The Dangers of Human Touch: Fingerprinting Browser Extensions through User Actions

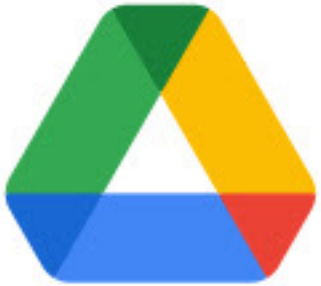
Konstantinos Solomos, Panagiotis Ilia, Soroush Karami,
Nick Nikiforakis, Jason Polakis
ksolom6@uic.edu

31ST USENIX
SECURITY SYMPOSIUM

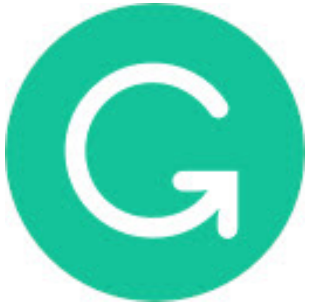
Stony Brook University

UIC

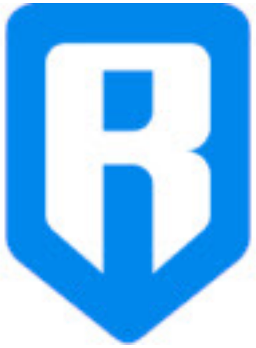
Browser Extensions



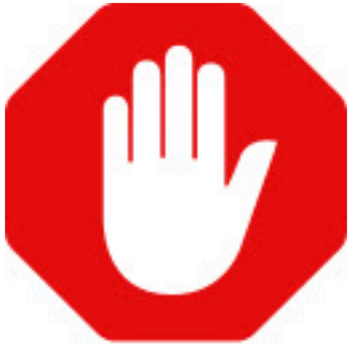
3 Million users



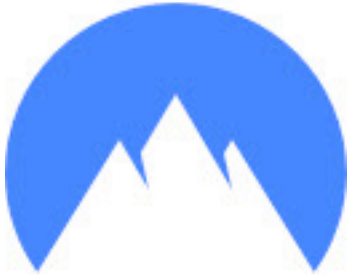
10 Million users



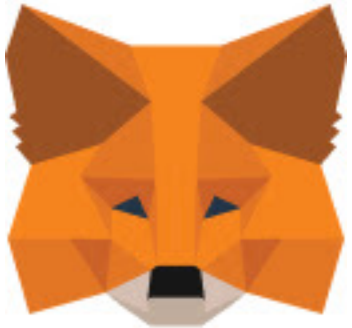
1 Million users



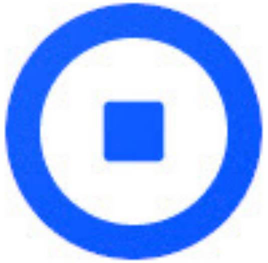
10 Million users



1 Million users



10 Million users



1 Million users

An Emerging Privacy Problem

- Fingerprinting browser extensions
  - Arbitrary websites detect extensions and track the user
  - No permissions
  - Reveal personal-sensitive information
- Side channel inference techniques
  - Web Accessible Resources (Sjosten et al. CODASPY ‘17)
  - Behavioral fingerprints (Starov & Nikiforakis IEEE S&P ’17, Karami et al. NDSS ’20)
  - Style Modifications (Laperdrix et al. USEC ‘21)

An Emerging Privacy Problem

- Fingerprinting browser extensions
  - Arbitrary websites detect extensions and track the user
  - No permissions
  - Reveal personal-sensitive information
- Side channel inference techniques
  - Web Accessible Resources (Sjosten et al. CODASPY ‘17)
  - Behavioral fingerprints (Starov & Nikiforakis IEEE S&P ‘17, Karami et al. NDSS ’20)
  - Style Modifications (Laperdrix et al. USEC ‘21)

Passive Detection!

