A Context-Oriented Programming Approach to Dependency Hell

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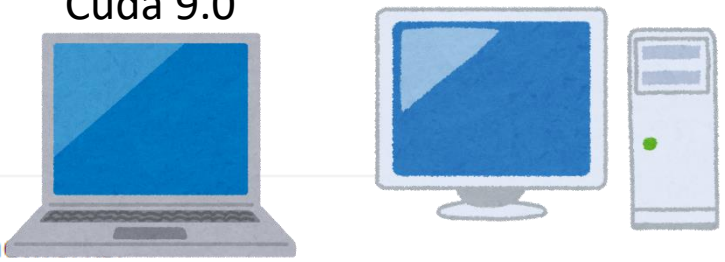
Downloading library
—Which library should we choose?—

Cuda 9.0

Cuda 8.0



cuDNN Download

NVIDIA cuDNN is a GPU-accelerated library of primitives for deep neural n

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Cuda 9.2

Three cuDNN libraries for three environment

Which one…?

rerequisi … pported GPU … ding.

ide, In … nd Release Notes on the Deep Learning SDK Documentation web page.

Download cuDNN v7.1.4 (May 16, 2018), for CUDA 9.2

Download cuDNN v7.1.4 (May 16, 2018), for CUDA 9.0

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Downloading cuDNN
—One library in any environment—

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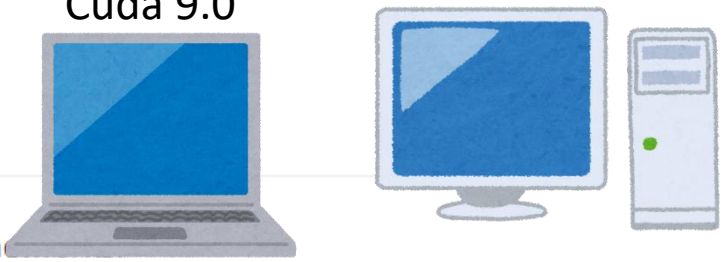
Cuda 8.0



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the Deep Learning SDK Documentation web page.

One cuDNN library
for three environment

Download cuDNN v7.1.14 (May 16, 2018)

Multiple versions of libraries
—“Untyped version abstraction”—

- Make libcurl work with any version of openssl
- openssl is not backwards compatible
- libcurl uses macros to abstract differences between versions of openssl
  - Macros are untyped

```
#if OPENSSL_VERSION_NUMBER >= 0x0090581fL
#define HAVE_SSL_GET1_SESSION 1
#else
#undef HAVE_SSL_GET1_SESSION
#endif

#if OPENSSL_VERSION_NUMBER >= 0x00904100L
#define HAVE_USERDATA_IN_PWD_CALLBACK 1
#else
#undef HAVE_USERDATA_IN_PWD_CALLBACK
#endif

#if OPENSSL_VERSION_NUMBER >= 0x00907001L
```

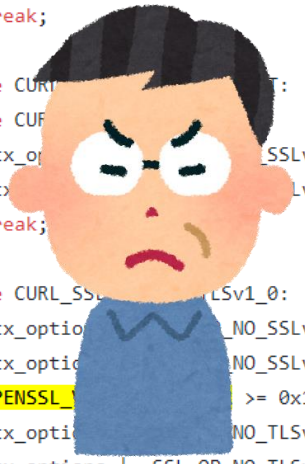
```
#if OPENSSL_VERSION_NUMBER >= 0x0090700
/* 0.9.6 didn't have X509_STORE_set_fla
#define HAVE_X509_STORE_SET_FLAGS 1
#else
#define X509_STORE_set_flags(x,y) Curl_
#endif

#if OPENSSL_VERSION_NUMBER >= 0x1000000
#define HAVE_ERR_REMOVE_THREAD_STATE 1
```

