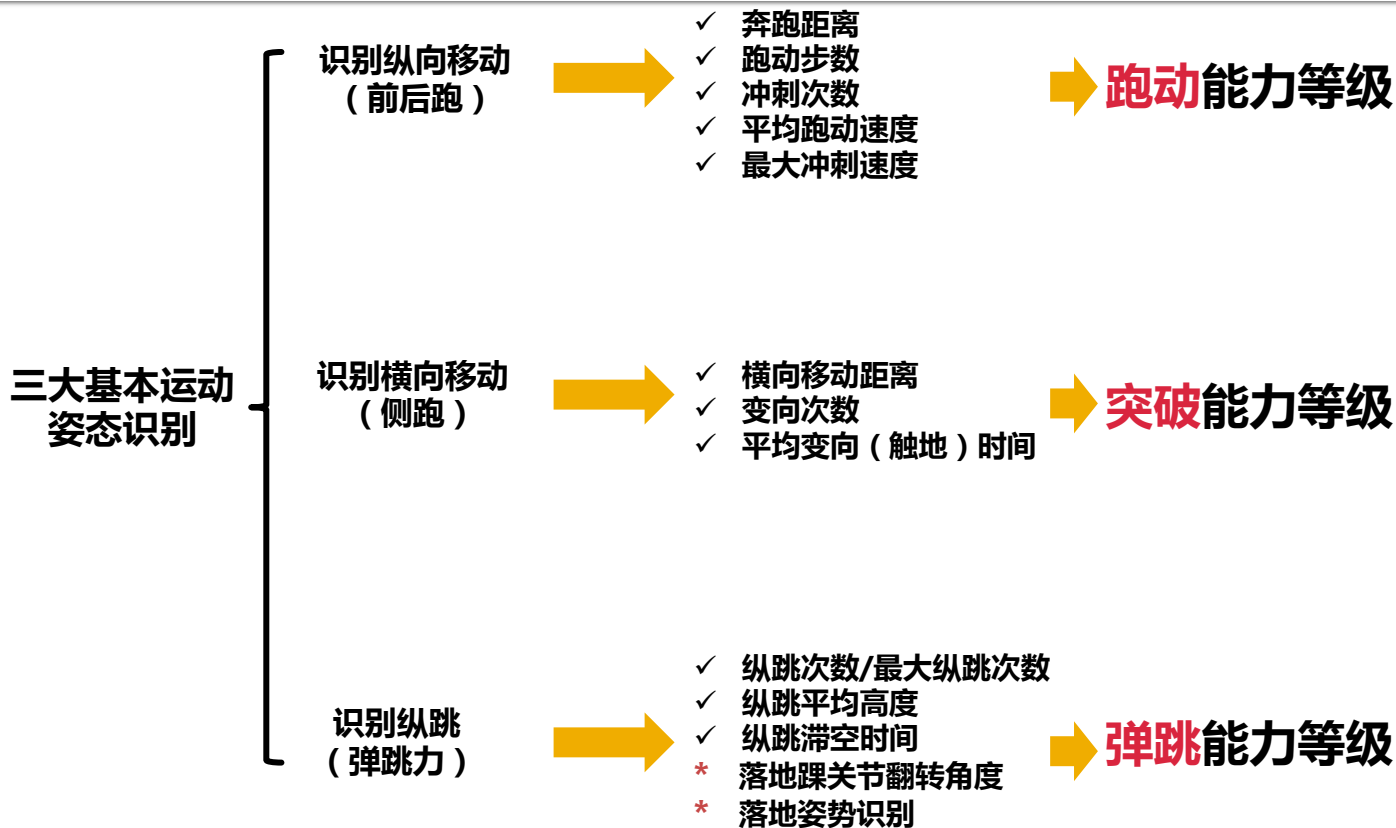
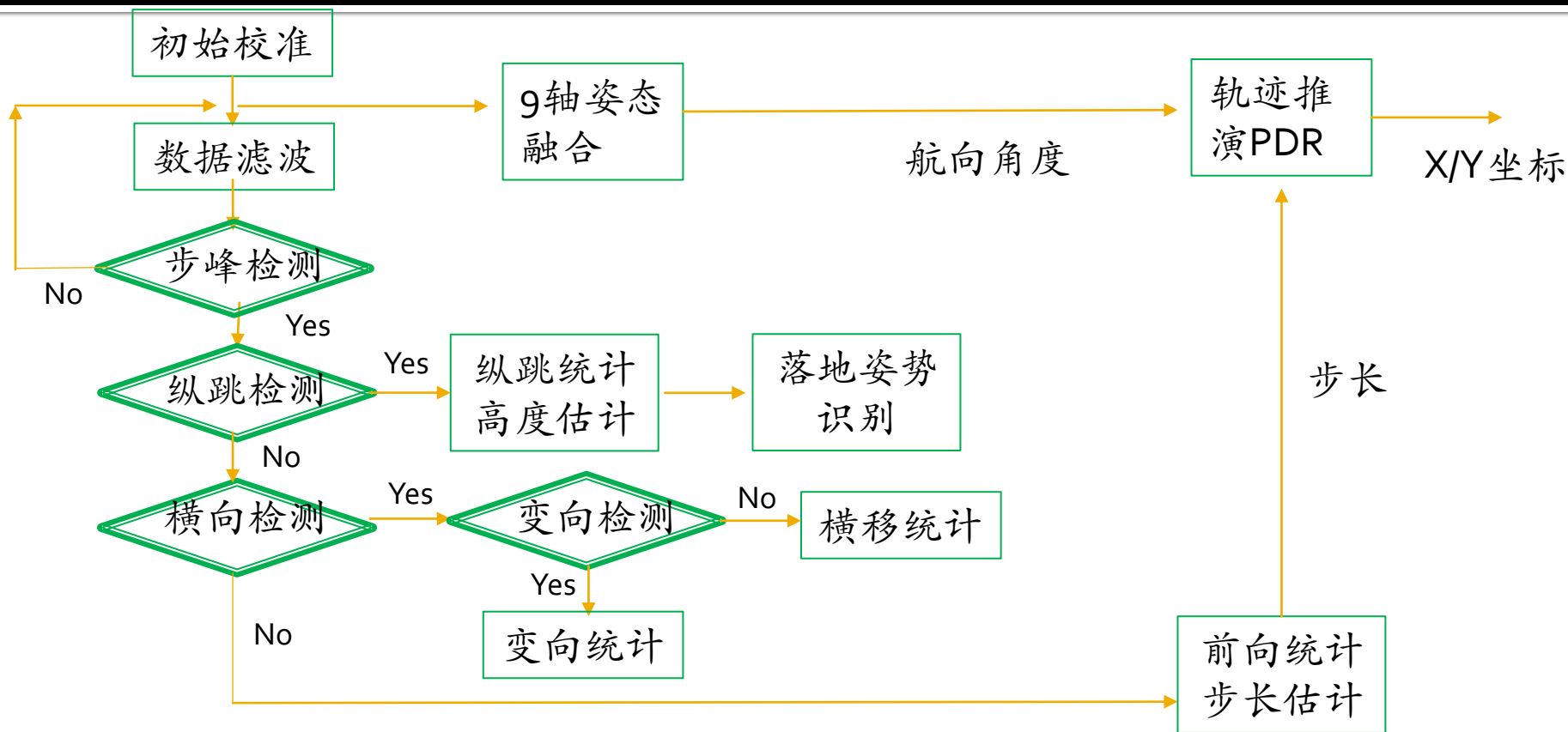


