Skills Assesment for Salsa Dancers Through the Phase Space Representation

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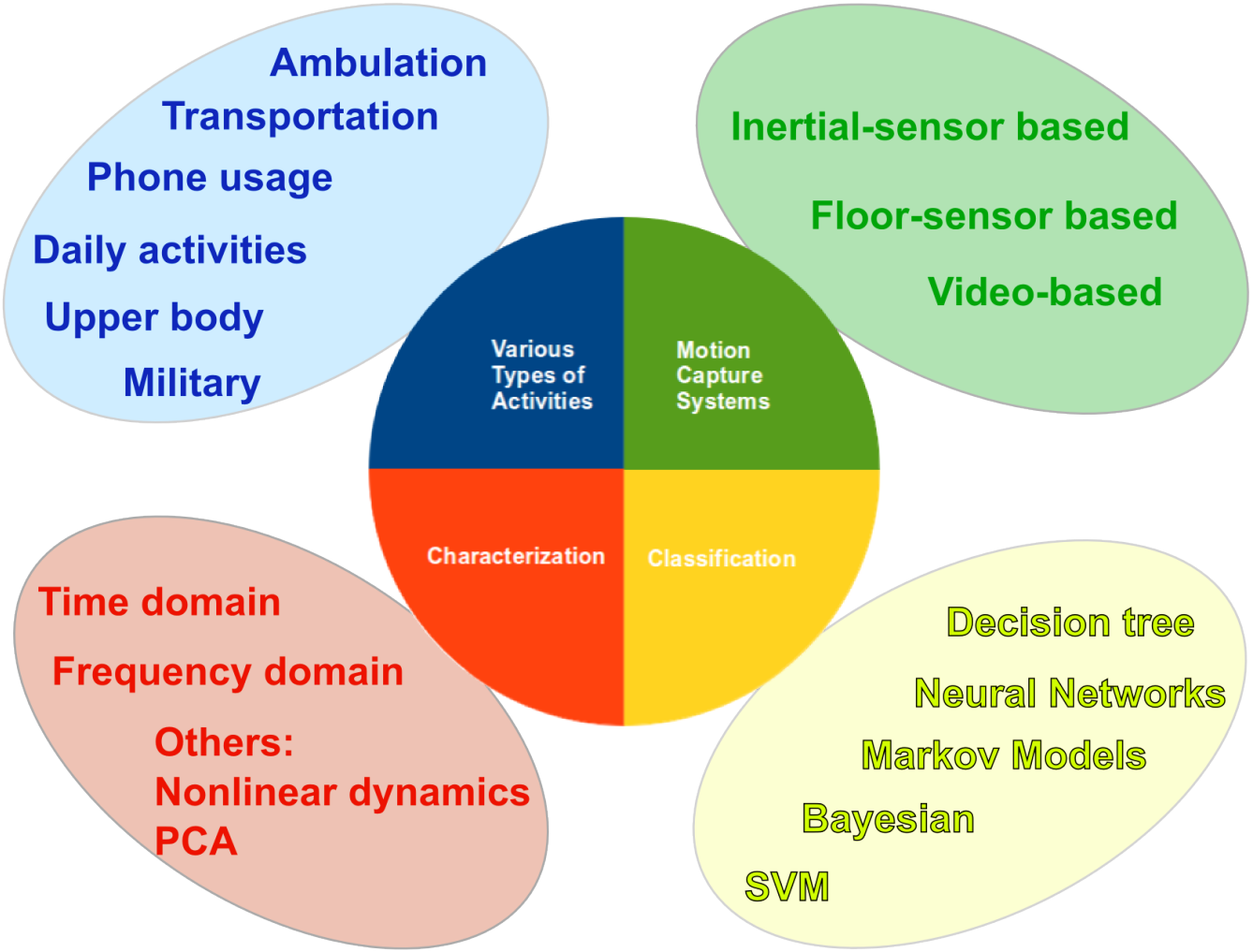
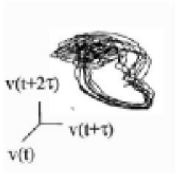
Research Awarness Day
EECE School
14th April 2015

UNIVERSITY OF BIRMINGHAM

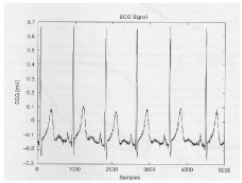
Why is HAR a challenging task?

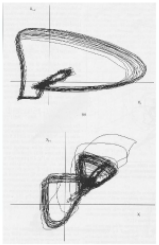


Study of electrophysiological time series

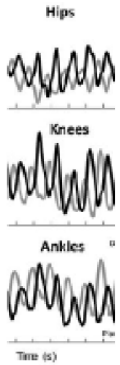


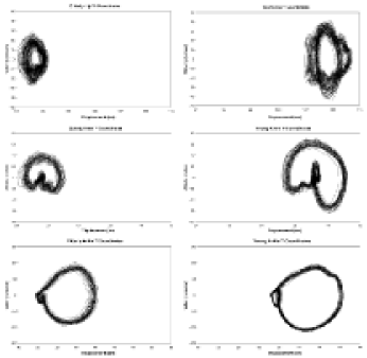
Korn et al (2003)





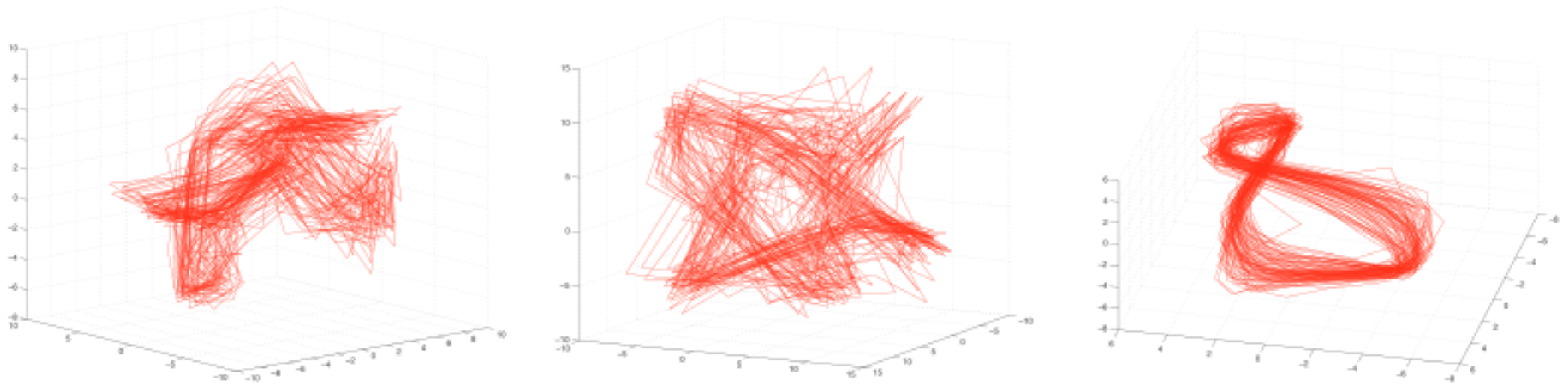
Fojt et al (1998)





