LangSec revisited: input security flaws of the 2nd kind

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Motivations

- Lots of (well-justified!) LangSec efforts to eliminate parser bugs, but *what about input problems that do not involve parser bugs?*
- (How) do existing efforts to tackle such input problems fit in with the LangSec paradigm?
  - Eg efforts at Google to combat XSS
- Can we extend the taxonomy of LangSec anti-patterns & remedies?

Caveats:

- Some answers are obvious, but took me some time to spot
- I'm only connecting some dots I happen to be aware of;
  there may well be others

(At least) two types of INPUT problems

1. Buggy processing

   - Bug in processing input causes application to go of the rails
   - Eg buggy parsing, parser differentials, flaw in program logic
   - Classic example: buffer overflow in a PDF viewer, leading to remote code execution

   This is *unintended* behaviour, introduced by *mistake*

2. Flawed forwarding (aka injection attacks)

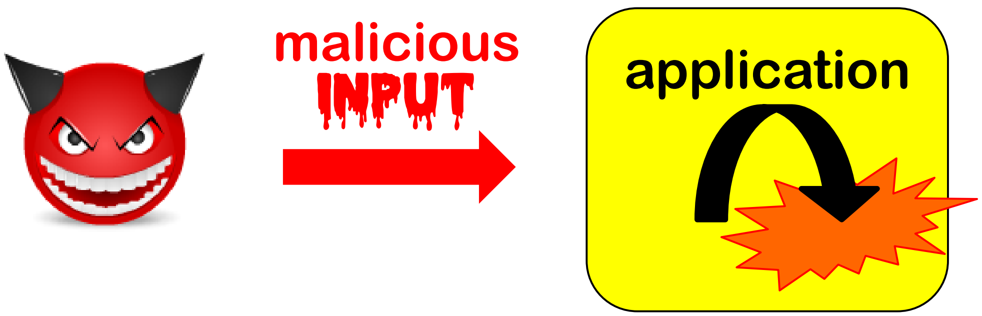
   - Input is forwarded to *back-end* service/system/API, to cause damage there
   - Classic example: SQL injection, XSS, Word macros

   This is *intended* behaviour of the back-end, introduced *deliberately*, but *exposed by mistake* by the front-end

Processing vs Forwarding Flaws

Processing Flaws

a bug !

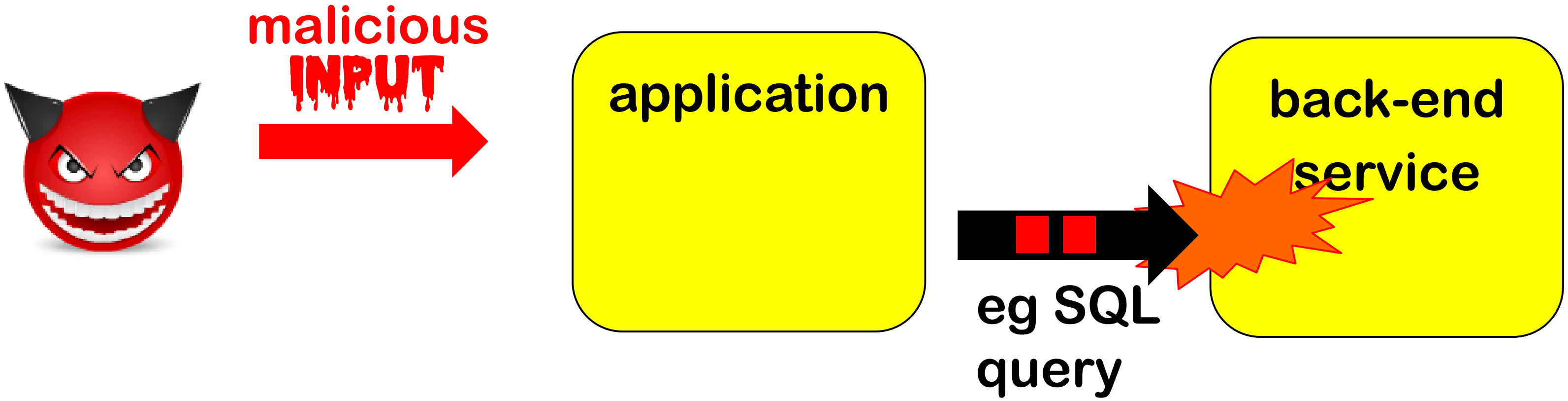


malicious INPUT

application

Forwarding Flaws

(abuse of) a feature !



