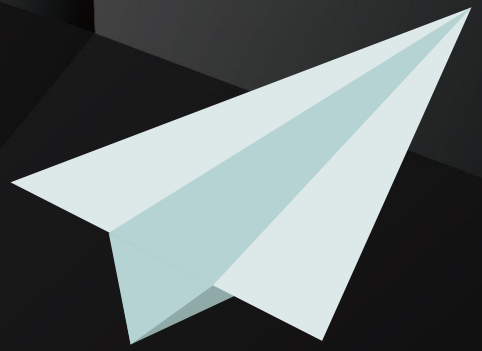

Touch location learning of phone screen basing motion sensors

Xiyuan Bao
Sixue Xu
Ziyi Xi

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Former work

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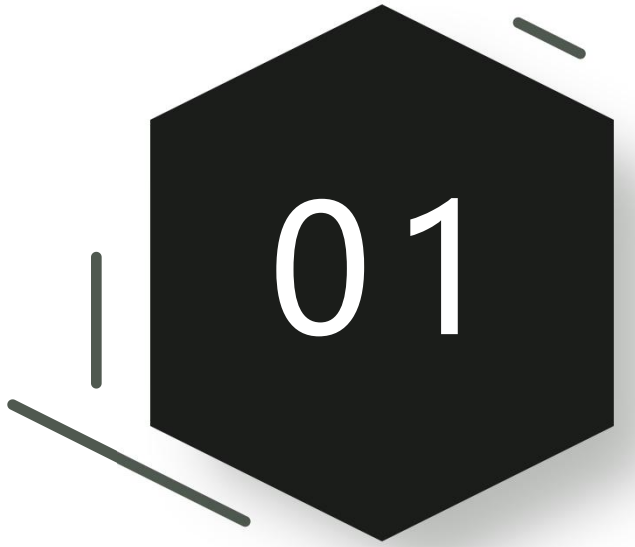
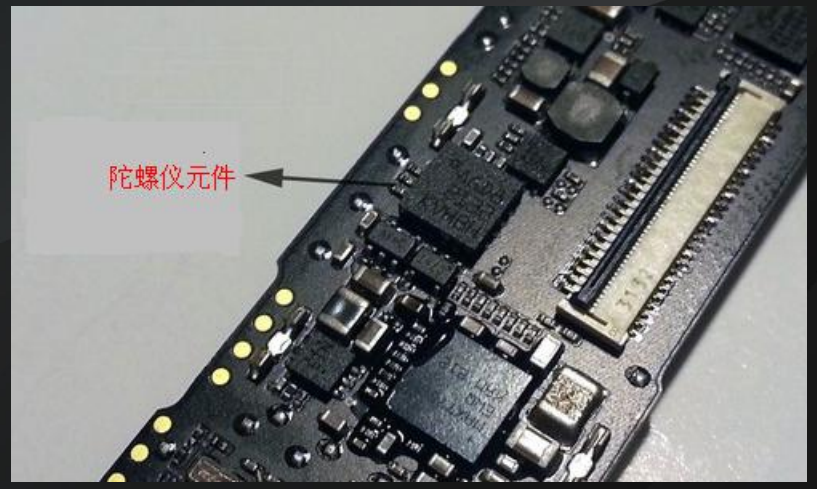
Future work

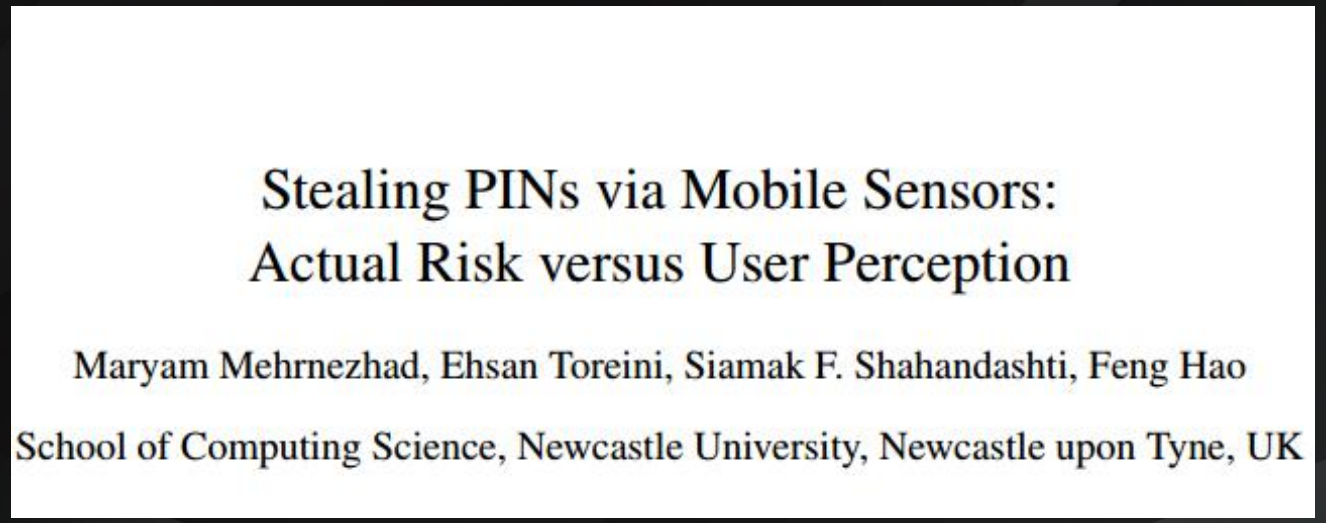


Former work

Motion sensor of smart phone and daily use



- Chasing rotation and direction of wrist using gyroscope to deduce four digit PIN with high accuracy
- Only a few sensors(GPS,camera) as for permission
- App and websites can monitor data from user's sensor freely



