Monadic Composition for Deterministic, Parallel Batch Processing

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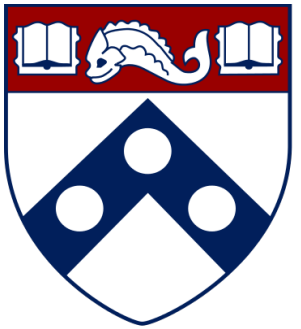


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github.com/RyanGlScott

Unintended nondeterminism sucks.

Same commit, different results #770

Closed **amitaibu** opened this issue on Nov 19, 2012 · 2 comments

amitaibu commented on Nov 19, 2012

I have a build that was successful, but after "rebuilding" it fails.

Success VS Fail -- so I assume it's related to the environment?

can't reproduce examples #21

Open **casanovarodrigo** opened this issue on Jul 3 · 8 comments

Can't reproduce nested grid method from Examples #621

Closed **shorty2240** opened this issue on Jul 7 · 3 comments

Can't Reproduce the Accuracy for "Pre-trained word embeddings in Keras" Example #5826

Closed **MadLily** opened this issue on Mar 16 · 4 comments

Assignees

No one assign

Labels

None yet

Projects

None yet

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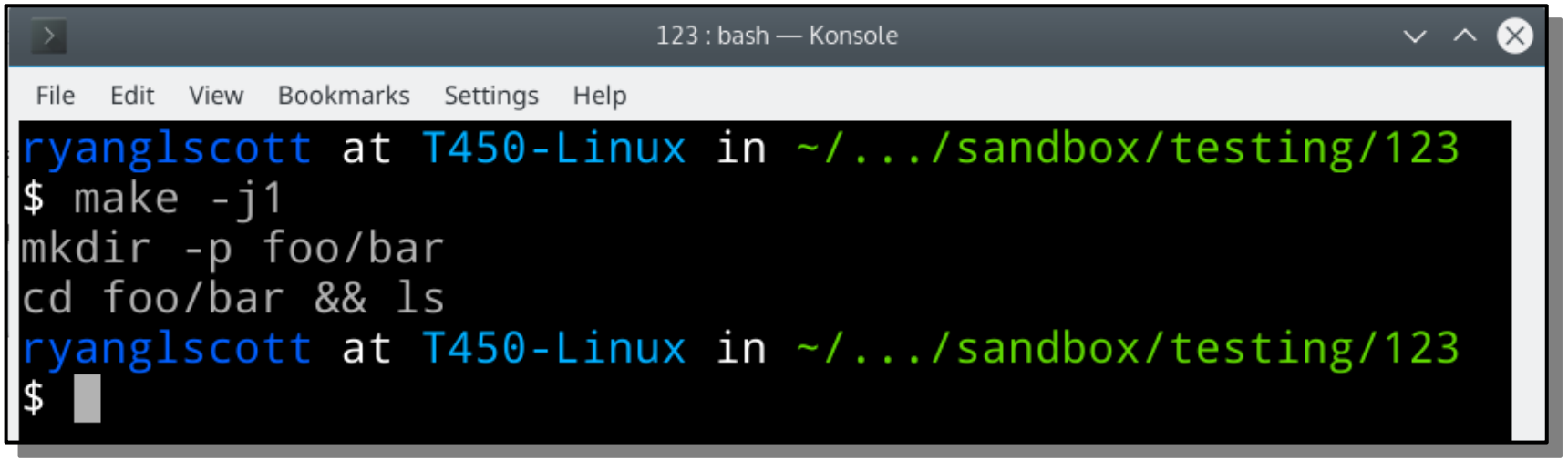
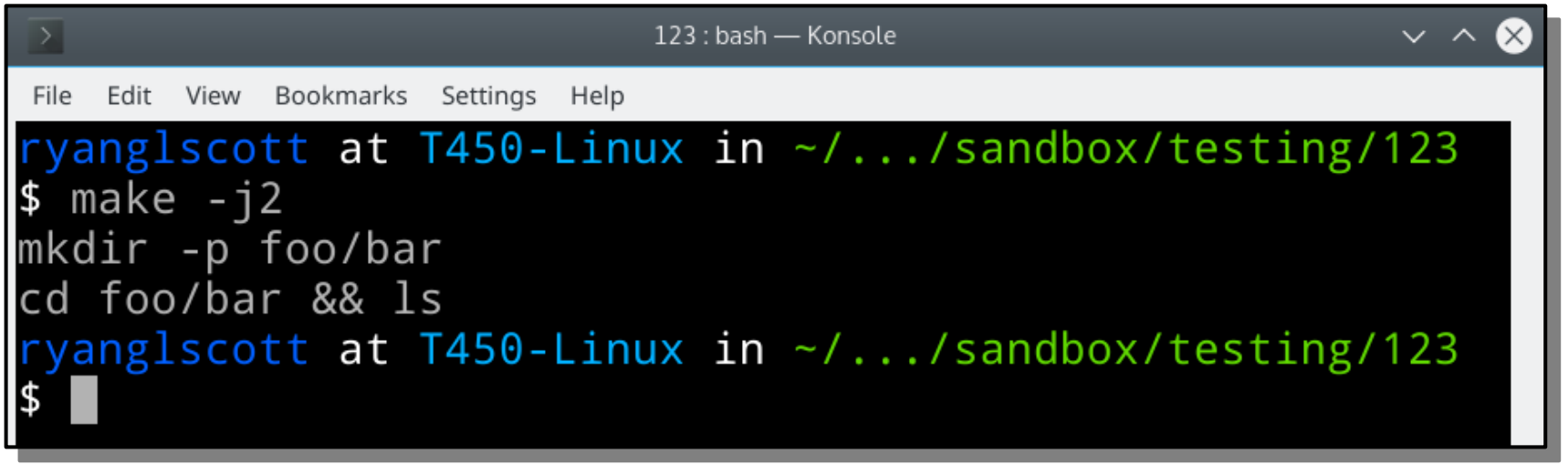
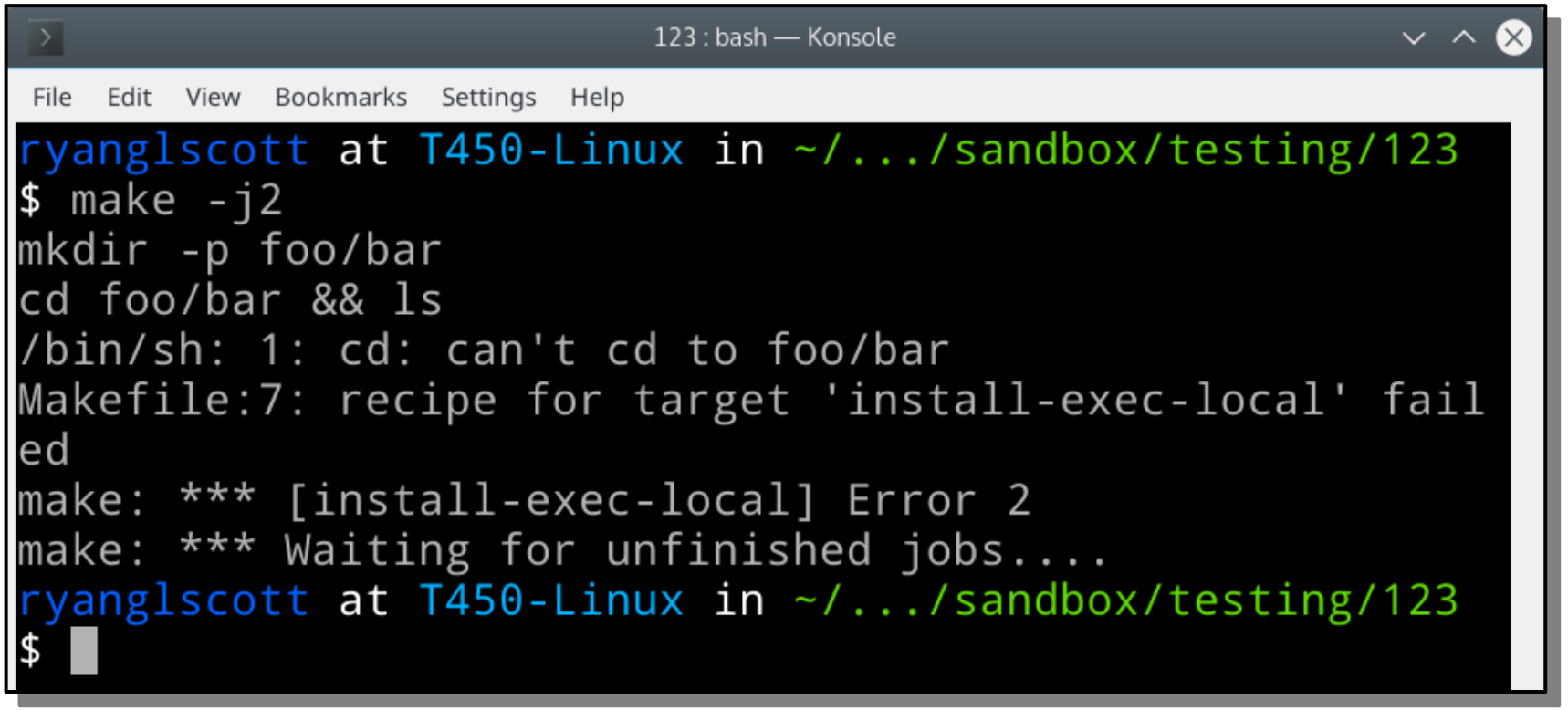
all: create-bindir install-exec-local

