UIHASH: Detecting Similar Android UIs through Grid-Based Visual Appearance Representation

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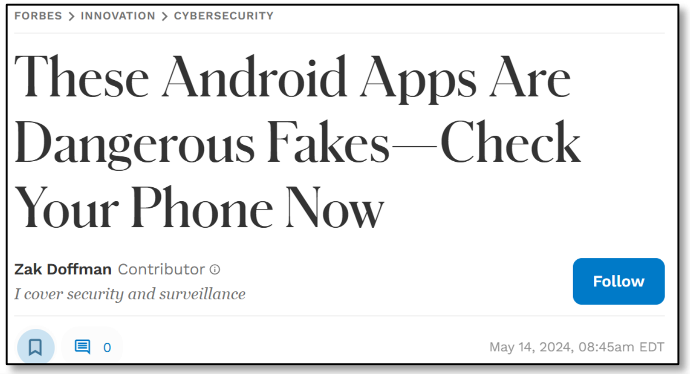
User Interface: A Popular Attack Surface

- Main channel for users to interact with mobile apps
- Attackers often deceive users via fake UIs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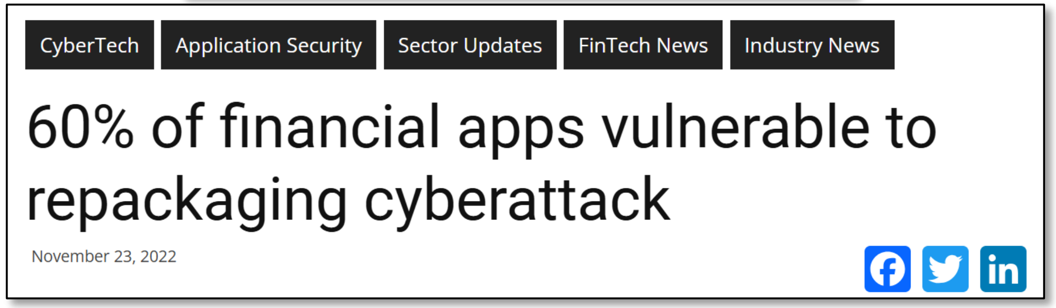
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60% of financial apps vulnerable to repackaging cyberattack

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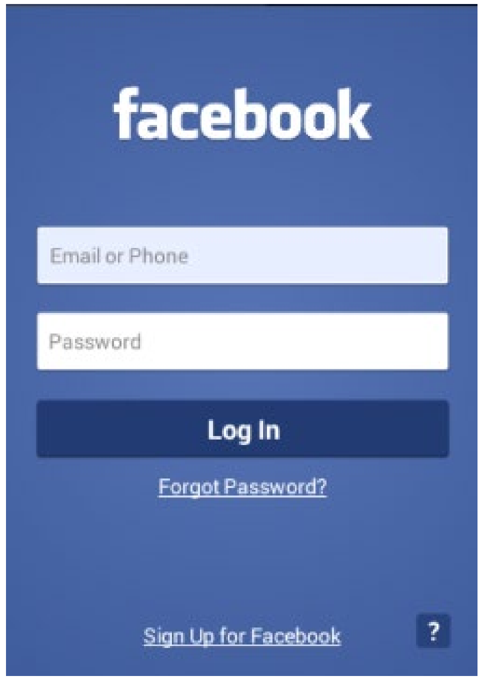
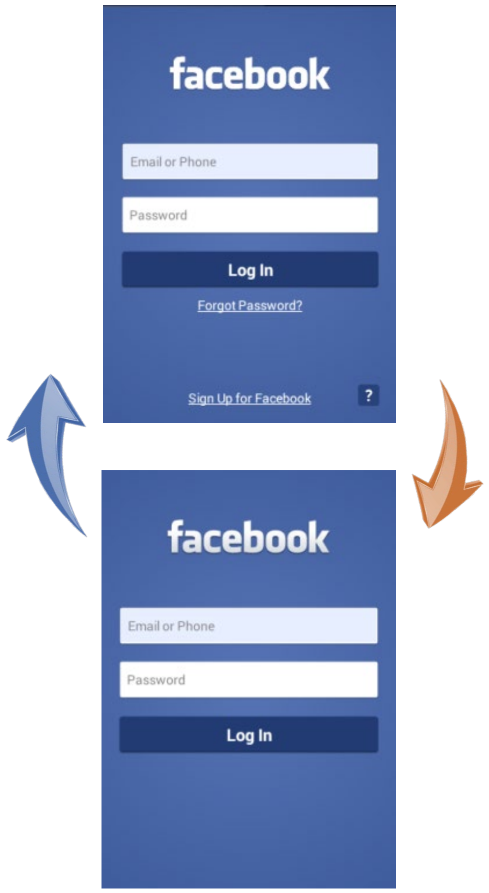


