USC University of Southern California

NSDI 2014

DECAF: Detecting and Characterizing Ad Fraud in Mobile Apps

Bin Liu

Suman Nath, Ramesh Govindan, Jie Liu

NSL

Microsoft Research

The Mobile Ad Ecosystem

App Developer

Paid by Impressions

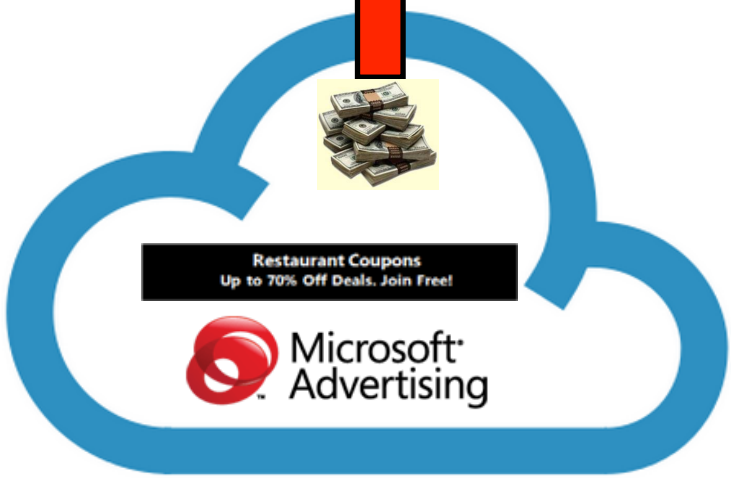
Paid by User Clicks

Ad Plugin

Phone/Tablet App

See/Click Ads

App User



Ad Network

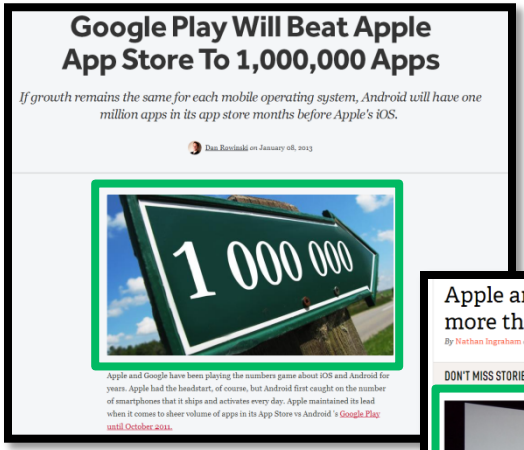
Mobile Ad Fraud

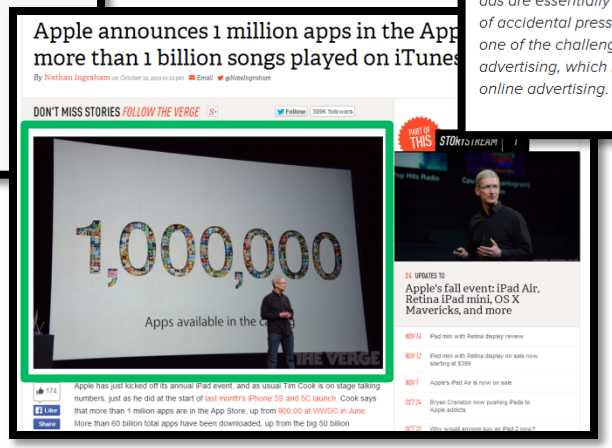
App developers have incentive to commit fraud
by inflating clicks and impressions

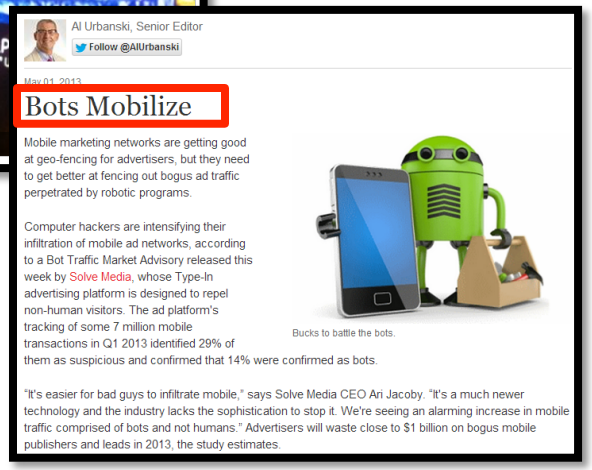
Ad Fraud: a Big Business

Very large mobile marketplaces

1 billion dollars lost due to ad fraud in 2013







Placement Ad Fraud

We explore a sub-class of ad fraud, called placement ad fraud

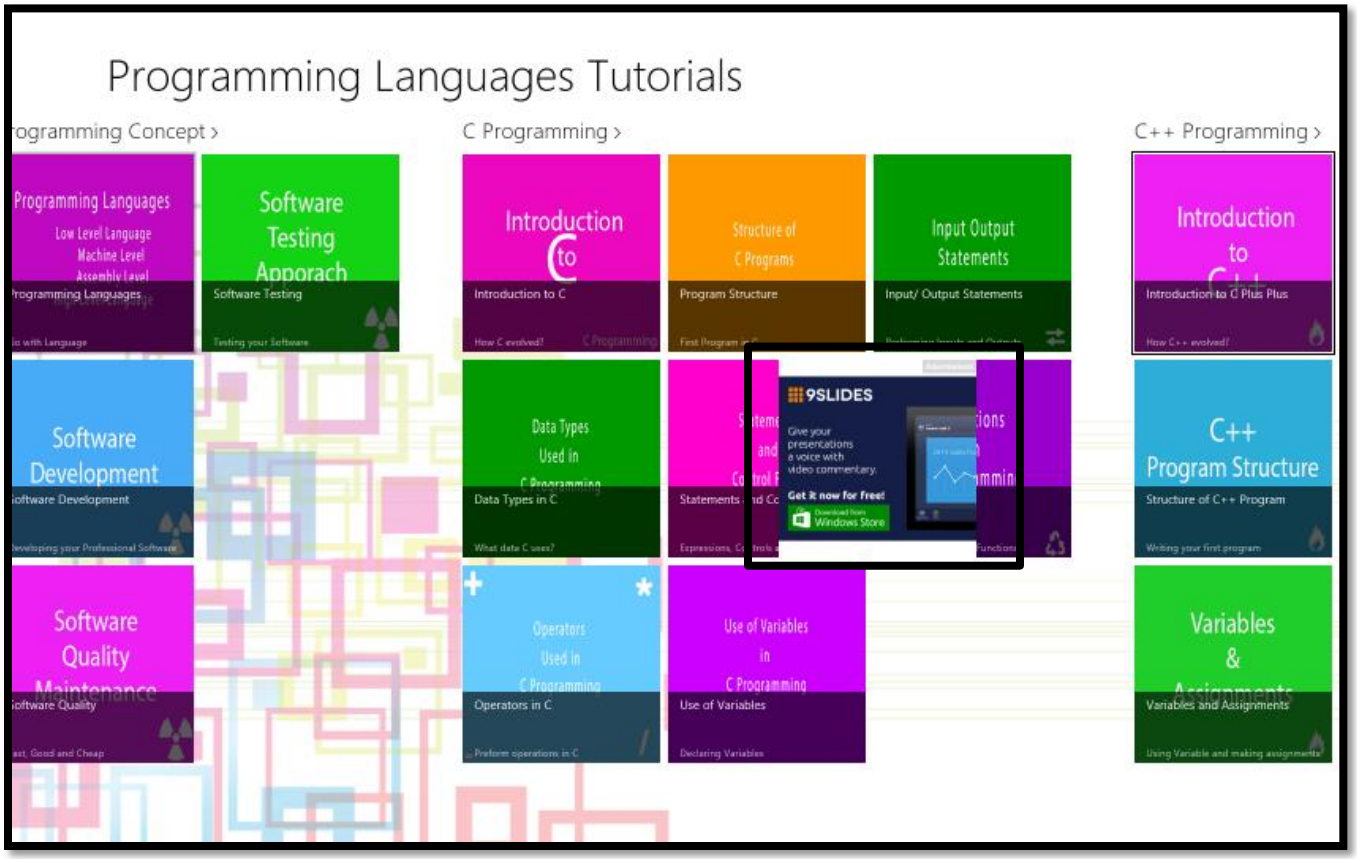
Developers manipulate visual layouts to trigger invisible impressions or unintentional clicks

