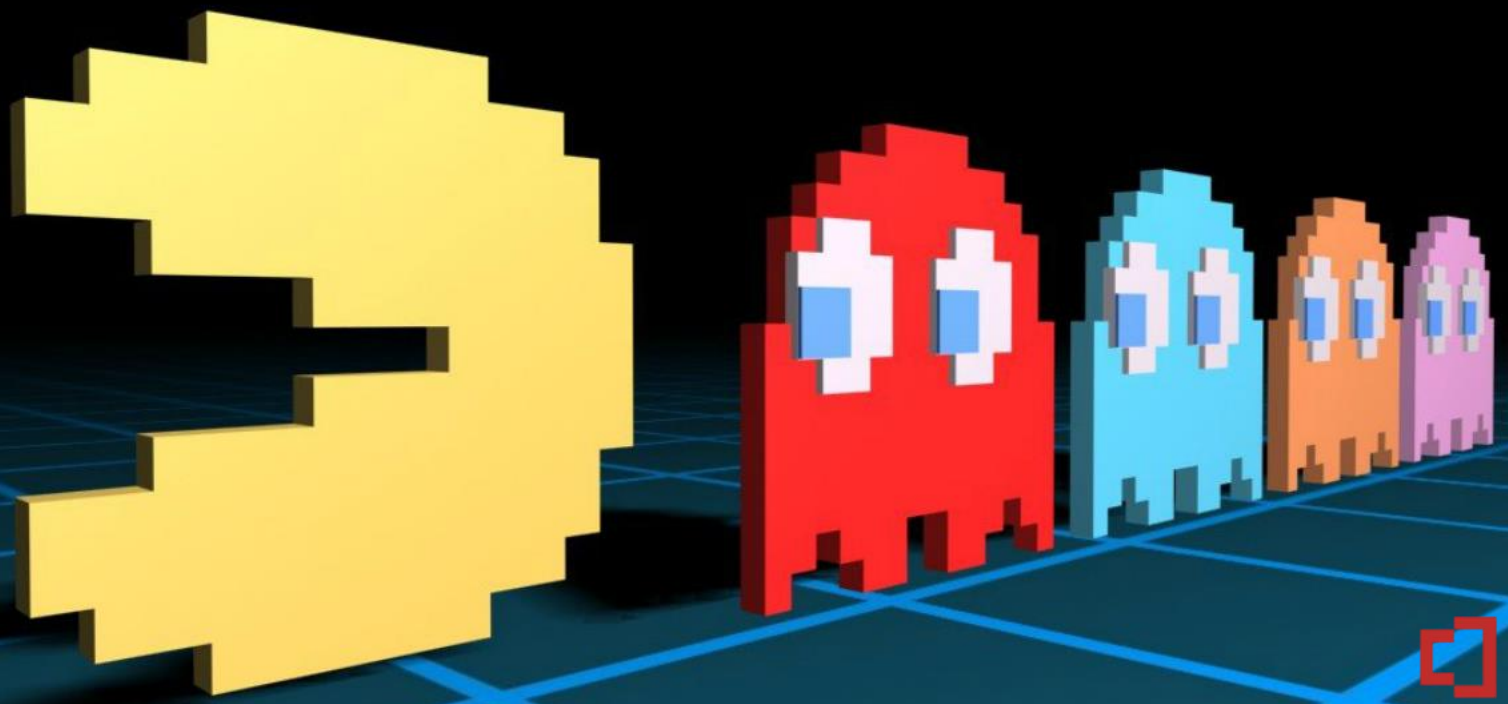
5 Unicode Vulnerabilities That Could Bite You



Presented by Philippe Arteau from GoSecure

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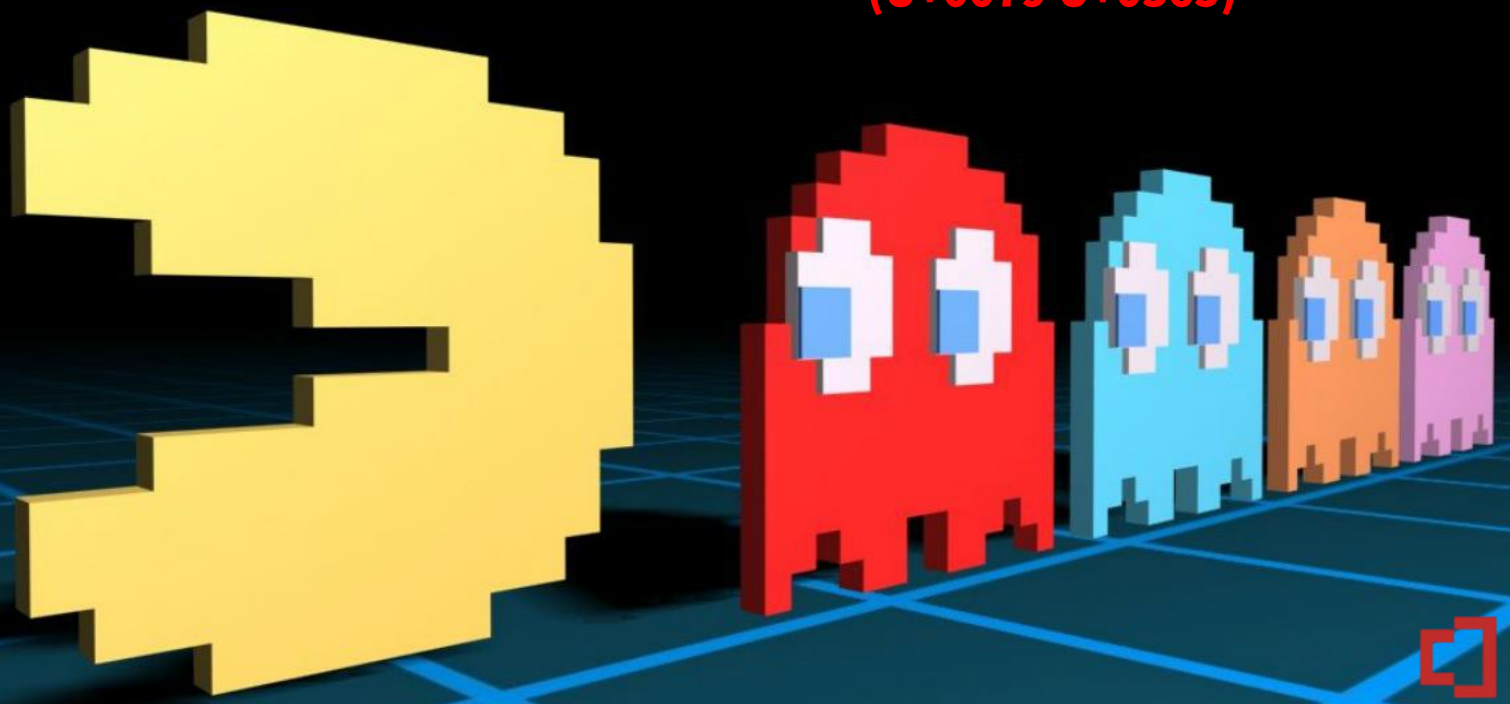
DEVELOPER CONFERENCE

5 Unicode Vulnerabilities That Could B i̇ te You

(U+0079 U+0365)



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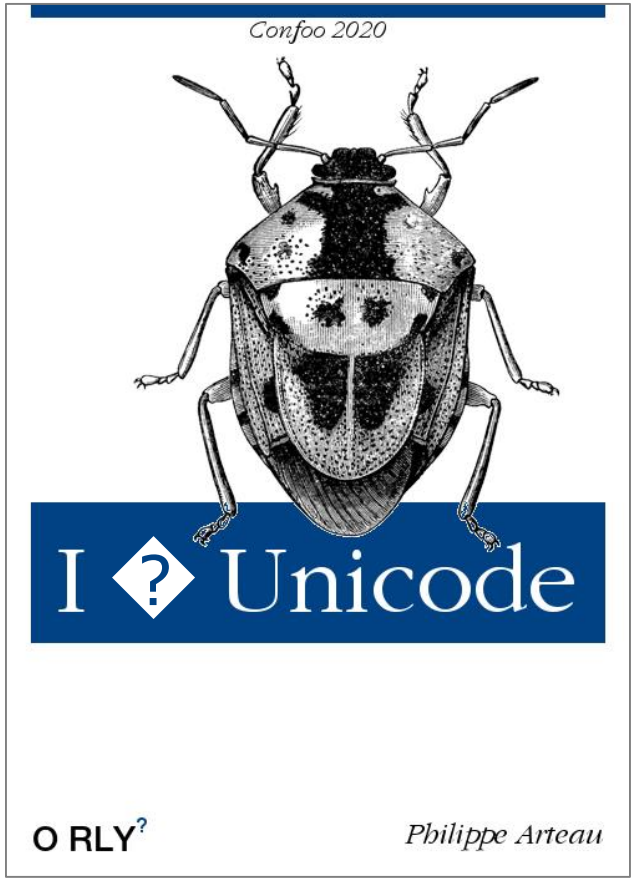
Agenda

