NIX

MICHAL SKALSKI

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- package manager
- main pilar of NixOS - operating system

ORIGINS

PhD project of Eelco Dolstra

- Imposing a Memory Management Discipline on Software Deployment (2004)
- The Purely Functional Software Deployment Model (2005)

Initially intended to be alternative to `make` and package managers like `rpm`

WHAT PROBLMES IT TRIED TO SOLVE?

Classical package managers issues:

- DLL hell
- Destructive upgrades
- No rollbacks
- Not atomic
- Hard to prevent undeclared dependencies

YouTube: Eelco Dolstra - The Evolution of Nix

FILESYSTEM HIERARCHY STANDARD

```
# list of files installed on filesystem by wget pkg
$ dpkg -L wget
...
/etc/wgetrc
/usr/bin/wget
/usr/share/doc/wget/README
/usr/share/man/man1/wget.1.gz
```

```
# dynamically linked libraries
$ ldd /usr/bin/wget
libpcre2-8.so.0 => /lib/x86_64-linux-gnu/libpcre2-8.so.0
libuuid.so.1 => /lib/x86_64-linux-gnu/libuuid.so.1
libidn2.so.0 => /lib/x86_64-linux-gnu/libidn2.so.0
libssl.so.3 => /lib/x86_64-linux-gnu/libssl.so.3
libcrypto.so.3 => /lib/x86_64-linux-gnu/libcrypto.so.3
libz.so.1 => /lib/x86_64-linux-gnu/libz.so.1
libpsl.so.5 => /lib/x86_64-linux-gnu/libpsl.so.5
libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6
/lib64/ld-linux-x86-64.so.2
libunistring.so.2 => /lib/x86_64-linux-gnu/libunistring.so.2
```

FILESYSTEM AS MEMORY

Programming Language Domain	**Deployment Domain**
memory	disk
value, object	file
address	path name
pointer dereference	file access
pointer arithmetic	string operations
dangling pointer	path to absent file
object graph	dependency graph
calling constructed object with reference to other object	runtime dependency
calling constructor with reference to other object, not stored	build-time dependency
calling constructor with reference to other object, stored	retained dependency
languages without pointer discipline (e.g. assembler)	typical Unix-style deployment
languages with enough pointer discipline to support conservative garbage collection (e.g. C, C++)	Nix
languages with full pointer discipline (e.g. Java, Haskell)	as-yet unknown deployment style not enabled by contemporary operating systems

Source: The Purely Functional Software Deployment Model

ISOLATION, RELIABLE IDENTIFICATION

How to avoid address (file path) collision problem?

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How to avoid address (file path) collision problem?

- component name, version is not enough
- random address is inefficient, generates duplicates

HASH

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The hash is computed over all inputs, including the following:

- The sources of the components.
- The script that performed the build.
- Any arguments or environment variables passed to the build script.
- All build time dependencies, typically including the compiler, linker, any libraries used at build time, standard Unix tools such as cp and tar, the shell, and so on..

