Nix

Reproducible development from theory to practice

ners

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https://github.com/ners/nix-lecture

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Introduction

Nix is a solution for getting **computer programs from one machine to another**

— Eelco Dolstra (2006)

Nix is a solution for getting **computer programs from one machine to another** and having them **still work** when they get there.

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Motivation

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  - The author of the software has all the dependencies installed
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- How can the author share their software with other people?
  - At the very least, specify the dependencies
  - The specification should be a program

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  - even with the recipe there is no guarantee it is complete or correct
  - these are repeatable, but not reproducible
  - outside of the scope of this lecture

What is Nix?

- **Reproducible**
  - if a package works on one machine, it will also work on another
  - if it built yesterday it will still build today

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- **Reproducible**
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- **Declarative**
  - requirements must be specified completely and correctly
  - specifications can be composed

What is Nix?

- **Reproducible**
  - if a package works on one machine, it will also work on another
  - if it built yesterday it will still build today
- **Declarative**
  - requirements must be specified completely and correctly
  - specifications can be composed
- **Reliable**
  - packages do not interfere with each other
  - atomic: roll back to previous versions

What is Nix?

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What is Nix?

- How do we ensure that a specification is complete and correct?
  - Run the program in an isolated environment
  - Only give it access to resources declared by the specification
  - Do not give it access to the network or hardware

What is Nix?

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- The Nix ecosystem is many things:
  - Nix: the package manager
  - Nix language: the functional language
  - Nixpkgs: the software repository
  - NixOS: the Linux distribution

Nix store

Nix store

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- Each store object is referenced by a **store path**
  - filesystem path e.g. `/nix/store/0xk3r0njrijv434qim2lia11j3x9ivkc-hello`
  - analogous to pointers, or memory addresses

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- Each store object is referenced by a **store path**
  - filesystem path e.g. `/nix/store/0xk3r0njrijv434qim2lia11j3x9ivkc-hello`
  - analogous to pointers, or memory addresses
- Store objects can reference each other via store paths

Nix store

If the Nix store is «heap memory», which program populates and uses this memory?

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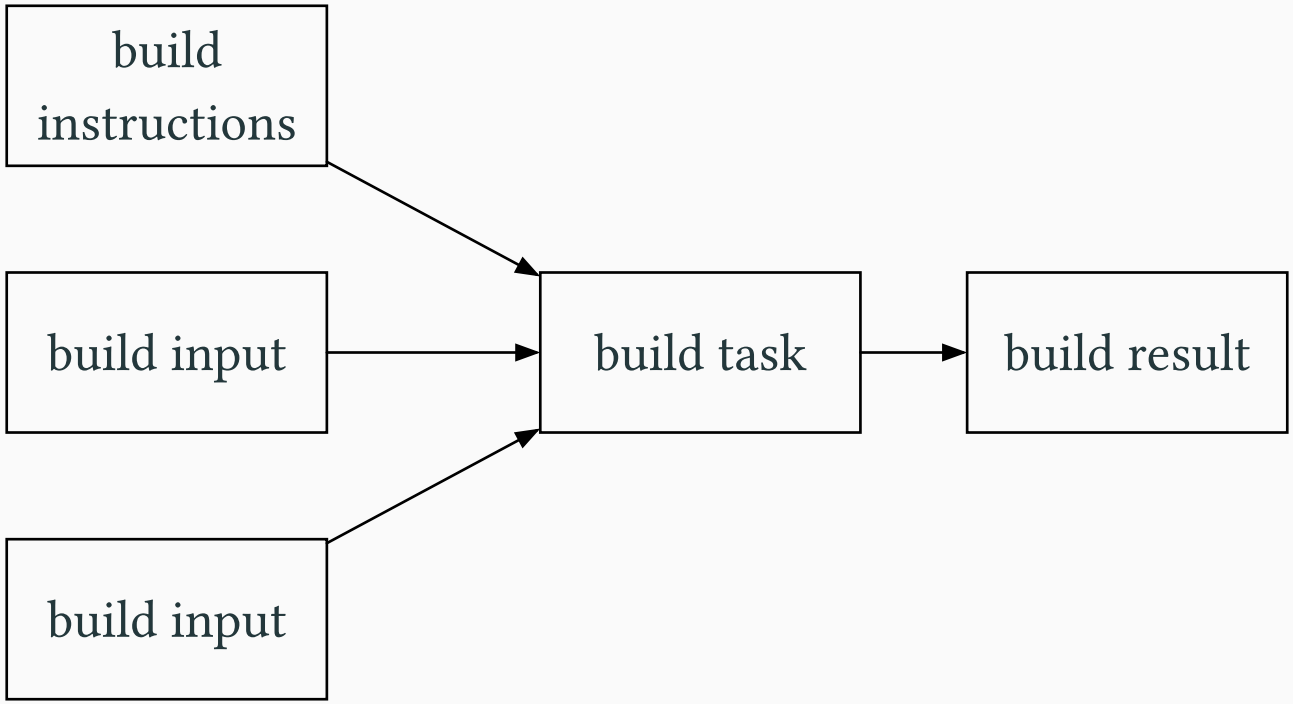
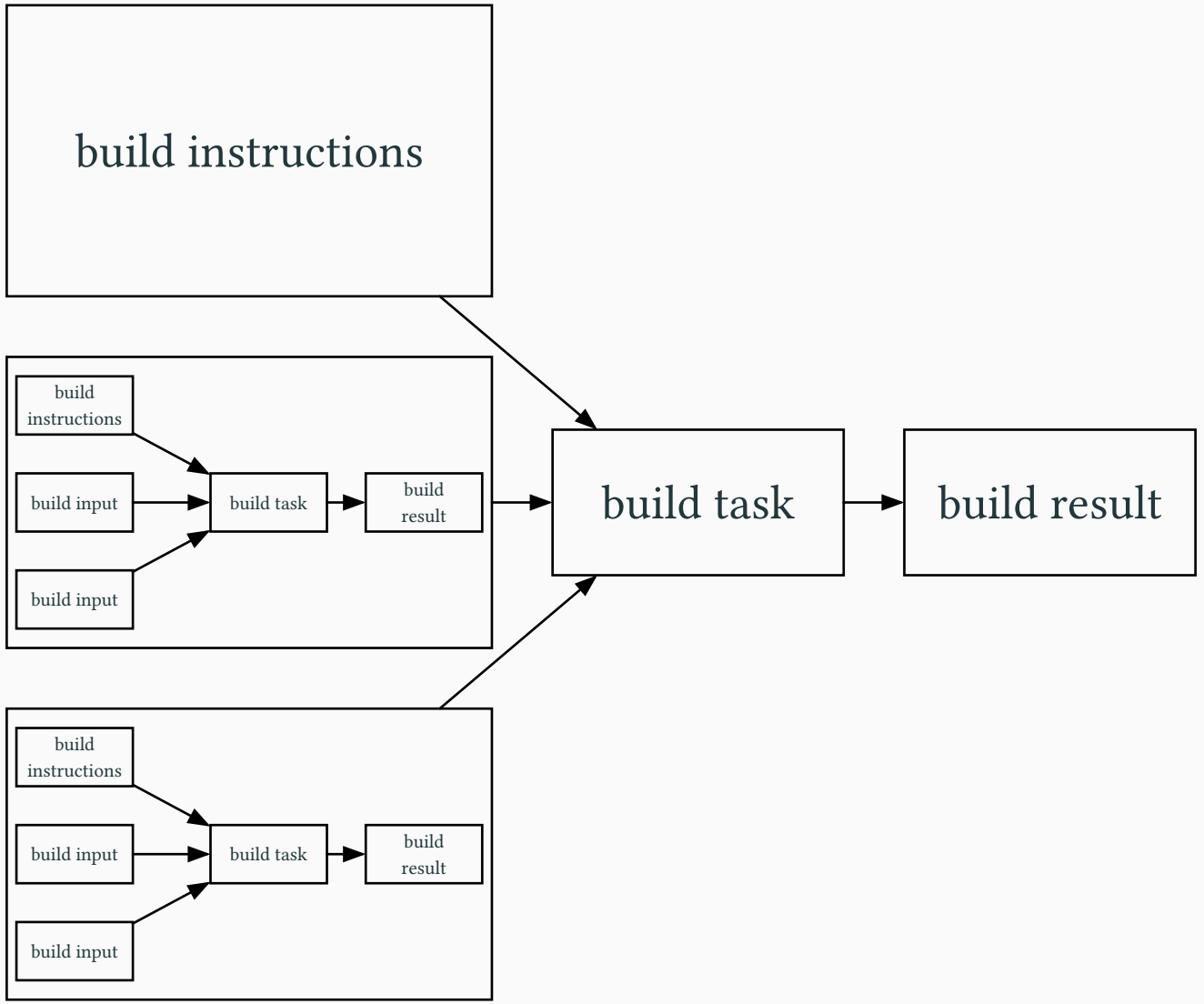
If the Nix store is «heap memory», which program populates and uses this memory?

