



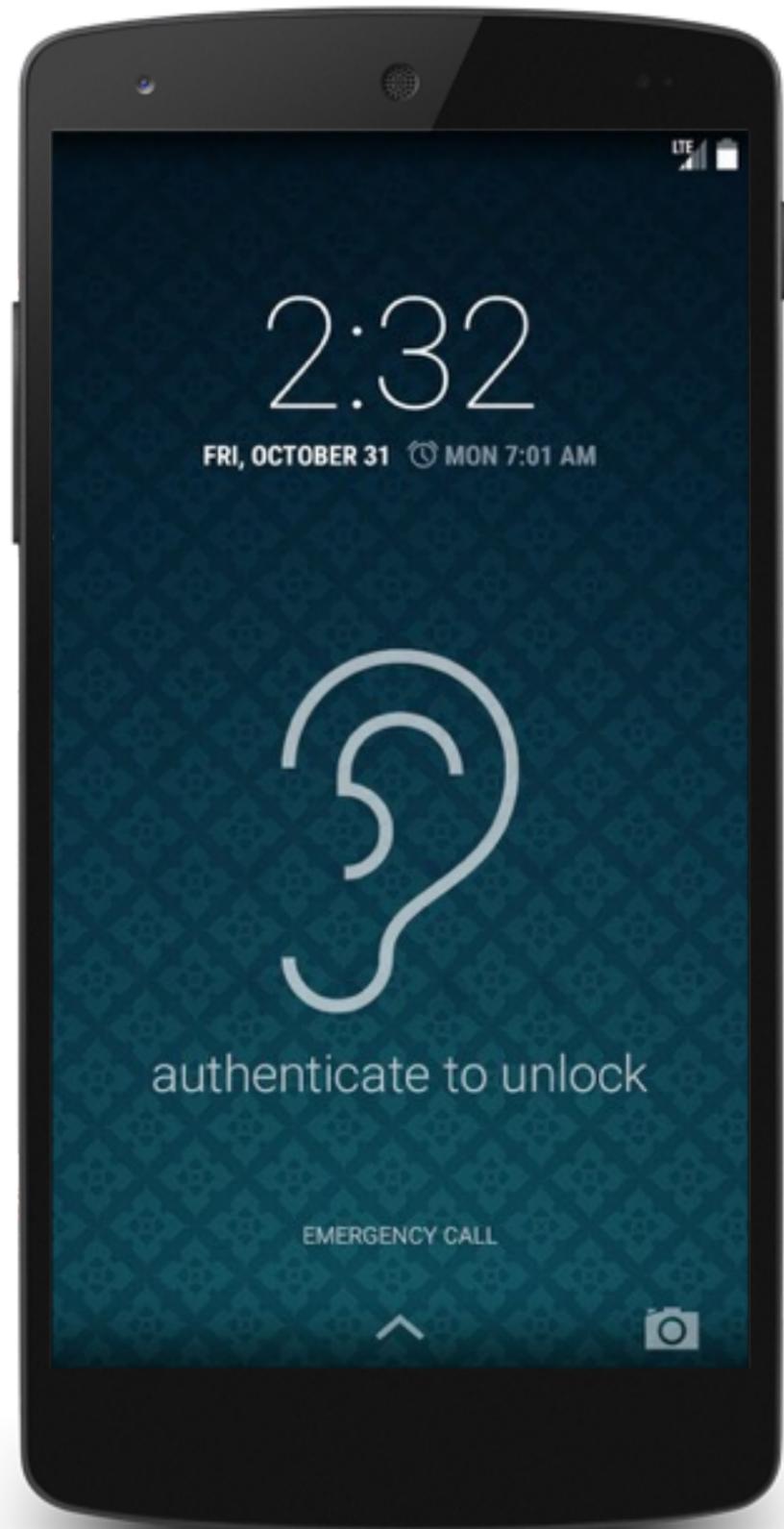
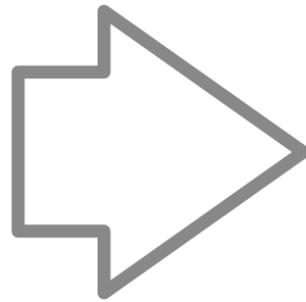
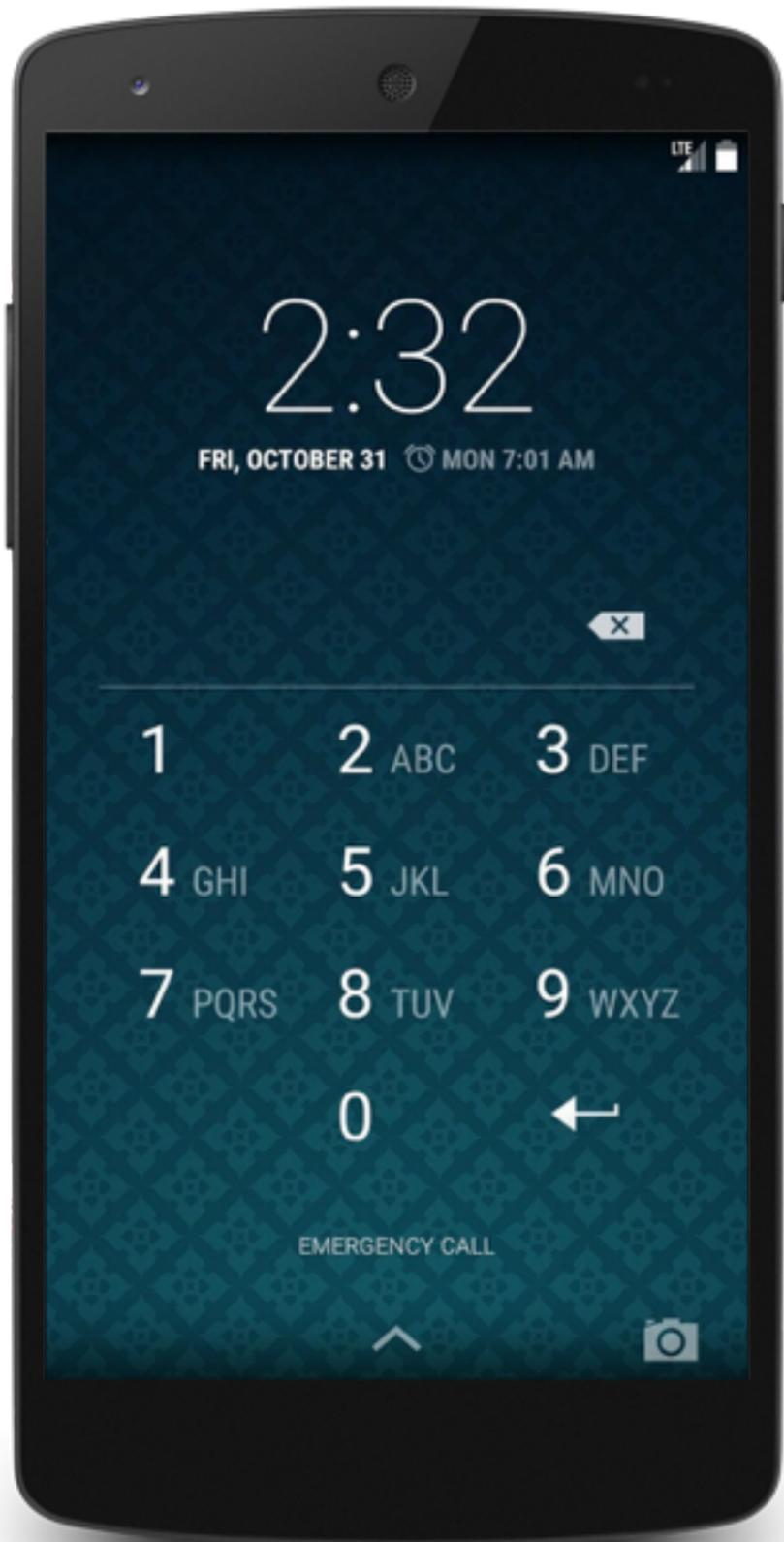
# Bodyprint

Biometric User Identification on Mobile Devices  
Using the Capacitive Touchscreen to Scan Body Parts

