Pre-Cognitive Processing: The Creation and Data Mining of 3D Visual Databases*

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Abstract

Visualization, perception and the cognitive process are inexorably linked. While many visualization techniques and strategies greatly enhance our mental abilities, others can be more confusing than they are useful. Since our eyes and brain are the main organs involved in the process of visualization and cognition, an understanding of their function should help develop more effective ways of enhancing our cognitive capabilities. While many of us would like to believe that we see a complete and detailed picture of the world, this notion is completely incorrect (O'Regan 1992). For example, our eyes collect image information via a non-uniform distribution of about 100 million receptors. Since the optic nerve linking the eyes to the brain, has about 1 million fibers, only a small fraction of this information becomes available for cognitive processes. The act of perception follows both bottom-up and top-down processes occurring simultaneously in different parts of the brain (Ware, 2008). Bottom-up processing is information driven, searching visual input progressively for features, patterns and objects. Top-down processing is more focused on a specific goal. While the brain is a massive parallel processing system creating complex patterns from features, only a few objects can be worked with at any one time. This very limited visual working memory is the main limitation that visualization techniques are developed to help overcome. Both top-down and bottom-up processing can be very powerful but tend to ignore most of the available information along with any significant information that this information may contain. Moreover, developing a perception of reality based on top-down processing can be very biased towards the goals we are trying to achieve.

Introduction

From research in cognitive science, we believe that our impression of the world actually consists of only small fragments of information that is obtained on more of an "as needed" basis; this knowledge helps to develop techniques that provide more insights into large datasets (O'Regan 1992). The commercialized techniques demonstrated in the oral presentation use automated pre-interpretation processing techniques to create visual databases of virtually all the peak and trough surfaces (Dirstein and Fallon, 2011) and also their morphometric properties (Dirstein et. al., 2013). Software tools allow users to create guided queries to these databases based on single or multiple criteria. Thereby enabling the user to visualize features and patterns as well as extract objects from both small and large data volumes.

Geo-Hazard Example

From the visual database of all peak and trough surfaces, several surfaces near the seafloor were selected along with the database of morphometric properties describing that database. The objective was to identify features, patterns and objects that are circular concave depressions located on or near the seafloor. These pockmarks (Hovland and Judd, 2007) provide insights into seafloor stability and fluid migration pathways. From the 3D visual database of all surfaces automatically extracted using genetic segmentation (Figure 1A), a selection of surfaces near our zone of interest are selected (Figure 1B).

The two-way time (TWT) rendered surface of the Seafloor (Figure 2A) highlights a dramatic change in water depth across a shelf-break along with a number of box canyons. Also of note is an area of slumping containing numerous pockmarks that are visible due to shading. To learn more about these objects a query is made to one or more of the morphometric databases associated with each surface. In this case, circular concave depressions of a specific size range. The result of this query for one surface is shown in Figure 2B. Note the pockmarks are located in the area of slumping. However, the query has also identified other similar objects elsewhere on the surface that were not evident when viewing the TWT map. The reason why these additional pockmarks were initially overlooked is due, in part, to the false color palette applied to the TWT surface and the larger features dominated our initial perception of picture. This visual competition affects upon perception (Cohen et. al. 2011). The orange circular objects shown in the image (Figure 2B) all have associated attributes (i.e. area, depth, aspect ratio, etc.,) that can be exported as a shape file for quantitative analysis or used to provide further visual discrimination. The pockmark density probability map shown (Figure 2C) grids multiple realizations of these pockmarks showing areas of highest pockmark density (yellow).

Conclusions

The cognitive process utilizes both bottom-up and top-down neural processes that help us develop our perceptions of reality. While these processes are greatly aided by computer-based visualization tools and techniques, they remain biased and often ignore large amounts of important information. Perhaps the only means of extracting this additional information requires multiple re-visits to the data. Normally this a very time consuming and biased mechanical process. Using pre-interpretation processing to extract all surfaces and the morphometric properties of those surfaces into visual databases enables consistent, time efficient cost effective and quantitative extraction of detailed information.