Buzzi et al (2013)

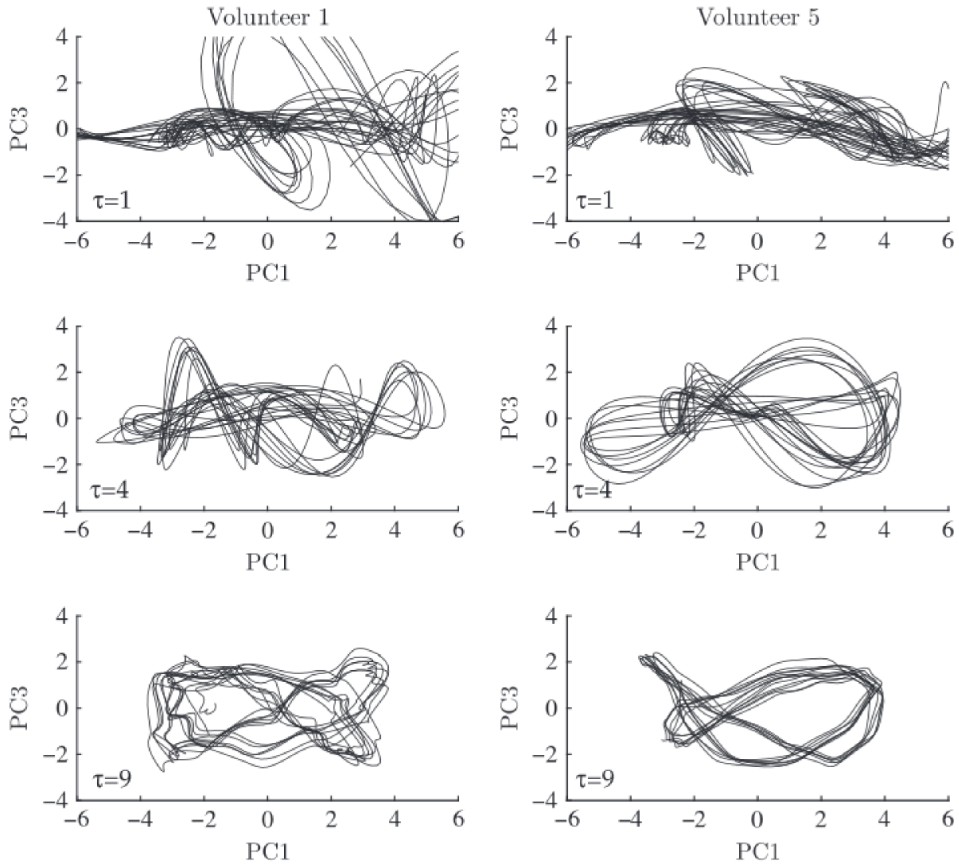
Time Series Classification



Jordan et at (2013)

Reconstructed state spaces for walking (left), running (middle), and biking (right) from noisy accelerometer data.

Gait Identification

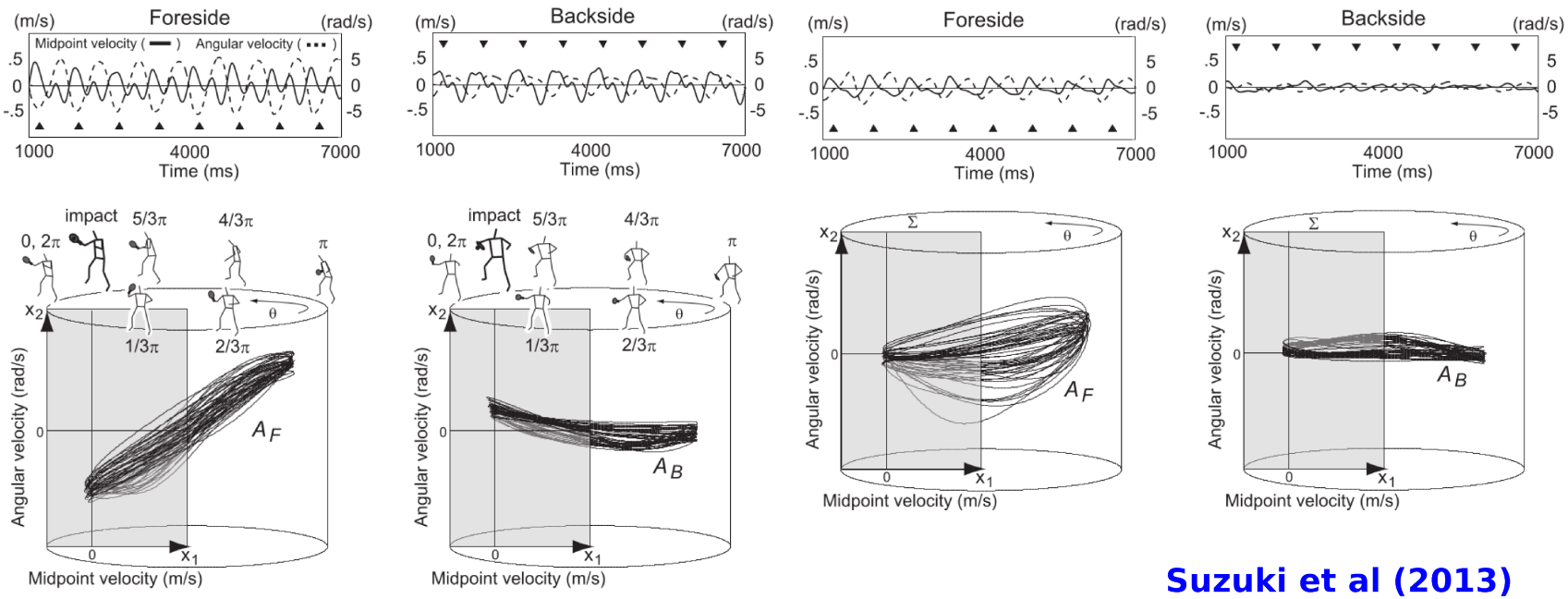


Sama et al (2013)

Reconstruction of the trajectory of the first and third PC for two indivials.

