UIPicker: User-Input Privacy Identification in Mobile Applications

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Motivation

Privacy leakage

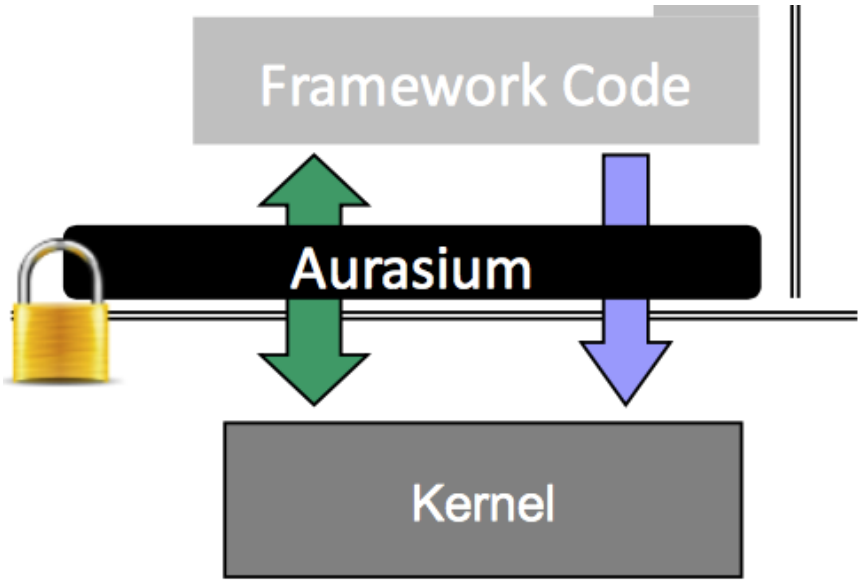
- App's insecure implementation
- Vulnerabilities in system

Motivation

Existing Works

Dynamic/Static taint analysis

- TaintDroid [OSDI' 10]
- FlowDroid [PLDI' 14]

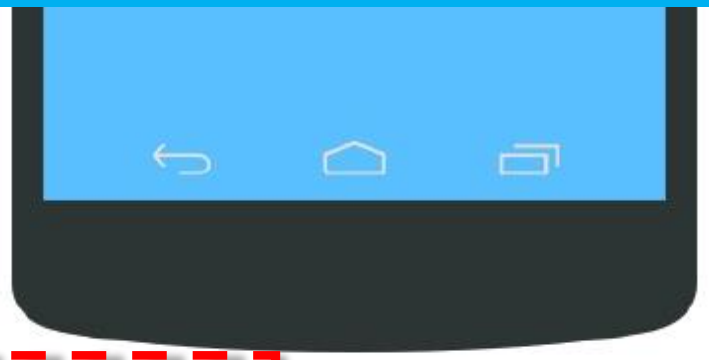



```
c = taint_source()
...
a = b + c
...
network_send(a)
```

Access control mechanisms

- SELinux on Android
- Auriasium [SECURITY'12]

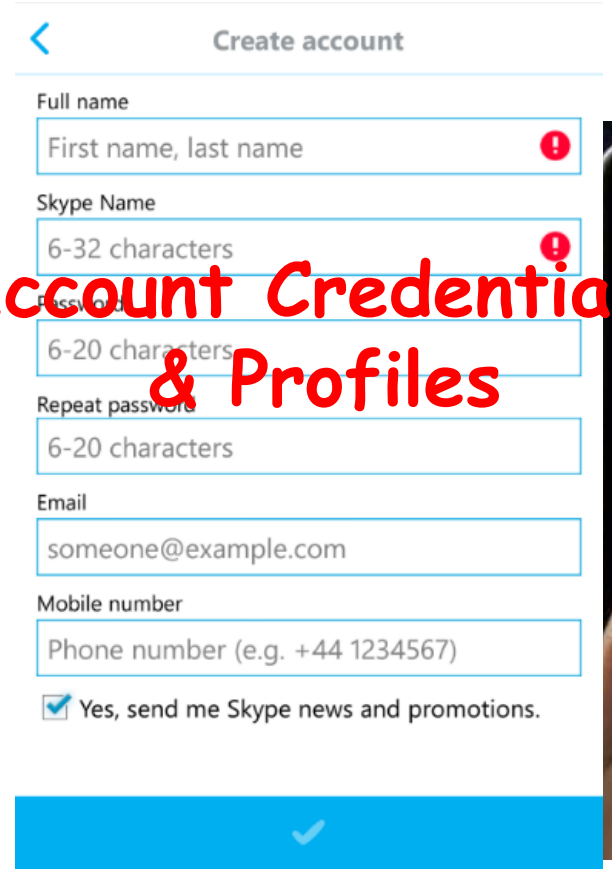
But wait …



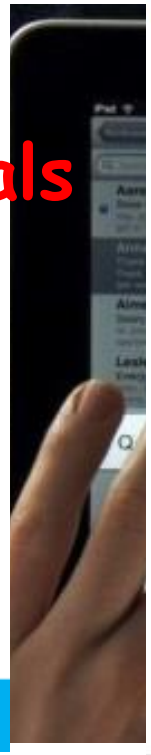
➢ Location	✓ LocationManager. getLastKnownLocation()
➢ Contact	✓ ContentResolver.query(CONTACT_URI)
➢ SMS	✓ SmsMessage. getMessageBody ()
➢ Phone Number	✓ TelephonyManager. getLine1Number()
➢ …	✓ …