- Small history of encoding

- Normalization
- Case modification
- Bypassing filters
- Homograph attacks
- Data integrity



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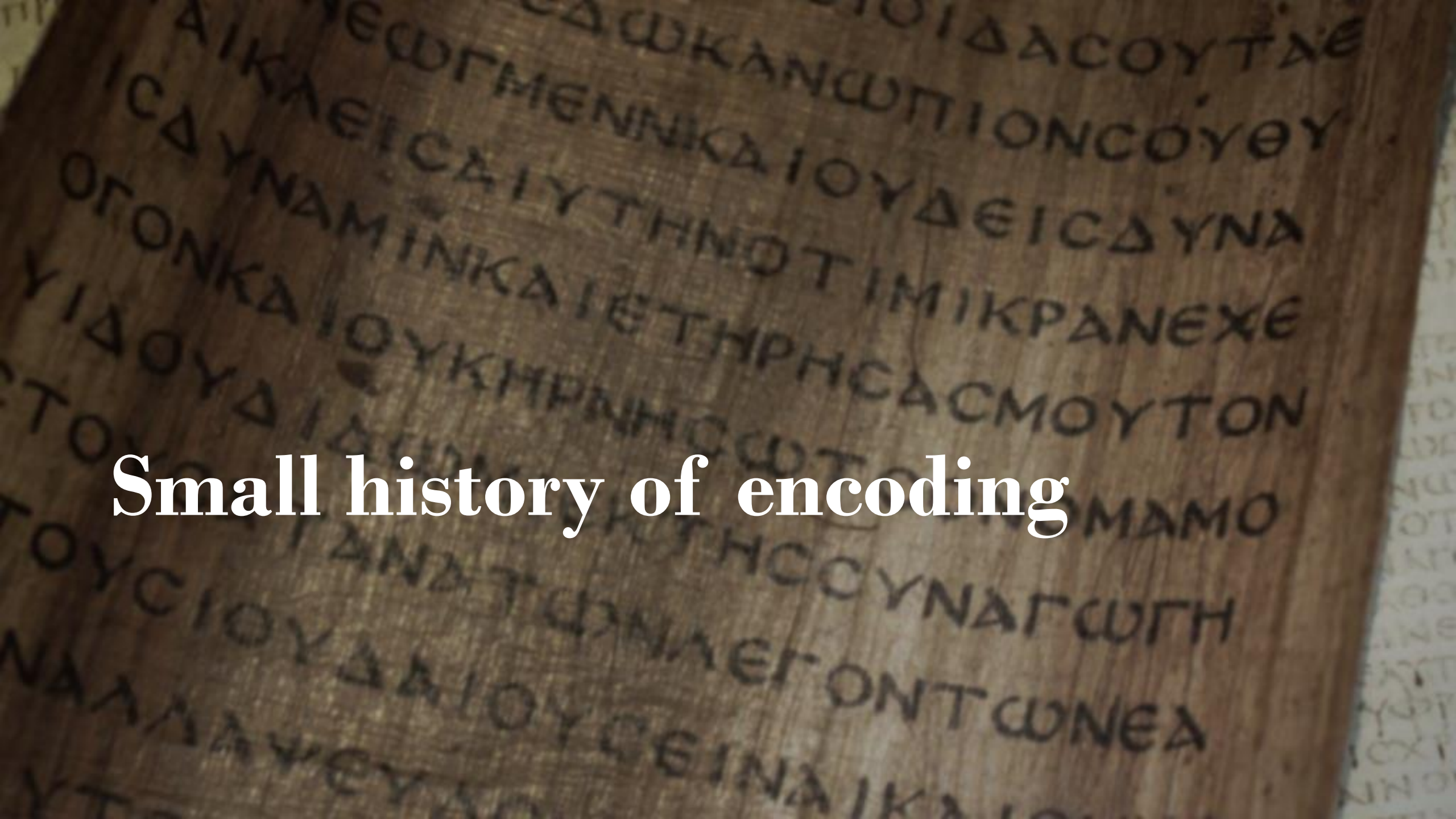
Bio

- Philippe Arteau
- Security Researcher at GoSecure
- Open-source developer
  - Find Security Bugs (SpotBugs - Static Analysis for Java)
  - Security Code Scan (Roslyn – Static Analysis for .NET)
  - Burp and ZAP Plugins (Retire.js, CSP Auditor)
- Volunteer for the nsec conference and former trainer



Small history of encoding

ASCII

Created in the 1960s

- Control Characters (0-31)
  - Null (0), Bell (7), Backspace (8), EOF (26)
- Standard Character Set (32-127)
  - A…Z, a-z,
- Extended character Set (128-255)
  - Accentuate characters, symbols, box characters

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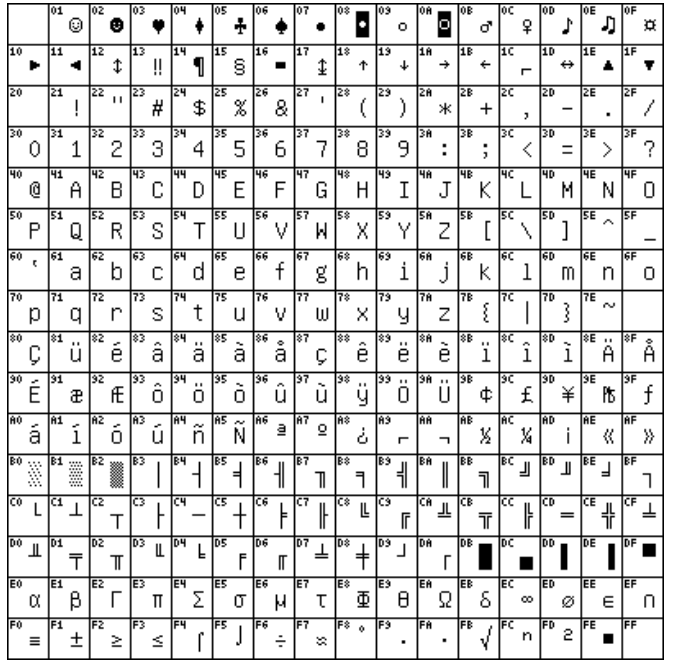
Code Pages

Attempt to standard ascii implementation to support special characters

- IBM-PC / DOS Latin US : Code page 437
- Greek : Code page 737
- Cyrillic : Code page 855
- ANSI / Windows-1252 : Code page 1252
- ...



