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# Metodologia delle misure delle attività sportive

Wednesday 30/10/2019 15:45÷17:15

Luca P. Ardigò Ph.D.

A class within an eight-class module

**Figure 2.** Laptop with the external analog-digital unit in the vehicle synchronously stored data from two GNSS systems and the vehicle speedometer.

measures

**Figure 7.** Bland Altman test of agreement between the Leica and other GNSS devices. On x axis is average speed of both compared devices; on y axis is difference in speed between both devices. The first row shows data for steady speed, the second for acceleration and the third deceleration. Full horizontal line represent the mean differences and the dash-dot line 1.96 SD (standard deviation) interval in each diagram. Note that the vertical scale change sometimes in order to improve the visibility of the diagrams.

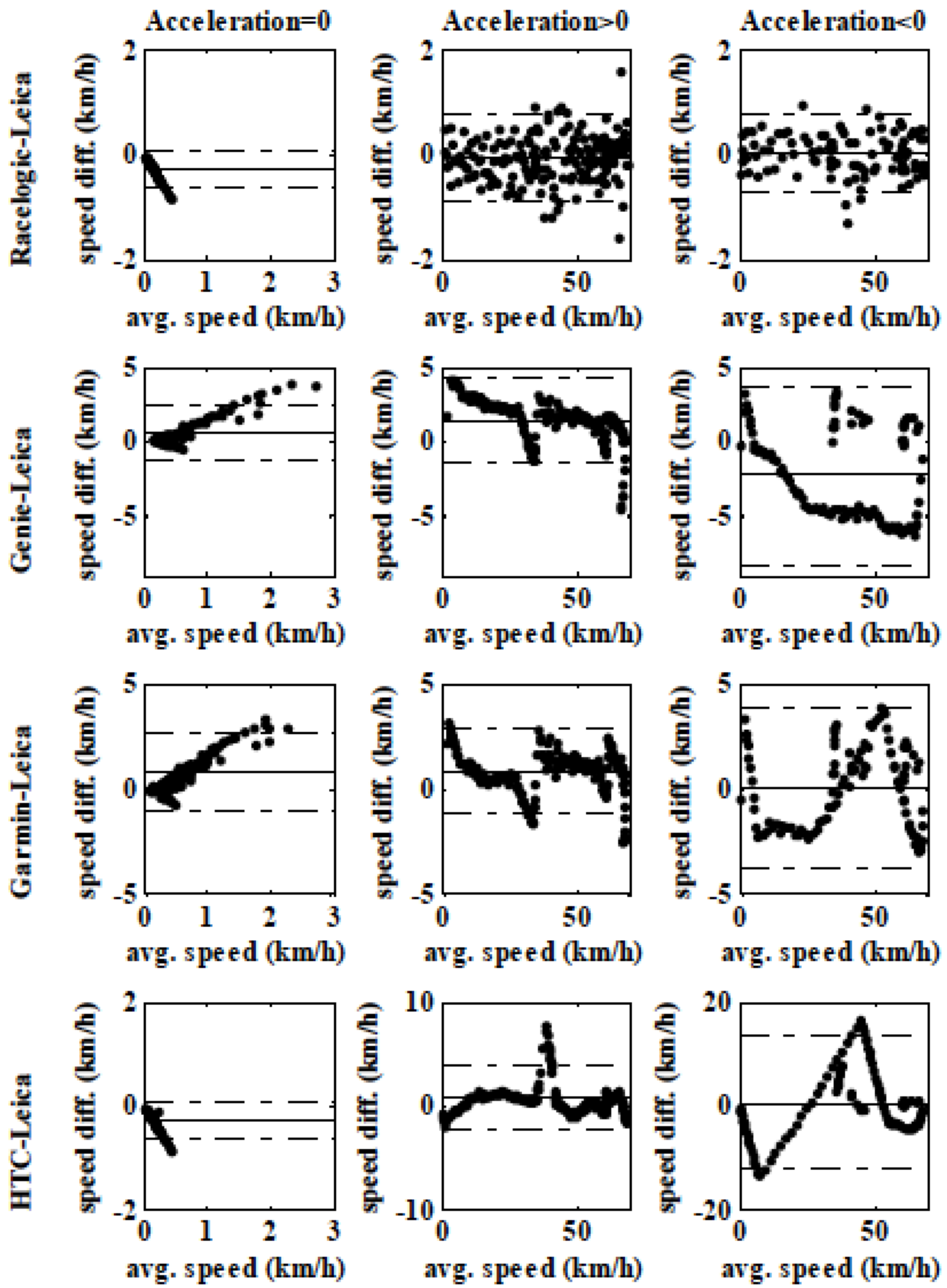
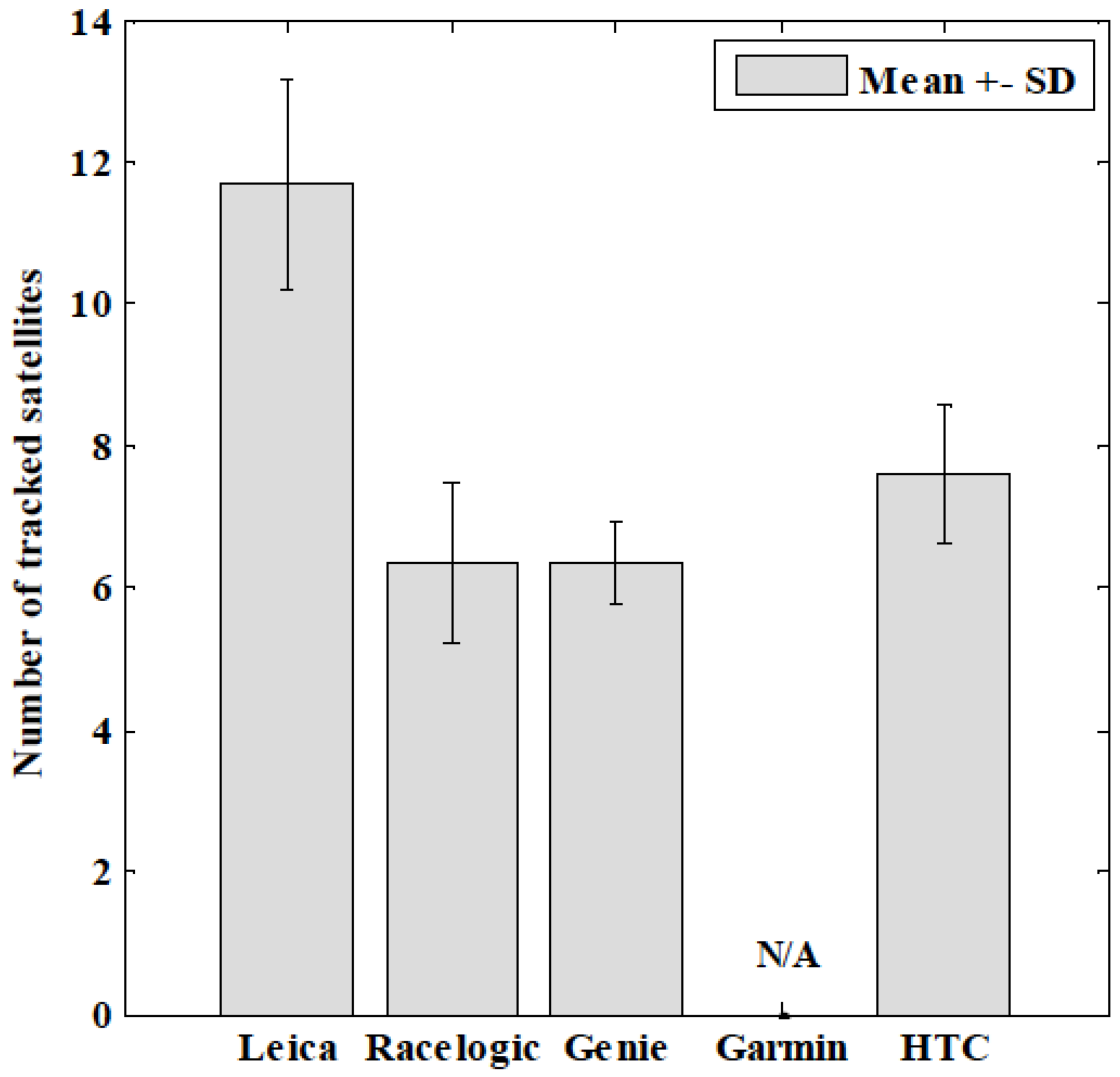


**Figure 8.** Mean number of tracked satellites (bars) for each GNSS device during the measurements and the corresponding standard deviations (SD) (error bars). Note that the number of tracked satellites for Garmin was not available (N/A).



# Other issues

- Specially patients are aware of being measured (effect of reactivity or interference) and therefore the use of portable instruments to measure PA might prevent them to perform some activities (e.g., a device could be used during a sport but not while having a shower, this may prevent the person from doing that sport);
- multi-sensor portable devices (e.g., Zephyr BioHarness, Hidalgo equivital)


# Other issues

- multi-sensor garments;

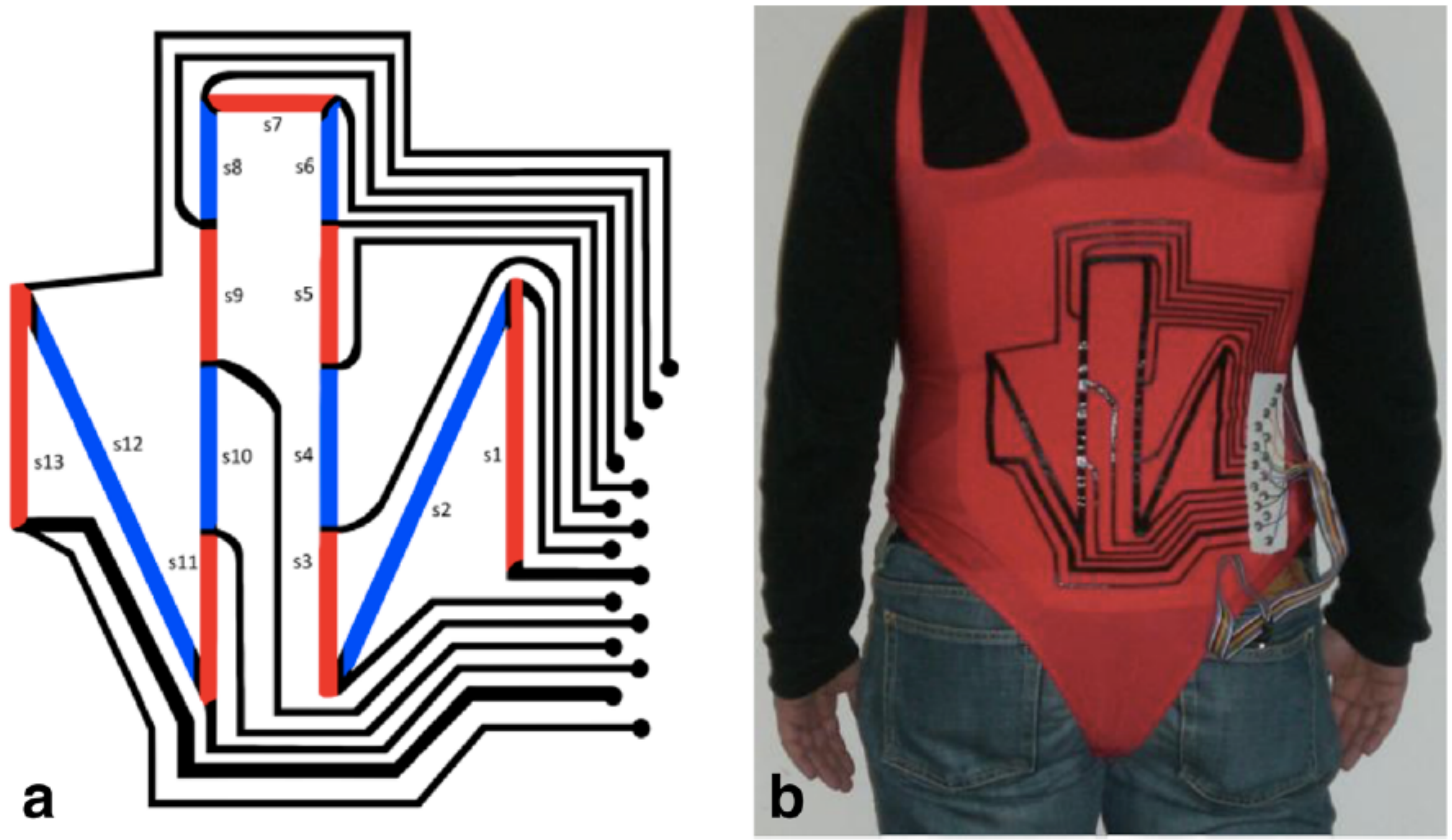



**Figure 1 Garment Prototype. a**) Layout of the placement of CE strain sensors on the garment prototype. Thick lines are sensors; thin lines are connection wires made of the same polymer. **b**) Picture of the garment from behind. The readout electronic device is placed in a pocket of the subject's pants.