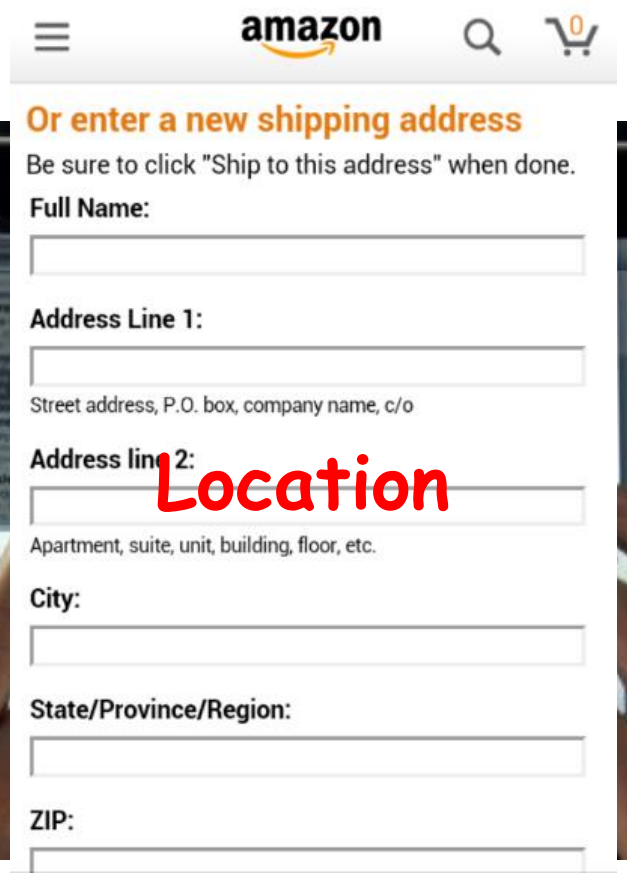
System Centric Privacy Data

But wait …



Account Credentials & Profiles





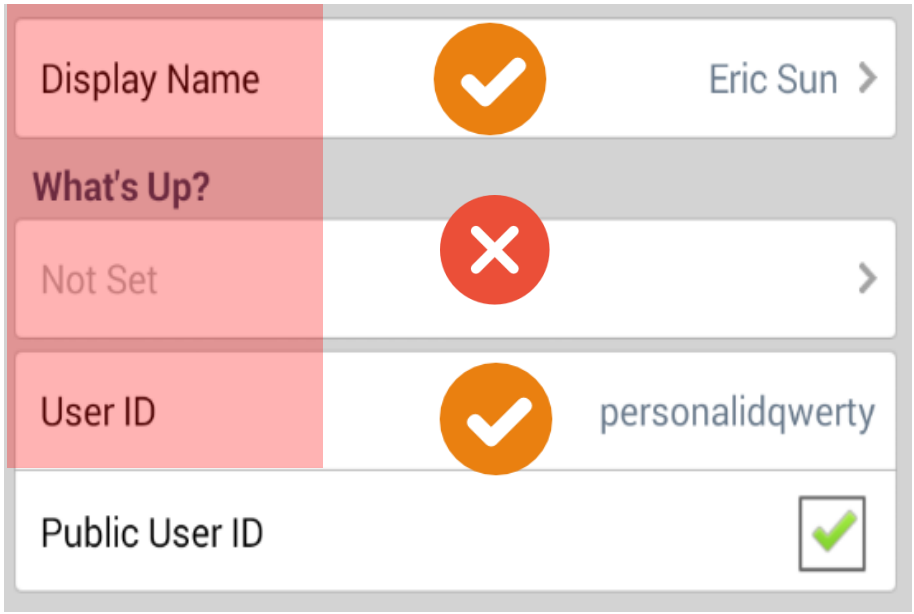
Location

Financial

User-Input Centric Privacy Data (UIP Data)

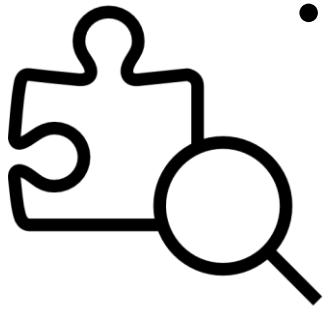
Challenges

- UIP data cannot be found without parsing the context and semantic of UIs



- Label all input as sensitive
  - Large number of false positives
- Manually specify such contents need to be protected
  - Intensive human intervention