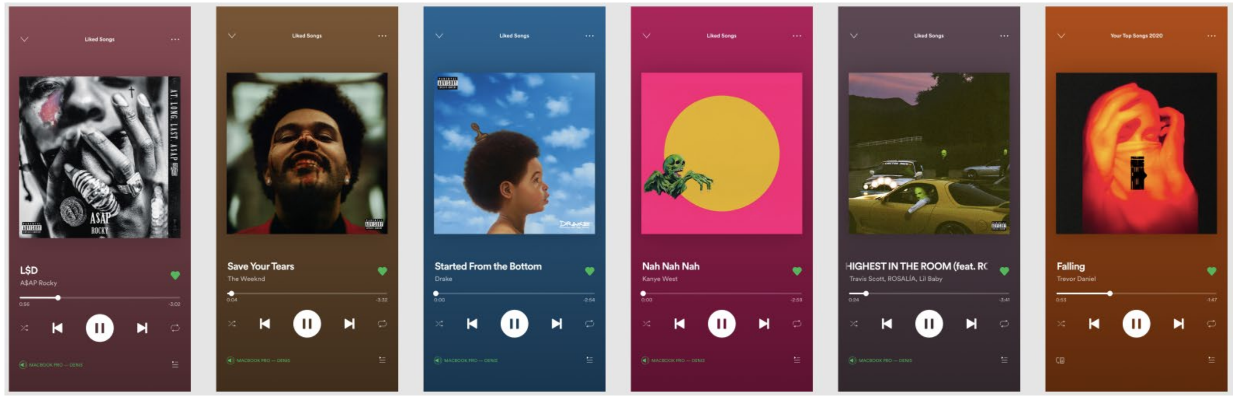
A Fake Facebook Login UI

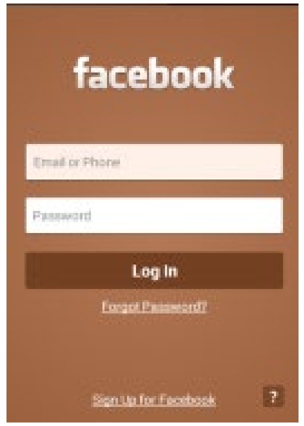
Related Work on Similar UI Detection



Screenshot image-based detection

- Compare UI images by pixel features
  - Users show high tolerance on images
  - Image content always updates
    - news apps, music apps, shopping apps…





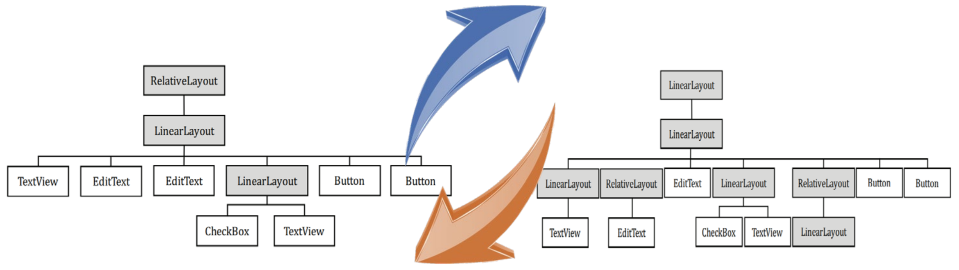
40% users login

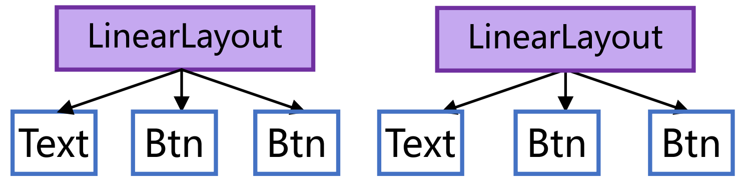
Screenshot images are not always reliable

