Go programming

Useful references:
http://golang.org/doc/
Ivo Balbaert, "The Way to Go", iUniverse, 2012
Mark Summerfield, "Programming in Go", Addison-Wesley, 2012

Background:
Robert Griesemer (don’t know him)
Rob Pike, Ken Thompson. Unix pioneers @ Bell Labs. Now at Google.

Philosophical (both stated and unstated)

* Strongly typed
  -- Avoids risks of C
  -- Lets compiler detect many program errors

* Dynamic allocation with garbage collection
  -- Avoids pitfalls of managing allocation

* Avoid redundant work
  -- Doesn’t require separate interface declarations
    * Compiler extracts interface directly from code
    * Distinction of global vs. local determined by first character of name
  -- Variable declarations (rely on type inference)

Example code:

type MyStruct struct {          # Type Declaration
    iField int                 # Note reversed ordering & lack of semicolons
    Rfield float32             # Case of field selectors matters
}                                # Go:
[Contrast to C declaration:

typedef struct {
    int iField;
    float Rfield;
} MyStruct

# Go:
# Ordering of type vs. name reversed
# Upper vs. lower case names matters
]}

ms := MyStruct{1, 3.14}         # Automatically determines that ms of type MyStruct
// Pointer to structure
p := &MyStruct{Rfield:15.0}     # Like C, & takes address of something. Can use it any
where
  # Field Rfield set to 15.0, iField set to 0

// Field selection same either way
p.iField = ms.iField            # Note mixing of pointer vs structure. Compiler figure
  # this out

// Alternative
var q *MyStruct = new(MyStruct) # New does allocation & returns pointer. Like malloc
q.Rfield = 15.0

* Handy features
   -- Minimize distinction between pointer and object pointed to
   -- Most semicolons inferred automatically
   -- Multi-assignment, multiple return values
   -- Order of type declarations reversed
   -- Simpler and more powerful loop & switch statements.
   -- Blank identifier

* Avoid limitations / weaknesses / risks of C(++)
   -- Lack of bounds checking on arrays
   -- Mutable strings
   -- Ability / need to do casting
   -- Nuances of signed vs. unsigned & other arithmetic type issues
   -- Separate boolean type.

* Powerful built-in data types
   -- Variable length arrays (slices)
   -- Dictionaries (maps)

* Cleaner concurrency
   -- Designed from outset to support multicore programming
   -- Low multithreading overhead
     + But carries limitation of non-preemptive scheduling

* Benefits of OO, while avoiding arcane & inefficient features
   -- Objects, but no type hierarchy
   -- "Generics" using dynamic type checking

* Important capabilities
   -- Slices: Variable length sequences
   -- Maps: Dictionaries
   -- Generic interfaces, rather than class hierarchy
   -- Control via switch & for + range
Let’s look at some code examples:

bufb: Implementation of FIFO buffer using linked list + tail pointer. Single-threaded operation

Operations:

NewBuf: Create new buffer
Insert: Insert element into buffer
Front: Get first element in buffer without changing buffer
Remove: Get & remove first element from buffer
Flush: Clear buffer

// Linked list element
type BufEle struct {                    # Structure definition
    val []byte                      # []byte is a slice of bytes
    next *BufEle
}

func NewBuf() *Buf {                    # Returns buffer with both pointers = nil
    return new(Buf)
}

func (bp *Buf) Insert(val []byte) {     # Declaration gives something like methods
    ele := &BufEle{val : val}       # Note allocation plus taking address. This is OK in Go
    if bp.head == nil {             # Standard implementation of list with tail pointer
        bp.head = ele
        bp.tail = ele
    } else {
        bp.tail.next = ele
        bp.tail = ele
    }
}

func (bp *Buf) Remove() ([]byte, error) {# List becoming empty
    e := bp.head
    if e == nil {
        err := errors.New("Empty Buffer")
        return nil, err
    }
    bp.head = e.next
    bp.tail = nil
    return e.val, nil
}

Shows typical style for reporting errors: functions have return value of type err. When non-nil, this indicates that something went wrong. String representing error message included.

Rest of code straightforward
Writing test code.

