FlowCog: Context-aware Semantics Extraction and Analysis of Information Flow Leaks in Android Apps

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Roadmap

1. **Motivating Example**
2. FlowCog Overview
3. Design
    a. View Dependency Explorer
    b. Flow and Semantics Correlation Inference
4. Implementation
5. Evaluation & Case Study
6. Conclusion

Main_activity

<Button an

"*perfomUp*

Pressure: 1012.0 hPa
Humidity: 51 %
Sunrise: 1:14 PM

MainActivity:p

(2) task=new Up ... (userLocation, **allowShareLoc**.isChecked())

task.execute

Wind: 1.4 m/s ↗

UpdateWeath ... ound()

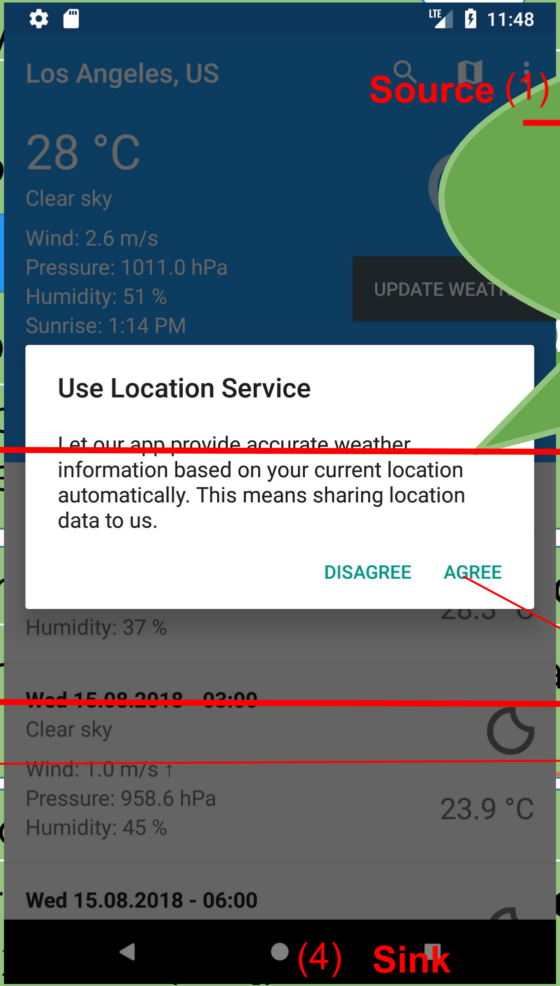
(3) **if** (allowShar ... ata(**location**)

else showDi

ServerApi.p

req = prepar ... **ocation**)

HttpClient.e



11:48

Los Angeles, US

28 °C

Clear sky

Wind: 2.6 m/s
Pressure: 1011.0 hPa
Humidity: 51 %
Sunrise: 1:14 PM

UPDATE WEAT

Use Location Service

Let our app provide accurate weather information based on your current location automatically. This means sharing location data to us.

DISAGREE AGREE

Humidity: 37 %

Wed 15.08.2018 - 03:00

Clear sky

Wind: 1.0 m/s ↑
Pressure: 958.6 hPa
Humidity: 45 %

23.9 °C

Wed 15.08.2018 - 06:00

Let our app provide accurate weather information based on your current location, this ...

“Share location to automatically update city”

PosBtnListener:onClick()

(3) ServerApi.postData(location)

Cannot tell which flow is legitimate!

[MockDroid] B l, Alastair R., et al. "Mockdroid: tradi for application fun rtphones." Proceedings of the 12th workshop on mobile computing systems a ACM, 2011.

[SmartDroid] Zheng, Cong, et al. " Proceedings of the second ACM

[AppIntent] Yang, Zhemin f the 2013 ACM SIGSAC confer

[Epicc] Octeau, Damien, et al. "Effectiv appl icc: An esse rds holistic security analysis." Effective Inter-Component Commun Mapping in An c: An Essent ds Holistic Security Ana (2013).

[AmanDroid] Wei, Fengguo, Sankardas Roy, and Xinming O android: A precise and gene al inter-component data flow analysis framework for security vetting of android apps." Proceedings of the 2014 ACM SIGS Conference on Computer and Communications Security. ACM, 2014.