**Christian Holz**  
Senaka Buthpitiya  
Marius Knaust

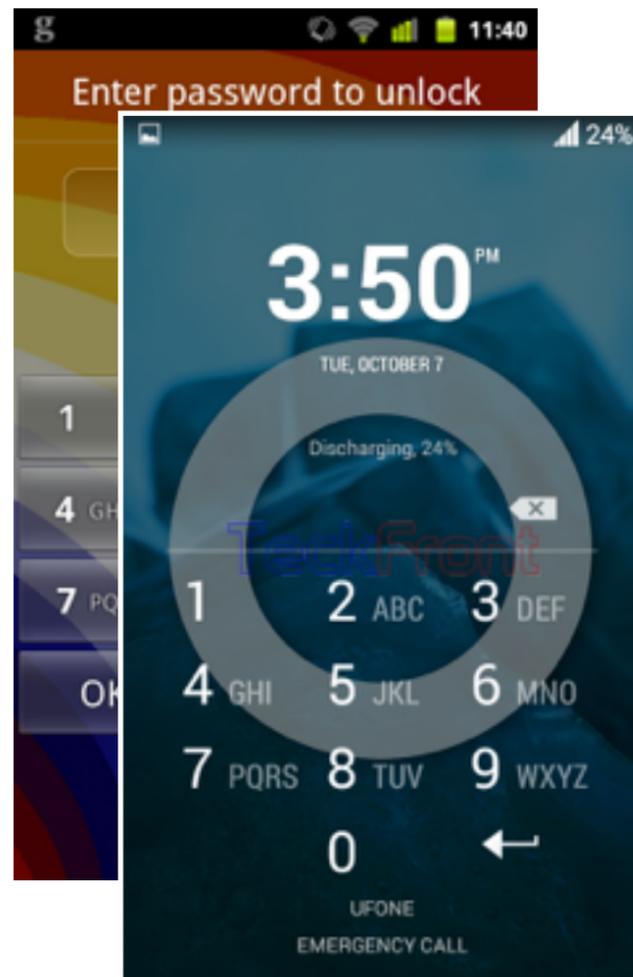
**YAHOO!**





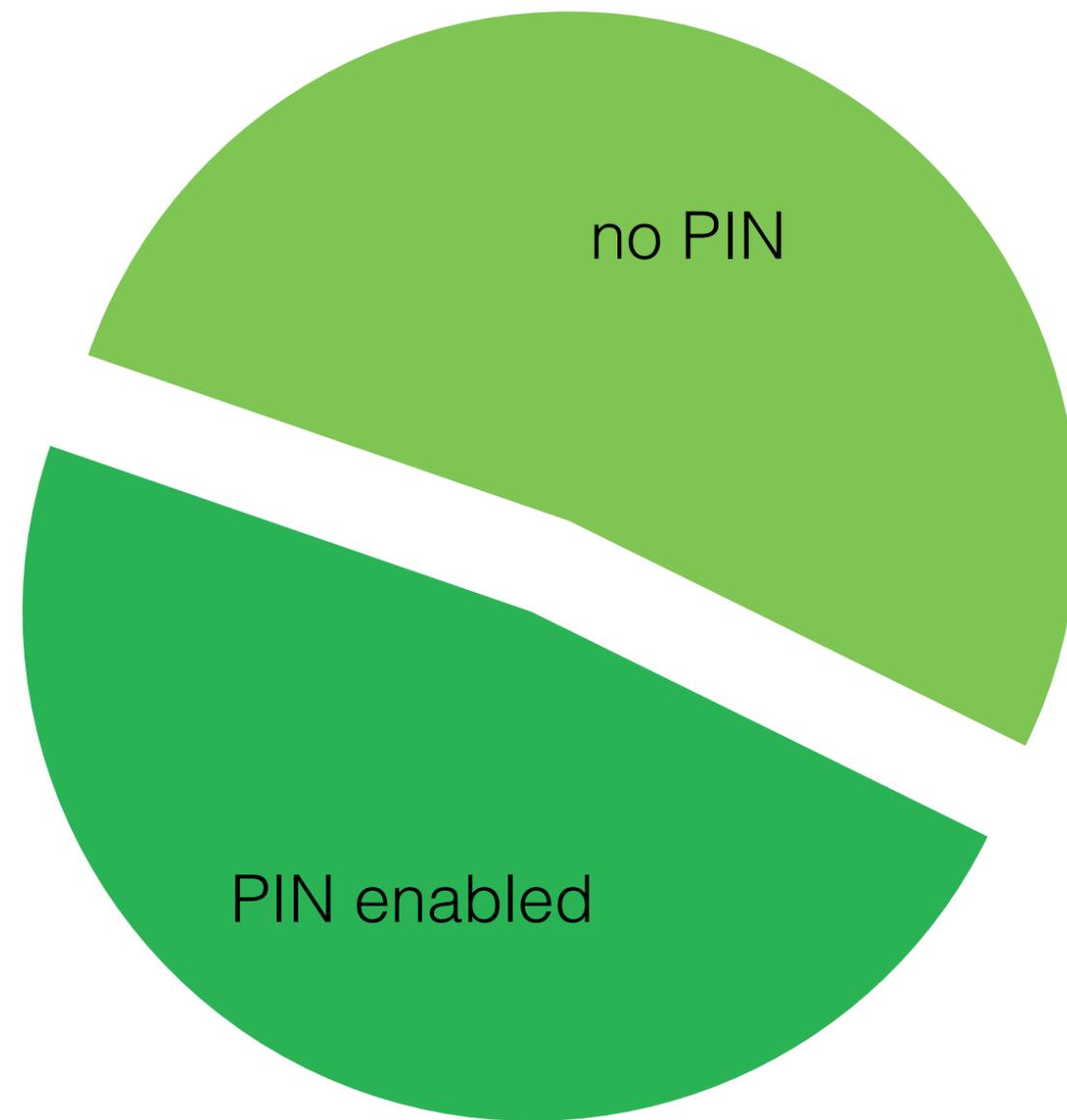
introduction

# mobile passcodes



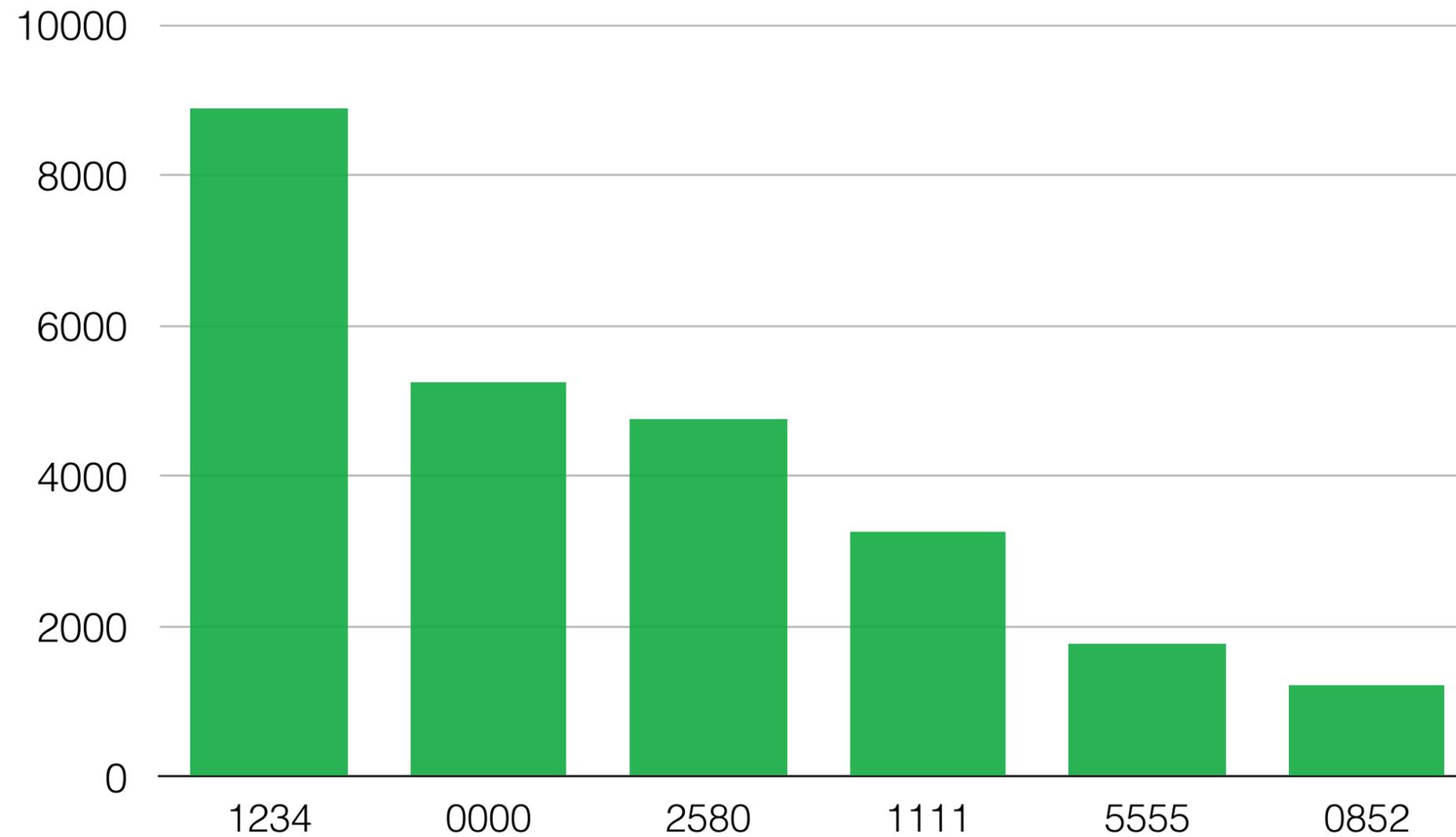
[Everitt et al. CHI '09]

# passcode enabled

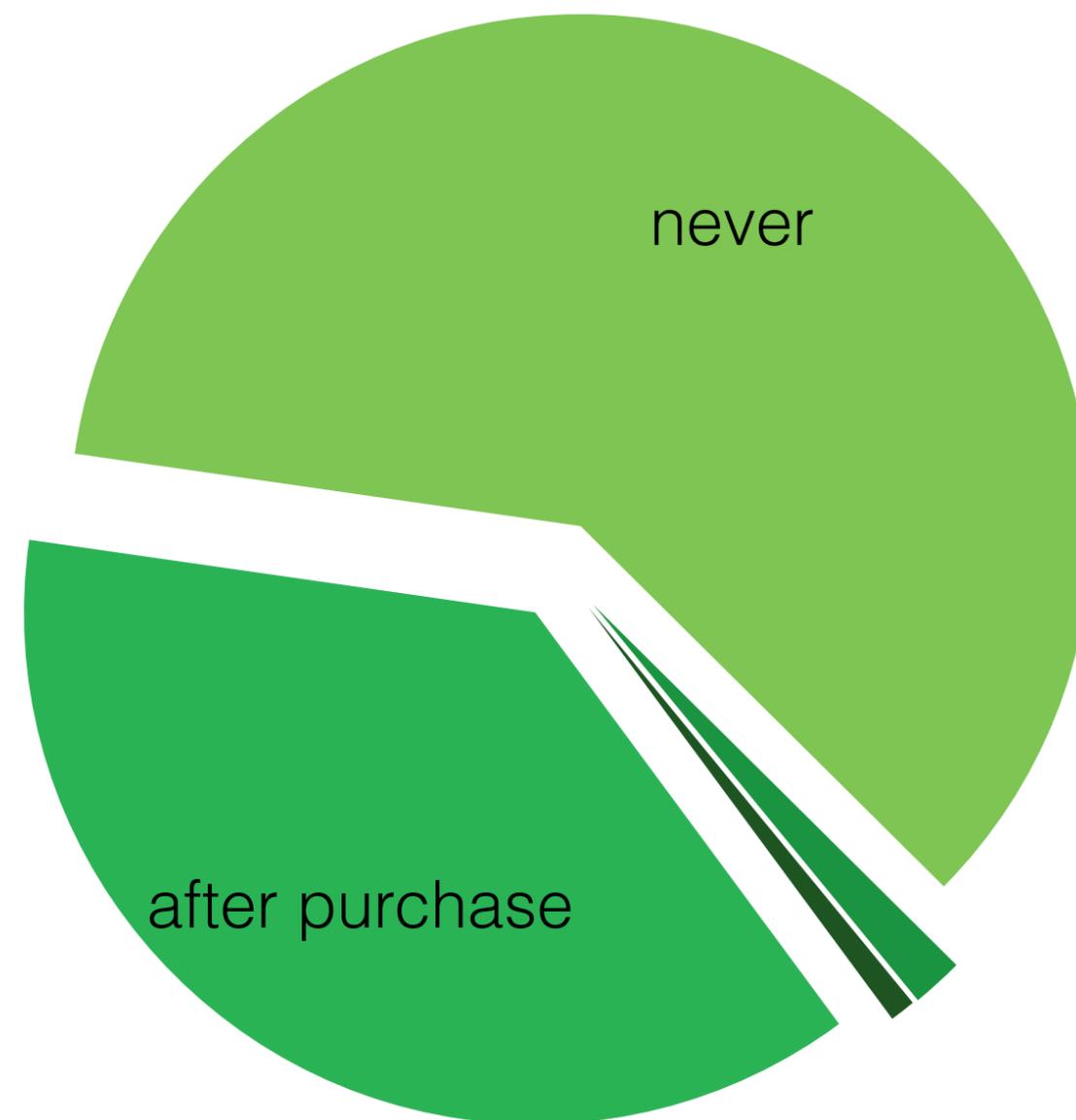


[Kurkovsky, ISTAS '10]  
[Apple '13]

# used PINs



# how often PINs are changed





2013-



**touchscreen**  
capacitive sensing at 6 dpi

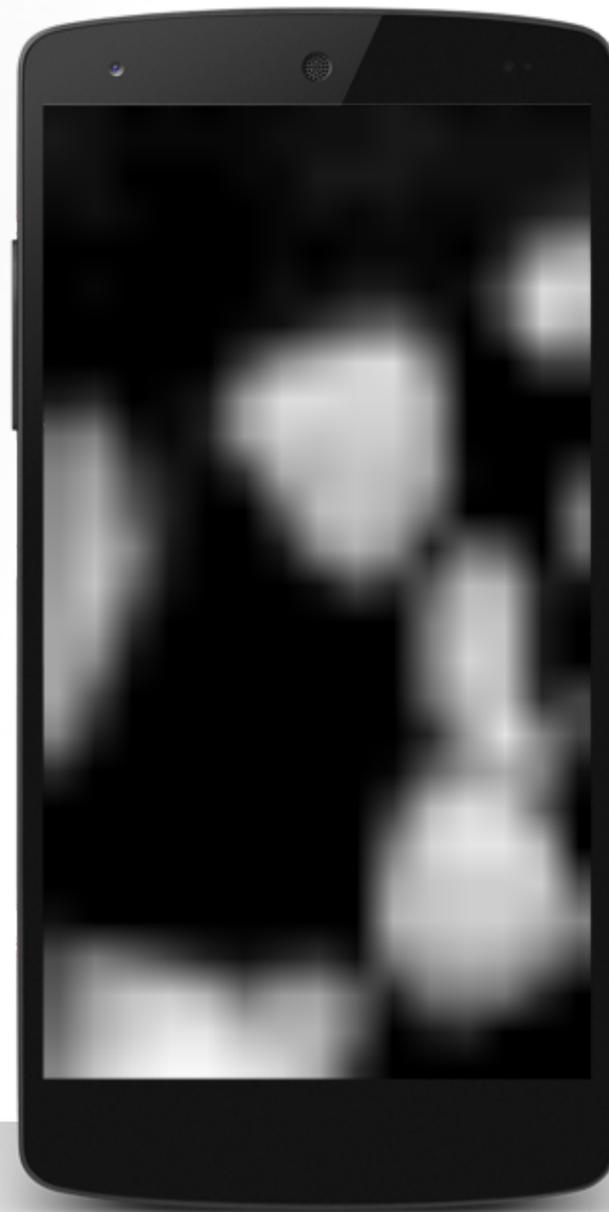
**fingerprint scanner**  
capacitive sensing at 500 dpi