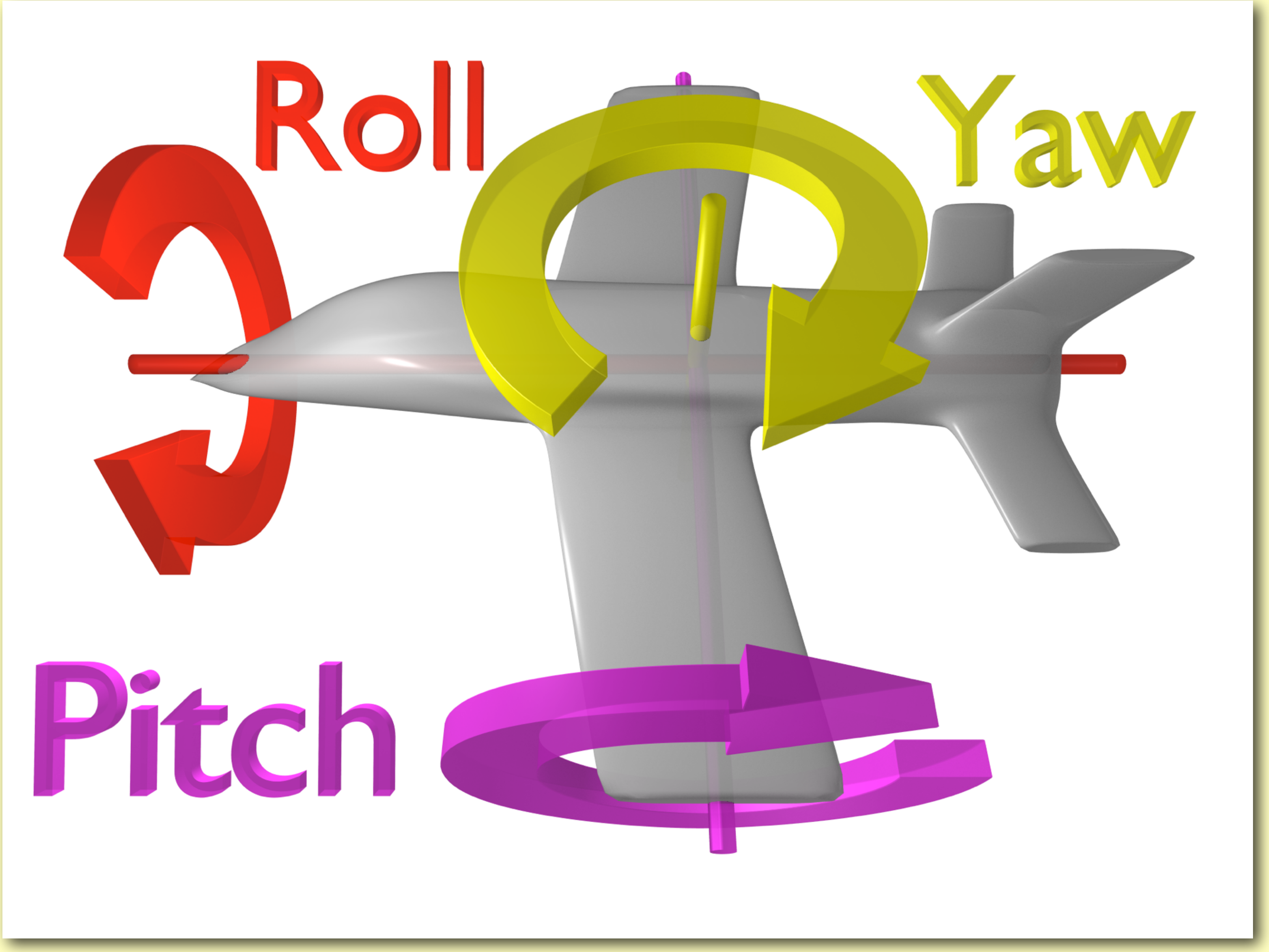
Tormene et al., 2012

# Other issues

- Inertial Measurement Units-based systems;
- IMU is an electronic device that measures and reports on a craft's (aircrafts, drones, missiles, spacecrafts, satellites, landers..., humans) speed, orientation, and gravitational forces, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. Recent developments allow for the production of IMU-enabled GPS devices. An IMU allows a GPS to work when GPS-signals are unavailable, such as in tunnels, inside buildings, or when electronic interference is present;
- data collected from the IMU's sensors allow a computer to track a craft's position, using a method known as dead reckoning;

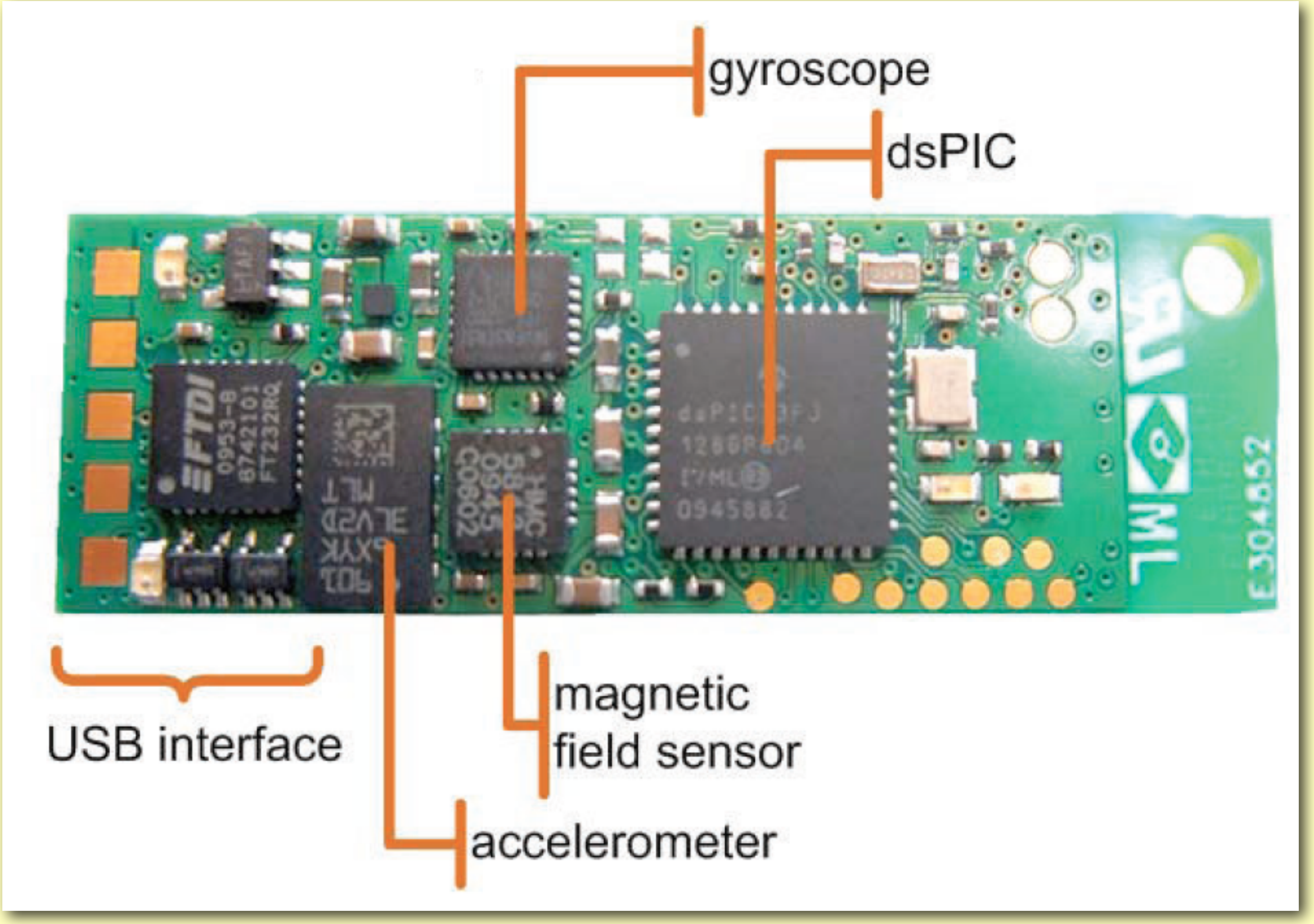
# Other issues

- IMU works by detecting the current acceleration using one or more accelerometers, and detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. And some also include a magnetometer, mostly to assist calibrate against orientation drift;



# Other issues

- inertial guidance systems are now usually combined with satellite navigation systems through a digital filtering system. The inertial system provides short term data, while the satellite system corrects accumulated errors of the inertial system (an integration over time -> s -> s integration over time -> position w/e);



# Other issues

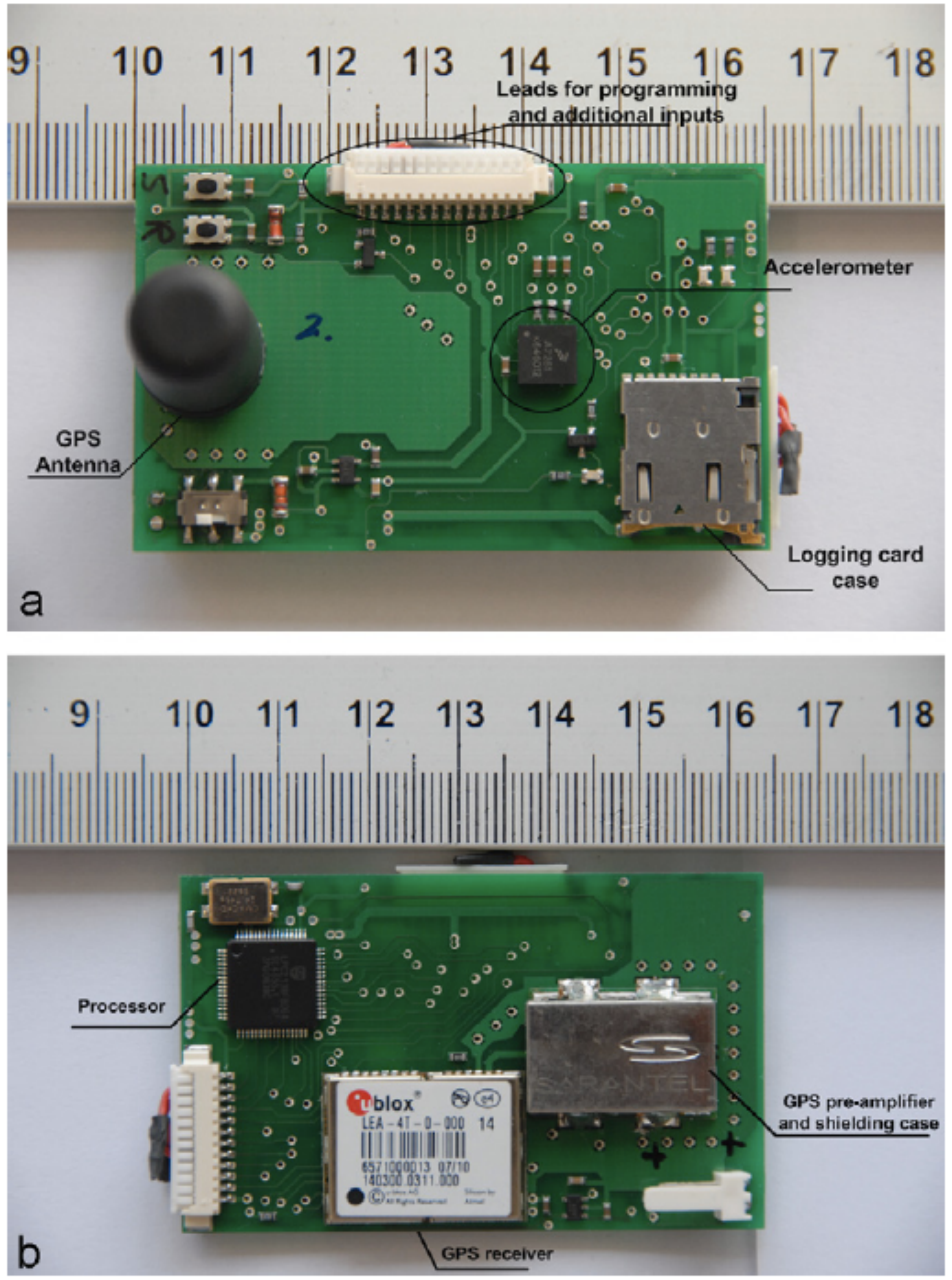



Fig. 1. Custom designed GPS/IMU system with a single frequency GPS receiver, a tri-axial accelerometer and ARM7 based logger: (a) front view and (b) back view.

