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Full-body movement pattern recognition & Movement phases detection in climbing

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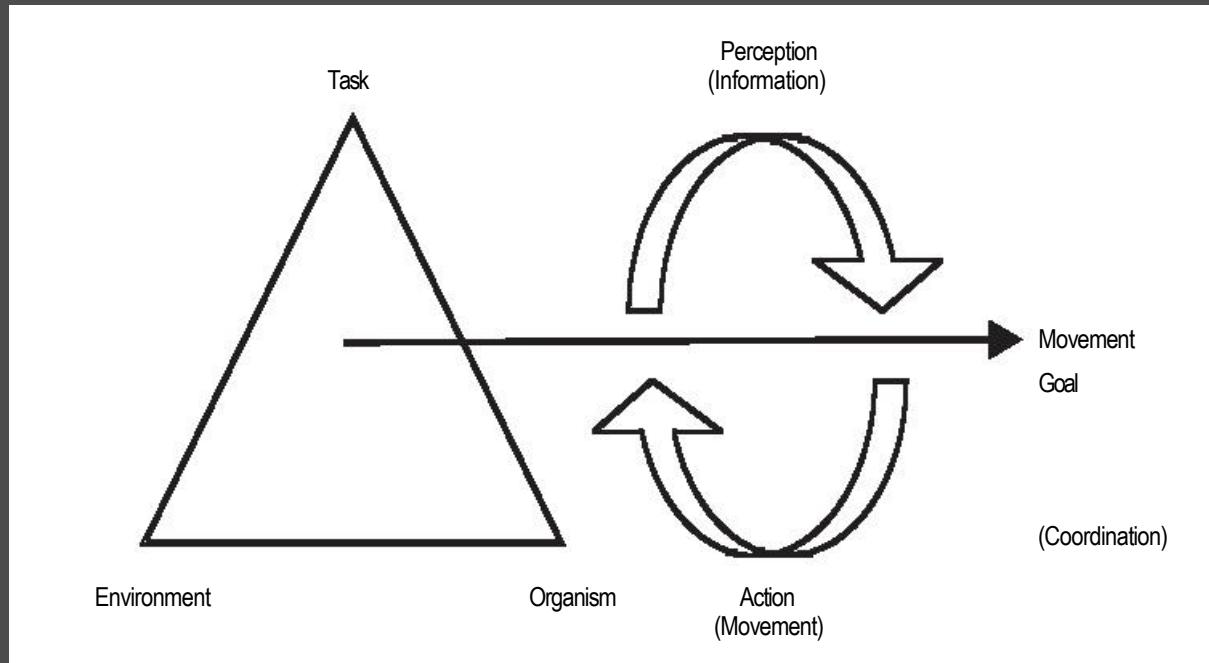
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1. Background

According to *Ecological Dynamics* framework (Davids et al., 2008; 2012), skill acquisition relates to perception and action coupling adaptation face to interacting constraints.



Tools from *Dynamical System* theory (attractor, transition, critical fluctuations, hysteresis, relaxation time; Kelso, 1995) to analyse perceptual-motor skills at ecological scale (following *Ecological Psychology* approach; Gibson, 1979).

From *Ecological Psychology* approach (Gibson, 1979):

- 1) Perception-action coupling means « direct » perception without mental representation; in other words, perceiving is already acting.
- 2) Coupling (circular relationships) between individual and environment : To perceive the world is to co-perceive oneself; we perceive the world in term of action possibilities (i.e., AFFORDANCES) that could be expressed in ABILITY: climb-ability of stairs, ladder, cliff; and more specifically, in climbing, it could be hold reach-ability, grasp-ability, use-ability, etc.
- 3) Affordances do not cause behavior, but constrain or control it (Gibson, 1979).
- 4) Affordances: *Invite* actions of individuals (Withagen et al., 2012).
- 5) Affordances are both objective (objects, surfaces, events) and subjective (ability to interact with environmental properties) in a way that you can pick up action opportunities without actualizing them.

Assumptions :

When environmental constraints offered explicit actions, there is few exploratory behaviours, i.e., easier affordance detection (Pijpers et al., 2006).

Assessment of how environment affords to a climber could be approached by « touched » hold (exploratory movement) / « grasped » hold (performatory movement) ratio (Pijpers et al., 2006).

Goal 1 :

To assess capability of *affordance detection* :

through the ratio between exploratory movements / performatory movements and more broadly by recognising several types of activity (immobility / movement...different patterns of movement: postural regulation, hold exploration, transition between holds, hold pulling...)

From *Dynamical System* theory (Kelso, 1995):

1) Behaviour *emerges* from interaction of a set of constraints (e.g., change in hold orientation – vertical vs. horizontal).

Moreover, greater is the range of movement patterns, easier is the adaptability to constraints (Seifert et al., 2014, ICPA).



