Imposing a Memory Management Discipline on Software Deployment

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Outline

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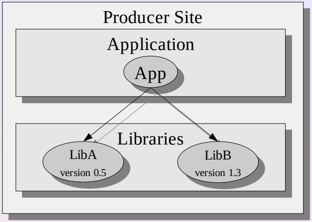
Why Does Software Deployment Fail?

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

- It's hard to ensure correctness (the software should work the same on the source and target systems).
- It's too much work.
- Deployment systems tend to be inflexible.

Unresolved Component Dependencies



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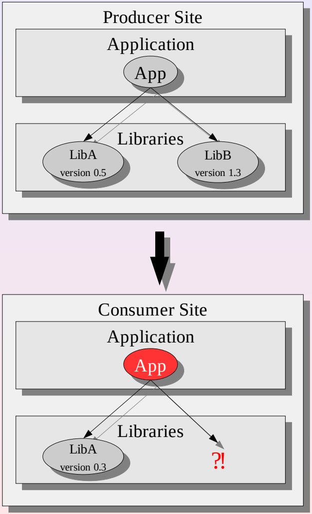

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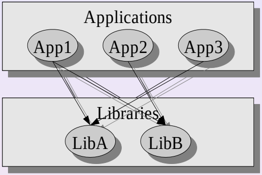

Operations on a component (install, upgrade, remove) often break other components (*interference*). E.g.:

- Upgrade of App2 breaks App1 due to upgrade of LibB to LibB'
- Removal of App3 breaks App1 due to removal of LibA

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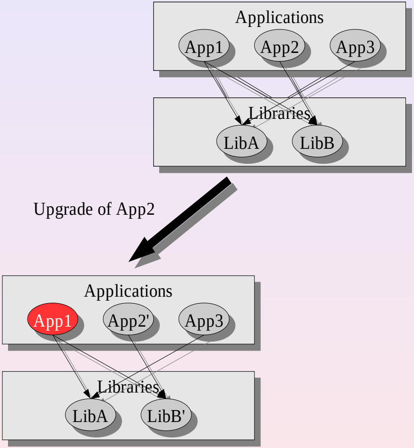

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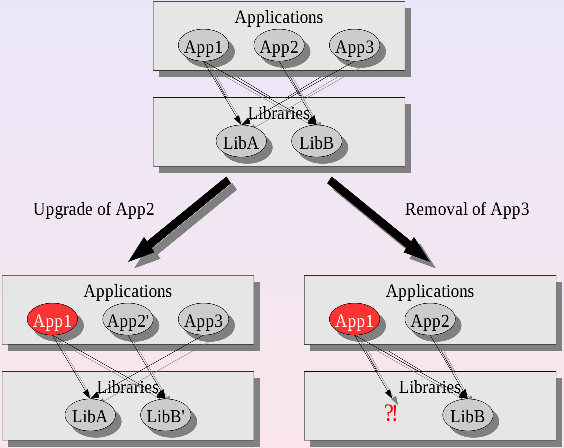

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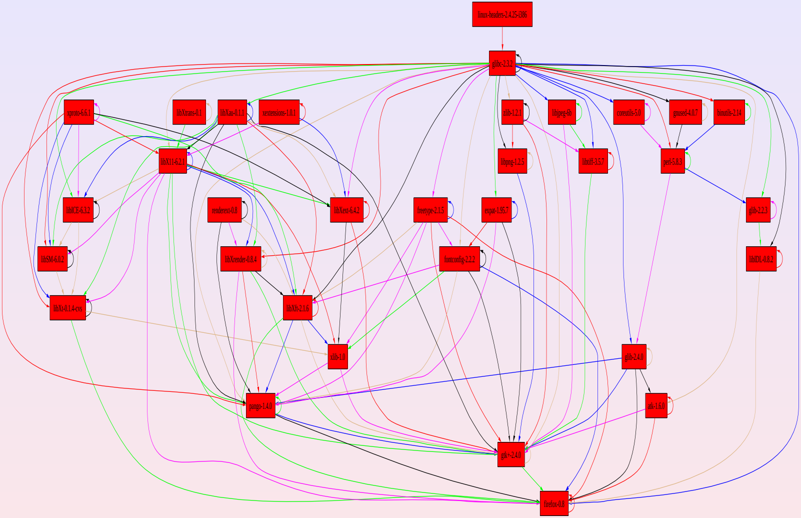
This Is a Big Problem



Note: these are runtime dependencies;
there are still more build time dependencies.