Tan et al., 2008

# Other issues

- IMU is often a box containing three accelerometers, three gyroscopes, optionally three magnetometers:
  . three accelerometers are placed such that their measuring axes are orthogonal to each other. They measure acceleration;
  . three gyroscopes are placed in a similar orthogonal pattern, measuring rotational position in reference to an arbitrarily chosen coordinate system;
  . three magnetometers in IMUs allow better performance for dynamic orientation calculation;

# Other issues


Fig. 5. Implementation of the sensor network: Three IMUs on the oars and the boat, indicated by red arrows.

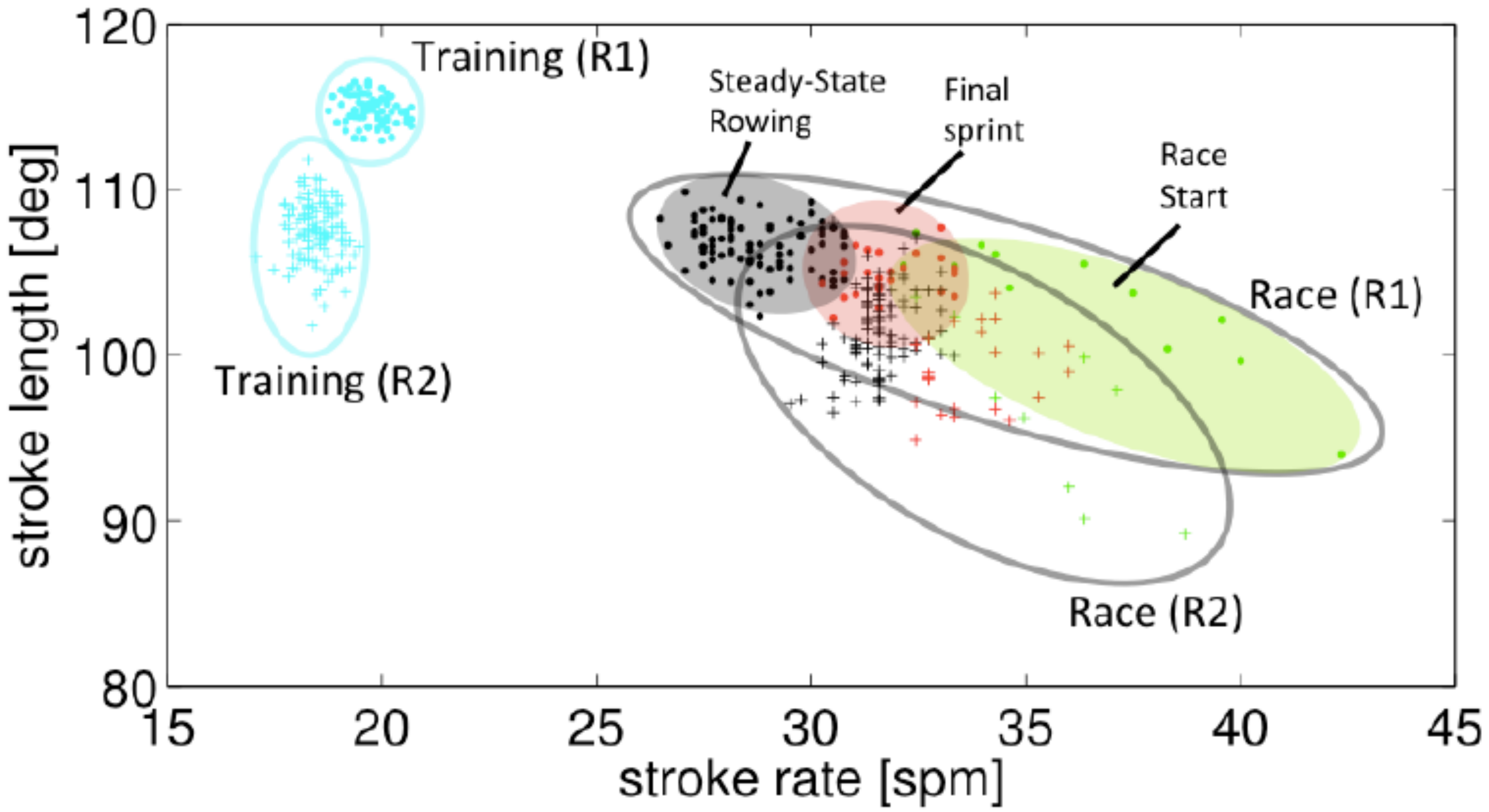



Fig. 7. Visualization of data of stroke length and stroke rate from two world-class rowers (R1 and R2) for training and racing sessions.

# Other issues

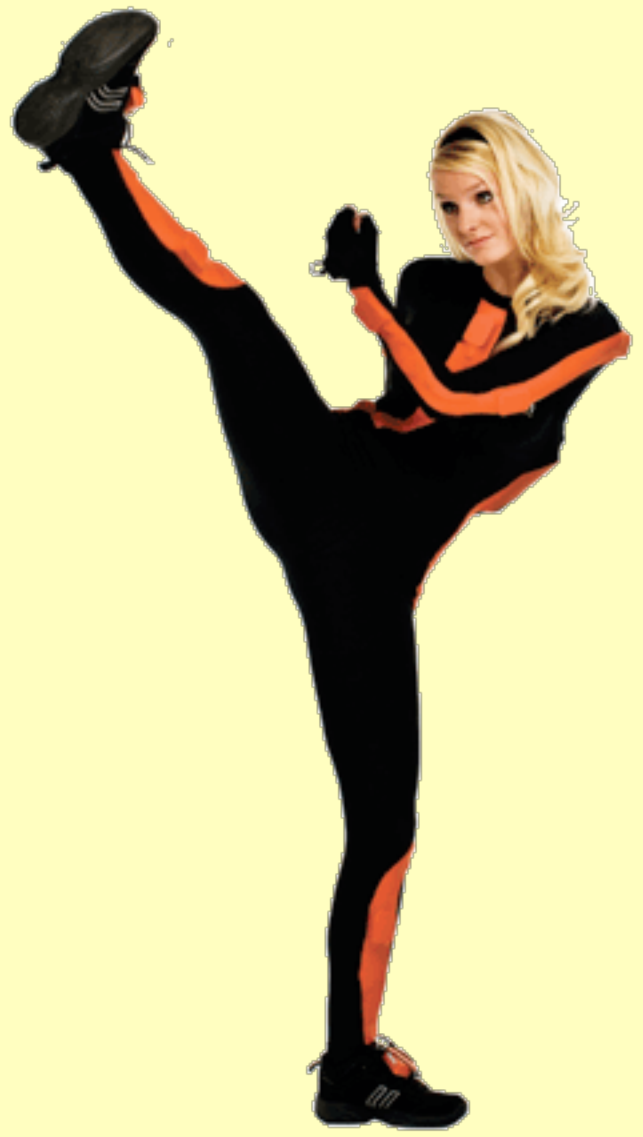
# Other issues

# Other issues

- dead reckoning:
  . (also ded (for deduced) reckoning or DR) is the process of calculating one's current position by using a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time, and course;
  . GPS receiver supports DR machine;
  . GPS receiver (e.g., parking garages, tunnels, urban canyons, forest, multipath propagation) & DR machine support each other;

