Analysis and modelling of motor coordination during a learning protocol in swimming

Ludovic Seifert*[1,2]

[1]Centre d'Etude des Transformations des Activités Physiques et Sportives (CETAPS EA3832) – Université de Rouen Normandie – France

[2]Institut Universitaire de France (IUF) – Institut universitaire de France – Paris, France

Résumé

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This presentation first introduces a method for detecting key points in the arm and leg cycle of the breaststroke using 3D accelerometric and 3D gyroscopic signal processing. These signals are collected via six inertial measurement units (IMUs) placed on the swimmer's wrists, ankles, pelvis, and neck (Komar et al., 2023). These key points allow for the detection the propulsive and non-propulsive phases of the swimming cycle, as well as the angular variations of the knees and elbows, in order to analyse the coordination between arm and leg movements-either by estimating the temporal gaps between key points of the cycle, or by computing the continuous relative phase between elbow-knee oscillators (Chollet et al., 2004; Seifert et al., 2011).

Second, we present how this method was applied in a 16-session breaststroke learning protocol involving seven novice swimmers. A clustering analysis was then applied to distinguish between several learner profiles (based on the different clusters of coordinating arms and legs). Finally, a drift Markov modelling (DMM) approach was used to estimate the probability of occurrence of the different coordination profiles over the learning process (Komar et al., 2023). This modelling is particularly insightful as it shows that some coordination modes, present in the novices' initial repertoire, are temporarily abandoned in favour of other coordination modes, which are themselves later replaced by more efficient and stabilised coordination patterns.

More specifically, the DMM allow for the identification of an intermittent regime during learning, in which the learner alternates between exploiting existing coordination modes and exploring new ones (Komar et al., 2023; Seifert et al., 2025). The coordination modes used temporarily during learning, which are later abandoned, might be used to explore in the future more effective coordination patterns. Conversely, existing coordination modes are used as fallback solutions when newly explored coordination patterns are not effective.

Finally, data sciences (e.g., signal processing, data mining, machine learning) enable the automatic processing (as opposed to manual notational analysis) and increased robustness of analyses. Furthermore, they go beyond descriptive approaches to provide modelling of the dynamic of learning. Grounded in complexity science, the modelling of individual learning

*Intervenant

dynamics contributes to a 'sustainable' approach to motor behaviour.

Bibliography

Chollet, D., Seifert, L., Leblanc, H., Boulesteix, L., & Carter, M. (2004). Evaluation of arm-leg coordination in flat breaststroke. *International Journal of Sports Medicine*, *25*, 486–495. http://www.thieme-connect.com/ejournals/abstract/sportsmed/doi/10.1055/s-2004-820943

Komar, J., Seifert, L., Vergne, N., & Newell, K. M. (2023). Narrowing the coordination solution space during motor learning standardizes individual patterns of search strategy but diversifies learning rates. *Scientific Reports*, *13*(1), 2009. https://doi.org/10.1038/s41598-023-29238-z

Seifert, L., Kalligeris, E. N., Komar, J., Hacques, G., Barbu, V., & Vergne, N. (2025). The application of drifting Markov modelling to dynamics skill acquisition. In *Stochastic Modeling and Statistical Methods: Advances and Applications* (Alex Karagrigoriou, Sonia Malefaki, Ioannis S. Triantafyllou). Elsevier Science Publishers. https://shop.elsevier.com/books/stochastic-modeling-and-statistical-methods/triantafyllou/978-0-443-31694-4

Seifert, L., Leblanc, H., Herault, R., Komar, J., Button, C., & Chollet, D. (2011). Inter-individual variability in the upper-lower limb breaststroke coordination. *Human Movement Science*, *30*(3), 550–565. https://doi.org/10.1016/j.humov.2010.12.003