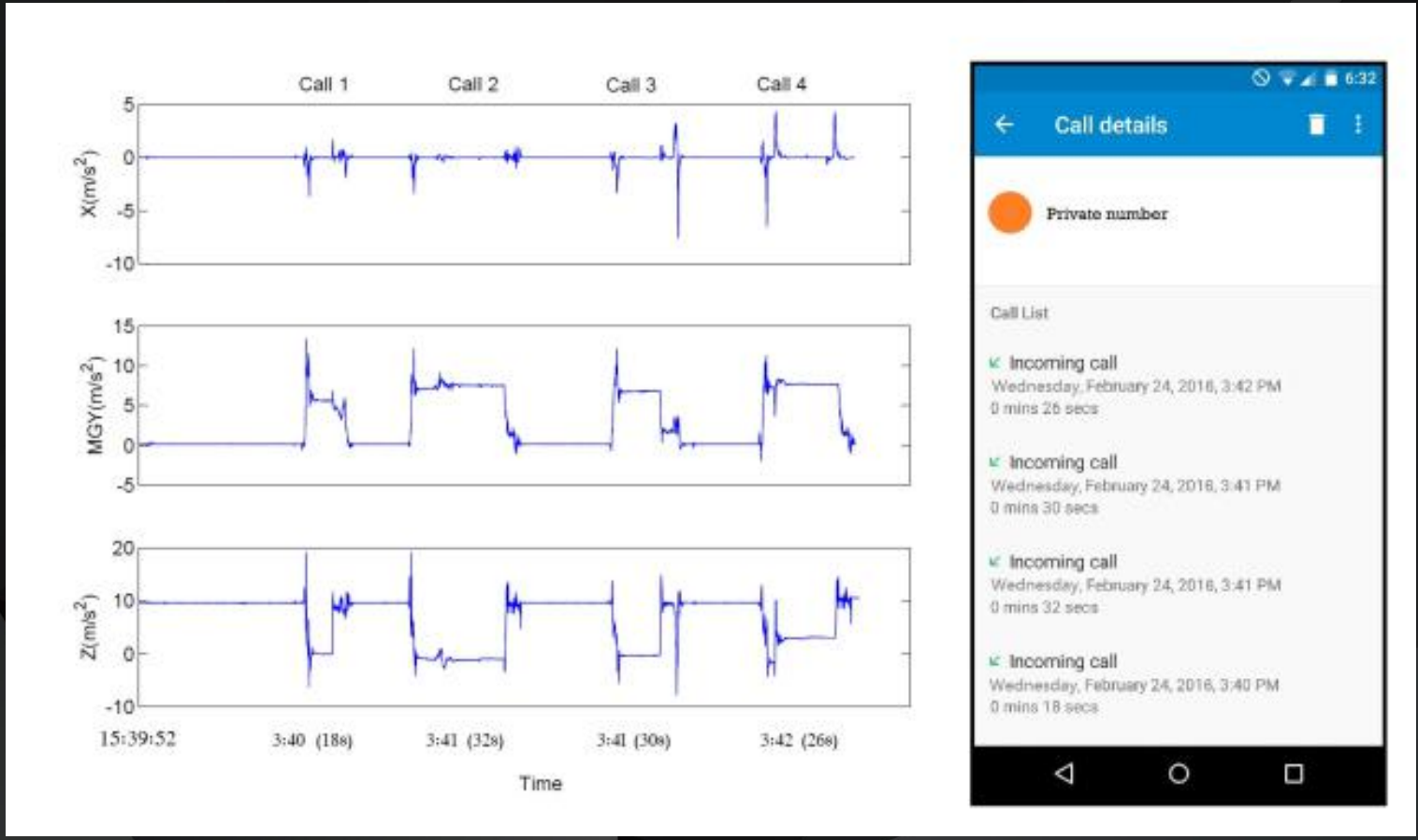
Stealing PINs via Mobile Sensors:
Actual Risk versus User Perception

Maryam Mehrnezhad, Ehsan Toreini, Siamak F. Shahandashti, Feng Hao

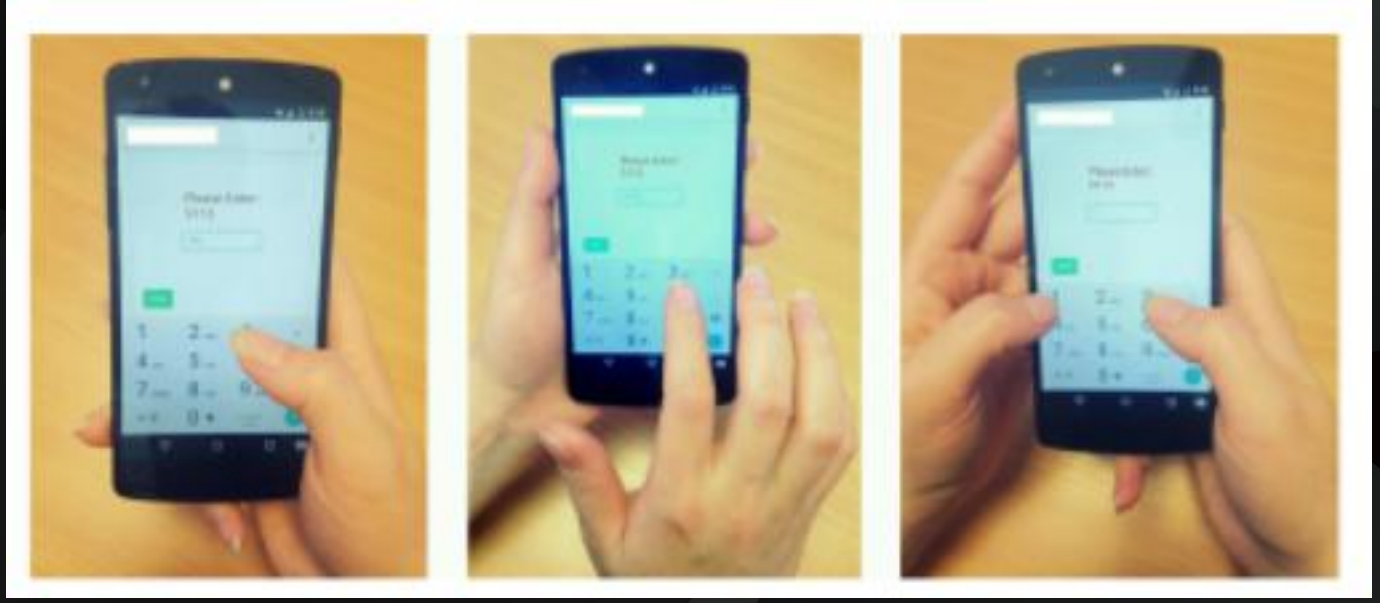
School of Computing Science, Newcastle University, Newcastle upon Tyne, UK

