A Combined Approach to 3D Seismic Data Segmentation and Rendering

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ABSTRACT

The problem of 3D seismic data segmentation and visualization is discussed. In several volume rendering algorithms, an opacity value is assigned to each voxel (volume element) based on local data characteristics. This approach is very limited in individualizing specific seismic events, since different parts of the data may share similar features. Our proposed framework incorporates a statistic segmentation scheme into the opacity function as a measure of spatial coherence. The proposed algorithm is demonstrated for visualization of stratigraphic features embedded in 3D data.

INTRODUCTION

Surface rendering and volume rendering are the two approaches to visualization of 3D data. In surface rendering, an intermediate representation is extracted from the data by using a surface detection scheme and then passed to a renderer. On the other hand, volume rendering techniques do not rely on any intermediate model of the data. The imaged data is assumed as a semitransparent volume. In several volume rendering methods, transparency (or opacity) values are assigned to voxels (volume elements) in order to emphasize more interesting parts of the data and make uninteresting parts transparent, with diffuse transitions in between. Opacity values can be computed as a function of voxel values, local gradient vectors or both. In any cases, it can be difficult to isolate a specific seismic event using only local (voxel) information. Different events usually share the same properties and a seismic event comprises a range of amplitude values that can be very variable and therefore difficult to pinpoint (Gerhardt et al., 1998; Gerhardt, 1998). Nevertheless, a seismic event can be segmented as a region of spatially coherent and connected voxels.

Segmentation is a partition of an image in a number of regions, each region related to a spatial pattern of the data. Volume rendering can be viewed as a fuzzy segmentation technique, since diffuse transitions are allowed between different regions. Other region-oriented segmentation methods partition the data into disjoint regions. Region growing is a well-known segmentation technique that belongs to this class. In this technique, a region is grown from a set of seed points by iteratively aggregating neighbor points with similar properties, eventually leading to a hard-segmented region. Regions segmented in such way do not fit well into the volume rendering philosophy, since diffuse transitions are not allowed.

In this paper we present an approach which combines the two techniques in order to allow interactive segmentation and visualization of seismic events.

VOLUME RENDERING

In contrast to traditional approaches in computer graphics, volume rendering does not intend to represent 3D objects as geometric surfaces and edges. Instead, volume rendering aims to represent the data directly as a reflective, light-emitting, semi-transparent cloudy object.

Classification, in the context of this work, is the process of assigning discrete values for the primary property that represents the sample, usually seismic amplitude. Color and opacity are the only primary properties of a data sample. Color is assigned using a color table (or grayscale in the case of monochromatic images). The samples are treated as being semi-transparent and the percentage of the background that does not show through the foreground is called opacity. Classifiers are usually user-defined smooth functions assigning opacity values between 0.0 (completely transparent) and 1.0 (completely opaque). Therefore, color and opacity values defined for a specific range of values are applied over the whole data volume. The final color of a pixel in the image plane is determined by successively interpolating between the background color and the semi-transparent foreground color (a process called *compositing*) for all the voxels that contribute to the pixel along the line of sight.

Volume rendering has proven to be a powerful tool for preview and analysis of 3D seismic data. Nonetheless, it is of little use for visualizing individual seismic events. Strategies to overcome this limitation rely on some previous segmentation of the data volume (trimming, picking, etc.), but an integrated segmentation-visualization approach is still missing.

We use a modified version of the splatting algorithm (Westover, 1991). Splatting is an object-order (feed-forward) algorithm (the data volume is traversed along rows of voxels mapping each one onto the final image plane) that integrates fundamental reconstruction and sampling issues into the volume rendering philosophy. This integration aims at achieving efficient and accurate interpolation of opacities and colors. The algorithm uses Gaussian kernels to reconstruct and project each voxel´s individual contribution (footprint) onto the image plane. The contributions are composited according to their opacity values as the data volume is traversed in a back-to-front order regarding the viewpoint. Our version is optimized for taking advantage of texture-mapping hardware acceleration when creating and projecting reconstruction kernels.