NIX STORE

```
$ which wget
/nix/store/d3kkv9vjb3ljh7hr5v38gls8iykvwkny-wget-1.21.4/bin/wget

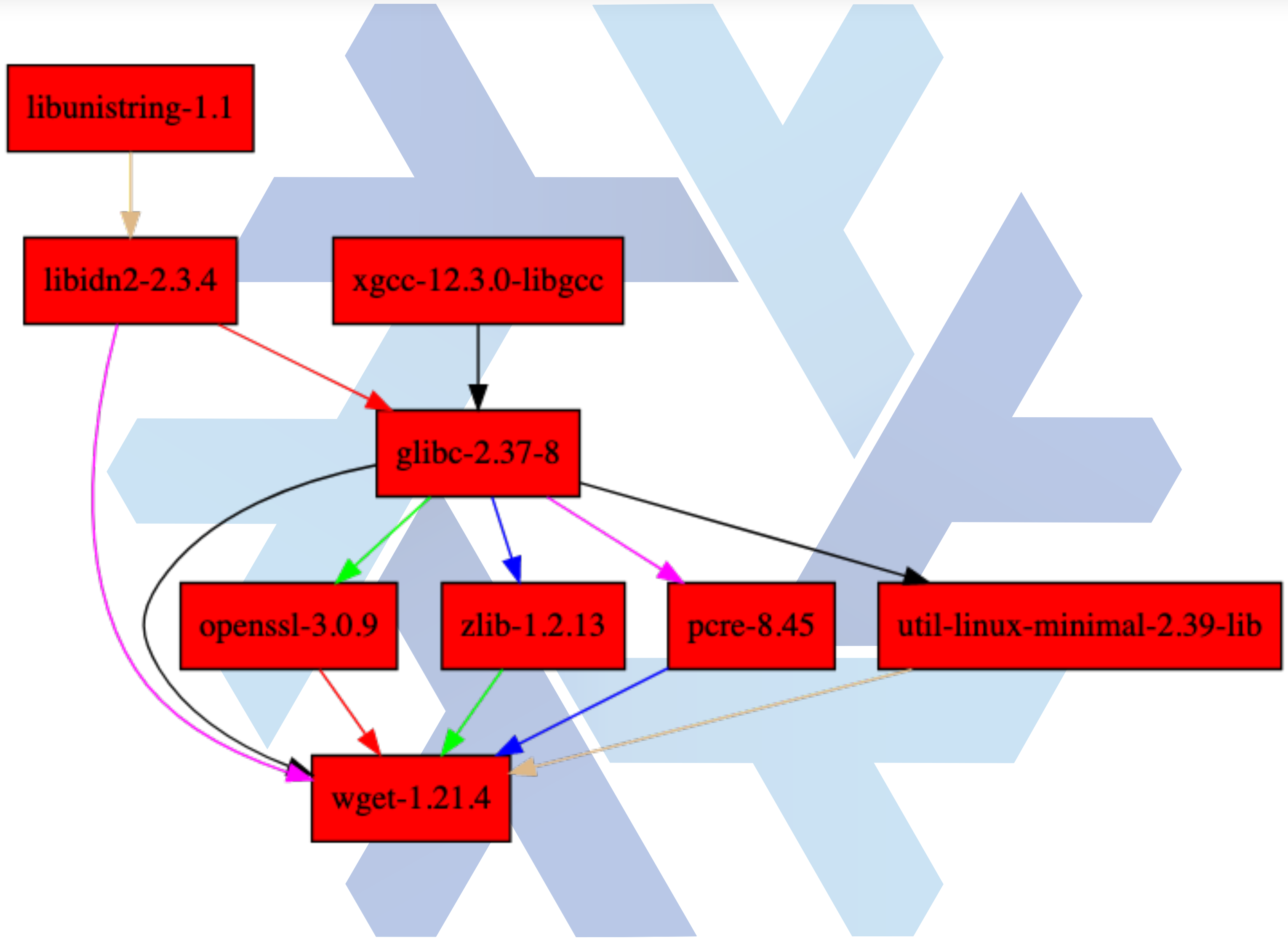
$ ldd /nix/store/d3kkv9vjb3ljh7hr5v38gls8iykvwkny-wget-1.21.4/bin/wget
libpcre.so.1 => /nix/store/pxl4n1lrns2xhc8f1s04srb4cphlg5cz-pcre-8.45/lib/libpcre.so.1
libuuid.so.1 => /nix/store/y5975fancsig22f6xw22mmmffn19n8zp-util-linux-minimal-2.39-lib/lib/libuuid.so.1
libidn2.so.0 => /nix/store/vh4pdds47783g12fmywazdx3v3kx0j4x-libidn2-2.3.4/lib/libidn2.so.0
libssl.so.3 => /nix/store/ix7cb1isdcdl4gq9hl4pdk6gyc4wrk14-openssl-3.0.9/lib/libssl.so.3
libcrypto.so.3 => /nix/store/ix7cb1isdcdl4gq9hl4pdk6gyc4wrk14-openssl-3.0.9/lib/libcrypto.so.3
libz.so.1 => /nix/store/mgz7sp9jxnk7c3rn1hvich9n0k2rjr7m-zlib-1.2.13/lib/libz.so.1
libc.so.6 => /nix/store/ayg065nw0xi1zsyi8glfh5pn4sfqd8xg-glibc-2.37-8/lib/libc.so.6
libunistring.so.5 => /nix/store/aw137ya6rvy61zw8ydsz22xwarsr8ynf-libunistring-1.1/lib/libunistring.so.5
libdl.so.2 => /nix/store/ayg065nw0xi1zsyi8glfh5pn4sfqd8xg-glibc-2.37-8/lib/libdl.so.2
libpthread.so.0 => /nix/store/ayg065nw0xi1zsyi8glfh5pn4sfqd8xg-glibc-2.37-8/lib/libpthread.so.0
```

