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Rehabilitation Movement Correctness Classification

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Contents

Introduction

- Human movement (or gesture) recognition is a classical computer vision problem which deals with identifying a certain movement from a set of available movements
- The problem can be addressed using either colour or depth images, or simplified by taking the angles (represented in degrees) between different body segments or the 3D positions (represented in millimetres) of various body joints
- A human action usually lasts from several seconds to a few minutes
- Data is spatio-temporal (a sequence of frames or images in time)

The Problem

- The main contribution of our research is that we do not focus on action or gesture recognition
- We expand the research to **gesture correctness**
- However, technically speaking, although a binary classification problem (determine whether an action is correctly executed or not), this problem is much more complex than just action recognition
- There is very limited work in the area of human action or movement correctness

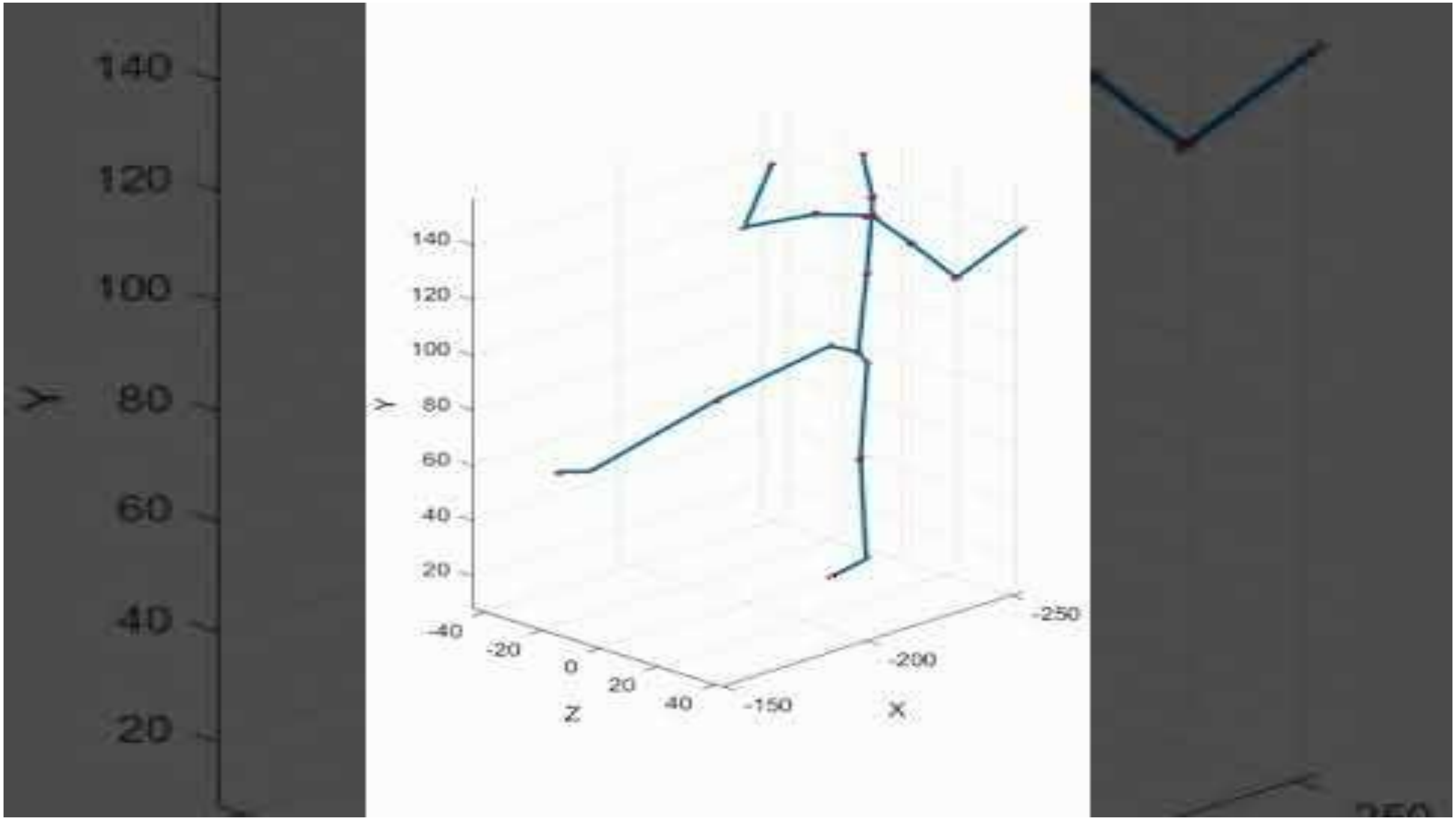
The Data

- Human action/motion 3D skeleton data captured using motion sensor devices
- Collected using Kinect sensor
- Contains angles and positions of several body joints
- Each joint is represented by three coordinates
- Data collected for several gestures (e.g. elbow flexion, shoulder abduction)

