A Look at Gforth Performance

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New performance features since Gforth 0.5.0 (2000)

- primitive-centric direct threaded code (EuroForth 2001)
- dynamic superinstructions with replication (PLDI 2003)
- static superinstructions (EuroForth 2003)
- multi-state static stack caching (IVME 2004, EuroForth 2005)
- automatic build tuning (explicit register allocation)
- workarounds for GCC performance bugs
- branch target alignment
- ...

What is the big picture?
How well do the performance features work relative to others?
How well does it work across machines and GCC versions?

Portability space

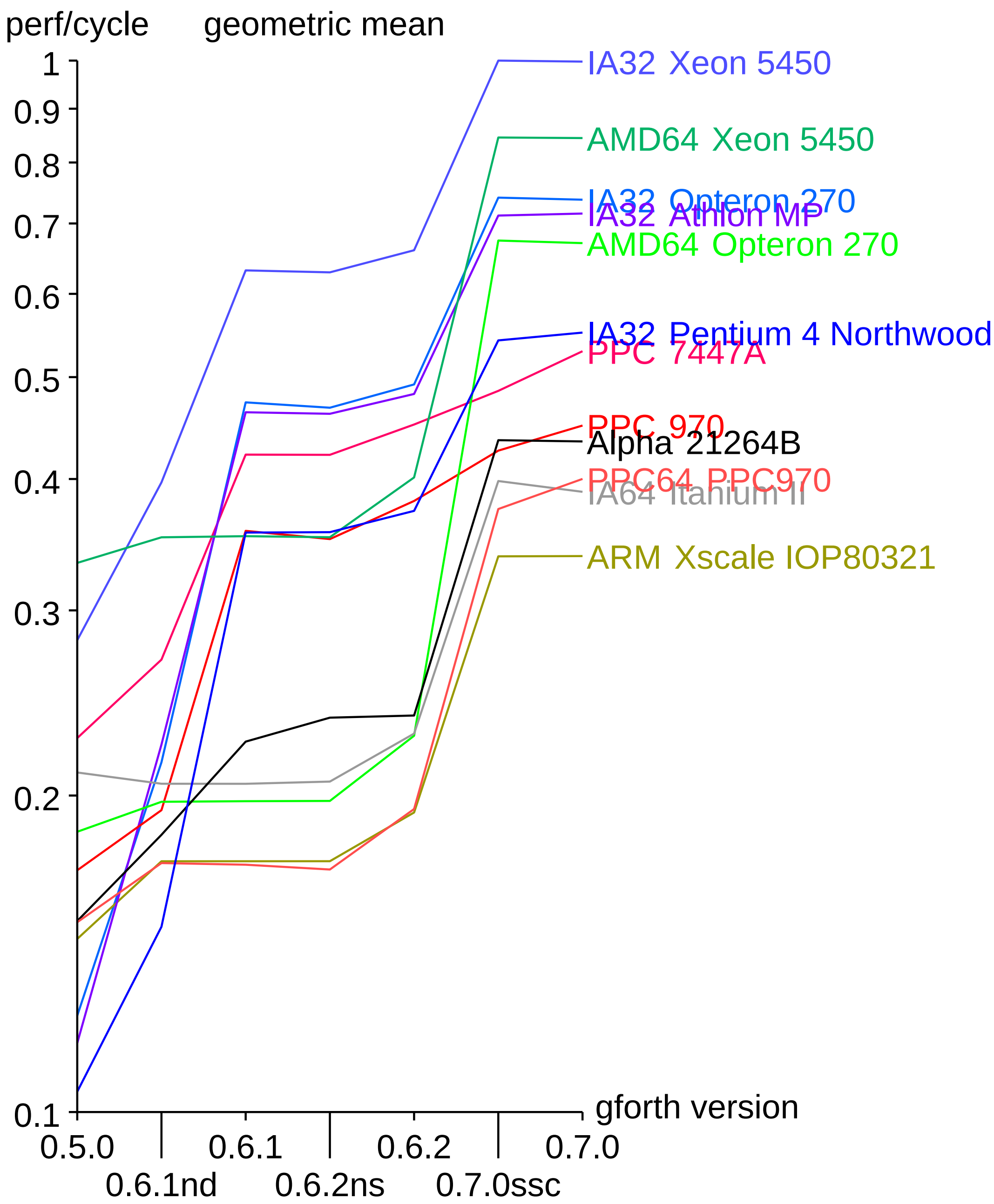
- 7 architectures, 12 architecture/CPU combinations
- up to 9 GCC versions per architecture

