Corona

Positioning Adjacent Device with Asymmetric Bluetooth Low Energy RSSI Distributions

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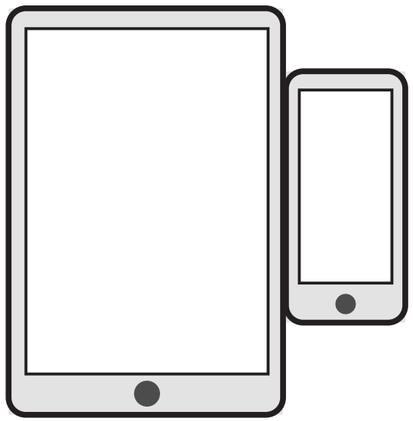
The devices remain independent even when they are just inches away.

radio

Received Signal Strength Indicator (RSSI)

0 cm - - - - - - - - 10 cm - - - - - - 2 m - - - - - - 90 m

RSSI	...	-20	-25	-30	-35	-40	-45	-50	-55	-60	-65	-70	-75	-80	-90	-100	-110	-120	...



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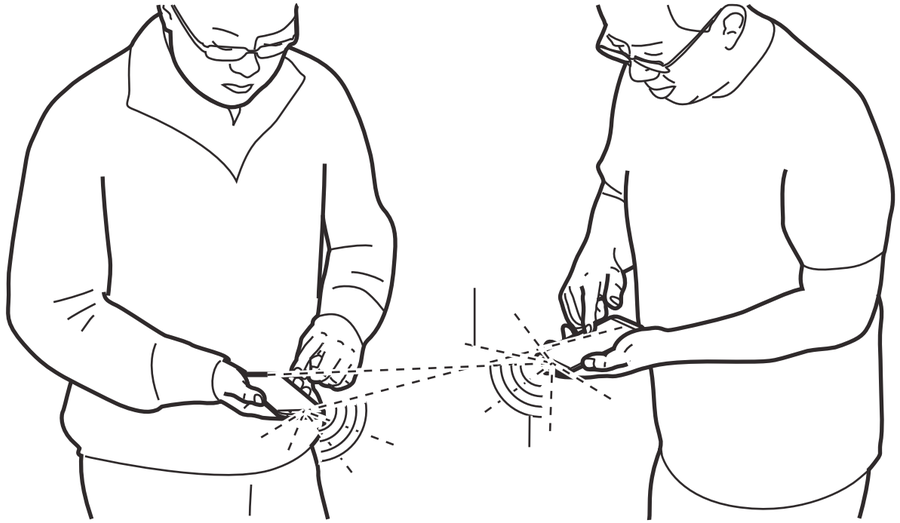
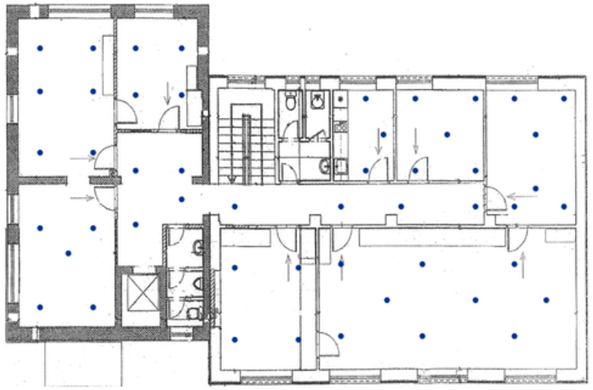
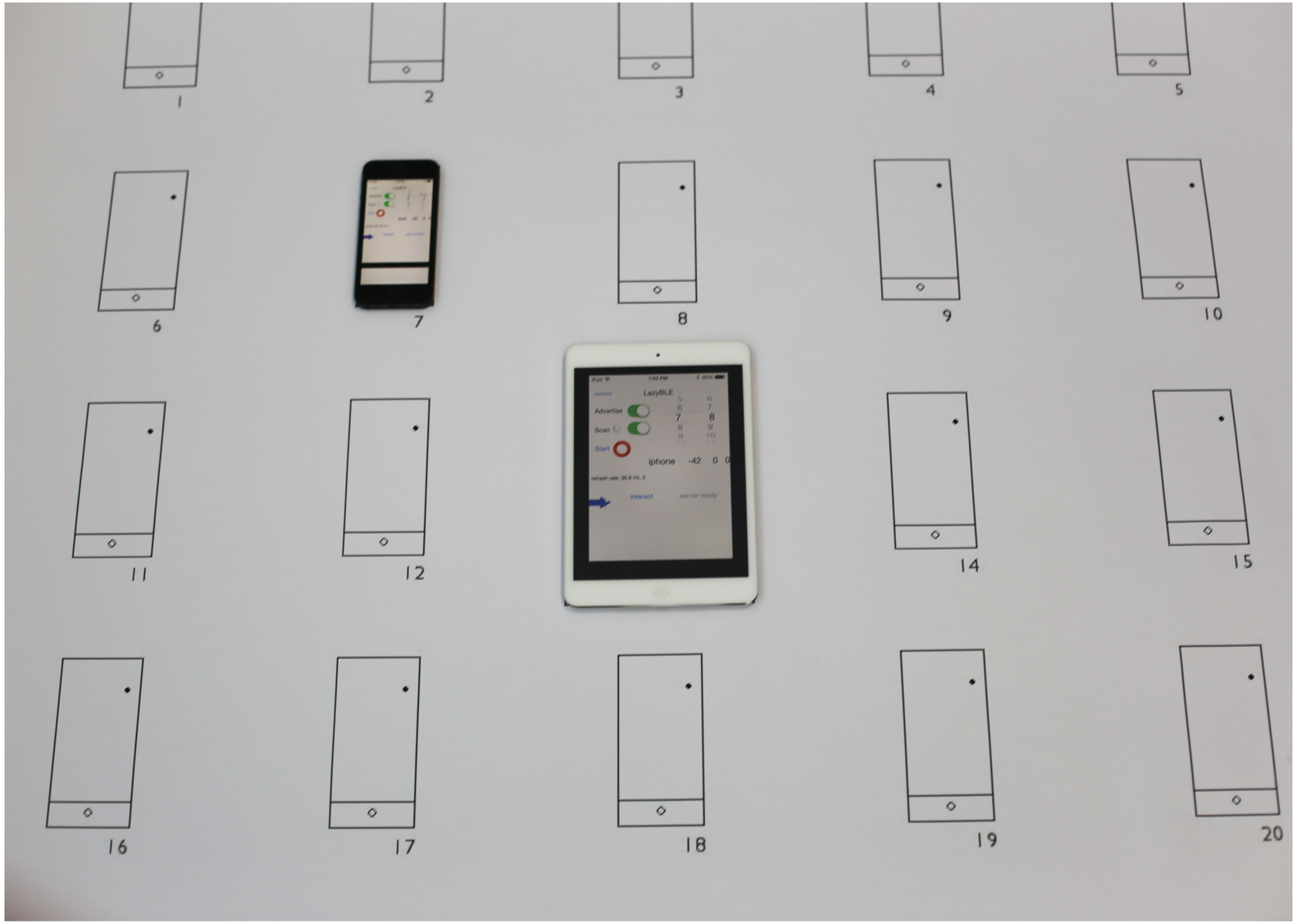


Tracko

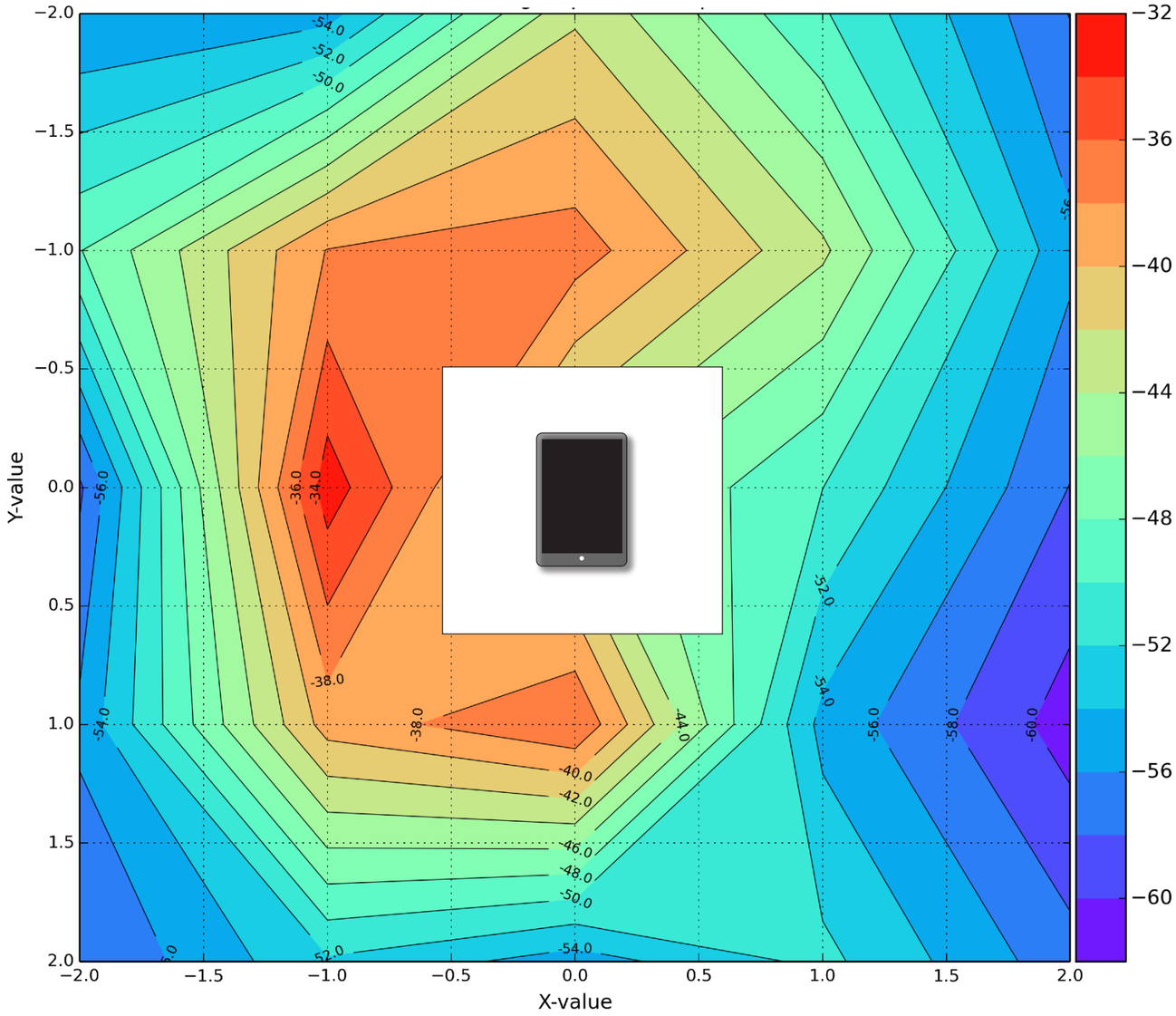


radio fingerprint

RSSI readings of iPhone from iPad



RSSI readings of iPhone from iPad



Why?

