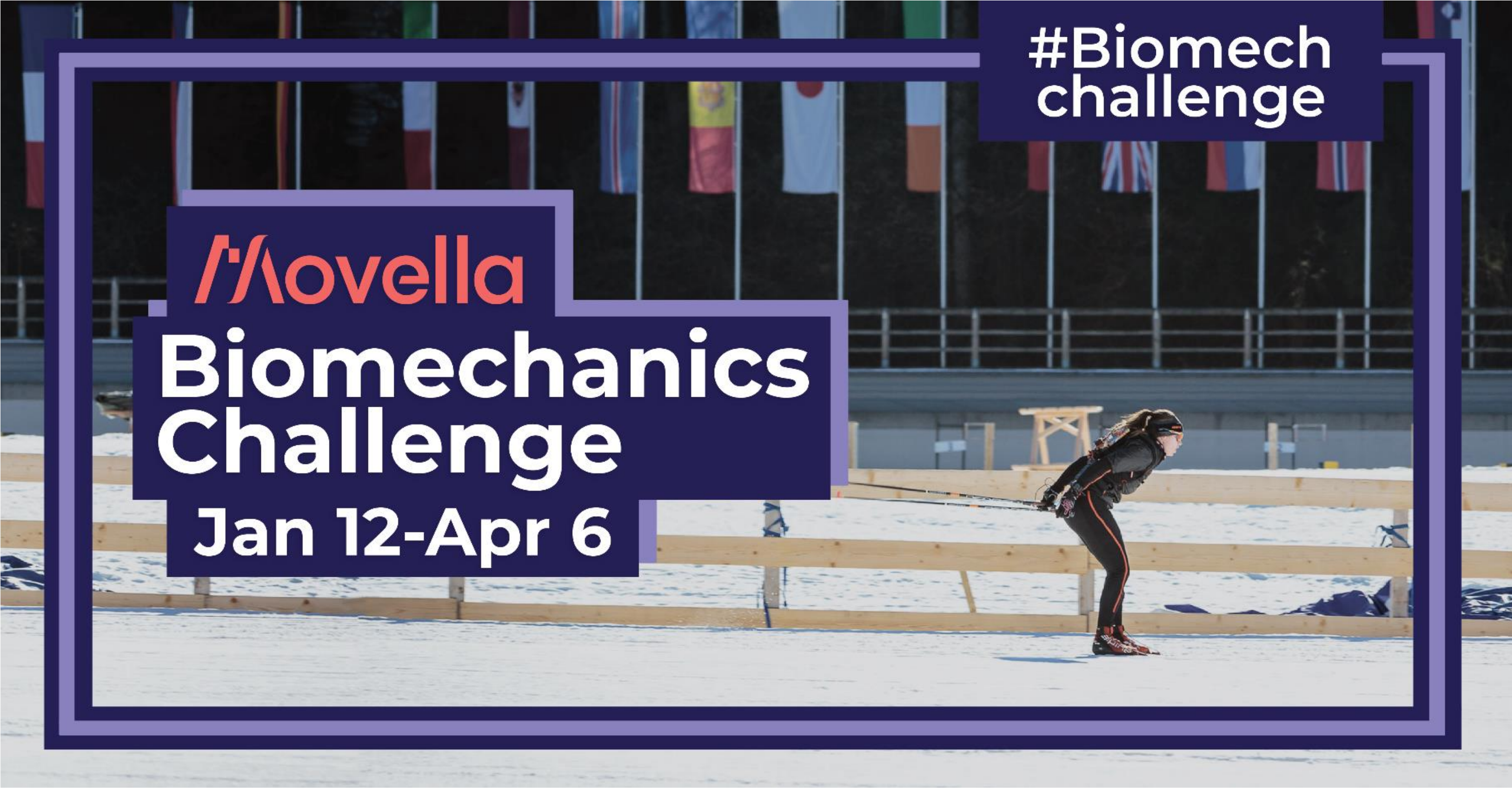

Case Study Document

Movella Biomechanics Challenge

9th March 2023

Contents

1 Welcome!

We are happy that you decided to be involved with the Movella Biomechanics Challenge. This challenge is a global event where students and researchers compete with other participants around the globe. This case study document contains information about the challenge as well as the expected workload for participating as a jury member.