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Deployment as Memory Management

memory	⇔	disk
objects (values)	⇔	components
addresses	⇔	path names
pointer dereference	⇔	I/O
pointer arithmetic	⇔	string operations
dangling pointer	⇔	reference to absent component

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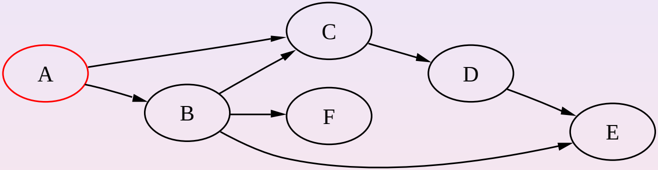
Deployment Requires Closures

- Correct deployment of component c requires distributing the smallest set of components C containing c closed under the "has-a-pointer-to" relation.



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- This is exactly what garbage collectors for programming languages have to do.

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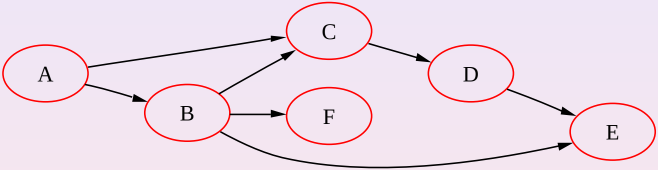

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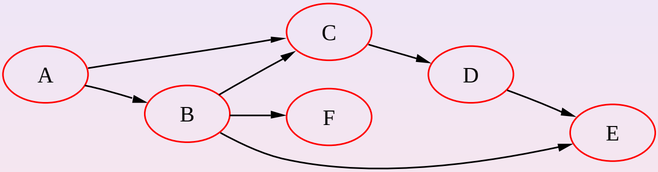

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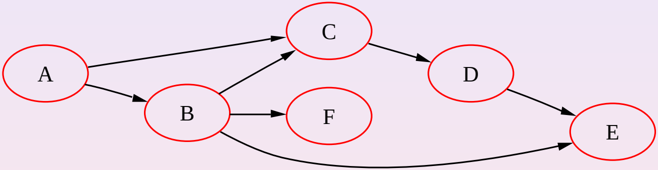

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Pointer Discipline in PLs

- GC requires a *pointer discipline*:
  - Ideally, entire memory layout is known, and no arbitrary pointer formation (e.g., integer ⇔ 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.

Imposing a Pointer Discipline on the FS

```
/nix/store
├── eeeeaf42e56b-subversion-0.32.1
│   ├── bin
│   │   └── svn
│   └── lib
│       ├── libsvn_wc.so
│       └── libsvn_ra_dav.so
├── a17fb5a6c48f-openssl-0.9.7c
│   └── lib
│       └── libssl.so.0.9.7
└── 8d013ea878d0-glibc-2.3.2
    └── lib
        └── libc.so.6
```

- Each component should include in its a path a unique identifying string.
- Then we can apply conservative GC techniques to find pointers. . .
- . . . which gives us the pointer graph!