Novice climbers mostly use ‘face’ body position, horizontal hold grasping and a small range of hand and foot patterns (‘duck’ -like)

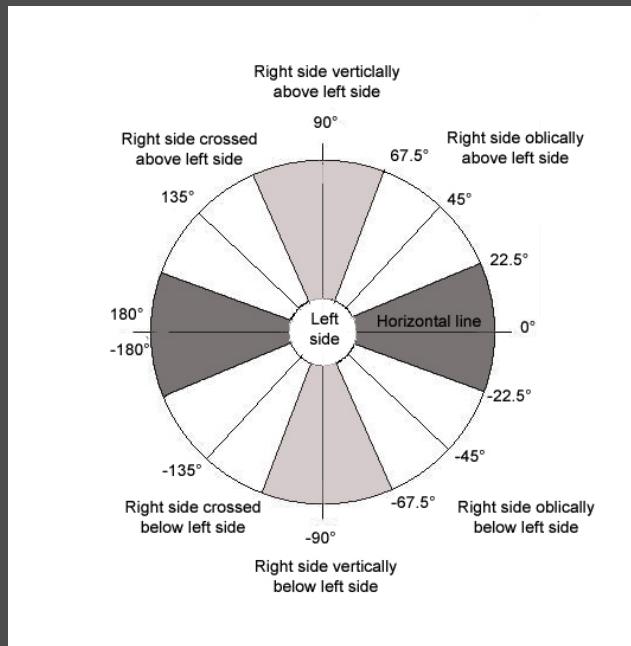
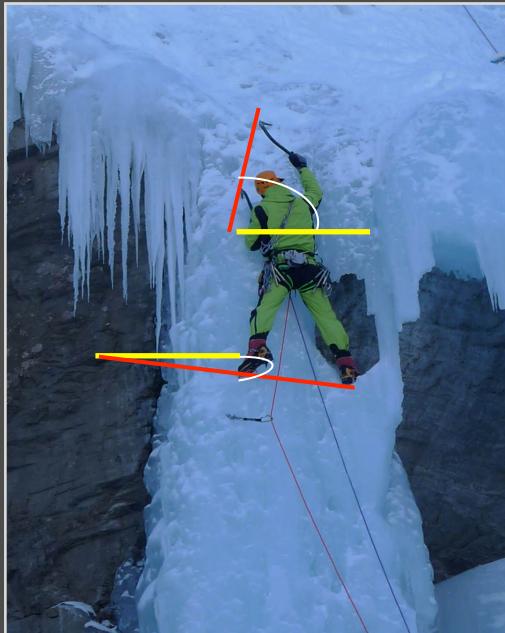


Experts are able to experience a variety of body, hand and foot positions, using mainly ‘side’ body position like ‘Cleopatra’ and both internal and external side of the climbing shoes

2) *Non-linearity* and *non-proportionality* between causes and consequences: microscopic change in constraints (e.g., hole design in icefall) can lead to macroscopic change of movement pattern.



In ice-climbing, beginners use ice tools as hammer and create their own holes to anchor ice tools. Conversely experts used existing holes in the ice fall, exhibiting larger range of motion and types of action (ice tools swinging and hooking) (Seifert et al., 2014, PlosOne).

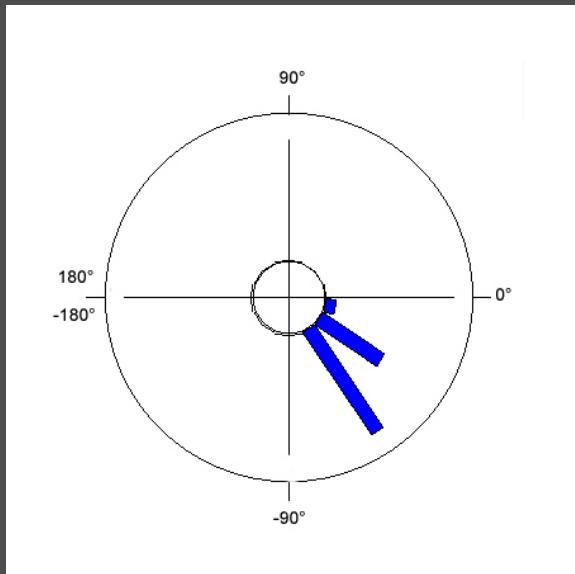


Limb coupling was assessed by the angle between the horizontal line and the left and right support.