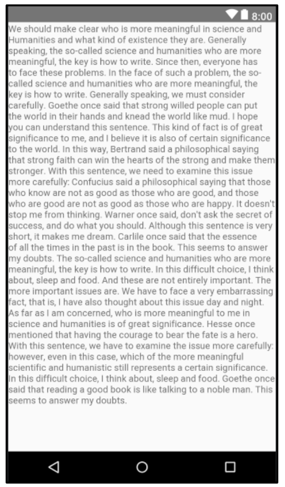
Related Work on Similar UI Detection

Layout tree-based detection

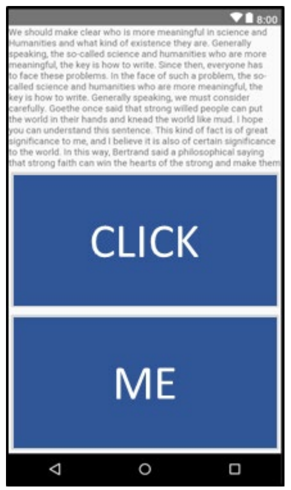
- Comparing tree structure similarity







We should make clear who is more meaningful in science and Humanities and what kind of existence they are. Generally speaking, the so-called science and humanities who are more meaningful, the key is how to write. Since then, everyone has to face these problems. In the face of such a problem, the so-called science and humanities who are more meaningful, the key is how to write. Generally speaking, we must consider carefully. Goethe once said that strong willed people can put the world in their hands and knead the world like mud. I hope you can understand this sentence. This kind of fact is of great significance to me, and I believe it is also of certain significance to the world. In this way, Bertrand said a philosophical saying that strong faith can win the hearts of the strong and make them stronger. With this sentence, we need to examine this issue more carefully: Confucius said a philosophical saying that those who know are not as good as those who are good, and those who are good are not as good as those who are happy. It doesn't stop me from thinking. Warner once said, don't ask the secret of success, and do what you should. Although this sentence is very short, it makes me dream. Carlile once said that the essence of all the times in the past is in the book. This seems to answer my doubts. The so-called science and humanities who are more meaningful, the key is how to write. In this difficult choice, I think about, sleep and food. And these are not entirely important. The more important issues are. We have to face a very embarrassing fact, that is, I have also thought about this issue day and night. As far as I am concerned, who is more meaningful to me in science and humanities is of great significance. Hesse once mentioned that having the courage to bear the fate is a hero. With this sentence, we have to examine the issue more carefully: however, even in this case, which of the more meaningful scientific and humanistic still represents a certain significance. In this difficult choice, I think about, sleep and food. Goethe once said that reading a good book is like talking to a noble man. This seems to answer my doubts.