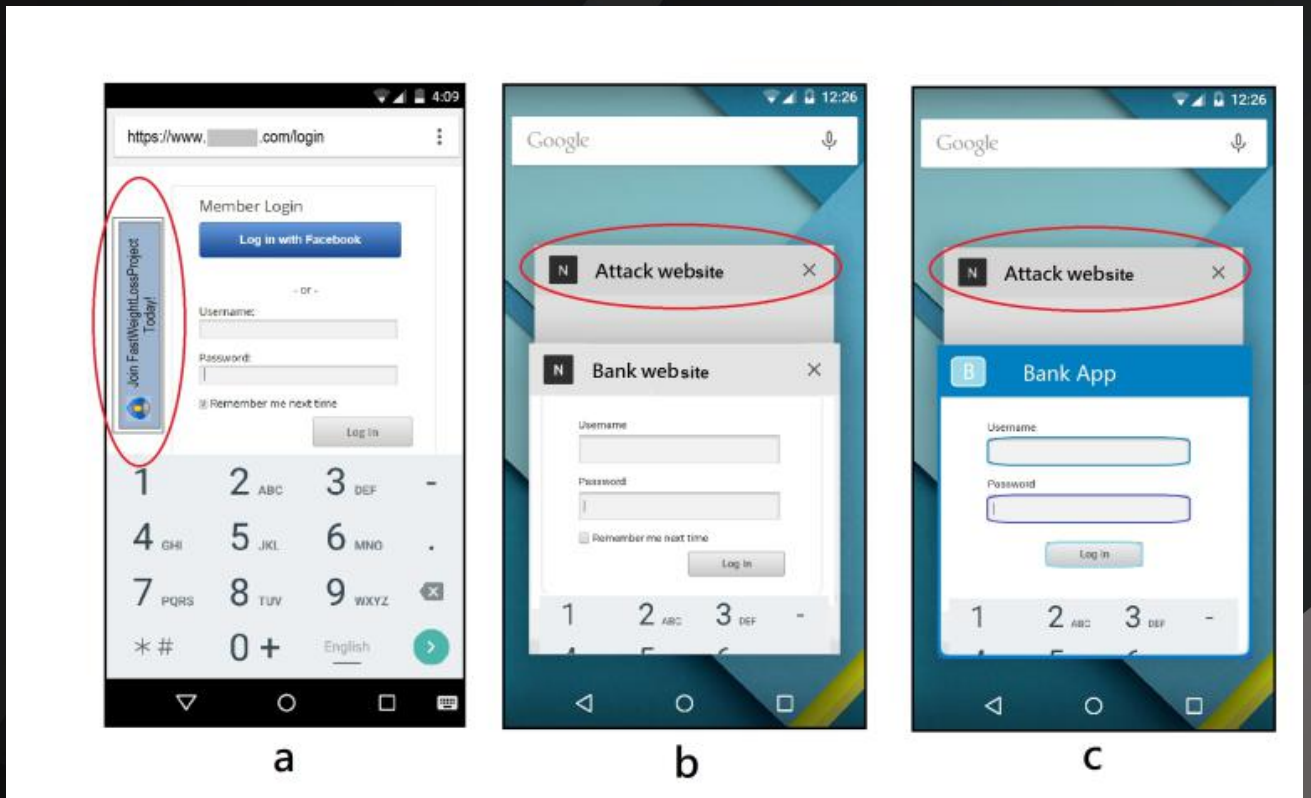
Theory

- Different user/gesture->click number button->different move of cellphone->different wave from sensors



- JS background monitor
- HTML5 GUI shows random PINs for input
- different gesture





- feature extraction using 12 components from 4 sensors
- Consider range,average,energy of the sequence in time and frequency domain(FFT)
- Correlation coefficient

$$R_{AB} = \frac{\mathrm{Cov}(A, B)}{\sqrt{\mathrm{Cov}(A, A) \cdot \mathrm{Cov}(B, B)}}$$

- ANN，2500 records from 10 people X 114 features
- 70%train15%validate15%test
- Matlab with one hidden layer and 1000 nodes

- success rate:one attempts <80%,increase for multiple ,3 times close to100%

Attempts	Multiple-users	Same-user
One	74%	79%
Two	86%	93%
Three	94%	97%

Table 1: PINlogger.js's PIN identification rates in different attempts.

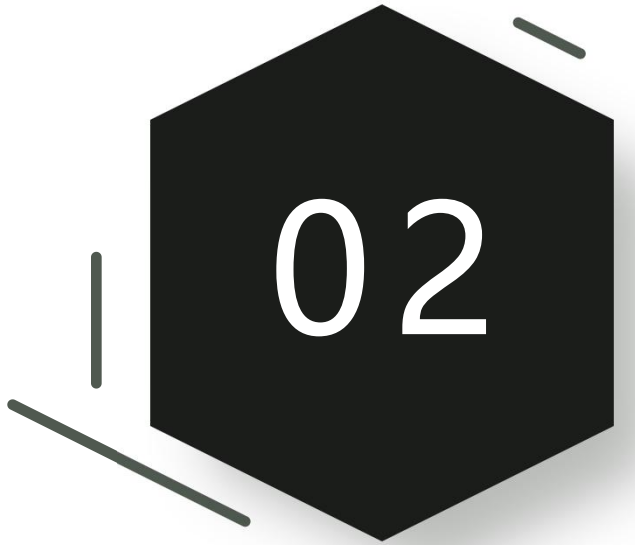
Attempts	Multiple-users	Same-user
One	70%	79%
Two	83%	90%
Three	92%	96%

Table 2: Average digit identification rates in different attempts.

We want to promote

- Study coordinates directly instead of buttons
- recognize more than PIN:complex keys, even all the touch events
- avoid error comparing to buttons