1. Off-center placement of the antenna

2. the antenna design

3. different material and shielding properties of the device.

asymmetric RSSI distribution

localization based on only two radios

1. adjacent in same plane
2. accuracy in centimeters
3. only two radios

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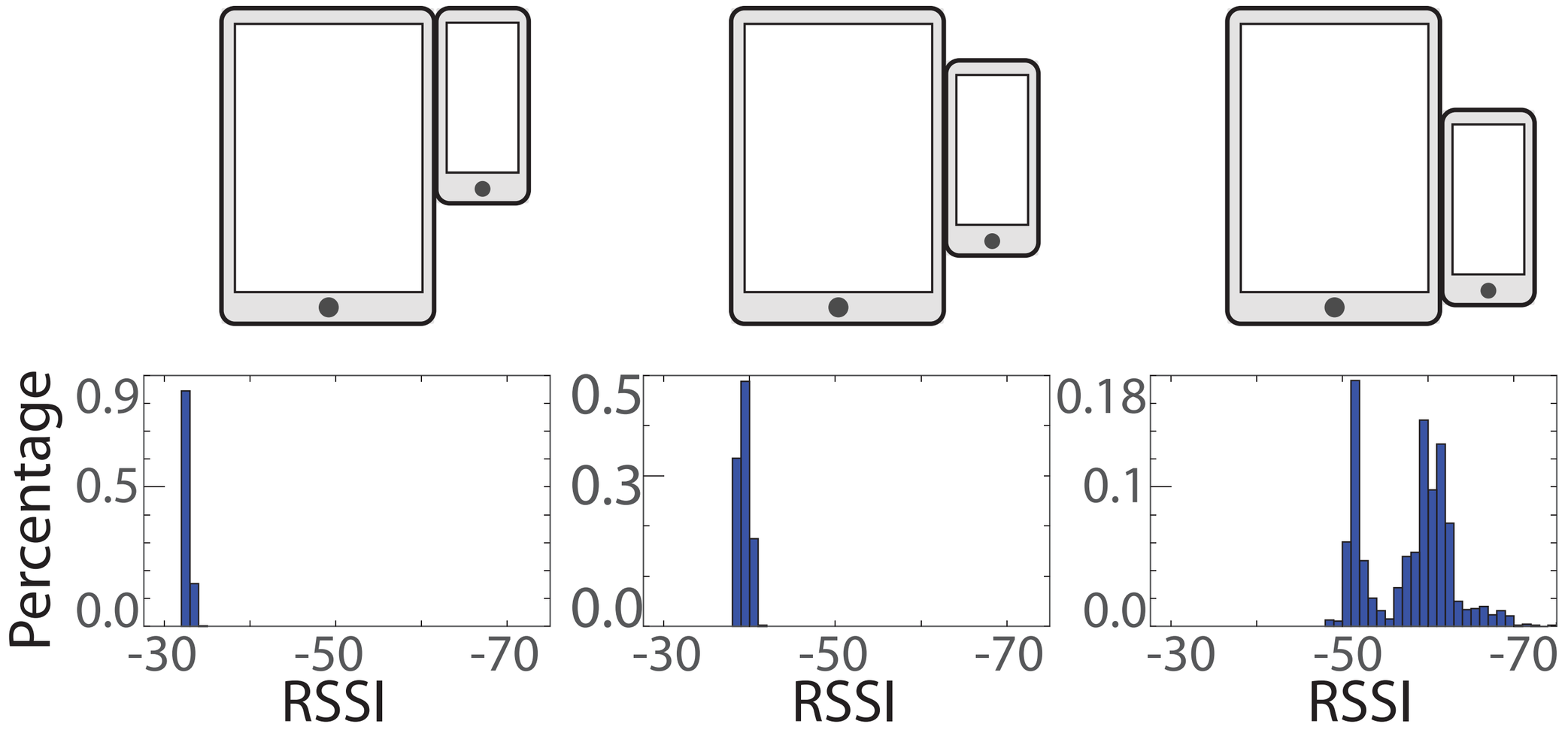
a technique that implicitly locates the position of adjacent mobile devices placed in the same plane.

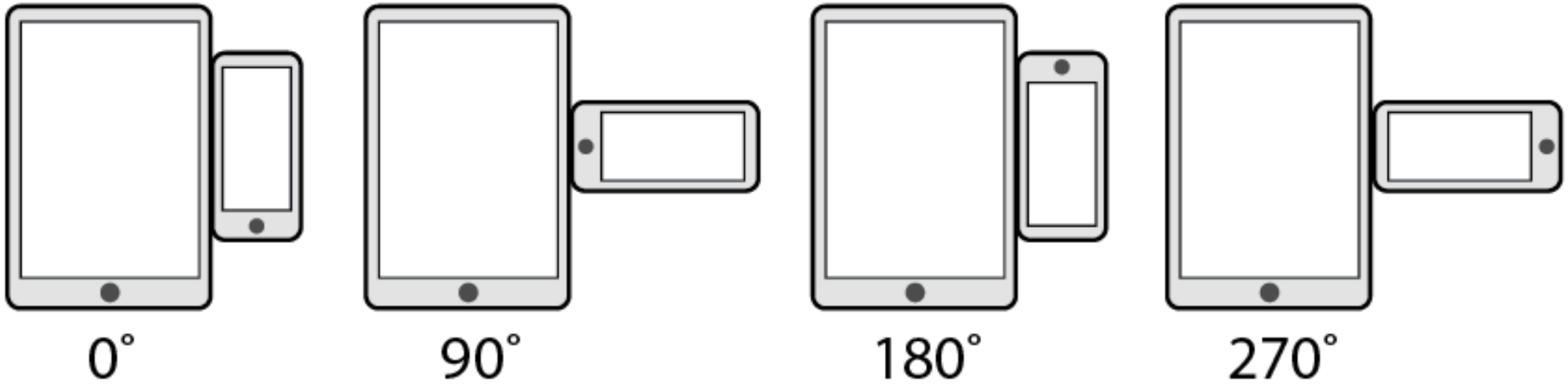
RSSI readings are repetitive in one position.

RSSI distributions are distinct between positions.

RSSI distributions at three positions along the device

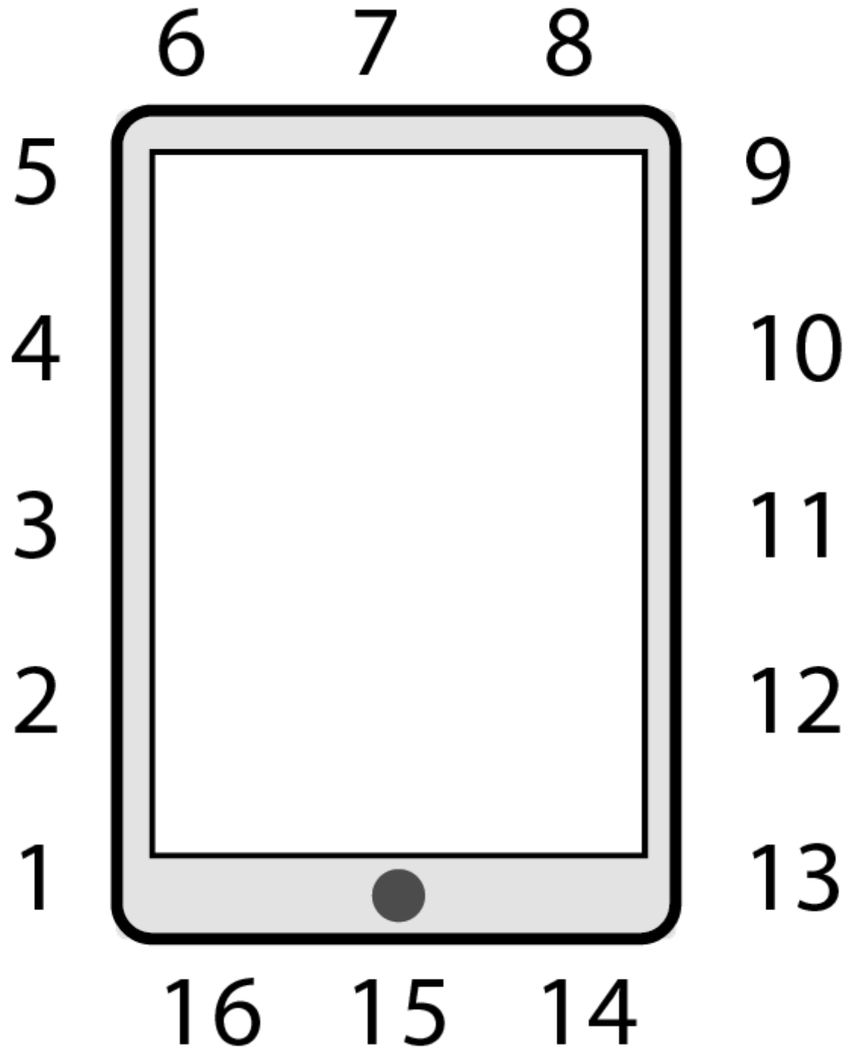


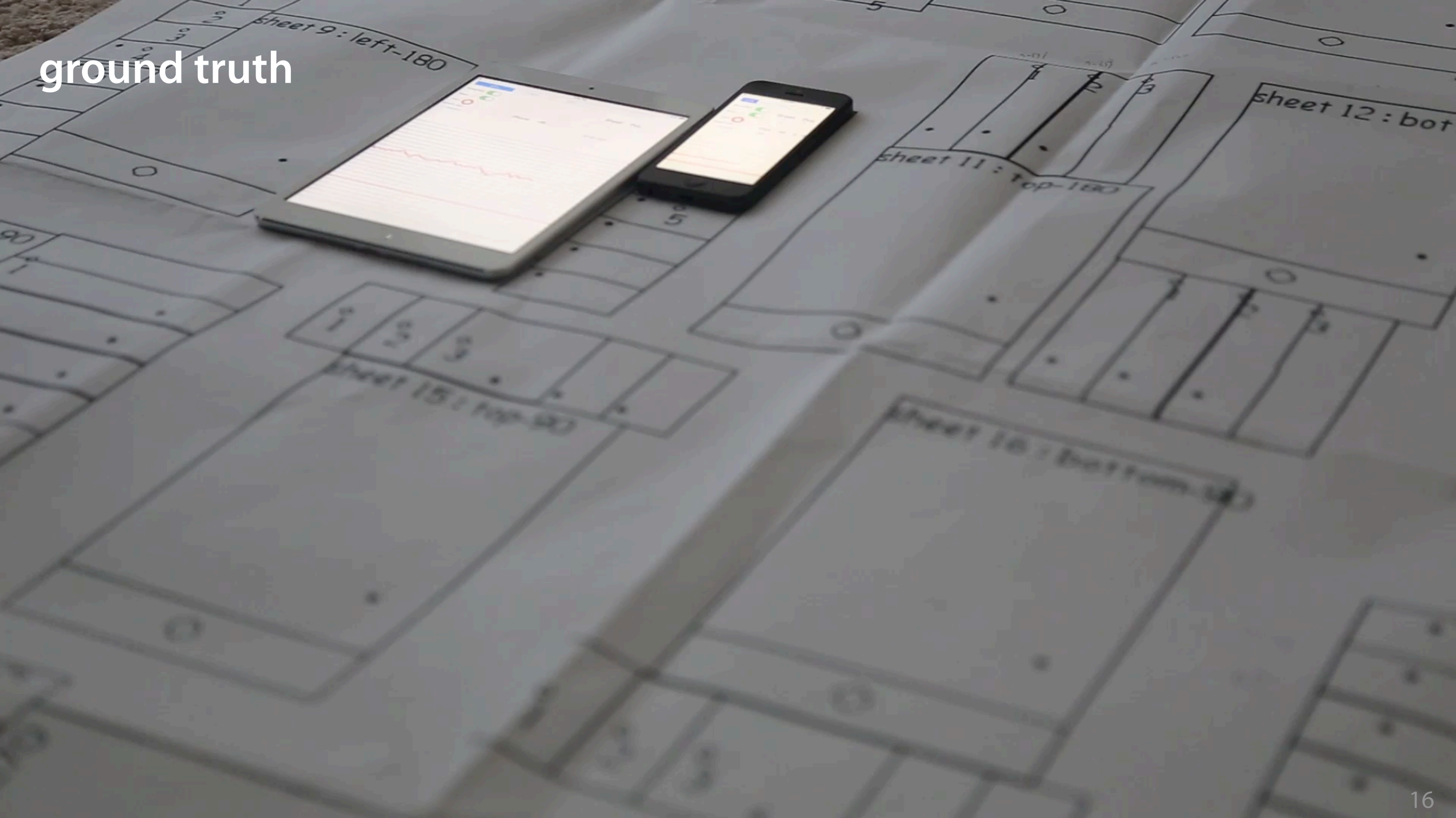
infer the orientation with compass and gyro



