Cracking Android Pattern Lock in 5 Attempts

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Attacking Scenario

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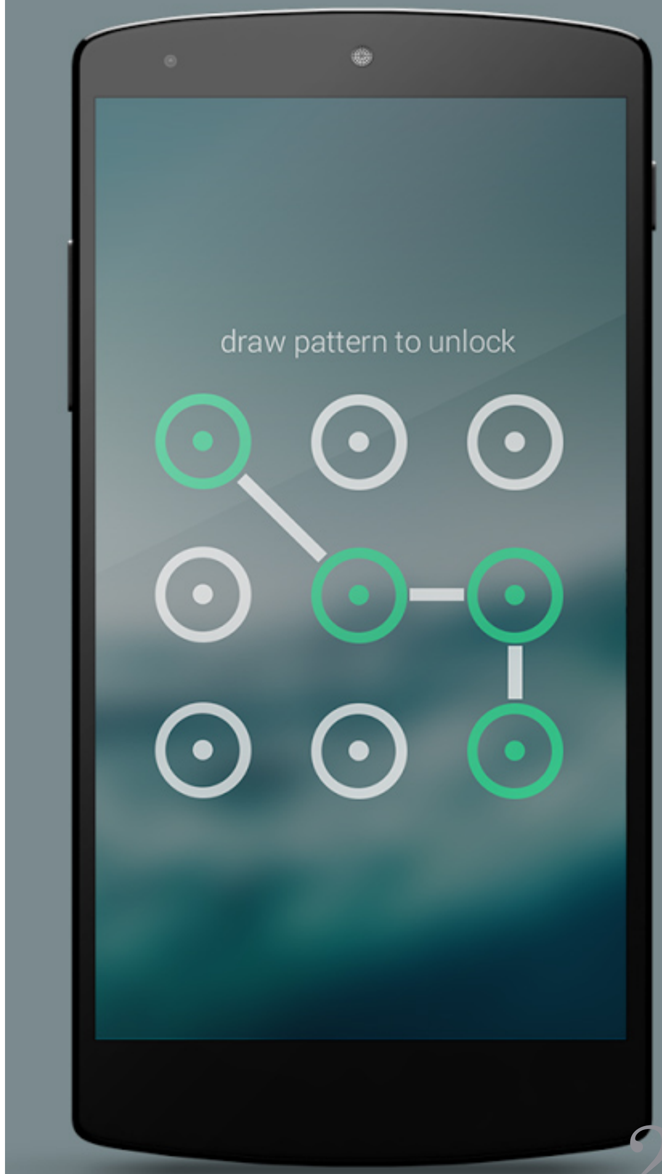
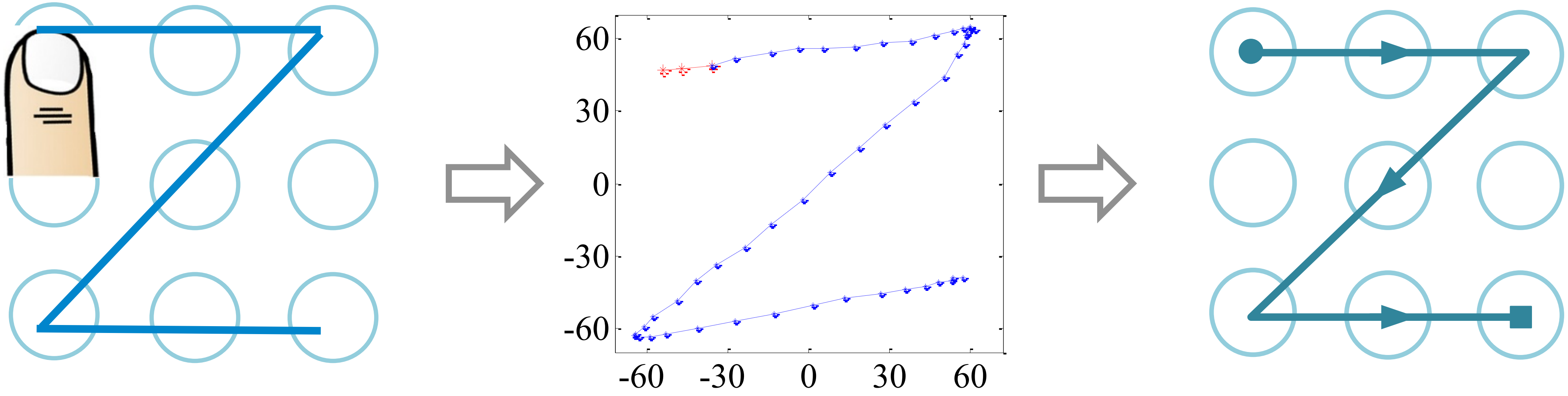
Ca

malware on Alice's phone?

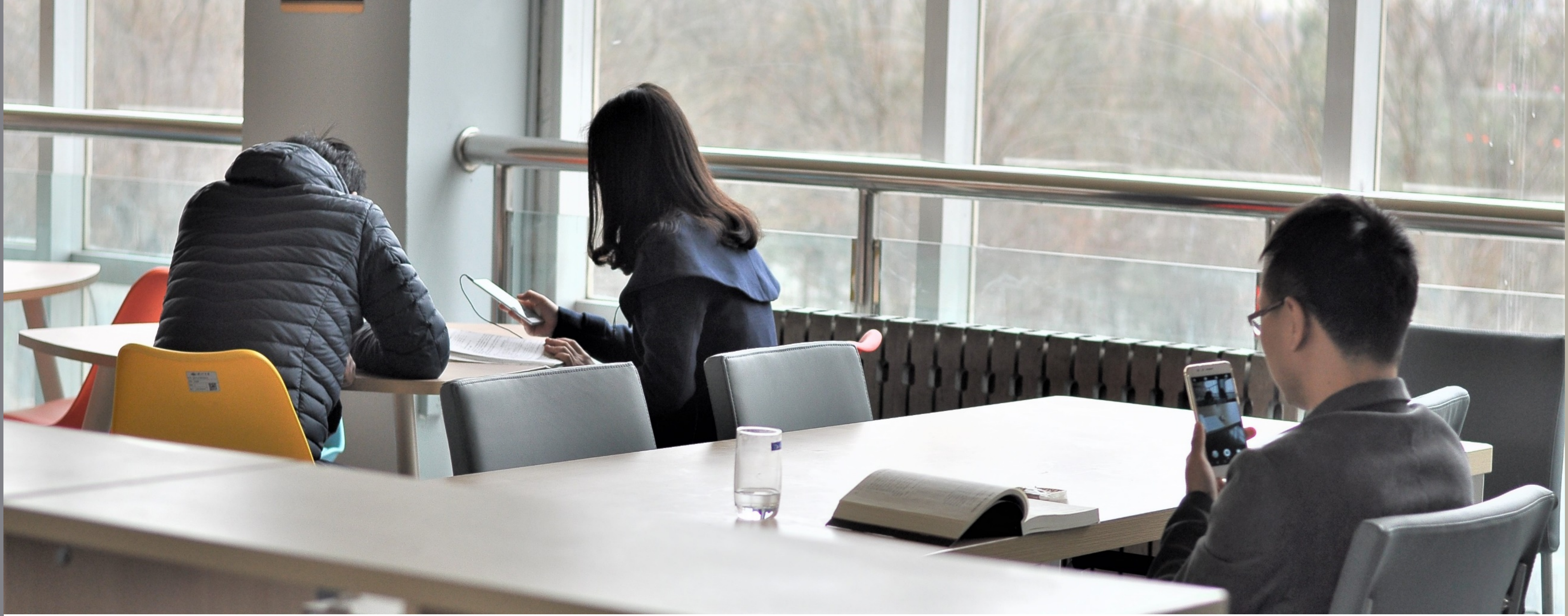
... MSR_IA32_APICBASE_MSR + 0x3ff:
... MSR_IA32_APICBASE_MSR + 0xff:



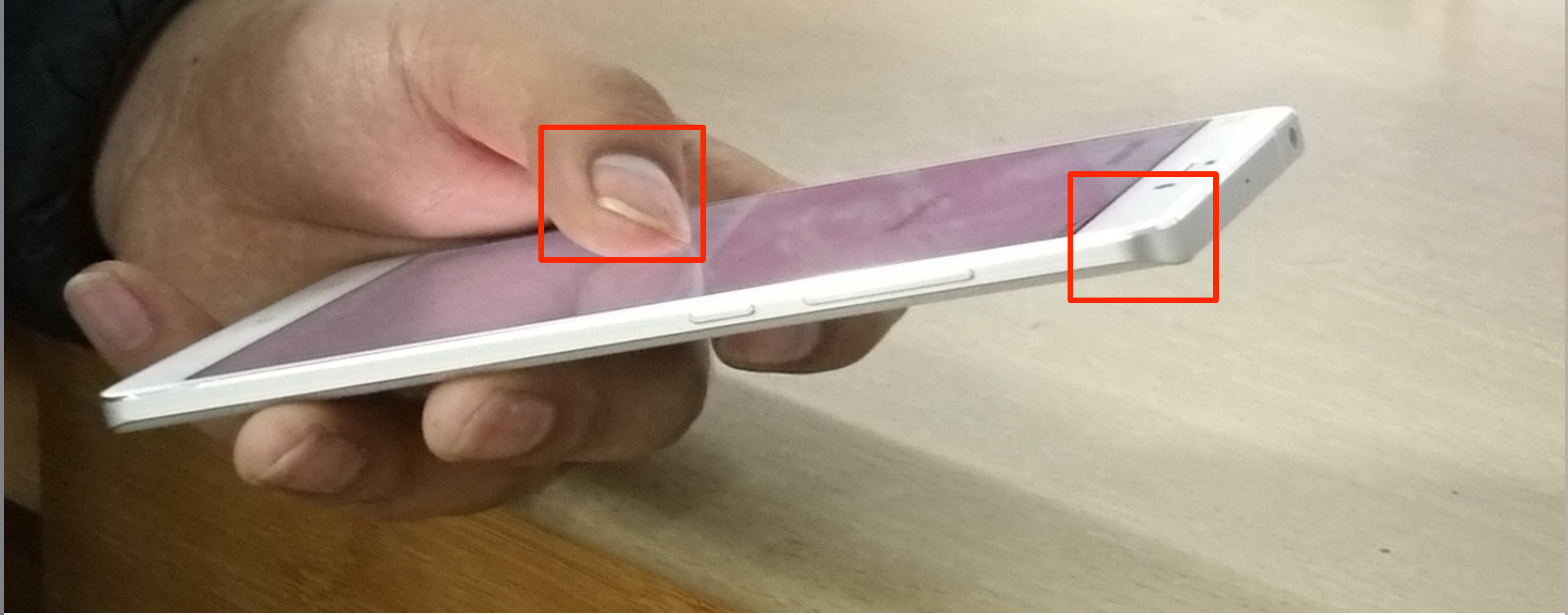
How can Bob bypass pattern lock?



Bob only need to observe the fingertip movement!



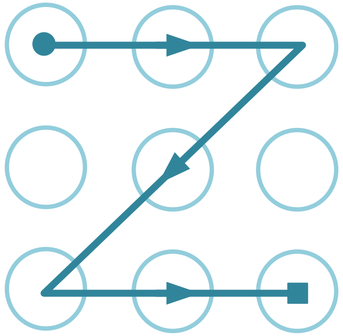
Evil Bob films how Alice draws the pattern from a distance of 2-3 meters. No need to see the screen content. 😈



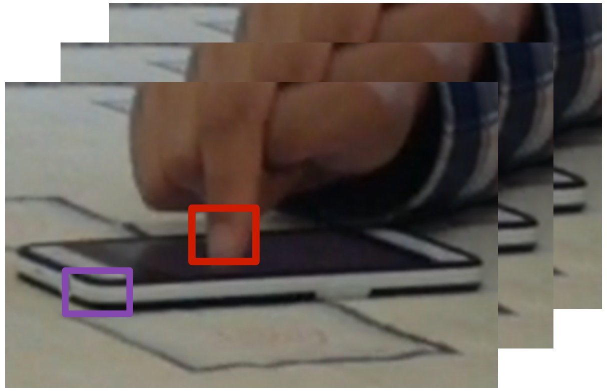
Tracking

Bob marks two areas of interest, and runs a vision algorithm to track the fingertip movement.

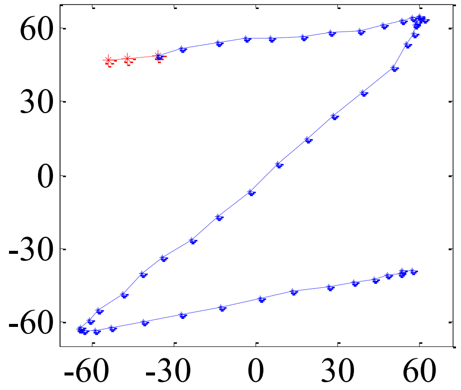
Tracking Example



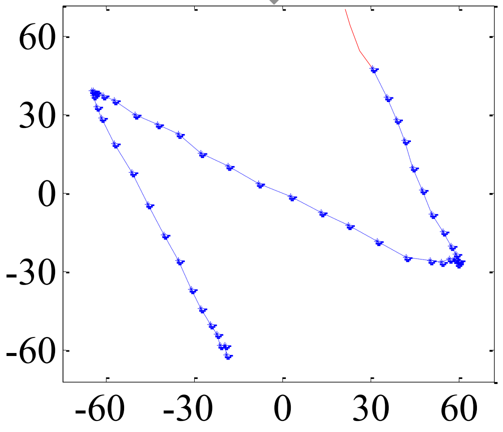
The pattern



Tracking algorithm

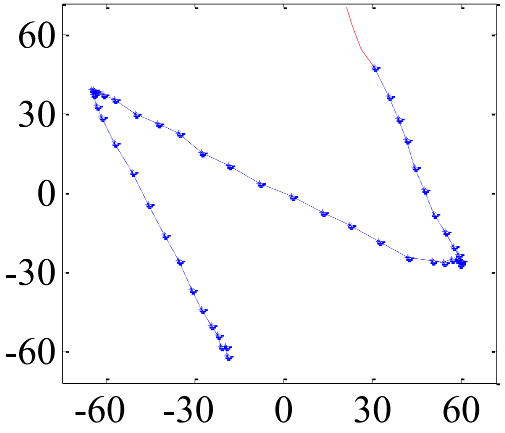


Bob wants this!



Resulted fingertip movement trajectory

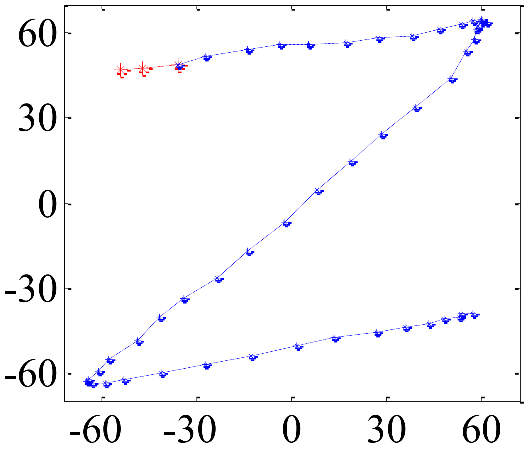
View Transformation



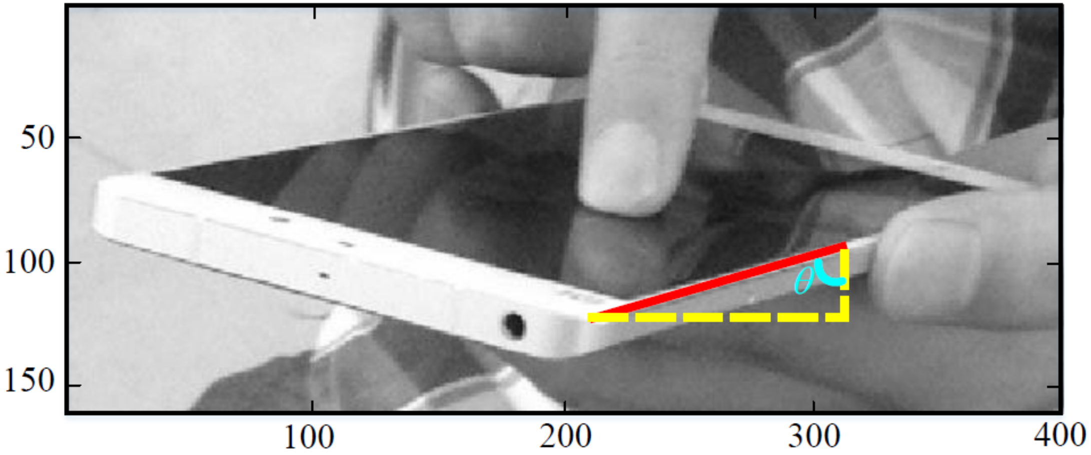
Camera's perspective

$$S = TS_1$$

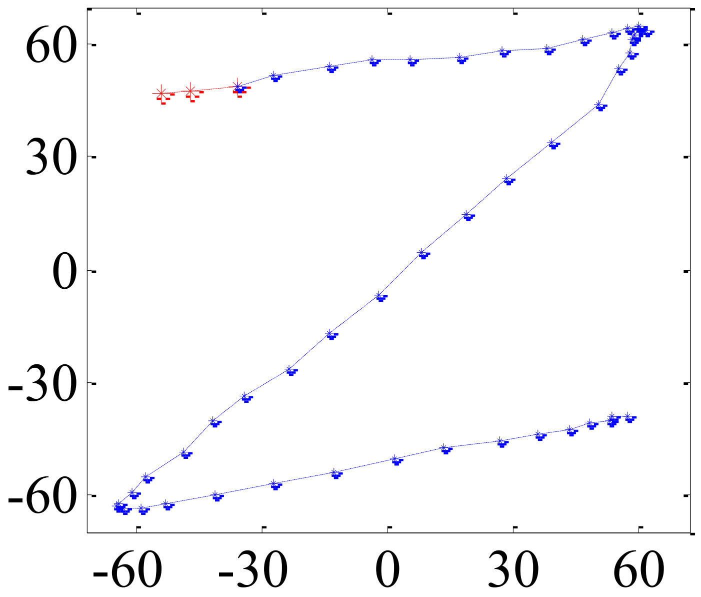
$$T = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$