DESTDIR=foo
bindir=bar

install-exec-local:
	cd $(DESTDIR)/$(bindir) && ls
create-bindir:
	mkdir -p $(DESTDIR)/$(bindir)
```


123 : bash — Konsole
File Edit View Bookmarks Settings Help
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$ make -j1
mkdir -p foo/bar
cd foo/bar && ls
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$


123 : bash — Konsole
File Edit View Bookmarks Settings Help
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$ make -j2
mkdir -p foo/bar
cd foo/bar && ls
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$


123 : bash — Konsole
File Edit View Bookmarks Settings Help
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$ make -j2
mkdir -p foo/bar
cd foo/bar && ls
/bin/sh: 1: cd: can't cd to foo/bar
Makefile:7: recipe for target 'install-exec-local' fail
ed
make: *** [install-exec-local] Error 2
make: *** Waiting for unfinished jobs....
ryanglscott at T450-Linux in ~/.../sandbox/testing/123
$

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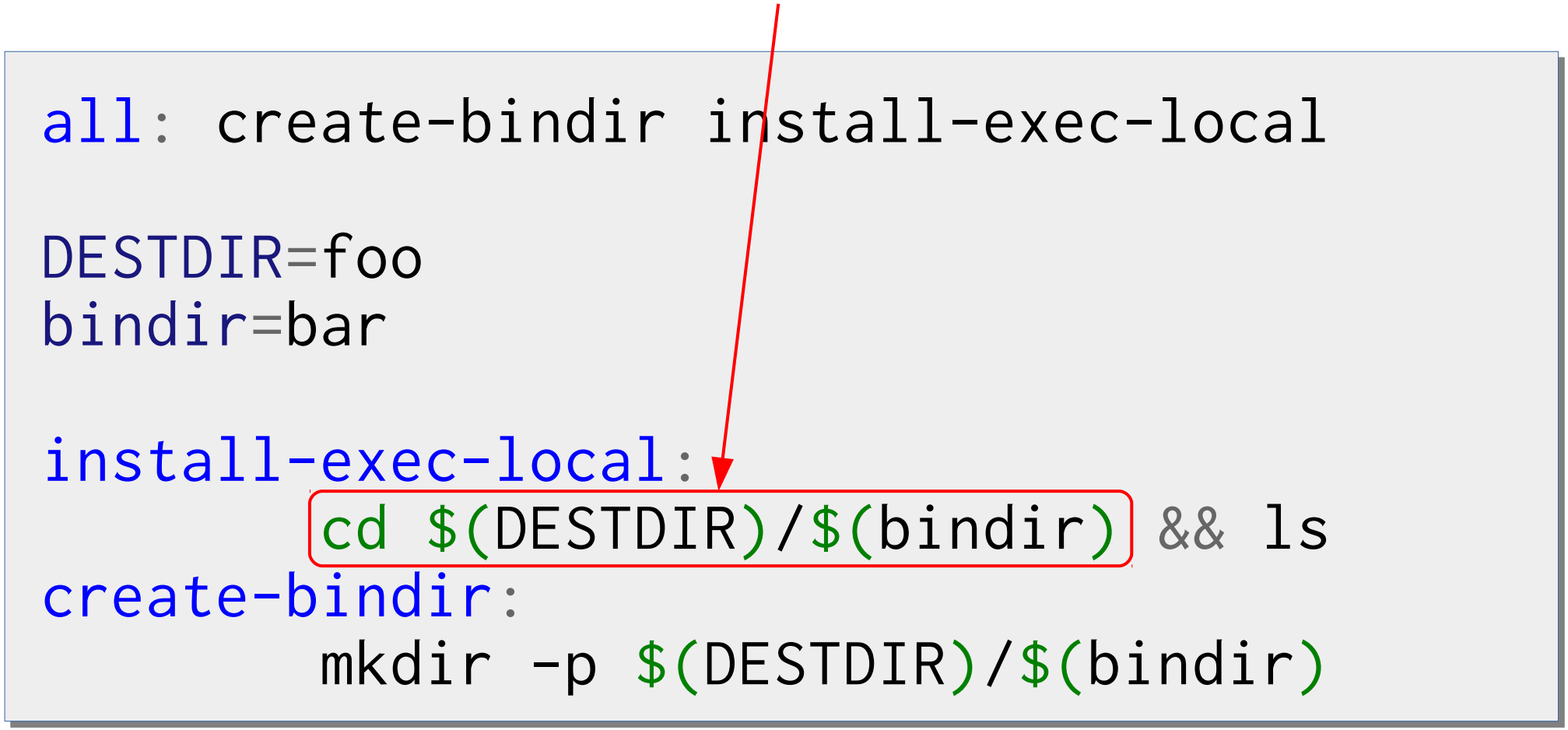
```

Race condition!



