with Clang

- Execute :
  - $ make clean
  - $ make



```
hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise$ make clean
rm -rf *.bc *~ *.json *.s *.dd *.out output.txt log.cov sat.cov score.cov temp_simpsons m_simpsons results
hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise$ make
/opt/llvm-3.0/bin/clang -emit-llvm -c -I/home/hiusr/Module-Precimonious/precimonious/logging/ -Wno-unused-value simpsons.c -o temp_simpsons.bc
/opt/llvm-3.0/bin/clang -emit-llvm -c /home/hiusr/Module-Precimonious/precimonious/logging//cov_checker.c -o cov_checker.bc
/opt/llvm-3.0/bin/clang -emit-llvm -c /home/hiusr/Module-Precimonious/precimonious/logging//timers.c -o timers.bc
/opt/llvm-3.0/bin/clang -emit-llvm -c /home/hiusr/Module-Precimonious/precimonious/logging//cov_serializer.c -o cov_serializer.bc
/opt/llvm-3.0/bin/clang -emit-llvm -c /home/hiusr/Module-Precimonious/precimonious/logging//cov_log.c -o cov_log.bc
/opt/llvm-3.0/bin/clang -emit-llvm -c /home/hiusr/Module-Precimonious/precimonious/logging//cov_rand.c -o cov_rand.bc
/opt/llvm-3.0/bin/llvm-link -o simpsons.bc temp_simpsons.bc cov_checker.bc cov_serializer.bc cov_log.bc cov_rand.bc timers.bc
/opt/llvm-3.0/bin/opt -O2 simpsons.bc -o original_simpsons.bc
/opt/llvm-3.0/bin/llc original_simpsons.bc -o original_simpsons.s
/opt/llvm-3.0/bin/clang original_simpsons.s -lm -o original_simpsons.out
```

- Creates LLVM bitcode file and optimized executable for later use

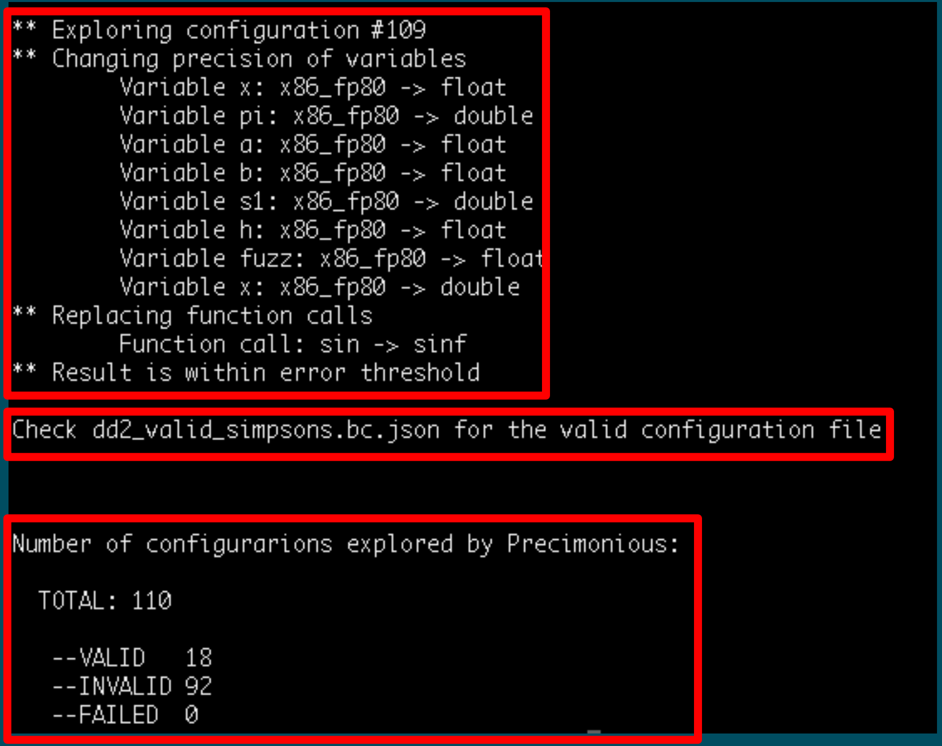


```
[hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise$ ls
Makefile           exclude_local.txt      reference            simpsons.c
cov_checker.bc     include.txt            run-analysis.sh      spec.cov
cov_log.bc         include_global.txt     run-config.sh        temp_simpsons.bc
cov_rand.bc        original_simpsons.bc   run-dependencies.sh  timers.bc
cov_serializer.bc  original_simpsons.out  setup.sh
exclude.txt        original_simpsons.s    simpsons.bc
```

Step 4: Run Analysis on Program

Sample output:

- Execute :
  - $ ./run-analysis.sh simpsons



```
** Exploring configuration #109
** Changing precision of variables
        Variable x: x86_fp80 -> float
        Variable pi: x86_fp80 -> double
        Variable a: x86_fp80 -> float
        Variable b: x86_fp80 -> float
        Variable s1: x86_fp80 -> double
        Variable h: x86_fp80 -> float
        Variable fuzz: x86_fp80 -> float
        Variable x: x86_fp80 -> double
** Replacing function calls
        Function call: sin -> sinf
** Result is within error threshold
```

```
Check dd2_valid_simpsons.bc.json for the valid configuration file
```

```
Number of configurarions explored by Precimonious:

  TOTAL: 110

   --VALID   18
   --INVALID 92
   --FAILED  0
```

