Future Tech

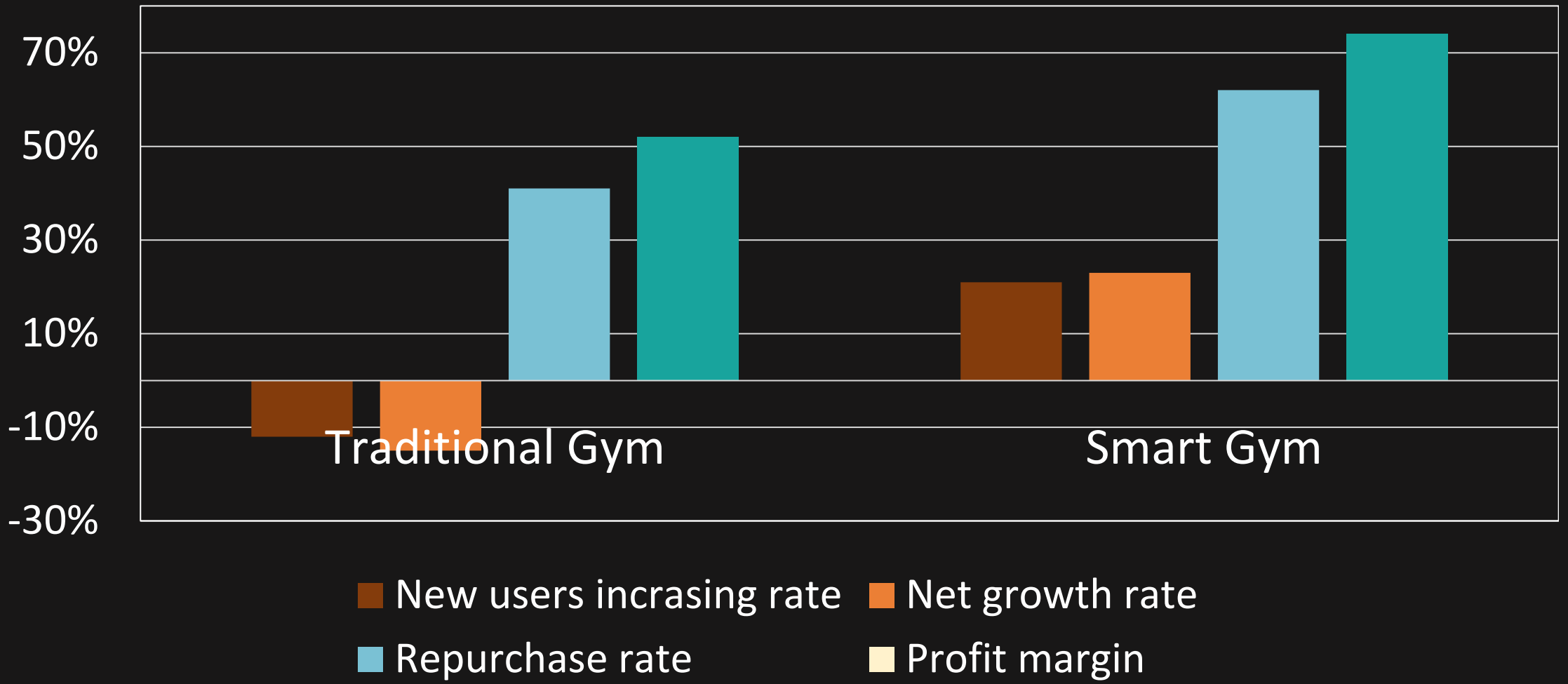
Multimodal Physiological and Behavioral Data Fusion Based Mass Fitness Intelligent Guidance System

基于多模态生理及行为数据融合的大众健身智慧指导系统

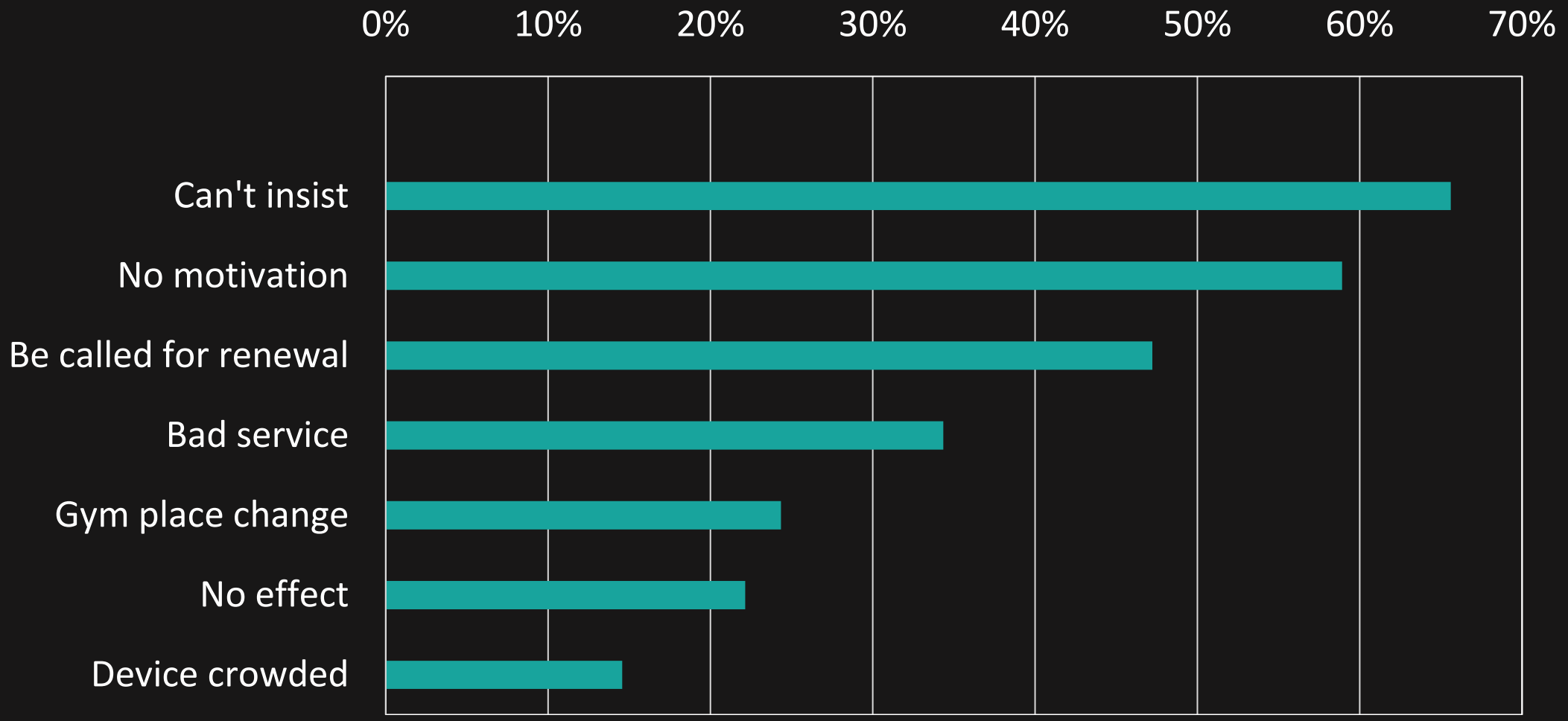
陈冠霖，沈鑫杰，吴洋

Instructor: 徐向民

Gym’ survey


70%
50%
30%
10%
-10%
-30%
Traditional Gym
Smart Gym
New users incrasing rate
Net growth rate
Repurchase rate
Profit margin

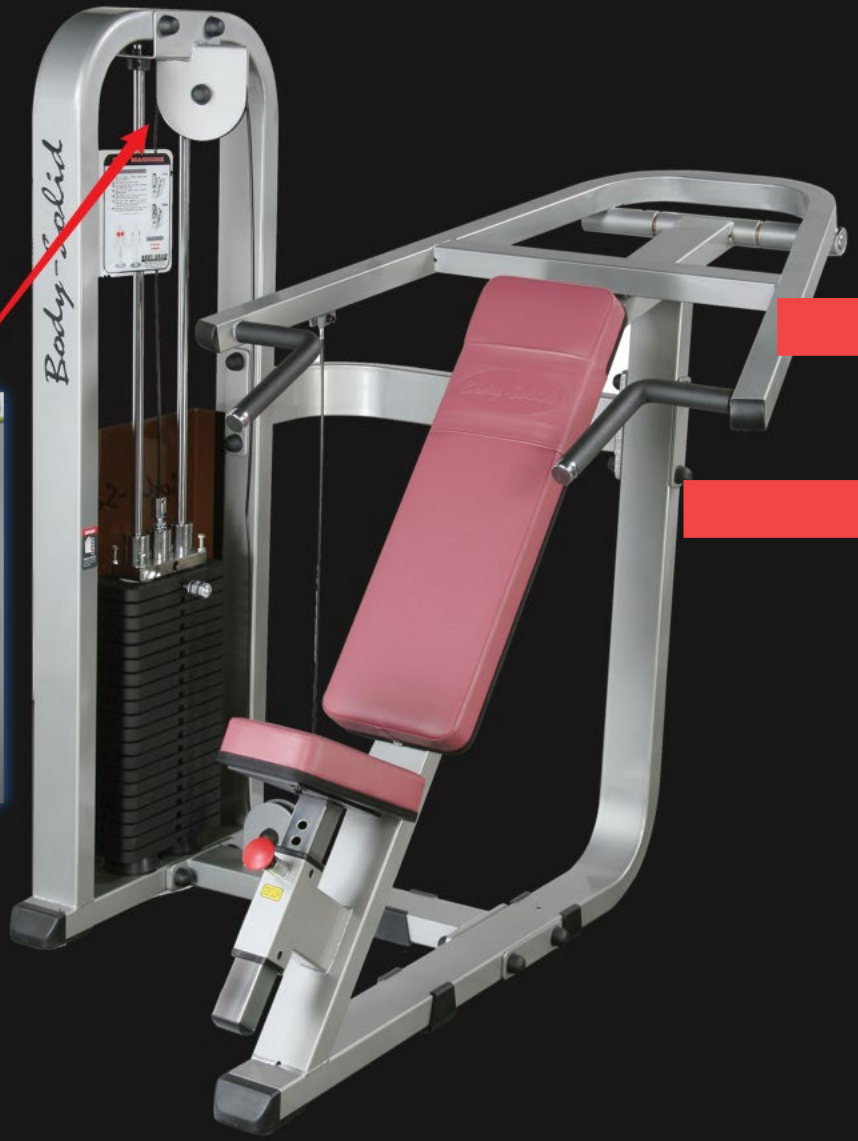
Users' survey



Data collected from 2020 China fitness industry data report

	Equipment Support	Fitness instructions	User Pose Correction	Fitness data acquirement	Closed-loop feedback
Our work	√	√	√	√	√
Keep	x	x	√	x	x
Sports bracelet	x	√	x	x	√
Future Magic Mirror	x	√	√	√	x