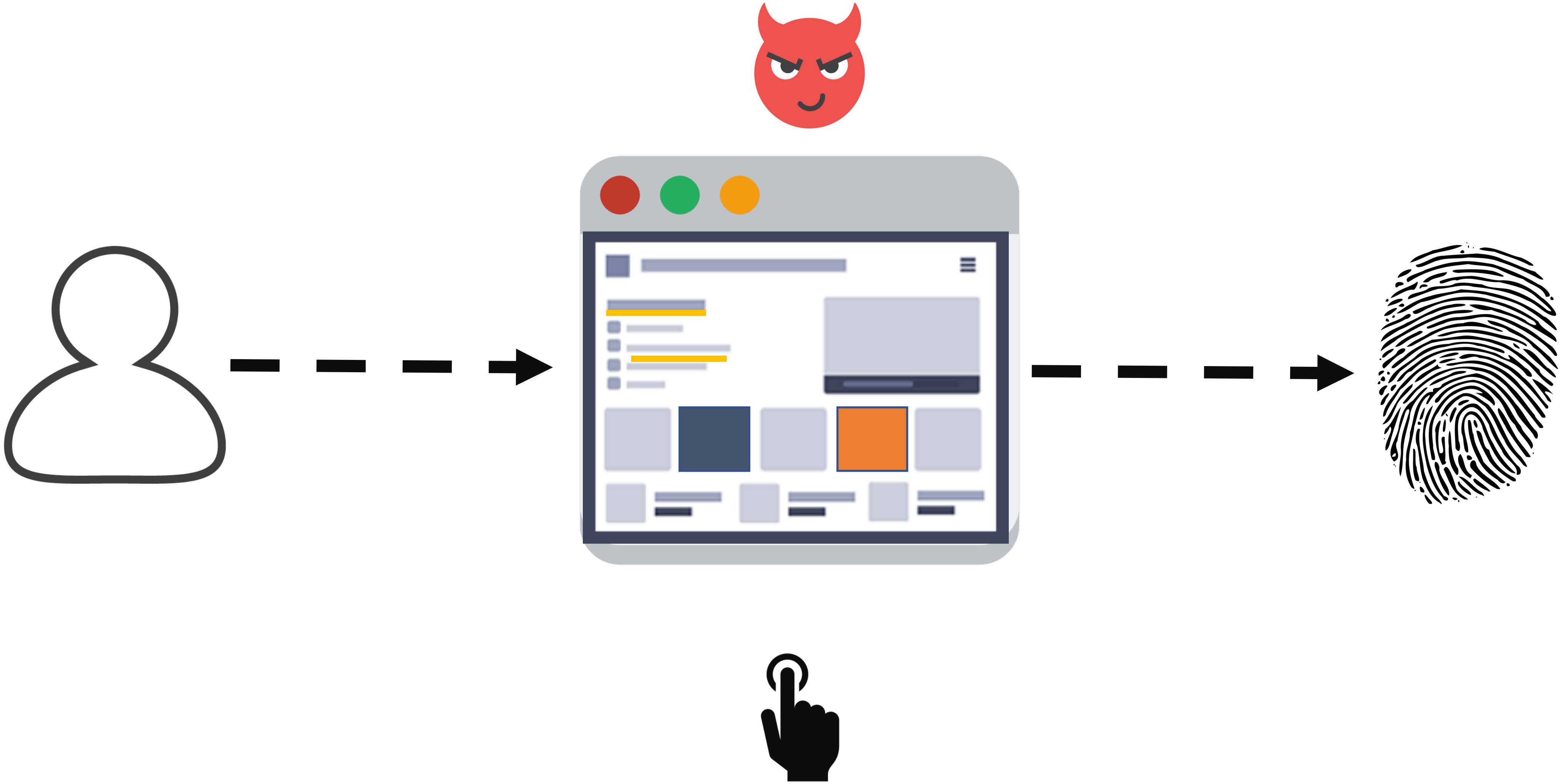
Extensions: Complex & Dynamic Behavior

- Specialized features triggered by **user interactions**
  - Text Selection
  - User Input
  - Right Click
  - Context Menu
  - Hotkeys