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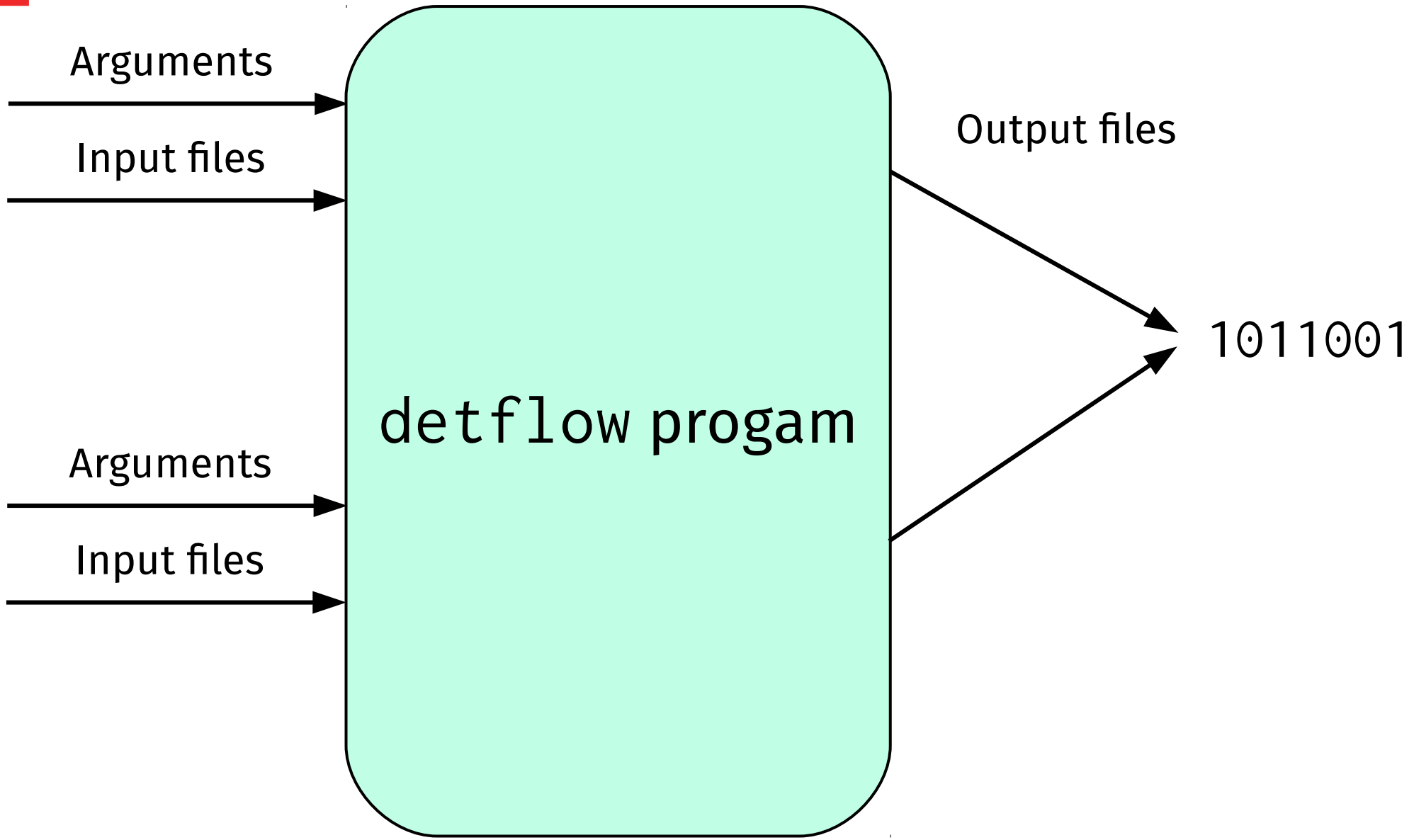
```

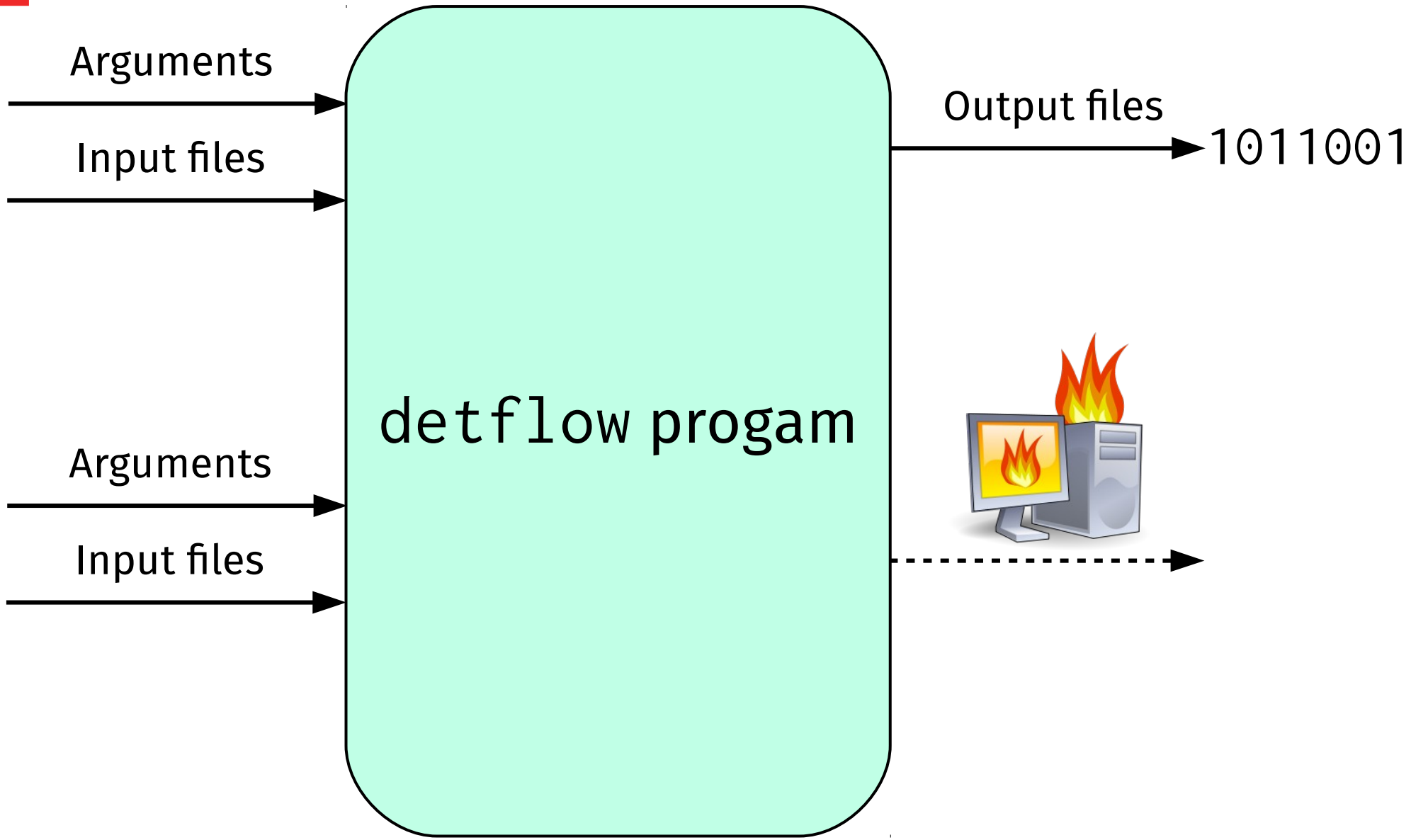
The `detflow` guarantee

If a program is invoked under detflow twice with identical inputs, and given sufficient machine resources to complete, then **both invocations will produce the same output**.

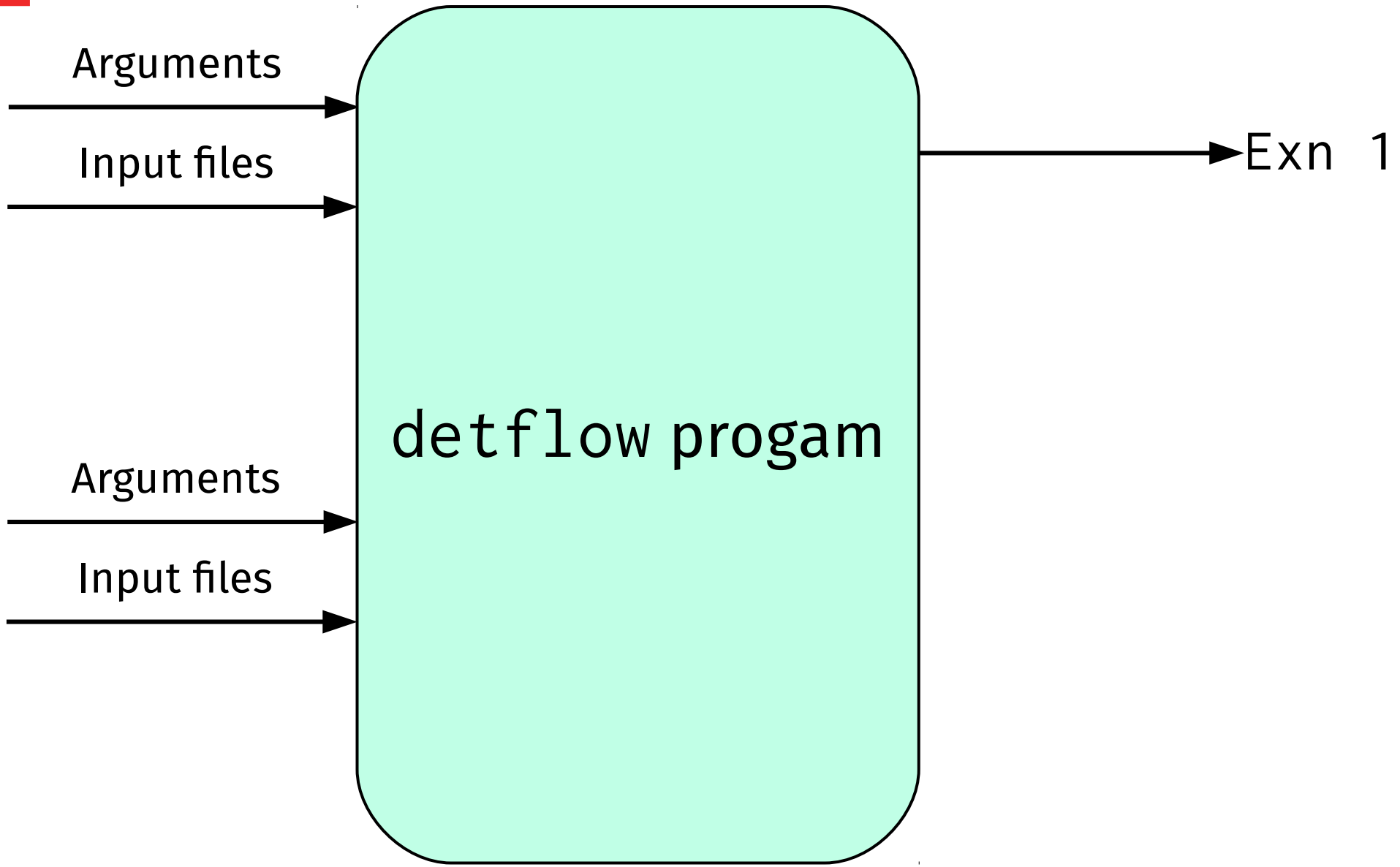