Our Work

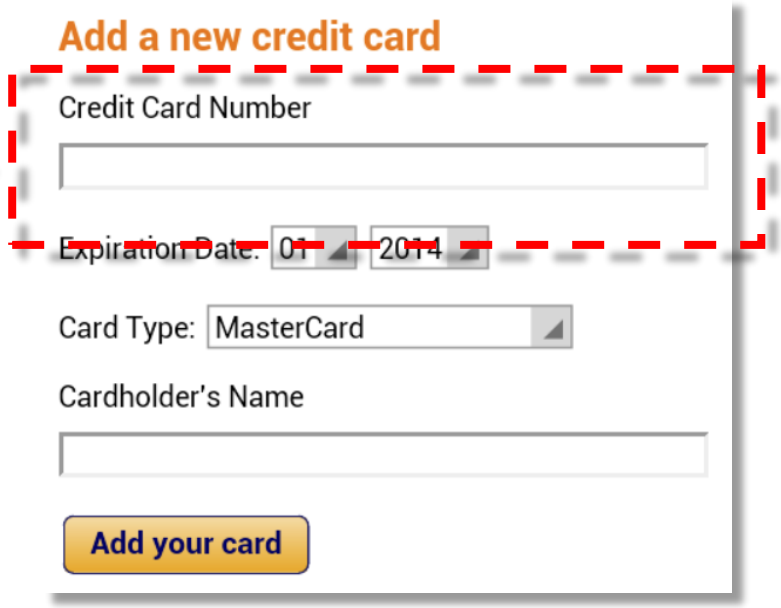


- UIPicker
  - Novel framework for automatic, large-scale User-Input Privacy (UIP data) identification within Android apps.

- Runtime Security-Enhancement Mechanism
  - Protect insecure UIP data transmission in app's runtime

Key Observation

- Privacy-related semantics exist in
  - UI Screens
  - Layout resource files



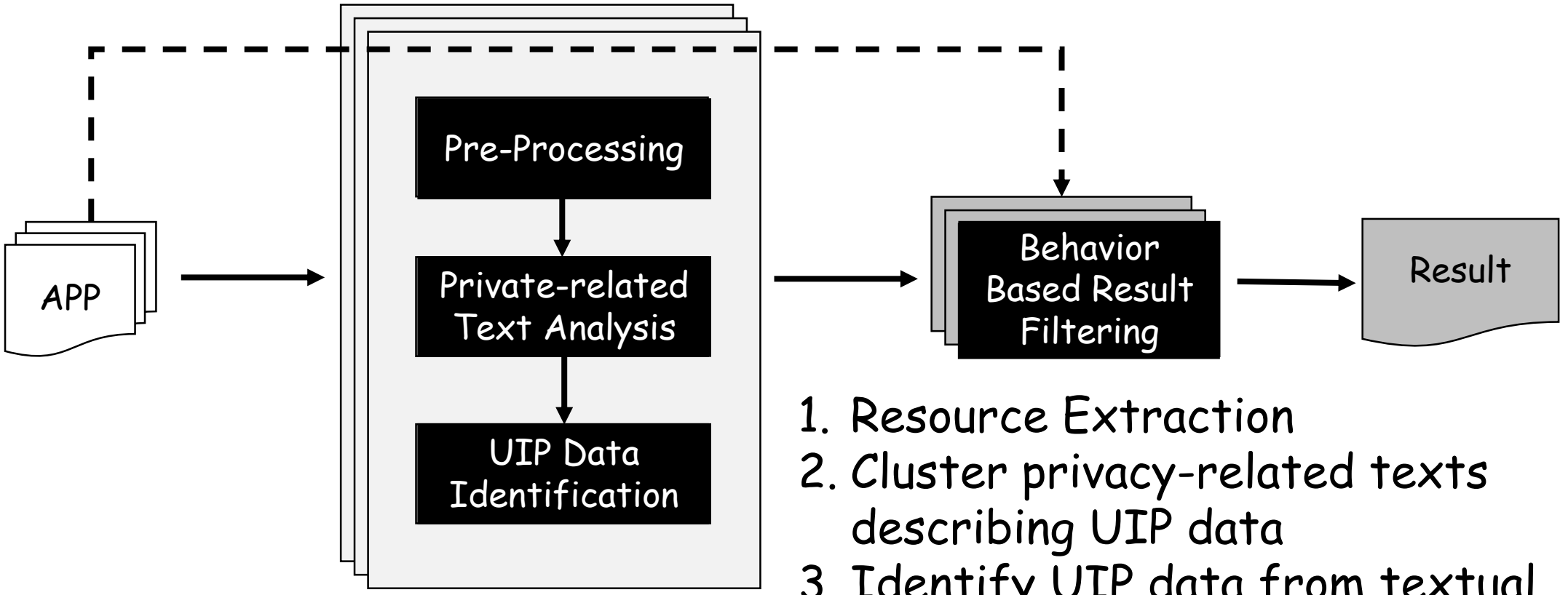

```
<TextView android:text="@string/opl_new_payment_credit_card_number" />
<EditText android:id="@id/opl_credit_card_number" android:inputType="number" />
```

