SUMMER INTERNSHIP REPORT

In

University of New Brunswick, Fredericton, Canada

Under the guidance of

Dr. Victoria Chester (Professor, Kinesiology)

Submitted by,

R.ABIRATH

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DEPARTMENT OF MECHANICAL ENGINEERING

National Institute of Technology, Tiruchirappalli-620 015

2022-02-28
Application ID: 99063

GLOBALINK RESEARCH INTERNSHIP AWARD
DISBURSEMENT INFORMATION AND PLACEMENT TERMS AND CONDITIONS

Dear Abirath Raju,

Congratulations! You have been selected by Mitacs and Professor Victoria Chester from University of New Brunswick – Fredericton to receive a 2022 Globalink Research Internship award. You are therefore invited to participate in a research project at **University of New Brunswick – Fredericton**. **Pursuant to an agreement with University of New Brunswick – Fredericton, Mitacs will administer your funding grant.**

Mitacs Globalink Research Internship is a competitive program that pairs top-ranked international students with specific research expertise with faculty at Canadian academic institutions for a twelve (12) week research project of mutual interest between May and October 2022. You have been selected by your Canadian host faculty project leader due to your background and skills in the research area and the unique contribution you will be making to the research during your stay. **The skills required for your role (as described in the research description below) were found to clearly match your skills set, education, and research experience.**

<u>**Research internship details**</u>

University/Institution:	University of New Brunswick – Fredericton
Host professor:	Victoria Chester
Research project title:	Biomechanics and Machine Learning
NOC code:	4012 Post-secondary teaching and research assistants
Research description:	We have a series of biomechanical gait databases from clinical studies (Autism), control groups (young and elderly), as well as elderly faller studies (dynamic and static balance) that we wish to reanalyze using machine learning, neural networks, classifiers, etc. The field of biomechanics has been slow to use these existing data analytic techniques to aid in determining optimal biomechanical parameters of clinical groups, differing age groups, and detecting fallers from non-fallers. The proposed work will lead to numerous conference and journal article proceedings.
During your internship, you will:	The student will be responsible for analyze biomechanical data using matlab (or other preferred software) to identify major determinants of gait patterns, classification of gait patterns, gait data reduction, determination of optimal gait/balance variables, etc. We have great student teams here from all over the world - come join us!
Duration of research:	12 weeks — to begin between May 1 and July 31, 2022 (unless otherwise approved by Mitacs) and end no later than October 31, 2022 (unless otherwise approved by Mitacs). Shortened durations must be agreed upon with the host professor and Mitacs. Durations of more than twelve (12) weeks will not be permitted.
Hours of work:	Minimum of forty (40) hours per week.

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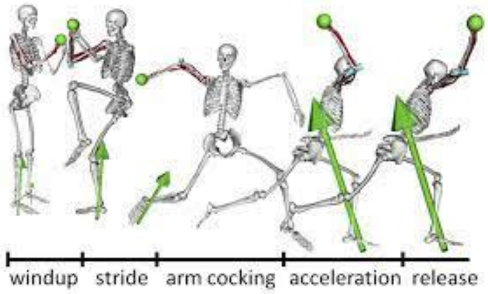
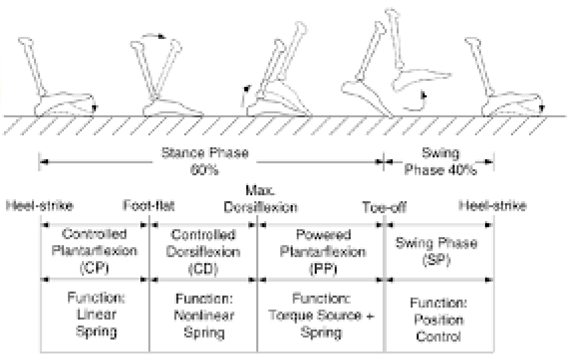
INTRODUCTION TO BIOMECHANICS AND MACHINE LEARNING

Biomechanics is the science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement. Biomechanics is part of the larger field of kinesiology, specifically focusing on the mechanics of the movement.

