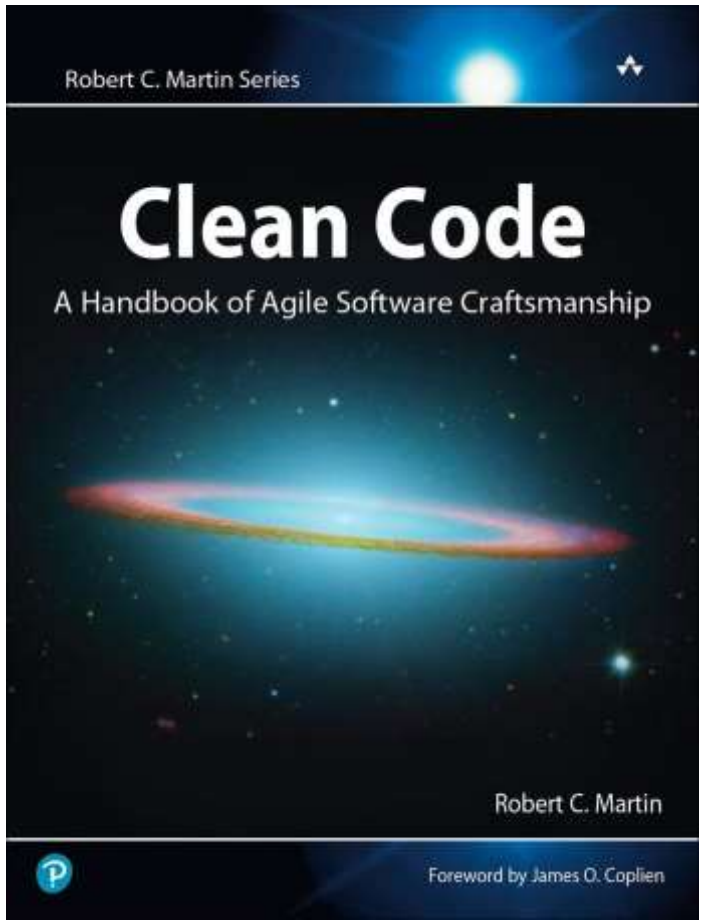
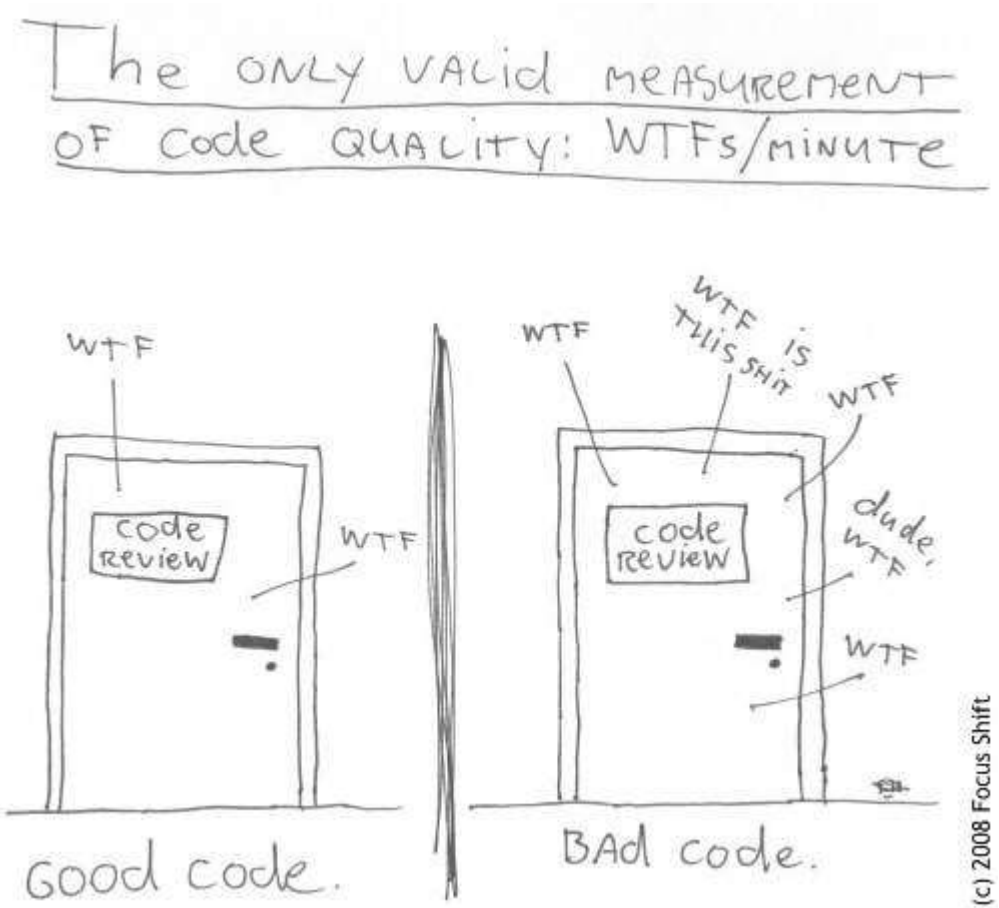
# Gyroscope & Accelerometer Data Fusion