Microsoft Advertising Prohibits Placement Ad Fraud

"A developer must not edit, resize, modify, filter, obscure, hide, make transparent, or reorder any advertising"

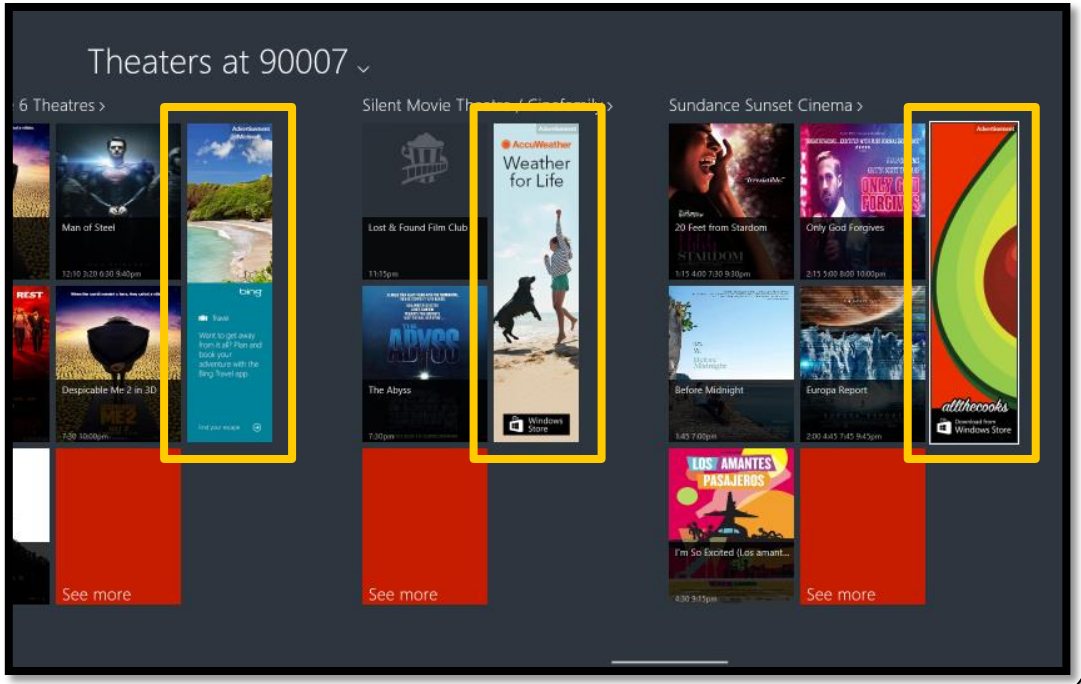
Placement Ad Fraud Examples

Intrusive ads



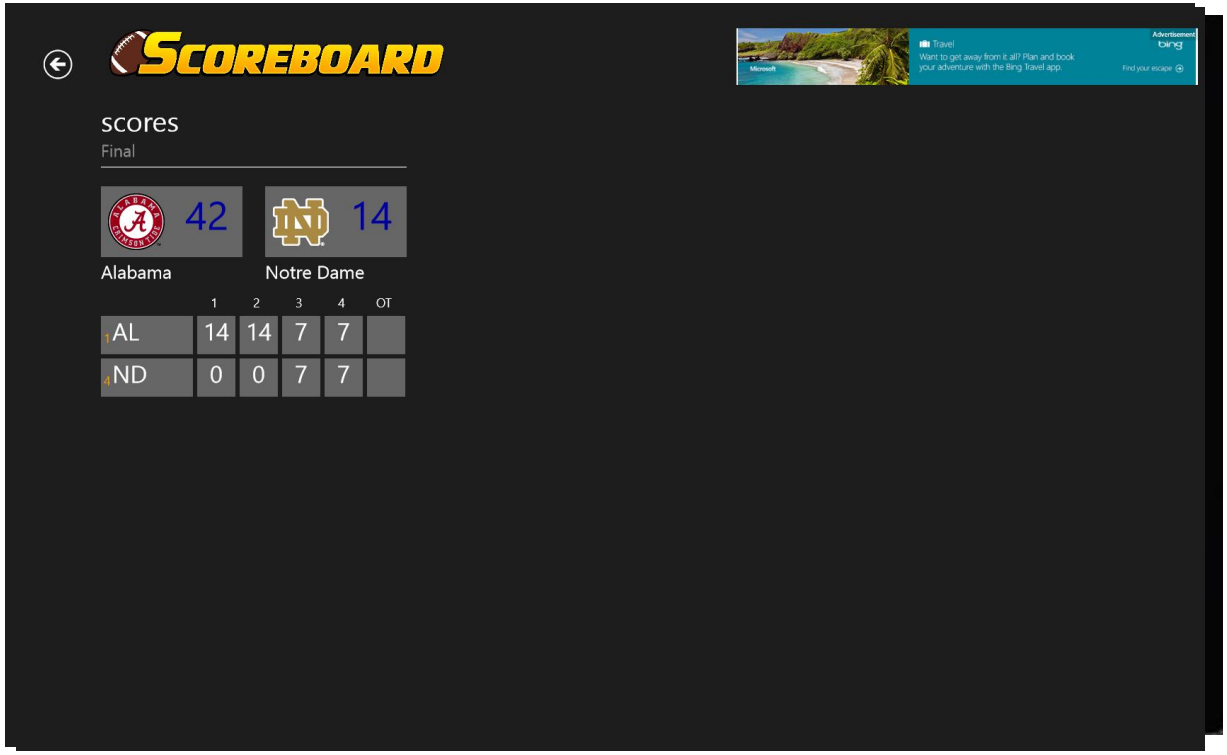
Placement Ad Fraud Examples

Many ads



Placement Ad Fraud Examples

Hidden ads



Current Approach

Manual inspection, which is labor-intensive and error-prone

Several tens of minutes to manually scan one app

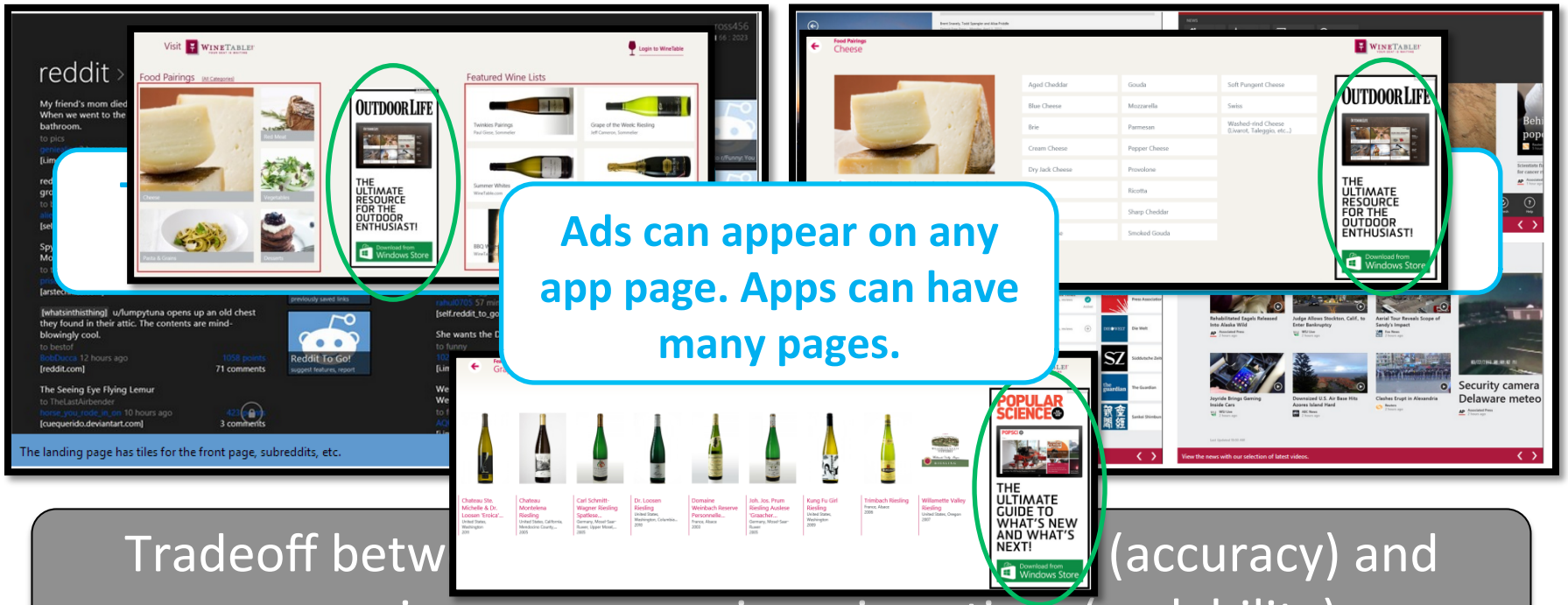
Cannot detect some placement ad fraud, like hidden ads

