



Croucher Summer Course - Sports Biomechanics

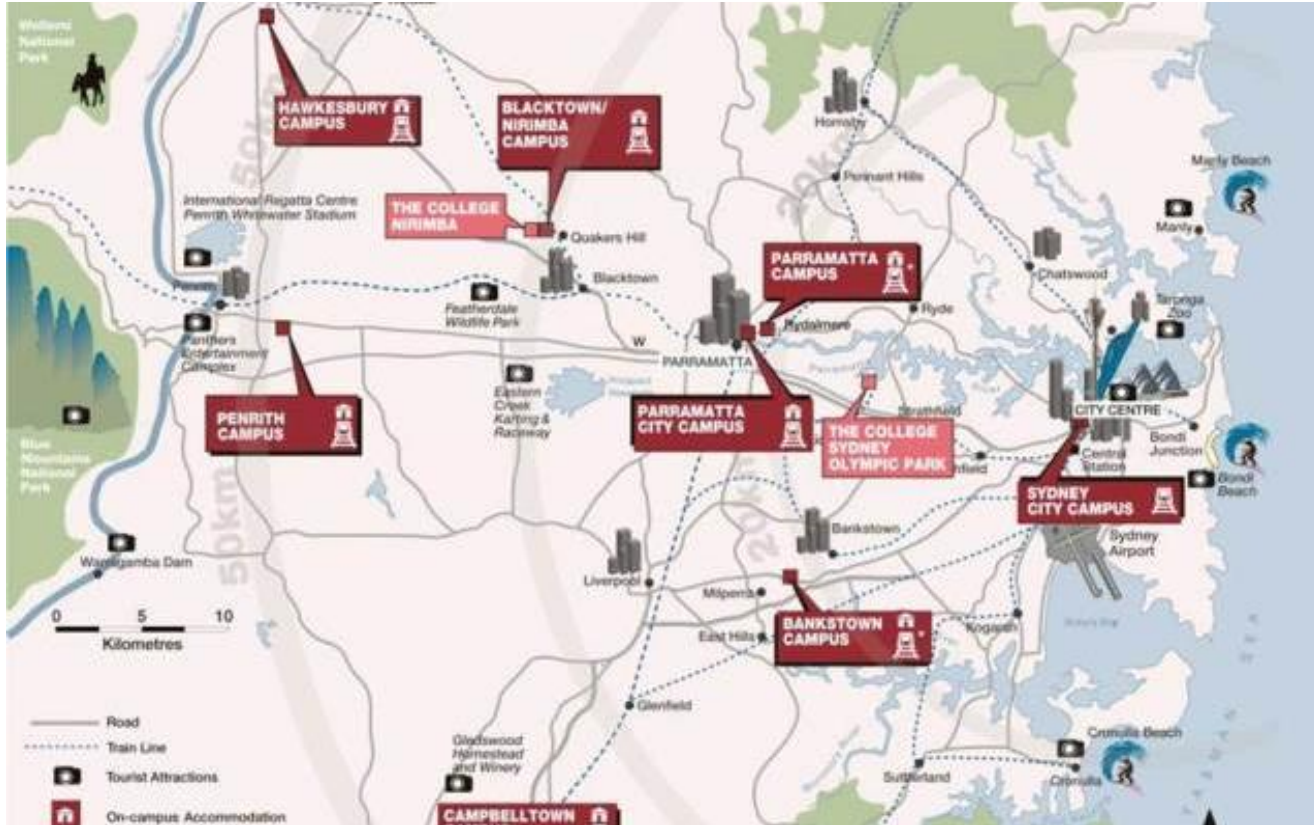
# Application of Wearable Sensor and Computer Vision for Sports Enhancement

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Professor in Physiotherapy, Head of Discipline

School of Health Sciences, Western Sydney University

# About WSU...



# Achievements



AGAIN.



# About myself...

- Academic qualifications
  - BSc (Hons) Physiotherapy
  - PhD in Biomechanics
  - Postdoctoral Fellow in Physical Medicine and Rehab
- Achievements
  - World Top 50 Scientist in Running Biomechanics
  - 15 Most Influential Chinese Scientists in Rehab
  - Owner of 5 patents (another under review)
  - Winner of international invention awards
  - Mentor of >50 postgraduates (e.g., physio, engineers, sonographers, computer scientists, etc.)



# Traditional Mocap

**Equipment:**

Cameras  
Force plates

**Setup:**

Markers  
Calibration

**Technicality:**

Complicated  
post-processing

**Subject:**

Hawthorne  
New environment

**High cost:**

Equipment  
Space

**High cost:**

Time

**High cost:**

Staff

**Data:**

May not apply in  
the real-world

# Biomechanics was known as...



Delayed results

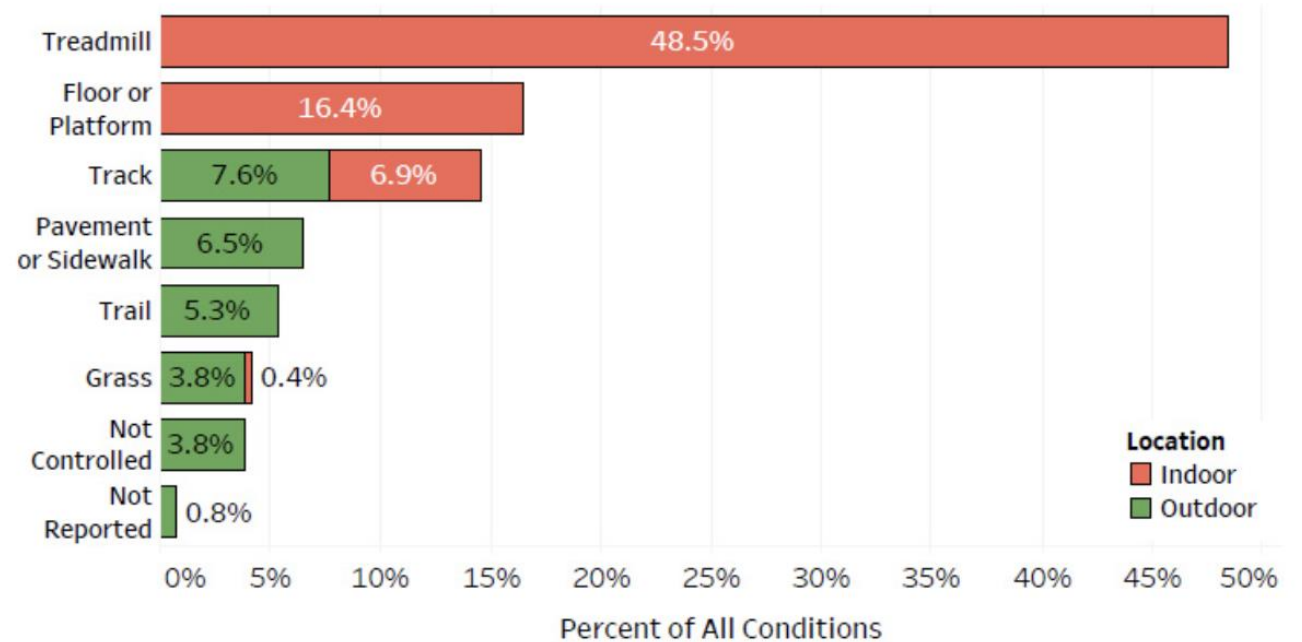
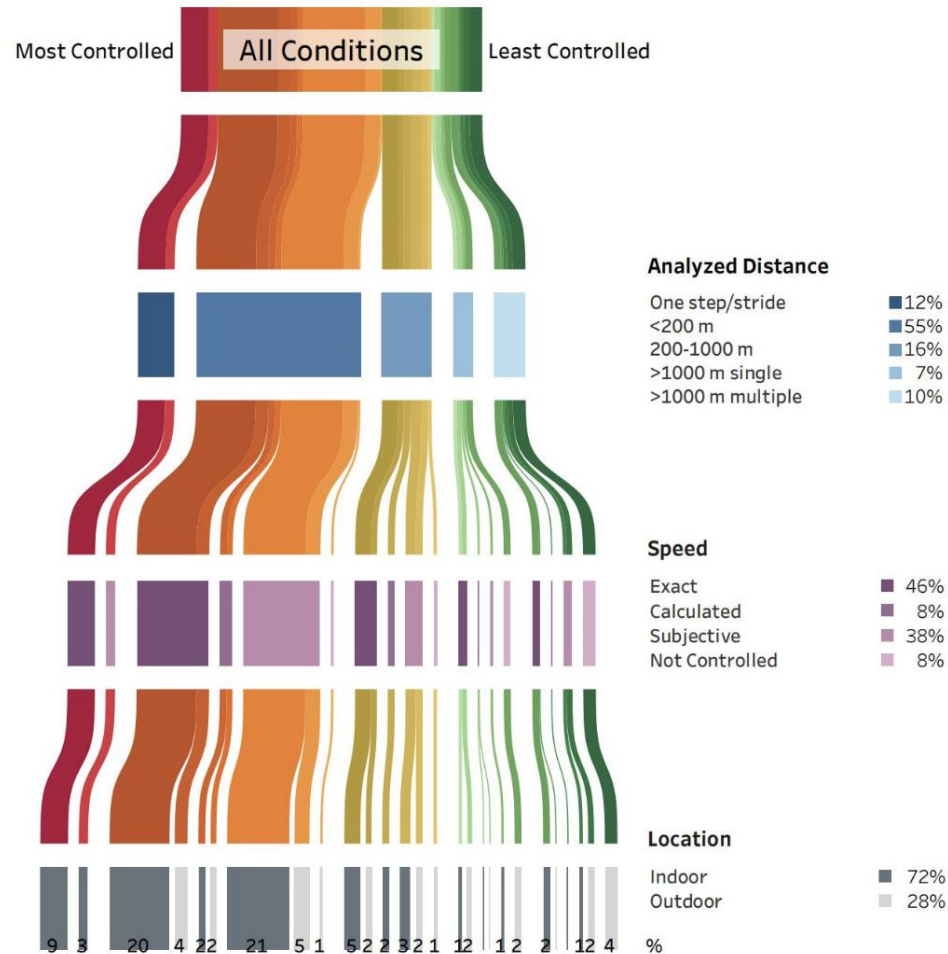


