Gait Analysis of Autistic Children with Echo State Networks

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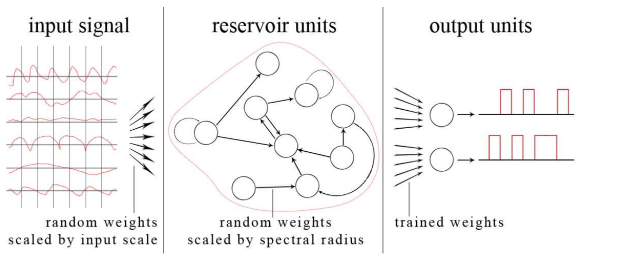
Motivations and Approach

- Discrimination of Autistic and Normal Children through analysis of gait cycles as time series.
- Previous works[1] remarking statistical differences in some gait parameters but without exploiting temporal correlations.
- Use of Echo State Networks to extract the differences in the cycles evolution.
- Tests with subsets of the walk motion data to locate the strongest discriminators.

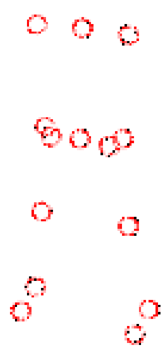
Echo State Network Model [2]



The input gait motion data is normalized and re-scaled and then fed to the reservoir neurons.
A reservoir of 200 sigmoid units randomly connected with a given connectivity and normalized by a given spectral radius is used to represent and process the input data. Two output sigmoid units gather the data from the reservoir units only (no direct input connection). No feedback connections link the output units to the reservoir.

Gait data collection

A set of 14 fluorescent markers are applied to the joints of the lower body of the child as well as to the shoulders and neck (figure)[3]. The 3d motion of two to three step cycles is captured for each child for three separate runs. The data is then normalized by the child's height. The markers are separated into three subsets, upper body, waist region and legs.



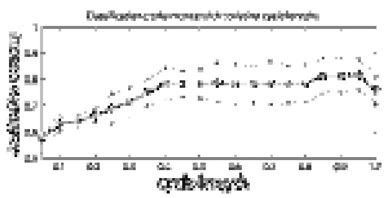
11 autistic children		11 control children	
Gender	2 female, 9 male	Gender	2 female, 9 male
Age	7.2y ± 2.5	Age	7.9y ± 2.1
Height	126.3cm ± 16.4	Height	132.2cm ± 12.0
Weight	26.6kg ± 6.65	Weight	29kg ± 11.1

Training and testing

Cross-validation was used on a randomized dataset. The training set consisting in 2/3 of the whole dataset, the remaining third being used for testing. The linear regression on the outputs for the ESN training was performed by computing the pseudo inverse on the internal states matrix. The decision function was computed by integrating the output signals over the input cycle length and choosing the class with the highest score.

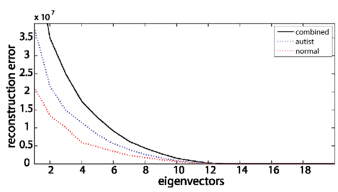
Input selection

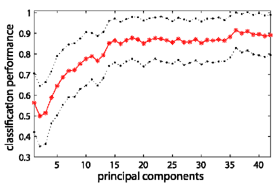
A full walk cycle (~100 frames) is considered from the start of the left stance period until the beginning of the next one (The left stance period begins when the left foot touches the ground). We tested the performance of the ESN using only fractions of the full walk cycle. Using more than 40% of the walk cycle the performance increases only gradually.



Principal and Independent Components

PCA and ICA were applied to the data set. Only 15 relevant eigenvalues resulted from the 42 inputs (rec.err. < 0.001%). The use of ICA does not provide better performances.





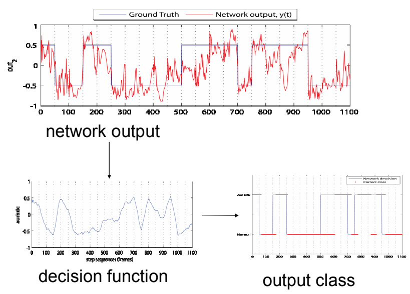
Analysis of Variance

stride duration	Aut	92.27	±20.06	ttest=0	p=0.064
	Norm	98.21	±15.56		
stride length	Aut	0.46	±0.11	ttest=1	p=0.000
	Norm	0.56	±0.07		
stride speed	Aut	0.53	±0.14	ttest=1	p=0.014
	Norm	0.58	±0.09		
stride cadence	Aut	72.93	±45.77	ttest=0	p=0.081
	Norm	62.52	±9.34		
swing period	Aut	41.86	±13.19	ttest=0	p=0.829
	Norm	43.04	±9.93		

Network Parameters

The values for reservoir Connectivity, Spectral Radius and Input Scale were tested. The Connectivity parameter has little to no effect on the classification. The Spectral Radius improves the performance slightly (+5%) with values above 1 (thus contradicting the echo-state property). The Input Scale shows the best results when set around ±1.4.

Output decision



Results

Subset	*Inputs*	*Performance*
Legs only	18	0.78 ± 0.12
Waist + Shoulders	24	0.80 ± 0.12
Legs + Shoulders	27	0.83 ± 0.12
Legs + Waist	33	0.80 ± 0.12
Full	42	0.85 ± 0.11
PCA-15	15	0.86 ± 0.12
PCA-36	**36**	**0.91 ± 0.09**
ICA-13	13	0.72 ± 0.13

(results computed over 20 runs per test)

Conclusions

- The ESN is able to exploit the differences in the gait motion to classify autistic and normal children with an accuracy of up to 91%.
- Using only half of the complete walk cycle provides good results already (reasonable as the motion tends to be symmetrical).
- Selecting only part of the input markers worsens the performances of the network (no evident strong discriminator).
- Using PCA increases the performance even with a reduced amount of eigenvectors, but the best results are obtained using most vectors.

References:
[1] S.Vernazza-Martin et Al. Goal Directed Locomotion and Balance Control in Autistic Children, *Autism and Developmental Disorders*, 35(1):91-102 (2005)
[2] Herbert Jaeger. The "Echo State" Approach to Analyzing and Training Recurrent Neural Networks, *GMD Report,* 148, 1435-2702 (2001).
[3] R. B. Davis III, S. Õunpuu, D. Tyburski and J. R. Gage. A gait analysis data collection and reduction technique, *Human Movement Science*, 10:575-587 (1991)