Movement

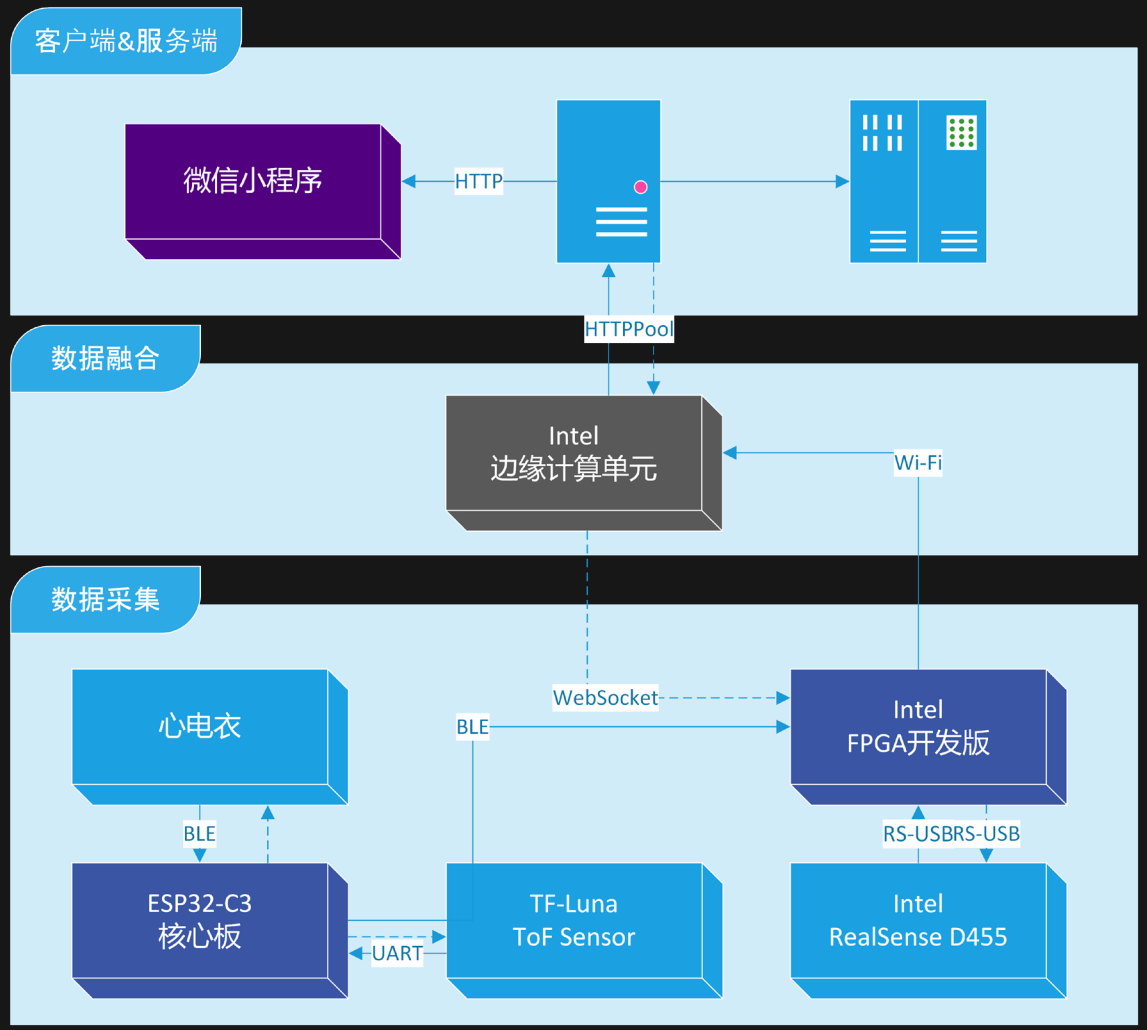


Scores

Feedback

Instructions

Overview



Using **hardware** to measure movement, and turn it into data

Algorithms which deployed in **sever** make data into scores and offer recommendation

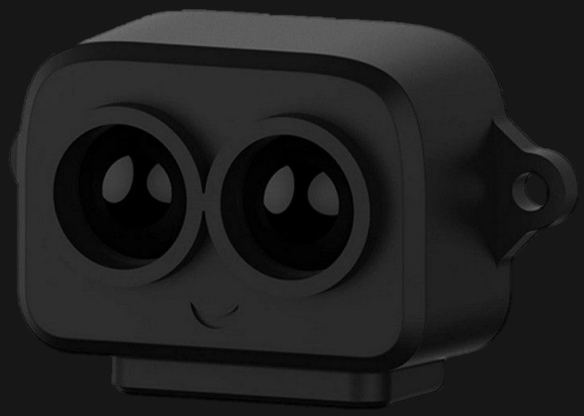
Scores and feedbacks are delivered to users' **apps**