Dexterity of Tennis Players

Expert #5 Novice #4



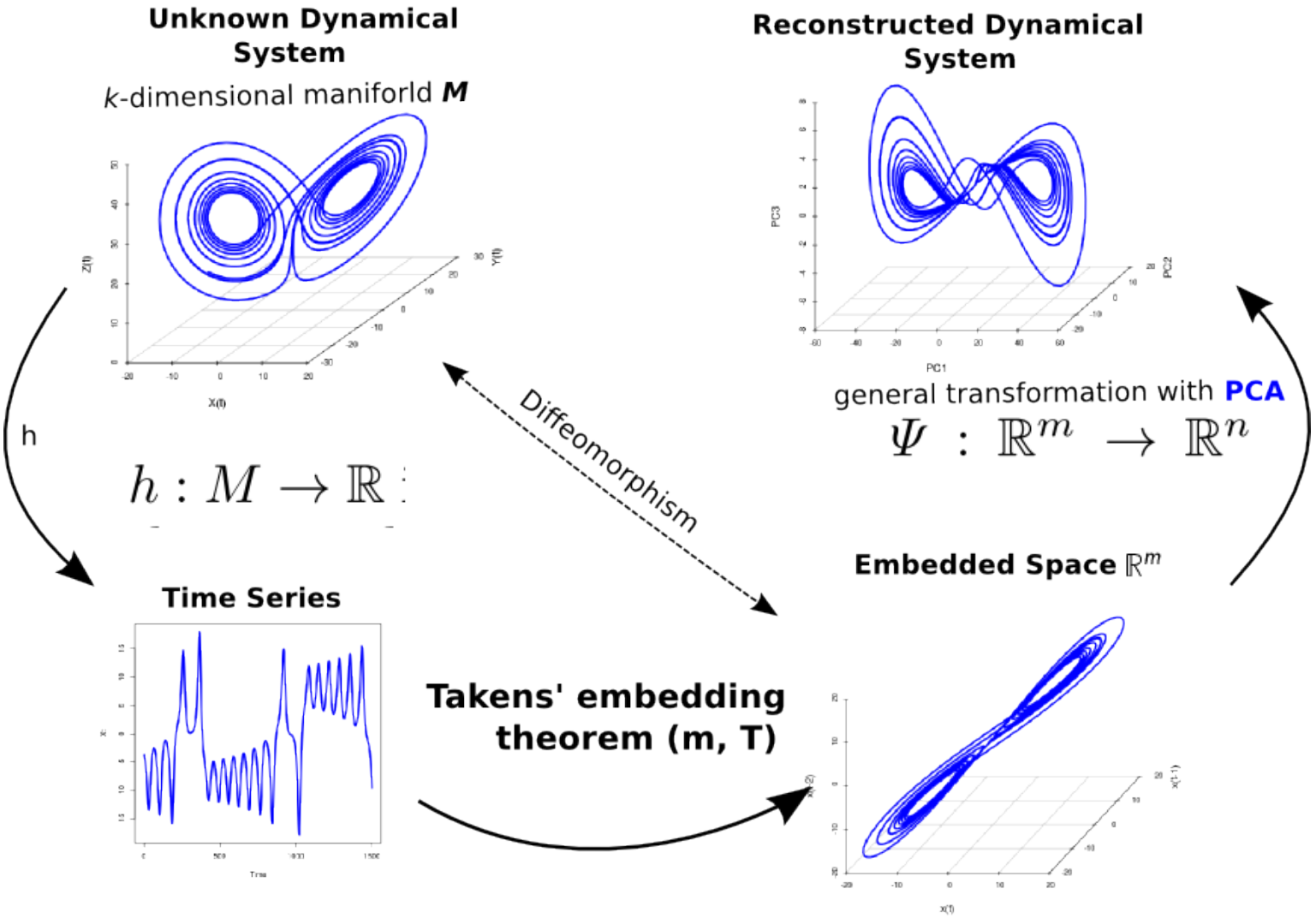
Suzuki et al (2013)

Time series and hyper-cylindrical phase space from Expert #5 and Novice #4.

Research Questions

- How the reconstructed state space can quantify the dexterity of human body activities?
- Is the Takens's Theorem the best tool to quantify Human Activities in terms of the reconstructed the state space?
- Which concepts from nonlinear dynamics can be used to characterize human body activities?

The Reconstructed State Space



Takens' Theorem (1981)

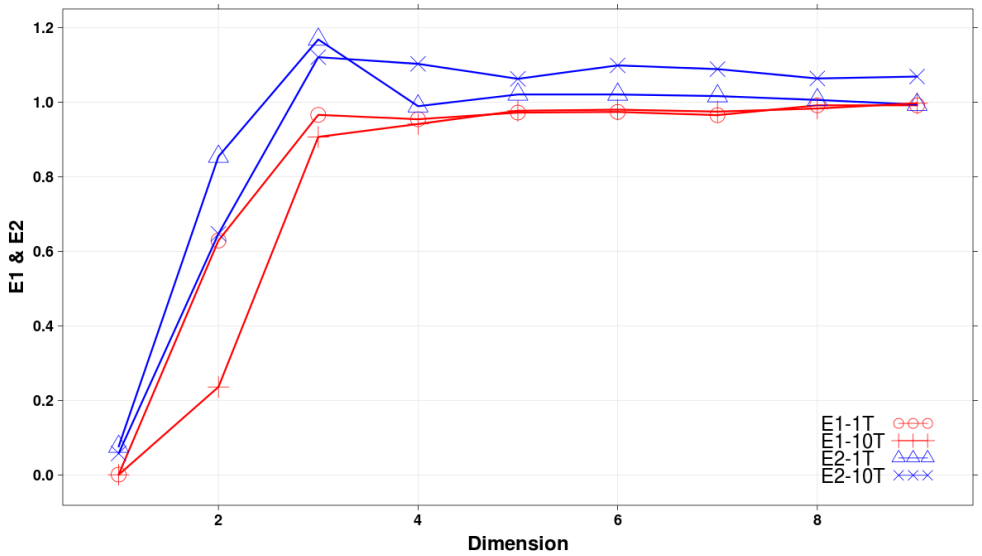
According to Takens' Theorem, the reconstructed state space in m **embedding dimension** with τ **embedding delay** of the original system is given by