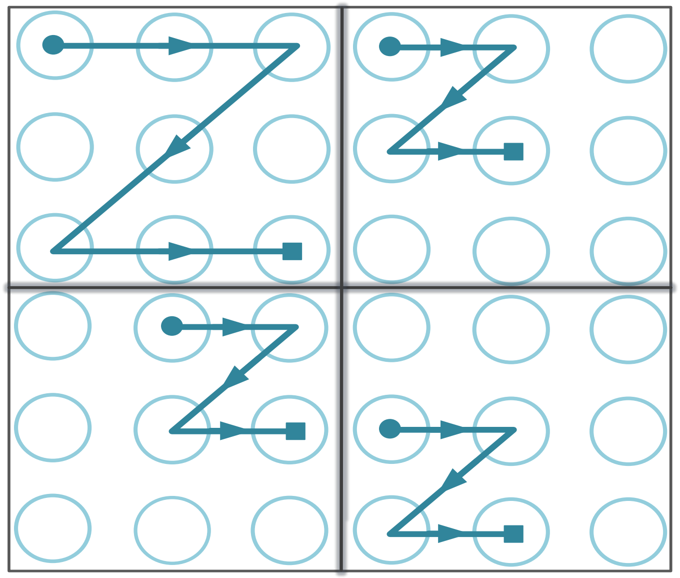
User's perspective



Trajectory to Candidate Patterns

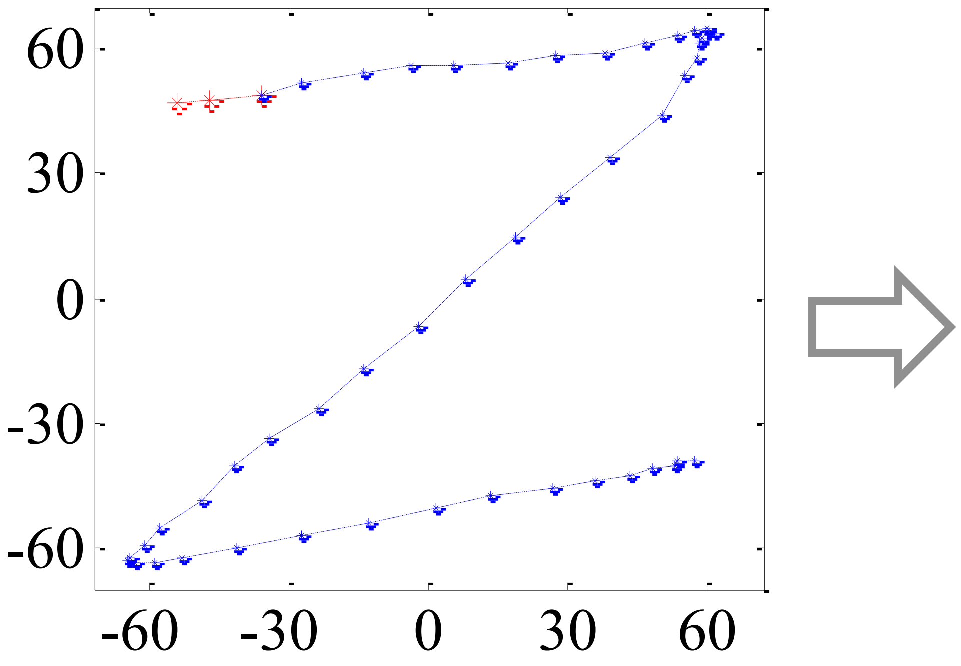


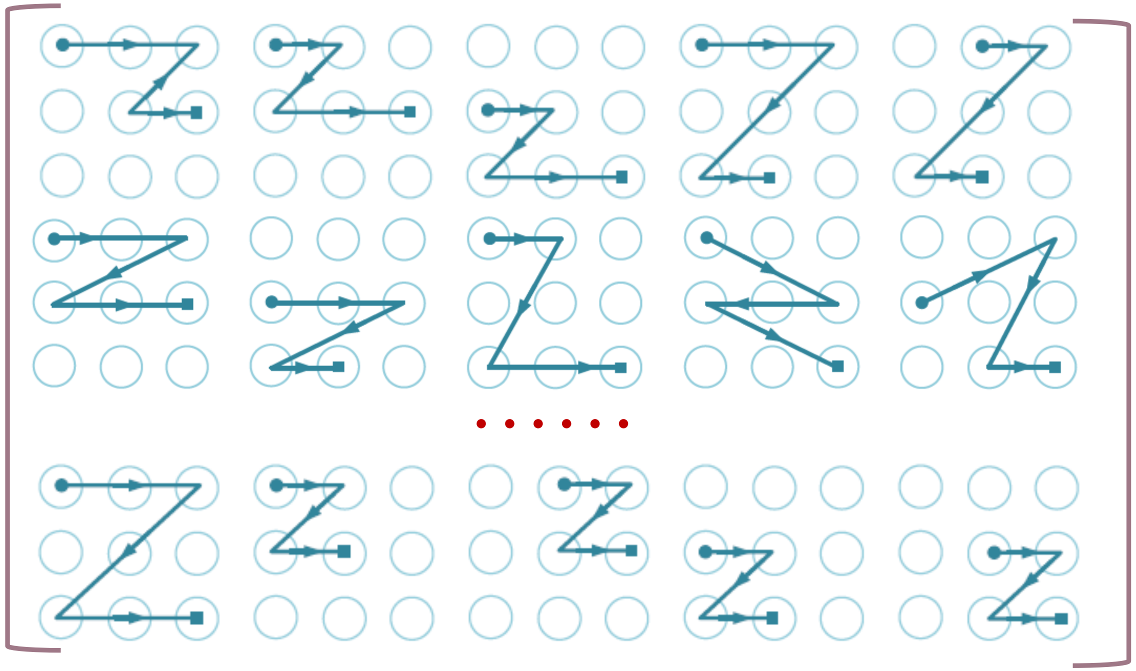
Fingertip Trajectory



Candidate Patterns

A large number of possibilities

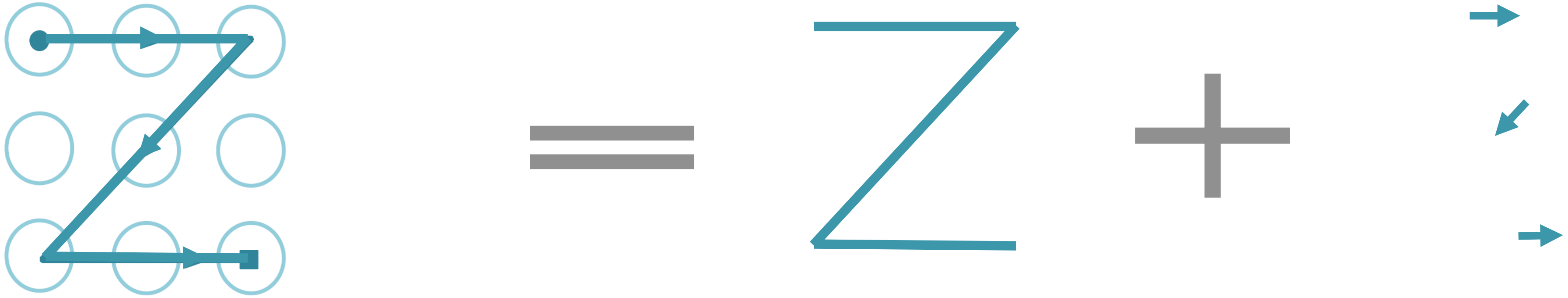




Fingertip Trajectory

Possible Patterns (>100)