of great importance for secure user's information



Collect and learn

Collecting program

Machine learning

Input test

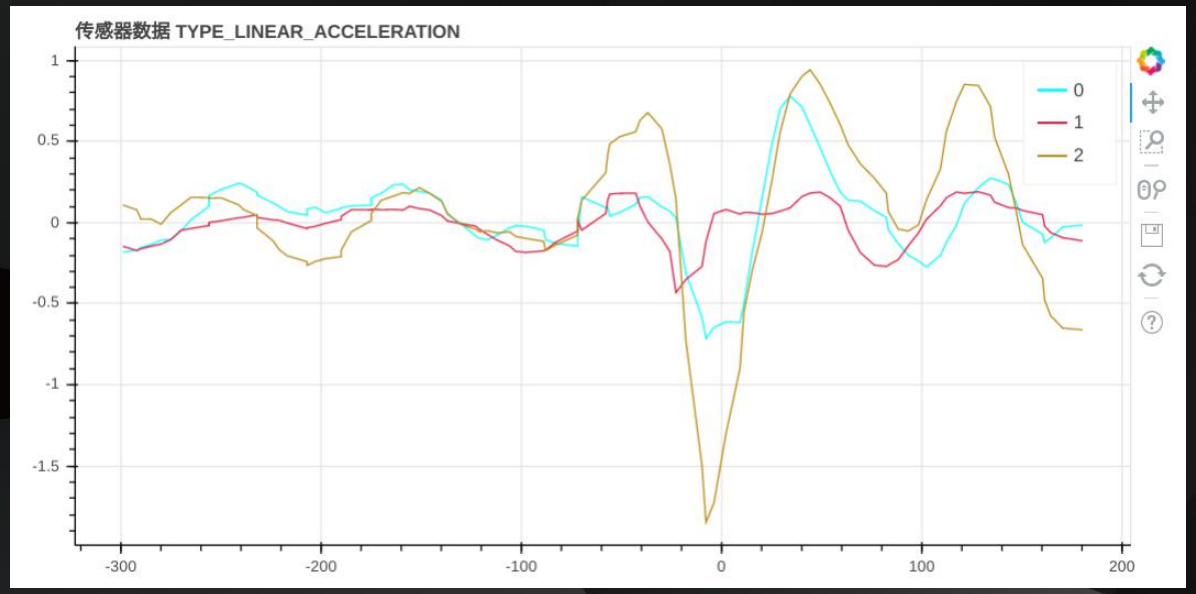
Collecting procedure

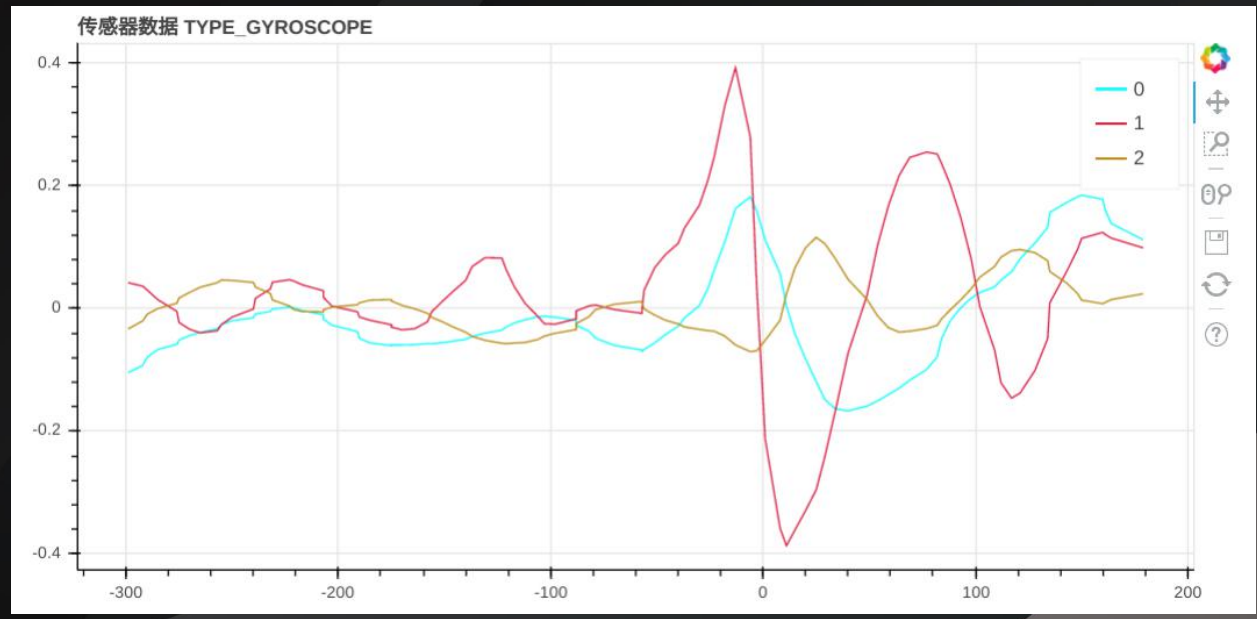
Collecting program:typical touch event

acceleration and rotation of barycentre

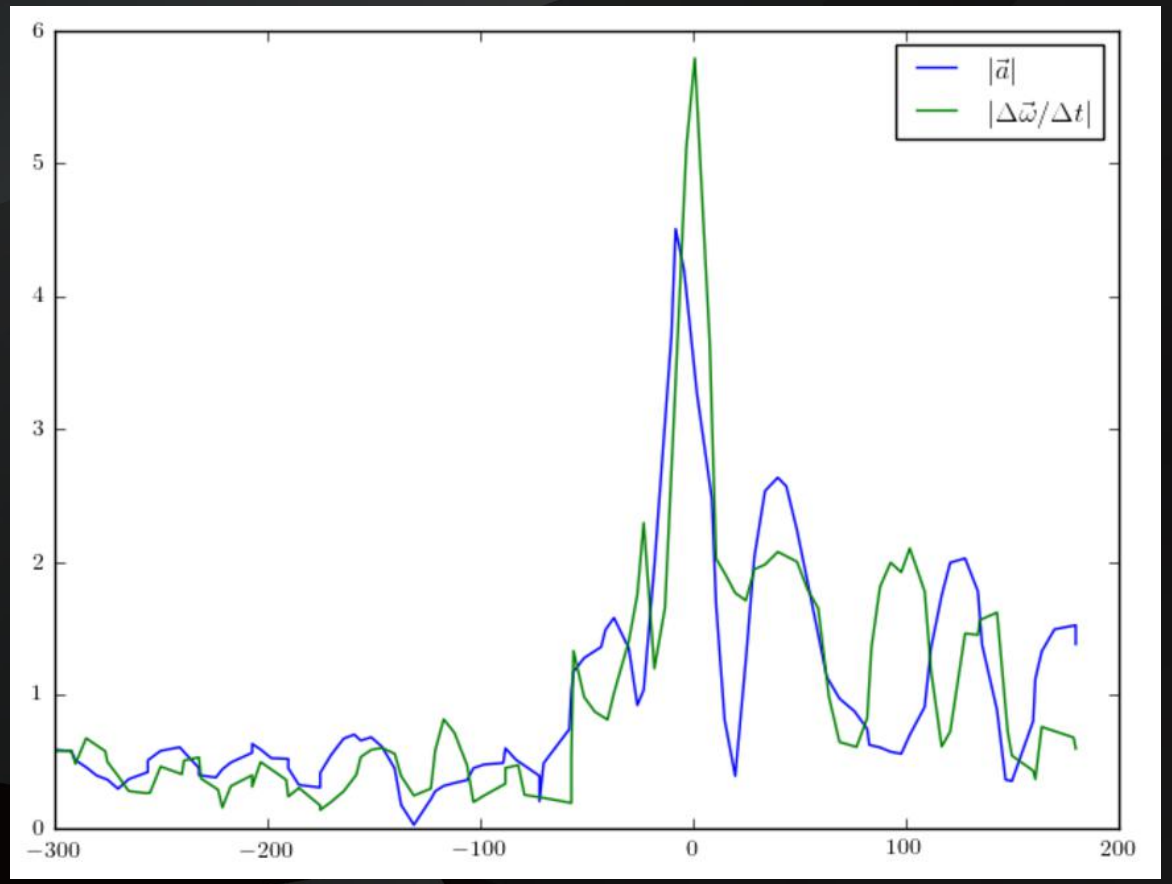
peak at the touching moment:

use theroshold to judge an event



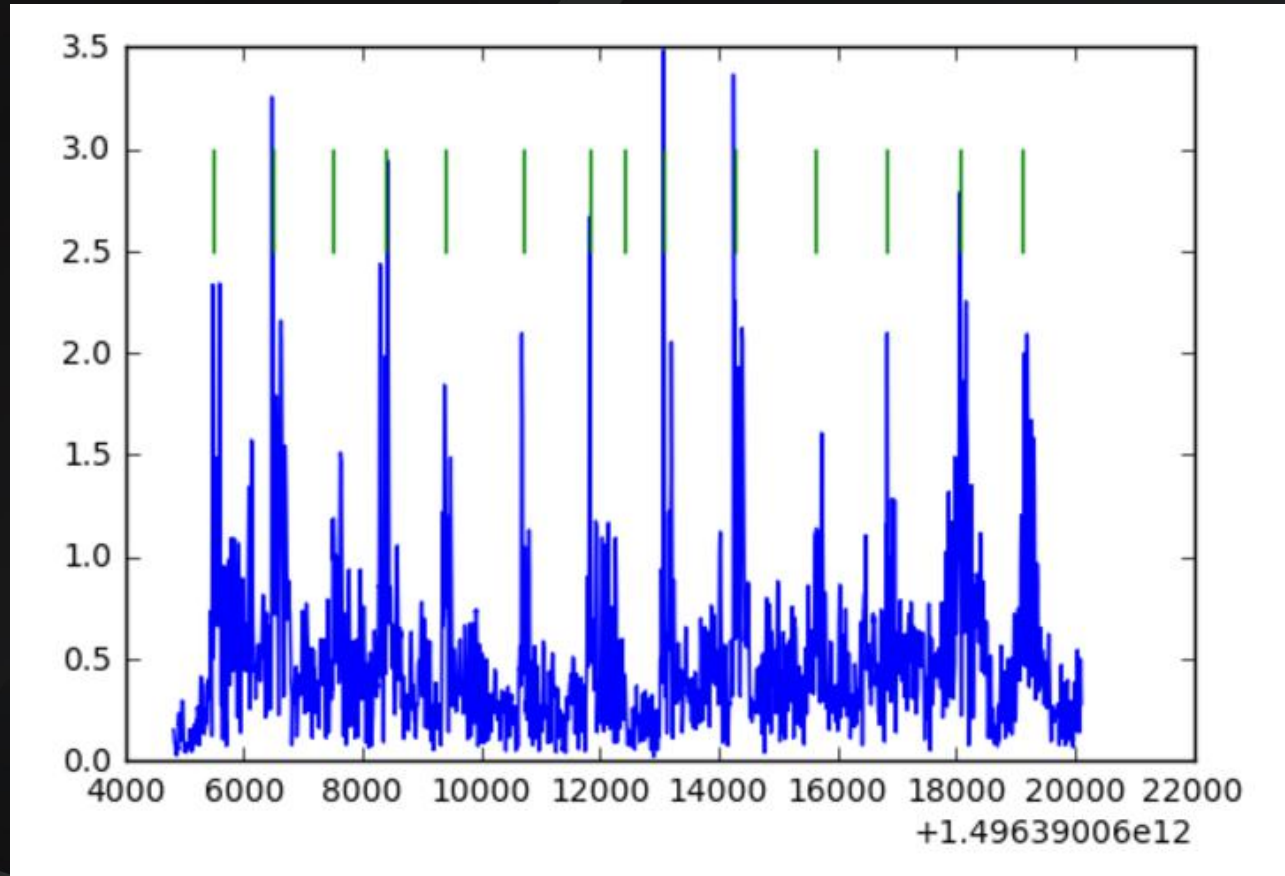


Collecting program:typical touch



time range

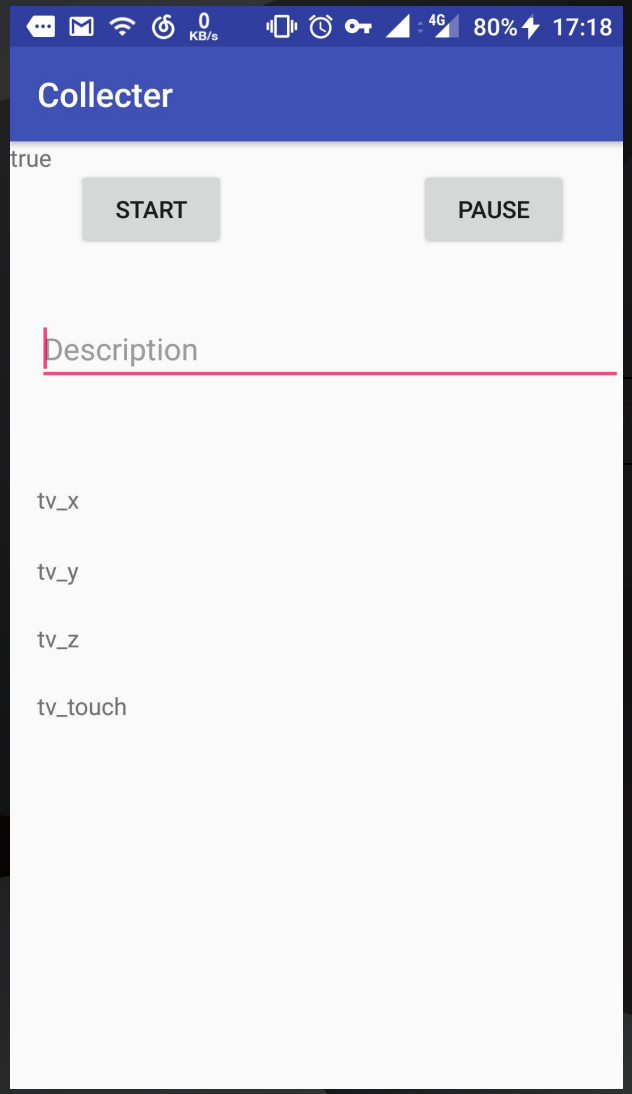
500ms



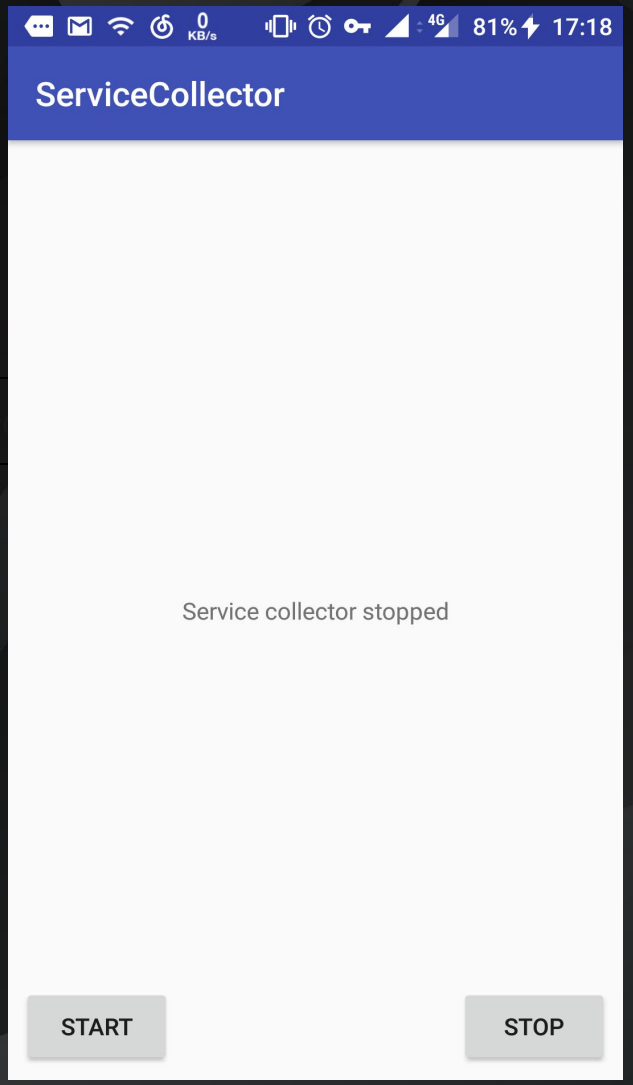
Collecting program：select the sensor

Sensor	Sensor event data	Description	Units of measure
TYPE_ACCELEROMETER	SensorEvent.values[0]	Acceleration force along the x axis (including gravity).	m/s^2
	SensorEvent.values[1]	Acceleration force along the y axis (including gravity).	
	SensorEvent.values[2]	Acceleration force along the z axis (including gravity).	
TYPE_GYROSCOPE	SensorEvent.values[0]	Rate of rotation around the x axis.	rad/s
	SensorEvent.values[1]	Rate of rotation around the y axis.	
	SensorEvent.values[2]	Rate of rotation around the z axis.	
TYPE_LINEAR_ACCELERATION	SensorEvent.values[0]	Acceleration force along the x axis (excluding gravity).	m/s^2
	SensorEvent.values[1]	Acceleration force along the y axis (excluding gravity).	
	SensorEvent.values[2]	Acceleration force along the z axis (excluding gravity).	
TYPE_ROTATION_VECTOR	SensorEvent.values[0]	Rotation vector component along the x axis (x * sin(θ/2)).	Unitless
	SensorEvent.values[1]	Rotation vector component along the y axis (y * sin(θ/2)).	
	SensorEvent.values[2]	Rotation vector component along the z axis (z * sin(θ/2)).	
	SensorEvent.values[3]	Scalar component of the rotation vector ((cos(θ/2)).[1]	

Collecting program@js:front and back



START
to coolect,
PAUSE
to write,
0,0
at left corner
of top.



Collecting program:code

```
// 第 tap_index 个触碰事件
object[<tap_index>][0].tap_t // 触碰时刻，long
object[<tap_index>][0].tap_x // 触碰坐标x，tap_y 坐标y
