Utilizing Gyroscope Data for Classifying Types of Fencer Movements in an Assistive Coaching System

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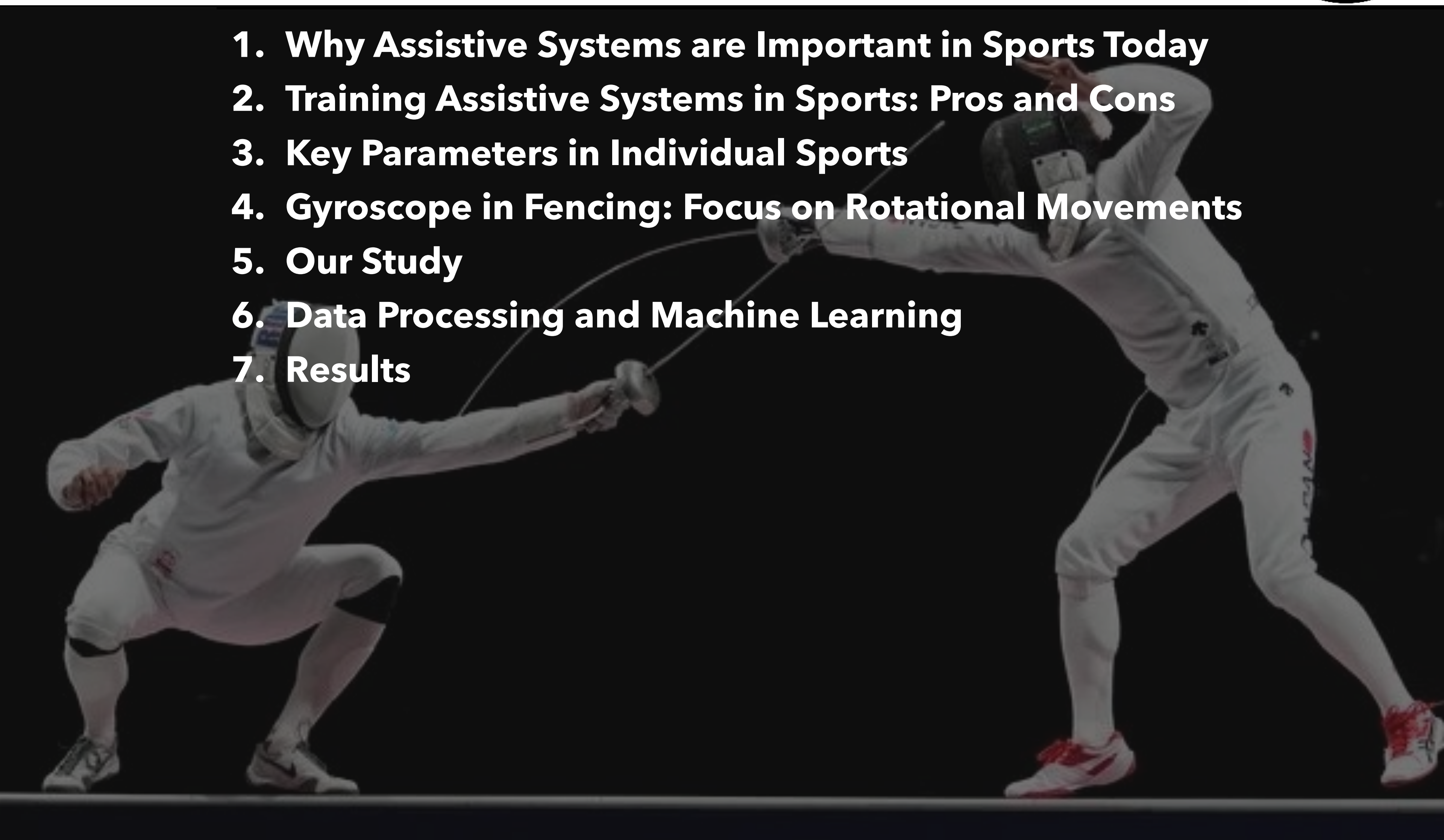
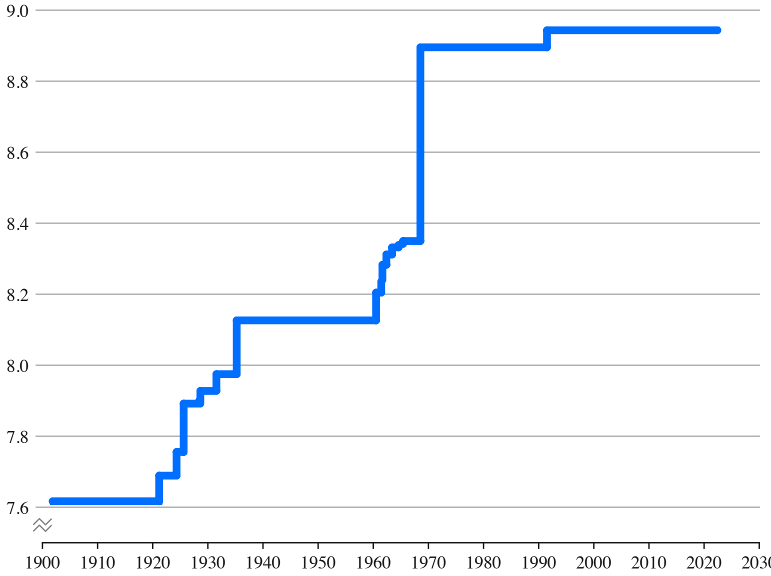