- The program would be written in a functional language
  - the basic building block is a **function**
  - functions can have **multiple inputs** and always produce **one output**
  - a function called with the **same inputs** will produce the **same output**
- The inputs and output are store objects
- We can only create new store objects, not delete or update them

Nix store


build instructions
build input
build input
build task
build result

Nix store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Nix store

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Nix store

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- We can copy files into the Nix store to turn them into store objects

Nix store

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- Unix processes that run **in a sandbox** to behave like pure functions

Nix store

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- Nix calls these functions **derivations**

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- Unix processes that run **in a sandbox** to behave like pure functions
  - we only allow it read access to the inputs
  - we only allow it write access to the output location
  - the output of the process will become a new store object
- Nix calls these functions **derivations**
- Derivations are also store objects!

Nix store


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{
  "/nix/store/djn4x0zqf8430kdighzz76wslr8g6alm-hello.drv": {
    "args": [
      "-c",
      "echo hello > $out"
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    "builder": "/nix/store/3zdjy6cy39hyfbfabqi2i949v50s3pcb-sh",
    "env": {
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      "name": "hello",
      "out": "/nix/store/dy93f4lj9xkv3gkm6zvnfl6x3vckmgad-hello",
      "system": "x86_64-linux"
    },
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Nix language

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Why do we need a new language?

Nix language

Why do we need a new language?

- Writing derivations is a complex, mechanical task

Nix language

Why do we need a new language?

- Writing derivations is a complex, mechanical task
- The Nix language automates this process with a concise syntax

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derivation {
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Properties of the Nix language

Nix language

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- Domain-specific language

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- Purely functional

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- Domain-specific language
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Names and values

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  f = x: x + 1;
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f 5
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```
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  f = x: y: x + y;
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```
let
  f = { a, b }: a + b;
in
f { a = 2; b = 3; }
```

Functional programming

Functional programming

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let
  fib = i:
    if i == 0 then 0
    else if i == 1 then 1
    else fib (i - 1) + fib (i - 2);
in
builtins.map fib [0 1 2 3 4 5 6 7 8 9 10]
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```
[ 0 1 1 2 3 5 8 13 21 34 55 ]
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Nix language

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- **First-class filesystem paths**
  - a raw path resolves to a store path

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- **First-class filesystem paths**
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- **First-class string templating**
  - we can encode snippets of any language in the Nix language
  - we can interpolate Nix expressions

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- **First-class filesystem paths**
  - a raw path resolves to a store path
- **First-class string templating**
  - we can encode snippets of any language in the Nix language
  - we can interpolate Nix expressions
- **String contexts**
  - a Nix string contains text and a set of dependencies
  - a string that refers to store objects contains their dependency closure

Nix language

```
derivation {
  name = "hello";
  builder = ./bash;
  args = [ "-c" "echo hello > $out" ];
  system = builtins.currentSystem;
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```

Nix language

```
derivation {
  name = "hello";
  builder = ./gcc;
  args = [ "-o" "$out" ./hello.c ];
  system = builtins.currentSystem;
}
```


```
{
  "/nix/store/f2a15br5nm0nn7c7sq1rzcibwabisxfx-hello.drv": {
    "args": [
      "-o",
      "$out",
      "/nix/store/pm04fgly1zxmdx64kkqwf3kf1c11smdr-hello.c"
    ],
    "builder": "/nix/store/i31w737kksgxlnnb0ggbaapc5134awrh-gcc",
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      }
    },
    "system": "x86_64-linux"
  }
}
```

Nix language

```
let
  buildScript =
    builtins.toFile "builder.sh" ''
      src=${./.}
      gcc=${./gcc}
      for c in $src/*.c; do
        $gcc -I$src -c -o $c.o $c
      done
      $gcc -o $out *.o
    '';
in
derivation {
  name = "hello";
  builder = ./bash;
  args = [ buildScript ];
  system = builtins.currentSystem;
}
```

```
mkdir $out
src=/nix/store/8854jh52mpd8g2rjqk9n2fhifsr20w81-hello-c-multiple
gcc=/nix/store/i31w737kksgxlnnb0ggbaapc5134awrh-gcc
for c in $src/*.c; do
  $gcc -I$src -c -o $c.o $c
done
$gcc -o $out *.o
```

Nix language

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  - This function is a template for how to build a platonic C project

Nix language

- Many real-world C projects are built with some standard utilities
  - Bash, GCC, Make, awk, sed, ...
  - These projects are built by running these tools in a sequence
- We can write a Nix function that builds a derivation with many standard utilities provided
  - This function is a template for how to build a platonic C project
  - We fill in the template with function parameters

Nix language

```
let
  make = import ./build-make.nix;
  mkDerivation = { src, ... }:
    builtins.toFile "builder.sh" ''
      cp -r ${src}/* .
      export PATH="${make}/bin:$PATH"
      make
      PREFIX=$out make install
    '';
in
derivation {
  name = "hello";
  builder = ./bash;
  args = [ (mkDerivation { src = ./.; }) ];
  system = builtins.currentSystem;
}
```

