

MAGPRINT: Deep Learning Based User Fingerprinting Using Electromagnetic Signals

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Outline

- Background
- Motivation
- Preliminary
- Challenge and Methodology
- Evaluation
- Conclusion and Future Work

Background

Smart Devices are everywhere...



Biological Feature Based Solutions

- 2D/3D Face Model
- Fingerprint

• Iris







cannot perform continuous user authentication!







User Behavior Feature Based Solutions



User Behavior Feature Based Solutions

• Common phenomenon: electromagnetic radiation signals



- We propose *MagPrint*, a novel EM signals based solution using *magnetometer*
- Advantages of *EM side channel* :
 - Contain rich user behavior information
 - Data accessibility, and easy to deploy



Preliminary

• Q1: Detection and distinction of users' operations.



Preliminary

• Q2: Distinction of users' operation habits.



Preliminary

• Q3: Consistence over spatial and temporal domain.



System Workflow



 Noisy EM signals caused by human movements because of the geomagnetic signal.



Noisy EM signals caused by background running APPs.



- Filter out noisy EM signals caused by human movement
 - Low-pass filter to capture interactions
 - Gaussian filter to eliminate random noise



Keyboard Inputs

- Cancel the noisy EM signals caused by background running APPs
 - EM signals of Background Running APP change over time.
 - This change is gradual, such as listening to music.
 - 2-layer LSTM regression model is applied to cancel the background APP noise.



Challenge II — Diversity of APPs on the market



Classify APPs into multiple categories

| Frequency of | Typing | Clicking | Moving |
|---------------|--------|----------|--------|
| Internet | 3 | 5 | 5 |
| Business | 5 | 5 | 3 |
| Communication | 5 | 3 | 3 |
| Game | 1 | 3 | 5 |
| Multimedia | 1 | 1 | 1 |
| SNS | 3 | 3 | 5 |
| System | 3 | 4 | 3 |

APP categories classified by interaction behaviors



Classify APP into categories can reduce train data needed and remain high accuracy







Challenge III — Users' Habits Tracking

- Mining users' habits from high-frequency EM signals.
- Users finish interactions in short time, while capturing users' habits need long time range.
- Present users' habits also depends on previous user interactions.
- Users' using habits change over time or mood, and there are also users with similar habits.

Users' Habits Extraction



Distinguish Similar User Habits



 $L = \max(d1 + \alpha - d2, 0)$

19

Prototype





Sensor Board

Sensor Chip

2.8 IOSETAD VERSIONING 2. IMORETEACK_S



MCU Board





Prototype on hand

Evaluation

TABLE II: List of 30 Apps collected in the experiments.

| App Category | Apps |
|---------------|---|
| Internet | Chrome, Firefox, Internet Explorer, |
| | Amazon Shopping, Baidu Cloud Download |
| Business | Microsoft Word, Excel, Power-point, |
| | Microsoft Notepad, Adobe Acrobat XI Pro |
| Communication | Skype, Tencent WeChat, QQ |
| Game | Zuma, Candy Crush Saga, Minecraft, |
| | Plants vs. Zombies, Agar Online |
| Multi Media | Youtube, Tencent Video, Aqiyi Video, Potplayer, |
| | NetEase cloud Music, Windows Media Player |
| SNS | Gmail, Github, Twitter |
| System | System Player, System Camera, System 3-D Plot |

TABLE III: List of 10 devices collected in the experiments.

| Model | OS versions | CPU Speed(GHZ) |
|-----------------------|--------------|----------------|
| MacBook Air MQD32CH/A | MacOS 10.13 | 1.7 |
| MacBook Pro MMGM2CH/A | MacOS 10.13 | 2.8 |
| Hp ENVY14-J102TX | Windows 10 | 1.6 |
| Hp 15-be101TX | Windows 10 | 2.5 |
| Lenovo T440 | Windows 10 | 2.4 |
| ASUS Vivobook 4000 | Windows 10 | 2.4 |
| ASUS FX-PRO | Windows 8 | 2.4 |
| Samsung 800G5M-X08 | Windows 8 | 2.5 |
| Dell Ins-15PD-7745BR | Ubuntu 17.10 | 2.3 |
| Acer SF314-52-59TW | Ubuntu 17.10 | 2.5 |





Evaluation



Accuracy across users

Same OS:92.0% Across OS: 83.7%



Leave-one-device-out cross validation

Conclusion and Feature Work

Conclusion

- Propose a novel continuous user fingerprinting method
- Deep learning based user interaction habits tracking
- Easy-to-deploy prototype

Future work

- Expand training set, improve accuracy and robustness
- New scenarios such as energy saving and privacy protection

