Genspio: Generate Your POSIX Shell Garbage

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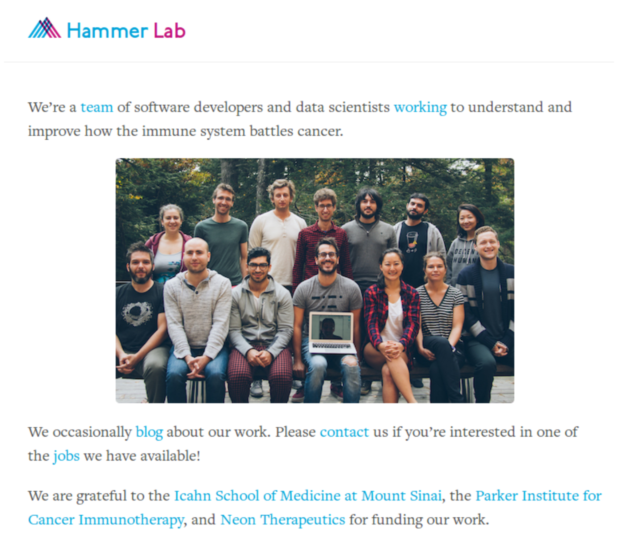
OCaml 2017 Workshop, *Sep 8, 2017*.

Context

Seb: Software Engineering / Dev Ops at the **Hammer Lab**.



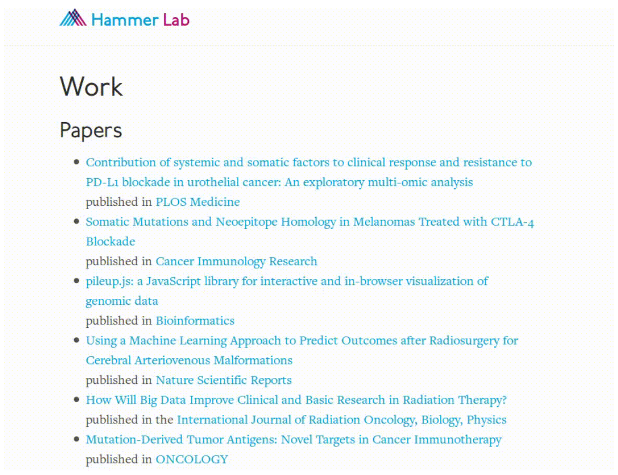
Hammer Lab

We're a team of software developers and data scientists working to understand and improve how the immune system battles cancer.

We occasionally blog about our work. Please contact us if you're interested in one of the jobs we have available!

We are grateful to the Icahn School of Medicine at Mount Sinai, the Parker Institute for Cancer Immunotherapy, and Neon Therapeutics for funding our work.

More Classical Now



Hammer Lab

Work

Papers

- Contribution of systemic and somatic factors to clinical response and resistance to PD-L1 blockade in urothelial cancer: An exploratory multi-omic analysis
  published in PLOS Medicine
- Somatic Mutations and Neoepitope Homology in Melanomas Treated with CTLA-4 Blockade
  published in Cancer Immunology Research
- pileup.js: a JavaScript library for interactive and in-browser visualization of genomic data
  published in Bioinformatics
- Using a Machine Learning Approach to Predict Outcomes after Radiosurgery for Cerebral Arteriovenous Malformations
  published in Nature Scientific Reports
- How Will Big Data Improve Clinical and Basic Research in Radiation Therapy?
  published in the International Journal of Radiation Oncology, Biology, Physics
- Mutation-Derived Tumor Antigens: Novel Targets in Cancer Immunotherapy
  published in ONCOLOGY

Computational Cancer Immunotherapy

- Run big computational pipelines.
  - Servers with WebUIs, databases.
  - HPC scheduling (Torque, YARN, Google Cloud, AWS, …).
- Deal with precious human data.
  - HDFS, (broken) disks, S3, Gcloud Buckets, NFSs.
- Interactive exploration.
  - Direct access for the users (IPython, R, `` `awk | wc` ``, …).

Infrastructure

- Need to setup local/cloud/datacenter-ish infrastructure for the lab.
- It's nobody's job.
- Nothing seems there for the "long term."