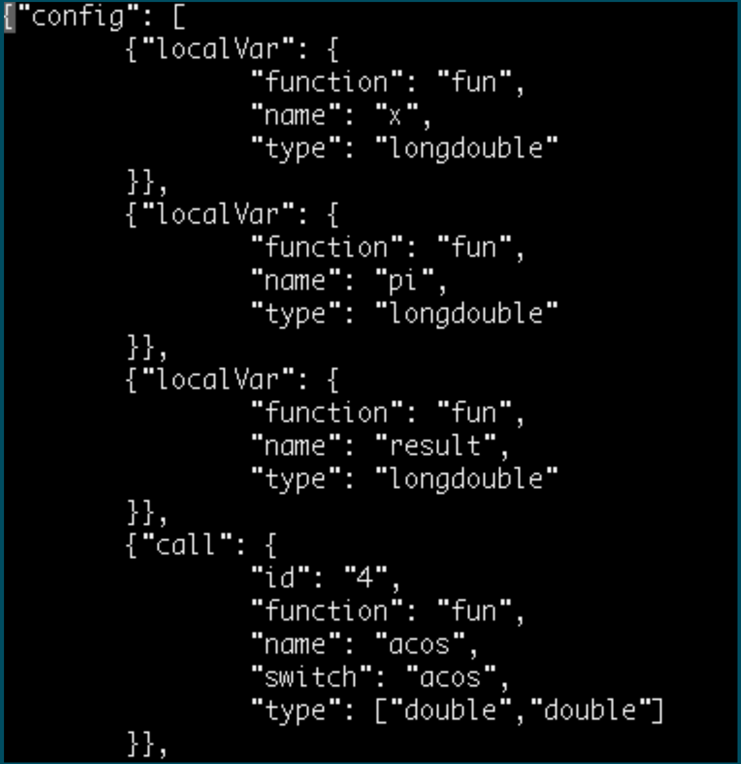
Type changes are listed for each explored configuration

Suggested type configuration

Number of explored configurations

Step 4: Run Analysis – Configuration File

- Open *config_simpsons.json*
- Original type configuration

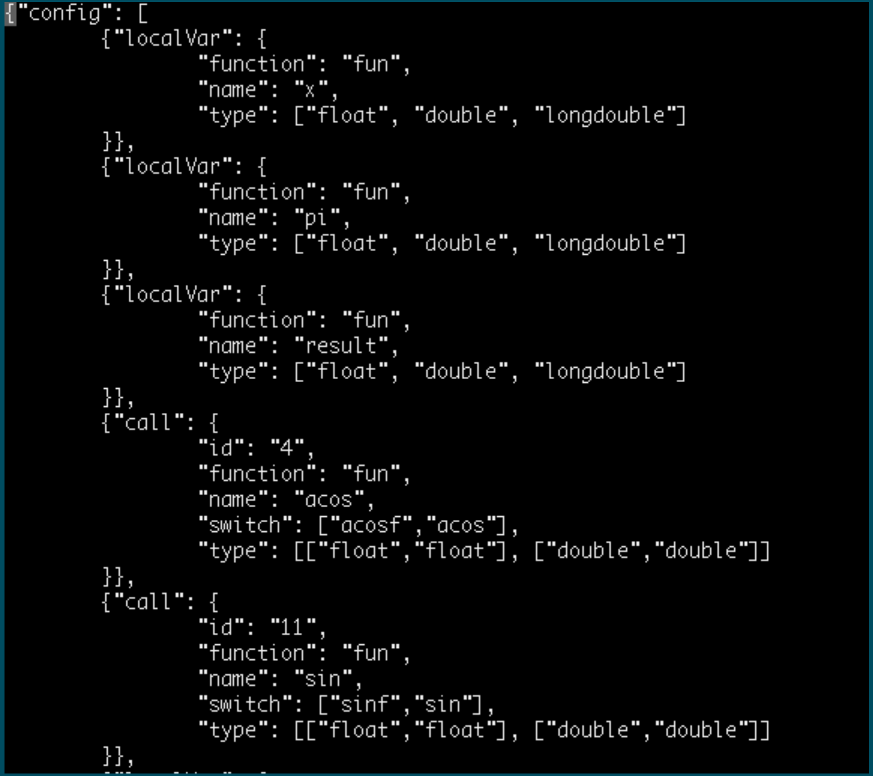


```
{"config": [
        {"localVar": {
                "function": "fun",
                "name": "x",
                "type": "longdouble"
        }},
        {"localVar": {
                "function": "fun",
                "name": "pi",
                "type": "longdouble"
        }},
        {"localVar": {
                "function": "fun",
                "name": "result",
                "type": "longdouble"
        }},
        {"call": {
                "id": "4",
                "function": "fun",
                "name": "acos",
                "switch": "acos",
                "type": ["double","double"]
        }},
```

