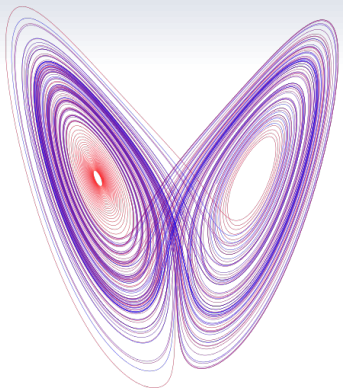

Understanding the Reconstructed State Space for Latin Dance Styles Using an IMU

Miguel Angel

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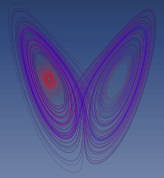
INAOE's Robotics Laboratory

1st October 2014



Presentation Outline

Open Challenge @ TMR 2013

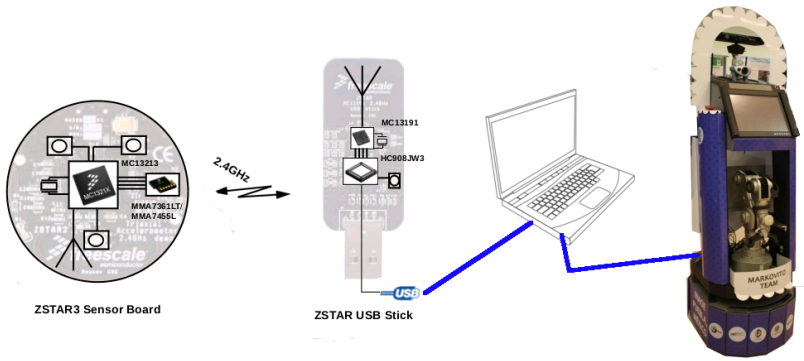


Figure 1: Human-Robot Interface

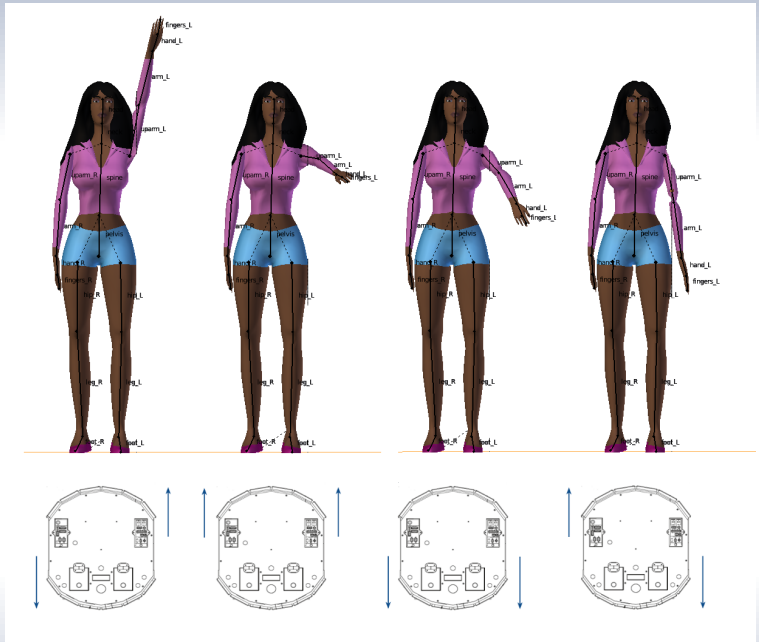
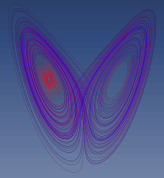
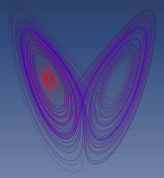


Figure 2: Human Body Gestures



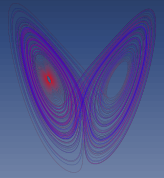
Presentation Outline



Various Types of Activities

Group	Activities
Ambulation	Walking, running, sitting, standing still, liying, climbing stairs descending stairs, riding escalator, and riding elevator.
Transportation	Riding a bus, cycling and driving.
Daily activities	Eating, drinking, working at the PC, watching TV, reading, brushing teeth, stretching, scrubbing, and vacuumming.
Exercise	Rowing, lifting weights, spinning, Nordic walking and doing push ups.
Military	Crawling, kneeling, situation assessment and openning a door.
Upper body	Chewing, speaking, swallwing, sighing, and moving the head
Others	Dancing different styles of music: latin, waltz, salsa, etc.

Table 1: Types of activities recognized by Human Activity Recognition Systems

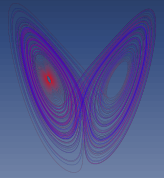


Signal Characterization

Group	Methods
Time domain	Mean, standard deviation, variance, interquartile range, mean absolute deviation, correlation between axes, entropy, and kurtosis.
Frequency domain	Fourier Transform, and Discrete Cosine Transform
Others	Reconstructed State Space, Principal Component Analysis, Linear Discriminant Analysis, Autoregresive Model, and HAAR filters.

Table 2: Featured Extraction Methods[Lara and Labrador, 2013].

Lara, O. D. and Labrador, M. A. (2013).
A Survey on Human Activity Recognition using Wearable Sensors.



Classification

Group	**Classifiers**
Decision tree	C4.5 and ID3
Instance Based	k-nearest neighbors
Neural Networks	Multilayer Perceptron
Domain transform	Support Vector Machines
Fuzzy Logic	Fuzzy Basis Function and Fuzzy Interference System
Regression methods	MLR, ALR
Markov models	Hidden Markov Models and Conditional Random Fields
Classifier ensembles	Boosting and Bagging

Table 3: Classification Algorithms [Lara and Labrador, 2013].

Motion Capture Systems

- Vision-based,
- Floor-sensor based,
- Intertial-sensor based:
  - Human Body-sensed
  - Foot-sensed

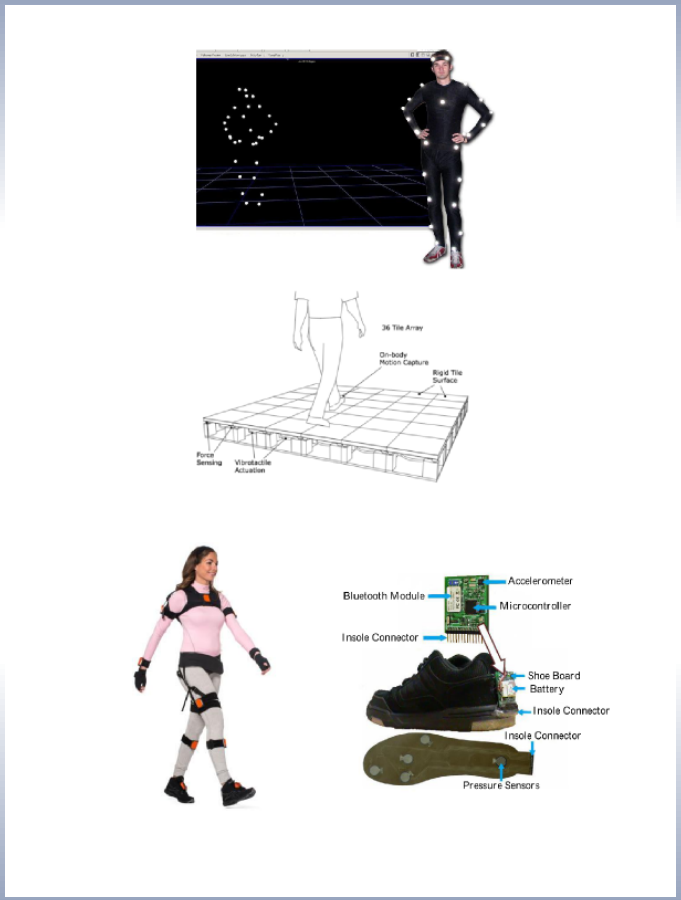
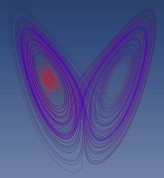
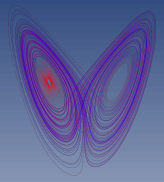


Figure 3: Motion Capture Systems



Presentation Outline

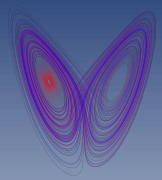


The Human Body as a Complex Dynamical System

Human Body Movement is the result of a complex dynamical system that include:

- Muscular system,
- Cardiovascular system,
- Skeletal system, and
- Nervous system.

Figure 4: Human Body Systems



Nonlinear Dynamics in the Human Body

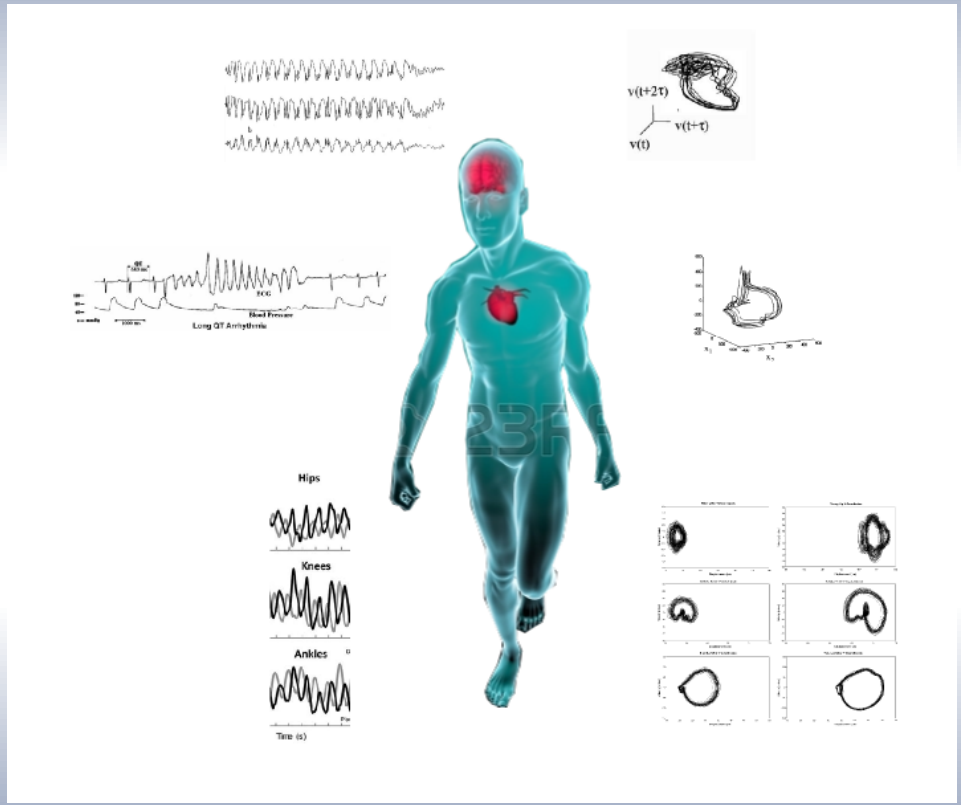
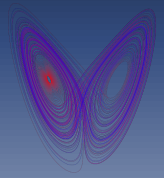


Figure 5: Some Time-Series from the Human Body



Time-Delay Embedding in HAR

[Jordan et al., 2010] and [Samà et al., 2013] have proposed the use Taken's Theorems so as to indenfity primitive human activities such as walking, cycling, and running. However, little has been done regarding the identification of complex activities that, for example, involve dance.

Jordan, F., Mannor, S., and Precup, D. (2010).
Activity and Gait Recognition with Time-Delay Embeddings.

Samà, A., Ruiz, F. J., Agell, Agell, N., Pérez-López, C., Català, A., and Cabestany, J. (2013).
Gait identification by means of box approximation geometry of reconstructed attractors in latent space.