Goal

To design an automated system for detecting placement fraud

Challenges

Challenge 1: Scaling to thousands of visually complex apps

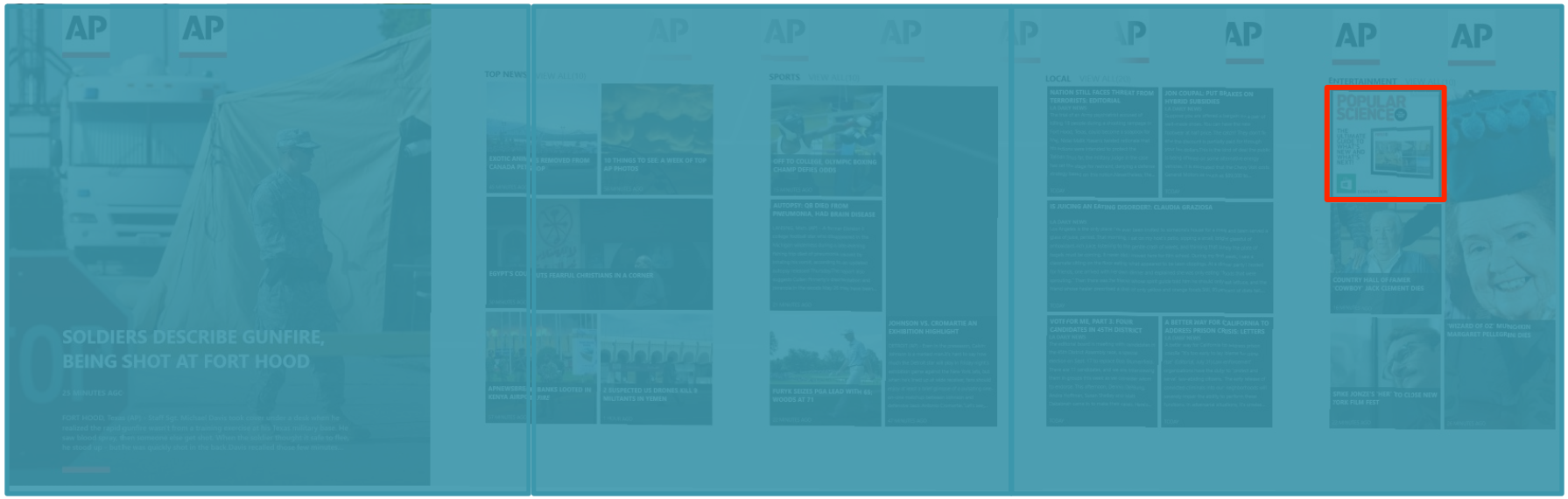


Ads can appear on any app page. Apps can have many pages.

Tradeoff betw (accuracy) and processing more apps in a given time (scalability)

Challenges

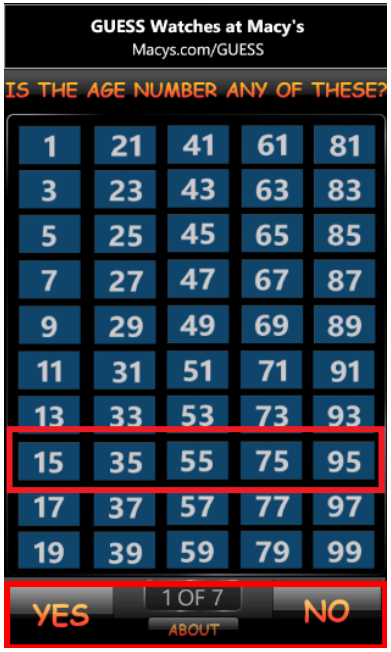
Challenge 2: accurately and quickly identify fraud

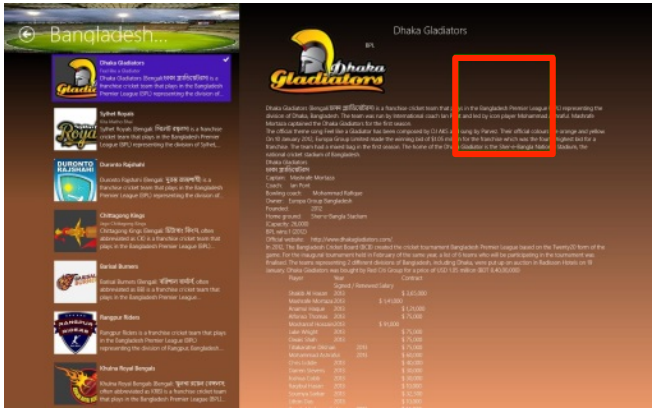


"Sliding Screen" Problem
(in a Panoramic Page)

Challenges

Challenge 2: accurately and quickly identify fraud





Hidden Ads
(Z-index not Available)

Our Approach – Dynamic Analysis

Use UI-automation based dynamic analysis to detect placement fraud

Dealing with Visual Complexity

Develop automated scalable navigation of app pages through dynamic execution

Accurate Fraud Detection

Design several efficient fraud detectors, one for each fraud type

Contributions

Design and implementation of the DECAF system to detect placement fraud

Characterization of placement fraud by analyzing 50,000 Windows Phone apps and 1,150 tablet apps using DECAF

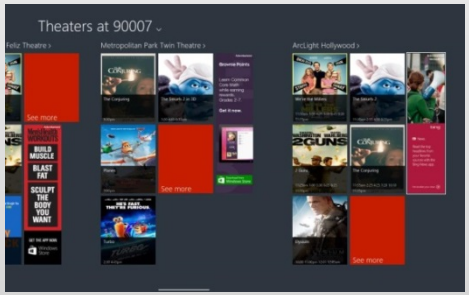
Deployment of DECAF in the ad fraud team at Microsoft, which has helped detect many instances of fraud

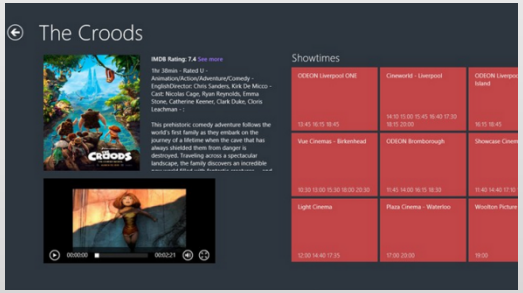
DECAF Overview

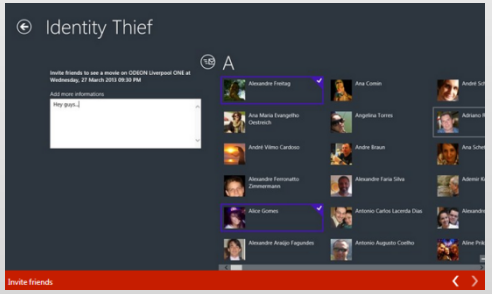
Movie ShowTime

DECAF

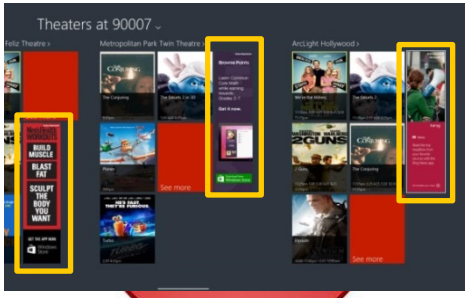
Automated UI Navigation (Monkey)