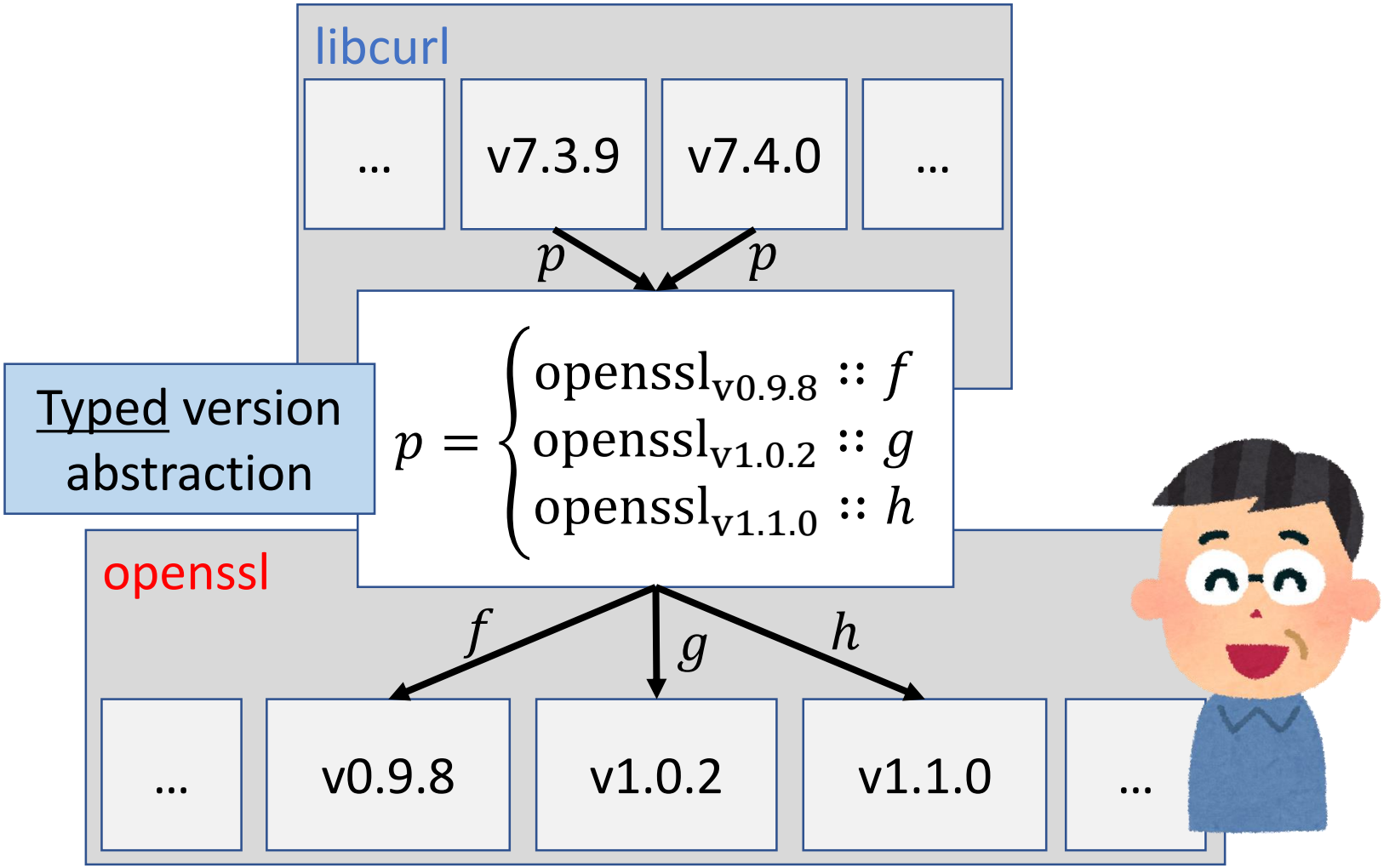
```
#if OPENSSL_VERSION_NUMBER >= 0x1000100F
    ctx_options |= SSL_OP_NO_TLSv1_1;
    ctx_options |= SSL_OP_NO_TLSv1_2;
#endif
    break;

 case CURL
 case CUR
    ctx_o                    SSLv2;
    ctx                      Lv3;
    break;

 case CURL_SS                LSv1_0:
    ctx_optio                NO_SSLv2;
    ctx_optio                NO_SSLv3;
#if OPENSSL_                 >= 0x1000100F
    ctx_opti                 NO_TLSv1_1;
    ctx_options |= SSL_OP_NO_TLSv1_2;
#endif
    break;
```

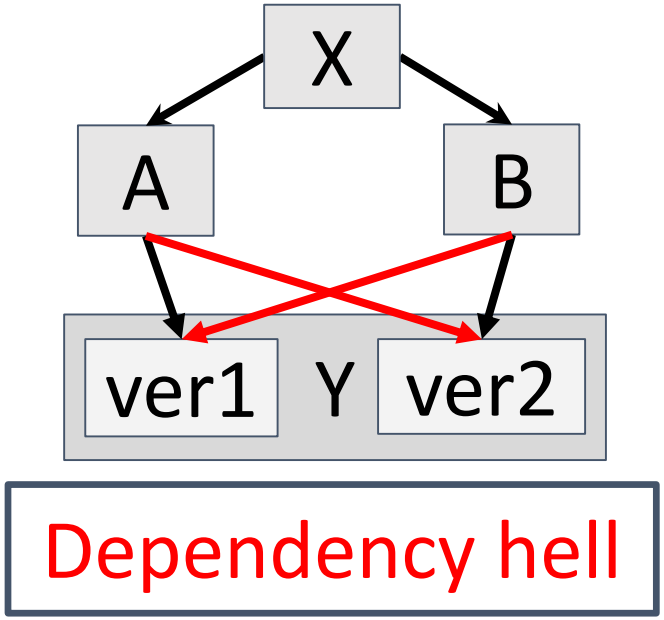


Multiple versions of libraries
—“Typed version abstraction”—



Dependency hell
—What is dependency hell?—

- **Dependency hell** : *when incompatible versions of a library are needed in one software artifact.*



depend on

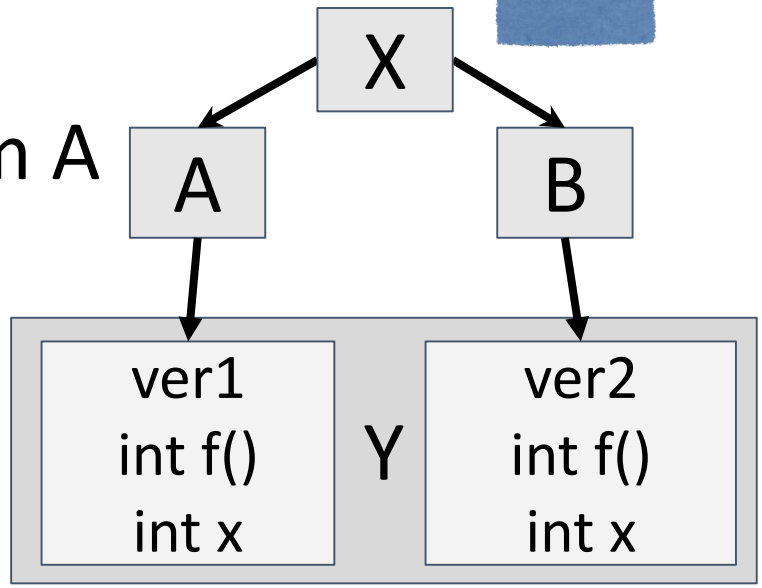
incompatible

Dependency hell
—How does dependency hell occur?—

For example:

Dependency hell
—One name, multiple definitions—

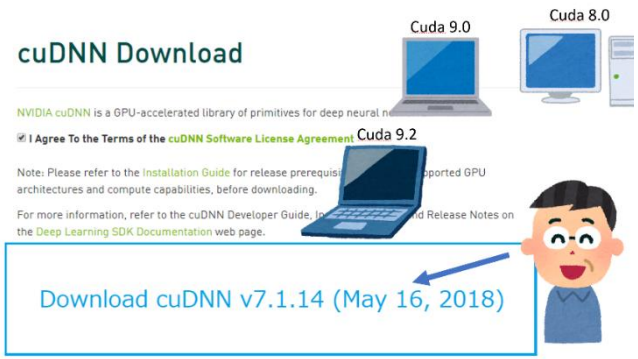
- Allows simultaneous use of multiple versions of a library
  - No collision even if there is a value / function with the same name
  - Allows selecting ver1 from A and ver2 from B

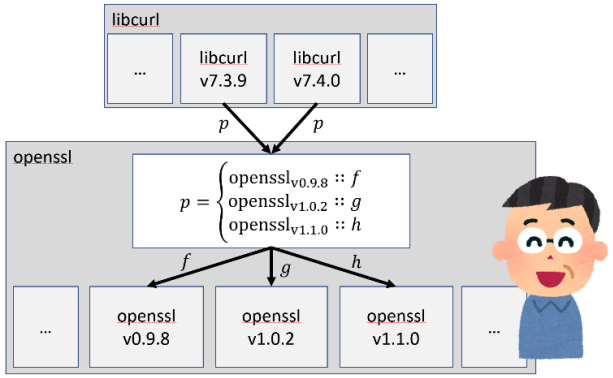


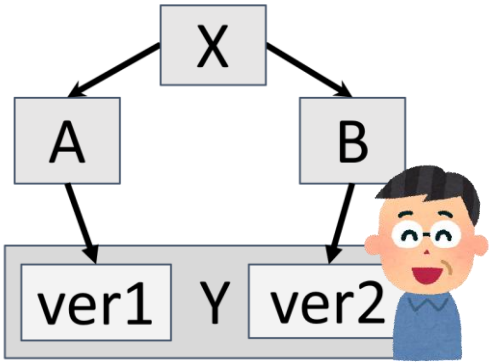
Our approach - COP

- We propose a solution to these problems using context-oriented programming.

