

**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 off 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



malicious
INPUT

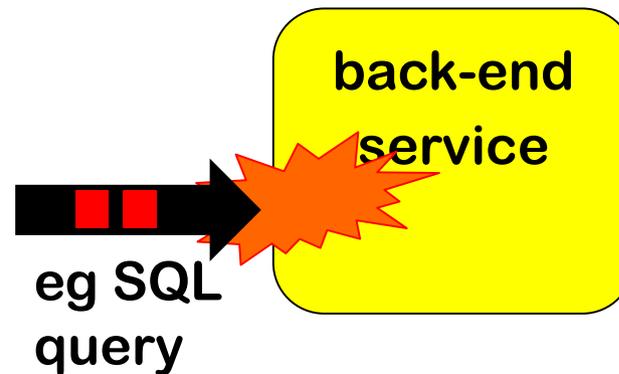


a bug !

Forwarding Flaws

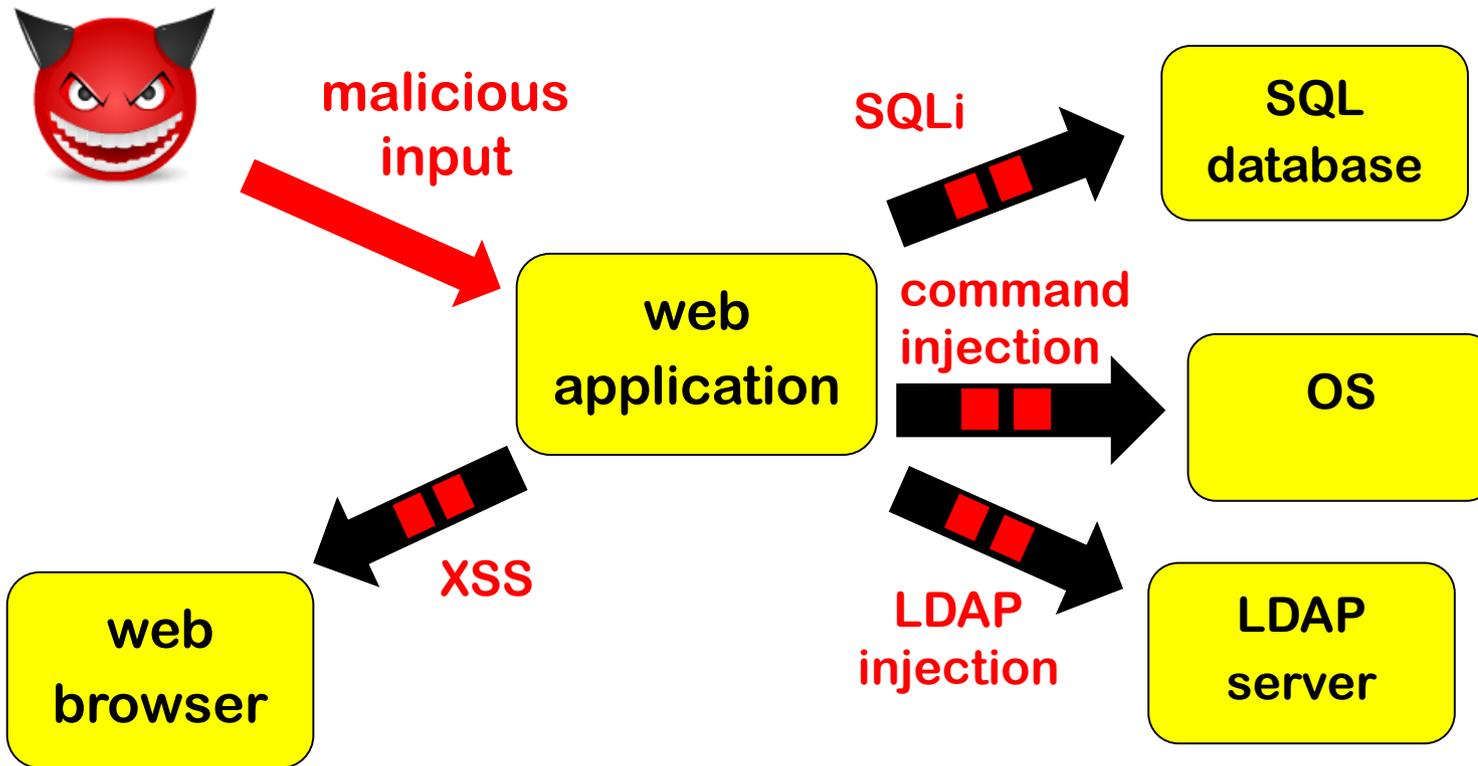


malicious
INPUT



(abuse of) a feature !