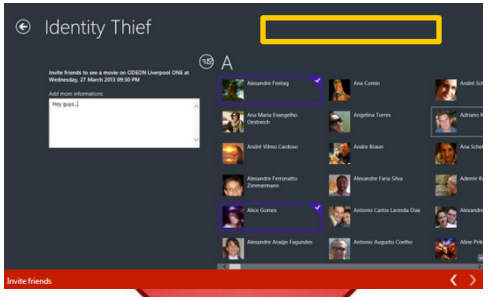




Fraud Checkers

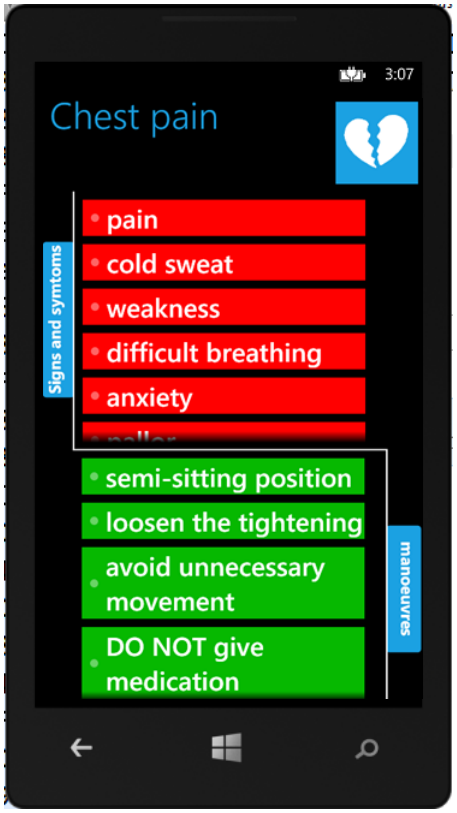


Many Ads



Hidden Ads

Automated UI Navigation



Next App Page

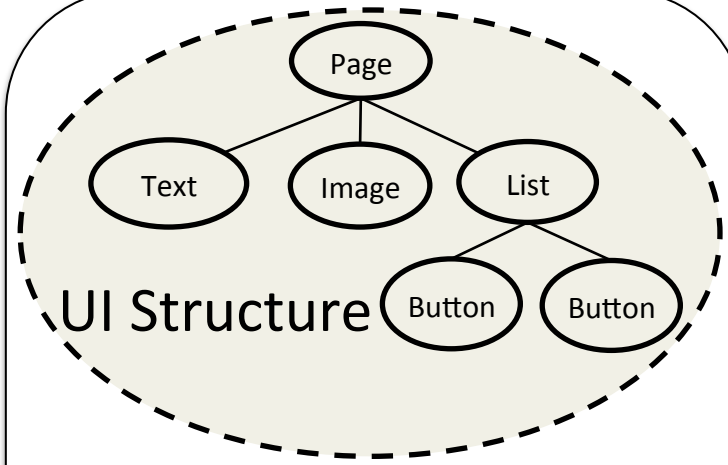
UI Extraction

UI Extraction Channel

UI Action Channel

Click “Continue” Button

UI Action



Monkey

Decide UI Action

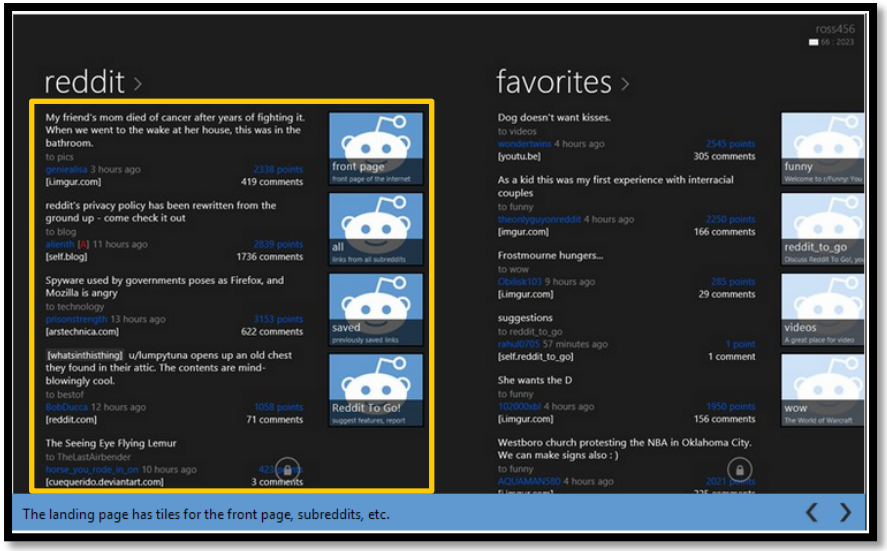
Action Dictionary	
Button	Click
Multipage	Swipe
List	Scroll

The set of previously visited pages

Problem: Reducing the Search Space

Avoid clicking UI elements on previously visited pages?

UI page space can be practically infinite



One Reddit App Page

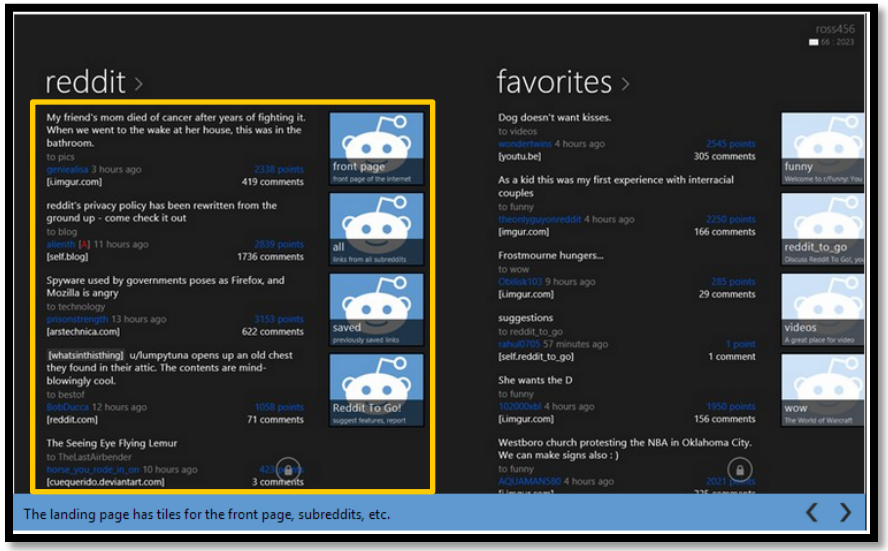
The post list is updated every several minutes

Reducing the Search Space

Key observation

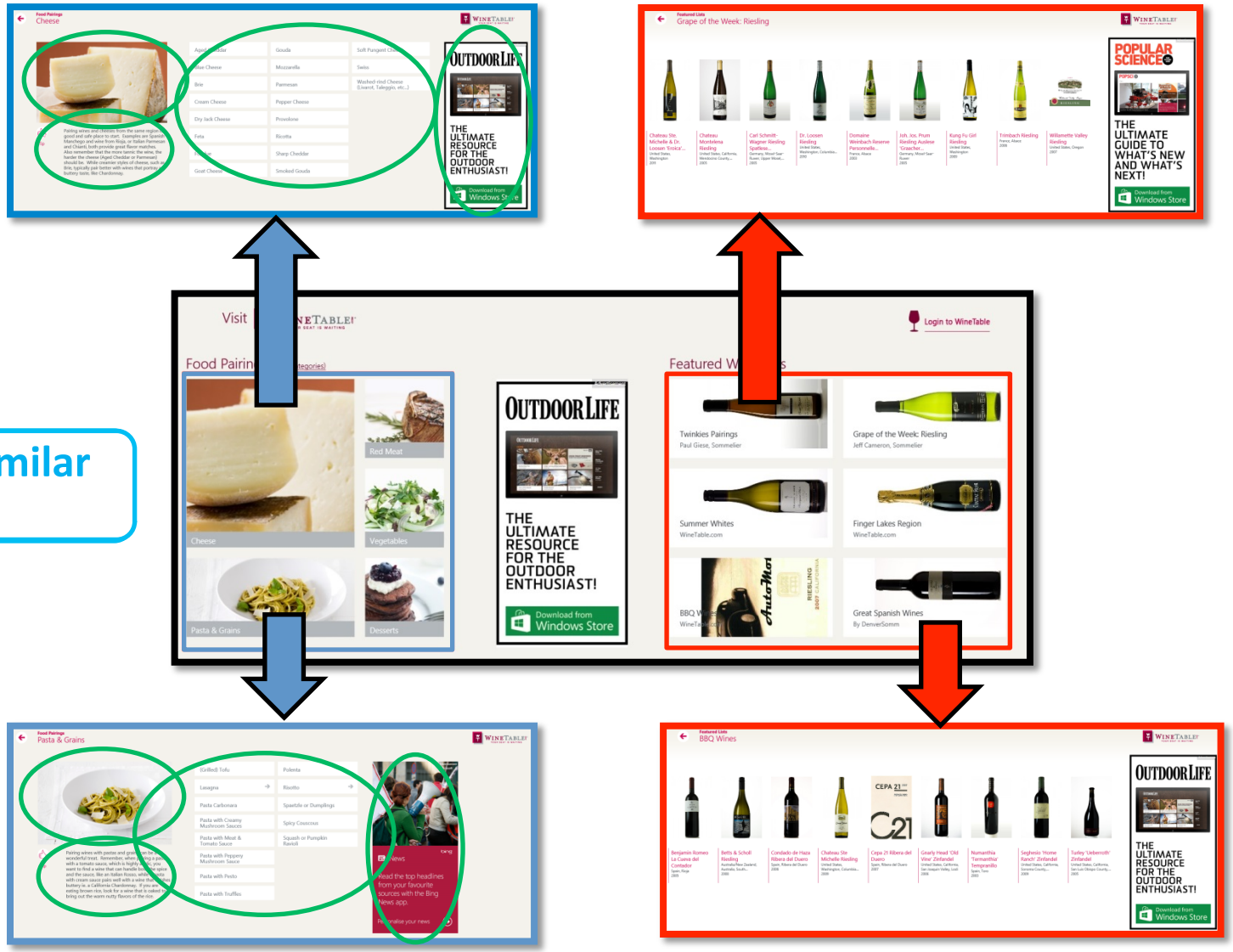
For placement fraud, it is sufficient to visit structurally dissimilar pages