Internet and Bluetooth help the interconnection among modules

Collecting Data

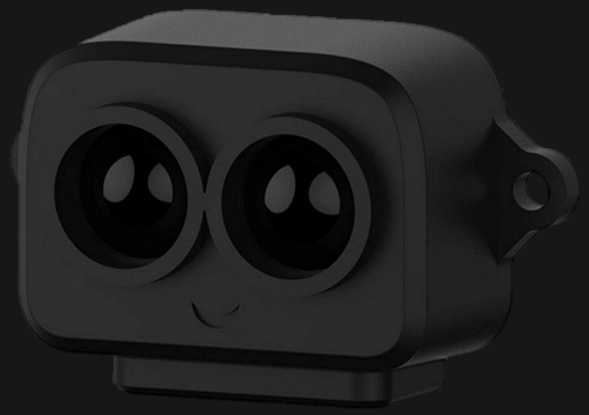
Depth Camera

Encoder

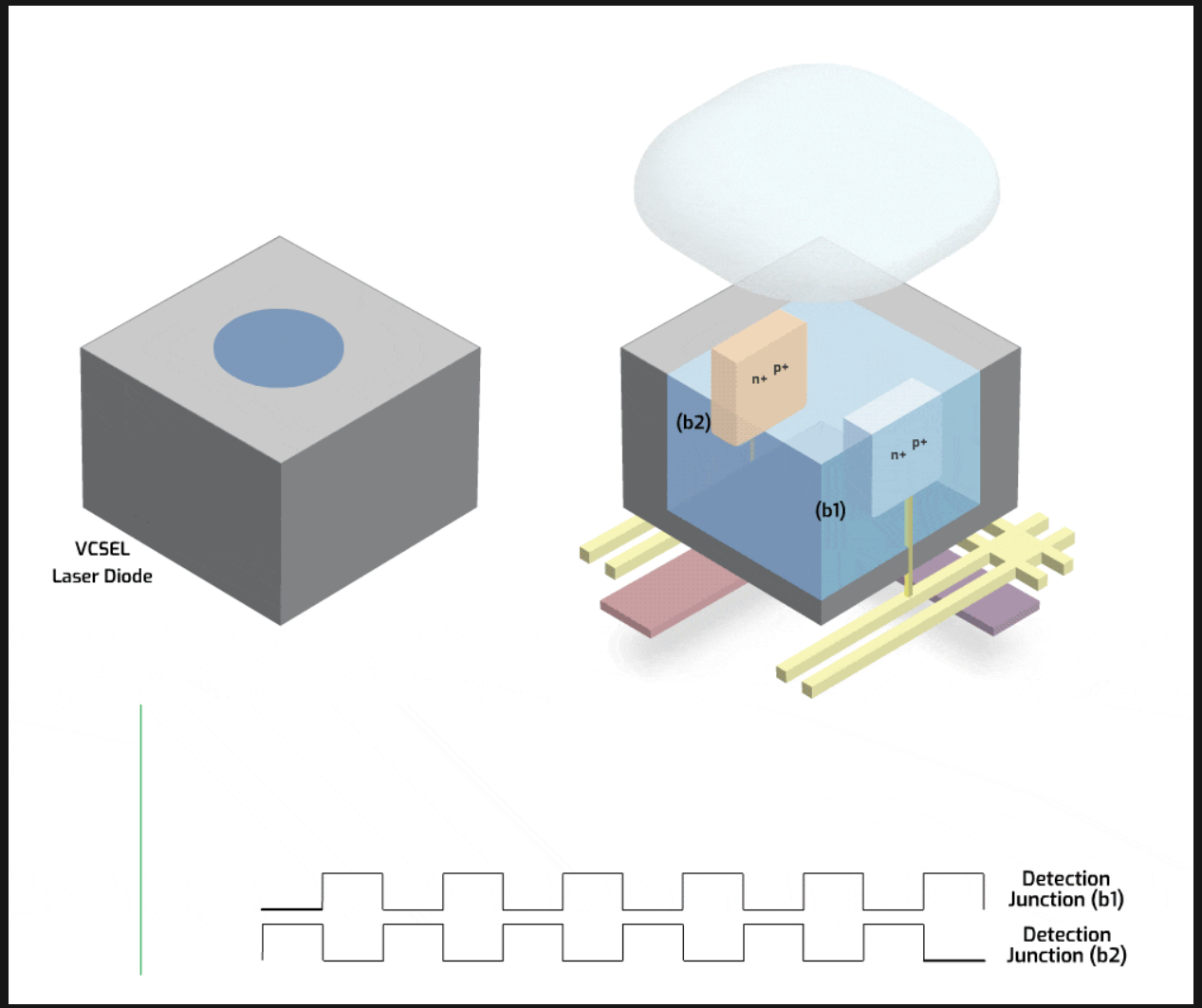


ToF Sensor

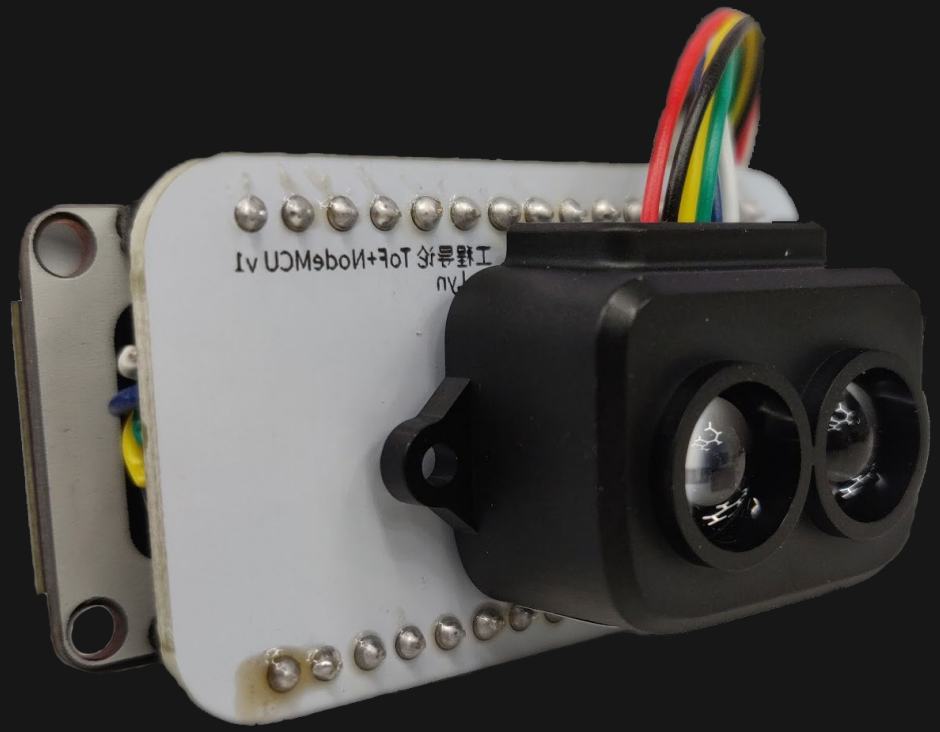
Collecting Data



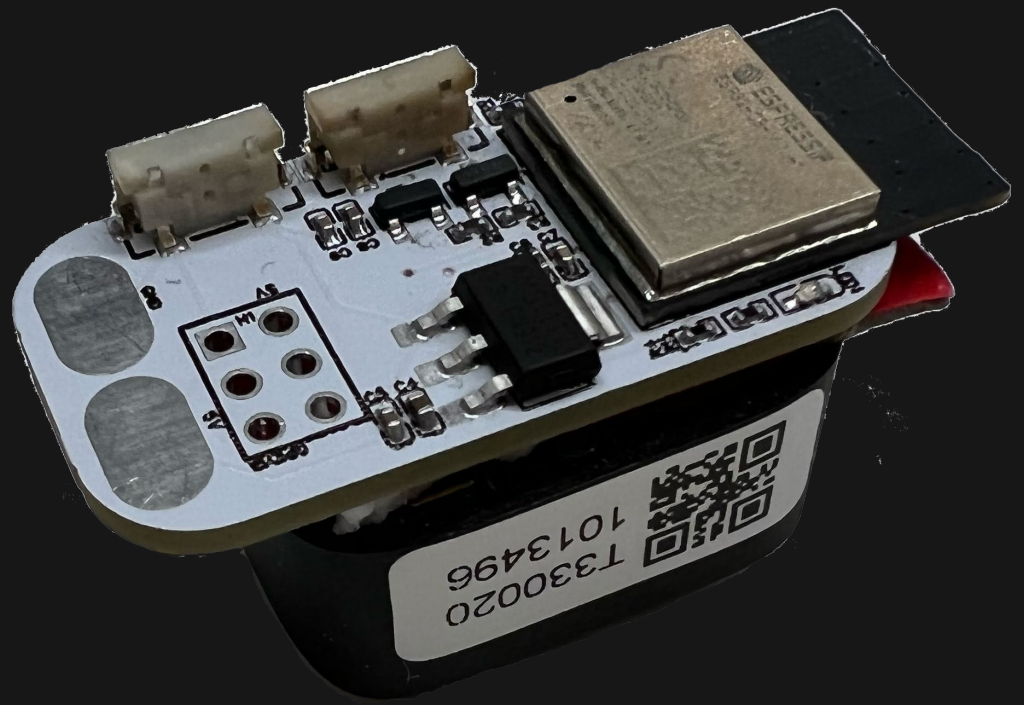
ToF Sensor



Core Board

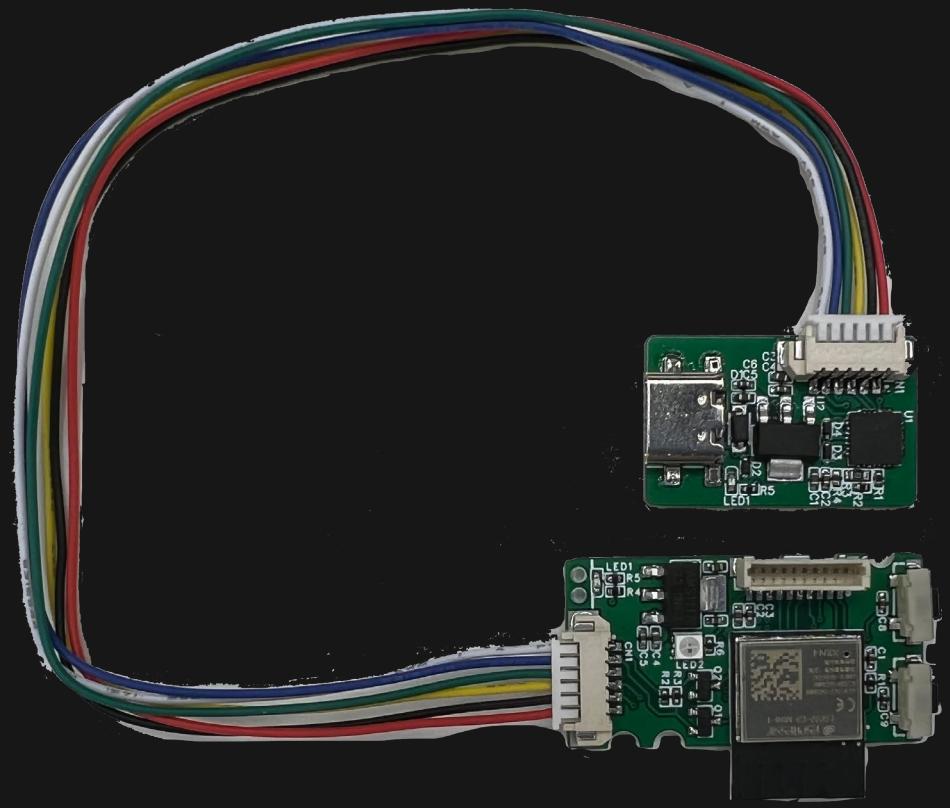


Core Board v1



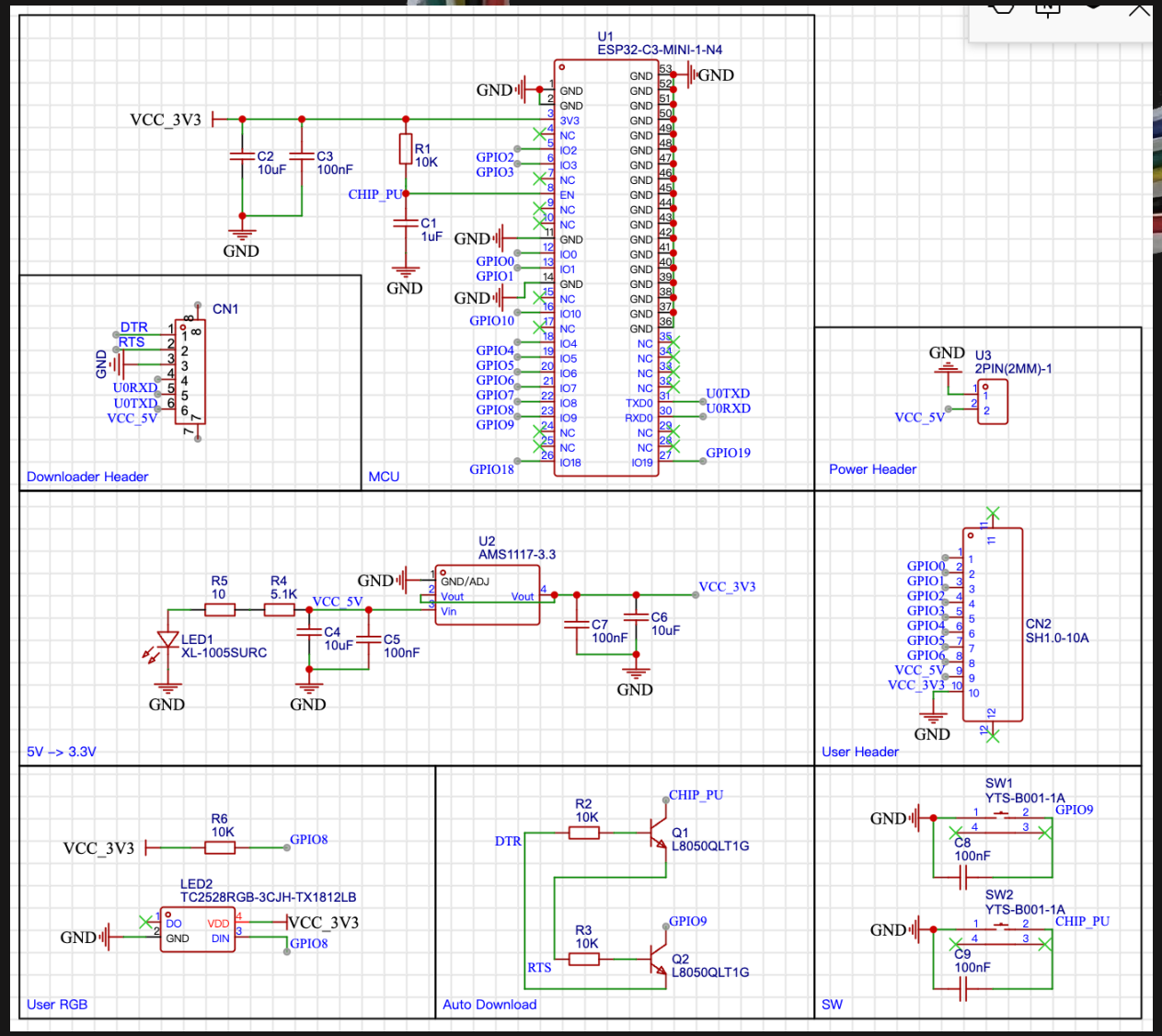
Core Board v2

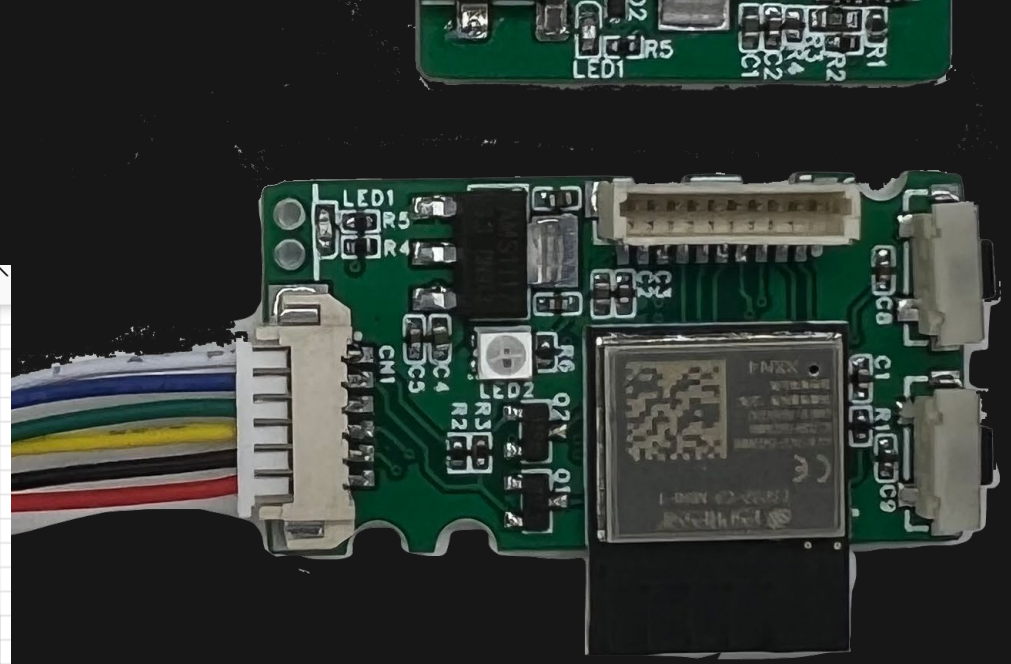
Core Board



Core Board v3

Core Board

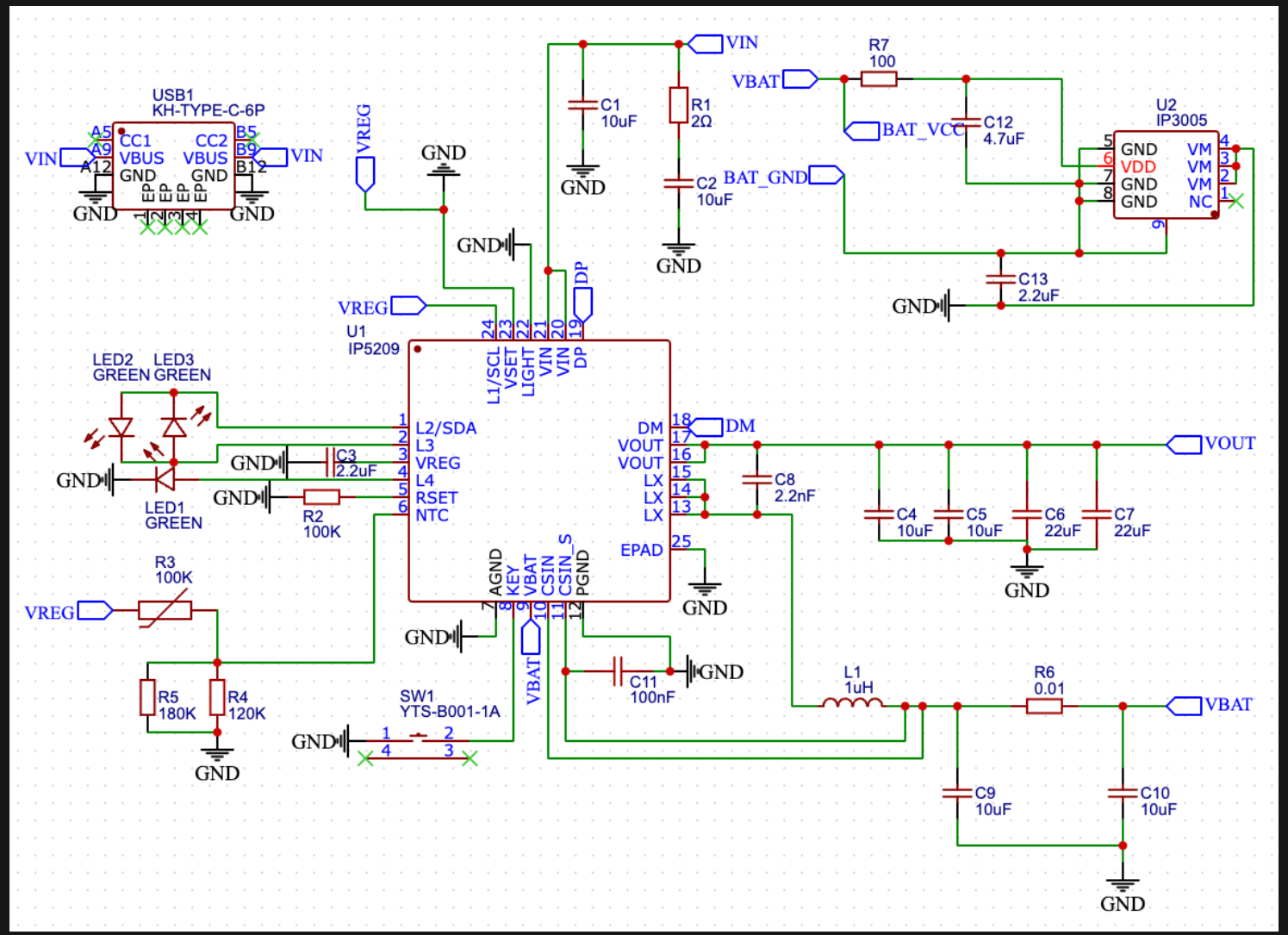