Imposing a Pointer Discipline on the FS

/nix/store/eeeeaf...-subversion/bin/svn:

```
2000000020000000040000000   ............
0400000050e57464e0420100   ....P.td.B..
e0c20508e0c205081400000000   ............
1400000004000000004000000   ............
2f6e69782f73746f72652f38   /nix/store/8
643031336561383738643038   d013ea878d08
663233346164353462303131   f234ad54b011
3138323135646662d676c6962   18215df-glib
632d322e332e322f6c69622f   c-2.3.2/lib/
6c642d6c696e75782e736f2e   ld-linux.so.
3200000004000000010000000   2...........
0100000474e550000000000   ....GNU.....
020000000000000000000000   ............
83000000bb000000580000000   ........X...
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663233346164353462303131   f234ad54b011
31383231356466 2d676c6962   18215df-glib
632d322e332e322f6c69622f   c-2.3.2/lib/
6c642d6c696e75782e736f2e   ld-linux.so.
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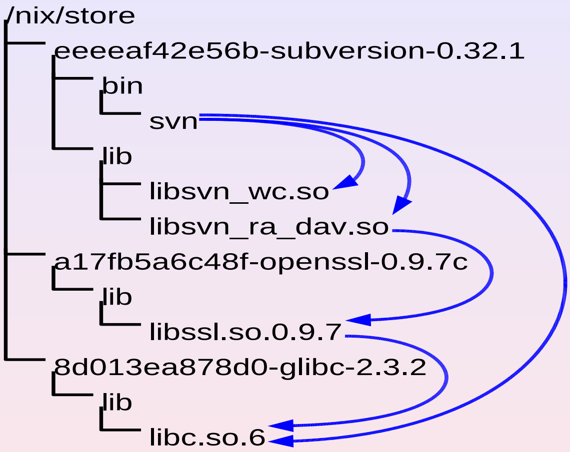

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Risks

- As in all conservative GC approaches, there is a risk of *pointer hiding*.
  - Compressed executables.
  - UTF-16 encoded paths.
- However, we haven't observed this yet, despite Nixifying some 170 Unix packages.
- I.e., this is a heuristic, but a reliable one.

Preventing Interference

- The unique strings are cryptographic MD5 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).

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End Users

- "I don't want to type /nix/store/*very-long-path*/bin/svn all the time!"
- Solution: synthesise a *user environment* of currently activated applications.
- These are components themselves, so multiple environments can co-exist.
- On Unix we can atomically switch between them.
- These are roots of the *garbage collector*.

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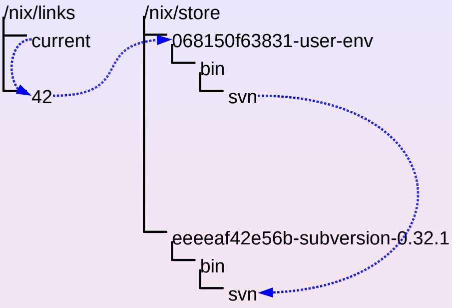

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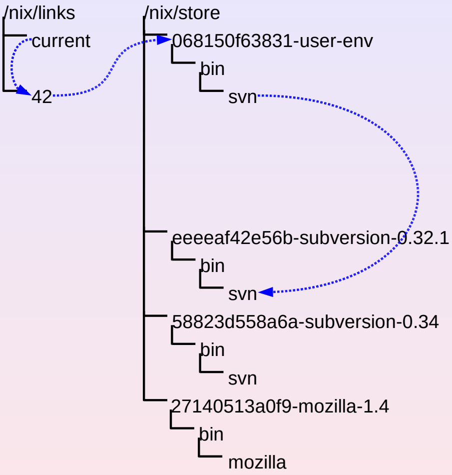

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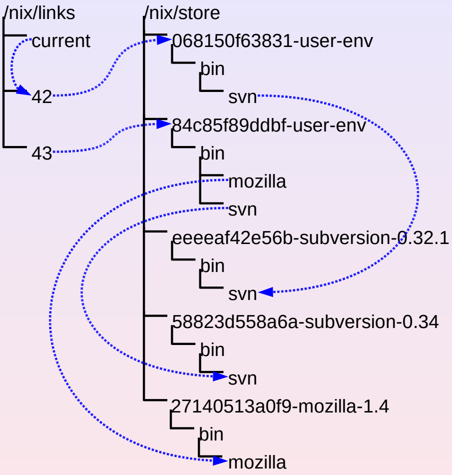

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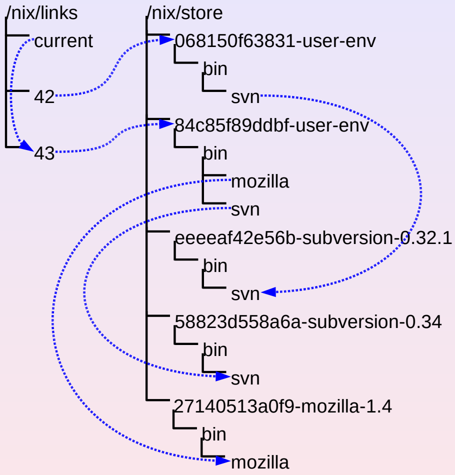

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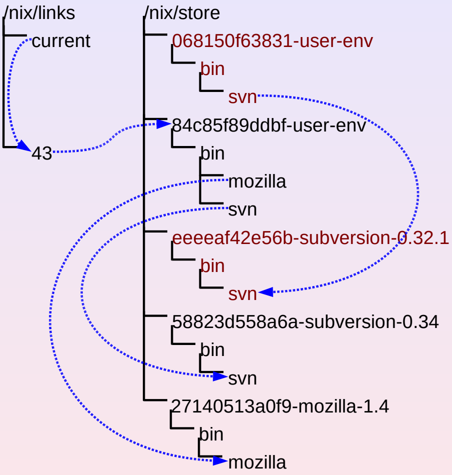

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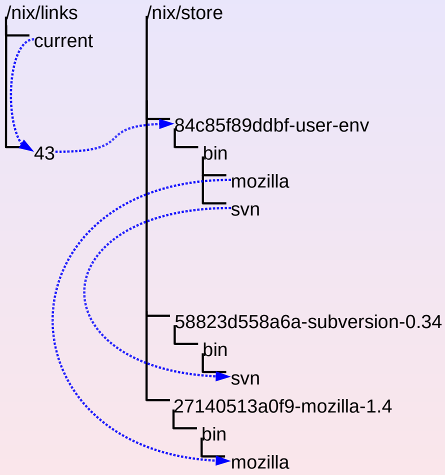

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- "I don't want to write /nix/store/*very-long-path*/... in my Makefiles all the time!"
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Nix expression for Subversion