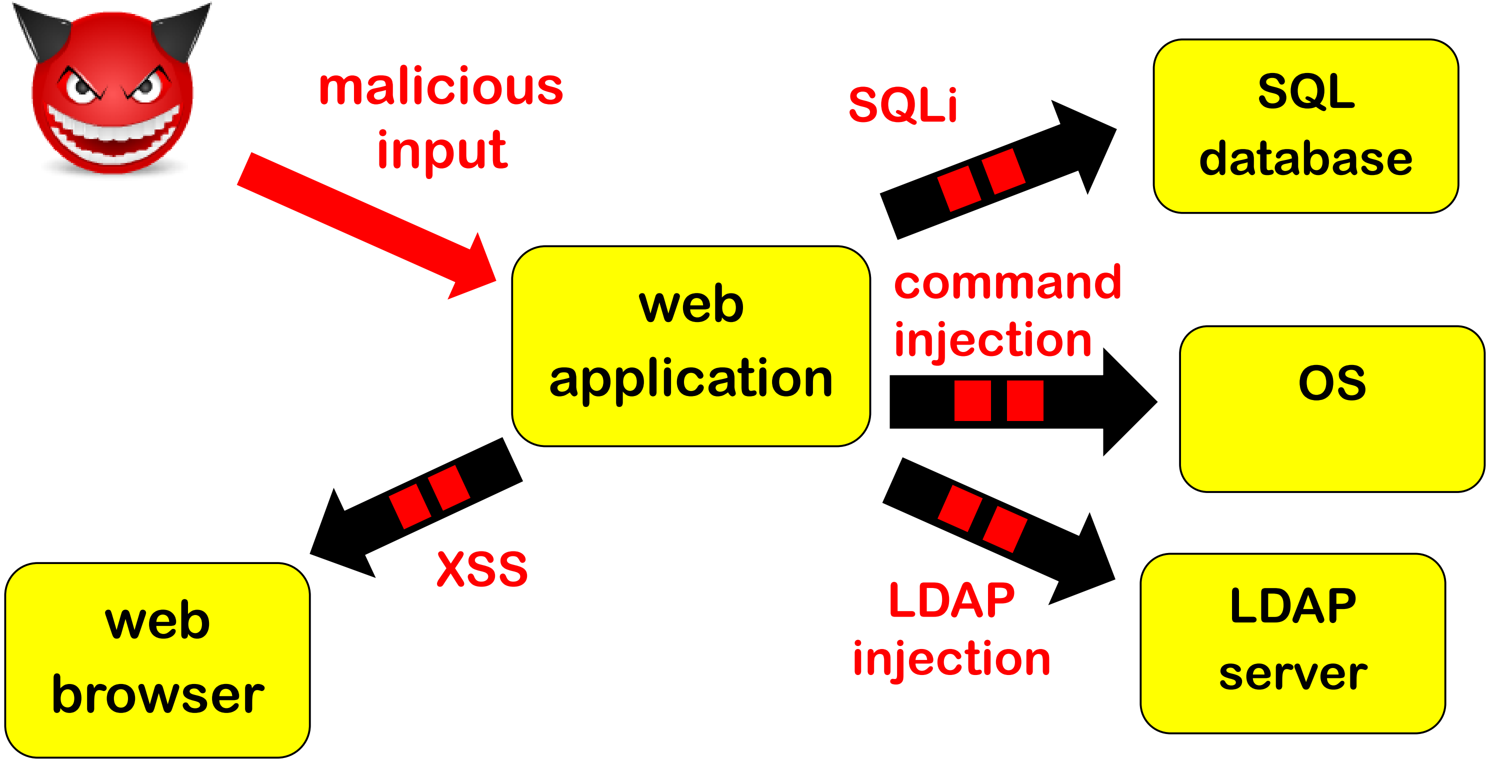
malicious INPUT

application

back-end service

eg SQL query

More back-ends, more languages, more problems



Familiar root causes of forwarding flaws

- **Input languages**:

  too many, overly complex, ill-specified, and overly expressive

  - eg SQL, OS commands, path names, HTML (incl. CSS & javascript), …

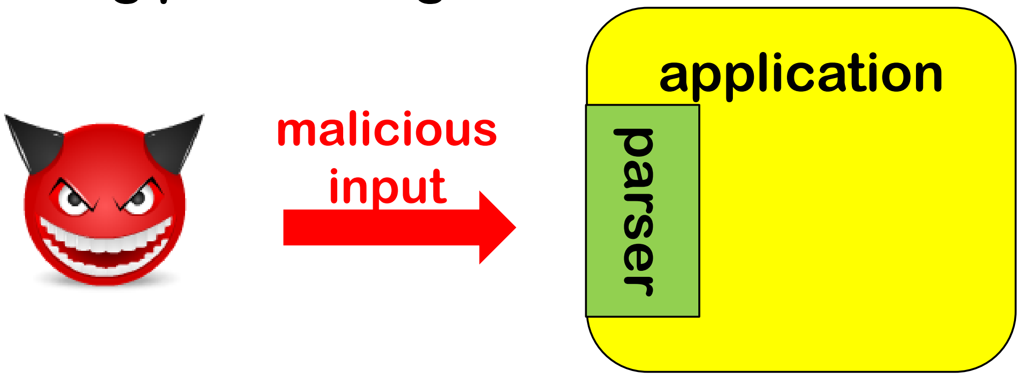
- **Parsing:**

  but unintended parsing, rather than buggy parsing.

  - Some shotgun parsing is unavoidable, as back-end will have to do some parsing

How & where to tackle input problems?

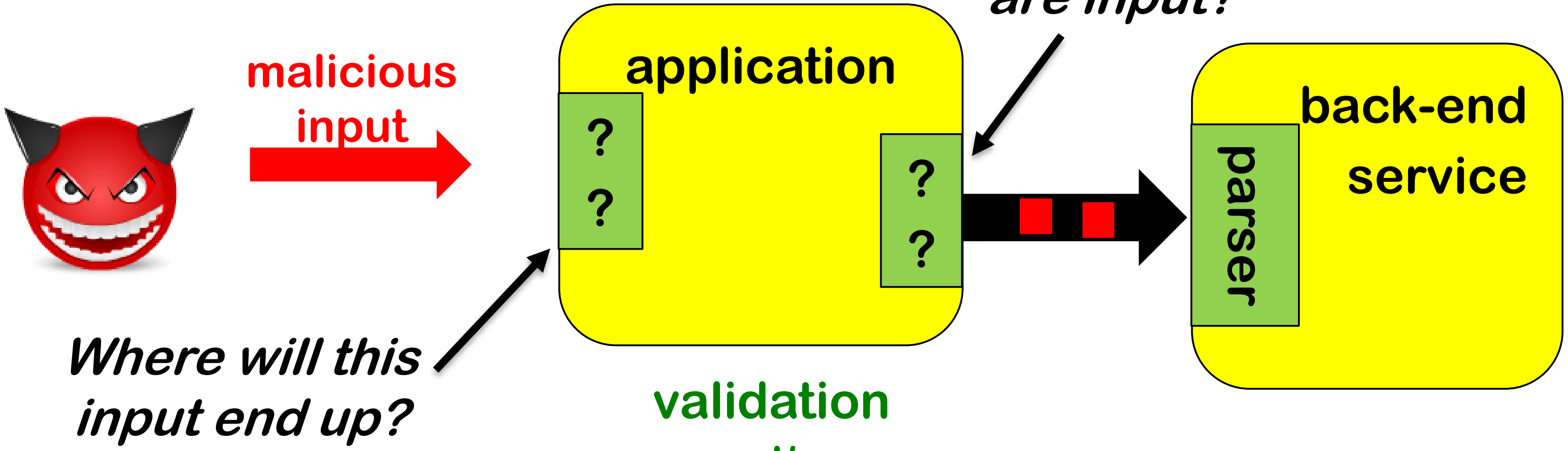
Tackling processing flaws ☺



Simple & clear language spec,
generated parser code,
complete parsing before
any further processing

Tackling forwarding flaws? ☹

Which bits are input?