Vincent van Hees – 7th of April 2021

Webinar series OS Software in Physical Behaviour Research Field

# Clean Code by Uncle Bob

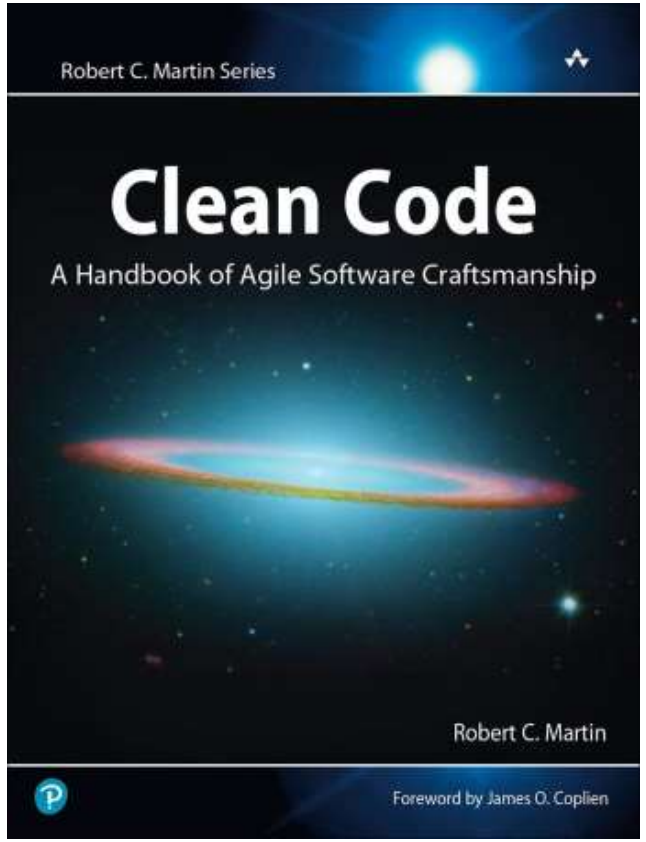



Training videos: https://cleancoders.com
Also 'free' recordings from conference talks on YouTube

# Clean Code by Uncle Bob

- Object names
- Function names
- Comment
- Formatting
- Object and data structures
- Error Handling
- Unit-tests
- ....