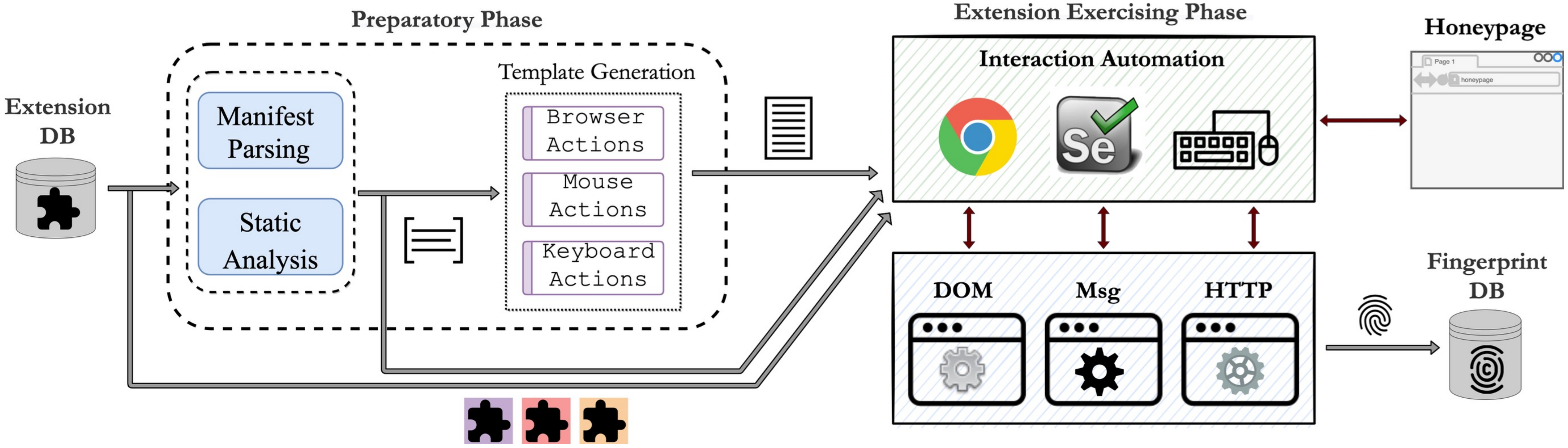
  . . .

➢ **How do user interactions affect the fingerprintability of extensions?**

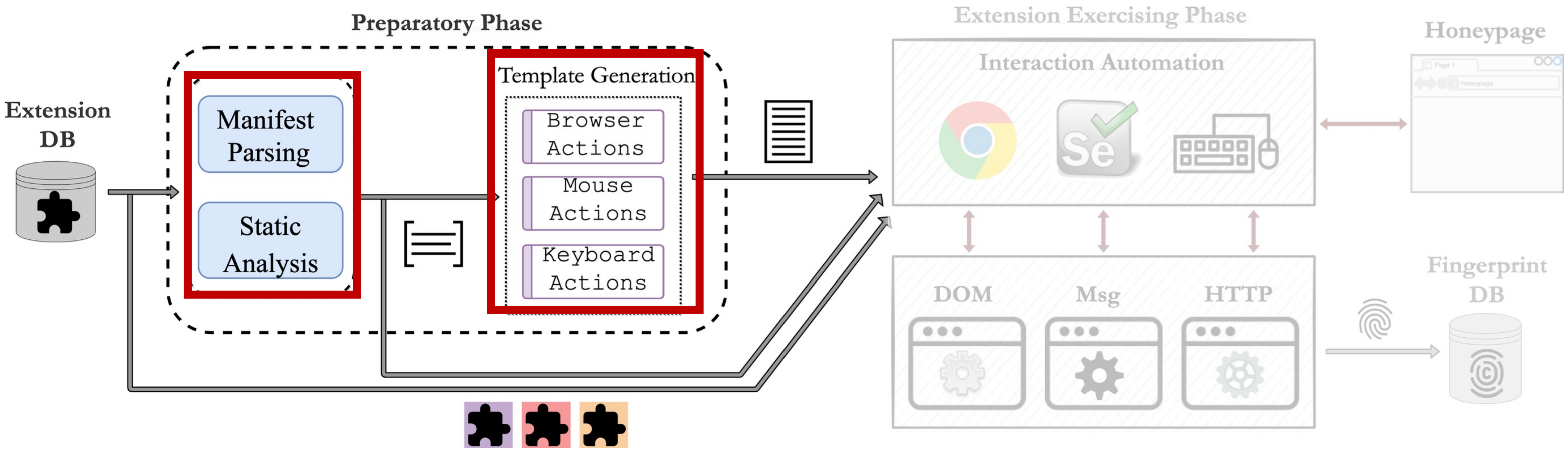
Threat model



Methodology



Methodology



Preparatory Phase

- Parse *manifest.json* extract permissions & structure
  - *ContextMenu* → Right-click action
  - *Browser_Action* → Extension icon

- Static analysis to identify user-driven capabilities
  - *addEventListener (click, scroll, keypress, …)*
  - Categorize and group by the target action
    - *Mouseup, Mousedown, Mousemove, Mouseover*
    - *Click, Doubleclick, Scroll, Select*
    - *Keypress, Keyup, Keydown*

….