CLOUSERS

Using hashes allow to identify **exact** build and runtime dependencies

```
$ nix-store -qR $(which wget)
/nix/store/6kyaqlxcmfadiiq0mcdj1symv1jsp58w-xgcc-12.3.0-libgcc
/nix/store/aw137ya6rvy61zw8ydsz22xwarsr8ynf-libunistring-1.1
/nix/store/vh4pdds47783g12fmywazdx3v3kx0j4x-libidn2-2.3.4
/nix/store/ayg065nw0xi1zsyi8glfh5pn4sfqd8xg-glibc-2.37-8
/nix/store/ix7cb1isdcdl4gq9hl4pdk6gyc4wrk14-openssl-3.0.9
/nix/store/mgz7sp9jxnk7c3rn1hvich9n0k2rjr7m-zlib-1.2.13
/nix/store/pxl4n1lrns2xhc8f1s04srb4cphlg5cz-pcre-8.45
/nix/store/y5975fancsig22f6xw22mmmffn19n8zp-util-linux-minimal-2.39
/nix/store/d3kkv9vjb3ljh7hr5v38gls8iykvwkny-wget-1.21.4
```

```
nix-store -q --graph $(which wget)
```



Clouser of runtime dependencies

Clousers can be distributed accross hosts

```
nix copy --to ssh-ng://remote-host /nix/store/qh4y4iw...
```

which is used to create distributed build and cache systems.

GARBAGE COLLECTION

```
$ nix-collect-garbage
finding garbage collector roots...
removing stale temporary roots file '/nix/var/nix/temproots/1023955'
deleting garbage...
deleting '/nix/store/mvqj8avzhkqabkg51cyz617qnhzzawhl-anstyle-wincon-1.0.1'
deleting '/nix/store/xzspb26l48b7hlhmlp6ac6sbivil0kgj-rust-operator-deps-0.1.0'
deleting '/nix/store/q512fyfmpmdw0ap391j8vkdd8j435545-rust-operator-deps-0.1.0'
deleting '/nix/store/gdnzfmns1ryh2pg5z9zbl0jgdspmmmx0-vendor-cargo-deps'
...
deleting unused links...
note: currently hard linking saves -0.00 MiB
1855 store paths deleted, 7729.65 MiB freed
```

NIX EXPRESSION LANGUAGE

- pure functional
- domain specific
- lazy evaluation

SYNTAX

```
# operators
nix-repl> 1 + 2
3
nix-repl> [ 1 2 ] ++ [ 3 ]
[ 1 2 3 ]

# let ... in ..., allow repeated use of variables in scope
# string interpolation
nix-repl> let
            name = "World";
          in
            "hello ${name}!"
hello World!

# attribute set, attributes accessible by '.'
# with ..., expose attributes directly
nix-repl> let
            attrs = { a = "str"; b = false; i = 3; };
          in
            with attrs; [ a attrs.b i ]
[ "str" false 3 ]
```

```
# merging attr sets
# dynamic typing
nix-repl> let
            attrs1 = { a = "str"; b = false; };
            attrs2 = { b = 10; i = 3; };
          in
            attrs1 // attrs2
{ a = "str"; b = 10; i = 3; }

# inherit, assign existing values in nested scope
nix-repl> :p let
            x = { b = 1; };
            y = 2;
            z = false;
          in
          {
            inherit x y;
            z = z;
          }
{ x = { b = 1; }; y = 2; z = false; }
```

FUNCTIONS

Nameless function (*lambda*) always takes exactly one argument

```
# argument: function body
nix-repl> let
            f = x: x + 1;
          in
          {
            type = builtins.typeOf f;
            result = f 1;
          }
{ result = 2; type = "lambda"; }

# nested functions, x: (y: x + y)
nix-repl> let
  f = x: y: x + y;
in
  f 1 2
3
```

```
# attr set as argument, defined attr must be passed
# ?, default value
# ... , extra attrs
# @name, named attr set
nix-repl> let
            f = {a, b ? 1, ...}@args: a + b + args.c;
          in
            f { a = 1; c = 1; }
3
```

DOMAIN SPECIFIC

```
nix-repl> 6/3
/Users/mskalski/org/6/3

nix-repl> let
            r = 6/3;
          in
            builtins.typeOf r
"path"
```

LAZY EVALUATION

```
nix-repl> let
            f = builtins.fetchurl "http://127.0.0.1:8000/f";
            b = 3;
          in
            b
3
# no request has been made to http server
```

WHAT I CAN DO WITH NIX?

TASK SHELL

Ephermal shell with new package

```
~ ❯ cowsay "nix is awesome!"
Unknown command: cowsay

~ ❯ nix-shell -p cowsay
[nix-shell:~]$ cowsay "nix is awesome!"
 _________________
< nix is awesome! >
 -----------------
        \   ^__^
         \  (oo)\_______
            (__)\       )\/\
                ||----w |
                ||     ||

[nix-shell:~]$ exit

~ ❯ cowsay "nix is awesome!"
Unknown command: cowsay
```

