IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

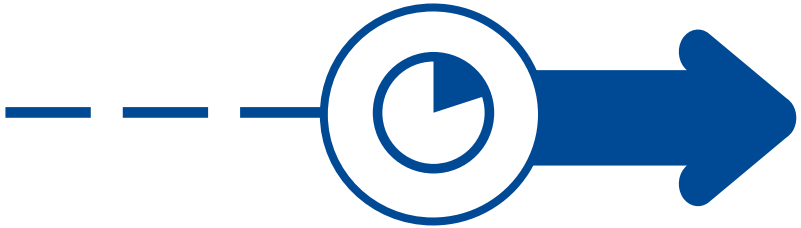
Balancing Accuracy and Wearability: Sensor Configuration Strategies for Real-World Near-Fall Detection

6th PEROSH Research Conference
9-11 September 2025
Manchester, United Kingdom
Moritz Schneider

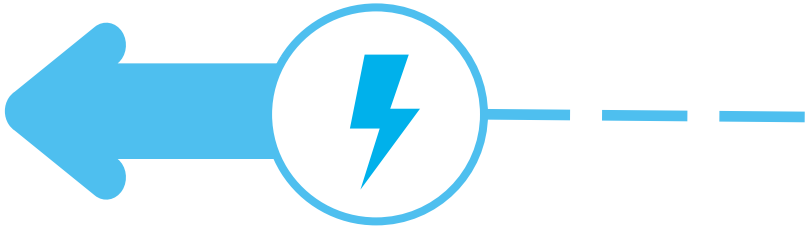
Prevention of tripping, slipping and falling accidents – why?

Frequency

One in five accidents at work is a trip, slip or fall accident (STF)
2024: Total 164.912. Fatal 10.
Pensions 2.374



