Health Monitoring for Machines and People

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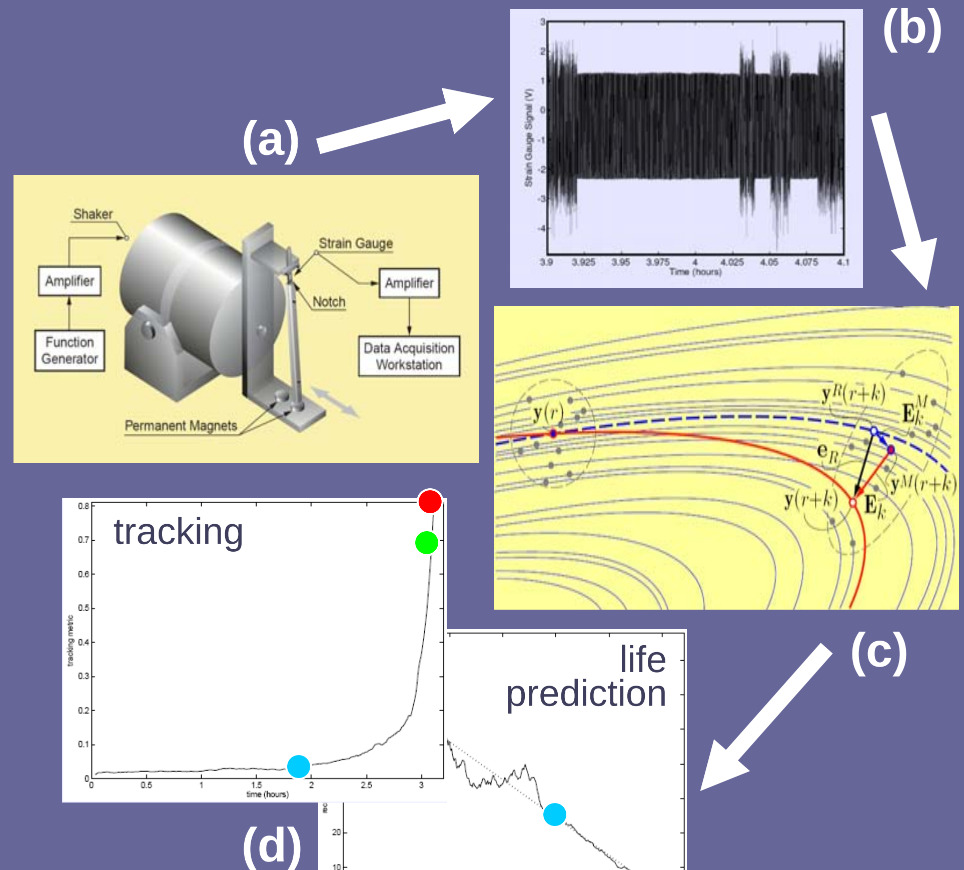
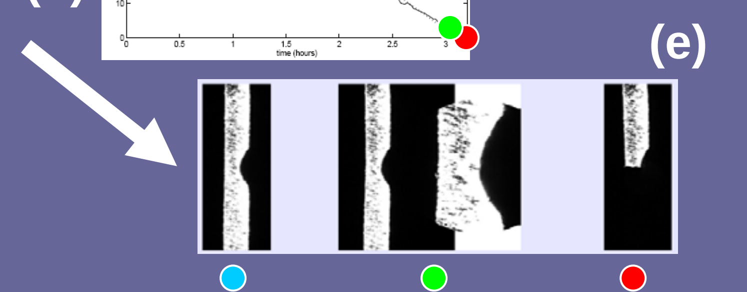
Phase Space Warping (PSW): Nonlinear Time-Series Analysis for Slowly Drifting Systems

This work aims to move past alarm-based diagnostics to the actual tracking of incipient damage states. Such "grey scale" damage state trackers form the basis for a true prognostic capability giving continuously updated estimates of remaining life.

Vibration data (b) from the system (a) is embedded in state space using nonlinear time series modeling (c). Short time prediction error is used to track the damage state and predict remaining life (d) in real time. Results are then compared to microscope observations (e).