$$\overline{x(t)} = (x(t), x(t-\tau), x(t-2\tau), ..., x(t-(m-1)\tau).$$

Takens' Theorem, also knows as time-delay embeddings method, states that for a large enough m to unfold the attractor and $\tau > 0$ chosen to maximize the information content of $x(t)$, this method provides a one-to-one reconstruction of the true dimension k system ($\mathbb{R}^k$).

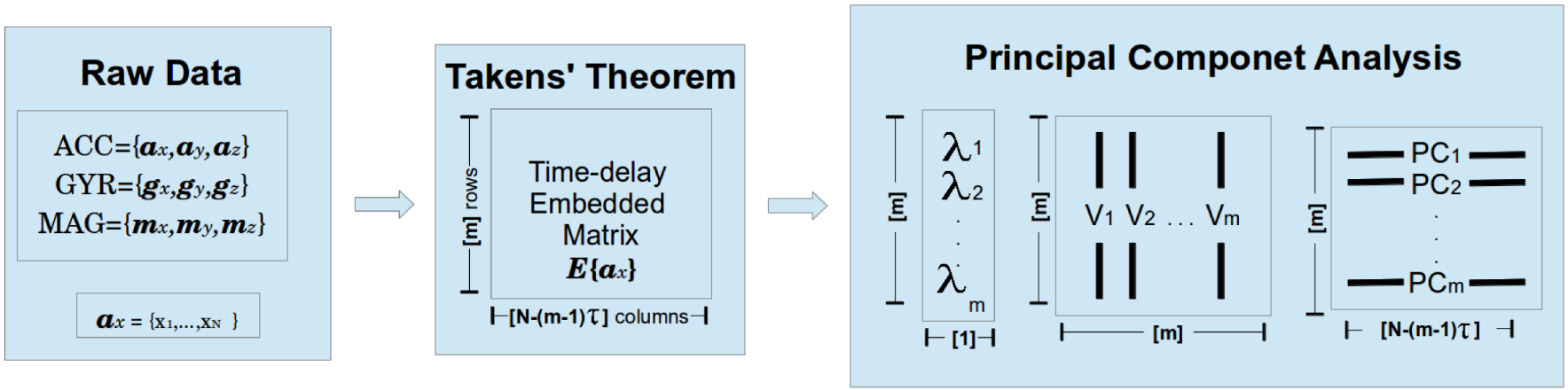
Minimum embedding parameters

Cao (1997) proposed a method based on the false neighbor method to determine the minimum embedding dimmension from time-series based on Taken's theorem.



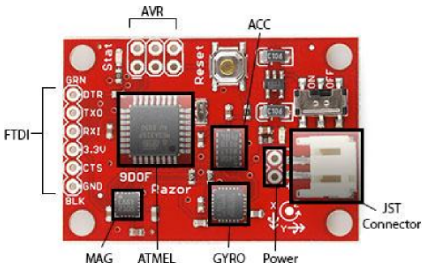
The values E1 and E2 from Lorenz attractor **Cao (1997)**

Phase Space Reconstruction



DECIMUS Class in C++

9DOF Razor IMU



Accelerometer **X Y Z |m|**

Magnetometer **X Y Z |m|**

Gyroscope **X Y Z |m|**

Yaw
Pitch
Roll

DECIMUS Class in C++

*time-**D**elay **E**mbedding theorem for*
*Re**C**onstructing state spaces*
*Using **I**nertial **M**easurement **U**nit**S***

Time-Delay Embedding Parameters

```
DataAnalysis.Set_SpaceReconstructionParameters(50,10,5); // (lengthwindowframe, dim, tau)
```

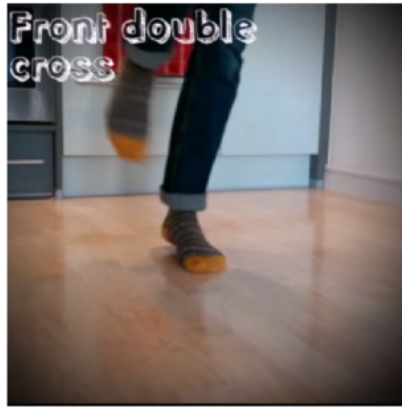
Decimus **DataAnalysis**
Kind: ***Variable*** definition
Decl.: main.cpp :66 Show uses
DataAnalysis Object