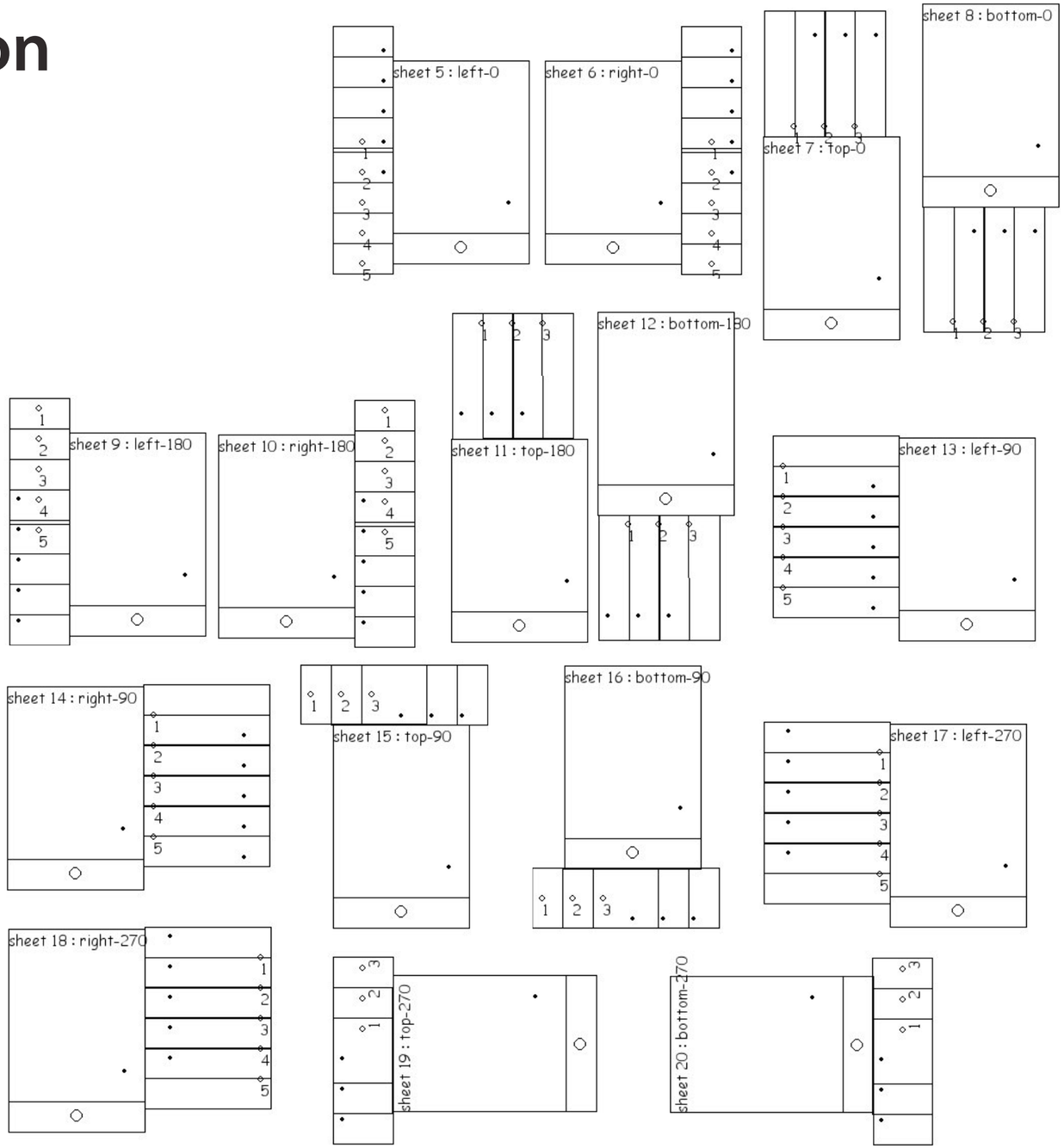
RSSI distribution model

positioning around iPad

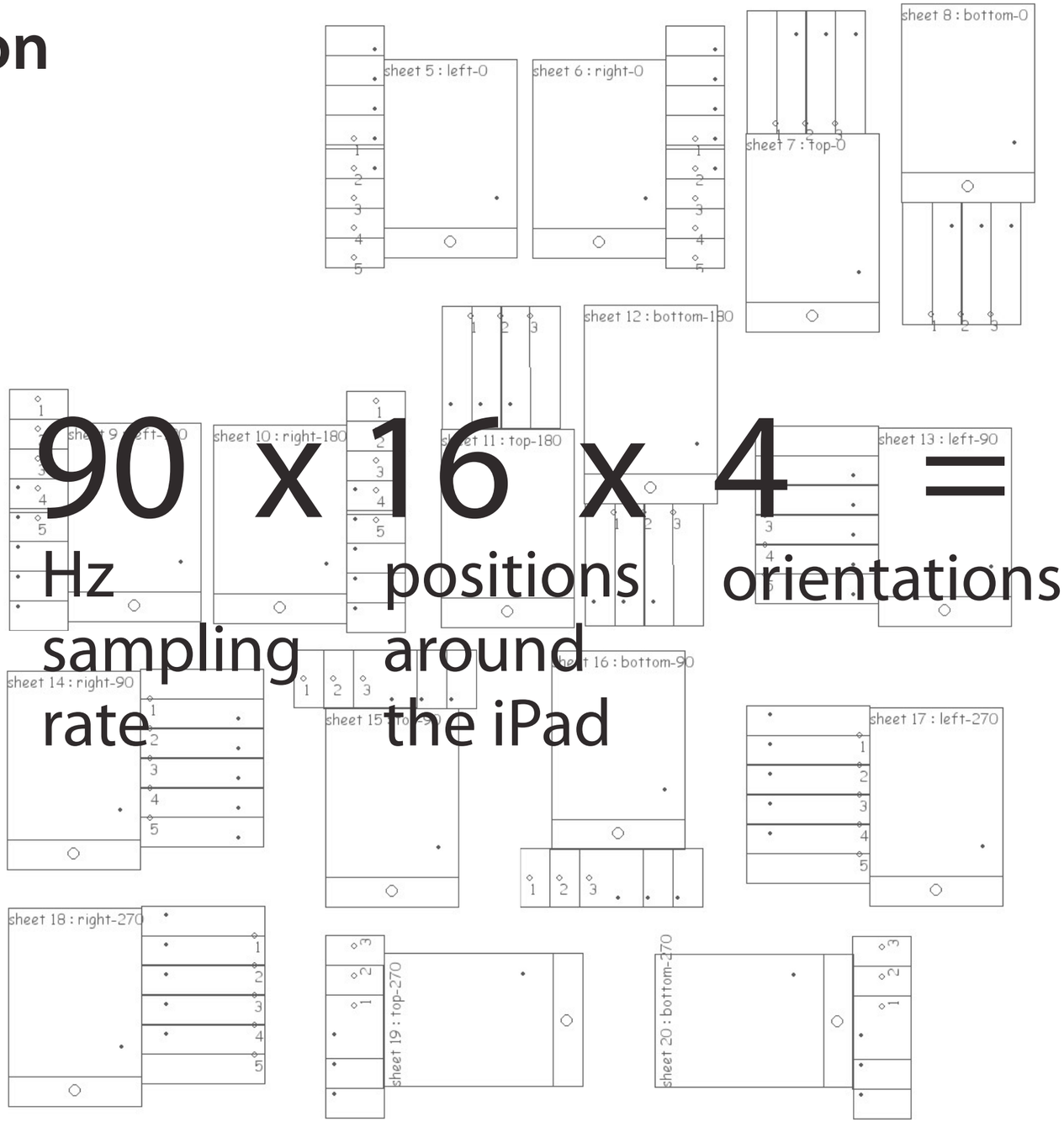



ground truth
sheet 9 : left-180
sheet 11 : top-180
sheet 12 : bot
sheet 15 : top-90
sheet 16 : bottom-up

data collection



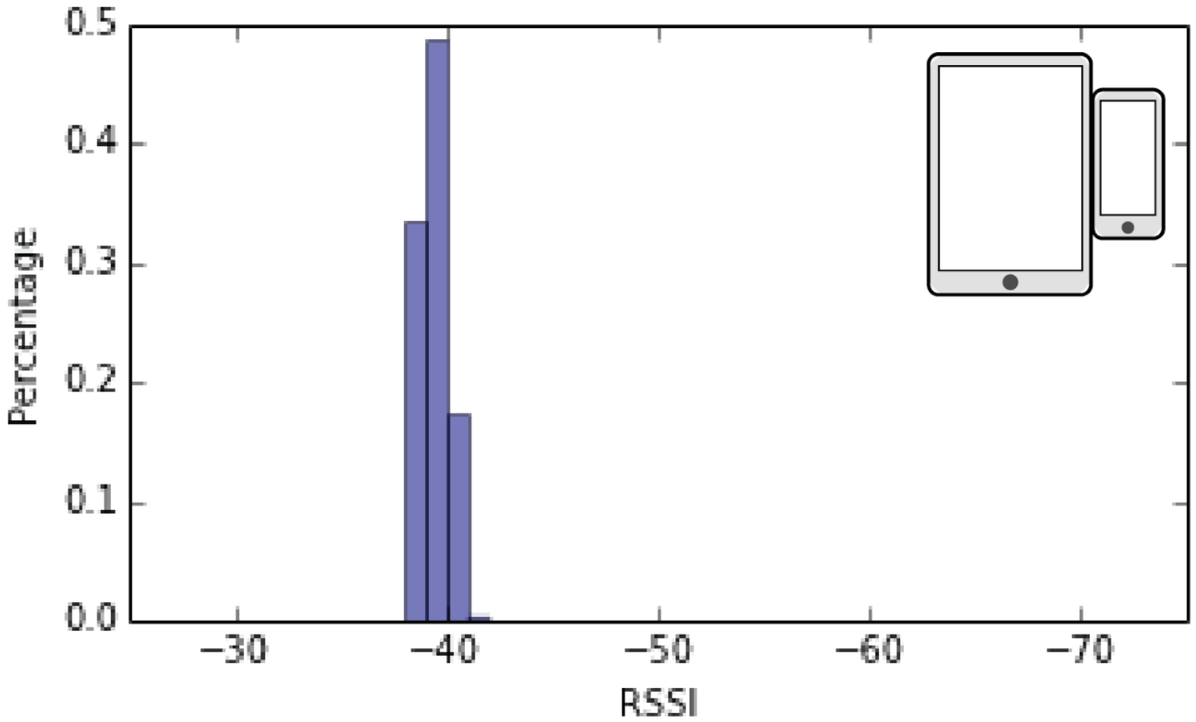
data collection



30 seconds per postion **x 90** Hz sampling rate **x 16** positions around the iPad **x 4** orientations **= 172,800** **RSSI readings**