How well do the performance features do in all variations?

Measurements

- 4 Gforth versions, 7 with options
- 5 *application* benchmarks (geometric mean reported)
- 3 runs (median reported)
- logarithmic graphs

Overall performance

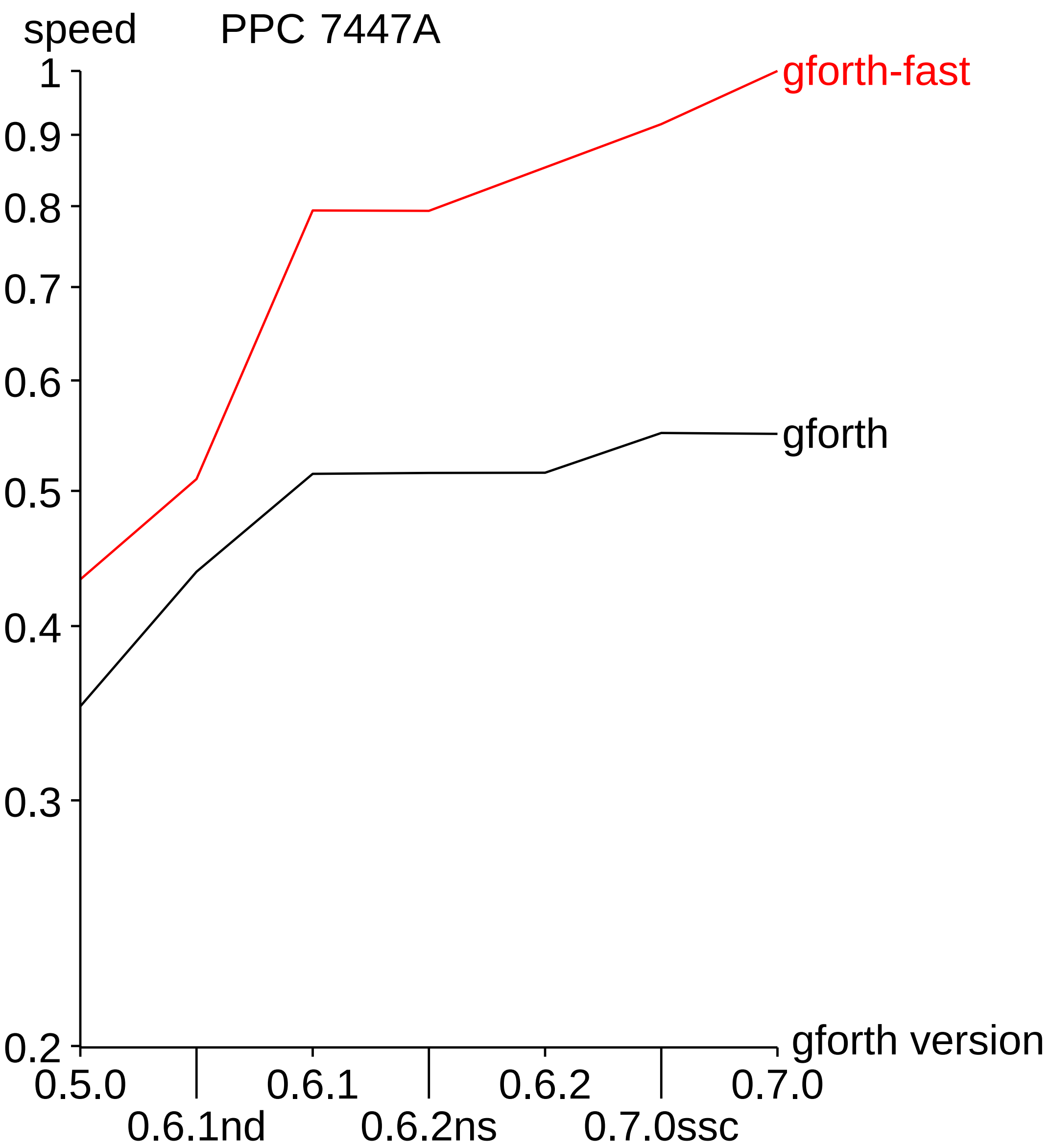


- Typical speedup factor: 3
- Biggest contribution:
  Dynamic superinstructions
  in 0.6.2 for Alpha IA32 PPC
  in 0.7.0 for others
- Automatic tuning (0.7.0)
  helps IA32
