kmul user manual

Title	kmul (Constant multiplication routine generator)
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Rev. history	
v0.1.4	2020-10-17 Add a binary decomposition algorithm.
v0.1.3	2016-07-29 Add support for C99, GNU89 data types, fix support for ANSI C ones.
v0.1.2	2016-04-12 Cumulative update; flag management cleanup, cleanup scripts.
v0.1.1	2014-11-29 Added project logo in README.
v0.1.0	2014-10-16 Documentation updates and fixes.
v0.0.7	2014-06-13 Changed README to README.rst.
v0.0.6	2014-06-12 Updated contact information. Replaced COPYING.BSD by LICENSE.
v0.0.5	2013-04-28 Converted documentation to RestructuredText.
v0.0.4	2012-03-17 Split build-and-test scripts to "build" and "test".
v0.0.3	2011-12-03 Minor README updates regarding multiple releases, tutorial usage.

v0.0.2	2011-11-20 Minor README, Makefile updates.
v0.0.1	2011-06-07 Initial release.

1. Introduction

`kmul` is a generator of routines for optimized multiplication by an integer constant. In order to calculate a constant integer multiplication, it uses the public domain routines presented in the work: Preston Briggs and Tim Harvey, "Multiplication by integer constants," Technical report, Rice University, July 1994. This technical report implements Bernstein's algorithm documented in: R. Bernstein, "Multiplication by integer constants," Software - Practice and Experience, Vol. 16, No. 7, pp. 641-652, July 1986.

A simpler algorithm based on binary decomposition can also be used for comparison.

`kmul` emits either a NAC (generic assembly language) or an ANSI C/C99 implementation of the multiplication.

2. File listing

The `kmul` distribution includes the following files:

/kmul	Top-level directory
LICENSE	Description of the Modified BSD license.
Makefile	Makefile for generating the `kmul` executable.
README.html	HTML version of README.rst.
README.pdf	PDF version of README.rst.
README.rst	This file.
build.sh	Build script for `kmul`.
clean.sh	Clean the files produced from `test.sh`.
clean2.sh	Clean the files produced from `test2.sh`.
kmul.c	The source code for the application.
kmul.png	PNG image for the `kmul` project logo.
rst2docs.sh	Bash script for generating the HTML and PDF versions.
test.c	Sample test file.
test.opt.c	Expected optimized version of `test.c`.
test.sh	Perform some sample runs.
test2.sh	Another test script to perform more sample runs.

3. Installation

There exists a quite portable Makefile (`Makefile` in the current directory). Running `make` from the command prompt should compile `kmul`.

4. Prerequisites

- [mandatory for building] Standard UNIX-based tools (make)
- gcc (tested with gcc-3.4.4+ on cygwin/x86 and gcc-4.6+ on linux/x64)
- bash

5. kmul usage

The `kmul` program can be invoked with several options (see complete option listing below). The usual tasks that can be accomplished with `kmul` are:

- generate a NAC optimized software routine for the multiplication
- generate an ANSI C optimized software routine for the multiplication.

ANSI C routines are emitted only for a width of 32-bits (see option below).
`kmul` can be invoked as:

```
$ ./kmul.exe [options]
```

The complete `kmul` options listing:

-h Print this help.

-d Enable debug/diagnostic output.

-bindecomp Use binary decomposition instead of the Bernstein-Briggs algorithm.

-mul <num> Set the value of the multiplier. Default: 1.

-width <num> Set the bitwidth of all operands: multiplier, multiplicand and product. Default: 32.

-signed Construct optimized routine for signed multiplication.

-unsigned Construct optimized routine for unsigned multiplication (default).

-nac Emit software routine in the NAC general assembly language (default).

-ansic Emit software routine in ANSI C (for widths up to 32 bits).

-gnu89 Emit software routine in ANSI C with GNU extensions (for widths up to 64 bits).

-c99 Emit software routine in C99 (for widths up to 64 bits).

Here follow some simple usage examples of `kmul`.

1. Generate the ANSI C implementation of the optimized routine for `n * 11`.

```
$ ./kmul.exe -mul 11 -width 32 -unsigned -ansic
```

2. Generate the NAC implementation of the optimized routine for `n * (-7)`.

```
$ ./kmul.exe -mul -7 -width 32 -signed -ansic
```

3. Generate the ANSI C implementation of the optimized routine for `n * 23` with debugging output.

```
$ ./kmul.exe -mul 23 -width 32 -unsigned -ansic -d
```

4. Generate the C99 implementation of the optimized routine for the signed `n * 23` multiplication and for a data width of 17 bits.

```
$ ./kmul.exe -mul 23 -width 17 -signed -c99
```

6. Quick tutorial

`kmul` can be used for arithmetic optimizations in user programs. Assume the following user program (`test.c`):

```
// test.c
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char *argv[]) {
  int a, b;
  a = atoi(argv[1]);
  b = a * 23;
  printf("b = %d\n", b);
  return b;
}
```

This file is compiled and run as follows with one additional argument:

```
$ gcc -Wall -O2 -o test.exe test.c
$ ./test.exe 155
```

and the expected result is:

```
$ b = 3565
```

The user can apply `kmul` for generating a constant multiplication routine for `a*23`:

```
$ ./kmul -mul 23 -width 32 -signed -ansic
```

and the corresponding routine is produced (local variables `t5` to `t15` can be deleted by the user; the compiler will be optimize them away eventually). Then, the user should

edit a new file, let's say `test.opt.c` and include the produced routine. The resulting optimized source file should be as follows:

```
// test.opt.c
#include <stdio.h>
#include <stdlib.h>

long kmul_o_s32_p_23 (long x)
{
  long t0;
  long t1;
  long t2;
  long t3;
  long t4;
  long t5;
  long t6;
  long t7;
  long t8;
  long t9;
  long t10;
  long t11;
  long t12;
  long t13;
  long t14;
  long t15;
  long y;
  t0 = x;
  t1 = t0 << 1;
  t2 = t1 + x;
  t3 = t2 << 3;
  t4 = t3 - x;
  y = t4;
  return (y);
}

int main(int argc, char *argv[])
{
  int a, b;
  a = atoi(argv[1]);
  b = kmul_o_s32_p_23(a);
  printf("b = %d\n", b);
  return b;
}
```

This file is compiled and run as follows with one additional argument:

```
$ gcc -Wall -O2 -o test.opt.exe test.opt.c
$ ./test.opt.exe 155
```

The target platform compiler (e.g., `gcc` or `llvm`) is expected to inline the `kmul_o_s32_p_23` function at its call site.

7. Running tests

In order to build and run a series of sample tests do the following:

```
$ ./build.sh
$ ./test.sh
```

or for a more extensive set of tests:

```
$ ./test2.sh
```

To clean-up the produced files and only these use:

```
$ ./clean.sh
```

or

```
$ ./clean2.sh
```

for `test.sh` and `test2.sh`, correspondingly.