Bayesian classification

discrete RSSI probability distribution

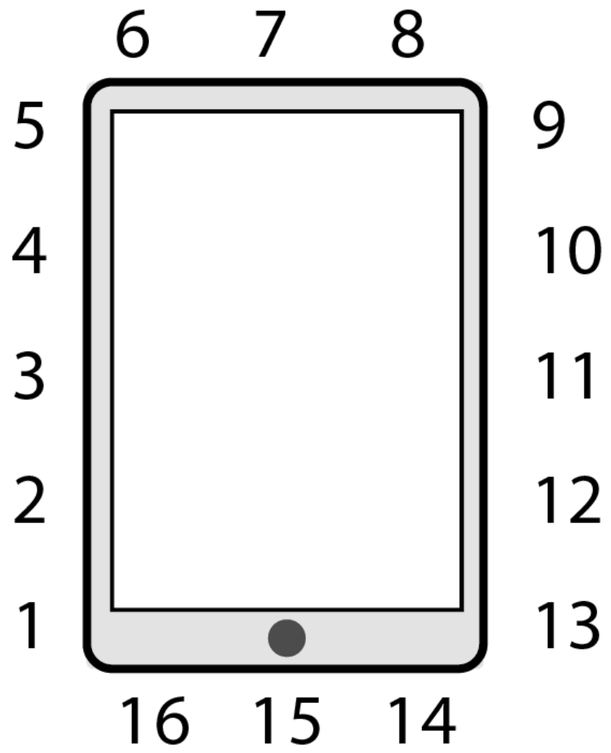


the possibility that RSSI *x*

happens at a specific position:

$$P(x|c) = \frac{count(x)}{totalcount}$$

bayesian classification



given the readings from iPhone and iPad

and the possibility distributions:

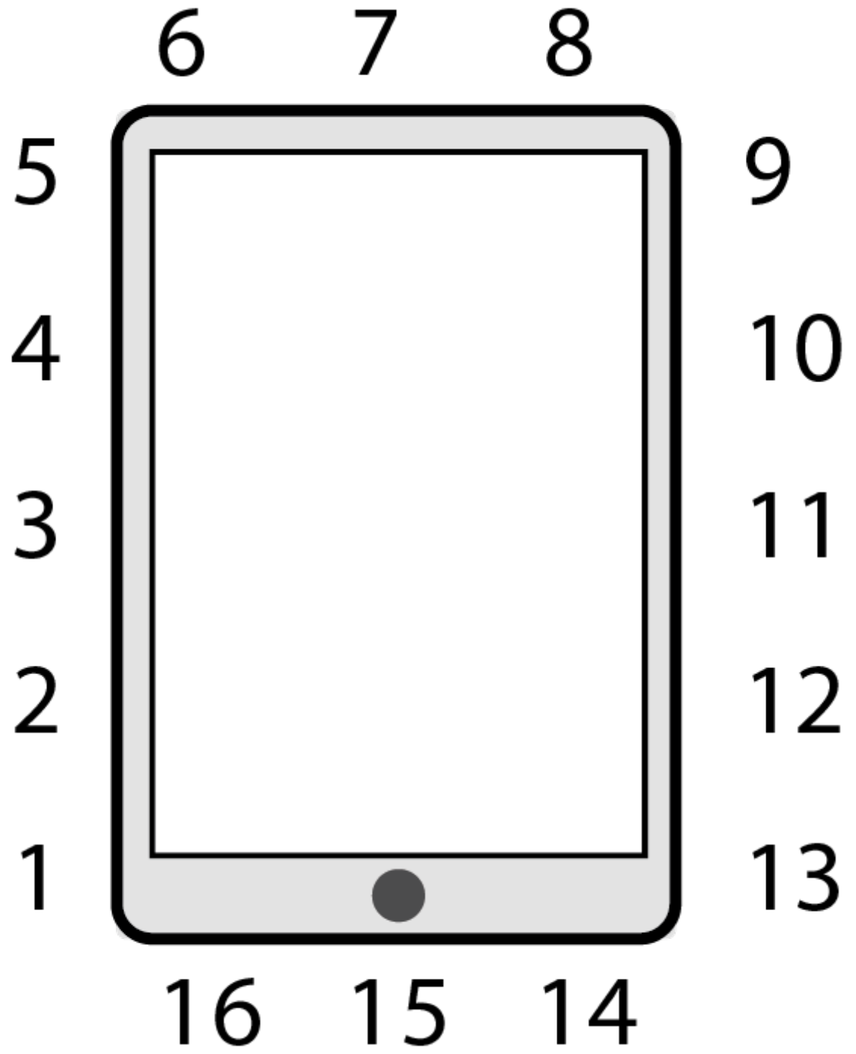
$$c^* = \underset{c}{\operatorname{argmax}} P(c|X,Y)$$

$$P(c|X,Y) = \frac{P(X,Y|c)P(c)}{P(X,Y)}$$

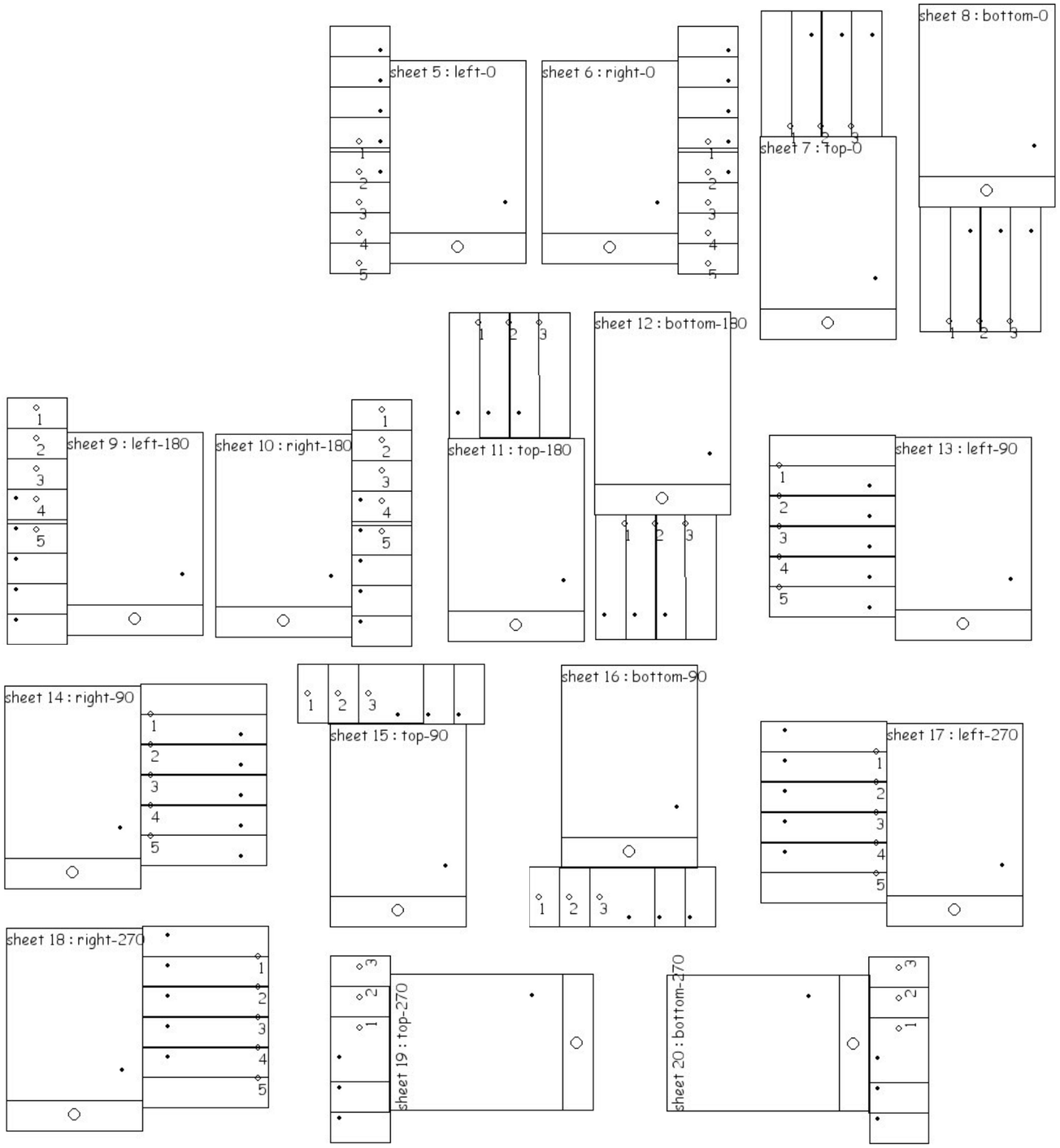
$$P(X,Y|c) \sim \log\left(\prod_{m=0}^{k} P(x_m|c) * \prod_{m=0}^{k} P(y_m|c)\right)$$