- Multi-state stack caching vs.
  static superinstructions
- Branch target alignment
  helps Alpha (0.7.0)
- best performance per cycle:
  IA32, AMD64
  Reason: indirect branch
  predictors

Dynamic Superinstructions

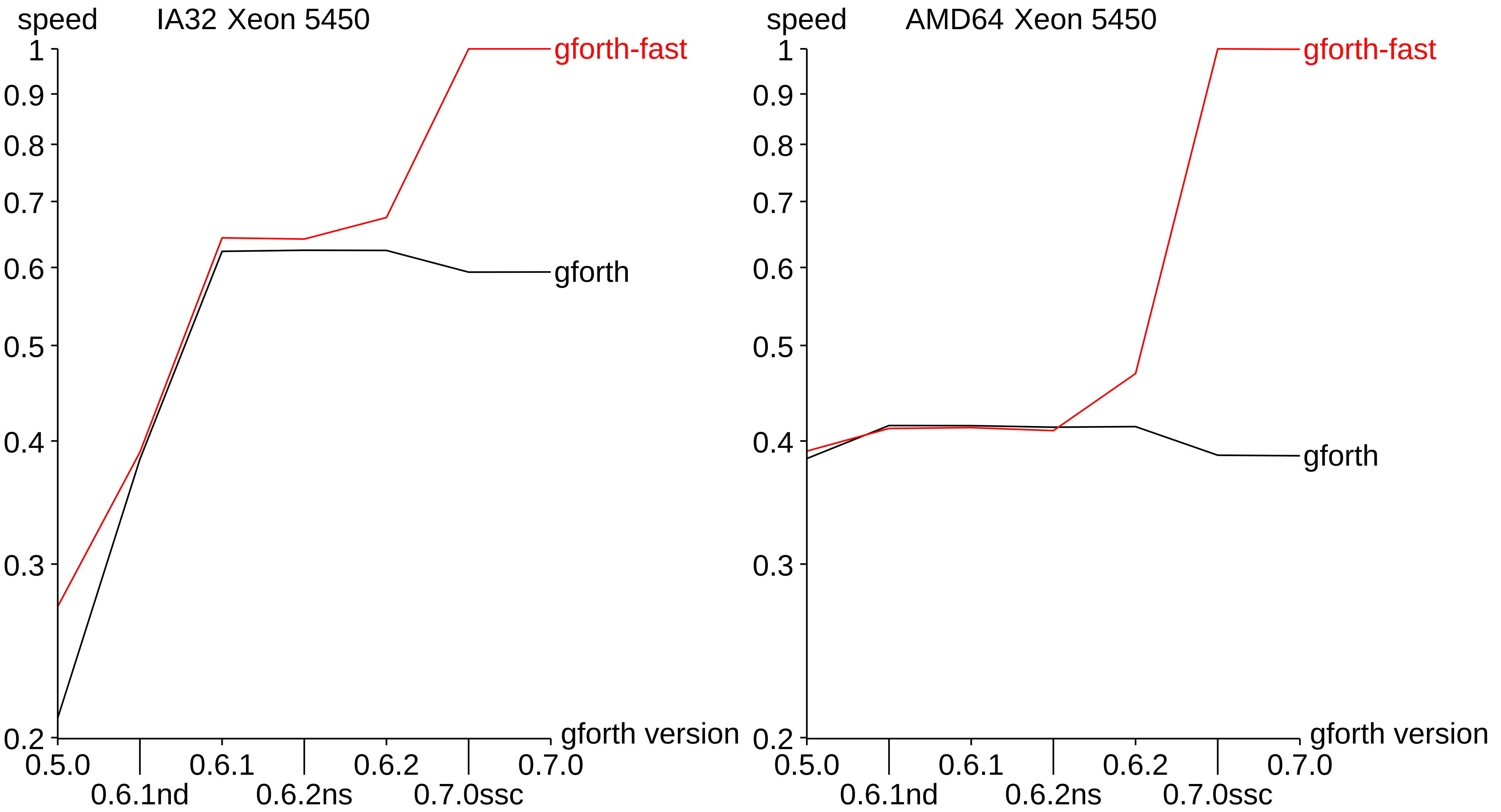
Forth	Threaded code	Native code
		mov [esi], ecx
	lit	mov ecx, [ebx]
: foo 5 ;	5	add ebx, #4
	;s	add esi, #-4
		add ebx, #4
		mov ebx, [edi]
		add edi, #4
		add ebx, #4
		jmp -4[ebx]