More code pages : https://www.ascii-codes.com/

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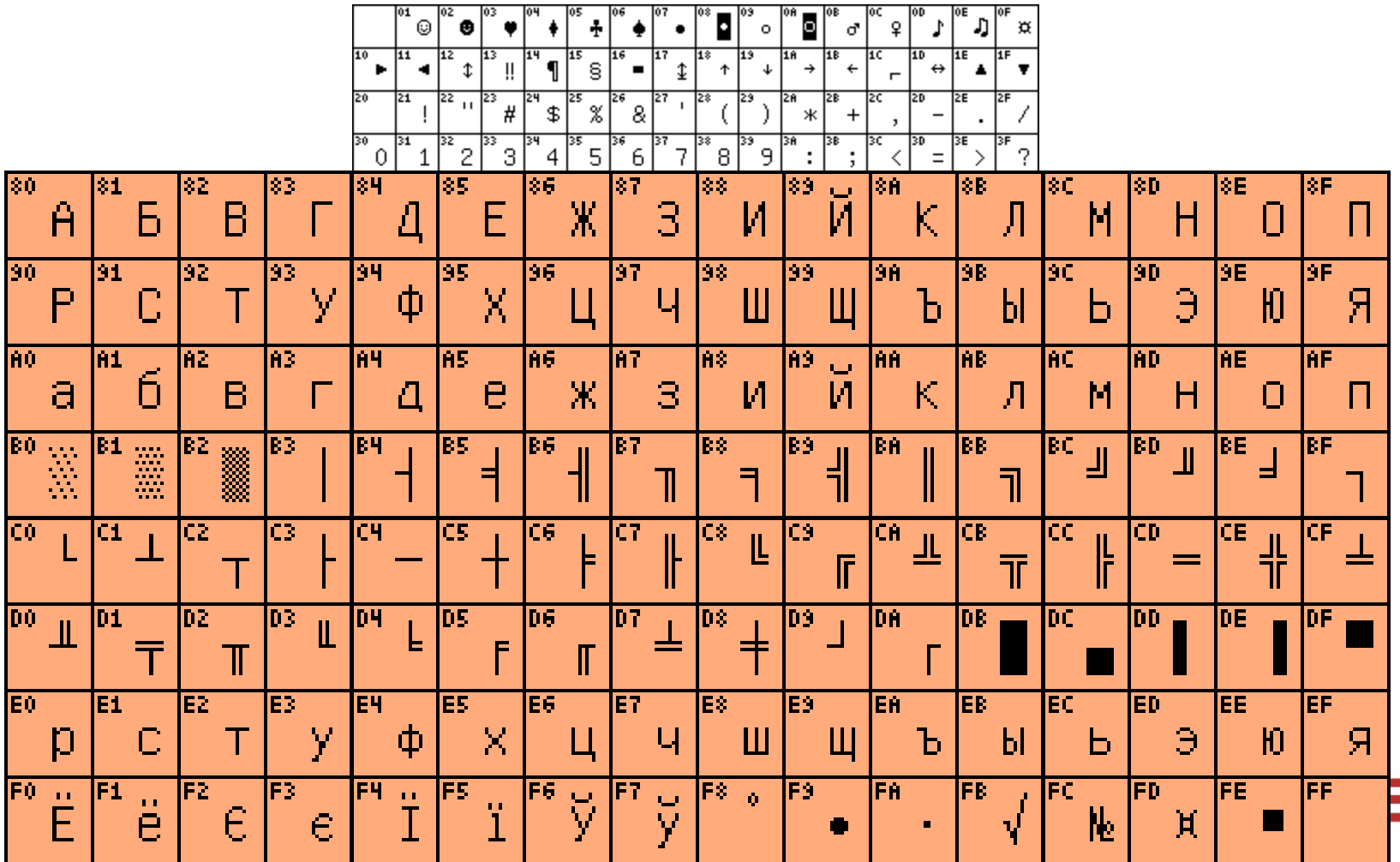
Code Pages

CP-866
DOS Cyrillic (Russian)

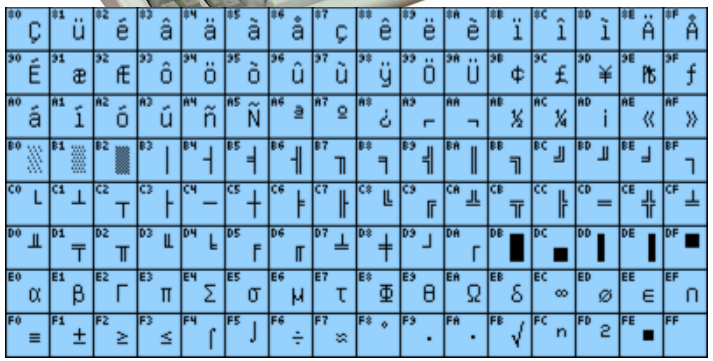


Unexpected Encoding

Déjà vu_

D\x82j\x85 vu

DBjE vu



CP-437
DOS Latin US

CP-866
DOS Cyrillic Russian

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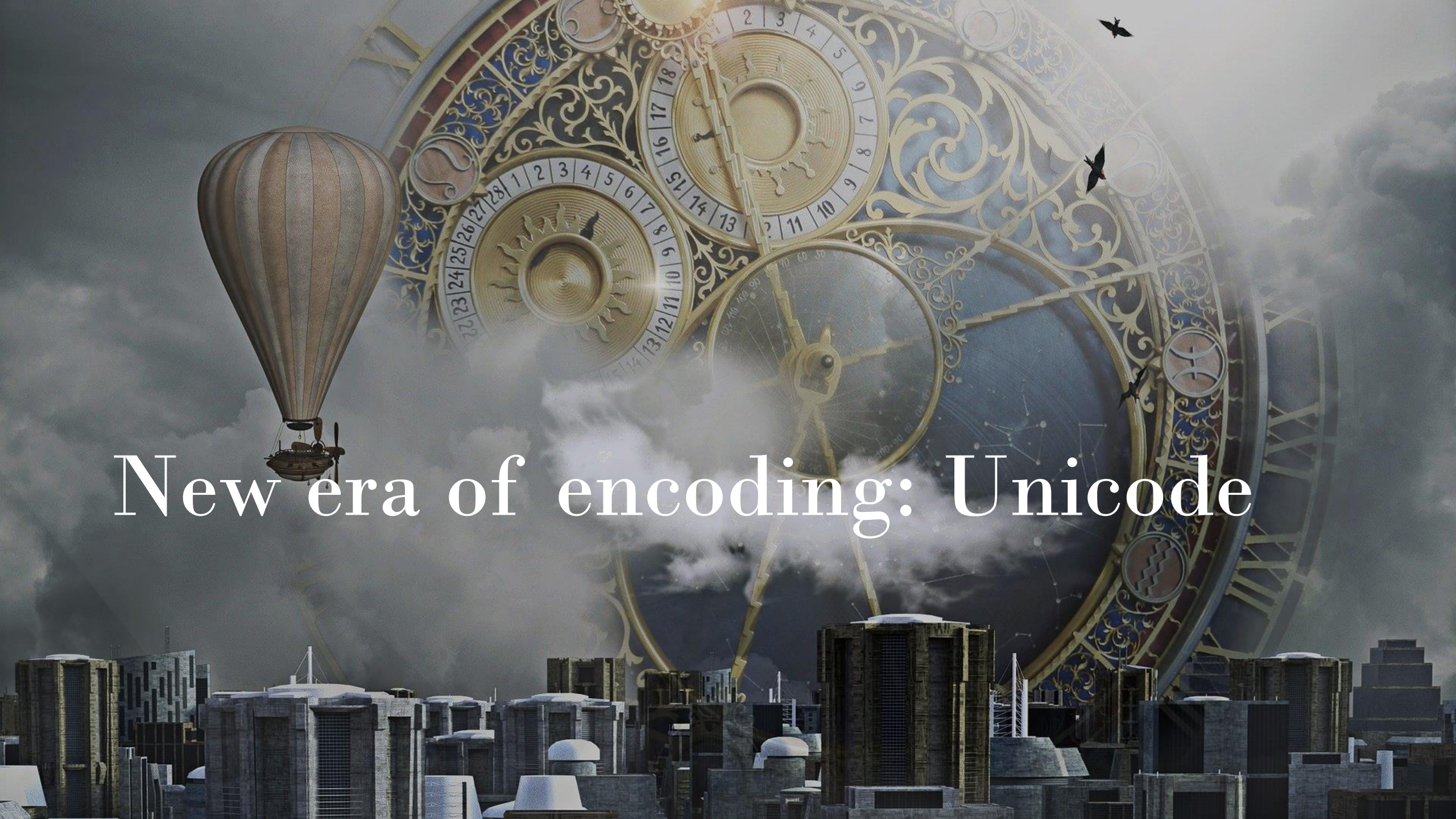

New era of encoding: Unicode

Unicode Code Points

- Uniquely index “all” characters : Latin, Cyrillic, Asian, African script, Mathematical symbol, Measuring Unit, Egyptian Hieroglyphs and Emojis.