Zero-interaction  
with  
subjects



So what?!

# Reality updated



[Benson et al., 2022]

# Not feeling natural...



## Hawthorne Effect

*[ 'hò-,thòrn i-'fekt ]*

When subjects of an experimental study change or improve their behavior because it is being evaluated or studied.

# “Contemporary” biomechanics

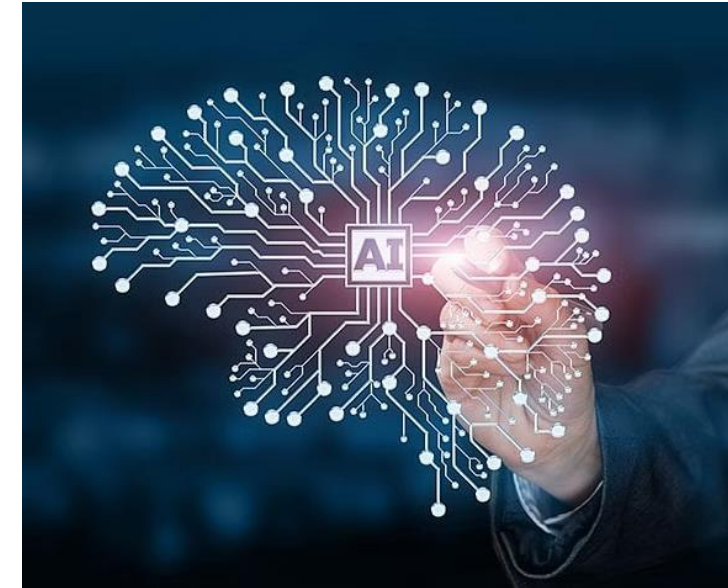
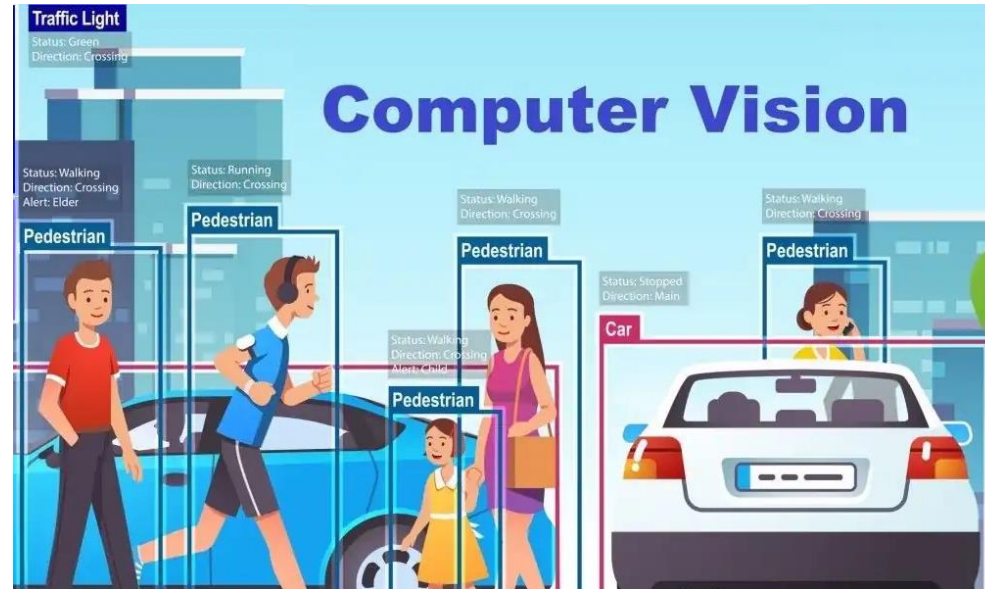


[Cheung et al., 2017]