Principal Component Analysis

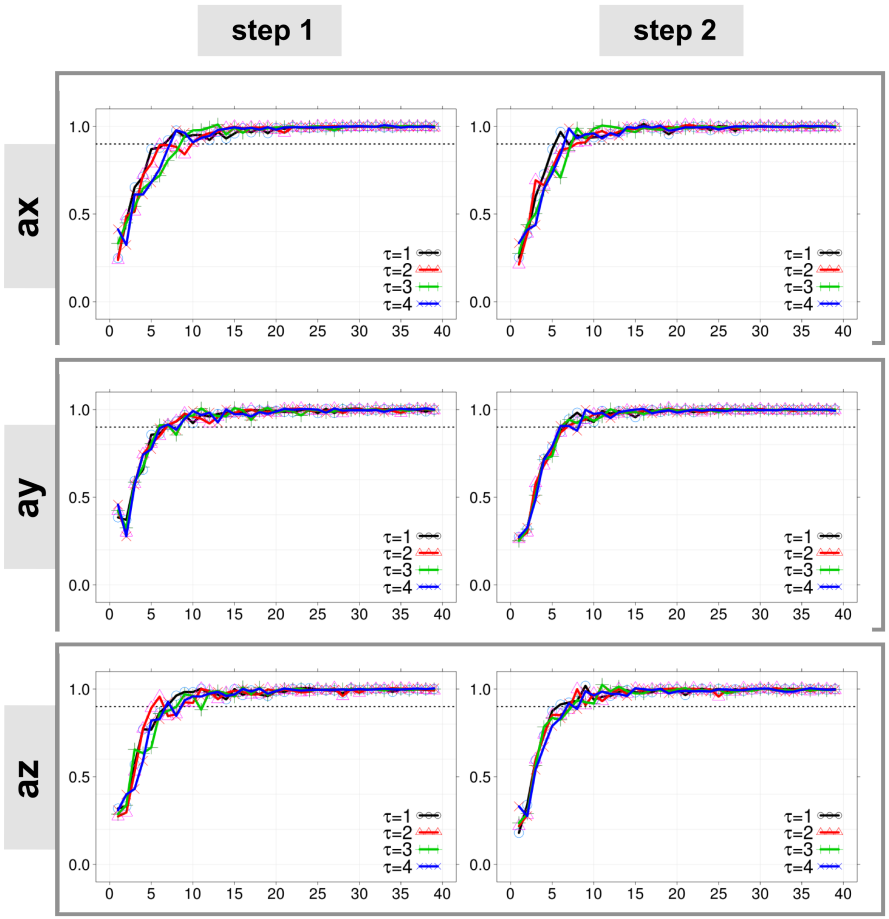
```
mat A;

 A= EmbeddedMatrix.t() * EmbeddedMatrix; // generate a symmetric matrix --- mat B = A.t()*A;


vec eigval_original, eigval;
mat eigvec_original, eigvec, transformedData;
eig_sym(eigval_original, eigvec_original, A.t(), "dc"); // divide-and-conquer

eigval = flipud(eigval_original);
eigvec = fliplr(eigvec_original);
transformedData = fliplr(eigvec_original).t()*EmbeddedMatrix.t();

cout << "DIY:eigenvalues \n" << eigval << endl;
cout << "DIY:eigenvectors \n" << eigvec << endl;
cout << "DIY:transformedData \n" << transformedData << endl;
```

