# UNOBTRUSIVE DATA COLLECTION AND PROCESSING DURING SPRAINED ANKLE REHABILITATION IN HOME ENVIRONMENTS

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## INTRODUCTION

Data collection is an integral part of monitoring systems that involve the use of both wearable and non-wearable sensing solutions (WeSSs) [1]. Although there are many advantages of using WeSSs for data acquisition, their disadvantages include battery-life, wearability and disruption due to the need to frequently charge the devices [2]. Therefore, this work proposes the use of non-wearable and unobtrusive sensing solutions for data collection and processing during Sprained Ankle Rehabilitation (SAR) in home environments.

## MATERIALS AND METHODS

The experimental set up involved the use of (i) Frequency Modulated Continuous Wave Radar sensors (ii) Infrared Thermopile Array sensors and (iii) Shimmer-3 accelerometers. The latter was used for ground truth measurement of velocity. The Radar and Thermal sensors were mounted on tripod stands and placed for side and front views of the ankles. The Shimmer-3 accelerometers were attached to the metatarsals of each foot to record the acceleration in the X, Y and Z directions. The rationale for taking measurements from the front and side views was to avoid occlusion. Furthermore, in an upright sitting position, 20 directional movements involving (i) flexion, (ii) extension, (iii) eversion, and (iv) inversion were performed by 15 participants for 20 seconds on each leg. These movements were recorded simultaneously by all the sensors. The parameters measured included the angle of approach and retreat (AAR) of the ankles from the sensors, the ankles' velocity during the twisting process, their distance from the unobtrusive sensing solutions (Radar and thermal) and the postures of participants.

## RESULTS

Thermal blobs gleaned from the thermal sensors indicated successive movements of the ankle in the four directions of ankle movements during the rehabilitation exercises as presented in Figure 1. Furthermore, the Radar sensor recorded the AAR, velocity, and distance (range) of the ankle during these exercises.

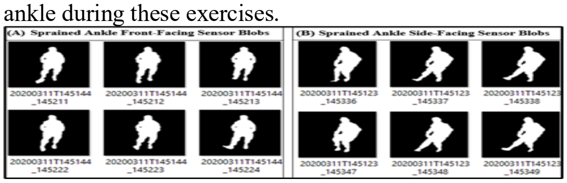


**Figure 1**. Thermal Images from Front (A) and Side (B) facing thermal sensors indicating instances of (i) flexion, (ii) extension, (iii) eversion, and (iv) inversion. 20200311T145144_145211 indicated an instance of eversion; 20200311T145144_145212 presented an instance of inversion; 20200311T145144_145337 indicated extension while 20200311T145144_145223, indicated flexion.

In Figure 1, instances of the four directional movements on the right-leg are presented. Thermal image code-name 20200311T145144_145211 indicated an instance of eversion; 20200311T145144_145212 and 20200311T145144_145348 presented instances of inversion. Furthermore, extension is observed in 20200311T145144_145337, while flexion is detected in 20200311T145144_145223. Data mining models were used to perform classification by clustering on the data gleaned from the thermal and Radar sensors. The results from the 574 instances from each sensing solution used in the analysis are presented in Table 1.

**Table 1.** Thermal and Radar data fusion using data mining models on 10-fold cross-validation. SVM = Support Vector Machine (SVM), SGD = Stochastic Gradient Descent.

| Model | AUC | CA | F1 | Precision | Recall |
|---|---|---|---|---|---|
| Tree | 0.997 | 0.995 | 0.995 | 0.995 | 0.995 |
| SVM | 0.999 | 0.984 | 0.984 | 0.984 | 0.984 |
| SGD | 0.995 | 0.993 | 0.993 | 0.993 | 0.993 |
| Random Forest | 0.979 | 0.899 | 0.899 | 0.899 | 0.899 |
| Neural Network | 0.997 | 0.990 | 0.990 | 0.990 | 0.990 |
| Naive Bayes | 0.932 | 0.807 | 0.809 | 0.815 | 0.807 |
| kNN | 0.998 | 0.991 | 0.991 | 0.991 | 0.991 |
| CN2 rule inducer | 0.996 | 0.995 | 0.995 | 0.995 | 0.995 |
| AdaBoost | 0.902 | 0.869 | 0.869 | 0.870 | 0.869 |

From Table 1, it can be observed that the Area Under the Curve (AUC) obtained an accuracy of more than 90% in all the models – K-Near Neighbors, Decision Tree (Tree), Support Vector Machine (SVM), Stochastic Gradient Descent (SGD), Random Forest, Neural Network, and Naïve Bayes. Furthermore, an average accuracy of more than 98% was obtained in six out of the nine models in Classification Accuracy (CA), weighted average (F1), Precision and Recall.

## DISCUSSION

Data collection and processing from unobtrusive sensing solutions such as thermal and Radar can help monitor SAR in home environments. The fusion of data from the sensing solutions can give useful and complementary information at each exercise stage. Furthermore, information such as posture, speed and range related to health parameters gathered during these exercises can help physiotherapists to ascertain if exercises have been performed as prescribed.

## CONCLUSION

This paper presented the use of unobtrusive sensing solutions for data collection and processing during SAR in home environments. Experimental results indicated the ability of the thermal sensing solution to monitor instances of flexion, extension, eversion, and inversion of the ankle. Data analysis using data mining models indicated average accuracies of more than 90% across most of the parameters. Data fusion helped obtain postural orientation, AAR, velocity, and range of participants simultaneously, at each stage of the exercises.

## REFERENCES

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