Takens' Theorem (1981)

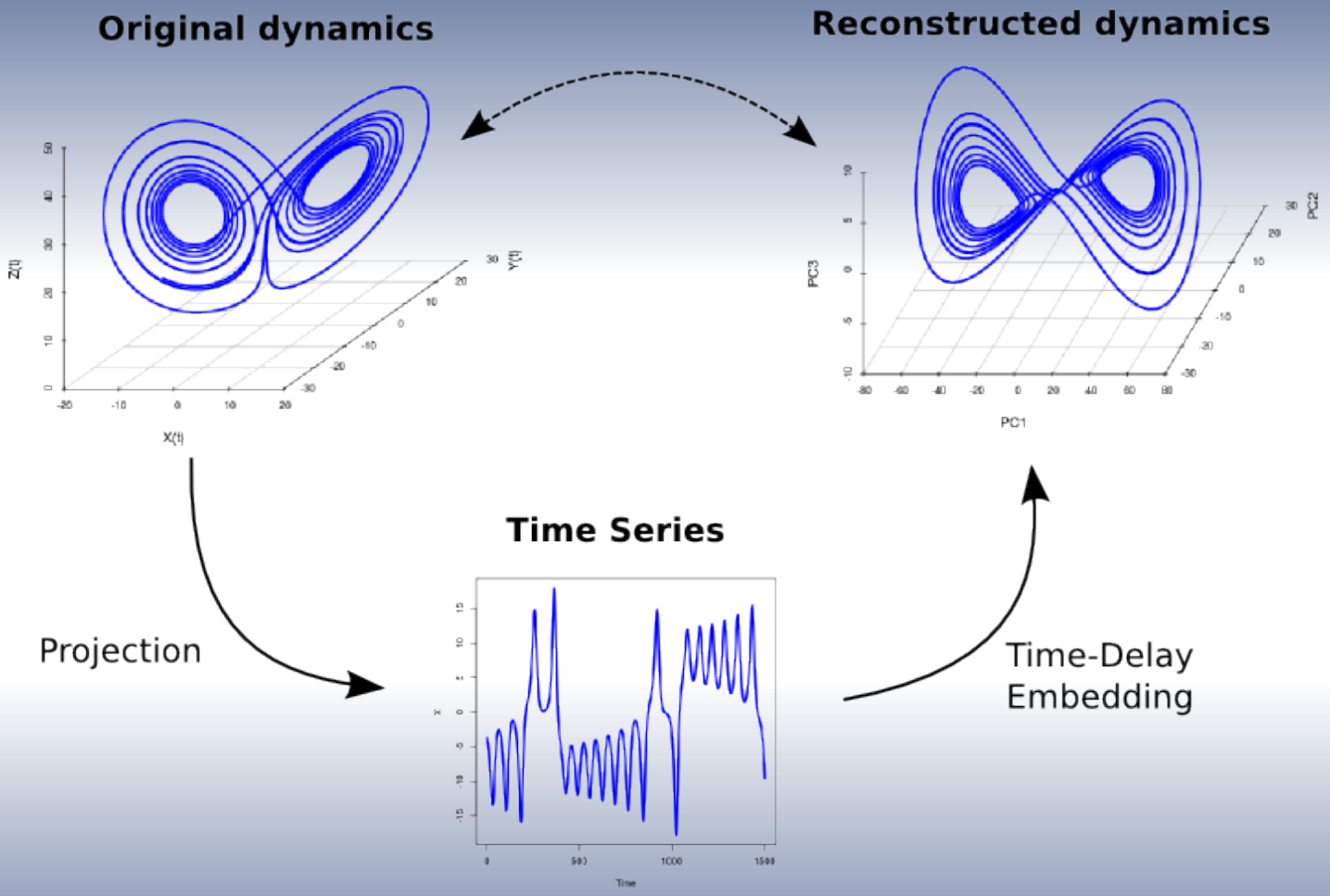
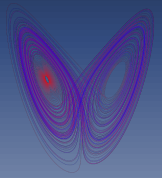


Figure 6: Reconstructed State Space Via Taken's Theorem

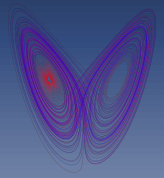


Takens' Theorem (1981)

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

$$E(i) = (x_i, x_{i+\tau}, x_i, x_{i+2\tau}, ..., x_i, x_{i+(m-1)\tau}).$$

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_i, this method provides a one-to-one reconstruction of the true dimension k system ($\mathbb{R}^k$).



Lorenz System

$$\begin{aligned}\frac{dx}{dt} &= \sigma(x-y),\\ \frac{dx}{dt} &= x(\rho-z)-y,\\ \frac{dx}{dt} &= xy-\beta z.\end{aligned}$$

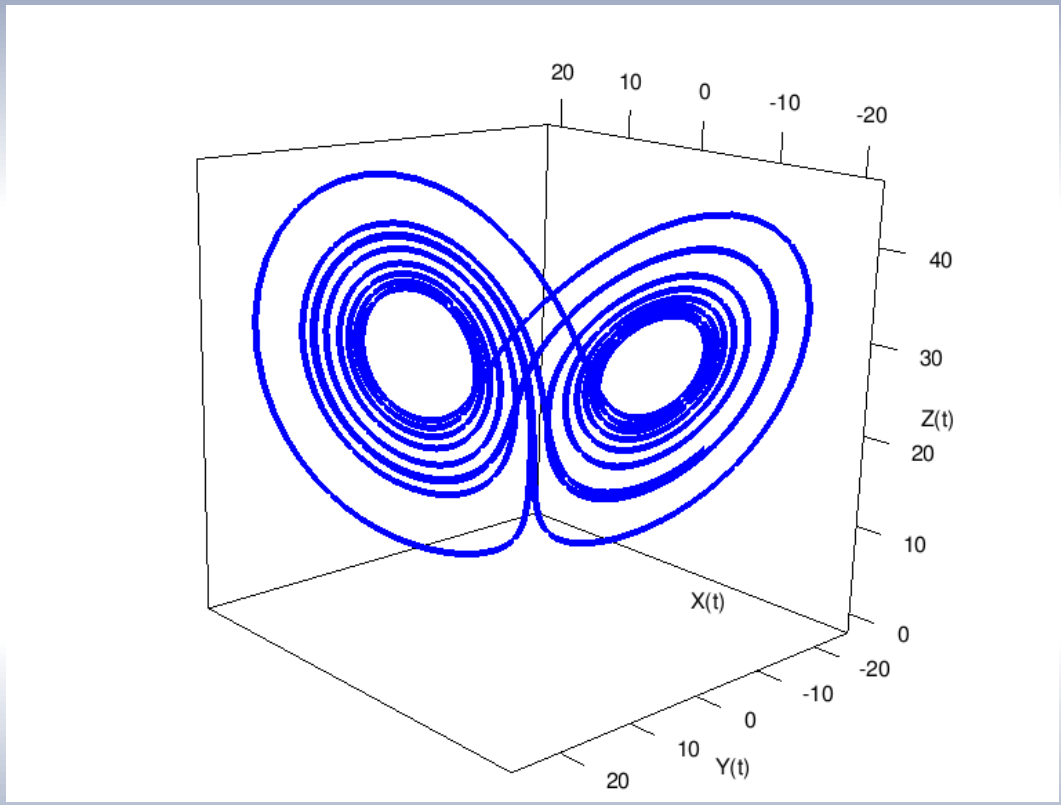


Figure 7: $\sigma = 10$, $\rho = 28$ and $\beta = 3/8$

Time-Delay Embedding Example

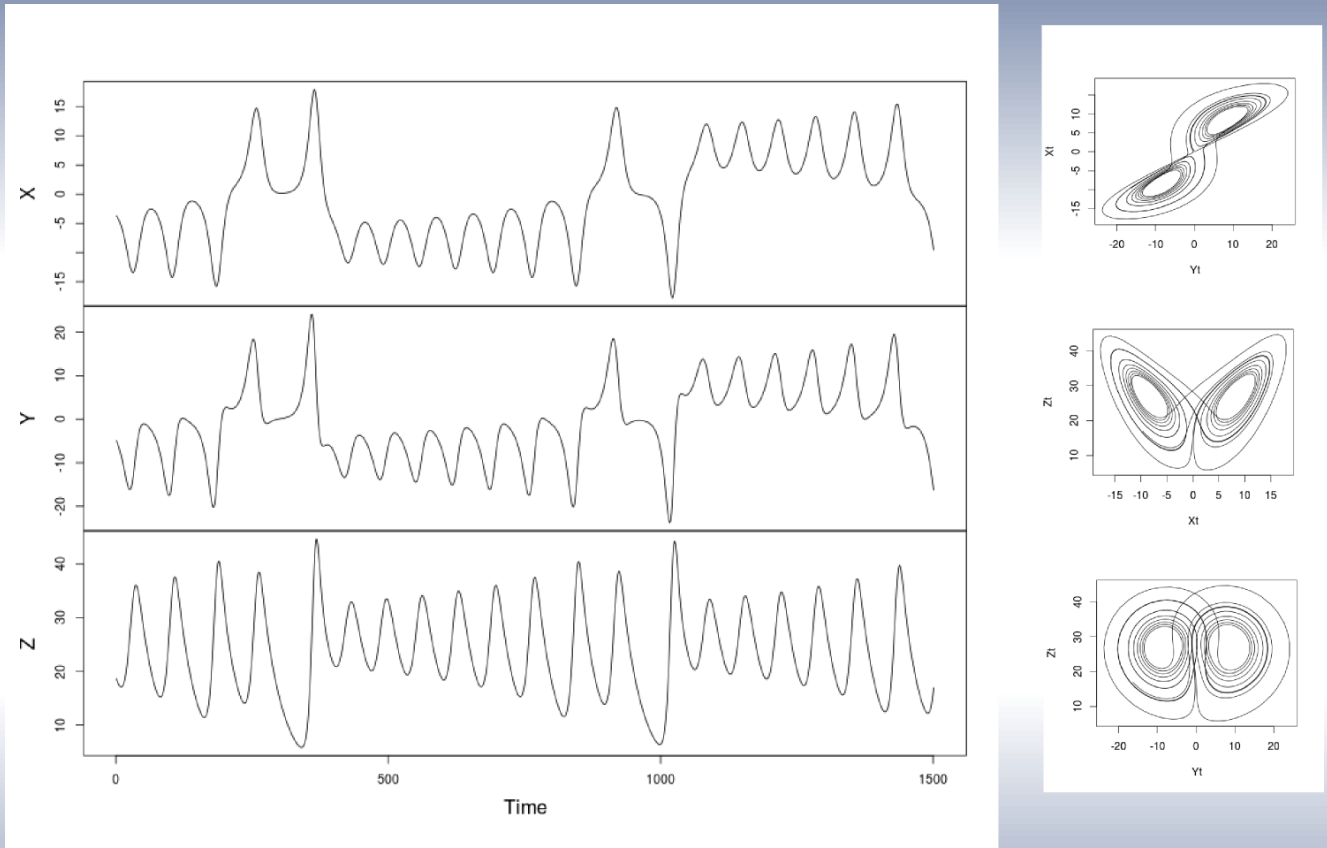
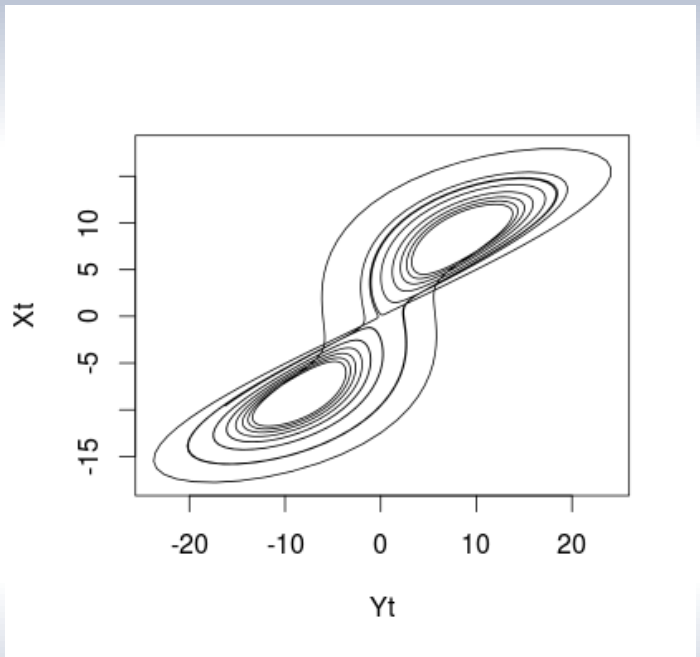


Figure 8: Time series of the Lorenz System and 2D manifolds

Time-Delay Embedding Example



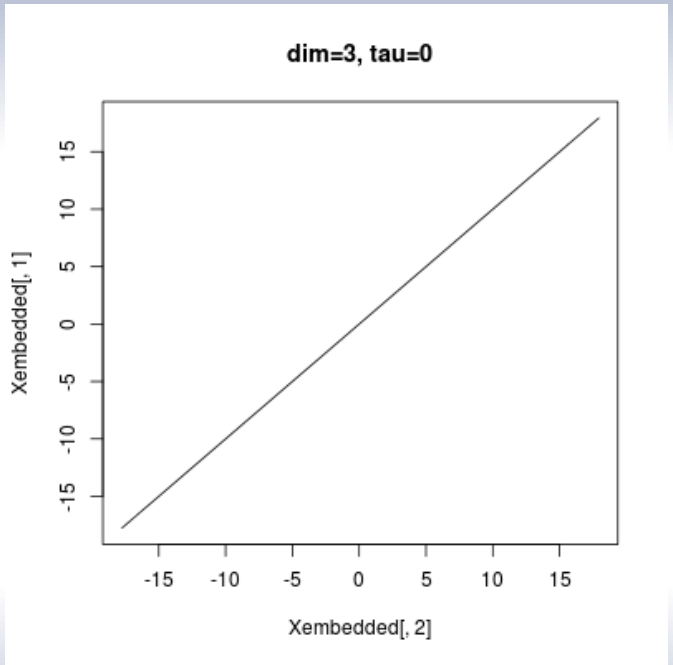
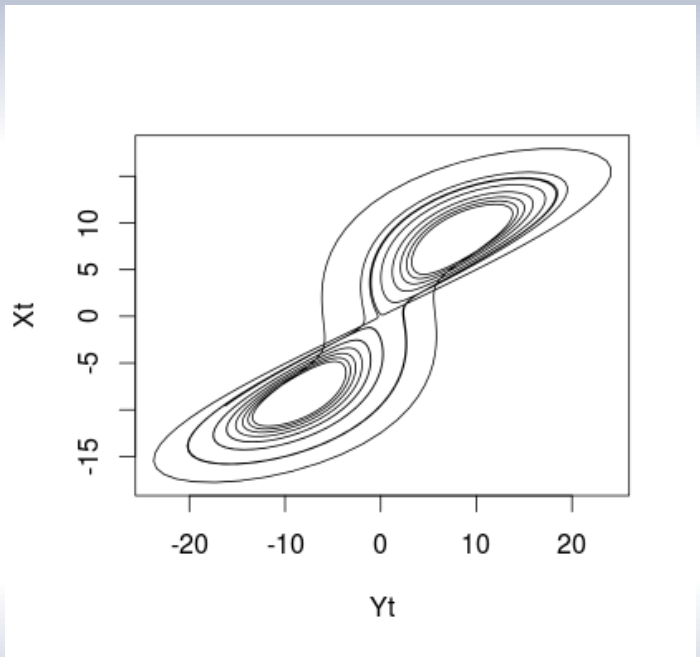
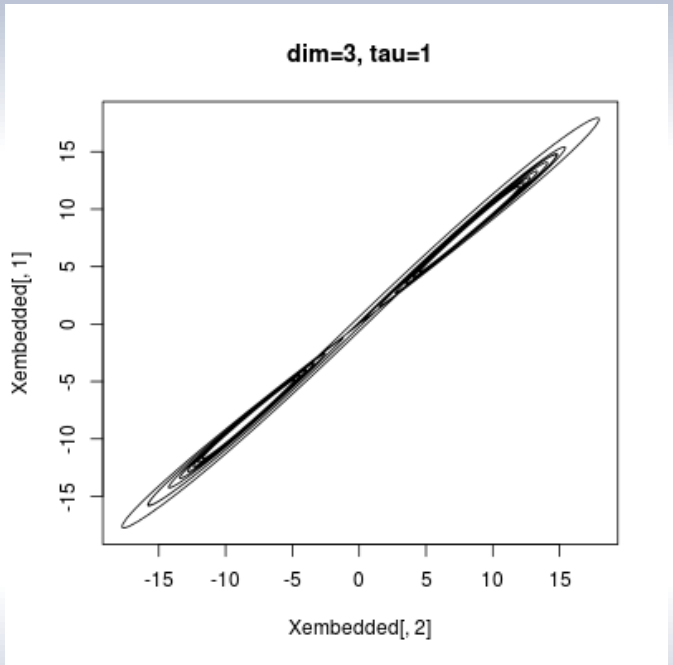