Lower limb coupling in beginners

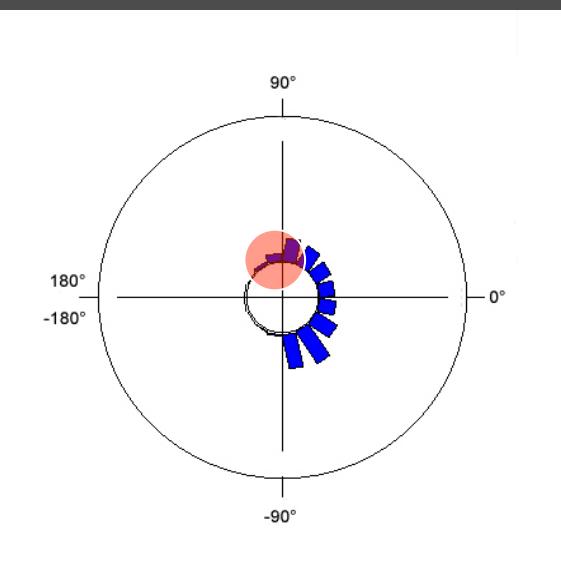
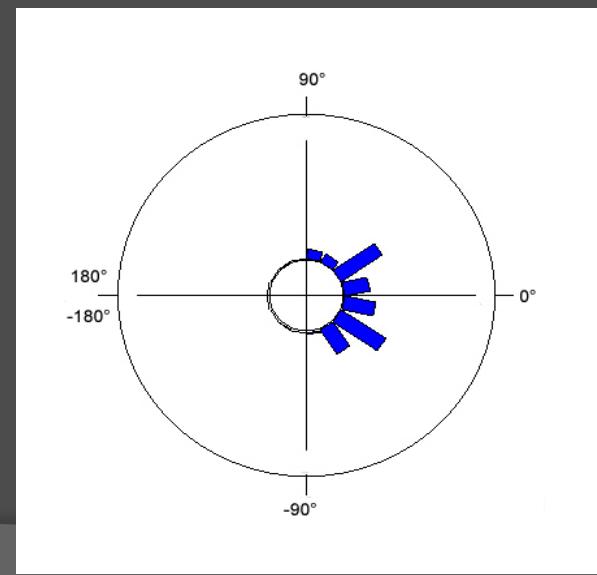
Upper limb coupling in beginners

(Seifert et al., 2014, PlosOne)



Lower limb coupling in elite climbers

Upper limb coupling in elite climbers



Goal 2 :



Analysing the way how individuals interact with constraints would provide understanding of the functional role played by movement variability.

The aim is to assess behavioural adaptability to constraints through change of full body (trunk + 4 limbs) orientation patterns.



Method :

Task:

One participant with an intermediate level of rock climbing ability (5c-6a French scale) climbed a route of a 5c grade in top-rope condition.

The route height is 10.30m with 20 hand holds.

3 minutes of route pre-viewing is given.

Self-paced ascent, but the given goal for the participant was to « *climb fluently, by minimizing stops and saccades* ».

Data collection:

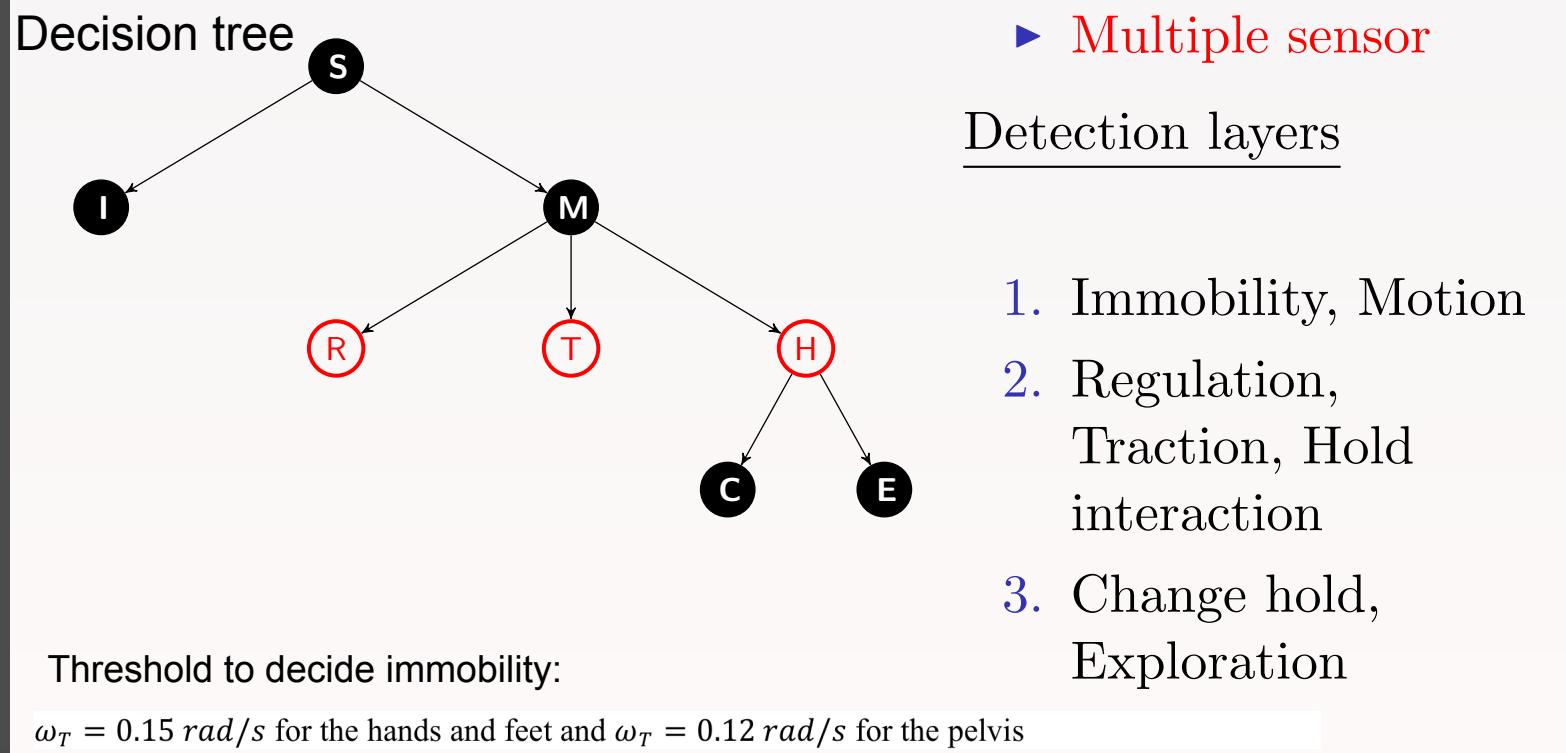


5 inertial measurement unit
combining 3D accelerometer, 3D
gyroscope, 3D magnetometer
(MotionPod3, www.movea.com,
Grenoble, France)

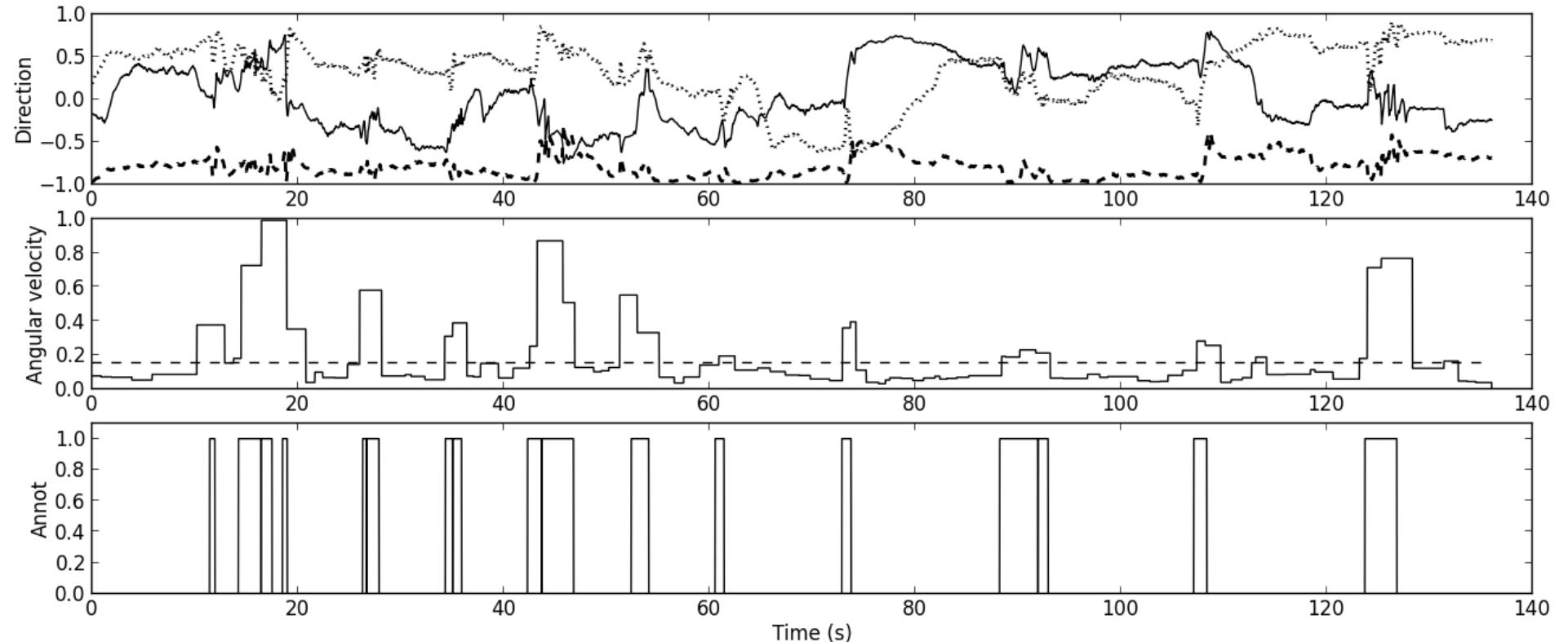


*Goal 1 : Affordances detection and more broadly,
Recognition of different types of activity*