Key idea: <u>Versions as contexts</u>

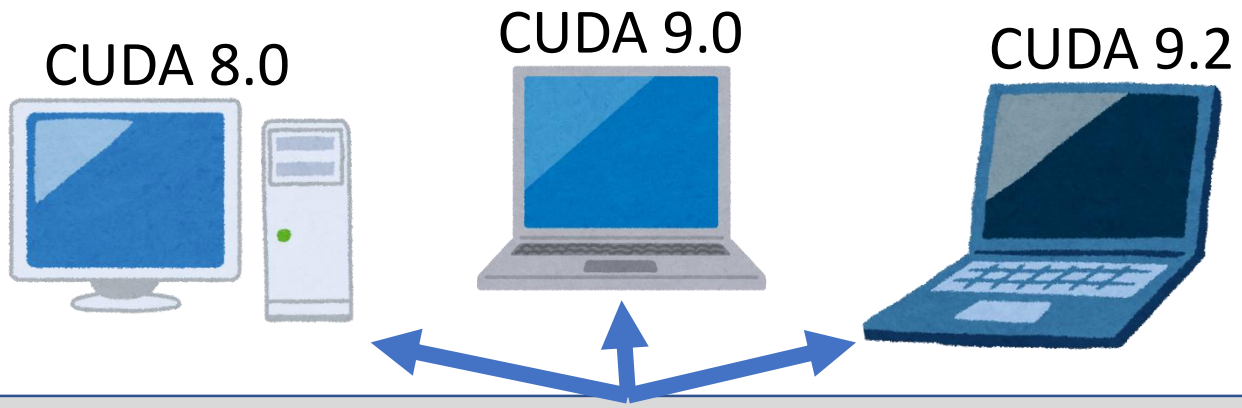




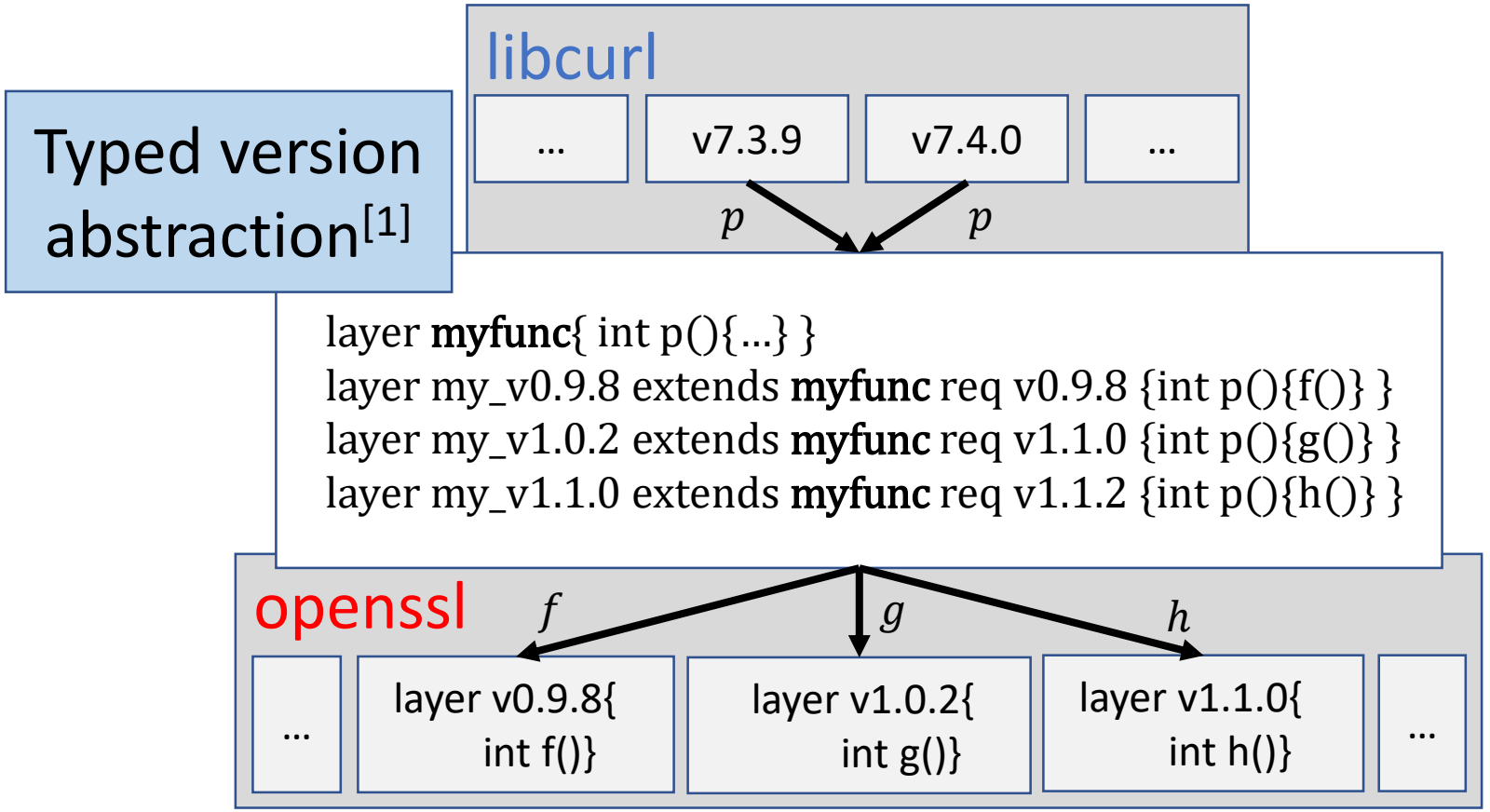


Application
—Downloading cuDNN—

- Can provide one version that will work properly in all environments



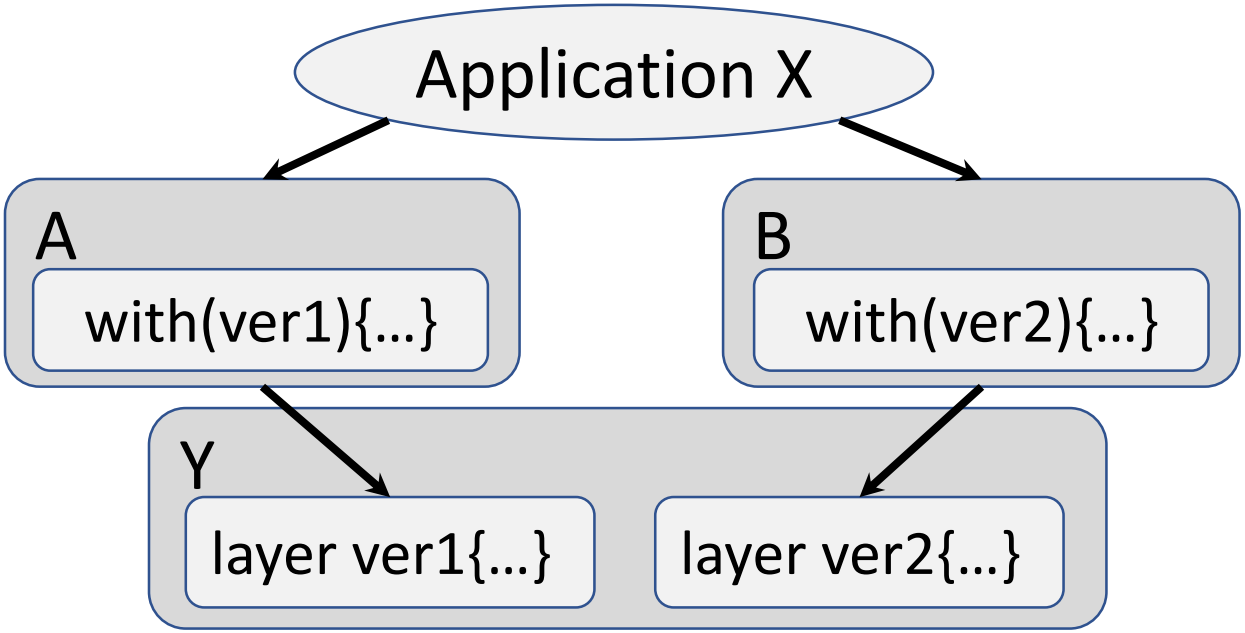
Application
—Depending on multiple versions of a library—



[1] Inoue H., Igarashi A: A Sound Type System for Layer Subtyping and Dynamically Activated First-Class Layers. In: APLAS 2015

Application
—Dependency hell—

- Each version of the library is represented *Layers*
- Allows selecting ver1 from A and ver2 from B using *with*



Basic idea

- Multiple versions of value and function definitions
- Put versions on *values* and propagate them
- Contexts are selected by extracting a specific version from the program

※ Assume the following for simplification

  - No I/O, no state.
  - The versions of library don't change from typechecking-time and at runtime.
  - Functions are values.