Step 4: Run Analysis – Search File

- Open search_funarc.json
- Search space file

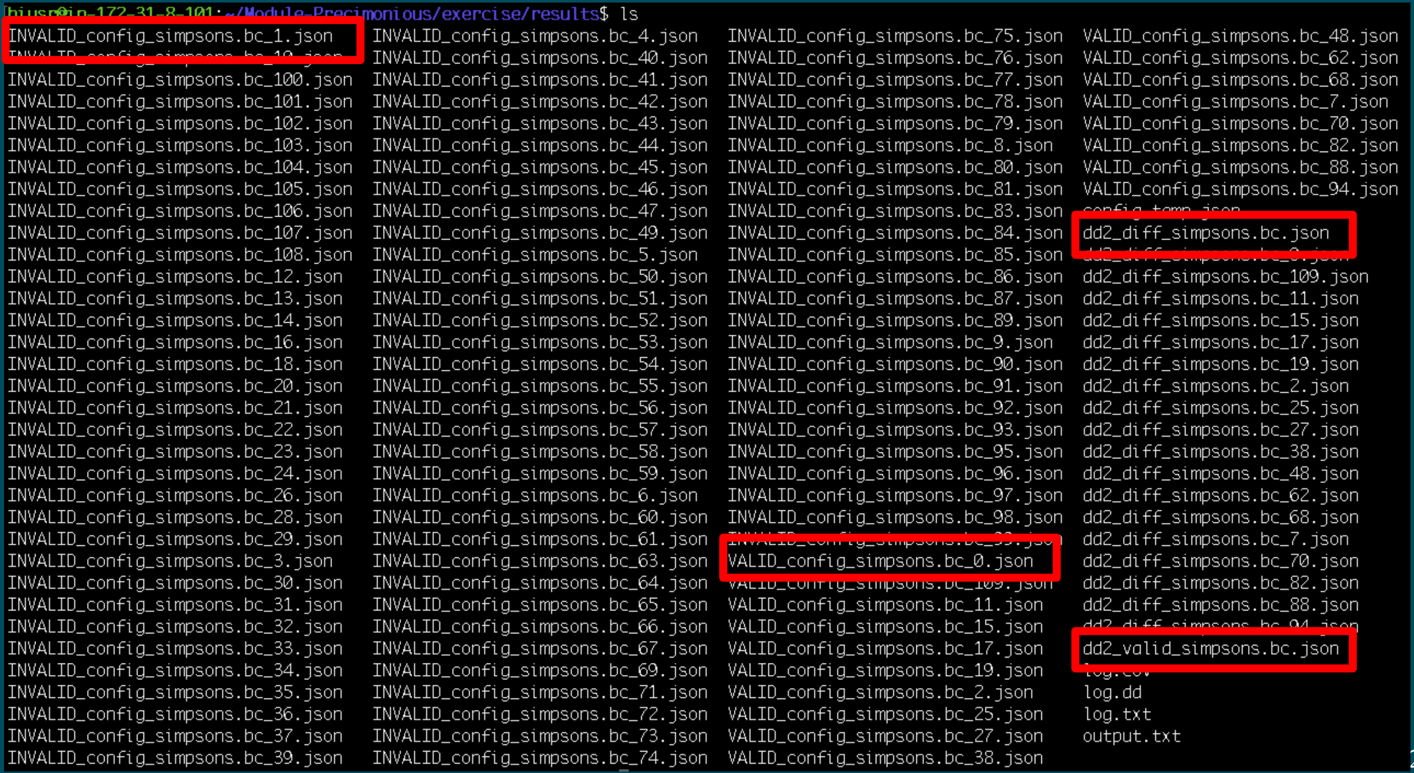
- To exclude functions edit exclude.txt
- To exclude variables edit exclude_local.txt
- Or you can directly edit search file prior to analysis



```
{"config": [
        {"localVar": {
                "function": "fun",
                "name": "x",
                "type": ["float", "double", "longdouble"]
        }},
        {"localVar": {
                "function": "fun",
                "name": "pi",
                "type": ["float", "double", "longdouble"]
        }},
        {"localVar": {
                "function": "fun",
                "name": "result",
                "type": ["float", "double", "longdouble"]
        }},
        {"call": {
                "id": "4",
                "function": "fun",
                "name": "acos",
                "switch": ["acosf","acos"],
                "type": [["float","float"], ["double","double"]]
        }},
        {"call": {
                "id": "11",
                "function": "fun",
                "name": "sin",
                "switch": ["sinf","sin"],
                "type": [["float","float"], ["double","double"]]
        }},
```