100x larger  
body parts

fingerprint scanners  
500 dpi

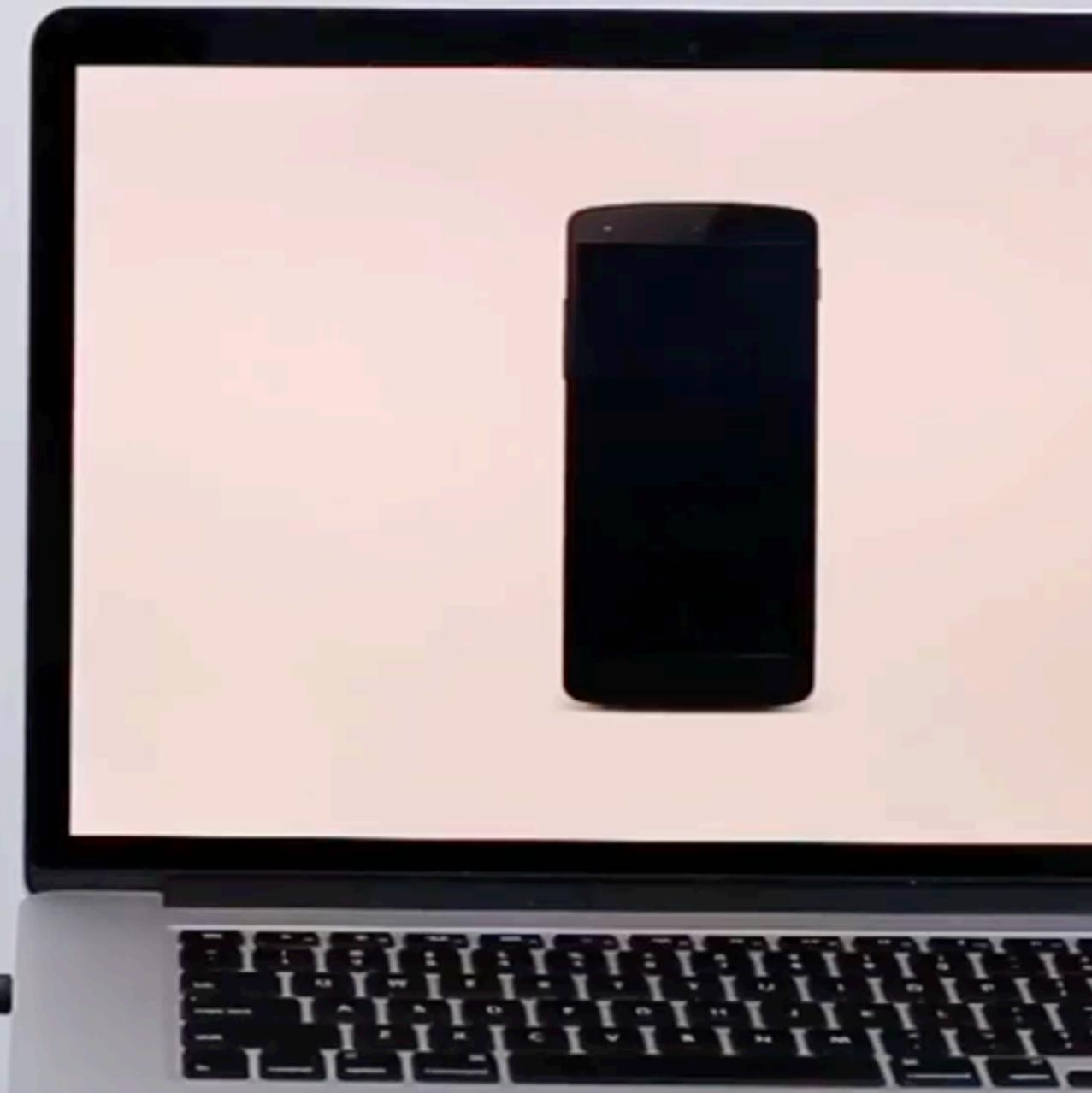
touchscreens  
6 dpi



# Bodyprint

mobile touchscreens  
as image sensors

5 body parts





LG Nexus 5

Synaptics ClearPad 3350

8-bit image, 30 fps

15 x 27 pixels

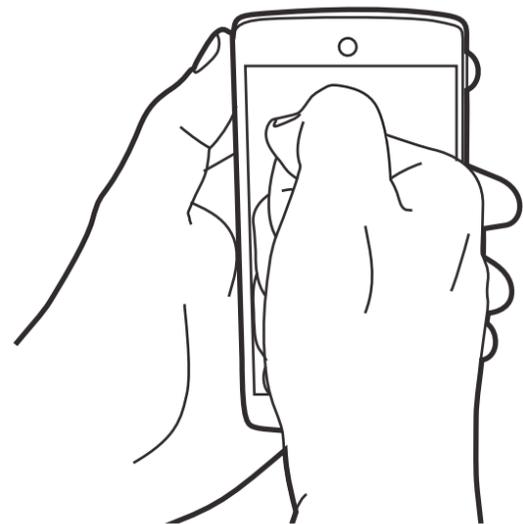
4.95" surface area (6.2 dpi)