Issues

- Without classes and objects,
  - How do you represent version-dependent programs?
  - How do you interpret version-independent programs?

Issues

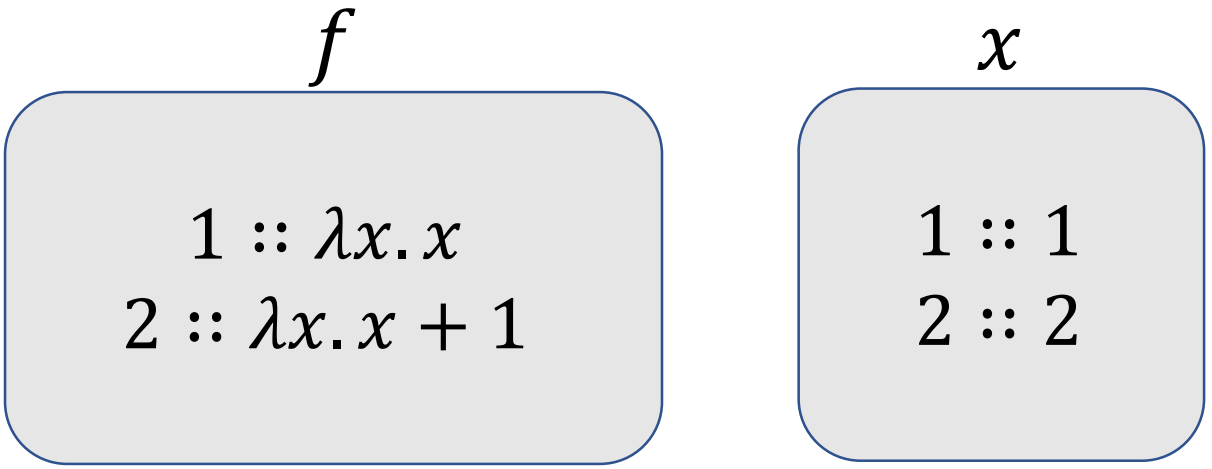
- Without classes and objects,
  - How do you represent version-dependent programs?
    - Ex.)

$$p = \begin{cases} \text{openssl}_{\text{v0.9.8}} :: f \\ \text{openssl}_{\text{v1.0.2}} :: g \\ \text{openssl}_{\text{v1.1.0}} :: h \end{cases} \qquad x = \begin{cases} \text{openssl}_{\text{v0.9.8}} :: v_1 \\ \text{openssl}_{\text{v1.0.2}} :: v_2 \end{cases}$$

  - How do you interpret version-independent programs?
    - Ex.)

$$p\ x = ???$$

Representation of version-dependent programs

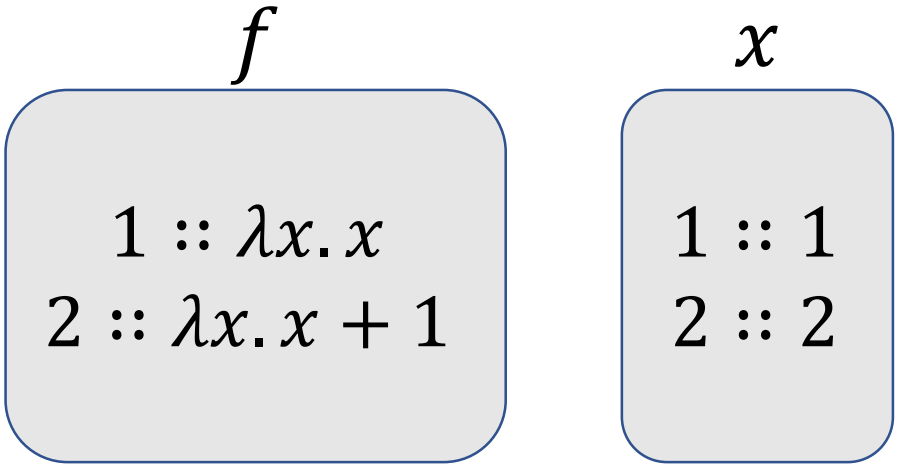


- Version abstraction are realized by packaging multiple versions of values into **versioned values** $\{\ldots\}$.

$$f = \{1 :: \lambda x.\, x, 2 :: \lambda x.\, x + 1\}$$
$$x = \{1 :: 1, 2 :: 2\}$$