object[<tap_index>][1-4].sensor //传感器类型名，String，"TYPE_ACCELEROMETER","TYPE_LINEAR_ACCELERATI
object[<tap_index>][1-4].timestamp //采集时间点，long [采集次数]
object[<tap_index>][1-4].data //采集的数据，float [采集次数][单次采集数据长度]
```

主体代码

```
app/src/main
├── AndroidManifest.xml
├── java
│   └── com
│       └── example
│           └── hzxusx
│               └── collecter
│                   ├── CollectingActivity.java
│                   └── SensorBuffer.java
└── res
    ├── drawable
    ├── layout
    │   ├── activity_collecting.xml
```

Collecting procedure

- Limited source:data from one people using right hand
- spread evenly in the keyboard area
- 5000 valid touch，data:coordinates(x,y),13 motion sensors

Machine learning@python3 Preprocessing

```
def getall(filedir,cutplace,crosslabel):
    feathers=[]
    labels=[]
    jsonFiles = list(filter(lambda name:name.endswith(".json"), os.listdir(filedir)))
    print(jsonFiles)
    for item in jsonFiles:
        temp1,temp2=myinitprocess(filedir+item)
        feathers.append(temp1)
        labels.append(temp2)
    temp3,temp4=np.concatenate(tuple(feathers)),np.concatenate(tuple(labels))
    train=np.zeros((np.shape(temp3)[0],100-start,13))
    trainlabel=np.zeros((np.shape(temp3)[0],2))
    for i in range((np.shape(temp3)[0])):
        train[i]=temp3[i].T
        trainlabel[i]=temp4[i]
    test=0;testlabel=0
    if(crosslabel==True):
        train,test,trainlabel,testlabel=cross_validation.train_test_split(train,trainlabel,test_size=cutplace, random_state=
    return train,test,trainlabel,testlabel
```

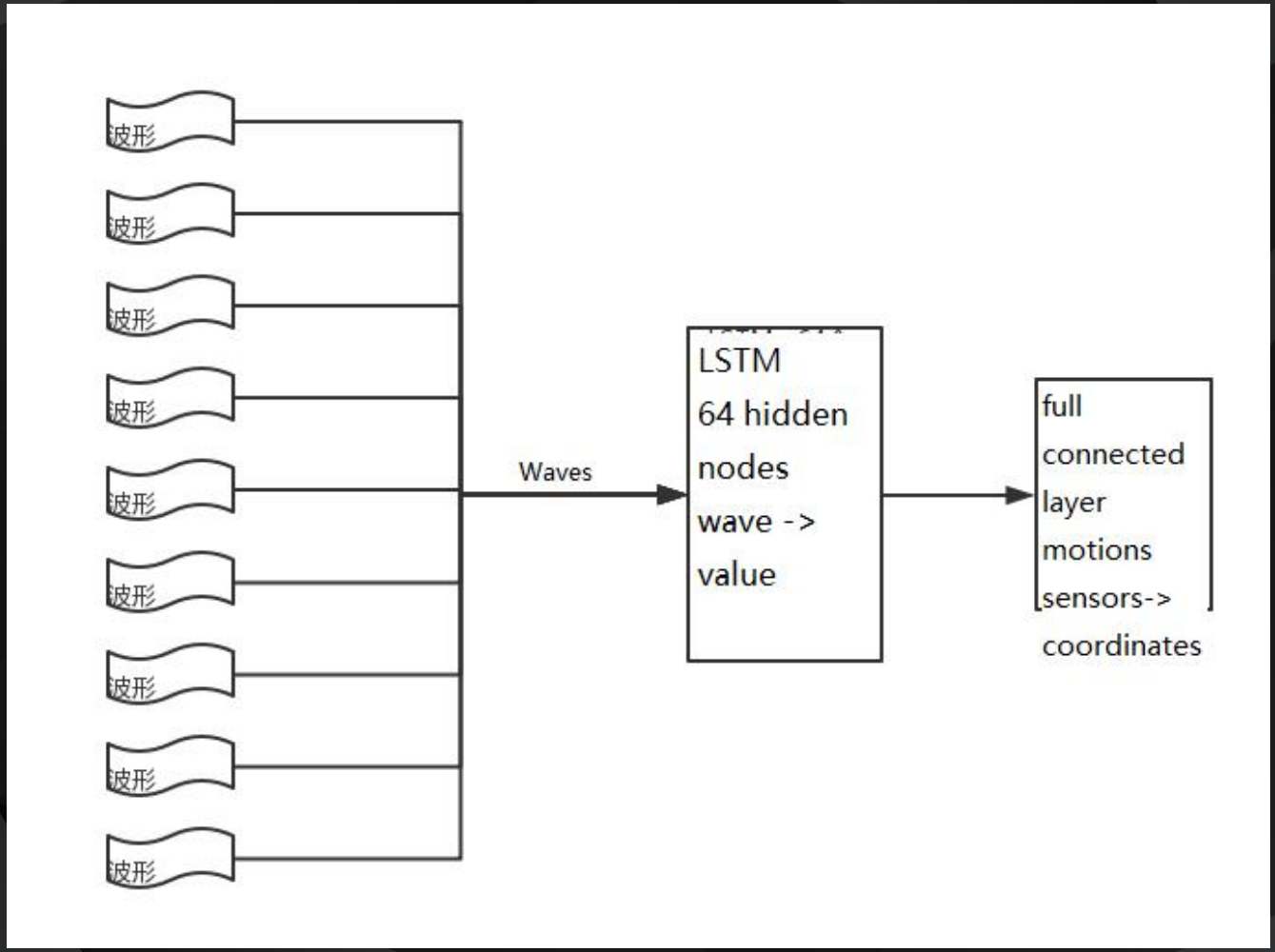
Machine learning:establish neural network