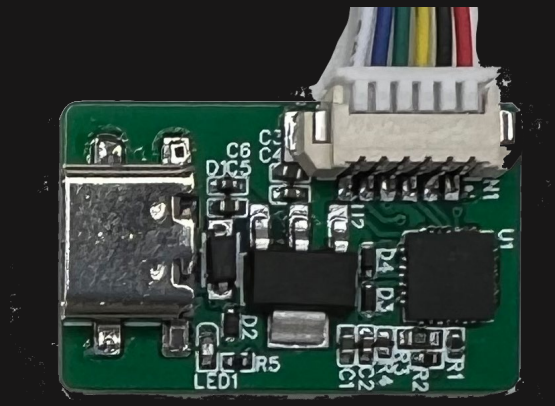
Core Board v3

CPU Freq.	20/160MHz
RF	2.4G(Wi-Fi/BLE)
Typ. I_w	200uA
Cost	￥72

Battery Module & Downloader

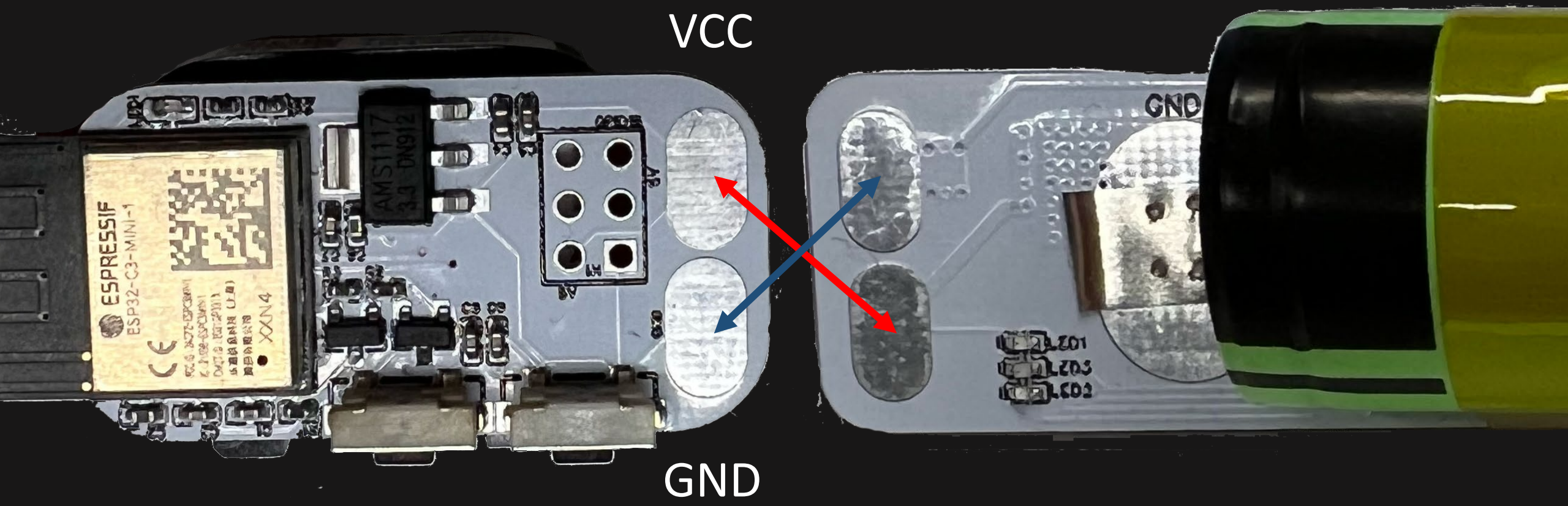


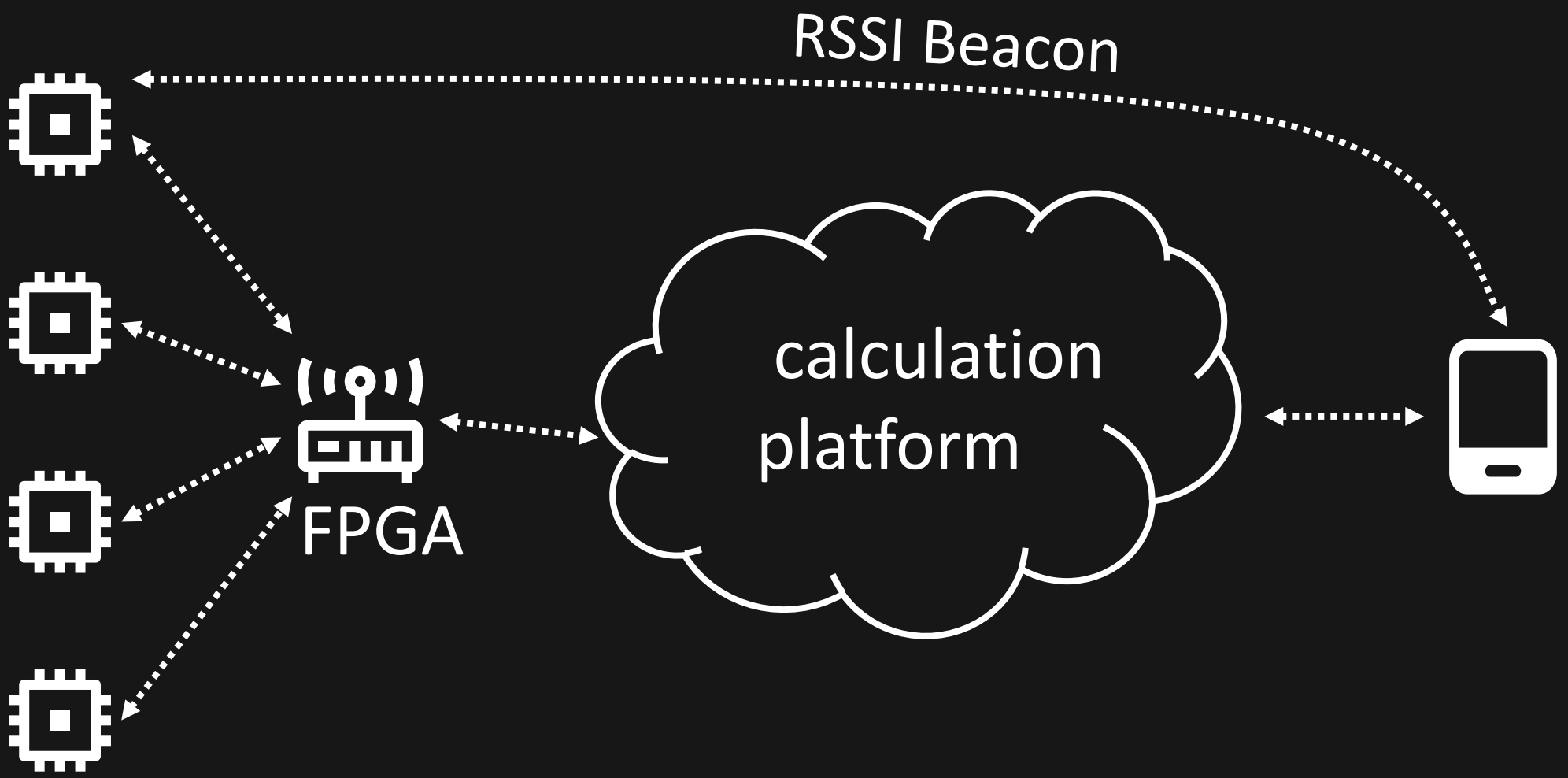
Battery Module



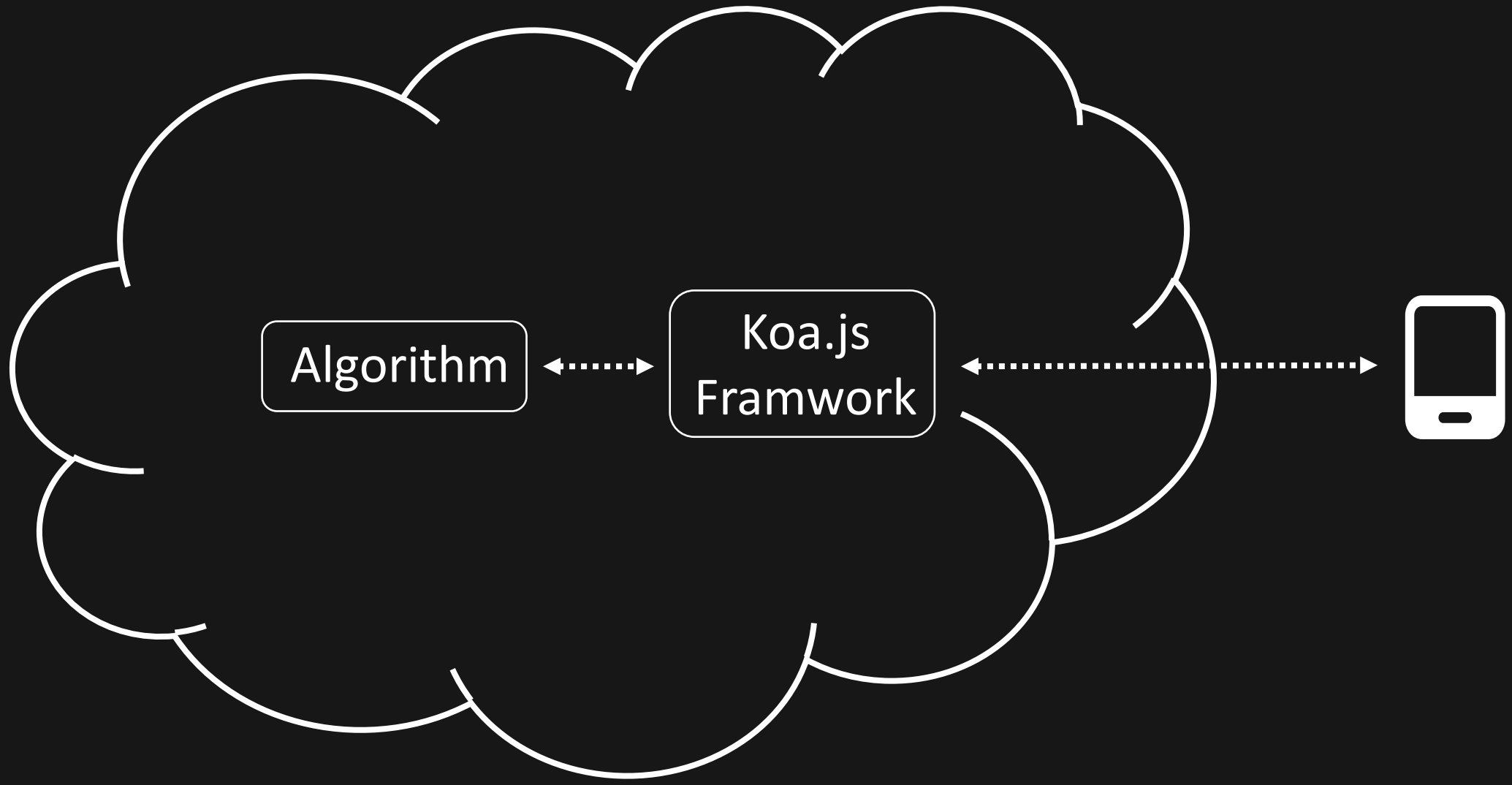
Downloader

Contactor

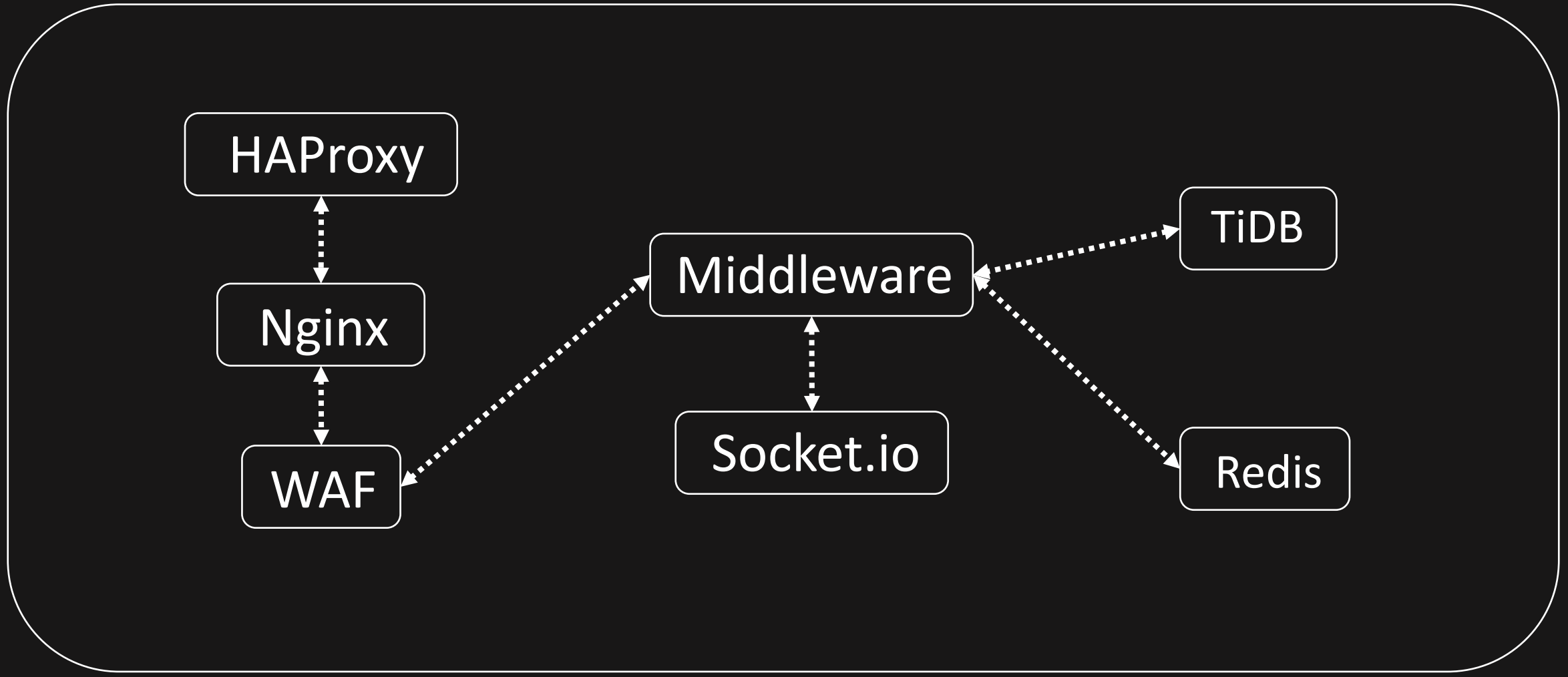



RSSI Beacon
calculation
platform
FPGA

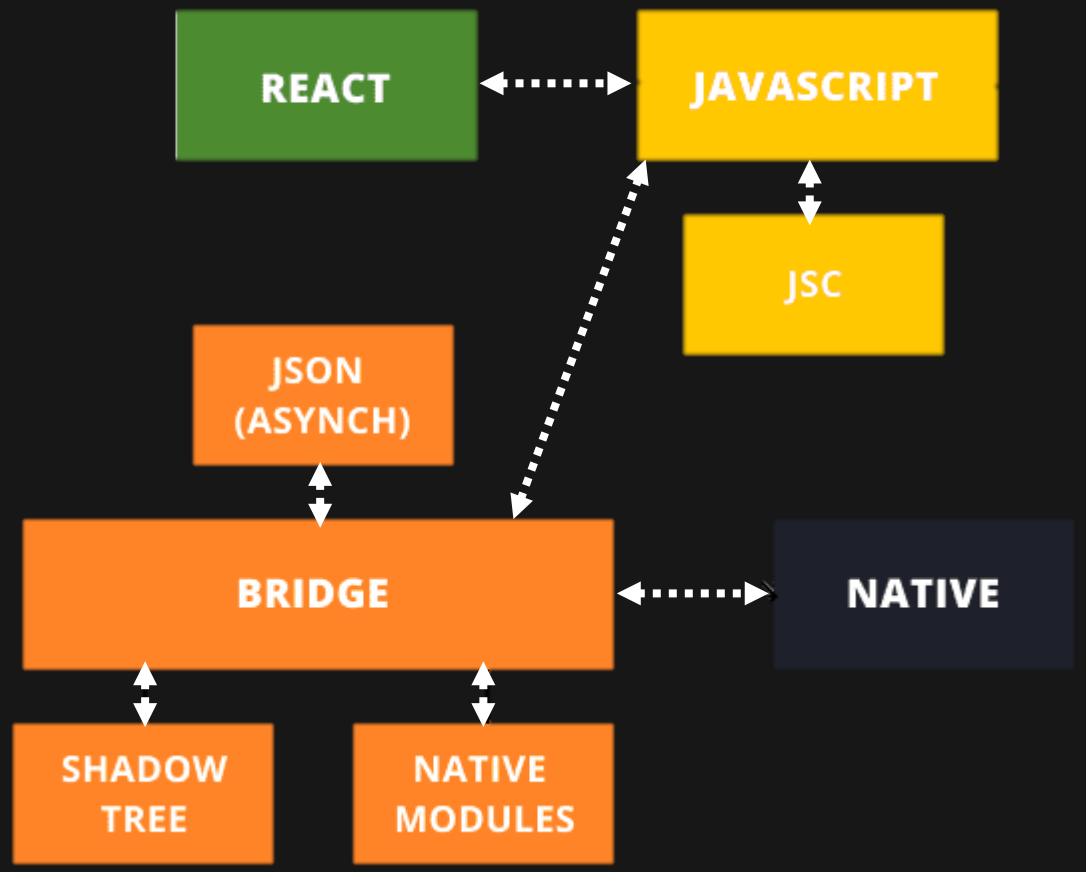
Server



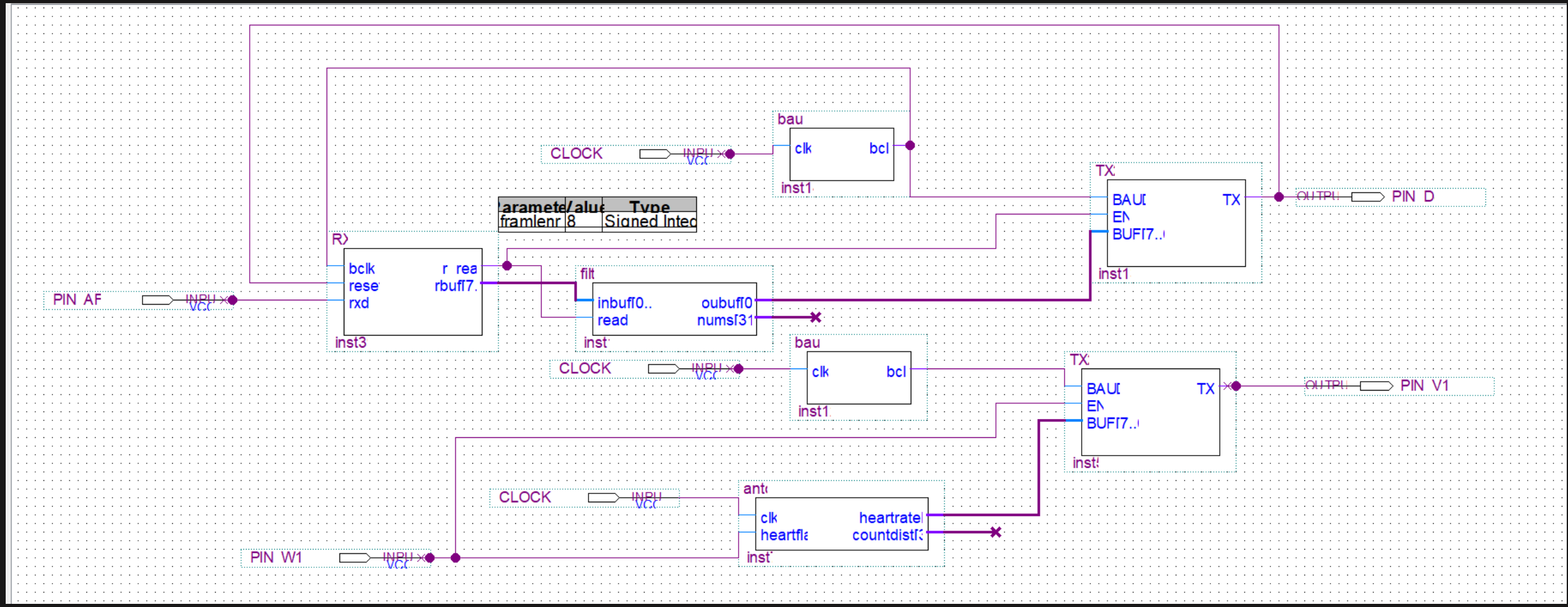
Server


HAProxy
Nginx
WAF
Middleware
Socket.io