Key dates of the challenge and descriptions of the corresponding events are listed below:

> **January 12, 2023: Registration opens**

> **March 8, 2023: Registration closes**

> **March 9, 2023: Kick-off Webinar & Case Study Release**

In this webinar the case study will be revealed. The webinars will be recorded in case you cannot attend. Don't miss it to make sure you get the most out of the Challenge! After the webinar is completed, registrants for the webinars will receive this Case Study document and an activation trial license for the Xsens MVN Analyze Software.

> **March 16, 2023: Technical training & Q&A Session**

There will be 2 one-hour sessions (one in a European time zone, and one in an American time zone) where registrants can ask questions about assignment of the challenge, MVN software, data processing, etc. These sessions will be recorded for your reference.

> **March 23, 2023: Project Delivery by 23:59 (11:59 PM) Central European Time (CET)**

Submit your project before the deadline via email to biomechanics.challenge@movella.com

> **April 6, 2023: Final Presentation Webinar**

The top candidates will be chosen to give a final presentation on their project. To assure a chance of winning the Movella Biomechanics Challenge, you must attend and present at this final presentation.

> **April 13, 2023: Winner Announced**

2 The Case Study

The case study for the Movella Biomechanics Challenge 2023 is about Winter sports. The University of Trento, in Italy, is our main partner for this edition. Together, we defined the concrete parameters each team needs to compute, and which topics need to be discussed in the reports.

The biomechanics of cross-country skiing (XC-skiing) is more challenging than that of other sports activities and movements. In skiing, athletes face various impacts and move at high speeds, on a surface with varying structure and inclination. Nonetheless, the interest in improving performance and prevention of injuries in the sport keeps growing.

A detailed data set with full body motions of skiers are required to tackle the challenges of the biomechanics of skiing. The Xsens Link system based on IMU data provides such detailed body motions. Fortunately, we had the possibility to measure athletes together with the University of Trento which brings the challenge to the next level. This challenge is a unique and valuable opportunity for you to contribute to the winter Olympics of Milano-Cortina 2026 (Italy).

It is now up to you and your team to work on the best solution to have the chance to present it to our group of experts that will evaluate the reports. Work hard to have a chance to work closely together with the Olympic committee bringing innovative solutions to the Winter Olympics of 2026!

2.1 Recordings

For this case study we recorded 8 different athletes of 4 different athletic levels. We did all recordings on the same cross-country ski track. Each athlete performed one round of the track in 3 different levels of intensity (moderate, somewhat hard, and all-out). Therefore, you find 3 MVN recordings for each athlete. In the Excel file data_details.xlsx you can find more details about the athletes. Note that only the athletic level of 4 athletes is given. One of your tasks is to define the level of performance of the other 4 athletes.

2.1.1 The track

The cross-country track that the athletes ski had an oval shape, for most of the run, the athletes sticked to the tracks craved on the floor (as shown in the Figure 1). However, to close the loop on the opposite where they begin the athletes must leave the tracks to close the loop and then come back to the track

Figure 2 - Example of the track

Figure 1 - Location of the tracks.

Additionally, the track had 2 points of elevation (as seen in the image below Figure 3). Going down the second small elevation, visible on the left in the figure, athletes were asked to keep a straight pose; this may be of relevance in some calculations.

Figure 3 - Image of the track. The second descend is marked by an orange x

2.1.2 MVN recordings

All the measurements were performed using the Xsens Link system with a GNSS antenna connected with 240Hz output frequency. All the MVN files have been already processed in a way that fits best the case study. So, there is no need to reprocess any files!
Also, all files have been already exported to MVNX, which is an xml format that is easy to import in Python or Matlab for you to continue with your calculations. More documentation on importing MVNX can be found on the Movella website:

https://base.xsens.com/s/article/MATLAB-script-to-read-MVNX-files?language=en_US
https://base.xsens.com/s/article/Reading-an-MVNX-file-with-Python?language=en_US

2.1.3 RTK GNSS data

Additional to the Link system, we recorded RTK GNSS data through an antenna that was connected to one of our MTi 680-G sensors. The RTK GNSS provides a very high position accuracy (<1,4 cm). The athletes were carrying the RTK antenna with them while performing the runs. You can find the files of this data also in the folder. Note that you will only need this information for the optional outputs (see sections below).
To open the mtb files, you need to use the MT manager software. However, we have exported the position from the GNSS and converted the coordinates into meters so you can directly use the data from the Excel files.