Nix language

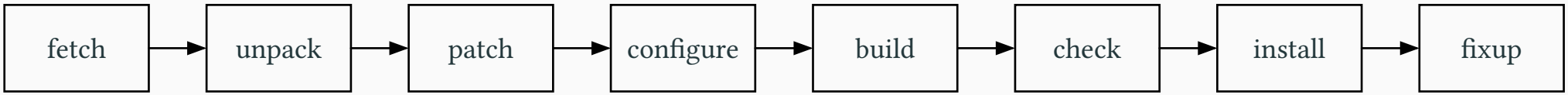
```
let
  make = import ./build-make.nix;
  glibc = import ./build-glibc.nix { inherit make; };
  mkDerivation = { src, buildInputs, ... }:
    let
      libraryPath = builtins.concatStringsSep ":" buildInputs;
    in
    builtins.toFile "builder.sh" ''
      cp -r ${src}/* .
      export PATH="${make}/bin:$PATH"
      export LD_LIBRARY_PATH="${libraryPath}:$LD_LIBRARY_PATH"
      make
      PREFIX=$out make install
    '';
in
derivation {
  name = "hello";
  builder = ./bash;
  args = [ (mkDerivation { src = ./.; buildInputs = [ glibc ]; }) ];
  system = builtins.currentSystem;
}
```

Nixpkgs

Nixpkgs

```
let
  pkgs = import <nixpkgs> {};
in
pkgs.stdenv.mkDerivation {
  pname = "hello";
  version = "0.0.1";
  source = ./.;
  buildInputs = [ ];
  buildPhase = "make";
  installPhase = "make install";
  meta.license = pkgs.lib.licenses.mit;
}
```

All software is built with The Pipeline™:



Nixpkgs

- A human-curated collection of software

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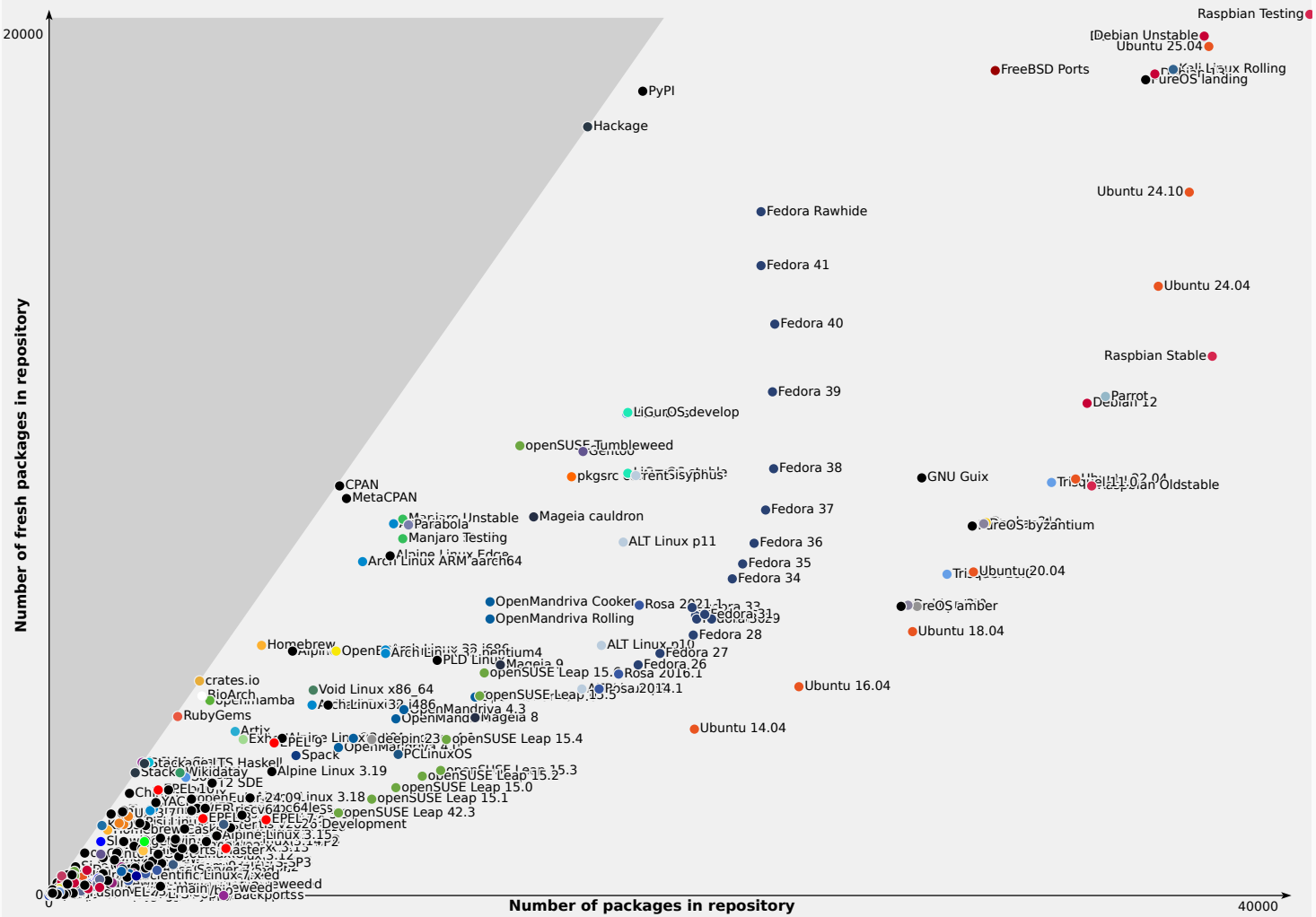
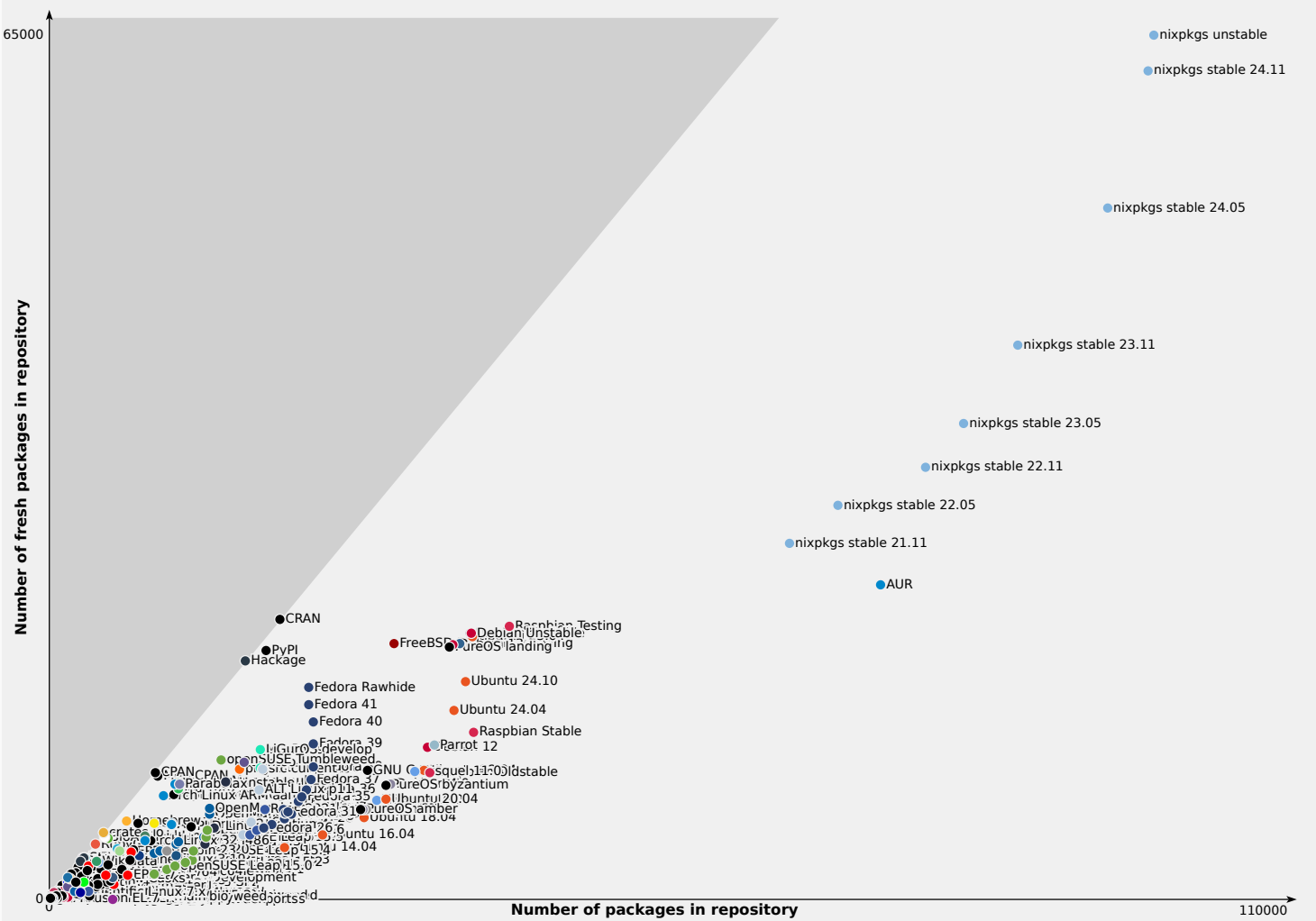
- We can have multiple versions of the same software
- The sources of packages are fetched deterministically
- Updating the sources can be automated