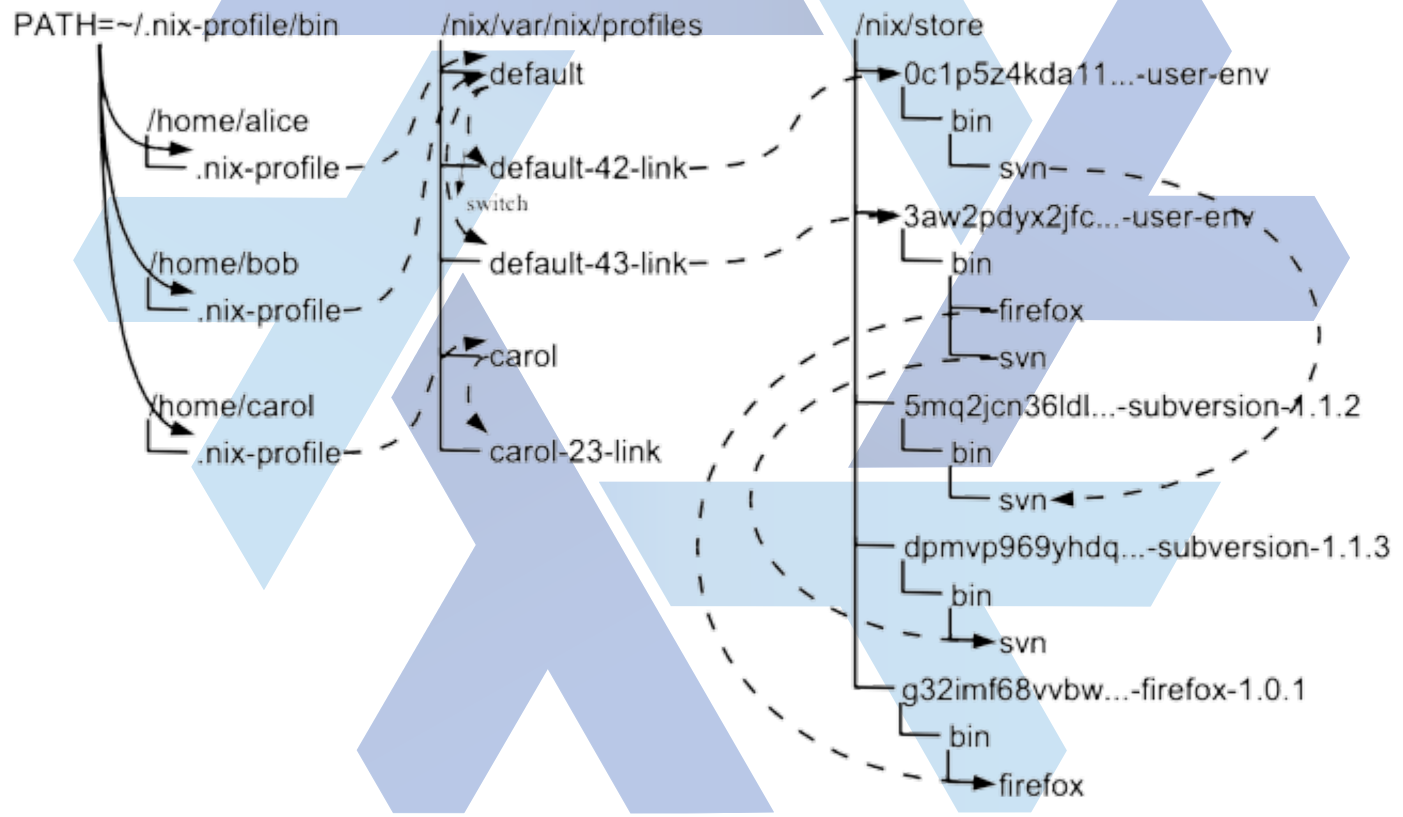
Create ad hoc env with python and needed modules

```
~ ❯ python3 -c "import bcrypt; print(bcrypt.__version__)"
Traceback (most recent call last):
  File "<string>", line 1, in <module>
ModuleNotFoundError: No module named 'bcrypt'

~ ❯ nix-shell -p "python3.withPackages(p: [ p.bcrypt ])"
[nix-shell:~]$ python3 -c "import bcrypt; print(bcrypt.__version__)"
4.0.1
```

PROFILES

Persistent environments with rollback history and atomic updates



Source: The Purely Functional Software Deployment Model

```
# Install btop package in user environment (new generation)
$ nix profile install nixpkgs#btop

# Compare changes between generations
$ nix profile diff-closures
Version 6 -> 7:
  btop: ∅ → 1.2.13, +1637.7 KiB
  gcc: ∅ → 12.3.0, +15845.2 KiB
  glibc: ∅ → 2.37-8, +29536.3 KiB
  libidn2: ∅ → 2.3.4, +350.4 KiB
  libunistring: ∅ → 1.1, +1813.8 KiB
  xgcc: ∅ → 12.3.0, +139.1 KiB

# Revert to previous generation
$ nix profile rollback
switching profile from version 7 to 6
```

FLAKES

Introduce `flake.nix` and `flake.lock` to clear definitions of inputs and their versions.