2.1.4 Weather forecast

Included in the recordings folder is the forecast for the 2 days of measurements. This information may also be used in your methods to compute the required outputs for the case study.

2.2 Project outputs

For this challenge we expect you to provide a clear justification and explanation on how you calculated and estimated the "Mandatory Outputs", in addition to present your results clearly.

2.2.1 Mandatory outputs

For this year's challenge, there is one main goal, which is to rank the different athletes in terms of performance. Therefore, you need to compute a performance parameter. Since a performance parameter is an extremely broad term, we divided it into different points and guidelines for you to base your calculations on. However, you are also welcome to add any additional conditions that you may find important to complement the performance parameter. Note that is very important that you provide background information that supports the assumptions and calculations you have done, a description of the methods you used to compute each parameter and finally, make sure to describe the applied relevance for the different conclusions you derived from the results. All these factors will be considered for the selection of the finalists.

Performance Parameter

- **Smoothness of movement, coordination and balance**
  - Analyse the kinematics of the movement
  - Explain how the kinematics can be converted into performance
- **Power output of the upper body vs lower body.**
  - Define the (mechanical) power output during cross-country skiing
  - If relevant, split it between upper body and lower body. Provide a ratio.
  - Are there any external factors that may influence the power output?
- **Adopted strategies and track**
  - Note that different athletes may adopted slightly different locomotion patterns (i.e., related to techniques or strategies) at different points in the course.
  - What is the influence of these strategies on the performance?
  - The estimation of the frontal area can be of interest to determine the aerodynamic drag force (frontal images of each athlete may be of useful)

You must:

- Clearly justify what methods, assumptions, and scientific knowledge you used to determine your performance parameter.
- Rank the 8 athletes with the performance parameter that you have defined.

You should:

- Have a mathematical method that describes your performance parameter per athlete.

You could:

- Have an automatically generated performance parameter per trial
- Automatically detect the ski cycles

2.2.2 Bonus topics to discuss

If you have some time to spare in the challenge and would like to take it a step further, we have a suggestion of topics:

- **Calculate the friction coefficient of the snow**
    - Depending on the weather conditions, type of snow, type of slope and even type of equipment, the friction coefficient of the snow can change.
    - This parameter is highly relevant for the athletes to adapt their strategies and improve their performance.
    - Can you estimate a friction coefficient out of the data provided?
- **Reconstruction of the ski slope**
    - Each track has a different trajectory with different inclinations. Being able to 3D reconstruct the track can be of high importance for the preparations and training of the athletes before going to the track.
    - All the recordings provided were done on the same track, are you able to reconstruct the 3D trajectory of the cross-country track?

2.3 Download the recording data

In the link below you can download all the data that you will need to complete this challenge.

https://we.tl/t-PbOAoU04uv

2.4 Deliverables

2.4.1 Report

At the end of the project, each team delivers a report explaining their solution for the presented case study. This should be provided in a written document with the following structure:

- Introduction:
    - Recap project description and objectives (including if you computed any additional optional outputs or deliverables)
    - What studies or theories you based your answer on
- Methods:
    - Explanation of calculations (including equations)
    - Explain parameters accounted for in calculations, including assumptions made, and justifications
- Results:
    - List the mandatory power output and repeatability results, in addition to any additional optional outputs computed
- Clinical Relevance and Application:
    - How can your solutions be applied in a clinic setting?
    - How clinically relevant are the results you found?
- Discussion:
    - Discuss how your chosen method to calculate power influenced the results
    - If you computed any additional or optional outputs or designed a coaching or training interface, explain how this interface can be used and any clinical or training benefits
- Conclusion:
    - Summarize your findings
    - Propose ideas for future work

The document should be a maximum of **four** pages (without bibliography) at size 10 Times New Roman. You are advised to use the IEEE format. (https://www.ieee.org/conferences/publishing/templates.html)

If additional optional outputs are created, the team may list these in an appendix. Any code or scripts used can be send separately to the report, this can help in the interpretation of the report. The report (including any optional additional outputs and the appendix) shall not exceed six pages. Any questions can be directed to biomechanics.challenge@movella.com.