Nixpkgs


Number of fresh packages in repository
Number of packages in repository
20000
40000
0
Raspbian Testing
Debian Unstable
Ubuntu 25.04
FreeBSD Ports
Kali Linux Rolling
PureOS landing
PyPI
Hackage
Ubuntu 24.10
Fedora Rawhide
Fedora 41
Ubuntu 24.04
Fedora 40
Raspbian Stable
Fedora 39
Parrot
Debian 12
LiGurOS develop
openSUSE Tumbleweed
Fedora 38
GNU Guix
CPAN
MetaCPAN
Fedora 37
Mageia cauldron
Parabola
Manjaro Testing
ALT Linux p11
Fedora 36
Arch Linux ARM aarch64
Fedora 35
Fedora 34
Ubuntu 20.04
OpenMandriva Cooker
OpenMandriva Rolling
Fedora 31
Fedora 28
Ubuntu 18.04
Homebrew
ALT Linux p10
Fedora 27
Fedora 26
crates.io
Void Linux x86_64
Rosa 2014.1
Ubuntu 16.04
BioArch
RubyGems
OpenMandriva 4.3
Mageia 8
Artix
openSUSE Leap 15.4
Ubuntu 14.04
Spack
PCLinuxOS
Alpine Linux 3.19
openSUSE Leap 15.2
openSUSE Leap 15.0
openSUSE Leap 15.1
openSUSE Leap 42.3
Development

Nixpkgs


65000
Number of fresh packages in repository
0
Number of packages in repository
110000
nixpkgs unstable
nixpkgs stable 24.11
nixpkgs stable 24.05
nixpkgs stable 23.11
nixpkgs stable 23.05
nixpkgs stable 22.11
nixpkgs stable 22.05
nixpkgs stable 21.11
AUR
CRAN
PyPI
Hackage
FreeBSD
Debian Unstable
Raspbian Testing
Fedora Rawhide
Fedora 41
Fedora 40
Fedora 39
Ubuntu 24.10
Ubuntu 24.04
Raspbian Stable
Parrot 12
openSUSE Tumbleweed
CPAN
Fedora 37
PureOS byzantium
Ubuntu20.04
Fedora 31
PureOS amber
Ubuntu 18.04
Fedora 26
Ubuntu 16.04
Ubuntu 14.04
openSUSE Leap 15.0

NixOS

- Software can also have environment requirements at run-time

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  - Configuration files

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- Software can also have environment requirements at run-time
  - Configuration files
  - Services such as databases
  - Hardware state such as network configuration
- How can we ensure that the environment meets the needs of our software?
  - Construct the entire environment in a disciplined way

- NixOS is merely a derivation that creates all the files required to run an OS

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  - bootloader, kernel, init process, service manager, configuration files, …

NixOS

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  - bootloader, kernel, init process, service manager, configuration files, …
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- NixOS is merely a derivation that creates all the files required to run an OS
  - bootloader, kernel, init process, service manager, configuration files, …
- There are multiple choices for each of these components
- How do we make sure they all work together?
  - Model the choices as constraints, use constraint solving to find a solution

- The module system is a DSL embedded in the Nix language

- The module system is a DSL embedded in the Nix language
- Its purpose is to build a big data structure from multiple interdependent declarations

- Features of the module system:

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  - Separate **declaration** and **definition** of configuration options

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- Features of the module system:
  - Separate **declaration** and **definition** of configuration options
  - A **type system** that constrains the values of options
  - Multiple definitions of the same option are **merged** according to the type of that option
- Configuration options can refer to each other via fix-point computation

```
{ lib, ... }:
{
  options = {
    name = lib.mkOption {
      type = lib.types.str;
    };
  };
}
```

```nix
{ lib, ... }:
{
  options = {
    name = lib.mkOption {
      type = lib.types.str;
    };
  };
}
```

```nix
{ ... }:
{
  config = {
    name = "Boaty McBoatface";
  };
}
```

```nix
{ lib, ... }:
{
  options = {
    name = lib.mkOption {
      type = lib.types.str;
    };
  };
}
```

```nix
{ ... }:
{
  config = {
    name = "Boaty McBoatface";
  };
}
```

```nix
let
  lib = import <nixpkgs/lib>;
  result = lib.evalModules {
    modules = [
      ./options.nix
      ./config.nix
    ];
  };
in
result.config
```