# Other issues

- Xsens products



# Other issues

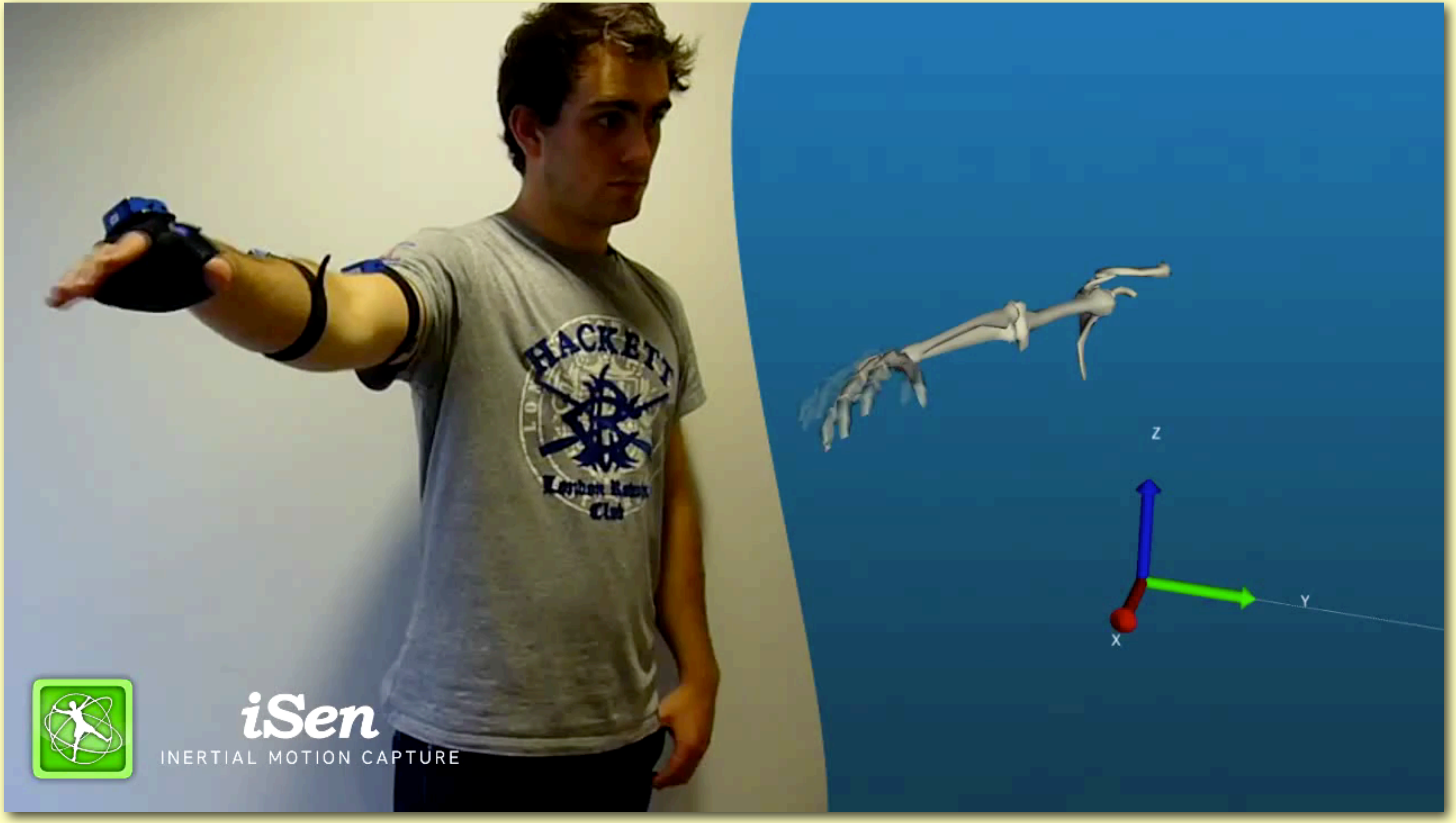
- Equinosis products

# Other issues

- Wiva products

# Other issues – stt products

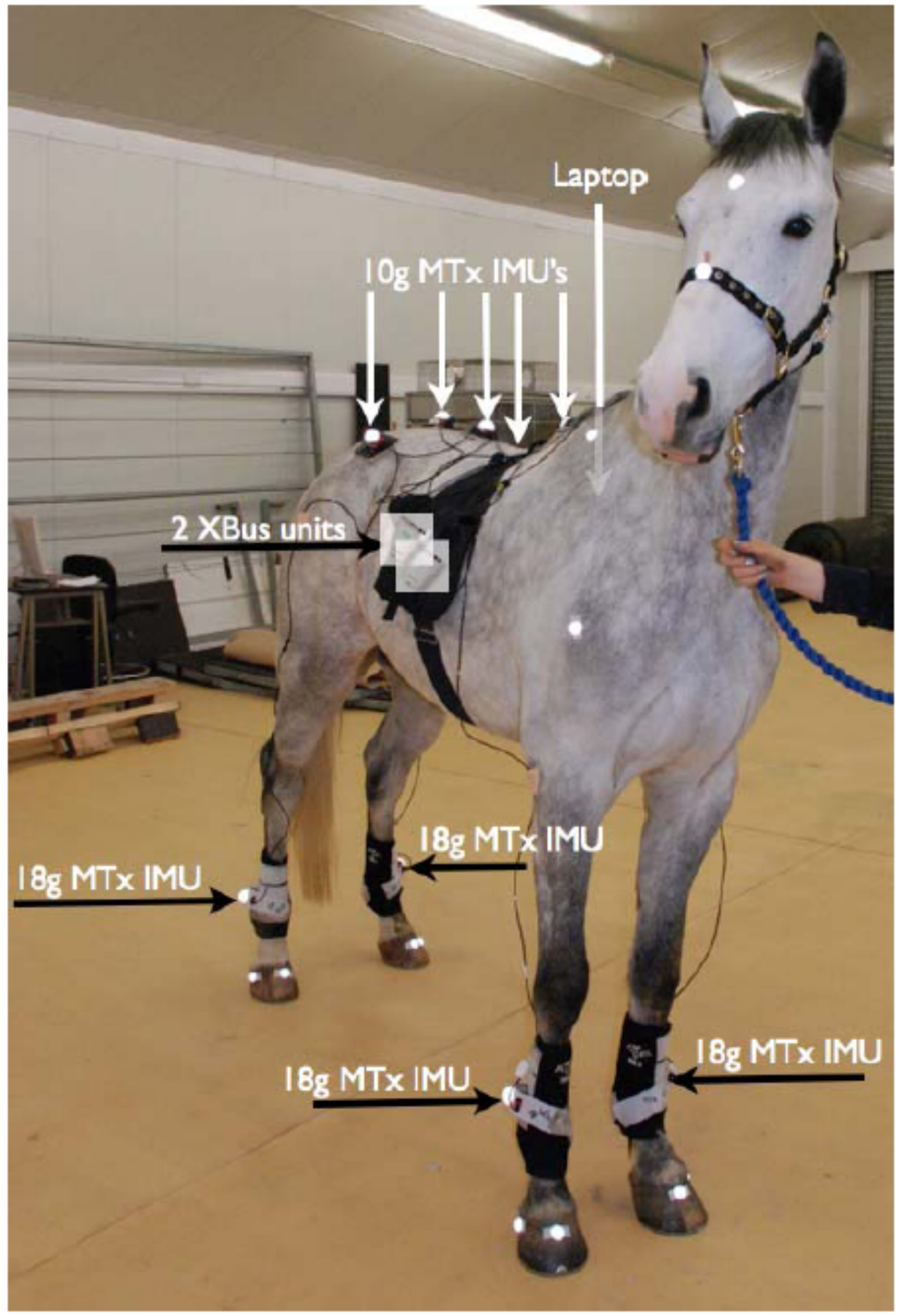




# Other issues

- horse gait analysis;

**Figure 1.** Distal limb mounted IMUs strapped onto a standard protective boot using Velcro. The IMUs are connected in series to two XBus Masters on the right side of the horse. The XBus Masters are plugged into a laptop mounted on the left side of the horse. Reflective markers are placed on the proximal dorsal and lateral hoof of each leg and on each of the IMUs.




Olsen et al., 2012

# Other issues – horse gait analysis; measures


**Fig. 1.** Experimental setup: rider (MVN suit) and horse (acceleration sensor on the cannon bone) with the applied measurement systems: rotation axes of the riders' segments are shown as arrows: red arrows indicating Roll angles and green arrows indicating Pitch angles.



Eckardt et al., 2014

# Other issues

- film industry;

Ted, 2012

# Other issues

- infant trunk posture and arm movement assessment

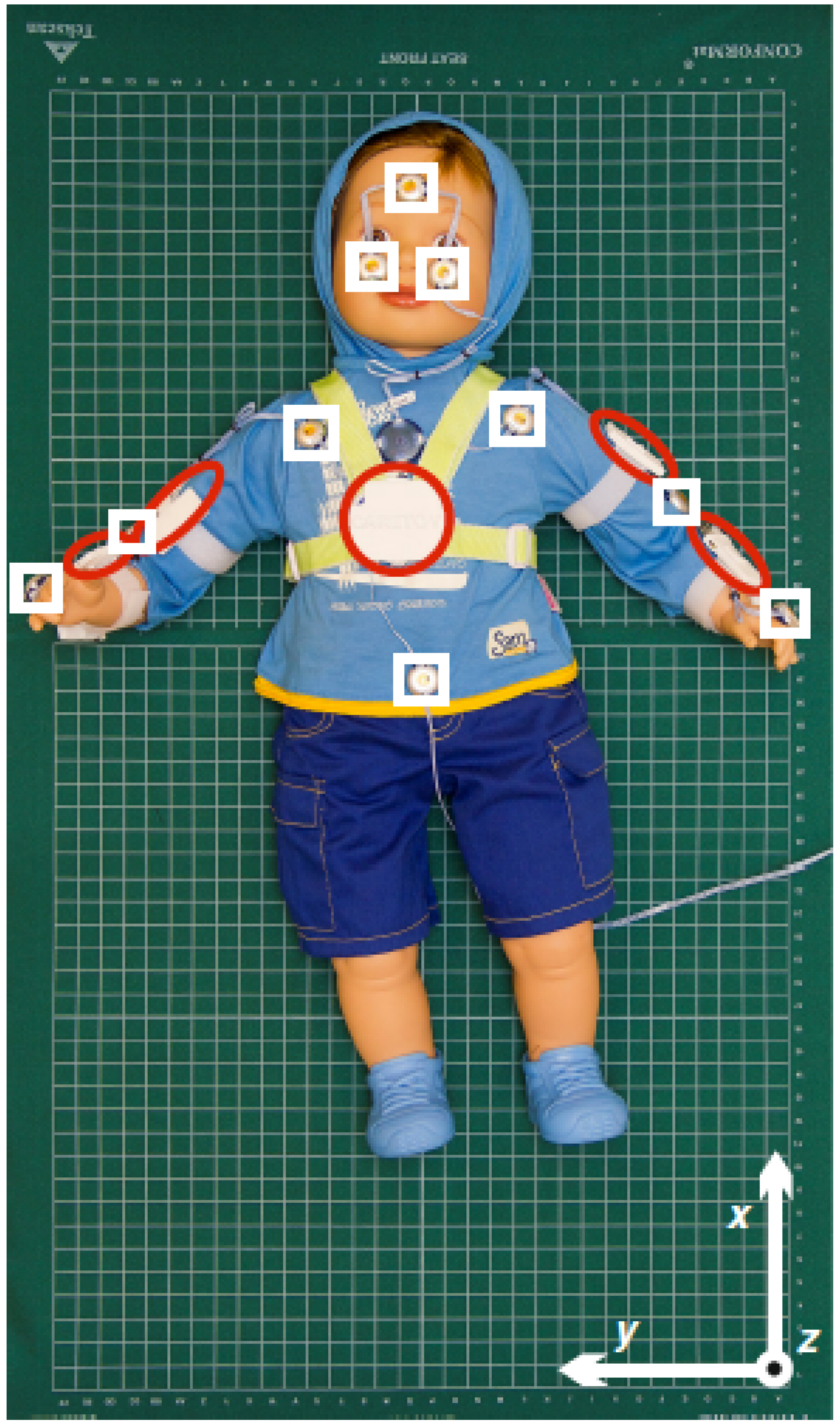
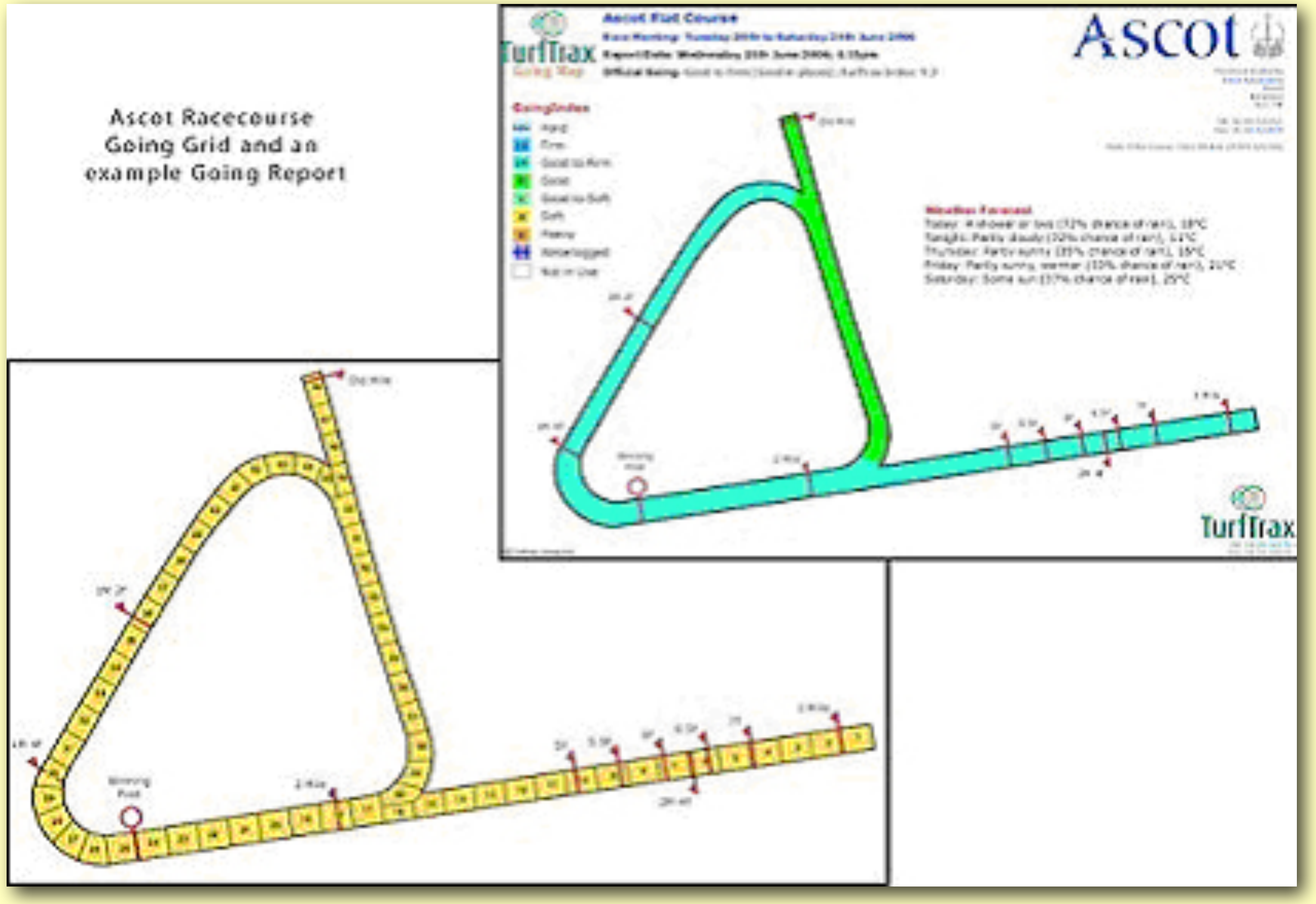