Figure 9: Original Manifold

Time-Delay Embedding Example





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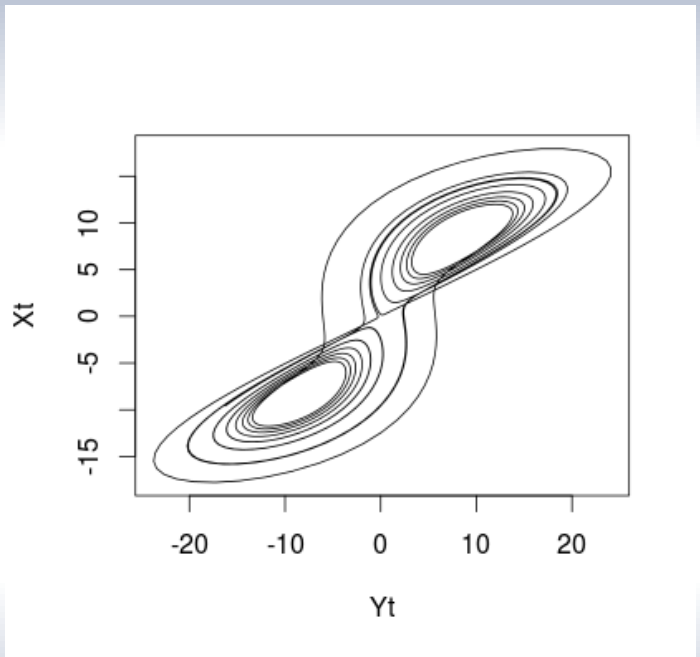
Time-Delay Embedding Example



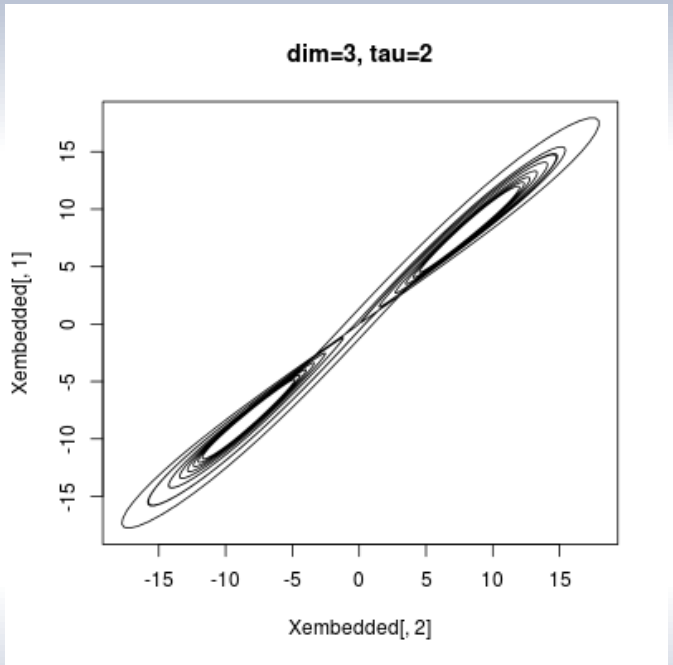
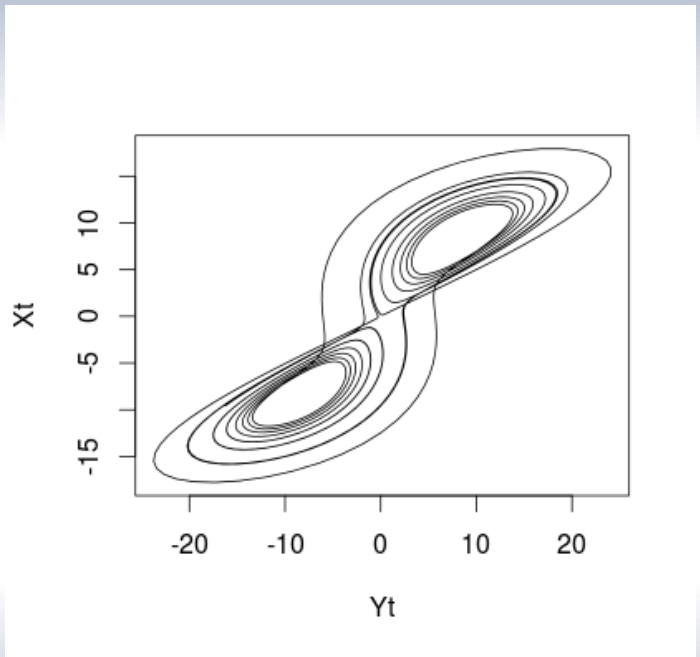
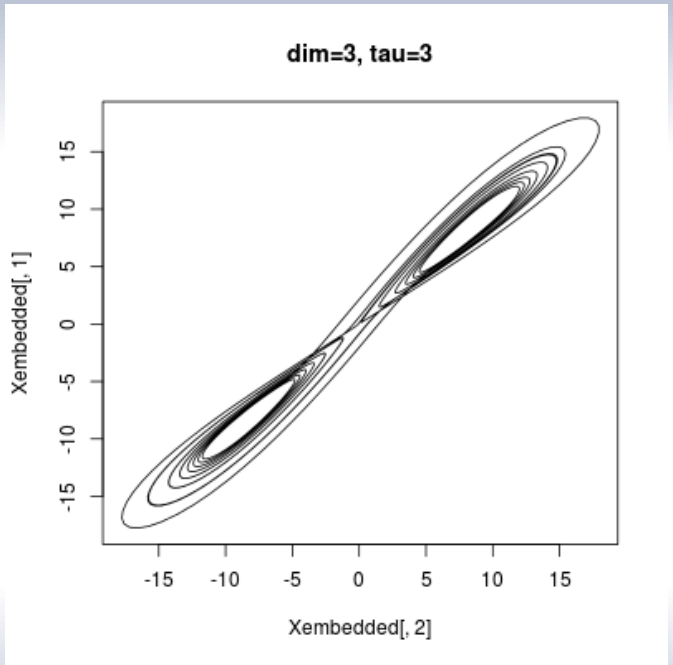


Figure 9: Original Manifold

Time-Delay Embedding Example





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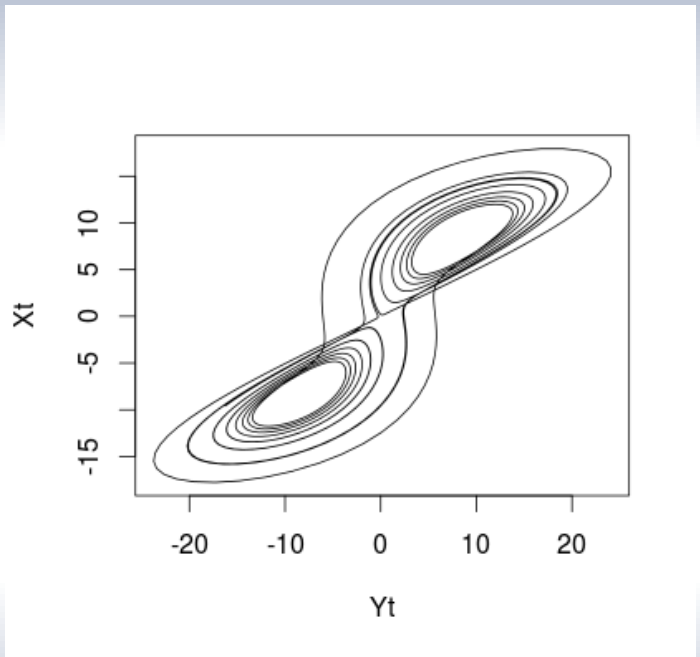

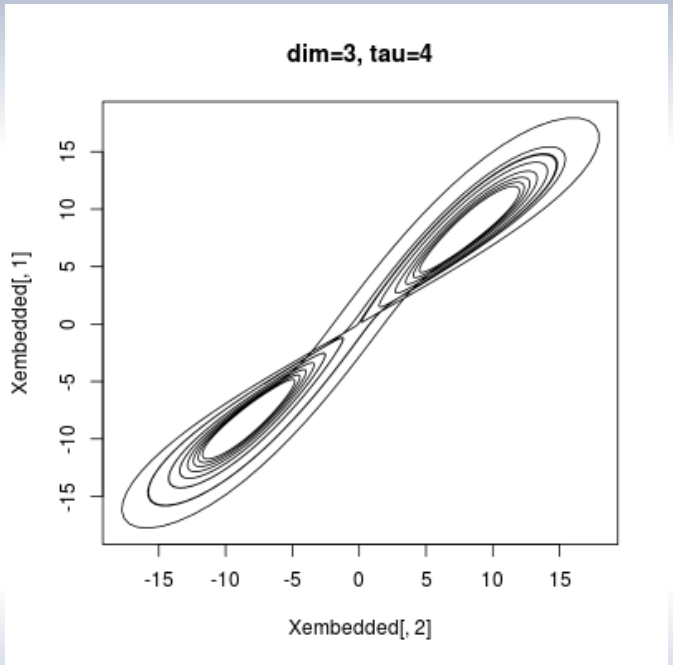

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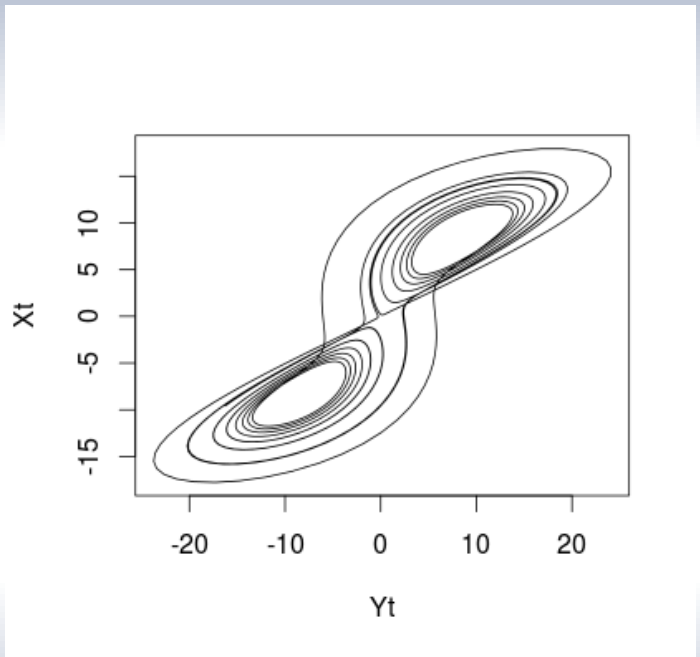