[TaintDroid] Enck, William, et al. "TaintDroid: an information-flow tracking system for realtime privacy monitoring on smartphones." AC M Transactions on Computer Systems (TOCS) 32.2 (2014): 5.

[Flow Arzt, Steven, Flowdro e context, flow, field, object-sensitive and ware ta fo gplan Notices4 259

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[A n: Revealing data flows in android applic d Applications (AINA), 2015 IE 015.

[Droidsafe] Gordon, Micha et al. "Infor on Flow Analysis of Android Applications in DroidSafe." NDSS. V 15. 2015.

[VetDroid] Pravin, Ms Nigan Paridhi. "Vetdroid: Analysis using permission for vetting undesirable behaviours in android applications." International Journal of Innovative and Emerging Research in Engineering 2.3 (2015): 131-136.

58% flows are legitimate!

Big burden on users!

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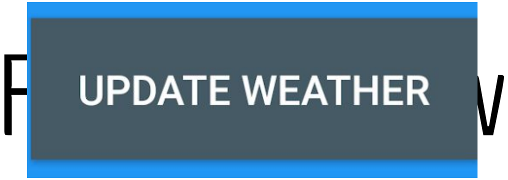
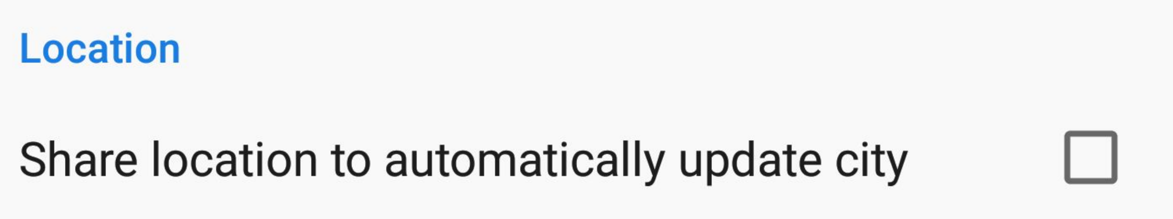
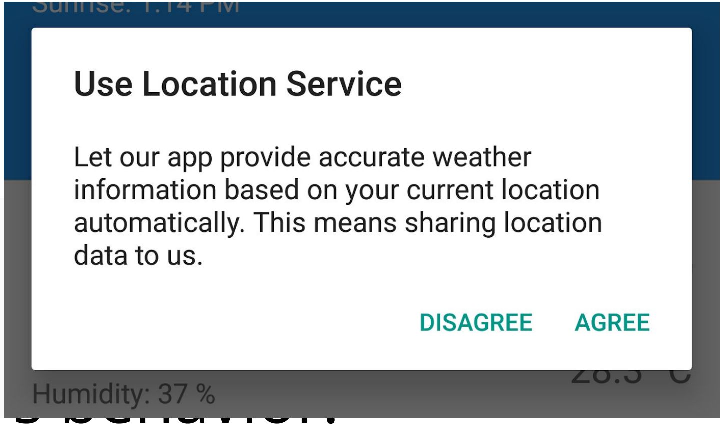
F view




Location

Share location to automatically update city □


Sunrise: 1:14 PM

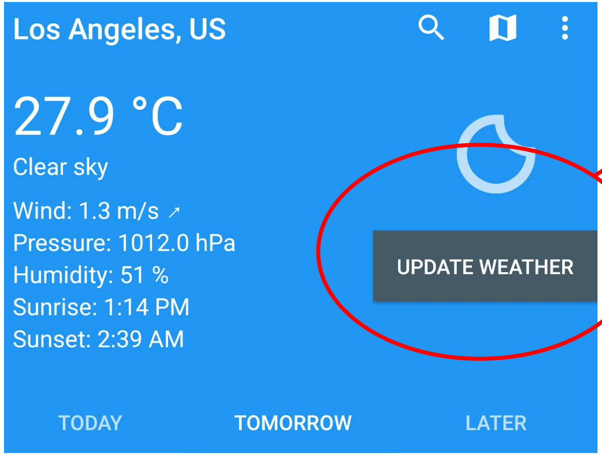
Use Location Service

Let our app provide accurate weather information based on your current location automatically. This means sharing location data to us.