Step 4: Run Analysis – Output Files

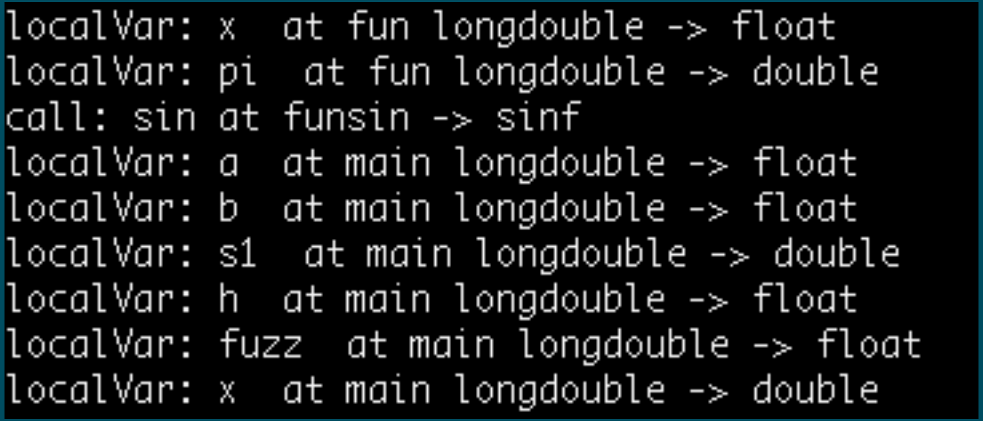
- Execute :
  - $ cd results
  - $ ls



```
hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise/results$ ls
INVALID_config_simpsons.bc_1.json    INVALID_config_simpsons.bc_4.json    INVALID_config_simpsons.bc_75.json   VALID_config_simpsons.bc_48.json
INVALID_config_simpsons.bc_10.json   INVALID_config_simpsons.bc_40.json   INVALID_config_simpsons.bc_76.json   VALID_config_simpsons.bc_62.json
INVALID_config_simpsons.bc_100.json  INVALID_config_simpsons.bc_41.json   INVALID_config_simpsons.bc_77.json   VALID_config_simpsons.bc_68.json
INVALID_config_simpsons.bc_101.json  INVALID_config_simpsons.bc_42.json   INVALID_config_simpsons.bc_78.json   VALID_config_simpsons.bc_7.json
INVALID_config_simpsons.bc_102.json  INVALID_config_simpsons.bc_43.json   INVALID_config_simpsons.bc_79.json   VALID_config_simpsons.bc_70.json
INVALID_config_simpsons.bc_103.json  INVALID_config_simpsons.bc_44.json   INVALID_config_simpsons.bc_8.json    VALID_config_simpsons.bc_82.json
INVALID_config_simpsons.bc_104.json  INVALID_config_simpsons.bc_45.json   INVALID_config_simpsons.bc_80.json   VALID_config_simpsons.bc_88.json
INVALID_config_simpsons.bc_105.json  INVALID_config_simpsons.bc_46.json   INVALID_config_simpsons.bc_81.json   VALID_config_simpsons.bc_94.json
INVALID_config_simpsons.bc_106.json  INVALID_config_simpsons.bc_47.json   INVALID_config_simpsons.bc_83.json   config_temp.json
INVALID_config_simpsons.bc_107.json  INVALID_config_simpsons.bc_49.json   INVALID_config_simpsons.bc_84.json   dd2_diff_simpsons.bc.json
INVALID_config_simpsons.bc_108.json  INVALID_config_simpsons.bc_5.json    INVALID_config_simpsons.bc_85.json   dd2_diff_simpsons.bc_0.json
INVALID_config_simpsons.bc_12.json   INVALID_config_simpsons.bc_50.json   INVALID_config_simpsons.bc_86.json   dd2_diff_simpsons.bc_109.json
INVALID_config_simpsons.bc_13.json   INVALID_config_simpsons.bc_51.json   INVALID_config_simpsons.bc_87.json   dd2_diff_simpsons.bc_11.json
INVALID_config_simpsons.bc_14.json   INVALID_config_simpsons.bc_52.json   INVALID_config_simpsons.bc_89.json   dd2_diff_simpsons.bc_15.json
INVALID_config_simpsons.bc_16.json   INVALID_config_simpsons.bc_53.json   INVALID_config_simpsons.bc_9.json    dd2_diff_simpsons.bc_17.json
INVALID_config_simpsons.bc_18.json   INVALID_config_simpsons.bc_54.json   INVALID_config_simpsons.bc_90.json   dd2_diff_simpsons.bc_19.json
INVALID_config_simpsons.bc_20.json   INVALID_config_simpsons.bc_55.json   INVALID_config_simpsons.bc_91.json   dd2_diff_simpsons.bc_2.json
INVALID_config_simpsons.bc_21.json   INVALID_config_simpsons.bc_56.json   INVALID_config_simpsons.bc_92.json   dd2_diff_simpsons.bc_25.json
INVALID_config_simpsons.bc_22.json   INVALID_config_simpsons.bc_57.json   INVALID_config_simpsons.bc_93.json   dd2_diff_simpsons.bc_27.json
INVALID_config_simpsons.bc_23.json   INVALID_config_simpsons.bc_58.json   INVALID_config_simpsons.bc_95.json   dd2_diff_simpsons.bc_38.json
INVALID_config_simpsons.bc_24.json   INVALID_config_simpsons.bc_59.json   INVALID_config_simpsons.bc_96.json   dd2_diff_simpsons.bc_48.json
INVALID_config_simpsons.bc_26.json   INVALID_config_simpsons.bc_6.json    INVALID_config_simpsons.bc_97.json   dd2_diff_simpsons.bc_62.json
INVALID_config_simpsons.bc_28.json   INVALID_config_simpsons.bc_60.json   INVALID_config_simpsons.bc_98.json   dd2_diff_simpsons.bc_68.json
INVALID_config_simpsons.bc_29.json   INVALID_config_simpsons.bc_61.json   INVALID_config_simpsons.bc_99.json   dd2_diff_simpsons.bc_7.json
INVALID_config_simpsons.bc_3.json    INVALID_config_simpsons.bc_63.json   VALID_config_simpsons.bc_0.json      dd2_diff_simpsons.bc_70.json
INVALID_config_simpsons.bc_30.json   INVALID_config_simpsons.bc_64.json   VALID_config_simpsons.bc_109.json    dd2_diff_simpsons.bc_82.json
INVALID_config_simpsons.bc_31.json   INVALID_config_simpsons.bc_65.json   VALID_config_simpsons.bc_11.json     dd2_diff_simpsons.bc_88.json
INVALID_config_simpsons.bc_32.json   INVALID_config_simpsons.bc_66.json   VALID_config_simpsons.bc_15.json     dd2_diff_simpsons.bc_94.json
INVALID_config_simpsons.bc_33.json   INVALID_config_simpsons.bc_67.json   VALID_config_simpsons.bc_17.json     dd2_valid_simpsons.bc.json
INVALID_config_simpsons.bc_34.json   INVALID_config_simpsons.bc_69.json   VALID_config_simpsons.bc_19.json     log.cov
INVALID_config_simpsons.bc_35.json   INVALID_config_simpsons.bc_71.json   VALID_config_simpsons.bc_2.json      log.dd
INVALID_config_simpsons.bc_36.json   INVALID_config_simpsons.bc_72.json   VALID_config_simpsons.bc_25.json     log.txt
INVALID_config_simpsons.bc_37.json   INVALID_config_simpsons.bc_73.json   VALID_config_simpsons.bc_27.json     output.txt
INVALID_config_simpsons.bc_39.json   INVALID_config_simpsons.bc_74.json   VALID_config_simpsons.bc_38.json
```