evaluation and results

evaluations with aligned positions

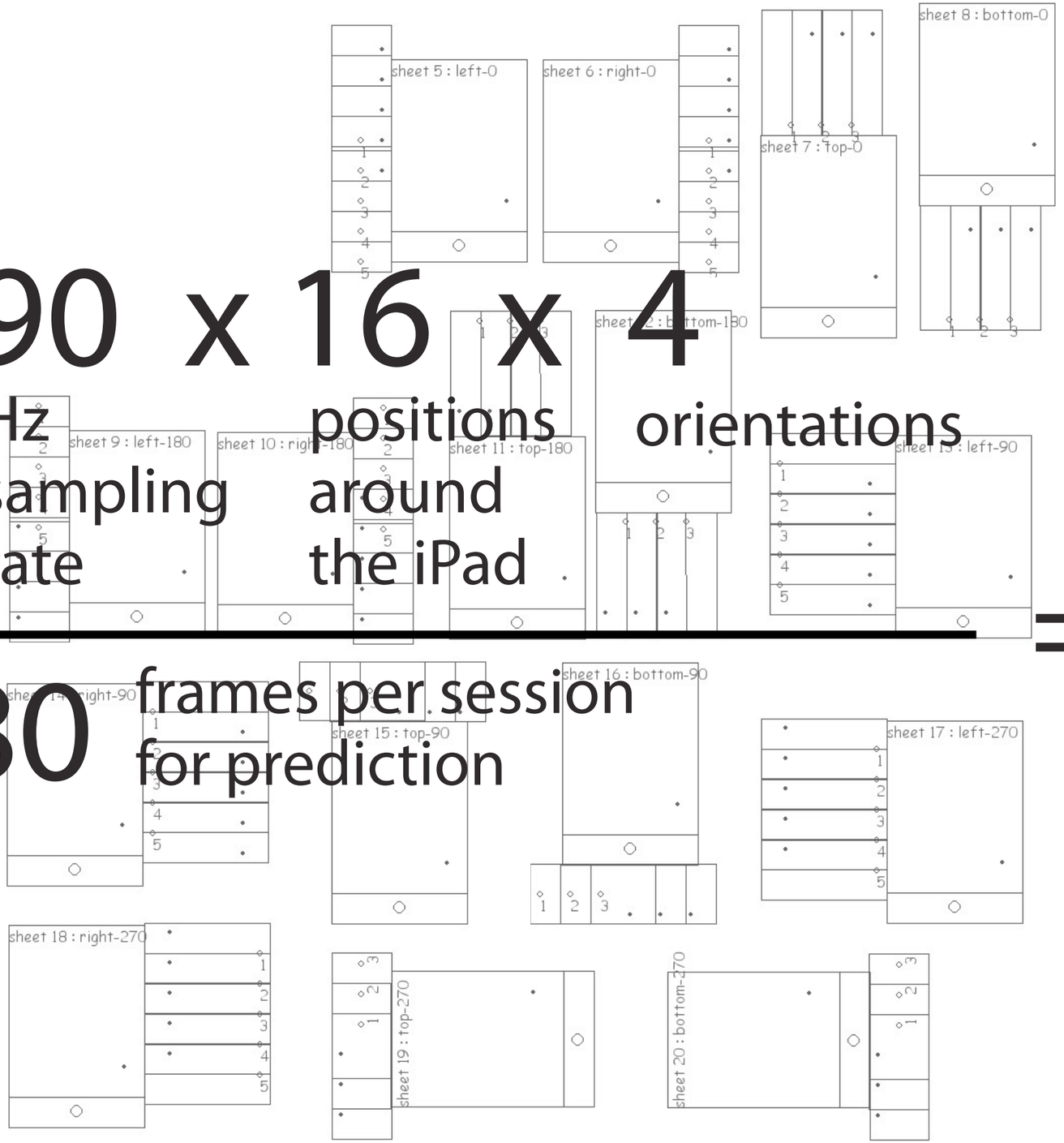


data collection

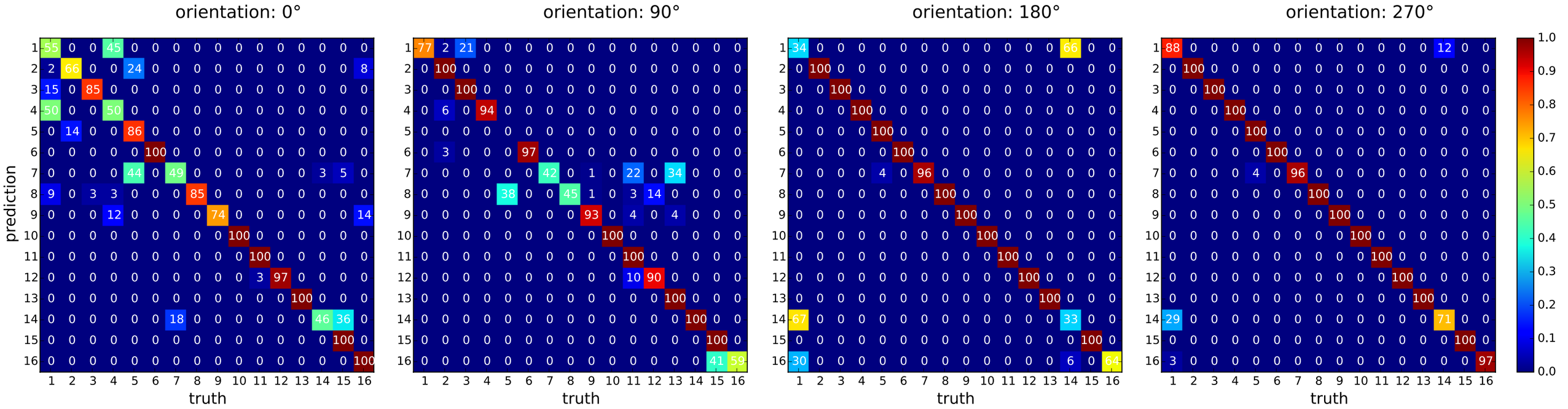


data collection

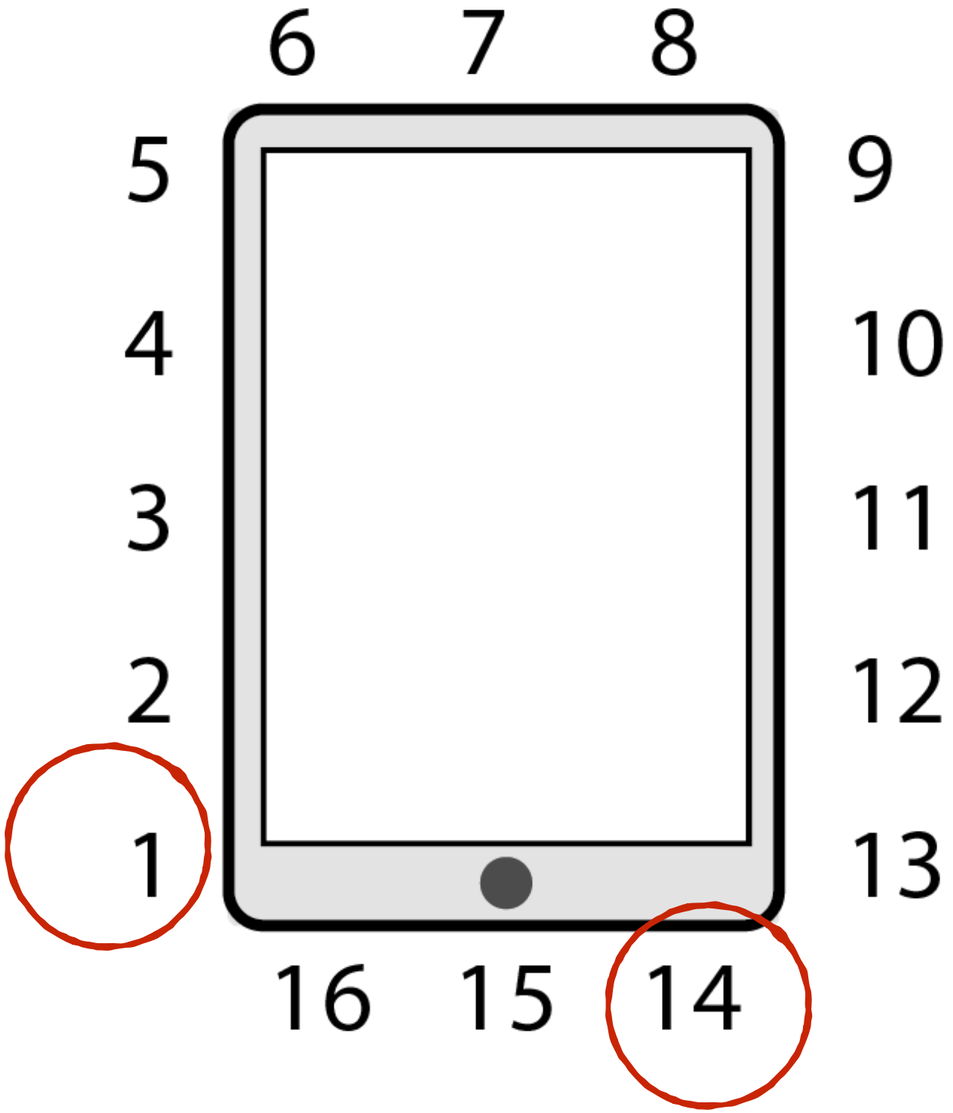
$$\frac{30 \text{ seconds per postion} \times 90 \text{ Hz sampling rate} \times 16 \text{ positions around the iPad} \times 4 \text{ orientations}}{80 \text{ frames per session for prediction}} = 2{,}160 \text{ predictions}$$