Technical challenges

- How to get complete privacy-related texts
  - Highly unstructured semantics
    - E.g. password, **pass**, **pwd**, …
  - Sparsely distributed in different UIs
    - Impractical for manual collecting

- To what extent, a layout element could be UIP data
  - Keyword based search? imprecise results
    - E.g. Split "Username" into "user" & "name"

UIPicker Overview

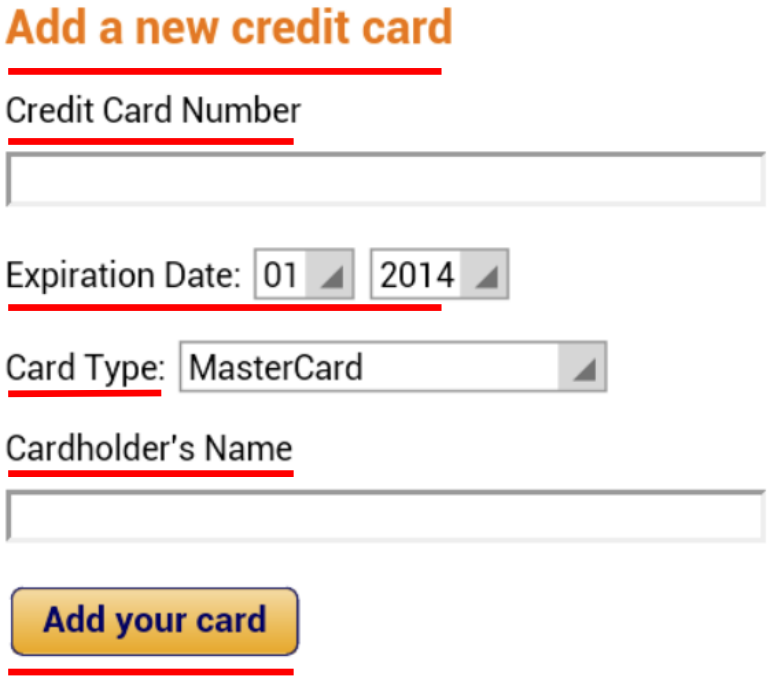


1. Resource Extraction
2. Cluster privacy-related texts describing UIP data
3. Identify UIP data from textual semantics
4. Confirm UIP data with application code behaviors

Pre-Processing

- Resource Extraction
- Word splitting
  - Delimiter/Letter-separated words
- Redundant content removal
  - Non-English strings/Stop words
- Stemming
  - Reduce the number of texts
  - E.g. Change "secured", "security" into "secure"

