Musings with ‘Go’ - addressing the multicore issues of today and the manycore problems of tomorrow ?

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Introduction

- Moore's law ceased to provide the traditional single-threaded performance increases
  - clock-frequency wall of 2003
  - still deliver increases in transistor density
- multicore systems become the norm
- need to "go parallel" to get scalability

In a C++ world...

- parallel programming in C++ is doable:
  - C/C++ "locking + threads" (pthreads, WinThreads)
    - excellent performance
    - good generality
    - relatively low productivity
  - multi-threaded applications...
    - hard to get right
    - hard to keep right
    - hard to keep efficient and optimized across releases
  - multi-process applications...
    - à la AthenaMP/GaudiMP
    - leverage fork+COW on GNU/Linux
    - event-level based parallelism

Parallel programming in C++ is doable,
but *no panacea*

In a C++ world. . .

- in `C++03`, we have libraries to help with parallel programming
  - `boost::lambda`
  - `boost::MPL`
  - `boost::thread`
  - Threading/Array Building Blocks (TBB/ArBB)
  - Concurrent Collections (CnC)
  - `OpenMP`
  - ...

In a C++11 world. . .

- in `C++11`, we get:
  - λ functions (and a new syntax to define them)
  - `std::thread`,
  - `std::future`,
  - `std::promise`

Helps taming the beast
... at the price of sprinkling templates everywhere...
... and complicating further a not so simple language...

In a C++11 world...

yay! for C++11, but old problems are still there...

- build scalability
  - templates
  - headers system
  - still no module system (WG21 - N2073)
    - maybe in the next Technical Report ?
- code distribution
  - no CPAN like readily available infrastructure (and cross-platform) for C++
  - remember ROOT/BOOT ? (CHEP-06)

Time for a new language ?

"Successful new languages build on existing languages and where possible, support legacy software. C++ grew our of C. java grew out of C++. To the programmer, they are all one continuous family of C languages." (T. Mattson)

- notable exception (which confirms the rule): python

Can we have a language:

- as easy as python,
- as fast (or nearly as fast) as `C/C++/FORTRAN`,
- with none of the deficiencies of `C++`,
- and is multicore/manycore friendly ?

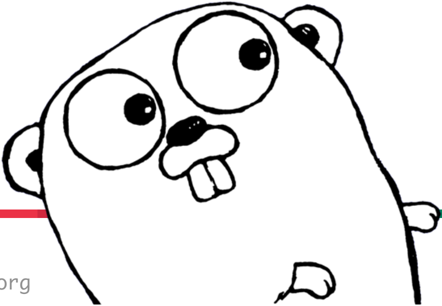
Why not `Go` ?

golang.org

Elements of go

- obligatory `hello world` example...

```go
package main
import "fmt"
func main() {
    fmt.Println("Hello, World")
}
```



http://golang.org

Elements of go - II

- founding fathers:
  - Russ Cox, Robert Griesemer, Ian Lance Taylor
  - Rob Pike, Ken Thompson
- concurrent, compiled
- garbage collected
- an open-source general programming language
- best of both 'worlds':
  - feel of a dynamic language
    - limited verbosity thanks to **type inference system**, map, slices
  - safety of a static type system
  - compiled down to machine language (so it is fast)
    - goal is within 10% of C
- object-oriented (but w/o classes), builtin reflection
- first-class functions with closures
- duck-typing à la `python`

Go concurrent

goroutines

- a function executing concurrently as other goroutines in the same address space
- starting a goroutine is done with the go keyword
  - `go myfct(arg1, arg2)`
- growable stack
  - lightweight threads
  - starts with a few kB, grows (and shrinks) as needed
    - now, also available in GCC 4.6 (thanks to the GCC-Go front-end)
  - no stack overflow

Go concurrent - II

channels

- provide (type safe) communication and synchronization

```go
// create a channel of mytype
my_chan := make(chan mytype)
my_chan <- some_data    // sending data
some_data = <- my_chan  // receiving data
```

- send and receive are atomic

"Do not communicate by sharing memory; instead, share memory by communicating"

Go concurrent - III

```
package evtproc
import "gaudi/kernel"

// --- evt state ---
type evtstate struct {
        idx  int
        sc   kernel.Error
        data kernel.DataStore
}

// --- evt processor ---
type evtproc struct {
        kernel.Service
        algs []kernel.IAlgorithm
        nworkers int
}

func (self *evtproc)
NextEvent(evtmax int) kernel.Error {

        if self.nworkers > 1 {
                return self.mp_NextEvent(evtmax)
        }
        return self.seq_NextEvent(evtmax)
}
```