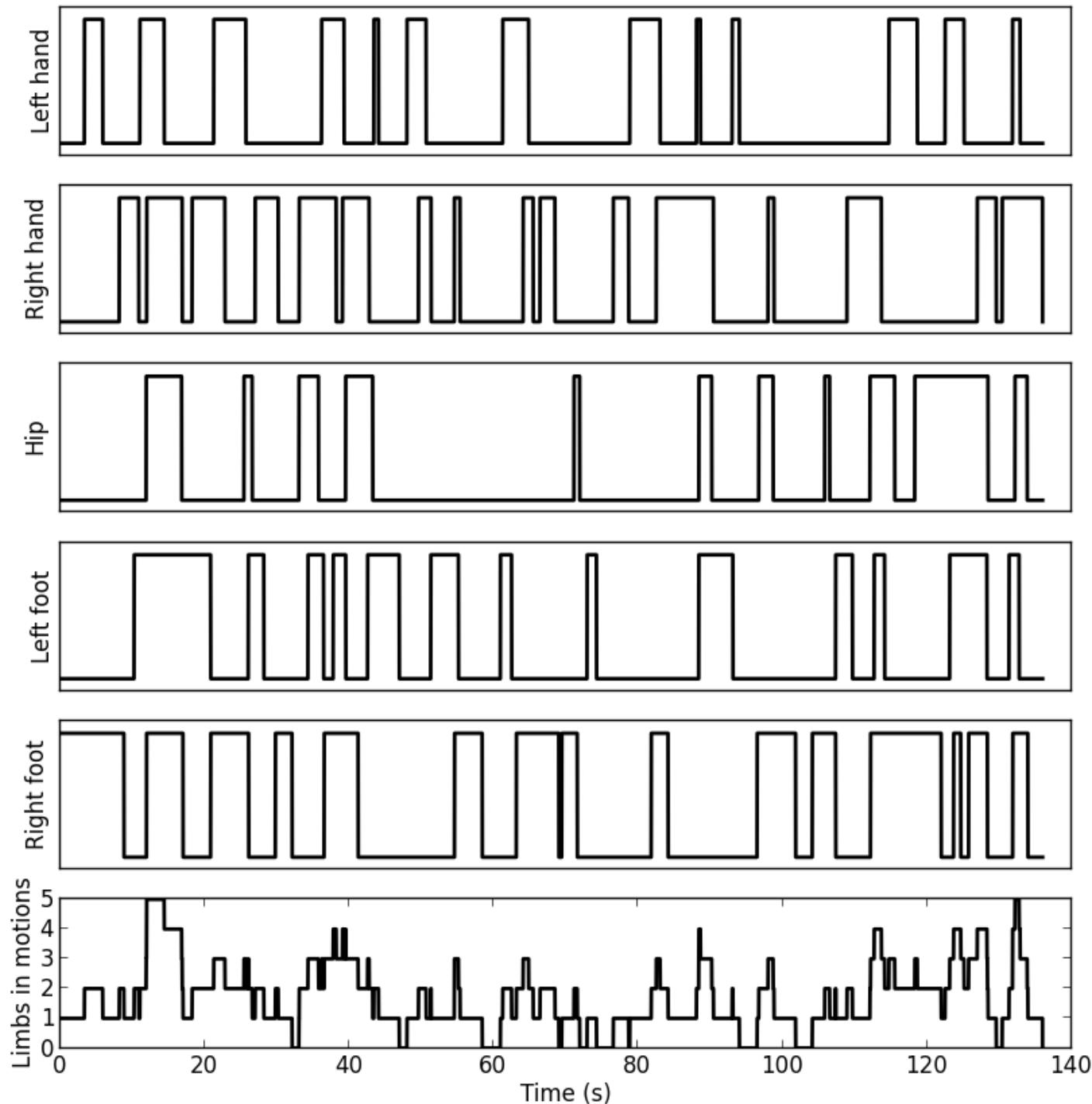
| | Limb immob | Limb (1+) mov |
|-----------|------------|------------------|
| Hip immob | Immobility | Hold interaction |
| Hip mov | Regulation | Traction |



Ex for one sensor:



Validation with manual video annotation obtained from blind process (cross of 2 operators analysis). Accuracy between 70% (pelvis) to 90% (hands & feet).



Ex of full-body analysis

| | Limb immob | Limb (1+) mov |
|-----------|------------|------------------|
| Hip immob | Immobility | Hold interaction |
| Hip mov | Regulation | Traction |