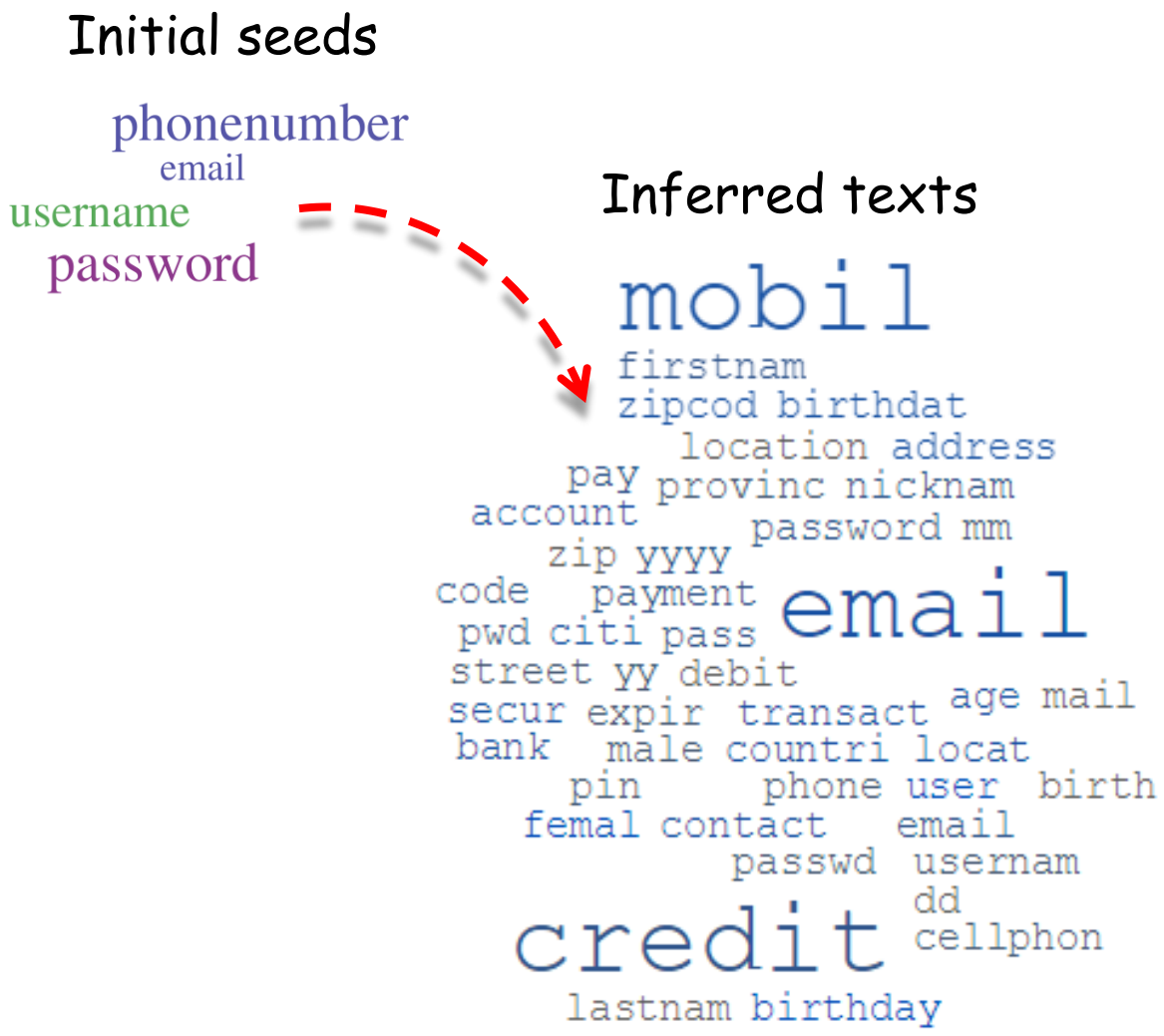
1 UI Texts



2 Layout Descriptions

@id/opl_credit_card_number
@string/opl_new_credit_card_expiration_date_month
@string/opl_new_credit_card_save_button

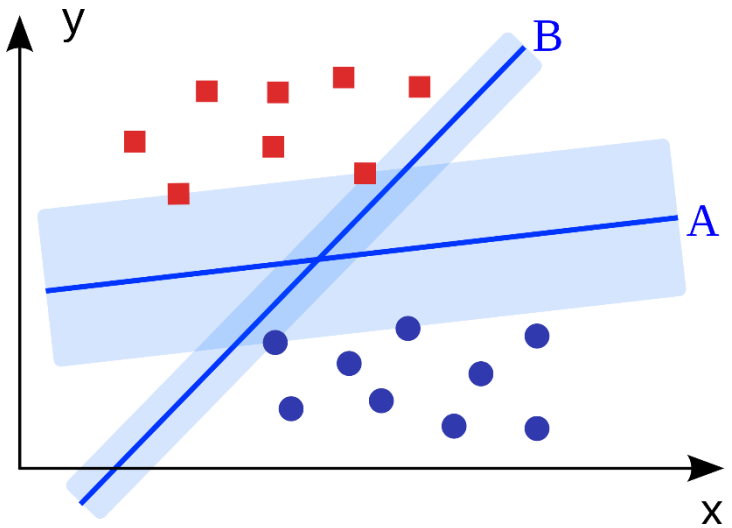
Privacy-related Texts Analysis



- Privacy-related layout Selection
  - E.g. Login, Registration, settings page.
  - By initial seeds with heuristic rules
- Privacy-related texts clustering
  - Words appeared most in privacy-related layouts rather than normal layouts.
  - By applying Chi-Square test.

UIP Data Identification

- Classifier: Support Vector Machine
- Features
  - Privacy-related texts
  - Sibling elements
    - E.g. Short phrase for describing the input field.



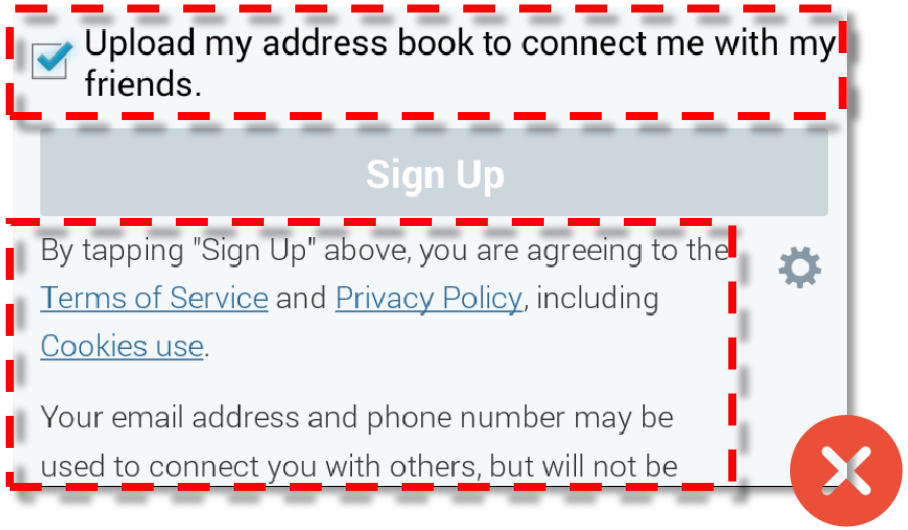
- Training Data
  - Subset of UIP data element
    - Text fields with sensitive **inputtype**.