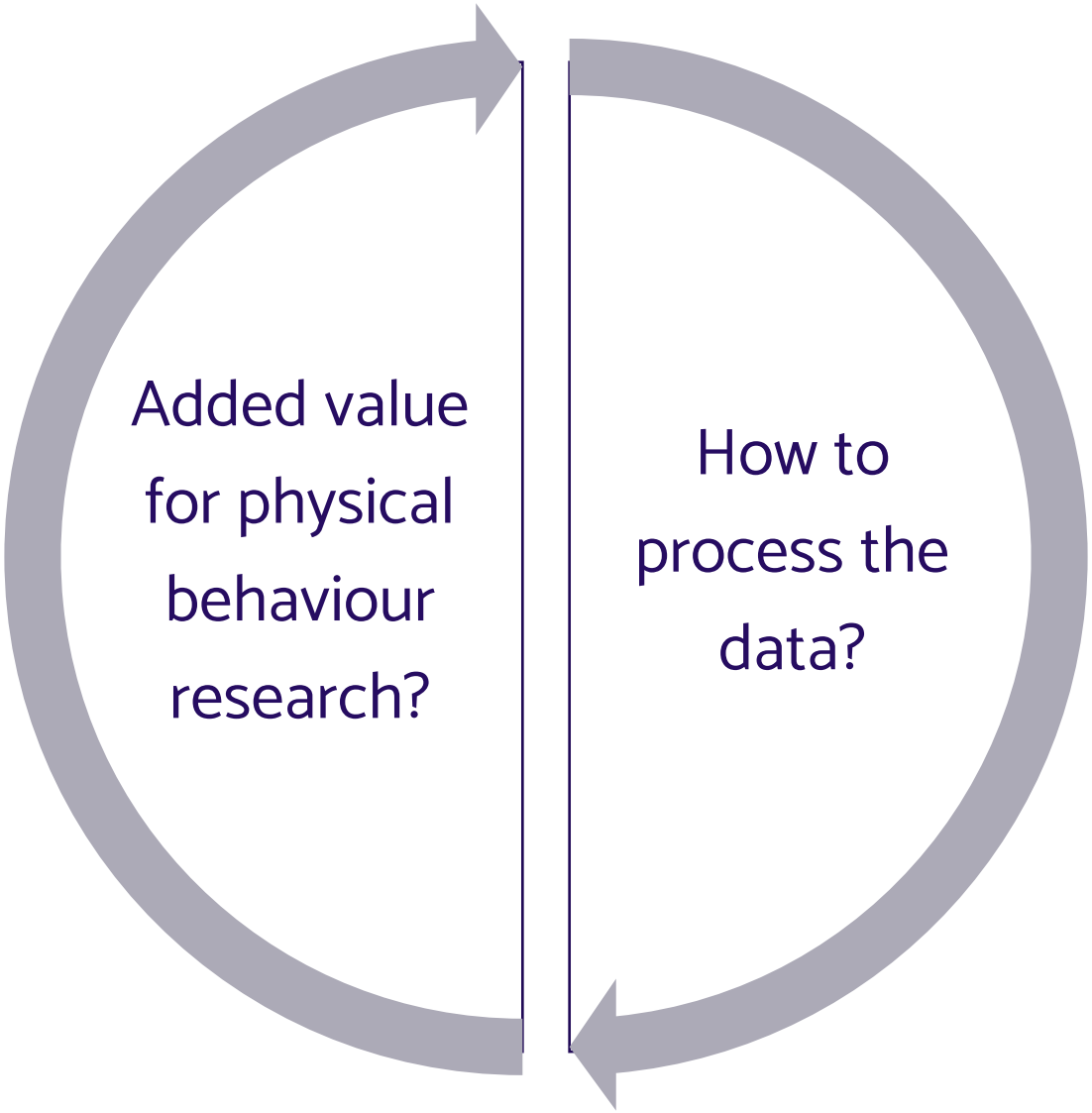


# Gyroscopes

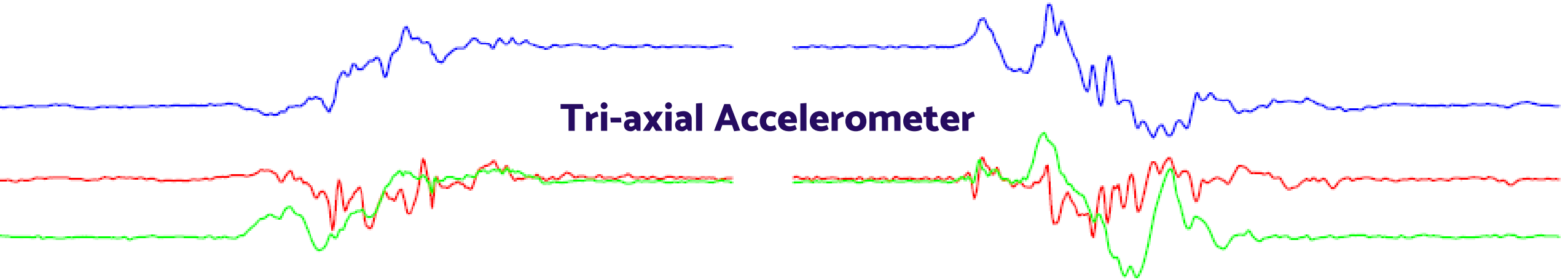
- Measures angular velocity around each axis
- Works based on resonating mass, see also [1, 2].
- Feasibility has improved in recent years
  - 7 days @ 100 Hertz with 3 accelerometer and 3 gyroscope
  - Based on small battery
- Potential challenges:
  - More data storage
  - More data processing
  - Higher price than accelerometer-only solutions


