Imposing a Memory Management Discipline on Software Deployment

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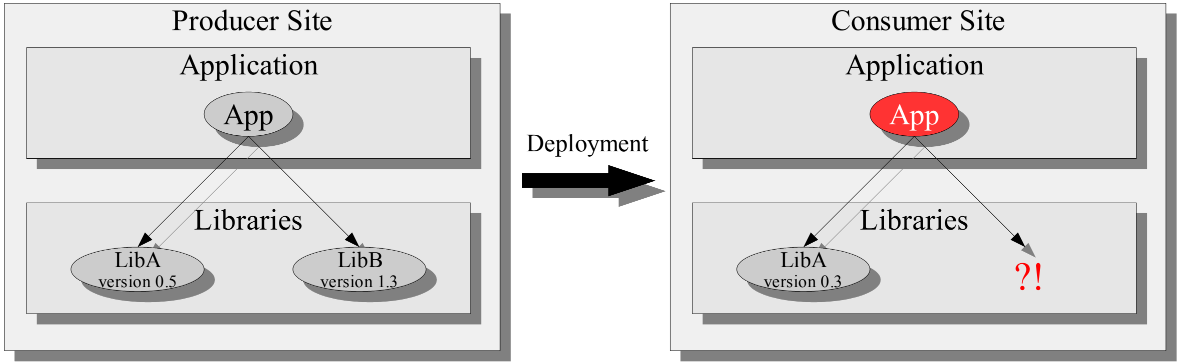
The problem

Software deployment (the act of transferring software to another system) is surprisingly hard.

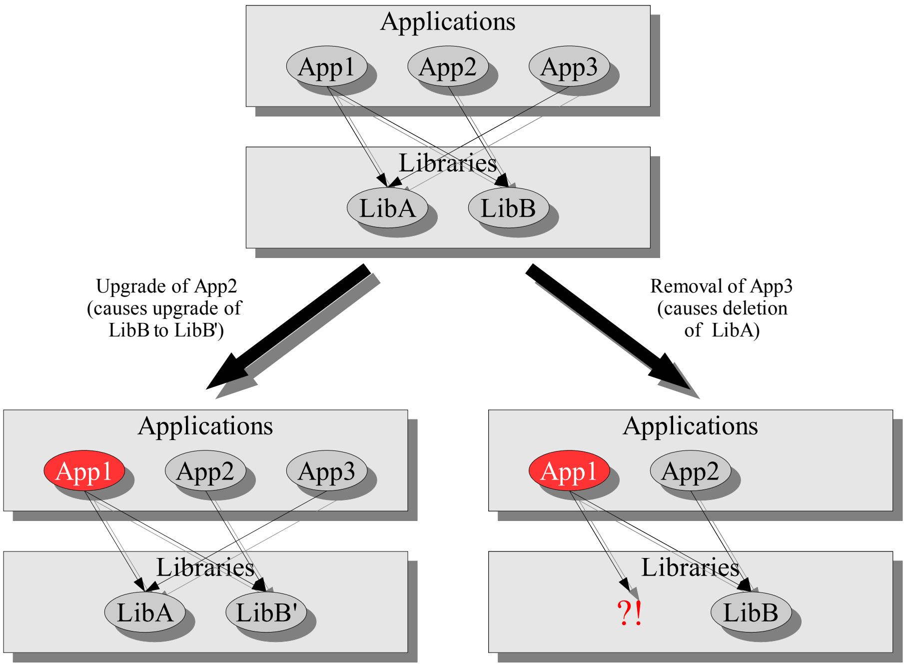
- Must ensure correctness.
  - Dependency information must be complete.
  - Component compatibility.
  - Atomicity of upgrades/downgrades.
  - Safe removal of unused components.

- Lot of effort.
  - Packaging is often (semi-)manual.
  - Source/binary distributions.
  - Must package each variant.
  - Don't want to install all component separately.
  - Especially a problem with small-grained reuse (e.g., StrategoXT).
- Should support multiple versions/variants.
  - Test a component before production use.
  - Multiple users.

Incomplete Dependencies



Interference



The core problems

- Must prevent *unresolved component dependencies*.
  - A component should never refer to another component not present on the target system.
  - Hard to validate; how to detect use of undeclared dependencies?
  - Timeline issues: (related) dependencies at build and run time.
- Must prevent *component interference*.
  - Different versions/variants of a component (or completely unrelated components) should not interfere with each other.
  - Upgrades are usually *destructive*. E.g., only one `/usr/bin/gcc`.

