UNIVERSITY OF LIVERPOOL

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Wearable Sensing For Non-Invasive Human Pose Recognition During Sleep

AI 2020

SGAI 40th International Conference on Artificial Intelligence

AI for Future Digital Health Workshop

Virtual Event - Dec. 8th, 2020

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1.
Research Motivation

Based on reports from WHO [1] and NHS [2]

1.1. Define the Problem

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Key Facts

- Affects 20% - 33% of people (including children) worldwide.
- Accounts for > 25% of all surgical interventions in the NHS currently.
- Account for 30% of GP consultations in England.

Musculoskeletal Disorders

- > 200 musculoskeletal conditions.
- Significantly limits one's mobility and dexterity.
- Commonly linked with co-morbidities, including depression, obesity, and diabetes.

Plantar Fasciopathy

Tightness of calf muscle
(23 x more vulnerable)

Obesity
(2.9 x more vulnerable)

Standing jobs
(3.6 x more vulnerable)

1.2. Current Clinical Practices

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Conservative Treatment

Orthosis, e.g. night splint.

Surgical Treatment

The possible treatment is determined by the degree of defect.

Prof. Dr Lyndon Mason
Consultant Trauma and Orthopaedic Surgeon,
University Hospital Aintree, Liverpool, UK

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Take a Step Back

Isn't it worth looking at how we sleep?

"Is there a correlation between sleep postures and the development of certain musculoskeletal diseases?"

1.3. Project Specifications

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Sleeping Postures

Project Deliverables

- A validated sleep-monitoring technology.
- A (light) network of inertial sensors distributed over the body to measure and track in-bed body postures.
- Streaming of data to a central storage database, where further analysis takes place to exploit correlations between collected data, sleeping postures and occurrence of musculoskeletal diseases.
- Device could then be used to further monitor the success of treatment.

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2.
Methods and Findings

2.1. Project Workflow

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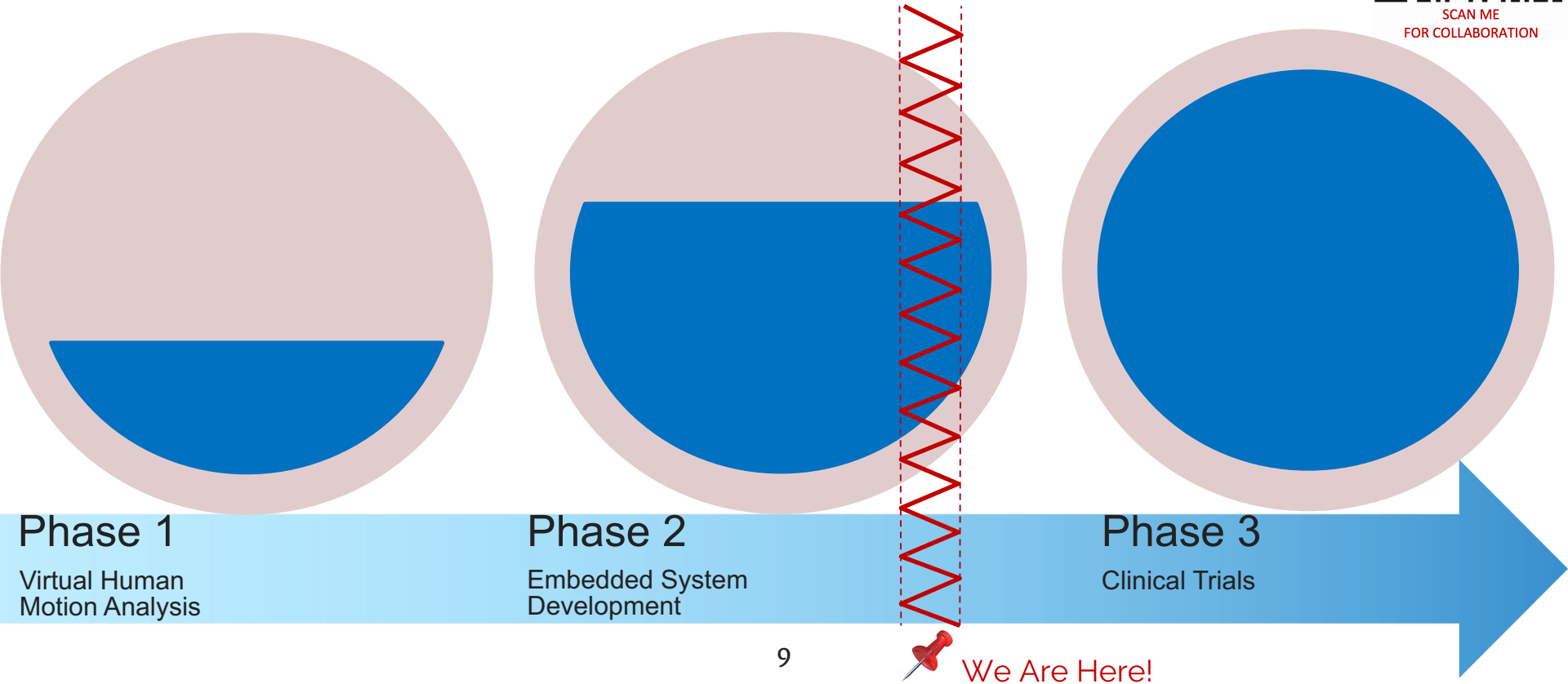