- tensorflow&tflearn&sklearn
- X,netlabel :input training data and placeholder of labels
- tflearn.lstm netwrok:default

```
tflearn.layers.recurrent.lstm (incoming, n_units, activation='tanh', inner_activation='sigmoid', dropout=None, bias=True, weights_init=None,
forget_bias=1.0, return_seq=False, return_state=False, initial_state=None, dynamic=False, trainable=True, restore=True, reuse=False,
scope=None, name='LSTM')
```

- lstm dropout ratio:0.7 ->avoid overfitting
- return_seq=False:return value for every wave（64nodes）
  tflearn.fully_connected:full connected layer
- least RMS for coordinates and training

Machine learning:establish neural network



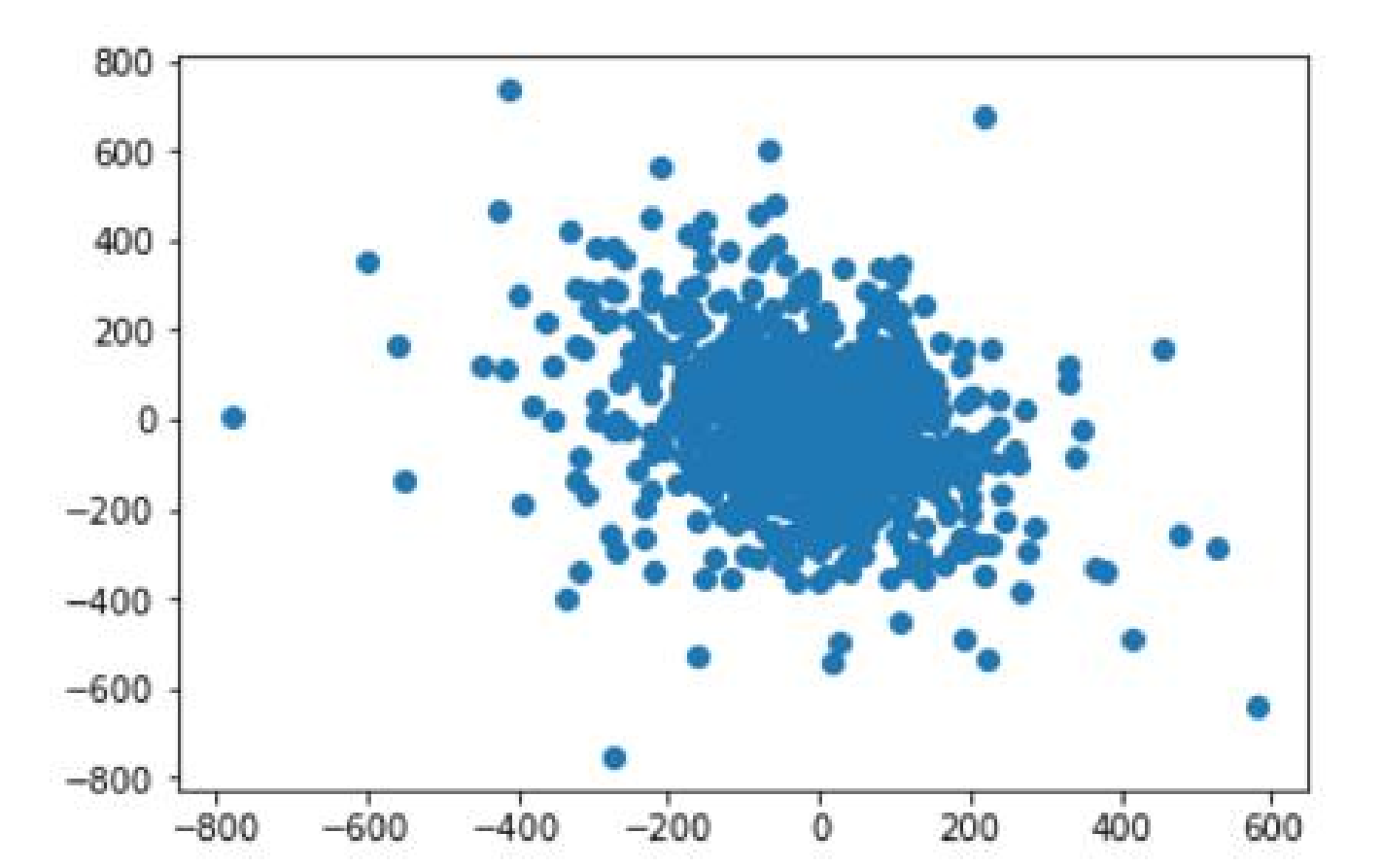
Machine learning:train neural network

- xaccuracy&yaccuracyphased accuracy on test set
- cost:loss

```
xaccuracx:0.171226 yaccuracy:0.002026 step: 0 cost 0.0652756
xaccuracx:0.678825 yaccuracy:0.530902 step: 40 cost 0.00792426
xaccuracx:0.722391 yaccuracy:0.547112 step: 80 cost 0.00719253
xaccuracx:0.736575 yaccuracy:0.552178 step: 120 cost 0.0070219
xaccuracx:0.730496 yaccuracy:0.551165 step: 160 cost 0.00688715
xaccuracx:0.739615 yaccuracy:0.551165 step: 200 cost 0.00671018
xaccuracx:0.738602 yaccuracy:0.642351 step: 240 cost 0.005837
xaccuracx:0.749747 yaccuracy:0.630193 step: 280 cost 0.00597559
xaccuracx:0.767984 yaccuracy:0.722391 step: 320 cost 0.00486835
xaccuracx:0.796353 yaccuracy:0.725431 step: 360 cost 0.00439627
xaccuracx:0.800405 yaccuracy:0.730496 step: 400 cost 0.00404178
xaccuracx:0.799392 yaccuracy:0.727457 step: 440 cost 0.00404576
xaccuracx:0.794326 yaccuracy:0.693009 step: 480 cost 0.00408823
xaccuracx:0.808511 yaccuracy:0.726444 step: 520 cost 0.00333054
xaccuracx:0.801418 yaccuracy:0.714286 step: 560 cost 0.00331399
xaccuracx:0.798379 yaccuracy:0.712259 step: 600 cost 0.00317743
xaccuracx:0.800405 yaccuracy:0.709220 step: 640 cost 0.00310957
xaccuracx:0.815603 yaccuracy:0.732523 step: 680 cost 0.00265303