1. N. Yazdi, F. Ayazi, and K. Najafi, "Micromachined inertial sensors," *Proceedings of the IEEE*, vol. 86, no. 8, pp. 1640–1658, 1998.
2. Motion tracking in field sports using GPS and IMU - MSc Thesis - Matthijs Roobeek

# Questions to be answered



# Example data collected from wrist



Tri-axial Accelerometer

stand -> sit

sit -> stand

Tri-axial Gyroscope

# Advantage of using a gyroscope?

| | Orientation tracking during Statistic conditions | Orientation tracking during Dynamic conditions |
|---|---|---|
| Accelerometer | Good | Poor |
| Gyroscope | Poor | Good* |
| 'Fusion' of Accelerometer and Gyroscope | Good* | Good* |

* Orientation relative to poles (north/south) remains difficult without additional magnetometer

Applications: Drones, Robots, Gait analysis, Animation industry, ...

# Fusion at what level?

- Classification
- Feature
- Raw data

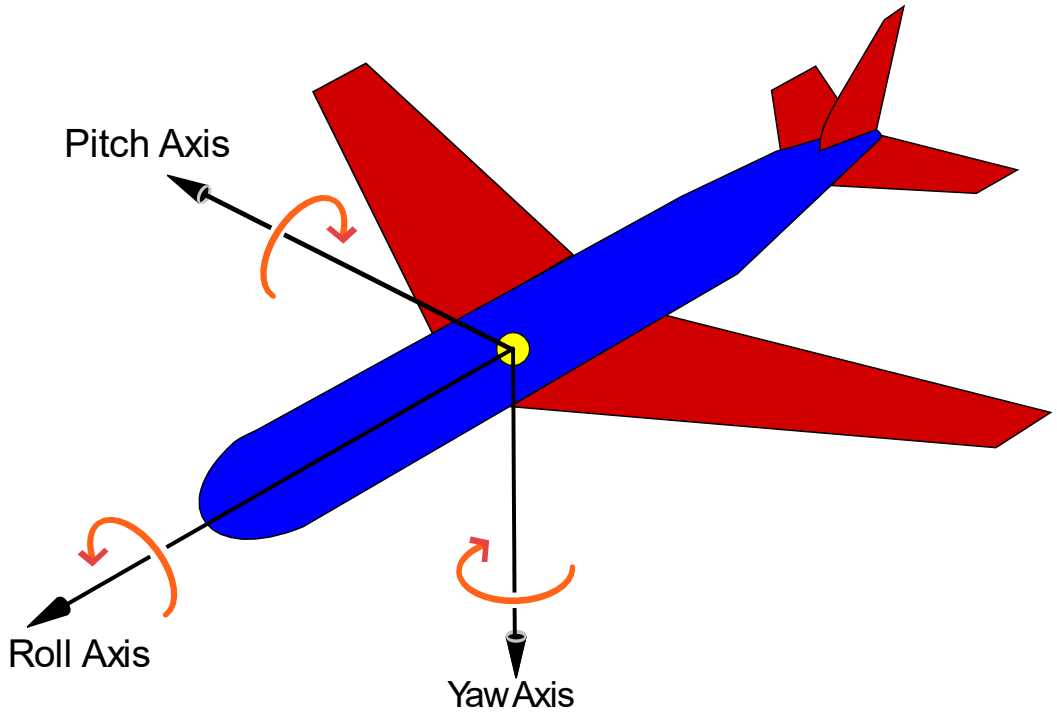
# Exploration of Fusion algorithms

Rotation axis
parallel to earth

Starting point:

- Pitch / Roll / Yaw angle from Accelerometer
- Pitch / Roll / Yaw angle change from Gyroscope