The Data (University of Idaho)

- University of Idaho-Physical Rehabilitation Movement Data (UI-PRMD)
- This dataset contains 10 exercises performed by 10 individuals (actors)
- Each individual performed each exercise 20 times
  - 10 correct
  - 10 incorrect
- It is freely available online
- More details: https://www.mdpi.com/2306-5729/3/1/2/htm

Data Visualisation



https://www.youtube.com/watch?v=RyObs6bdZYo

Data Contents

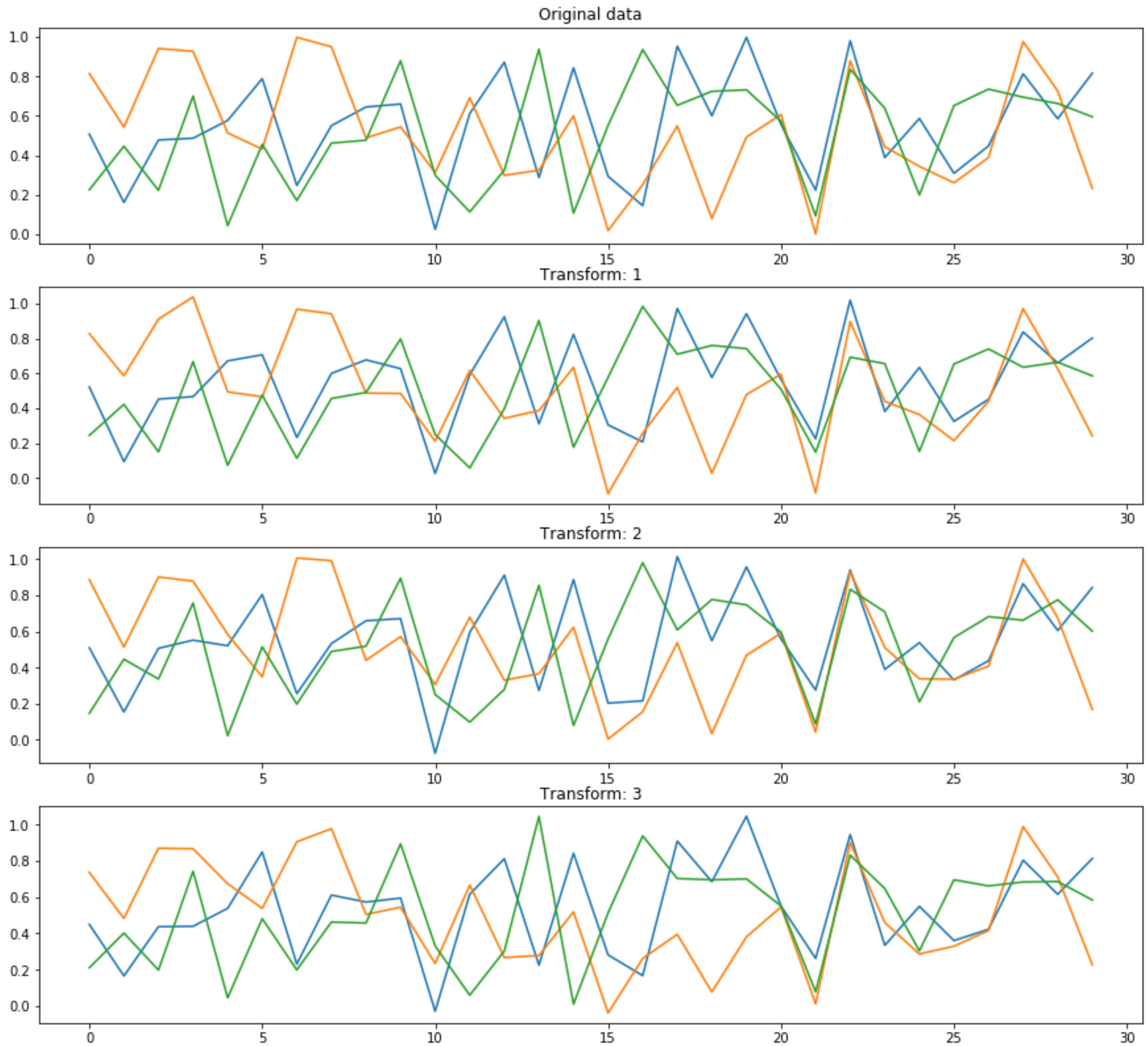
...	f_67	f_68	f_69	f_70	f_71	f_72	f_73	f_74	Subject	Class
...	-0.681504	0.347874	0.204270	-0.691752	0.443918	0.309931	-0.680854	0.550113	104	1
...	-0.637890	0.183466	0.250281	-0.669973	0.295313	0.223179	-0.618648	0.346856	104	1
...	-0.585461	0.065661	0.293015	-0.617426	0.105410	0.384913	-0.597577	0.147588	104	1
...	-0.520454	-0.125984	0.391445	-0.542725	-0.099277	0.468084	-0.535048	-0.107662	104	1
...	-0.428489	0.110594	-0.143572	-0.404433	0.092959	-0.111962	-0.403617	0.092209	207	0
...	-0.330326	0.022125	-0.178073	-0.329374	0.097060	-0.163124	-0.361476	0.099523	207	0
...	-0.301870	0.232226	-0.133484	-0.304038	0.147896	-0.131207	-0.333599	0.133827	207	0
...	-0.521136	0.307125	-0.194082	-0.553467	0.304564	-0.163071	-0.433682	0.314631	207	0
...	-0.663165	0.278687	0.071155	-0.585036	-0.140067	0.094612	-0.660406	-0.154199	307	1
...	-0.642945	0.132191	0.058350	-0.575190	-0.179318	0.085885	-0.649062	-0.191543	307	1
...	-0.617545	-0.015575	0.072791	-0.563034	-0.324120	0.097274	-0.635047	-0.346438	307	1
...	-0.565359	-0.254088	0.189721	-0.479409	-0.278942	0.188890	-0.538735	-0.298131	307	1

