Chaotic Invariants for Human Action Recognition

Acknowledgement: This research was funded by the US government's VACE program.

Saad Ali, Arslan Basharat, Mubarak Shah

Computer Vision Lab, University of Central Florida

Our Contributions ...

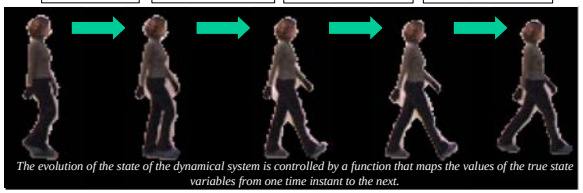
1) Investigation of the appropriateness of theory of chaotic systems for human action modeling and recognition,

1) A new set of features to characterize nonlinear dynamics of human actions,

2) Experimental validation of the feasibility and potential merits of carrying out action recognition using methods from theory of chaotic systems.

Proposed Idea ...

$f(\theta_1^t, \theta_2^t, ..., \theta_N^t)$ $f(\theta_1^{t+1}, \theta_2^{t+1}, ..., \theta_N^{t+1})$ $f(\theta_1^{t+2}, \theta_2^{t+2}, ..., \theta_N^{t+2})$ $f(\theta_1^{t+3}, \theta_2^{t+3}, ..., \theta_N^{t+3})$



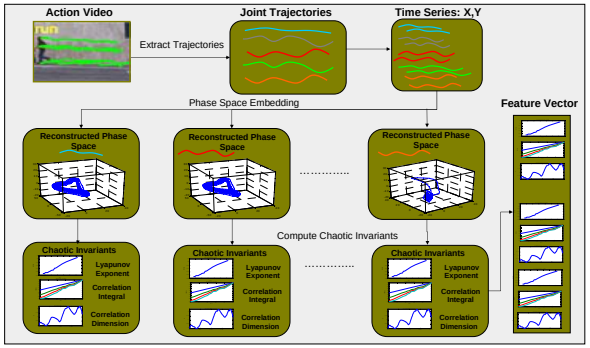
The evolution of the state of the dynamical system is controlled by a function that maps the values of the true state variables from one time instant to the next.

Unknown f Function that maps current state to the next state.

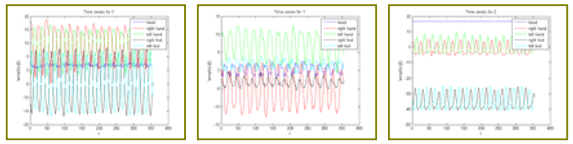
$(\theta_1^t, \theta_2^t, ..., \theta_N^t)$ True State Space Variables

- We have the access to the data (trajectories of body joints) generated by the dynamical system controlling the action !
- From this data construct the phase space corresponding to the dynamical system responsible for generating the data.
- Let the data speak about the mechanisms generating the observed behavior.

Algorithmic Overview ...



Phase Space Embedding ...



Six Body Joints: Two Hands, Two Feet, Head, Belly. Normalized with respect to the belly point.

Underlying Idea: All variables of the system influence each.

$$= (z_1, z_2, z_3, ..., z_t)$$

Every point z_i of the series results from the intricate combination of influences of all the true state variables.

$(\theta_1, \theta_2, ..., \theta_N)$

τ

Therefore, $z_{i,i+\tau}$ can be considered as a second substitute variable which carries the influence of all the true state variables during time interval τ.

$(\theta_1, \theta_2, ..., \theta_N)$

Using this reasoning, introduce a series of substitute variables and obtain the whole m-dimensional space.

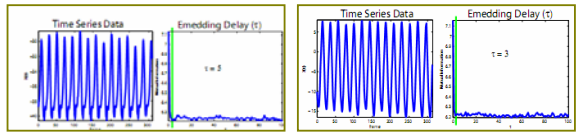
Thus, for optimal m and τ , delay vectors

$$z_i, z_{i+\tau}, z_{i+2\tau}, ..., z_{i+(m-1)\tau}$$

generates a phase space that has exactly the same properties as the original/true variables of the system.

Embedding Delay & Embedding Dimension ...

τ : Mutual information between z_i & $z_{i+\tau}$



First minima of mutual information as the optimal time delay

$$I(\tau) = -\sum_{h=1}^{i}\sum_{k=1}^{j} P_{j,k}(\tau) \ln \frac{P_{h,k}(\tau)}{P_h P_k}$$

P_h Probability that variable assumes a value inside h*th* bin

P_k Probability that variable assumes a value inside k*th* bin

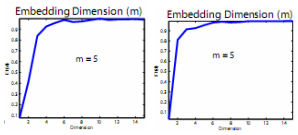
$P_{h,k}$ Probability that z_i is in h*th* bin and $z_{i+\tau}$ is in k*th* bin

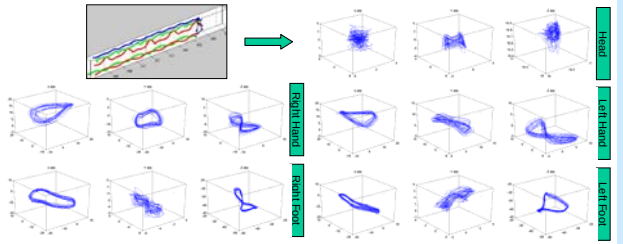
m : False Nearest Neighbour Algorithm: Unfold the observed orbits from self overlap arising due to projection of system's attractor to a lower dimensional space.

$$R_i = \frac{|x_{i+m\tau} - x_{j+m\tau}|}{\|p(i) - p(j)\|}$$

Calculate normalized distance R_i between (m+1)th coordinates of p(i) and p(j)

Repeat for various values of m until fraction of points for which $R_i > threshold$ is negligible.





Reconstructed phase spaces of trajectories corresponding to different body joints.

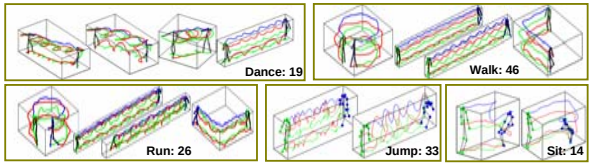
Chaotic Invariants ...

Lyapunov Exponent: Dynamical invariant which measures the divergence of nearby trajectories in the phase space.

Correlation Integral: Metric invariant which measures the percentage of points within a specific neighbourhood averaged over entire phase space.

Correlation Dimension: Metric invariant which change in the density of phase space with respect to neighborhood radius.

Results ...



	Dance	Jump	Run	Sit	Walk
Dance	28				2
Jump		13			1
Run	2	1	22	1	4
Sit				33	
Walk	3		2		43

Mean Accuracy: 89.7%

Leave one out cross validation using K-means classifier.

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	9								
A2		9							
A3			5	2	2				
A4				9					
A5					8		1		
A6					1	8			
A7							9		
A8								9	
A9									9

Mean Accuracy: 92.6%

A1: Bend, A2: Jumping Jack, A3: Jump in Place, A4: Run, A5: Side Gallop, A6: Walk, A7: Wave1, A8: Wave2

Experiments with Missing Trajectories

Without Head Trajectory: 81.2% (confusion observed in bending and jumping actions)

Without Left Hand Trajectory: 86.1%