164.912



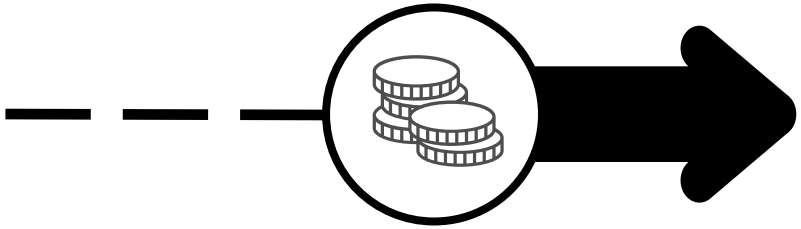
Strains
Contusions
Fractures

Impacts

From painful injuries to long-term damage

Economy

Total 2024: €292,26 million
Rehab. costs: €290,20 million



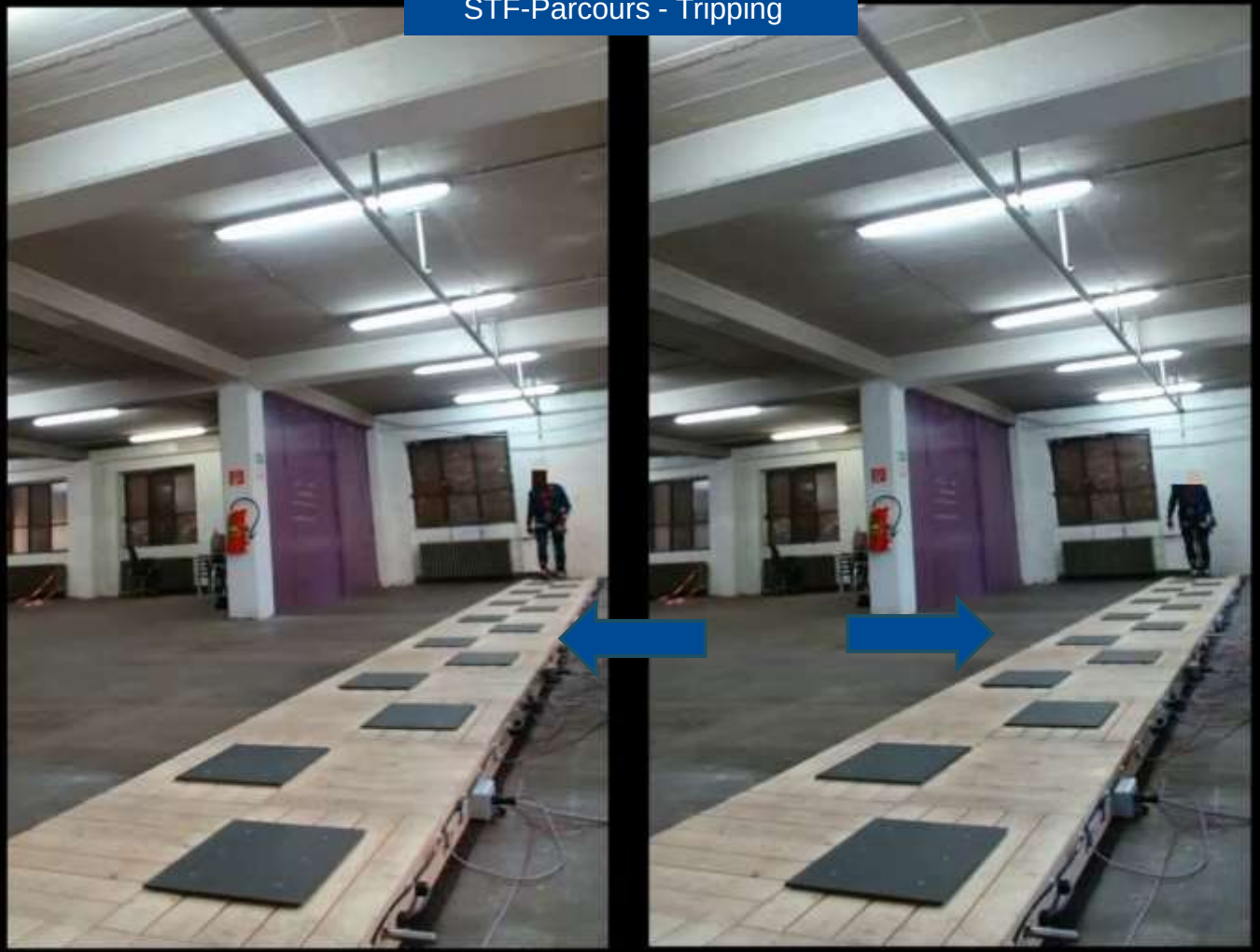
292.26 M. €

Deutsche Gesetzliche Unfallversicherung e.V.; (German Social Accident Insurance, DGUV), "Statistik Arbeitsunfallgeschehen 2024," Deutsche Gesetzliche Unfallversicherung e.V., Berlin, 2025.

Slip, Trip, Misstep
Parcours

Assessment of severity of stumbling before and after training

STF-Parcours - Tripping



Full-body measurement sensors

Schneider, M., Reich, K., Hartmann, U., Hermanns, I., Kaufmann, M., Kluge, A., ... & Ellegast, R. (2024). Acquisition of Data on Kinematic Responses to Unpredictable Gait Perturbations: Collection and Quality Assurance of Data for Use in Machine Learning Algorithms for (Near-) Fall Detection. *Sensors (Basel, Switzerland)*, *24*(16), 5381.

Ellegast, R., Hartmann, U., Karamanidis, K., Kluge, A., Kaufmann, M., Krugmann, L., Schneider, M., Zimmermann, J., Lungfiel, A., Bohlscheid, A., Nickel, P., Schiefer, C., Hermanns-Truxius, I., Werth, J., & Weber, A.; “Final Report of the ENTRAPon Project: Development of Additional Training Ele-ments for the Prevention of Slip, Trip and Fall Accidents Supported by Virtual Reality and Mechanical Perturbation Training”;

PrevFall Dataset

110 Subjects

50% HKM — Steelworker

50% DHL — Parcel delivery

~1 MILLION

kinematic data points

~500 K

Tripping, slipping and missteps Data points

~500 K

Baseline walking data points

Class Balance

17% Slip

16% Trip

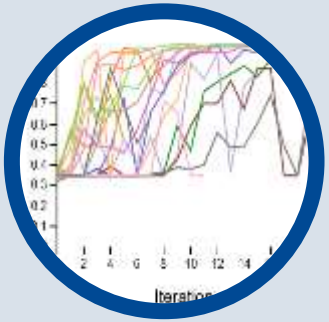
17% Misstep

50% Base

Schneider, M., Reich, K., Hartmann, U., Hermanns, I., Kaufmann, M., Kluge, A., ... & Ellegast, R. (2024). Acquisition of Data on Kinematic Responses to Unpredictable Gait Perturbations: Collection and Quality Assurance of Data for Use in Machine Learning Algorithms for (Near-) Fall Detection. *Sensors (Basel, Switzerland)*, *24*(16), 5381.