→ Make composable tools that allow people to setup/monitor/clean-up their own infrastructure.
(and it's more fun, and a better use of software people's time)

`Unix.execve`

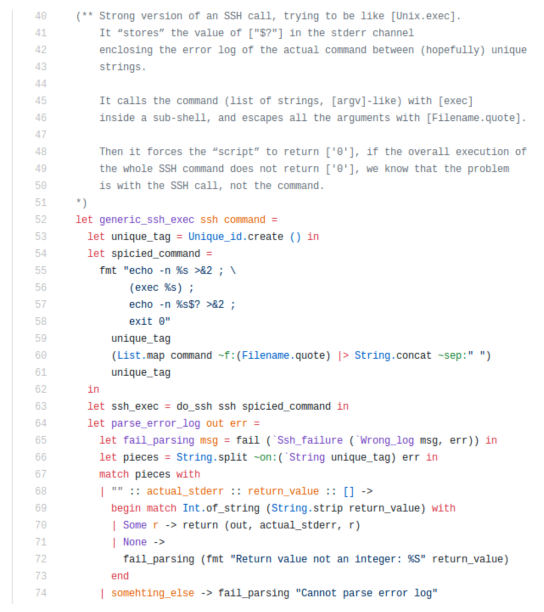
It always looks simple at first …

```
Unix.execv "/usr/bin/apt-get" [| "apt-get";"install"; "-y"; "postgresql" |]
```

```
let cmd =
  ["apt-get";"install"; "-y"; "postgresql"]
  |> List.map ~f:Filename.quote
  |> String.concat ~sep:" "
in
Unix.execv "/usr/bin/ssh" [| "ssh"; host_info ; cmd |]
```

Who failed? `ssh` or `apt-get`?

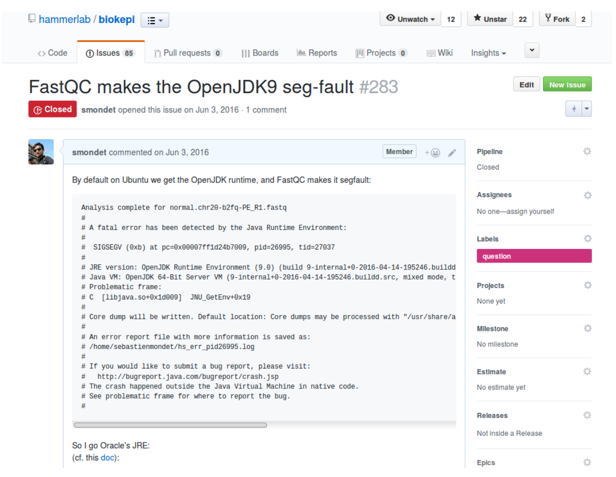
Ketrew's SSH Call


```ocaml
(** Strong version of an SSH call, trying to be like [Unix.exec].
    It “stores” the value of ["$?"] in the stderr channel
    enclosing the error log of the actual command between (hopefully) unique
    strings.

    It calls the command (list of strings, [argv]-like) with [exec]
    inside a sub-shell, and escapes all the arguments with [Filename.quote].

    Then it forces the “script” to return ['0'], if the overall execution of
    the whole SSH command does not return ['0'], we know that the problem
    is with the SSH call, not the command.
*)
let generic_ssh_exec ssh command =
  let unique_tag = Unique_id.create () in
  let spicied_command =
    fmt "echo -n %s >&2 ; \
         (exec %s) ;
         echo -n %s$? >&2 ;
         exit 0"
      unique_tag
      (List.map command ~f:(Filename.quote) |> String.concat ~sep:" ")
      unique_tag
  in
  let ssh_exec = do_ssh ssh spicied_command in
  let parse_error_log out err =
    let fail_parsing msg = fail (`Ssh_failure (`Wrong_log msg, err)) in
    let pieces = String.split ~on:(`String unique_tag) err in
    match pieces with
    | "" :: actual_stderr :: return_value :: [] ->
      begin match Int.of_string (String.strip return_value) with
      | Some r -> return (out, actual_stderr, r)
      | None ->
        fail_parsing (fmt "Return value not an integer: %S" return_value)
      end
    | somehting_else -> fail_parsing "Cannot parse error log"
```

:facepalm: after :facepalm:



FastQC makes the OpenJDK9 seg-fault #283

Closed smondet opened this issue on Jun 3, 2016 · 1 comment

smondet commented on Jun 3, 2016

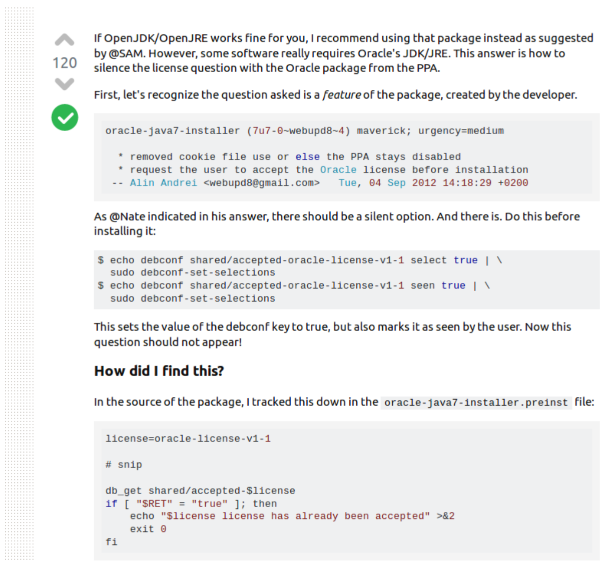
By default on Ubuntu we get the OpenJDK runtime, and FastQC makes it segfault:

```
Analysis complete for normal.chr20-b2fq-PE_R1.fastq
#
# A fatal error has been detected by the Java Runtime Environment:
#
#  SIGSEGV (0xb) at pc=0x00007ff1d24b7009, pid=26995, tid=27037
#
# JRE version: OpenJDK Runtime Environment (9.0) (build 9-internal+0-2016-04-14-195246.buildd
# Java VM: OpenJDK 64-Bit Server VM (9-internal+0-2016-04-14-195246.buildd.src, mixed mode, t
# Problematic frame:
# C  [libjava.so+0x1d009]  JNU_GetEnv+0x19
#
# Core dump will be written. Default location: Core dumps may be processed with "/usr/share/a
#
# An error report file with more information is saved as:
# /home/sebastienmondet/hs_err_pid26995.log
#
# If you would like to submit a bug report, please visit:
#   http://bugreport.java.com/bugreport/crash.jsp
# The crash happened outside the Java Virtual Machine in native code.
# See problematic frame for where to report the bug.
#
```

So I go Oracle's JRE:
(cf. this doc):

DevOps 101: Install The Oracle JDK

Everybody ends-up reading some Stack-overflow answer



If OpenJDK/OpenJRE works fine for you, I recommend using that package instead as suggested by @SAM. However, some software really requires Oracle's JDK/JRE. This answer is how to silence the license question with the Oracle package from the PPA.

First, let's recognize the question asked is a *feature* of the package, created by the developer.

```
oracle-java7-installer (7u7-0~webupd8~4) maverick; urgency=medium

  * removed cookie file use or else the PPA stays disabled
  * request the user to accept the Oracle license before installation
 -- Alin Andrei <webupd8@gmail.com>   Tue, 04 Sep 2012 14:18:29 +0200
```

As @Nate indicated in his answer, there should be a silent option. And there is. Do this before installing it:

```
$ echo debconf shared/accepted-oracle-license-v1-1 select true | \
  sudo debconf-set-selections
$ echo debconf shared/accepted-oracle-license-v1-1 seen true | \
  sudo debconf-set-selections
```

This sets the value of the debconf key to true, but also marks it as seen by the user. Now this question should not appear!

How did I find this?

In the source of the package, I tracked this down in the `oracle-java7-installer.preinst` file:

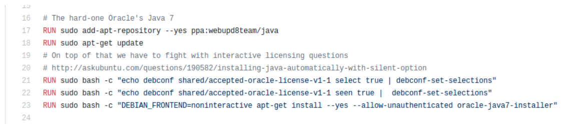
```
license=oracle-license-v1-1

# snip

db_get shared/accepted-$license
if [ "$RET" = "true" ]; then
    echo "$license license has already been accepted" >&2
    exit 0
fi
```