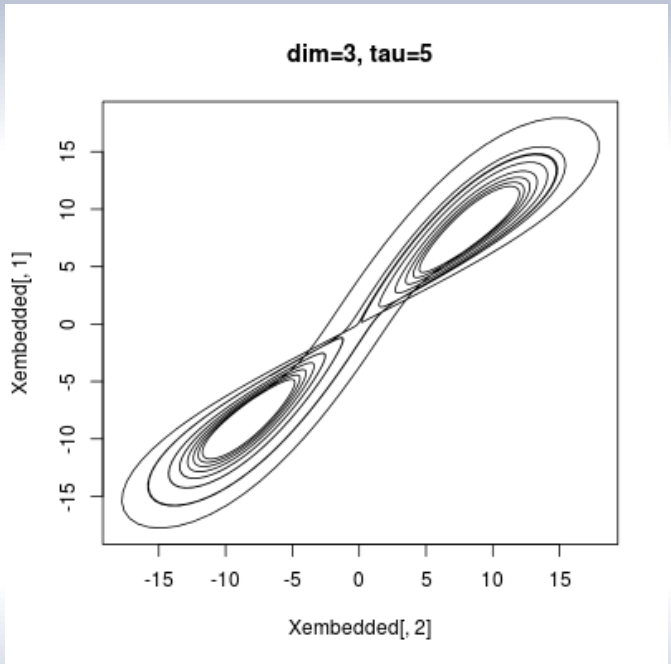

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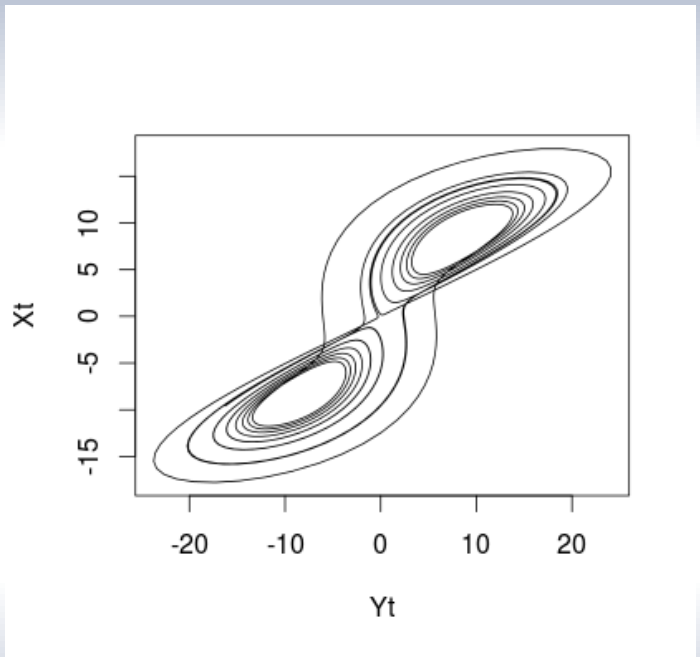

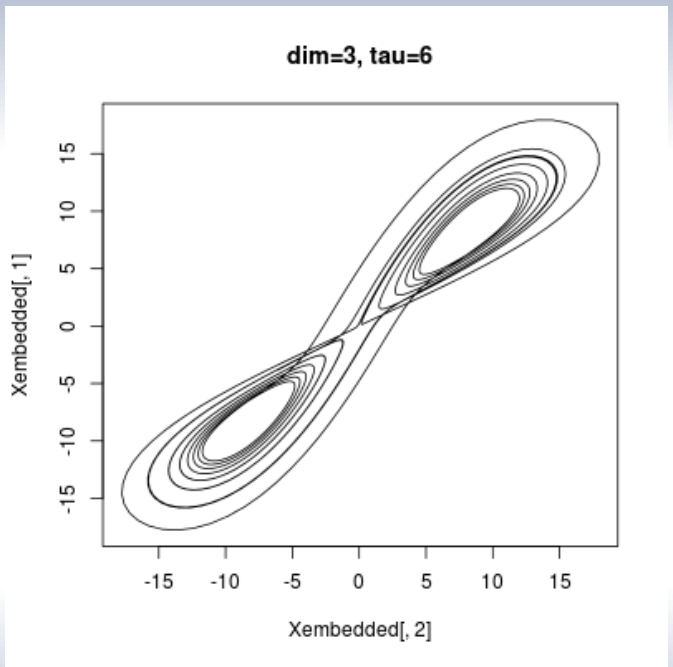

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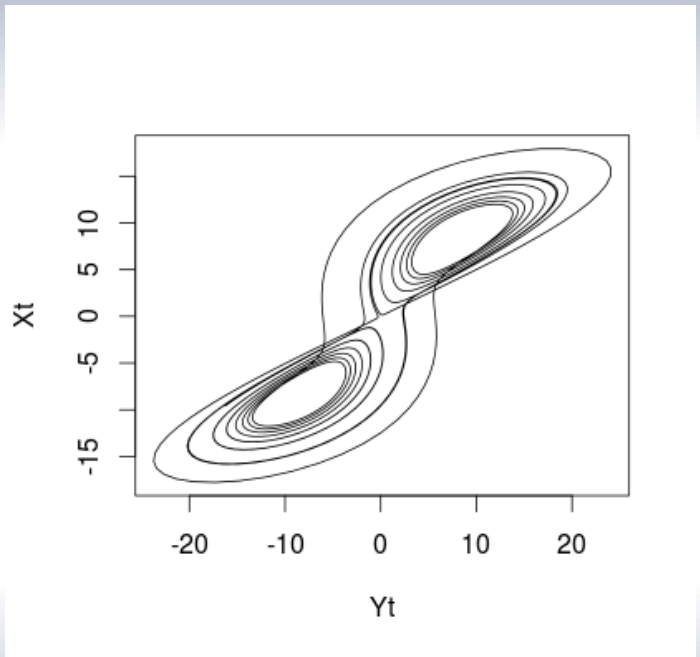

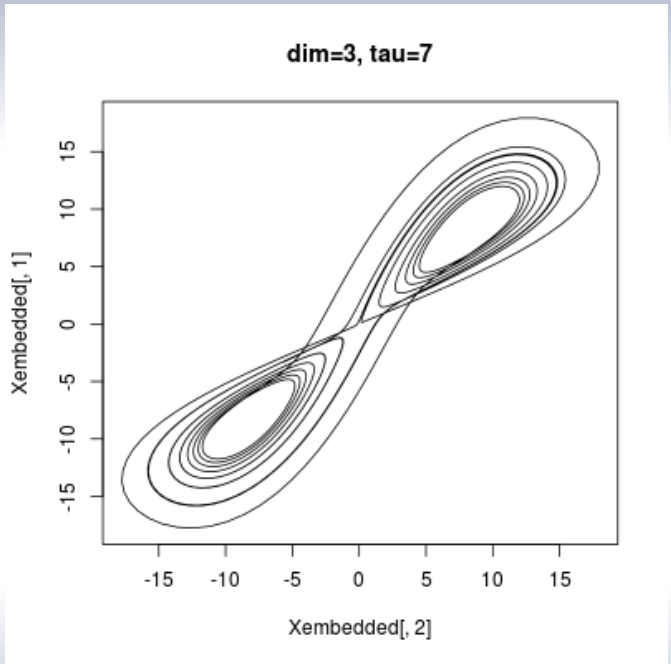

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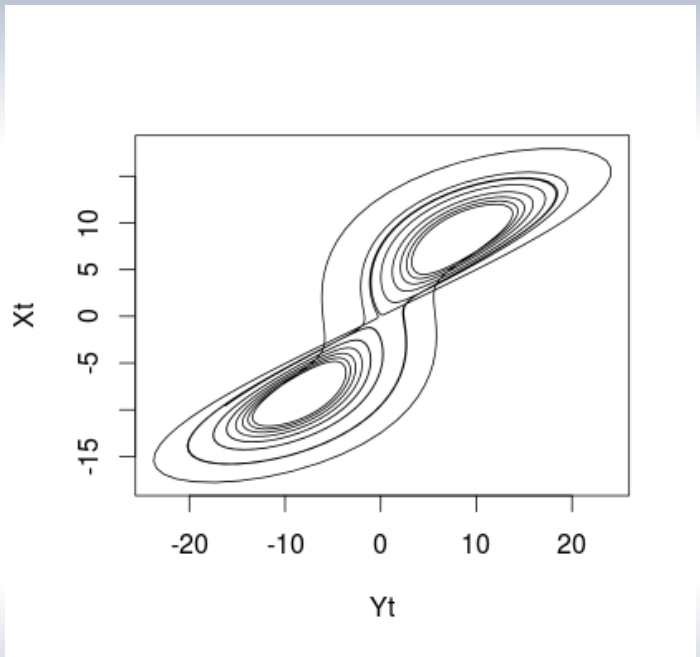

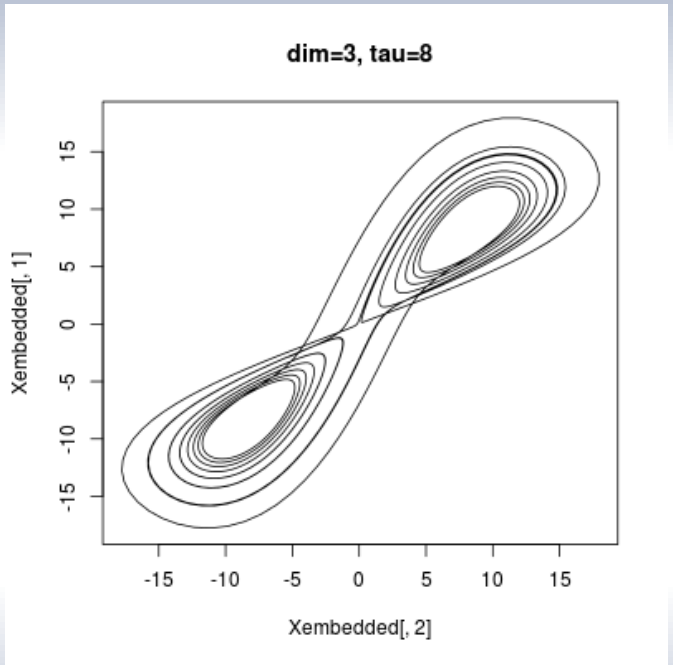

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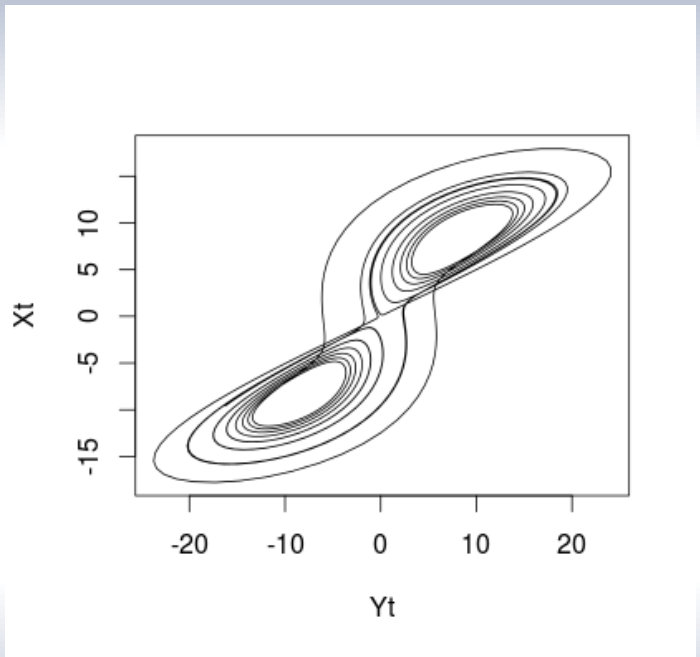

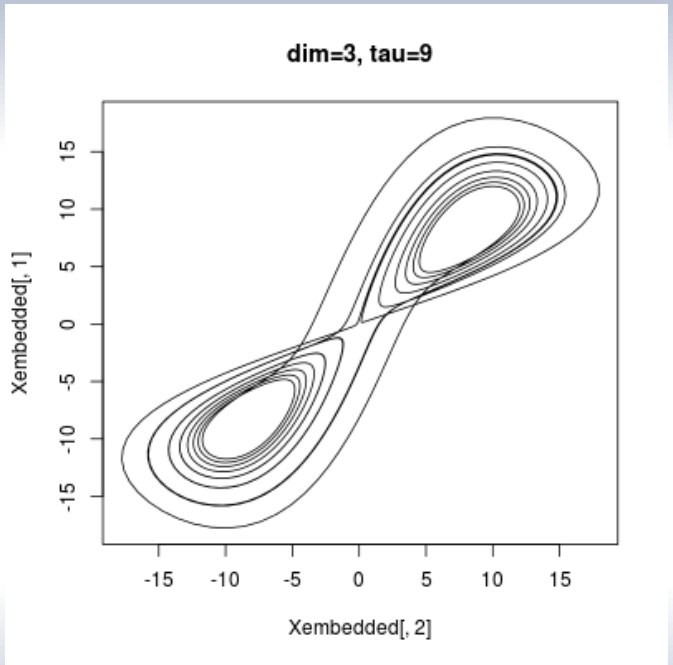

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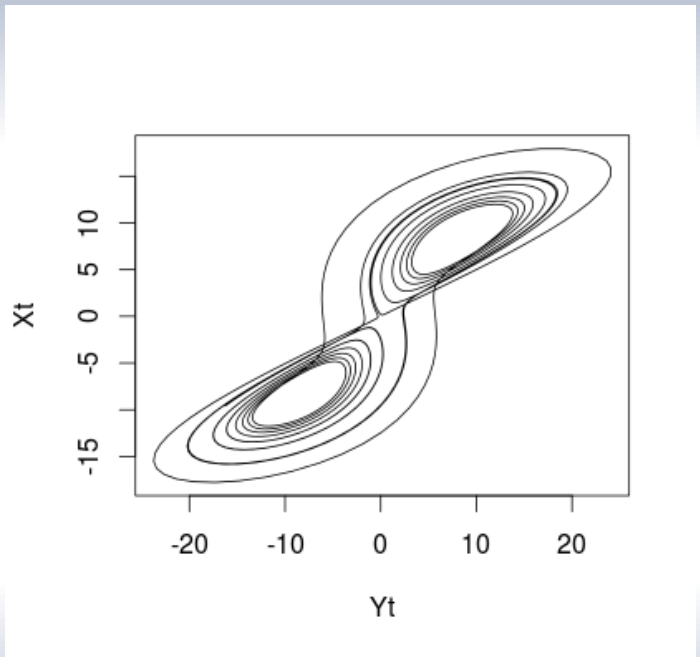