xaccuracx:0.815603 yaccuracy:0.720365 step: 720 cost 0.00261896
xaccuracx:0.824721 yaccuracy:0.724417 step: 760 cost 0.0023168
xaccuracx:0.828774 yaccuracy:0.728470 step: 800 cost 0.00217134
xaccuracx:0.823708 yaccuracy:0.728470 step: 840 cost 0.00212671
xaccuracx:0.818642 yaccuracy:0.716312 step: 880 cost 0.00193261
xaccuracx:0.798379 yaccuracy:0.720365 step: 920 cost 0.00192573
xaccuracx:0.812563 yaccuracy:0.717325 step: 960 cost 0.00188861
```

Machine learning:evaluation

- Standard：half finger point，±150px
- Error distribution：centered around orgin point



Machine learning:evaluation

- Very small average(compared to 150):accurate enough

```
print(np.average(a[:,0]))
print(np.average(a[:,1]))
```

```
-17.2657368359
-8.93085081647
```

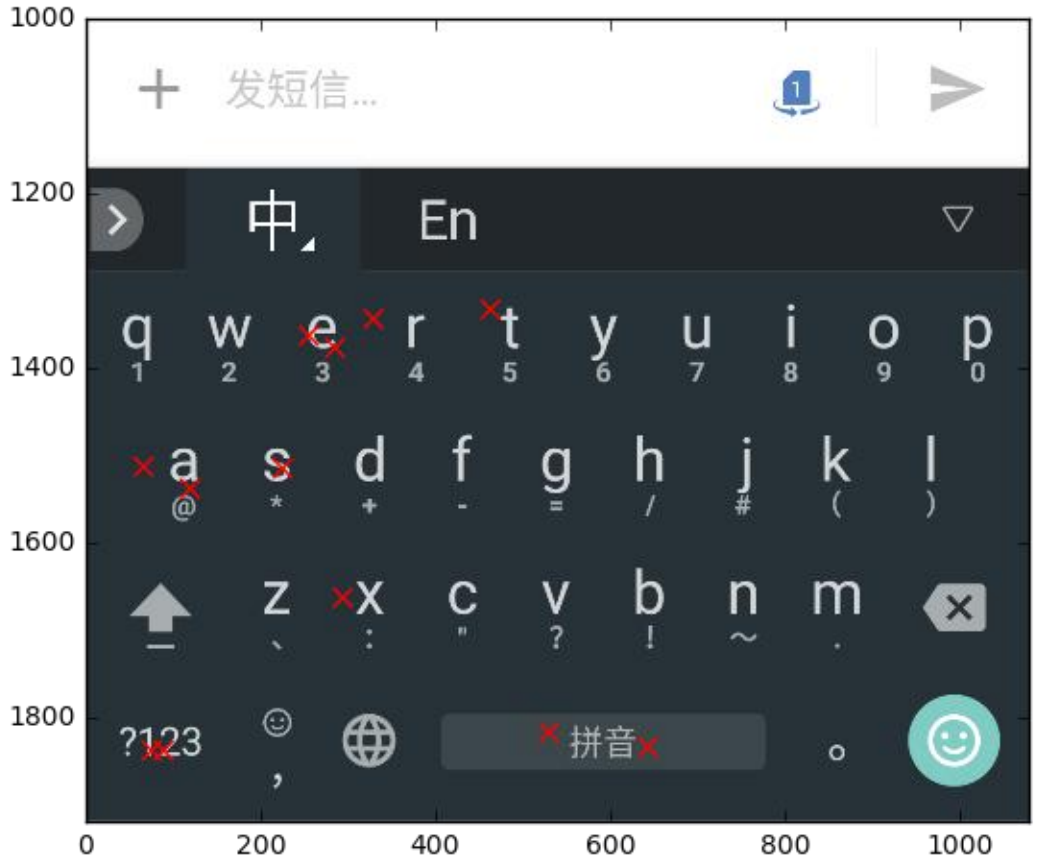
- ultimate accuracy

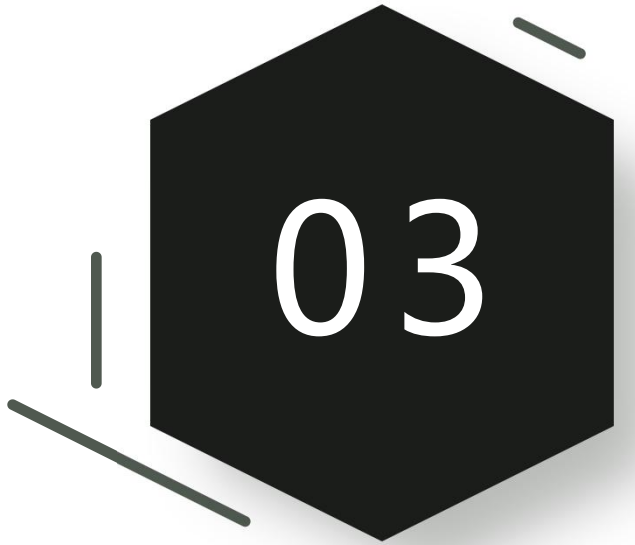
```
countx=0
county=0
for i in a:
    if(abs(i[0])<150):
        countx+=1
    if(abs(i[1])<150):
        county+=1
print('x:',countx/np.shape(test)[0])
print('y:',county/np.shape(test)[0])
```

```
x: 0.8014184397163121
y: 0.7223910840932117
```

Input test

- Input a sentence and recognize letters in sequence
- error :1/12，accuracy:91.7%





Future work

Shortcomings

- limited time and computaion abilities
- gpu:840m
- time costing collecting work
- not general enough(only 1 people, 1 gesture)

Improvement in the future

- Shrink collecting time, get more features , using less data
- better neural network
- better computer
- more people,more gesture
- from coordinates to contents
- study more than coordinates

From coordinates to contents

- PIN
- slide PIN
- full QWERTY,Pinyin 9 keys

More:

- APP history
- web history
- shopping history

Study more than coordinates

- pedometer,gait analysis
- optimal path in racing games
- using phone sensor to control aircrafts

More:

- dectect conditions of patients with epencephalondisease
- path analysis, guidance for the old and the kids

THANKS