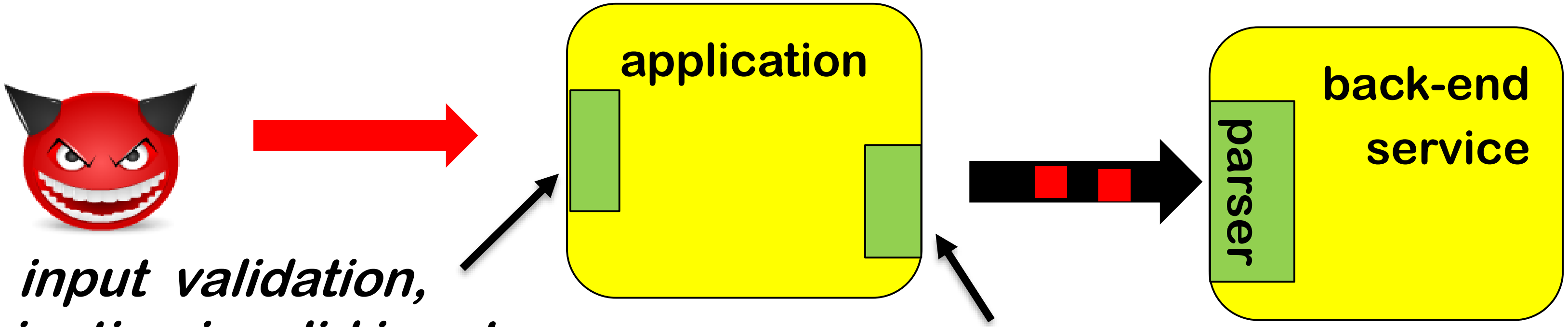
Where will this input end up?

validation
and/or
sanitisation (aka encoding aka escaping)?

Anti-patterns in tackling forwarding flaws

Anti-pattern: INPUT ESCAPING

- *Input* escaping, eg. processing *inputs* to escape dangerous meta-characters, is a bad idea
  - at the point of input, the context in which inputs will be used (eg as path name, in SQL query, or as HTML) is unclear, and different contexts require different solutions
  - classic anti-example: PHP magic-quotes
- *Output* escaping makes more sense, because there context is known
  - but there it can be unclear which data originates from input



input validation, rejecting invalid input

output sanitisation aka escaping to make output harmless

Anti-pattern: STRING CONCATENATION

- Recipe for disaster: *concatenate* several pieces of data, some of them user input, and pass this on to some API
  - Classic example: SQL injection
- Note: string concatenation is inverse of parsing
- Forwarding flaws *can be* parsing problems, namely if back-end parses data differently than the front-end serialised it
  - but, you can still have forwarding problems *without* any serialisation in the front-end, eg in format string attack like

```
printf(user_input);
```

Anti-pattern: STRINGS

More generally, the use of strings in itself is already troublesome

  - incl. `String, string, char*, char[], StringBuilder, ...`

- Strings are *useful*, because you use them to represent many things:
  eg. name, file name, email address, URL, shell command, bit of SQL, HTML,…

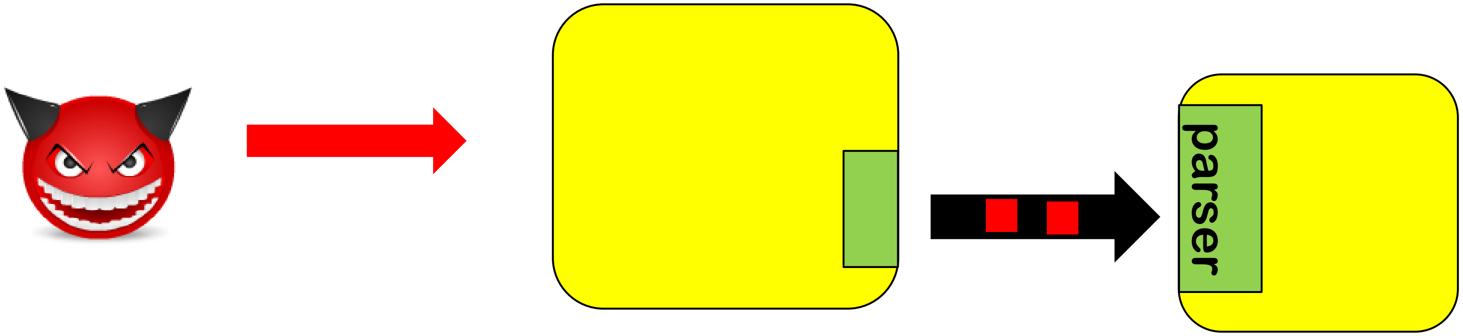
- This also make strings *dangerous:*

  1. Strings are unstructured & unparsed data, and processing may involve some interpretation
     - If you have a shotgun parser, your code will use strings
  2. The same string may be handled & interpreted in many – possibly unexpected – ways
  3. A string parameter in an API call can – and often does – hide a very expressive & powerful language