Rotation axis
equals sensor axis



# Exploration of Fusion algorithms

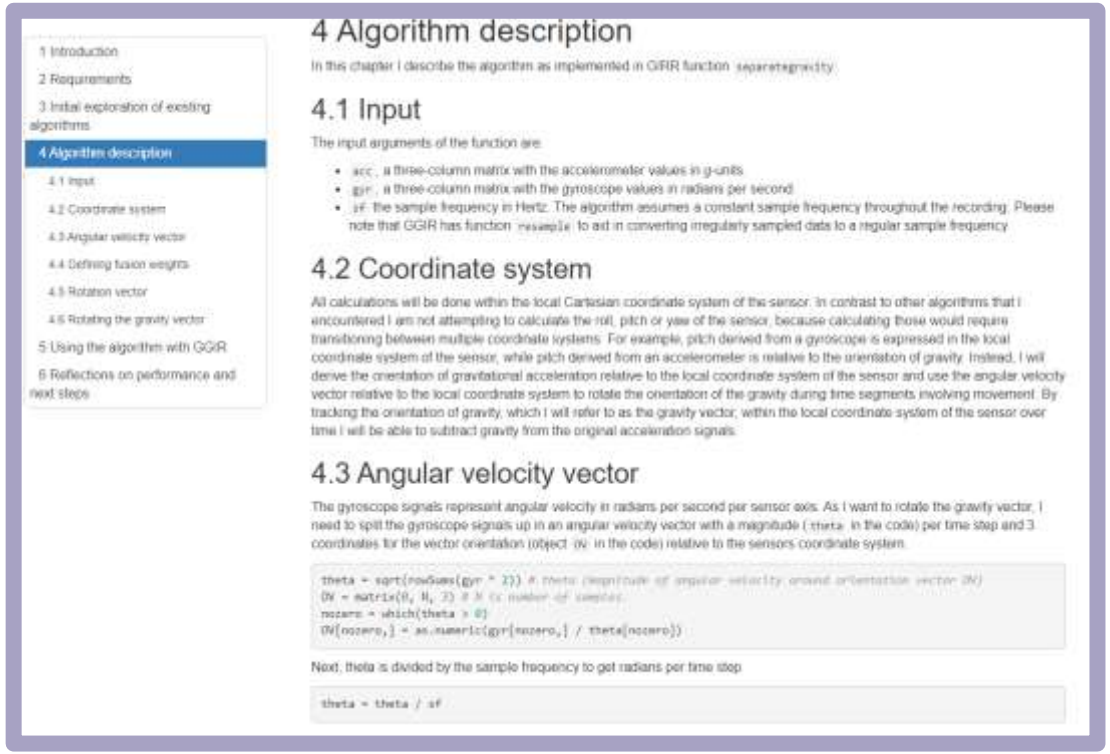
- Luinge and Veltink 2005 https://link.springer.com/article/10.1007/BF02345966
  - No code with original paper
  - External implementations:
    - Matlab: https://github.com/tytell/accelmat
- Madgwick *et al.* 2009 https://ieeexplore.ieee.org/document/5975346
  - C and Matlab code with original paper https://x-io.co.uk/open-source-imu-and-ahrs-algorithms
  - External implementations:
    - Python: https://github.com/Mayitzin/ahrs/, https://github.com/morgil/madgwick_py, and more
    - R: https://github.com/cran/RAHRS (not on CRAN anymore)
    - C++: https://github.com/arduino-libraries/MadgwickAHRS
- … and more

# … but without a full understanding this may be risky

# Own attempt to write a fusion algorithm

- Input:
  - 3 x gyro and 3 x acc
  - Function *g.cwaread* from the GGIR R-package to read Axivity's AX6 .cwa data
- Output:
  - Orientation of gravity relative to sensor coordinate system
  - Local acceleration without gravity
- Accuracy: Not well tested, only visual checks
- Speed: 24 hours @ 100 Hertz in 30 seconds

https://cran.r-project.org/web/packages/GGIR/vignettes/SensorFusionWithGGIR.html



# Lessons learnt so far

1. Algorithm speed is critical
2. Gold standard benchmark needed
3. Do not give up on existing algorithms yet
4. Unclear role of hardware specifications
5. Output of interest varies between algorithms

# Next steps

- Find / create benchmarks:
  - Simulated data
  - Optical system to track orientation
  - Energy expenditure or Activity type classification
- Get standard algorithms to work, e.g. Madgwick
- Look into gyroscope calibration:
  - Check for bias based on non-movement episodes?
  - Check for scaling error based on …?
- Look into role of hardware specifications
- Work out how to go from pitch/roll/yaw to *g*-orientation
- Collaboration

# Questions?