Why Assistive Systems are Important in Sports Today

- **Moving from traditional analyze methods** to data-driven approaches can identify even the most subtle aspects of an athlete's performance.
- In 2024 total budget for:
  'Development of Physical Culture and Sports': **70.32 billion RUB***.
  'High Achievement Sports' project funding: 7.026 billion RUB*.
- Athletes are reaching **the peak of what's possible** with traditional training methods, assistive systems provide the extra edge.

Men's long jump world record progression



* По данным www.forbes.ru

Training Assistive Systems in Sports: Pros and Cons

Types of Assistive Systems	Advantages	Disadvantages
Notational Analysis	• Understanding of tactics and strategies	• Time-consuming Requires expert analysis • Subjective
Physiological Analysis	• Data on an athlete's physical condition	• Requires specialized equipment • May not directly correlate with performance in all sports
Video Analysis	• Visual feedback • Can be used post-competition for detailed analysis	• Doesn’t provide real-time feedback
Standardized Tests and Competition Statistics	• Tracking progress and setting goals • Benchmark for comparing athletes.	• Influenced by external factors
Wearable MEMS Sensors	• Provide real-time, quantitative data • Small, unobtrusive • Temporal resolution	• May not always comply with competition regulations

Key Parameters in Individual Sports

- ✓ Technique
- ✓ Coordination
- ✓ Speed
- ✓ Endurance

Goal of Motion Recognition:

- Focus on measuring how well movements are performed.

Process:

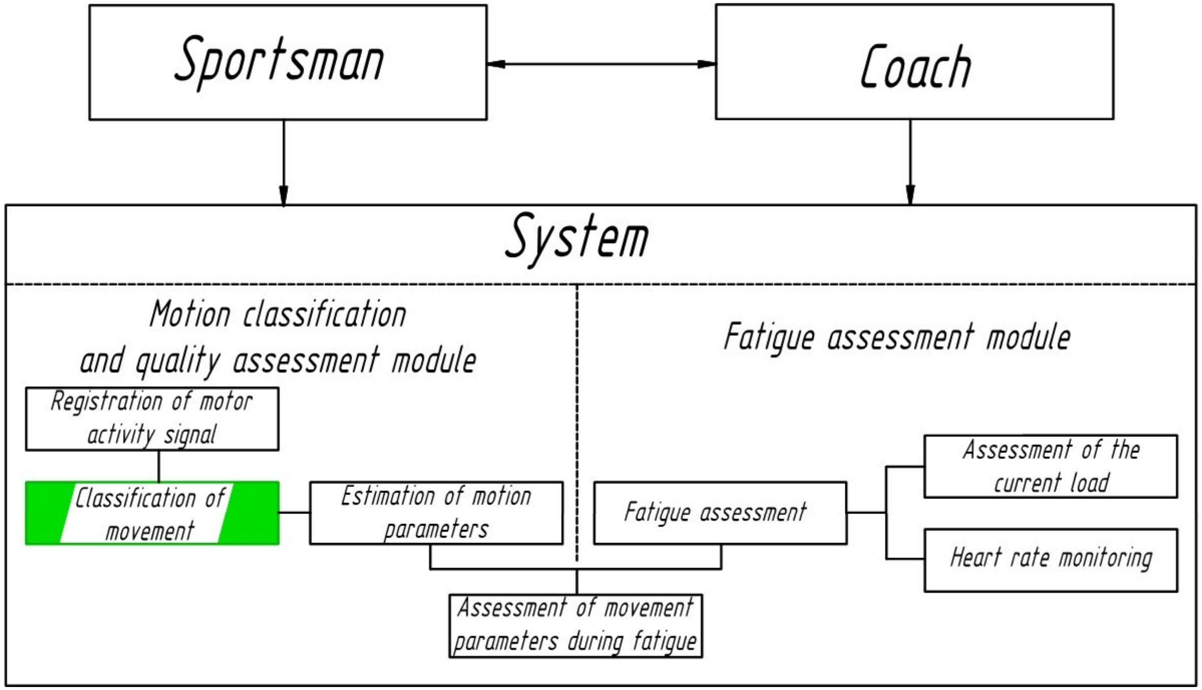
- Break down complex actions into simpler parts.
- Analyze each part for quality and efficiency.