- The collection of NixOS modules is a uniform interface for configuring an entire OS

- The collection of NixOS modules is a uniform interface for configuring an entire OS
- The data structure produced by the module system is the final configuration for our OS

Example NixOS configuration

```
{ config, pkgs, ... }:
{
  imports = [
    # Include the results of the hardware scan.
    ./hardware-configuration.nix
  ];

  # Enable the OpenSSH server.
  services.sshd.enable = true;

  # Install GNOME desktop environment
  services.xserver.enable = true;
  services.xserver.displayManager.gdm.enable = true;
  services.xserver.desktopManager.gnome.enable = true;

  # Use nVidia drivers
  nixpkgs.config.allowUnfree = true;
  services.xserver.videoDrivers = [ "nvidia" ];

  # Set up the firewall for HTTP
  networking.firewall.allowedTCPPorts = [ 80 443 ];
}
```

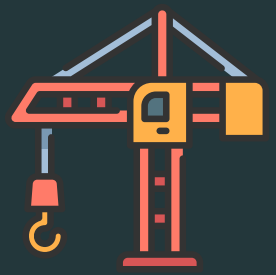
Intermezzo

We'll return after these messages!

Intermezzo

1. Install Nix
   https://nixos.org/download.html
2. Enable flakes
   ```
   mkdir -p ~/.config/nix
   echo "experimental-features = nix-command flakes" > ~/.config/nix/nix.conf
   ```
3. Test it out
   ```
   nix run nixpkgs#hello
   ```

Construction ahead!



Flakes are still a work in progress, and small details of their design may change in the future.

Nix CLI

Nix shell

```
$ git --version
```

Nix shell

```
$ git --version
git version 2.47.0
```

Nix shell

```
$ git --version
git version 2.47.0

$ fortune
```

Nix shell

```
$ git --version
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$ fortune
zsh: fortune: command not found
```

Nix shell

```
$ git --version
git version 2.47.0

$ fortune
zsh: fortune: command not found

$ nix run nixpkgs#fortune
```

Nix shell

```
$ git --version
git version 2.47.0

$ fortune
zsh: fortune: command not found

$ nix run nixpkgs#fortune
A banker is a fellow who lends you his umbrella when the sun is shining and
wants it back the minute it begins to rain.
  -- Mark Twain
```

Nix shell

```
$ nix run nixpkgs#fortune | nix run nixpkgs#cowsay
```

Nix shell

```
$ nix run nixpkgs#fortune | nix run nixpkgs#cowsay
 _____________________________________
< Offer void where prohibited by law. >
 -------------------------------------
        \   ^__^
         \  (oo)\_______
            (__)\       )\/\
                ||----w |
                ||     ||
```

Nix shell

```
$ nix shell nixpkgs#fortune nixpkgs#cowsay
$ fortune | cowsay
```

Nix shell

```
$ nix shell nixpkgs#fortune nixpkgs#cowsay
$ fortune | cowsay
 _________________________________________
/ He who has imagination without learning \
\ has wings but no feet.                  /
 -----------------------------------------
        \   ^__^
         \  (oo)\_______
            (__)\       )\/\
                ||----w |
                ||     ||
```

Nix shell

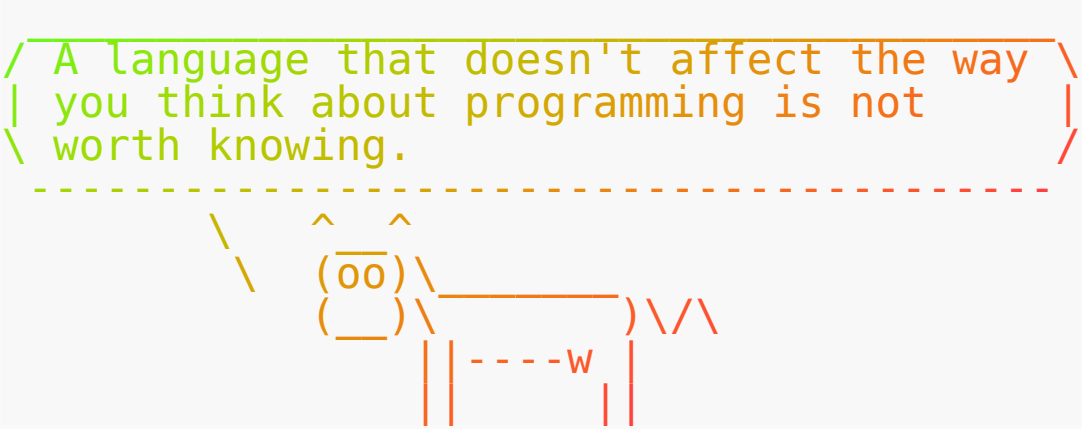
```
$ nix shell nixpkgs#fortune nixpkgs#cowsay
$ fortune | cowsay
 _________________________________________
/ He who has imagination without learning \
\ has wings but no feet.                  /
 -----------------------------------------
        \   ^__^
         \  (oo)\_______
            (__)\       )\/\
                ||----w |
                ||     ||
$ exit
```

Nix shell

```
$ nix shell nixpkgs#{fortune,cowsay,lolcat}
$ fortune | cowsay | lolcat
```

Nix shell

```
$ nix shell nixpkgs#{fortune,cowsay,lolcat}
$ fortune | cowsay | lolcat
```



Nix shell

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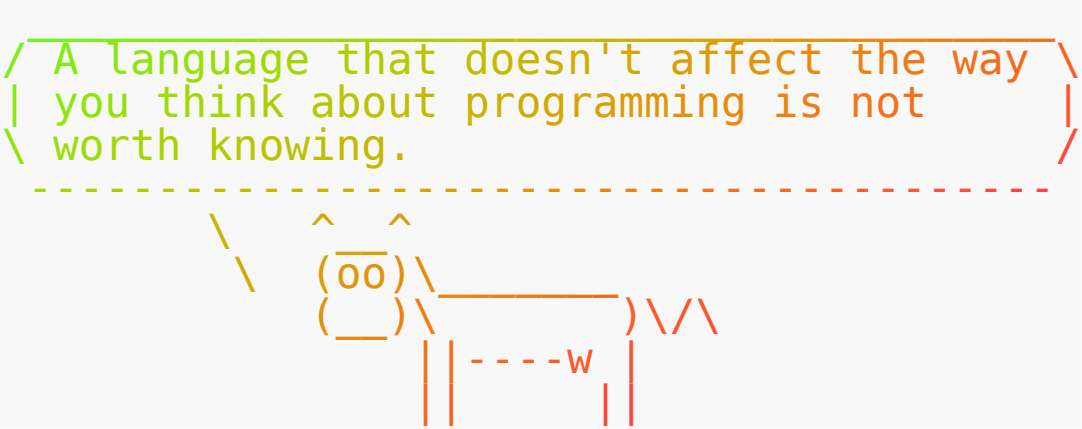
$ nix shell nixpkgs#{fortune,cowsay,lolcat}
$ fortune | cowsay | lolcat
```




