MANIFOLD COORDINATE REPRESENTATIONS OF HYPERSPECTRAL IMAGERY: IMPROVEMENTS IN ALGORITHM PERFORMANCE AND COMPUTATIONAL EFFICIENCY

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NRL has developed an approach to modeling nonlinear structure in hyperspectral imagery using manifold coordinate representations [1][2][3]. This scalable approach to deriving an intrinsic coordinate system for the data has allowed us to develop a practical framework for processing large-scale remote sensing imagery in a variety of applications such as water column retrievals, e.g. bathymetry and bottom type [3], as well as land-cover [2] and anomaly finding. Along the way, we have improved modeling of the local curvature as a means of providing higher fidelity models [4][5]. These earlier papers describe an information theoretic approach that uses local averages to determine local intrinsic dimensionality. Departures, or changes in this dimensionality, can be used to estimate when curvature onset occurs in the high-dimensional data set. This in turn allows one to determine in different regions of the data, what the appropriate neighborhood size to choose to remain in the linear region for the graph distance calculations. Thus, rather than choosing the number of neighbors K for the locally linear region to be a fixed number, the graph calculations, using this approach, have a variable K that depends on the local curvature. In [4], we showed an example that indicated that class separability can be enhanced using this approach.

In this paper, we re-examine the manifold curvature calculations described in [4], using some of the metrics generated in these curvature calculations as a means of further enhancing the discriminative capability of the manifold coordinate representation. Curvature metrics are used to partition the manifold representation into sub-manifolds. Adding an extra element to the representation which indicates the value of K at which curvature onset occurs, using our adaptive K estimation procedure, will have the effect of sub-dividing the manifold into sets of varying degree of curvature. We demonstrate this approach for the problem of scene anomaly finding using PROBE airborne HSI data of Smith Island, VA, originally described in [6][7]. Scene anomalies, in manifold representation or in the new sub-manifold derivations, tend to project off of the background data distribution. In order to provide a practical implementation for this application, we have developed methods which use properties of the local neighborhood to automatically flag anomalous points in the scene. For example, local distribution of neighbor-to-neighbor angles in each neighborhood can serve a test for determining these points. This is not the only possibility, but calculations based on this approach tend to find the ends of the anomalous data distributions sticking out from the main background manifold.

Although we initially demonstrated a scalable method that could practically run on a conventional single CPU in a matter of hours, the advent of new hardware such as graphical processing units (GPU) has ushered in a new era of high-performance computation. Working with the Naval Research Laboratory through a Cooperative Research and Development Agreement (CRADA), Celestech has implemented the NRL manifold representation algorithm described in [2]. On the GPU, the computation speed of this algorithm has increased by 2 orders of magnitude over optimal CPU-based implementations. Specifically, recent implementations of the NRL manifold coordinate representations algorithm on the GPU (a NVIDIA GeForce GTX 295) have demonstrated a performance increase in speed which reduces overall computational time from a number of hours to a few minutes, indicating that practical calculation can be accomplished in near real-time for scene with roughly two million pixels. This represents a very practical scale for evaluation, and could be further accelerated by employing multiple GPU processing. The paper will also discuss the GPU implementation and performance as well as the scalability in this application.

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