Engines



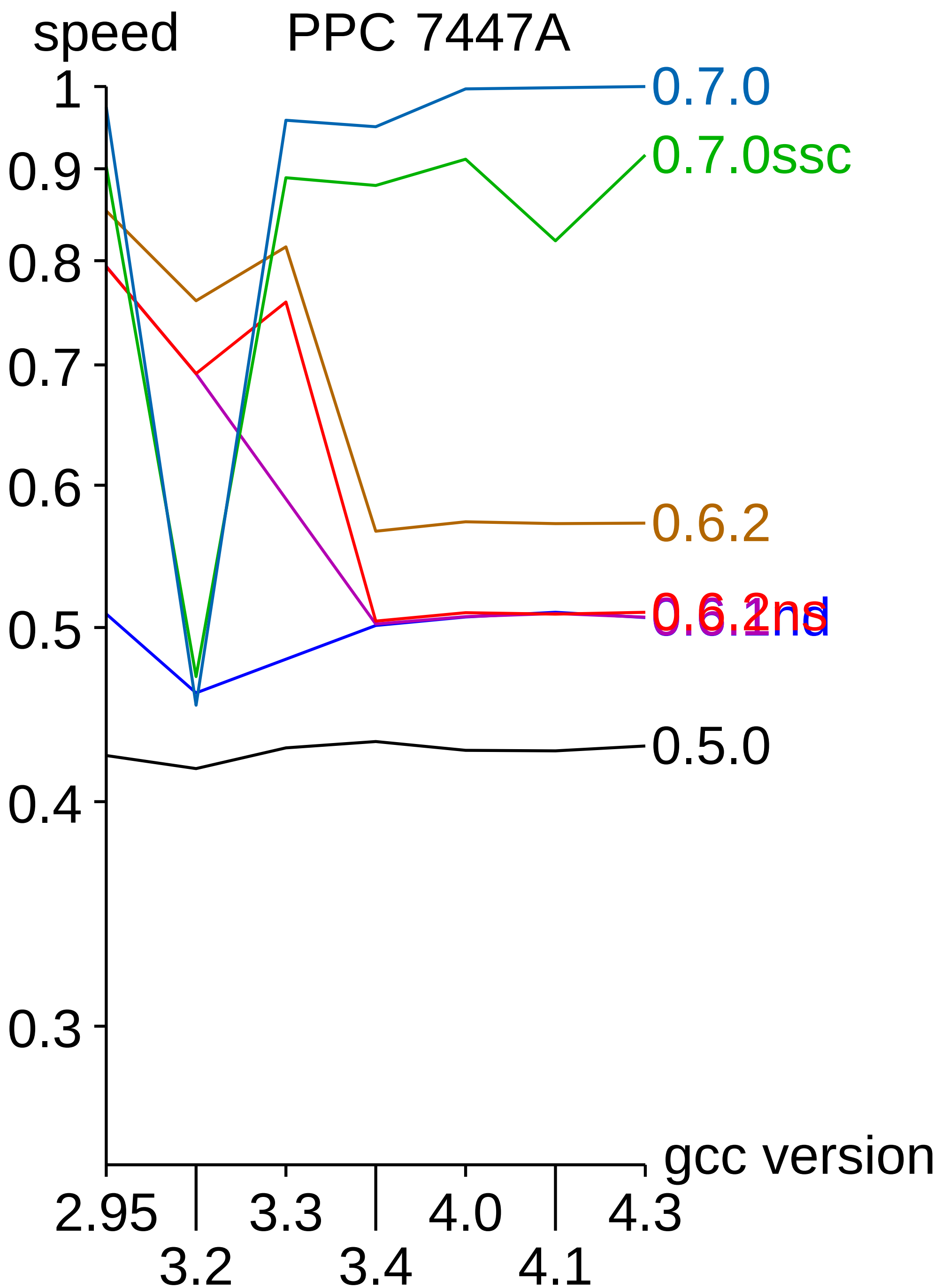
- Benchmarking: gforth-fast
- Debugging: gforth
  Error detection and reporting
- Typical difference: factor 2
- Debugging engine:
  dynamic superinstructions
  no static superinstructions
  no multi-state stack caching
  no automatic tuning