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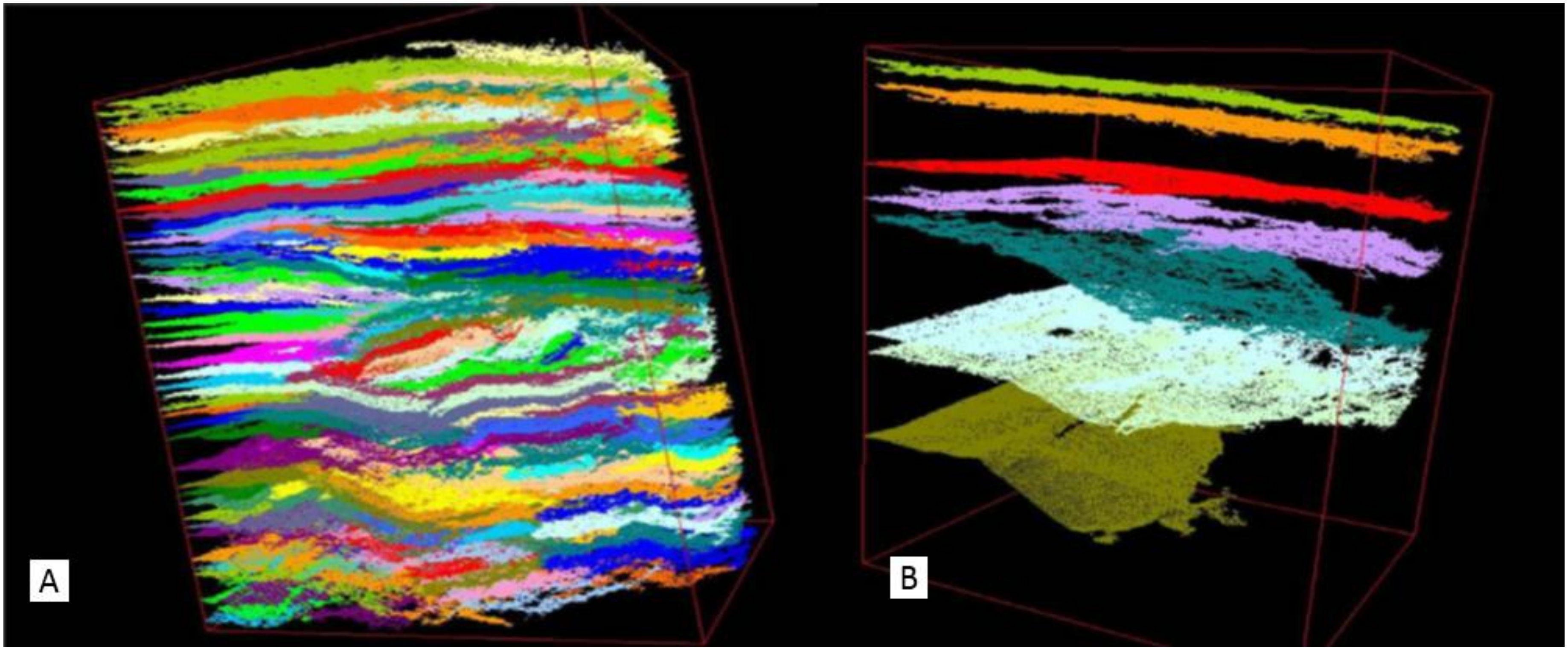

Figure 1. (A) Pre-Interpretation processing produces a 3D visual database containing virtually all peak and trough surfaces. (B) Depending on objectives, a selection of the surfaces can be isolated for more focused examination.