- Each joint is represented by three coordinates (columns)
- This example contains positions of 25 joints

Data Augmentation

- **Data augmentation** is a way of creating new '**data**' with different orientations
- The benefits of this are two-fold:
  - The ability to generate 'more **data**' from limited **data**
  - It prevents overfitting
- Currently we have several techniques such as Jittering, Scaling, Permutation, Rotation and Time Warping

Data Augmentation Example

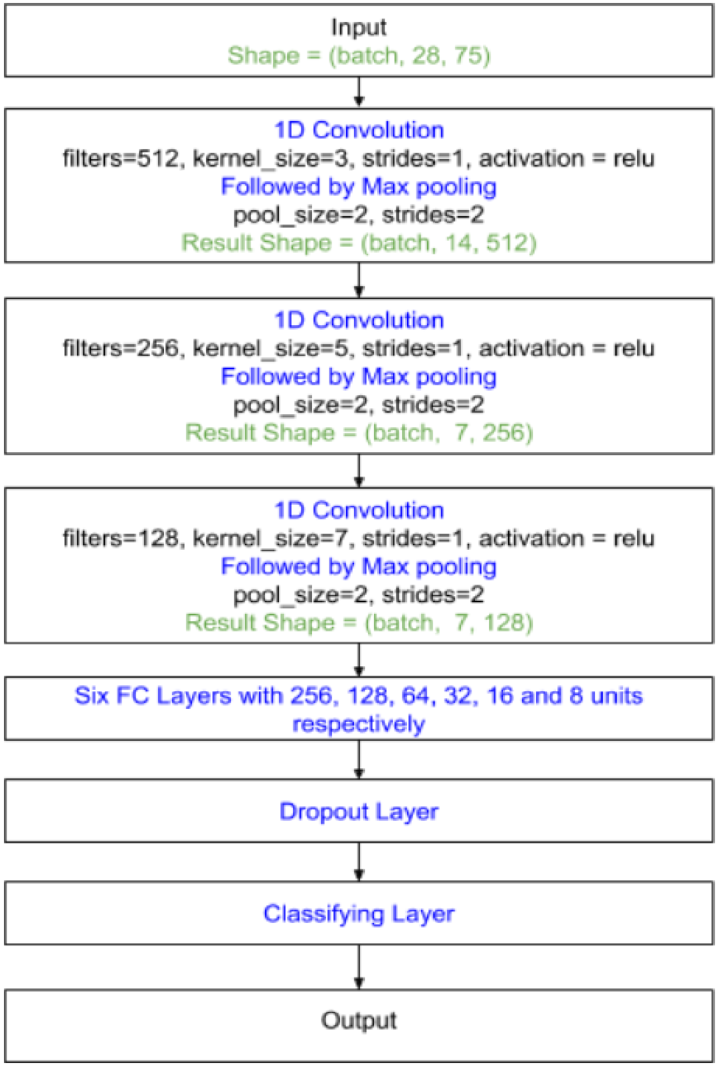


Convolutional Neural Networks (CNNs) 1/2

- CNNs work by generating filters (aka kernels) that capture patterns in the data
- Most common application is image analysis (2D or 3D kernels)
- We use CNNs for time-series analysis by learning 1D filters
- Dimension of data is normally reduced as we add more convolutional layers (can keep original dimension)
- Pooling layers are also used to reduce dimension further
- Filter size, how much steps to move (stride), pooling type are subject to experimentation
- Dropout technique to avoid overfitting

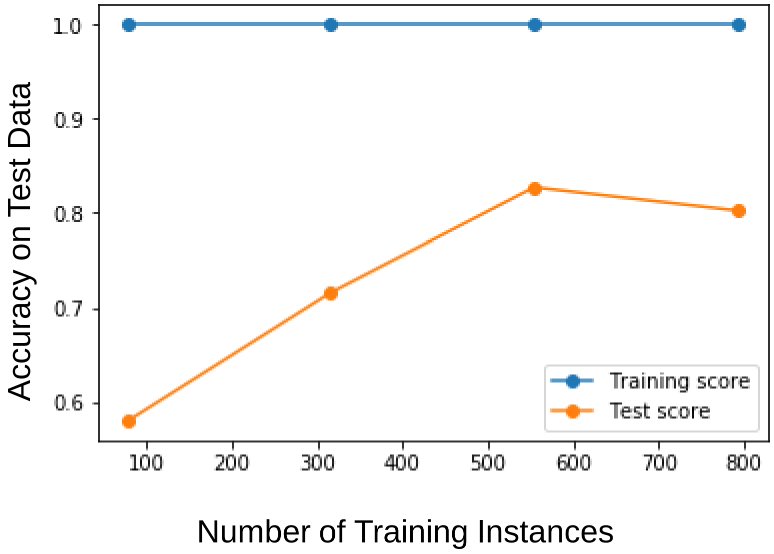
Convolutional Neural Networks (CNNs) 2/2