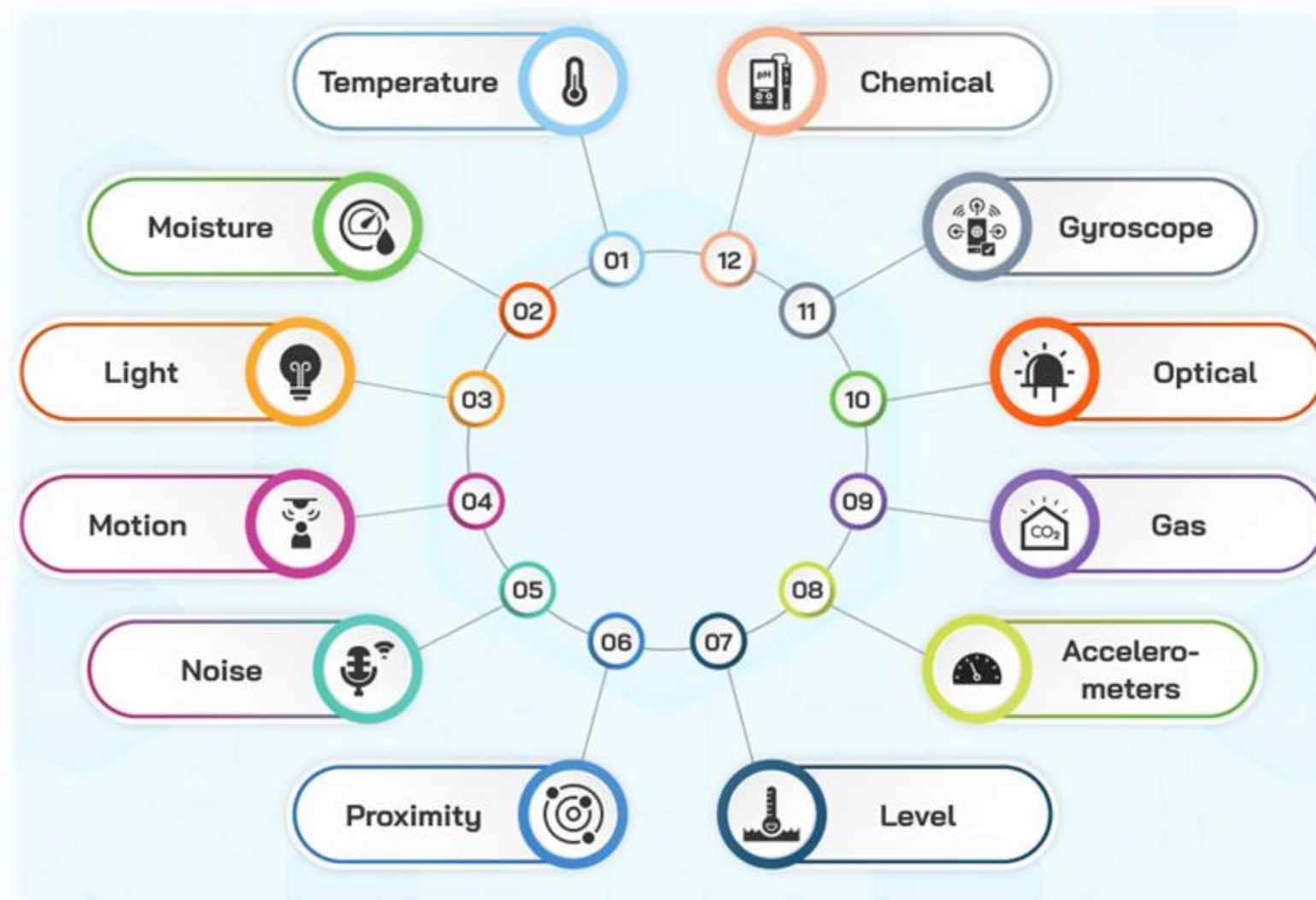
# Out of lab applications



# Technology



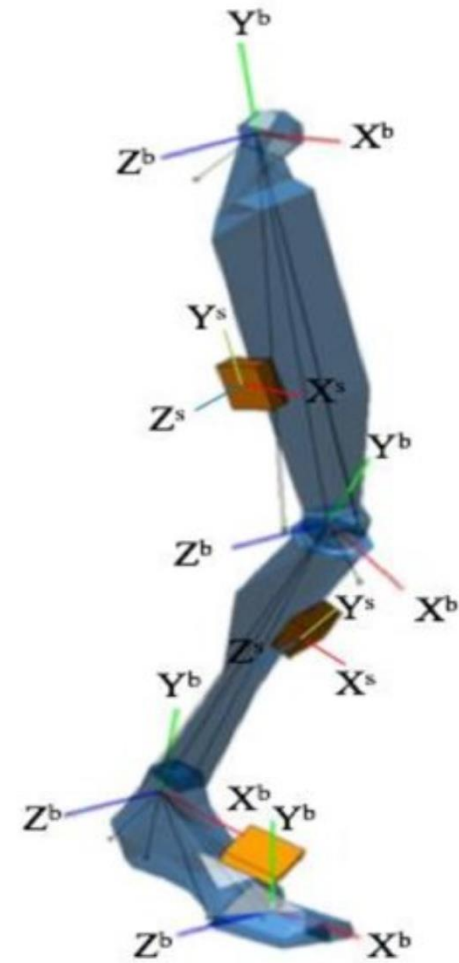
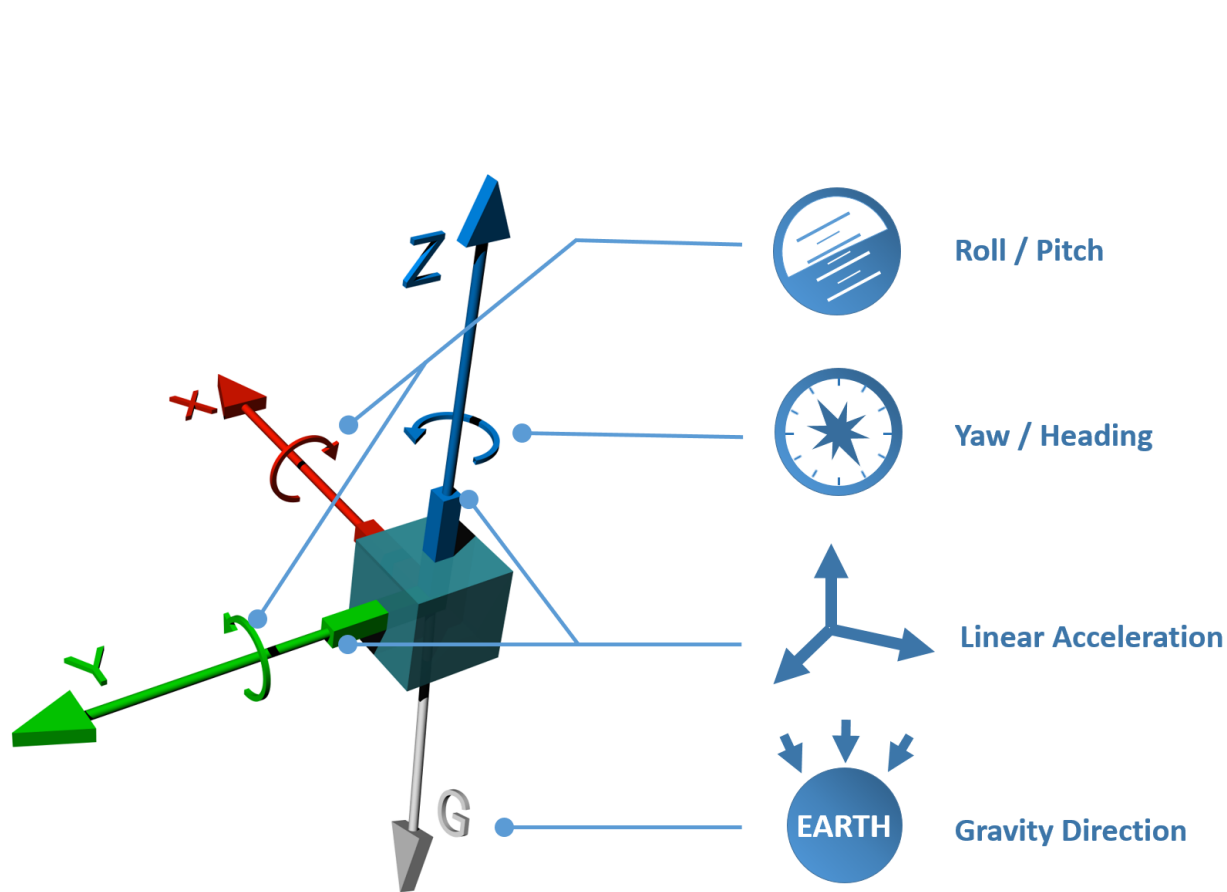
# Types of sensors