Step 4: Run Analysis – Output Files

- Open dd2_valid_funarc.bc.json: suggested configuration file in JSON format
- Open dd2_diff_funarc.bc.json: summary of type changes

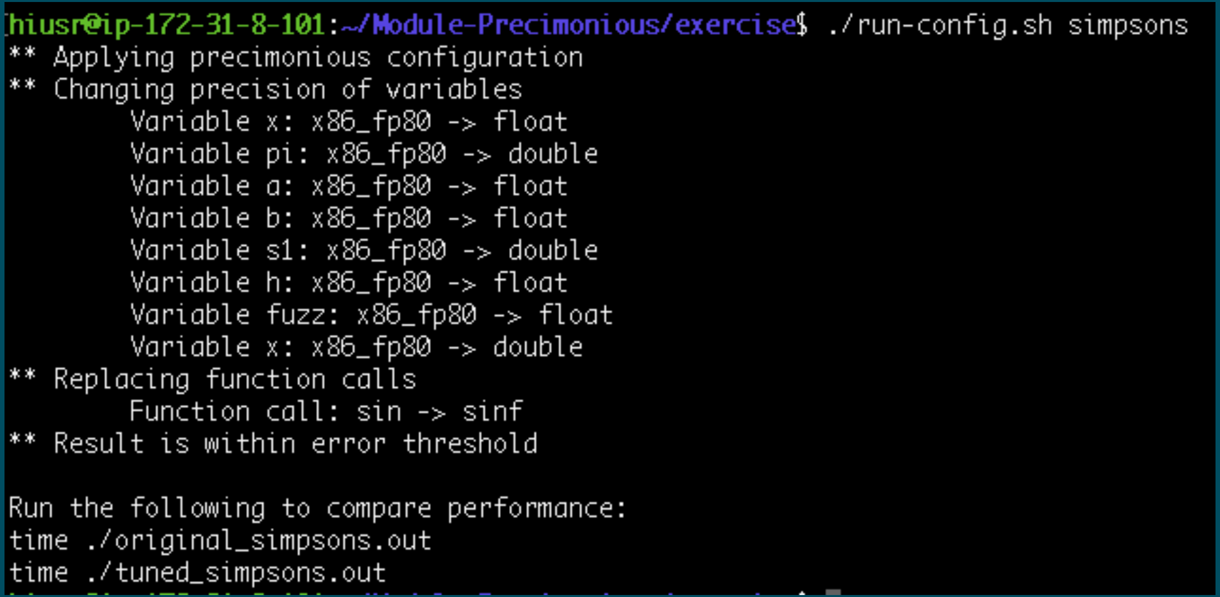


```
localVar: x  at fun longdouble -> float
localVar: pi  at fun longdouble -> double
call: sin at funsin -> sinf
localVar: a  at main longdouble -> float
localVar: b  at main longdouble -> float
localVar: s1  at main longdouble -> double
localVar: h  at main longdouble -> float
localVar: fuzz  at main longdouble -> float
localVar: x  at main longdouble -> double
```

Step 5: Apply Result Configuration & Compare Performance

- Execute :
  - $ cd ..
  - $ ./run-config.sh simpsons

- Execute :
  - $ time ./original_simpsons.out
  - $ time ./tuned_simpsons.out



```
hiusr@ip-172-31-8-101:~/Module-Precimonious/exercise$ ./run-config.sh simpsons
** Applying precimonious configuration
** Changing precision of variables
        Variable x: x86_fp80 -> float
        Variable pi: x86_fp80 -> double
        Variable a: x86_fp80 -> float
        Variable b: x86_fp80 -> float
        Variable s1: x86_fp80 -> double
        Variable h: x86_fp80 -> float
        Variable fuzz: x86_fp80 -> float
        Variable x: x86_fp80 -> double
** Replacing function calls
        Function call: sin -> sinf
** Result is within error threshold

Run the following to compare performance:
time ./original_simpsons.out
time ./tuned_simpsons.out
```