Use Geometric information

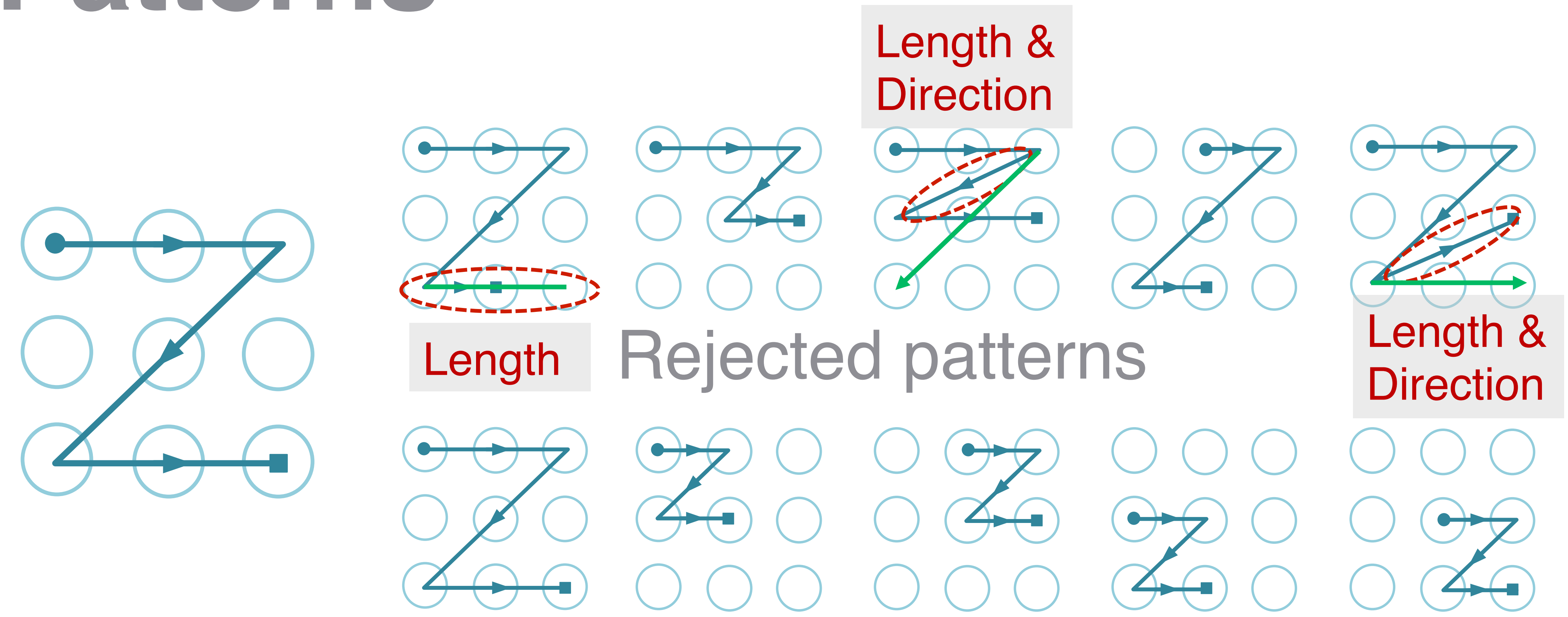


Pattern Lock

Line Length

Line Direction

Example: Identify Candidate Patterns



Length & Direction

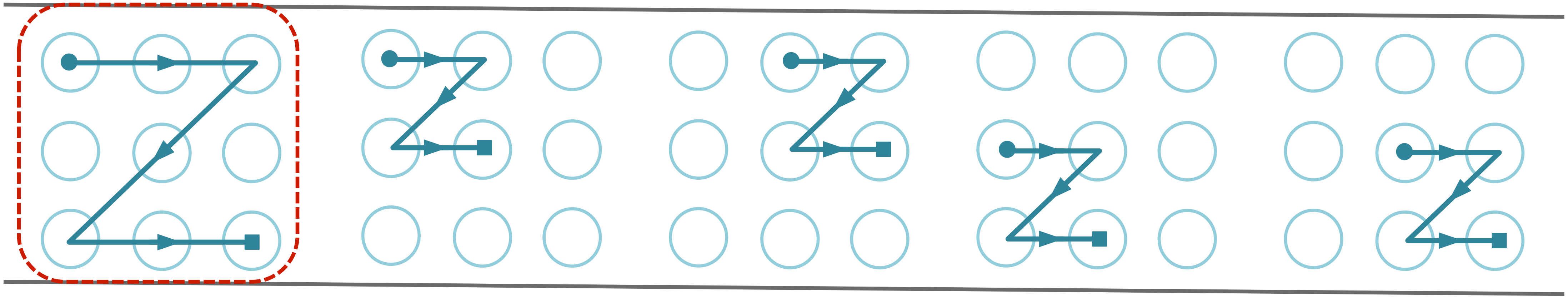
Length

Rejected patterns

Length & Direction

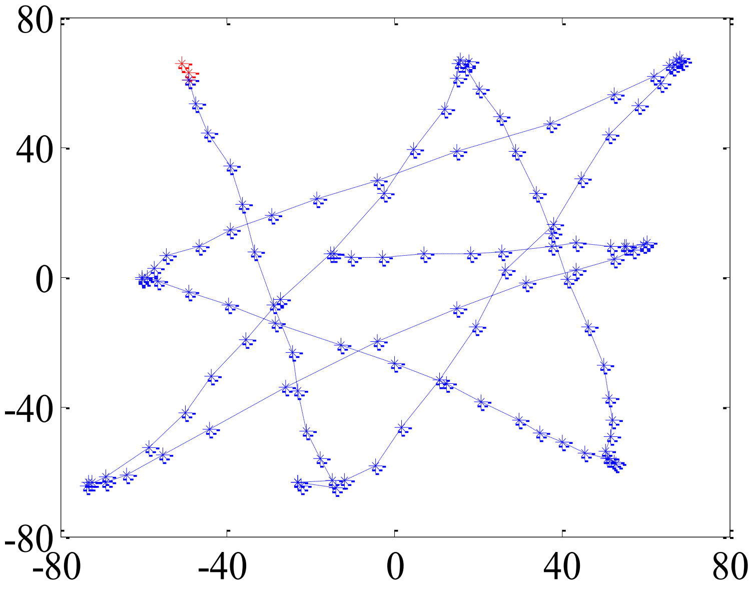
Candidate patterns

Test on Alice's Phone

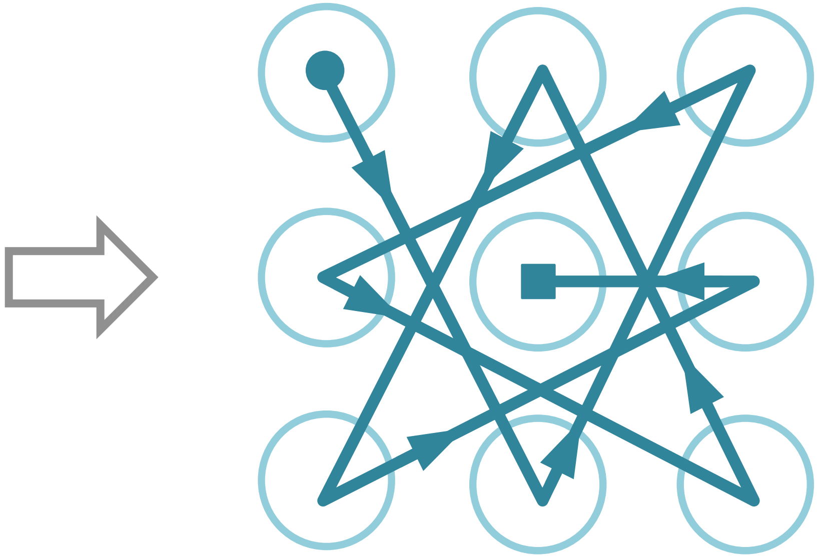


Correct pattern

Another Example



Pattern Trajectory

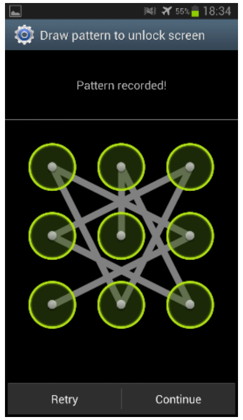


Complex Pattern

Evaluation Setup

research ethics board

APPROVED

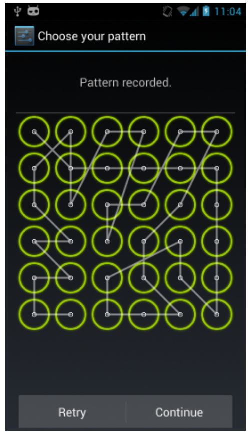

Draw pattern to unlock screen

Pattern recorded!

120 patterns from 215 users

plus

some of the most complex patterns

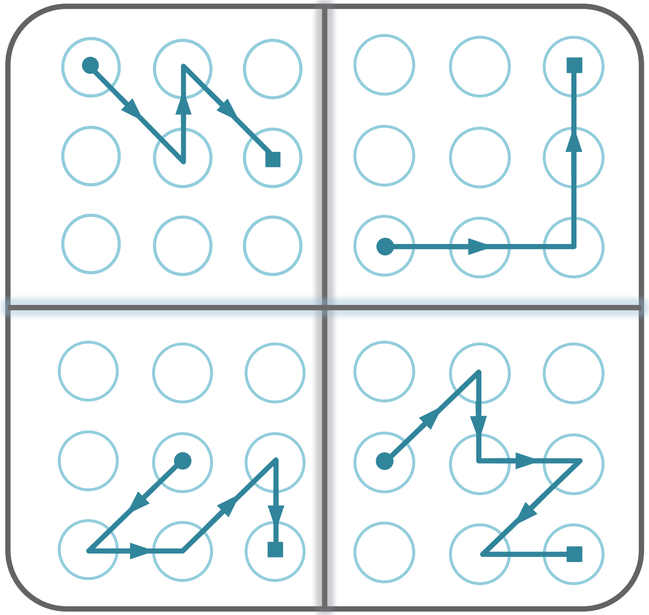

Choose your pattern

Pattern recorded.