A	é	水	∑	
U+0041	U+00e9	U+6C34	U+2211	U+ 1f4a9

- It **does not** define how it should be **encoded** (bytes representation)

To get detailed CP info:
https://www.fileformat.info/info/unicode/char/1f4a9/index.htm

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UTF-8

- Encoding format supporting Unicode Code Points
- The most popular encoding format
- First presented in 1993, Officialized in 2003 (RFC 3629)
- Variable width length encoding … 1 byte != 1 character

0___ ____					
110_ ____	10__ ____				
1110 ____	10__ ____	10__ ____	10__ ____		
[…]					
1111 110_	10__ ____	10__ ____	10__ ____	10__ ____	10__ ____

https://en.wikipedia.org/wiki/UTF-8#History

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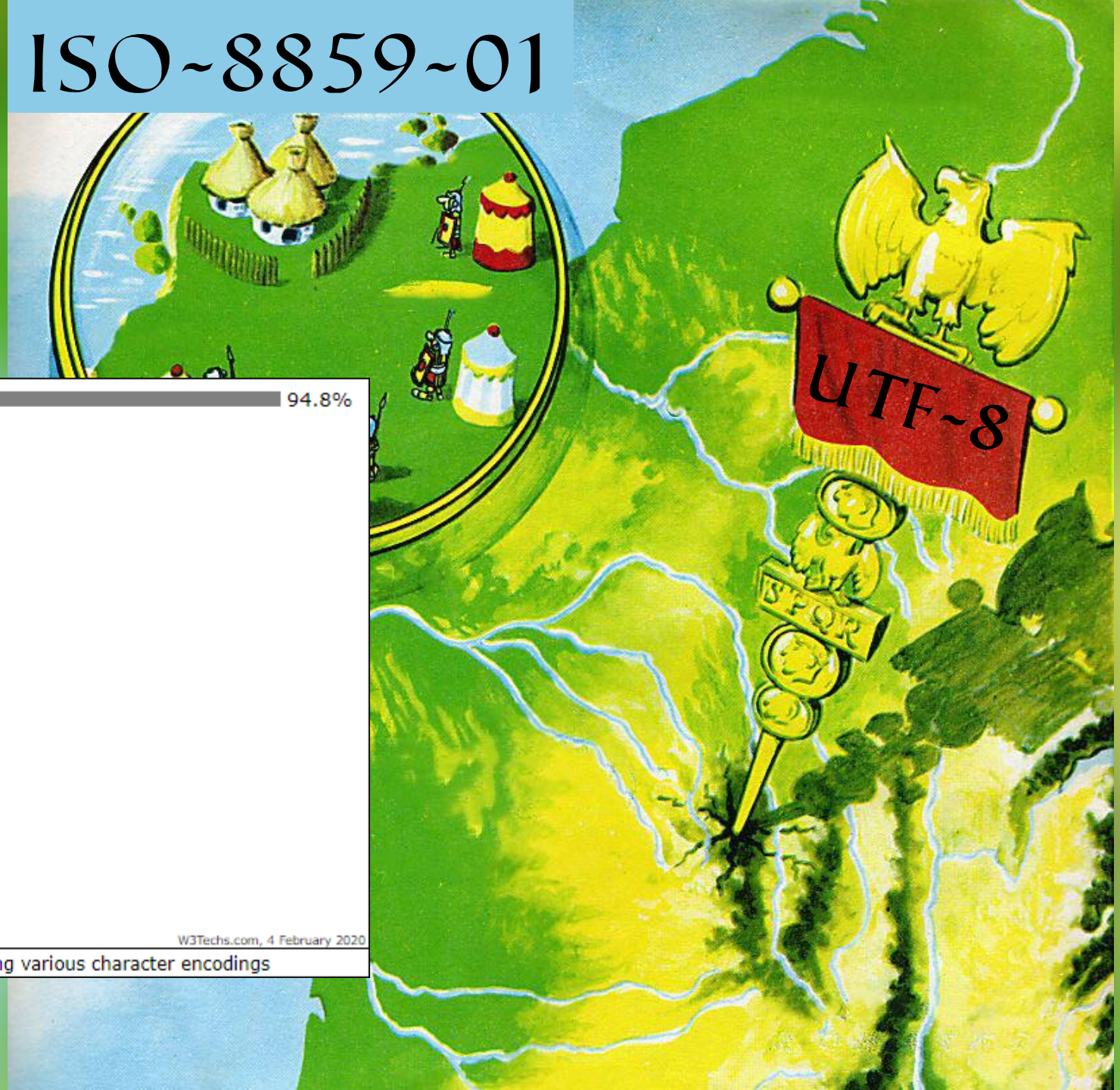
ISO-8859-01

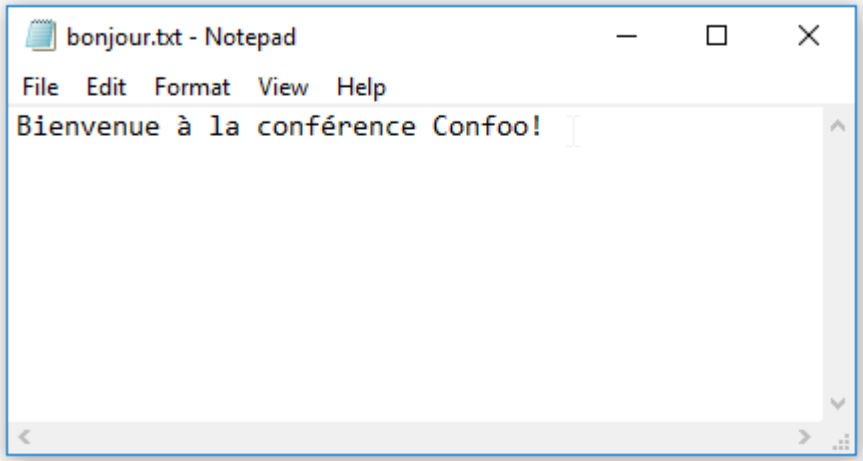


UTF-8	94.8%
ISO-8859-1	2.4%
Windows-1251	1.0%
Windows-1252	0.5%
Shift JIS	0.2%
GB2312	0.2%
EUC-KR	0.2%
EUC-JP	0.1%
ISO-8859-9	0.1%
GBK	0.1%
ISO-8859-2	0.1%
Windows-1250	0.1%
Big5	0.1%
Windows-1254	0.1%

W3Techs.com, 4 February 2020

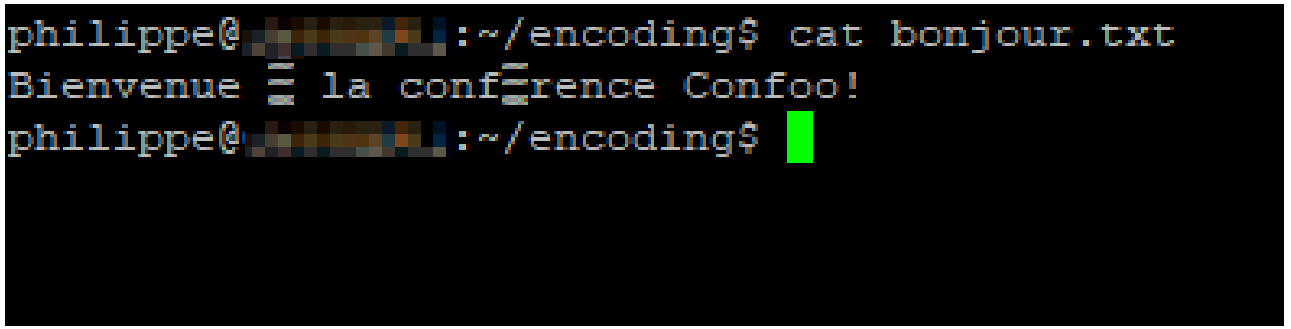
Percentages of websites using various character encodings

Unexpected Encoding



ISO-8859-1

… \xe0 la conf\xe9rence



UTF-8

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Normalization issues

NFC/NFKC Normalisation

Objective :

- Converting any Unicode string to Basic Latin (ASCII) only string.

Use case example:

- Including username, name, ids, description in URL or path.

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Normalisation

When building URL or path, normalization can lead to security issues.

℅ (U+8453)	℅u (U+8454)
﹫ (U+FE6B)	／ (U+FF0F)
﹖ (U+FE56)	‥ (U+2025)
ａ (U+FF41)	ⓒ (U+9426)

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Normalization in action (1/5)

https://www.evil.c%61%63.microsoft.com

https://www.evil.ca/c.microsoft.com

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Normalization in action (2/5)

https://hola@www.microsoft.com

https://hola@www.microsoft.com

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Normalization in action (3/5)

[…]/documents/1_?_view=admin&?view=user

[…]/documents/1?view=admin&?view=user

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Normalization in action (4/5)

[…]/user/admin／/info

[…]/user/admin//info

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Normalization in action (5/5)

[...]/documents/download/：／：／admin／secret

[...]/documents/download/../../admin/secret

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Normalization Recommendations

- If you need to do normalization, normalized prior to security validation
- Review your library (HTTP and Network)
- Prefer whitelist over blacklist
- Strict validation on user input stored or pass to other API

Case modification

Case modification

What happens when « to upper case » and « to lower case » are called?