Benefits:

- Improves exercise technique.
- Boosts sports performance.
- Lowers risk of injuries.

For Everyone:

- Useful for both professional athletes and hobbyists.
- Helps understand and improve physical condition and technique.



Gyroscope in Fencing: Focus on Rotational Movements

Existing Research in Fencing:

Study	Zhu et al. (2022)	Malawski & Kwolek (2018)	Malawski (2018)	Bober et al. (2016)	Mantovani et al. (2010)	Our Study
System Used	**Kinect and x-IMU sensor (3D skeleton & inertial data)**	**Kinect & x-IMU sensor (Depth, skeleton & inertial data)**	**Active markers & first-person perspective RGB camera (2D motion tracking)**	**BTS Smart system & Kistler platform (Kinematics & kinetics)**	**Vicon motion capture system (Kinematic data)**	**Kolibri by Neurotech (Gyroscope data)**
Method Used	Temporal Convolutional Networks (TCN)	Multimodal data fusion, neural network	Tracking system with active markers and camera	Kinematic and kinetic analysis	Wavelet-based analysis, PCA, Feature extraction	Machine learning, logistic regression
Measurement Focus	Fine-grained footwork techniques in fencing	Dynamics of various fencing lunges	Tracking blade trajectories and rotations in fencing	Dynamics of lunge and fleche steps in fencing	Classification of fundamental fencing motions	Classification of fundamental fencing motions
Conclusion	85.4% accuracy in footwork recognition	Recognizing subtle differences in the dynamics of fencing lunges	Useful for real-time feedback in fencing training	Analysis of body dynamics and joint kinematics in common fencing steps	88% accuracy in complex motion fencing recognition	99% accuracy for both right-handers and left-handers

Innovation with Gyroscopes:

- Our study introduces gyroscope technology to analyze fencing movements.
- Aim: To assess the effectiveness of gyroscopes in providing detailed and accurate recognition of specific fencing movements.
- Gyroscopes offer potential advantages in understanding complex rotational movements in fencing, not fully captured by previous methods.