IMU, Axes and C++ Class

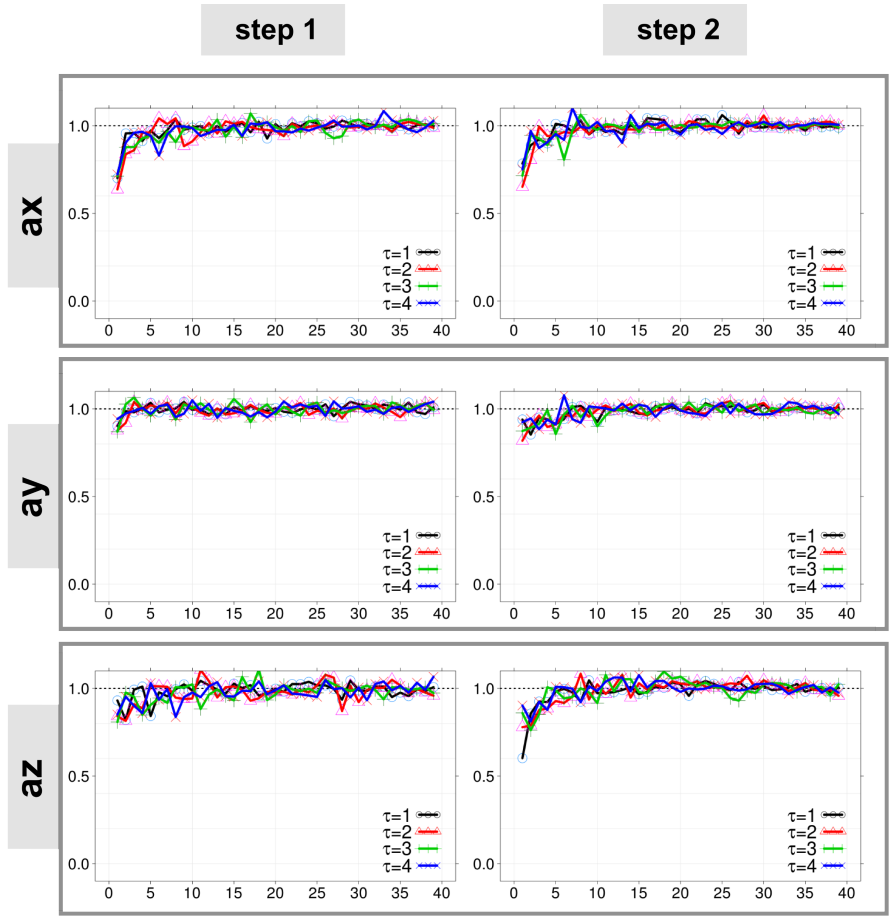
Seven Beginner Salsa Feet Patterns



$E1(d)$ and $E2(d)$ values

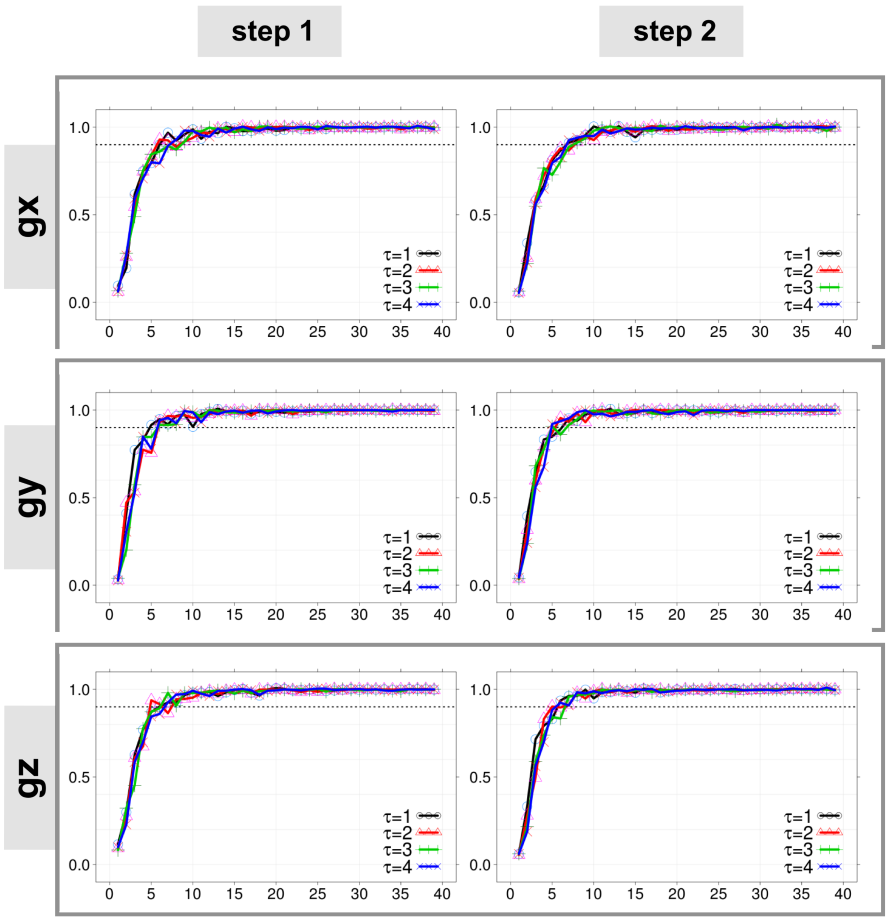


E1(d)

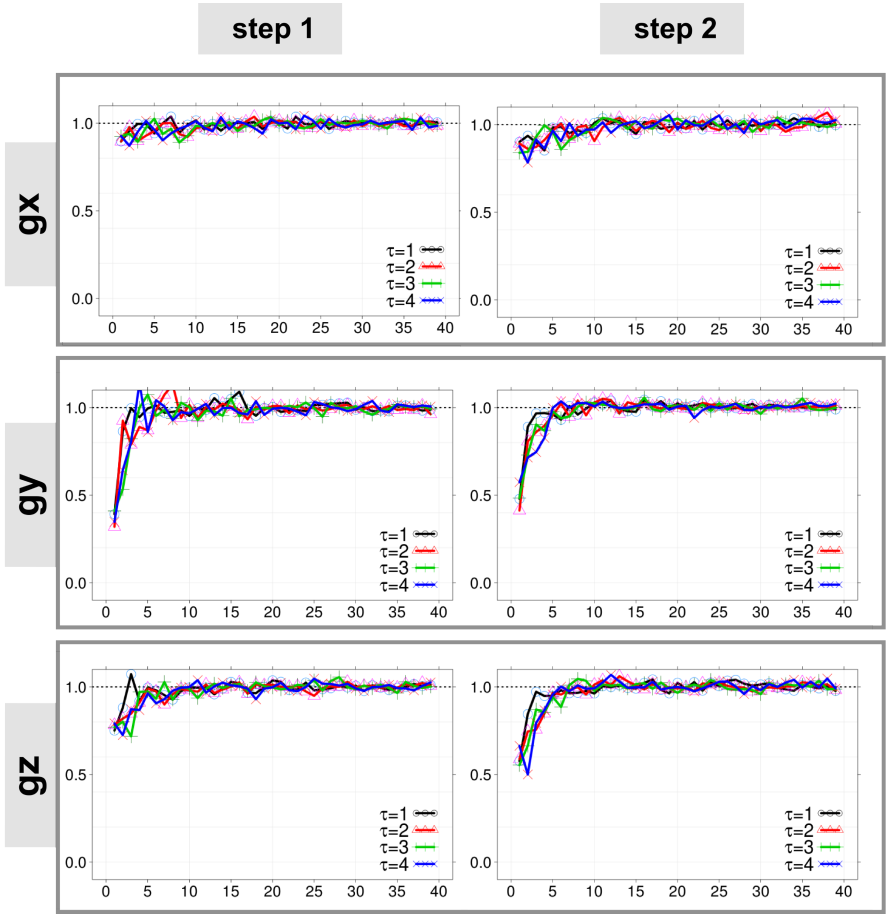


E2(d)

$E1(d)$ and $E2(d)$ values

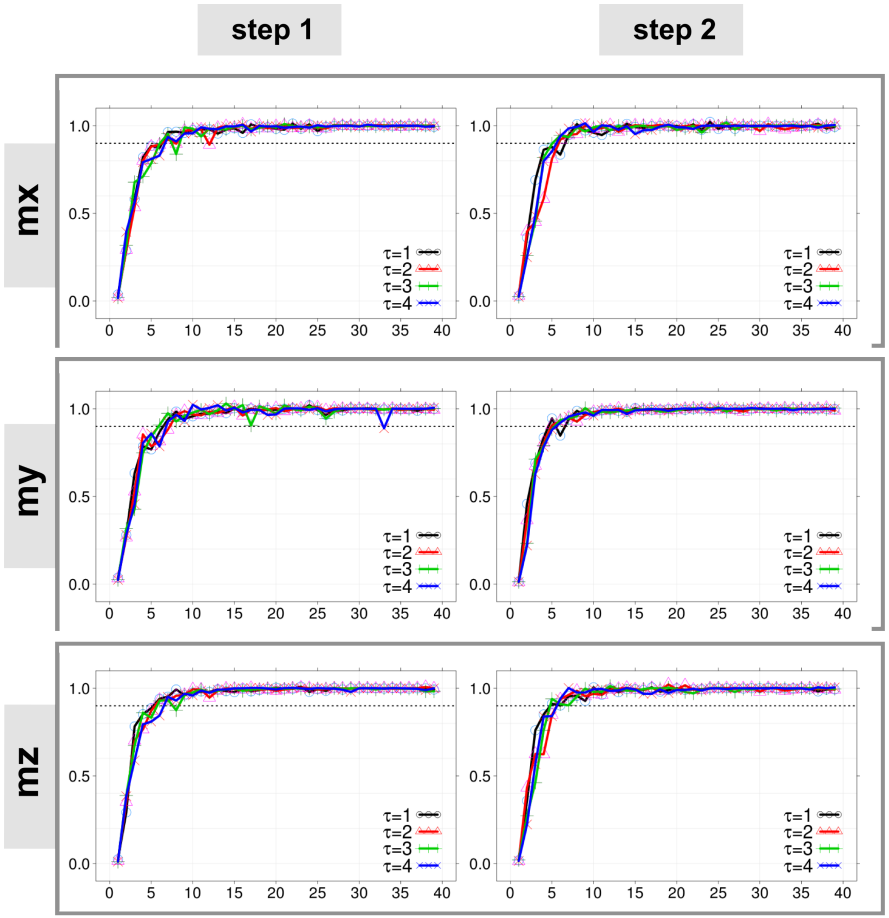


E1(d)