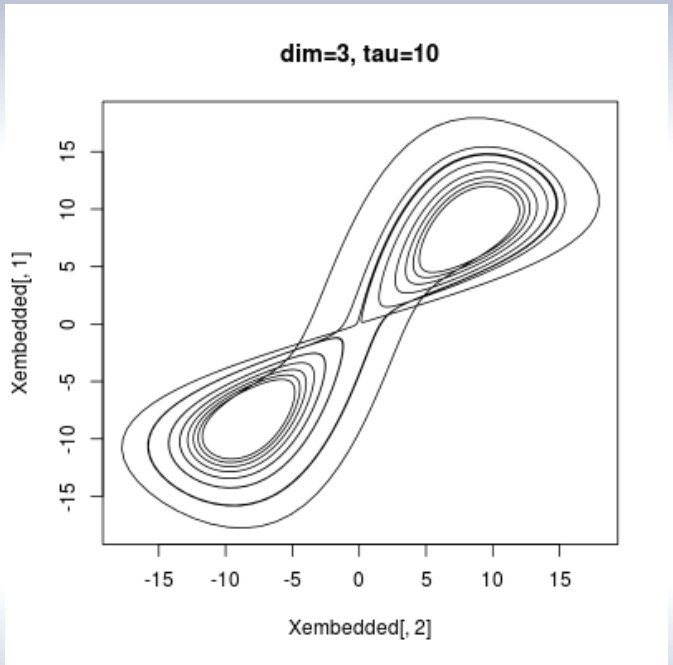

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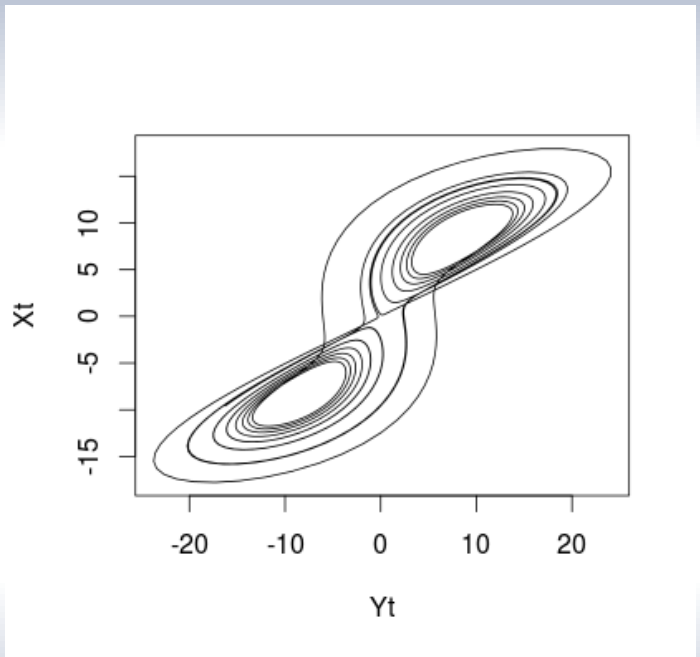

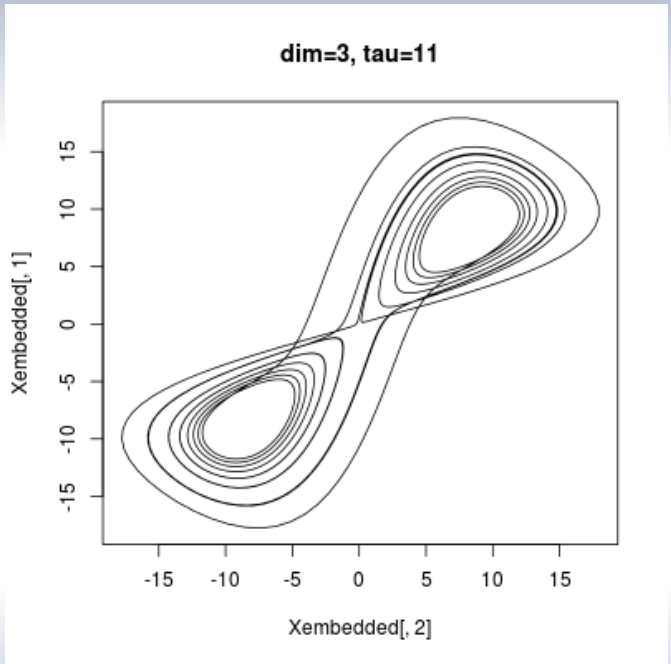

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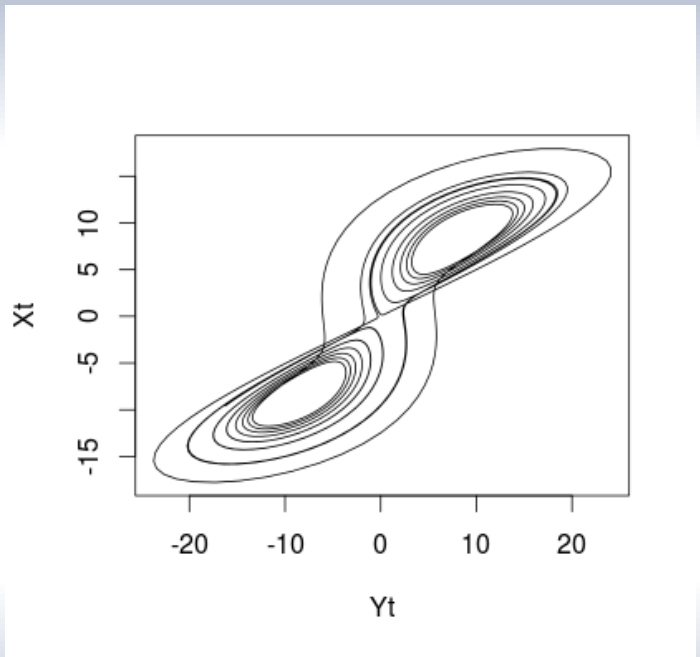
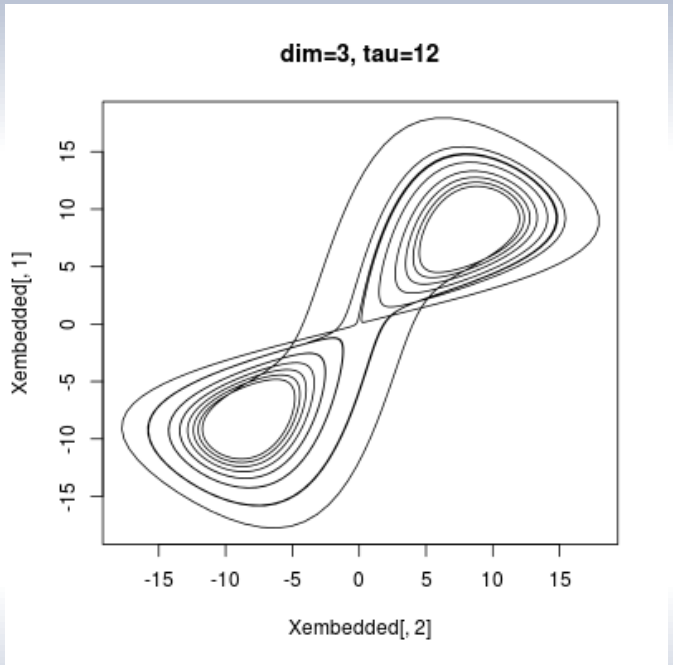
Time-Delay Embedding Example





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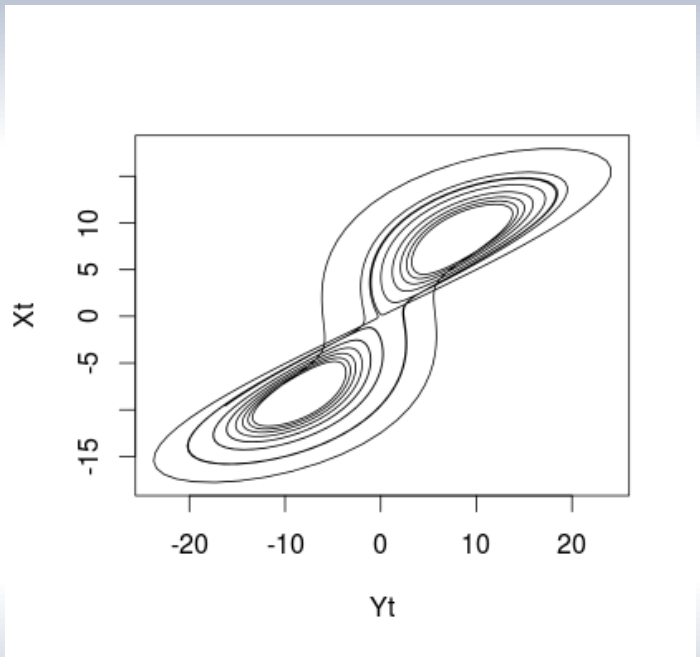

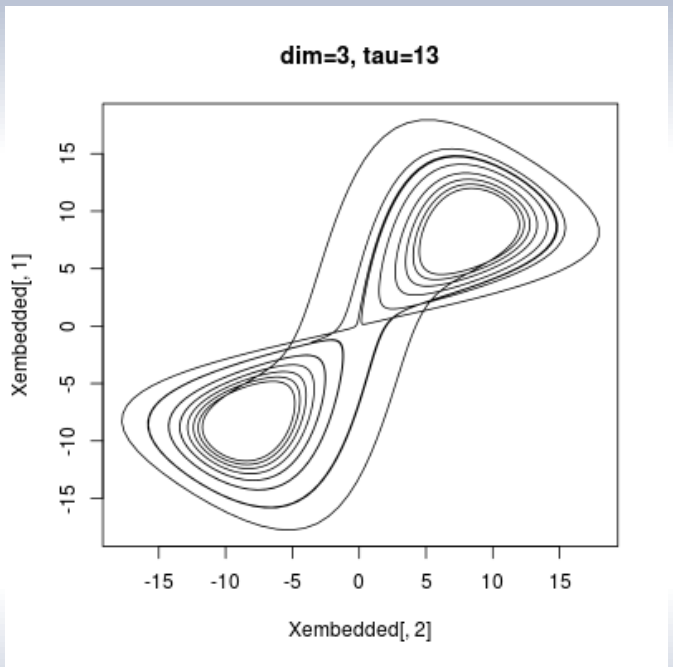

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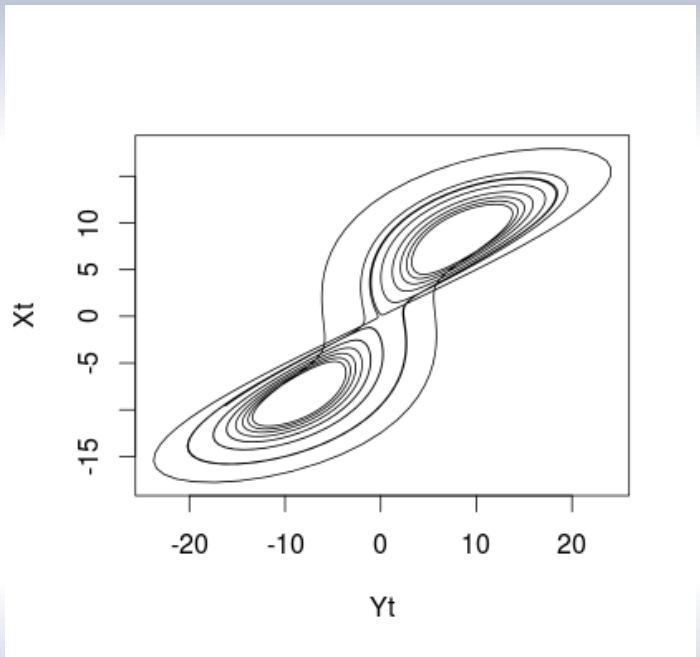