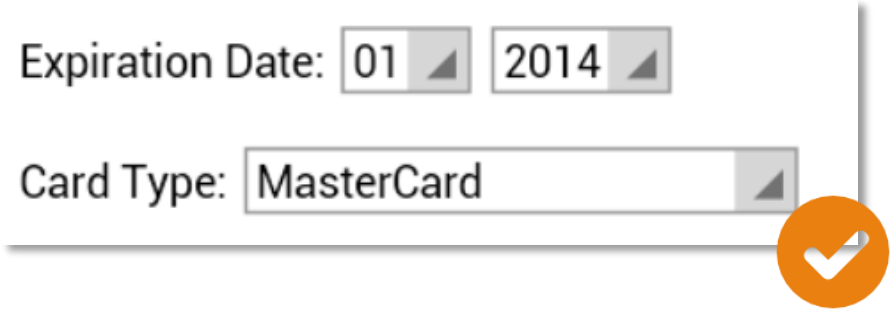
```
<EditText android:id="@id/password_edittext"  android:inputType="textPassword" />
```

    - Manual labelled element for **Financial inputs**

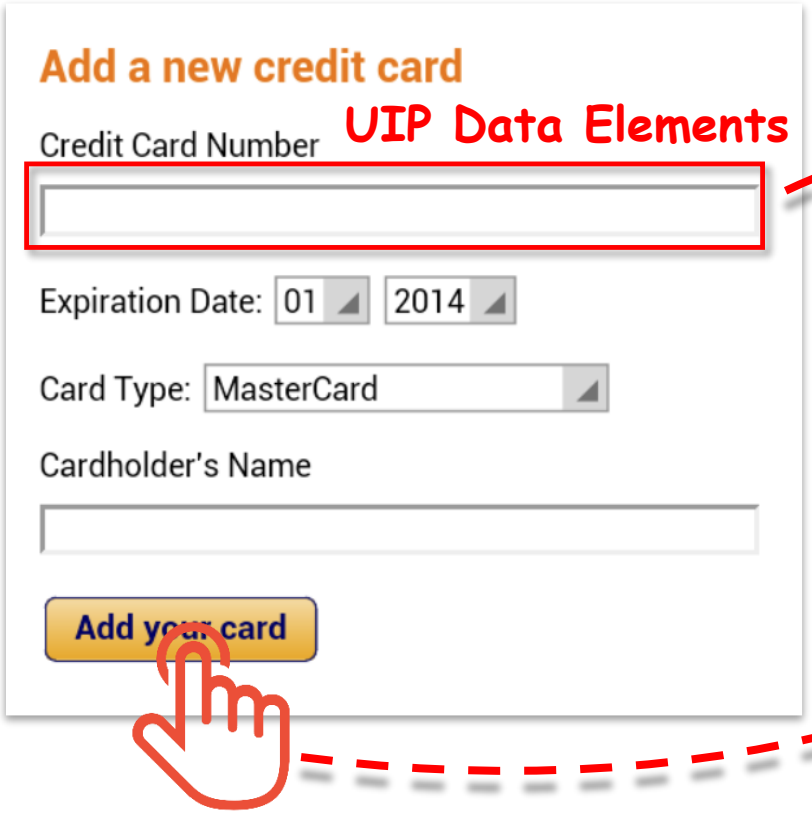
Behavior Based Result Filtering

- Matching UIP data behaviors reflected in application's program code
- Filter out **static labels** which **only contain** privacy-related semantics
- Recover Input fields other than "EditText"
  - Implicit user input
    - E.g. Drop down list
  - Customized input
    - E.g. com.alipay.inputBox