基本功能定义：



总体处理流程图



1. 纵向移动

✓ 奔跑距离

定义为球员在场上水平移动的总距离（纵向移动+横向移动）

✓ 跑动步数

定义为球员在场上移动的总步数

✓ 冲刺次数

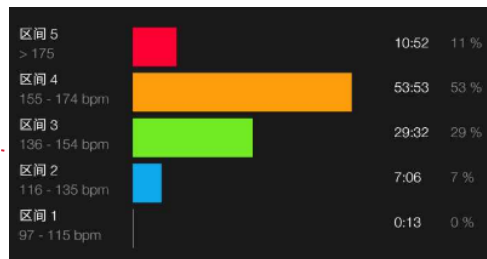
1、区分球员正常匀速跑与冲刺跑；2、计算球员冲刺次数
冲刺定义为：瞬时持续加速度（或速度）大于某一阈值（比如15km/h），即该次跑动记为一次冲刺

✓ 平均跑动速度

定义为球员在场上水平移动的平均速度；并将移动速度区间统计出来

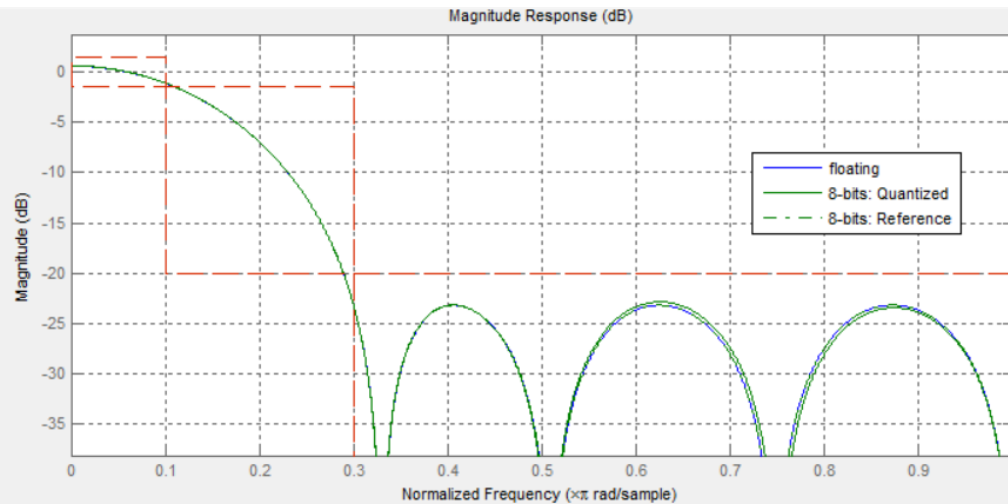
✓ 最大冲刺速度

在识别冲刺的基础上，计算球员冲刺的最大速度和平均速度

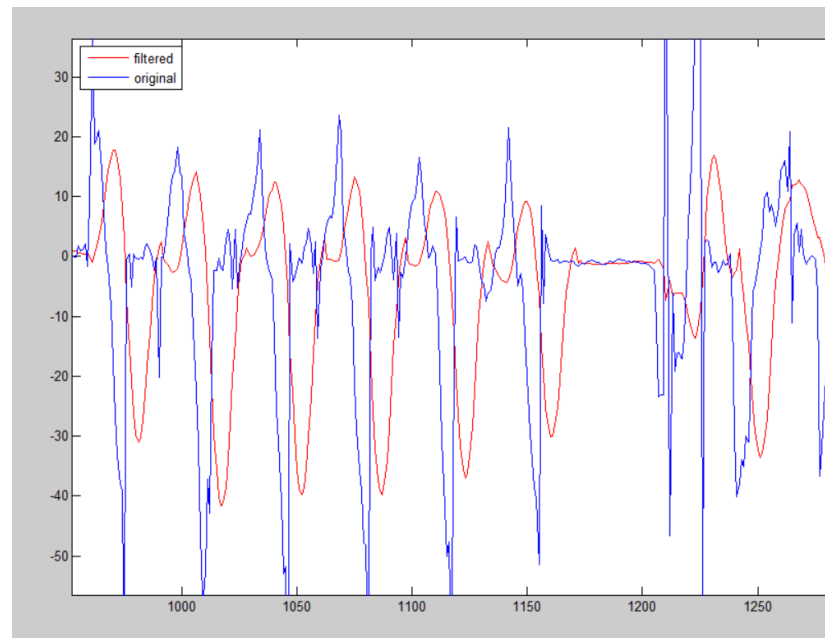


球员移动速度区间分布

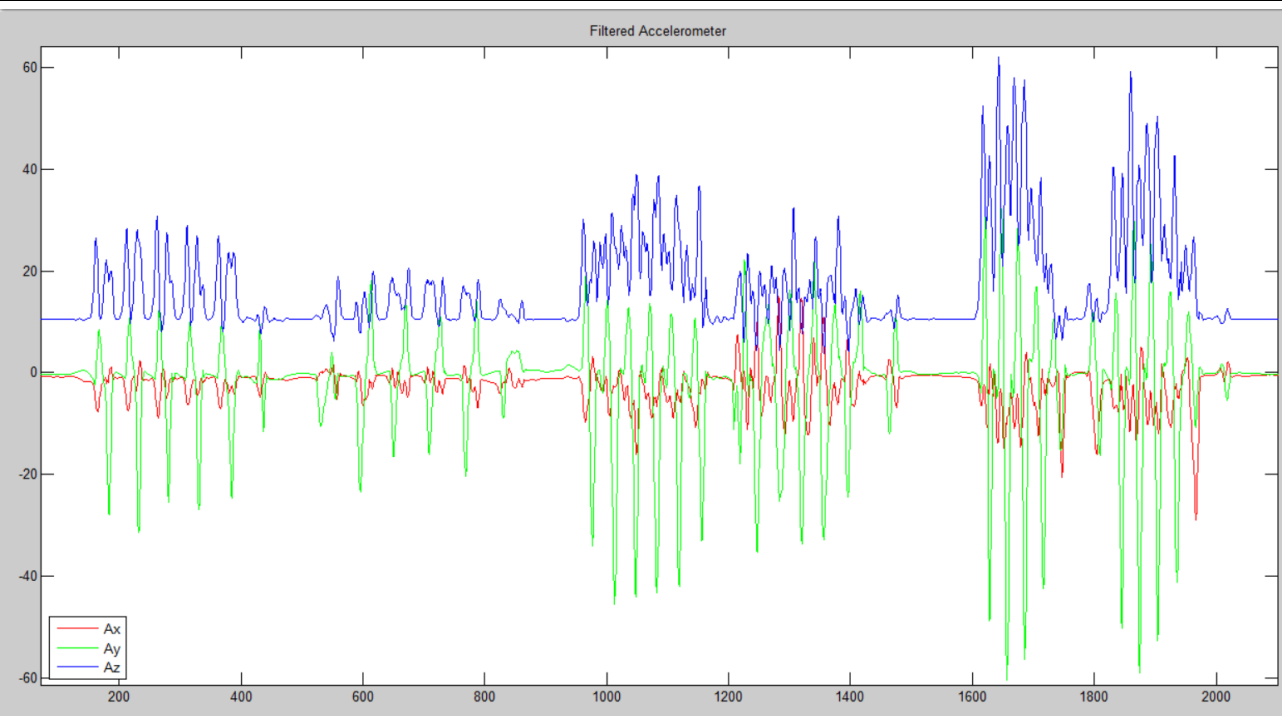