2.2. Virtual Sleeping Pose Recognition

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Sleeping Pose Replication in Software

- Computer Graphics Software
- Human Body Modelling
- Virtual body calibration
- Replication of sleeping poses

Synthetic Dataset of Limb Orientations

- Exportation of pose data
- Extraction of necessary pose parameters
- Augmentation of inertial data

Mapping Limb Orientations to Sleeping Poses

- Implementation of a multi-class classifier

Sleeping Pose ✅

VIDEO

2.3. Virtual Sleeping Pose Replication

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Skeleton Tracking Algorithm

2.4. Parameterisation of Sleeping Poses

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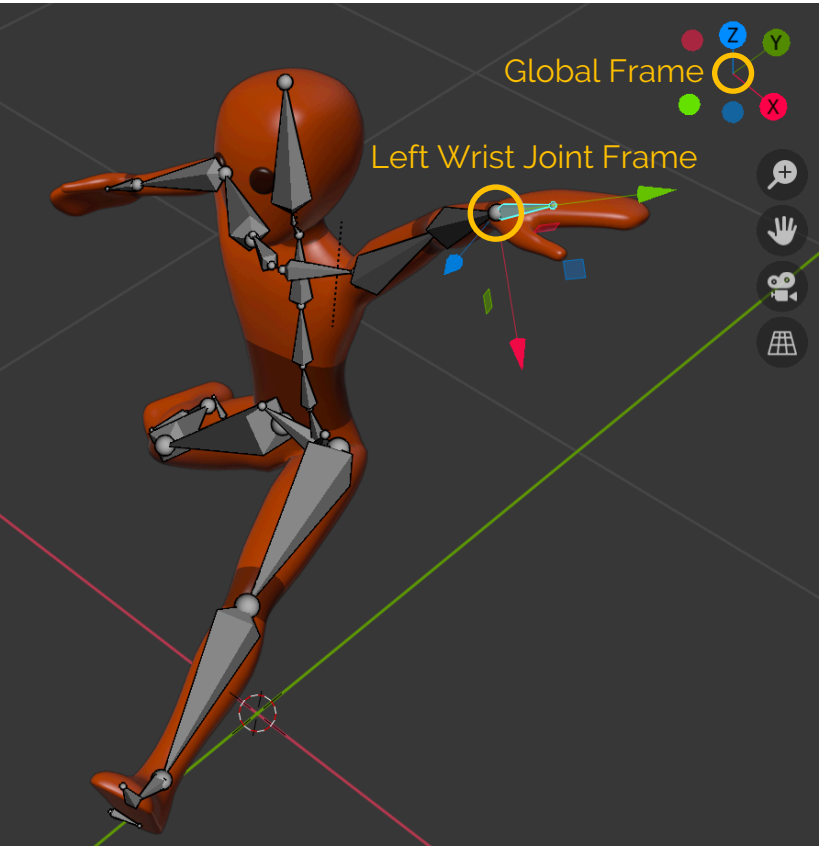

- **A virtual limb calibration method is proposed** [3] to identify the local joint frames of the 4 extremity limbs:
  - Right and Left wrist joints.
  - Right and Left ankle joints.

- The ***axis-angle*** kinematic representation is used to parameterise the local joint frame transformations.

- Due to the scarcity of labelled inertial data, **a novel *Jittering-based augmentation technique* is proposed** [3] to produce synthetic datasets for classifier training.