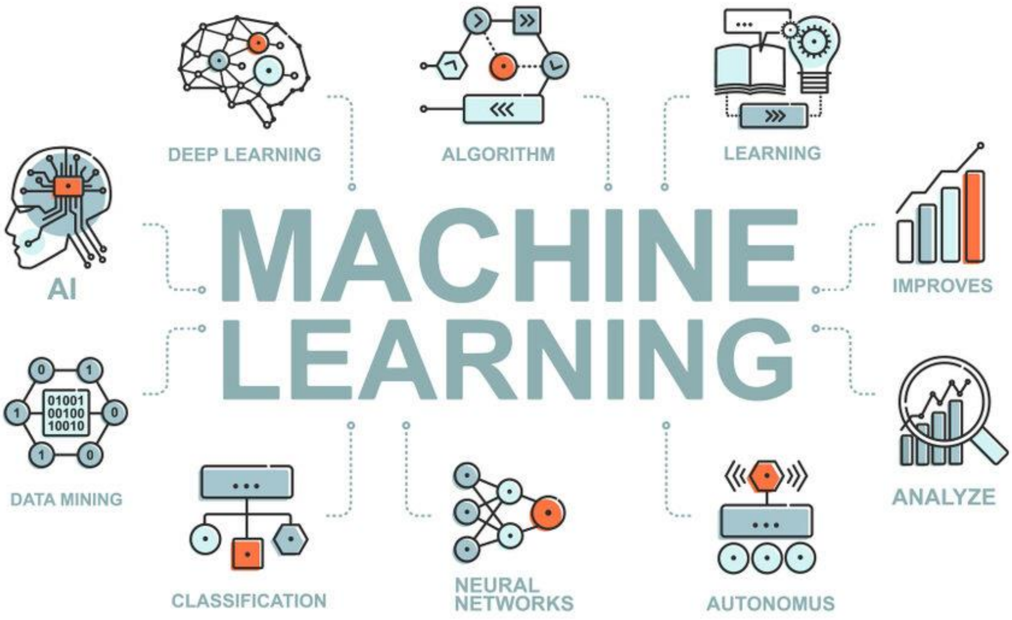
These are the key areas that biomechanics focuses on:

- **Dynamics**: Studying systems that are in motion with acceleration and deceleration
- **Kinematics**: Describing the effect of forces on a system, motion patterns including linear and angular changes in velocity over time as well as position, displacement, velocity, and acceleration are studied.
- **Kinetics**: Studying what causes motion, the forces, and moments at work
- **Statics**: Studying systems that are in equilibrium, either at rest or moving at a constant velocity





Machine learning on the other hand, is a field of inquiry devoted to understanding and building methods that 'learn', that is, methods that leverage data to improve performance on some set of tasks. It is seen as a part of artificial intelligence. Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so. Machine learning algorithms are used in a wide variety of applications, such as in medicine, email filtering, speech recognition, and computer vision, where it is difficult or unfeasible to develop conventional algorithms to perform the needed tasks.



The field of biomechanics has been slow to adopt the powerful techniques of machine learning and deep learning to gain deeper insights into the field and understand it better. So, this research is aimed at implementing such techniques in the field of biomechanics.

OBJECTIVE

Objective:

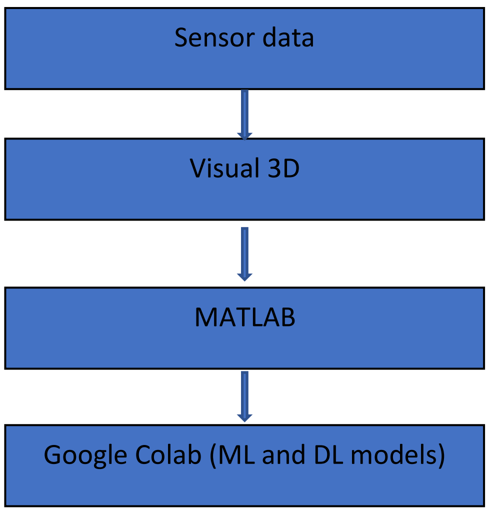
Biomechanical parameters such as the multi-segment foot data from autism patients such as Cal_Mid, Cal_Met, Sha_Cal, Sha_Foot and Mid_Met were collected. Each of these angles have multiple projections and parameters. This data was analysed using various machine learning and deep learning algorithms such as linear SVM, SVM with a radial basis function kernel, CNN's, RNN's and LSTM's to predict whether the given patient has autism or not.