These ideas have given rise to a patented algorithm for machinery diagnostics and prognostics. Optical measurements of crack size demonstrate successful tracking and failure prediction well in advance of complete failure



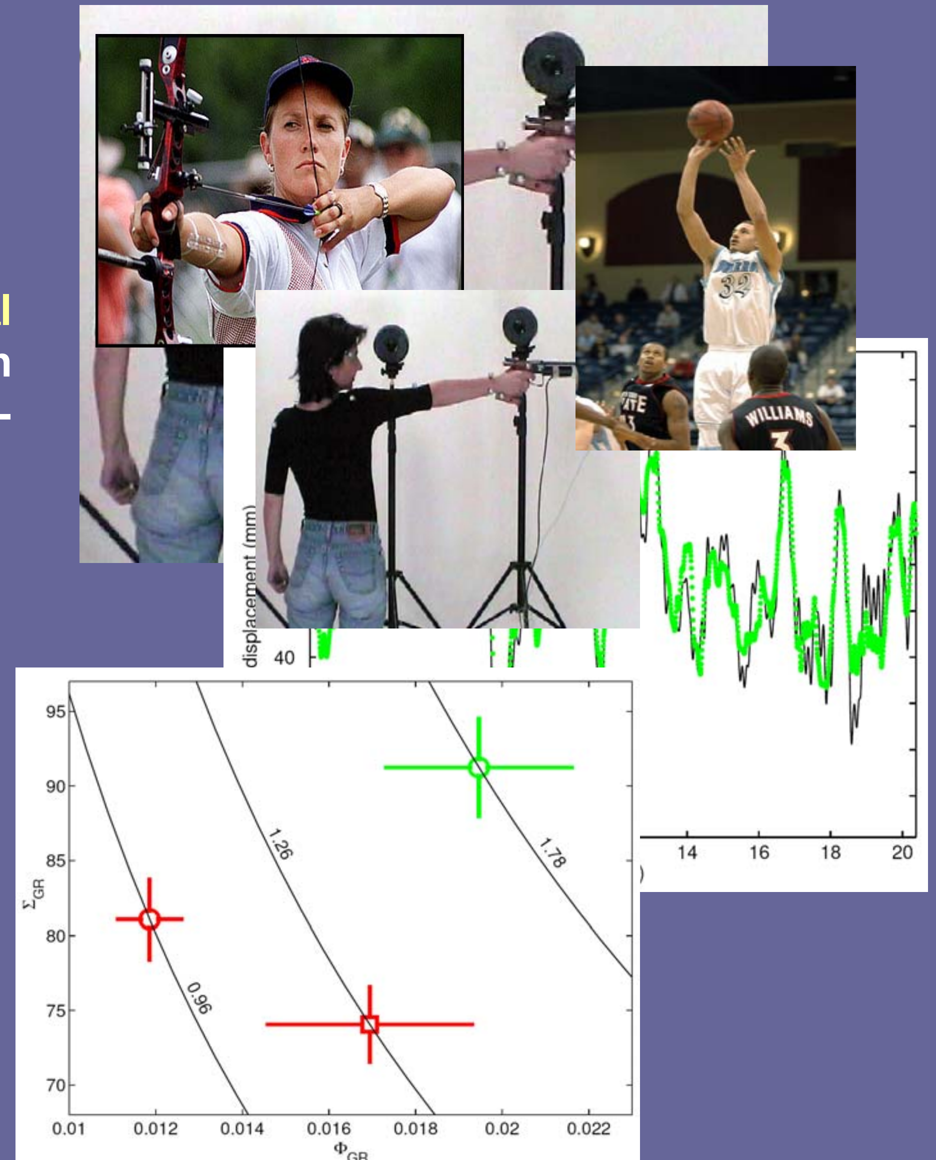
Dynamics of Task Execution: Goal Equivalence, Sensitivity, and Performance

Throwing a ball, playing darts, aiming at a target, or touching your nose: what factors determine the precision and repeatability of skilled human movements?