2.5. Sleeping Pose Classification

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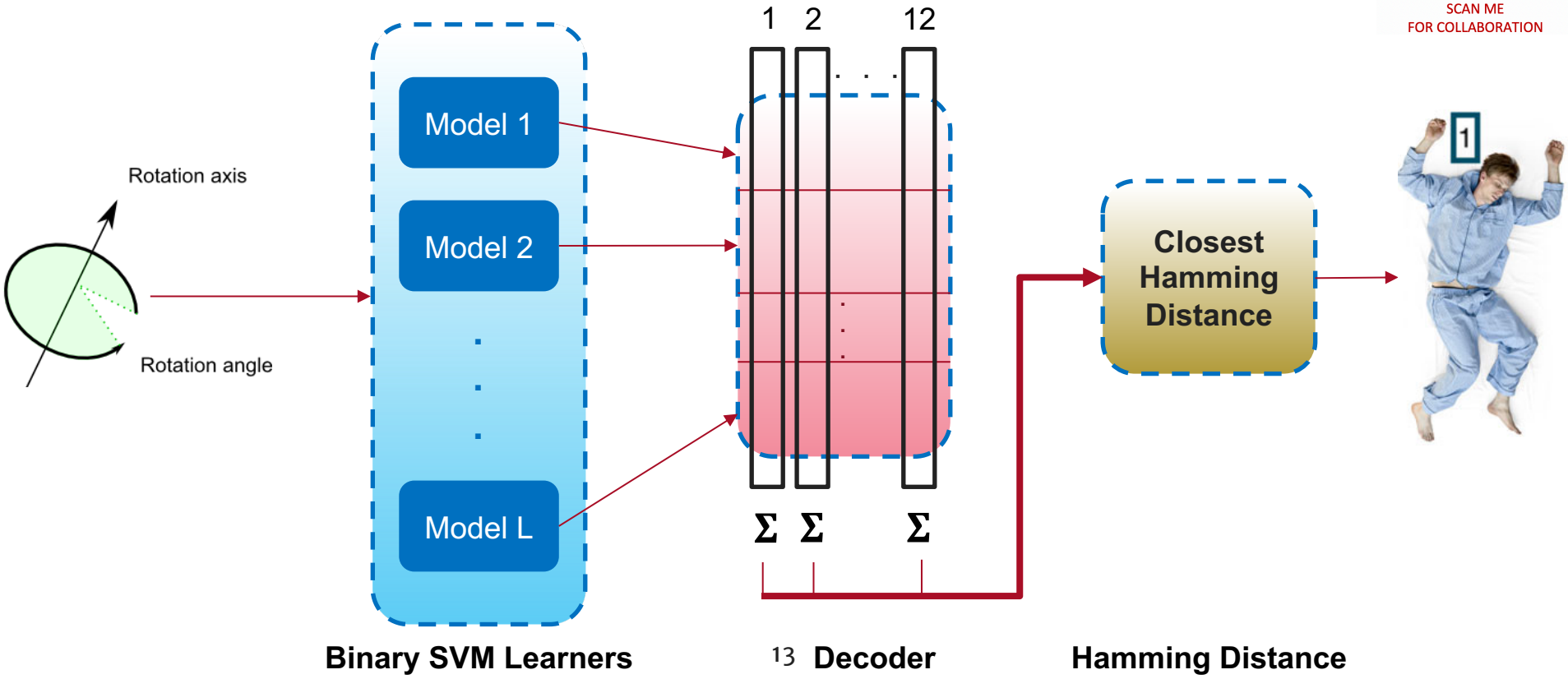