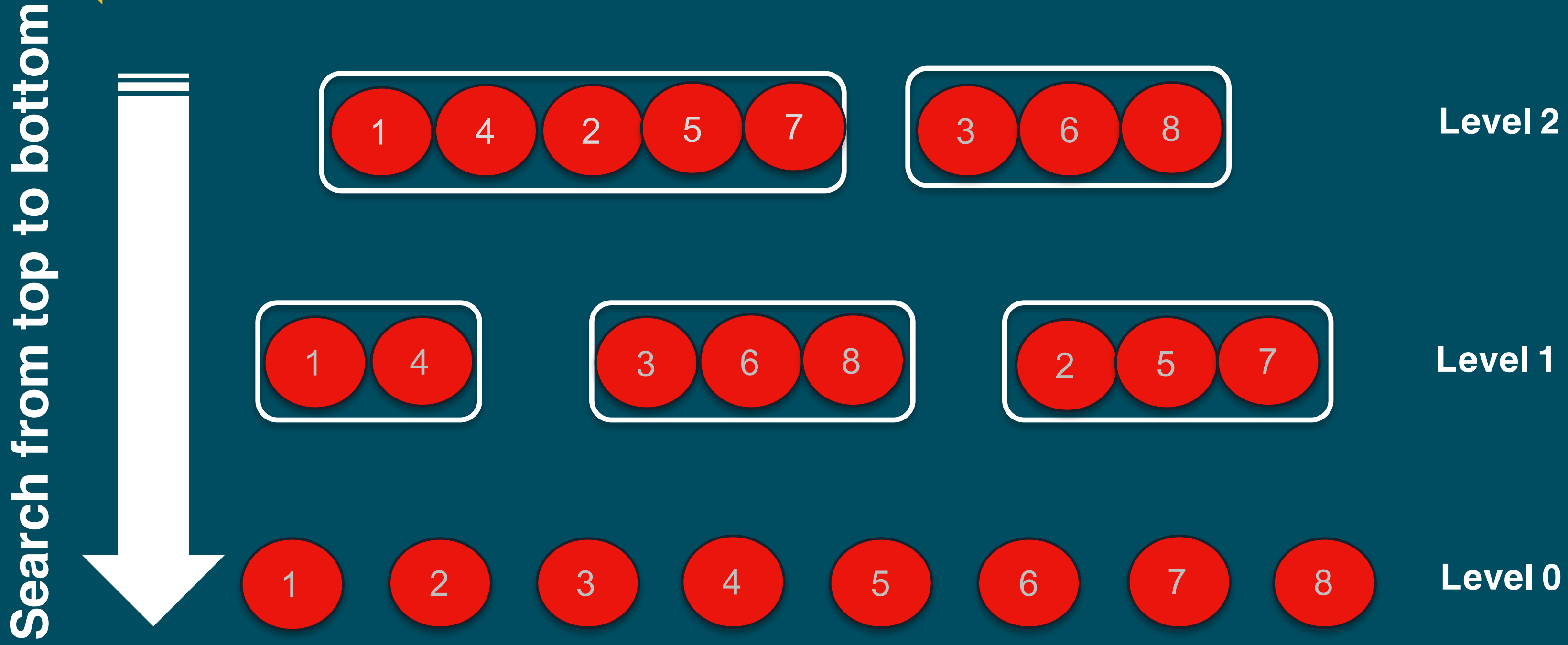
Exercise 2: Run Precimonious on funarc program

- Open exercise-2/funarc.c to see annotated program
- Execute :
  - cd ../exercise-2
  - make clean
  - make
  - ./run-analysis.sh funarc
  - ./run-config.sh funarc
- Open results/dd2_valid_funarc.bc.json to see configuration in JSON format
- Open results/dd2_diff_funarc.bc.json to see difference between original program and proposed configuration

Limitations of Precimonious

- Type configurations rely on inputs tested
  - No guarantees if worse conditioned input
  - Could be combined with input generation tools (e.g., S3FP)
- Getting trapped in local minimum
- Analysis scalability
  - Approach does not scale well for long-running applications
  - Need to reduce search space and reduce number of runs
  - Check out our follow up work on Blame Analysis (ICSE'16)
- Analysis effectiveness
  - Approach does not exploit relationship among variables
  - Check out our follow up work on HiFPTuner (ISSTA'18)

HiFPTuner: exploiting the community structure of the variables in precision tuning