Bash Minus C

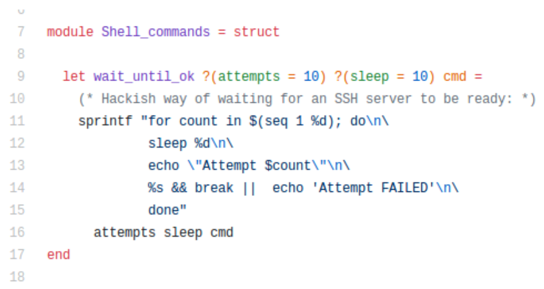
It's all strings after all:


```dockerfile
# The hard-one Oracle's Java 7
RUN sudo add-apt-repository --yes ppa:webupd8team/java
RUN sudo apt-get update
# On top of that we have to fight with interactive licensing questions
# http://askubuntu.com/questions/190582/installing-java-automatically-with-silent-option
RUN sudo bash -c "echo debconf shared/accepted-oracle-license-v1-1 select true | debconf-set-selections"
RUN sudo bash -c "echo debconf shared/accepted-oracle-license-v1-1 seen true |  debconf-set-selections"
RUN sudo bash -c "DEBIAN_FRONTEND=noninteractive apt-get install --yes --allow-unauthenticated oracle-java7-installer"

```

What Could Go Wrong?

`gcloud compute create` deprecates the already dysfunctional `--wait` option

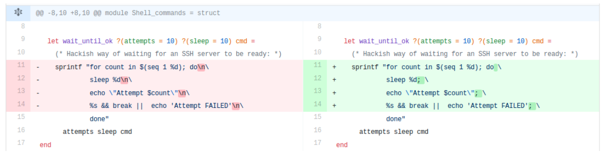

```ocaml
module Shell_commands = struct

  let wait_until_ok ?(attempts = 10) ?(sleep = 10) cmd =
    (* Hackish way of waiting for an SSH server to be ready: *)
    sprintf "for count in $(seq 1 %d); do\n\
                  sleep %d\n\
                  echo \"Attempt $count\"\n\
                  %s && break ||  echo 'Attempt FAILED'\n\
                  done"
      attempts sleep cmd
end

```

Write Once – Debug Everywhere™

`sudo` in some Debian version **erases** new lines …


```diff
@@ -8,10 +8,10 @@ module Shell_commands = struct

   let wait_until_ok ?(attempts = 10) ?(sleep = 10) cmd =
     (* Hackish way of waiting for an SSH server to be ready: *)
-    sprintf "for count in $(seq 1 %d); do\n\
-                  sleep %d\n\
-                  echo \"Attempt $count\"\n\
-                  %s && break ||  echo 'Attempt FAILED'\n\
+    sprintf "for count in $(seq 1 %d); do \
+                  sleep %d; \
+                  echo \"Attempt $count\"; \
+                  %s && break ||  echo 'Attempt FAILED'; \
                   done"
       attempts sleep cmd
 end
```

Typed/Functional Step Back

1. Start writing simple combinators.
2. Add more typing info.
3. Hit portability / representation problems.
4. Go full-blown EDSL that compiles to pure POSIX shell.

Genspio `0.0.0`

- Simple, typed EDSL
- `Language.t` is a 30+ entry GADT.
  - Boolean, Integer arithmetic + `to_string`/`of_string` + (very) basic lists.
  - `if-then-else`, loops.
  - `exec`.
  - Redirects, pipes, and captures.
  - Basic exception-like jumping.
- Compiler to POSIX shell.
  - Either one-liners, or multi-line scripts.
  - Unreadable output *by default*, but tries to do better when it statically knows.

Examples

```
let username_trimmed : string t =
  (* The usual shell-pipe operator is ||>,
     output_as_string takes stdout from a unit t as a string t. *)
 (exec ["whoami"] ||> exec ["tr"; "-d"; "\\n"]) |> output_as_string
```

Now Jump!

```
with_failwith (fun error_function ->
  let get_user = (* the contents of `$USER`: *) getenv (string "USER") in
  (* The operator `=$=` is `string t` equality, it returns a `bool t` that
     we can use with `if_seq`: *)
  if_seq
    (get_user =$= username_trimmed)
     ~t:[ (* more commands *) ]
     ~e:[
       (* `$USER` is different from `whoami`, system is broken,
          we exit using the failwith funtion: *)
       error_function
         ~message:(string "I'm dying") ~return:(int 1)
     ])
```