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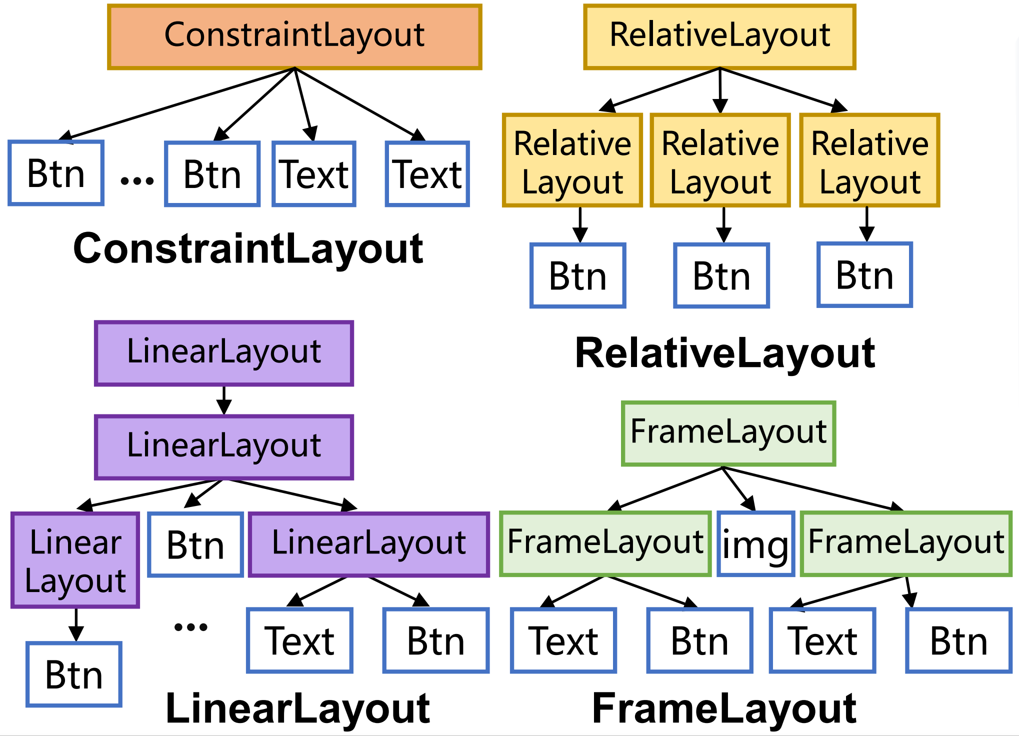
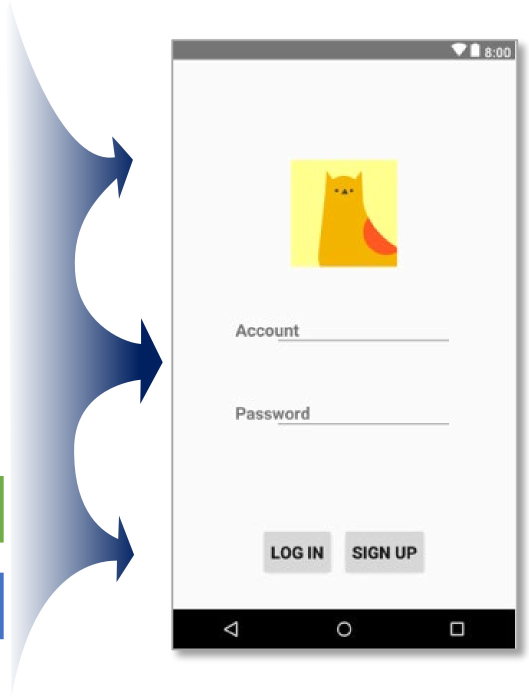
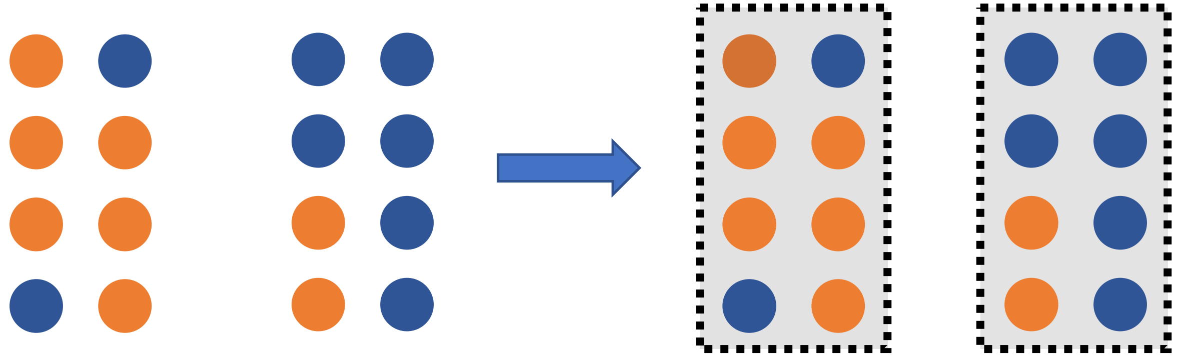
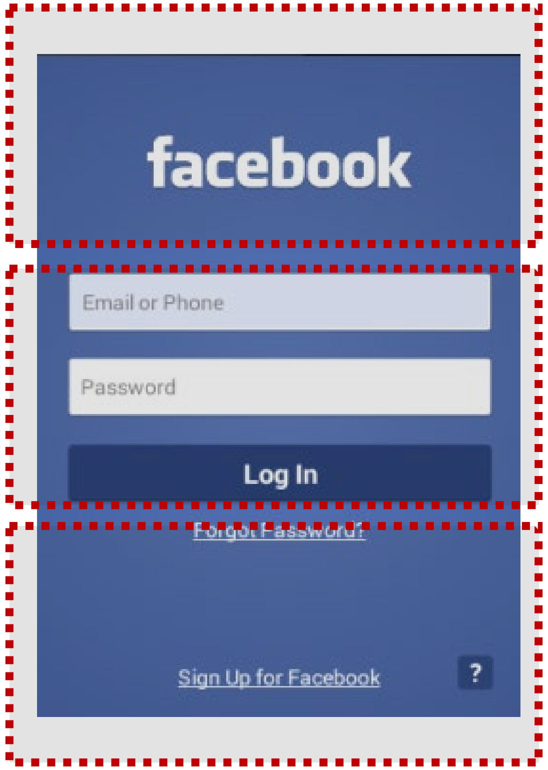