TiDB
Redis
Koa.js Framwork

App

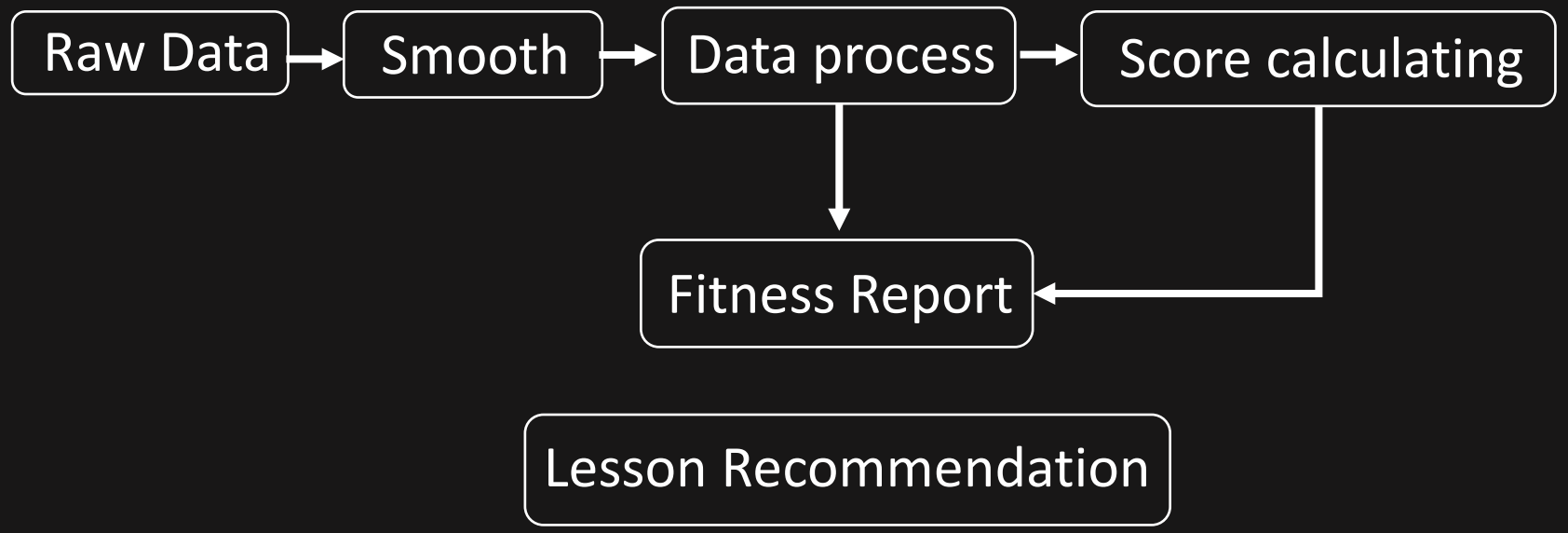

REACT
JAVASCRIPT
JSC
JSON
(ASYNCH)
BRIDGE
NATIVE
SHADOW
TREE
NATIVE
MODULES

FPGA

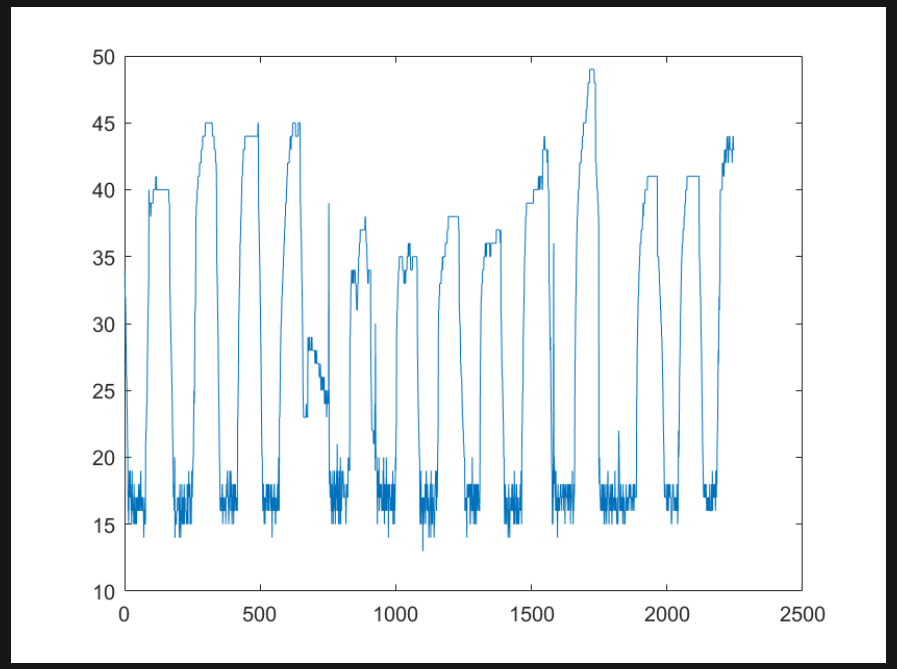

CLOCK
INPU
VCC
bau
clk
bcl
inst1
TX
BAUI
EN
BUFI7..
TX
OUTPU
PIN_D
aramete
alue
Type
framlenr
8
Signed Intec
RX
bclk
rese
rxd
r_rea
rbuff7..
inst3
PIN_AF
INPU
VCC
filt
inbuff0..
read
oubuff0
numsf31
inst
CLOCK
INPU
VCC
bau
clk
bcl
inst1
TX
BAUI
EN
BUFI7..
TX
OUTPU
PIN_V1
inst
CLOCK
INPU
VCC
ant
clk
heartfla
heartrate
countdistf
inst
PIN_W1
INPU
VCC