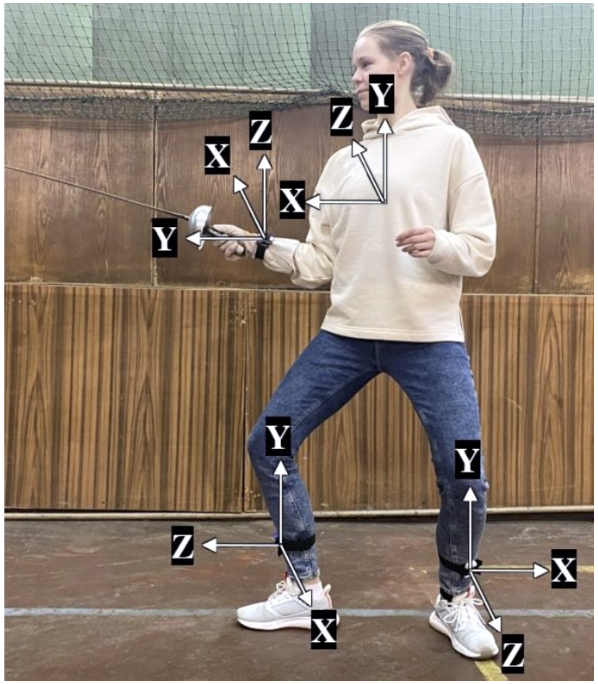
Our Study: Data Collection

Basic data about the fencing volunteers

	Fencer 1	Fencer 2	Fencer 3	Fencer 4
Age	20	18	17	20
Leading hand	Right	Right	Left	Right
Experience	6-7 yrs	7-8 yrs	4-5 yrs	6-7 yrs

- ✓ 3 of the athletes held the title of Candidate for Master of Sports in Russia in fencing and had participated in national and international competitions.
- ✓ Sensors was placed on key movement points.
- ✓ 70 repetitions of each movement, varied among athletes.

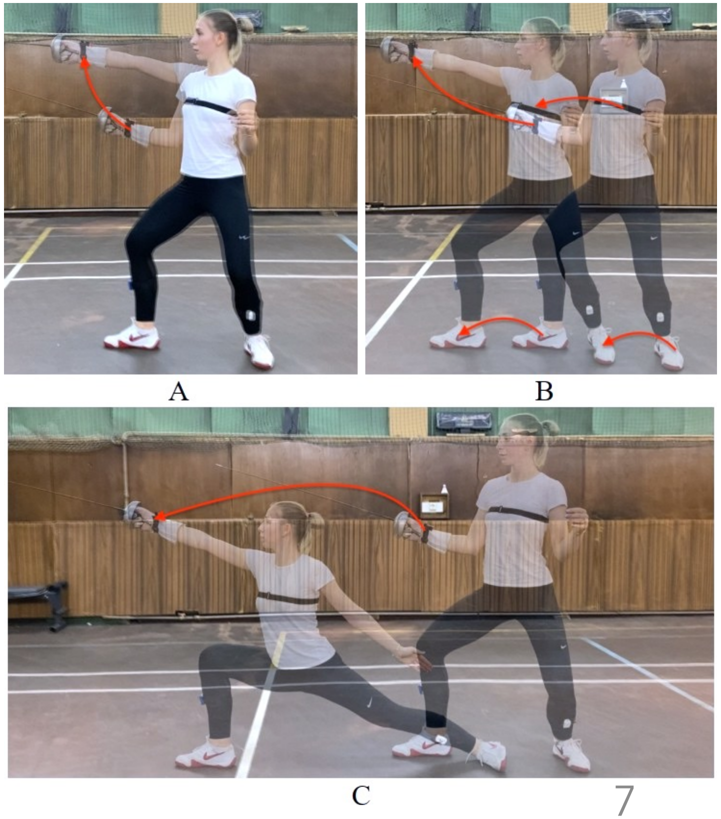
Sensor placement and axis orientation



Typical movements in fencing include:

- Hand thrust (Fig. A)
- Hand closure
- Step thrust (Fig. B)
- Step closure
- Lunge thrust (Fig. C)
- Lunge closure

Biomechanics of fencing movements



Data Processing and Machine Learning

Data Processing Steps:

- Using Python for gyroscope signal analysis.
- Two main stages: separating movements and extracting parameters.

Stage 1: Separation of Movements:

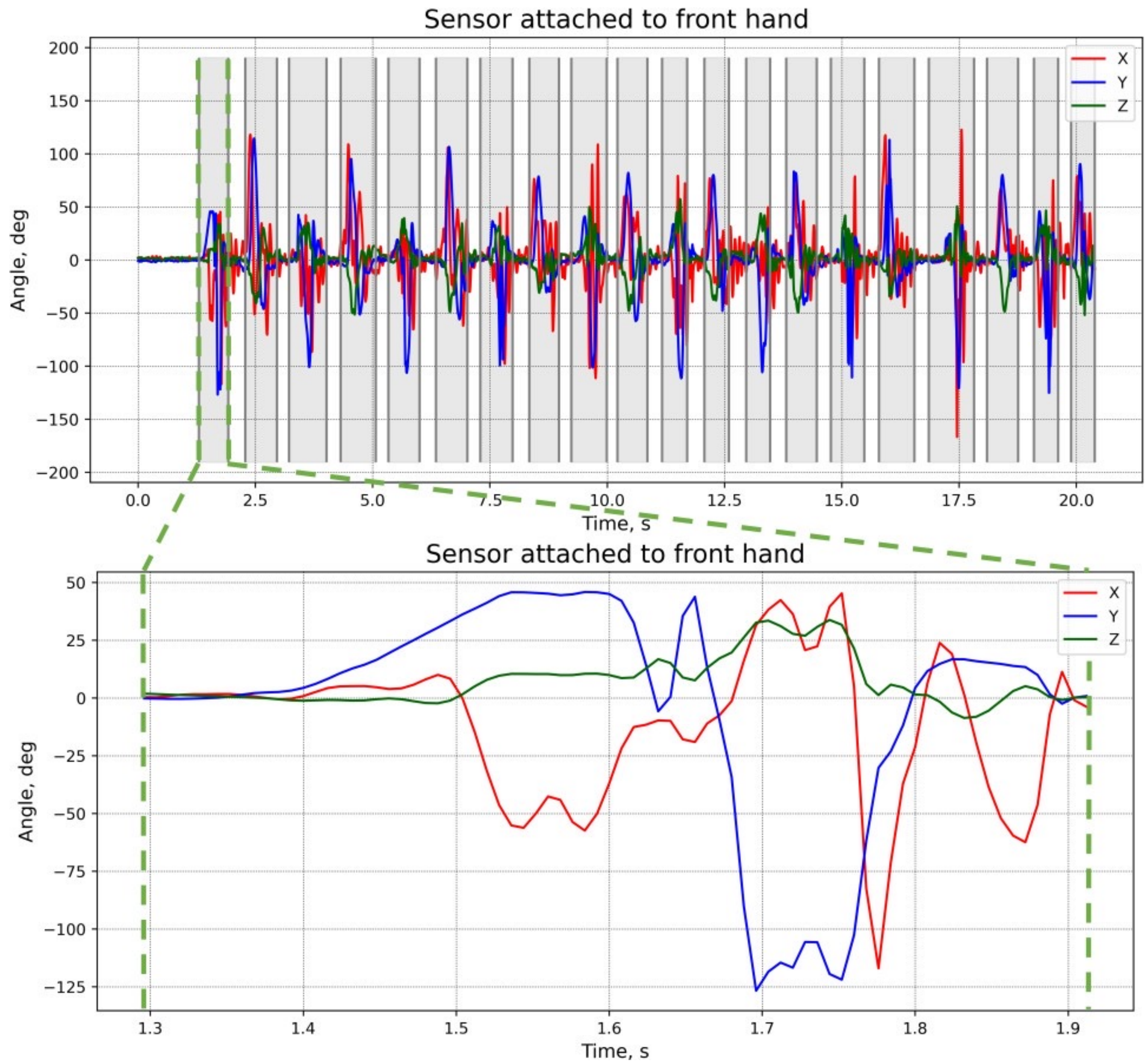
- Used a threshold algorithm to split signals into individual movements.
- Aimed to automate data processing, not to isolate movements in real-time fencing.

Stage 2: Parameter Extraction:

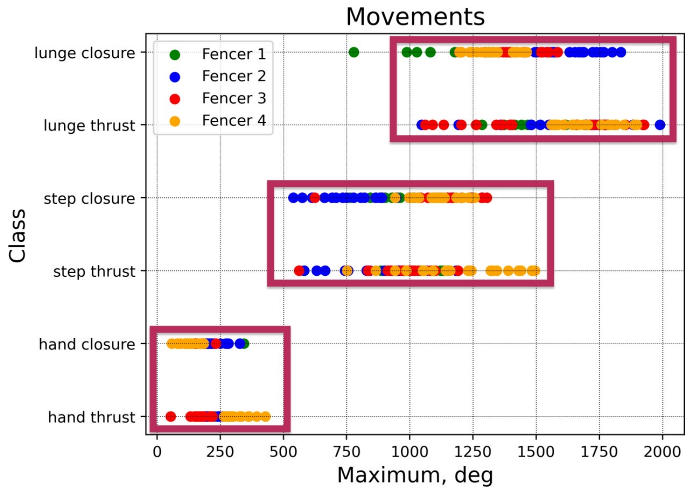
- Analyzed data from 4 sensors, each capturing 3 axes of rotation.
- Each movement resulted in 12 signals with 8 parameters each.
- Parameters included: duration, average value, standard deviation, min/max values, median, and percentiles.