Tree structures are not always reliable

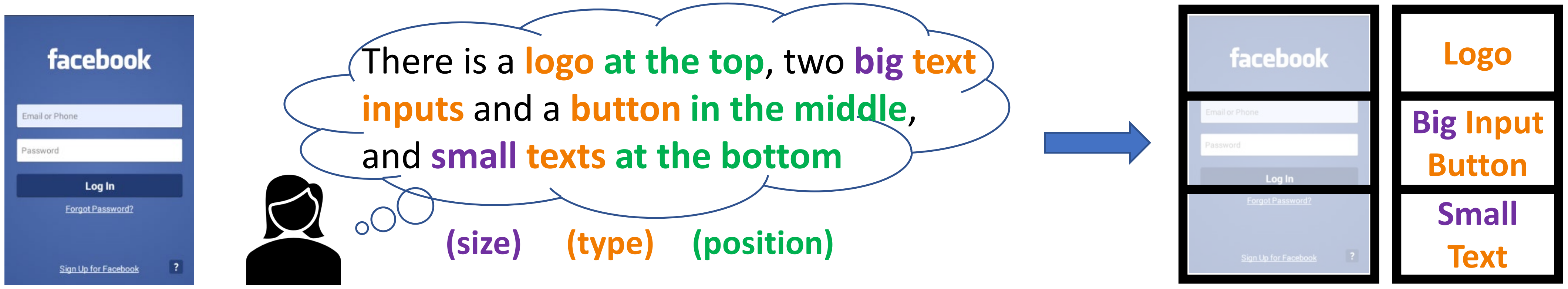
Our Motivation





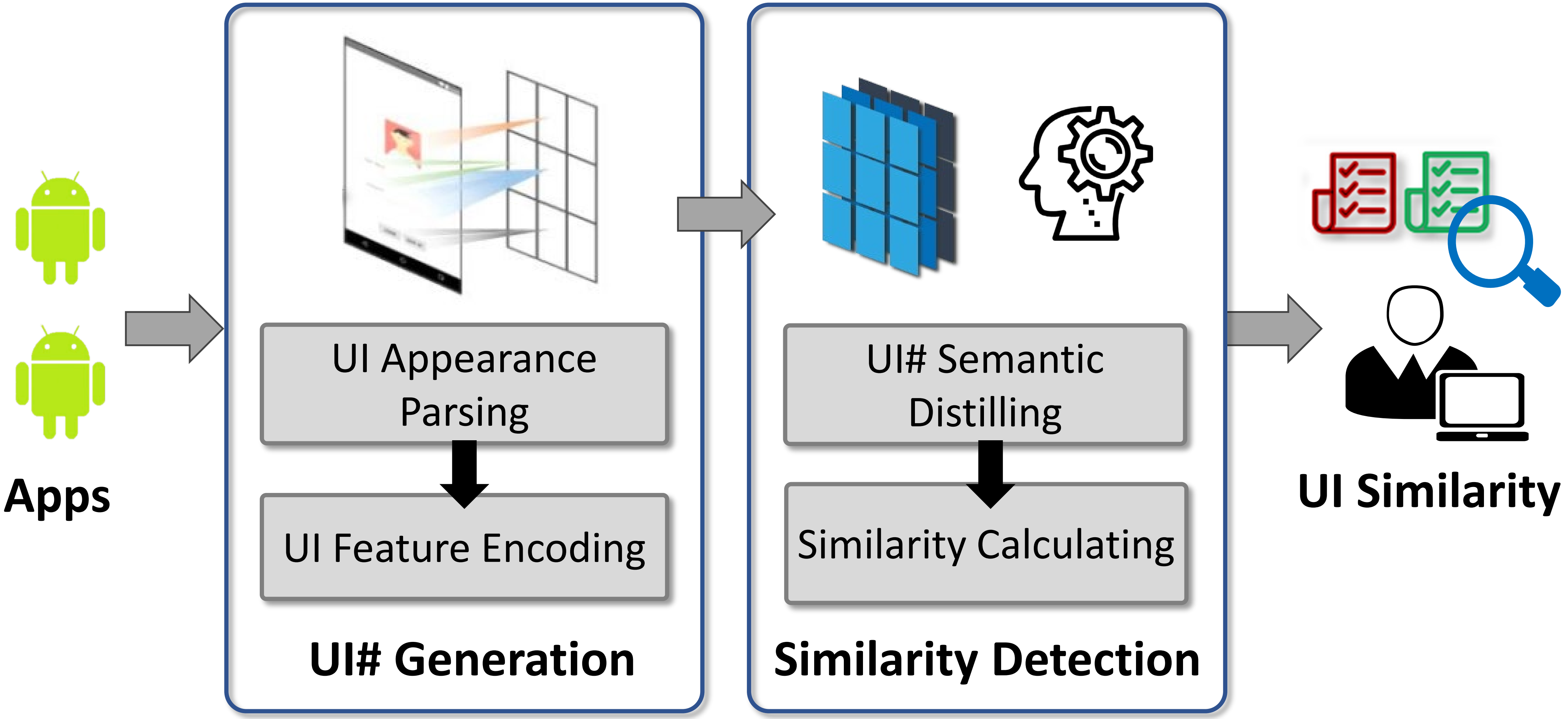
- The principle of *proximity*
  - A powerful Gestalt principle
  - **People treat objects close together as a group**
- By grouping UI controls, detect similar UIs with **mutations** on screenshot images or layout trees that bypass prior detections

UI#: A New UI Representation



- Abstract UI visual appearance and tolerate minor variations **based on grid**
  - In each grid, encode visual features that are **important to users** (i.e., low tolerance for changes)
  - Aggregate semantics in individual grid regions to **capture a high-level layout** characteristic of UI

UIHash Overview



Parsing UI Appearance

“ToggleButton” “Switch” “ImageButton” “CheckBox” “Button” “CompoundButton”