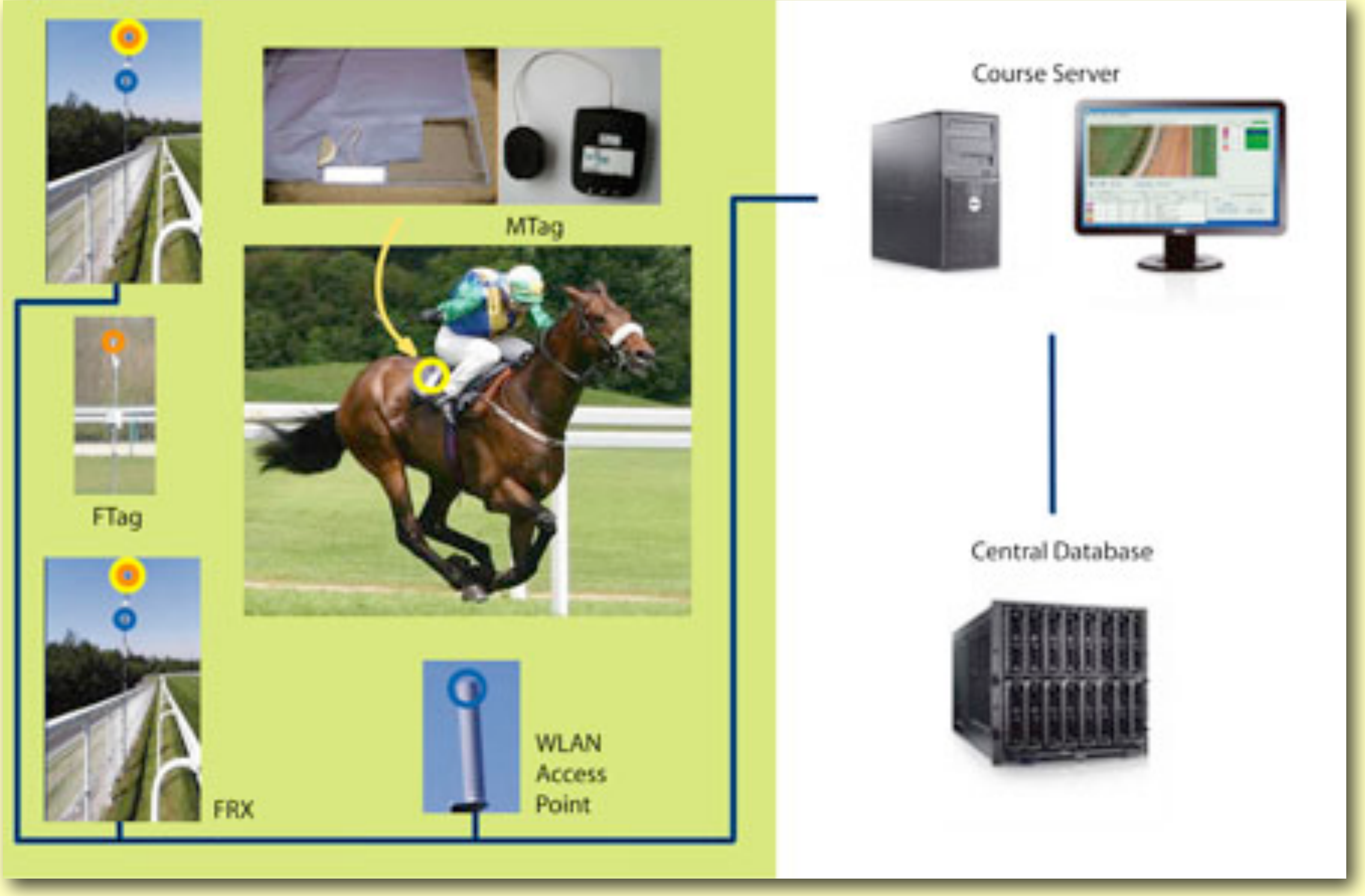

**Figure 1 Experimental setup.** Baby doll is positioned on top of two pressure mattresses, and equipped with five IMU bracelets (red ellipses), positioned one on baby doll's chest, one on each forearm, and one on each upper arm. Ten Optotrak markers (one on baby doll's forehead, one on each cheek, one on the frontal side of lower abdomen, one on the frontal side of each shoulder joint, one on the lateral side of each elbow joint, one on the dorsal side of each hand) serve as reference (white rectangles). Referential Optotrak and IMU coordinate system orientation is indicated in the lower right corner (white arrows).

Riharetal, 2014

# Other issues

- TurfTrax wireless tracking system;



# Other issues



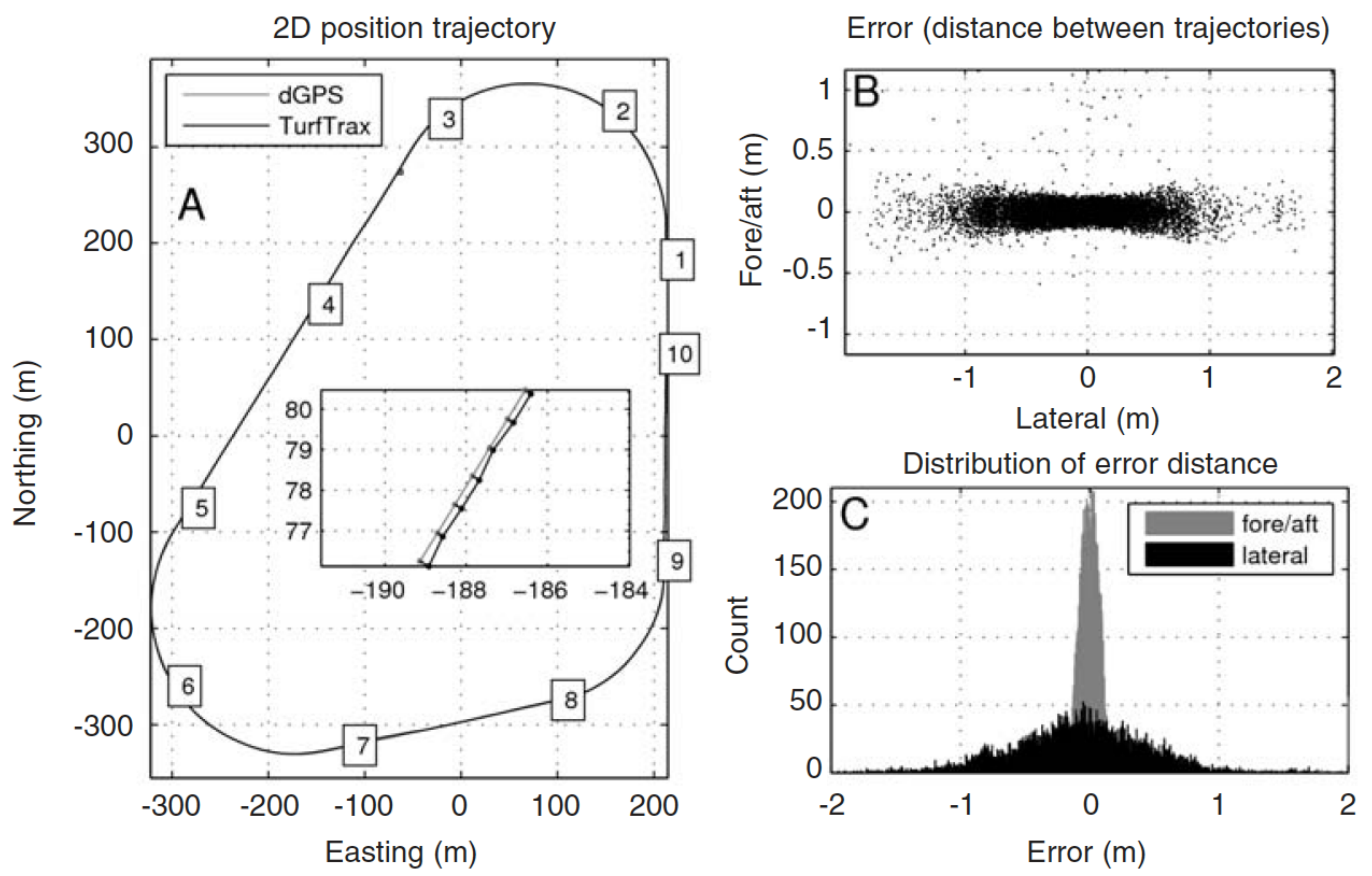



*Fig 1: Comparison of position trajectories of the TurfTrax and DGPS systems. An overlay of trajectories provided by both systems for a 2 km run around Lingfield racecourse (A), the distance between the 2 trajectories at each GPS sample point (B), and the distributions of the difference between the trajectories (C). The mean ± s.d. difference between the systems was 2.2 ± 24 cm in the direction of travel and -8.9 ± 51 cm perpendicular to the direction of travel.*

Spence et al., 2008

# Other issues

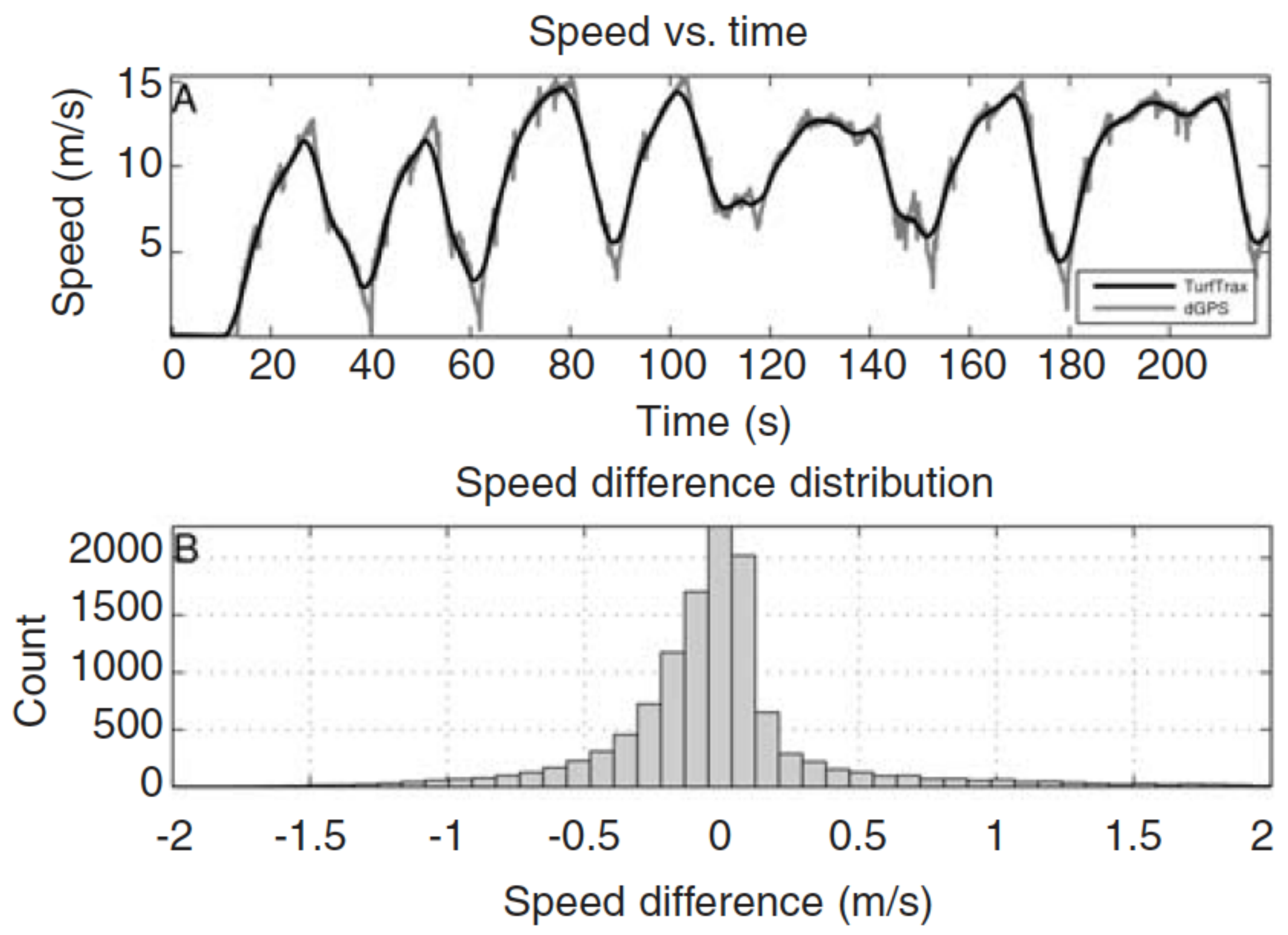



*Fig 2: Comparison of the speed estimates of the TurfTrax and DGPS systems. Overlay of speed vs. time for both systems during run 2 (A), and the distribution of the difference between the speed estimates (B). The systems give very similar estimates of speed, with the TurfTrax system yielding smoother data. The long tails of the difference distribution are due to periods of high acceleration, where the 2 estimates diverge. For periods of low acceleration where the data are similar, the bulk of the data fall within 0.15 m/s of the mean value.*