Two pages can be structurally similar even if their content differs



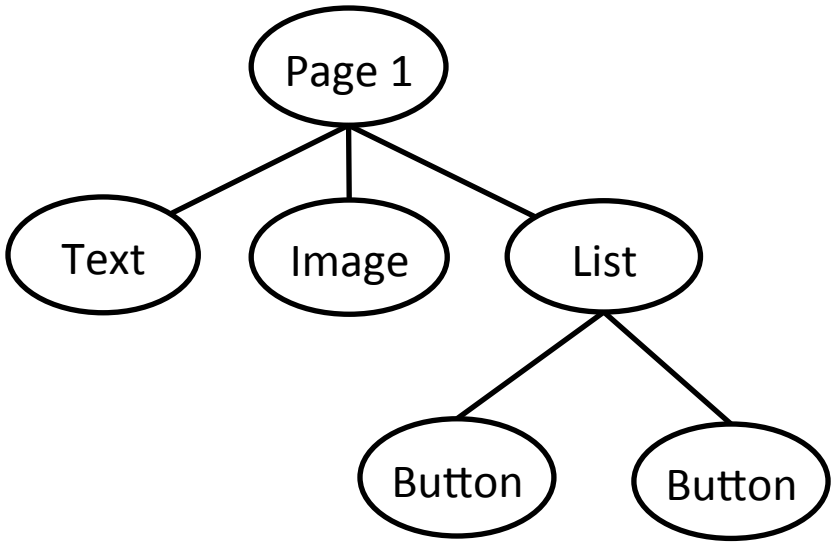
Structurally Similar Pages

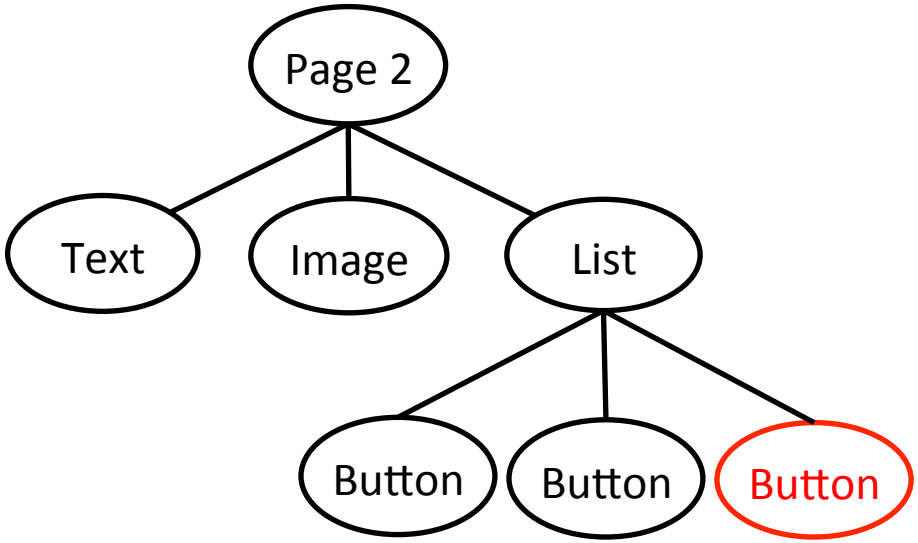
Structurally Similar Pages!