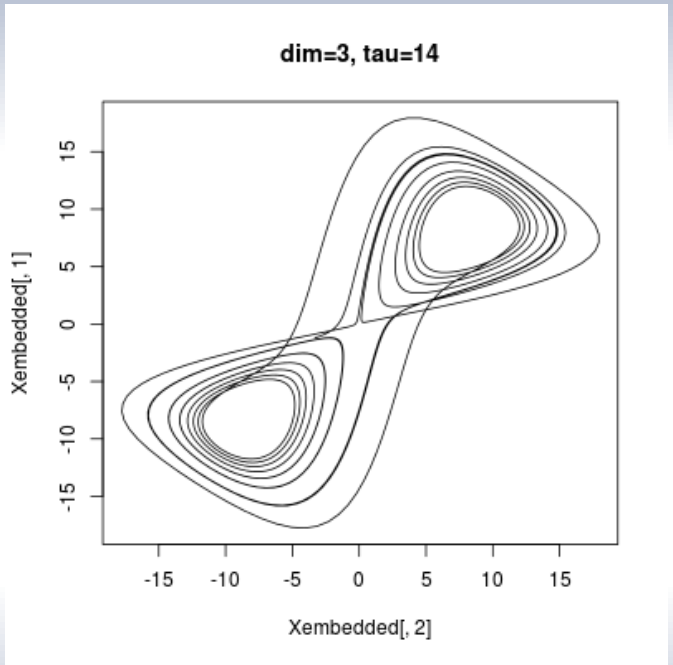

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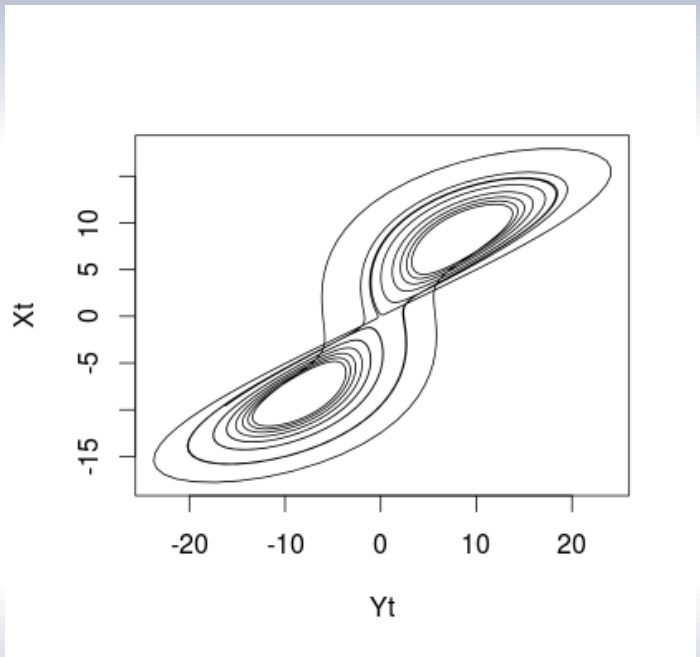

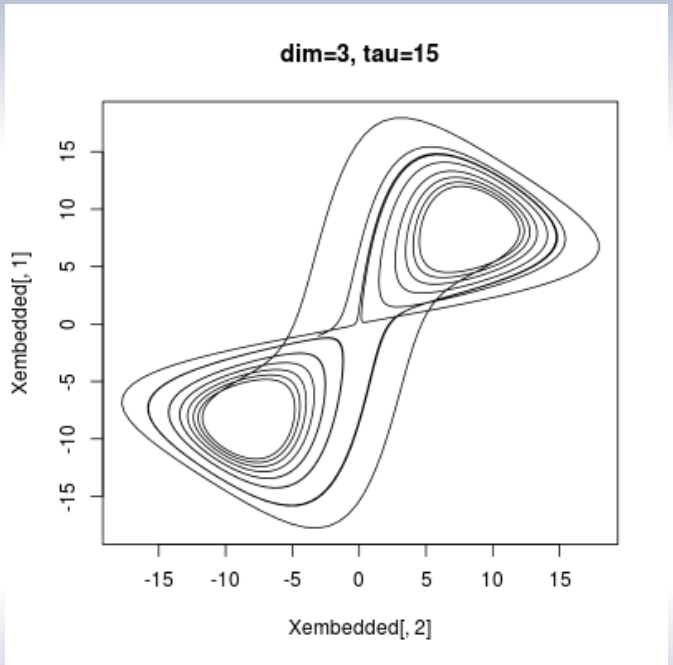

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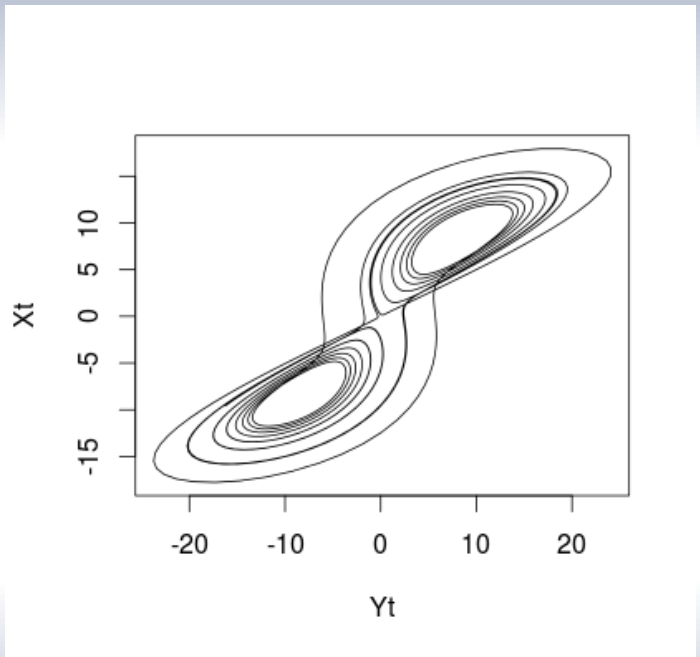
Time-Delay Embedding Example



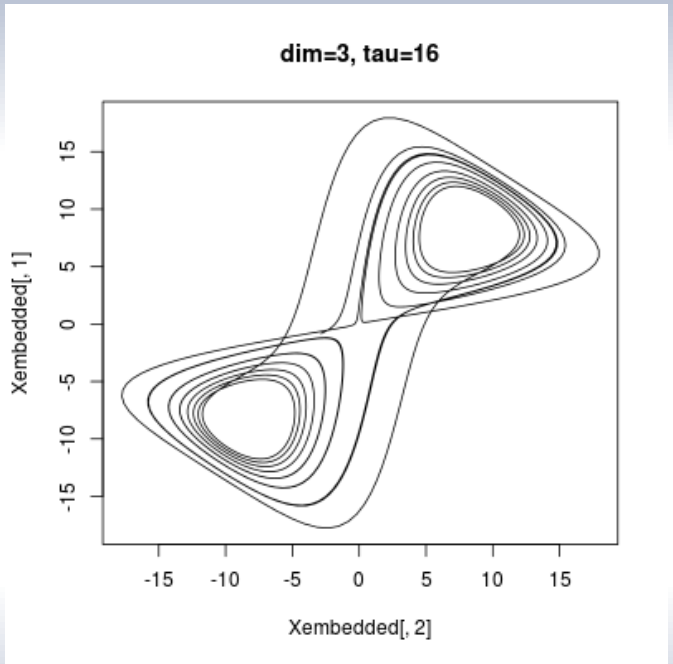
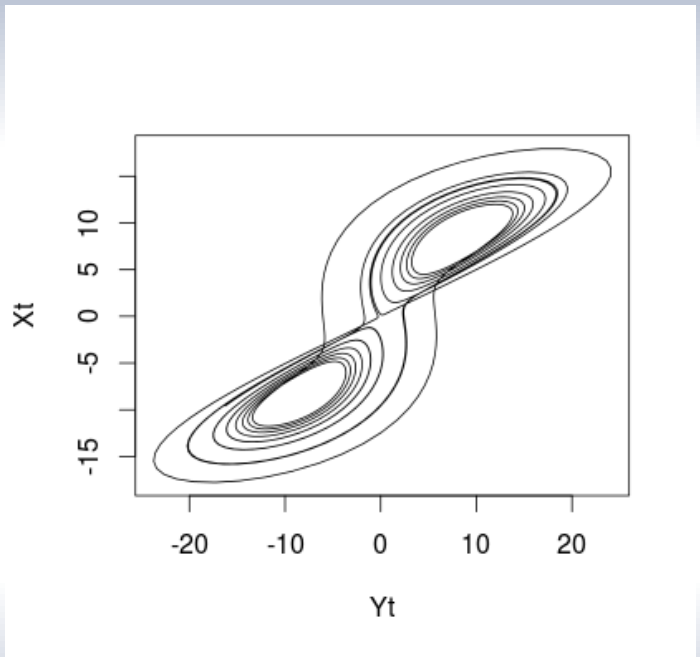


Figure 9: Original Manifold

Time-Delay Embedding Example



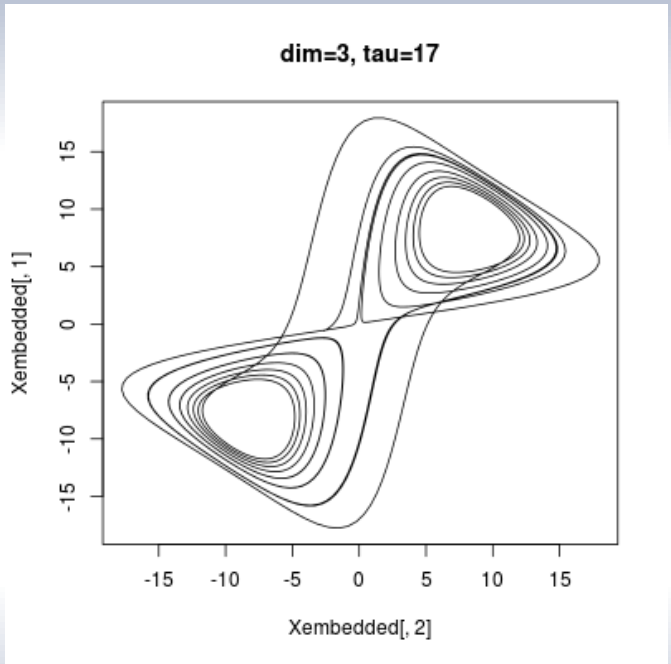
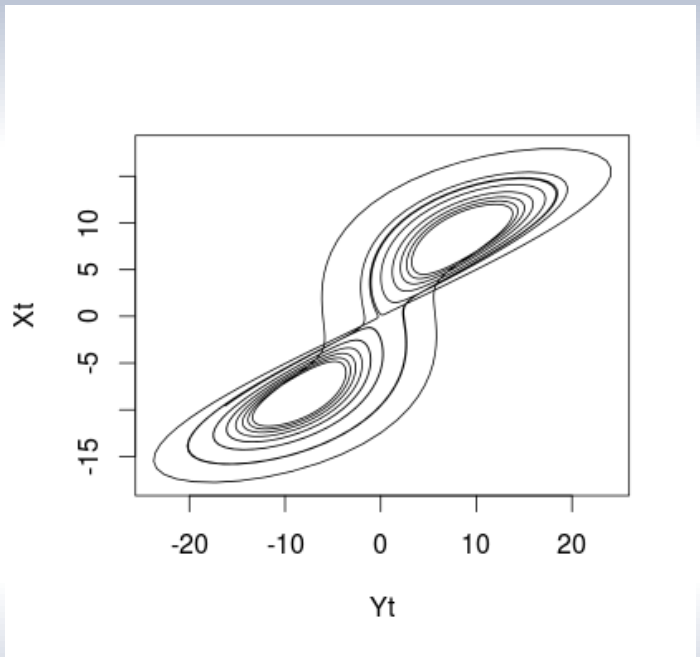


Figure 9: Original Manifold

Time-Delay Embedding Example



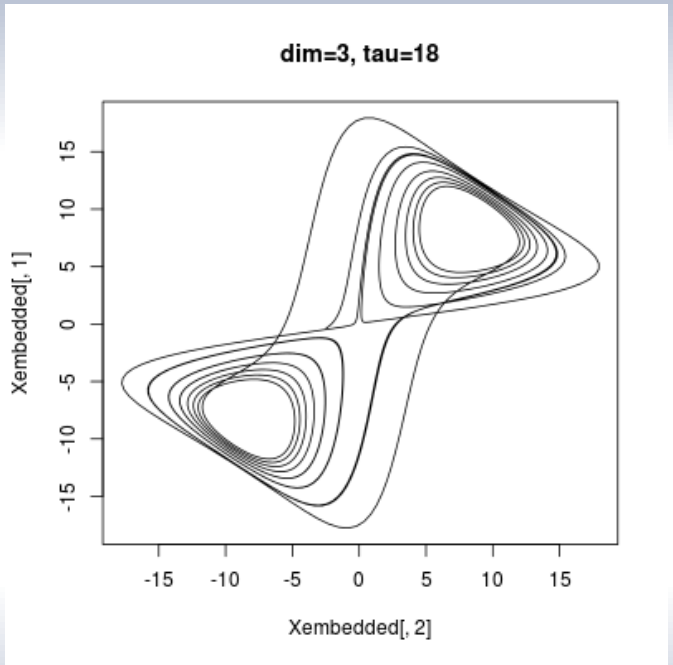
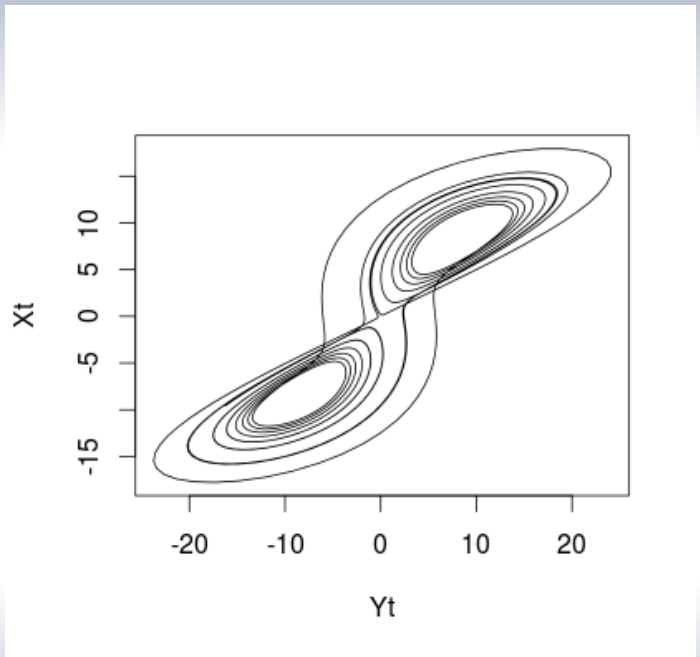