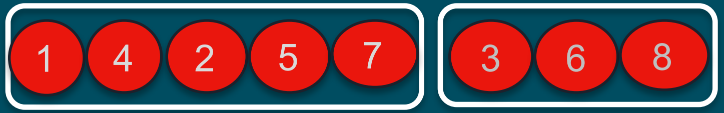
Search from top to bottom

Level 2

Level 1

Level 0

Search Faster and Reach Better Configurations



Same type for variables in one community

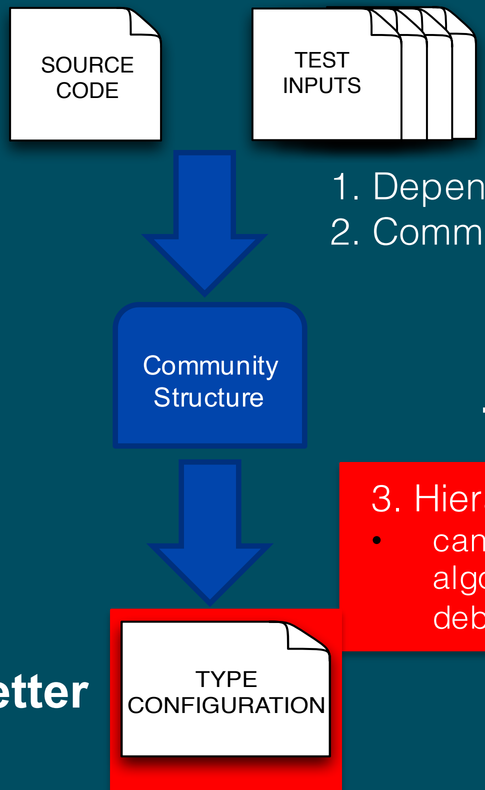
- Decreased search space - only exploring the configurations which satisfy the community structure of the variables
- Better configurations for speed-up - dependent variables are assigned with the same type which avoids type casts

One type per variable

- Exponential number of type configurations with regard to the number of variables – large search space
- Trapped in local optimum introducing many type casts

HiFPTuner

Hierarchical Floating-Point Precision Tuning



SOURCE CODE

TEST INPUTS

1. Dependence analysis
2. Community detection

Community Structure

faster

3. Hierarchical Search
   - can be combined with any base search algorithm such as binary search or delta-debugging algorithm

better

TYPE CONFIGURATION

Source : https://github.com/ucd-plse/HiFPTuner

Exercise

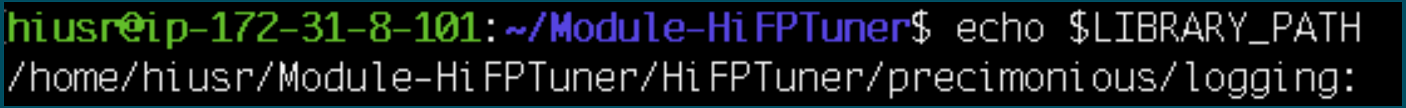
```
$ cd Module-HiFPTuner
```

Build HiFPTuner

```
$ source ./setup.sh
```

Check the environment variable

```
$ echo $LIBRARY_PATH
```



```
hiusr@ip-172-31-8-101:~/Module-HiFPTuner$ echo $LIBRARY_PATH
/home/hiusr/Module-HiFPTuner/HiFPTuner/precimonious/logging:
```

Step 1: Annotate Program and Compile it to *bitcode* File

```
$ cd exercise
$ ls
```

Source: *simpsons.c* (annotated with accuracy logging/checking functions and timing code shown before)

Compile *simpsons.c* to LLVM *bitcode* file

```
$ make clean; make
```

It generates *simpson.bc* and the executable *original_simpsons.out*

Note: *original_simpsons.out* will be used later for performance comparison

Step 2: Run HiFPTuner

Run HiFPTuner on *simpsons.bc*

```
$ ./run-hifptuner.sh simpsons
```

Output files:

./results-hifptuner

result file

- dd2_valid_simpsons.bc.json : the precision configuration file

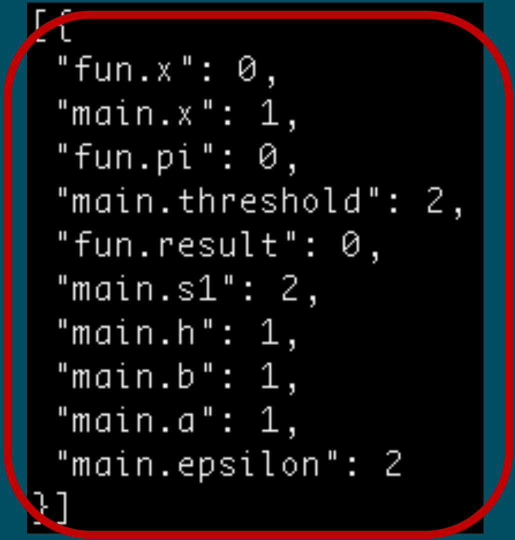
log files

- log.txt, log.dd : search log of HiFPTuner
- sorted_partition.json : the community structure of floating-point variables
- auto-tuning_analyze_time.txt : dependence analysis time
- auto-tuning_config_time.txt : community detecton time

Step 2: Run HiFPTuner – community detection

Input : *varDepPairs_pro.json, edgeProfilingOut.json*

Output : *sorted_partition.json*



```
[{
 "fun.x": 0,
 "main.x": 1,
 "fun.pi": 0,
 "main.threshold": 2,
 "fun.result": 0,
 "main.s1": 2,
 "main.h": 1,
 "main.b": 1,
 "main.a": 1,
 "main.epsilon": 2
}]
```

Hierarchy height : 1

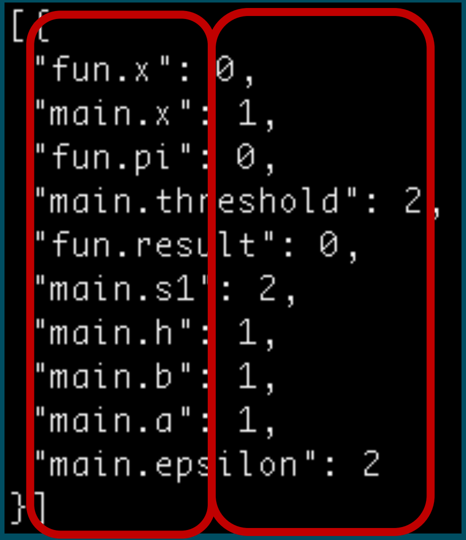
Step 2: Run HiFPTuner – community detection