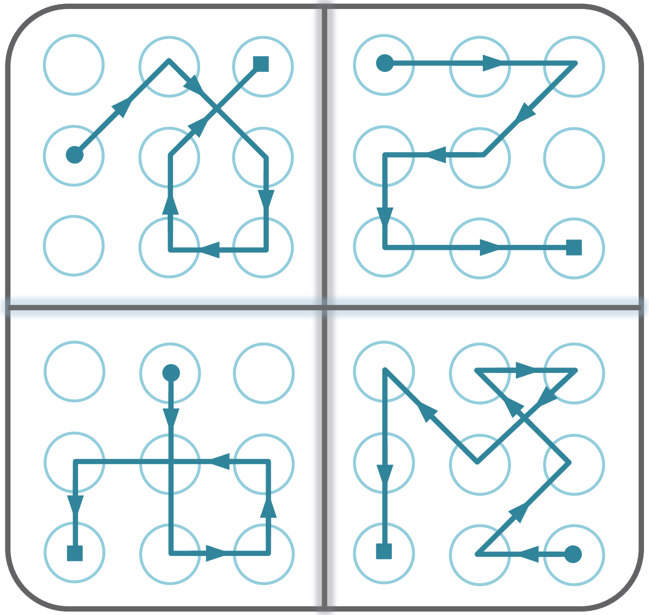
Other pattern grids

Xiaomi MI4, Meizu2, Huawei Honor7, Samsung Note4

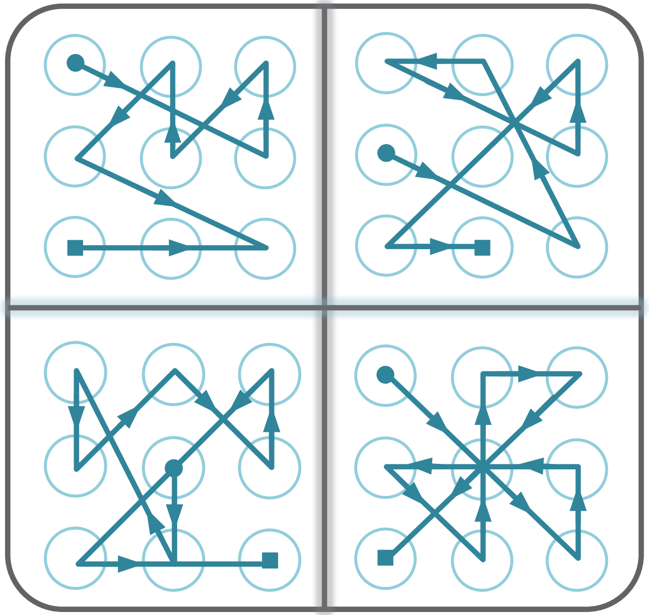
Example Patterns



Simple

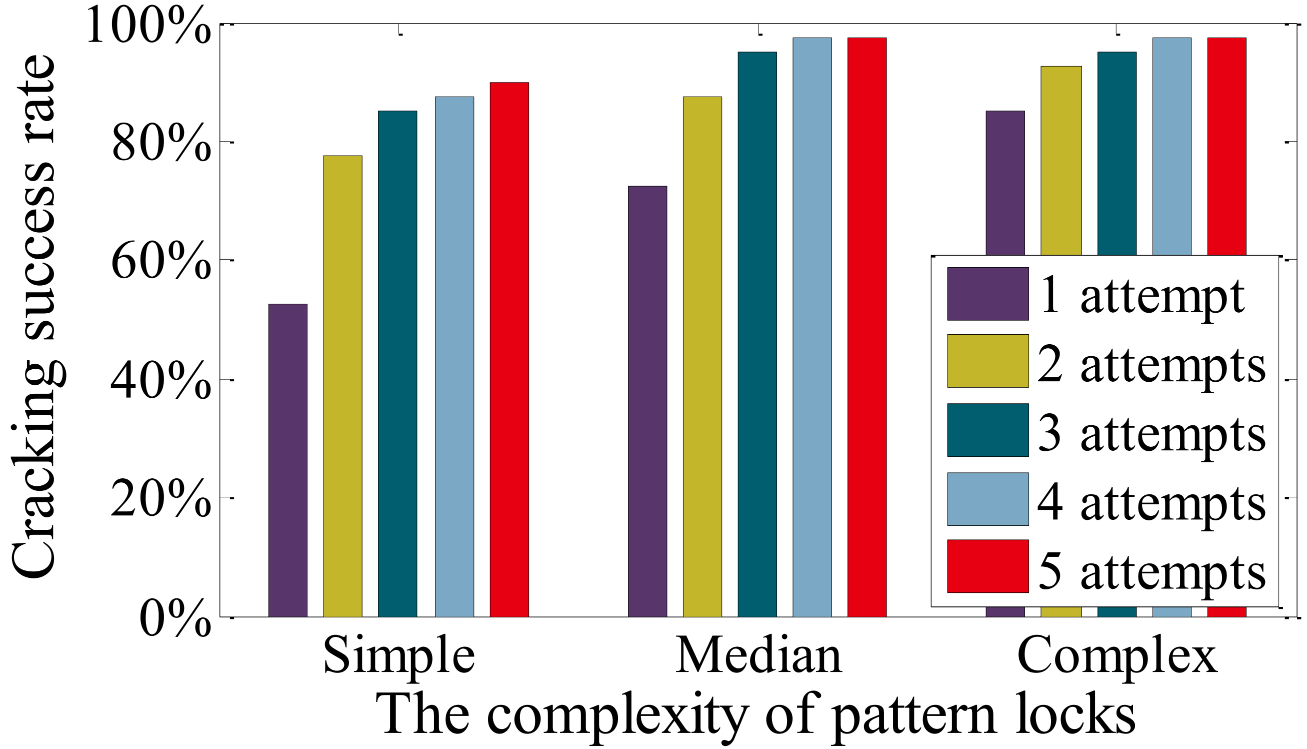


Medium



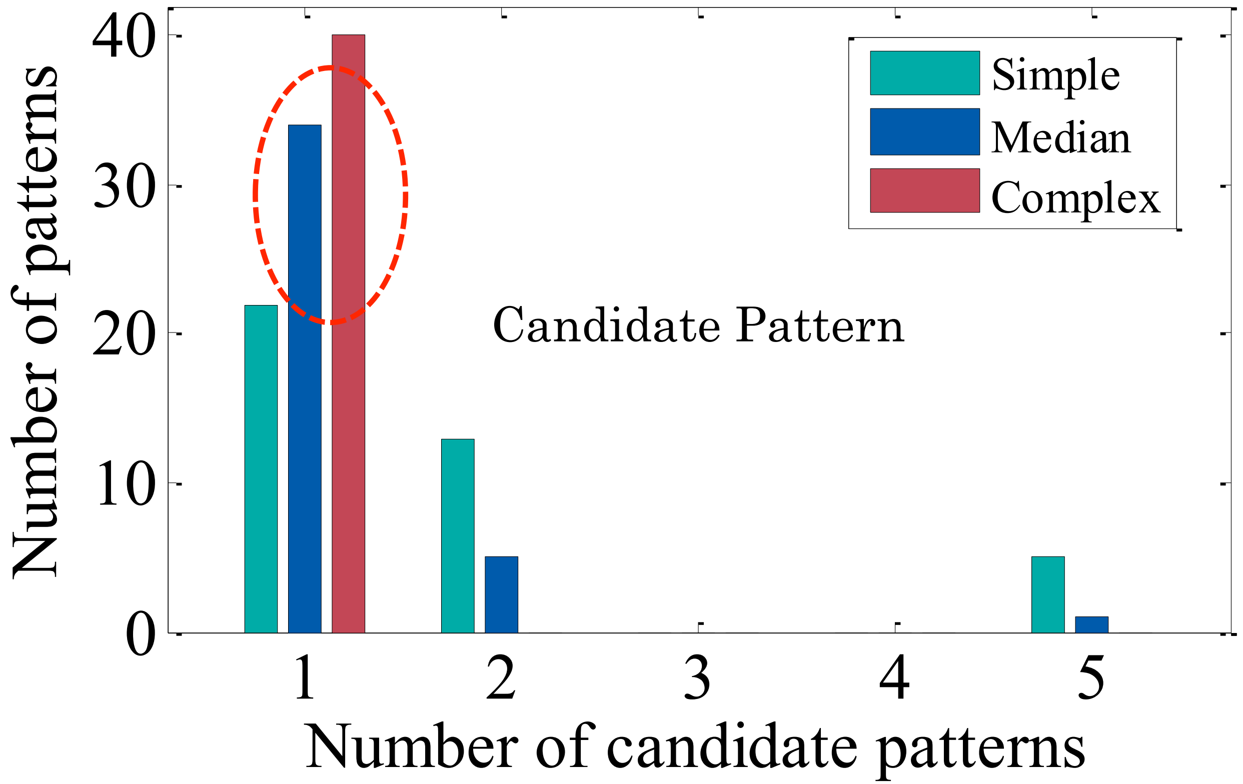
Complex

Complex patterns are less secure



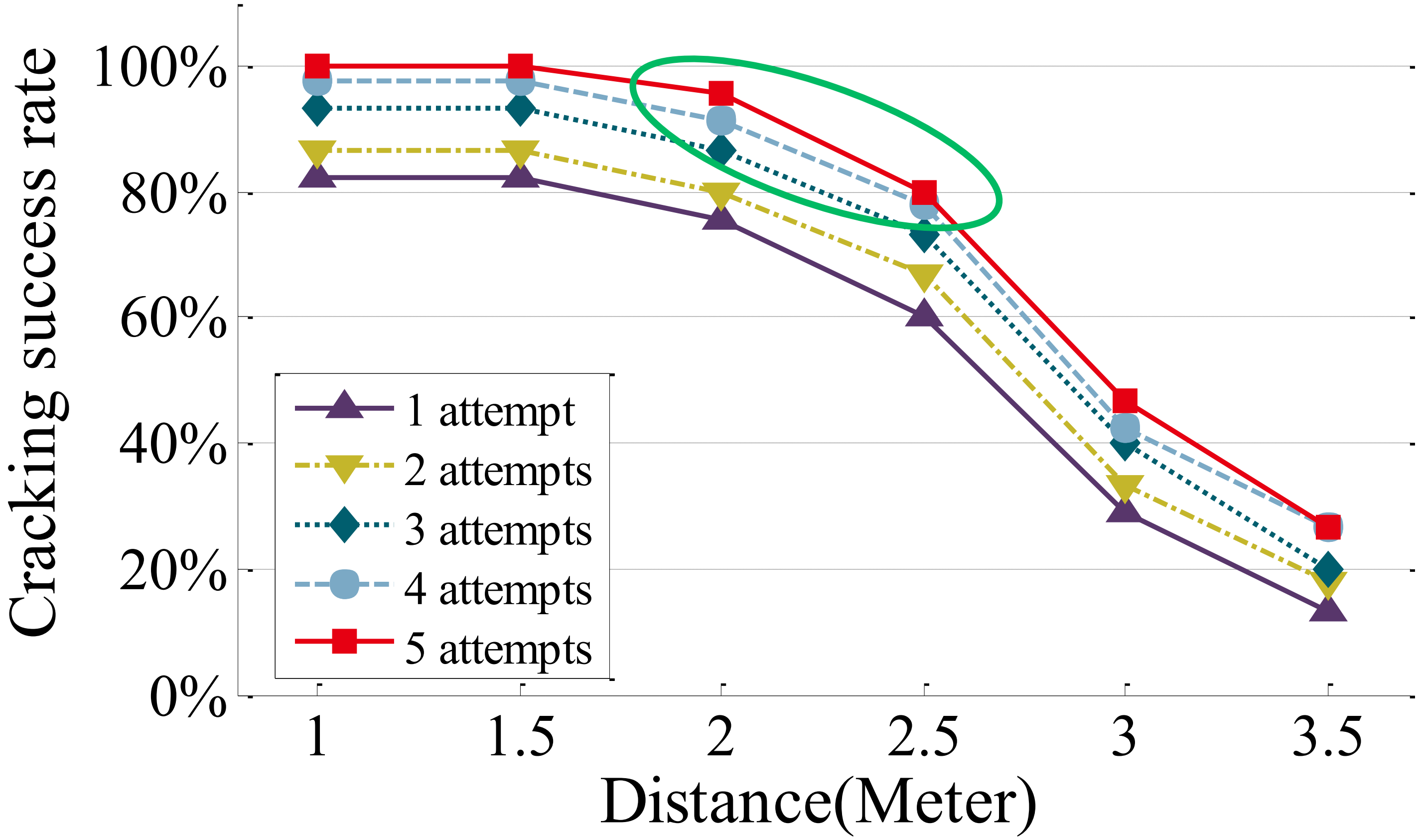