3 Practicalities

3.1 Download the MVN Software

1. Go to the Movella Website (www.movella.com)
2. Go to Support -> Software & documentation -> Software downloads -> MVN Analyze -> Latest stable software
3. Install the Program
4. After installing, click in License Manager
5. Activate the free trial license (valid until the 24th of March):

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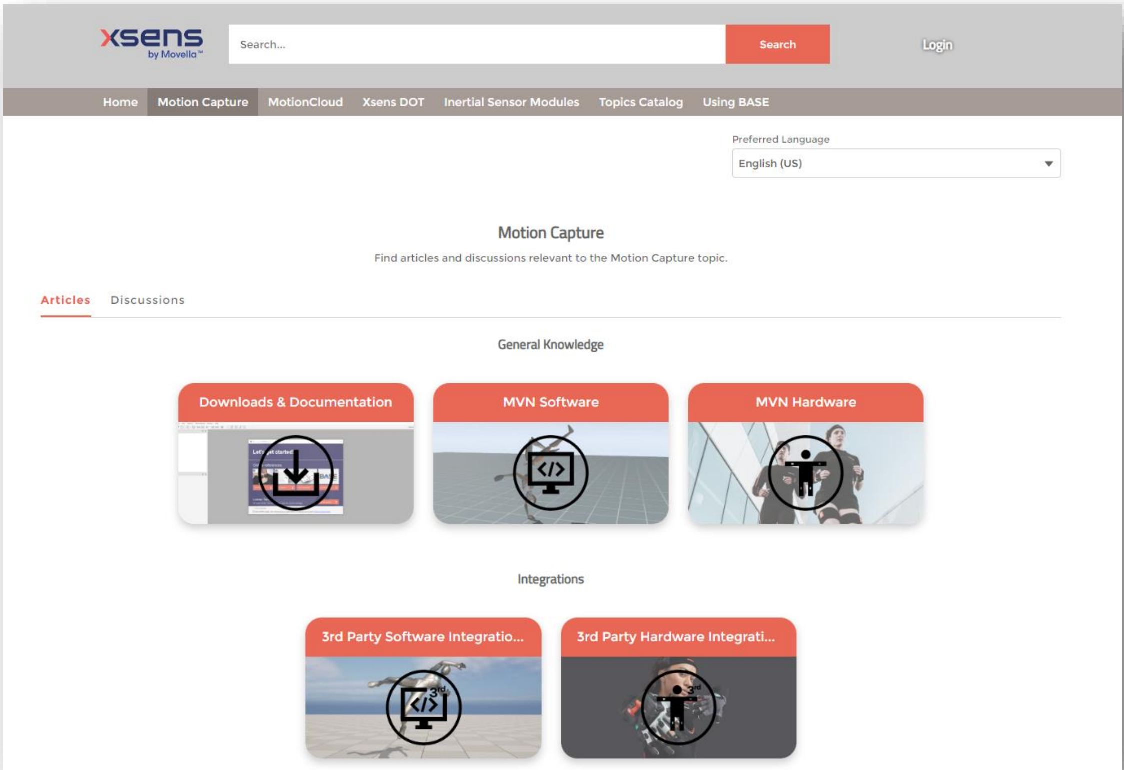
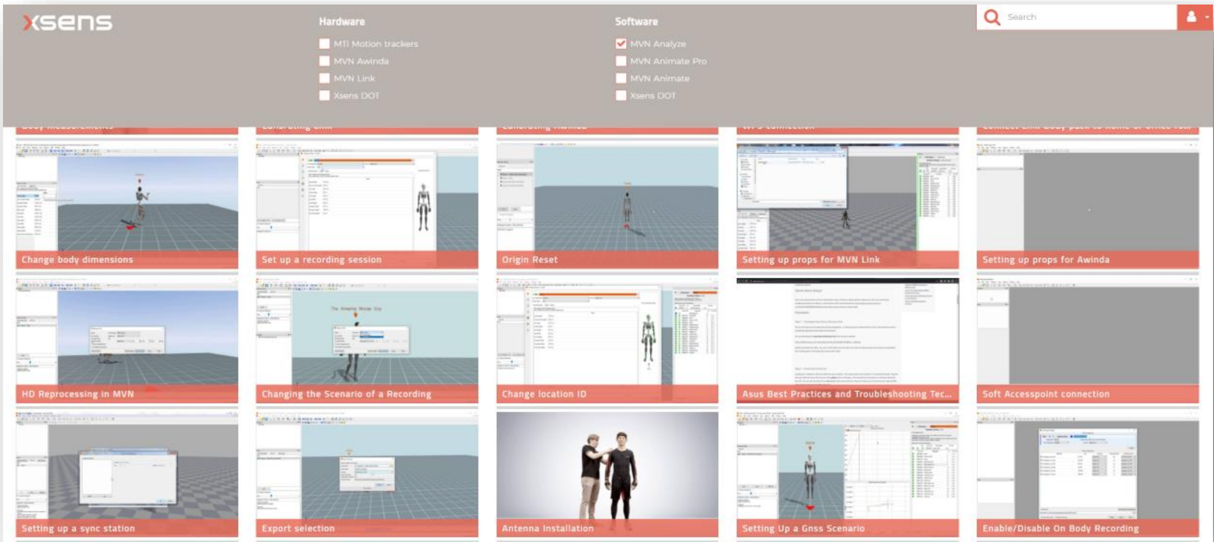
6. Run the MVN Analyze software