User Interaction Templates

- **Browser actions**
  - Extension’s browser icon, Popup page, Configuration page

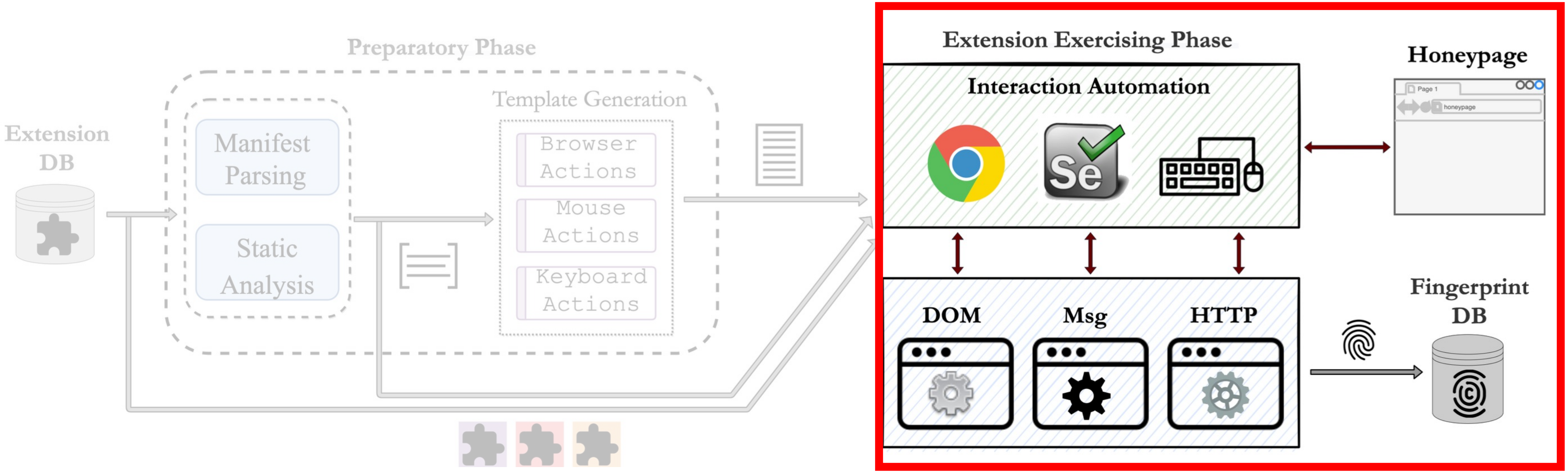
User Interaction Templates

- Browser actions
  - Extension's browser icon, Popup page, Configuration page
- **Mouse actions**
  - Doubleclick, Select, Highlight
  - Mousemove, Mousedown, Mouseup, Mouseover

User Interaction Templates

- Browser actions
  - Extension’s browser icon, Popup page, Configuration page
- Mouse actions
  - Doubleclick, Select, Highlight
  - Click, Mousedown, Mouseup, Blur, Focus
- **Keyboard actions**
  - Single keystroke, Repetitive keystroke
  - Combined Hotkeys

Methodology



Extension Fingerprinting via User Actions

- Honey Page
  - Adopted by Carnus [Karami et al.]
  - Forms, clickable elements, dynamic elements, dropdown lists
  - Textual content of 8 popular languages

- Exercise extension according to their structure & permissions

$Actions_{exti}$: *{extension-icon, right-click, mouse, keyboard, . . .}*

$Actions_{extj}$: *{right-click, popup page, mouse, keyboard, . . . }*

Extension Fingerprinting via User Actions

- Generate fingerprint after each action
  - Trigger each action **independently**
  - Collect the behavioral fingerprint
    - Outer HTML modifications (DOM)
    - Intra-communication (broadcasted messages)
    - Inter-communication (resources loaded)

$Fingerprint_{exti}$: {***right-click*** *[background-color:blue]*, ***key_M*** *[msg:abc]*}