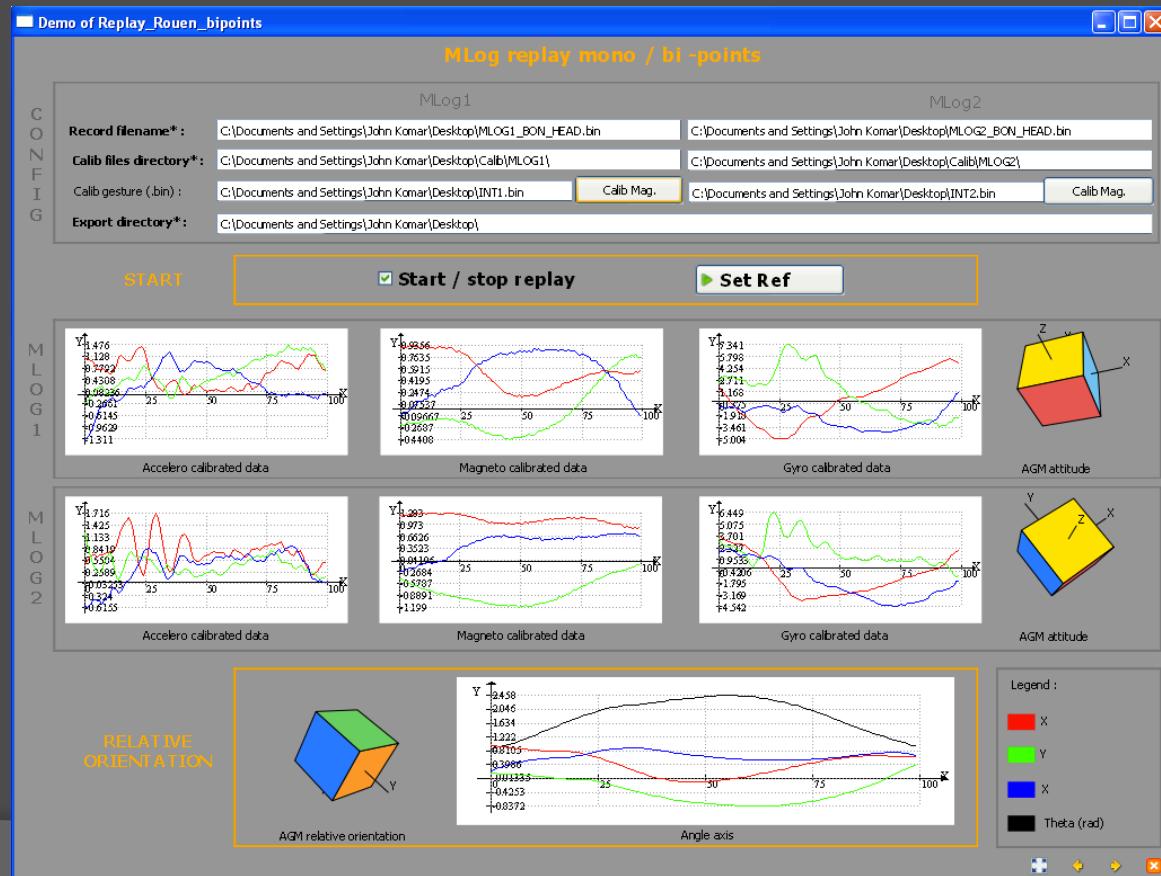


| | |
|------------------|-----|
| Immobility | 25% |
| Regulation | 5% |
| Hold interaction | 43% |
| Traction | 27% |

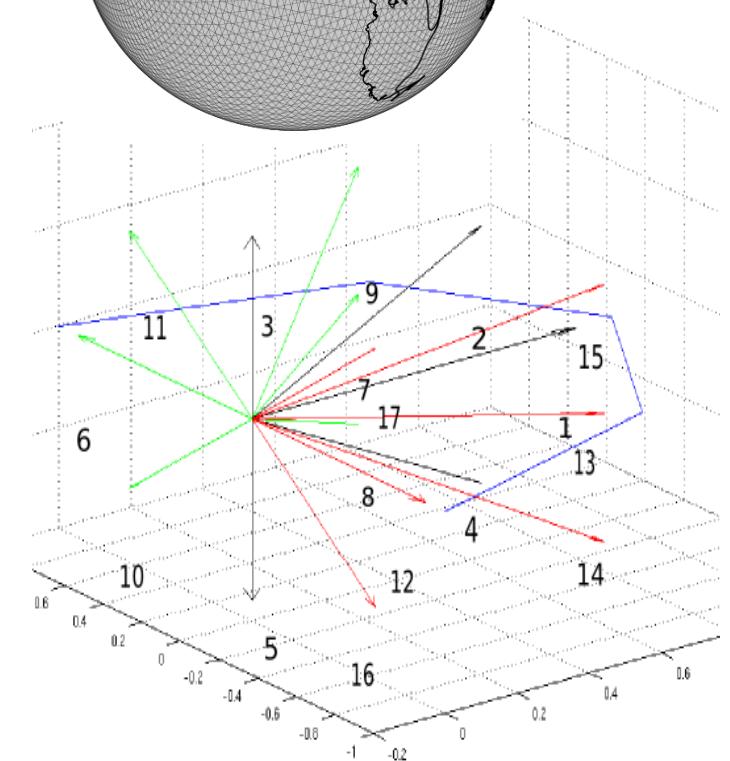
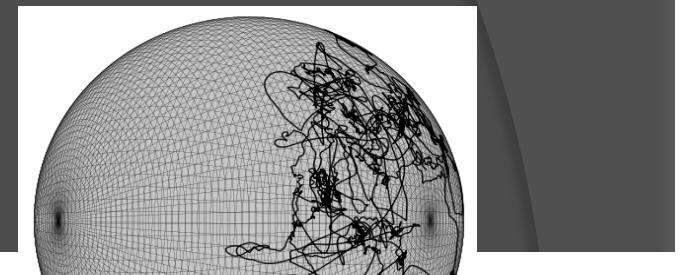
Goal 2: full body (trunk + 4 limbs) 3D orientation patterns recognition

(Seifert et al., 2014 *Procedia Engineering*)