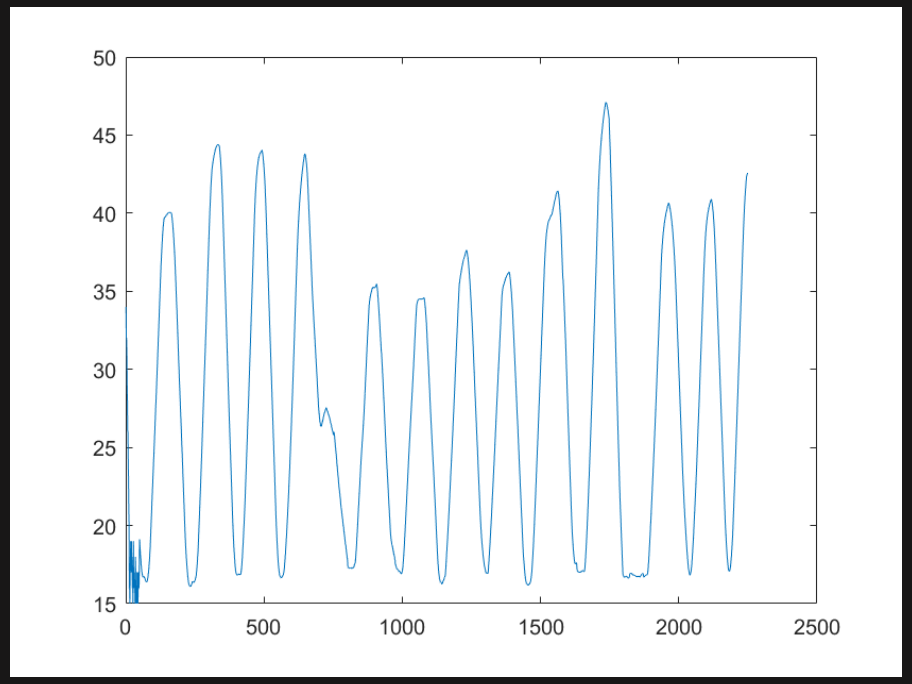
Algorithms

Hardware deliver the raw data to the sever,
which will be processed by algorithms



Smooth Data





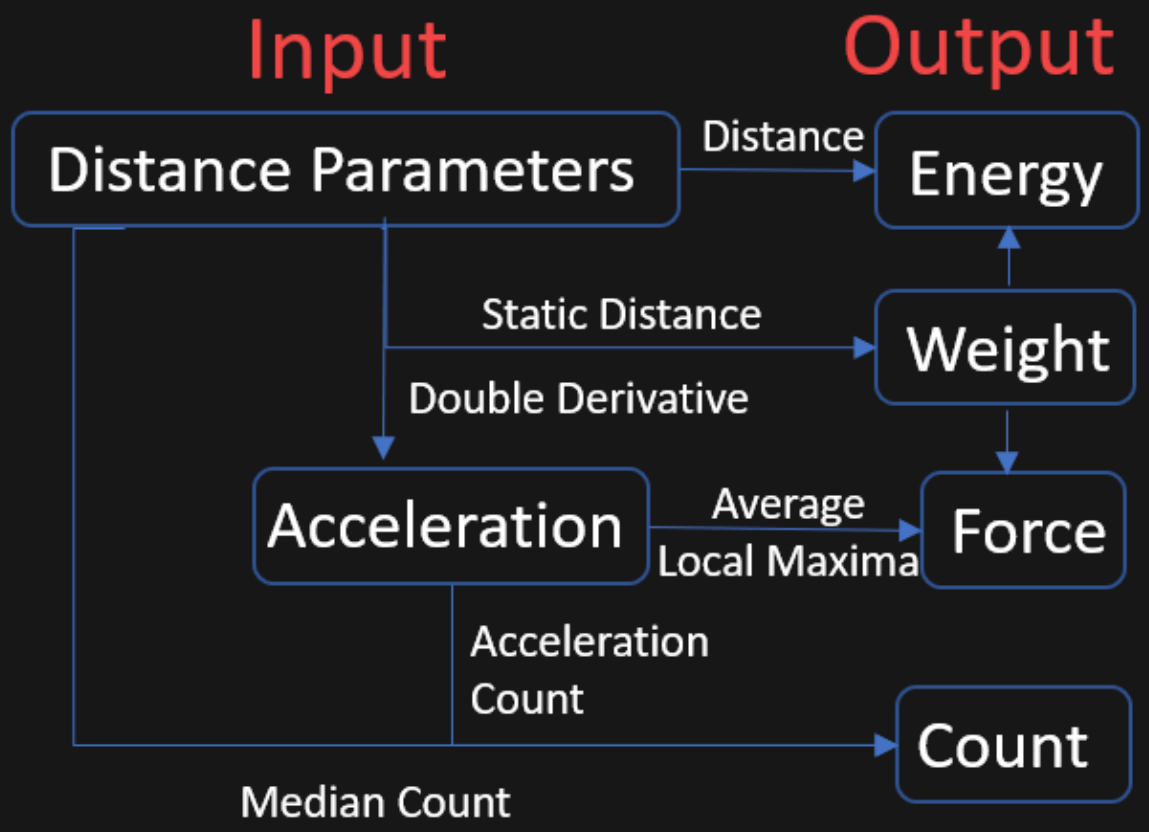
weight:20 force:571 energy:412 count:15

weight:20 force:568 energy:212 count:15

Sliding Window Algorithm

Window length:50

Data Process



Average force?

Users do not effort at any time.

Average the Local Maxima Force

How to count?

Median count:

set the median as a boundary and count the cross times.

Acceleration count:

The acceleration will be extremely big when we finished once.

Calculate scores: Mathematical model

What is an available workout?

Suitable weight

Predicting suitable weight by user's force.

Suitable strength

Use normal distribution to evaluate suitable strength.
The more count and weight, the slower scores get.

Calculate scores: Mathematical model

$$Scores = 0.35 * N(count)(|weight * 0.04 - force| < 20? 0.8: 1) * [\ln(weight^4 + 1) - 0.69][\ln(count^4 + 1) - 0.69]^{1.23}$$

N(x) represents the normal distribution, μ=15,σ=0.004

$$y = \ln(x^4 + 1) - 0.69$$

Calculate scores: Workout ability

How to show ability of users?

Ability = Work / Exercise Load

Exercise Load = 100 / (220 – Heartrate)

Calculate scores: Encouraging scores

How to encourage users?

Possibility for decreasing
Suitable increasing by exercise

Scores = Average(Last 3 scores, Best 10 scores)

Calculate Scores: Mathematical model

Parameter's source

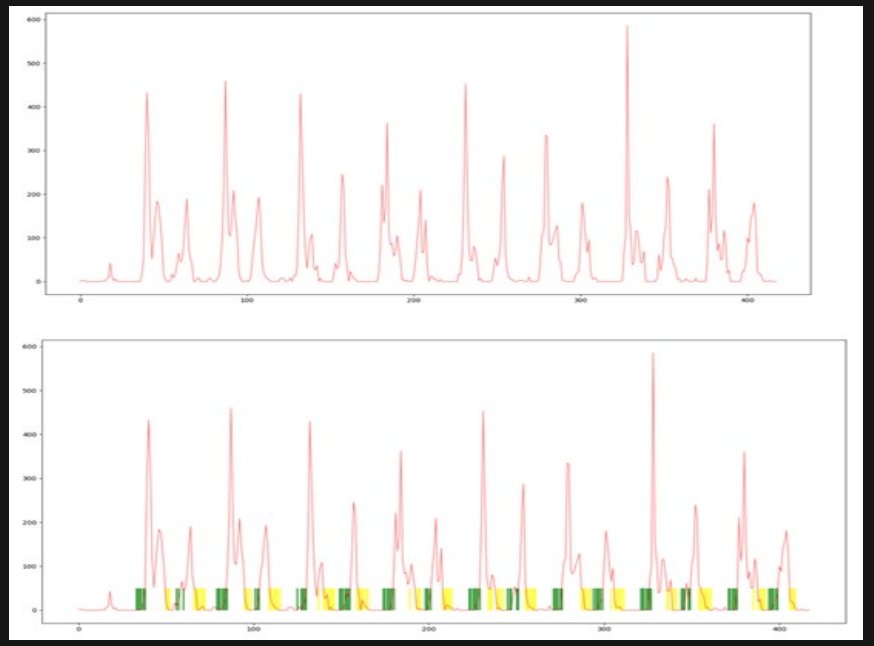
We invite professor 万发达 and other bodybuilders for standard workout data. Use python’s coefficient fitting to choose parameters.

Optimization

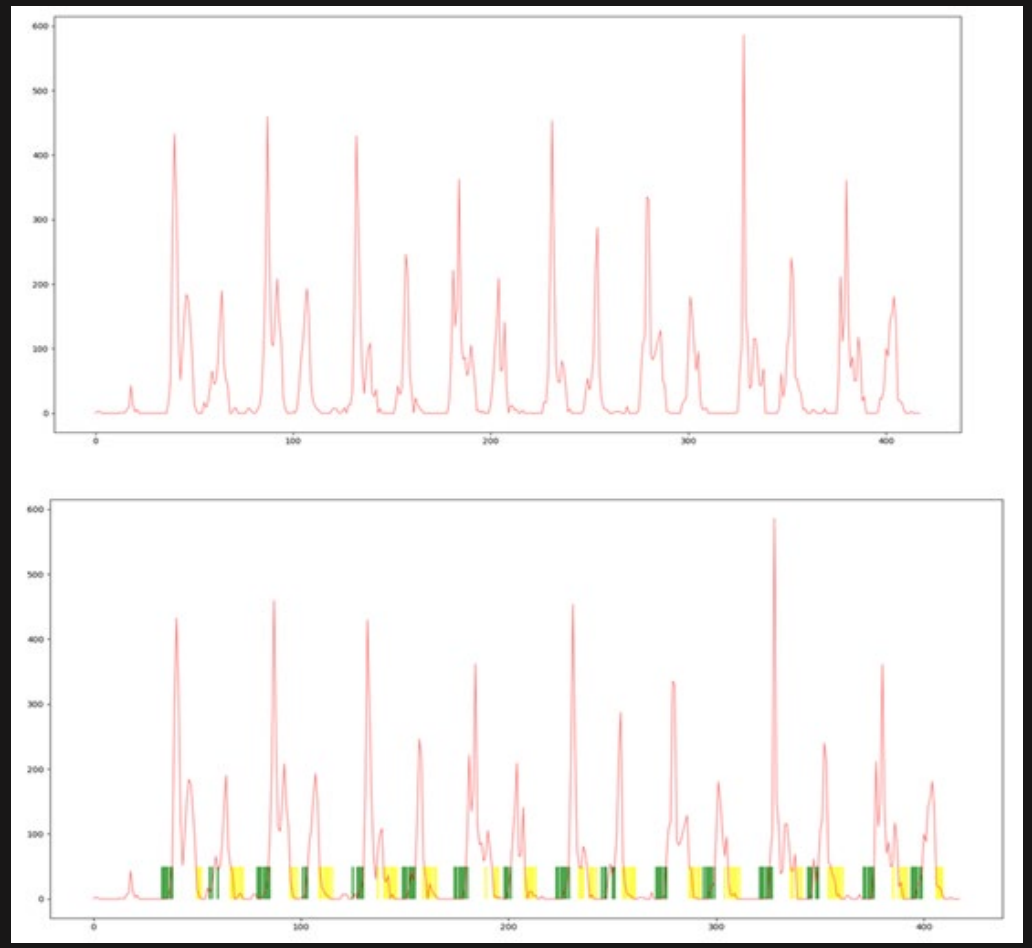
ToF correction
Weights and bias optimization