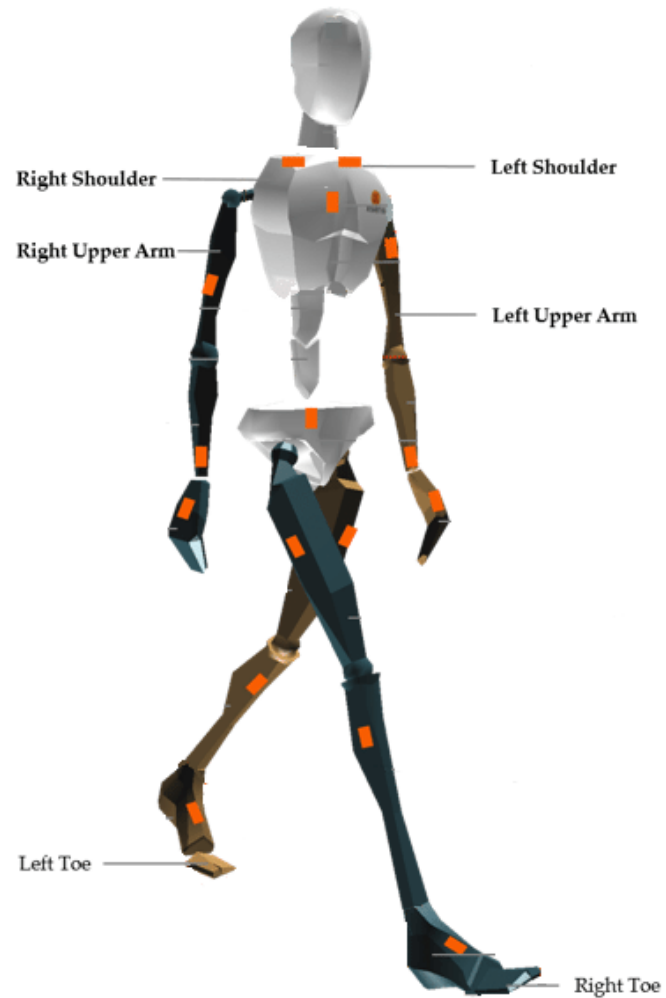
# Hottest in biomechanics



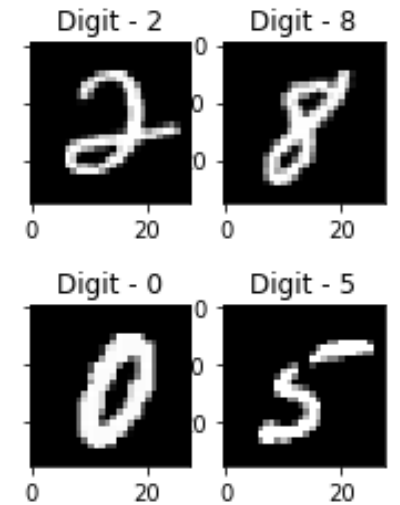
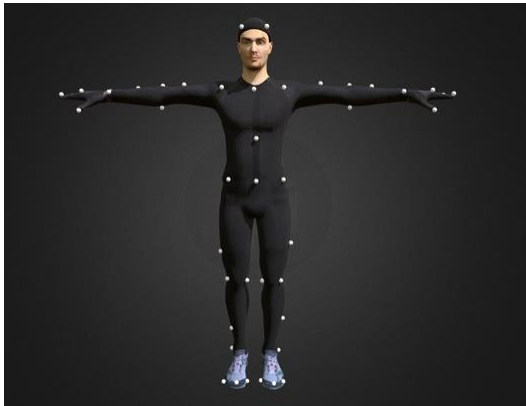
# Traditional use of IMU



# User friendliness



# Typical development flow



Ground truth  
labels



Synchronised  
IMU data

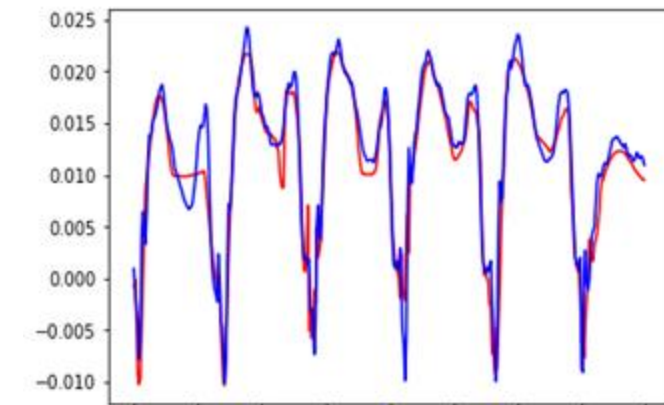
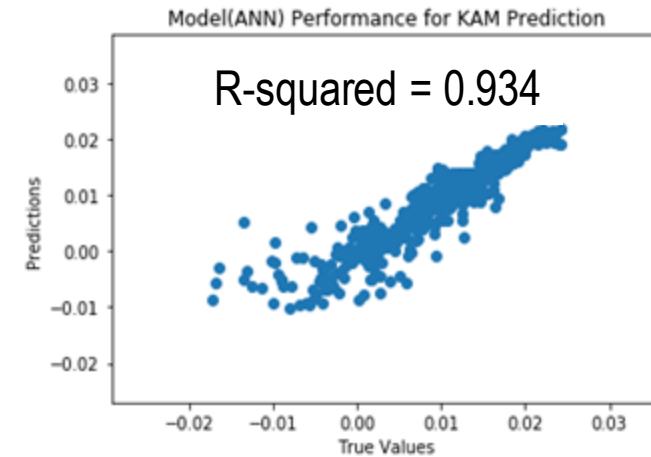
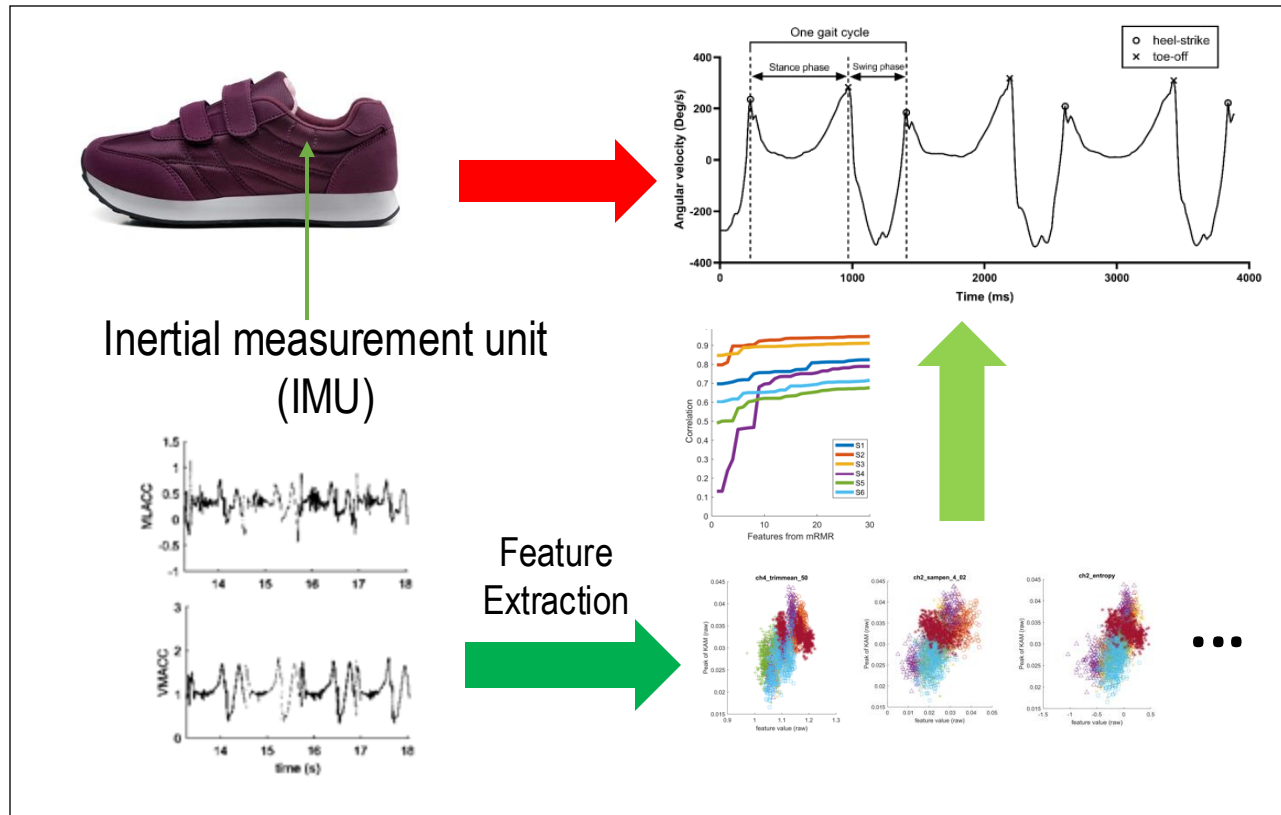