3.2 Movella Support Platforms

If you are looking for any information, there is a lot of information in the Knowledge Base:
https://base.xsens.com/s/motion-capture-landing-page?language=en_US



Or in the tutorial video page: https://tutorial.movella.com/



3.3 Data Submission Note

The recorded data used for the case study has shared ownership between Movella and the University of Trento. Any documentation related to the challenge including the project reports, code files, recording data or personal information from participants will be kept confidential between Movella, the University of Trento and the jury committee who agreed with confidentially of the information.

The students may publish their projects externally but will be recommended to inform Movella and the University of Trento before publication.

3.4 Additional Terms & Conditions

- The algorithms and reports are developed for the latest version of MVN software (MVN Analyze 2023) and for the Xsens Link system.
- Movella is not a medical company, the developed algorithms and/or Xsens Link sensors do not give medical advice. Interpretation of the data is not within the responsibility of Movella.
- Movella does not hold any liability that can be related to the use of algorithms and reports, in whatever way.

4 Jury Committee

We're happy to introduce you to the 2023 Jury committee. They'll be responsible for the valuation of your work and will employ their various expertise to achieve it.

Daniel Debertin

Daniel was born and grew up in Karlsruhe, Germany. By the age of three, his parents put him on some kind of cross-country skis in the Black Forest. From that, he developed special interests in sports, mainly outdoor and winter sports.

Although he decided to study mechanical engineering at the Karlsruhe Institute of Technology (KIT), he always tried to link the technical perspective to the field of sports science. Therefore, his bachelor thesis dealt with reconstructing knee marker positions during gait analyses with orthoses. His master thesis then – conducted in Innsbruck at the Department of Sport Science – was about recognizing movement patterns and components in alpine skiing technique recorded by means of the Xsens technology (https://doi.org/10.3389/fbioe.2022.1003619).

Daniel now scientifically analyses technique in various sports (e.g. cross-country skiing) as a PhD student at the "Neurophysiology Research Group" in Innsbruck, combining it with his experiences in mechanical and software engineering. He therefore regularly uses and applies Xsens MVN hardware and software.

Jeroen van der Eb

As researcher and embedded scientist, Jeroen van der Eb, strives to understand a particular movement in sports from a biomechanical point of view. And with that knowledge provide meaningful feedback to coach and athlete. In different sports, like gymnastics and speed skating, this has led to new measurement devices dedicated to enhance performance.

Damiano Fruet

Damiano Fruet is a Biomedical Engineer currently carrying out research at the University of Trento. He primarily studies individuals' performance analysis and physiological data processing in sports and medical fields. His research projects mainly focus on physiological and environmental data acquisition, processing and analysis employing features extraction and deep learning-based strategies.

Dr. April McPherson

Dr. April McPherson completed her undergraduate degree in Biomedical Engineering at the University of Cincinnati, where she also ran track and field. She then completed her PhD at the Mayo Clinic, where her thesis focused on how neural contributions affect ACL injury risk and recovery. She supported Team USA for 3 years as an associate data scientist for sports medicine and performance. She recently transitioned to The Ohio State University and Emory Sports Performance and Research Center (SPARC) in Flowery Branch, GA as a research scientist.

Andrea Zignoli

Andrea Zignoli is a self-employed engineer specialised in the design of mathematical models of sports physiology and performance. He is interested in the application of deep learning technologies to the process of cardiopulmonary exercise tests and running kinematics, as well as the application of first-principles physics to the study of 3D cycling dynamics. He is currently working as a data scientist at Supersapiens (continuous glucose monitoring in athletes) and Athletica (web platform for automatic training plan generation), where he uses modelling techniques to guide product development.