Write code in file "bufb_test.go" in same directory
Include test function(s) named TestXXXX
Run go test

// Convert integer to byte array
func i2b(i int) []byte {
    b, _ := json.Marshal(i)
    return b
}

// Convert byte array back to integer
func b2i(b []byte) int {
    var i int
    json.Unmarshal(b, &i)
    return i
}

func TestBuf(t *testing.T) {
    // Run same test ntest times
    for i := 0; i < ntest; i++ {
        bp := NewBuf()
        runtest(t, bp)
        if !bp.Empty() {
            t.Logf("Expected empty buffer")
            t.Fail()
        }
    }
}

func runtest(t *testing.T, bp *Buf) {
    inserted := 0
    removed := 0
    emptycount := 0
    for removed < nele { // Note for loop is like while loop
        if bp.Empty() { emptycount ++ }
        // Choose action: insert or remove
        insert := !(inserted == nele) // Cannot insert if have done all insertions
        if inserted > removed && rand.Int31n(2) == 0 { // Randomly choose whether to insert or remove
            insert = false
            // Called by test code. Must have single argument
            // Run same test ntest times
            for i := 0; i < ntest; i++ {
                bp := NewBuf()
                runtest(t, bp)
                if !bp.Empty() {
                    t.Logf("Expected empty buffer")
                    t.Fail()
                }
            }
        }
        if insert { // Called by test code. Must have single argument
            bp.Insert(i2b(inserted))
            inserted ++
        } else {
            b, err := bp.Remove()
            if err != nil {
                t.Logf("Attempt to remove from empty buffer\n")
                t.Fail()
            }
            v := b2i(b)
            if v != removed {
                t.Logf("Removed %d. Expected %d\n", v, removed)
                t.Fail()
            }
            removed ++
        }
    }
}
Weakness of this code: Requires data in byte slices. Can always use marshaling, but that seems inelegant.
Using interface types. Go’s version of templates / generics
File bufi.go
Same idea, but use dynamically-typed buffer data

Implementation: Interface data dynamically typed. Carries type information with it.

Operation x.(T) converts x to type T if possible, and fails otherwise.

// Linked list element
type BufEle struct {
    val interface{}         // interface defines required capabilities of val. None here
    next *BufEle
}

Rest of code basically the same

Now look at testing

Case 1: Feed slices of byte arrays.
func btest(t *testing.T, bp *Buf) {
    inserted := 0
    removed := 0
    emptycount := 0
    fmt.Printf("Byte array data: ")
    for removed < nele {
        if bp.Empty() ( emptycount ++ )
            // Choose action: insert or remove
            insert := !(inserted == nele)
        if inserted > removed & rand.Int31n(2) == 0 {
            insert = false
        }
        if insert {
            bp.Insert(i2b(inserted))        // Nothing special required here
            inserted ++
        } else {                                // This is interesting
            x, err := bp.Remove() // Type = interface()
            if err != nil {
                t.Logf("Attempt to remove from empty buffer\n")
                t.Fail()
            }
            // Type assertion: x is not nil & is of designated type
            b := x.([]byte) // Type = []byte        # Assign type to valu
            e.

            // Can also use form b, ok := x.([]byte)
            v := b2i(b)
            if v != removed {
                t.Logf("Removed %d. Expected %d\n", v, removed)
                t.Fail()
            }
            removed ++
        }
    }
    fmt.Printf("Empty buffer %d/%d times\n", emptycount, nele)
}

Same thing, but for integer data. Just look at conversion part

x, err := bp.Remove()       // Type = interface()
...
v := x.(int)                // Type = int
More interesting: Use random choices on type. Code must figure out type of object:

```go
# Insertion
if rand.Int31n(2) == 0 {
    // Insert as integer
    bp.Insert(inserted)
} else {
    // Insert as byte array
    bp.Insert(i2b(inserted))
}

# Removal
x, err := bp.Remove() // Type = interface{}
...
var iv int
switch v := x.(type) {
case int:
    iv = v
case []byte:
    iv = b2i(v)
default:
    t.Logf("Invalid data\n")
    t.Fail()
}
```
Another example: UDP proxy. Serves as interface between server & set of clients.

For each client, maintain "connection" identifying client and connection to server. Must come from proxy over separate port, so that server can distinguish different clients.