CLI Parsing

```
  let cli_spec =
    Command_line.Arg.(
      string
        ~doc:"The URL to the stuff" ["-u"; "--url"]
        ~default:no_value
      & flag ["-c"; "--all-in-tmp"] ~doc:"Do everything in the temp-dir"
      & string ["-f"; "--local-filename"]
        ~doc:"Override the downloaded file-name"
        ~default:no_value
      & string ["-t"; "--tmp-dir"]
        ~doc:"Use <dir> as temp-dir"
        ~default:(Genspio.EDSL.string "/tmp/genspio-downloader-tmpdir")
      & usage "Download archives and decrypt/unarchive them.\n\
               ./downloader -u URL [-c] [-f <file>] [-t <tmpdir>]"
    ) in
  Command_line.parse cli_spec
    begin fun ~anon url all_in_tmp filename_ov tmp_dir ->
```

Line-by-line

```
let on_stdin_lines ~body =
  let fresh =
    sprintf "var_%d_%s" Random.(int 10_000)
      (Genspio.Language.to_one_liner (body (string "bouh"))
       |> Digest.string |> Digest.to_hex) in
  loop_while (exec ["read"; "-r"; fresh] |> succeeds)
    ~body:(seq [
        exec ["export"; fresh];
        body (getenv (string fresh));
      ])
```

smondet/habust/.../main.ml#L29-38

Nice Call

```
(* ... *)
    exec ["ldd"; exe]
    ||> exec ["awk"; "{ if ( $2 ~ /=>/ ) { print $3 } else { print $1 } }"]
    ||> on_stdin_lines begin fun line ->
      seq [
        call [string "printf"; string "Line %s\\n"; line];
        call [string "cp"; line; string ("/tmp" // basename)];
      ]
    end
```

smondet/habust/.../main.ml#L196-203

Under The Hood: String Representation

That's when *"crazy"* really means *"insane."*

```
| Output_as_string e ->
  sprintf "\"$( { %s ; } | od -t o1 -An -v | tr -d ' \\n' )\"" (continue e)
```

Vs

```
let expand_octal s =
  sprintf
    {sh| printf -- "$(printf -- '%%s' %s | sed -e 's/\(.\{3\}\)/\\\1/g')" |sh}
    s in
```

Still Work To Do

```
let to_argument varprefix =
 let argument ?declaration ?variable_name argument =
 (* ... *)
 function
 | `String (Literal (Literal.String s)) when Literal.String.easy_to_escape s ->
   argument (Filename.quote s)
 | `String (Literal (Literal.String s)) when
     Literal.String.impossible_to_escape_for_variable s ->
   ksprintf failwith "to_shell: sorry literal %S is impossible to \
                      escape as `exec` argument" s
 | `String v ->
   let variable_name = Unique_name.variable varprefix in
   let declaration =
     sprintf "%s=$(%s; printf 'x')" variable_name (continue v |> expand_octal) in
   argument ~variable_name ~declaration
     (sprintf "\"${%s%%?}\"" variable_name)
```

Future work: 2 string types …

C-Strings Vs Byte-arrays

In the beginning there was UNIX …

```
#include <stdio.h>

int main (int argc, char *argv[])
{

  /* Insert VULN Here */
}
```

Testing, Locally

Test tries all the shells it knows about on the current host:

```
Summary:

* Test "dash" (`'dash' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 0 / 190 failures
    - time: 13.31 s.
    - version: `"Version: 0.5.8-2.1ubuntu2"`.
* Test "bash" (`'bash' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 0 / 190 failures
    - time: 23.37 s.
    - version: `"GNU bash, version 4.3.46(1)-release (x86_64-pc-linux-gnu)"`.
* Test "sh" (`'sh' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 0 / 190 failures
    - time: 13.59 s.
    - version: `""`.
* Test "busybox" (`'busybox' 'ash' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 0 / 190 failures
    - time: 8.80 s.
    - version: `"BusyBox v1.22.1 (Ubuntu 1:1.22.0-15ubuntu1) multi-call binary."`.
* Test "ksh" (`'ksh' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 20 / 190 failures
    - time: 14.78 s.
    - version: `"version         sh (AT&T Research) 93u+ 2012-08-01"`.
    - Cf. `/tmp/genspio-test-ksh-failures.txt`.
* Test "mksh" (`'mksh' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 2 / 190 failures
    - time: 25.56 s.
    - version: `"Version: 52c-2"`.
    - Cf. `/tmp/genspio-test-mksh-failures.txt`.
* Test "posh" (`'posh' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 2 / 190 failures
    - time: 24.40 s.
    - version: `"Version: 0.12.6"`.
    - Cf. `/tmp/genspio-test-posh-failures.txt`.
* Test "zsh" (`'zsh' '-x' '-c' '<command>' '--' '<arg1>' '<arg2>' '<arg-n>'`):
    - 20 / 190 failures
    - time: 17.94 s.
    - version: `"zsh 5.1.1 (x86_64-ubuntu-linux-gnu)"`.
    - Cf. `/tmp/genspio-test-zsh-failures.txt`.

All “known” shells were tested ☺


--------------------------------------------------------------------------------
```