Humidity: 37 %

- Associate the semantics with flow's behavior?

- High level steps:
  - Associate each flow with its related views via static analysis and an optional dynamic analysis.
  - Extract view semantics. (e.g., “Update Weather”)
  - Determine if semantics provides information about flow behavior.

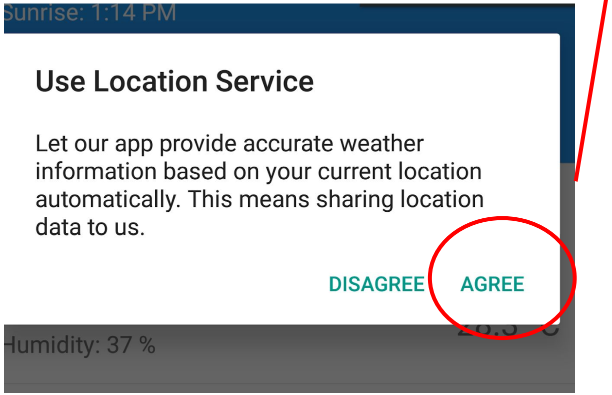


Los Angeles, US

27.9 °C

Clear sky

Wind: 1.3 m/s ↗
Pressure: 1012.0 hPa
Humidity: 51 %
Sunrise: 1:14 PM
Sunset: 2:39 AM



Sunrise: 1:14 PM

Use Location Service

Let our app provide accurate weather information based on your current location automatically. This means sharing location data to us.