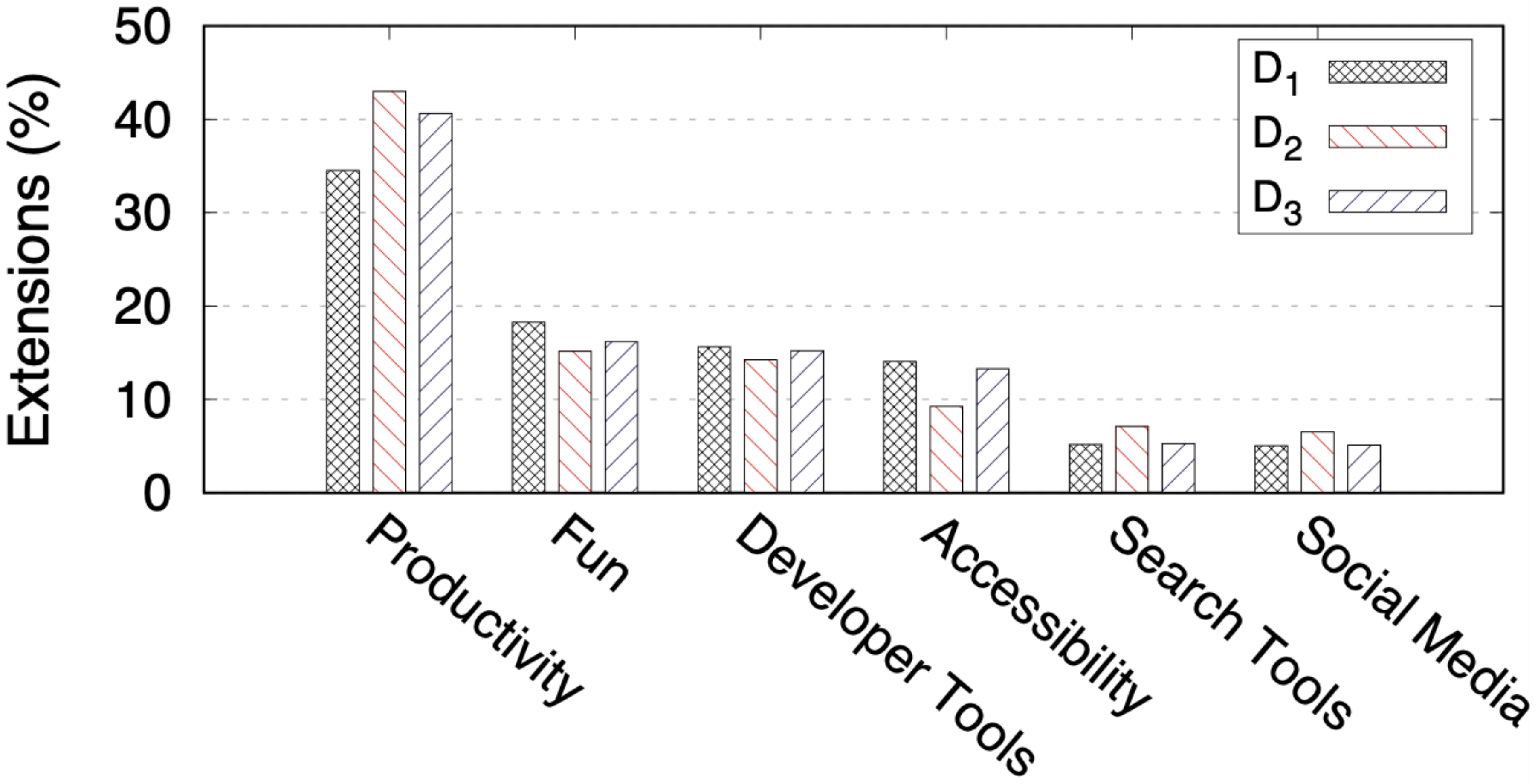
Experimental Evaluation

- 3 Datasets [2018-2021]
  - 41K extensions
  - Fingerprinted : **5,531** (13%)

- Overview
  - 89% of extensions triggered by extension icon
  - Mouse events: highlight term and right-click (75%)
  - Keyboard interactions: single keystroke and 2 key combination (83%)