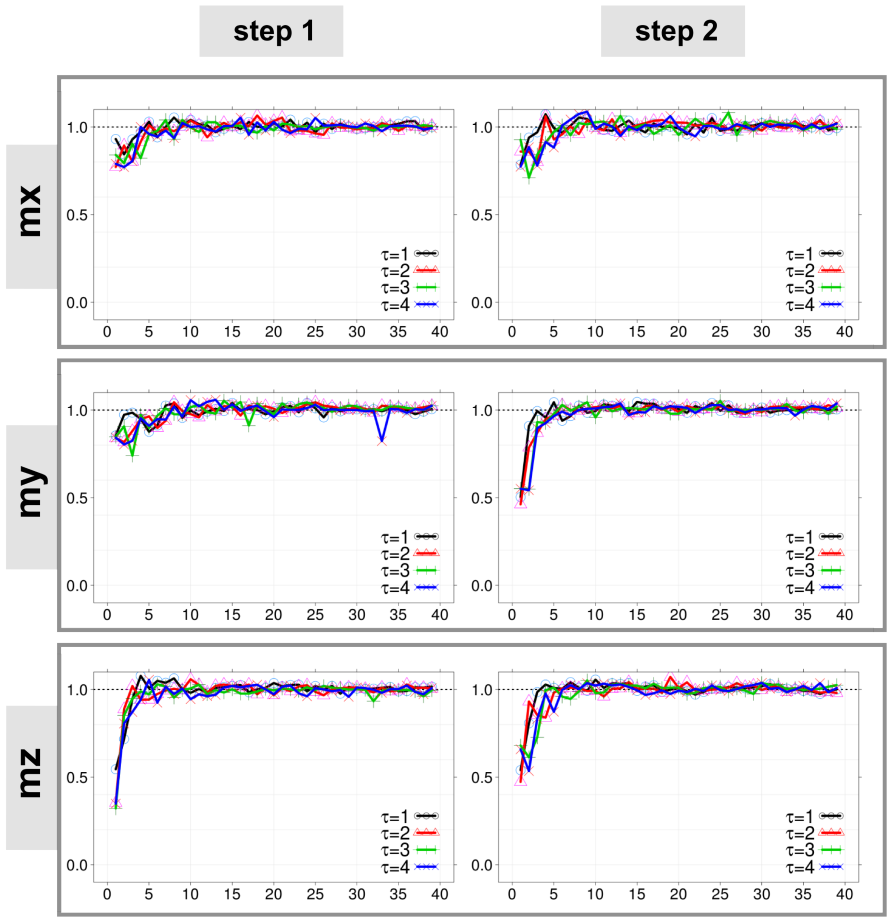


E2(d)

$E1(d)$ and $E2(d)$ values



E1(d)



E2(d)

Percentages of variances

Expert

	Step 1			Step 2		
	C_1	C_2	$C_1 + C_2$	C_1	C_2	$C_1 + C_2$
$\boldsymbol{E}a_x$	37.83	33.82	67.65	37.83	31.27	69.11
$\boldsymbol{E}a_y$	18.12	17.20	35.32	30.49	23.99	54.48
$\boldsymbol{E}a_z$	29.57	25.68	55.25	21.24	21.09	42.34
$\boldsymbol{E}g_x$	29.98	24.89	54.87	32.73	27.68	60.42
$\boldsymbol{E}g_y$	42.20	41.43	83.63	40.61	36.43	77.04
$\boldsymbol{E}g_z$	40.07	36.18	76.25	43.32	41.38	84.71
$\boldsymbol{E}m_x$	79.18	10.81	89.99	82.13	10.42	92.56
$\boldsymbol{E}m_y$	67.43	9.03	76.46	73.31	21.00	94.31
$\boldsymbol{E}m_z$	66.36	28.19	94.55	61.58	25.78	87.37