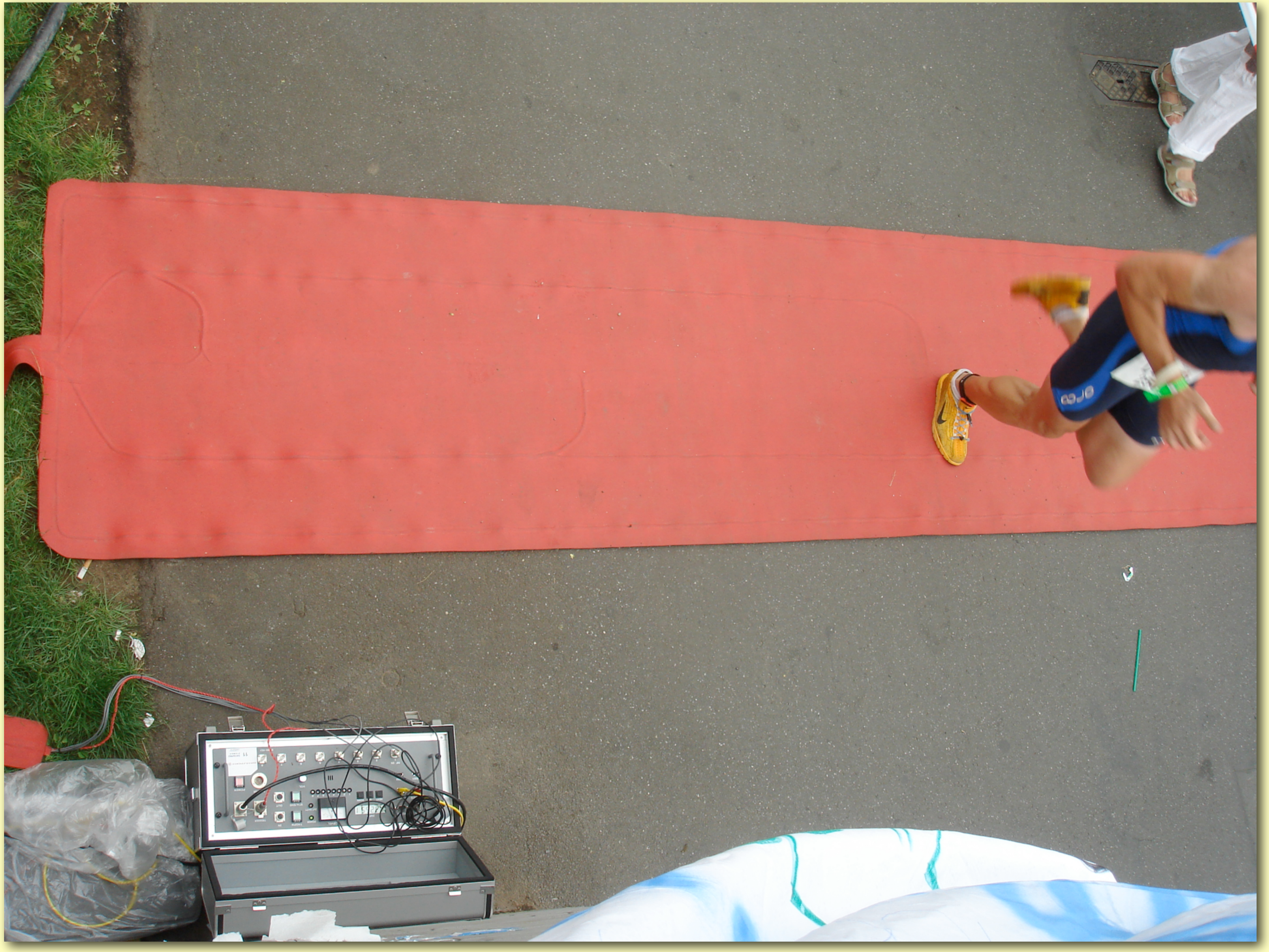
Spence et al., 2008

# Other issues

- radio-frequency identification (RFID) chip;
- RFID is the wireless non-contact use of radio-frequency electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects;
- RFID tags contain electronically stored information;
- some tags are powered by and read at short ranges (a few meters) via magnetic fields (electromagnetic induction);
- others use a local power source such as a battery, or else have no battery but collect energy from the interrogating EM field, and then act as a passive transponder to emit microwaves or UHF radio waves (i.e., electromagnetic radiation at high frequencies);
- battery powered tags may operate at hundreds of meters;
- unlike a bar code, the tag does not necessarily need to be within line of sight of the reader, and may be embedded in the tracked object

# Other issues





- RFID for timing races;

# Other issues



# Other issues

Road cycling

MTB

Running

Triathlon

# Other issues

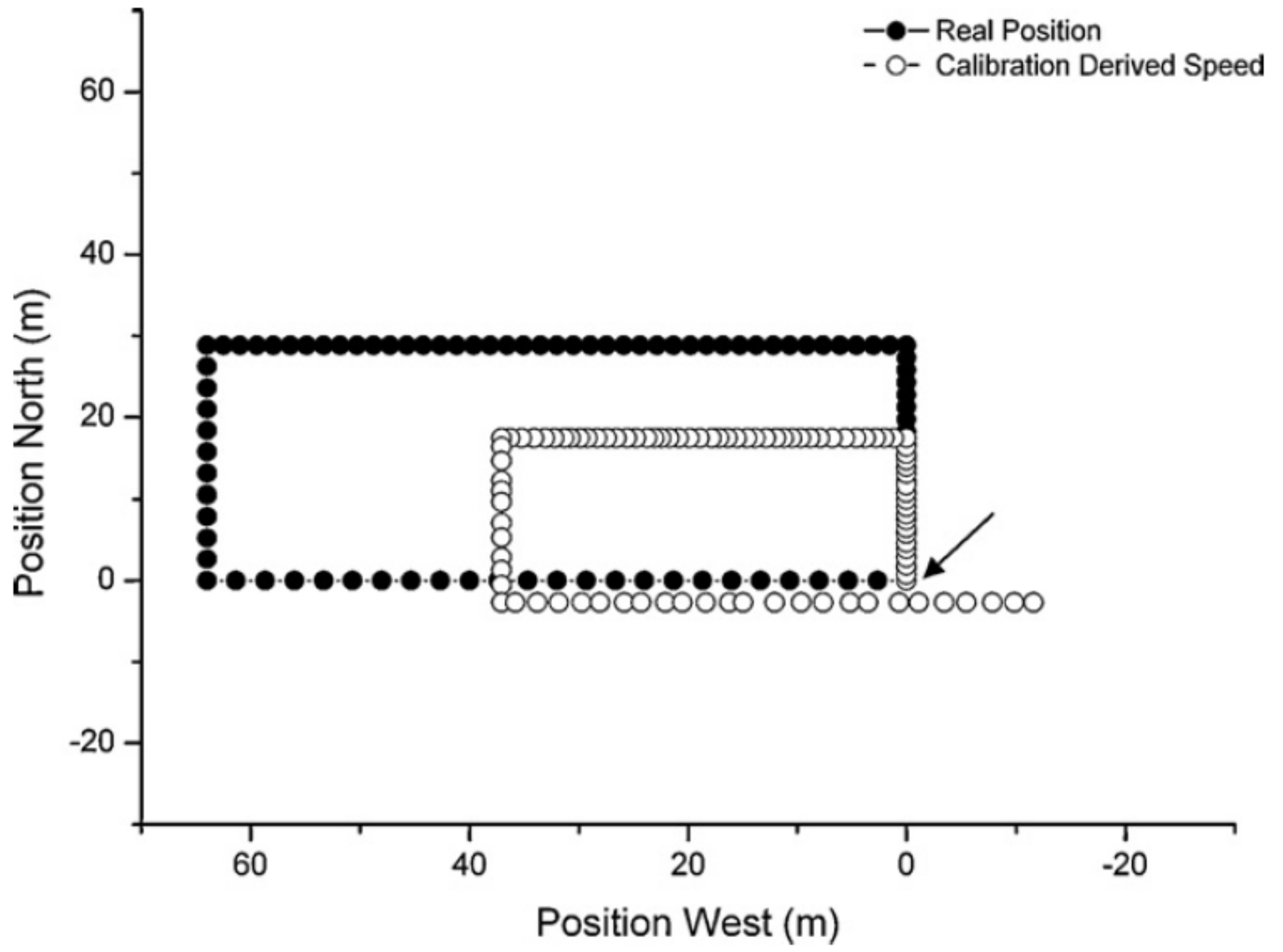



**Fig. 4.** Comparison of dead-reckoned tracks derived from the real position and the calibration-derived speed. The track begins at the point marked by the arrow moving anti-clockwise.

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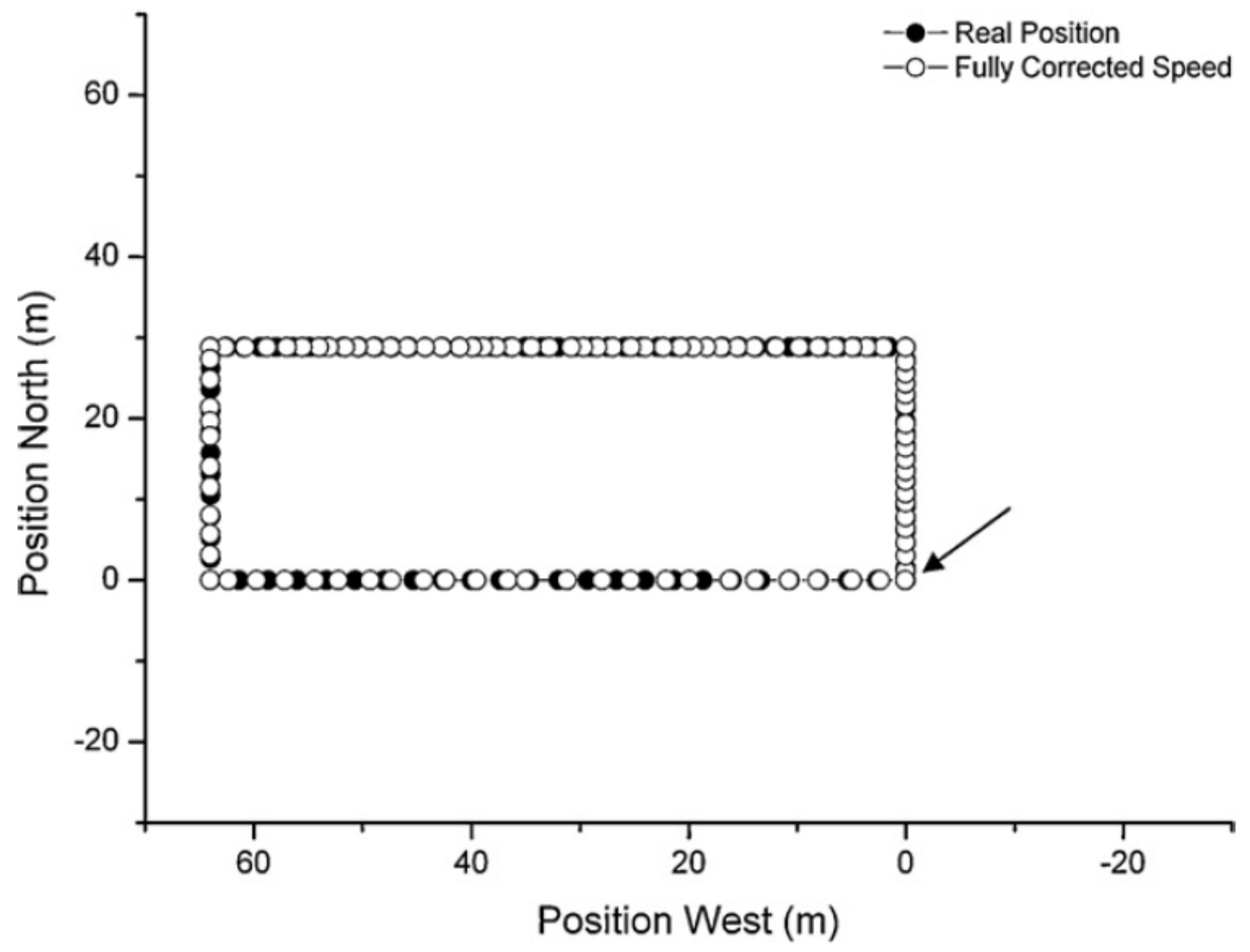



**Fig. 5.** Comparison of dead-reckoned tracks derived from the real position and the fully corrected speed. The track begins at the point marked by the arrow moving anti-clockwise. Initially, the gradient for the regression of speed against ODBA from the treadmill calibration had been 2.3796. After the correction it was set at 3.928 for legs 1 and 2, 3.990 for leg 3, and 3.521 for leg 4.