Quasideterminism



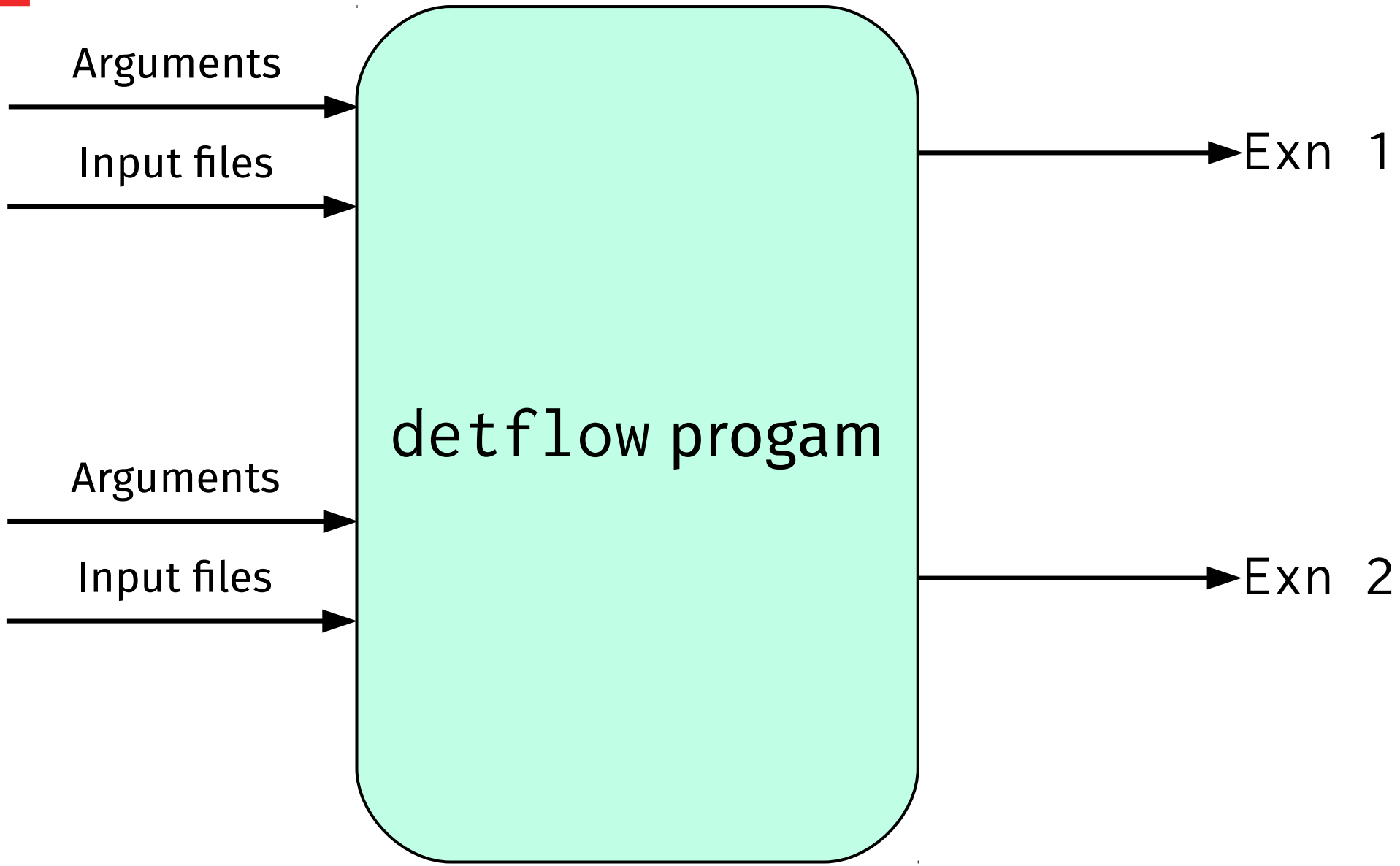
Quasideterminism



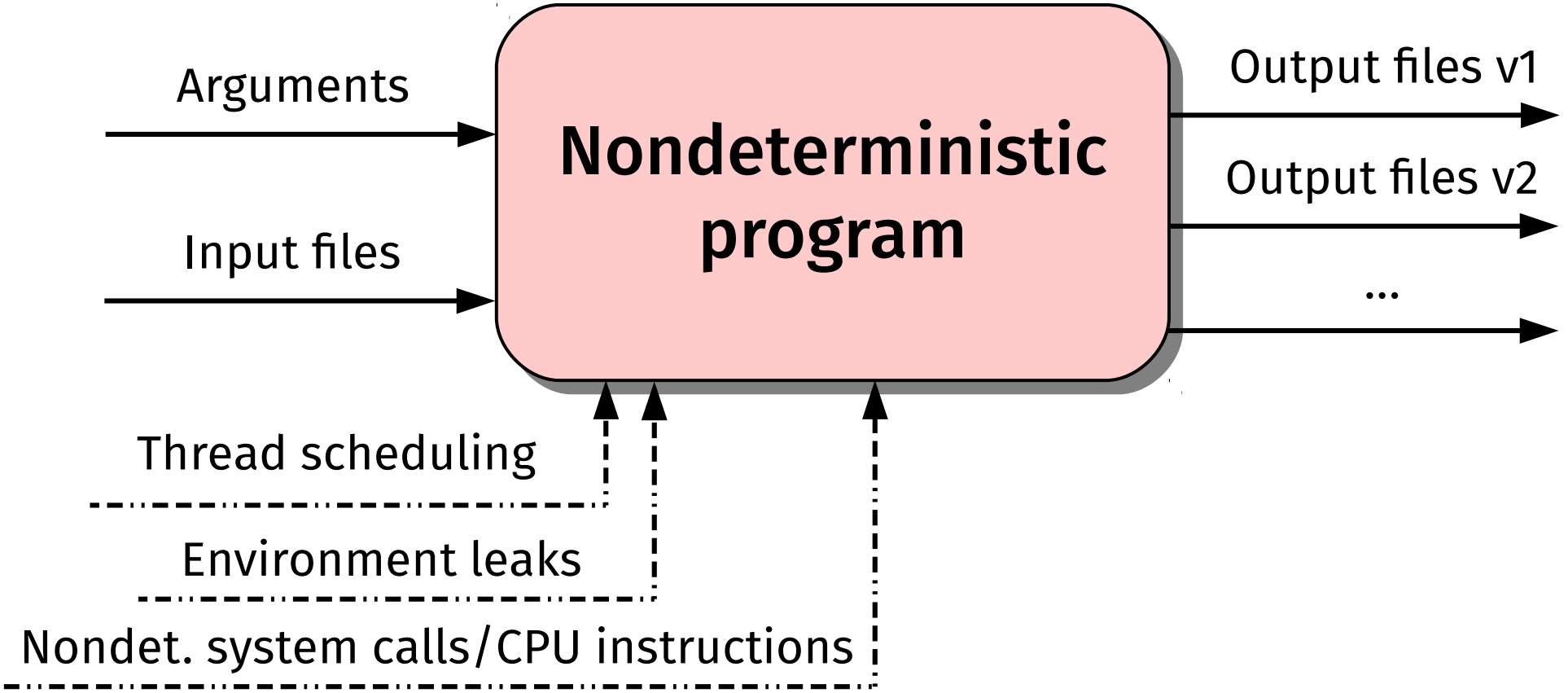
Quasideterminism



Quasideterminism




Arguments
Input files
Nondeterministic program
Output files v1
Output files v2
...


Arguments
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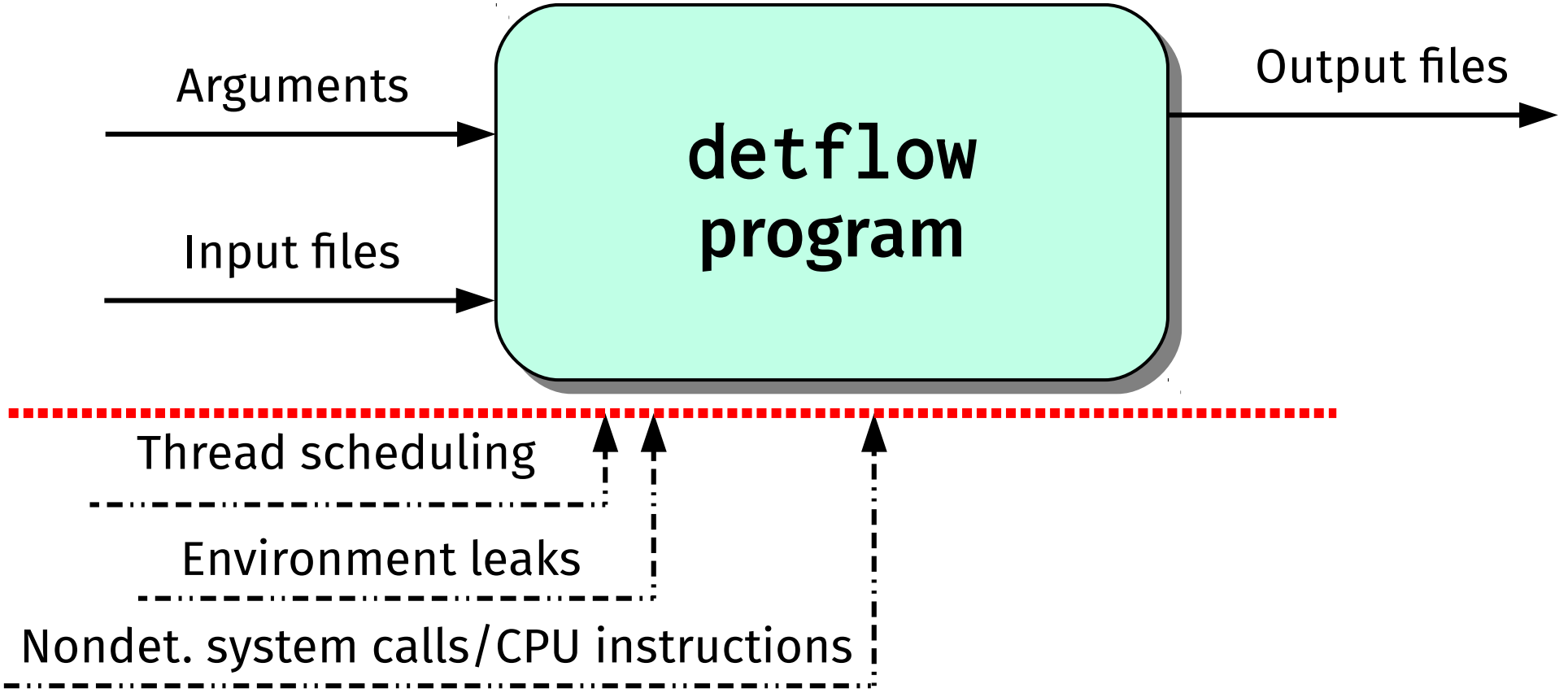
