# DAMOCO: MATLAB toolbox for multivariate data analysis, based on coupled oscillators approach
# Example 4

January 16, 2011

## 1 Data and method

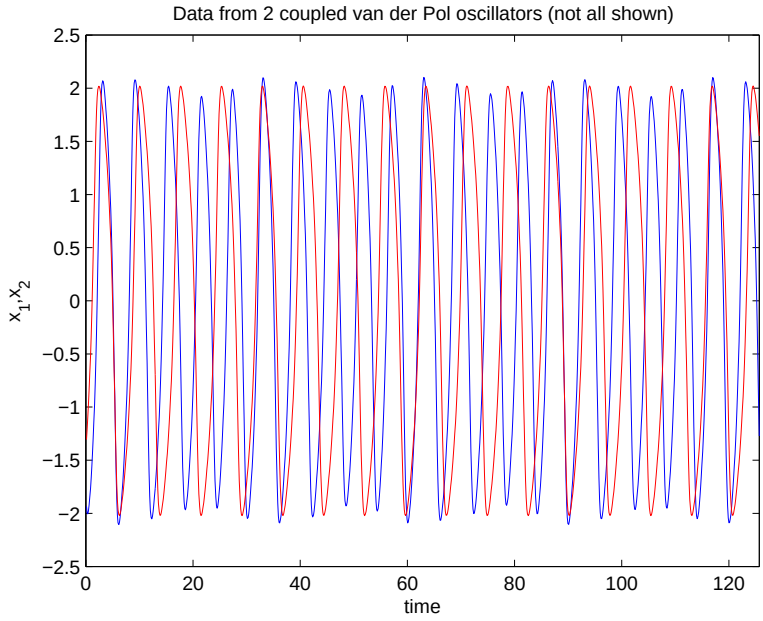
This example is implemented by the function `co_example4`; it uses the data file `co_vdp2uni.mat`. The data for this example are generated by a model of two unidirectionally coupled van der Pol oscillators:

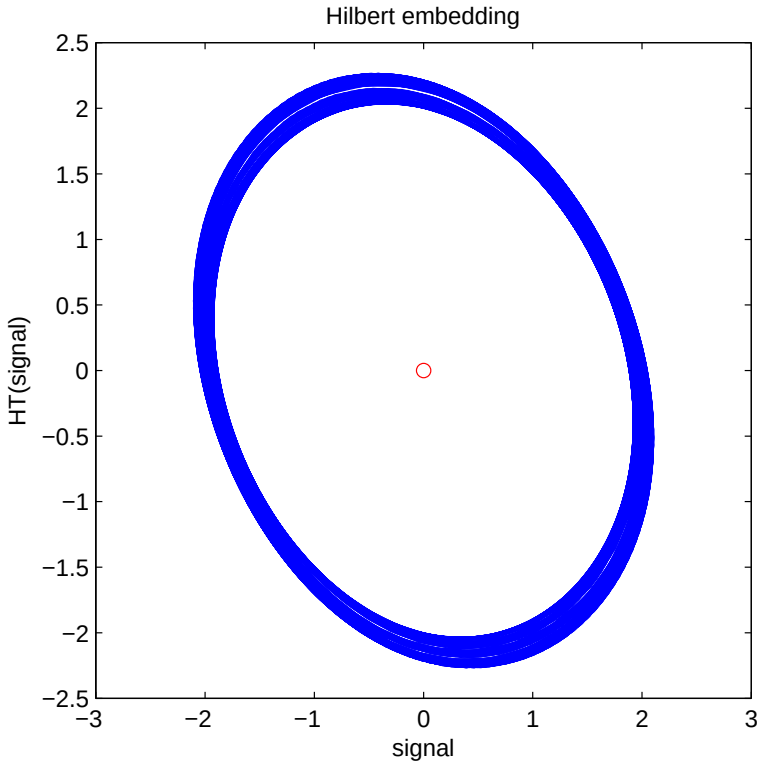
$$\begin{aligned} \ddot{x}_1 - \mu(1-x_1^2)\dot{x}_1 + \omega_1^2 x &= \varepsilon_1(\dot{x}_2 - \dot{x}_1) \ , \\ \ddot{x}_2 - \mu(1-x_2^2)\dot{x}_2 + \omega_2^2 x &= 0 \ . \end{aligned} \tag{1}$$