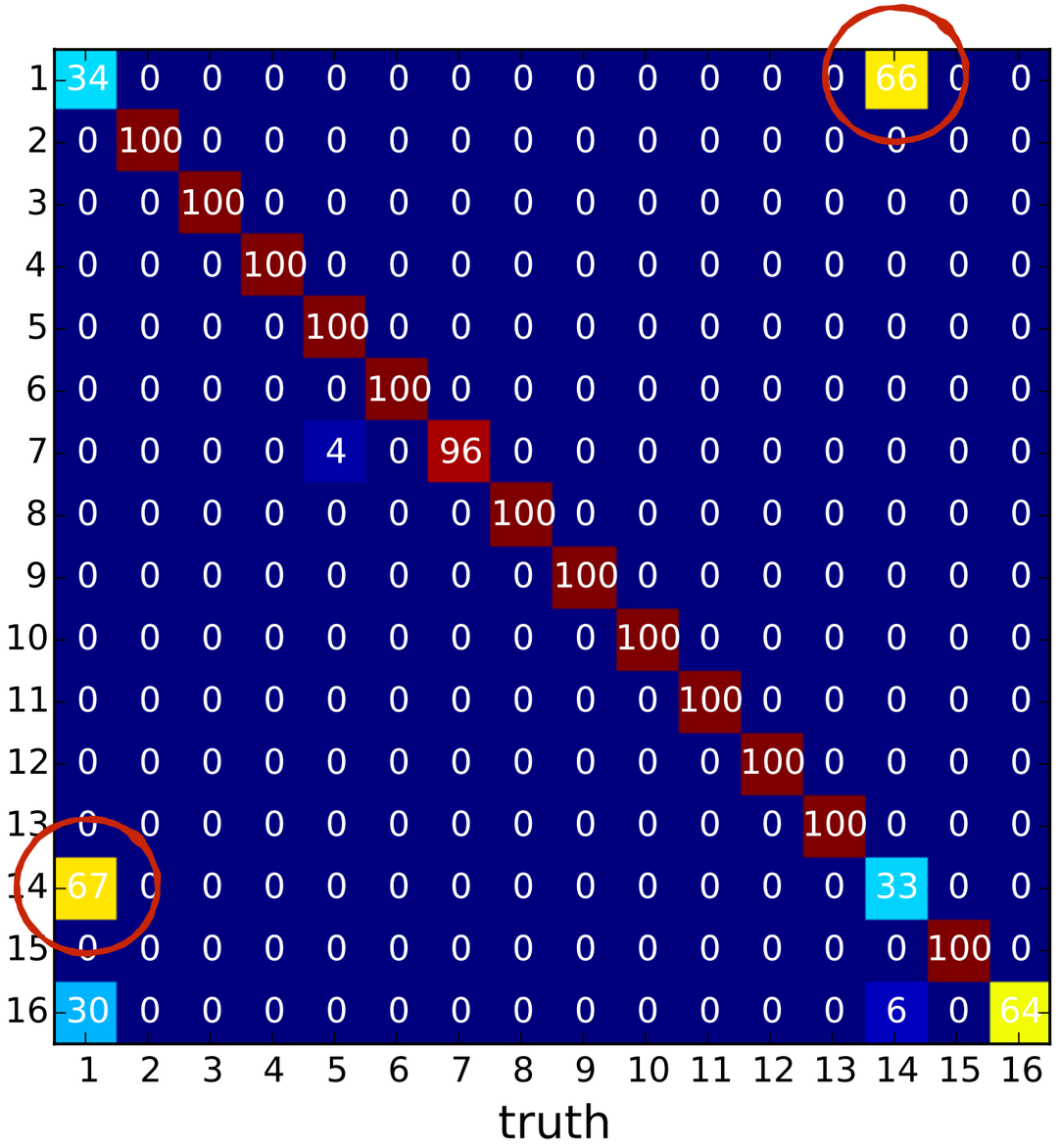
evaluations with aligned positions



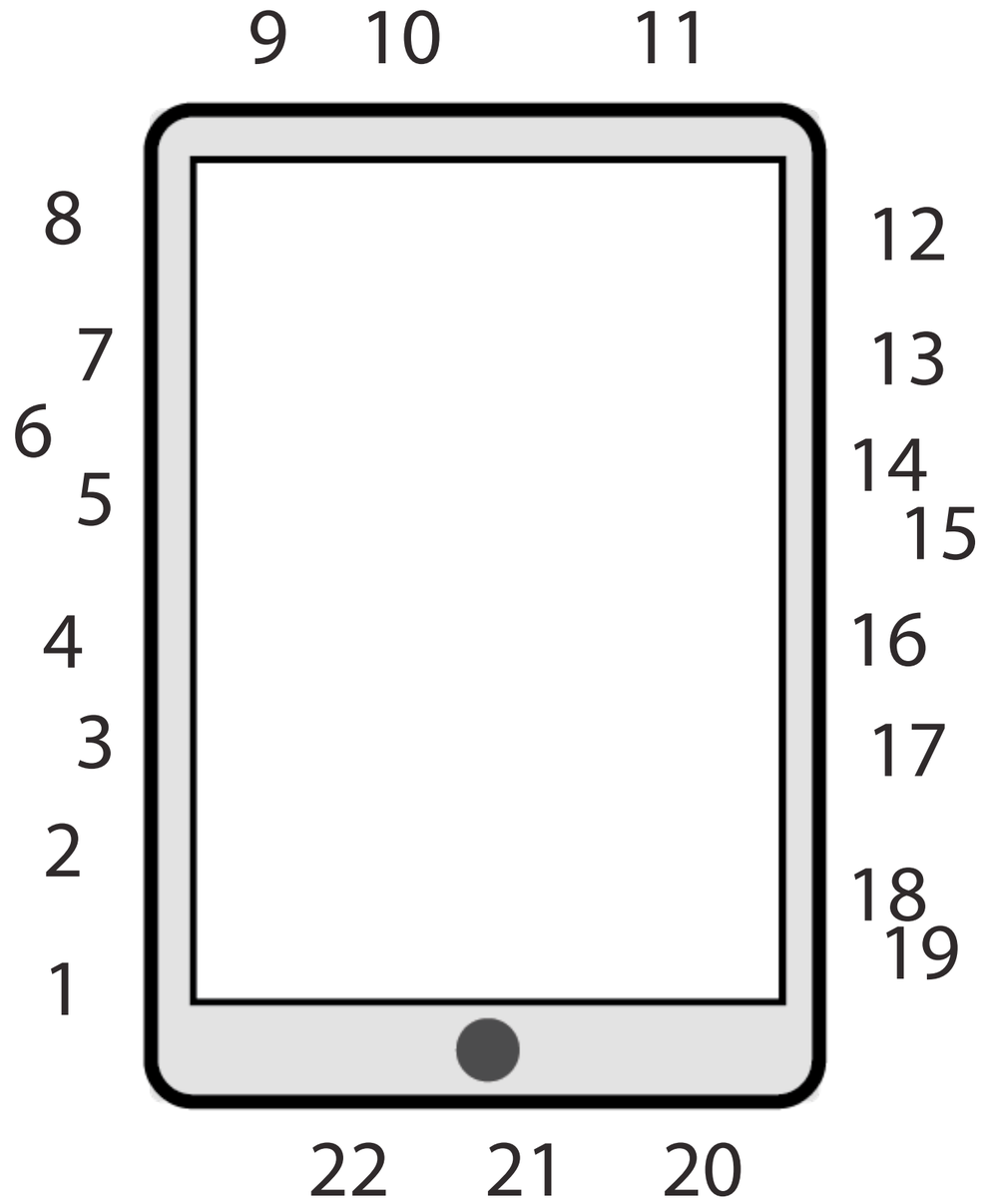
ambiguity areas



orientation: 180°



evaluations with unaligned positions

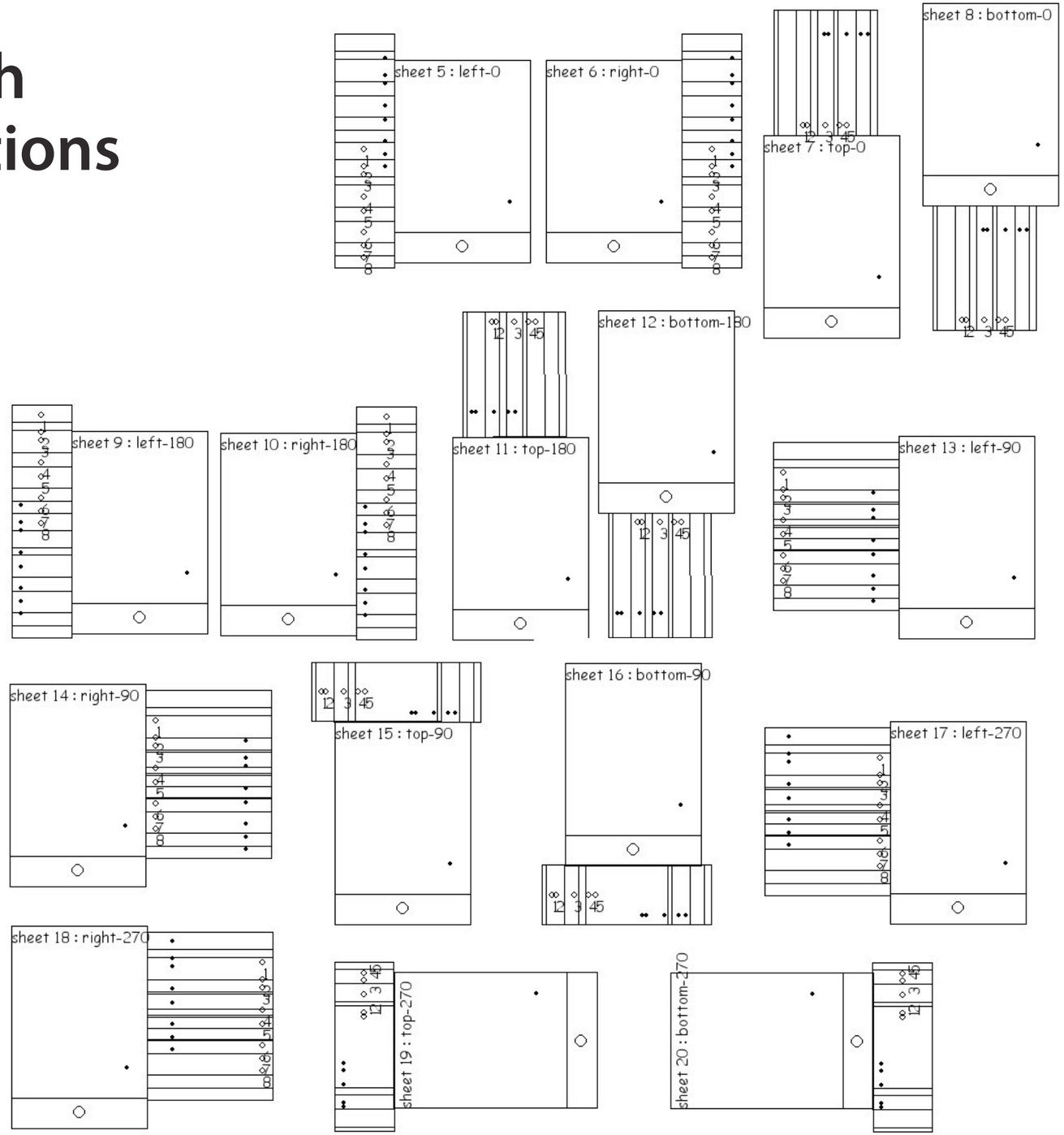


position interpolation

linear interpolation of adjacent candidates with top scores

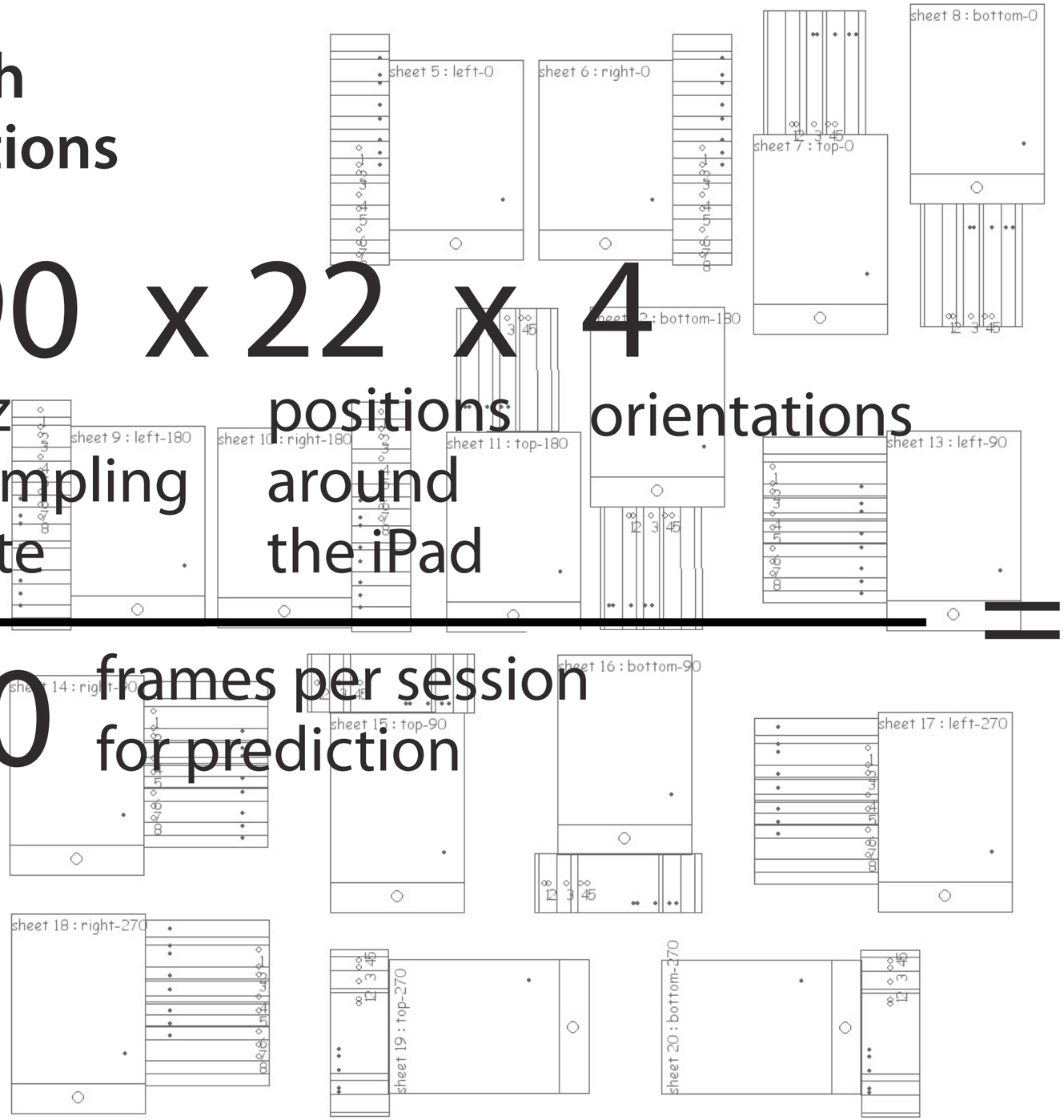
$$c_{final} = \frac{c^* * P(X|c^*) + c_{next} * P(X|c_{next})}{P(X|c^*) + P(X|c_{next})}$$