Statistical Learning Model:

- Used logistic regression from the sklearn library for classifying movements.
- Data split into training and test samples (2:1 ratio).

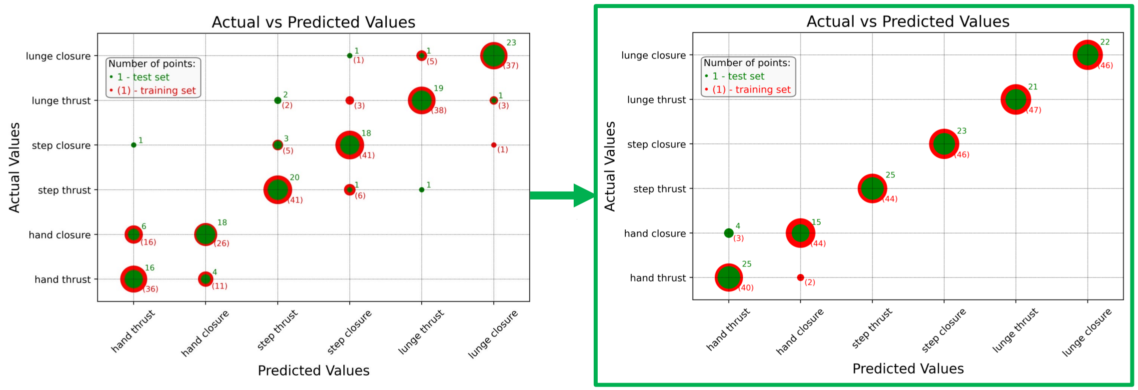


Results

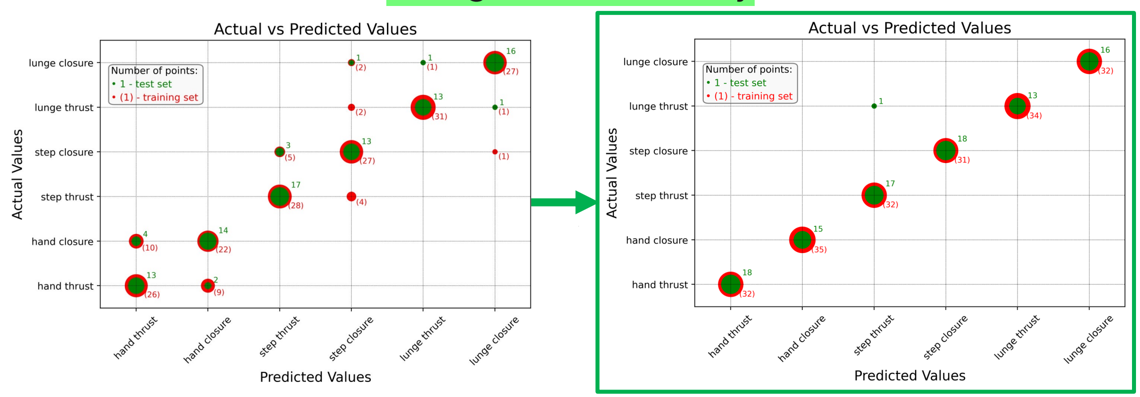


Classification algorithm results on training and test samples before and after improvement

for right-handers and left-handers



for right-handers only



- ✓ Gyroscope data successfully classified fencing movements.
- ✓ The developed algorithm works for both right-handers and left-handers without the need for additional tuning.
- ✓ Adding accelerometer signals could lead to a more distinct separation of direct and reverse movements.

Accuracy has improved:

- ❖ from 0.84 to 0.97 for both right and left-handers
- ❖ from 0.87 to 0.99 for right-handers only

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