Behavior Based Result Filtering



1. Locating UIP candidate & its layout

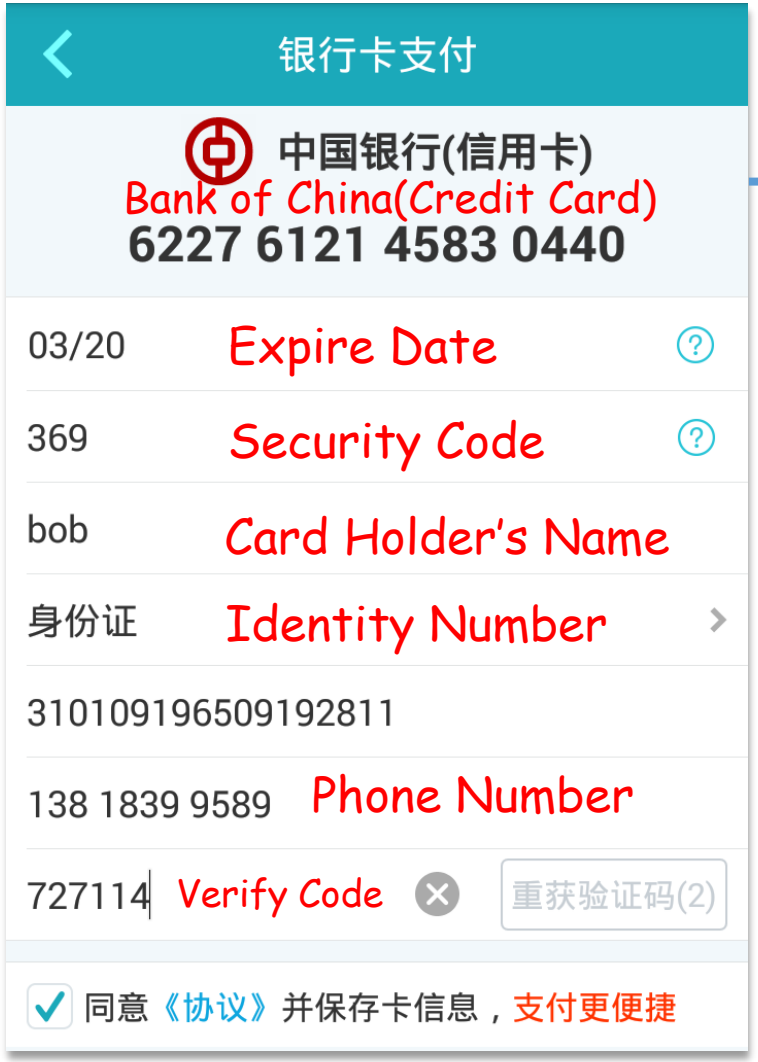
```
Activity.setContentView(R.layout.add_credit_card.xml)

Void OnCreate(Bundle bundle){
    InputBox IB = findViewById(2131231511);
    submitBtn = findViewById(2131623982);
    submitBtn.setOnClickListener(new addCardListener());
}
```

2. User-Triggered Event handling

```
addCardListener.onClick(View v) {
        ……
        creditCard = IB.getText();
        sendContent(creditCard)
        …..
}
```