Determining Structural Similarity

Two pages are structurally similar if they have "similar" UI hierarchies

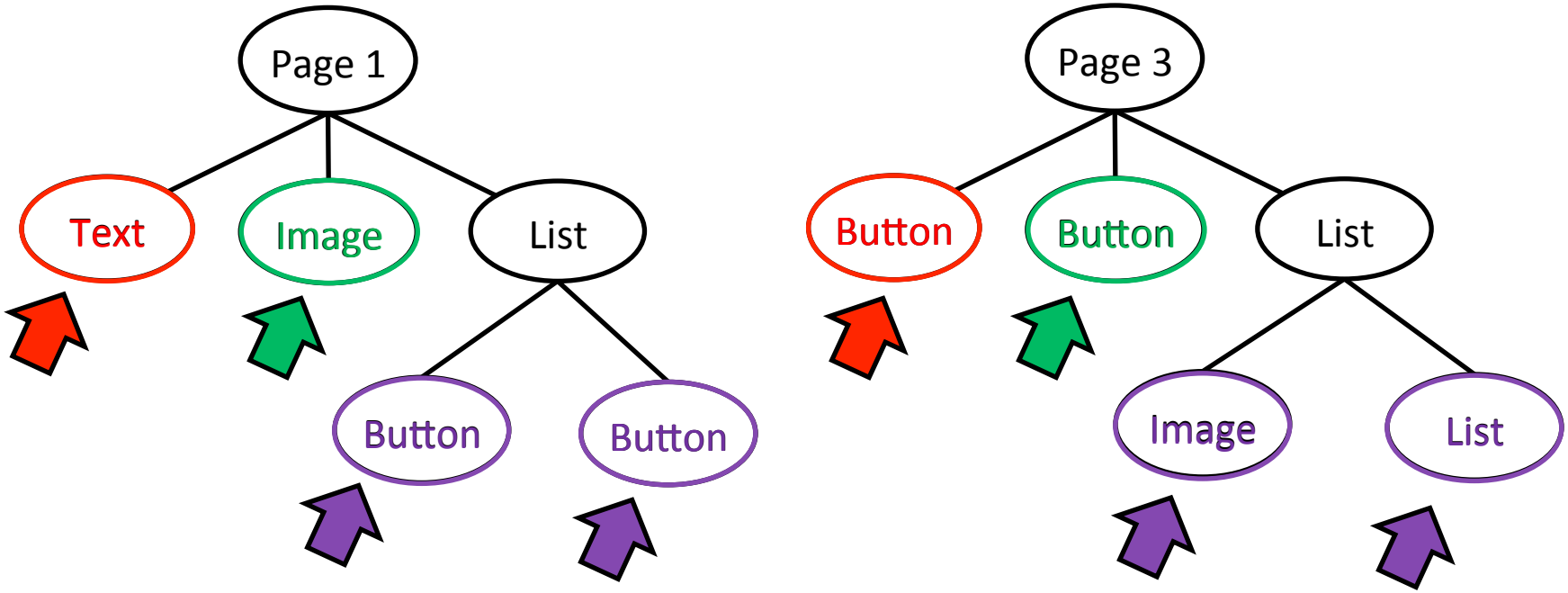




Structurally Similar

Determining Structural Similarity

Two pages are structurally similar if they have "similar" UI hierarchies

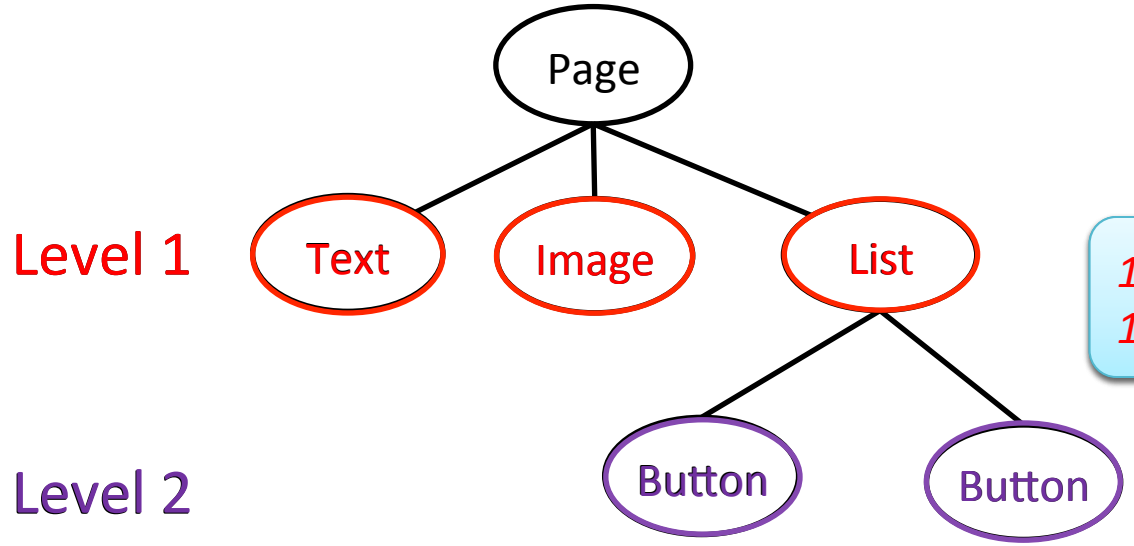


Structurally Dissimilar

Defining Structural Similarity

Feature vector defined on UI elements

Encodes type of UI element and position in hierarchy



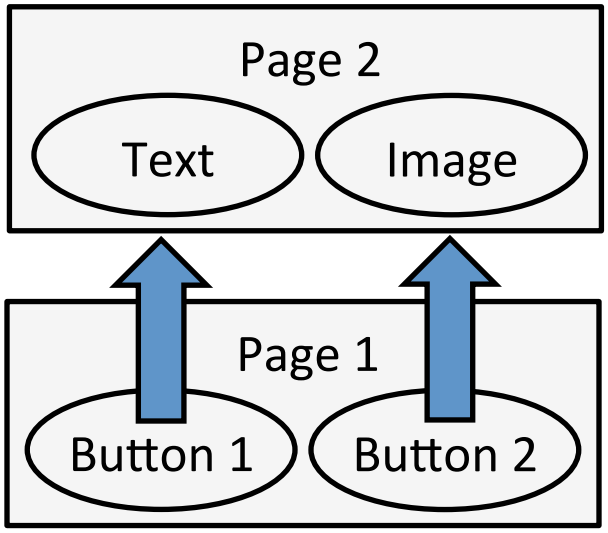
*1*Text@Level_1, 1*Image@Level_1, 1*List@Level_1, 2*Button@Level_2*

Use cosine similarity metric

Users specify a *similarity threshold*

Problem: Avoid previously visited states

Monkey can waste time by visiting previously visited pages

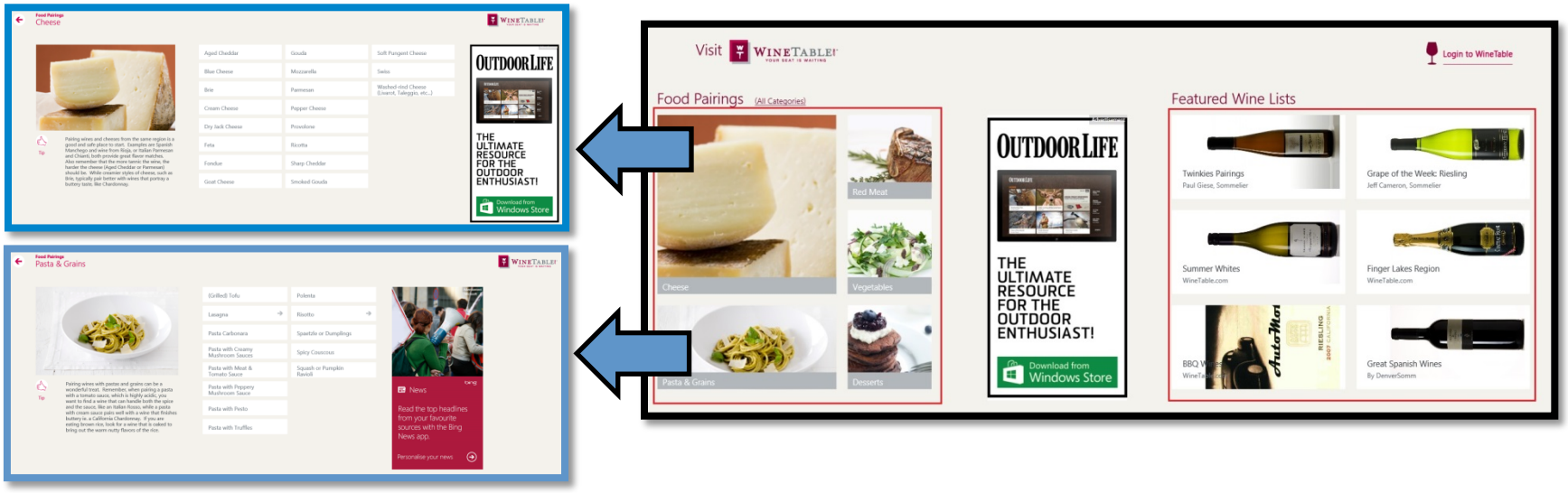


Not necessary to click Button 2. However, to detect this…

Extra time (up to several minutes) for backtracking is needed

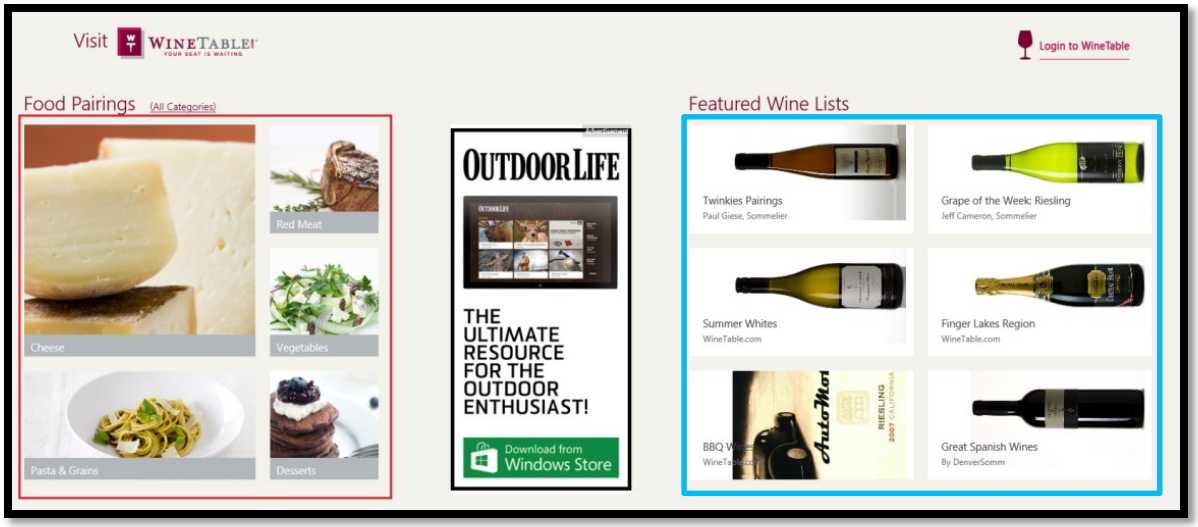
The Monkey needs to anyway go back to page 1 again and click button 2

Avoiding Previously Visited States



To avoid backtracking costs, can we predict if two buttons on a page lead to structurally similar pages?