HARDWARE SETUP

A 12-camera T160 Vicon motion capture system (Oxford Metrics Group, Oxford, UK), sampling at 100 Hz, was used to track the 3D trajectories of 32 reflective markers placed on the participant's skin. Six force plates (Kistler Instruments, Winterthur, Switzerland) were used to aid in the identification of gait cycle events and sampled at 1000Hz. Participants were asked to perform at least 12 gait trials at self-selected speeds. Displacement data were filtered using a zero phase lag, second order Butterworth filter with a cut-off frequency of 8Hz. Relative joint angles were computed using Euler angles. Joint angle data were normalized to 100% of the gait cycle.

STUDY

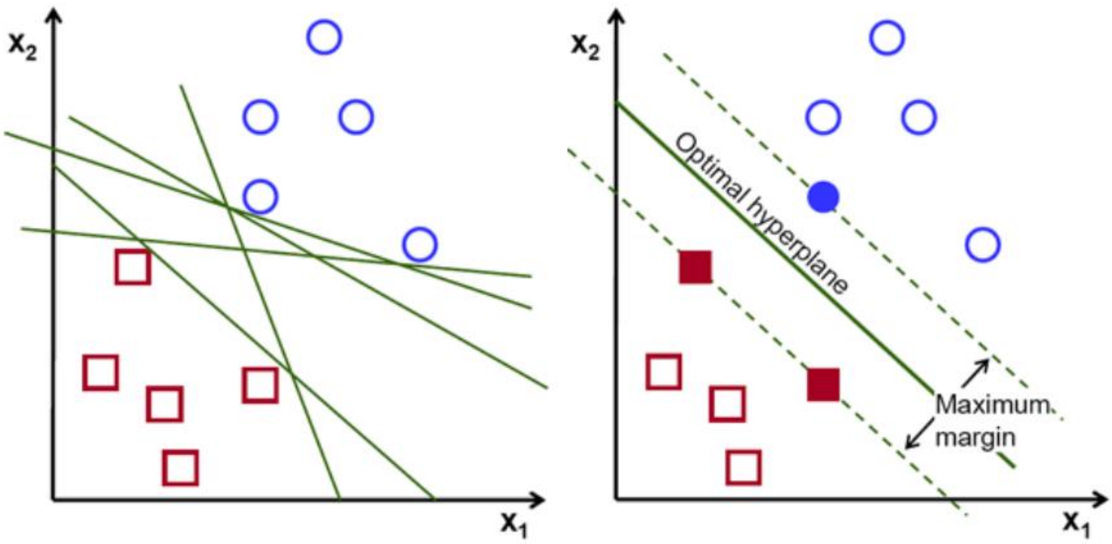
Data pre-processing was done extensively on the raw data collected from the sensors. Sensor data was first fed into Visual 3-D which is a software used to correct the placement of biomechanical markers and find any outlier values in the data. The data was then passed through a MATLAB code developed by the lab to extract the necessary features to be fed into the machine learning models. It includes features such as Max_Stance_Time, Min_Swing_Time and Time_Of_Flight. Once all the necessary features are extracted, it is run through models namely SVM(Linear and RBF kernels), CatBoost algorithm, Random Forest Classifier, CNN's (Convolutional Neural Networks) and LSTM's(Long short term memory networks) to see which model gives the best output classification score.



IMPLEMENTATION OF RBF SVM

RBF SVM stands for Support Vector Machines with a radial basis function kernel.

The objective of the support vector machine algorithm is to find a hyperplane in an N-dimensional space(N — the number of features) that distinctly classifies the data points.