Testing: FreeBSD/SSH

```
export add_shells="
Freebsd-gcloud, escape, <cmd>,
   printf '%s' <cmd> | ssh -i ~/.ssh/google_compute_engine $(freebsd_ip_address) 'sh -x'
"
export only_dash=true # We don't run all the other local tests this time
export single_test_timeout=50
_build/src/test/genspio-test.byte
```

We get the usual report:

```
* Test "Freebsd-gcloud" (`printf '%s' 'askjdeidjiedjjjdjekjdeijjjidejdejlksi () { <command> ; } ;  askjdeidjiedjjjdjekjdeijjjidejdejlksi '\''<arg1>'\'' '\''<arg2>'\'' '\''<arg-n>'\''' | s
    - 0 / 190 failures
    - time: 165.19 s.
    - version: `"Command-line"`.
```

Testing: OpenWRT/Qemu/SSH

```
qemu-system-arm -M realview-pbx-a9 -m 1024M \
                -kernel openwrt-realview-vmlinux.elf \
                -net nic  \
                -net user,hostfwd=tcp::10022-:22 \
                -nographic \
                -sd openwrt-realview-sdcard.img \
                -append "console=ttyAMA0 verbose debug root=/dev/mmcblk0p1"

root@OpenWrt:/# df -h
Filesystem                Size      Used Available Use% Mounted on
/dev/root                46.5M      2.9M     42.7M   6% /
tmpfs                   378.1M    612.0K    377.5M   0% /tmp
tmpfs                   512.0K         0    512.0K   0% /dev

* Test "OpenWRT-qemu-arm" (`printf '%s' 'askjdeidjiedjjjdjekjdeijjjidejdejlksi () { <command> ; } ;  askjdeidjiedjjjdjekjdeijjjidejdejlksi '\''<arg1>'\'' '\''<arg2>'\'' '\''<arg-n>'\''' |
    - 0 / 190 failures
    - time: 800.90 s.
    - version: `"Command-line"`.
```

Example of Rabbit Hole

For a given `shell`, trying:

```
$shell -c ' exec 4>&3 ; echo "Exec-returns: $?"' ; echo "Shell-returns: $?"
```

The POSIX ones:

- `shell=dash`, `shell=sh`, `shell='busbox ash'`: `Shell-returns: 2`
- `shell=ksh`, `shell=mksh`: `Shell-returns: 1`

The non-POSIX ones:

- `shell=bash`, `shell=zsh`: `Exec-returns: 1 Shell-returns: 0`

→ even bash not always POSIX.

Secotrec

Real-world example.

- Library of Hammerlab-like deployment lego-bricks.
  - Ketrew, Coclobas, NGinx auth, TLS tunnel
  - Let’s Encrypt, GCloud DNS, …
  - “Interactive exploration containers.”
  - Kubernetes/AWS-Batch clusters.
  - Take down everything, restart partially …
- With pre-assembled (but configurable) “examples” for GCloud, AWS, and “Local-docker” standard setups.

https://github.com/hammerlab/secotrec

Secotrec

- Got to “scale” Genspio:
  - Quickly hitting max length of command line argument.
  - “Standard Library” that may merge into Genspio.
  - *Integration* with `docker-compose`.
- “*GCPocalypse:*”
  - Too easy for users to setup their own infrastructure.
  - Forgetful about cleaning up.
  - → our benefactor said it’s too much
  - Fast move of all ops back to local infrastructure.