Go concurrent - IV

```
import "gaudi/kernel"

func (self *evtproc) mp_NextEvent(evtmax int) kernel.Error {
        // ... setup event server ...
        in_queue, out_queue, quit := start_evt_server(self.nworkers,
        for i := 0; i < evtmax; i++ {
                in_queue <- new_evtstate(i)
        }

        for evt := range out_queue {
                if !evt.sc.IsSuccess() {
                        n_fails++
                }
                n_processed++
                if n_processed == evtmax {
                        quit <- true
                        close(out_queue)
                        break
                }
        }
        if n_fails != 0 {
                return kernel.StatusCode(1)
        }
```

Go concurrent - V

```
func (self *evtproc) mp_NextEvent(evtmax int) kernel.Error {

        start_evt_server := func(nworkers int) (in_evt_queue,
                                                 out_evt_queue chan *evtstate,
                                                quit chan bool) {
                in_evt_queue = make(chan *evtstate, nworkers)
                out_evt_queue = make(chan *evtstate)
                quit = make(chan bool)
                go serve_evts(in_evt_queue, out_evt_queue, quit)
                return in_evt_queue, out_evt_queue, quit
        }

        // ...
        return kernel.StatusCode(0)
}
```

Go concurrent - VI

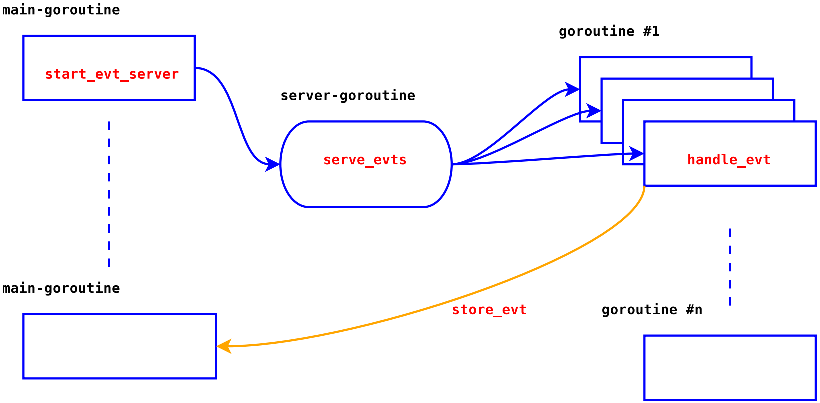
```
func (self *evtproc) mp_NextEvent(evtmax int) kernel.Error {

	handle := func(evt *evtstate, out_queue chan *evtstate) {
		self.MsgInfo("nextEvent[%v]...\n", evt.idx)
		evt.sc = self.ExecuteEvent(evt)
		out_queue <- evt
	}

	serve_evts := func(in_evt_queue, out_evt_queue chan *evtstate,
	                   quit chan bool) {
		for {
			select {
			case ievt := <-in_evt_queue:
				go handle(ievt, out_evt_queue)
			case <-quit:
				return
			}
		}
	}

	// ...
	return kernel.StatusCode(0)
}
```

Go concurrent - VII



Go concurrent with ng-go-gaudi

- very minimal implementation of Gaudi in Go:
  - appmgr
  - evtproc
  - datastoresvc
  - algorithm, messages, tools, services, properties
  - simple JSON output stream
  - simple go bytestream (gob) output stream
  - simple test algorithms (adder, counter, ...)

A simple jobo.py example

- create 500 adder algorithms, 500 dumper algorithms
- process 10000 events, spawn off 5000 concurrent workers

```
app.props.EvtMax = 10000
app.props.OutputLevel = 1

app.svcs += Svc("gaudi/kernel/evtproc:evtproc",
                "evt-proc",
                OutputLevel=Lvl.INFO,
                NbrWorkers=5000)

app.svcs += Svc("gaudi/kernel/datastore:datastoresvc", "evt-store")
app.svcs += Svc("gaudi/kernel/datastore:datastoresvc", "det-store")

for i in xrange(500):
    app.algs += Alg("gaudi/tests/pkg2:alg_adder",
                    "addr--%04i" % i,
                    SimpleCounter="my_counter")
    app.algs += Alg("gaudi/tests/pkg2:alg_dumper",
                    "dump--%04i" % i,
                    SimpleCounter="my_counter",
                    ExpectedValue=i+1)
```

Non-elements of Go

- no dynamic libraries (frown upon)
- no dynamic loading (yet)
  - but can either rely on separate processes
    - `IPC` is made easy *via* the `netchan` package
  - or rebuild executables on the fly
    - compilation of `Go` code is fast
    - even faster than `FORTRAN` and/or `C`
- no templates/generics
  - still open issue
  - looking for the proper `Go` -friendly design
- no operator overloading