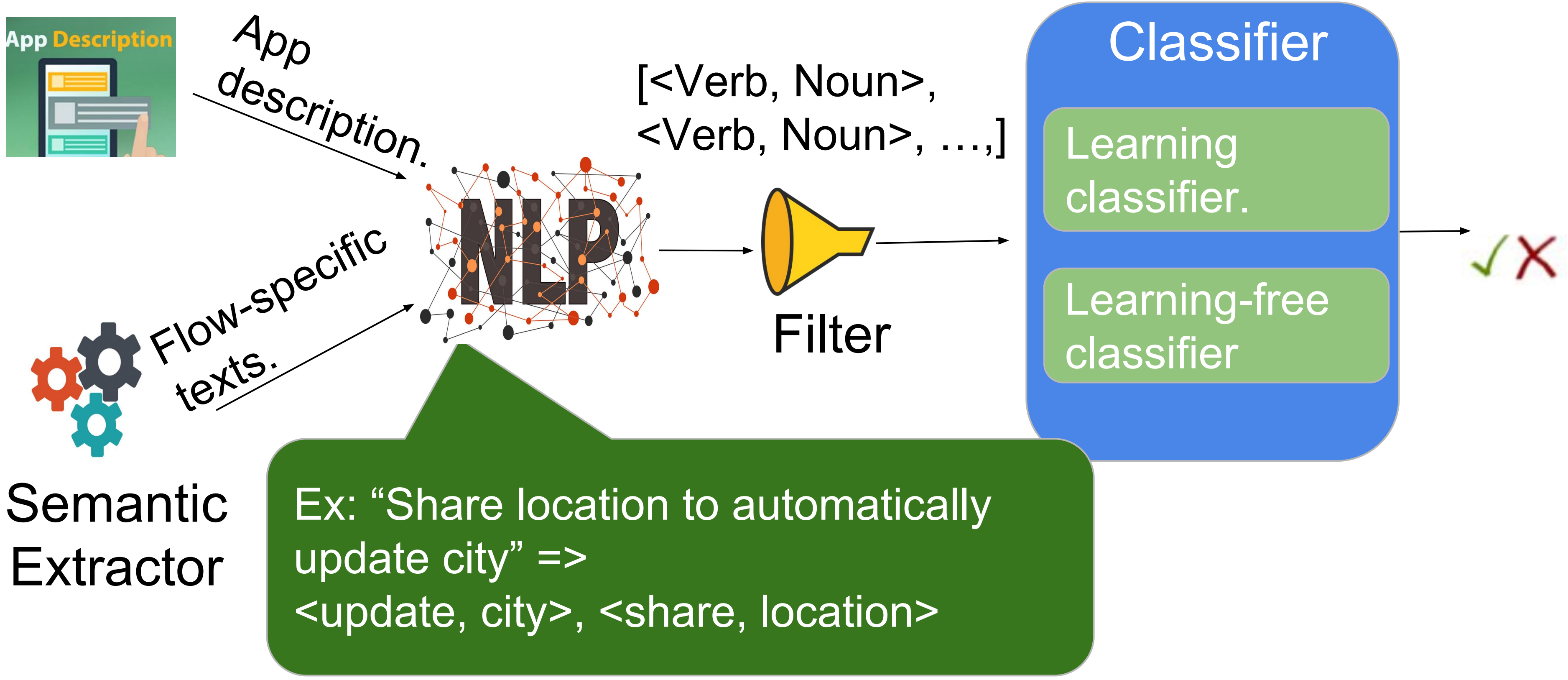
Humidity: 37 %

Activation Event.

```
UpdateWeatherAsyncTask:doInBackground
  if (allowShareLoc) sendData
  else ...
```

Guarding Condition

FlowCog: Flow and Semantics Correlation Inference (2/2)



App description.

Flow-specific texts.

Semantic Extractor

[<Verb, Noun>, <Verb, Noun>, …,]

Filter

Classifier

Learning classifier.

Learning-free classifier

✓ ✗

Ex: “Share location to automatically update city” =>
<update, city>, <share, location>

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Design: View Dependency Explorer

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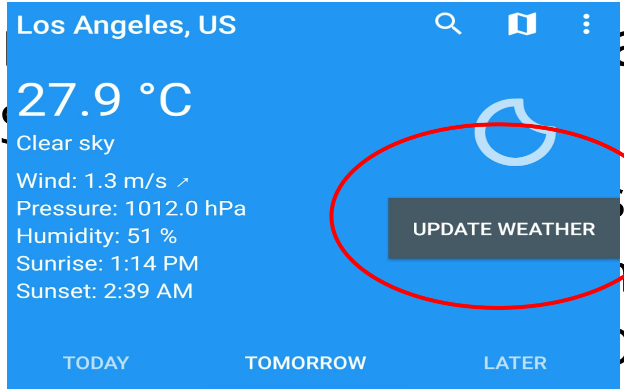
  - S statemer at creat s) Dialog cla



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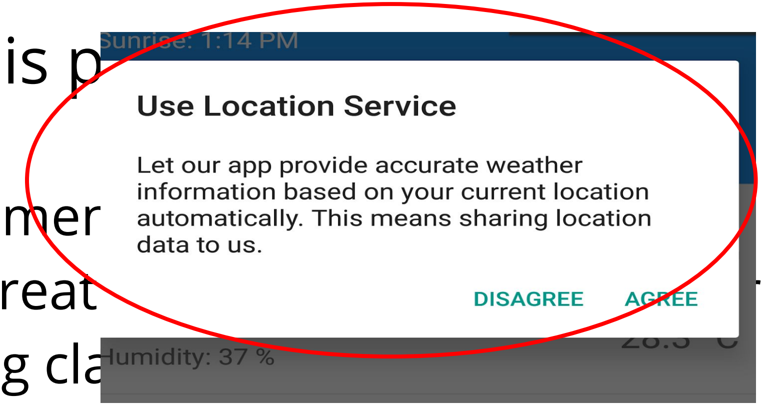

Sunrise: 1:14 PM

Use Location Service

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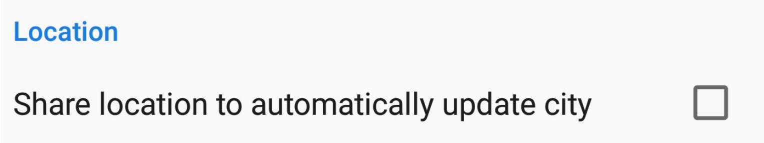
Humidity: 37 %

- Sink:
  - Statements in given data flow.
  - Guarding condition statements.
  - All the activation events’ registration statements.