Software deployment as a memory-management problem

memory	$\Leftrightarrow$	disk
objects (values)	$\Leftrightarrow$	components
addresses	$\Leftrightarrow$	path names
pointers are numbers	$\Leftrightarrow$	pointers are strings
pointer dereference	$\Leftrightarrow$	I/O
pointer arithmetic	$\Leftrightarrow$	string operations
dangling pointer	$\Leftrightarrow$	reference to absent component
object graph	$\Leftrightarrow$	dependency graph
persistence/serialisation	$\Leftrightarrow$	deployment

Closures

- Correct deployment of component c requires distributing the smallest set of components C containing c closed under the "has-a-pointer-to" relation.
- I.e., we have to discover the pointer graph.

Determining the pointer graph

- This is just what garbage collectors for programming languages have to do.
- GC requires a *pointer discipline*:
  - Ideally, entire memory layout is known, and no arbitrary pointer formation (e.g., integer $\Leftrightarrow$ pointer casts).
  - But even C/C++ has rules: pointer arithmetic is not allowed to move a pointer out of the object it points to.
  - This is why *conservative GC* works: assume that everything that looks like a pointer *is* a pointer.
- But software components do not have any pointer discipline.
  - Any string can be a pointer.
  - Pointer arithmetic and dereferencing directories can produce pointers to any object in the file system.

A pointer discipline

Solution: *impose* a pointer discipline.

- Each component should include in its a path a unique identifying string.

  `/nix/store/15373f8c93776a3a5f86fec65914e59d-subversion-0.37.0`

  `/nix/store/b70b48128d8d13725346684ea43963c4-strategoxt-0.9.3`

- Then we can apply conservative GC techniques to determine the pointer graph.

Scanning for pointers

```
080   00 80 04 08 34 41 01 00 34 41 01 00 05 00 00 00   |....4A..4A......|
090   00 10 00 00 01 00 00 00 34 41 01 00 34 d1 05 08   |........4A..4...|
0a0   34 d1 05 08 b4 04 00 00 c4 04 00 00 06 00 00 00   |4...............|
0b0   00 10 00 00 02 00 00 00 7c 41 01 00 7c d1 05 08   |........|A..|...|
0c0   7c d1 05 08 90 01 00 00 90 01 00 00 06 00 00 00   ||...............|
0d0   04 00 00 00 04 00 00 00 60 01 00 00 60 81 04 08   |........`...`...|
0e0   60 81 04 08 20 00 00 00 20 00 00 00 04 00 00 00   |`...............|
0e0   60 81 04 08 20 00 00 00 20 00 00 00 04 00 00 00   |`...............|
0f0   04 00 00 00 50 e5 74 64 20 41 01 00 20 c1 05 08   |....P.td A......|
100   20 c1 05 08 14 00 00 00 14 00 00 00 04 00 00 00   |................|
110   04 00 00 00 2f 6e 69 78 2f 73 74 6f 72 65 2f 38   |..../nix/store/8|
120   64 30 31 33 65 61 38 37 38 64 30 66 66 38 34 63   |d013ea878d0ff84c|
130   62 31 37 38 61 34 62 31 36 30 65 34 30 32 36 2d   |b178a4b160e4026-|
140   67 6c 69 62 63 2d 32 2e 33 2e 32 2f 6c 69 62 2f   |glibc-2.3.2/lib/|
150   6c 64 2d 6c 69 6e 75 78 2e 73 6f 2e 32 00 00 00   |ld-linux.so.2...|
160   04 00 00 00 10 00 00 00 01 00 00 00 47 4e 55 00   |............GNU.|
170   00 00 00 00 02 00 00 00 02 00 00 00 05 00 00 00   |................|
180   83 00 00 00 bb 00 00 00 58 00 00 00 ab 00 00 00   |........X.......|
190   ae 00 00 00 a1 00 00 00 00 00 00 00 6c 00 00 00   |............l...|
```

Risks

- Like all conservative GC approaches, there is a risk of *pointer hiding*.
  - Compressed executables.
  - UTF-16 encoded paths.
- Hasn't happened yet, though.

Persistence

- The unique strings should be cryptographic hashes of all inputs involved in building the component.
- This prevents address collisions in the target address space (i.e., path name collisions in the target file system).