COMPOSE PROJECTS

Easy access, locked inputs, can produce variety of outputs: binaries, container images etc..

```
$ nix flake show github:michalskalski/axact
github:michalskalski/axact/9ca2f50dc4fb836af6e16dc03190cd2055d9f24b
├───devShell
│   ├───aarch64-darwin omitted (use '--all-systems' to show)
│   ├───aarch64-linux omitted (use '--all-systems' to show)
│   ├───x86_64-darwin omitted (use '--all-systems' to show)
│   └───x86_64-linux: development environment 'nix-shell'
└───packages
    ├───aarch64-darwin
    │   ├───bin omitted (use '--all-systems' to show)
    │   ├───default omitted (use '--all-systems' to show)
    │   └───ociImage omitted (use '--all-systems' to show)
    ├───aarch64-linux
    │   ├───bin omitted (use '--all-systems' to show)
    │   ├───default omitted (use '--all-systems' to show)
    │   └───ociImage omitted (use '--all-systems' to show)
    ├───x86_64-darwin
    │   ├───bin omitted (use '--all-systems' to show)
    │   ├───default omitted (use '--all-systems' to show)
    │   └───ociImage omitted (use '--all-systems' to show)
    └───x86_64-linux
        ├───bin: package 'axact-0.1.0'
        ├───default: package 'axact-0.1.0'
        └───ociImage: package 'docker-image-axact.tar.gz'
```

Build binary

```
$ nix build github:michalskalski/axact#packages.x86_64-linux.bin

# by default it produce 'result' symlink in current directory
$ ls -l
result -> /nix/store/qh4y4iwh0q40q5xxlp61bimhx8i6dp9i-axact-0.1.0

$ nix path-info --json $(realpath result) | jq .
[
  {
    "deriver": "/nix/store/gkxa58jxq5a9z7187afx0lywkckxr05b-axact-0.1.0.drv",
    "narHash": "sha256-cLMwsb0BQCRGXB1M+KGruZB+lR0gZRV3UKOFalkgONE=",
    "narSize": 6295640,
    "path": "/nix/store/qh4y4iwh0q40q5xxlp61bimhx8i6dp9i-axact-0.1.0",
    "references": [
      "/nix/store/c50v7bf341jsza0n07784yvzp5fzjpn5-gcc-12.3.0-lib",
      "/nix/store/vq3sdi8l15rzfl5zvmwpafrzis4sm6xf-glibc-2.37-8"
    ],
    "registrationTime": 1692975733,
    "ultimate": true,
    "valid": true
  }
]
```

Build container image

```
$ nix build github:michalskalski/axact#packages.x86_64-linux.ociImage

$ ls -l result
result -> /nix/store/sn1yivqy1c1qjhypq3n515g4r47rgp0k-docker-image-axact.tar.gz

# load image to local docker instance
$ docker load < result
941c04e2c681: Loading layer [==================================================>]  47.59MB/47.59MB
Loaded image: axact:latest

# but docker is not needed
$ skopeo copy "docker-archive://$(realpath result)" "docker://registry-address/img:tag"
```

DEVELOPMENT SHELL

Allow define development environment where all dependencies for your app are available, and share the same experience with other developers.

```
$ nix develop github:michalskalski/axact
```

```
# flake.nix
...
devShell = mkShell {
    inputsFrom = [ bin ];
    buildInputs = [dive skopeo] ++ darwinPkgs;
};
```