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**.

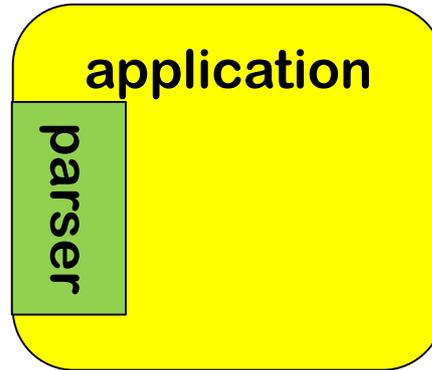
- Some shotgun parsing is unavoidable, as back-end will have to do some parsing

How & where to tackle input problems?

Tackling processing flaws 😊



malicious
input →

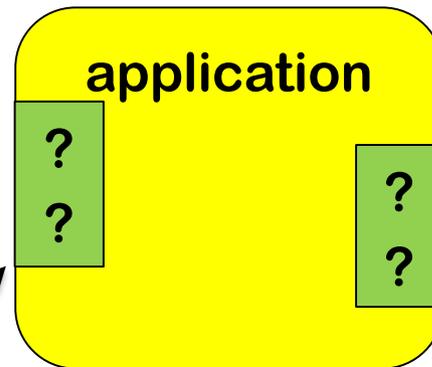


Simple & clear language spec,
generated parser code,
complete parsing before
any further processing

Tackling forwarding flaws? ☹️



malicious
input →

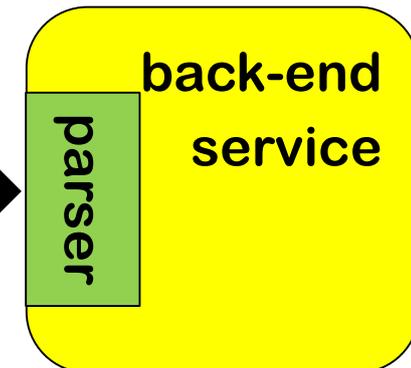


*Where will this
input end up?*

validation
and/or

sanitisation (aka encoding aka escaping)?

