From Shells to Temperature

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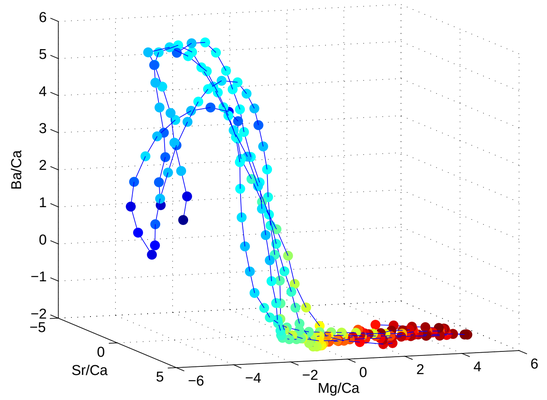
To estimate the past climate, for example the ocean temperature 1000 years ago, one has to turn to naturally occurring climate recorders. There exist a number of climate recorders in nature from which the past temperature can be extracted. However, only a few natural archives are able to record climate fluctuations with high enough resolution so that the seasonal variations can be reconstructed. One such archive is a bivalve shell.

The chemical composition of a shell of a bivalve depends on a number of chemical and physical parameters of the water in which the shell was composed. Of these parameters, the water temperature is probably the most important one. It should therefore be possible to estimate the water temperature for the years the shell was built, from measurements of the shell's chemical composition.

Measurements on a Manifold!

To find an estimate for the temperature we first observe that the chemical measurements lie on a one-dimensional manifold parameterized by the water temperature. This manifold can be utilized in the regression to obtain accurate estimates of past water temperatures.



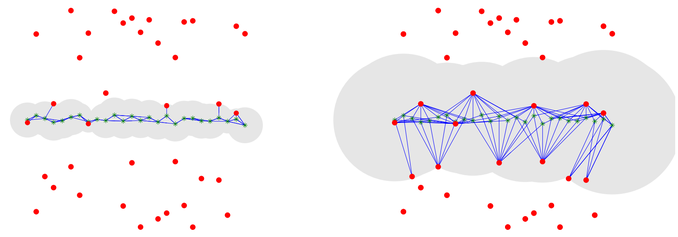
Chemical composition measurements. Temperature color coded.

From Manifold to Temperature

Manifold learning is an umbrella term for methods for parameterizing manifolds. A manifold learning method can hence be used to find a parameterization of the one-dimensional manifold in the chemical composition measurement space. However, this parameterization will not coincide with the temperature by itself. To adjust the parameterization, and imitate the temperature parameterization, *Weight Determination by Manifold Regularization* (WDMR, [3, 2]) can be used.

WDMR

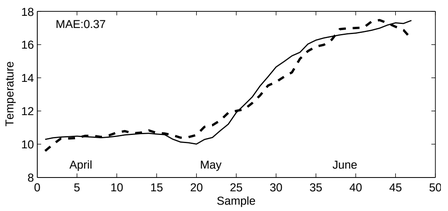
WDMR, just like a manifold learning algorithm, finds a parameterization of a manifold. The parameterization computed by a manifold learning algorithm is usually constrained to have a unit variance, zero mean etc (depending on the manifold learning algorithm used). This constraint is in WDMR replaced by fixating a number of values of the parameterization. If we for example know the associated temperature of some chemical composition measurements, this can be used to fix the parameterization to imitate the temperature parameterization.



A comparison between WDMR (left) and a classical supervised estimation method (right).

Result

Using 6 estimation shells (with known water temperatures), the temperature associated with validation shells were estimated with a mean average error under one degree Celsius [1].



References

[1] M. Bauwens, Henrik Ohlsson, K. Barbé, V. Beelaerts, F. Dehairs, and J. Schoukens. On climate reconstruction using bivalve shells: Three methods to interpret the chemical signature of a shell. In *7th IFAC Symposium on Modelling and Control in Biomedical Systems*, April 2009.

[2] Henrik Ohlsson. *Regression on Manifolds with Implications for System Identification*. Licentiate thesis no. 1382, Department of Electrical Engineering, Linköping University, SE-581 83 Linköping, Sweden, November 2008.

[3] Henrik Ohlsson, Jacob Roll, and Lennart Ljung. Manifold-constrained regressors in system identification. In *Proc. 47st IEEE Conference on Decision and Control*, pages 1364–1369, December 2008. doi: 10.1109/CDC.2008.4739302.