Over 95% of the patterns can be cracked in 5 attempts

Up to 5 candidate patterns generated



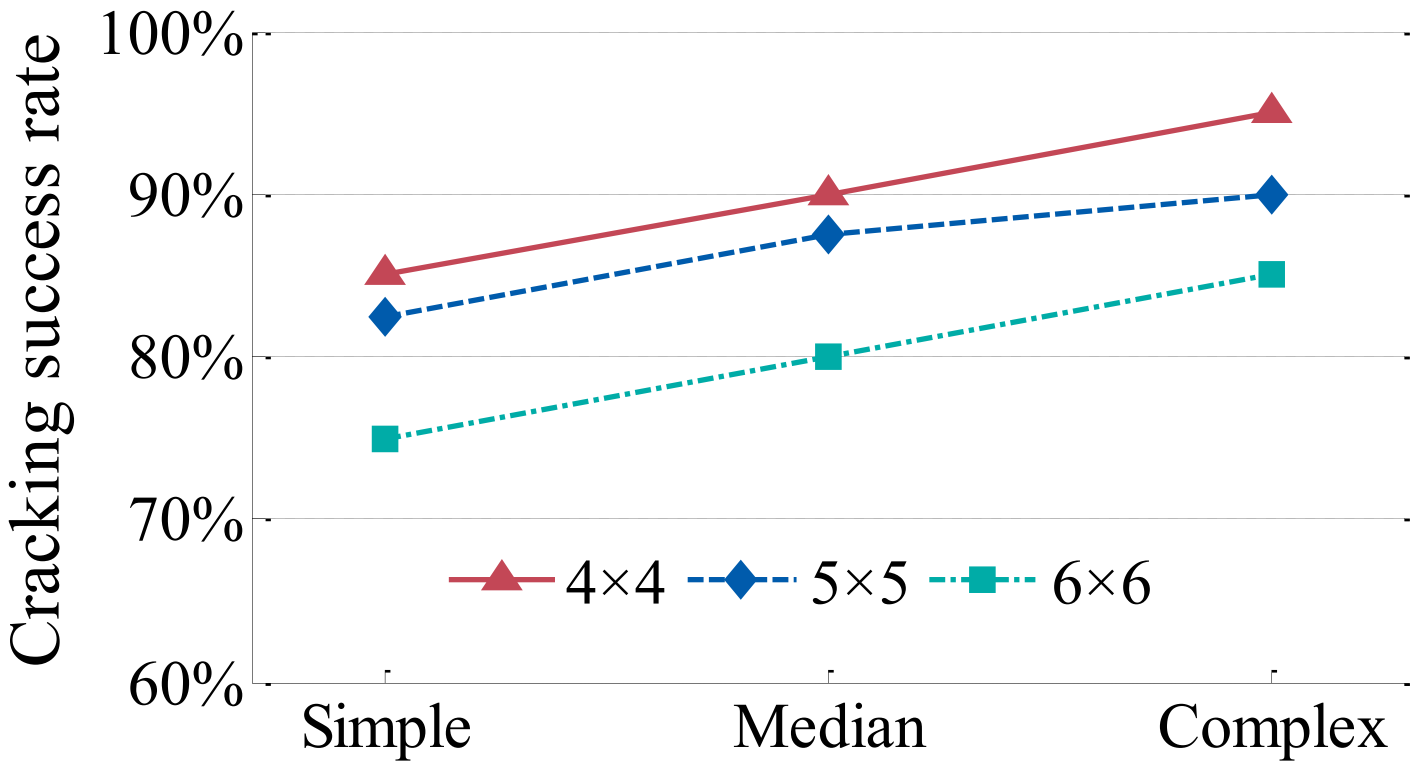
For most median and all complex patterns, our system produces just ONE candidate pattern.

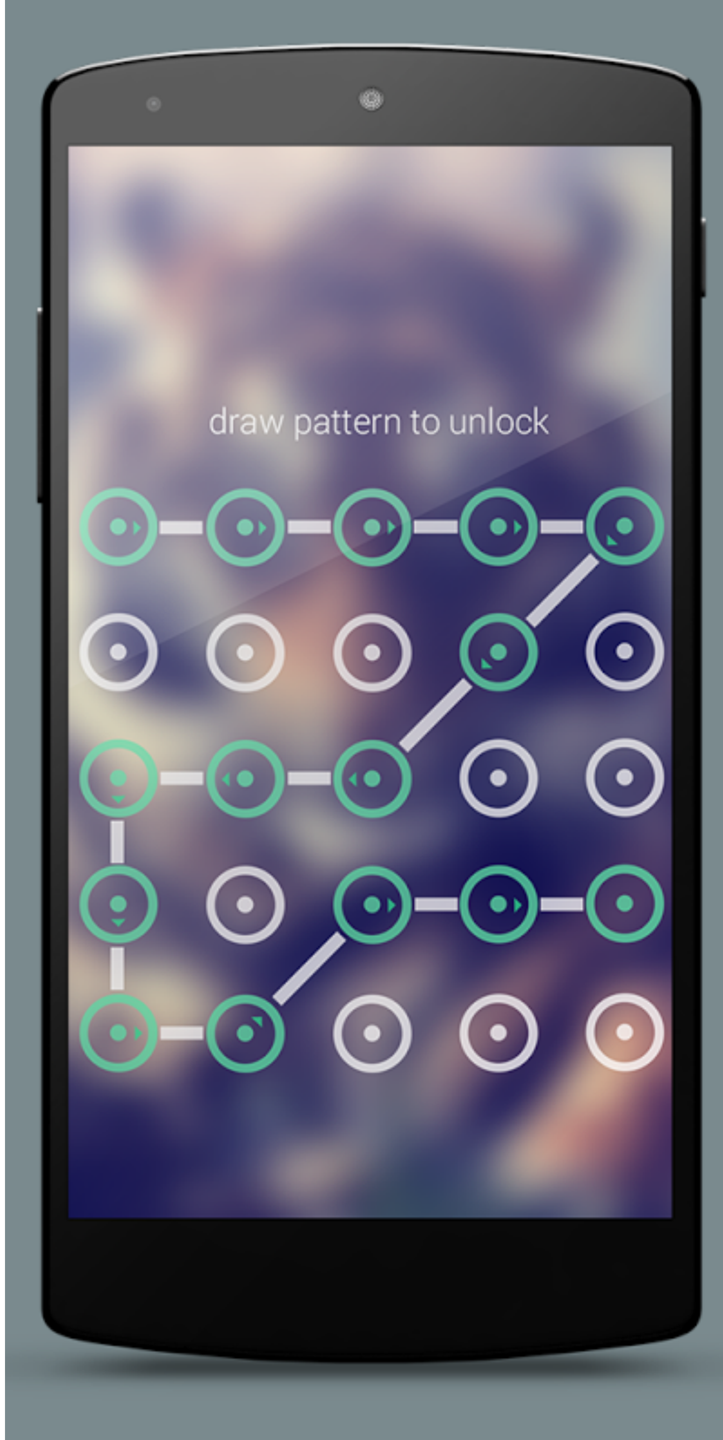
Threat distance reaches 2.5m



Over 80% of the patterns can be cracked within a distance of 2.5 meters away from the target device.