Kinematic redundancy gives rise to goal equivalent manifolds (GEMs) that contain all body states satisfying the task requirements.

The GEM concept has led to a new time series analysis method based on the body goal variability map that has been applied to movement data.

Using the method, goal level performance is shown to decompose into components measuring sensitivity, the magnitude of body fluctuations, and the orientation of fluctuations with the GEM.



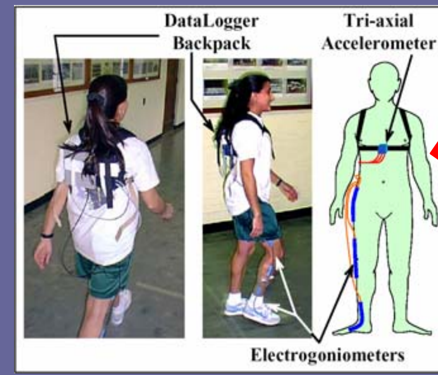
Characterizing Stability and Variability in Locomotion

Quantifying dynamic stability in walking is important for assessing people with peripheral neuropathy, who have **a greater risk of falling**.

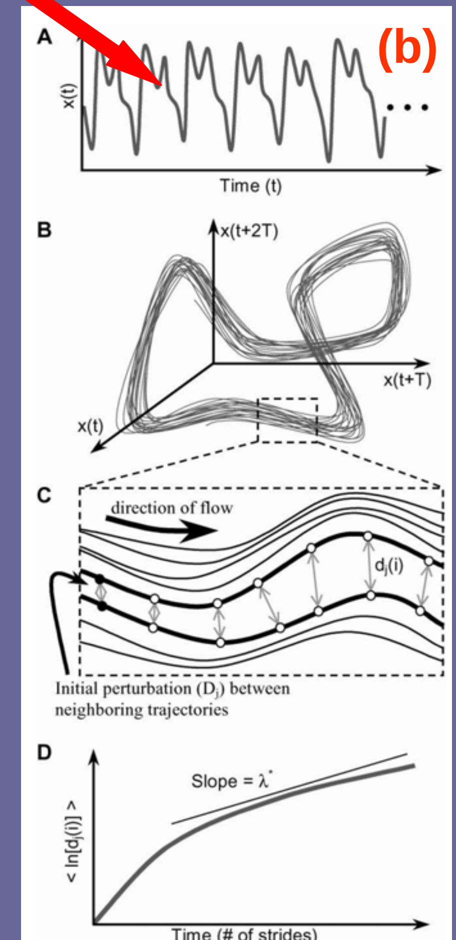
Nonlinear times series methods have been applied to walking kinematic data (a) to study the **effect of neuromotor disease on local dynamic stability** using finite time Lyapunov exponents (b).

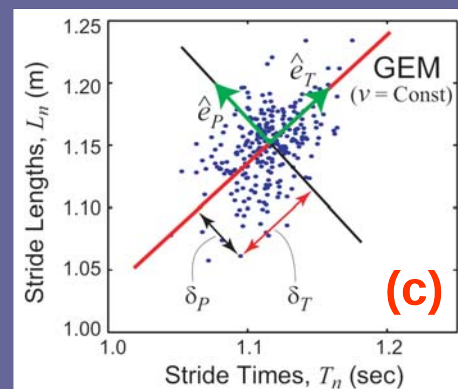
More recently, the GEM concept (c) has been used to obtain decompositions of stride data that allow for a better study of the **role of active control in stride-to-stride variability** using detrended fluctuation analysis (d).

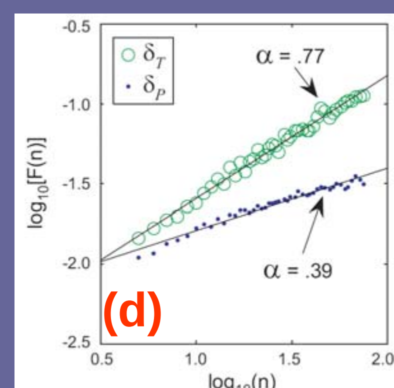
The **PSW algorithm** can also be applied to study the effects of fatigue, disease, and injury on gait dynamics.