Thread scheduling
Environment leaks
Nondet. system calls/CPU instructions


Arguments
Input files
detflow
program
Output files
Thread scheduling
Environment leaks
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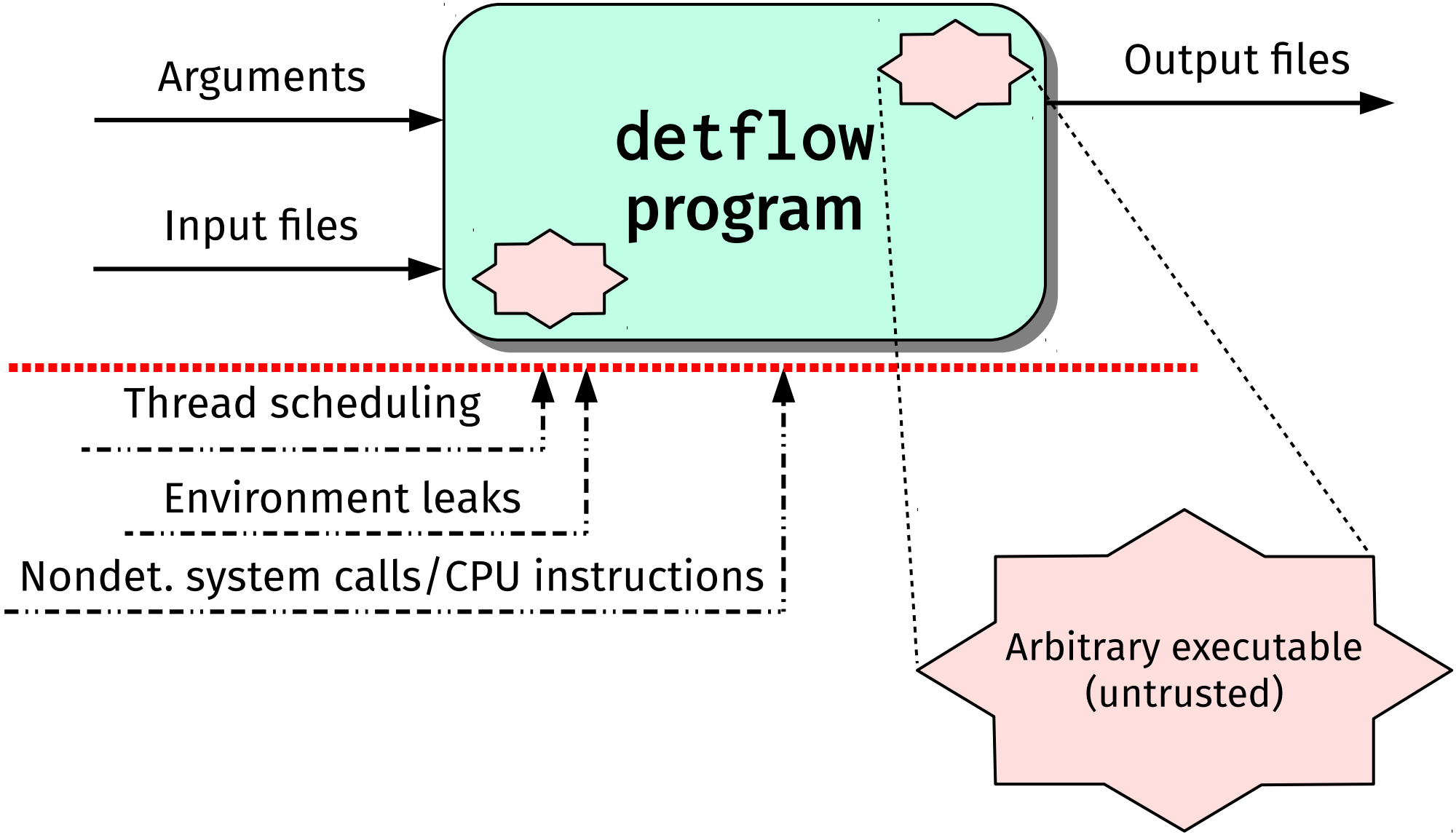
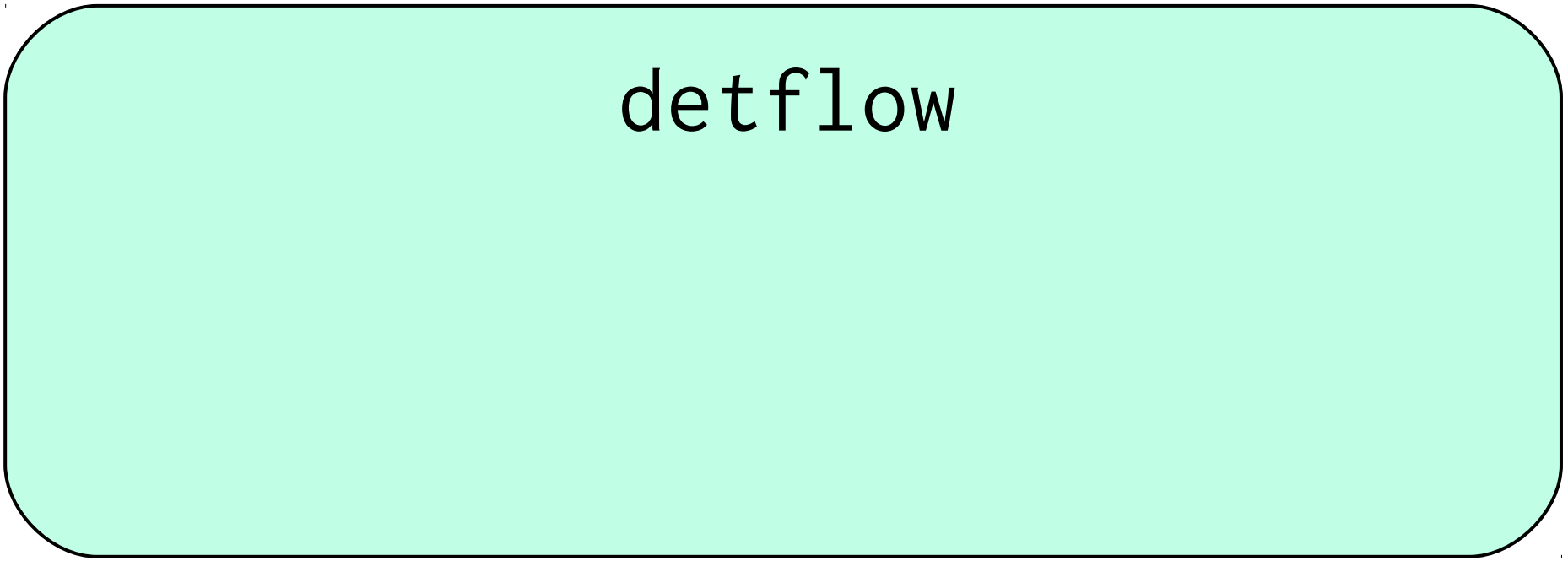
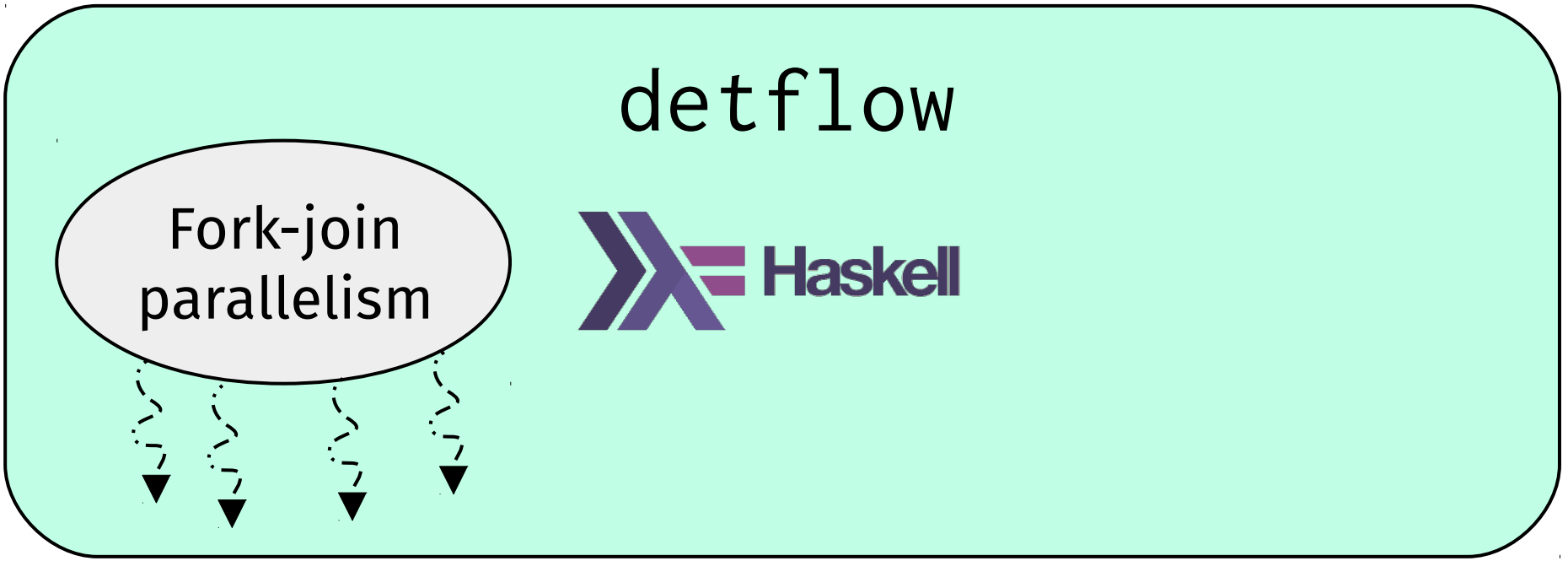
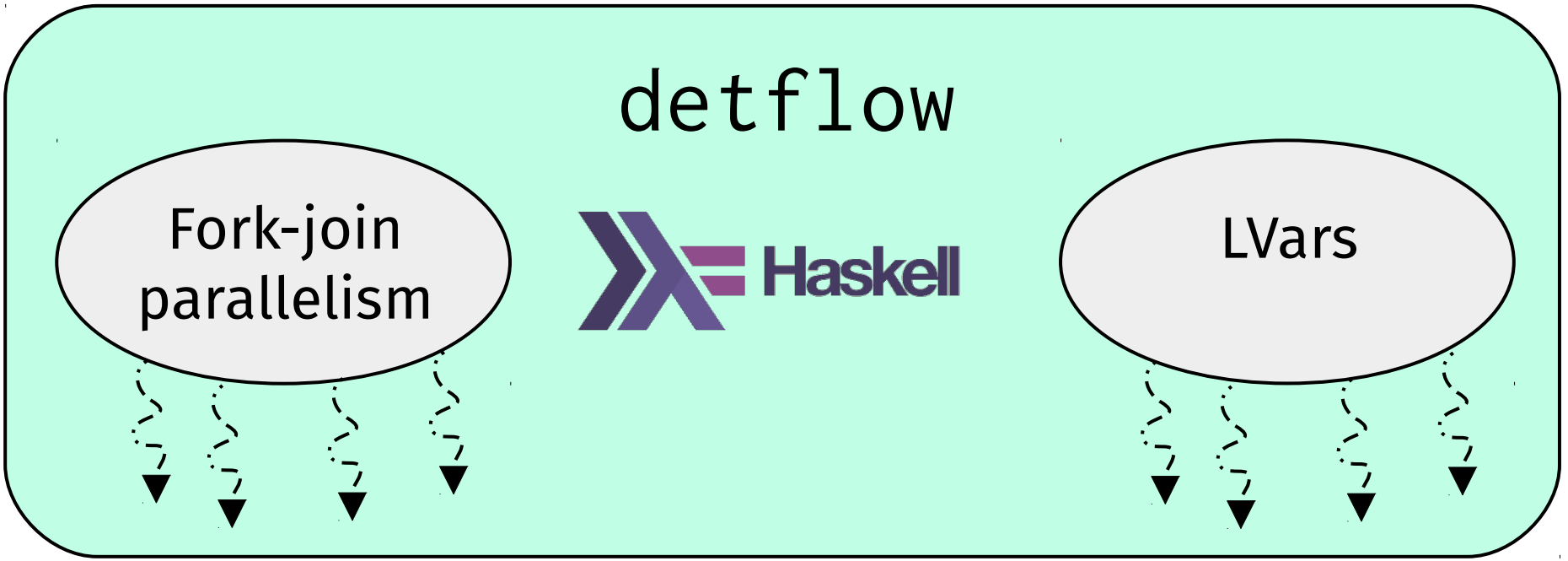