Habust

Simple “build-stuff” EDSL, compiled to a `Makefile` + scripts:

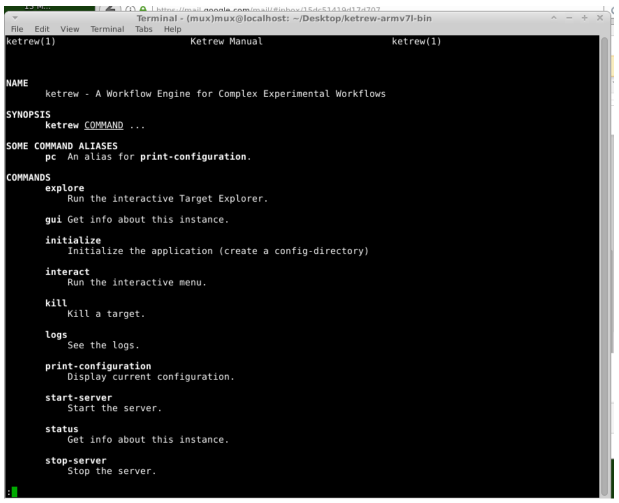
- Download Qemu images.
- Setup/start qemu VM.
- Run recipe on the VM in a mostly restartable way.
- Grab artifacts from the VM into a `.tgz` (e.g. an executable + output of `ldd`).

`#HackyExample` `#WIP` https://gitlab.com/smondet/habust

Habust Recipes

```
 "deb-arm-emacs", Build_definition.Construct.(
   within (qemu_arm debian_wheezy) [
     exec ["apt-get"; "update"];
     exec ["apt-get"; "install"; "--yes"; "emacs23"];
     get_executable "/usr/bin/emacs" ~dest:"emacs-armv7l-bin";
   ]
 );
 "deb-arm-ketrew", Build_definition.Construct.(
   (* ... *)
   within (qemu_arm debian_wheezy) [
     ensure (executables_available ["unzip"; "gcc"; "make"; "git"]) [
       (* ... *)
     ];
     ensure (md5 opam_bin (`Contains "46e25cc5b26")) [
       ["wget"; opam_arm7l_url; "-O"; opam_bin];
     ];
     (* ... *)
     ensure (returns_zero @@ opam_exec ["vidimetro"; "--version"]) [
      (* opam_exec ["opam"; "remove"; "--yes"; "ocamlfind"]; *)
      pin_github "ketrew";
      opam_exec ["opam"; "depext"; "--yes"; "ketrew"];
      opam_install ["ketrew"];
    ];
    get_executable (strf "/opam-root/%s/bin/ketrew" ocaml_version) ~dest:"ketrew-armv7l-bin";
  (* ... *)
```

Ketrew on ARM64


Terminal - (mux)mux@localhost: ~/Desktop/ketrew-armv7l-bin
File Edit View Terminal Tabs Help

```
ketrew(1)                        Ketrew Manual                       ketrew(1)



NAME
       ketrew - A Workflow Engine for Complex Experimental Workflows

SYNOPSIS
       ketrew COMMAND ...

SOME COMMAND ALIASES
       pc  An alias for print-configuration.

COMMANDS
       explore
           Run the interactive Target Explorer.

       gui Get info about this instance.

       initialize
           Initialize the application (create a config-directory)

       interact
           Run the interactive menu.

       kill
           Kill a target.

       logs
           See the logs.

       print-configuration
           Display current configuration.

       start-server
           Start the server.

       status
           Get info about this instance.

       stop-server
           Stop the server.

:
```

Silence on ARM64

Could not get the graphical apps I wanted to show:

```
#=== ERROR while installing uri.1.9.4 ================================#
# opam-version         1.2.2
# os                   linux
# command              jbuilder build -p uri -j 4
# path                 /opam-root/4.03.0/build/uri.1.9.4
# compiler             4.03.0
# [...]
### stderr ###
# [...]
# /tmp/camlasm6e1b43.s:445651: Error: offset out of range
# /tmp/camlasm6e1b43.s:445679: Error: offset out of range
# /tmp/camlasm6e1b43.s:445687: Error: offset out of range
# File "etc/uri_services_full.ml", line 1:
# Error: Assembler error, input left in file /tmp/camlasm6e1b43.s
```

`mantis#7608`, `mirage/ocaml-uri#106`, `janestreet/ppx_ast#3`

Future Work

- Byte-array Vs C-String type.
- GADT Vs TTFI discussion (cf. this afternoon): we want to call the compiler within a “script” to use its output as a literal string
- More combinators (integration of Secotrec/Habust functions).

The End

Questions?