Bidder et al., 2012

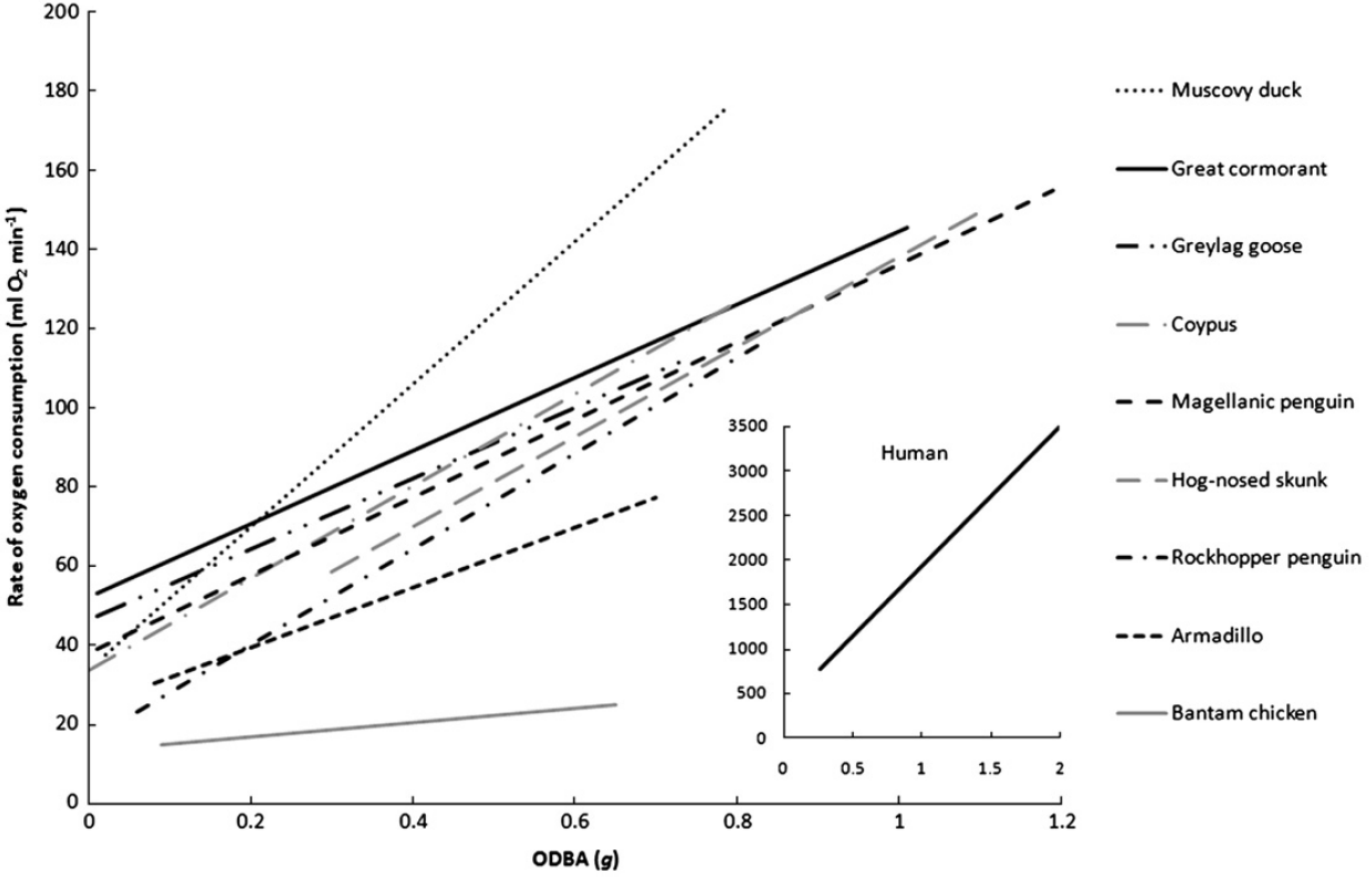



**Fig. 1.** Best fit linear relationships between rate of oxygen consumption and ODBA for a range of bipedal and quadrupedal species while resting and walking/running on a treadmill. Other behaviours were also displayed. Where data are available for multiple individuals of a species, a common slope is shown, derived from a linear mixed effects model. For clarity, the running order of species on the legend follows the order of slopes on the graph from top to bottom. Data for humans are included in an inset figure because values for rate of oxygen consumption are an order of magnitude greater than that of the other species.

Halsey et al., 2009

# Other species




Muscovy Duck


Great Cormorant


Greylag Goose


Coypu


Magellanic Penguin


Hog-nosed skunk


Southern Rockhopper Penguin


Big hairy armadillo


Bantam chicken


Human

# Other issues

**Fig. 1.** Tri-axial accelerometer data logger attached directly to the dorsal carapace surface of a lobster using industrial strength Velcro® and adhesive.

Lobster

Lyons et al., 2013

# Other issues

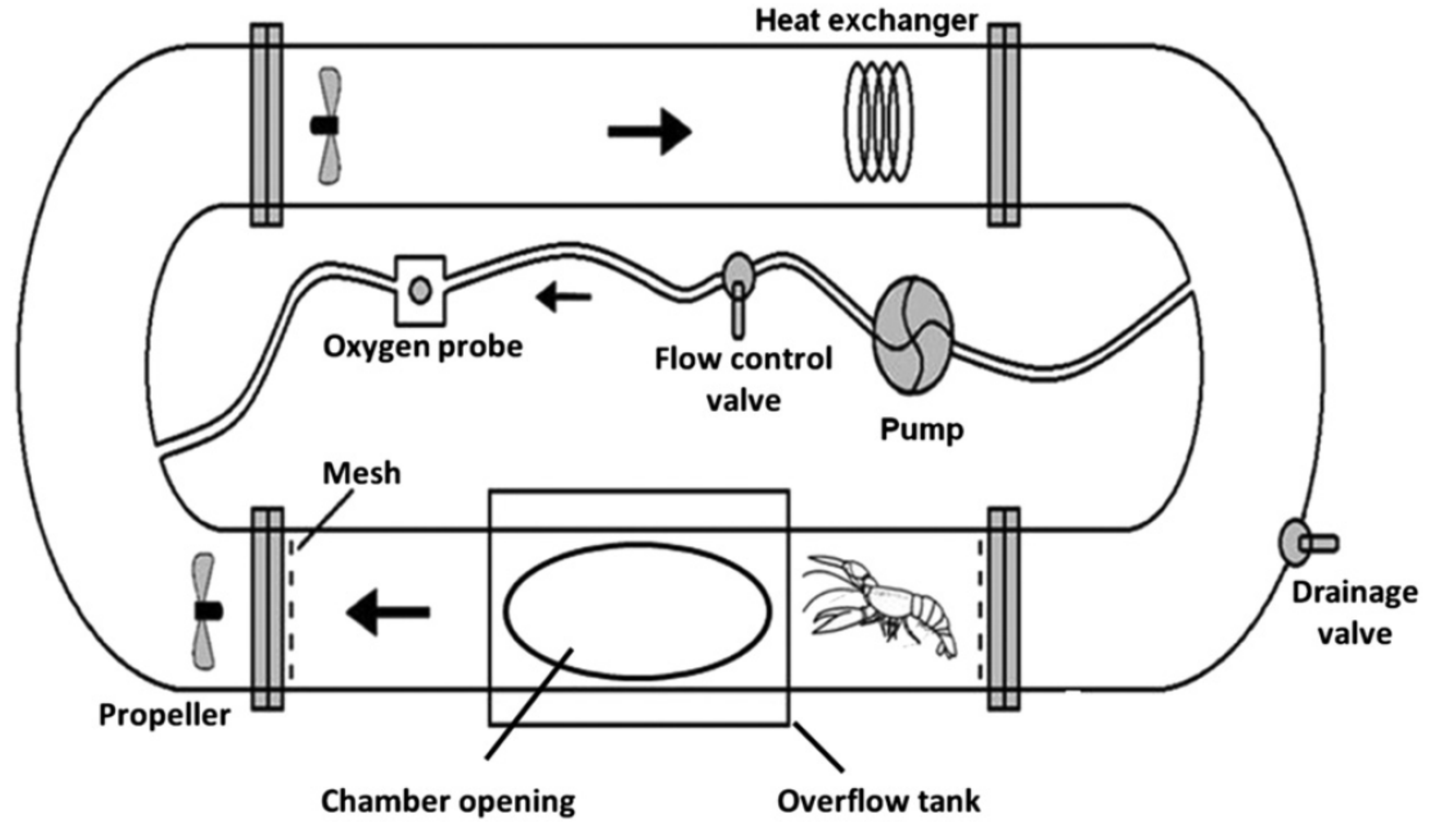



**Fig. 2.** The circulating aquatic respirometer. The lower two meshes (hatched lines) show the area the lobster was confined to.

Lyons et al., 2013

# Other issues

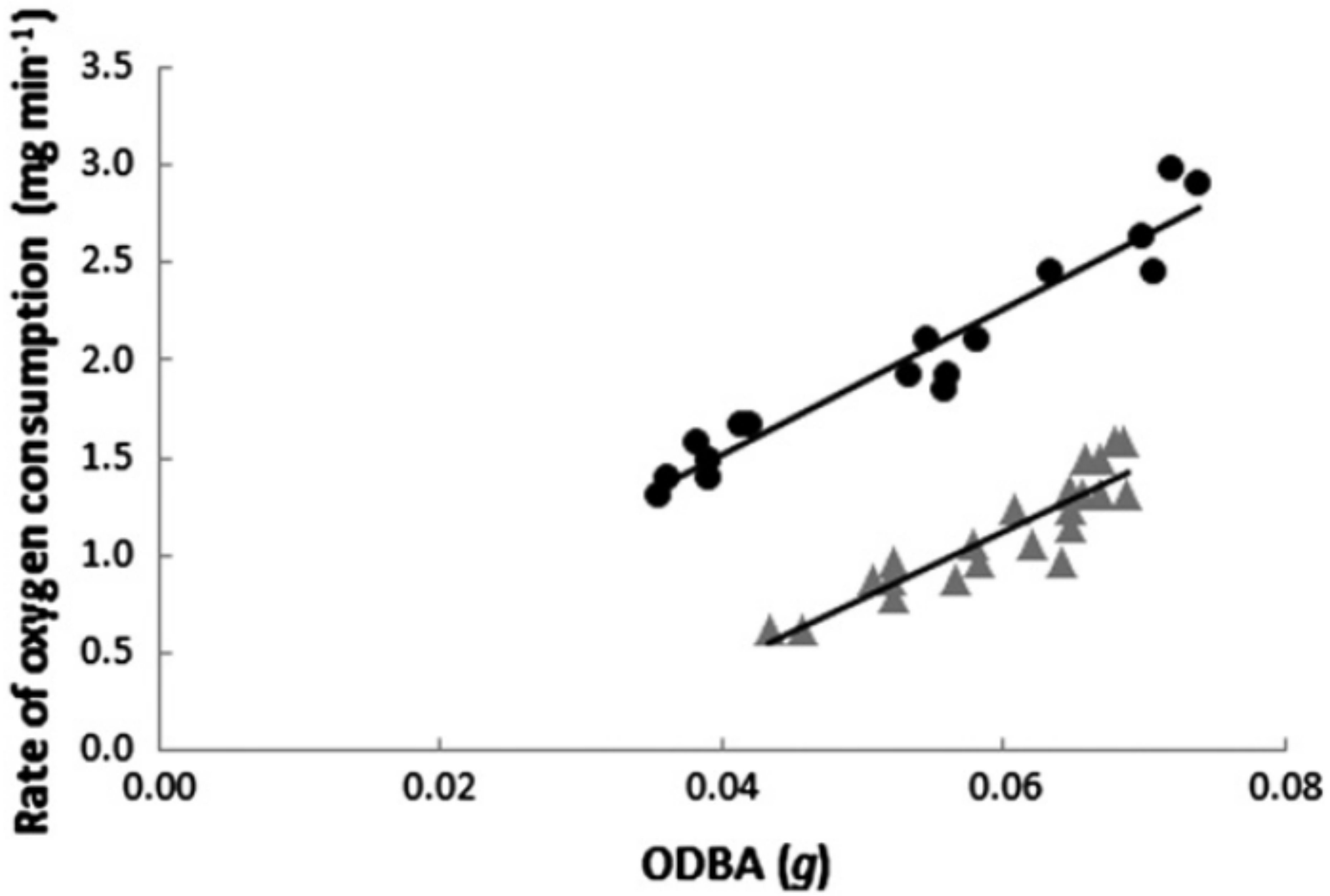



**Fig. 4.** The calibration data for two lobsters at 13 °C. Circles represent a lobster of 1017 g while triangles represent a lobster of 478 g.