Arguments
Input files
detflow
program
Output files
Thread scheduling
Environment leaks
Nondet. system calls/CPU instructions
Arbitrary executable
(untrusted)


detflow

detflow


detflow
Fork-join
parallelism
Haskell


detflow
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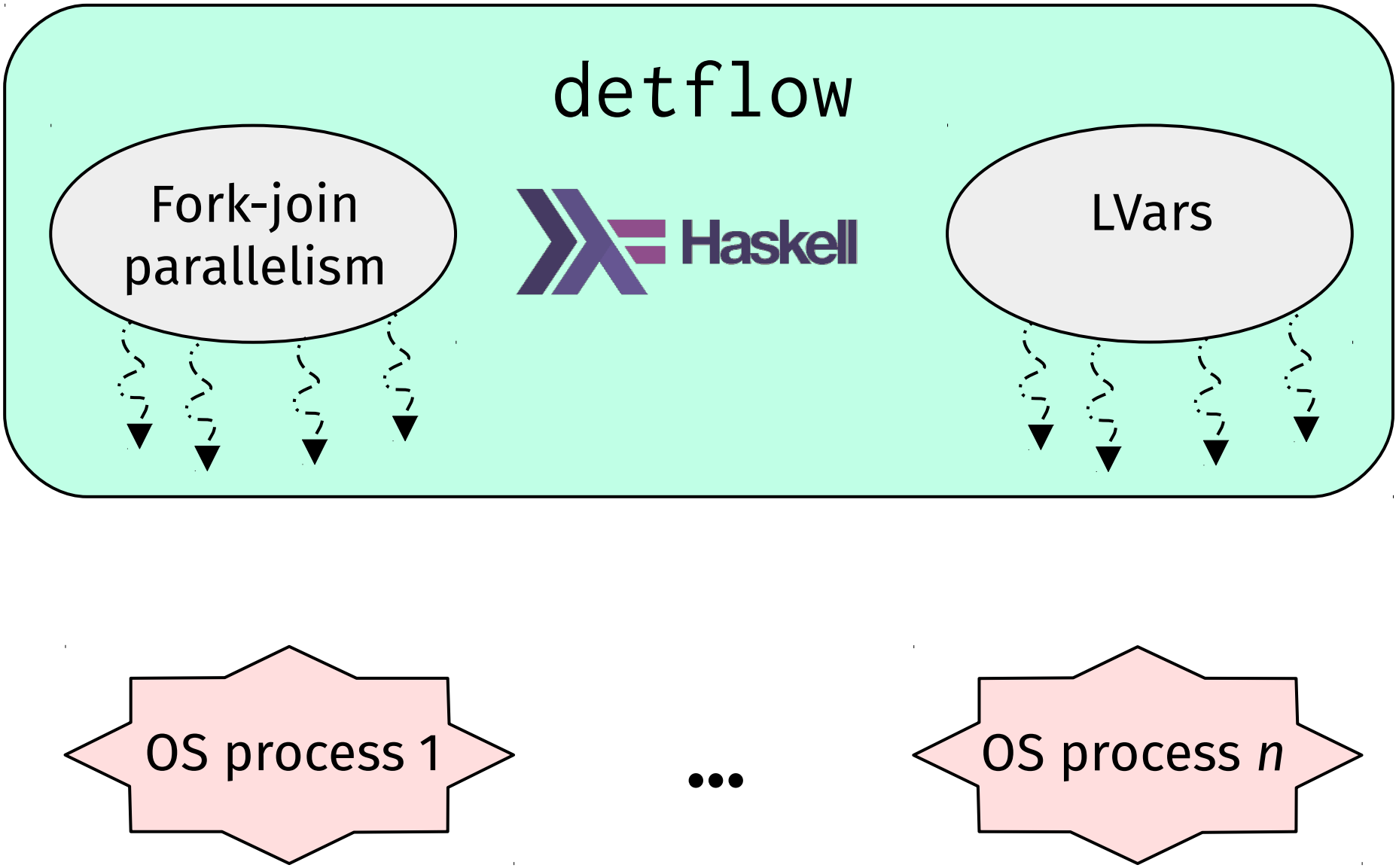
LVars


detflow
