Object-Based Dynamic Tomography

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Many tomographic-type inverse problem applications are focused on the extraction of information pretaining to a discrete set of objects in the field of view. Further, these applications often have limited or poor quality data. Often the interest is primarily in the localized physical properties of the underlying target objects, such as size, shape, location, density, permittivity, etc and less in the distributed behavior of the field as a whole. A further challenges arise when the underlying objects also evolve as the data are being acquired. Typical approaches to these problems are sub-optimal, performing a pixel-based reconstruction followed by object boundary extraction and often ignoring the dynamics of the scene.

In this work, we present a unified variational framework for reconstruction of 3-D dynamic objects from tomographic observations. We focus on problems where the interest is in primarily in object geometry or shape and where intensity is either less important or reasonably captured through low order parametric models. We assume that the scene is assumed to be composed of a discrete set of objects and capture this through a series of continuous surface boundaries. Thus, we use a fundamentally geometric scene model. Object dynamics are are treated by using separate intensity and shape evolution models, which capture our prior knowledge of the temporal evolution of the scene. Finally, a prior model on spatial shape based on boundary area is used. These models are then combined in a unified variational framework which incorporates the observation data, shape and intensity dynamics, and prior information on object spatial behavior. To incorporate the shape dynamics we define a new distance measure between surfaces based on a function of their signed distance functions. This new measure is computable, leads to tractable optimization problems, and avoids the need to establish object boundary correspondence. The sequence of object surfaces and corresponding intensity values are estimated jointly as the minimizer of the resulting energy function. A coordinate descent algorithm based on surface evolution is developed to solve this nonlinear optimization problem. Efficient level set methods are used to implement the algorithm. This approach evolves the surfaces from their initial position to the final solution and handles topological uncertainties automatically.