```
$ exit
```

Nix projects

Nix files

- A project has Nix powers if it has one or more of these files in its root:
  - `flake.nix` (new: build and shell)
  - `default.nix` (old: just build)
  - `shell.nix` (old: just shell)

Nix files

- A project has Nix powers if it has one or more of these files in its root:
  - `flake.nix` (new: build and shell)
  - `default.nix` (old: just build)
  - `shell.nix` (old: just shell)
- Ideally no other changes to the project are required!

My first flake

```
{
    inputs = {};

    outputs = inputs: {};
}
```

My first flake

```
{
    inputs = {
        nixpkgs = {
            url = "github:nixos/nixpkgs/nixos-24.11";
        };
    };

    outputs = inputs: {};
}
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs: {};
}
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs: {
        hello = "world";
    };
}
```

My first flake

```
$ nix flake show
```

My first flake

```
$ nix flake show
git+file:/tmp/nix-lecture?dir=examples/flake-c
└───hello: unknown
```

My first flake

```
$ nix flake show
git+file:/tmp/nix-lecture?dir=examples/flake-c
└───hello: unknown

$ nix eval .#hello
```

My first flake

```
$ nix flake show
git+file:/tmp/nix-lecture?dir=examples/flake-c
└───hello: unknown

$ nix eval .#hello
"world"
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs:
      let
        system = "x86_64-linux";
      in
      {
      };
}
```

Some other options for `system`:

- `x86_64-darwin`
- `aarch64-darwin`

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs:
      let
        system = "x86_64-linux";
        pkgs = import inputs.nixpkgs { inherit system; };
      in
      {
      };
}
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs:
      let
        system = "x86_64-linux";
        pkgs = import inputs.nixpkgs { inherit system; };
      in
      {
        devShells.${system}.default = pkgs.mkShell { ... };
      };
}
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs:
      let
        system = "x86_64-linux";
        pkgs = import inputs.nixpkgs { inherit system; };
      in
      {
        devShells.${system}.default = pkgs.mkShell {
          packages = [
            pkgs.fortune
            pkgs.cowsay
            pkgs.lolcat
          ];
        };
      };
}
```

My first flake

```
{
    inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

    outputs = inputs:
      let
        system = "x86_64-linux";
        pkgs = import inputs.nixpkgs { inherit system; };
      in
      {
        devShells.${system}.default = pkgs.mkShell {
          packages = with pkgs; [
            fortune
            cowsay
            lolcat
          ];
        };
      };
}
```

My first flake

- If a project has a `flake.nix` file (new), enter its development shell with:

  ```
  $ nix develop
  ```

My first flake

- If a project has a `flake.nix` file (new), enter its development shell with:

  ```
  $ nix develop
  ```

- If a project has a `shell.nix` file (old), enter its development shell with:

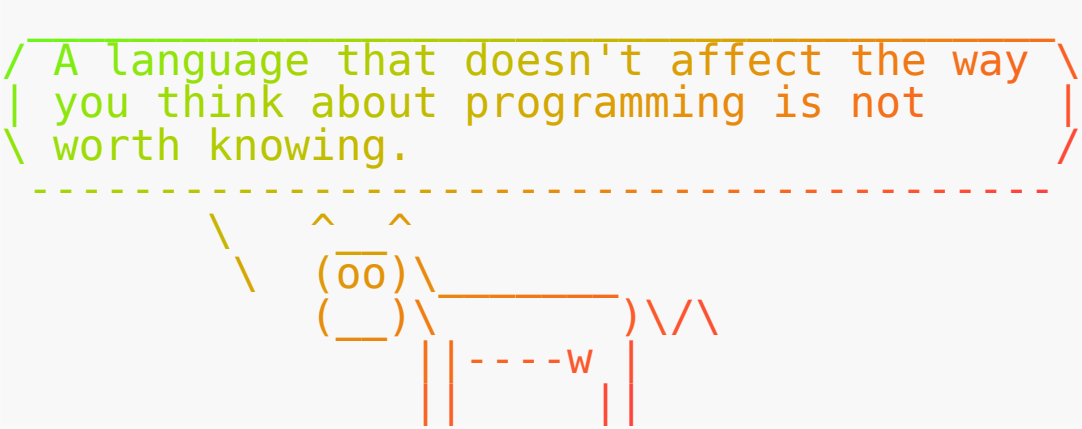
  ```
  $ nix-shell
  ```

My first flake

```
$ nix develop
$ fortune | cowsay | lolcat
```

My first flake

```
$ nix develop
$ fortune | cowsay | lolcat
```



Lockfiles

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Lockfiles

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- We wish to specify the exact version of flake inputs
  - But we also still want to easily update them …
- A Nix flake locks its inputs with a lockfile
  - Each input gets resolved to its current version and its contents are hashed

Lockfiles

- Online resources change over time
- We wish to specify the exact version of flake inputs
  - But we also still want to easily update them …
- A Nix flake locks its inputs with a lockfile
  - Each input gets resolved to its current version and its contents are hashed
  - The version and hash or each input are written into the lockfile

Lockfiles

- Online resources change over time
- We wish to specify the exact version of flake inputs
  - But we also still want to easily update them …
- A Nix flake locks its inputs with a lockfile
  - Each input gets resolved to its current version and its contents are hashed
  - The version and hash or each input are written into the lockfile
  - Every subsequent interaction with the flake will use the lockfile

Lockfiles


```
{
  "nodes": {
    "nixpkgs": {
      "locked": {
        "lastModified": 1734083684,
        "narHash": "sha256-5fNndbndxSx5d+C/D0p/VF32xDiJCJzyOqorOYW4JEo=",
        "owner": "nixos",
        "repo": "nixpkgs",
        "rev": "314e12ba369ccdb9b352a4db26ff419f7c49fa84",
        "type": "github"
      },
      "original": {
        "owner": "nixos",
        "ref": "nixos-24.11",
        "repo": "nixpkgs",
        "type": "github"
      }
    },
    "root": {
      "inputs": {
        "nixpkgs": "nixpkgs"
      }
    }
  },
  "root": "root",
  "version": 7
}
```

Building a C project

```c
#include <stdio.h>

int main(void) {
    printf("Hello world!\n");
    return 0;
}
```

Building a C project

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      packages.${system}.default = pkgs.stdenv.mkDerivation {
        name = "hello";
        src = ./.;
      };
    };
}
```

Building a C project

```
$ nix build
```

Building a C project

```
$ nix build
error: builder for '/nix/store/y4pwjdz73s1s1wmvsc5pnrx9va74d760-hello.drv'
failed to produce output path for output 'out' at '/nix/store/
y4pwjdz73s1s1wmvsc5pnrx9va74d760-hello.drv.chroot/root/nix/store/
wpwvpa6m5gq1fghqzbf7n4s7zbrzafzy-hello'
```

Building a C project

C projects are usually built with a Makefile!