Model training



Model  
validation

# Example



Measured (blue) vs. Predicted (red)

[Wang et al., 2020; US Patent # 16/447,636]

# Computer vision



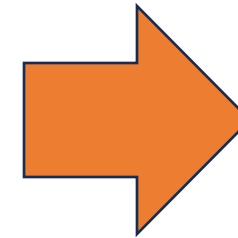
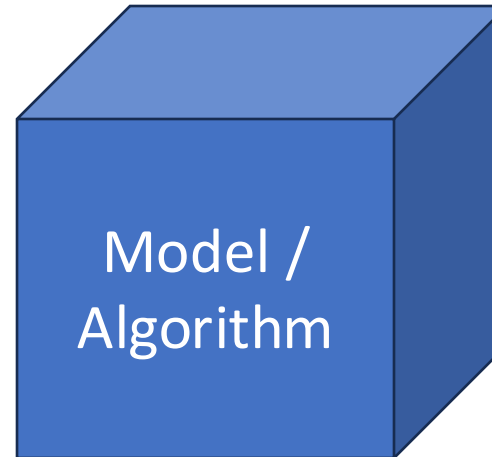
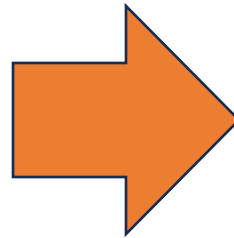
# A well-known example