evaluations with unaligned positions



evaluations with unaligned positions

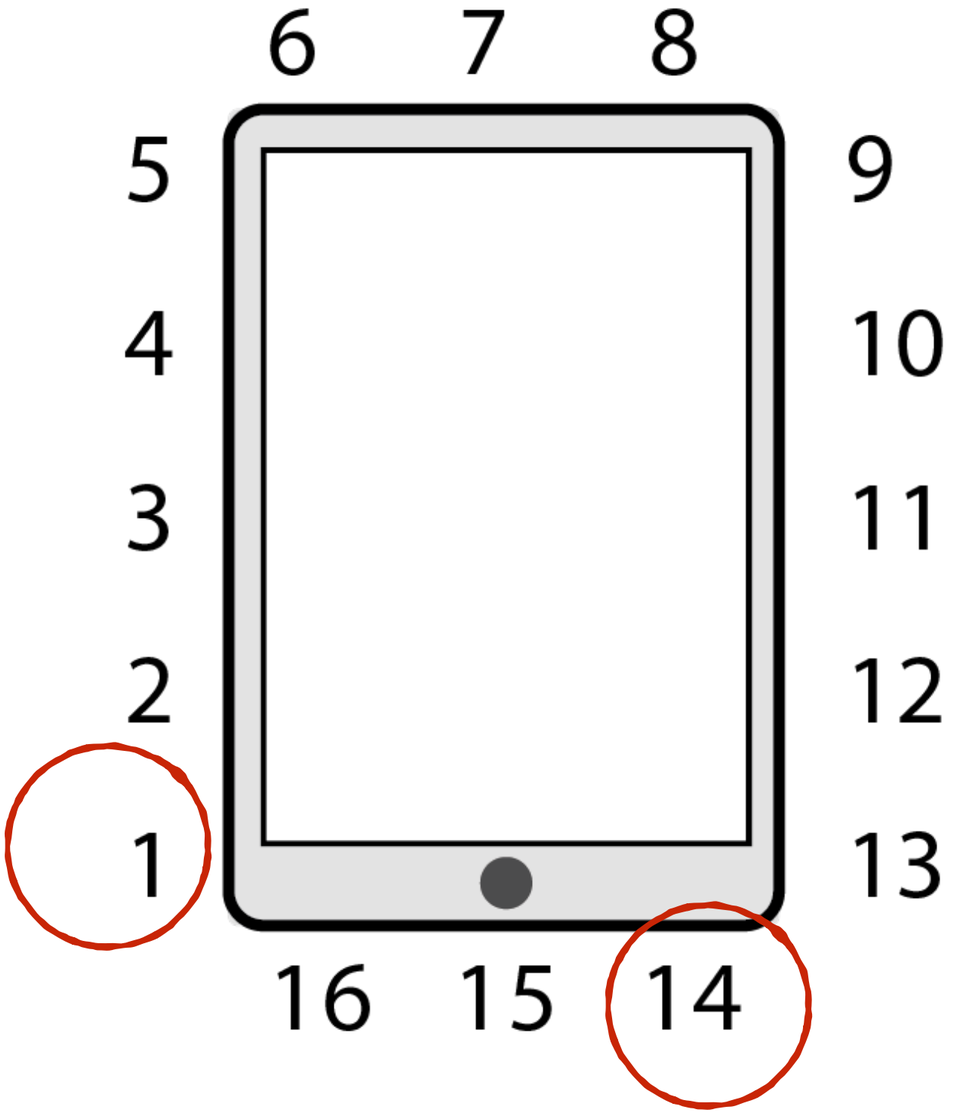
$$\frac{30 \text{ seconds per postion} \times 90 \text{ Hz sampling rate} \times 22 \text{ positions around the iPad} \times 4 \text{ orientations}}{80 \text{ frames per session for prediction}} = 2{,}970 \text{ predictions}$$



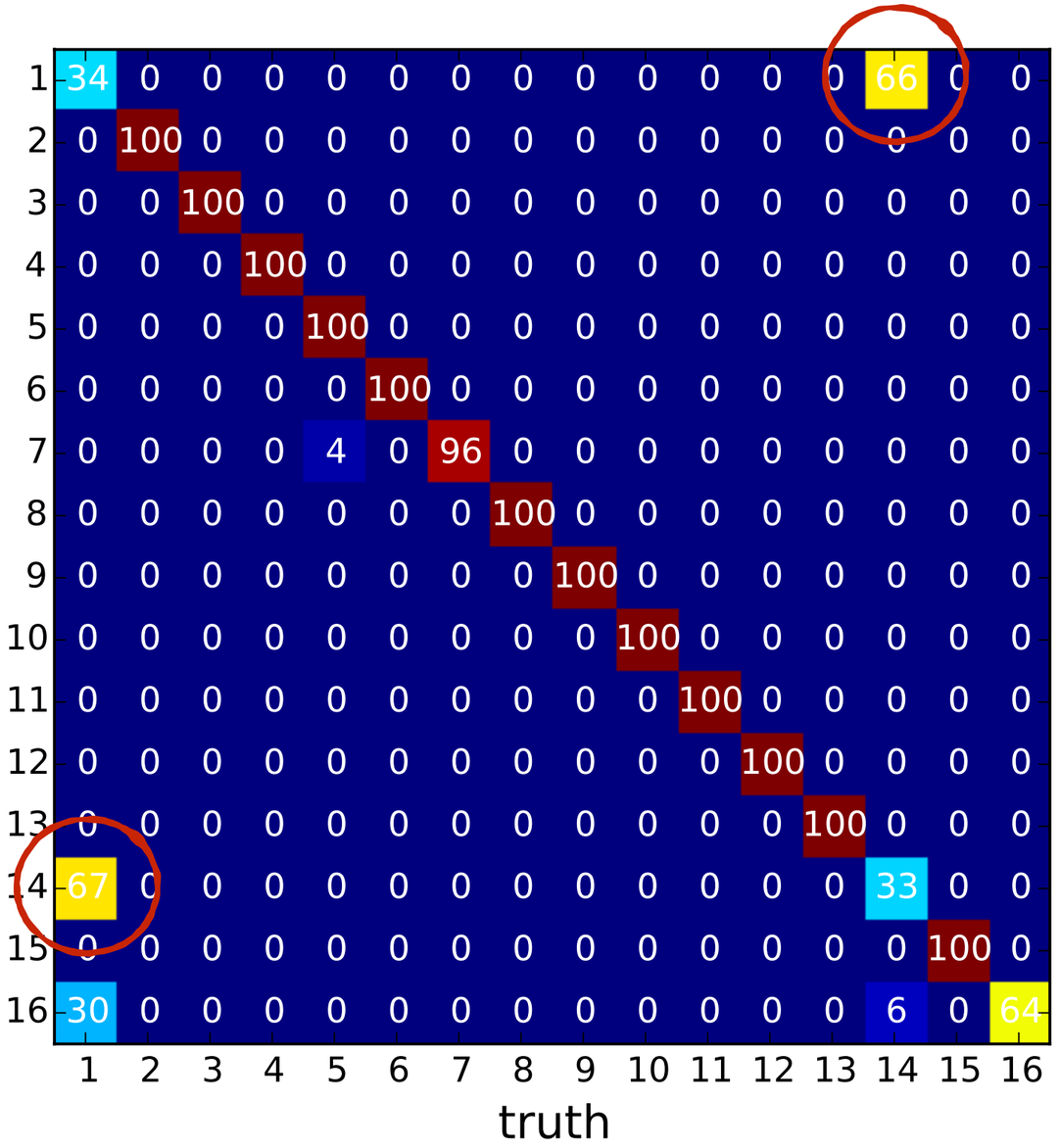
evaluations with unaligned positions

Orientations	Top-1	Top-2
0°	63.75%	90.14%
90°	41.79%	79.48%
180°	50.87%	88.84%
270°	50.92%	85.32%