- Unicode define the behavior when characters are converted to a lower case or uppercase variant.
- Not all character have a variant.
- Many characters share the same variant [1]

[1] Reference: Why there are no uppercase character for X? (collision)
http://unicode.org/faq/casemap_charprop.html#10

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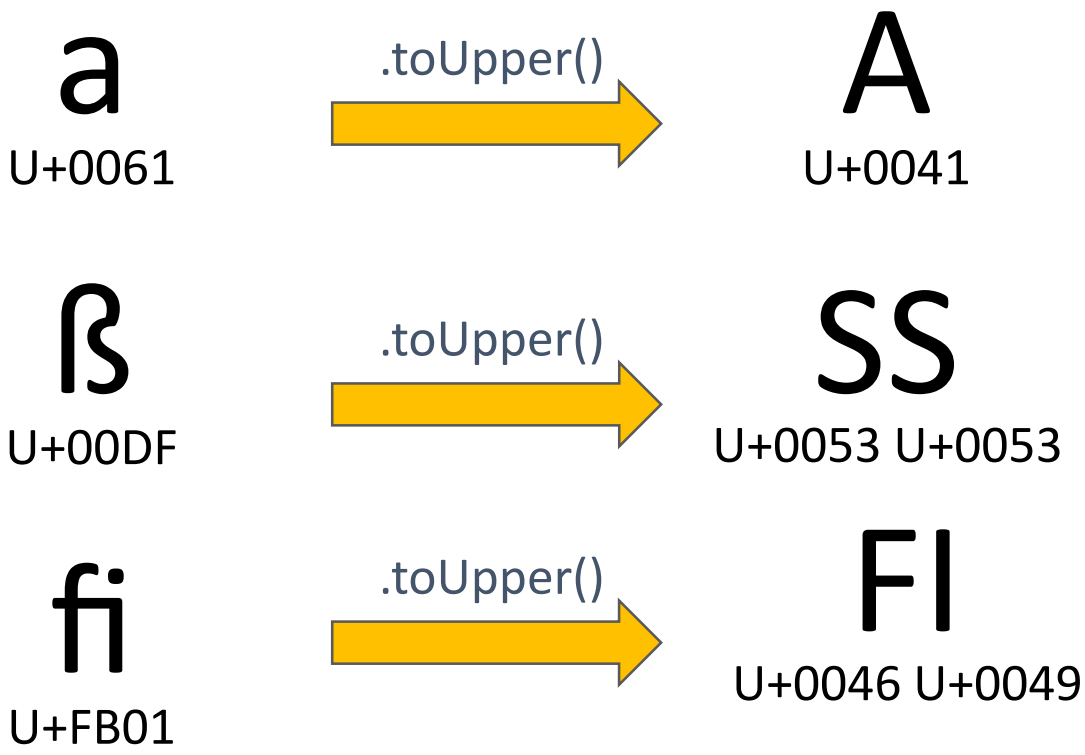
Upper case modification examples



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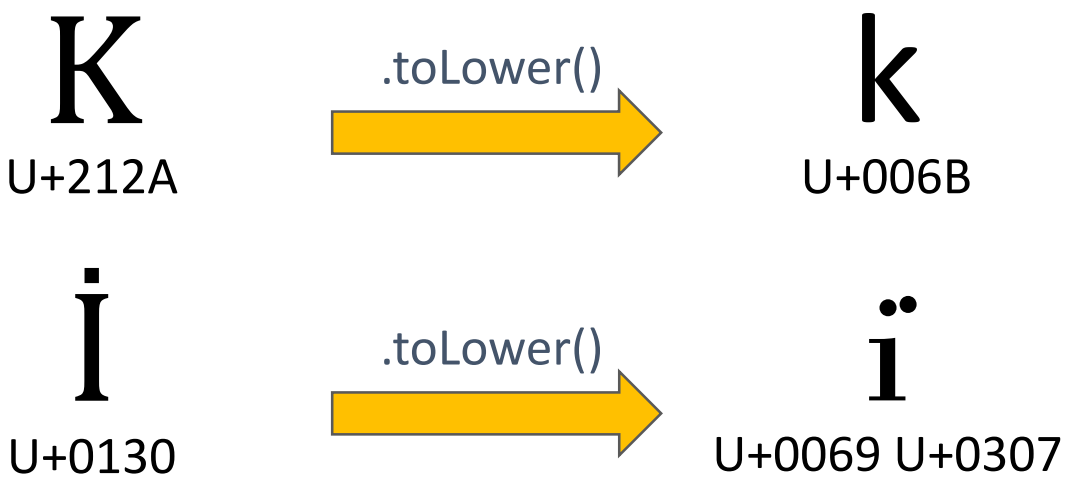
Lower case modification examples



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Potential issues

- Hostname comparison
- Username/permission name comparison
- Unexpected collision
- Any whitelisting or blacklisting mechanism
- WAF bypass

```
if current_user.upper() == "ADMIN":
"adm\u0131n".upper() == "ADMIN"
```

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Certificate validation weakness

```
private static boolean matchAllWildcards(String name,
     String template) {
    name = name.toLowerCase();
    template = template.toLowerCase();
    StringTokenizer nameSt = new StringTokenizer(name, ".");
    StringTokenizer templateSt = new StringTokenizer(template, ".");

    if (nameSt.countTokens() != templateSt.countTokens()) {
        return false;
    }

    while (nameSt.hasMoreTokens()) {
        if (!matchWildCards(nameSt.nextToken(),
                    templateSt.nextToken())) {
            return false;
        }
    }
    return true;
}
```

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Forgot password request in Django (CVE-2019-19844)

Vulnerable implementation

```
278     def save(self, domain_override=None,
279              subject_template_name='registration/password_reset_subject.txt',
280              email_template_name='registration/password_reset_email.html',
281              use_https=False, token_generator=default_token_generator,
282              from_email=None, request=None, html_email_template_name=None,
283              extra_email_context=None):
284         """
285         Generate a one-use only link for resetting password and send it to the
286         user.
287         """
288         email = self.cleaned_data["email"]
289         for user in self.get_users(email):
290             if not domain_override:
291                 current_site = get_current_site(request)
292                 site_name = current_site.name
293                 domain = current_site.domain
294             else:
295                 site_name = domain = domain_override
296             context = {
297                 'email': email,
298                 'domain': domain,
299                 'site_name': site_name,
300                 'uid': urlsafe_base64_encode(force_bytes(user.pk)),
301                 'user': user,
302                 'token': token_generator.make_token(user),
303                 'protocol': 'https' if use_https else 'http',
304                 **(extra_email_context or {}),
305             }
306             self.send_mail(
307                 subject_template_name, email_template_name, context, from_email,
308                 email, html_email_template_name=html_email_template_name,
309             )
310
```

super-admin@email.com

super-adm**\u0130**n@email.com

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Forgot password request in Django (CVE-2019-19844)

Correct implementation

```
292     def save(self, domain_override=None,
293              subject_template_name='registration/password_reset_subject.txt',
294              email_template_name='registration/password_reset_email.html',
295              use_https=False, token_generator=default_token_generator,
296              from_email=None, request=None, html_email_template_name=None,
297              extra_email_context=None):
298         """
299         Generate a one-use only link for resetting password and send it to the
300         user.
301         """
302         email = self.cleaned_data["email"]
303         email_field_name = UserModel.get_email_field_name()
304         for user in self.get_users(email):
305             if not domain_override:
306                 current_site = get_current_site(request)
307                 site_name = current_site.name
308                 domain = current_site.domain
309             else:
310                 site_name = domain = domain_override
311             user_email = getattr(user, email_field_name)
312             context = {
313                 'email': user_email,
314                 'domain': domain,
315                 'site_name': site_name,
316                 'uid': urlsafe_base64_encode(force_bytes(user.pk)),
317                 'user': user,
318                 'token': token_generator.make_token(user),
319                 'protocol': 'https' if use_https else 'http',
320                 **(extra_email_context or {}),
321             }
322             self.send_mail(
323                 subject_template_name, email_template_name, context, from_email,
324                 user_email, html_email_template_name=html_email_template_name,
325             )
```