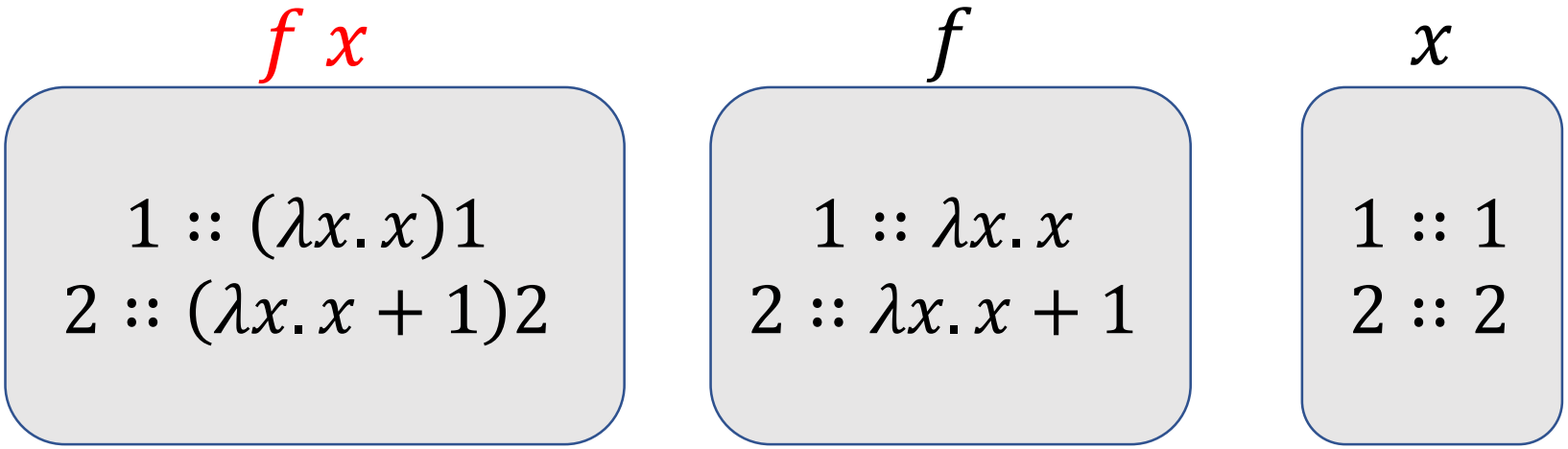
Interpretation of version-independent applications

$f\ x = ???$



- So, how should version-independent program: $f\ x$ be interpreted?
- We want to compute $f\ x$ in the current version, but how to get the version?

Interpretation of version-independent applications

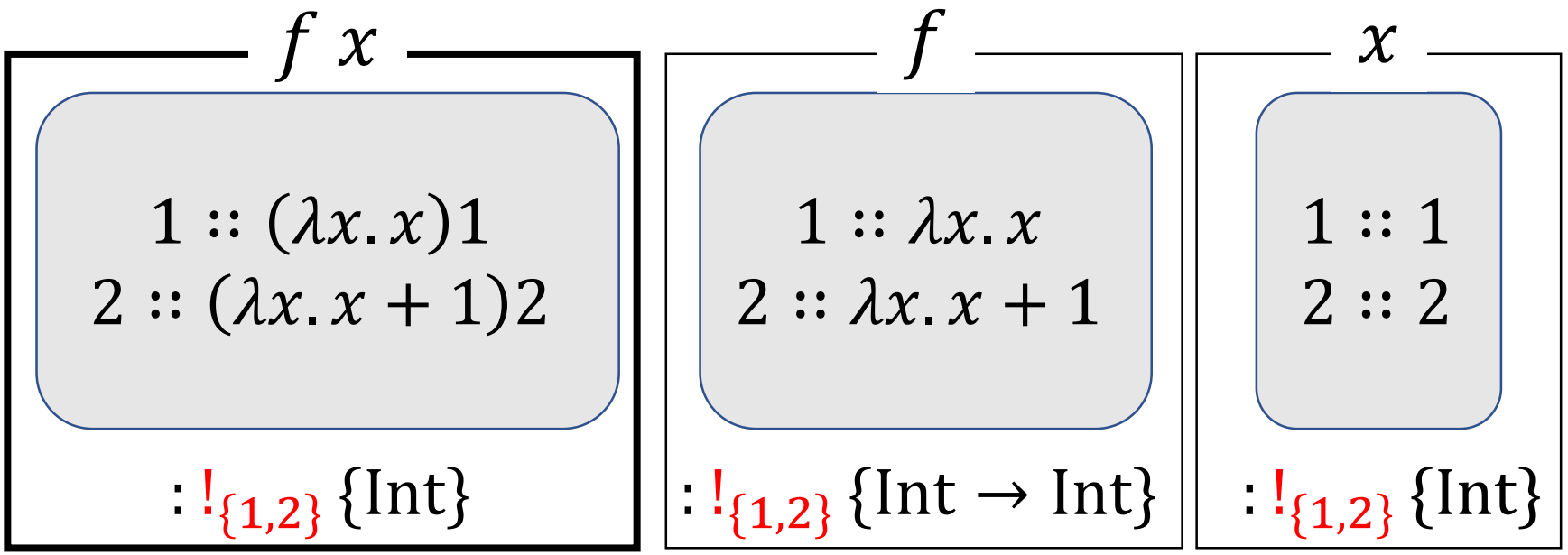


- We define $f\ x$ as calculating values <u>in all shared versions</u>.