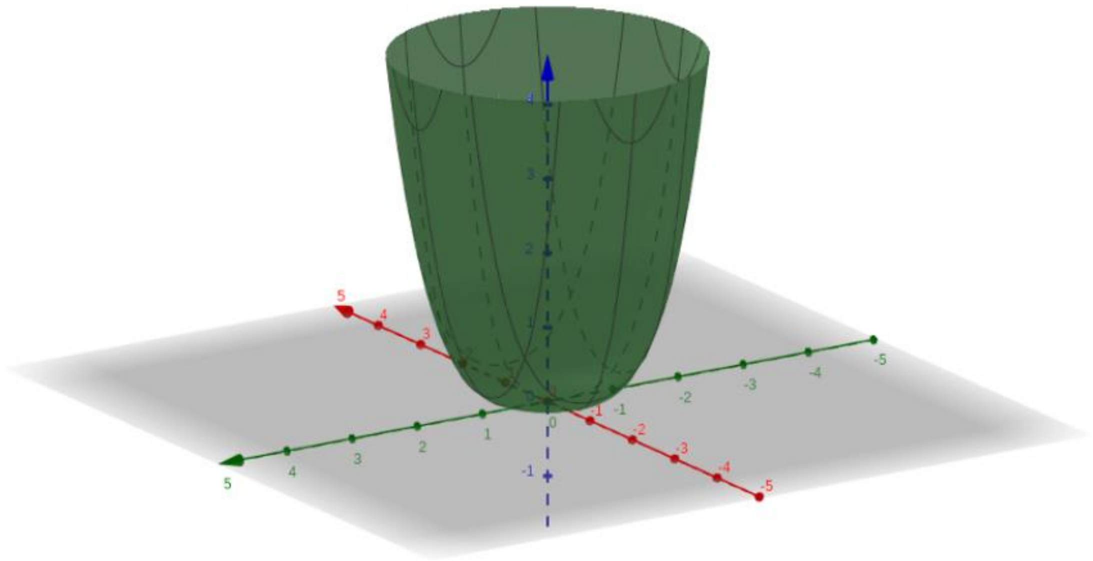


Possible hyperplanes

Many possible hyperplanes can be chosen. Objective is to find hyperplane with maximum margin. Hyperplanes are decision boundaries that help classify the data points.

- Data points falling on either side of the hyperplane can be attributed to different classes.
- The dimension of the hyperplane depends upon the number of features.
- If the number of input features is 2, then the hyperplane is just a line.
- If the number of input features is 3, then the hyperplane becomes a two-dimensional plane.
- Support vectors are data points that are closer to the hyperplane and influence the position and orientation of the hyperplane.
- Using these support vectors, we maximize the margin of the classifier.

The Objective function:



ADVANTAGES:

1. SVM works relatively well when there is a clear margin of separation between classes.
2. SVM is more effective in high dimensional spaces.
3. SVM is effective in cases where the number of dimensions is greater than the number of samples.
4. SVM is relatively memory efficient

DISADVANTAGES:

1. SVM algorithm is not suitable for large data sets.
2. SVM does not perform very well when the data set has more noise i.e. target classes are overlapping.

RESULT

The characteristics of an autistic patient were differentiated from a non autistic patient with an accuracy of 98 percentage as shown in the below table.

Segment	Method	Accuracy	Specificity	Sensitivity	NPV	PPV	F1	MCC
TS + ALL KINETICS	RBF	0.988	1	0.975	0.977	1	0.987	0.976
Hip	RBF	0.878	0.881	0.875	0.881	0.875	0.875	0.756
Ankle	RBF	0.866	0.929	0.8	0.83	0.914	0.853	0.736
Knee	RBF	0.841	0.833	0.85	0.854	0.829	0.84	0.683
Hip	Linear	0.841	0.857	0.825	0.837	0.846	0.835	0.683

CONCLUSION

This is a very big breakthrough in the field of biomechanics as we were able to predict the onset of autism in young adults with an accuracy of 96.3 percent just by examining the biomechanical gait parameters of the subjects. This study will soon be put in clinical practice with the help of collaboration with hospitals to develop the necessary gear and instruments required to test on patients in real time.

We were also able to extract the useful features that contributed to the result (decoding the model's black box) using Explainable AI techniques such as LIME.

Extensive analysis of the results was done and presented in the form of SHAP plots and graphs for interpretation.