$\underbrace{\hspace{20em}}$

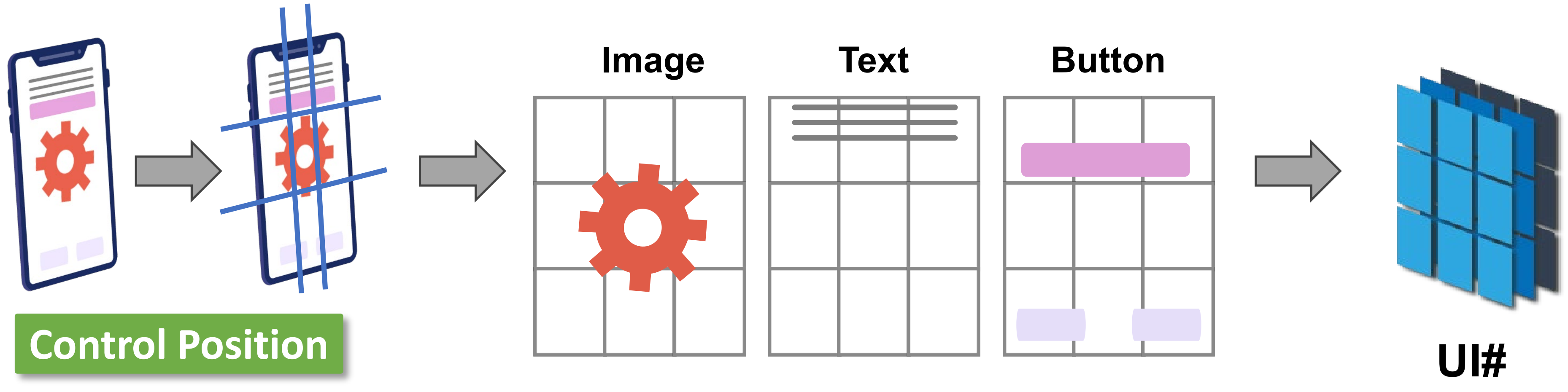
Toggle

- Get appearance semantics **that match user perception**
  - Take as input UI **runtime** semantics instead of static trees
  - Re-identify controls based on visual appearance instead of sticking to their claimed names to better represent **UI appearance**

Generating UI Representation

- Collect and integrate UI visual semantics from different grid regions
  - Selected features: position, size and type of UI control

Control Type separate control types in different channels



Control Position

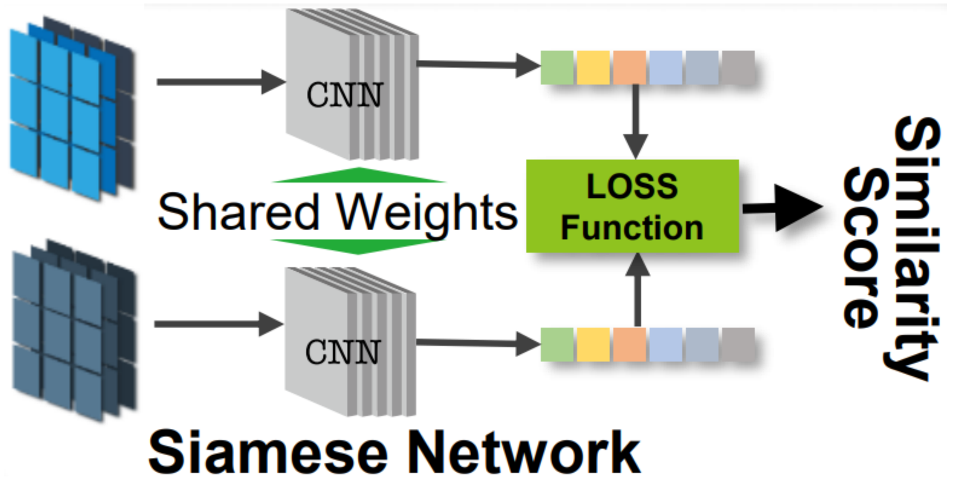
collect regional visual semantics via grid

Control Size encode control size by Intersection over Union (control vs. region)

Similarity Detection

Distilling semantics of UI# to compare UI similarity

- Generalize visual features when embedding
- Apply a CNN-based Siamese network to calculate pairwise similarity score



Evaluation

- Evaluation Setup
  - RePack dataset: a repackaging app dataset: 18,359 apps
  - RmvDroid dataset: a malicious app dataset: 9,133 apps
  - Recent apps collected from six markets: 8,963 apps

- Effectiveness of Representing UI
  - How effective is UIHash as a UI similarity detection system?
- Active Evasion UI Identification
  - How common are active evasion UIs in the wild?
- Use case of UIHash
  - What benefits can analysts gain from our UI representation?