Nix expressions

Component description in a pure functional language.

```
{stdenv, fetchurl, aterm, sdf}:

derivation {
  name = "strategoxt-0.9.3";
  system = stdenv.system;
  builder = ./builder.sh;
  src = fetchurl {
    url = ftp://.../strategoxt-0.9.3.tar.gz;
    md5 = "3425e7ae896426481bd258817737e3d6";
  };
  inherit stdenv, aterm, sdf;
}
```

Nix expressions (2)

Build script:

```
#! .../bin/sh

buildinputs="$aterm $sdf"
. $stdenv/setup || exit 1

tar zxf $src || exit 1
cd stratego* || exit 1
./configure --prefix=$out --with-aterm=$aterm \
  --with-sdf=$sdf || exit 1
make || exit 1
make install || exit 1
```

Nix expressions (3)

Composition: (`all-packages.nix`)

```
rec {
  strategoxt = (import ../development/compilers/strategoxt) {
    inherit fetchurl stdenv aterm;
    sdf = sdf2;
  };
  aterm = (import ../development/libraries/aterm) {
    inherit fetchurl stdenv;
  };
  sdf2 = (import ../development/tools/parsing/sdf2) {
    inherit fetchurl stdenv aterm getopt;
  };
  stdenv = ...;
  ...
}
```

Nix expressions (4)

Consistency between components / variation points:

```
{ localServer ? false, httpServer ? false
, sslSupport ? false, swigBindings ? false
, stdenv, fetchurl
, openssl ? null, httpd ? null, db4 ? null, swig ? null
}:

assert expat != null;
assert localServer -> db4 != null;
assert httpServer -> httpd != null && httpd.expat == expat;
assert sslSupport -> openssl != null &&
  (httpServer -> httpd.openssl == openssl);
assert swigBindings -> swig != null && swig.pythonSupport;

derivation {
  name = "subversion-0.37.0";
  ...  }
```

User operations

To build and install StrategoXT:

```
$ nix-env -if .../all-packages.nix strategoxt
```

When a new version comes along:

```
$ nix-env -uf .../all-packages.nix strategoxt
```

If it doesn't work:

```
$ nix-env --rollback
```

Delete unused components:

```
$ nix-collect-garbage
```

Transparent binary deployment

On the producer side:

```
$ nix-push $(nix-instantiate .../all-packages.nix) \
   http://server/cache
```

On the client side:

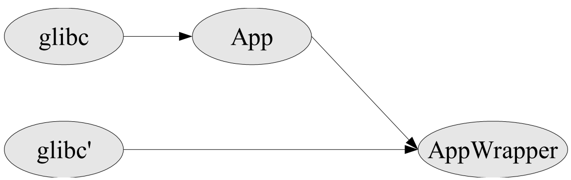
```
$ nix-pull http://server/cache
```

Installation will now reuse pre-built components, *iff* they are exactly the same.

FAQ

"How to handle security patches (e.g., in the C library)? There you *do* want destructive updates."

- No you don't. How to roll-back if the patch breaks stuff?
- Just deploy new Nix expressions; to the extent that there is sharing with old ones, no rebuilds / redownloads are necessary.
- In the case of dynamic libraries, wrapper packages can be used to prevent a mass rebuild.



- A nice aspect of Nix is that we can generically find all components impacted by some source file.

Future work

- Build management $\Rightarrow$ unify the whole build and deployment problem into a single formalism.
- Shared Nix stores $\Rightarrow$ thanks to cryptographic hashes we can allow closures to be shared among different users without fear of trojans etc.
- (G)UI for selecting variants; interesting satisfiability problem.
- Should address *component state*.

Related work

- Deployment / package managers: RPM, Gentoo, etc.
  - Unsafe — incomplete deployment, not atomic.
  - Little or no support for variability.
- Build managers: Make.
  - Unsafe.
- Better build managers: Vesta, ClearCase.
  - Do not do deployment.
  - Cannot handle retained dependencies.
  - Not portable; rely on virtual file system.
- Autoconf.
  - Automatic adaptation to target environment is dangerous; shouldn't be done by end-user.

Conclusion

- Concurrent installation of multiple versions and variants.
- Atomic upgrades and downgrades.
- Multiple user environments.
- Safe dependencies.
- Complete deployment.
- Transparent source and binary deployment.
- Safe garbage collection.
- Portability.

More information

- Website: `http://www.cs.uu.nl/groups/ST/Trace/Nix`.
- Eelco Dolstra, Eelco Visser and Merijn de Jonge. *Imposing a Memory Management Discipline on Software Deployment*. In *26th International Conference on Software Engineering (ICSE-2004)*, May 2004, Edinburgh (to appear).