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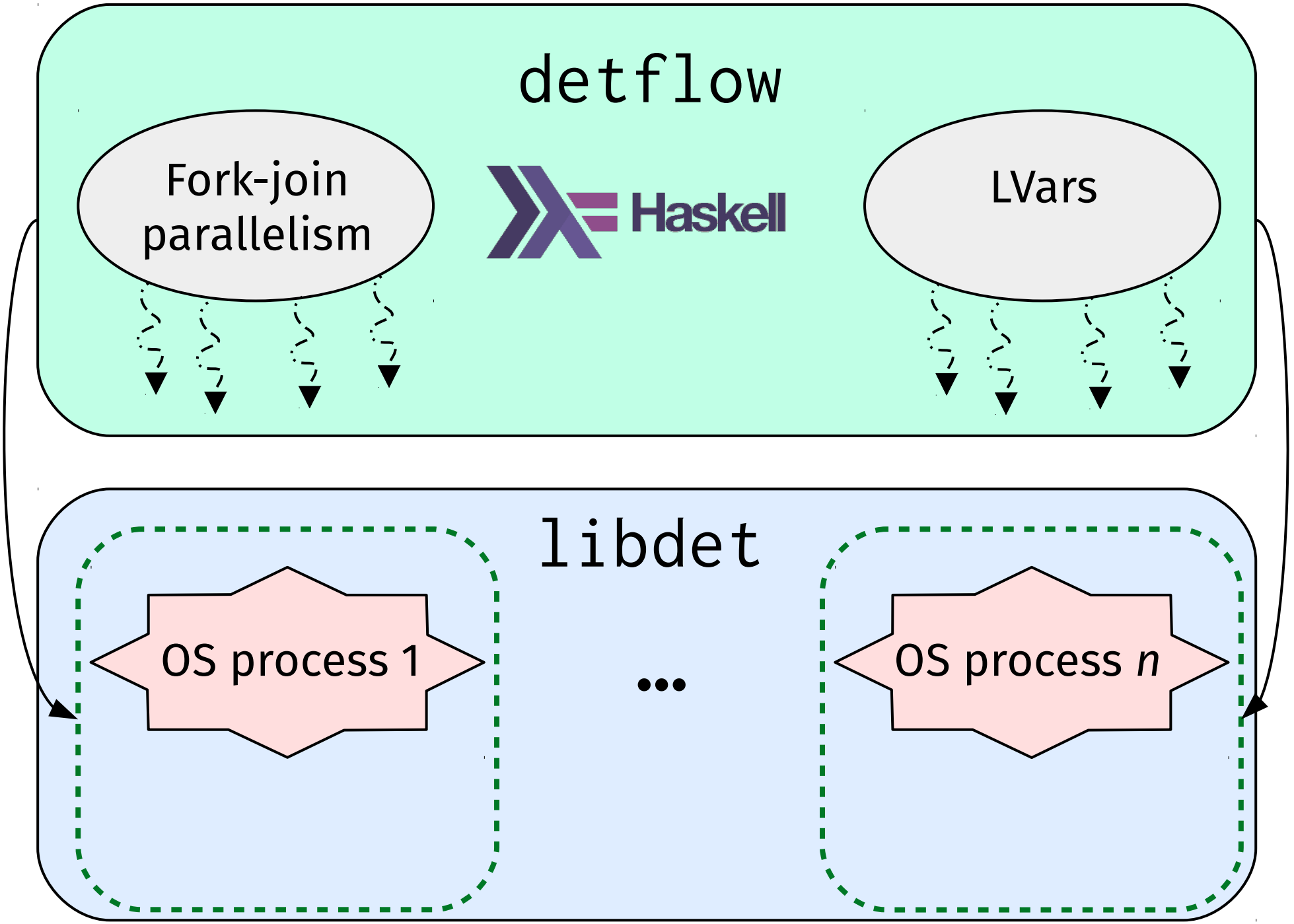
OS process 1
...
OS process *n*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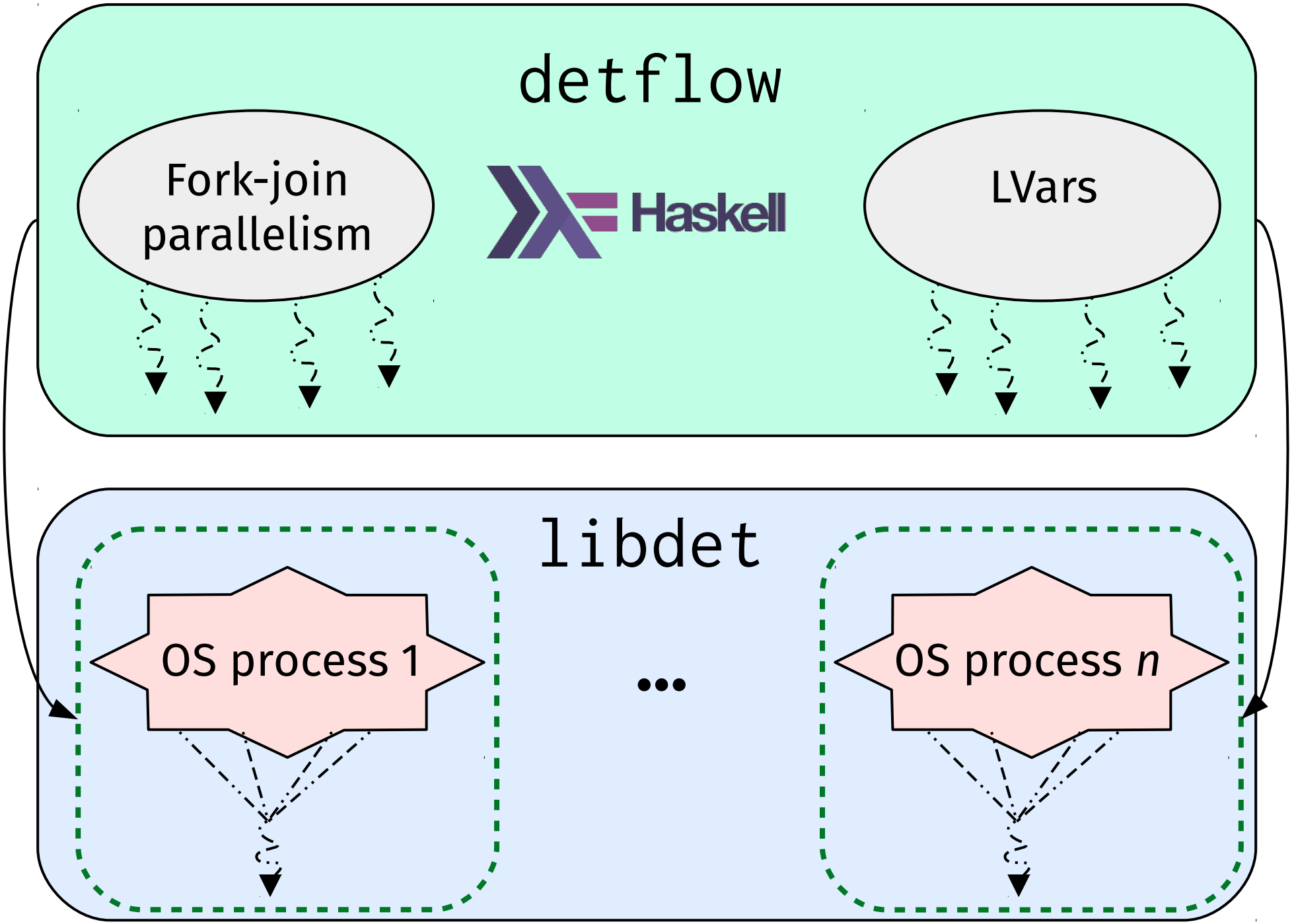
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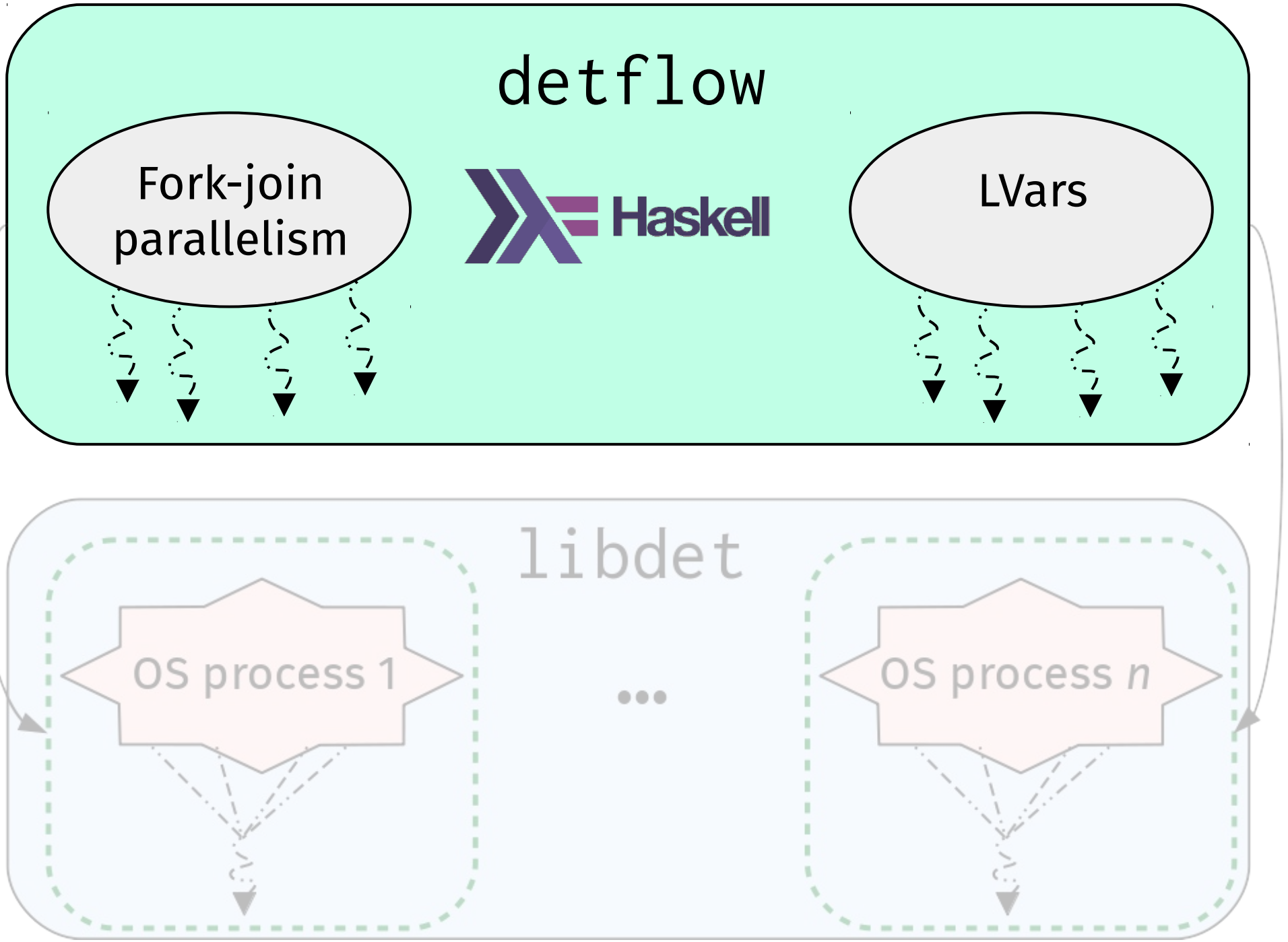
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Traditional Haskell program