Use direnv for seamless experience, your editor probably understand it too.

```
$ ls -a project/
.envrc  flake.nix ..

$ cat project/.envrc
use flake

$ cd project/
direnv: error project/.envrc is blocked.
Run `direnv allow` to approve its content

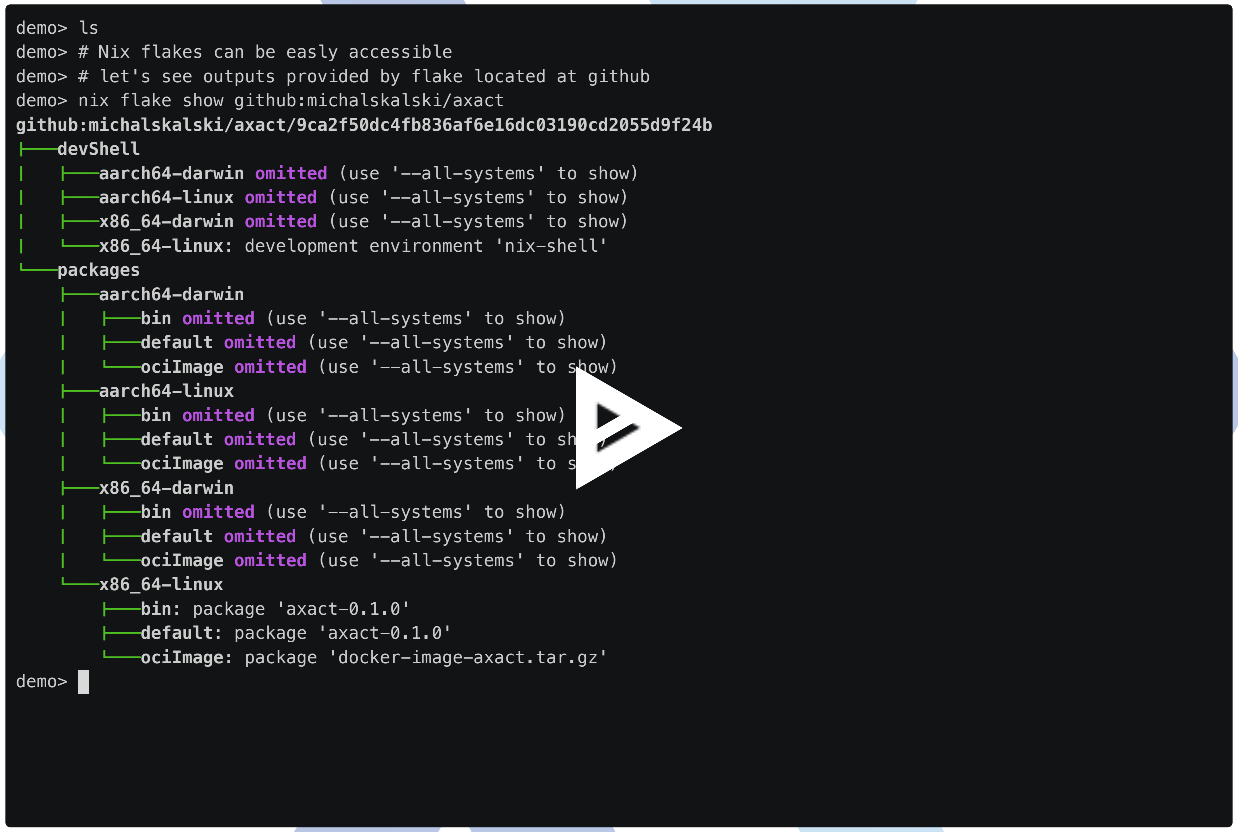
$ direnv allow
direnv: loading project/.envrc
direnv: using flake
direnv: nix-direnv: using cached dev shell
```

OVERLAYS

If your project depends on specific version of system library, or you need extra patches, you can easly modify it at your project level with overlays.

```
example_overlay = final: prev: {
  package = prev.package.overrideAttrs (old: {
    version = "";
    src = prev.fetchurl {
      url = "";
      hash = "";
    };
  });
}
```

DEMO



```
demo> ls
demo> # Nix flakes can be easly accessible
demo> # let's see outputs provided by flake located at github
demo> nix flake show github:michalskalski/axact
github:michalskalski/axact/9ca2f50dc4fb836af6e16dc03190cd2055d9f24b
├───devShell
│   ├───aarch64-darwin omitted (use '--all-systems' to show)
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    │   ├───default omitted (use '--all-systems' to sh
    │   └───ociImage omitted (use '--all-systems' to s
    ├───x86_64-darwin
    │   ├───bin omitted (use '--all-systems' to show)
    │   ├───default omitted (use '--all-systems' to show)
    │   └───ociImage omitted (use '--all-systems' to show)
    └───x86_64-linux
        ├───bin: package 'axact-0.1.0'
        ├───default: package 'axact-0.1.0'
        └───ociImage: package 'docker-image-axact.tar.gz'
demo> █
```

ONE ~~RING~~ SYSTEM TO RULE THEM ALL

Nix can be use to install and configure applications but also take care about whole OS configuration.

NIXOS

Fully integrated with nix, both from packages and configuration standpoint

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- stable channels released every six month (for ex. 22.11, 23.05)
- unstable - rolling release

DECLARATIVE DESCRIPTION OF OS

Entire system can be described through declarative configuration.

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Store configuration in repository, even better, make it `flake` and describe multiple hosts as separate outputs.

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Store configuration in repository, even better, make it `flake` and describe multiple hosts as separate outputs.