Remedies
to tackle forwarding flaws

Remedy: Parameterised queries

- The best-known & most robust way to tackle SQL injection is to use parameterised queries (or stored procedures)
  - reduces the expressive power of the interface to the back-end
  - avoids unparsing in front-end & (hence) parsing in back-end
- Note: this replaces a generic API call that takes a single STRING as argument

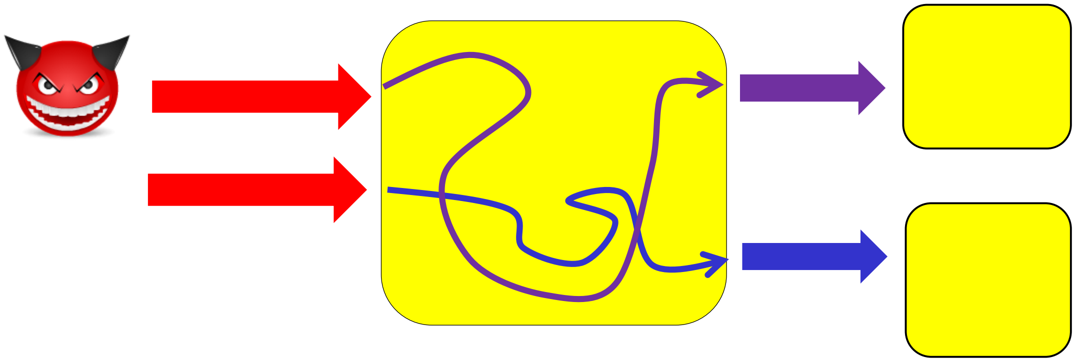


Remedy: Types (1) to distinguish *languages*

- Instead of using strings for everything,
  use different types to distinguish different kinds of data

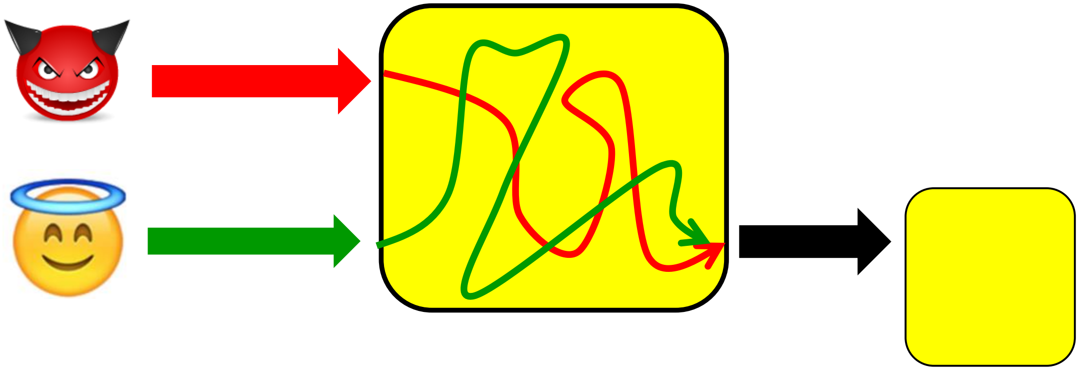
  Eg different types for HTML, URLs, file names, user names, paths, …

- Advantages
  - Types provide structured data
  - No ambiguity about the intended use of data



Remedy: Types (2) to distinguish *trust levels*

- Information flow types can be used to track the origins of data and/or control destinations
  - Ancient idea, going back to [Denning 1976]
  - Eg untrusted user input vs compile-time constants



The two uses of types, to distinguish (1) languages or (2) trust levels, are orthogonal and can be combined.

