Gradual Enforcement of IO Trace Properties - Cezar Andrici

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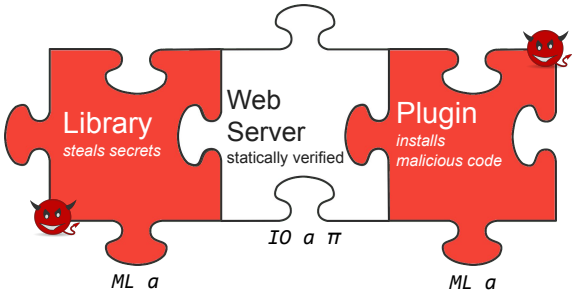
Motivation and problem. Modern web servers are linked with *unverified* third-party plugins, therefore they can have *unintended_behavior*. How can we offer guarantees about what safety properties hold?




```
(Openfile,"file.md",fd),(Read,fd,"abc"),(Close,fd,())
```

Example of a IO trace of a program that reads from a file

I. Static verification of IO

The IO Effect:
➔ Annotate functions with pre-/postconditions
➔ Trace is allocated and updated at runtime
➔ Enforces trace properties
➔ Parametric in the underlying primitive actions
➔ Primitives can throw exceptions

```
val read : (fd:file_descr) → IO string
 (requires (λ trace → is_open fd trace))
 (ensures (λ msg lt → lt = [(Read,fd,msg)]))
```

Example. Primitive read

Build and verified in F* for programs with input-output behavior

Safety Properties - π

Allows or blocks the current execution:
➔ bool function
➔ **Future work:** extract π from LTL formulas

```
let π trace next_operation : bool =
  match next_operation with
  | (Openfile, fnm) → fnm != "secret.txt"
  | _ → true
```

Example of a trace property

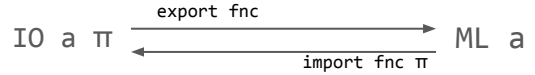
II. Gradual verification of IO

Extended primitives by using wrapping:
➔ Accept an extra precondition - π
➔ variants: static / mixed / dynamic enforcement
➔ Postconditions are enforced statically
➔ **Future work:** a more efficient representation of the trace

```
let example1 () : IO string π =
  let fd = mixed_openfile π "secret.txt" in
  dynamic_close π fd;
  mixed_read π fd
```

Example. this does not statically verify, because *fd* is read after it is closed (for any property *π*)

New transformation functions between F* effects:
➔ Effect ML can not have specification
➔ Effect ML is a safe subset of a Meta Language
➔ *export* - converts static pre-conditions to dynamic checks
➔ *import* - enforces π on each IO operation
➔ **Future work:** extend IO with state and divergence



III. Interoperability verified-unverified

➔ We can prove that the whole program respects π
➔ Only the plugin is monitored

```
val webserver : (int → IO int π) → IO unit π
val plugin : int → ML int
let main () : IO unit π =
  webserver (import plugin π)
```

Results

→ seamless interoperability between static and dynamic checking of IO trace properties
→ seamless interoperability between verified and unverified code
→ ongoing case study on how to extend a verified web server with a ML-plugin mechanism.