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Mitigations for case modification

- Use ASCII only lower/upper functions
- Use invariant variation if available in your language.
  - In CSharp: “user input”.ToLowerInvariant()

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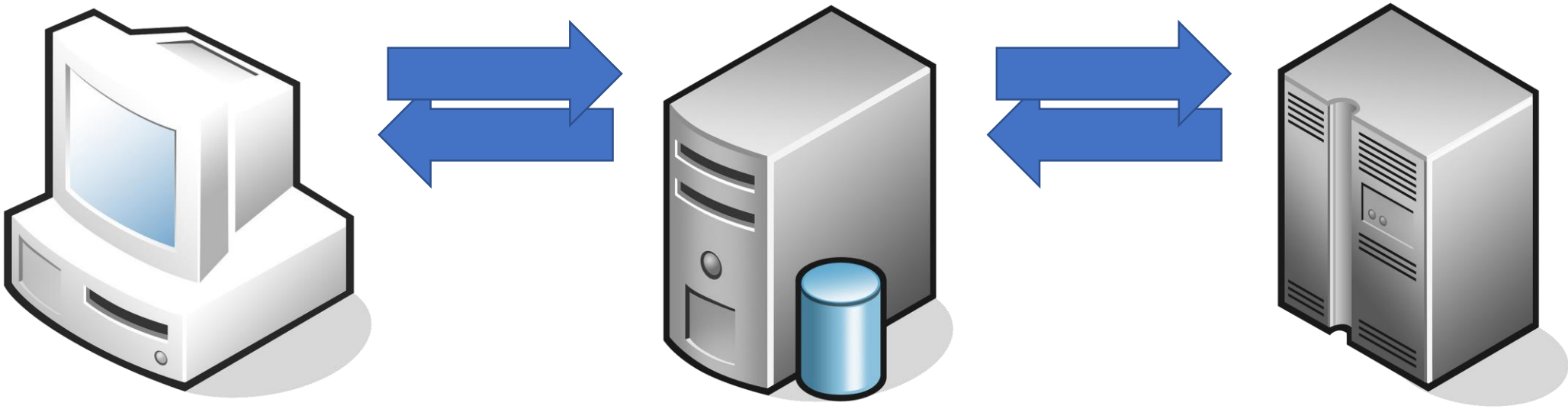
When encoding allows security bypasses

Reason why security filtering can fail



Web Application Firewall

Web Application

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Alternative to UTF-8

Unicode is not the only way to encode characters

Here are standard encoding commonly supported

- UTF-7
- UTF-16LE
- UTF-16BE
- UTF-32…

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Malicious XML document in UTF-16

In UTF-16, every character is stored on two bytes

<book: 3c 62 6f 6f 6b => **00**3c **00**62 **00**6f **00**6f **00**6b

Byte Order Mark:

- First two bytes are used to define the endianness

Encoding	Byte Order Mark (bytes in hex)
UTF-8	EF BB BF
UTF-16BE	FE FF
UTF-16LE	FF FE

These bytes are more likely to be honored when a file is read than an HTTP request.

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Malicious XML document in UTF-16

How the bytes are stored

```
> cat book_utf16be.xml
 < b o o k   x m l : i d = " s i m p l e _ b o o k "   x m l n s = " h t t p : / / d o c b o o k . o r g / n s / d o c b o o k
"   v e r s i o n = " 5 . 0 " >
   < t i t l e > V e r y   s i m p l e   b o o k < / t i t l e >
   < c h a p t e r   x m l : i d = " c h a p t e r _ 1 " >
      < t i t l e > C h a p t e r   1 < / t i t l e >
      < p a r a > H e l l o   w o r l d ! < / p a r a >
      < p a r a >
        I   h o p e   t h a t   y o u r   d a y   i s   p r o c e e d i n g   < e m p h a s i s > s p l e n d i d l y < / e
m p h a s i s > !
      < / p a r a >
   < / c h a p t e r >
   < c h a p t e r   x m l : i d = " c h a p t e r _ 2 " >
      < t i t l e > C h a p t e r   2 < / t i t l e >
      < p a r a > H e l l o   a g a i n ,   w o r l d ! < / p a r a >
   < / c h a p t e r >
< / b o o k >
```

How your application will see it

book_utf16be.xml

```
1  <book xml:id="simple_book" xmlns="http://docbook.org/ns/docbook" version="5.0">
2    <title>Very simple book</title>
3    <chapter xml:id="chapter_1">
4      <title>Chapter 1</title>
5      <para>Hello world!</para>
6      <para>
7        I hope that your day is proceeding <emphasis>splendidly</emphasis>!
8      </para>
9    </chapter>
10   <chapter xml:id="chapter_2">
11     <title>Chapter 2</title>
12     <para>Hello again, world!</para>
13   </chapter>
14 </book>
```

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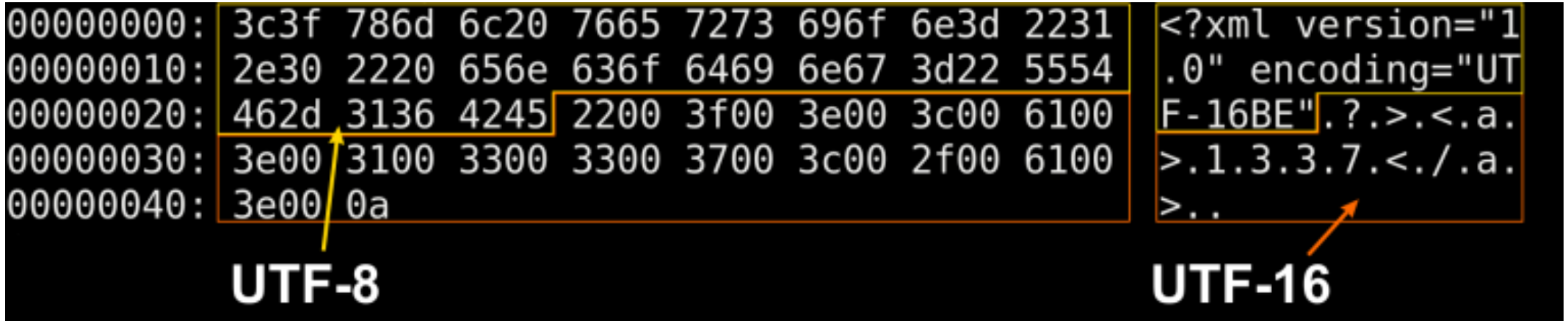
Malicious XML document with mixed encoding

- In protocols where encoding is defined, Byte Order Mark is not enough.
- XML support change encoding in the XML declaration section.



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Other avenues

There are plenty obfuscation techniques that are do not require fancy Unicode encoding (out-of-scope for this presentation)

- XML entities (inside XML) /etc/passwd
- Double encoding %253C -> %3C -> <
- Non-printable characters java**\t**script:
- Partial encoding /etc/passwd
- Parser specific behavior

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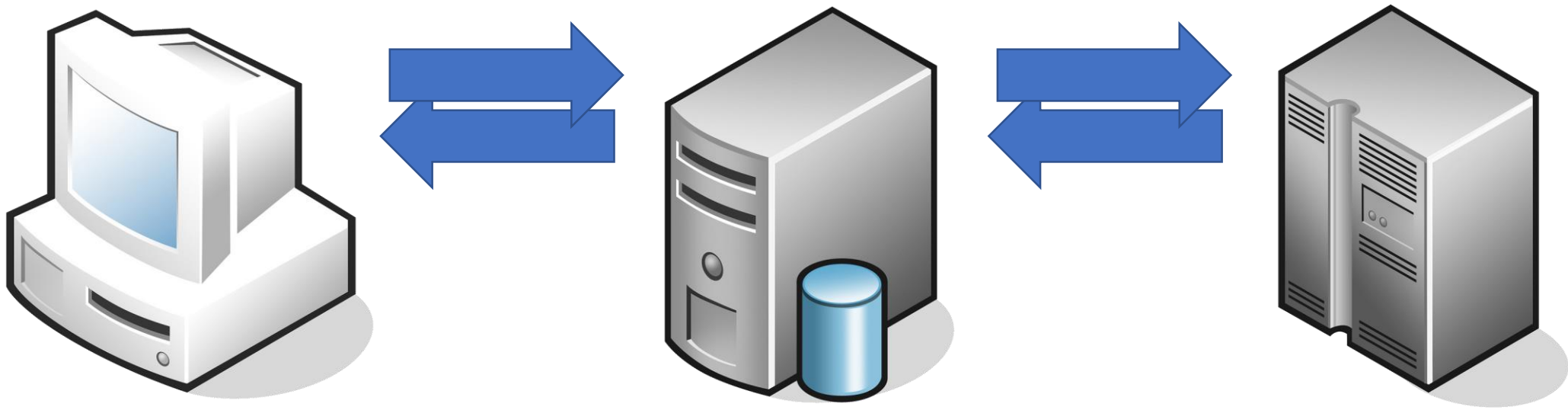
Storing user input inside a database



Web Application

Database

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Persistent XSS inside database

Query

INSERT INTO ContentTable
VALUES (…,'＜img src=…')

＜img src=…

U+FF1C

Data once stored

<img src=…

U+003C

Example tested on SQL Server with default collation **SQL_Latin1_General_CP1_CI_AS**

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Homograph attacks

With punycode domains

Punycode domains

Punycode is a representation of Unicode characters using ASCII characters.