Figure 9: Original Manifold

Time-Delay Embedding Example



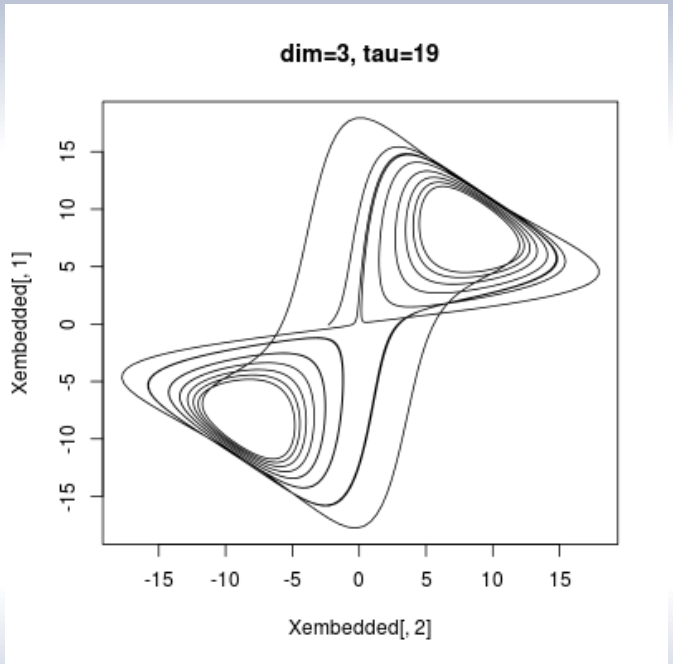


Figure 9: Original Manifold

Time-Delay Embedding Example

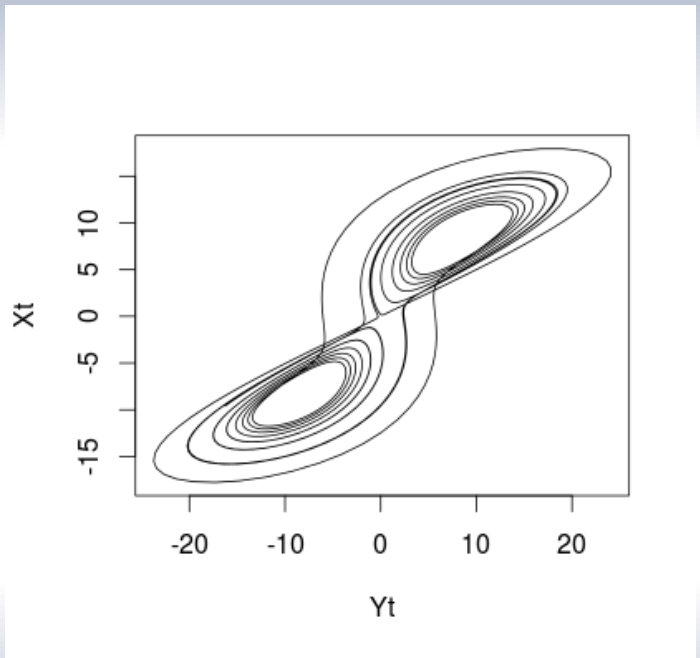


Figure 9: Original Manifold

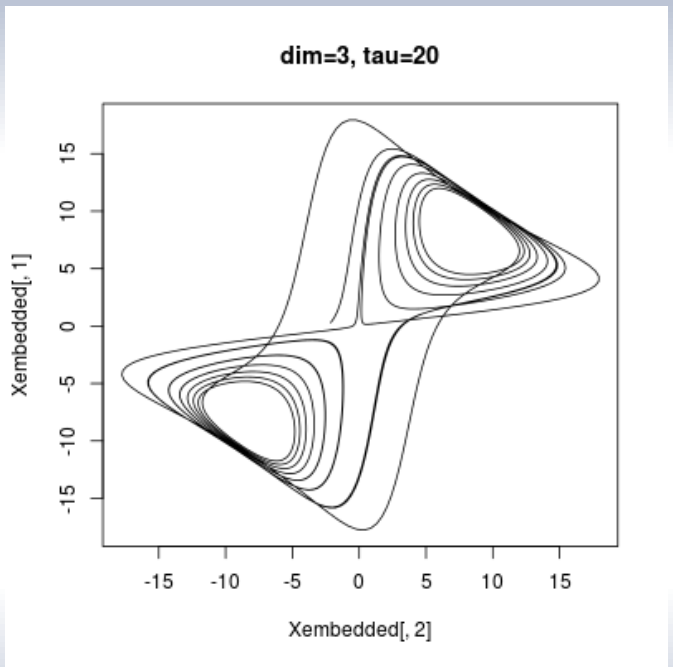


Figure 10: Reconstructed Manifold

Optimal embedding parameters

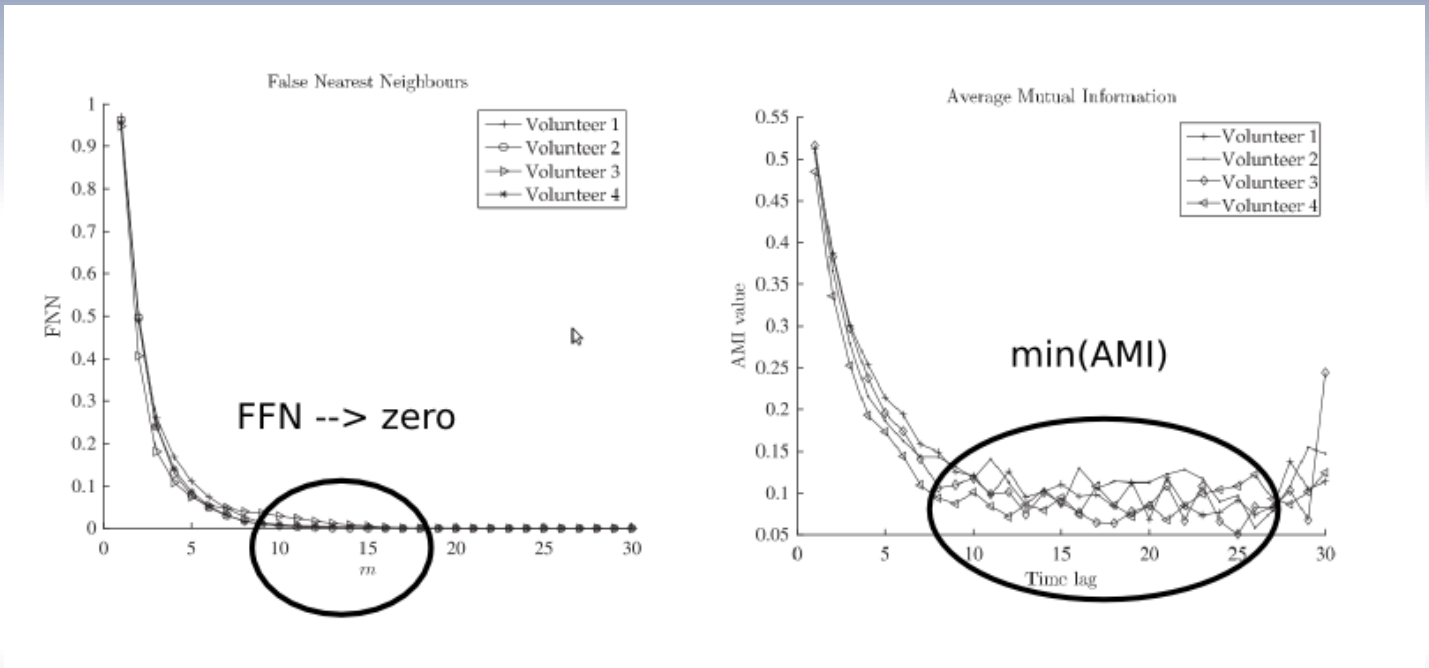
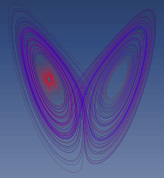


Figure 11: FFN and AMI Plots for different volunteers [Samà et al., 2013]