*Which bits
are input?*

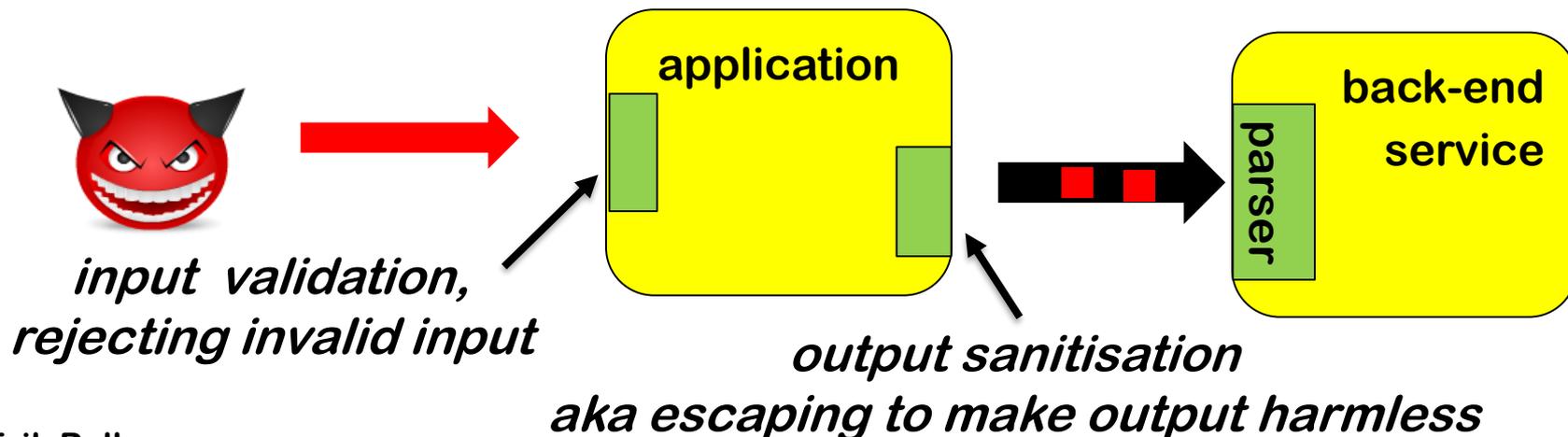


Anti-patterns in tackling forwarding flaws

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



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



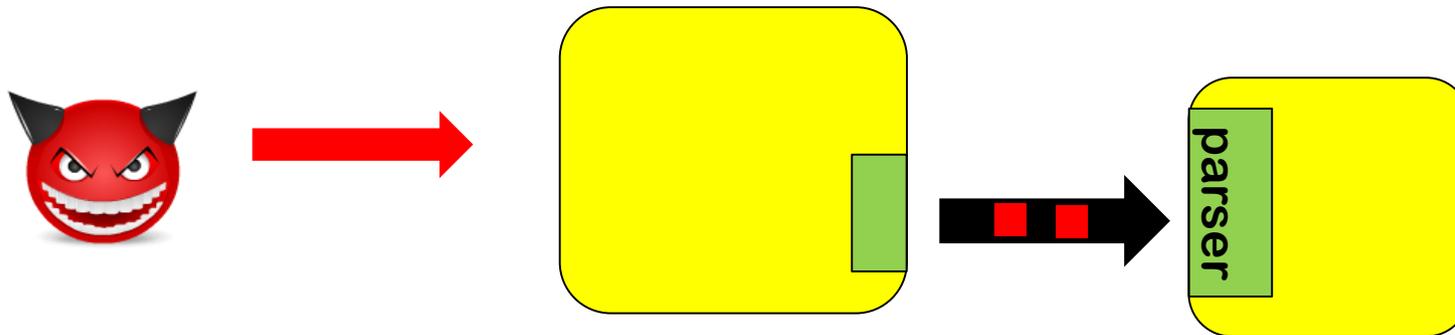
More generally, the use of strings in itself is already troublesome

- 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

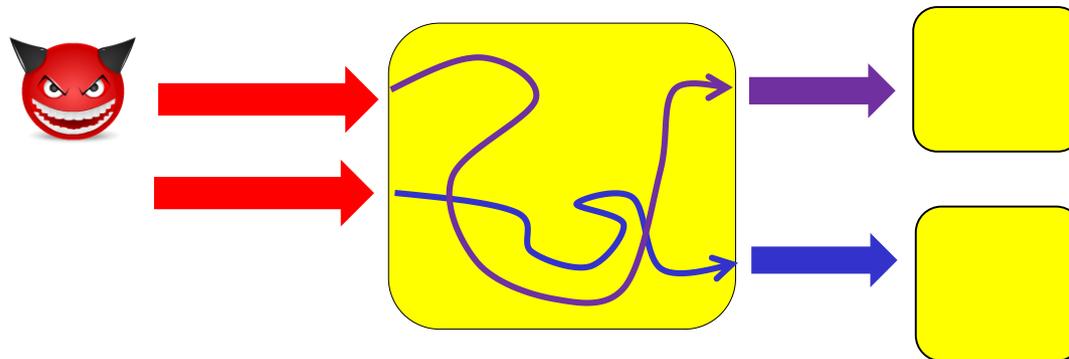
Remedy: Parameterised queries

- 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



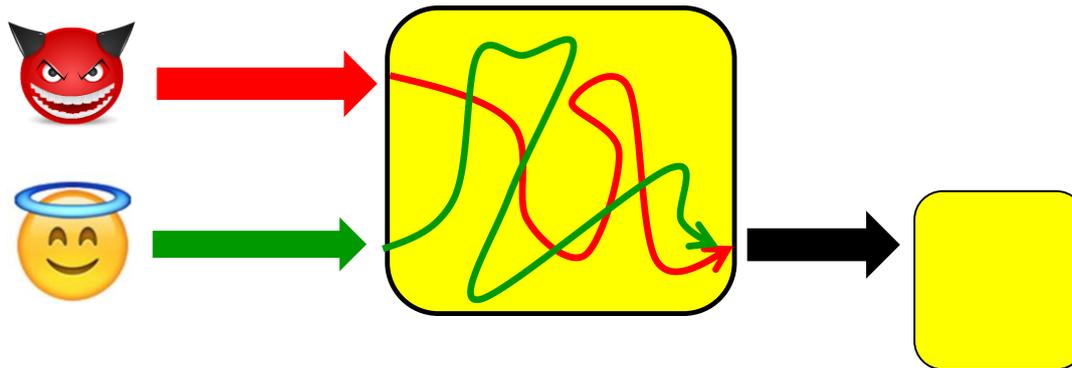
Remedy: Types (1) to distinguish *languages*

- 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