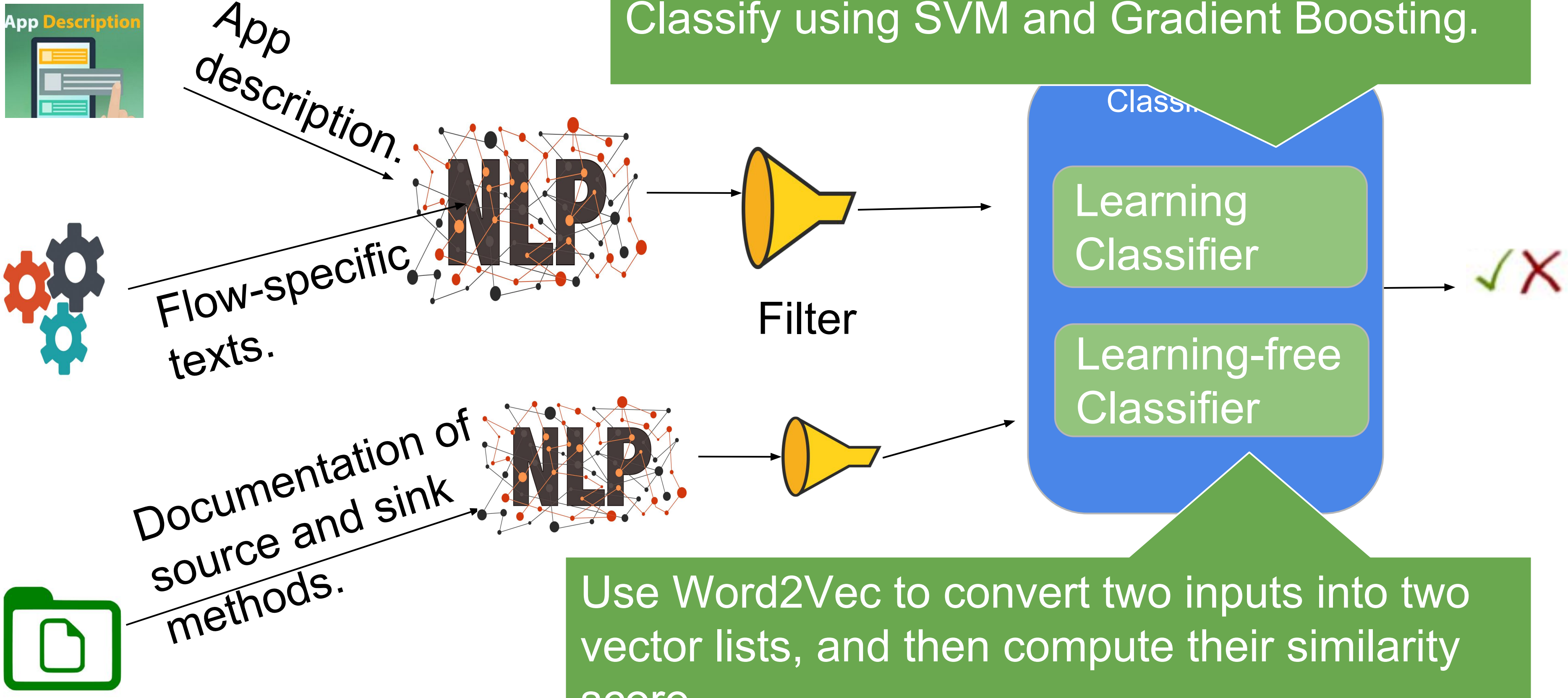
Location

Share location to automatically update city □

- Use IFDS framework provided by FlowDroid.

Design: Flow and Semant

Vectorize input using TF-IDF.
Classify using SVM and Gradient Boosting.



Use Word2Vec to convert two inputs into two vector lists, and then compute their similarity score.