debug interface of the touch chip

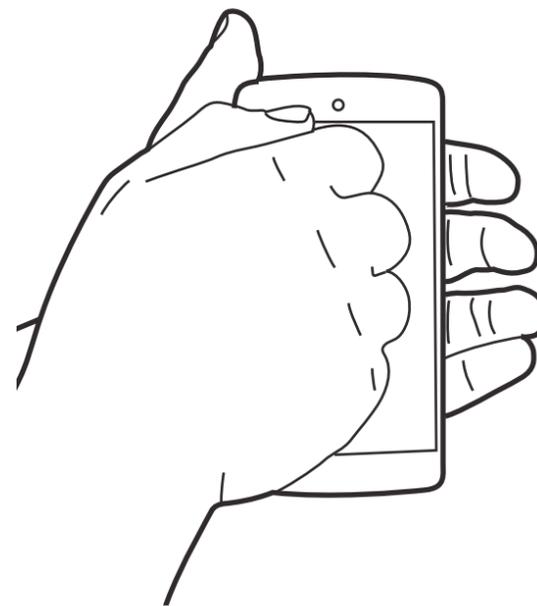
# 5 body parts



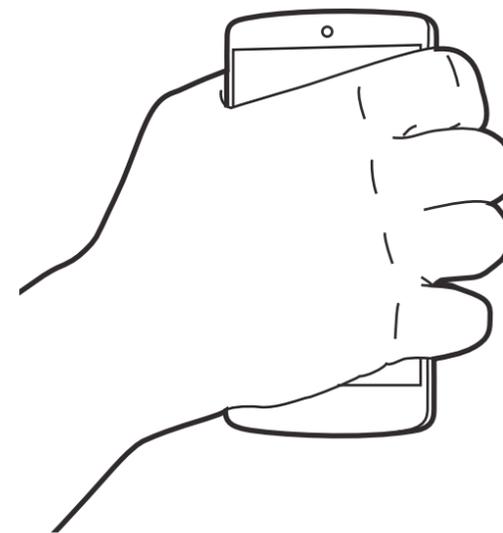
ear



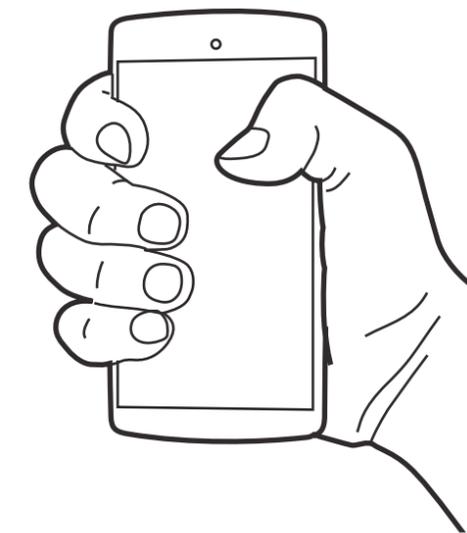
fist



phalanges



palm



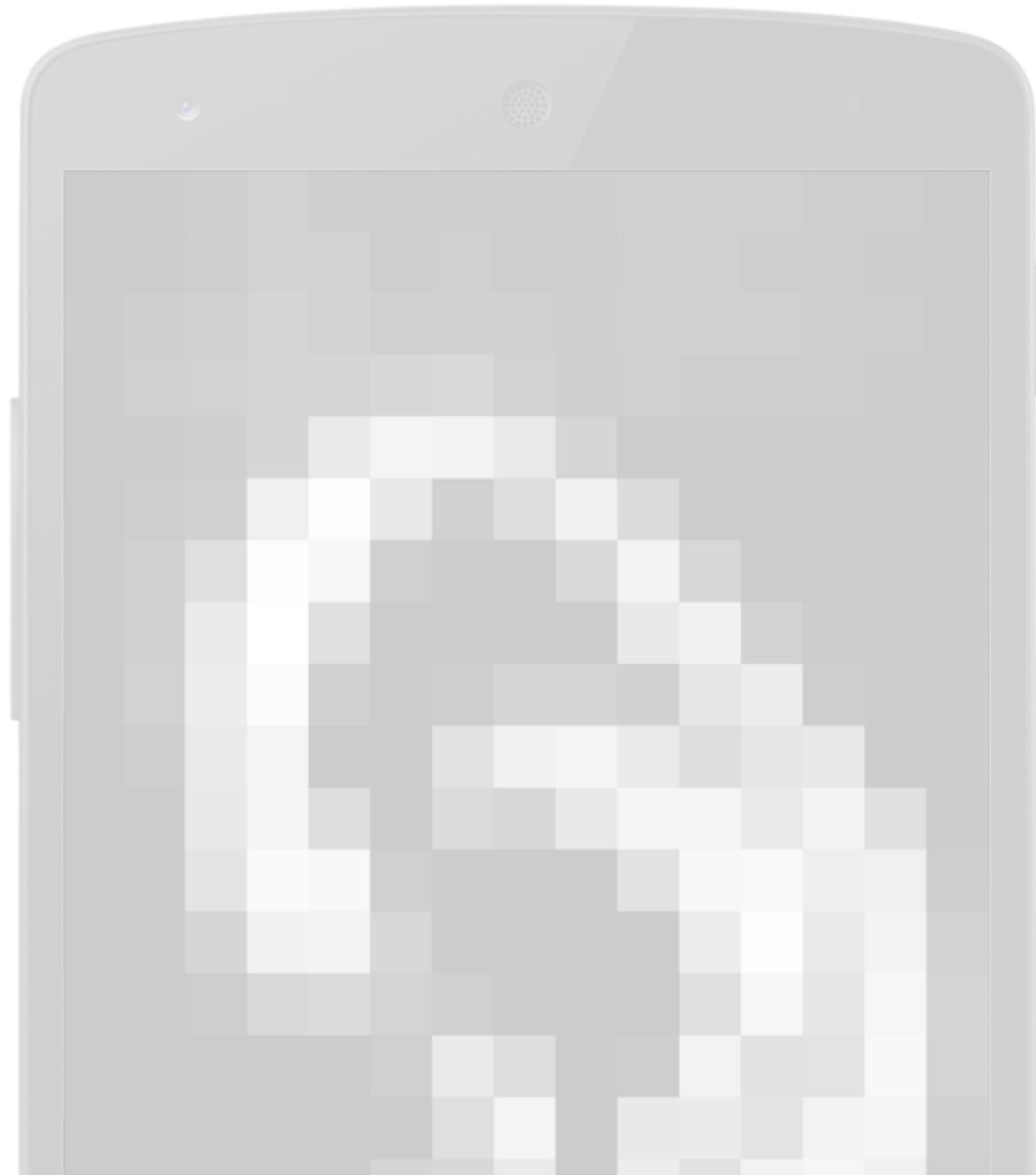
fingers





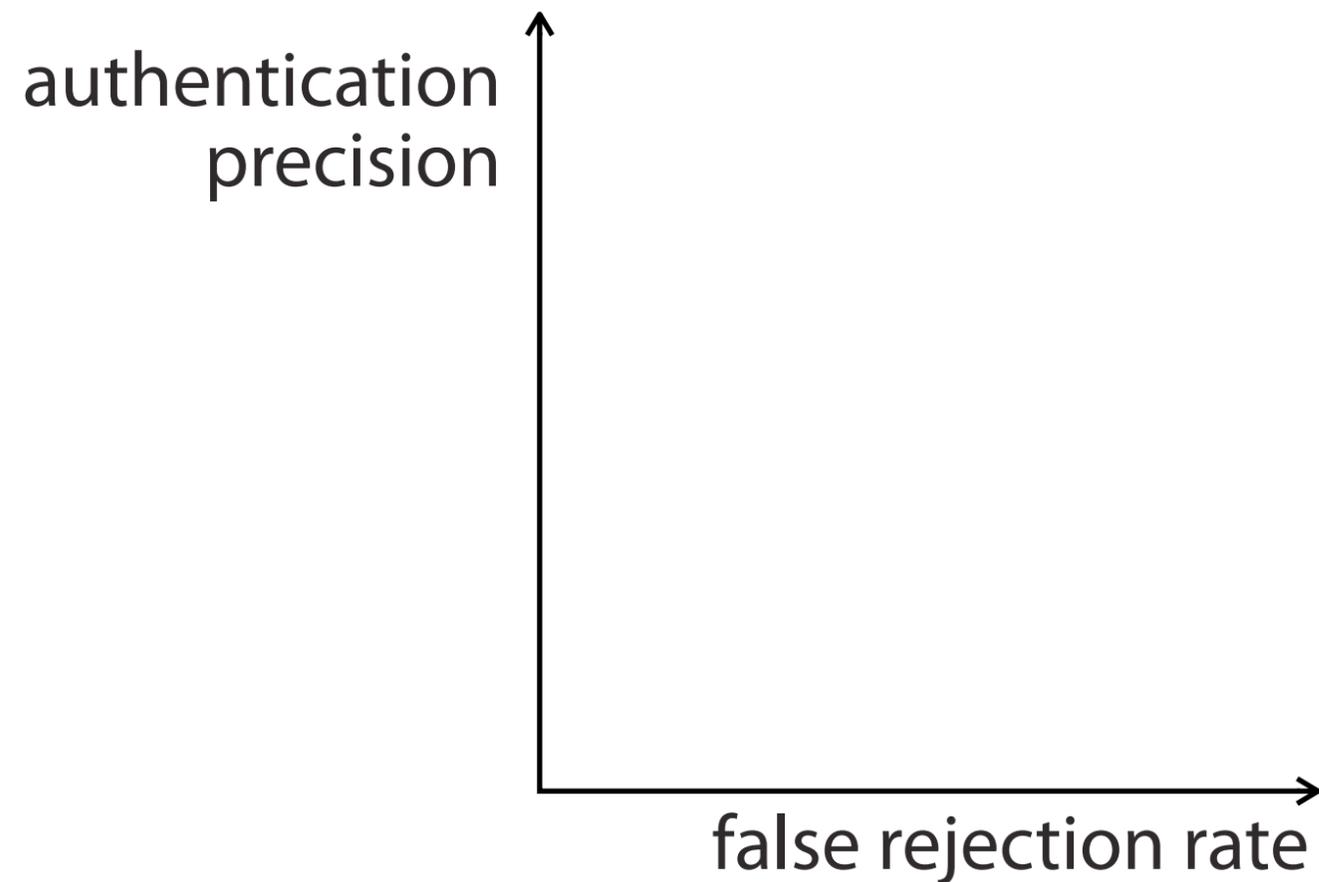
flat touchscreen **surface** for capturing  
scale and perspective **invariant**  
constant **1-1 mapping** over time

# Bodyprint's benefits



processing

# tradeoff: three thresholds



we want high precision,  
but have **low** resolution

⇒ need to sacrifice false rejection rate

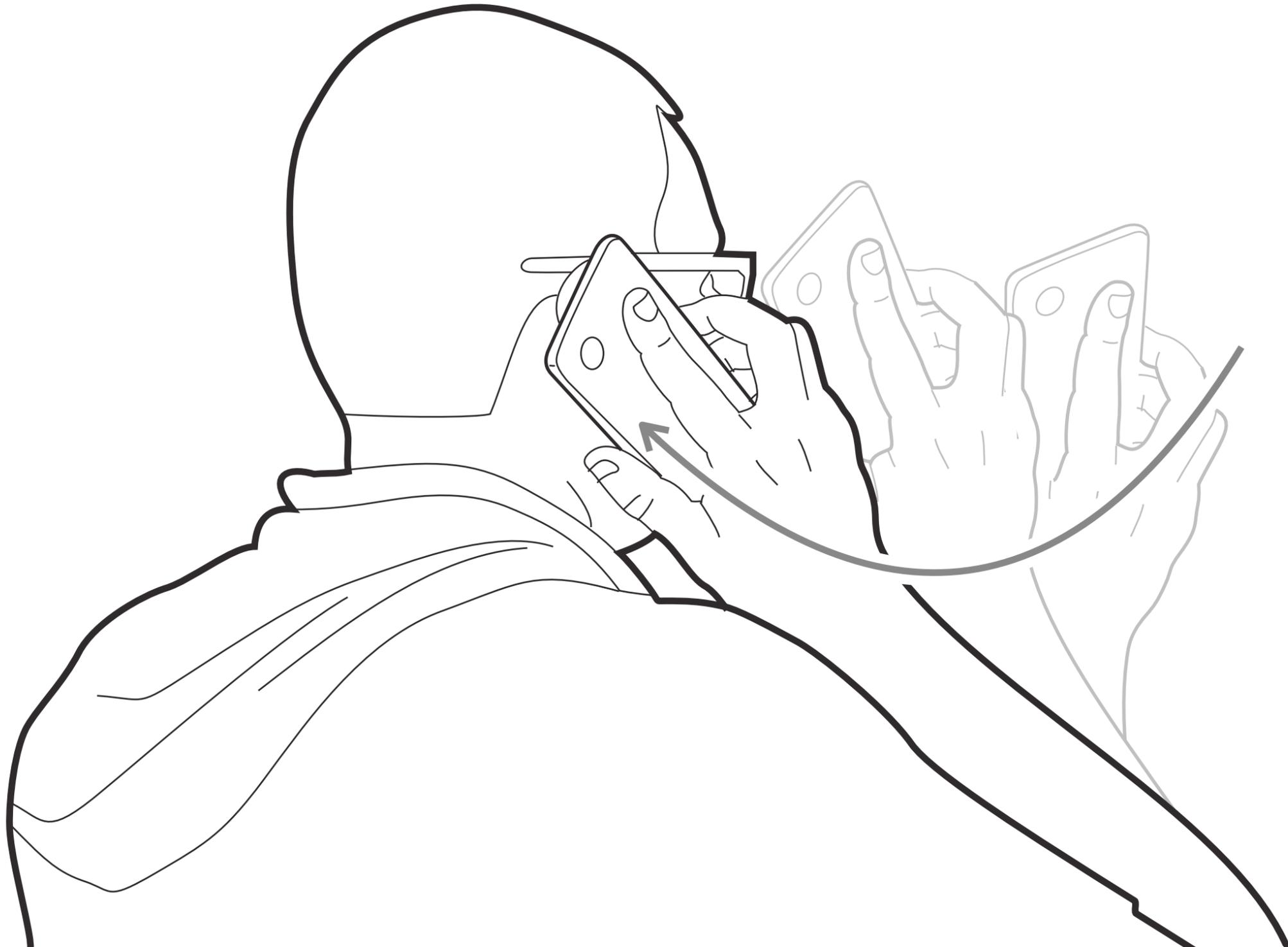
3 thresholds to tune the system:

$th_{bodypart}$ ,  $th_{rotation}$ ,  $th_{votes}$

1 preprocessing

2 body-part classification

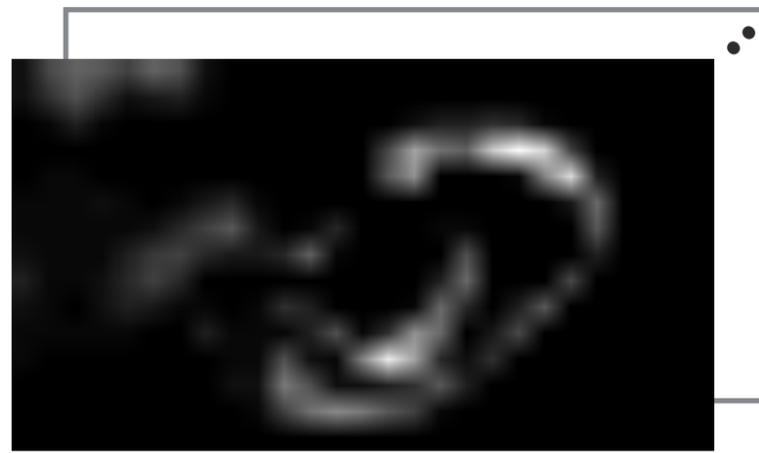
3 user identification



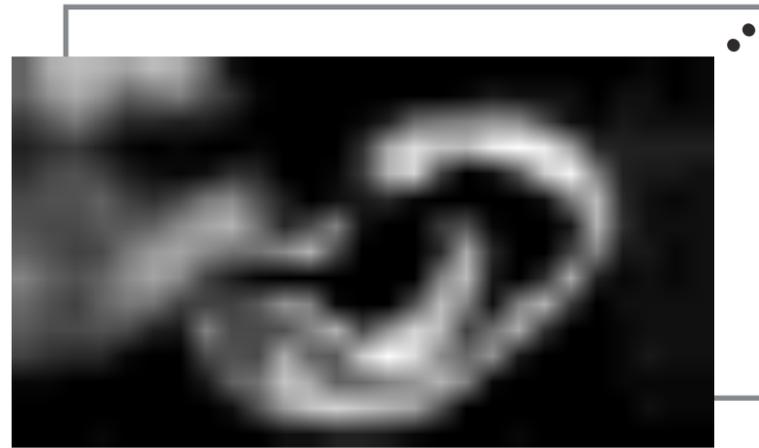
“trial”



trial



exponential



linear



logarithmic

1 preprocessing: tone mapping



darkest

middle

brightest

1 preprocessing: buckets



1 preprocessing: 12 key frames

<p>&lt;0.1,0.2,0.3, .. ,0.128&gt;, .. &lt;0.83,0.13,0.74,..,0.21&gt;</p>	<p>&lt;0.48,0.96,0.40,..,0.01&gt;, .. &lt;0.63,0.81,0.39,..,0.57&gt;</p>	<p>&lt;0.98,0.84,0.64,..,0.42&gt;, .. &lt;0.72,0.66,0.20,..,0.60&gt;</p>	<p>&lt;0.32,0.38,0.74,..,0.04&gt;, .. &lt;0.12,0.27,0.96,..,0.85&gt;</p>
<p>&lt;0.11,0.48,0.21,..,0.04&gt;, .. &lt;0.96,0.60,0.51,..,0.42&gt;</p>	<p>&lt;0.23,0.55,0.96,..,0.63&gt;, .. &lt;0.50,0.31,0.22,..,0.68&gt;</p>	<p>&lt;0.70,0.48,0.54,..,0.04&gt;, .. &lt;0.50,0.42,0.43,..,0.36&gt;</p>	<p>&lt;0.82,0.89,0.63,..,0.41&gt;, .. &lt;0.81,0.20,0.53,..,0.83&gt;</p>
<p>&lt;0.20,0.71,0.70,..,0.37&gt;, .. &lt;0.60,0.83,0.99,..,0.60&gt;</p>	<p>&lt;0.22,0.60,0.01,..,0.01&gt;, .. &lt;0.08,0.83,0.47,..,0.17&gt;</p>	<p>&lt;0.07,0.99,0.13,..,0.33&gt;, .. &lt;0.91,0.12,0.90,..,0.94&gt;</p>	<p>&lt;0.72,0.21,0.09,..,0.16&gt;, .. &lt;0.18,0.93,0.62,..,0.36&gt;</p>

