The Role of Dynamics in Extracting Information Sparsely Encoded in Video and Other High Dimensional Data Streams

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We live in a world overflowing with data collection and non-stop communications. Cameras are ubiquitous everywhere and hold the promise of significantly changing the way we live and interact with our environment. Dynamic vision systems are uniquely positioned to address the needs of a growing segment of the population. Smart environments that are aware of user activities would enable an aging population to carry on independent lives for as long as possible. Computers that interpret facial expressions to obtain cues to user confusion can lead to simpler interfaces. Finally, activity monitoring systems capable of recognizing and correlating actions at different locations can improve security and reduce the time response to emergencies. However, a major roadblock in taking full advantage of the exponential growth in data collection and actuation capabilities stems from the *curse of dimensionality*. As an example, a short video sequence from a single camera contains mega bytes of (highly redundant) data. Similar situations arise when dealing with time-traces of gene promoters in systems biology. Simply put, existing techniques are ill-equipped to deal with the resulting overwhelming volume of data.

This talk discusses the key role that systems theory can play in timely extracting and exploiting actionable information that is very sparsely encoded in high dimensional data streams. The central theme of this approach is the use of dynamical models as information encoding paradigms. Our basic premise is that spatio/temporal dynamic information can be compactly encapsulated in dynamic models, whose rank, a measure of the dimension of useful information, is often far lower than the raw data dimension. This premise amounts to a reasonable localization hypothesis for spatio/temporal correlations, and is a given in mechanical and biological processes. Embedding problems in the conceptual world of dynamical systems makes available a rich, extremely powerful resource base, leading to robust solutions, or, in cases where the underlying problem is intrinsically hard, to computationally tractable approximations with suboptimality certificates. For instance, in this context, changes in the underlying process can be detected by simply computing the rank of a Hankel matrix constructed from the data, and missing information can be recovered by solving a rank minimization problem that can be relaxed to a tractable semi-definite program.

These ideas are illustrated with several examples from different applications, including change detection in video sequences, motion segmentation, still and video inpainting and uncovering co-promoted genes.

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