Avoiding Revisiting Similar Pages



Our method is to use machine learning classifiers

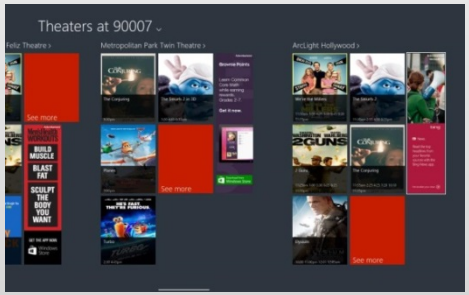
Two buttons that have a similar neighborhoods in UI hierarchy likely to lead to structurally similar pages

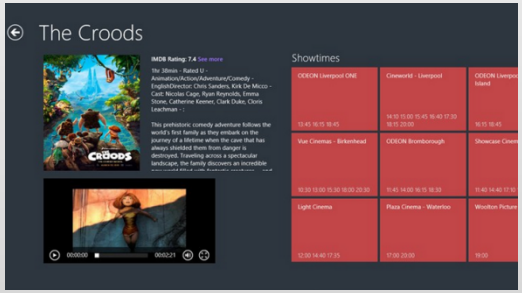
DECAF Overview

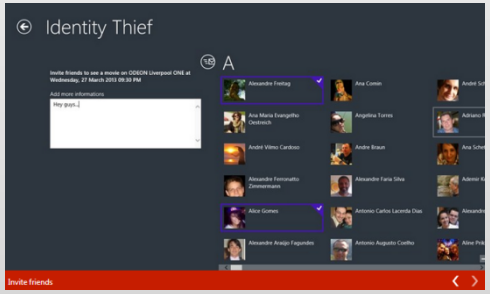
Movie ShowTime

DECAF

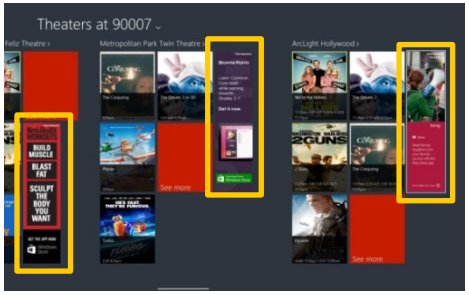
Automated UI Navigation (A Monkey)



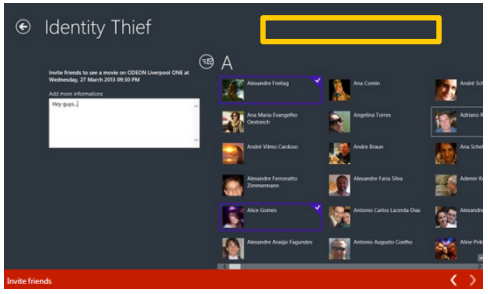




Fraud Checkers



Many Ads



Hidden Ads

Fraud Checkers

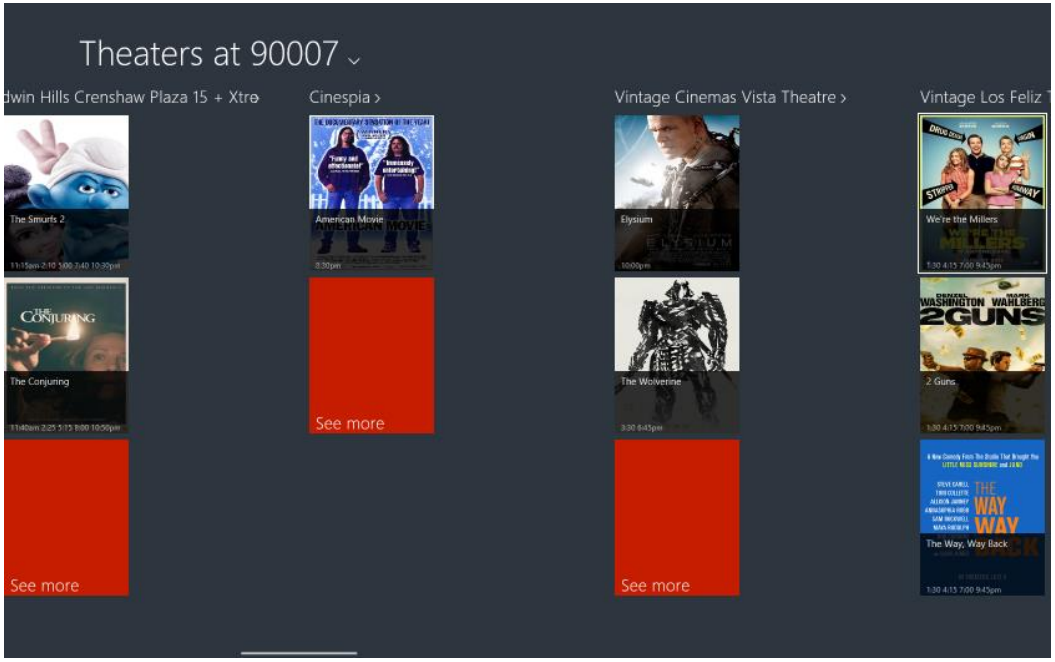
Input to checkers: structural data of ad and non-ad elements

Fraud Type	Checker Summary
Invisible/Hidden Ads	Whether visual elements are overlapped with ads
Smaller Ads	Compare the actual display size of the ad with the minimal valid size
Intrusive Ads	Compare the distance between an ad and clickable non-ad elements
Many Ads	Whether the number of viewable ads is more than the maximum allowed