$$f\ x = \{1 :: (\lambda x.x)1, 2 :: (\lambda x.x+1)2\ \}$$

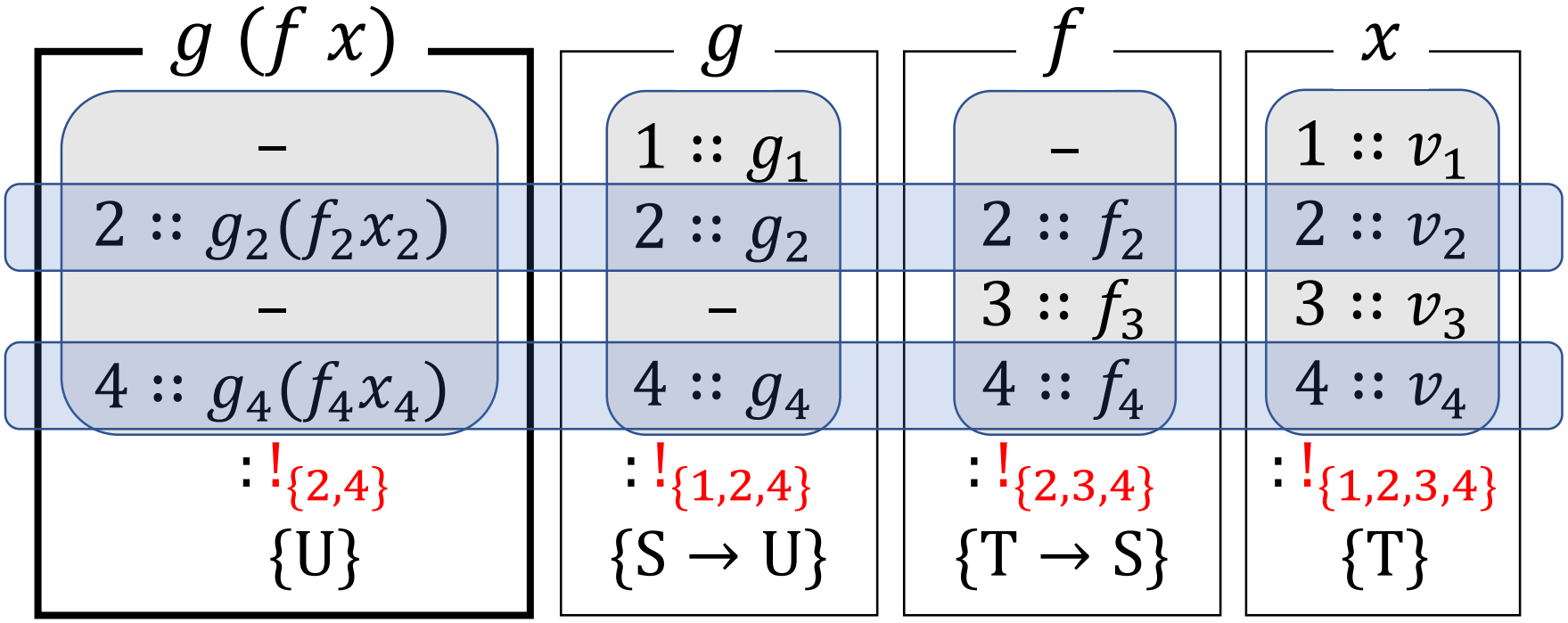
- $f\ x$ is defined in versions 1 and 2 where definitions exist in both f and x.

Types of versioned values



- The types of versioned values are defined using a ! annotation.

Flow of versions



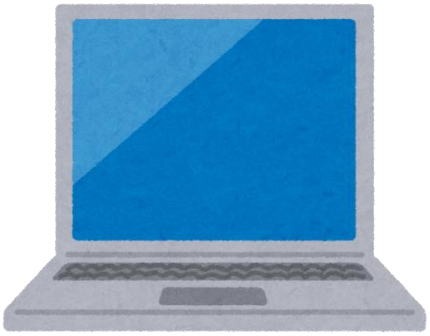
- Functional application is computed in all shared versions.