Automatic detection of near falls using AI

Neural Architecture Search



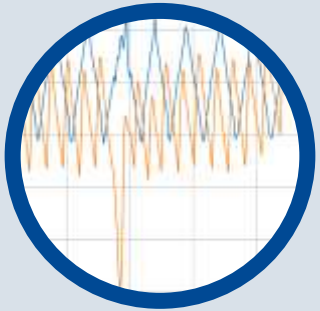
DeepConvLSTM
F1 91.95

CNN
F1 96.22

ResNet
F1 95.31

InceptionTime
F1 96.32

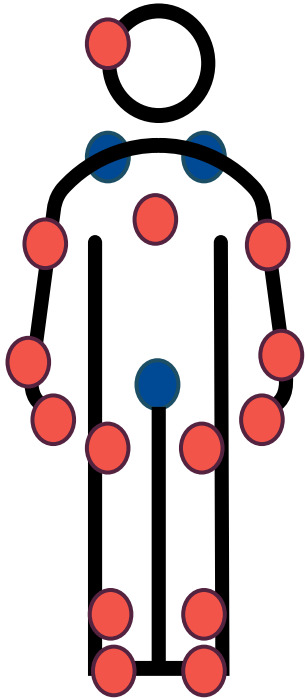
LDA demonstrates class separability



No differences in linear correlation between and within classes

Schneider, M., Seeser-Reich, K., Fiedler, A., & Frese, U. (2025). Enhancing Slip, Trip, and Fall Prevention: Real-World Near-Fall Detection with Advanced Machine Learning Technique. *Sensors (Basel, Switzerland)*, *25*(5), 1468.

Objective: Minimal sensor configurations for STF detection



Front

Back

Complete sensor system achieves good results, but:

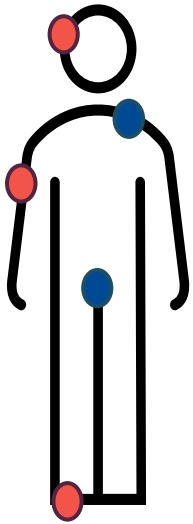
- expensive
- computationally intensive
- restricts movement in everyday working life
- time-consuming to set up

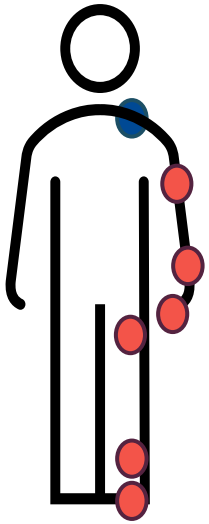
Three strategies for sensor reduction:

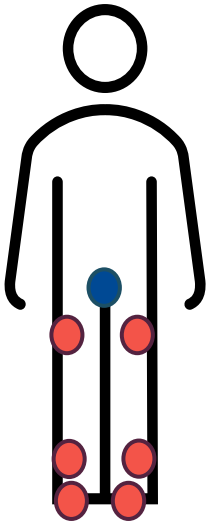
I. Optimised coverage of anatomical regions
II. Unilateral reduction
III. Optimised coverage of critical regions

Three strategies for sensor reduction

Front
Back







Hypothesis:
One representative sensor per region suffices to capture essential motion patterns

Hypothesis:
One body side contains sufficient information for accurate classification.