1 preprocessing: 12 key frames


ears


fists


phalanges


palms


fingers

body-part database


user 1, trial 1, *body part*


user 1, trial 2, *body part*

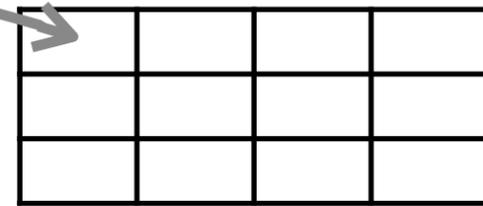
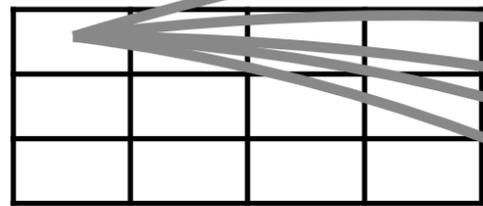

user 1, trial 3, *body part*

:

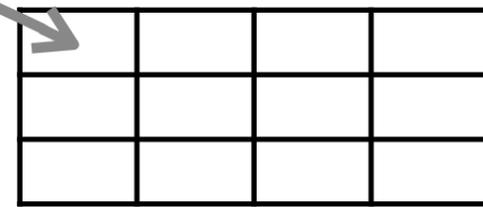

user  $n$ , trial  $t$ , *body part*

user database

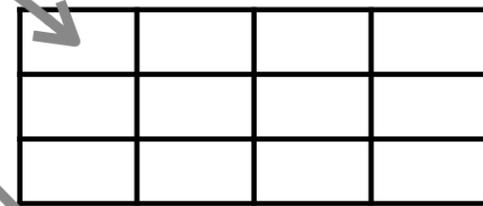
incoming  
12 key frames



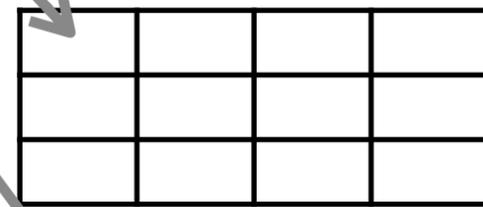
ears



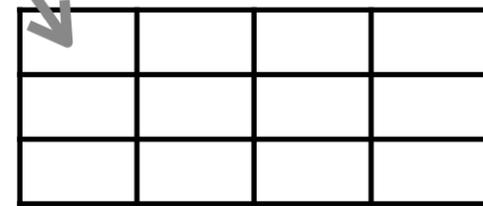
fists



phalanges



palms

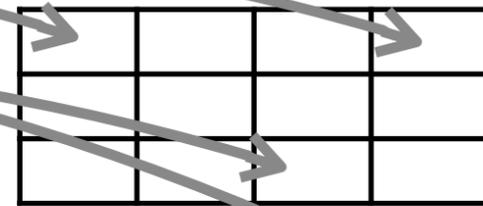
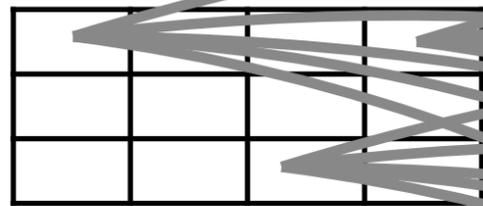


fingers

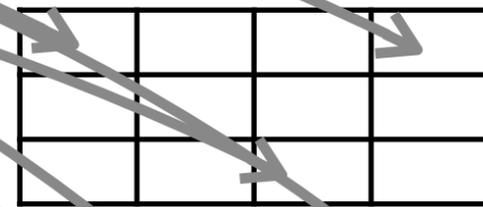
count valid matches  
calculate average distances  
vote on one body part

# 2 body-part classification

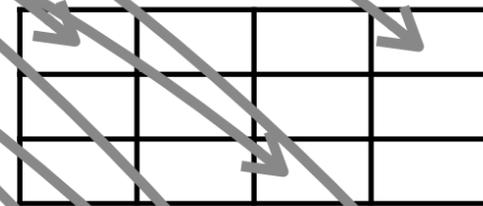
incoming  
12 key frames



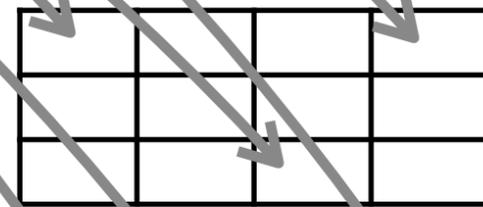
ears



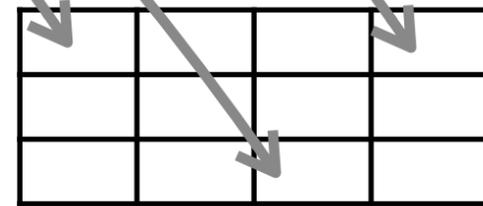
fists



phalanges



palms



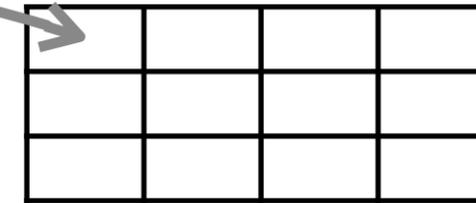
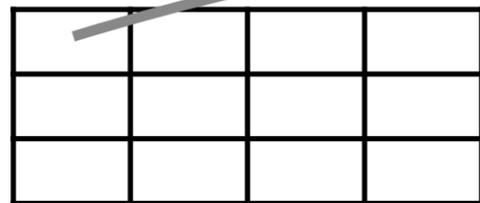
fingers

count valid matches  
calculate average distances  
vote on one body part

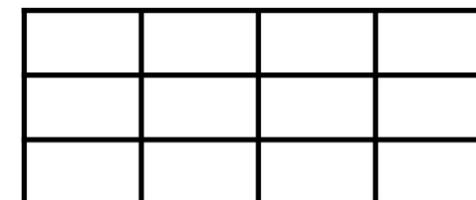
result majority vote  
with threshold  $th_{bodypart}$

# 2 body-part classification

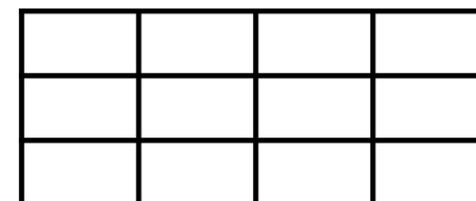
incoming  
12 key frames  
+ body part result



user 1, trial 1,  
*body part*

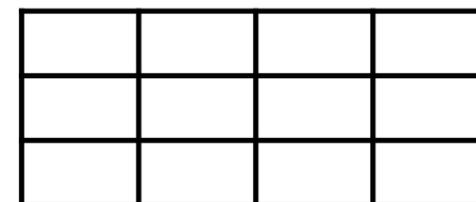


user 1, trial 2,  
*body part*



user 2, trial 1,  
*body part*

:



user  $n$ , trial  $t$ ,  
*body part*

count valid matches

prevent vote if  $< 10$  matches

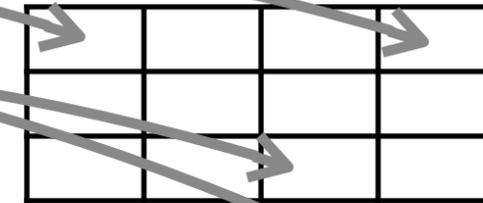
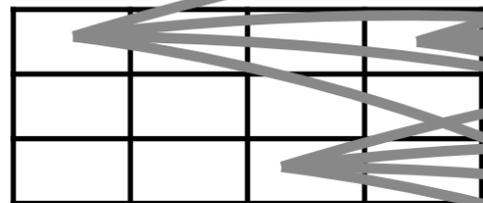
compute 2D rigid transform

count vote for *user*

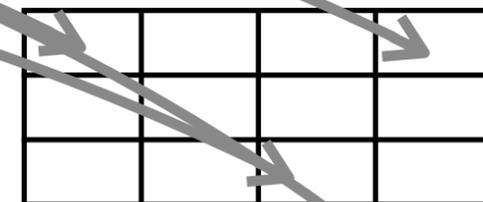
if transformation error  $< th_{rotation}$

# 3 user identification

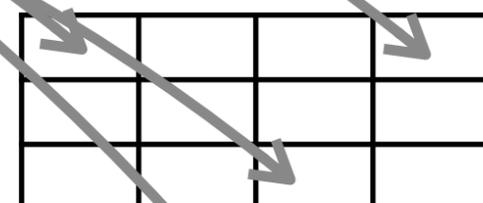
incoming  
12 key frames  
+ body part result



user 1, trial 1,  
*body part*

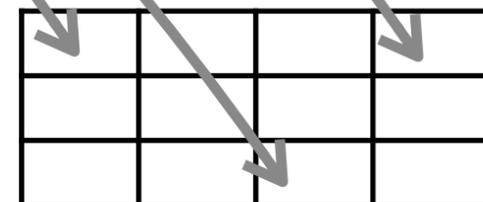


user 1, trial 2,  
*body part*



user 2, trial 1,  
*body part*

:



user  $n$ , trial  $t$ ,  
*body part*

sum votes

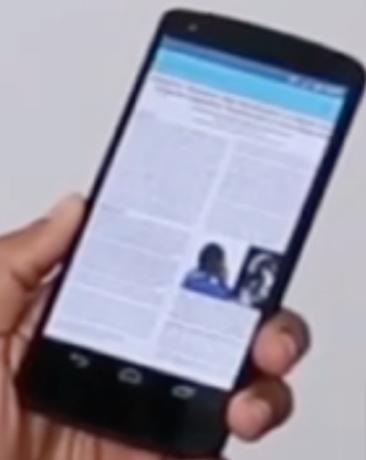
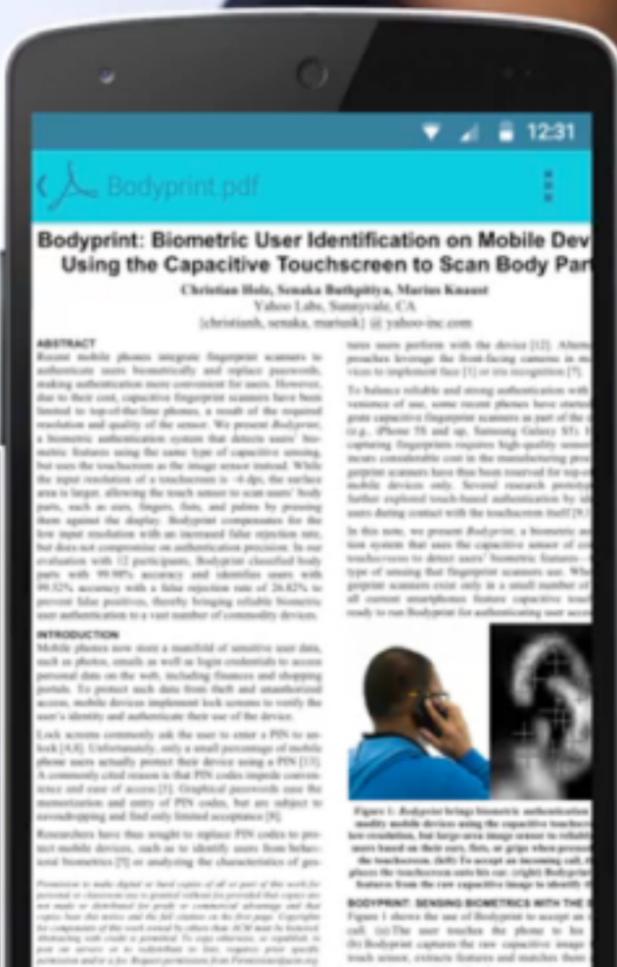
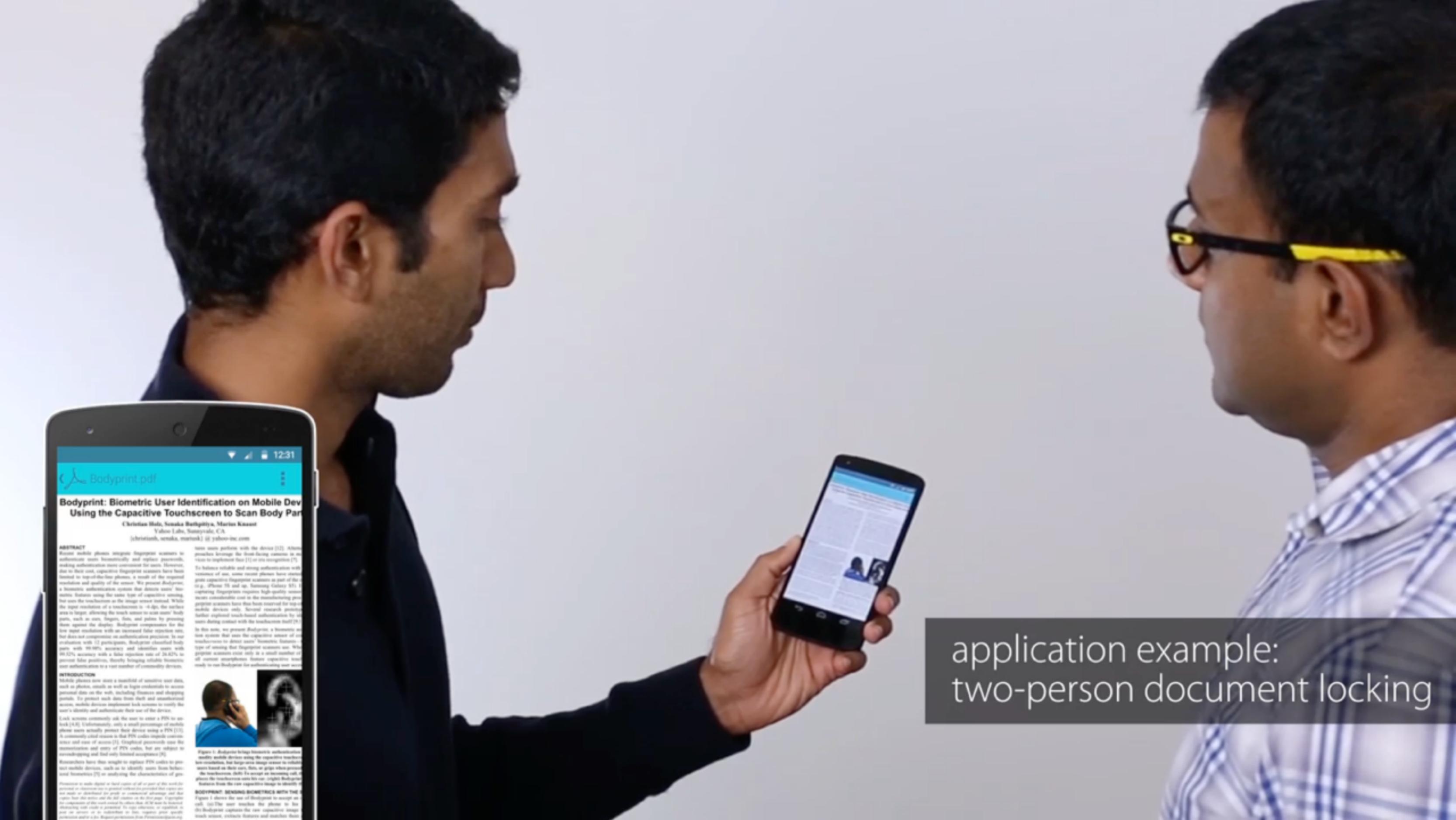
normalize by #trials/user

result

majority vote

with threshold  $th_{votes}$

# 3 user identification



application example:  
two-person document locking



technical evaluation

5 body parts

× 12 participants  
ages 24–53, 4 female

× 12 repetitions

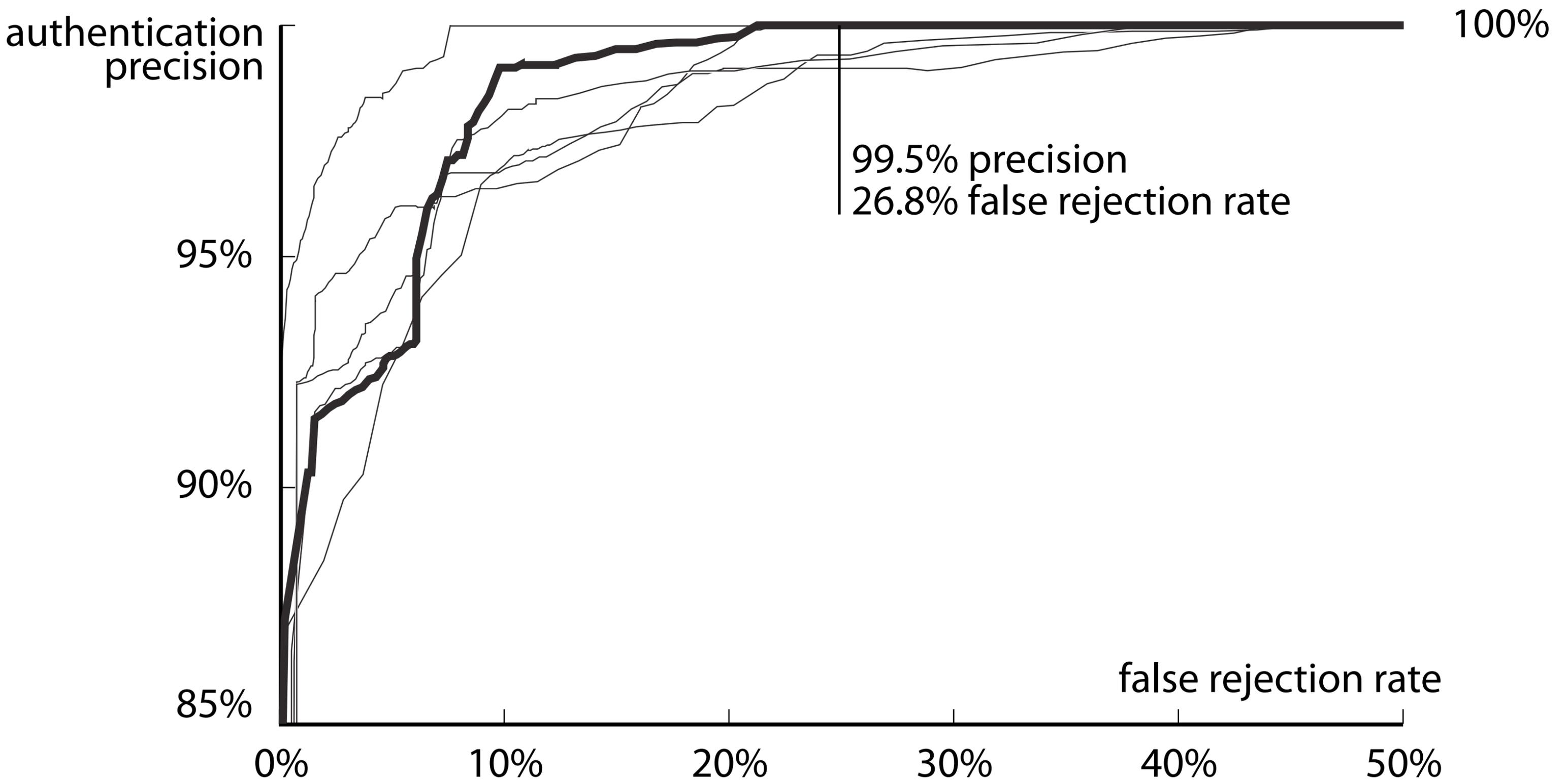
**= 720 trials**

design

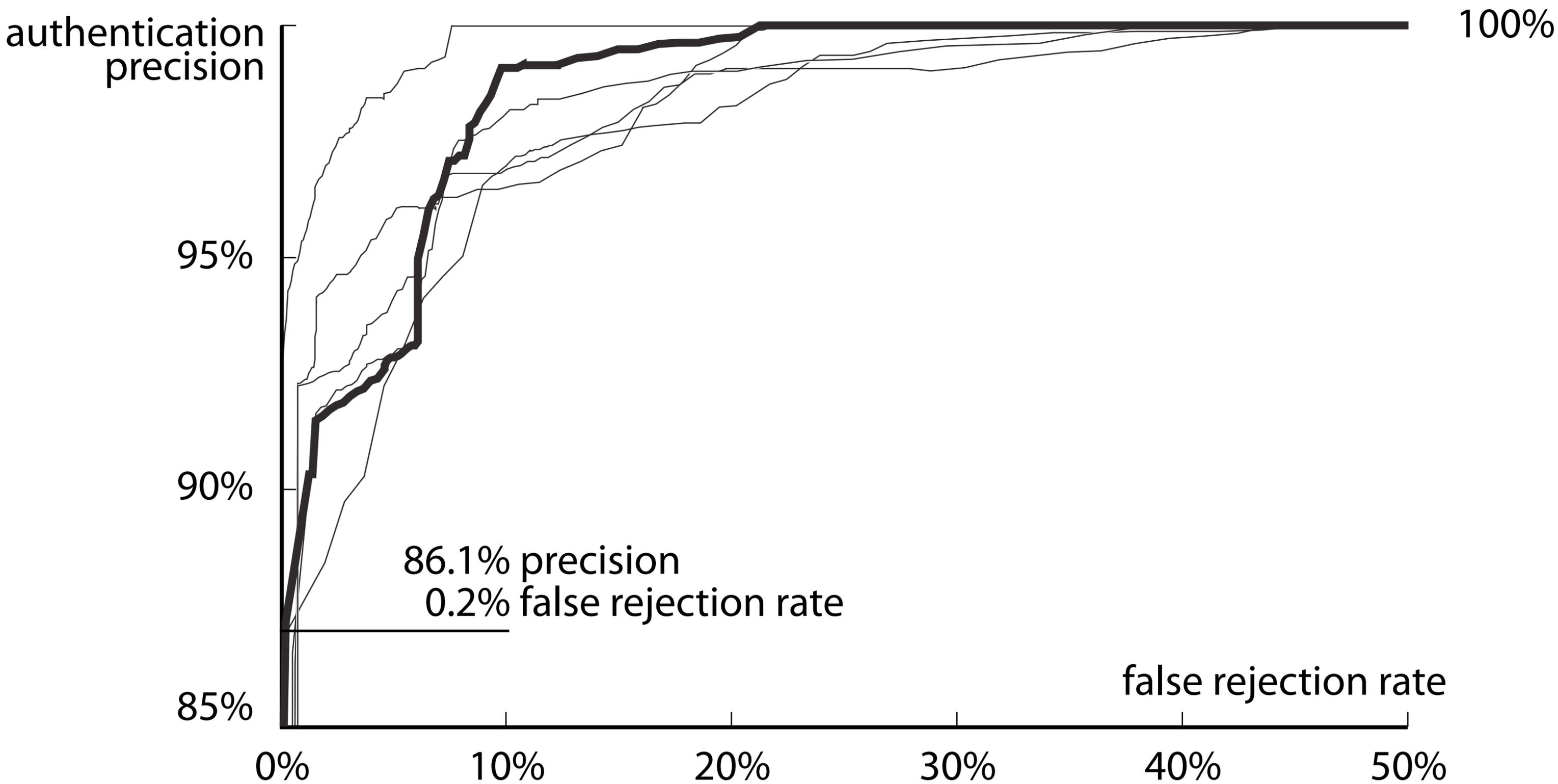
12-fold cross validation to evaluate  
identification accuracy  
rejecting unknown users