FIR 滤波处理



$$y(n) = x(n) * 0.0779 + x(n-1) * 0.1124 + x(n-2) * 0.1587 + x(n-3) * 0.1867 + x(n-4) * 0.1867 + x(n-5) * 0.1587 + x(n-6) * 0.1124 + x(n-7) * 0.0779$$



走/跑/冲刺检测



ag_0312_bob.txt

步伐检测:

- Ay轴正/负峰交替, 大于一个幅度的阈值。
- 每一个峰对应一次脚落地 (累计一步)

步长/速度估计:

- 与检测到的步频(f)和幅度(A)成正比。

$$L = c_1 \times f + c_2 \times A + c_0$$

$c_0/c_1/c_2$ 为待拟合系数

步伐与步长分析

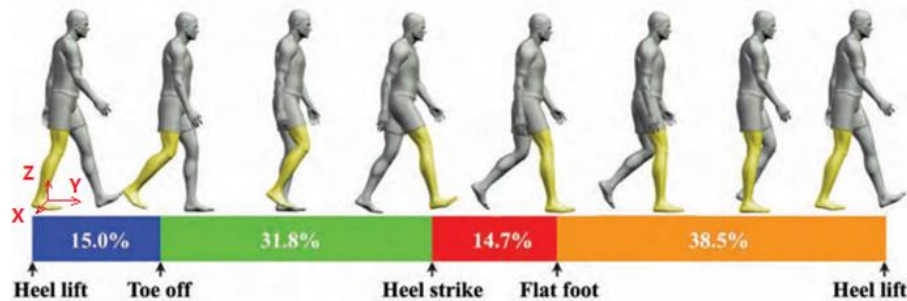
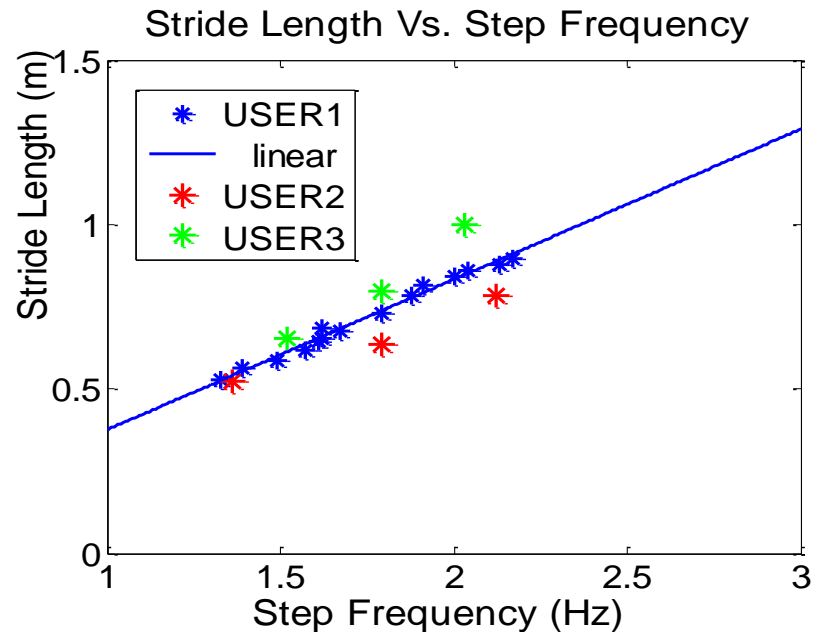