Example: Trusted Types for DOM Manipulation

DOM-based XSS flaws are proving difficult to root out

- as attacks using script gadgets demonstrate
  [Lekies et al., Code-Reuse Attacks for the Web: Breaking Cross-Site Scripting Mitigations via Script Gadgets, CCS'17]

Trusted Types initiative [https://github.com/WICG/trusted-types]
replaces string-based APIs with typed APIs

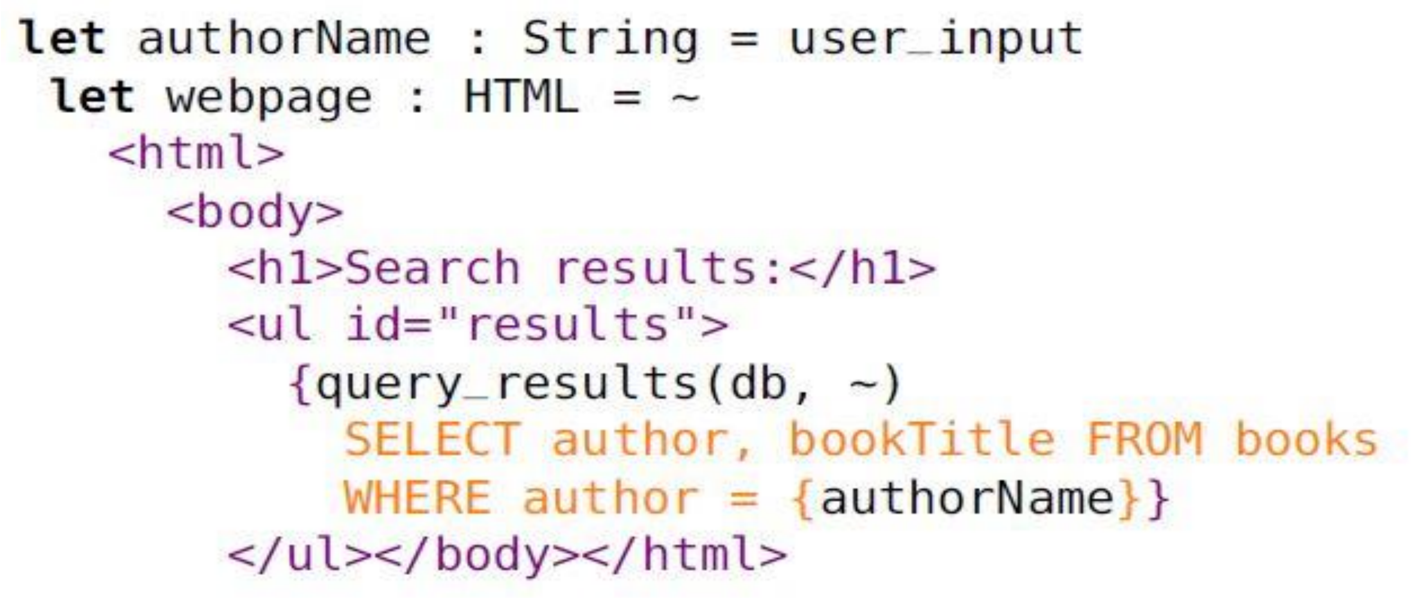
- using TrustedHtml, TrustedUrl, TrustedScriptUrl, TrustedJavaScript,...
- 'safe' APIs for back-ends that auto-escape untrusted inputs

[Sebastian Lekies' talk at OWASP Benelux 2017: Don't trust the DOM]

[Christoph Kern, Securing the Tangled Web, CACM 2014]

Beyond types: extending programming language

Wyvern programming language by Jonathan Aldrich et al. allows domain-specific extensions, eg



```
let authorName : String = user_input
 let webpage : HTML = ~
   <html>
     <body>
       <h1>Search results:</h1>
       <ul id="results">
         {query_results(db, ~)
           SELECT author, bookTitle FROM books
           WHERE author = {authorName}}
       </ul></body></html>
```

where HTML and SQL are ‘built-in’ types of the programming language

Added advantage over types: more convenient syntax

[D. Kurilova et al, Wyvern: Impacting Software Security via Programming Language Design, PLATEAU 2014, ACM]

Conclusions

- Forwarding flaws vs processing flaws is a useful taxonomy to analyse input problems & LangSec solutions
- Don’t use STRINGS
- Do use types, to distinguish

    1) different languages, and/or
    2) different trust levels

  Output escaping then becomes safe(r) & sane(r)
- Or even extend the programming language for this

These do’s are (programming) language-*based* security
as much as (input) language-*theoretic* security

Are there more forwarding anti-patterns & remedies,
or more good examples of these?

Thanks for your attention