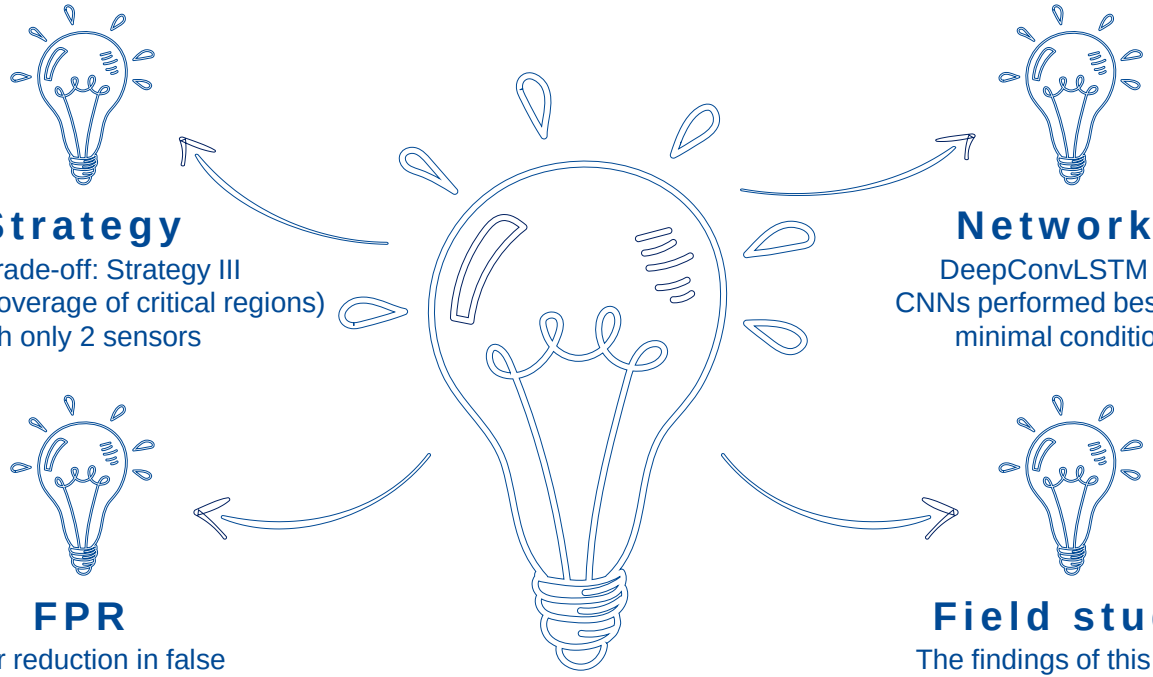
Hypothesis:
Sensors on arms, head, and chest are less informative and can be removed.

Brief overview results

Strategie	# Sensoren	Sensorpositionen	Acc. (%)	Weighted F1-Score	FPR (%) vs. Full-Body*
I - Optimised coverage of anatomical regions	4	Head, Left Shoulder, Pelvis, Right Foot	86.97	0.910	10.59 (–32.33 %)
	3	Left Shoulder, Pelvis, Right Foot	83.73	0.880	—
	2	Pelvis, Right Foot	77.39	0.814	—
II - Single-sided reduction	4	Left Shoulder, Left Upper Arm, Left Forearm, Left Foot	82.94	0.871	15.68 (+0.19 %)
	3	Left Shoulder, Left Upper Arm, Left Foot	81.69	0.858	—
	2	Left Shoulder, Left Forearm	81.69	0.857	—
III -Optimised coverage of critical regions	4	Left Foot, Right Foot, Left Lower LegL, Right Lower Leg	84.51	0.889	1.52 (–90.29 %)
	3	Left Lower Leg, Right Lower Leg, Left Foot	82.78	0.874	—
	2	Left Lower Leg, Left Foot	84.59	0.889	—

* Schneider, M., Seeser-Reich, K., Fiedler, A., & Frese, U. (2025). Enhancing Slip, Trip, and Fall Prevention: Real-World Near-Fall Detection with Advanced Machine Learning Technique. *Sensors (Basel, Switzerland)*, *25*(5), 1468.