Figure 5.4: The walking gait cycle broken into phases; (blue) push-off, (green) swing, (red) heel strike, and (orange) stance.

[Kwakkel 2008]



2. 横向移动

✓ 横向移动距离

定义为球员在场上横向移动的总距离（并步、滑步、侧步等）

✓ 变向次数

识别横向移动步伐模式中，移动方向切换一次，记为1次变向



GIF动态图

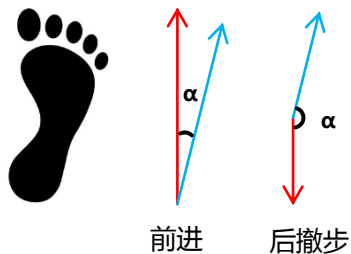


✓ 平均变向（触地）时间

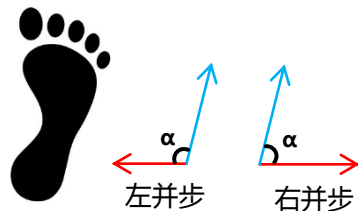
记录球员每次变向时鞋与地面接触时间，并统计计算平均触地均值

移动方向判定

智能芯片轴向
步伐移动方向



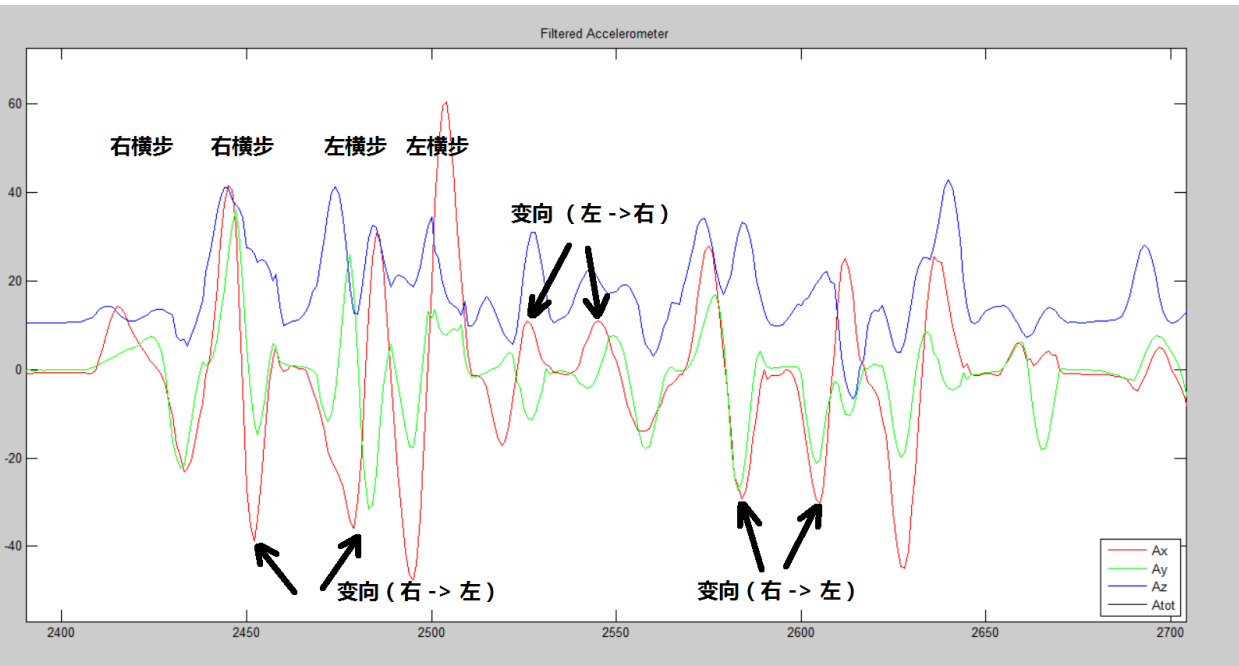
两者夹角 α 小于 45° （以及大于 135° ）时，定义为纵向移动



两者夹角 α 介于两者之间（ $45^\circ < \alpha < 135^\circ$ ）时，定义为横向移动

注： 45° 、 135° 为暂定值，结合后期大量实验数据，可能会作进一步调整

横向检测



Zhongzheng 0313.csv

横向检测:

- Ax轴一个周期幅度积分 > Ay轴
- 每一个峰对应一次脚落地 (累计一步)

变向检测:

- 一个正峰后又出现一个正峰
or
一个负峰后又出现一个负峰



3. 纵跳

✓ 纵跳次数/最大纵跳次数

纵跳次数：定义为球员在场上运动时累计跳跃次数（三步上篮的**单腿跳**、抢篮板动作的**纵跳**、投篮动作的**跳投**）

最大纵跳：定义为起跳瞬时垂直加速度大于某一**阈值**，即该次纵跳记为一次冲刺

✓ 纵跳平均高度

定义为球员在场上运动时跳跃动作的平均跳跃高度

✓ 纵跳滞空时间

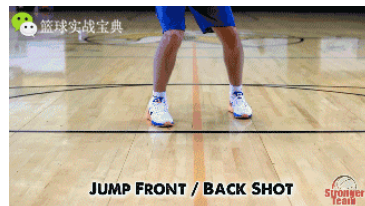
定义为球员在场上运动时跳跃动作的平均滞空时间



三步上篮 - GIF动态图

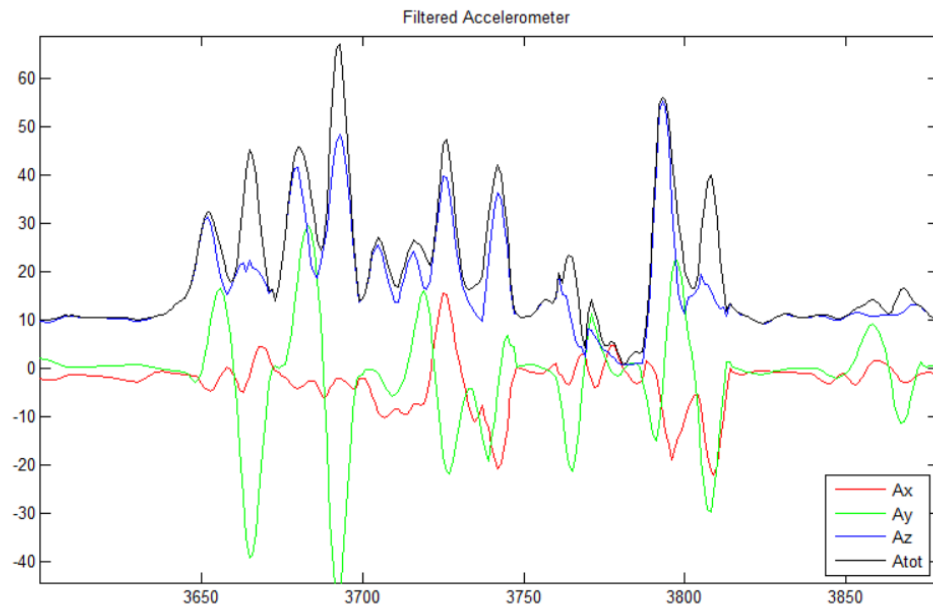


纵跳 - GIF动态图



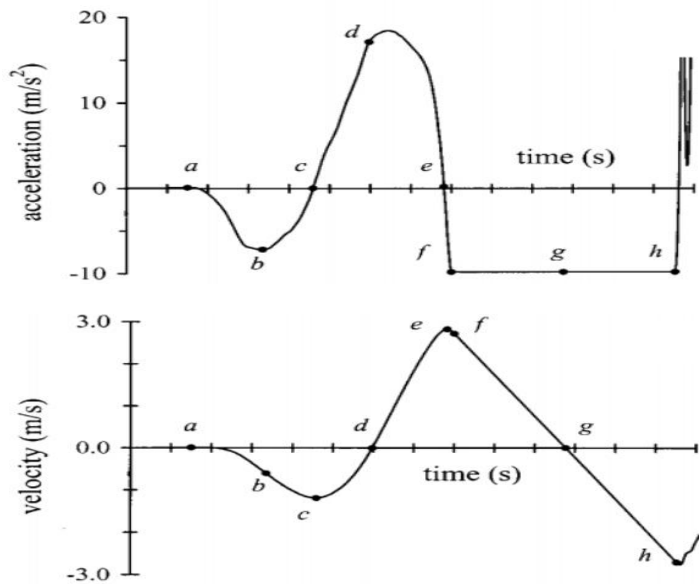
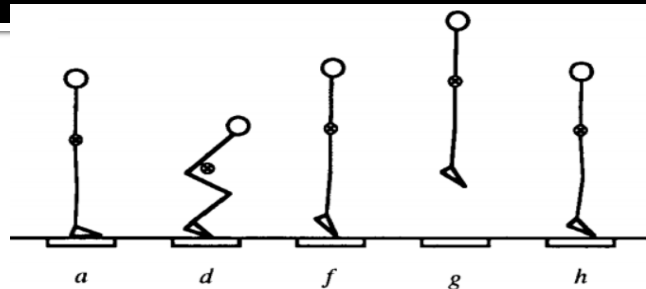
跳投 - GIF动态图

纵跳检测



三步上篮过程

弹跳高度



估计方法:

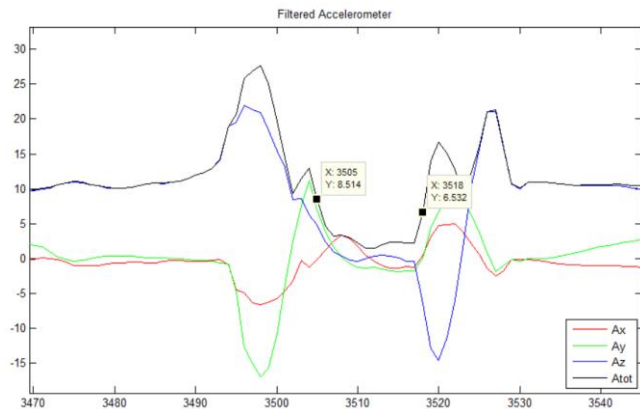
- 根据起落时间差

$$v_{to} = \frac{gt_{flight}}{2}$$

- 根据起跳冲量

$$\int_{t_i}^{t_{to}} (F_{GRF} - mg) dt = m v_{to}$$

- 根据经验估计公式



ag_0312_bob.txt

落地姿势识别

* 落地踝关节翻转角度

* 落地姿势识别

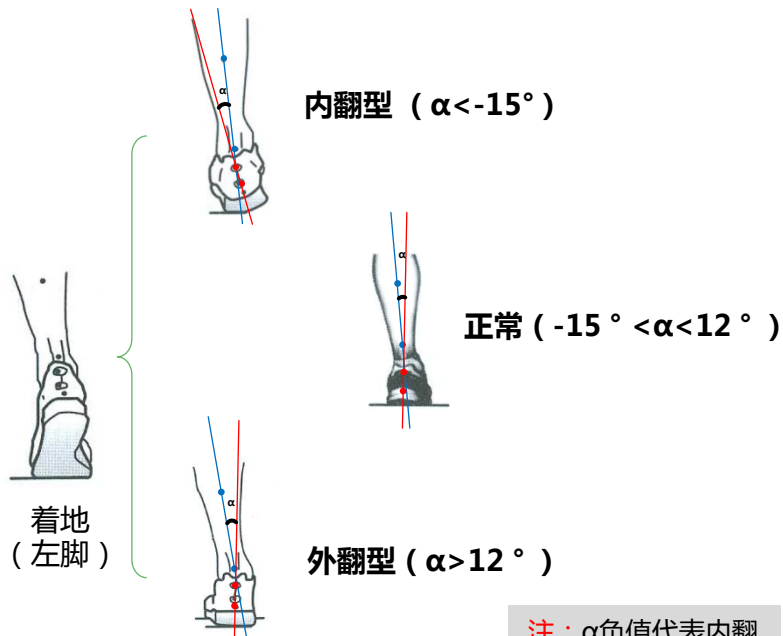
落地踝关节翻转角度：定义为球员在跳跃动作中（包括三步上篮的**单腿跳**、抢篮板动作的**纵跳**、投篮动作的**跳投**），着地瞬间踝关节的内外翻角度

落地姿势识别：在判断着地内外翻角度的基础上，统计三种着地方式的**分布概率**

足内翻	足外翻	正常
0%	0%	100%

跳投 - GIF动态图

篮球运动三种着地方式



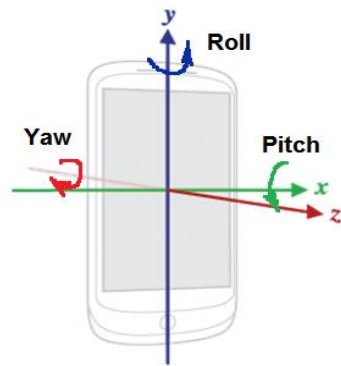
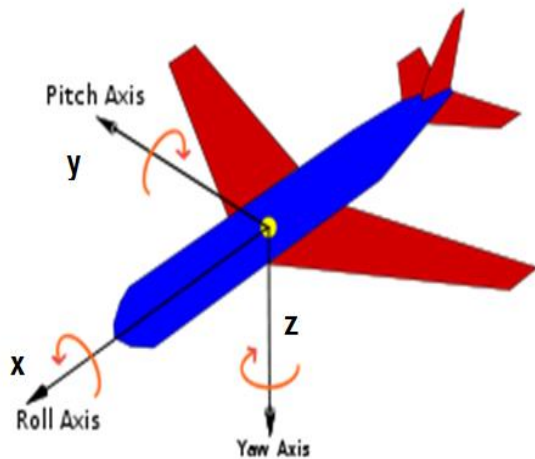
注： α 负值代表内翻， α 正值代表外翻

结合落地陀螺仪数据

6/9-Axis Sensors Fusion (姿态融合)

- Orientation representation

Euler angle definition



Aircraft versus Android phone

Attitude Representation

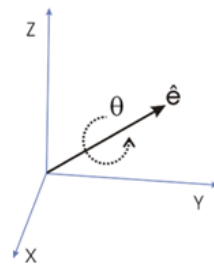
- Roll, pitch and yaw angles are denoted as (R, P, H) / (ϕ, ϑ, ψ)

- Direction Cosine Matrix

- Quaternions

$$\mathbf{x}^b = \mathbf{C}_a^b \mathbf{x}^a = \begin{pmatrix} \mathbf{i}_a \cdot \mathbf{i}_b & \mathbf{j}_a \cdot \mathbf{i}_b & \mathbf{k}_a \cdot \mathbf{i}_b \\ \mathbf{i}_a \cdot \mathbf{j}_b & \mathbf{j}_a \cdot \mathbf{j}_b & \mathbf{k}_a \cdot \mathbf{j}_b \\ \mathbf{i}_a \cdot \mathbf{k}_b & \mathbf{j}_a \cdot \mathbf{k}_b & \mathbf{k}_a \cdot \mathbf{k}_b \end{pmatrix} \mathbf{x}^a$$

- Rotation vector: rotate $\bar{\mathbf{q}} = q_0 + q_1\mathbf{i} + q_2\mathbf{j} + q_3\mathbf{k}$ by angle θ around a unit vector $\mathbf{e} = \langle x, y, z \rangle$ (rotation axis: $\bar{\mathbf{q}} = q_1\mathbf{i} + q_2\mathbf{j} + q_3\mathbf{k} + q_4$)



Navigation/Body Frame Def.

	Aerospace	Mobile(Android)
Navigation Frame	x-axis points true North y-axis points East z-axis points Down (N-E-D)	x-axis points East y-axis points magnetic North positive z-axis points Up (E-N-U)
Body Frame	x-axis in the longitudinal axis pointing Forward y-axis points to Right-side to form a right-handed system z-axis points Down (F-R-D)	x-axis points out the Right of the screen y-axis points out of the top of the screen z-axis points out of the screen (R-F-U)
Yaw	Rotation about z-axis, Range of 0° to 360°	Rotation about negative z-axis Range of 0° to 360°
Pitch	Rotation about y-axis, Range of -90° to 90°	Rotation about negative x-axis Range of -180° to 180°
Roll	Rotation about x-axis, Range of -180° to 180°	Rotation about y-axis Range of -90° to 90°

Coordinate Transformation

$SO(3)$

3D rotation group is a Lie group, the special orthogonal group of all rotations about the origin of three-dimensional Euclidean space R_3 under the operation of composition. [Kuniper 99]