Presentation Outline

Basic Dance Foot Patterns

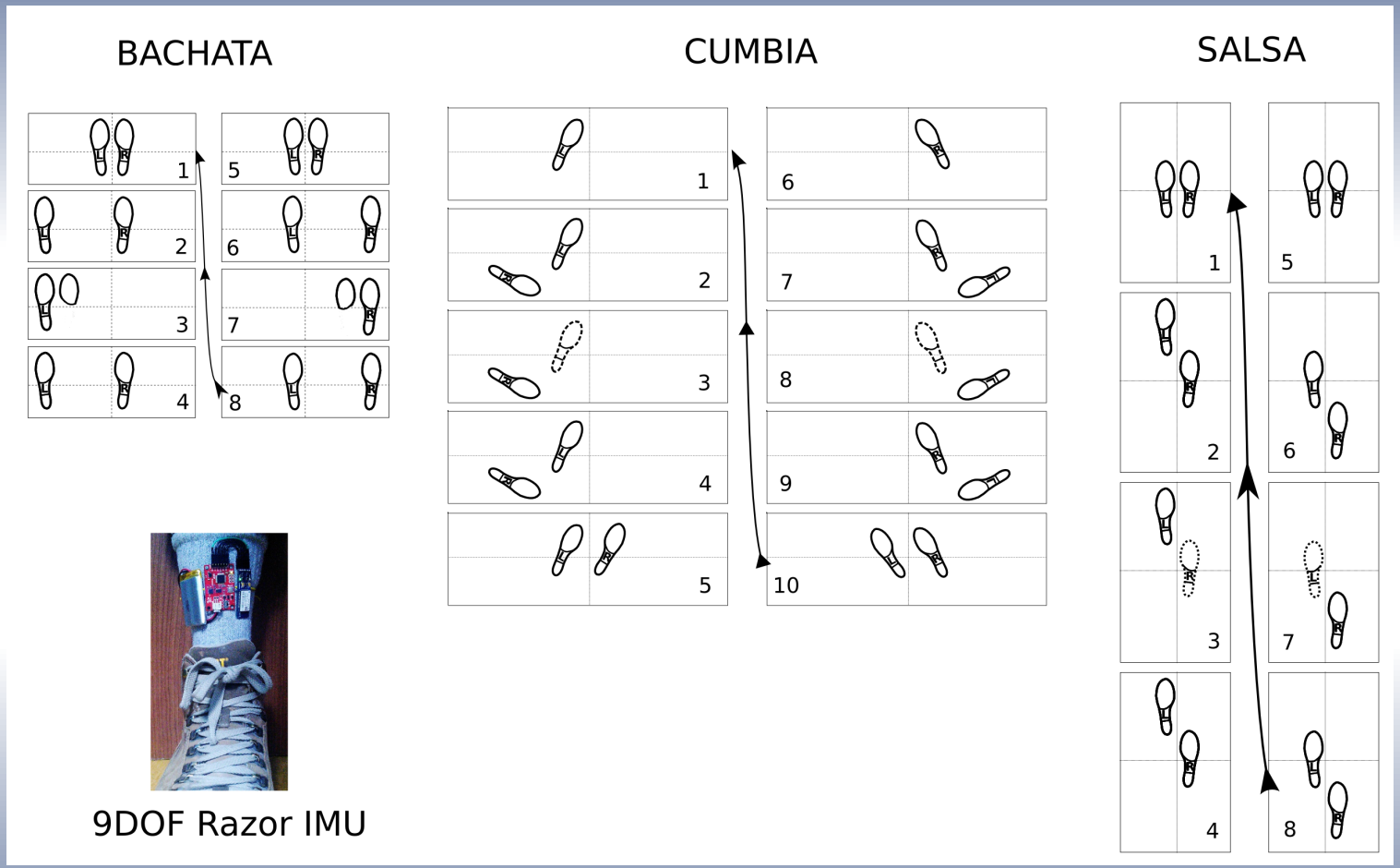


Figure 12: Latin Dance Foot Patterns

Reconstructed State Spaces

BACHATA CUMBIA SALSA

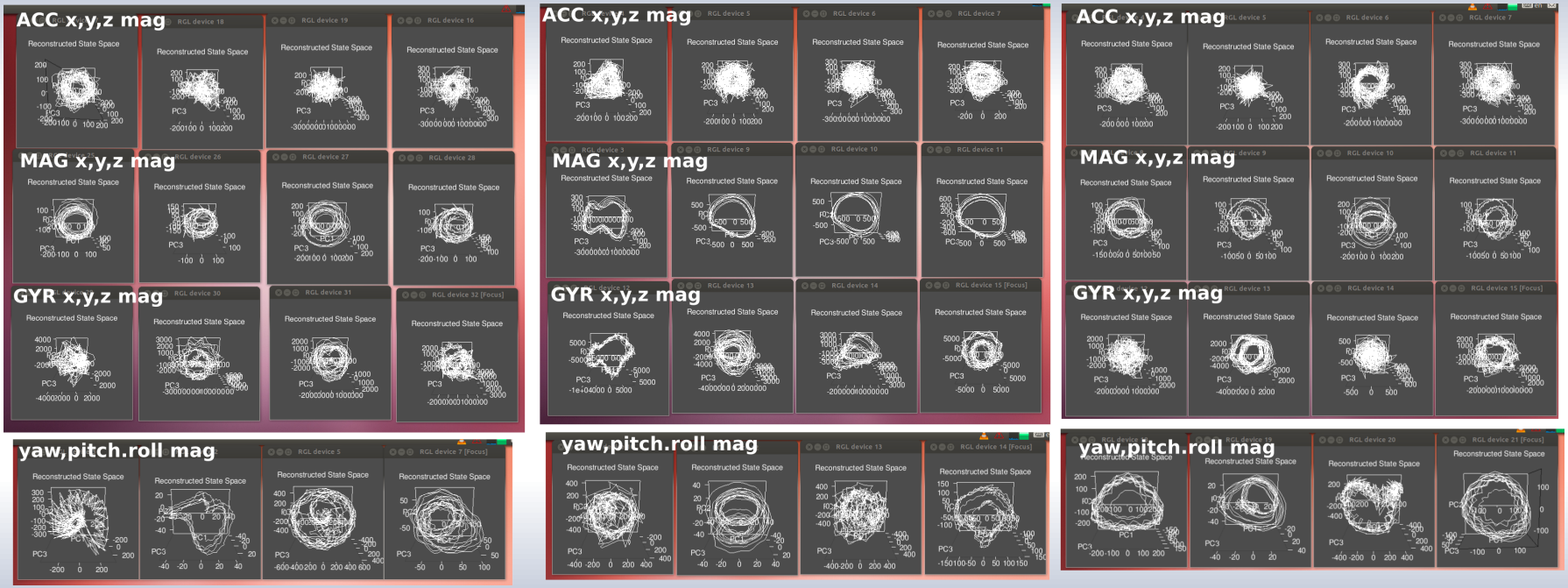


Figure 13: 3D Reconstructed State Space with $m = 20$ and $\tau = 5$ for a WF=1000.

Pitch Angle Time Series for Bachata

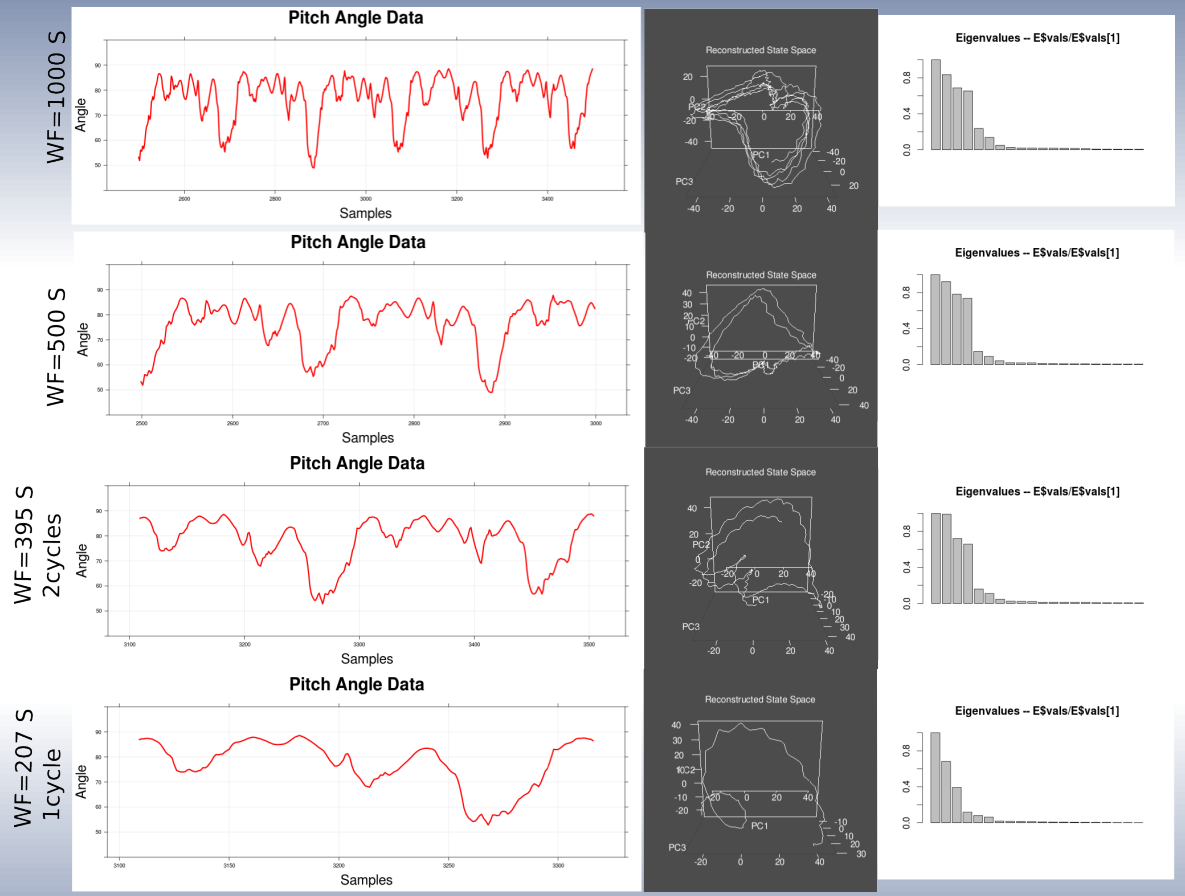


Figure 14: 3D Reconstructed State Space and Eigenvalues

Pitch Angle Time Series for Cumbia

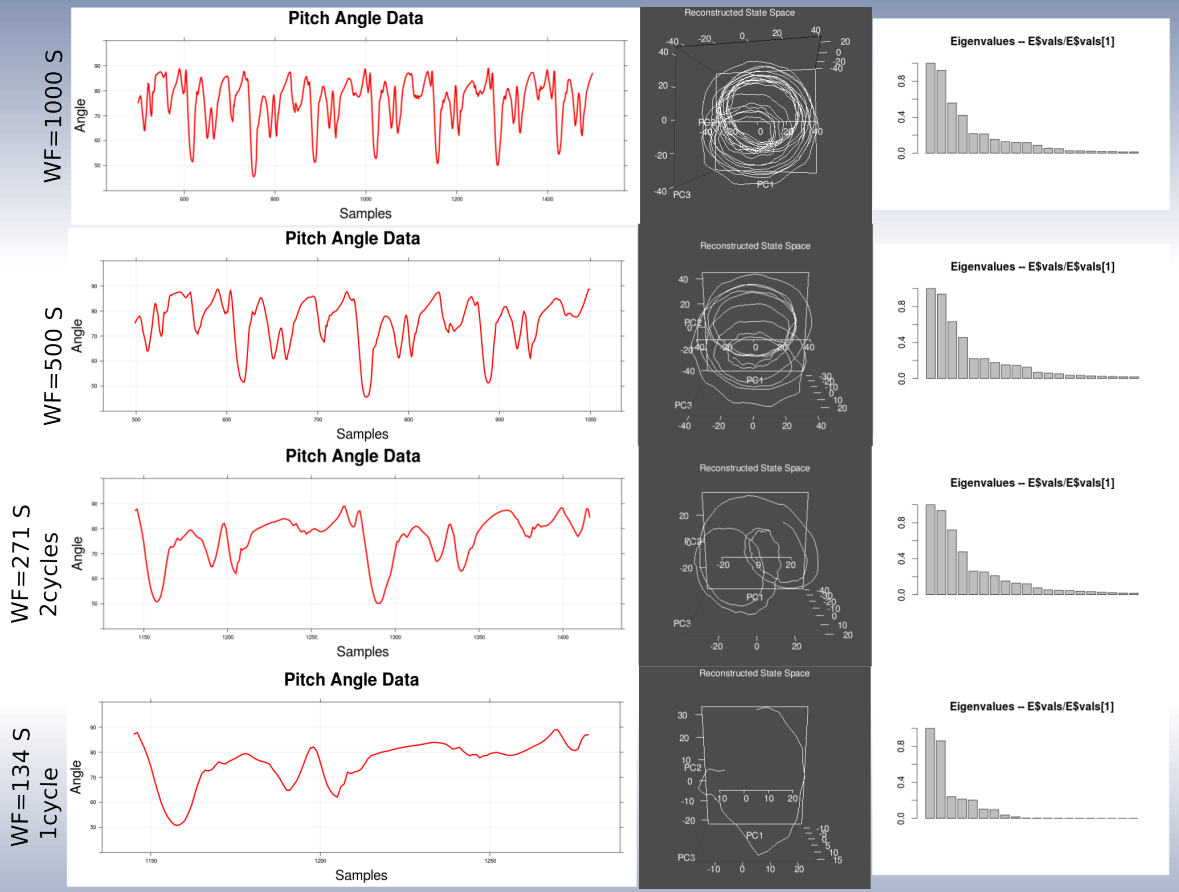


Figure 15: 3D Reconstructed State Space and Eigenvalues

Pitch Angle Time Series for Salsa

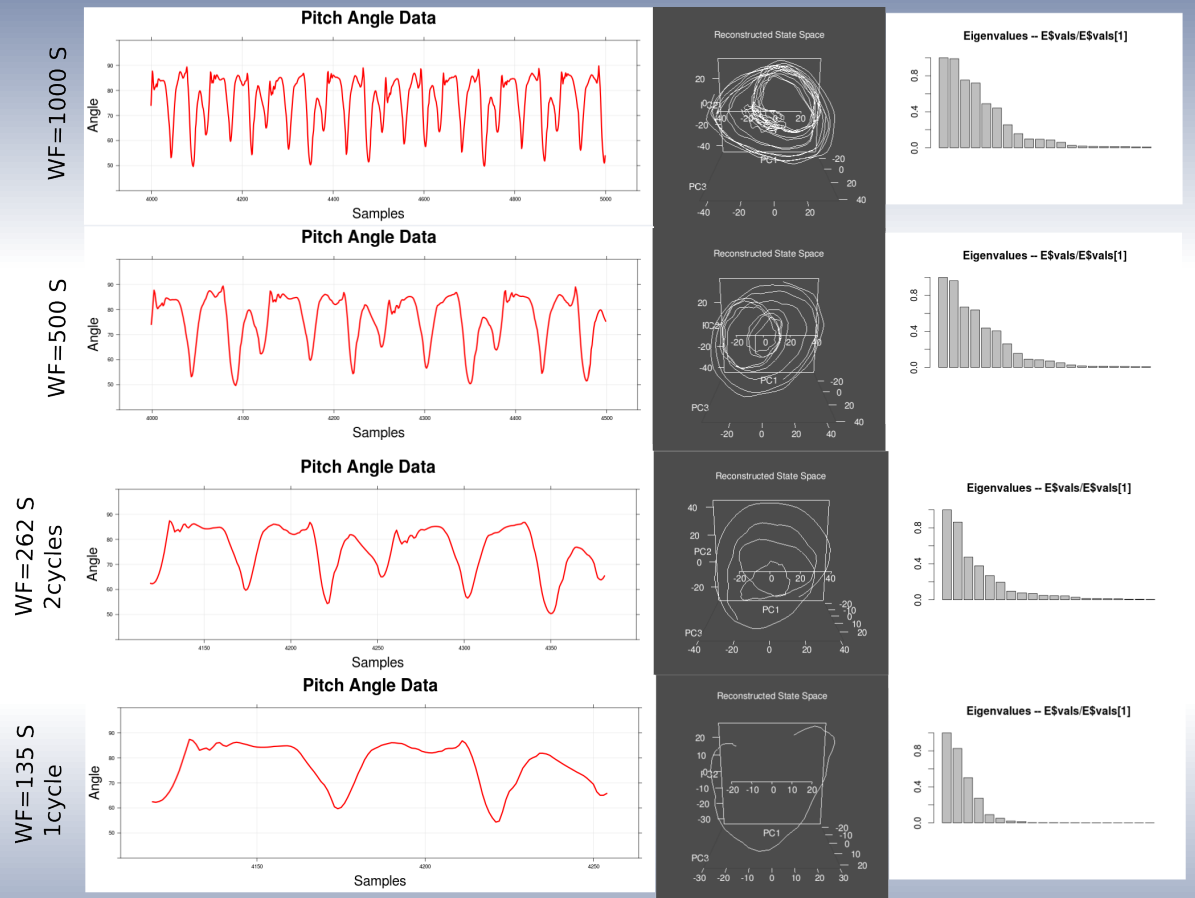
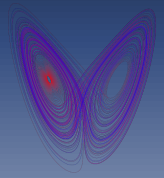
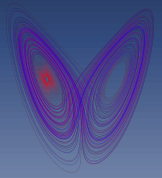


Figure 16: 3D Reconstructed State Space and Eigenvalues



Presentation Outline



Some questions for my PhD investigation

??????????????????????

- Which non-reported concepts from nonlinear dynamics can be used to obtain features in the human body analysis?
- It has been reported that up to 50 human activities can be recognized using video based approach. How many human activities and with what accuracy can be recognised using the current work?
- Will it be useful to obtain mathematical models for each human body activity?