Input : *varDepPairs_pro.json, edgeProfilingOut.json*

Output : *sorted_partition.json*

Hierarchy height : 1

Floating-point variable



```
[{
 "fun.x": 0,
 "main.x": 1,
 "fun.pi": 0,
 "main.threshold": 2,
 "fun.result": 0,
 "main.s1": 2,
 "main.h": 1,
 "main.b": 1,
 "main.a": 1,
 "main.epsilon": 2
}]
```

Community number

(sorted in the topological order of dependence)

Step 2: Run HiFPTuner – hierarchical search

Input : *simpsons.bc,*
search_simpsons.json, config_simpsons.json,
sorted_partition.json
Output : *dd2_valid_simpsons.bc.json*

Step 3: Tuned Program VS Original Program

Generate tuned executable *hifptuner_tuned_simpsons.out*

```
$ cd ..
$ ./run-config.sh simpsons
```

Time the execution of the original program and the tuned program and compare the execution time

```
$ time ./original_simpsons.out
$ time ./hifptuner_tuned_simpsons.out
```

0m1.710s VS 0m0.951s

Step 4: HiFPTuner VS Precimonious

- Tuned program: which is faster?
- Search time: which explored less configurations?

Step 4: HiFPTuner VS Precimonious : tuned program

Time the execution of the tuned programs of Precimonious and HiFPTuner, and compare the execution time

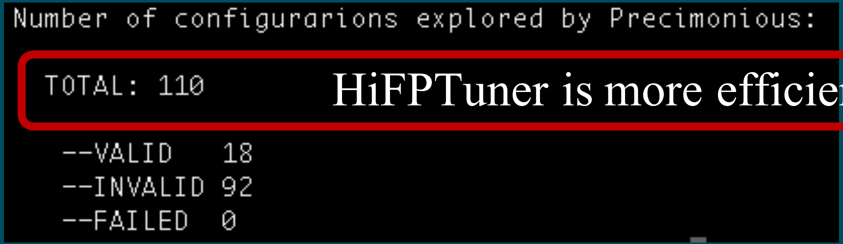
```
$ time ../../Module-Precimonious/exercise/tuned_simpsons.out
$ time ./hifptuner_tuned_simpsons.out
```

0m1.191s VS 0m0.951s: HiFPTuner found better configuration.

Step 4: HiFPTuner VS Precimonious : search time

Compare the search effort of Precimonious and HiFPTuner:

```
$ cat ../../Module-Precimonious/exercise/results/log.txt
```

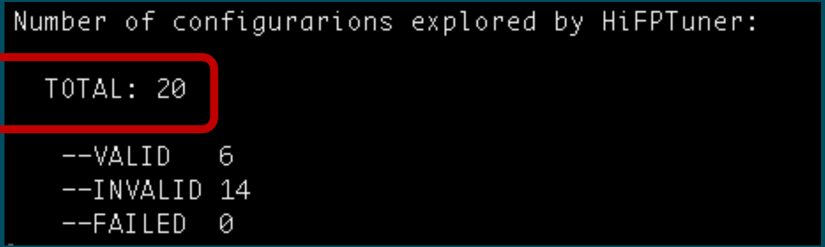


```
Number of configurarions explored by Precimonious:

 TOTAL: 110

   --VALID   18
   --INVALID 92
   --FAILED  0
```

```
$ cat results-hifptuner/log.txt
```



```
Number of configurarions explored by HiFPTuner:

 TOTAL: 20

   --VALID   6
   --INVALID 14
   --FAILED  0
```

HiFPTuner is more efficient.

VALID configuration : accuracy check ✔
INVALID configuration : accuracy check X
FAILED configuration : it crashes

Exercise 2: Run HiFPTuner on funarc program

- Open exercise-2/funarc.c to see annotated program
- Execute :
  - cd ../exercise-2
  - make clean
  - make
  - ./run-hifptuner.sh funarc
  - ./run-config.sh funarc
- Open results-hifptuner/dd2_valid_funarc.bc.json to see configuration in JSON format
- Open results-hifptuner/dd2_diff_funarc.bc.json to see difference between original program and proposed configuration

Run Precimonious or HiFPTuner on Your Program

- Annotate your program with our utility functions

Accuracy log and check

- cov_spec_log: log the accurate result yielded by original precision to file “spec.cov”
- cov_log: log the result of the program in each execution to file “log.cov”
- cov_check: check whether the result in current execution satisfies the accuracy criterion

Performance log

- log the execution time of the code of interest to the file: “score.cov”

- Compile your program to LLVM *bitcode*

WLLVM, https://github.com/travitch/whole-program-llvm - for large projects

- Download the precision tuning docker image

“$ docker pull ucdavisplse/precision-tuning”, https://github.com/ucd-plse/tutorial-precision-tuning

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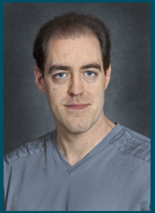
Wim Lavrijsen

Oracle

David Hough

Precimonious:
https://github.com/ucd-plse/precimonious

HiFPTuner:
https://github.com/ucd-plse/HiFPTuner

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Questions?