// Information maintained for each client/server connection
type Connection struct {
    ClientAddr *net.UDPAddr // Address of the client  # Note use of package "net"
    ServerConn *net.UDPConn // UDP connection to server
}

Simple concurrency: Have different "goroutine" for each connection, to manage flow from server to client.

Basic scheme:
* Incoming packet from client:
  See if already have connection (look up host:port in dictionary)
    No: Create one
    Send to server along connection
* Packet from server:
  Read directly by goroutine for connection. Sent over shared port back to client.
// Global state
// Connection used by clients as the proxy server
var ProxyConn *net.UDPConn

// Address of server
var ServerAddr *net.UDPAddr

# Go map is like a dictionary. Mapping from one type to another.
# Can map most "flat" types. Not structures. So, convert client host + port into string

# Reference structures allocated via "make" (not "new")
// Mapping from client addresses (as host:port) to connection
var ClientDict map[string]*Connection = make(map[string]*Connection)

# Need to protect dictionary with lock, since will have concurrent access
# We’ll see in future lesson how to use Go-style concurrency. For now,
# do something like pthread mutex.

// Mutex used to serialize access to the dictionary
var dmutex *sync.Mutex = new(sync.Mutex)

func dlock() {
    dmutex.Lock()
}

func dunlock() {
    dmutex.Unlock()
}

func setup(hostport string, port int) bool {
    // Set up Proxy
    saddr, err := net.ResolveUDPAddr("udp", fmt.Sprintf(":%d", port))
    if checkreport(1, err) { return false }
    pudp, err := net.ListenUDP("udp", saddr)        # Set up listening port
    if checkreport(1, err) { return false }
    ProxyConn = pudp
    Vlogf(2, "Proxy serving on port %d\n", port)     # My technique for printing status.

    // Get server address
    srvaddr, err := net.ResolveUDPAddr("udp", hostport)
    if checkreport(1, err) { return false }
    ServerAddr = srvaddr
    Vlogf(2, "Connected to server at %s\n", hostport)
    return true
}
Creating connection:

// Generate a new connection by opening a UDP connection to the server
func NewConnection(srvAddr, cliAddr *net.UDPAddr) *Connection {
    conn := new(Connection)
    conn.ClientAddr = cliAddr
    srvudp, err := net.DialUDP("udp", nil, srvAddr) # Note use of :=
    if checkreport(1, err) { return nil }           # Check error code
    conn.ServerConn = srvudp
    return conn
}

// Go routine which manages connection from server to single client
func RunConnection(conn *Connection) {
    var buffer [1500]byte           # Limit payload to 1500 bytes
    for {
        // Read from server
        n, err := conn.ServerConn.Read(buffer[0:])  # Pass slice of array
        if checkreport(1, err) { continue }        # Check error code
        // Relay it to client
        _ = ProxyConn.WriteToUDP(buffer[0:n], conn.ClientAddr) # Note [0:n] is very important
        if checkreport(1, err) { continue }        # Check error code
        Vlogf(3, "Relayed ‘%s’ from server to %s.
        string(buffer[0:n]), conn.ClientAddr.String())
    }
}
func RunProxy() {
    var buffer[1500]byte
    for {
        n, cliaddr, err := ProxyConn.ReadFromUDP(buffer[0:]) // ReadFrom return
        if checkreport(1, err) { continue }
        Vlogf(3, "Read '%s' from client %s\n", string(buffer[0:n]), cliaddr.String())
        saddr := cliaddr.String() // Convert address to string
        dlock()
        conn, found := ClientDict[saddr] // Access dictionary
        if !found {
            conn = NewConnection(ServerAddr, cliaddr)
            if conn == nil {
                dunlock() // Failure
                continue
            }
            ClientDict[saddr] = conn // Add entry to dictionary
            dunlock()
            Vlogf(2, "Created new connection for client %s\n", saddr)
            // Fire up routine to manage new connection
            go RunConnection(conn) // Start goroutine
        } else {
            Vlogf(5, "Found connection for client %s\n", saddr)
            dunlock()
        }
        // Relay to server
        ## Note use of Write instead of WriteToUDP. Address part of connection
        _, err = conn.ServerConn.Write(buffer[0:n])
        if checkreport(1, err) { continue }
    }
}

// Routine to handle inputs to Proxy port