Lyons et al., 2013

# Other issues

# Other issues

# An example

measures

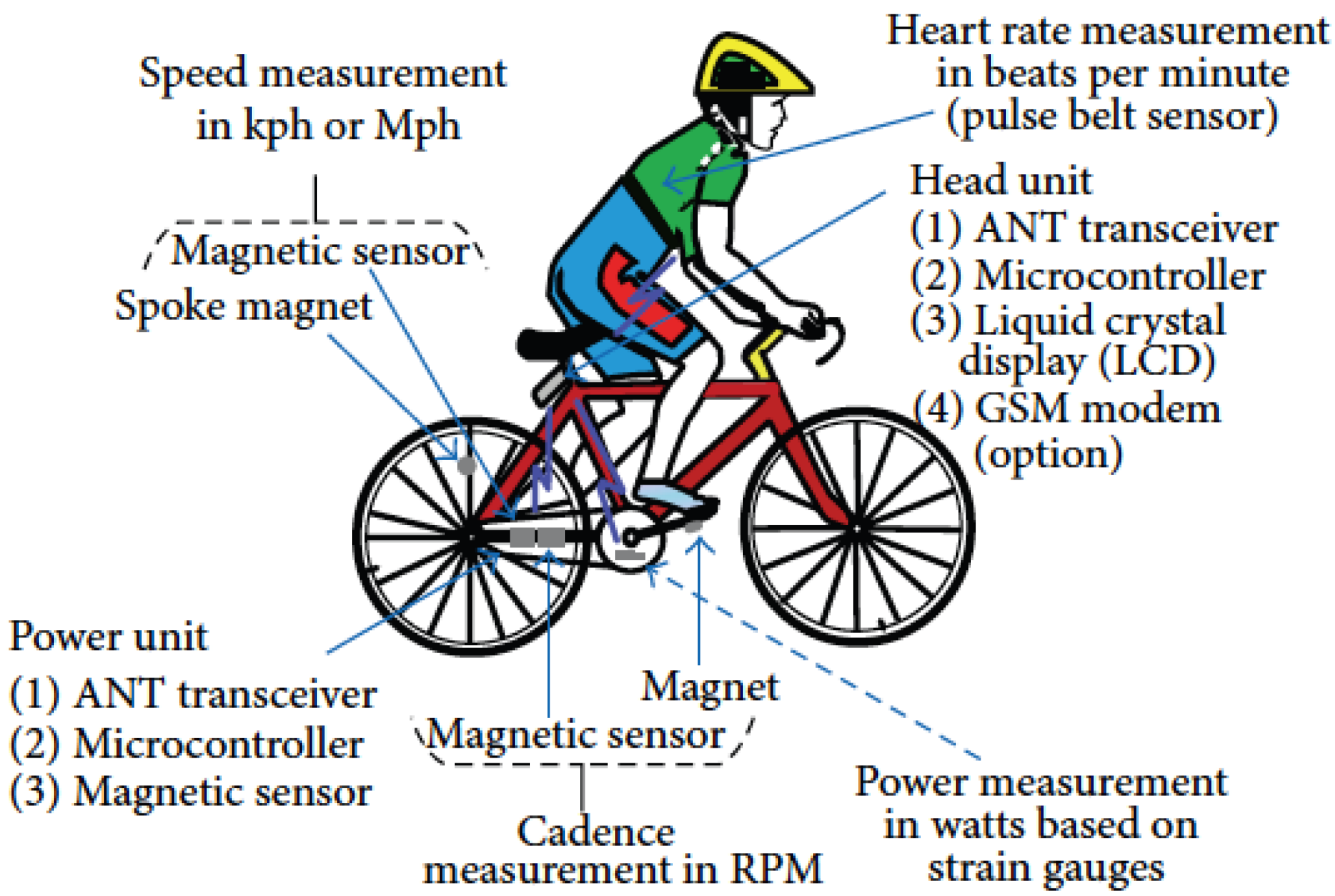



FIGURE 4: An overview of relevant wireless sensors and networks related to a bicycle and cyclist monitoring system.

Gharghan et al. 2014

Specs


Vital sign: HR, HRV, temperature
Battery lifetime: Up to 10h (Rechargeable)
Charging time: Appr. 1h
Weight: 6,5g
Dimensions: 4,5 x 1,8 x 3,8 cm (H x D x W)
Radio frequency: 2,4 GHz
Compatibilty: Bluetooth 4.0 & ANT+ (certification coming soon)

cosinuss° One

Mocap options

measures

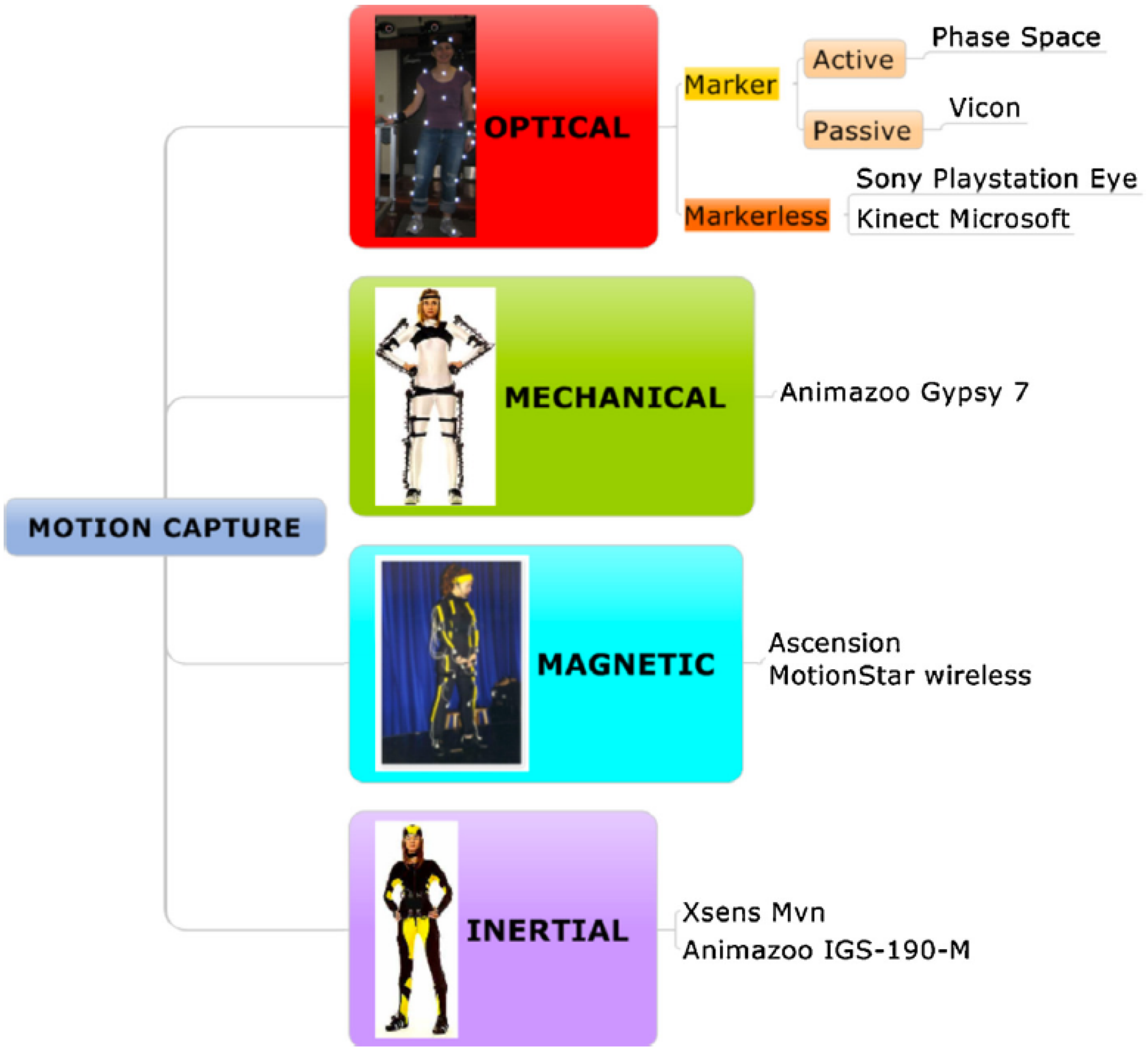
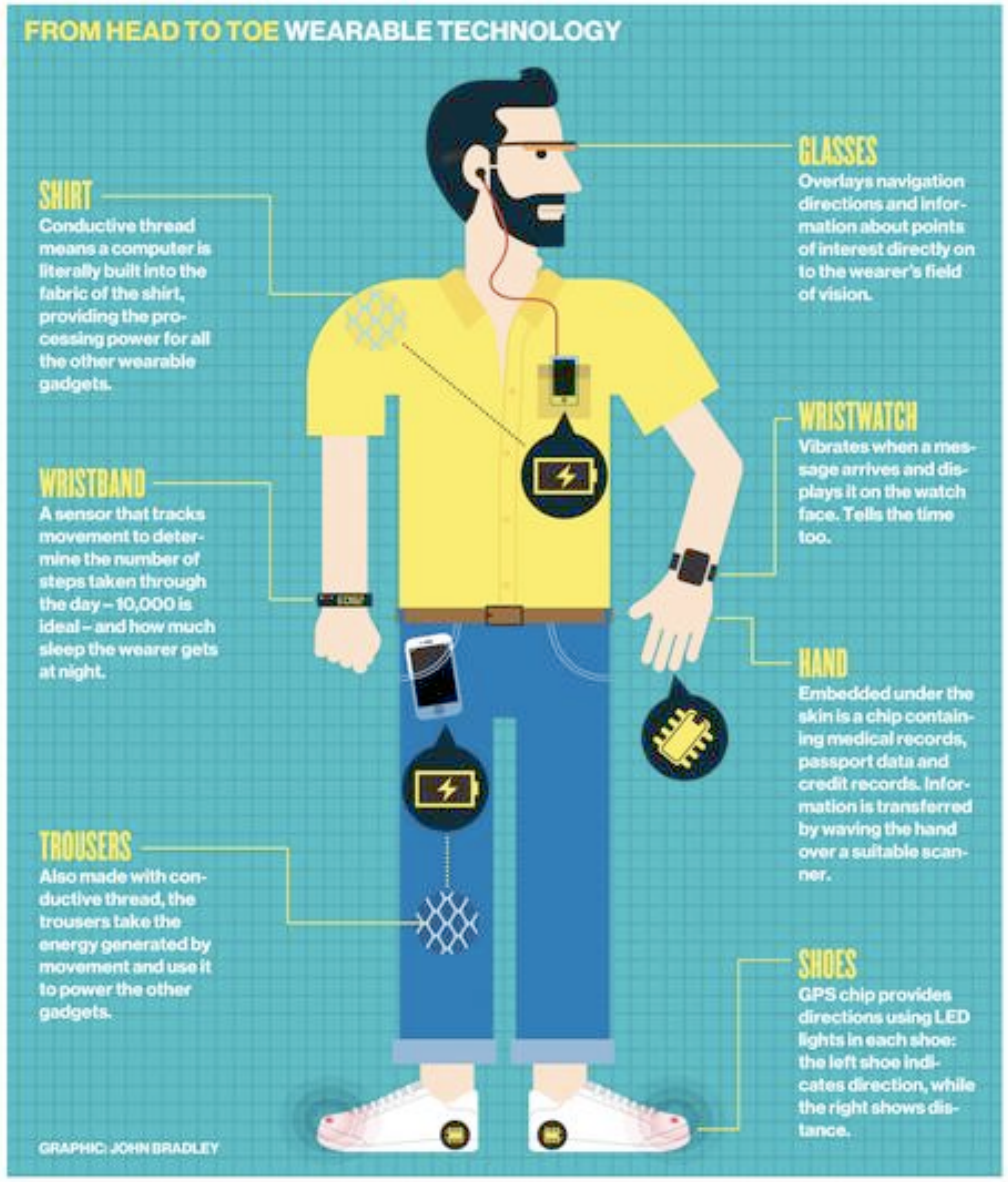



**Fig. 1.** Mocap system classification depending on the technology used.

Regazzoni et al, 2015

# Wearable technology

# Wearable technology



# Summary



- PA & ME overview;
- PA & ME measures overview;
- pedometry;
- first generation accelerometry;
- portable HR measure overview;
- V'O2 measure overview;
- DLW method overview;
- second generation accelerometry (purely physical sensors);
- second generation accelerometry (physical + physiological sensors);
- GPS;
- GIS overview;
- DGPS overview;

# Summary

- multisensor portable devices/garments overview;
- IMUs overview;
- TurfTrax overview;
- RFID chip overview;
- ODBA overview

# Thank you for your attention

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