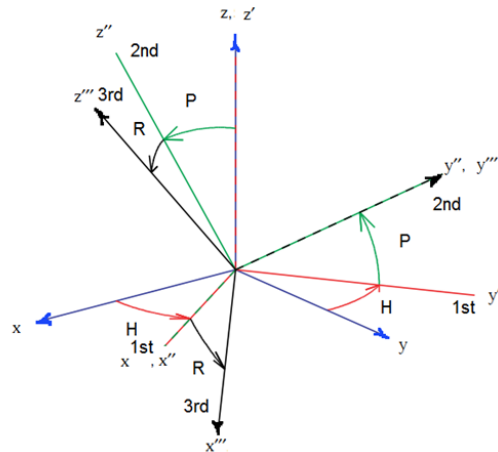
$SE(3)$

Special Euclidean Group, a 6-dimensional manifold(流形), 3D translation vector + 3D rotation of a rigid body transformation

Euler Theorem

Any two independent orthonormal coordinate frames can be related by a sequence of rotations(not more than 3) about coordinate axes, where no two successive rotations may be about the same axis.

Cn->b Transformation



$$(x, y, z)^n \xrightarrow{R_z(H)} (x', y', z')^1 \xrightarrow{R_x(P)} (x'', y'', z'')^2 \xrightarrow{R_y(R)} (x''', y''', z''')^b$$

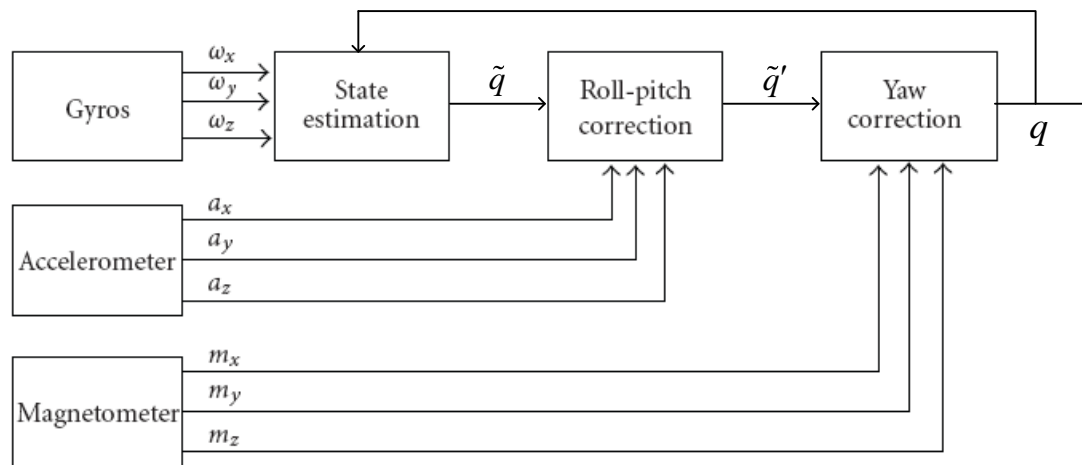
$$C_n^b = R_y(R)R_x(P)R_z(H)$$

$$= \begin{pmatrix} \cos R \cos H - \sin P \sin R \sin H & \cos R \sin H + \sin R \sin P \cos H & -\cos P \sin R \\ -\cos P \sin H & \cos P \cos H & \sin P \\ \sin R \cos H + \sin P \cos R \sin H & \sin R \sin H - \sin P \cos R \cos H & \cos P \cos R \end{pmatrix}$$

10/15

Orientation Fusion Algorithm

- Filter: Quaternion-based EKF
- System state: Quaternion (Derived by gyroscope output)
- Measurement: Accelerometer and Magnetometer output



Orientation Fusion Algorithm (Cont.)

■ State Vector: $X = [q_0 \quad q_1 \quad q_2 \quad q_3]^T$

■ State Equation:

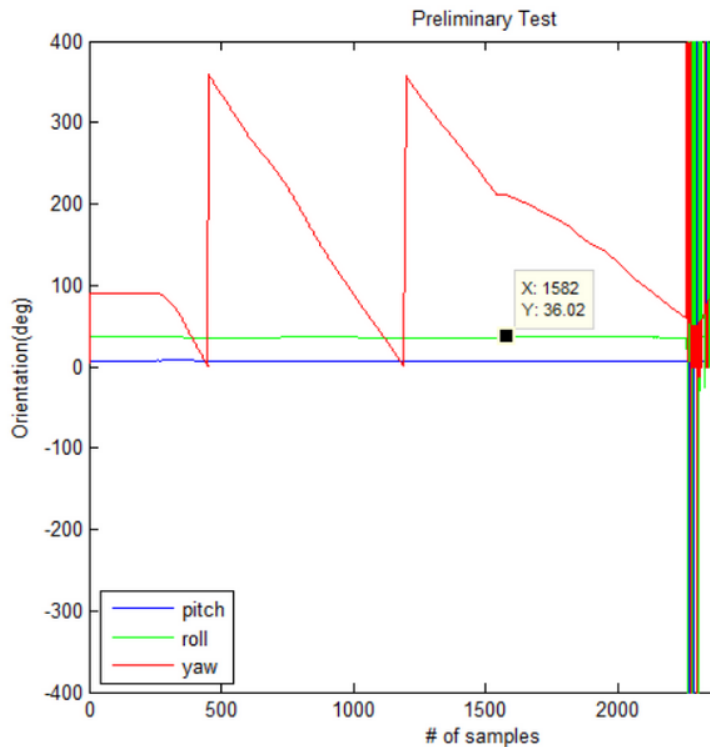
$$\dot{X} = \frac{1}{2} \begin{bmatrix} 0 & -\omega_x & -\omega_y & -\omega_z \\ \omega_x & 0 & \omega_z & -\omega_y \\ \omega_y & -\omega_z & 0 & \omega_x \\ \omega_z & \omega_y & -\omega_x & 0 \end{bmatrix} X$$

■ Measurement Equation:

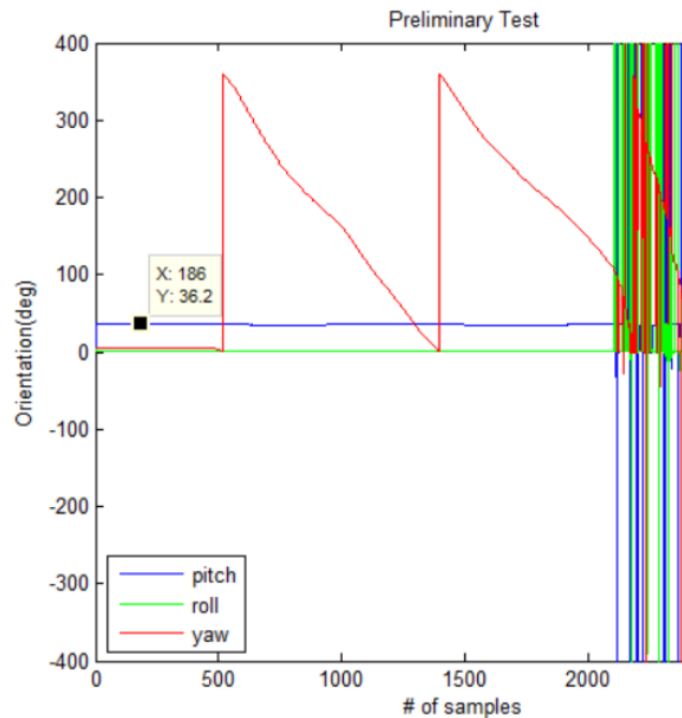
$$Z_{k+1} = \begin{bmatrix} a_{k+1} \\ m_{k+1} \end{bmatrix} = h(X_{k+1}) + v_{k+1} = \begin{bmatrix} C_n^b(q_{k+1}) & 0 \\ 0 & C_n^b(q_{k+1}) \end{bmatrix} \begin{bmatrix} \overrightarrow{g_n} \\ \overrightarrow{m_n} \end{bmatrix} + \begin{bmatrix} v_{k+1}^a \\ v_{k+1}^m \end{bmatrix}$$

处理结果

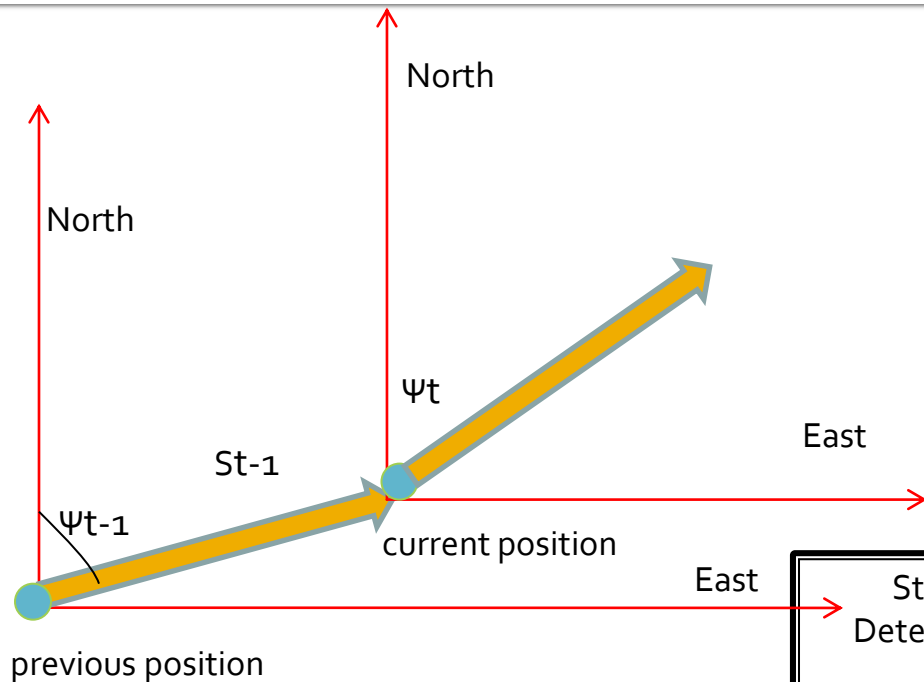
3) covert_0311_45x_4.csv x轴向下45度, 然后水平旋转3圈
实际处理结果ROLL 35度左右;



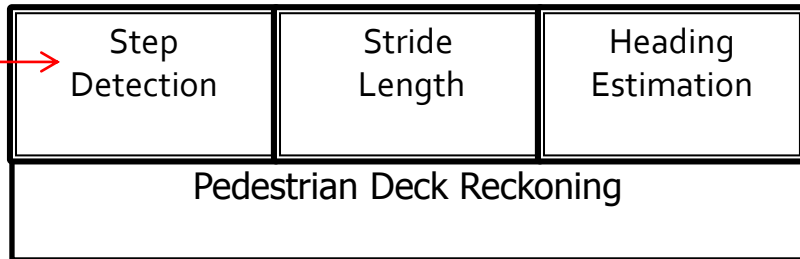
4) covert_0311_45y_4_default.csv y轴向下45度, 然后水平旋转3圈
实际处理结果PITCH 35度左右;



轨迹推演 Pedestrian Dead Reckoning



$$E_t = E_{t-1} + \hat{s}_{[t-1,t]} \sin \psi_{t-1}$$
$$N_t = N_{t-1} + \hat{s}_{[t-1,t]} \cos \psi_{t-1}$$



测试结果

- 分别选取不同身高体重年龄测试人员进行大量测试,综合测试各项数据精度如下:
- 测试内容 准确度
- 步数检测 99%
- 横向步数检测 92%
- 跳跃检测 83%
- 步长&移动距离 93%

测试结果

■ 变向检测	88%
■ 移动速度	93%
■ 跳跃高度	90%
■ 落地姿势检测	95%