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Implementation

Component	Language	Loc
Flow-related Semantics Extraction	Java	~12,000
Classifier	Python	~3,000
Dynamic Analysis	Python, Java	~1,000
Total	Python, Java	~16,000

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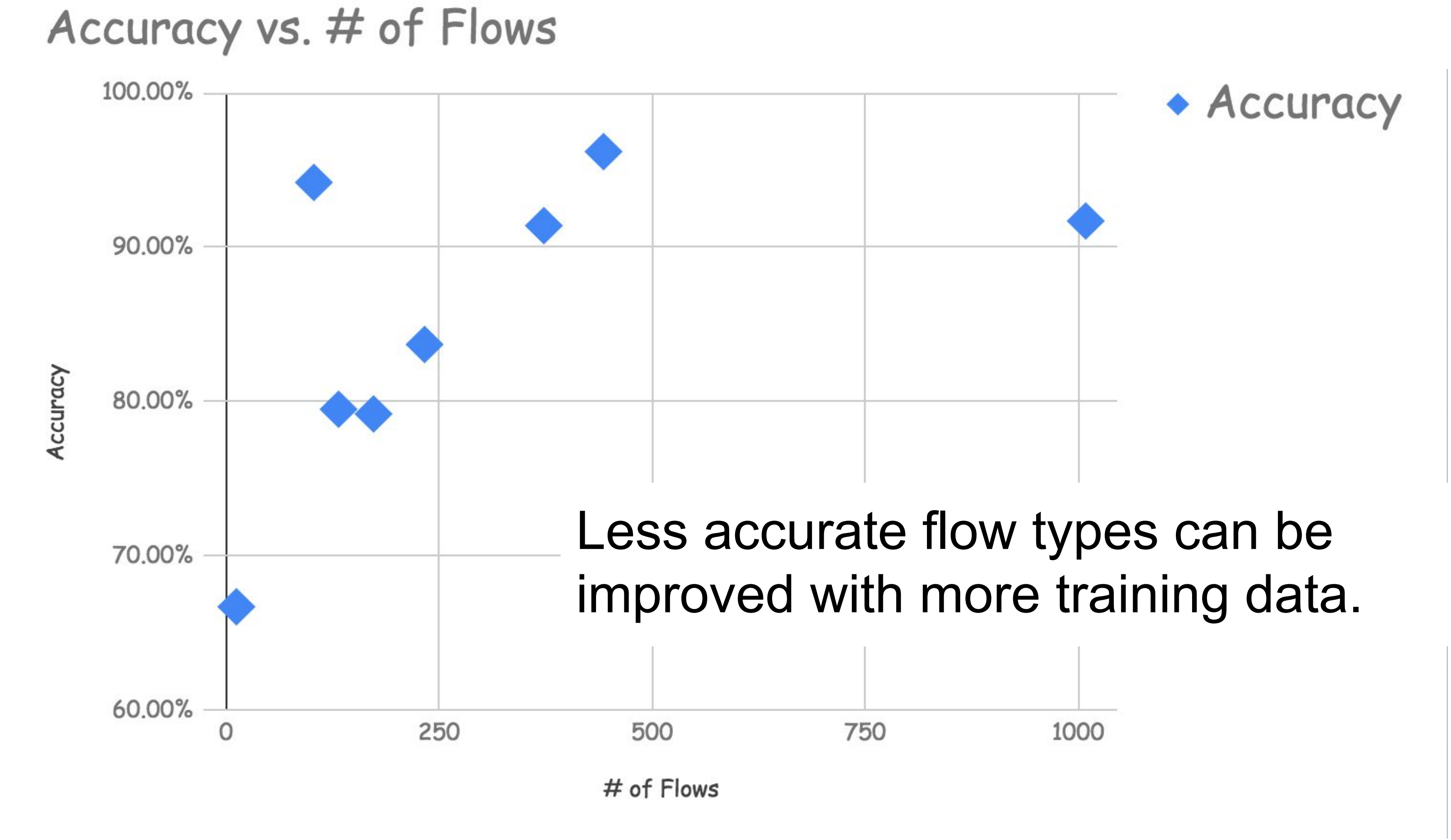
Evaluation: Ground Truth

Type	**Apps**	**Apps with Flows**	**Legitimate Flows**	**Malicious Flows**	**Total Flows**
Benign	1,299/4,500	361	688	355	1,043
Malicious [Drebin dataset]	586/1,500	255	675	624	1,299
Overall	1,885/6,000	616	**1,363**	**979**	2,342

Evaluation: FlowCog Achieves High Accuracy.