Go from anywhere to everywhere

- code compilation and distribution are (*de facto*) standardized
- put your code on some repository
  - `bitbucket`, `launchpad`, `googlecode`, `github`, ...
- check out, compile and install in one go with goinstall:
  - `goinstall bitbucket.org/binet/igo`
  - no `root` access required
  - automatically handle dependencies
- `goinstall` -able packages are listed on the dashboard:
  - godashboard.appspot.com

Go and C/C++

Interfacing with C:

- done with the CGo foreign function interface
- #include the header file to the C library to be wrapped
- access the C types and functions under the artificial "C" package

```
package myclib
// #include <stdio.h>
// #include <stdlib.h>
import "C"
import "unsafe"

func foo(s string) {
  c_str := C.CString(s)  // create a C string from a Go o
  C.fputs(c_str, C.stdout)
  C.free(unsafe.Pointer(c_str))
}
```

Go and C/C++

Interfacing with C++:

- a bit more involved
- uses SWIG
  - you write the SWIG interface file for the library to be wrapped
  - SWIG will generate the C stub functions
  - which can then be called using the CGo machinery
  - the Go files doing so are automatically generated as well
- handles overloading, multiple inheritance
- allows to provide a Go implementation for a C++ abstract class

Problem

SWIG doesn't understand all of C++03

- *e.g.* can't parse TObject.h

Go and FORTRAN

Two cases:

- lucky enough to wrap "legacy" `Fortran 03` code with the `ISO C` interface:
  - just use `CGo`
- wrapping legacy `F77` code:
  - write the `C` interface code
  - use `CGo` to call this interface code
- examples:
  - http://bitbucket.org/binet/go-hepevt
  - http://bitbucket.org/binet/go-herwig

- no automatic press-button solution
  - although there is no technical blocker to write such a thing
  - this has been done for `python` (*e.g.:* `fwrap`)

Go and ROOT

- step 1 of evil plan for (HENP) world domination:
  - Go bindings to ROOT
- http://bitbucket.org/binet/go-croot
  - hand written CGo bindings to a hand written library exposing a C interface to (a subset of) ROOT
    - TFile, TTree/TChain
    - Reflex, Cint
    - TRandom
  - handles automatic conversion of Go structs into their C counter-part
  - and *vice versa*
    - two-way conversion is done by connecting the C++ introspection library (Reflex) with its Go counter-part (the reflect package)

Go and ROOT

- running the ROOT TTree example, in C++, via the C API and through go-croot over 10000000 events:

```
29.04s user  1.03s system 86% cpu 34.83 total (C++)
29.12s user  1.09s system 85% cpu 35.48 total (CRoot)
44.83s user  1.24s system 87% cpu 54.36 total (go-croot)
```

```
$ uname -a
Linux farnsworth 3.0-ARCH #1 SMP PREEMPT
x86_64 Intel(R) Core(TM)2 Duo
CPU T9400 @ 2.53GHz GenuineIntel GNU/Linux
```

additional overhead *w.r.t.* CRoot

- different calling conventions (b/w C and Go) need to be handled
- *Note:* for such loopy-code, using GCC-Go would be better

Conclusions

Can Go address the (non-) multicore problems of yesterday ?

- yes:
  - productivity (dev cycle of a scripting language)
  - build scalability (package system)
  - deployment (goinstall)
  - support for "legacy" `C/C++/Fortran` software (cgo+swig)

Can Go address the multicore issues of tomorrow ?

- yes:
  - easier to write concurrent code with the builtin abstractions (goroutines, channels)
  - easier to have efficient concurrent code (stack management)
  - still have to actually write efficient concurrent code, though...
    - work partitioning, load balancing, ...
- **but:** no such thing as a magic wand for multicores/manycores

Prospects - what's missing ?

- better support for C++ libraries
  - building on ROOT C++ dictionary infrastructure
    - now using GCC-Xml + a modified version of genreflex
    - tomorrow using LLVM/CLang
  - automatically generate the Go bindings
- bind more HEP libraries ?
- provide a Go interpreter ?
  - bitbucket.org/binet/igo

Resources

- golang.org
- root.cern.ch
- swig.org
- godashboard.appspot.com
- bitbucket.org/binet/go-hepevt
- bitbucket.org/binet/go-herwig
- bitbucket.org/binet/go-croot
- bitbucket.org/binet/ng-go-gaudi
- fwrap
- LLVM
- CLang