method

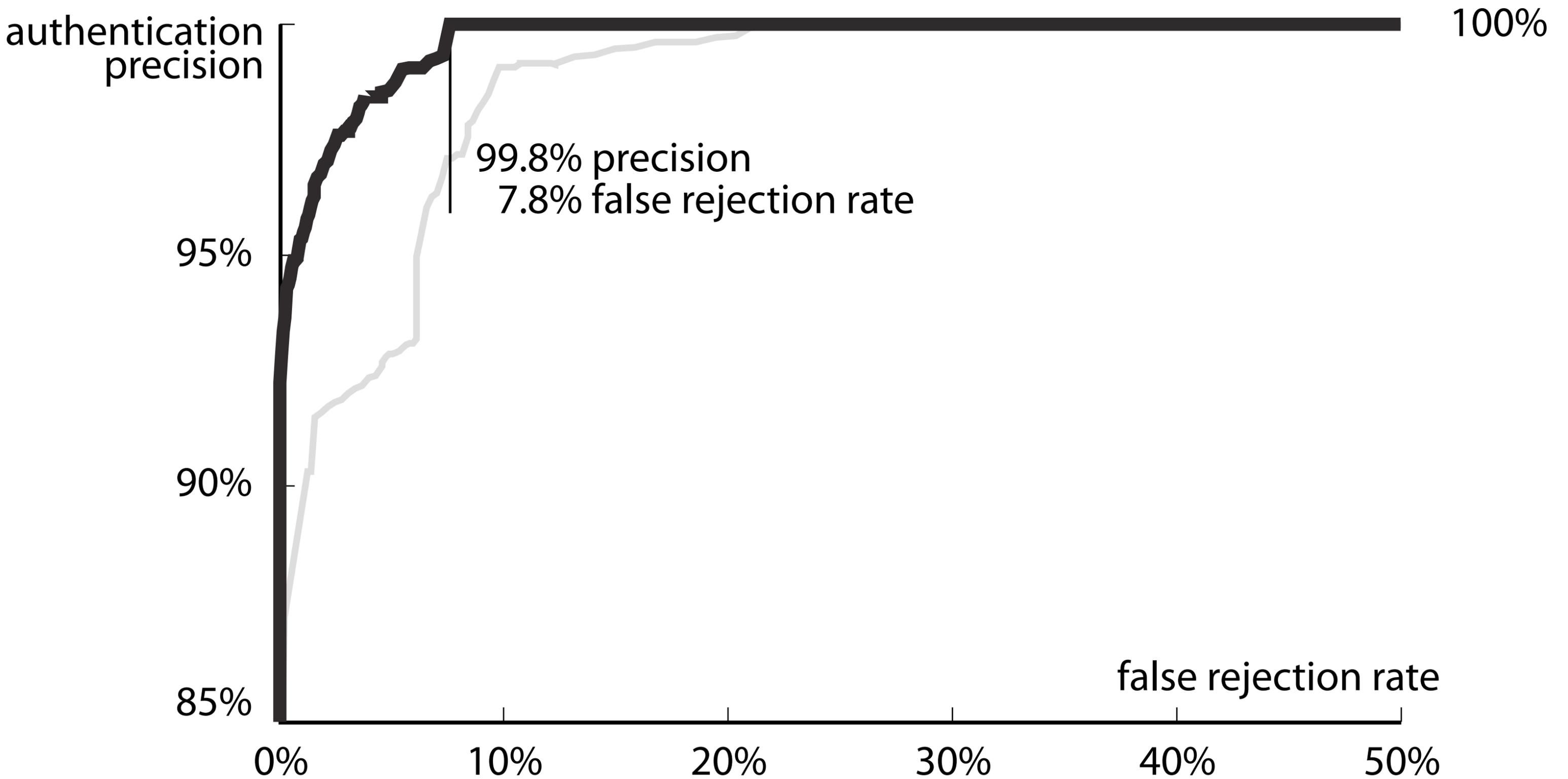
# results: all 5 body parts



# results: all 5 body parts



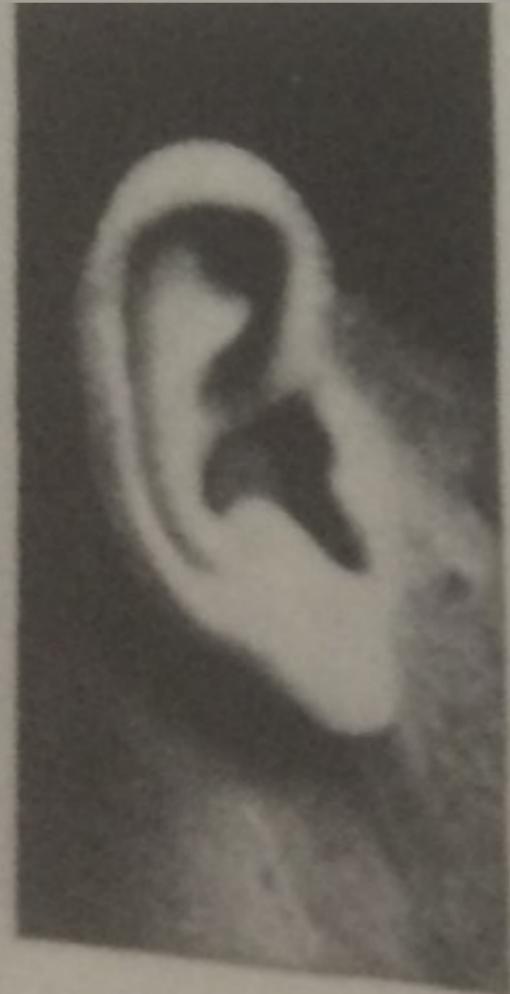
# results: ear only



results: ear only



3. *Oblique.*



6. *Projecting.*



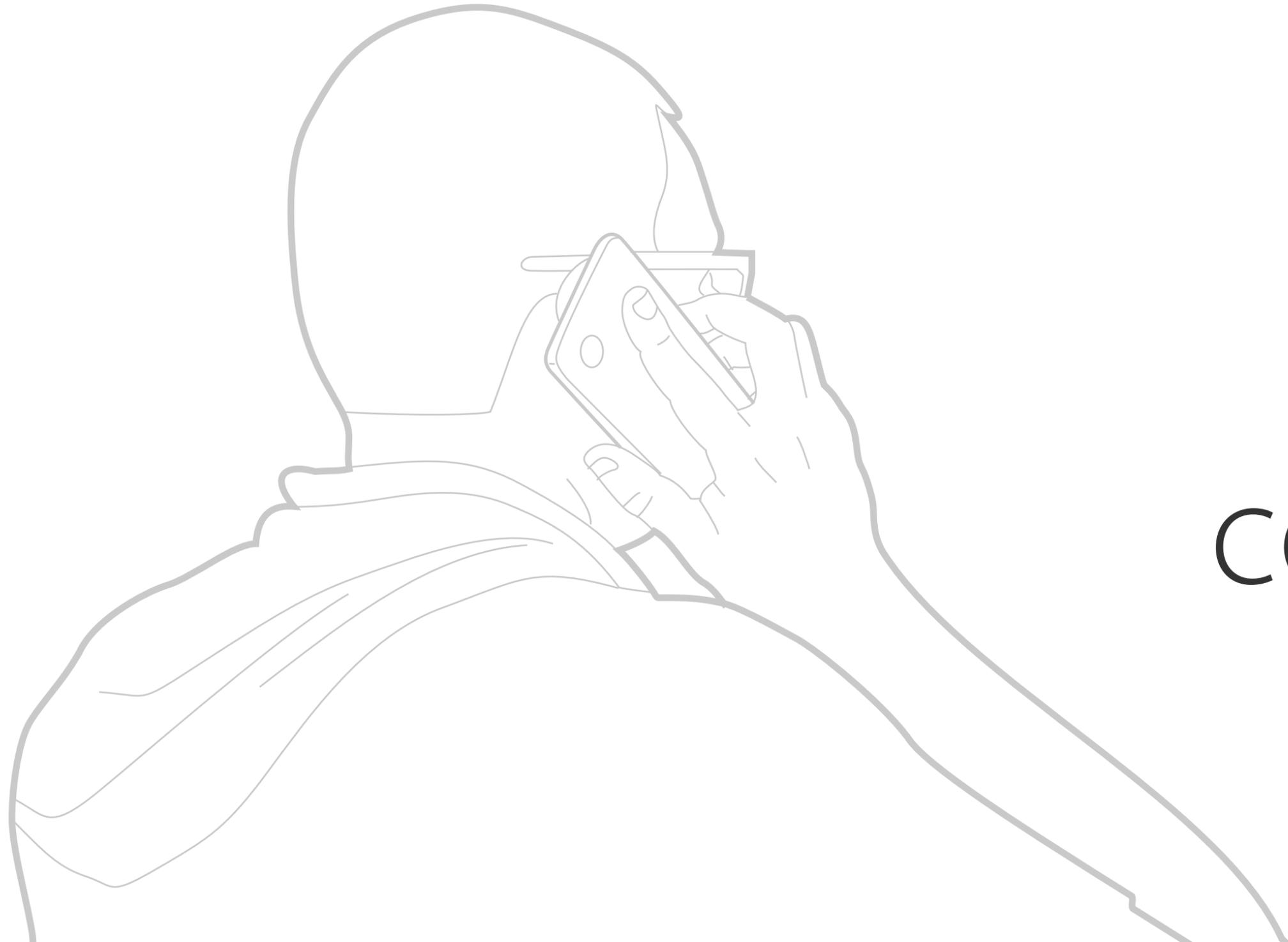
9. *Erect.*



12. *Lop.*

4. Classification of the ear according to the Bertillon system.

these pe  
individ  
unrel  
Phot  
Bertill  
neere  
the p  
the i  
prof  
eith  
of c  
am



conclusions



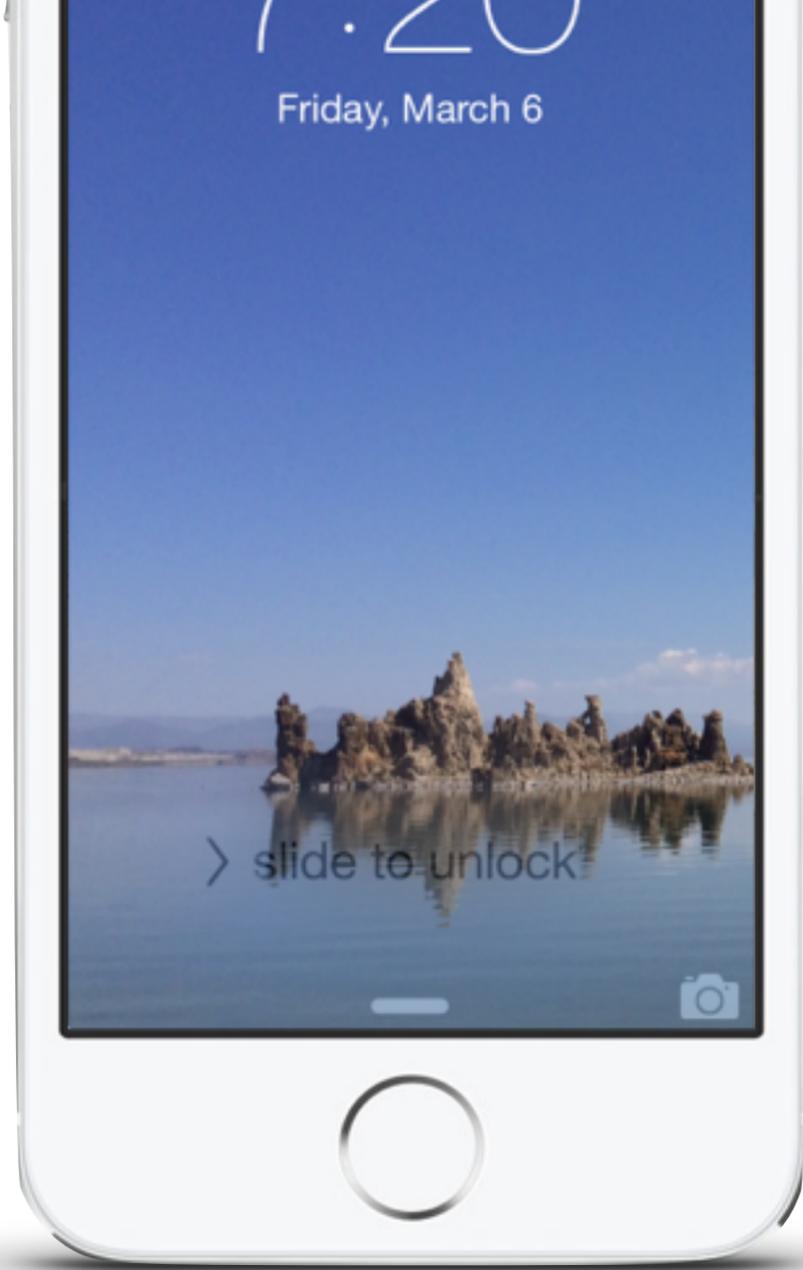
viable password replacement on  
**commodity** mobile devices