Type	**Flows**	**Precision**	**Recall**	**Accuracy**
Benign	1,043	90.3%	95.1%	90.7%
Malicious	1,299	89.9%	91.0%	89.6%
Overall	2,342	90.1%	93.1%	90.2%

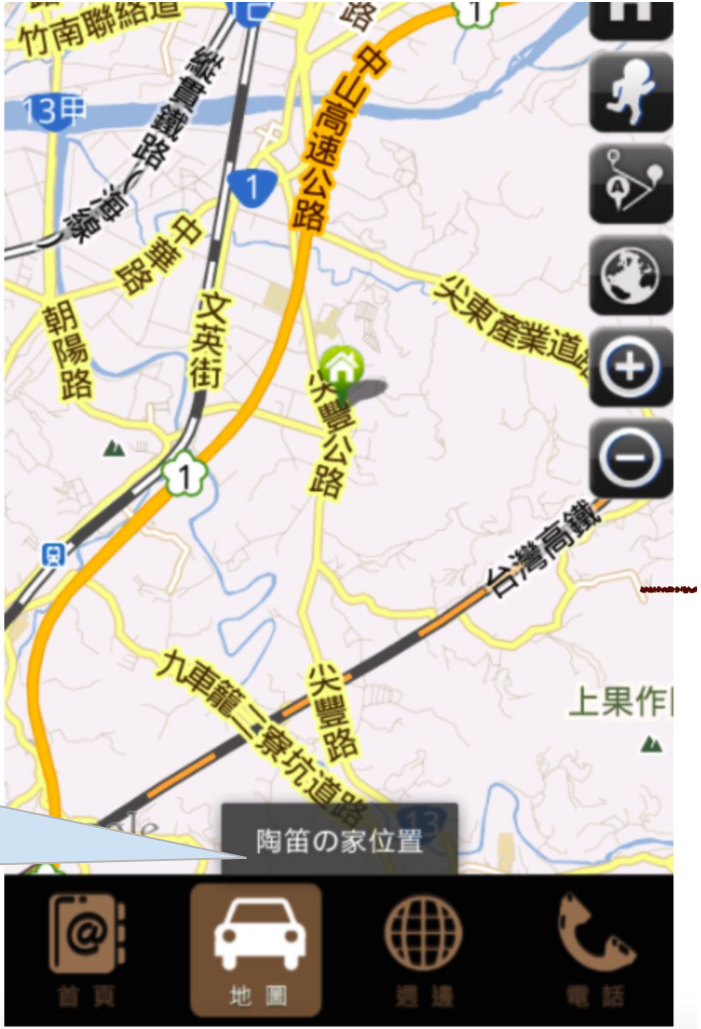


Less accurate flow types can be improved with more training data.

Case Study: Home of Ocarina

- Leaks out users’ geo-location.
- Labeled as legitimate because of extracted semantics.

