

The Sports Data work package has addressed all areas described in the project plan. In the following an overview is given of how the scientific publications and reports contribute to these areas.

Kinematic and Kinetic feature extraction algorithms

In initial research focus was on the selection of IMU placements, the construction and selection of signal features, and the construction of volleyball action recognition classifiers using machine learning techniques. Initially the project focused on recognition of volleyball actions purely based on the analysis of kinematic data. This has resulted in the following scientific publication.

The following scientific publications are the result of this research activity:

- Salim, F. A., [Reidsma, D.](#), & [van Delden, R.](#) (2019). [Modeling Behavior of Volleyball Players For Analysis and Interactive Multimodal Feedback](#). Poster session presented at 6th International Conference on Ambulatory Monitoring of Physical Activity and Movement, ICAMPAM 2019, Maastricht, Netherlands.
- Salim, F. A., Haider, F., Yengec Tasdemir, S. B., Naghashi, V., Tengiz, I., Cengiz, K., Postma, D. B. W., [van Delden, R.](#), [Reidsma, D.](#), Luz, S., & [van Beijnum, B.-J.](#) (2020). [Volleyball Action Modelling for Behavior Analysis and Interactive Multi-modal Feedback](#). In *eINTERFACE'19, 15th International Summer Workshop on Multimodal Interface* Bilkent University.
- Fasih Haider, Fahim Salim, Vahid Naghashi, Sena Busra Yengec Tasdemir, Izem Tengiz, Kubra Cengiz, Dees Postma, Robby van Delden, Dennis Reidsma, Bert-Jan van Beijnum, Saturnino Luz; Evaluation of Dominant and Non-Dominant Hand Movements For Volleyball Action Modelling; ICMI '19: Adjunct of the 2019 International Conference on Multimodal Interaction; October 2019 Article No.: 8; Pages 1–6; <https://doi.org/10.1145/3351529.3360651>
- Haider, F., Salim, F. A., Postma, D. B. W., [Delden, R. V.](#), [Reidsma, D.](#), [Beijnum, B. J. V.](#), & Luz, S. (2020). [A super-bagging method for volleyball action recognition using wearable sensors](#). *Multimodal Technologies and Interaction*, 4(2), [33]. <https://doi.org/10.3390/mti4020033>
- Salim, F. A., Haider, F., Postma, D. B. W., [van Delden, R.](#), [Reidsma, D.](#), Luz, S., & [van Beijnum, B. J. F.](#) (2020). [Towards Automatic Modeling of Volleyball Players' Behavior for Analysis, Feedback, and Hybrid Training](#). *Journal for the Measurement of Physical Behaviour*, 3(4), 323-330. <https://doi.org/10.1123/jmpb.2020-0012>

In addition to these scientific publications, 4 BSc thesis reports have been published.

IN the next step, kinetic data was also measured (floor data measured by the pressure sensors integrated in the LEDGO floor) and used to track player positions on the floor. In addition, for specific exercise context, dedicated kinetic and kinematic data was inferred from floor and IMU sensor data. This specifically holds for the jump-spike exercise case.

Automatic context inference

A stratification of data-processing has been proposed and realized. Starting with the action recognition layer, actions of individual players are recognized. Context can be imposed by

the exercise selected and in progress, limiting or focusing the domain of relevant volleyball related actions. This way dedicated and optimized action recognition algorithms can be deployed and thereby increasing the effectiveness and usability of the system. Context may also be inferred from data retrieved from actual exercises and matches creating a model of action sequences displaying player interactions. Ground work for this has led to a probabilistic process like models which may either be designed as part of an exercise design or may be inferred from captured motion data and provide the models the enable understanding volleyball actions in their respective contexts.

The results of this research have been reported in:

- [Beenhakker, L., Salim, F., Postma, D., van Delden, R., Reidsma, D., & van Beijnum, B.-J.](#) (2020). *How Good is Good Enough? The Impact of Errors in Single Person Action Classification on the Modeling of Group Interactions in Volleyball*. 278. Paper presented at 22nd ACM International Conference on Multimodal Interaction, ICMI 2020, Virtual, Online, Netherlands. <https://doi.org/10.1145/3382507.3418846>

Algorithms and first results of short term and long-term performance mining.