# How it works?



Inputs and labels

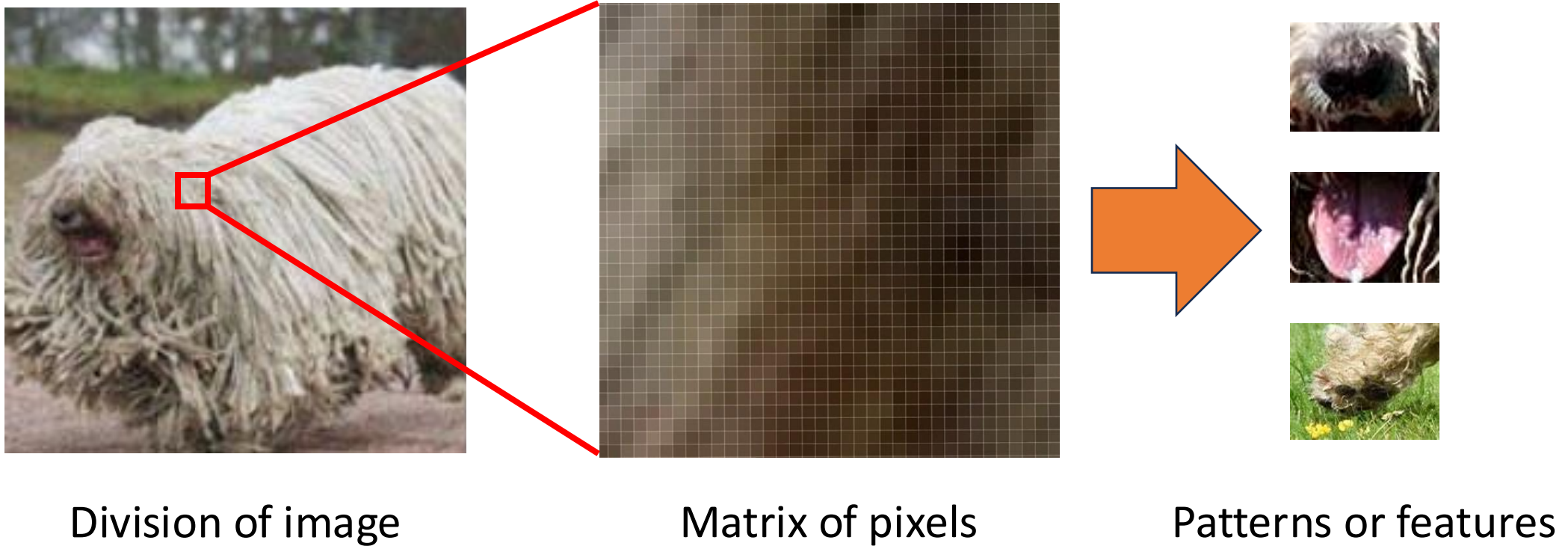


Sheep dog

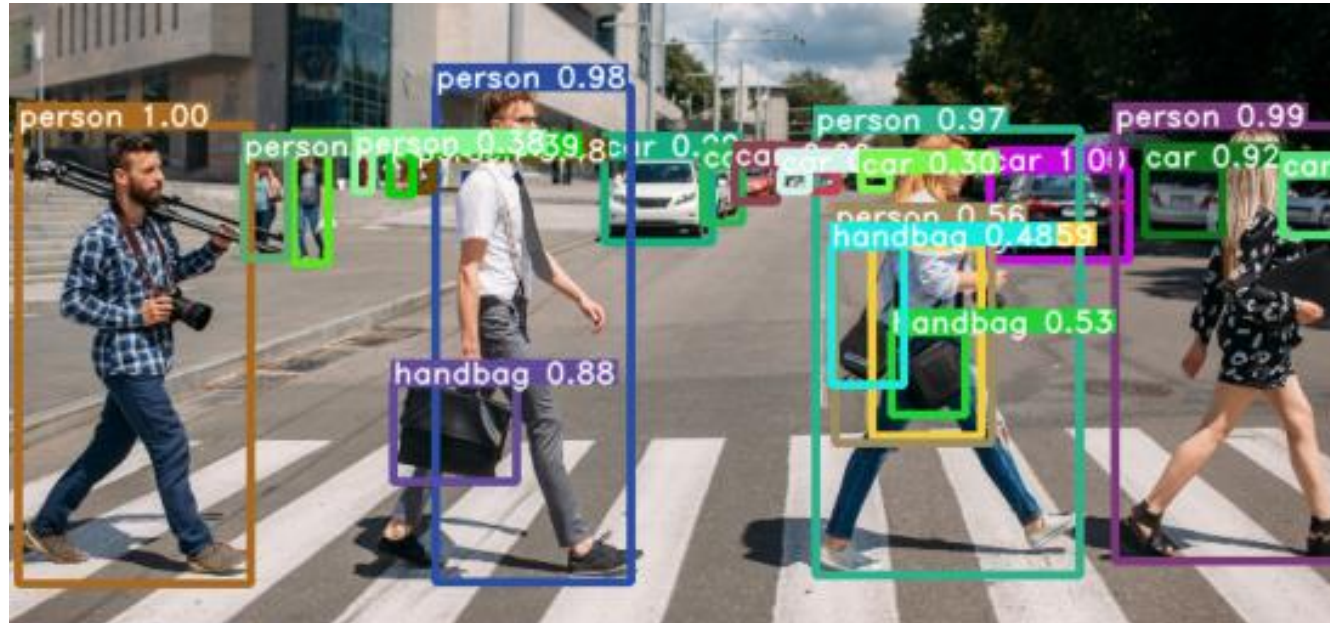
Or

Mop

# Convolutional neural network



# YOLO



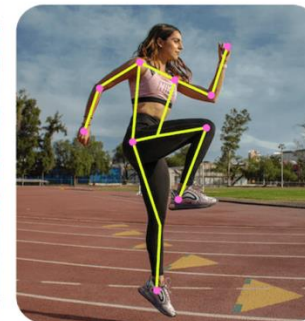
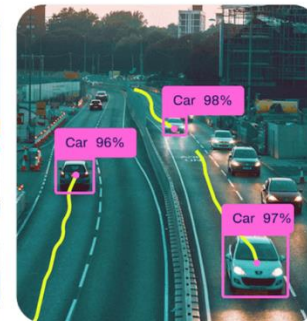
## Classify

Detect

Segment

Track

## Pose





# Sport applications

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# Distance running

51-79% injury risk  
per annum

Lun et al., 2004; Burke et al., 2023

Switching footstrike  
pattern may reduce  
injury risk

Futrell et al., 2021



Relates to faulty  
kinematics

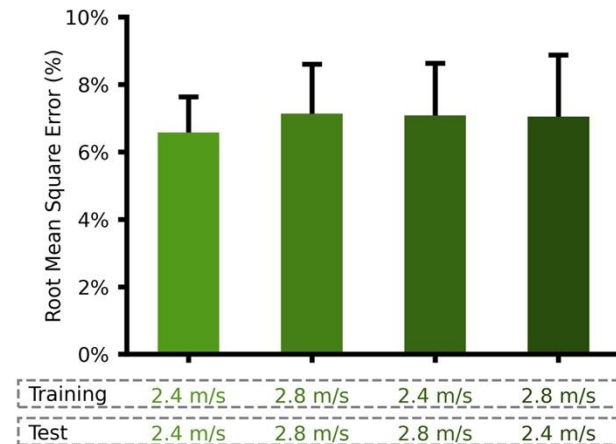
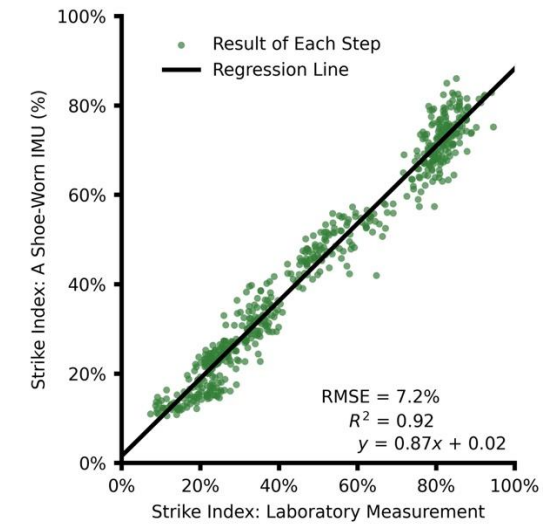
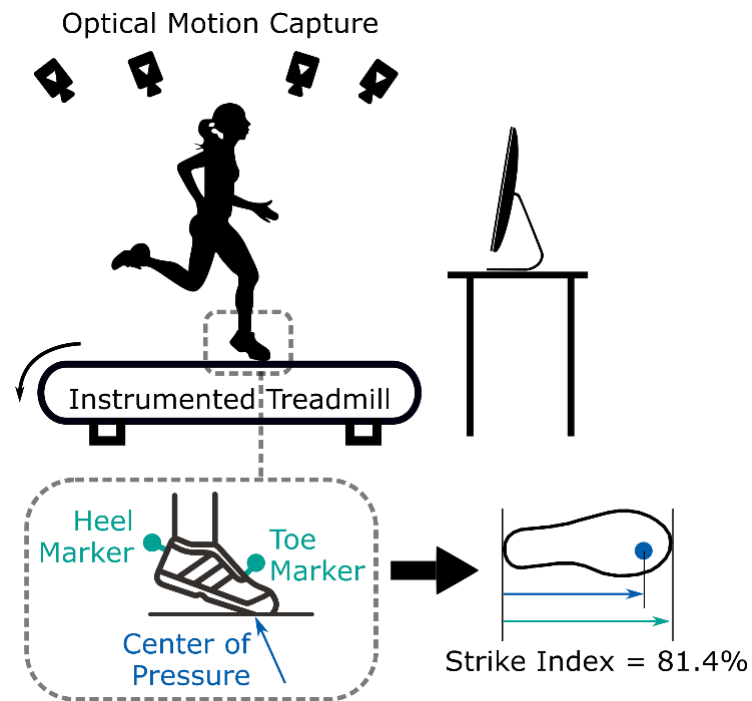
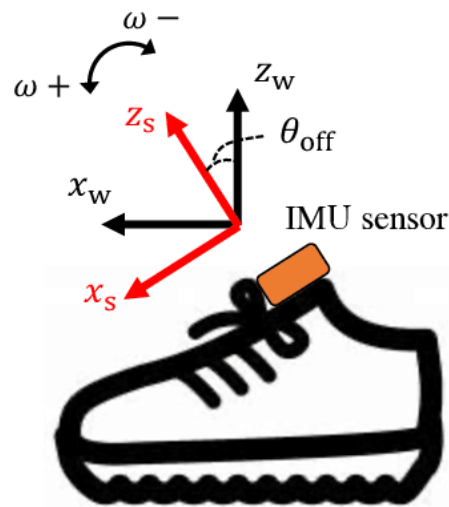
Foch et al., 2023

Synergy differs between  
elite and recreational  
runners

Cheung et al., 2020

Will talk more about this in the Biomechanics Summit this weekend!