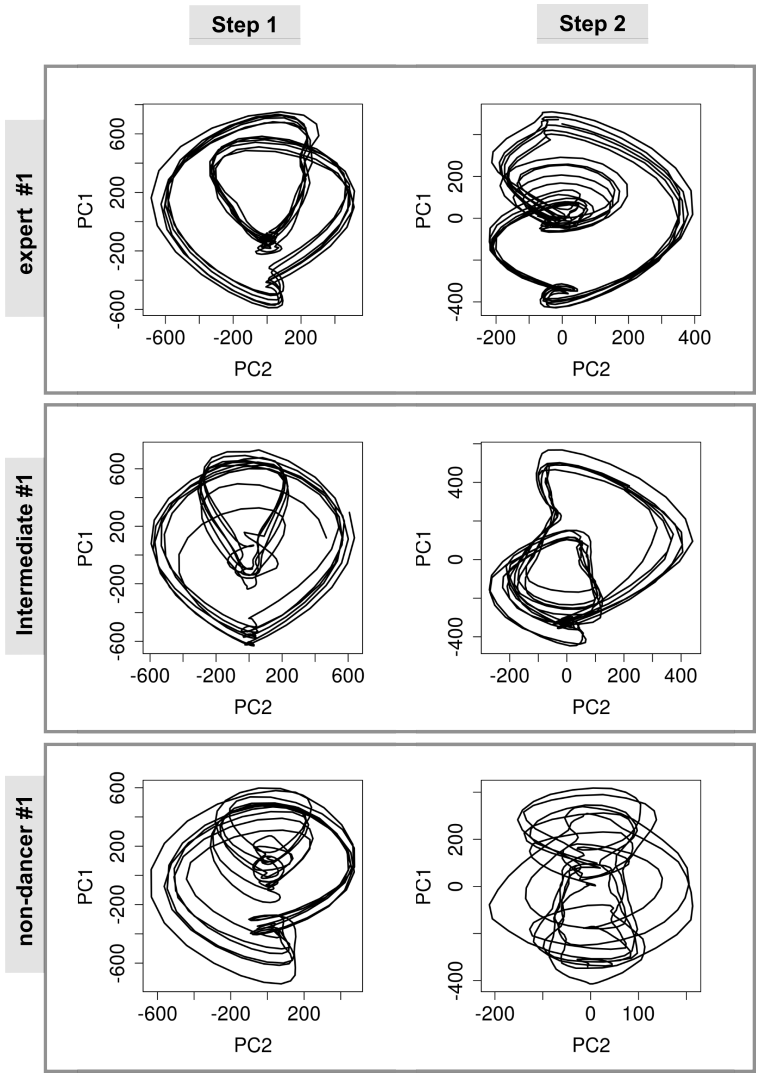
Intermedium

	Step 1			Step 2		
	C_1	C_2	$C_1 + C_2$	C_1	C_2	$C_1 + C_2$
$\boldsymbol{E}a_x$	37.51	32.28	69.79	23.11	22.17	45.28
$\boldsymbol{E}a_y$	20.66	20.58	41.24	23.07	18.15	41.23
$\boldsymbol{E}a_z$	32.77	29.85	62.62	14.35	13.65	28.00
$\boldsymbol{E}g_x$	22.77	20.79	43.56	18.58	17.49	36.08
$\boldsymbol{E}g_y$	46.85	40.58	87.43	40.32	39.21	79.53
$\boldsymbol{E}g_z$	42.43	40.21	82.64	53.13	32.90	86.04
$\boldsymbol{E}m_x$	84.91	9.40	94.31	81.80	15.01	96.81
$\boldsymbol{E}m_y$	64.00	28.66	92.66	77.41	18.17	95.59
$\boldsymbol{E}m_z$	70.24	25.43	95.67	79.29	16.45	95.75

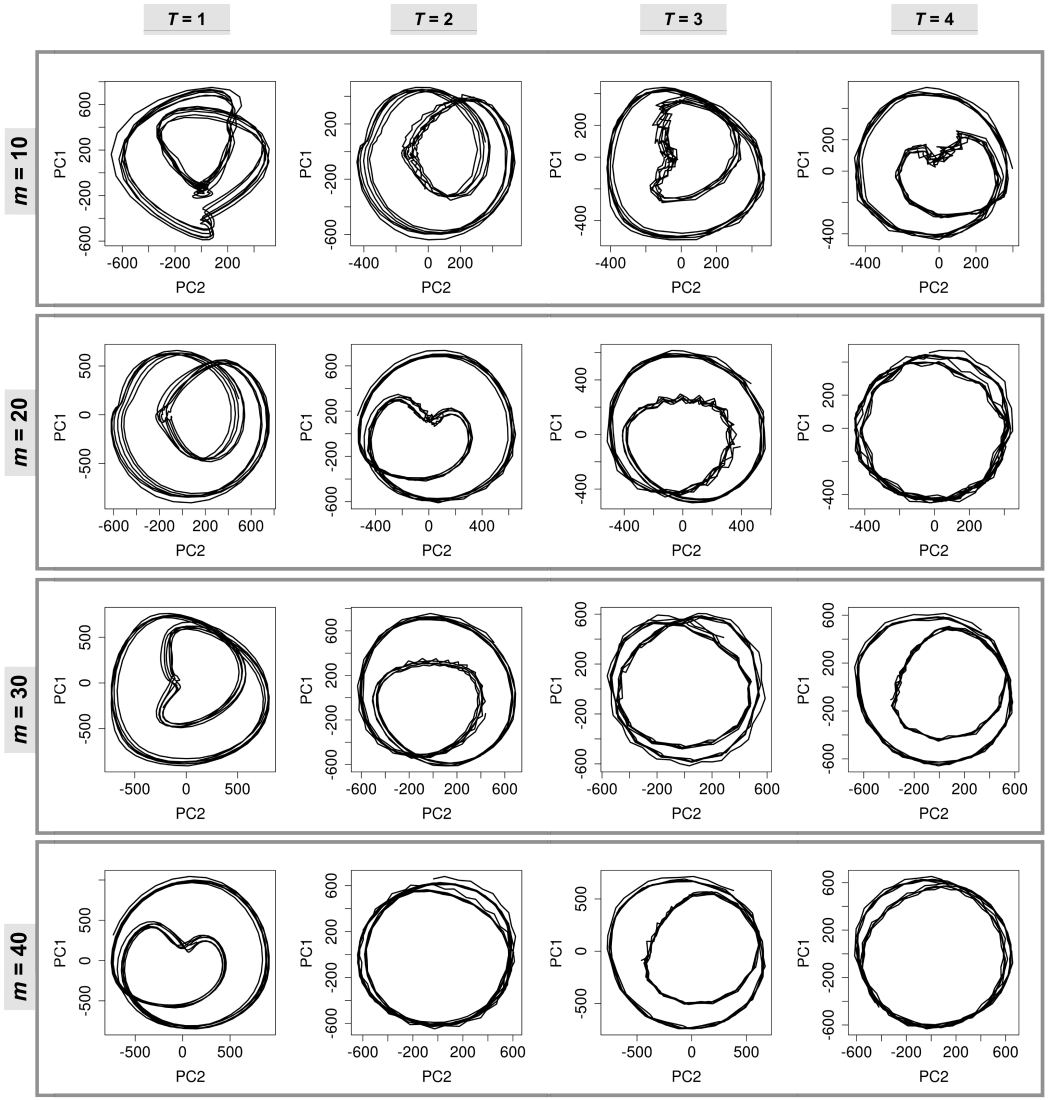
Non-dancer

	Step 1			Step 2		
	C_1	C_2	$C_1 + C_2$	C_1	C_2	$C_1 + C_2$
$\boldsymbol{E}a_x$	26.41	21.57	47.98	31.27	23.92	55.20
$\boldsymbol{E}a_y$	12.89	12.51	25.4	19.79	18.88	38.68
$\boldsymbol{E}a_z$	15.12	14.84	29.96	20.22	18.75	38.98
$\boldsymbol{E}g_x$	18.45	16.66	35.11	18.78	15.12	33.90
$\boldsymbol{E}g_y$	44.11	38.84	82.95	43.20	33.99	77.20
$\boldsymbol{E}g_z$	37.95	37.24	75.19	49.76	30.21	79.97
$\boldsymbol{E}m_x$	64.24	23.82	88.06	83.79	12.43	96.23
$\boldsymbol{E}m_y$	58.45	32.08	90.53	85.71	12.06	97.77
$\boldsymbol{E}m_z$	66.58	27.88	94.46	72.99	20.96	93.96

2-D reconstructed state spaces (RSS)



Different embedded parameters



PhD Framework