- CNNs are known to work well on temporal data (several application areas)
- Usually data format is crucial (how to feed them data)
- Known to be data hungry (hence data augmentation is often used)



Long Short-Term Memory Network (LSTM)

- Units of a recurrent neural networks (RNNs)
- Remembers values over arbitrary time intervals
- Well-suited to classifying, processing and making predictions based on time series data
- But .. requires plenty of data
- See learning curve on the right



Rough Paths Theory 1/2

- This is a powerful signature method for sequential data representation and feature extraction
- It is derived from the theory of rough paths in stochastic analysis
- Given a path (time series), it extracts a unique feature vector
- No matter how long the series is (i.e. number of time points is irrelevant)
  - Size of resulting signature (i.e. feature vector) is the same
- Works well in many areas (e.g. financial data)

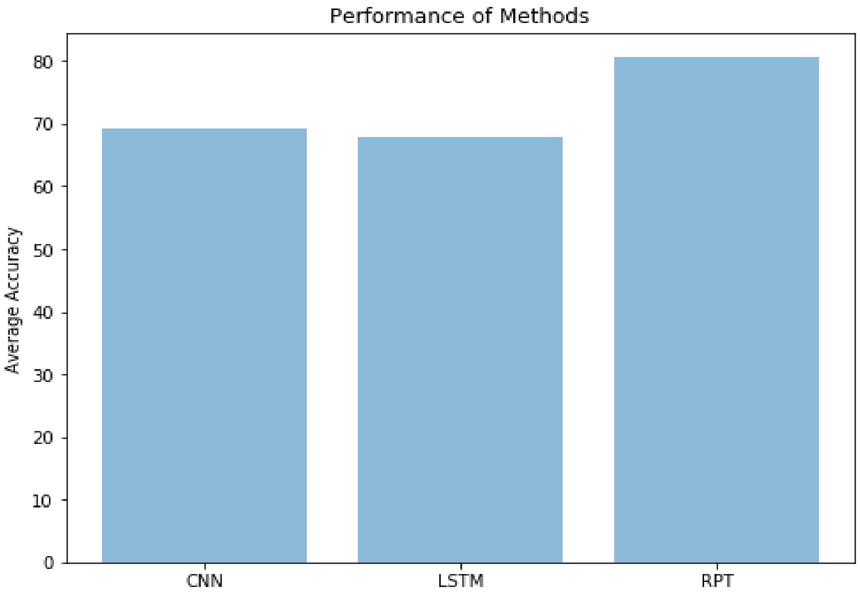
Rough Paths Theory 2/2

- In our case, each move (regardless of how many frames it has) is represented by one feature vector
- This means each move becomes one instance
- This makes classification (predict if a move is right/wrong) easy!