Runtime Security Enhancement

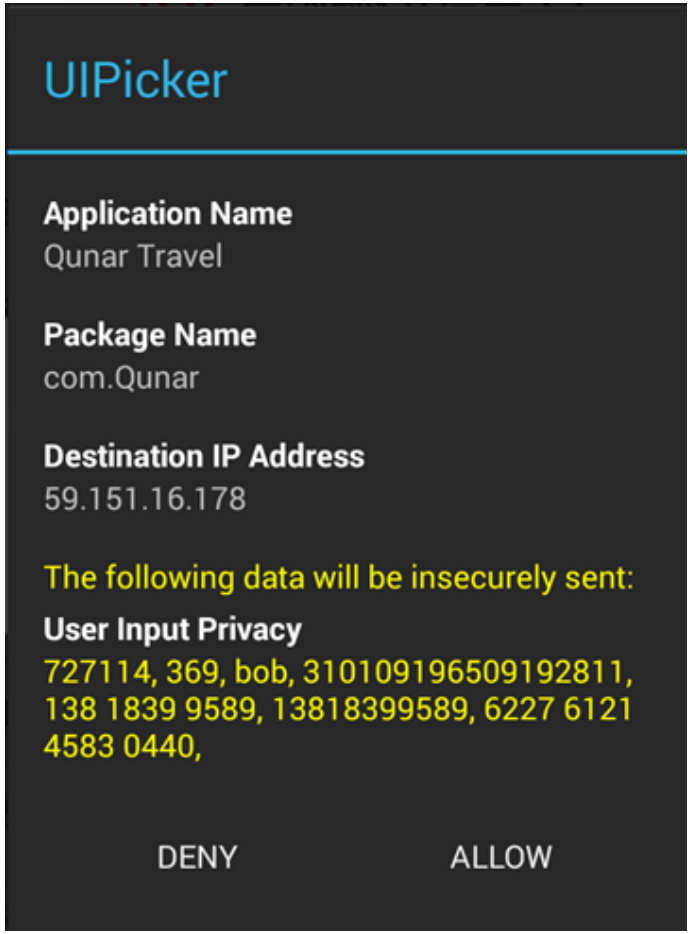


Taint Tracking based on UIPicker

TaintDroid

```
c = taint_source()
...
a = b + c
...
network_send(a)
```

WARNING



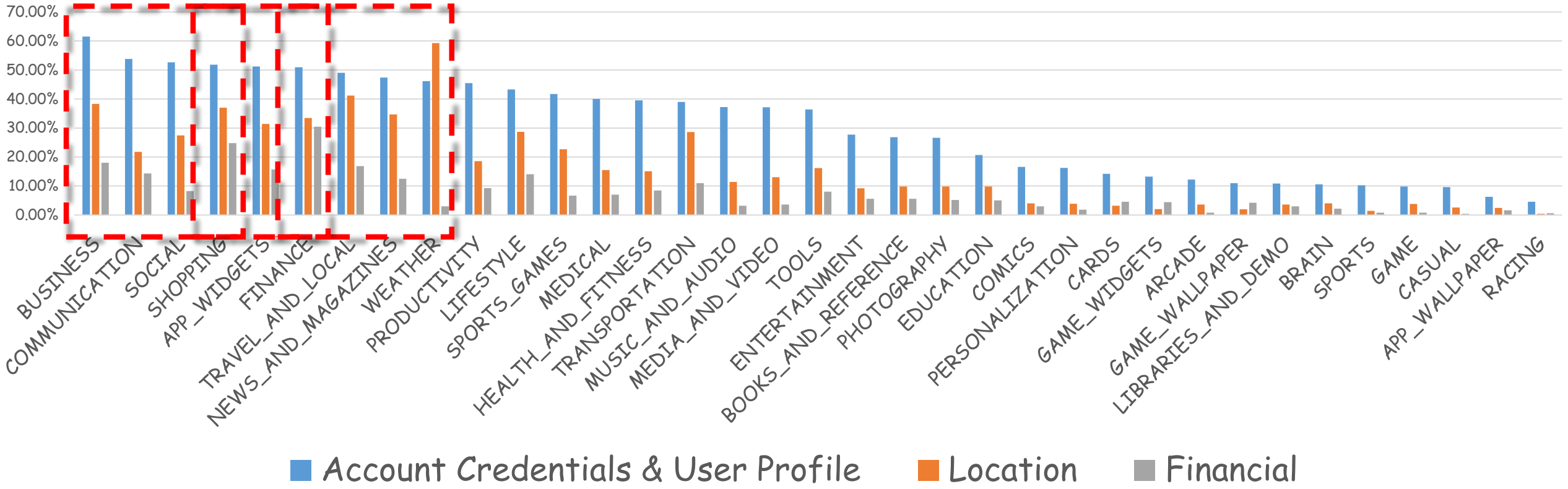
- Plain Text transmission
  - Runtime checking
- Insecure SSL implementation
  - Offline analysis with MalloDroid [CCS' 12]

UIPicker Evaluation

- Dataset
  - 17,425 apps crawled from Google-Play in Oct.2014
  - 35 categories, 500 apps for each

UIP Data Distribution

- 6,179 (35.46%) contain UIP data in 17,425 Apps
- Exist in more than half of apps in 9 out of 35 categories.



Effectiveness

- Compare with System Defined APIs (# Apps)

TelephonyManager.**getLine1Number**()
AccountManager.**getAccounts**()

LocationManager.**getLastKnownLocation**()
Location.**getLongitude**()
Location.**getLatitude**()

Category	System Defined APIs	UIPicker	Overlap
Account Credentials & User Profile	4,900	5,330	1,340
Location	15,221	2,883	2,282
Financial	-	1,318	-
Total	15,632	6,179	-

Effectiveness

- Compare with Sensitive Attributes(# Elements)

textEmailAddress textPersonName
textPassword textVisiblePassword
password/email/phoneNumber

textPostalAddress

Category	InputType	UIPicker	Incremental
Account Credentials & User Profile	24,021	46,227	26,087
Location	941	14,311	13,370
Financial	-	6,353	-
Total	24,962	71,224	46,262

15x

2x

Effectiveness

- Compare with Sensitive Attributes(# Elements)

Type	# Elements	% in UIP Data
TextView	10,582	14.86%
Customized	5,075	7.13%
Spinner	1,962	2.75%
Others	784	1.10%
Total	18,403	25.84%

Precision

- Manual Validation
  - 200 random selected apps in 10 categories (20 in each)
  - False Positives: 67/1042 elements
  - False Negatives: 107 elements
  - Overall: **93.6% Precision and 90.1% Recall**

$$Precision = \frac{TP}{TP + FP} \qquad Recall = \frac{TP}{TP + FN}$$

Conclusion

- UIPicker: Identify UIP data based on novel combination of NLP, machine-learning approach, and static analysis techniques
- Runtime security enhancement based on UIPicker
- Easily be deployed for other existing mechanisms for privacy analysis/protection.

Thanks

Questions?