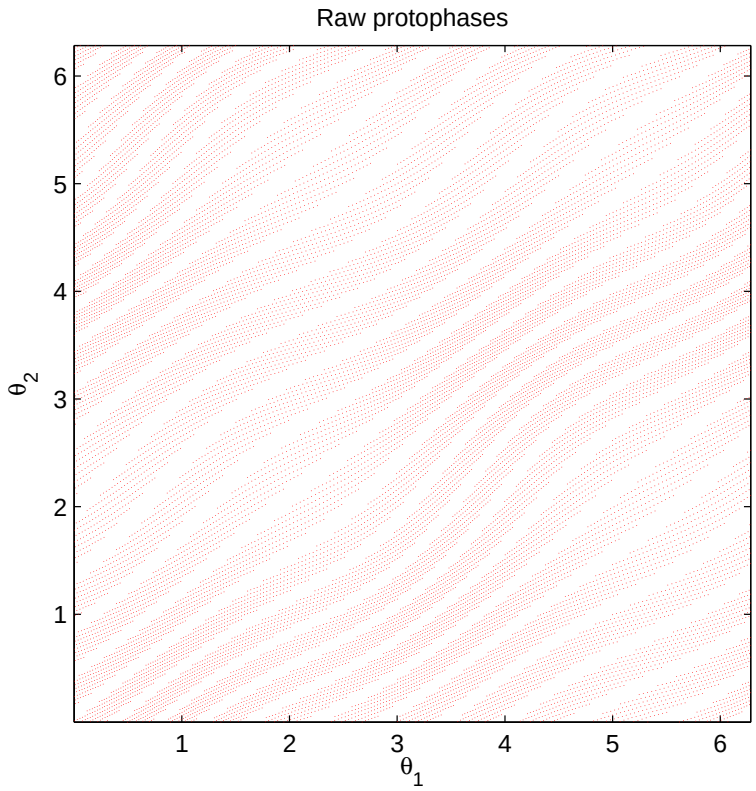
Parameters are: $\mu = 0.5$, $\omega_1 = 1.11$, $\omega_2 = 0.89$, and $\varepsilon_1 = 0.1$.
In this example, we illustrate every step of the procedure and plot all intermediate results. The iteration technique is used, see manual and related publications for details.