Engines (2)



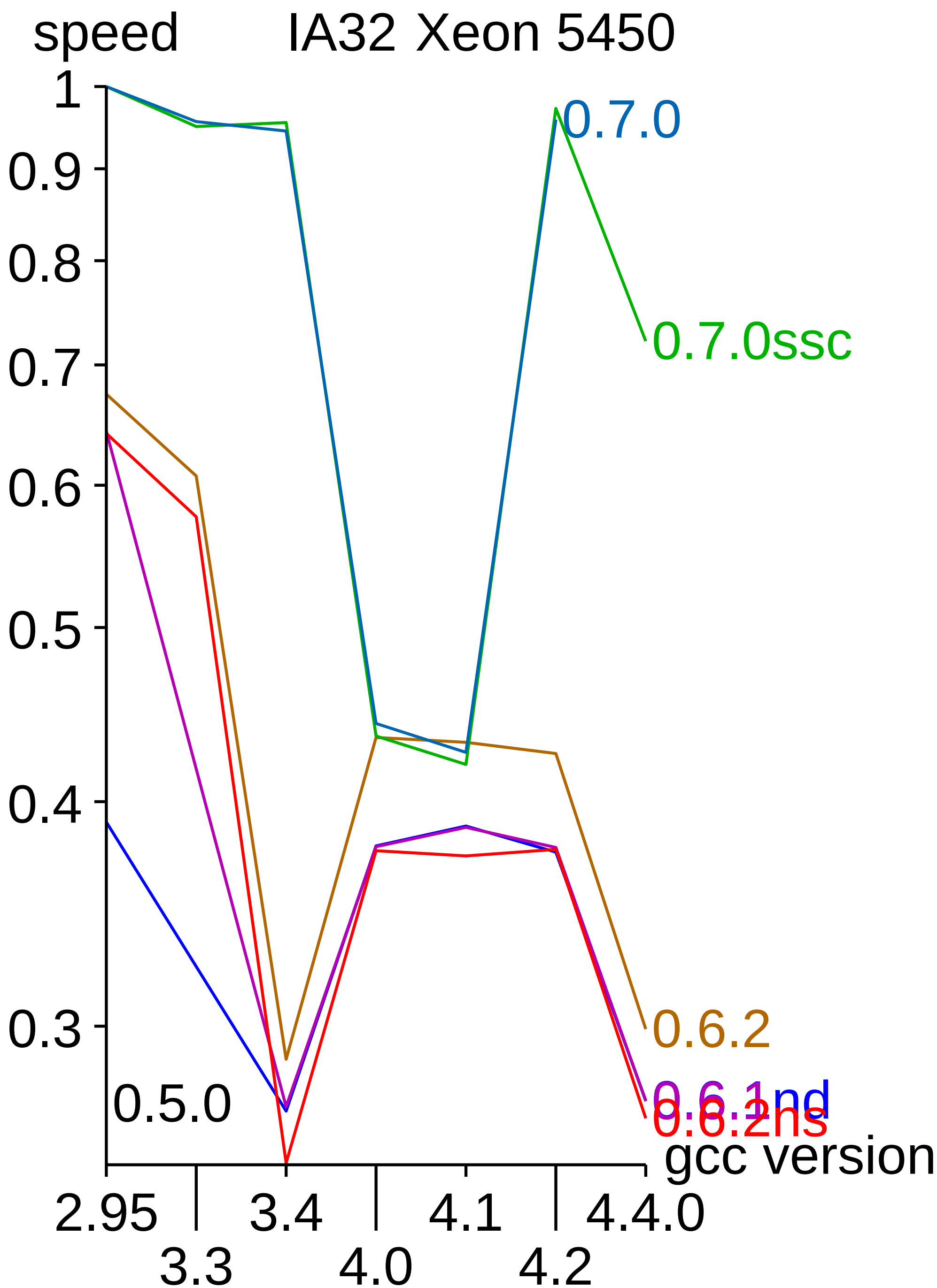
speed
IA32 Xeon 5450
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
gforth-fast
gforth
gforth version
0.5.0
0.6.1nd
0.6.1
0.6.2ns
0.6.2
0.7.0ssc
0.7.0
speed
AMD64 Xeon 5450
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
gforth-fast
gforth
gforth version
0.5.0
0.6.1nd
0.6.1
0.6.2ns
0.6.2
0.7.0ssc
0.7.0