affords high authentication precision

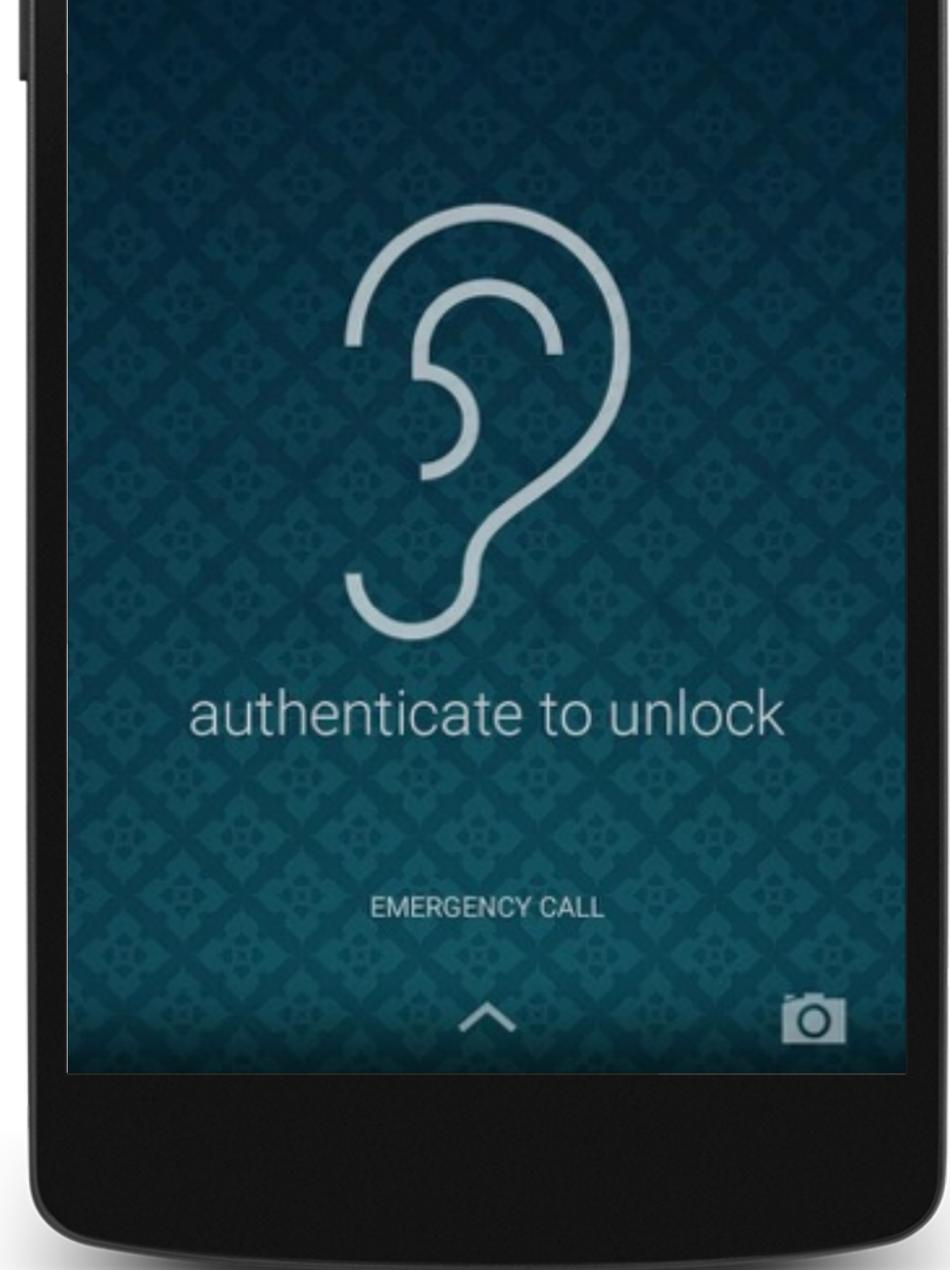
touchscreen acts as **area sensor**

performance will only increase  
with increased input resolutions

Bodyprint



fingerprint scanners  
15% market share



Bodyprint  
potentially 75%



# Bodyprint

Christian Holz, Senaka Buthpitiya, Marius Knaust  
<http://www.christianholz.net>

ear

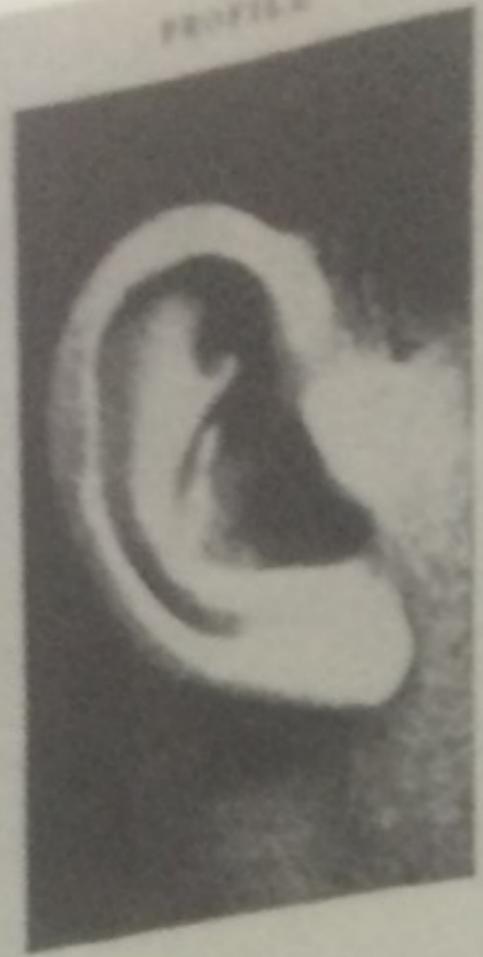
SUSPECT IDENTITIES

INCLINATION



1. Horizontal.

PROFILE



4. Rectilinear.

REVERSION



7. Turned outward.

SIZE



10. Small.

Measuring the

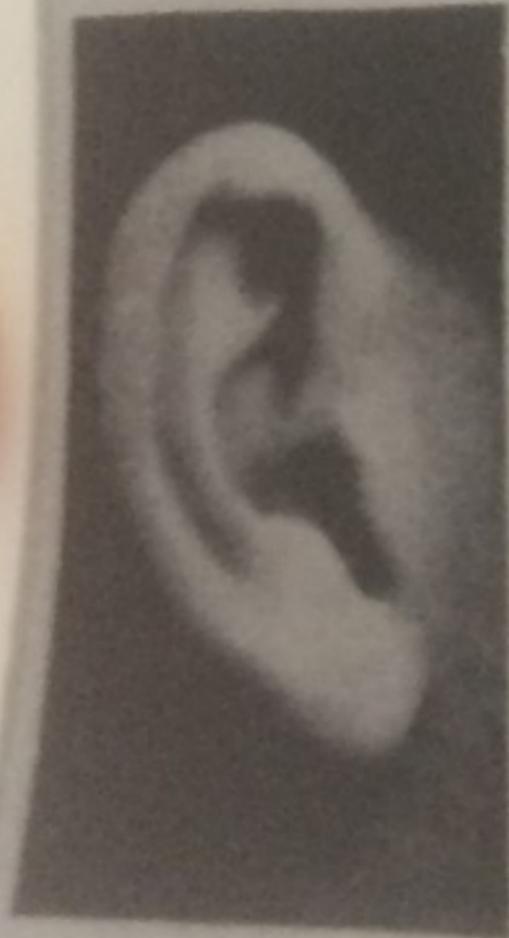
ing their shape, mea-  
 ized idiom for recor-  
 called "cicatrical sen-

cicatrix, rectilinea-  
 nal, on middle sec-

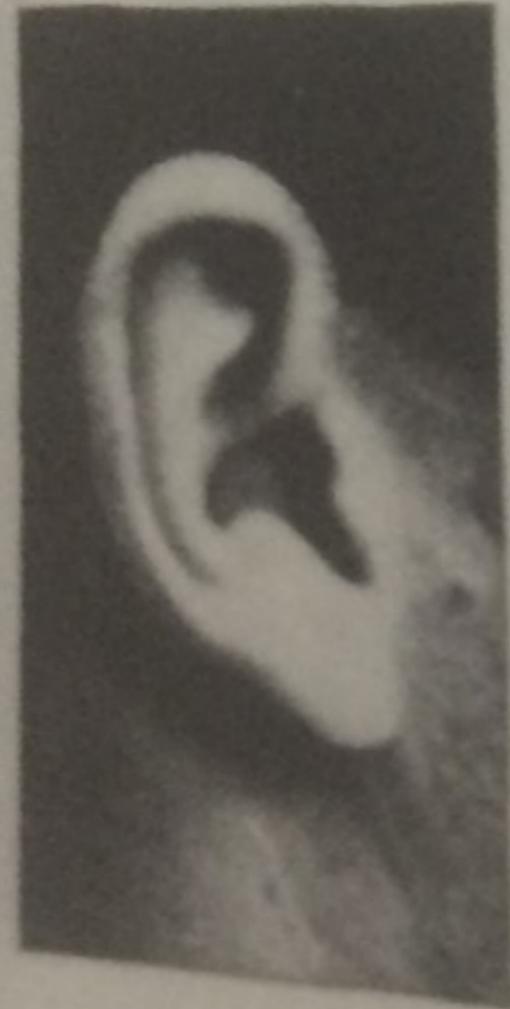
But Bertillon did n-  
 ized abbreviations  
 The above senten-

On the front of t-  
 ing to describe  
 marks. Compar-  
 ance or marks  
 mation to be c-  
 description. In  
 choosing whi-  
 to the

2. Intermediate.



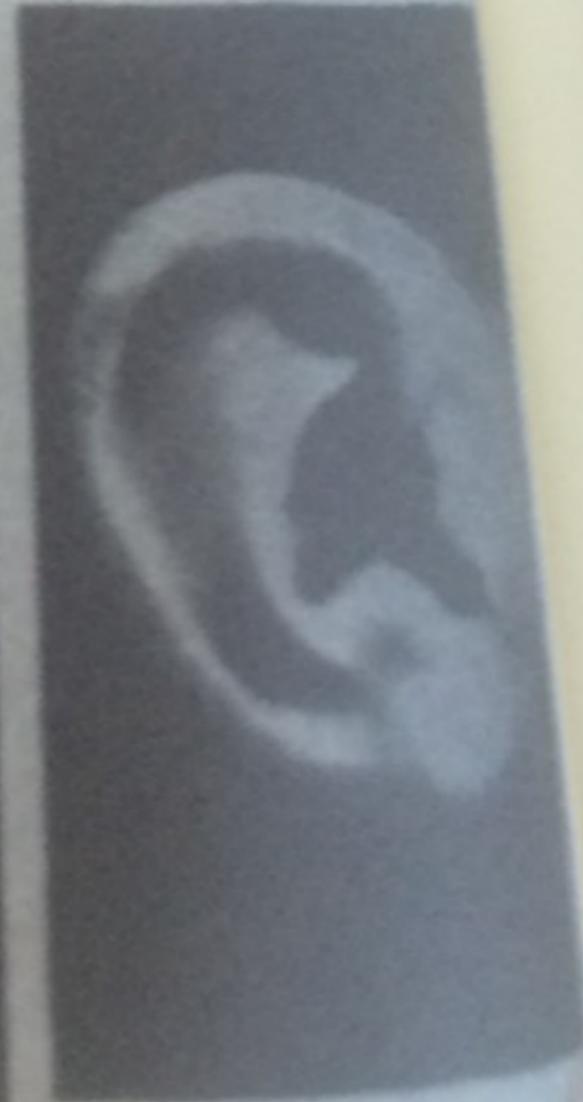
5. Intermediate.



8. Intermediate.



11. Medium.



3. Oblique.

6. Projecting.

9. Erect.

12. Lopsided.

4. Classification of the ear according to the Bertillon system.

recon  
cular ma  
surement  
called "t  
these pe  
individ  
unrel  
Phot  
Bertill  
neere  
the p  
the i  
prof  
eith  
of c  
am



Fiberio, *UIST '13*