It use the bootstring encoding system.

Example:

- cönfoo.ca
- xn--cnfoo-jua.ca

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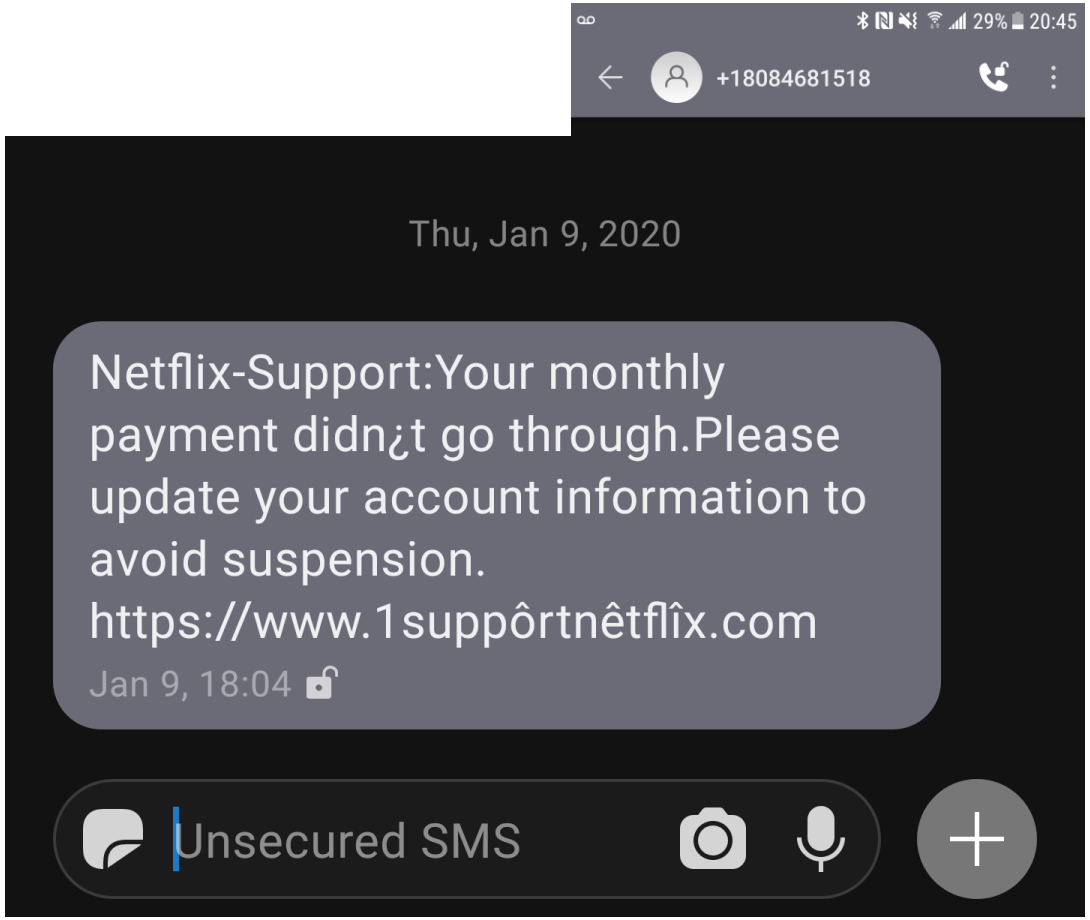
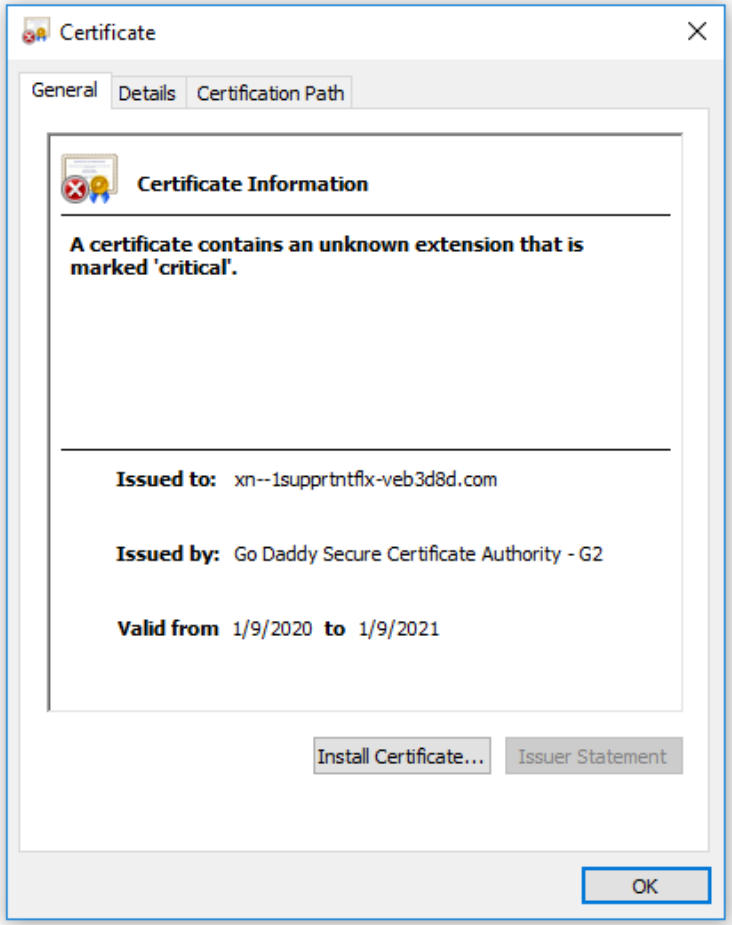
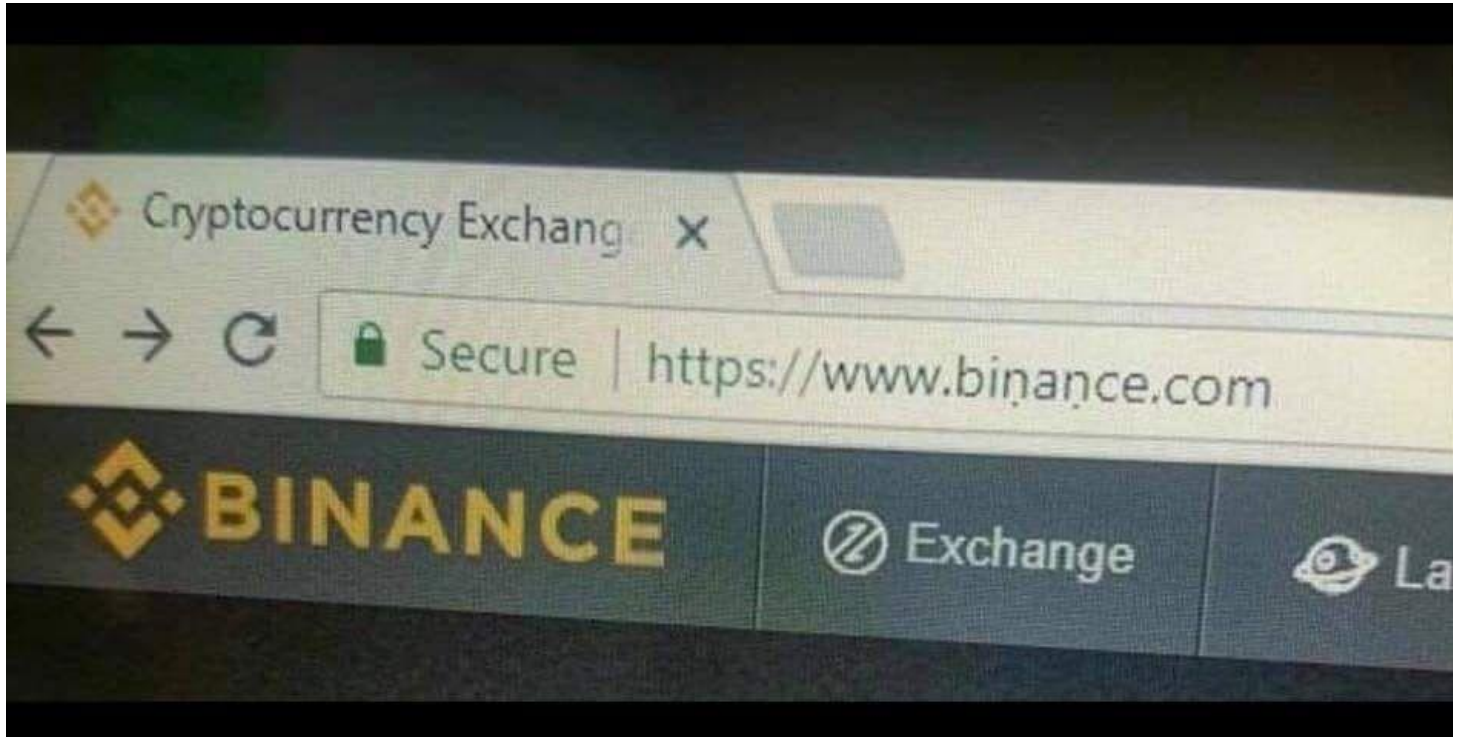
Homograph SMS Phishing