Action and interaction models, once created are used to as an execution model to derive performance metrics per player, per action in their specific context. This approach can be used to track both short-term and long term performance data. This work has been reported in:

- [Beenhakker, L., Salim, F., Postma, D., van Delden, R., Reidsma, D., & van Beijnum, B.-J.](#) (2020). *How Good is Good Enough? The Impact of Errors in Single Person Action Classification on the Modeling of Group Interactions in Volleyball*. 278. Paper presented at 22nd ACM International Conference on Multimodal Interaction, ICMI 2020, Virtual, Online, Netherlands. <https://doi.org/10.1145/3382507.3418846>

Another approach to performance mining has been studied, whereby action recognition and video-recordings of plays (exercises or matches) are combined with system intelligence so that players and coaches can easily navigate and search the recordings for specific actions and action replays. This gives players and coaches a fast and meaningful tool in their day-to-day coaching an practicing work. This research output has been reported in:

- Fahim Salim, Fasih Haider, Sena Busra Yengec Tasmemir, Vahid Naghashi, Izem Tengiz, Kubra Cengiz, Dees Postma, [Robby Van Delden](#), [Dennis Reidsma](#), Saturnino Luz, [Bert-Jan van Beijnum](#); A searching and automatic video tagging tool for events of interest during volleyball training sessions; [ICMI '19: 2019 International Conference on Multimodal Interaction](#); October 2019 Pages 501–503; <https://doi.org/10.1145/3340555.3358660>

Initial and Final Validation, testing and integration

Prototyping work has led to the final prototype named SSE_MOAD version 2. This prototypes uses the Model-View-Controller pattern as implementation paradigm. This way modularity and extensibility of the code is promoted. The prototype implementation is in Python. IMU data can be flexibly captured, IMU's used in the prototype implementation are NGIMU's (<https://x-io.co.uk/ngimu/>), other data source is the pressure sensor data of the LEDGO interactive floor. Sensor data processing is supported for selected SSE interactive exercises.

For users of the software a user manual has been written which is made available in the document "SSE_MOAD_V2_Manual.pdf"

Scientific Output

Peer Reviewed Poster:

Salim, F. A. , [Reidsma, D. , & van Delden, R.](#) (2019). [Modeling Behavior of Volleyball Players For Analysis and Interactive Multimodal Feedback](#). Poster session presented at 6th International Conference on Ambulatory Monitoring of Physical Activity and Movement, ICAMPAM 2019, Maastricht, Netherlands.

Peer Reviewed Conference Papers:

Salim, F. A., Haider, F., Yengec Tasdemir, S. B., Naghashi, V., Tengiz, I., Cengiz, K., Postma, D. B. W. , [van Delden, R. , Reidsma, D.](#), Luz, S. , [& van Beijnum, B-J.](#) (2020). [Volleyball Action Modelling for Behavior Analysis and Interactive Multi-modal Feedback](#). In *eINTERFACE'19, 15th International Summer Workshop on Multimodal Interface* Bilkent University.

Fasih Haider, Fahim Salim, Vahid Naghashi, Sena Busra Yengec Tasdemir, Izem Tengiz, Kubra Cengiz, Dees Postma, Robby van Delden, Dennis Reidsma, Bert-Jan van Beijnum, Saturnino Luz; Evaluation of Dominant and Non-Dominant Hand Movements For Volleyball Action Modelling; ICMI '19: Adjunct of the 2019 International Conference on Multimodal Interaction; October 2019 Article No.: 8; Pages 1–6;
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<https://doi.org/10.3390/mti4020033>

Salim, F. A., Haider, F., Postma, D. B. W. , [van Delden, R. , Reidsma, D.](#), Luz, S. , [& van Beijnum, B. J. F.](#) (2020). [Towards Automatic Modeling of Volleyball Players' Behavior for](#)

[Analysis, Feedback, and Hybrid Training](https://doi.org/10.1123/jmpb.2020-0012). *Journal for the Measurement of Physical Behaviour*, 3(4), 323-330. <https://doi.org/10.1123/jmpb.2020-0012>