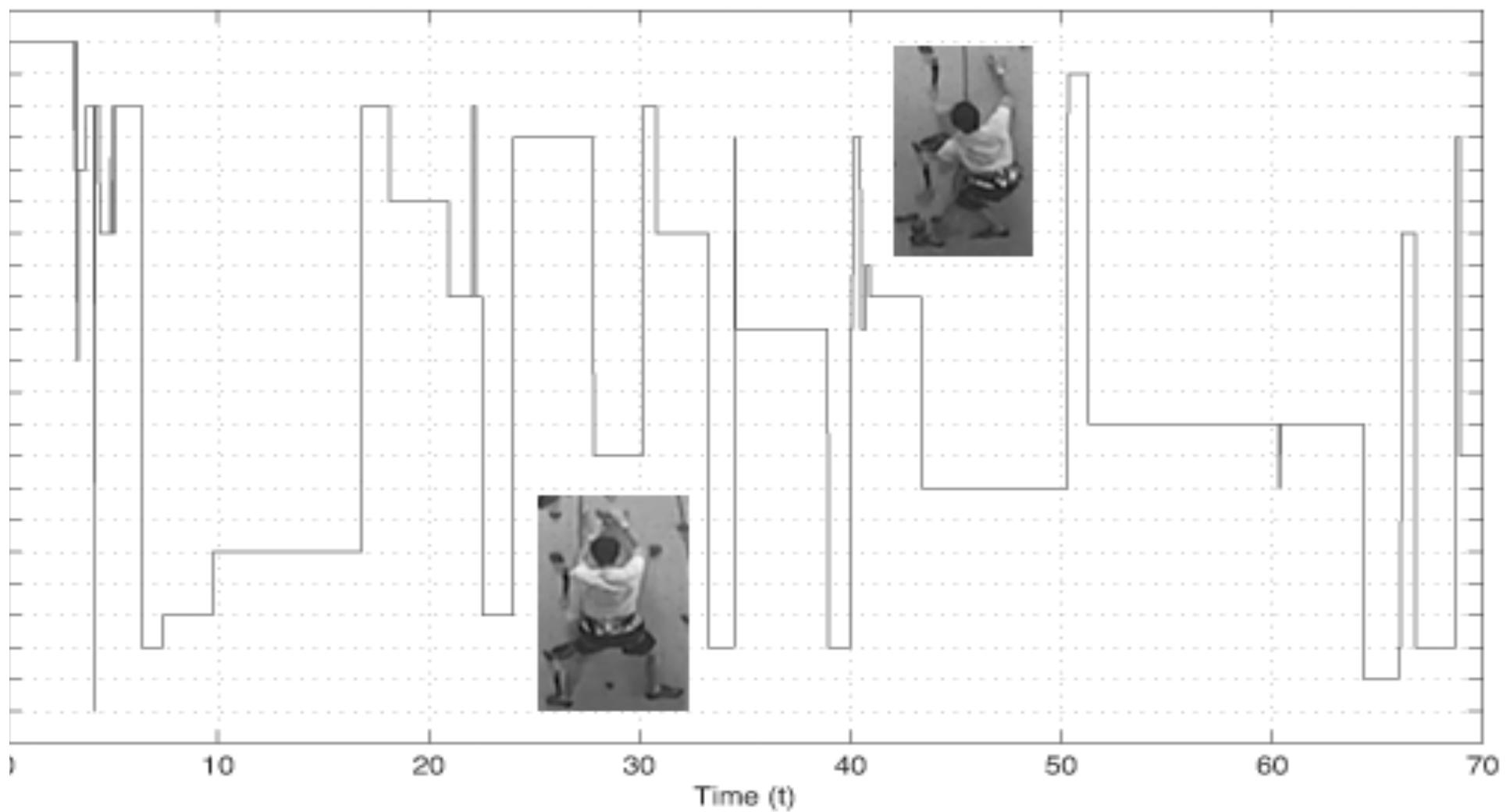
Combination of 3D accelerometer, 3D gyroscope, 3D magnetometer to get quaternion (according to Madgwick et al. 2011. *IEEE International Conference on Rehabilitation Robotic*) and then 3D unitary vector in Earth reference.



Pattern recognition algorithm corresponds to calculate the scalar product of one of the 17 possible vectors (with interval of 22.5°) and the current vector. Higher is the scalar product, more aligned are the two vectors. The current vector is assigned to the closest pre-defined pattern.



| Theoretic patterns | Coordinates | | | Direction label |
|--------------------|-------------|-------|------|--------------------------|
| | X | Y | Z | |
| 1 | 0.00 | 0.00 | 1.00 | 'Forward' |
| 2 | -0.71 | 0.00 | 0.71 | 'Oblique Downward' |
| 3 | -1.00 | 0.00 | 0.00 | 'Downward' |
| 4 | 0.71 | 0.00 | 0.71 | 'Oblique Upward' |
| 5 | 1.00 | 0.00 | 0.00 | 'Upward' |
| 6 | 0.00 | 1.00 | 0.00 | 'Right' |
| 7 | 0.00 | 0.71 | 0.71 | 'Oblique Right' |
| 8 | 0.58 | 0.58 | 0.58 | 'Oblique Upward Right' |
| 9 | -0.58 | 0.58 | 0.58 | 'Oblique Downward Right' |
| 10 | 0.71 | 0.71 | 0.00 | 'Upward Right' |
| 11 | -0.71 | 0.71 | 0.00 | 'Downward Right' |
| 12 | 0.00 | -1.00 | 0.00 | 'Left' |
| 13 | 0.00 | -0.71 | 0.71 | 'Oblique Left' |
| 14 | 0.58 | -0.58 | 0.58 | 'Oblique Upward Left' |
| 15 | -0.58 | -0.58 | 0.58 | 'Oblique Downward Left' |
| 16 | 0.71 | -0.71 | 0.00 | 'Upward Left' |
| 17 | -0.71 | -0.71 | 0.00 | 'Downward Left' |