$$\{2,4\} = \{1,2,4\} \cap \{2,3,4\} \cap \{1,2,3,4\}$$

Evaluating versioned values

Source program

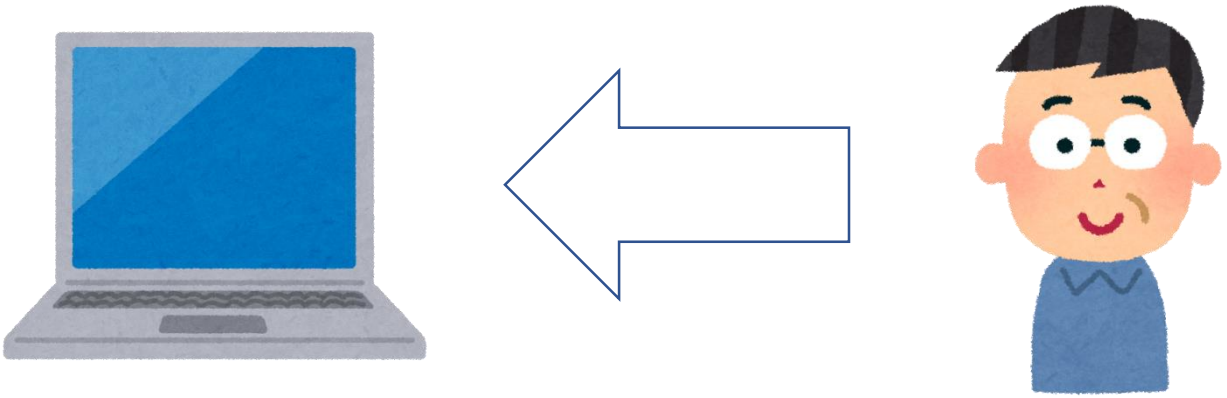
$g\ (f\ x)$



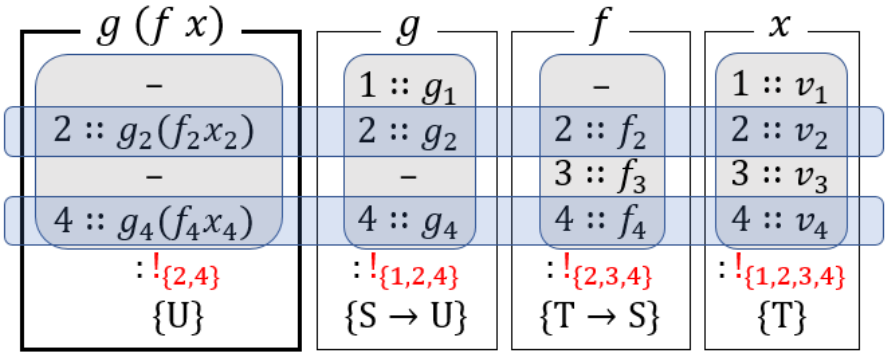
Evaluating versioned values

Source program
$g\ (f\ x)$

Compile the program



Evaluating versioned values



Source program
$g\ (f\ x)$

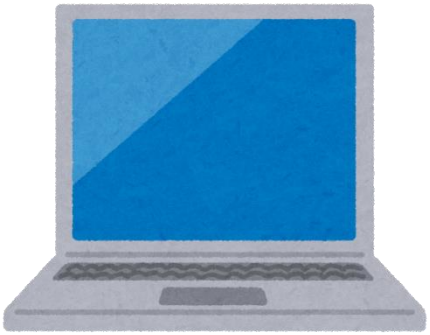
Compile the program

Type checking…

Evaluating versioned values

Compiled program
$g\ (f\ x)$: $!_{\{2,4\}}\ \{\mathrm{U}\}$

Compilation completed

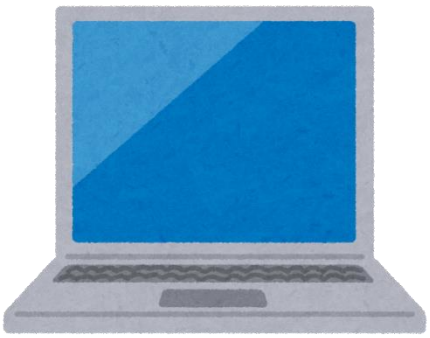


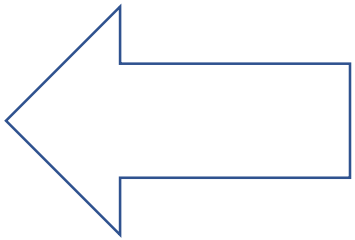
Evaluating versioned values

Compiled program

$g\ (f\ x)$: $!_{\{2,4\}}\ \{\mathrm{U}\}$

Run the program

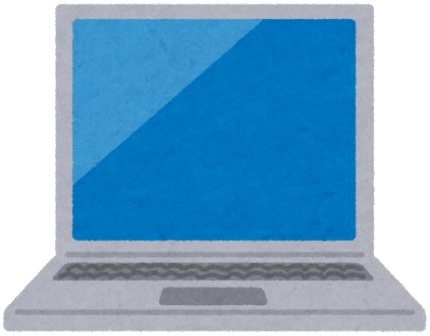


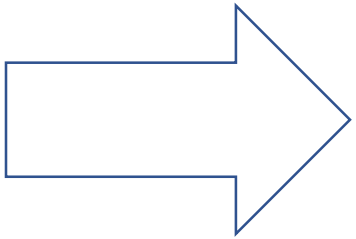


Evaluating versioned values

Compiled program
$g\ (f\ x)$: $!_{\{2,4\}}\ \{\mathrm{U}\}$

Which version do you want to run?



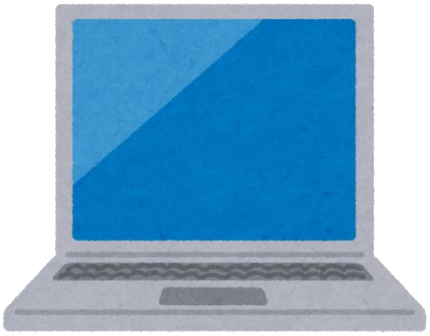


Evaluating versioned values

Compiled program
$g\ (f\ x)$: $!_{\{2,4\}}\ \{\mathrm{U}\}$

Which version do you want to run?

Version 2

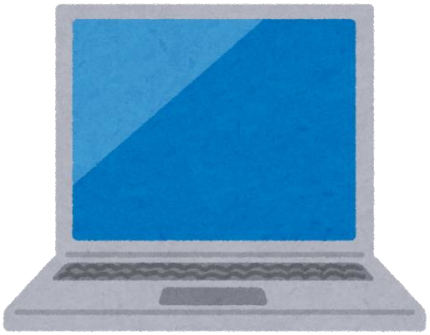


Evaluating versioned values

Compiled program
$g\ (f\ x)$: $!_{\{2,4\}}\ \{\mathrm{U}\}$

Evaluate $g\ (f\ x)$
at version 2

Version 2



Conclusion

- We propose the use of COP as a solution to dependency hell.
  - We allow libraries to have multiple versions of definitions and users to select one specific version.
  - We have developed a core calculus λ_{VL} and proven its soundness.

Difference from package managers

- For example, maven, sbt, OPAM, …
- Package managers aims to distinguish the package set with dependency
- Package managers don’t provide a mechanism to abstract versions

Relationship to COP

- Similarities:
  - Multiple-versioned programs
    ≃ using a COP layer as a version
  - Extracting specific versions
    ≃ COP layer activation