REGION GROWING

This algorithm begins by seeding voxels in suitable places of the volume where the existence of the target feature is known. This task can be done manually, by visual inspection and picking of the data, or automatically, by thresholding either the data or the transfer function. A region is then grown from this set of seed points by iteratively aggregating neighbor points with similar properties, eventually leading the segmentation of the target feature. Two different connectivity schemes for growing can be used. Six-way restricts the search to only the neighboring voxels that share a common face with the seed voxel, while twenty-six-way connectivity includes also edge- and corner-connected voxels. The scheme used affects the results, with the twenty-six-way producing larger regions. The membership criterion for accepting candidate voxels is the most critical step in the method, and for region growing algorithms in general. Most criteria rely on the statistics of the data. They are in general sensitive to poor signal-to-noise ratio data and dependent on the seed point value, variability of the region, etc.

We start making some assumptions about the problem:

- The data is signed and we want to segment only the negative or the positive range of values;
- The feature of interest is easily identifiable by eye;
- The signal-to-noise ratio is high.

We use a seed-centered box to initialize the basic statistical parameters for growing. An algorithm simulating an expanding wavefront is used in order to avoid any directional effect. Recursive region-growing algorithms, although commonly used due to its efficiency, can perturb the growing process since far voxels may be taken into account too early in the process. As the region builds up, we keep track of some statistics of both amplitude and gradient volumes, namely the mean, the median, and the variance. When the algorithm reaches a point of high gradient the voxel´s intensity is checked against an assumed threshold, which must be close to the region’s distribution median. The growing of the region is terminated when the membership criteria are no longer satisfied by any of the possible neighbor candidates. More seed points can be used to append parts of the feature not segmented with a single seed.

After the entire event is segmented, we eliminate small regions and smooth out the resulting shape using the morphological erode and closing operators, respectively.

INTEGRATING BOTH METHODS

Three methodologies can be used in order to embed the region growing segmentation into volume rendering algorithms, as follows:

a) Use the region as a region of interest (ROI) mask;
b) Define opacity values directly from the probability of each voxel belonging to the region;
c) Combine (b) with a user supplied transfer function.

In the first case, the segmented region is seen as a binary ROI mask defining where the transfer function is effective, making everything outside it transparent. This is the simplest application of the results provided by the region growing algorithm, essentially a hard-segmentation technique. The analysis of the extracted feature relies exclusively on the definition of a user supplied transfer function. However, since seismic amplitudes can vary considerably, a much broader transfer function is needed in order to visualize the entire seismic event.

The second case is the most automatic one, since no transfer function is needed. It is extracted directly from the probability values of each class of amplitudes or gradients of belonging to the region. Therefore, the region growing algorithm defines not only a ROI mask but also incorporates a probabilistic measure of ownership. This information can be calculated either while growing the region or after the final ROI mask has been defined. The result is similar to a fuzzy-segmentation technique in the sense that the voxels less likely to belong to the region are made more transparent. Similar results can be obtained with other schemes. Steen (1996) used Dijkstra´s algorithm with a probabilistic cost function to define ownership. However, the results may be not the same as the ones produced in (a) since the most opaque voxels may not be the most interesting ones. Besides, the method lacks the flexibility of changing opacities in order to emphasize internal features possibly present inside the segmented seismic event.

The third method, used in this work, is the most flexible one. It is somewhat a complement of the both preceding methods. The final image has the entire seismic event segmented and displayed, as well as the most important amplitudes emphasized. It also bears information on the ownership as voxels with lower probability of belonging to the event are made diffuse. The user has the flexibility of changing the transfer function in order to highlight different amplitude ranges. Additionally, the same transfer function used to analyse the whole seismic data volume can be used with no modifications. The modifications necessary to integrate the information provided by the region growing process are quite easily introduced in the volume rendering algorithm. The probability of each voxel is calculated assuming a Gaussian distribution. These values, normalised to a user-defined threshold, are mapped directly onto the corresponding classes of the transfer function. If an opacity value has been already assigned to any of those classes, the values are accumulated and checked for maximum opacity. The modified transfer function is then used to classify the data volume. However, this function is valid only inside the ROI mask. Everywhere else the original transfer function is used.

