Beating C in Scientific Computing Applications

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Introduction

Myths and legends...

- **Facts:**
  - "LISP is slow" ... **NOT !** (it's been 20 years)
  - Image processing libraries written in C or C++ (sacrificing expressiveness for performance)
  - LISP achieving 60% speed of C (recent studies)
- $\Rightarrow$ **We have to do better:**
  - Studying behavior and performance of LISP (part 1: full dedication)
  - 4 simple image processing algorithms
  - Pixel storage and access / arithmetic operations
- $\Rightarrow$ **Equivalent performance**
  (LISP 10% better in some cases)

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Experimental conditions

- **The algorithms:** the “point-wise” class
  - Pixel assignment / addition / multiplication / division
  - Soft parameters: image size / type / storage / access
  - Hard parameters: compilers / optimization level
  - $\Rightarrow$ More than 1000 individual test cases
- **The protocol**
  - Debian GNU Linux / 2.4.27-2-686 packaged kernel
  - Pentium 4 / 3GHz / 1GB RAM / 1MB level 2 cache
  - Single user mode / SMP off (no hyperthreading)
  - Measures on 200 consecutive iterations

C code sample

The `add` function

```c
void add (image *to, image *from, float val)
{
  int i;
  const int n = ima->n;

  for (i = 0; i < n; ++i)
    to->data[i] = from->data[i] + val;
}
```

- *Gcc* 4.0.3 (Debian package)
- Full optimization: `-O3 -DNDEBUG` plus inlining
- *Note:* inlining should be almost negligible

Results

In terms of behavior

- **1D implementation *slightly* better** (10% ⇒ 20%)
- **Linear access faster** (15 ⇒ 35 times)
  - Arithmetic overhead: only 4x – 6x
  - Main cause: hardware cache optimization
- **Optimized code** faster (60%) in linear case, irrelevant in pseudo-random access
  - Causes currently unknown
- **Inlining negligible** (2%)

Results

In terms of performance

Fully optimized inlined C code

Algorithm	Integer Image	Float Image
Assignment	0.29	0.29
Addition	0.48	0.47
Multiplication	0.48	0.46
Division	0.58	1.93

- Not much difference between pixel types
- **Surprise:** integer division should be costly
  - "Constant Integer Optimization" (with inlining)
  - **Do not neglect inlining !**

LISP code sample

The add function

```
(defun add (to from val)
  (declare (type (simple-array single-float (*)) to from))
  (declare (type single-float val))
  (let ((size (array-dimension to 0)))
    (dotimes (i size)
      (setf (aref to i) (+ (aref from i) val)))))
```

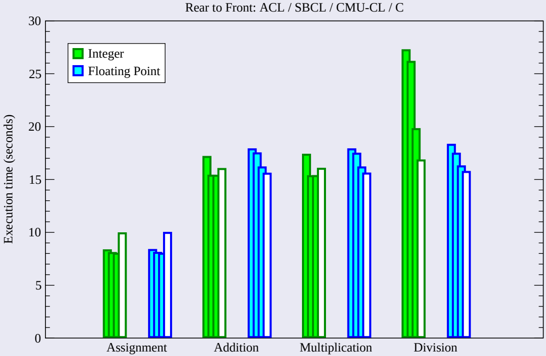
- CMU-CL (19c), SBCL (0.9.9), ACL (7.0)
- Full optimization: `(speed 3)`, 0 elsewhere
- Array type: 1D, 2D
- Array access: `aref`, `row-major-aref`, `svref`

Comparative results

In terms of behavior

- $\neq$ **Plain 2D implementation *much* slower** (2.8x $\Rightarrow$ 4.5x)
- $=$ **Linear access faster** (30 times)
  - Same reasons, same behavior…
- $=$ **Optimized code** faster in linear case, irrelevant in pseudo-random access
  - $\neq$ Gain more important in LISP (3x $\Rightarrow$ 5x)
  - $\neq$ Gain more important on floating point numbers
  - $\Rightarrow$ In LISP, *safety* is costly
- $=$ **Inlining negligible**
  - $\neq$ No “Constant Integer Optimization”
  - $\neq$ Negative impact on performance (-15%), if any
  - $\Rightarrow$ Inlining still a “hot” topic (register allocation policies ?)

Pseudo-random access

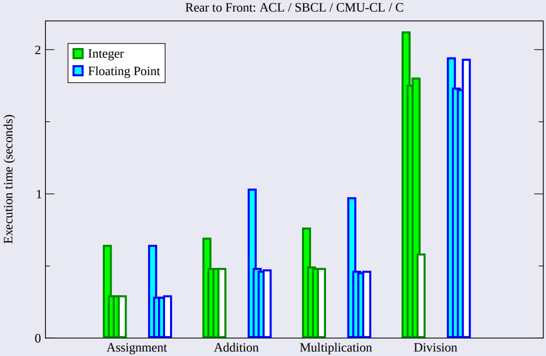


- Assignment: LISP 19% faster than C
- Other: insignificant (5%)
- Exception: integer division

Comparative results

In terms of performance

Linear access



- ACL: poor performance
- CMU-CL, SBCL: strictly equivalent to C
- C wins on integer division, loses on floating-point one

Type inference

A weakness of COMMON-LISP …

- **Static typing cumbersome** (source code annotations)
  - Can we provide *minimal* type declarations …
  - …and rely on type inference ?
- **Incremental typing** by compilation log examination
- **Unfortunately:**
  - Compiler messages not necessarily ergonomic
  - Type inference systems not necessarily clever

Example of (missing) type inference

`multiply` excerpt

```
;; ...
(declare (type (simple-array fixnum (*)) to from))
(declare (type fixnum val))
;; ...
(setf (aref to i) (the fixnum (* (aref from i) val))))))
```

- `(* fixnum fixnum)` ≠ `fixnum` in general, but…
  - `to` declared as an array of `fixnum`'s,
  - so the multiplication **has** to return a fixnum
- CMU-CL and SBCL ok, ACL not ok.
  - Need for further explicit type information
  - *worse* in ACL: `declared-fixnums-remain-fixnums-switch`

Conclusion

- **In terms of behavior**
  - External parameters: no surprise
  - Internal parameters: differences, attenuated by optimization
- **In terms of performance**
  - Comparable results in both languages
  - Very smart LISP compilers (given language expressiveness)
- **However:**
  - Typing can be cumbersome
  - Difficult to provide both correct and minimal information (weakness of the COMMON-LISP standard)
  - Inlining is still an issue

Perspectives

- **Low level:** try other compilers / architectures (and compiler / architecture specific optimization settings)
- **Medium level:** try more sophisticated algorithms (neighborhoods, front-propagation)
- **High level:** try different levels of genericity (dynamic object orientation, static meta-programming)

- **Do not restrict to image processing**

Quesλions ?

Logo by Manfred Spiller