```
build: hello

hello: hello.c
  $(CC) $(CFLAGS) -o hello hello.c

BINDIR ?= $(out)/bin
install: hello
  install -D --mode=755 hello ${BINDIR}/hello
```

Building a C project

```
$ nix build
```

Building a C project

```
$ nix build
$

$ nix run
```

Building a C project

```
$ nix build
$

$ nix run
Hello world!
```

Building a C project with dependencies

Let's add a depedency on TensorFlow

```c
#include <stdio.h>
#include <tensorflow/c/c_api.h>

int main() {
  printf(
    "TensorFlow C library version: %s\n",
    TF_Version()
  );
}
```

Building a C project with dependencies

```
build: hello

hello: hello.c
  $(CC) $(CFLAGS) -ltensorflow -o hello hello.c

BINDIR ?= $(out)/bin
install: hello
  install -D --mode=755 hello ${BINDIR}/hello
```

Building a C project with dependencies

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      packages.${system}.default = pkgs.stdenv.mkDerivation {
        name = "hello";
        src = ./.;
      };
    };
}
```

Building a C project with dependencies

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      packages.${system}.default = pkgs.stdenv.mkDerivation {
        name = "hello";
        src = ./.;
        buildInputs = [ pkgs.libtensorflow ];
      };
    };
}
```

Building a C project with dependencies

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      devShells.${system}.default = pkgs.mkShell {
        packages = with pkgs; [ libtensorflow ];
      };

      packages.${system}.default = pkgs.stdenv.mkDerivation {
        name = "hello";
        src = ./.;
        buildInputs = [ pkgs.libtensorflow ];
      };
    };
}
```

Python shell

```
import tensorflow as tf

print("TensorFlow Python library version:", tf.__version__)
```

Python shell

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      devShells.${system}.default = pkgs.mkShell {
        nativeBuildInputs = [
          (pkgs.python311.withPackages (ps: [ ps.tensorflow ]))
        ];
      };
    };
}
```

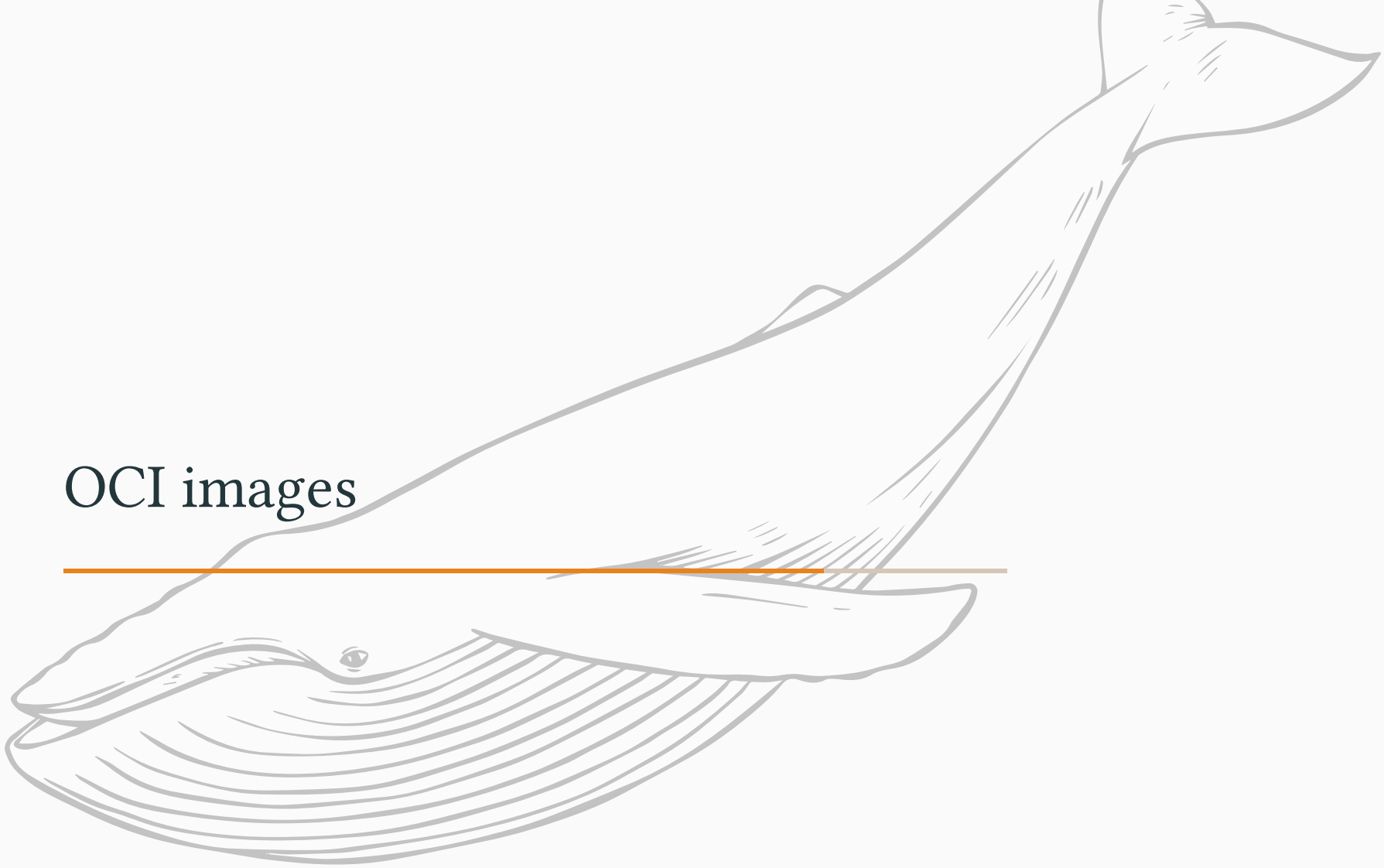
Python shell

```
$ nix develop --command python hello.py
```

Python shell

```
$ nix develop --command python hello.py
TensorFlow Python library version: 2.13.0
```

OCI images



Building OCI images

- If Nix can build a package, it can also build an OCI image with it!

Building OCI images

- If Nix can build a package, it can also build an OCI image with it!
- Let's package a little Haskell server in Nix and Docker

Building a Haskell project

```
cabal-version: 3.0
name: hello
version: 0.1.0.0

executable hello
  hs-source-dirs: .
  main-is: Main.hs
  build-depends:
    base,
    http-types,
    wai,
    warp,
```

```
{-# LANGUAGE OverloadedStrings #-}

import Network.HTTP.Types
import Network.Wai
import Network.Wai.Handler.Warp

response =
    responseLBS
        status200
        [(hContentType, "text/plain")]
        "Hello Haskell!"

app _ f = f response

main = runSettings defaultSettings app
```

Building a Haskell project

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
    in
    {
      packages.${system}.default =
        pkgs.haskellPackages.callCabal2nix "hello" ./. { };
    };
}
```

Building a Haskell project

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
      hello = pkgs.haskellPackages.callCabal2nix "hello" ./. { };
    in
    {
      packages.${system}.default = hello;
    };
}
```

Building a Haskell project