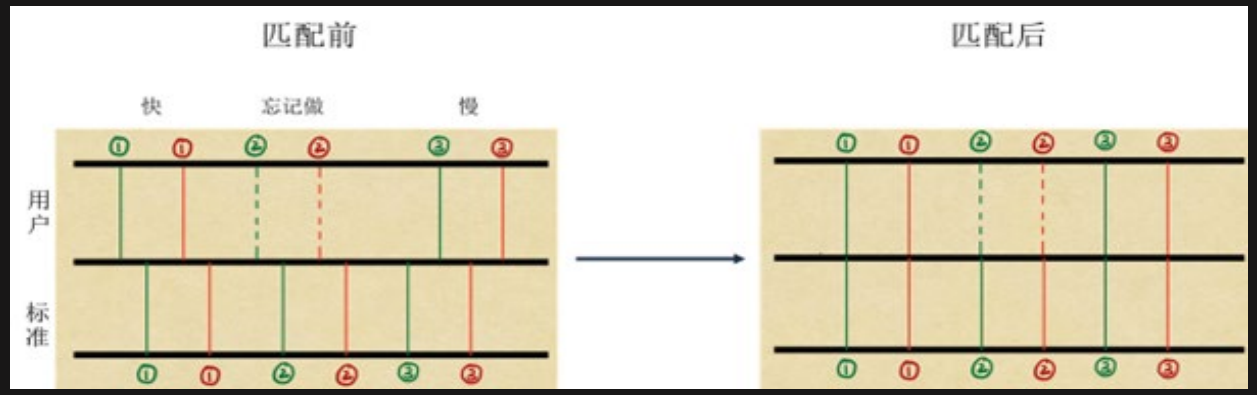
Yellow represents the original results
Green represents the guard truths

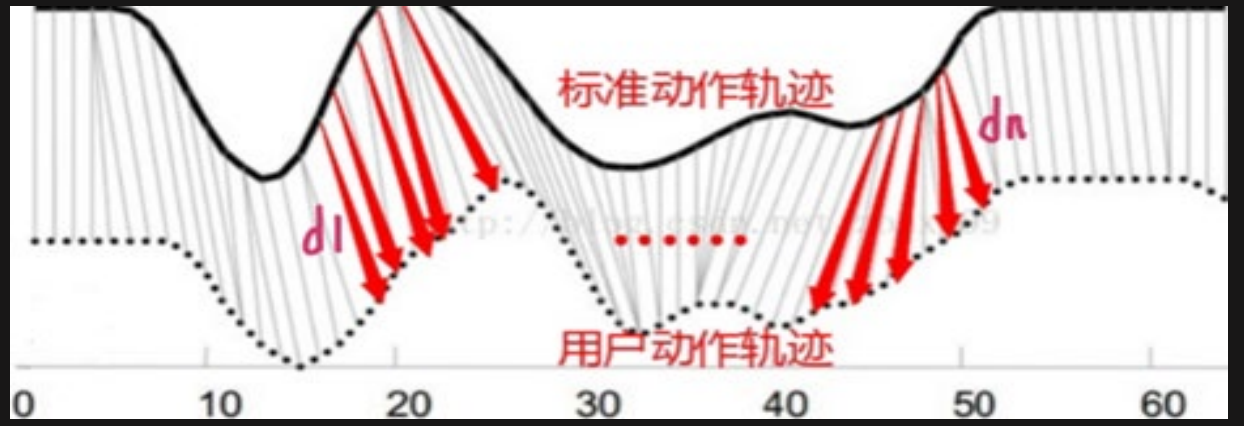
Matching



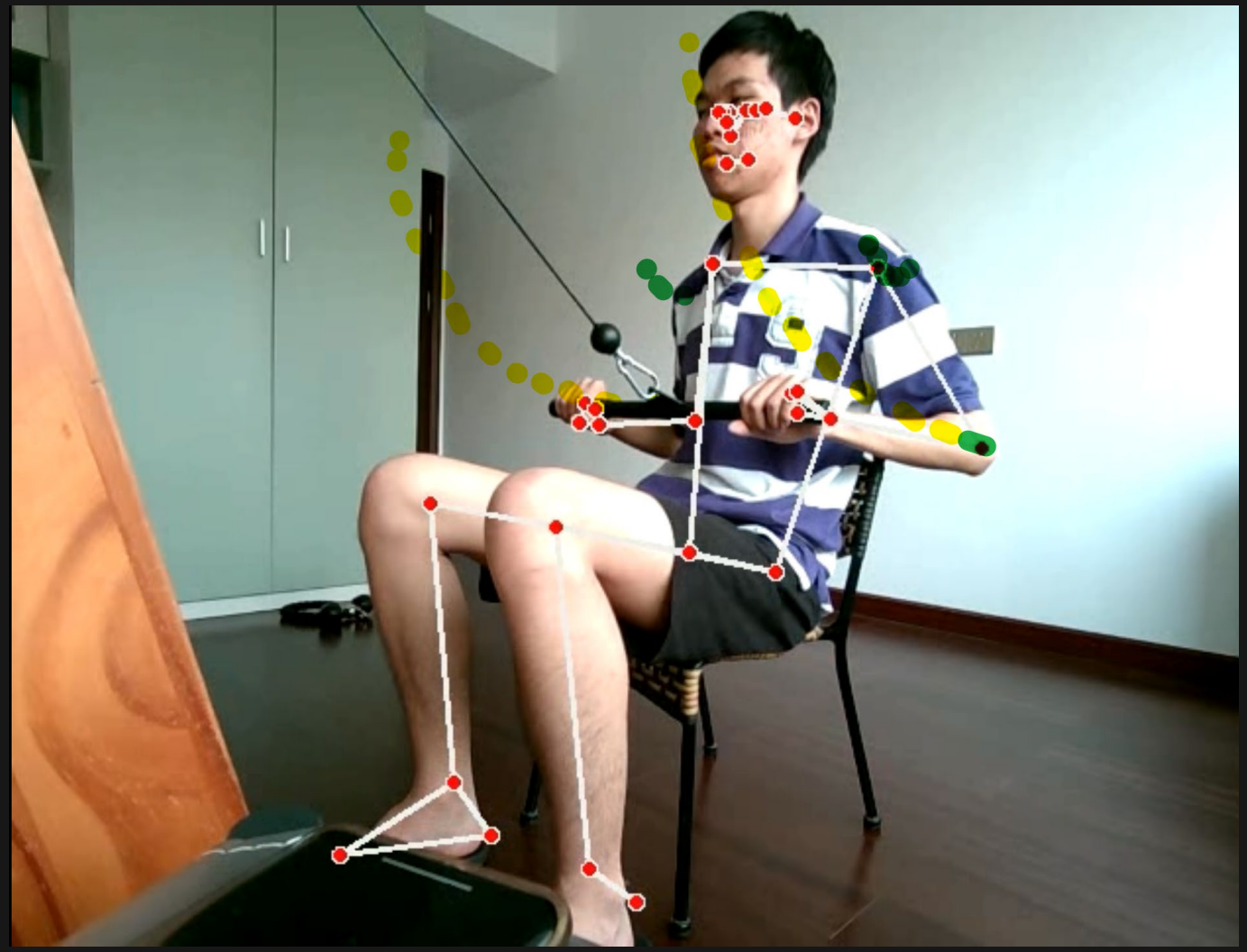
Matching





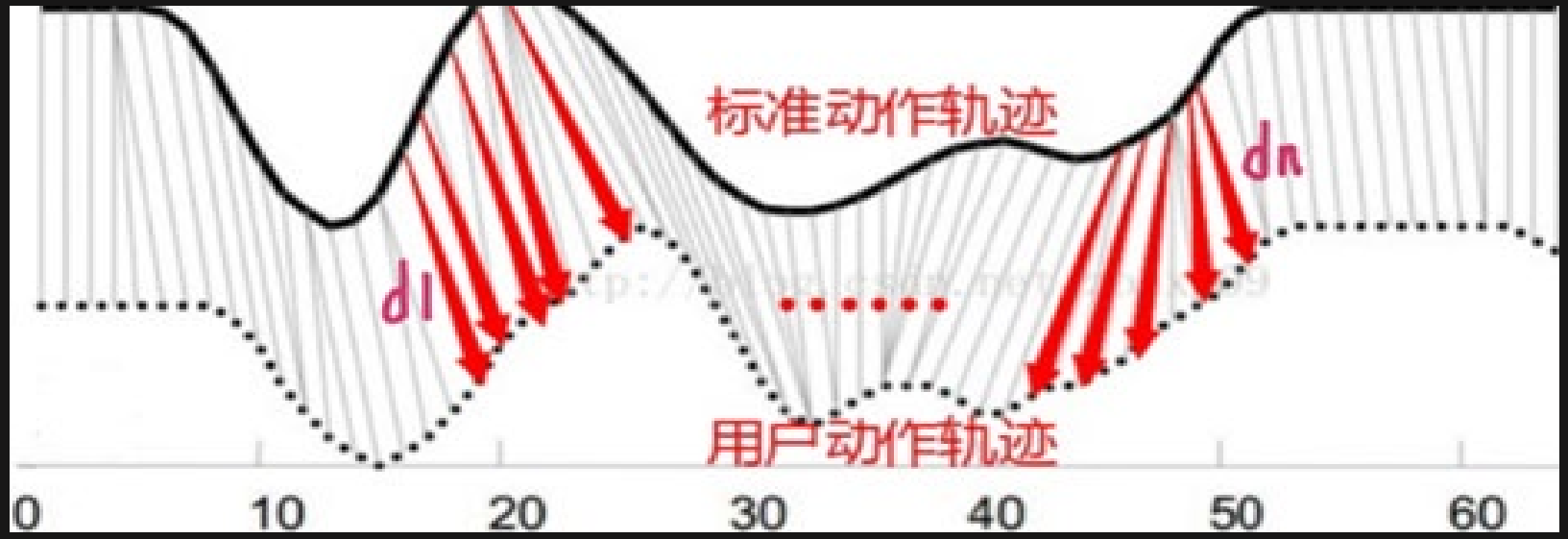


Matching



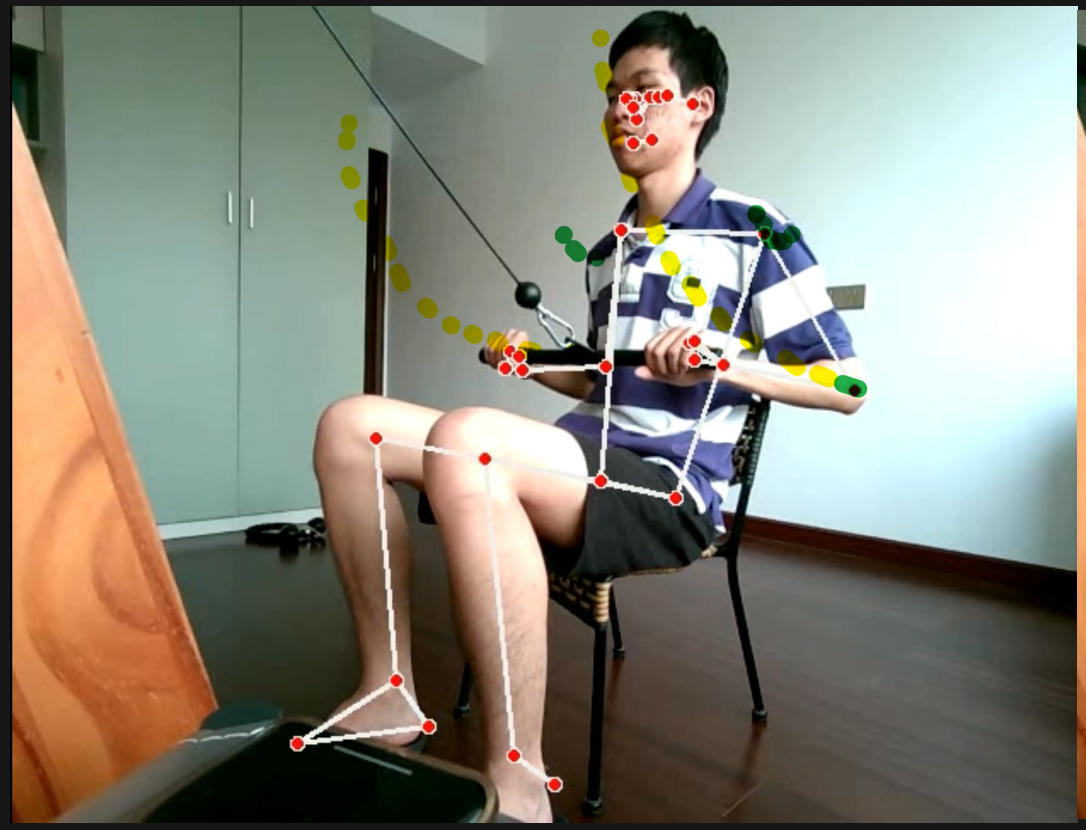
Grading

The scoring weights of individual joints.
Where 0.005 is the base weight of each joint



$$\text{weight\_joint} = \frac{fv\_\text{joint}}{fv\_\text{all\_\_\_joints}} \cdot 0.93 + 0.005$$