➢ **Effectively replicate user interactions and trigger extensions**

Experimental Evaluation

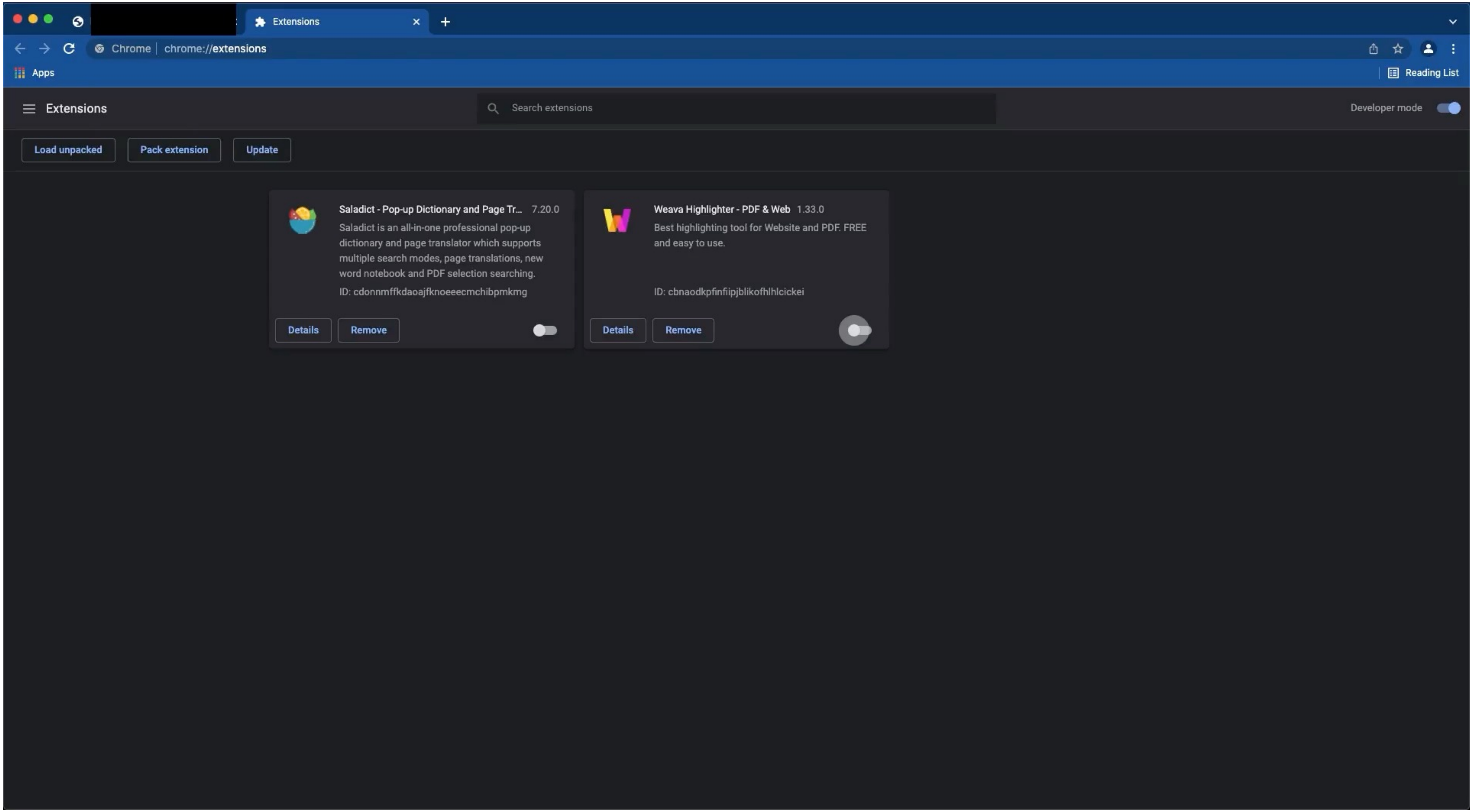


Attack : Page Simulated Events

- Generate artificially crafted interaction events
  - JavaScript API Dispatch Event
  - Replicate all mouse and keyboard events
    - Click, Scroll, Select, Mouse Move, …
  - Bypass real user interactions
- Browsers origin verification mechanism
  - *event.isTrusted* {True, False}
  - Rarely used by developers

Attack Evaluation

- Leverage artificial events to trigger extensions
  - Select term {*mousemove, … , mouseover, highlight, … , doubleclick*}
  - Enable form {*mousemove, … , mouseup, click, … , click*}
- Vulnerable extensions: 1,513 (67 %)
  - 88% of mouse events
  - 65% of keyboard events
- Triggering 20 extensions < 0.5 seconds



Developer mode ●

Saladict - Pop-up Dictionary and Page Tr... 7.20.0

Saladict is an all-in-one professional pop-up dictionary and page translator which supports multiple search modes, page translations, new word notebook and PDF selection searching.

ID: cdonnmffkdaoajfknoeeecmchibpmkmg

Weava Highlighter - PDF & Web 1.33.0

Best highlighting tool for Website and PDF. FREE and easy to use.

ID: cbnaodkpfinfiipjblikofhlhlcickei

Conclusion

- Novel extension fingerprinting vector that employs user interactions to fingerprint extensions

- Evaluated user-triggered extension fingerprinting and detected 1,820 *hidden* extensions

- Demonstrated the lack of security checks by triggering extensions through artificial actions

- Proposed a countermeasure for automatic incorporation of safeguards in the extension’s code

Thank you!

Feel free to reach out with any questions:

ksolom6@uic.edu