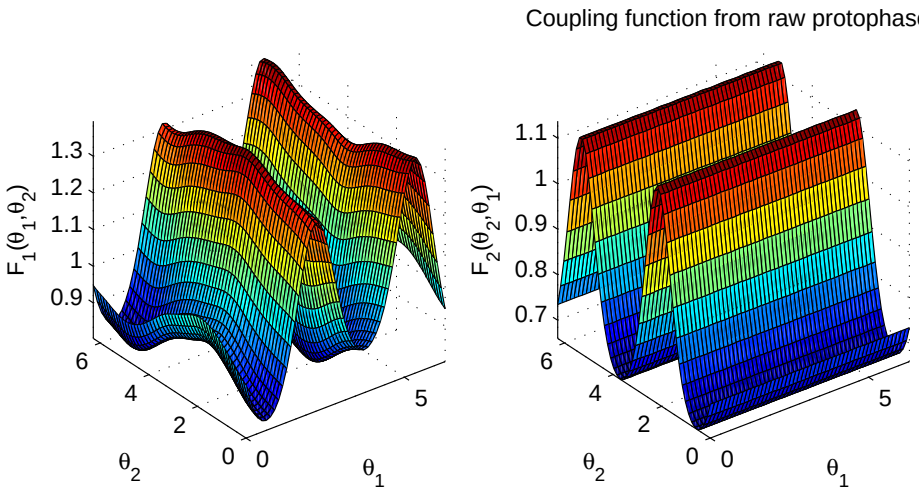
## 2 Output and comments

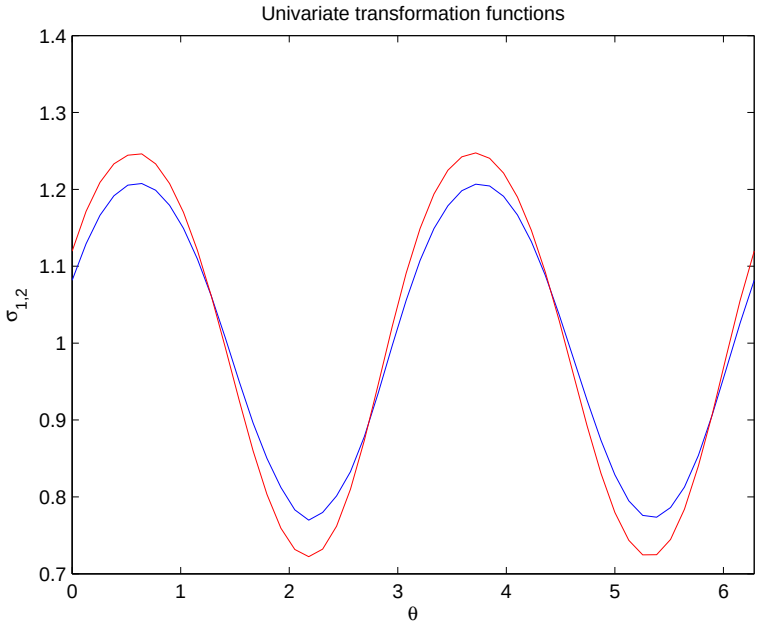
```
--------  Starting co_example4  -----------
--  Plotting a piece of bivariate data  --
--  Computung and plotting protophases via Hilbert transform  --
Minimal amplitude over average amplitude is 0.86738
--  Reconstructing phase dynamics from 1D transformed protophases  --
iteration 1: omega1=1.0541 omega2=0.8235
iteration 2: omega1=1.0541 omega2=0.8235
iteration 3: omega1=1.0541 omega2=0.8235
Constant terms of the coupling functions
   (estimates of natural frequencies) are:
omega1 = 1.0541, omega2 = 0.8235
Synchronization index from protophases 0.11089
Synchronization index from phases 0.11247
Directionality index 0.99147
--------  End of co_example2  --------
```