More dots helps, but only for simple patterns





Conclusions

Pattern lock is vulnerable under video based attacks

Complex patterns could be less secure

Data available at:

https://dx.doi.org/10.17635/lancaster/researchdata/113

Back Up

Related work

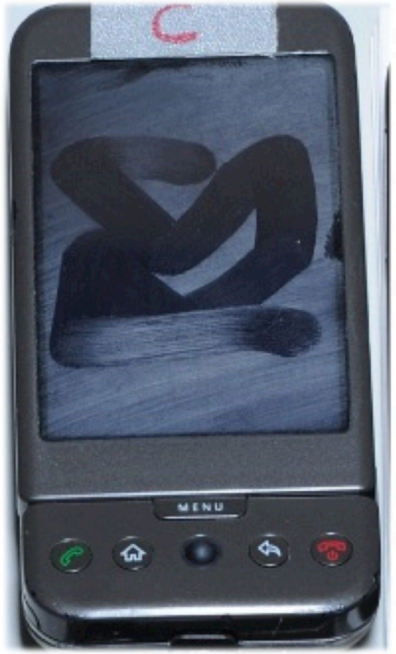
Camera Shake

How to identify candidate pattern

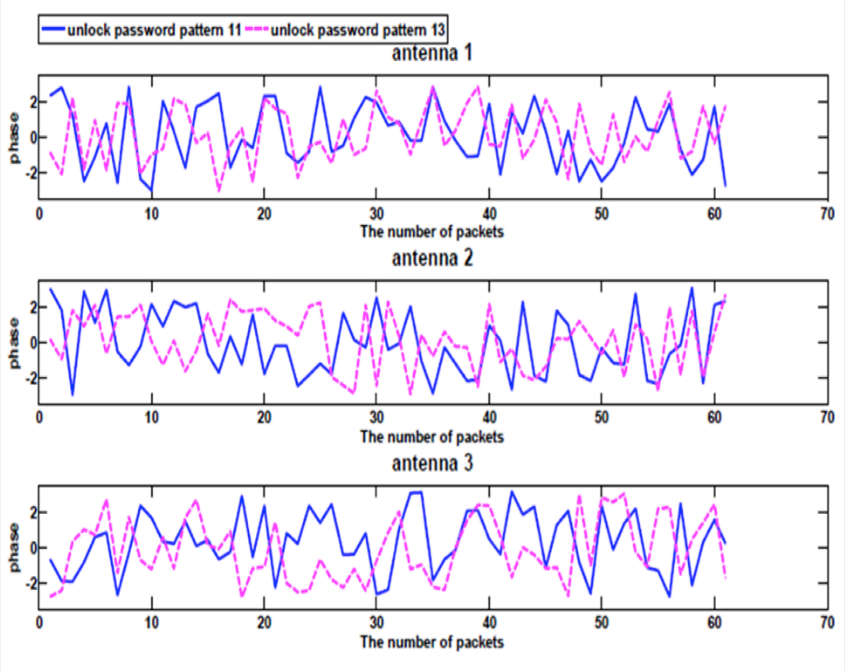
How to define the complexity of pattern lock

Video recording devices

Existing Researches on Pattern Lock



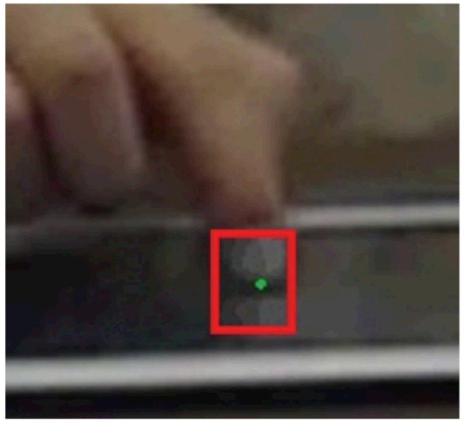
Smudge Attack

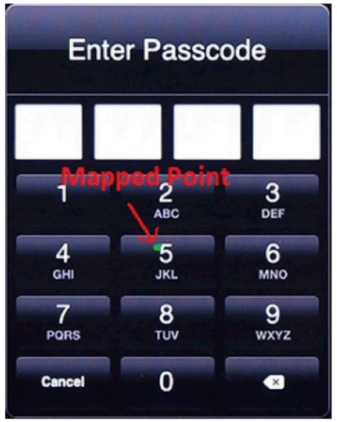


Wireless-based Attack

Video-based Attacks on PIN- or text-based passwords

Text-based: Directly facing the keyboard or the screen



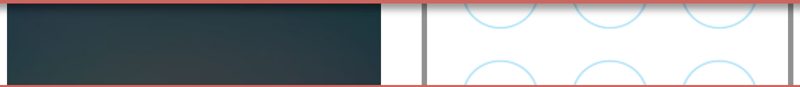


PIN-based: The dynamics of hand during typing

Pattern Lock v.s. PIN- or text-based password

How to map the fingertip movements to a graphical structure?