Effectiveness on Detecting Similar UIs

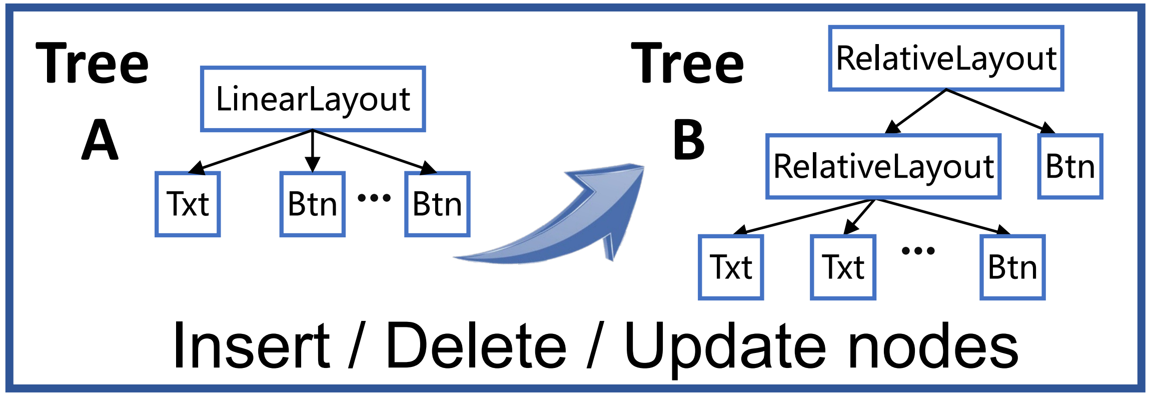
- UIHash outperforms prior tree-based / image-based UI similarity detectors
  - Higher recall, more similar UI can be detected

Approach	Precision	Recall	F1	AUC
Image-based	85.1%	79.7%	0.823	0.77
DroidEagle	96.8%	86.5%	0.914	N/A
GeminiScope	95.6%	94.3%	0.949	0.92
Text-based	31.7%	83.0%	0.459	0.74
UIHash	**97.0%**	**99.8%**	**0.984**	**0.99**

Active Evasion UI Detected

Similar UIs that bypass tree-based methods

- Many detected similar UIs have large tree differences
  - Measured by TED: change A's node to make A=B



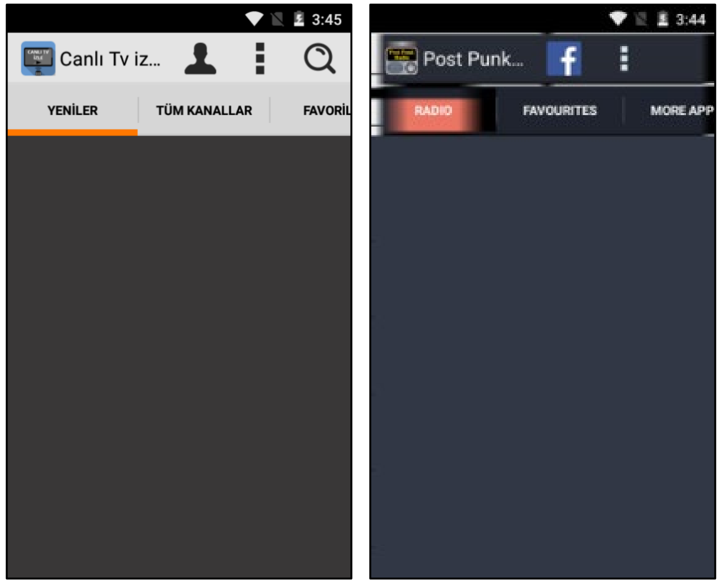
In all similar pairs, given the node num of the small tree n

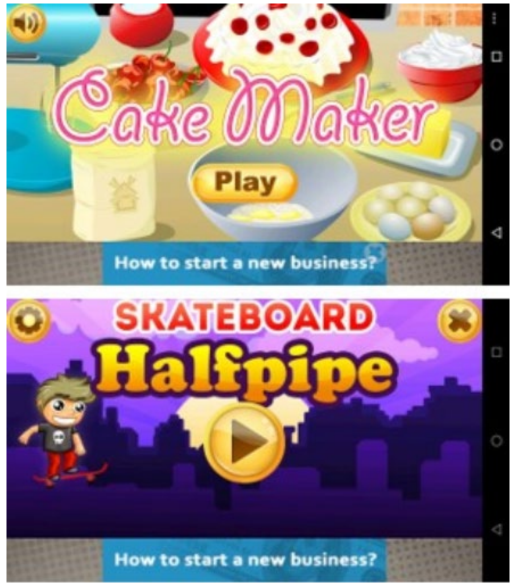
- 5% pairs have $TED \geq n$
- 27% pairs have $TED \geq \frac{1}{4}n$
- TED is up to $4n$