Brief overview results – Key findings



Strategy
Best trade-off: Strategy III
(Optimised coverage of critical regions)
with only 2 sensors

Networks
DeepConvLSTM and
CNNs performed best under
minimal conditions

FPR
Clear reduction in false
positives, especially when
excluding upper-body sensors

Field study
The findings of this study
indicate that minimal sensor configuration
are ready to be validated in the field

Sources / Preliminary work

- Ellegast, R., Hartmann, U., Karamanidis, K., Kluge, A., Kaufmann, M., Krugmann, L., **Schneider, M**., Zimmermann, J., Lungfiel, A., Bohlscheid, A., Nickel, P., Schiefer, C., Hermanns-Truxius, I., Werth, J., & Weber, A.; “Final Report of the ENTRAPon Project: Development of Additional Training Elements for the Prevention of Slip, Trip and Fall Accidents Supported by Virtual Reality and Mechanical Perturbation Training”; [https://www.dguv.de/projektdatenbank/0470/2025_02_20_ab_final.pdf#:~:text=Prof.%20Dr.%20Dipl.,Anika%20Weber] (visited 2025/05/20)
- **Schneider, M.**; Weber, A.; Kaufmann, M.; Kluge, A.; Hartmann, U.; Karamanidis, K.; Ellegast, R.P. Generation of Consistent Slip, Trip and Fall Kinematic Data via Instability Detection and Recovery Performance Analysis for Use in Machine Learning Algorithms for (Near) Fall Detection. In Proceedings of the Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management—14th International Conference; Volume 14029 of Lecture Notes in Computer Science, Copenhagen, Denmark, 23–28 July 2023; pp. 298–305 [https://link.springer.com/chapter/10.1007/978-3-031-35748-0_22] (visited 2025/05/17)
- **Schneider, M.**; Reich, K.; Hartmann, U.; Hermanns, I.; Kaufmann, M.; Kluge, A.; Fiedler, A.; Frese, U.; Ellegast, R. Acquisition of Data on Kinematic Responses to Unpredictable Gait Perturbations: Collection and Quality Assurance of Data for Use in Machine Learning Algorithms for (Near-)Fall Detection. Sensors 2024, 24, 5381. [https://www.mdpi.com/1424-8220/24/16/5381] (visited 2025/05/17)
- **Schneider, M.**; Seeser-Reich, K.; Fiedler, A.; Frese, U. Enhancing Slip, Trip, and Fall Prevention: Real-World Near-Fall Detection with Advanced Machine Learning Technique. Sensors 2025, 25, 1468. [https://www.mdpi.com/1424-8220/25/5/1468] (visited 2025/05/18)

Thank you for your attention

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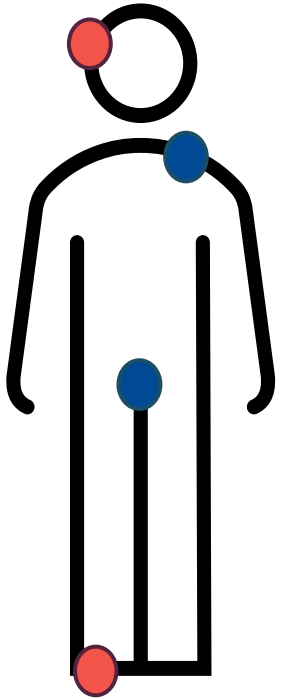
STF-Parcours - Rutschen