```
{ localServer, stdenv, fetchurl
, openssl ? null, db4 ? null, ... }:

assert localServer -> db4 != null;

stdenv.mkDerivation {
  name = "subversion-1.0.3";
  builder = ./builder.sh;
  src = fetchurl {url=...};
  db4 = if localServer
        then db4 else null;
  ...
}
```

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Build script for Subversion

```
tar xvfj $src
cd subversion-*
if test "$localServer"; then
  extraFlags=\
    --with-berkeley-db=$db4
fi
./configure --prefix=$out \
  $extraFlags
make
make install
```

Related Work

- Deployment / package managers: RPM, Gentoo, etc.
  - Unsafe — incomplete deployment, not atomic.
- Better build managers: Vesta, ClearCase.
  - Do not do deployment.
  - Cannot handle retained dependencies.
  - Not portable; rely on virtual file system.
- .NET / Java WebStart
  - Covers only executable resources.
  - "Unmanaged" file system.
  - Bound to a specific component technology.

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Conclusion

- Paradigm: solving deployment problems by applying PL techniques.
- Safe deployment requires identification and deployment of closures.
- Closures can be identified using unique hashes.
- These also ensure non-interference between versions/variants.
- Multiple user environments.
- Safe garbage collection.

More information:
`http://www.cs.uu.nl/groups/ST/Trace/Nix`.

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 things?
- Just deploy the new components; 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.