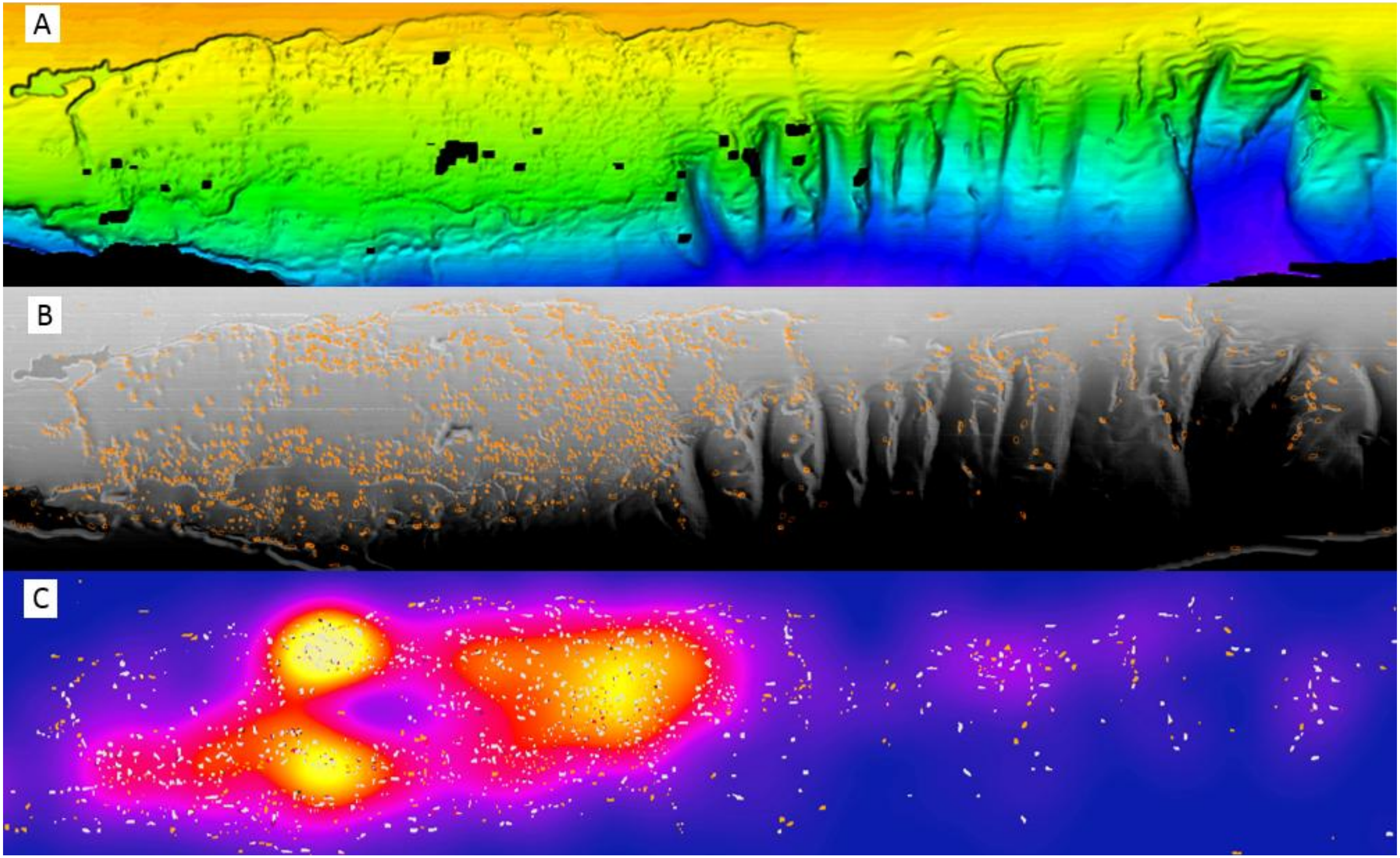

Figure 2. (A) TWT surface (Seafloor) ~ 500 km^2 with rainbow false color palette applied and shading. Extracted from Seisnetics™ visual database. (B) TWT surface (Seafloor) grayscale with circular concave depressions (orange) resulting from query to morphometric database (GeoProxima™). (C) Pockmark objects from multiple realizations used to calculate density probability map.