handle ambiguity areas

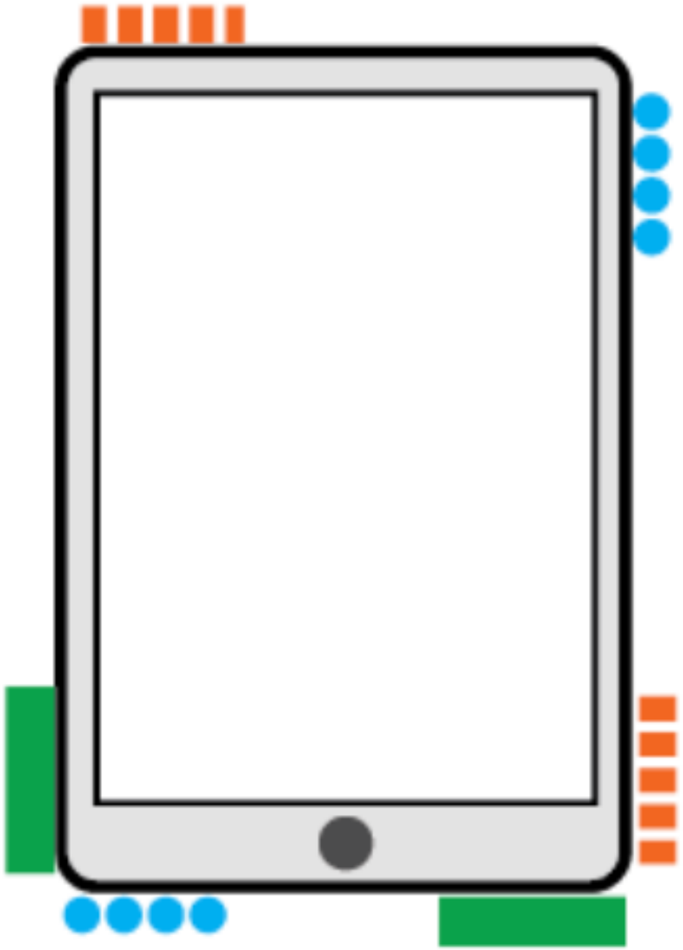


orientation: 180°



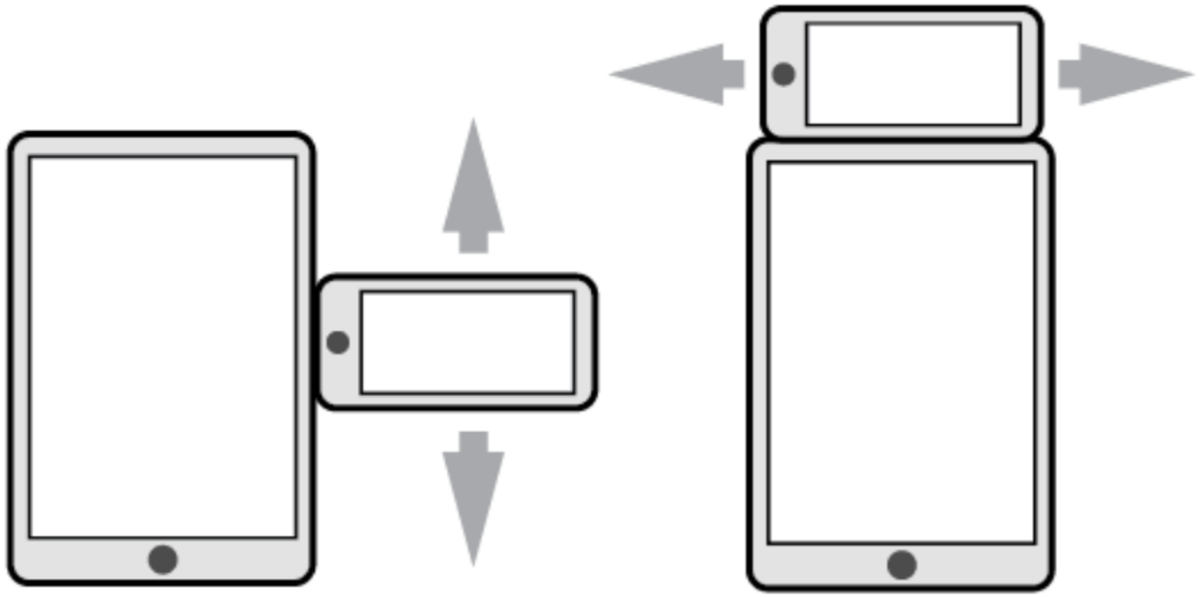
sensor fusion in application

ambiguity



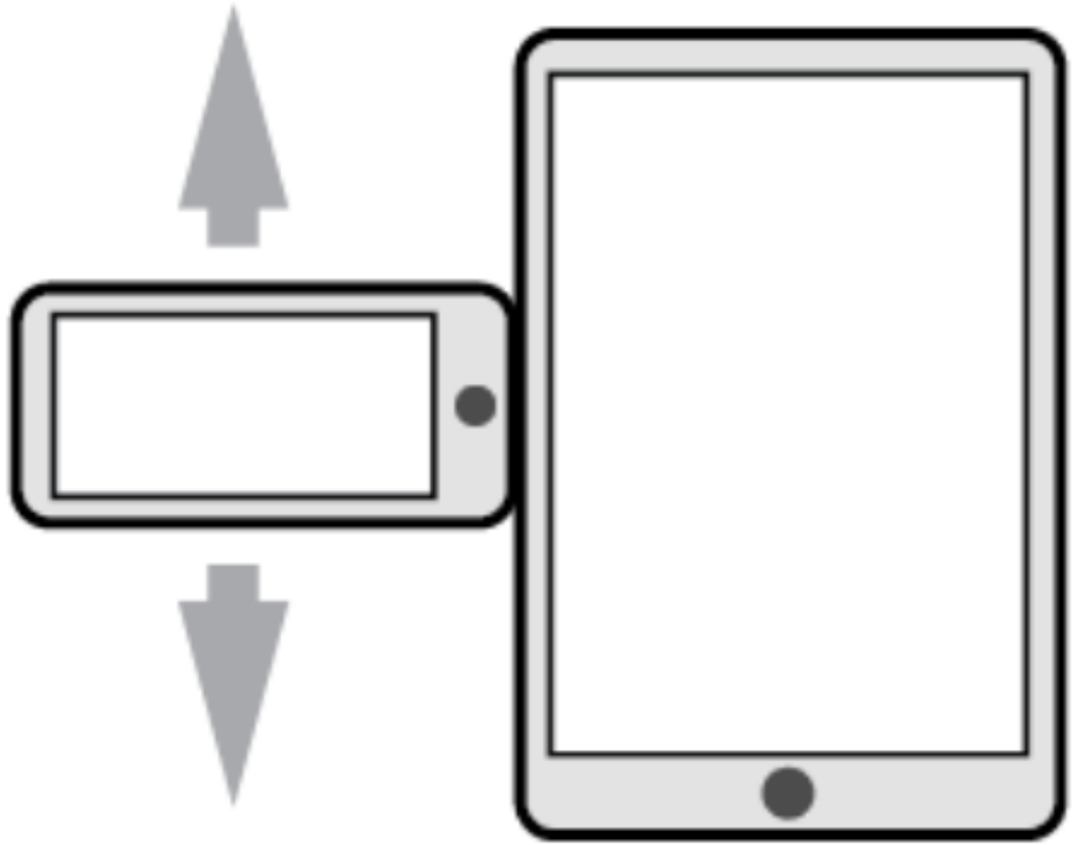
most ambiguity happens on different sides.

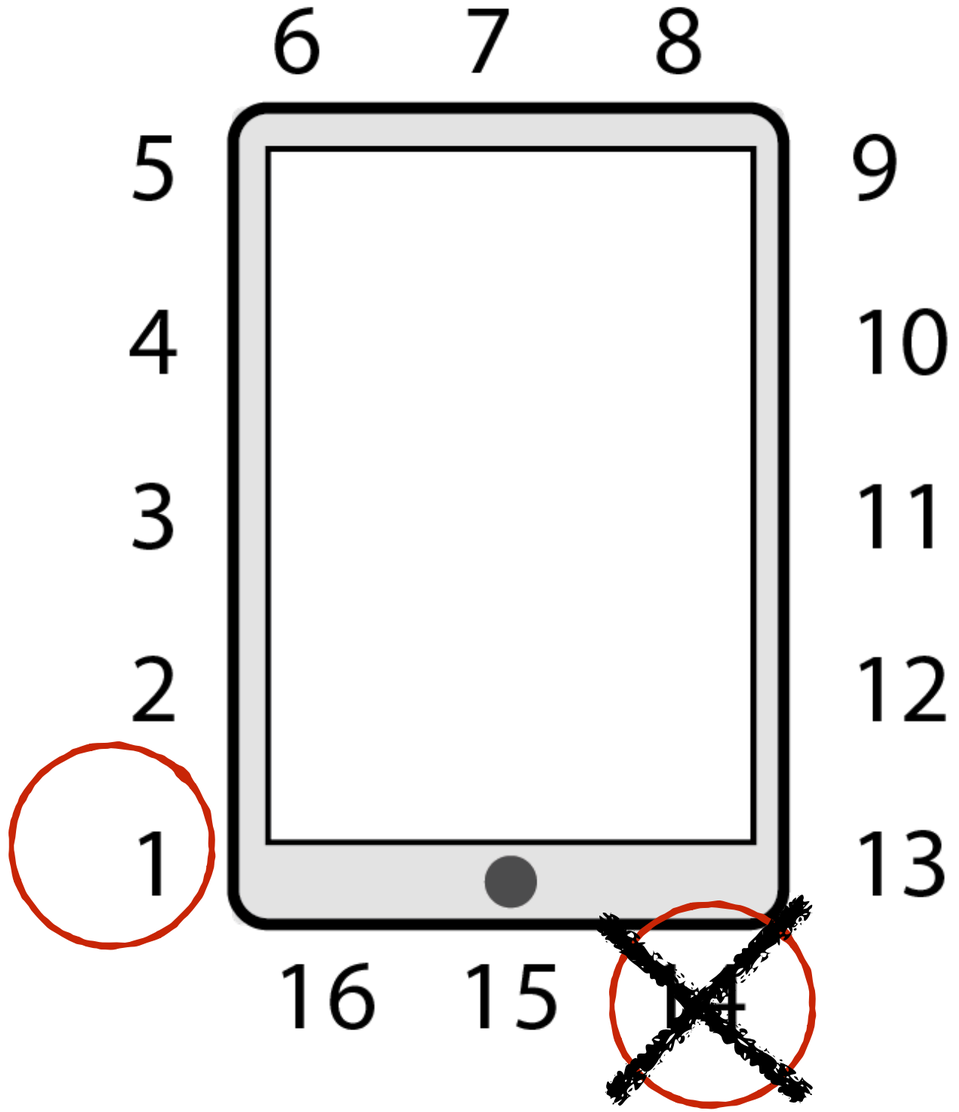
ambiguity



the movement direction determines the device on long sides or short sides

ambiguity





future work

generalizability

1. Other devices of the same type
2. Devices of different types
3. Additional device interference.
4. Battery level influences


same plane in the air

more angles than the same plane

Corona

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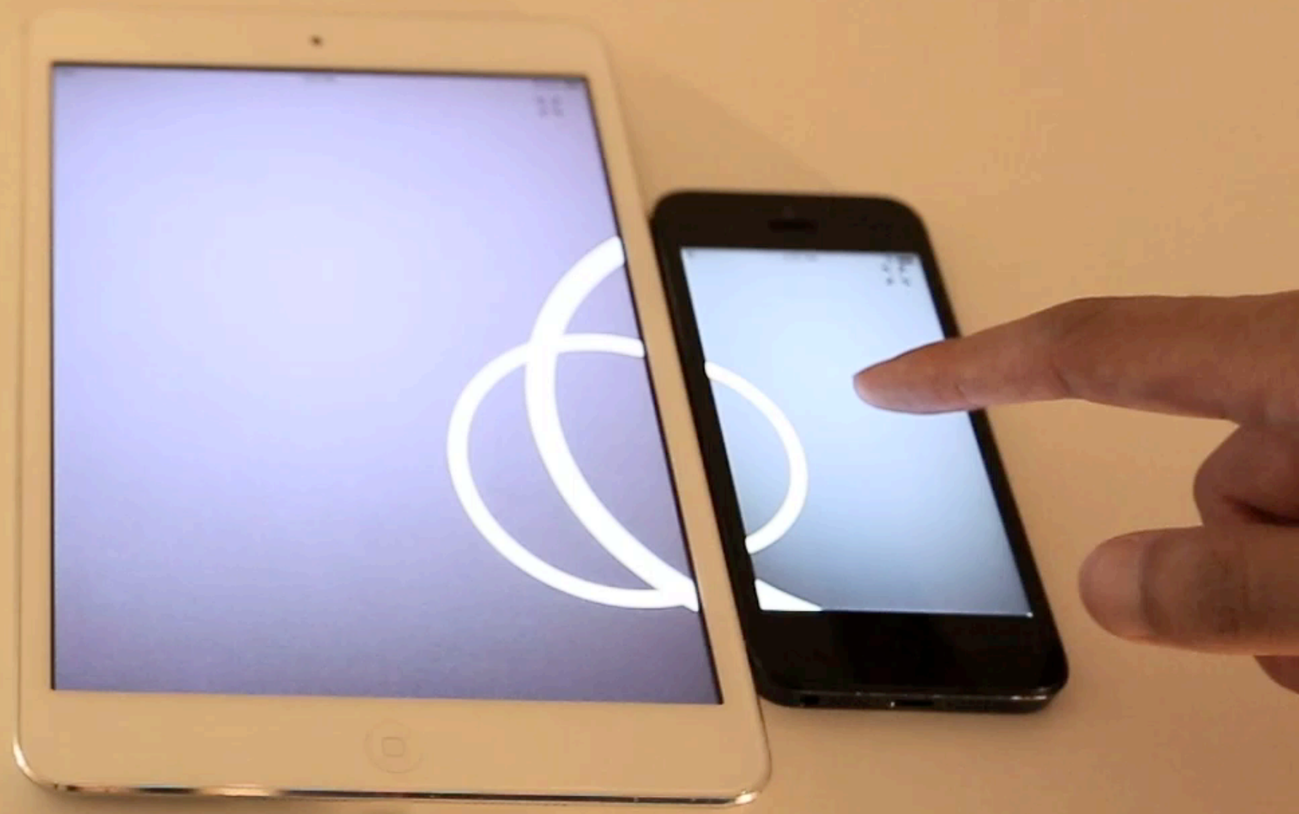

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