```
main :: IO ()
```

Traditional Haskell program

```haskell
main :: IO ()
     -- ^ Lots of ways to sneak in
     --   nondeterminism!
```

`detflow` Haskell programs

```
main :: DetIO ()
```

DetIO

```
data DetIO a -- Abstract
```

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-- Expose only deterministic API calls
getLine  :: DetIO String
putStrLn :: String -> DetIO ()
-- etc.
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Key idea: Only expose deterministic operations that can be *composed* in a deterministic fashion

DetIO

```
data DetIO a -- Abstract
-- Expose only deterministic API calls
getLine  :: DetIO String
putStrLn :: String -> DetIO ()
-- etc.
```

```
main :: DetIO ()
main = do x <- getLine
          system (“gcc -c ” ++ x)
          putStrLn x
```

Parallel file access

- `detflow` uses the filesystem as a mutable, shared store
- Should this be allowed?

```
readFile  :: FilePath -> DetIO String
writeFile :: FilePath -> String
          -> DetIO String
fork      :: DetIO a -> DetIO (Thread a)
```

Problem: racing file access

Thread 1

```
do writeFile “foo.txt”
     “Hello, World”
```

Thread 2

```
do foo <- readFile “foo.txt”
   if foo == “Hello, World”
      then ...
      else ...
```

Problem: racing file access

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Solution: permissions

- Every thread holds separate permissions on system filepaths

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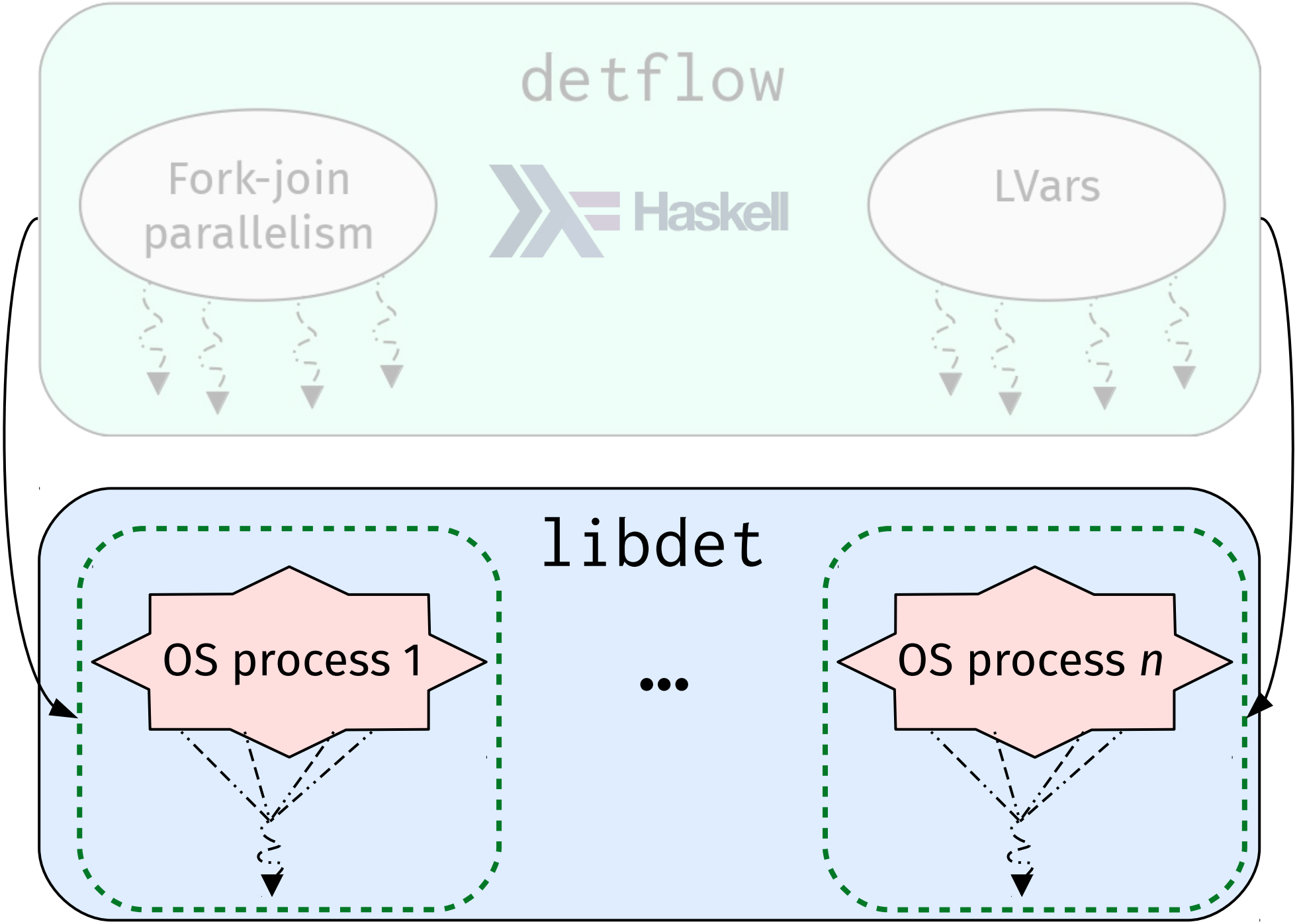
	/abcdef/	ghijkl/	mnopqr
Thread 1	R	R	RW
Thread 2	R	R	

Parallel file access, revisited

```
data Perm -- (R/RW) + path

forkWPerms :: [PathPerm] -> DetIO a
           -> DetIO (Thread a)
```

- `readFile` and `writeFile` must respect the permissions in a thread's local state


detflow
Fork-join parallelism
Haskell
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OS process 1
...
OS process *n*

`system` shell calls

```
system :: String -> DetIO ()

main :: DetIO ()
main = system “gcc foo.c -o foo”
```

libdet

`libdet` must intercept potential sources of nondeterminism at runtime.

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Reading from “banned” directories

- /dev/urandom
- /proc
- etc.

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Reading from “banned” directories

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- /proc
- etc.

Solution

- Intercept calls to fopen() (with LD_PRELOAD), error if they read anything blacklisted

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Uncontrolled concurrency

- e.g., with pthreads

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Uncontrolled concurrency

- e.g., with `pthreads`

Solution

- Intercept calls to `pthread_create()` (with `LD_PRELOAD`) to run everything sequentially

libdet

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Nondeterministic OS properties

- e.g., reading addresses returned by `mmap()`

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- e.g., reading addresses returned by `mmap()`

Solution

- Disable address-space layout randomization (ASLR)

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Path operations with insufficient permissions

- e.g., reading `/foo` without read permissions on `/foo`

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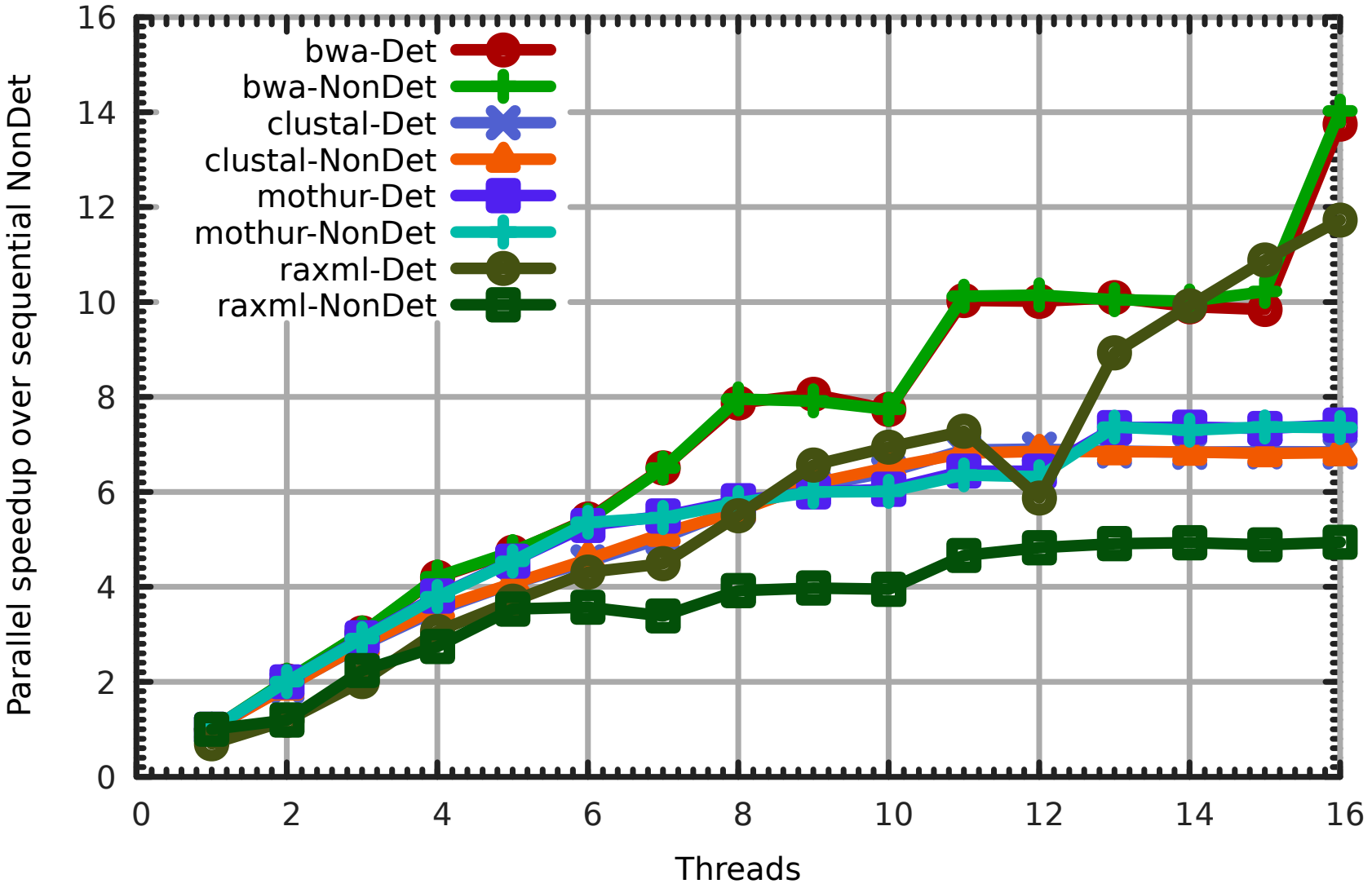
Solution

- Inherit permissions from `detflow`!

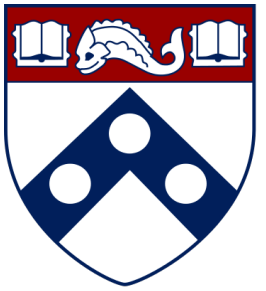
Bioinfo. apps, parallel speedup



(Higher is better)

Future work

- Reach closer to catching *all* sources of nondeterminism in runtime
- Dynamic (at-runtime) checkout of permissions
- Make more programs feasible to determinize



Penn

UNIVERSITY of PENNSYLVANIA

`detflow` can be used to construct and run parallel batch processing jobs deterministically (including legacy binaries) with less than 5% overhead.

Approach:

- Statically-typed root process: allows multithreading
- Each thread may shell out to legacy binaries: internally sequentialized by sandbox
- Legacy binaries can create subprocesses: also sequentialized
- Each thread and subprocess holds distinct file system permissions to prevent races

`https://github.com/iu-parfunc/detmonad`