Binary SVM Learners

13 Decoder

Hamming Distance

2.6. Performance Evaluation

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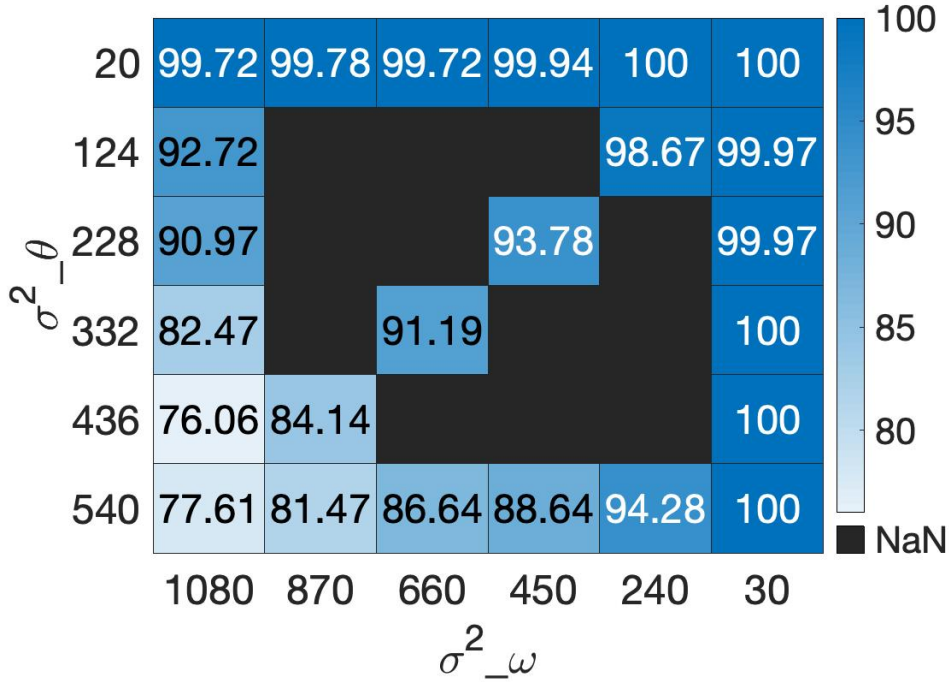
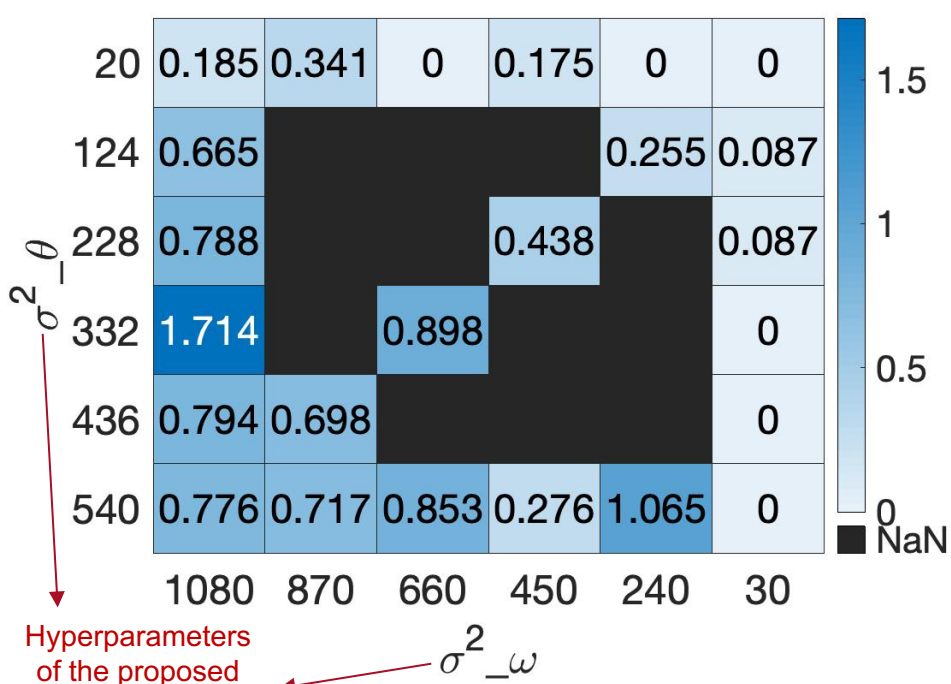
Mean Pose Classification Accuracy (%)



10-Trial Standard Deviation of Pose Classification Accuracy (%)



Hyperparameters of the proposed data augmentation technique

2.7. Guide for Further Information

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Further details on the proposed approach will be provided during the presentation of our technical paper [3]:

- Articulated body kinematics for human pose tracking.
- Virtual extremity limb calibration procedure.
- Review of the proposed inertial data augmentation.

Date: Thursday December 17th, 2020

Time: 12 noon to 1:30 pm

Application Session: (A3) Medical and Legal Applications

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3.
Conclusion, Future Work and References

3.1. Summary of Work, Future Work and References

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Highlights

- ✅ Replicating 12 in-bed sleeping poses in a graphics simulation software.
- ✅ A quick calibration procedure that can be conveniently completed by the user.
- ✅ An efficient limb orientation tracking algorithm.
- ✅ A novel data augmentation technique to address the scarcity of labelled inertial data.
- ✅ An SVM-based ECOC model that is robust to noise levels beyond normally encountered.

Future Work

- ◉ Setup of wearable sensors.
- ◉ Stream sensor data to a secure Cloud system for data storage and processing.
- ◉ Validation of the proposed approach in realistic scenarios.

References

[1] World Health Organisation, "**Musculoskeletal Conditions"**. [online] Available at: <https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions#:~:text=Key%20facts,prevalent%20across%20the%20life%2Dcourse.> [Accessed 3 December 2020].

[2] NHS England, **"Musculoskeletal Conditions"**. [online] England.nhs.uk. Available at: <https://www.england.nhs.uk/ourwork/clinical-policy/ltc/our-work-on-long-term-conditions/musculoskeletal/> [Accessed 3 December 2020].

[3] O. Elnaggar, F. Coenen, and P. Paoletti, **"In-Bed Human Pose Classification Using Sparse Inertial Signals",** Artificial Intelligence XXXVII, 2020.