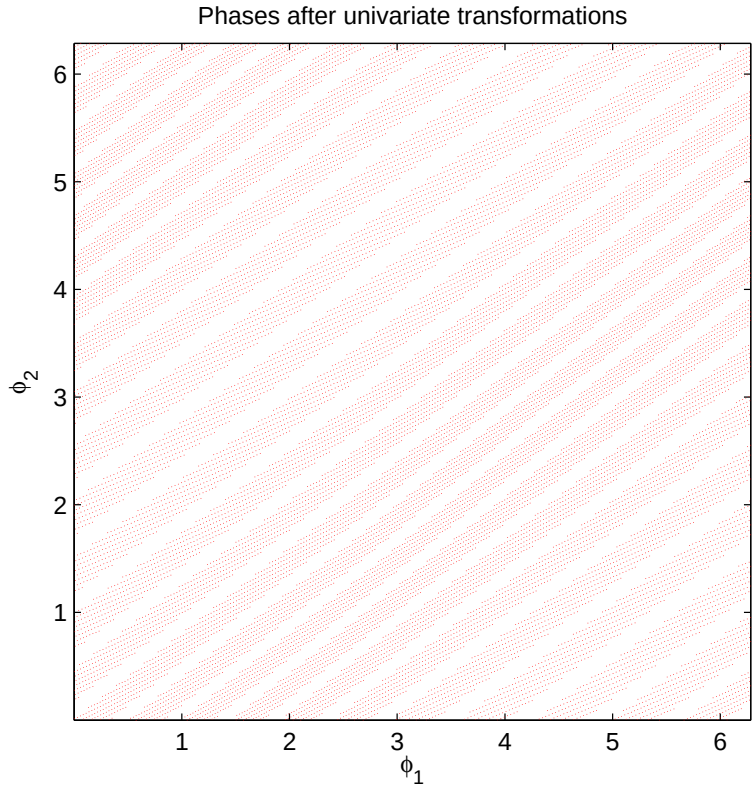

Data from 2 coupled van der Pol oscillators (not all shown)
x1,x2
time

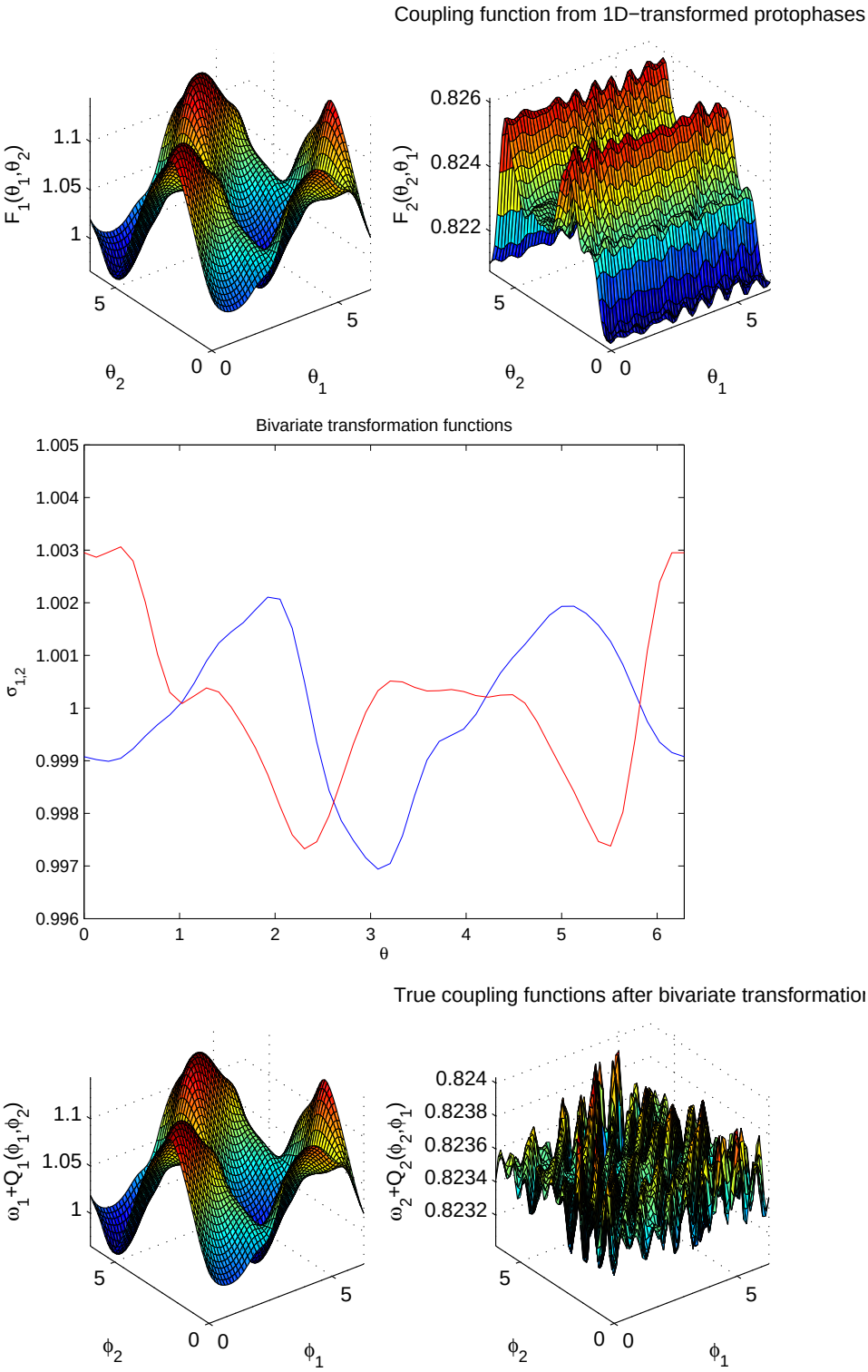

Hilbert embedding
HT(signal)
signal


Raw protophases
θ2
θ1
1
2
3
4
5
6


Coupling function from raw protophases
F1(θ1,θ2)
θ2
θ1
0.9
1
1.1
1.2
1.3
F2(θ2,θ1)
0.7
0.8
0.9
1
1.1
0
2
4
5
6


Univariate transformation functions
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
σ1,2
0
1
2
3
4
5
6
θ


Phases after univariate transformations
6
5
4
3
2
1
ϕ2
1
2
3
4
5
6
ϕ1




Note differente scales in the plots of coupling function. In fact, the true 2nd coupling function is flat, as expected for the case of unidirectional