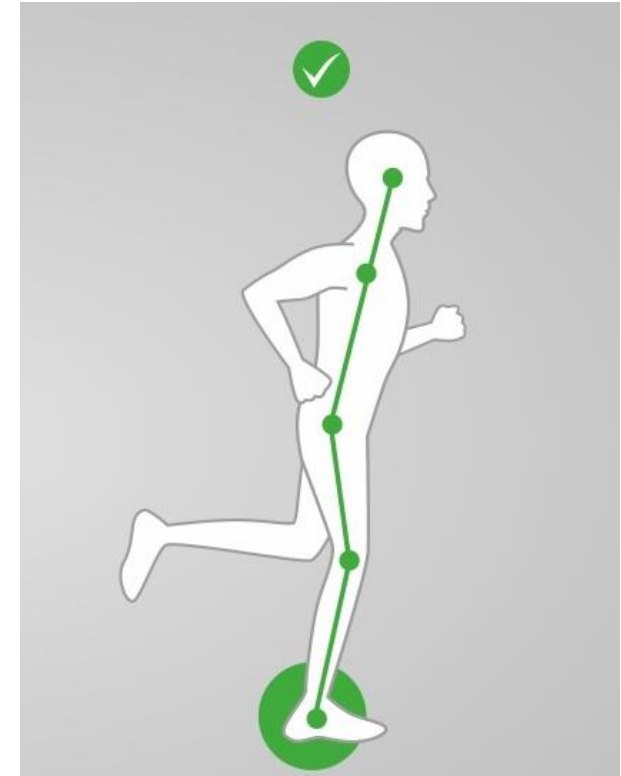
# Footstrike pattern



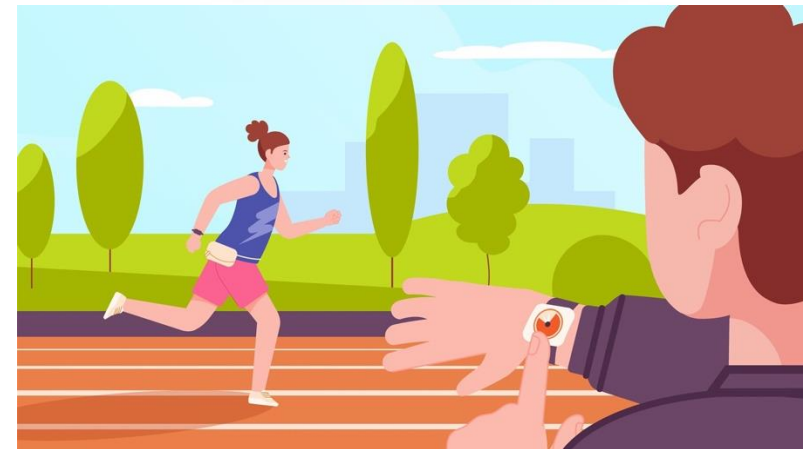
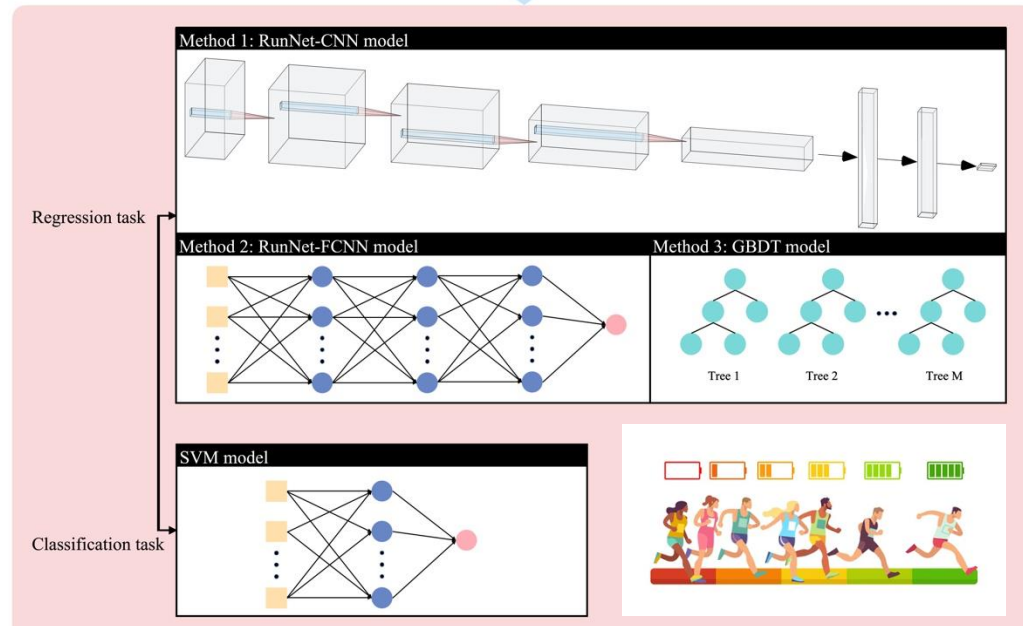
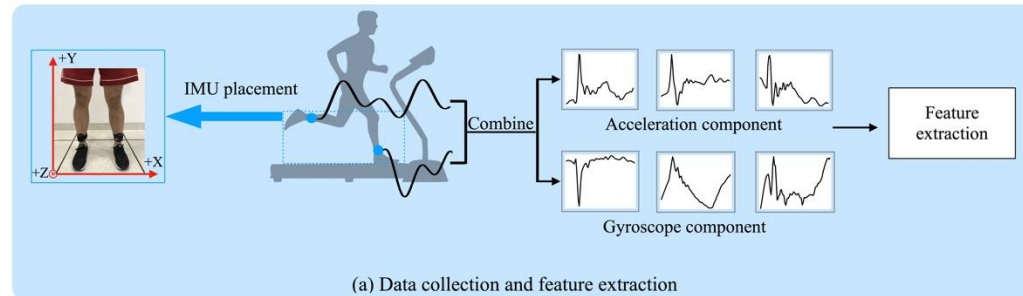
[Tan et al., 2022]



# Why concerning running kinematics?



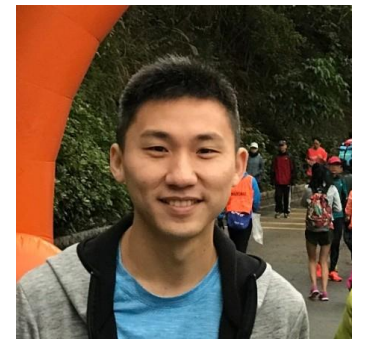
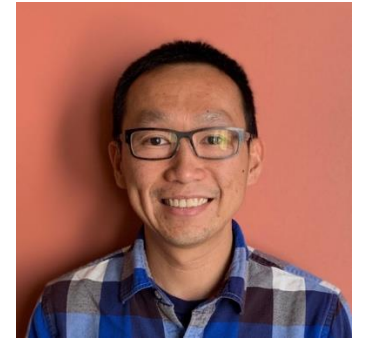
# Classification of skill level



[Liu et al., 2020]



# CV in basketball



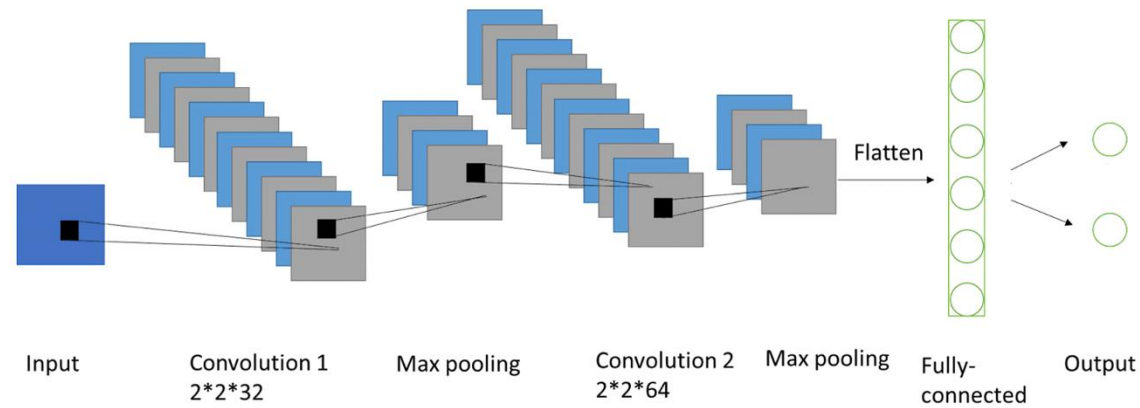
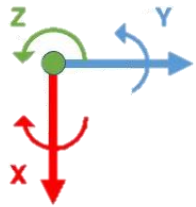
# Basketball



# Basketball wearable



# Free-throw sensor

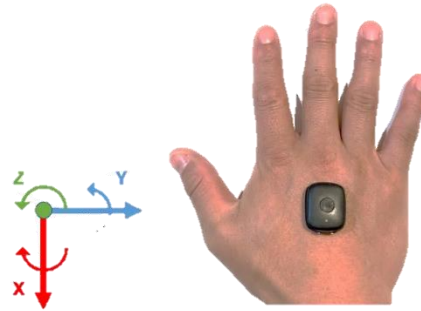


[Guo et al., 2023]