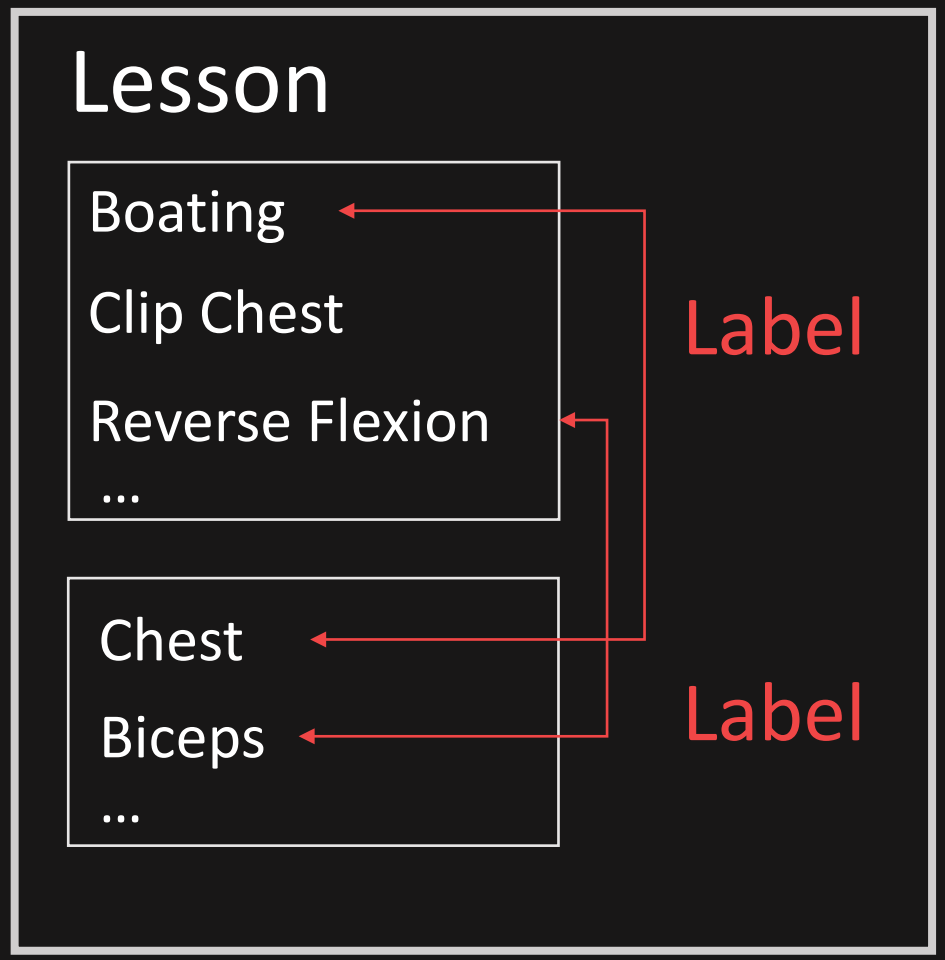
Grading



Score： 75.42/100
Sim:90.12

Score： 68.42/100
Sim:83.64

Recommendation



User retention rate ~ Social activity

Moments

Find similar users

Find potential likes

Jaccard Similarity

$$U = \{User1, U2, U3, U4 \dots\}$$

$$[r_{ij}] = \begin{bmatrix} & Lesson1 & L2 & L3 & L4 & L5 & \dots \\ User1 & 1 & 3 & 4 & 1 & 5 & \dots \\ U2 & 2 & 2 & 5 & 1 & 4 & \dots \\ U3 & 1 & 3 & 5 & 2 & 3 & \dots \\ U4 & 2 & 1 & 4 & 1 & 5 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix}$$

Fitness user - Fitness course rating matrix

$$CosSim(j,k) = \frac{\sum_{i=1}^{U} r_{ij}\, r_{ik}}{\sqrt{\sum_{i=1}^{U} r_{ij}^2 \sum_{i=1}^{U} r_{ik}^2}}$$

Starwar Modification

$$[r_{ij}] = \begin{bmatrix} & Lesson1 & L2 & \dots \\ User1 & 1 & 2 & \dots \\ U2 & 4 & 5 & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix}$$

$$CosSim = 0.98$$

Starwar Modification

$$[r_{ij}] = \begin{bmatrix} & Lesson1 & L2 & \dots \\ User1 & 1 & 2 & \dots \\ U2 & 4 & 5 & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix}$$

$$CosSim = 0.98$$

$$NewCosSim(j,k) = \frac{\sum_{i=1}^{U}(r_{ij} - \overline{r_i})(r_{ik} - \overline{r_i})}{\sqrt{\sum_{i=1}^{U}(r_{ij} - \overline{r_i})^2 \sum_{i=1}^{U}(r_{ik} - \overline{r_i})^2}}$$

Lesson similarities

$$r_{ij} = \begin{bmatrix} & Label1 & L2 & L3 & L4 & L5 & \dots \\ Lesson1 & 1 & 0 & 0 & 1 & 1 & \dots \\ L2 & 1 & 1 & 1 & 1 & 0 & \dots \\ L3 & 1 & 0 & 0 & 1 & 0 & \dots \\ L4 & 0 & 1 & 0 & 1 & 1 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix}$$

Fitness course- Fitness label matrix

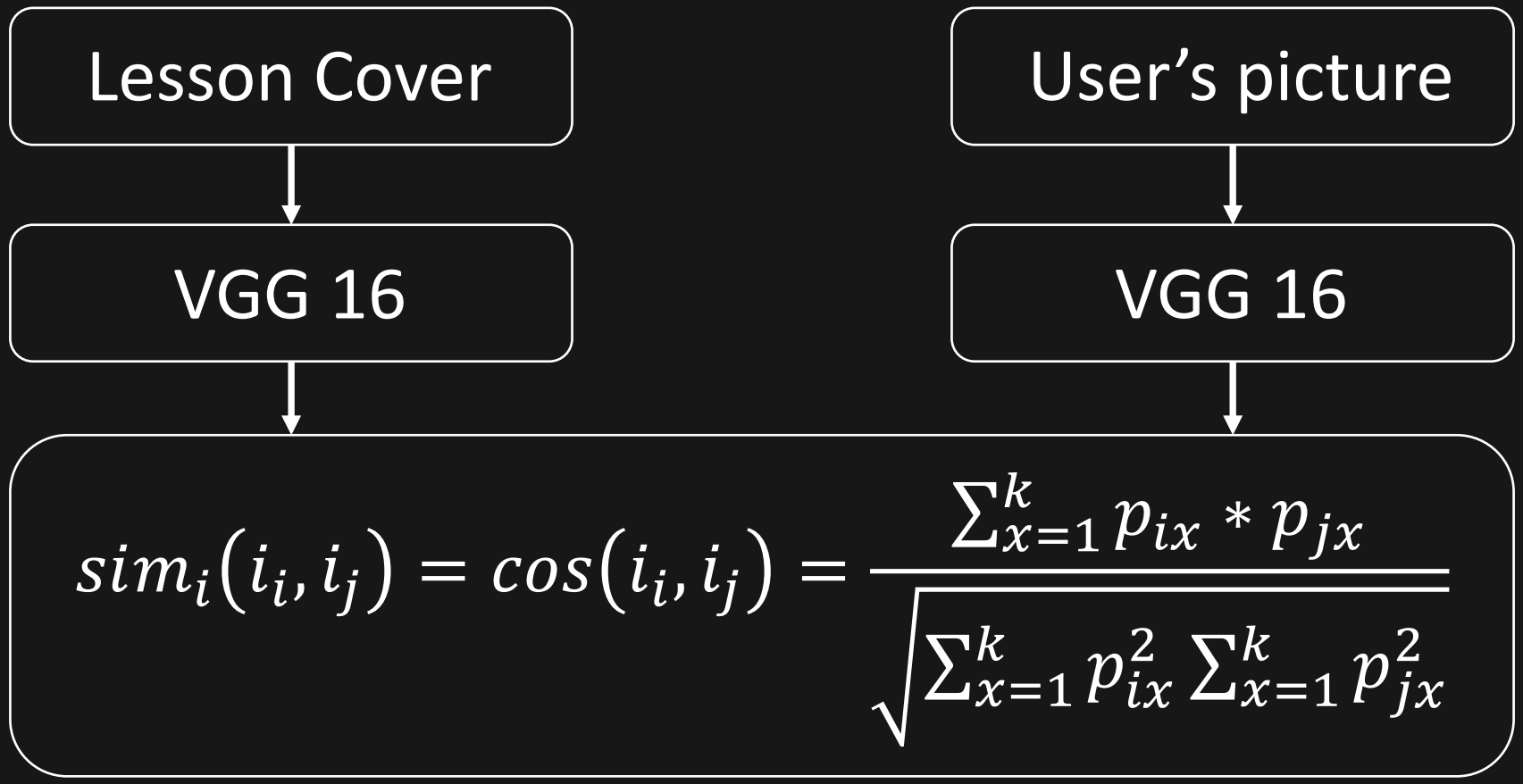
$$i_i = [1 \quad 0 \quad 1 \quad 0 \quad 1 \quad \dots.]^T$$

$$a_{11} = 1$$

$$k = 6$$

$$sim_a(i_i, i_j) = cos(i_i, i_j) = \frac{\sum_{x=1}^{k} \frac{a_{ix}}{g(a_{ix})} \frac{a_{jx}}{g(a_{jx})}}{\sqrt{\sum_{x=1}^{k} \frac{{a_{ix}}^2}{g(a_{ix})^2} \sum_{x=1}^{k} \frac{{a_{jx}}^2}{g(a_{jx})^2}}}$$

Recommendation



K is the length of eigenvector, p_{ix} is picture i_i 's eigenvector's No. x element

Recommendation

$$sim_{ia}(i_i, i_j) = \beta * sim(i_i, i_j) + (1 - \beta) * sim_a(i_i, i_j)$$
$$\beta = 0.2$$

Sort

Choose k lessons as K-closest lesson for present lesson

$$D'_{ui} = \frac{\sum_{n=1}^{k} sim_{ia}(i_i, i_j) * r_{uj}}{\sum_{n=1}^{k} |sim_{ia}(i_i, i_j)|}$$

Evaluation

$$Precision = \frac{\sum_{u \in U} |R(u) \cap T(u)|}{\sum_{u \in U} |R(u)|}$$

$$Recall = \frac{\sum_{u \in U} |R(u) \cap T(u)|}{\sum_{u \in U} |T(u)|}$$

$R(u)$ is the recommendation list train set provides
$T(u)$ is the recommendation list test set provides

Innovation

Independent system design

Various Recommendation

Physical Meaning Score

Motivate Users

Presentation

Q&A

Thank you