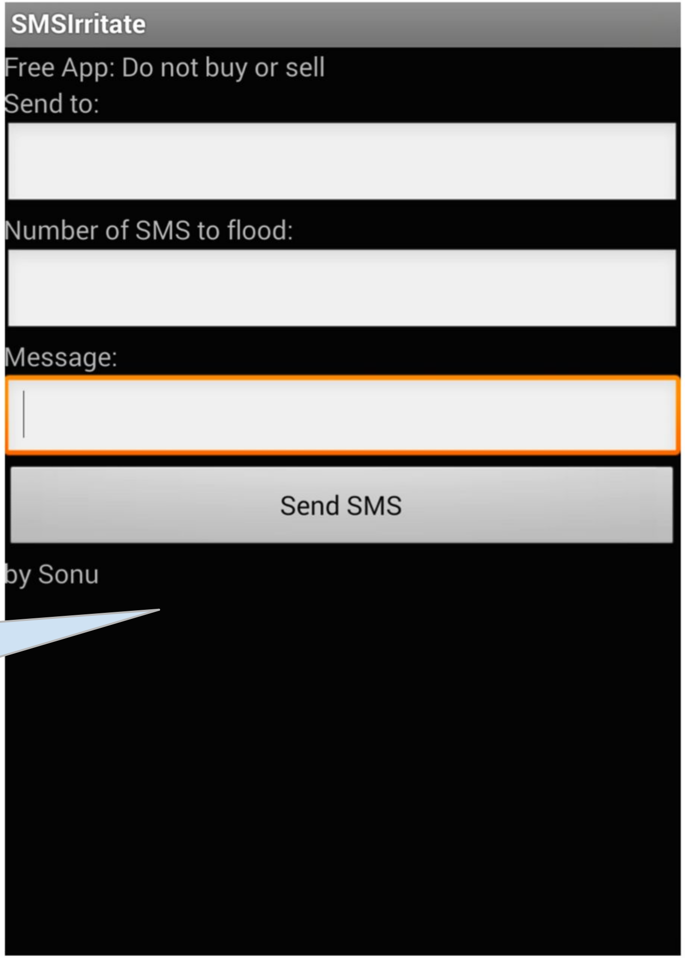
“Map”, “The location of home of Ocarina”



Case Study: SMS Irritate

- Leaks out user-specific information via SMS.
- Labeled as legitimate.

“Send SMS”, “Number of SMS to flood”, “Message”



SMSIrritate

Free App: Do not buy or sell

Send to:

Number of SMS to flood:

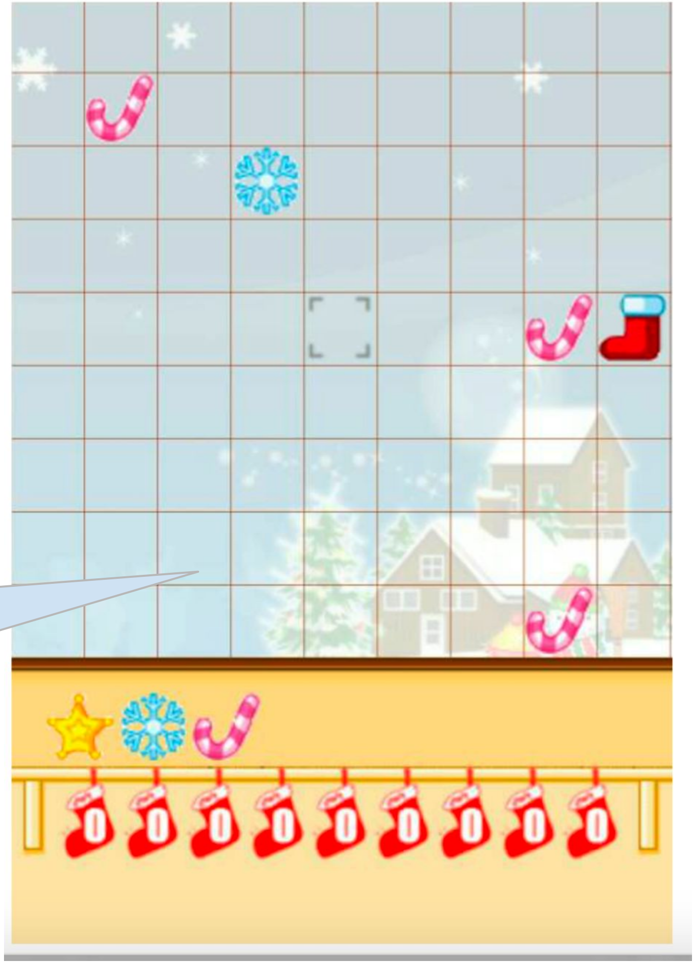
Message:

by Sonu

Case Study: Merry Christmas

- Leaks out users' information to Internet.
- Labeled as malicious.

"Move the box to the target empty position..."



Conclusion

- FlowCog is **the first system** to extract flow-specific semantics.
- FlowCog adopts NLP techniques to associate flow-specific semantics with flow behaviors.
- Our evaluation results show that FlowCog can achieve a precision of **90.1%** and a recall of **93.1%.**

Thanks!

FlowCog open-source at: **https: //github.com/SocietyMaster/FlowCog**