# Feature analysis

| Input         | Accuracy | Sensitivity | Specificity |
|---------------|----------|-------------|-------------|
| $A_x A_y$     | 0.85     | 0.84        | 0.87        |
| $A_x A_z$     | 0.87     | 0.86        | 0.87        |
| $A_y A_z$     | 0.82     | 0.81        | 0.83        |
| $G_x G_y$     | 0.82     | 0.81        | 0.83        |
| $G_x G_z$     | 0.80     | 0.77        | 0.82        |
| $G_y G_z$     | 0.81     | 0.78        | 0.83        |
| $A_x G_x$     | 0.85     | 0.83        | 0.87        |
| $A_y G_y$     | 0.84     | 0.82        | 0.85        |
| $A_z G_z$     | 0.83     | 0.82        | 0.85        |
| $A_x A_y A_z$ | 0.87     | 0.86        | 0.88        |
| $G_x G_y G_z$ | 0.86     | 0.84        | 0.88        |
| $A_x A_z G_y$ | 0.88     | 0.87        | 0.90        |

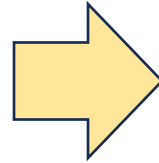


- The machine learning algorithm can classify skill level between novice and professional with **88% accuracy**
- Foundation work for building a biofeedback device to improve free-throw performance



WESTERN SYDNEY  
UNIVERSITY

# Actual motivation



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# Squash

Sport / Hong Kong

## Hong Kong squash players still processing ‘unreal’ decision to include sport in 2028 LA Olympics

- City’s top women’s player Tomato Ho says she had almost given up hope squash would ever be an Olympic sport
- Five sports added for the Games in the US, with cricket, flag football, lacrosse and baseball/softball also included

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**Mike Chan**

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Published: 2:21pm, 19 Oct 2023 ▼

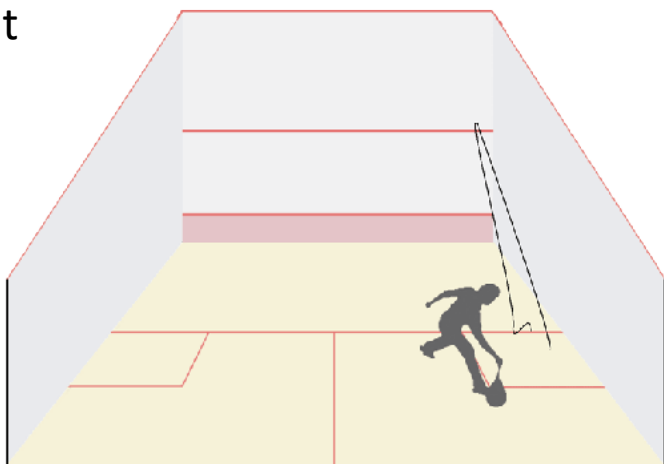
 [Why you can trust](#)



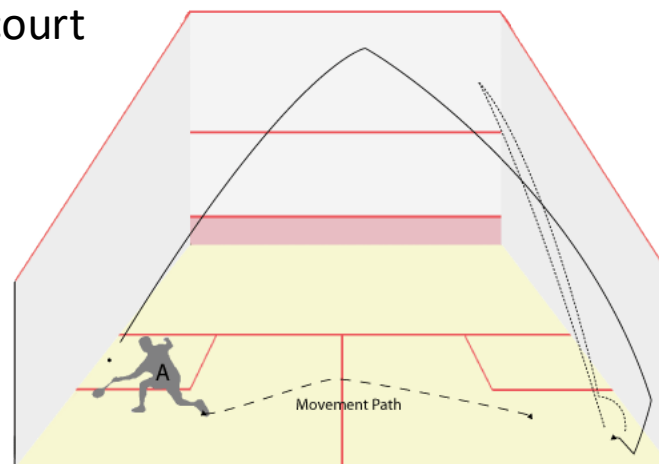
Tomato Ho takes on world No 1 Nouran Gohar at the 2022 Hong Kong Squash Open. Photo: Handout

# Classification of maneuvers

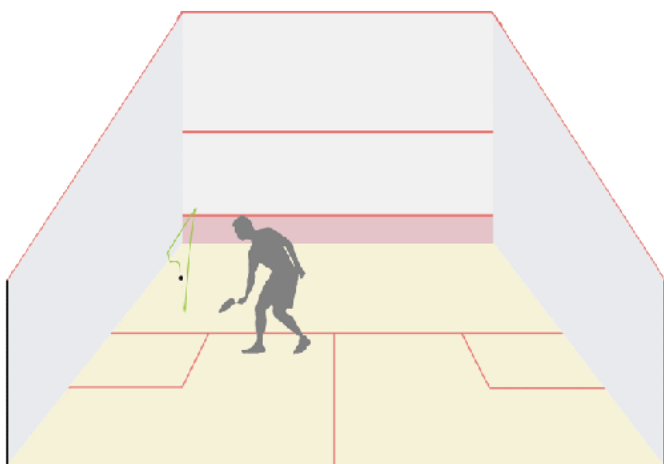
Straight Drive



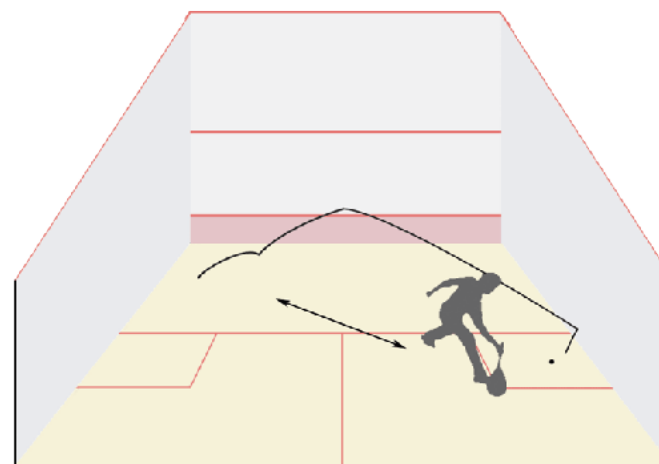
Cross-court Drive



Drop Shot



Boast



| Input      | Accuracy |
|------------|----------|
| Ax Ay Az   | 74-86%   |
| Gx Gy Gz   | 83-93%   |
| All 6 axes | 89-94%   |



# Other applications



Determine ball speed  
and target

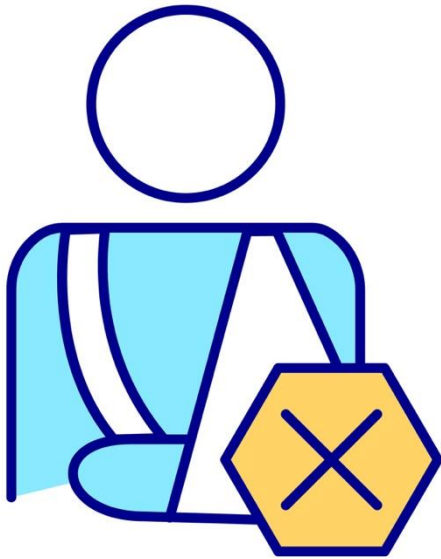


Facilitate coaching



Information for  
commentators

# Research impact



# Take-home messages

- Biomechanics is no longer confined to laboratory environments
- We can interact with sportsmen and referees using wearable sensors and computer vision
- Next generation solutions for performance enhancement, injury prevention and refereeing



# Personal message



# Acknowledgements

- Funding bodies
  - National Institute of Health (NIH), USA
  - Western Sydney University, Australia
  - Translational Health Research Institute, Australia
  - University Grants Committee, HK
  - Food & Health Bureau, HK
  - Innovation & Technology Commission, HK
- Collaborators, teammates and students





Thank you