5 Academic Credits

Graduate schools in different Universities in the Netherlands have been actively contacted to ensure that the quality and structure of the event are adequate to provide academic credits (ECTs) to the students that will participate.

Three Dutch universities have confirmed that they will guarantee ECTs to this challenge. To request these academic credits, students need to contact their graduate school with the certificate of completion and in some cases the case study document that was provided at the event.

Additional to the three Dutch universities, more universities might be open to giving study credits for participating in the challenge. If you want to check if your university is also open to providing credits, please contact your graduate school. If you need any help or guidance on this, feel free to contact us at biomechanicschallenge@movella.com

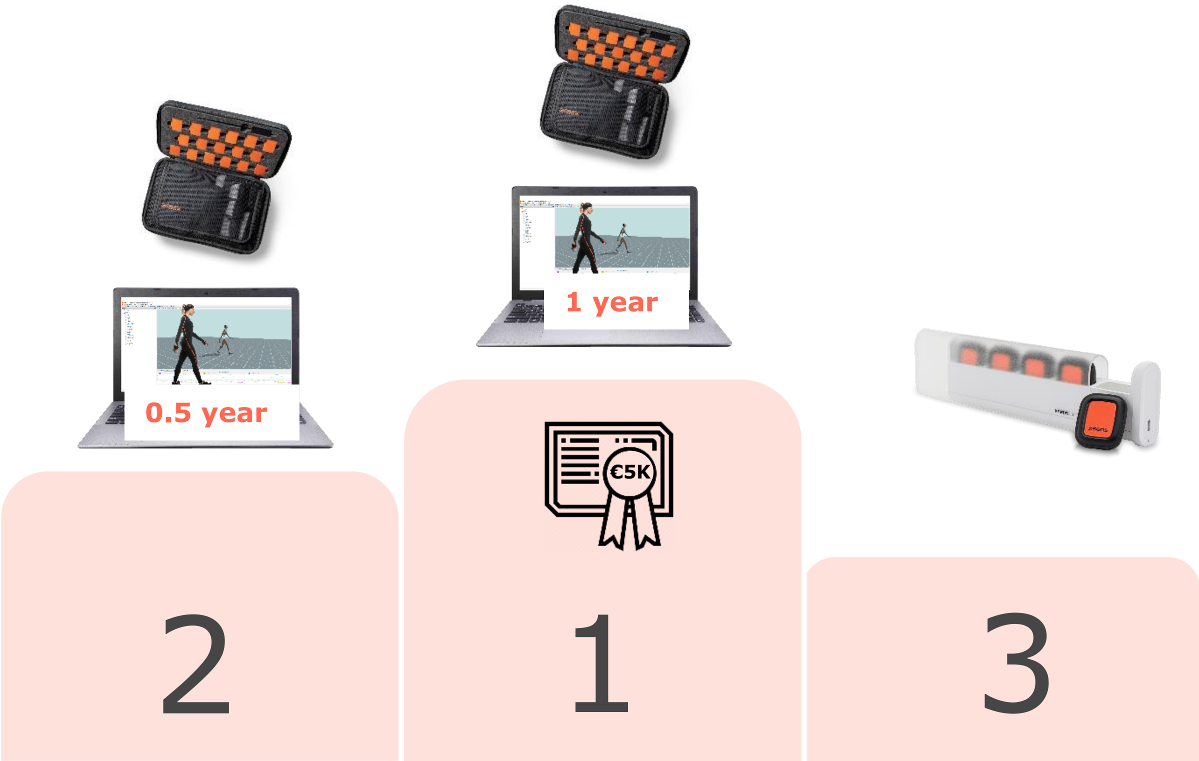
university of groningen

UNIVERSITY OF TWENTE.

VU UNIVERSITY AMSTERDAM

6 Awards

The first prize is an Awinda starter kit with an Awinda station and a license for the MVN Analyse Pro software for 1 year. The second prize is the same as the first one, but the MVN Analyse PRO software license is just for half a year. The third price is a Xsens DOT kit, with 5 sensors and the charging station.



Additionally, the winning team will get a **5K** development grant which can be used by the winning team to further develop the project started in the Challenge.