Existing attacks methods cannot be used to crack pattern lock

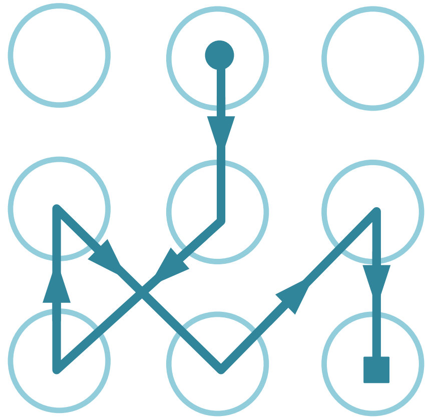


How can the algorithm adapt to the different size of pattern grid

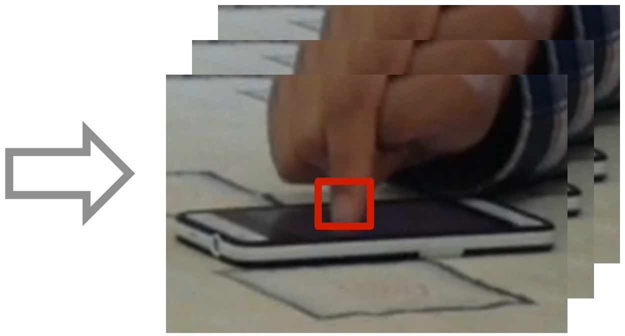
Overlapping lines

Different size of pattern grid

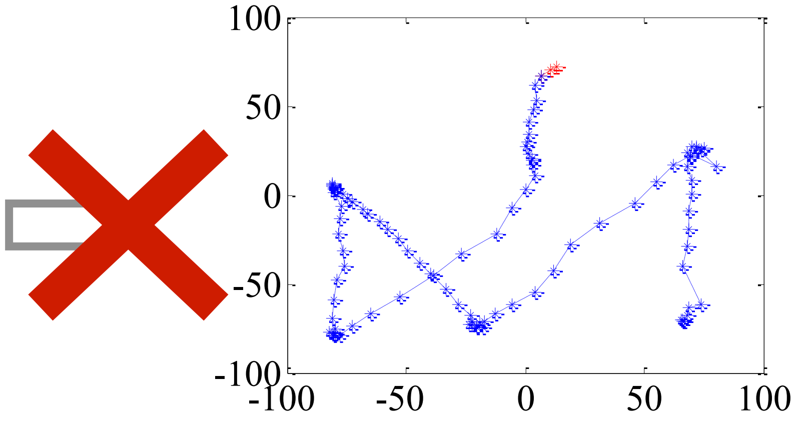
Camera Shake Effect



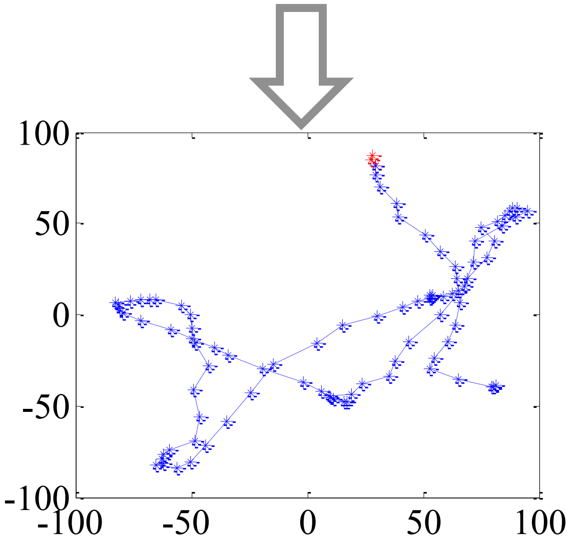
Unique pattern



Tracking process

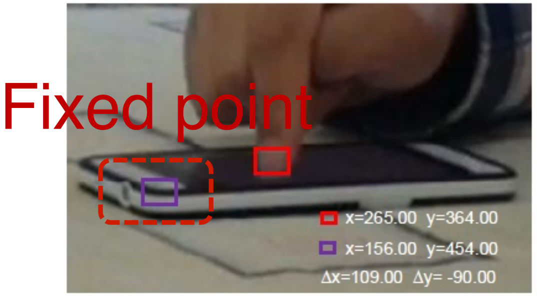


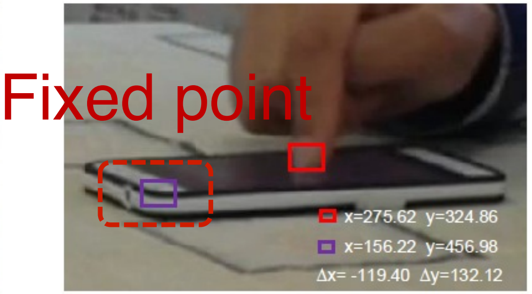
Expected trajectory

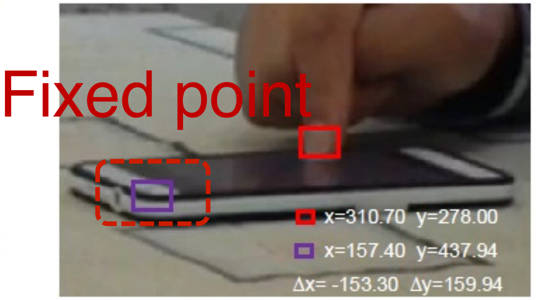


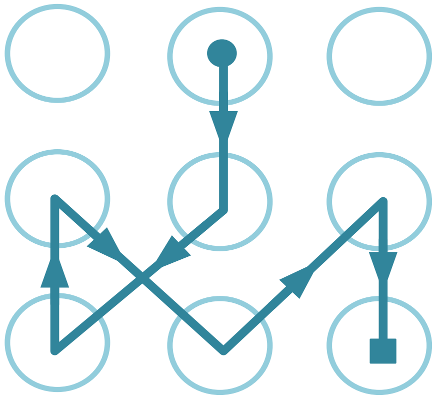
Actual trajectory

Camera Shake Calibration

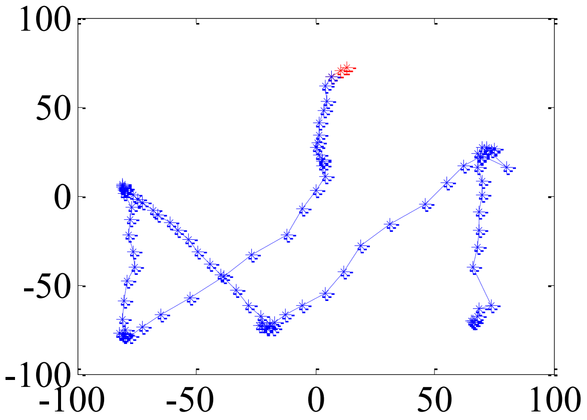






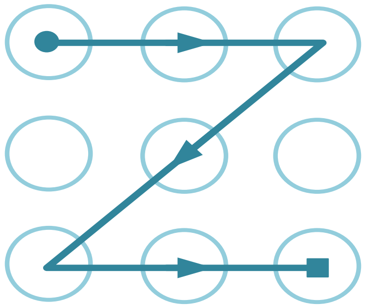


Correct pattern



w/ camera shake calibration

Solution: Identify Candidate Patterns



Fingertip Trajectory

$$CP = \{L; D\}$$

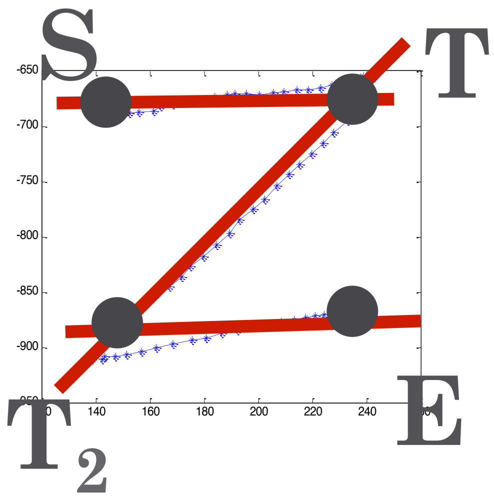
$$(l_1, l_2, l_3; d_{l_1}, d_{l_2}, d_{l_3})$$

Geometric Features

- *L* is the collection of the relative line segments.
- *D* is collection of the directions corresponding to the line segment.

Example: Extracting Geometric Features

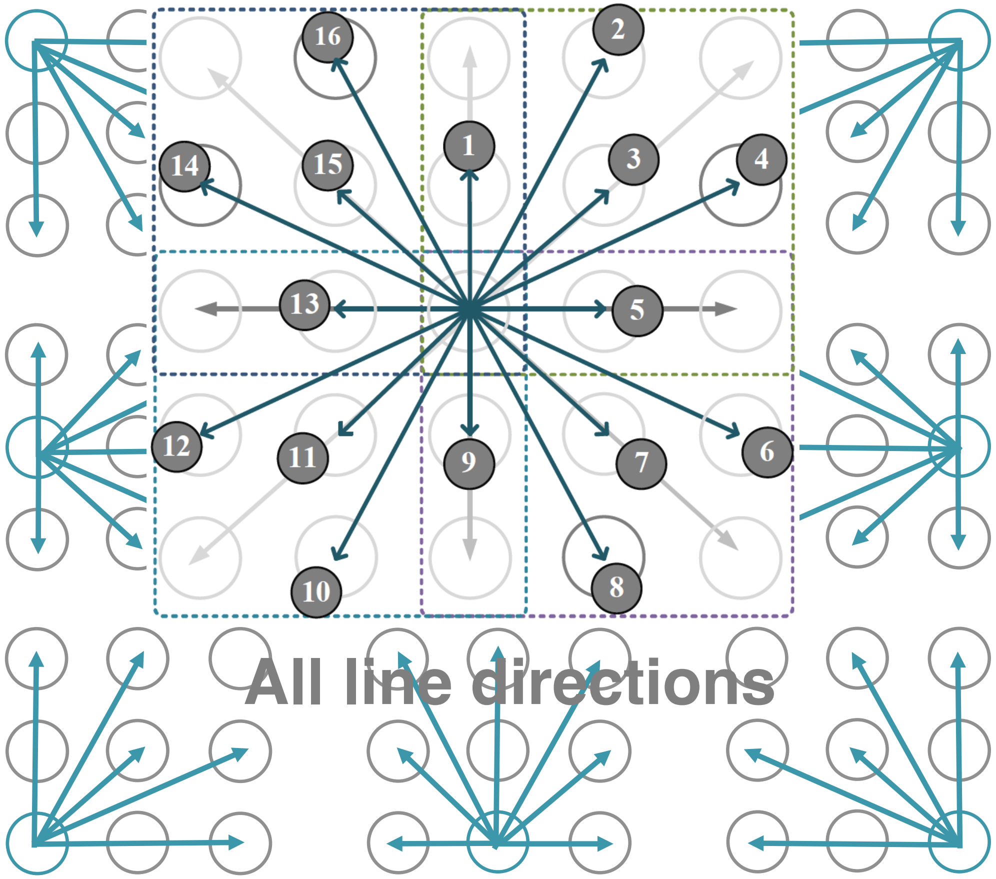
Length Feature



$$L:(l_{ST_1},l_{T_1T_2},l_{T_2E})$$

$$D:(5,11,5)$$

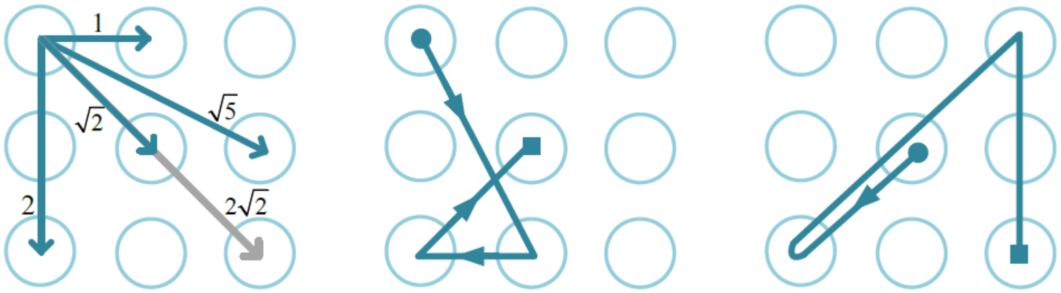
Direction Feature



All line directions

Pattern Collection and Category

$$CS_P = S_P \times \log_2 (L_P + I_P + O_P)$$



(a) line length

(b) line intersection

(c) overlapping lines

- ✓ S_P is the number of connected dots
- ✓ L_P is the total length of all line segments that form the pattern
- ✓ I_P are the number of intersections
- ✓ O_P are the number of overlapping linear segments

- ✓ Simple pattern（40）： $S_P \in [6.34,19)$
- ✓ Median Pattern（40）： $S_P \in [19,33)$
- ✓ Complex pattern（40）： $S_P \in [33,46.8)$

Video Recording

- User Participation

  10 postgraduate: 5 male and 5 female students

- Test Phones

Brands Size	Xiaomi MI4	Huawei Honor7	Samsung Note4
Height(cm)×Height(cm)	13.9×6.9	14.3×7.2	15.4×7.9

- Record Device

  Apple iPhone4S, Xiaomi MI4 and Meizu2