f_286	f_287	f_288	f_289	f_290	f_291	f_292	f_293	Subject	Episode	Class
24.37187	-2.60782	7.891094	0.559548	-0.93861	-0.52385	-0.14681	0.121384	s10	e01	1
-75.7342	273.283	223.9442	-886.73	496.6683	93.91177	318.3616	-228.791	s10	e02	1
-20.4365	2.782783	-40.9448	7.959409	0.34136	7.660096	-1.47306	-0.05107	s10	e03	1
-29.0088	4.283595	-31.0922	5.60431	0.314028	6.275178	-1.1472	-0.0443	s10	e04	1
-5.35235	-0.34986	11.44848	-4.15883	-2.49329	0.163605	0.334498	0.437155	s10	e05	1
153.311	-6180.37	109.0356	17784.43	-12104	-9529.23	-14193.1	22613.63	s10	e06	1
8608.123	-5205.53	-8844.9	5124.356	451.3286	5457.731	-3162.63	-260.144	s10	e07	1
9007.654	-6566.02	-8713.89	6854.021	-384.624	4263.108	-3534.89	273.3172	s10	e08	1
3834.145	-1844.26	-5476.3	2217.126	782.4025	3476.954	-1504.2	-411.73	s10	e09	1
3024.98	-1858.87	-5102.77	3026.25	135.1768	2875.013	-1651.82	-133.841	s10	e10	1
13829.62	-7739.84	-4358.21	8824.094	-1397.8	-78.6748	-3184.33	637.7229	s01	e01	0
-2650.45	2010.609	598.434	-805.664	56.77526	86.10546	204.8903	-20.4261	s01	e02	0
139.165	-49.3173	-49.5817	18.40719	-1.48456	-2.5137	-0.06733	0.010845	s01	e03	0
13266.02	-4523.06	-7205.5	2737.917	-44.624	8482.937	-3446.47	-550.907	s01	e04	0
-926.872	1309.588	190.7581	-1409.82	526.8846	859.019	215.3294	-259.577	s01	e05	0
250.7809	728.8904	-52.771	-530.693	92.68891	324.577	116.495	-47.7112	s01	e06	0
27936.54	-13951.4	-13015	11998.68	-898.776	8882.349	-6736.89	91.86347	s01	e07	0
20451.31	-10390.9	379.4598	5725.811	-2568.34	-3114.64	-1334.7	1392.924	s01	e08	0
16007.47	-10927.8	-2640.3	3669.844	-597.901	978.3946	-1683.35	394.0647	s01	e09	0
9913.817	-6324.28	-4219.84	1406.533	331.7384	3574.332	-1408.54	-168.206	s01	e10	0
-450.781	407.1644	-475.83	85.99942	-48.0335	440.199	-140.308	30.44196	s02	e01	0
-1931.76	972.4146	-87.3228	-58.5762	30.12503	147.2131	-63.1716	-14.7199	s02	e02	0

Current Results

- Experiments performed on the Idaho data
- Evaluation on subjects not used for training the models
- Currently best is **RPT** with Extreme Boosting algorithm
  - Average accuracy is > 80%
- We are working on improving this even further



Challenges

- Cross-subject evaluation is challenging but this ensures that the trained model can generalize to new subjects
- There is a great variability in how the gestures are executed (i.e. some subjects execute them with left hand while others with the right hand)
- The small dataset (10 subjects) might disadvantage the CNNs and LSTMs

Summary and Conclusions

- Experiments performed on the Idaho data
- Evaluation on subjects not used for training the models (cross-subject evaluation)
- Currently best is **RPT** with Extreme Boosting algorithm
  - Average accuracy is > 80%
- We are working on **improving** this even further and test the system in real life situations
  - We have collected data from real patients executing a variety of motions in collaboration with Perkeso Rehab Centre Malaysia

Thank you