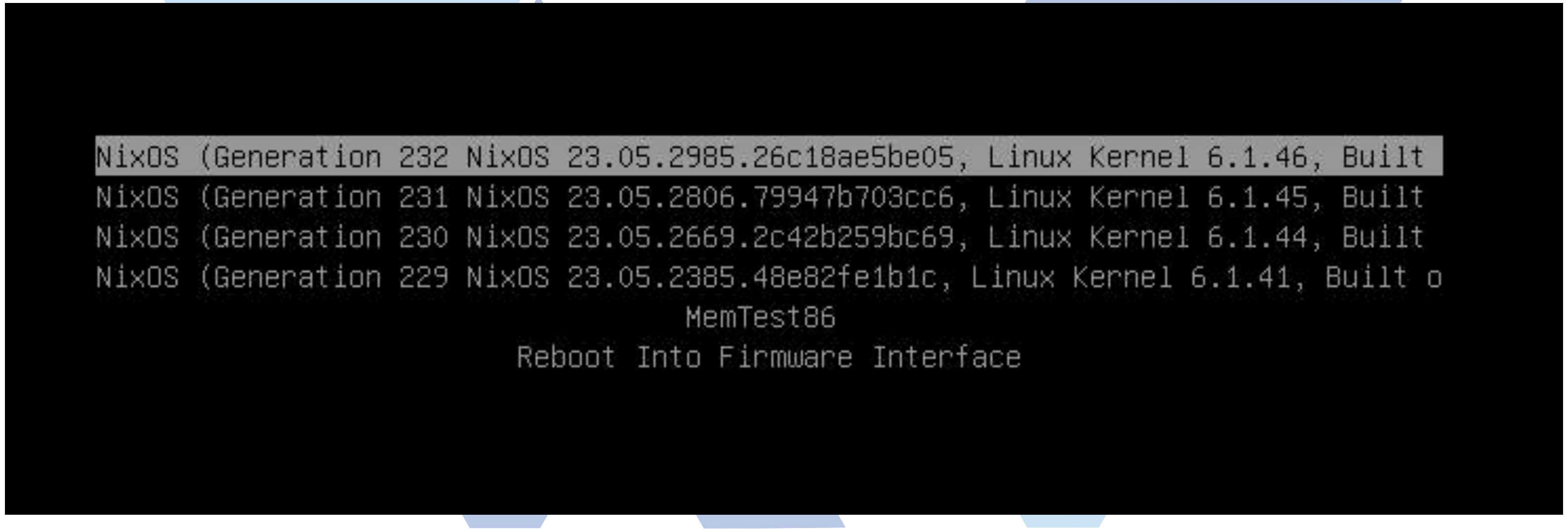
Share common configuration between hosts, making it more modular.

SAFE CHANGES

Test your new configuration in VM before applying on host:

```
# will start local vm with current system configuration
$ nixos-rebuild build-vm
```

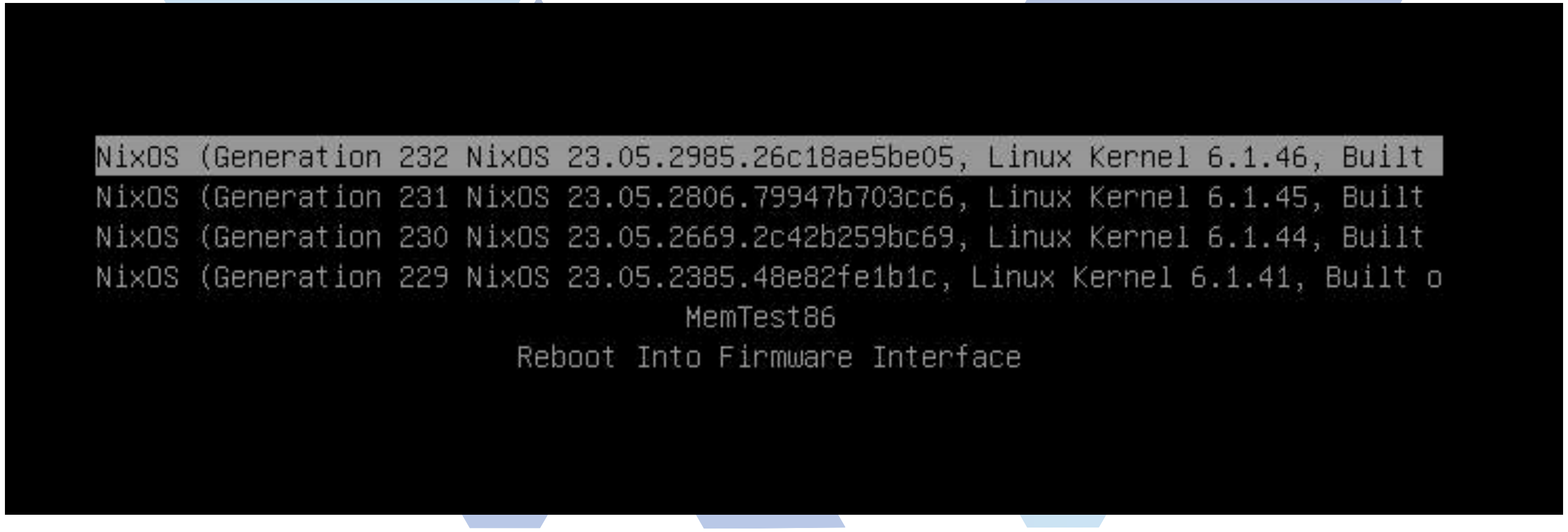
Every package install in system profile creates new generation and entry for it in bootloader.



```
NixOS (Generation 232 NixOS 23.05.2985.26c18ae5be05, Linux Kernel 6.1.46, Built
NixOS (Generation 231 NixOS 23.05.2806.79947b703cc6, Linux Kernel 6.1.45, Built
NixOS (Generation 230 NixOS 23.05.2669.2c42b259bc69, Linux Kernel 6.1.44, Built
NixOS (Generation 229 NixOS 23.05.2385.48e82fe1b1c, Linux Kernel 6.1.41, Built o
                              MemTest86
                    Reboot Into Firmware Interface
```