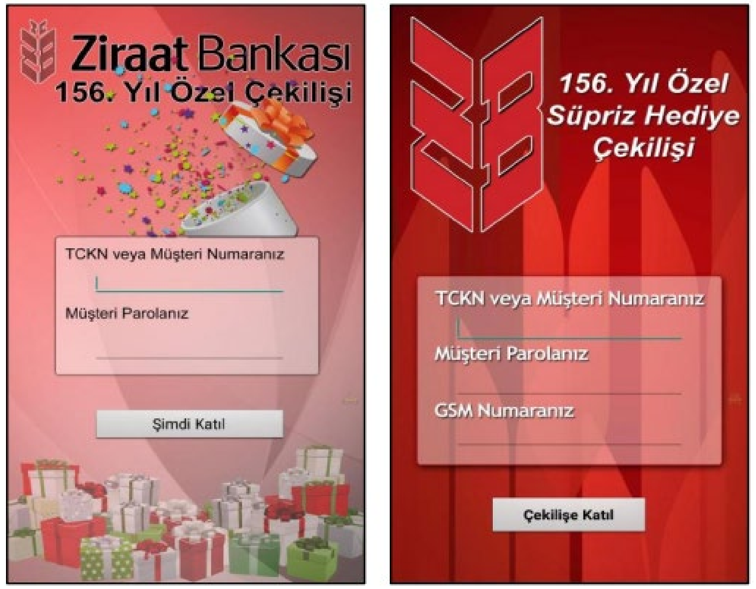
  - Evasion techniques we identified to **change tree structure**
    - Flexible use of View groups (e.g., LinearLayout, RelativeLayout)
    - Add controls (Views) that are invisible to human

Active Evasion UI Detected

Similar UIs that bypass image-based methods





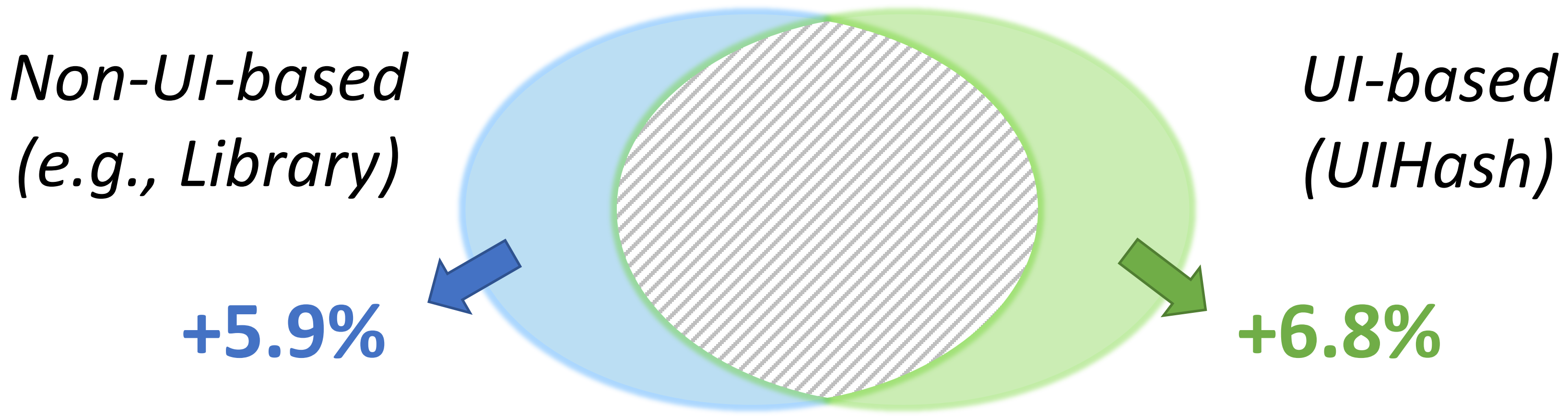


	Cloning Radio Apps	Repackaging Games with Ad	Phishing Bank Apps
User Rating	★ ★ ★ ⯪ ☆	★ ★ ★ ★ ☆	★ ★ ★ ★ ★

Although detailed contents differ, users rated them as similar UI

Collaborate with Other App Features

- We combine UI-based similarity detection with other app features, e.g., code semantics
- More similar apps can be detected for different methods



Combining multiple app features to better study app similarity

Summary

- We propose **UIHASH**:
  - Guided by Proximity principle, use a grid to integrate UI control appearance by groups
  - Use a new representation UI#: Capture and abstract UI layout semantics
  - Powerful in finding similar UIs that bypass prior detections
- Insight
  - Represent UI in consistent with human perception

UIHASH: Detecting Similar Android UIs through Grid-Based Visual Appearance Representation

Thank you!

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https://github.com/DaweiX/UIHash