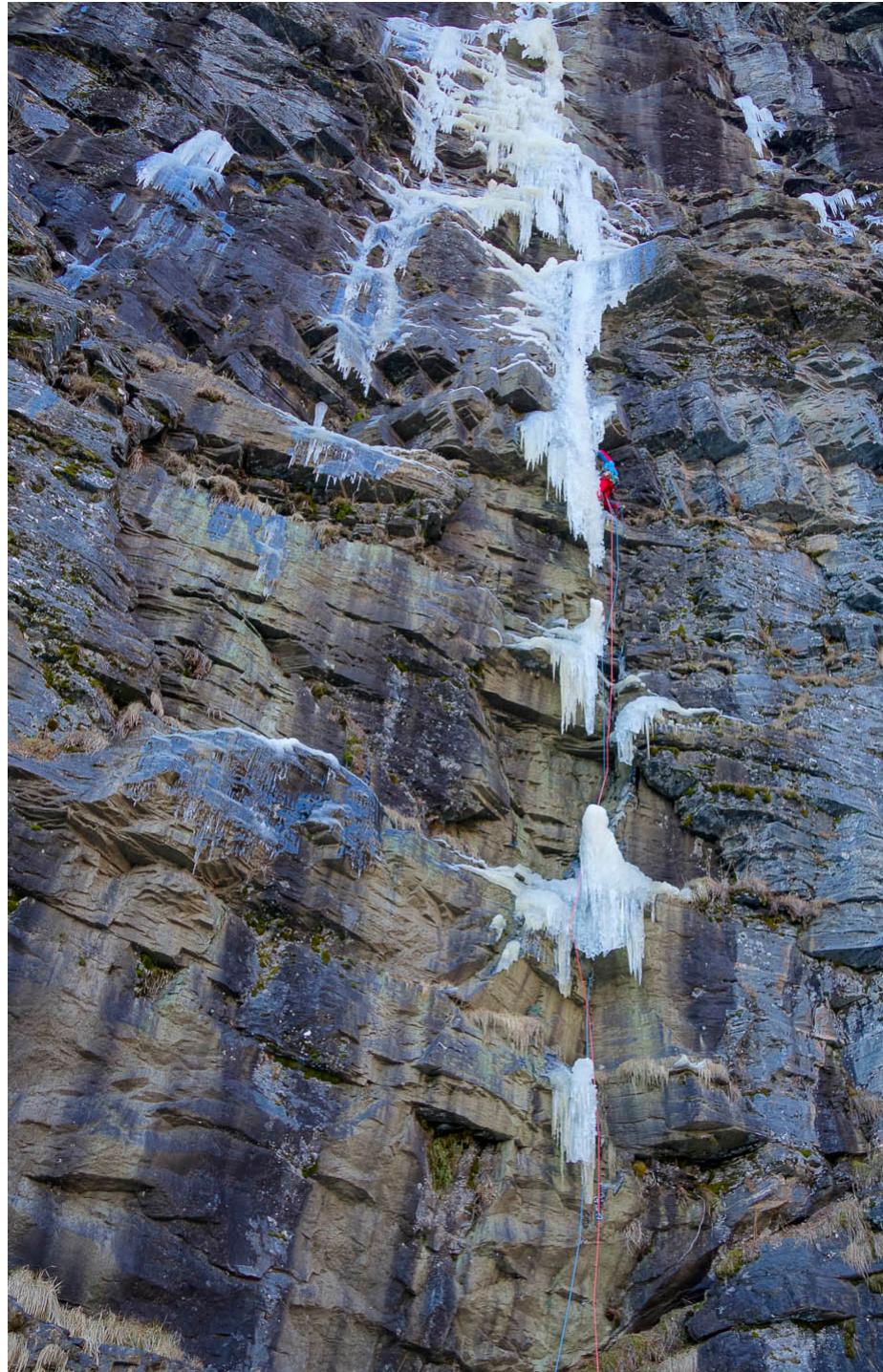
Discussion & Conclusion

IMU enables :

- automatic climbing movement phases detection to know how climbers interact with their environment.
- analysis in ecological context because embedded and light device.
- provide rapid feedback on affordances detection which is particularly useful to examine how climbers deal with « crux » points.
- assessment of 3D orientation of limbs and trunk in wall reference; then movement pattern recognition according to reference.
- examination of range of movement patterns and inter-limb coordination patterns.



THANK YOU
FOR YOUR ATTENTION



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