RESULTS

The method has been applied to a marine 3D data. The data enclose a channel feature filled with positive and negative seismic amplitudes. We show results obtained by picking the positive amplitudes. Figure 1 shows the whole volume with a transfer function carefully designed to highlight amplitudes present in the channel. The channel is unidentifiable since other features sharing the same amplitudes occlude it. Figure 2 shows the same dataset using the proposed method. The same transfer function is used, as well as the viewpoint. The improvement in over the original method is evident.

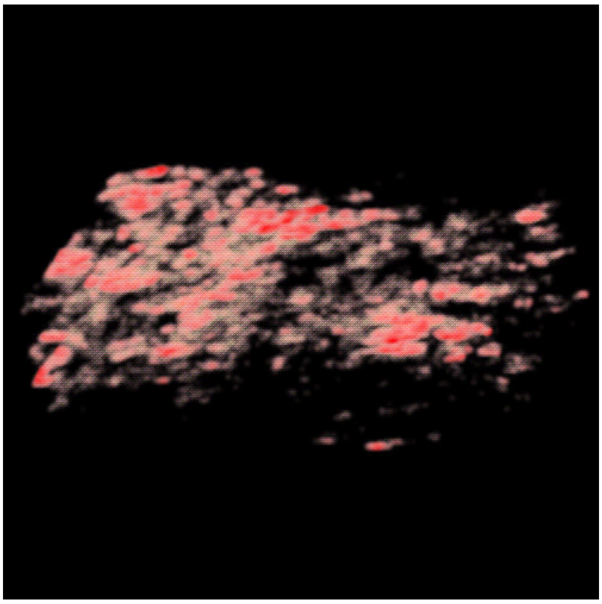

Figure 1: Original splatting algorithm.

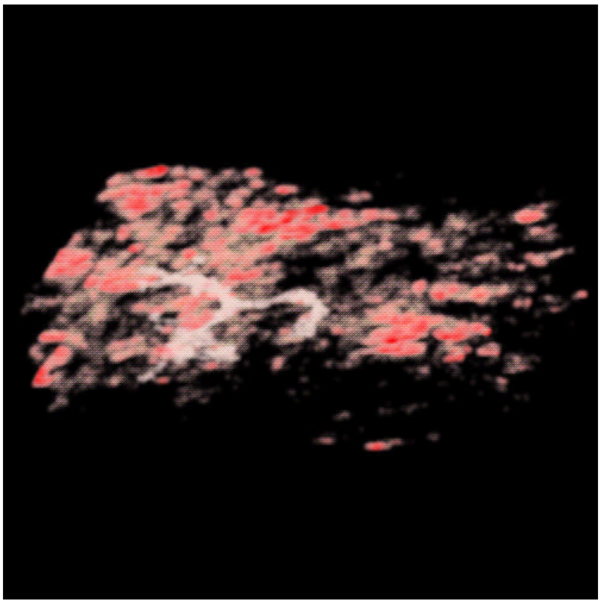

Figure 2: Modified splatting algorithm.

The definition of a consistent membership criterion is a difficult task. Leaking from the feature of interest during the region growing process is frequent, and some can be seen in Figure 2. Very conservative parameters must be used, requiring several seeds and user input to fulfill the segmentation of the entire channel. A more robust criterion for automatic seismic data segmentation is still a field of research.

CONCLUSIONS

We have presented a method to improve volume rendering of individual seismic events. The method combines a probabilistic region growing algorithm with a volume rendering algorithm, allowing a single seismic event to be visualized. The method is simple and can be easily adapted to any volume rendering algorithm.

The membership criteria are the most critical point of the method. In order to deal with generic seismic features, more robust growing engines are still to be developed.

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