```
$ nix run
```

Building a Haskell project

```
$ nix run
```

```
$ curl localhost:3000
```

Building a Haskell project

```
$ nix run
```

```
$ curl localhost:3000
Hello Haskell!
```

Building an OCI image

Let's inspect the runtime dependencies of our executable:

```
$ nix build
$ ldd result/bin/server
```

Building an OCI image

Let's inspect the runtime dependencies of our executable:

```
$ nix build
$ ldd result/bin/server
  linux-vdso.so.1 (0x00007f41c3cb6000)
  libm.so.6 => /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/libm.so.6 (0x00007f41c3bc9000)
  libz.so.1 => /nix/store/bzk3q2l71qwhycsip23y6rl5n881la4n-zlib-1.3.1/lib/libz.so.1 (0x00007f41c3bab000)
  libpthread.so.0 => /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/libpthread.so.0 (0x00007f41c3ba6000)
  libgmp.so.10 => /nix/store/ga9ymzd1mc47z7j5l945j7hld5n4g0a6-gmp-with-cxx-6.3.0/lib/libgmp.so.10 (0x00007f41c3b01000)
  libc.so.6 => /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/libc.so.6 (0x00007f41c3906000)
  librt.so.1 => /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/librt.so.1 (0x00007f41c3901000)
  libdl.so.2 => /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/libdl.so.2 (0x00007f41c38fc000)
  libffi.so.8 => /nix/store/lw7psn749bfn2nrn943jdh68hh2im8yl-libffi-3.4.6/lib/libffi.so.8 (0x00007f41c38eb000)
  libelf.so.1 => /nix/store/y1563grxzk23mapa57a6qzsjaqyvcw76-elfutils-0.191/lib/libelf.so.1 (0x00007f41c38ce000)
  libdw.so.1 => /nix/store/y1563grxzk23mapa57a6qzsjaqyvcw76-elfutils-0.191/lib/libdw.so.1 (0x00007f41c3826000)
  /nix/store/wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib/ld-linux-x86-64.so.2 => /nix/store/
wn7v2vhyyyi6clcyn0s9ixvl7d4d87ic-glibc-2.40-36/lib64/ld-linux-x86-64.so.2 (0x00007f41c3cb8000)
  libzstd.so.1 => /nix/store/8pys6a47askf0g75a1k73p3rx2wim7m6-zstd-1.5.6/lib/libzstd.so.1 (0x00007f41c3752000)
  liblzma.so.5 => /nix/store/bdpc1864983kf51r3cznbrvnlkv4d9ff-xz-5.6.3/lib/liblzma.so.5 (0x00007f41c3721000)
  libbz2.so.1 => /nix/store/hl3iw85v12gh9mwgvr9yfgjgy0rk81hb-bzip2-1.0.8/lib/libbz2.so.1 (0x00007f41c370e000)
```

That's a lot of dependencies! Sure would be a shame if we forgot some...

Building an OCI image

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
      hello = pkgs.haskellPackages.callCabal2nix "hello" ./. { };
    in
    {
      packages.${system}.default = hello;
    };
}
```

Building an OCI image

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
      hello = pkgs.haskellPackages.callCabal2nix "hello" ./. { };
      image = pkgs.dockerTools.buildLayeredImage {
        name = hello.pname;
        config.Cmd = [ hello.meta.mainProgram ];
        contents = [ hello ];
        tag = "latest";
      };
    in
    {
      packages.${system} = {
        default = hello;
        image = image;
      };
    };
}
```

Building an OCI image

```
$ nix build .#image
$ podman load -i result
$ podman run --publish 3000:3000 hello
```

Building an OCI image

```
$ nix build .#image
$ podman load -i result
$ podman run --publish 3000:3000 hello

$ curl localhost:3000
```

Building an OCI image

```
$ nix build .#image
$ podman load -i result
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$ curl localhost:3000
Hello Haskell!
```

NixOS tests

NixOS tests

- NixOS tests set up a network of NixOS-powered virtual machines

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- NixOS tests set up a network of NixOS-powered virtual machines
- These virtual machines can run any program and communicate with each other over the network
- This is especially useful for client-server tests!

NixOS tests

Let's test our Haskell app

```
{
  inputs.nixpkgs.url = "github:nixos/nixpkgs/nixos-24.11";

  outputs = inputs:
    let
      system = "x86_64-linux";
      pkgs = import inputs.nixpkgs { inherit system; };
      hello = pkgs.haskellPackages.callCabal2nix "hello" ./. { };
    in
    {
      packages.${system}.default = hello;
      checks.${system}.nixosTest = pkgs.nixosTest { ... };
    };
}
```

NixOS tests

```
pkgs.nixosTest {
    name = "hello-test";
    nodes = { ... };
    testScript = ''
        ...
    '';
};
```

NixOS tests

```
pkgs.nixosTest {
  name = "hello-test";
  nodes = {
    server = { ... };
    client = { ... };
  };
  testScript = ''
      ...
  '';
};
```

NixOS tests

```
pkgs.nixosTest {
  name = "hello-test";
  nodes = {
    server = {
      networking.firewall.allowedTCPPorts = [ 3000 ];
      systemd.services.server = {
        wantedBy = [ "multi-user.target" ];
        script = "${hello}/bin/hello";
      };
    };
    client = { ... };
  };
  testScript = ''
      ...
  '';
};
```

NixOS tests

```
pkgs.nixosTest {
  name = "hello-test";
  nodes = {
    server = {
      networking.firewall.allowedTCPPorts = [ 3000 ];
      systemd.services.server = {
        wantedBy = [ "multi-user.target" ];
        script = "${hello}/bin/hello";
      };
    };
    client = {
      environment.systemPackages = [ pkgs.curl ];
    };
  };
  testScript = ''
      ...
  '';
};
```

NixOS tests

```
pkgs.nixosTest {
  name = "hello-test";
  nodes = {
    server = {
      networking.firewall.allowedTCPPorts = [ 3000 ];
      systemd.services.server = {
        wantedBy = [ "multi-user.target" ];
        script = "${hello}/bin/hello";
      };
    };
    client = {
      environment.systemPackages = [ pkgs.curl ];
    };
  };
  testScript = ''
    start_all()
    server.wait_for_open_port(3000)
    expected = "Hello Haskell!"
    actual = client.succeed("curl http://server:3000")
    assert expected == actual, "server says hello"
  '';
};
```

NixOS tests

```
$ nix build .#test -L
```

NixOS tests

```
$ nix build .#test -L
... lots of terminal output ...
```

NixOS tests

```
$ nix build .#test -L
... lots of terminal output ...
$
```

NixOS tests

```
$ nix build .#test -L
... lots of terminal output ...
$

$ echo $?
```

NixOS tests

```
$ nix build .#test -L
... lots of terminal output ...
$

$ echo $?
0
```

That’s all, folks!

Stay in touch

https://zurich.nix.ug