STF-Parcours - Fehltreten

Strategy I: Optimised coverage of anatomical regions



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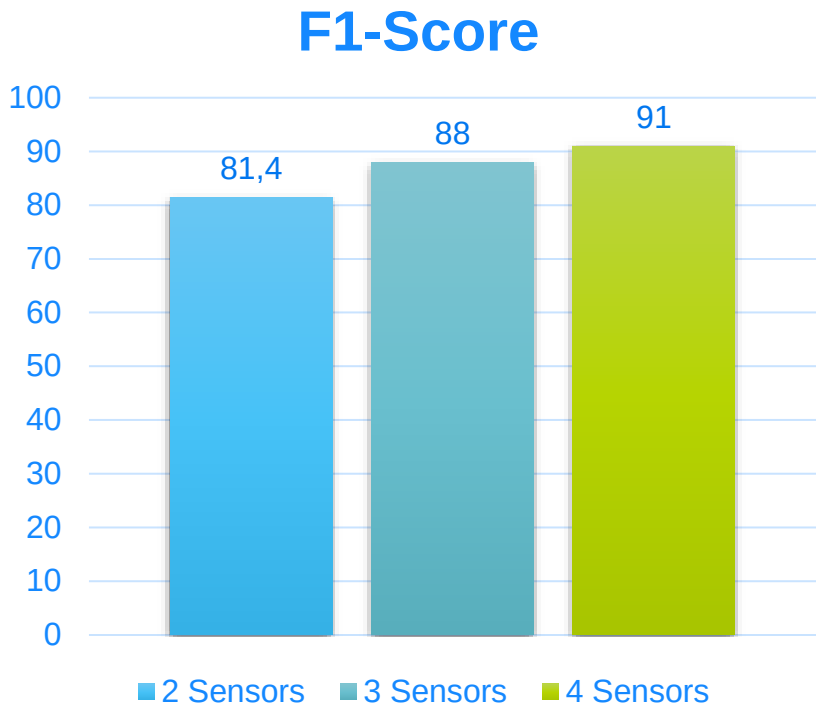
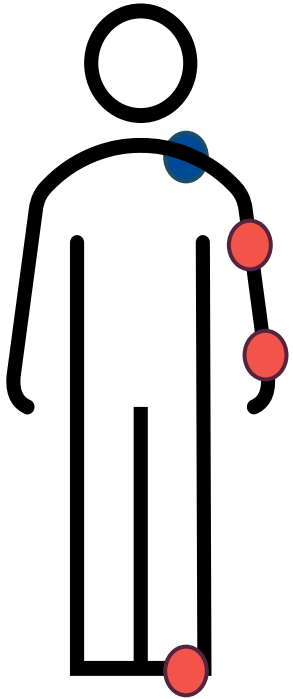


Strategy II: Single-sided reduction



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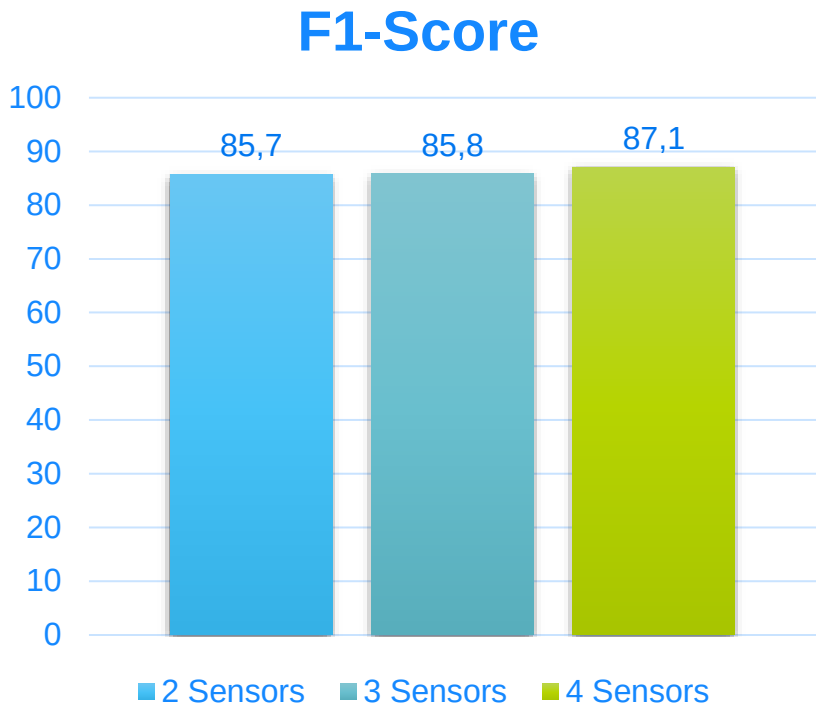
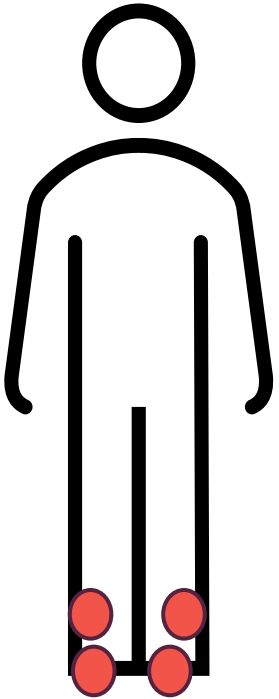


Strategy III: Optimised coverage of critical regions



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Back