Every package install in system profile creates new generation and entry for it in bootloader.

System does not start after upgrade?



```
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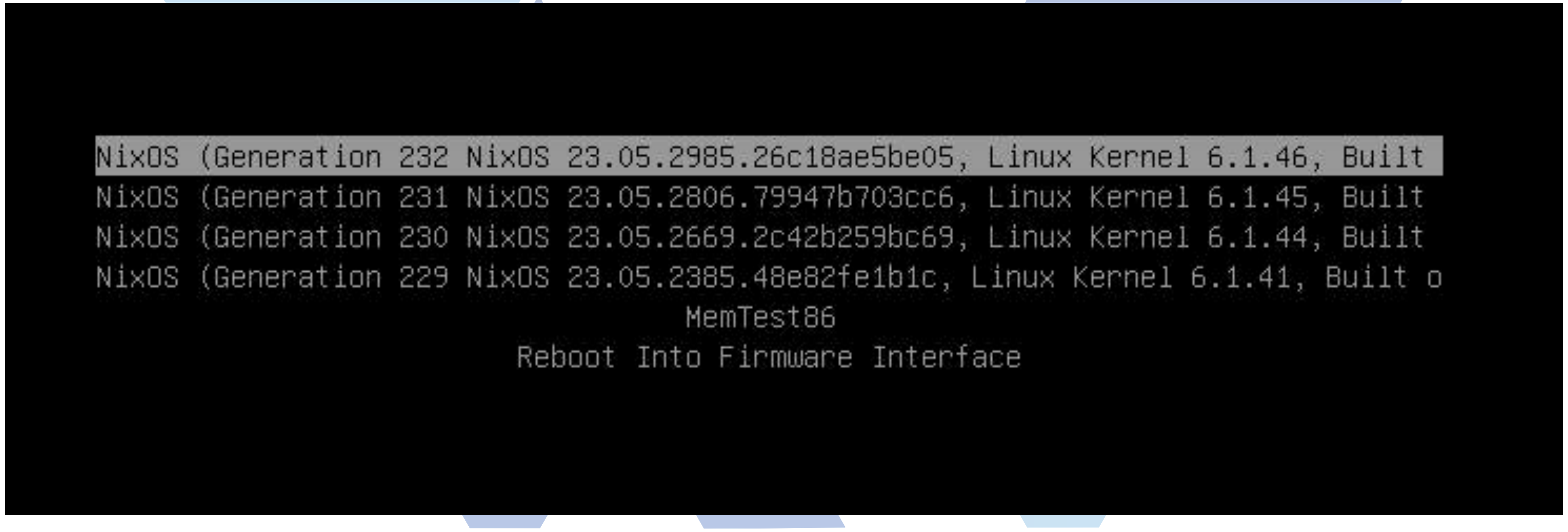
                              MemTest86
                    Reboot Into Firmware Interface
```

Every package install in system profile creates new generation and entry for it in bootloader.

System does not start after upgrade?

Boot from previous generation.



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                                   MemTest86
                         Reboot Into Firmware Interface
```

Run from livecd and restore system from existing config with one command, or generate disk image ahead.

NIX-DARWIN

Tries to replicate NixOS behaviour on macOS

https://github.com/LnL7/nix-darwin

HOME MANAGER

https://github.com/nix-community/home-manager

Standalone or module for NixOS or nix-darwin

Rich library of software configuration.

ADDITIONAL RESOURCES

Nix:

- https://nixos.org/learn
- https://zero-to-nix.com/
- https://nixos.org/guides/nix-pills/

Build systems:

- Build Systems à la Carte (2018)
- YouTube: Build Systems à la Carte