(a)

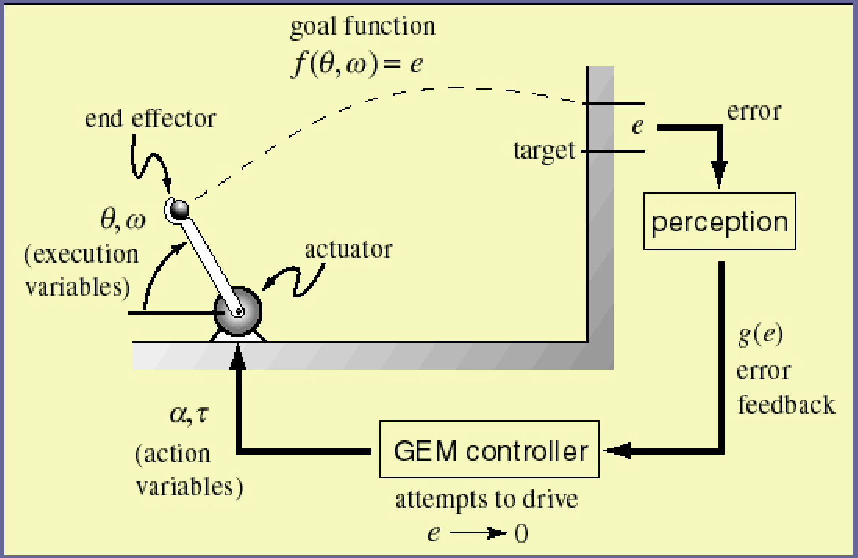


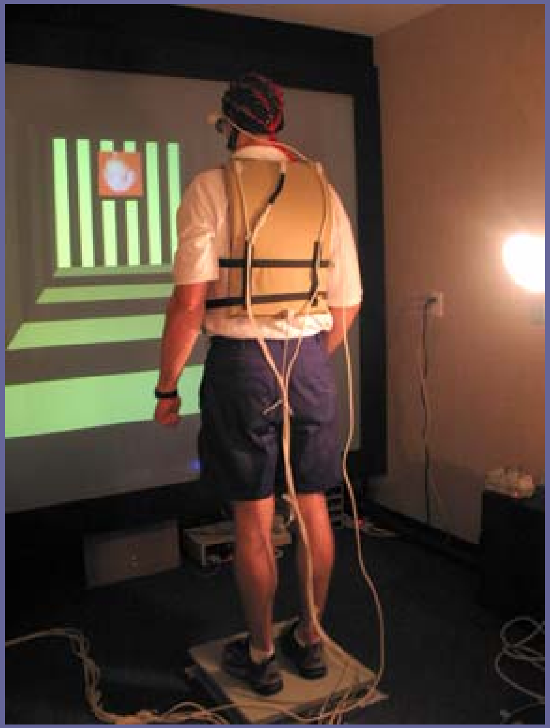




Ongoing Work

We are developing dynamical models of repeated, goal-directed, kinematically redundant human movements. With these inter-trial task dynamical systems, one can study the origin of human movement variability and learn how to better observe changes caused by disease, injury, and during rehabilitation.





With researchers in the Penn State Visualization Group, we are developing a virtual environment for goal-directed tasks. In addition to helping us test models and data analysis approaches, future collaboration with researchers at the Hershey Medical Center will aim to develop new diagnostic methods based on observations of performance changes in neuropathic, aging, and injured populations

Collaborations

Dimensionality and stability of walking in neuropathic and aging subjects
Jonathan Dingwell, UT Austin Department of Kinesiology and Health Education

Local dynamic stability and gait variability in walking and running
Karl Newell, Department of Kinesiology, Penn State University

Intertrial task dynamics and body-goal variability mapping in aiming tasks
Paola Cesari, Facoltà di Scienze Motorie, Università di Verona, Italy

Frequency scaling in coupled oscillator models of free rhythmic actions
Dagmar Sternad, Department of Kinesiology, Penn State University

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