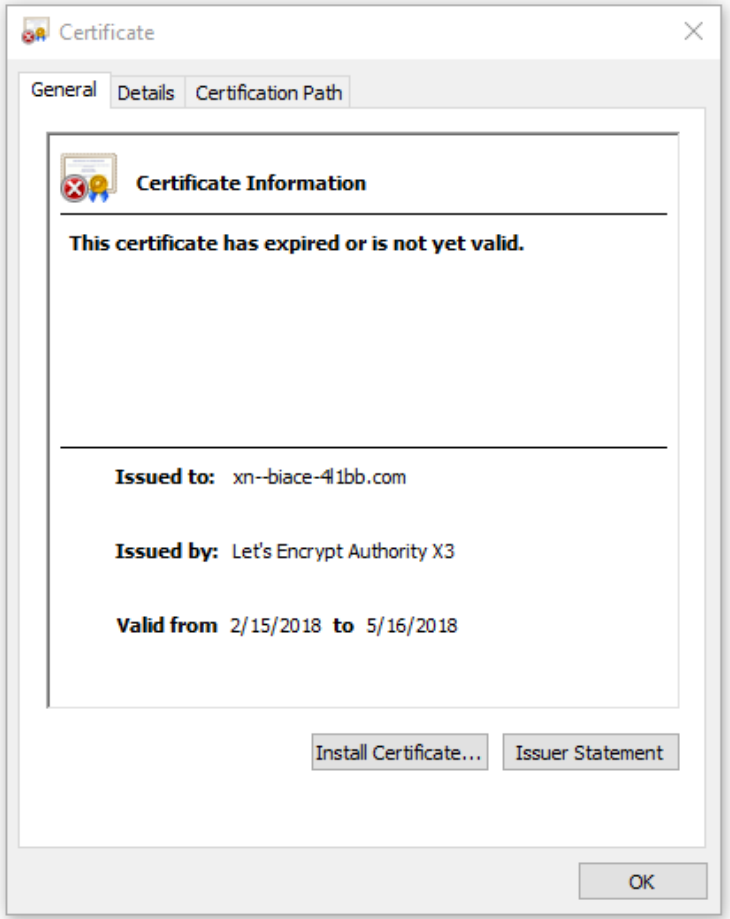




Source : https://crt.sh/?id=2310598224

Homograph phishing attack





Source : https://bitcointalk.org/index.php?topic=5184169.0 & https://crt.sh/?id=331930167

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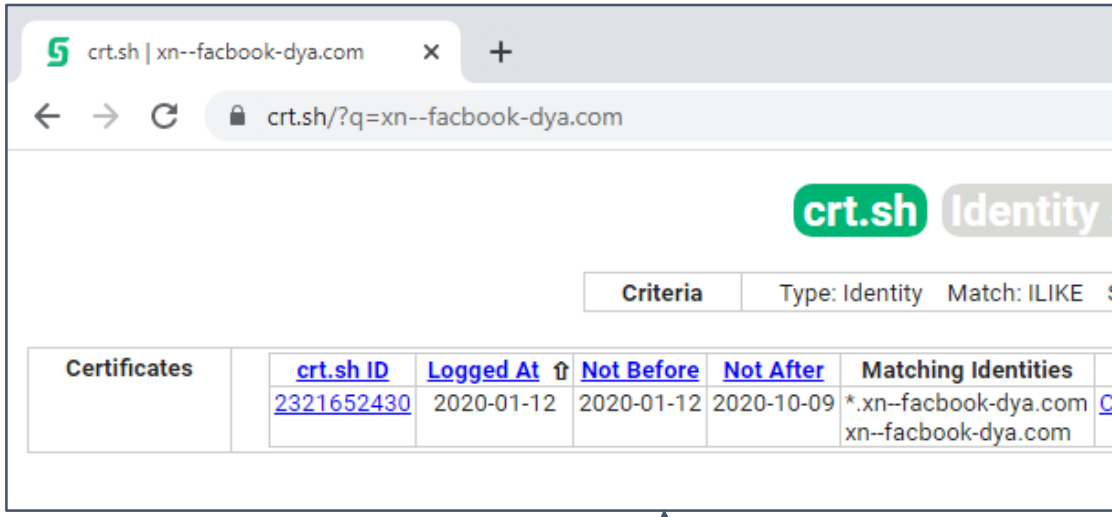
Mitigations

Defenses

- Browser defense (mostly Chrome)
- Sender Policy Framework (SPF)
- Awareness training
- Find phishing domains on the TLS transparency log



Additional Reference:
https://us.norton.com/internetsecurity-how-to-cyber-security-best-practices-for-employees.html

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Data integrity

Losing data because of encoding..

Data integrity

- Improper conversion can lead to partial data loss

- If the decoder does not recognize the encoding…
  - it may raise an exception
  - or the characters can be silently replaced.

'conf**\xe9**rence confoo' ➡ 'conf**\ufffd**rence confoo'

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Do NOT use

- Java : new String(binary_file_content, Encoding.UTF8)
- Python : binary_file_content.decode("utf-8", errors="ignore")

You SHOULD use

- Java:
  - CharsetDecoder decoder = Charsets.UTF_8.newDecoder().onMalformedInput(**CodingErrorAction.REPORT**);
    CharBuffer decoded = decoder.decode(ByteBuffer.wrap(input));
- Python
  - binary_file_content.decode("utf-8“)

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Conclusion

Recommendation

- Be cautious when using
  - Case changing function (.upper(), .lower())
  - Normalization function (UTF-8 to ASCII)
  - Internalization function (Punycode to UTF-8)
- Restrict to ASCII (CP < 128) (username, service name, id)
- Declare explicitly the encoding to avoid implicit default that vary

Questions

Contact information

- parteau@gosecure.ca
- @GoSecure_Inc
- @h3xStream

Slides

https://github.com/confooca/yul2020-slides

References

References for normalization

- Black Hat presentation of HostSplit: https://i.blackhat.com/USA-19/Thursday/us-19-Birch-HostSplit-Exploitable-Antipatterns-In-Unicode-Normalization.pdf

- GitHub vulnerabilities with lowercase issue: https://eng.getwisdom.io/hacking-github-with-unicode-dotless-i/

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References for Punycode

- Good presentation on Punycode visual attack: http://www.irongeek.com/i.php?page=security/out-of-character-use-of-punycode-and-homoglyph-attacks-to-obfuscate-urls-for-phishing

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