GCC versions (1)



- Gcc $\geq$ 3.4 disables dynamic superinstructions in gforth 0.6.x
- Gforth 0.7.0 works around that
- gcc-2.95 works well

GCC versions (2)



- PR15242 lowers branch prediction accuracy (gcc-3.4, gcc-4.4.0)
- Gforth 0.7.0 works around that
- Gforth 0.7.0 affected by
  bad register allocation (4.1, 4.2)
  NEXT expansion (4.4.0)
- gcc-2.95 works well

GCC performance bug: PR15242

```
Code 1+
( $804B6D8 ) add ebx, #4
( $804B6DB ) inc ebp
( $804B6DC ) mov esi, -4[ebx]
( $804B6DF ) mov eax, esi
( $804B6E1 ) jmp 804AE8C
...
( $804AE8C ) jmp eax
```

instead of

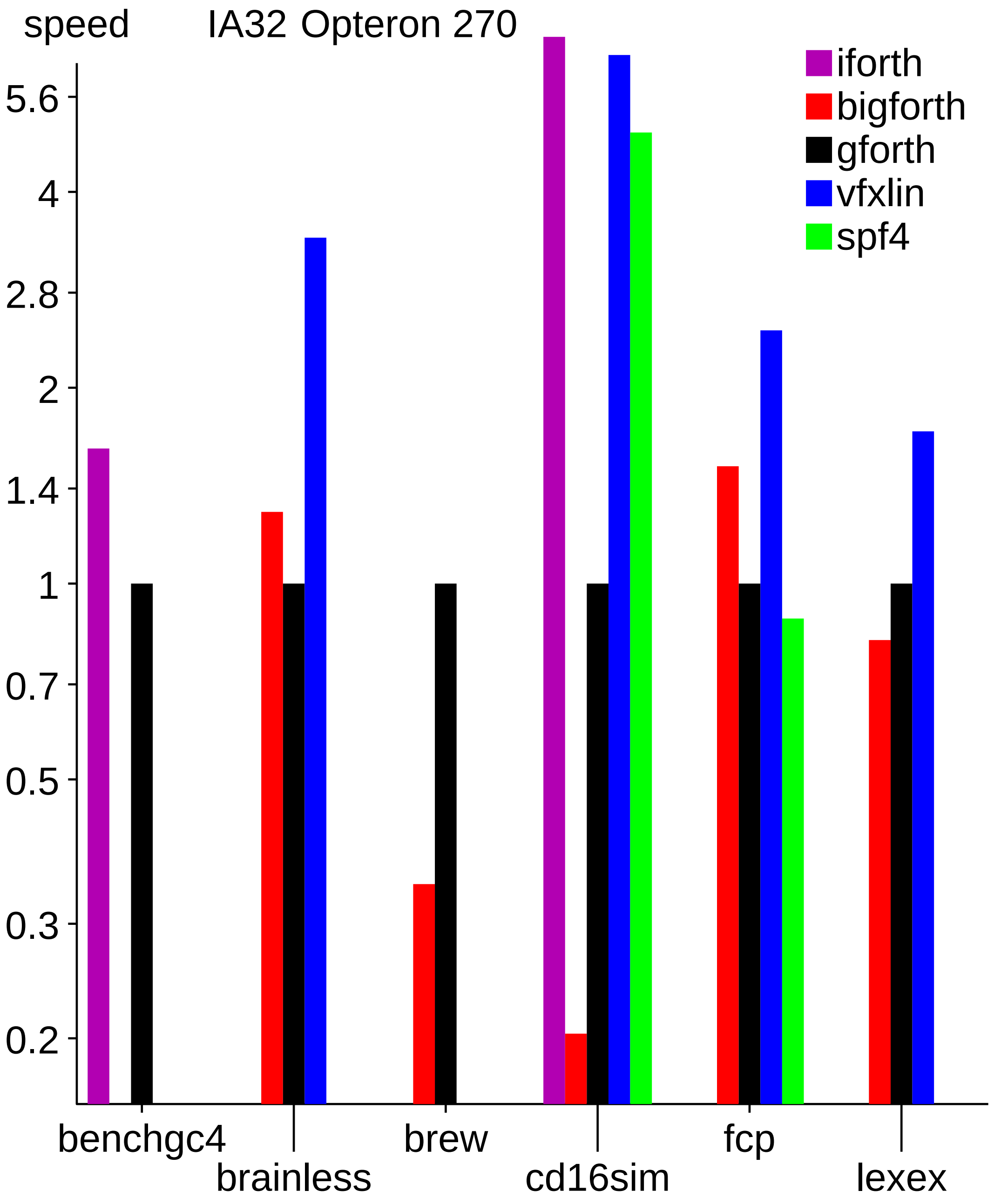
```
Code 1+
( $804B6D8 ) add ebx, #4
( $804B6DB ) inc ebp
( $804B6DC ) jmp -4[ebx]
```

GCC performance bug: NEXT expansion

```
before_goto:
  goto *real_ca;
```

is compiled to:	instead of:
`mov edx, 58 [esp]`	`jmp esi`
`mov eax, esi`	
`mov 68 [esp], edx`	
`mov 6C [esp], edx`	
`mov 70 [esp], edx`	
`mov 74 [esp], edx`	
`jmp eax`	

Other Forth systems



Conclusion

- Typical speedup factor: 3
- Most important optimization: dynamic superinstructions
  New gcc versions often disable it $\Rightarrow$ workarounds
- Important on IA32: Explicit register allocation
  Automatic enabling and testing to get it into Linux distributions
- Other optimizations have small or architecture-specific effect
  But their combination is still significant
- Gforth is very portable
  0.5.0 runs on architectures that were not available on release
- Future work
  Inlining
  Compilation through C (independence from GCC)
  Native code generation