Efficient Many-Ads Checkers

Many ads in one display screen

Challenge: the “sliding screen” problem

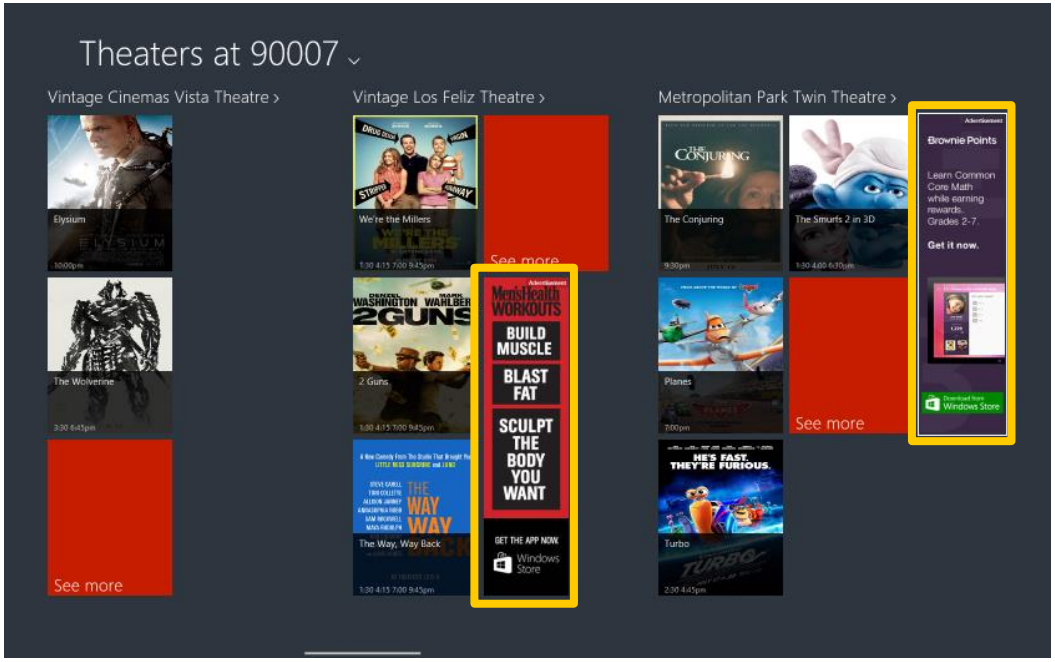


No Ad

Efficient Many-Ads Checkers

Many ads in one display screen

Challenge: the “sliding screen” problem

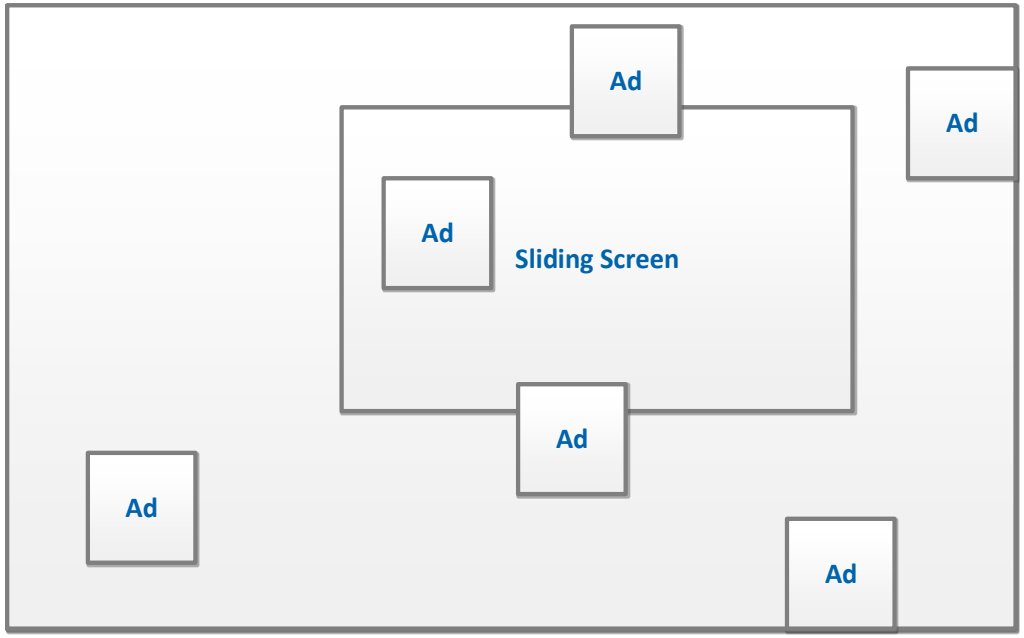


Two Ads

Efficient Many-Ad Checker

Many ads in one display screen

Challenge: the “sliding screen” problem



We have designed an efficient algorithm to detect many-ad fraud

Other Optimizations

State Importance Assessment to further reduce the number of app pages that the Monkey needs to explore

Rendering Order Inference and Proxy-Assisted Screen Analysis to efficiently detect hidden ads

Evaluation and Characterization

Basic Setup

- Run DECAF on each app for 20 minutes
- Collect information from structurally different pages

Structural Page Coverage

- Manually find ground truth number of page structure
- Limited to 100 top free apps from the tablet app store

Evaluation and Characterization

Basic Setup

Run DECAF on each app for 20 minutes

Collect information from structurally different pages

Characterization of Placement Ad Fraud

Run DECAF on 50,000 phone apps and 1,150 tablet apps

Characterize fraud by fraud type, rating and publisher

Structural Page Coverage

A Basic Monkey

A Classifier-Enhanced Monkey

71 apps finish with the Classifier-Enhanced Monkey, but only 30 finish with the Basic monkey

29 apps cannot finish in 20 minutes

- The Monkey fails to recognize some clickable elements
- Some scenarios require app-specific text input that Monkey cannot handle
- Some apps simply have a very large set of structural pages

Characterizing Fraud by Types

Fraud Type	Phone Apps (1000+)	Tablet Apps (50+)
Too Many Ads	11%	4%
Smaller Ads	33%	48%
Hidden Ads	47%	32%
Intrusive Ads	9%	16%

1,000+ phone apps (out of 50,000) and 50+ tablet apps (out of 1,150) commit at least one fraud

Characterizing Fraud by Types

Fraud Type	Phone Apps (1000+)	Tablet Apps (50+)
Too Many Ads	11%	4%
Smaller Ads	33%	48%
Hidden Ads	47%	32%
Intrusive Ads	9%	16%

"Hidden Ads" violations are more prevalent on the phone, which has a smaller screen for displaying content

Characterizing Fraud by Types

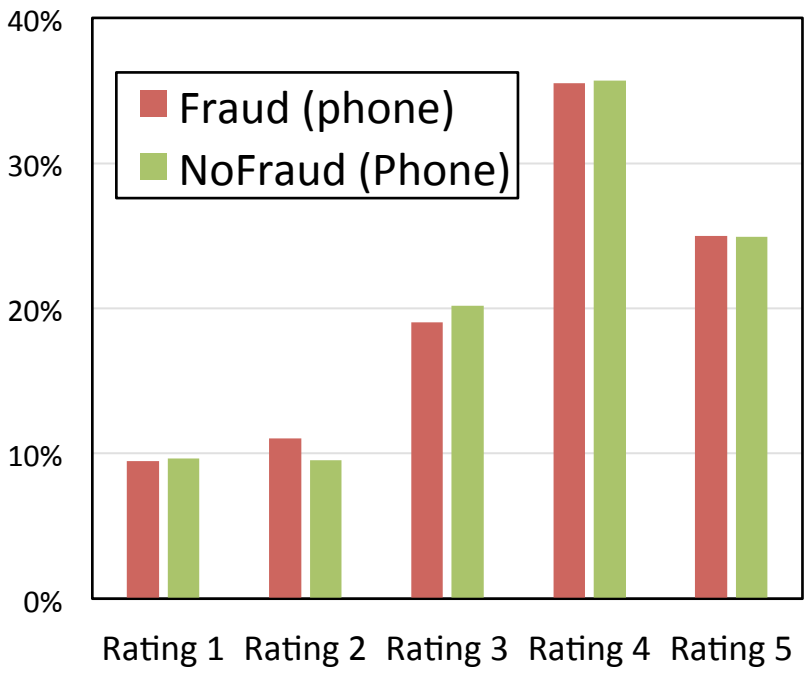
Fraud Type	Phone Apps (1000+)	Tablet Apps (50+)
Too Many Ads	11%	4%
Smaller Ads	33%	48%
Hidden Ads	47%	32%
Intrusive Ads	9%	16%

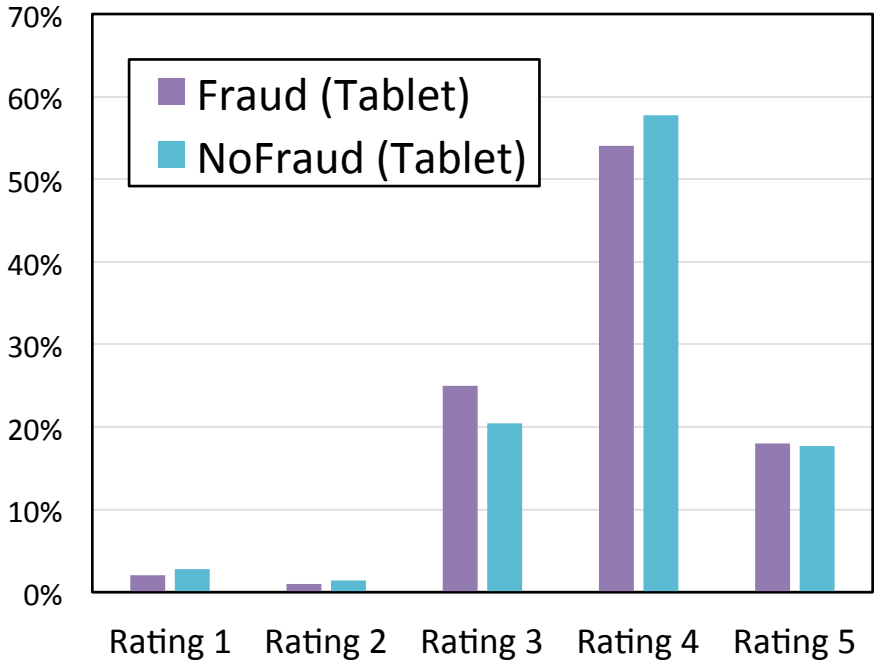
"Intrusive Ads" violations are more prevalent on the tablet, which has richer controls to be used to trigger accidental clicks

Characterizing Fraud by Rating

Rating values are rounded to a number from 1-5

Fraud level does not seem to depend on rating





Fraudulent App Count per Publisher

Each app is developed by a publisher

The distribution of the number of fraud across publishers who commit fraud exhibits a heavy tail

A small number of publishers are responsible for most of the fraud

Conclusion

Mobile ad fraud is a 1 billion dollar business, and ad networks need effective tools to detect fraud

Conclusion

DECAF: a system for detecting placement ad fraud in mobile apps

Efficiently explore structurally different pages of mobile apps

Accurately detect placement ad fraud in a fast and scalable way

Case study of 51,150 apps reveals interesting variability in the prevalence of fraud by type, rating, publisher and etc.