Computers & Geosciences 96 (2016) 47–55

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Research paper

TiConverter: A training image converting tool for multiple-point geostatistics

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ARTICLE INFO

Article history:
Received 6 January 2015
Received in revised form
12 June 2016
Accepted 8 July 2016
Available online 9 July 2016

Keywords:
Training image
Multiple-point geostatistics
Multiple-point statistics
Segmentation
SGeMS

ABSTRACT

TiConverter is a tool developed to ease the application of multiple-point geostatistics whether by the open source Stanford Geostatistical Modeling Software (SGeMS) or other available commercial software. TiConverter has a user-friendly interface and it allows the conversion of 2D training images into numerical representations in four different file formats without the need for additional code writing. These are the ASCII (.txt), the geostatistical software library (GSLIB) (.txt), the Isatis (.dat), and the VTK formats. It performs the conversion based on the RGB color system. In addition, TiConverter offers several useful tools including image resizing, smoothing, and segmenting tools. The purpose of this study is to introduce the TiConverter, and to demonstrate its application and advantages with several examples from the literature.

1. Introduction

The scarcity of geological subsurface information is one of the most significant sources of uncertainty in a reservoir modeling process. As a result, stochastic simulation techniques have been developed to reduce this kind of uncertainty. These techniques generate multiple equiprobable reservoir models while maintaining the geological structure. The traditional geostatistical modeling techniques, including the Sequential Gaussian and the Sequential Indicator simulation techniques, simulate any structure based on a Variogram model which represents its spatial heterogeneity or continuity. Thus, these traditional techniques are limited to the reproduction of two-point statistics; however, modeling complex geological structures such as channels, which are curvilinear formations meandering in 3D space, requires multiple-point correlation. Therefore, the traditional two-point based geostatistical modeling techniques, such as the sequential indicator simulation (Deutsch and Journel, 1998), fail to capture complex geological structures (Caers and Journel, 1998; Strebelle, 2000; Strebelle and Journel, 2001; Caers and Zhang, 2004). On the contrary, the multiple-point geostatistics simulation technique (MPG) (known also as multiple-point statistics; MPS) proposed by Guardiano et al. (1993) has proven to be powerful in modeling such complex structures (Journel, 2005). Unfortunately, the original technique of Guardiano et al. (1993) was central processing unit (CPU) demanding, in other words, it was a calculation intensive and required an excessive amount of computation time. Thus, MPG was not widely used until the implementation of the search tree by Strebelle (2000). He Also developed the single normal equation simulation (SNESIM) algorithm, a non-iterative sequential simulation algorithm that obtains multiple-point statistics from conceptual geological models called 'training images' and anchors them to the subsurface well-log, seismic and production data (Feyen and Caers, 2006). Following the work of Strebelle (2000), a significant amount of effort was spent to improve the MPG simulation techniques. As a result, different MPG algorithms were developed. Some of these algorithms are SIMPAT (Arpat, 2005; Arpat and Caers, 2007), FILTERSIM (Zhang, 2006), IMPALA (Straubhaar et al., 2011), and CCSIM (Tahmasebi et al., 2012).

MPG algorithms rely on training images to deliver the structural information of questioned reservoirs. A training image is defined as the numerical representation of expected subsurface heterogeneities believed to exist in the area being modeled and does not necessarily carry any locally accurate information (Strebelle, 2000; Strebelle and Journel, 2001; Arpat and Caers, 2007). However, a training image should reflect a spatial continuity style similar to the actual phenomenon (Arpat and Caers, 2007). In summary, a training image is used to deliver prior geological concepts about the geometry or shape of the questioned heterogeneities.

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http://dx.doi.org/10.1016/j.cageo.2016.07.002

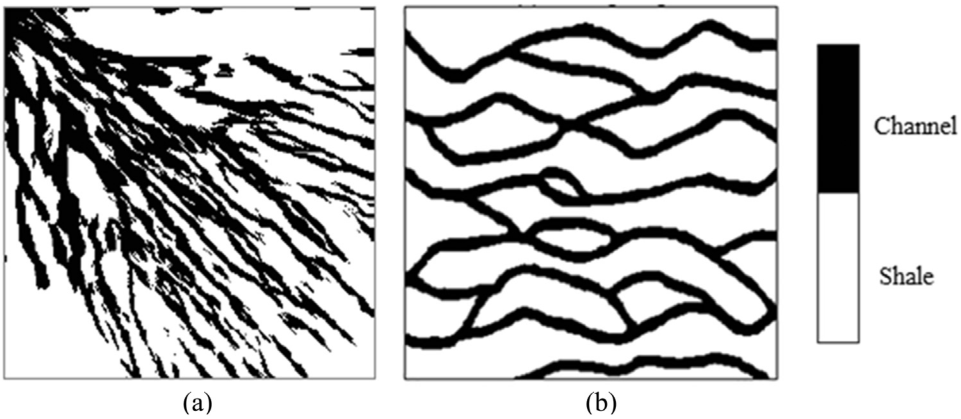

Fig. 1. Examples of 2D training images representing a channel structure (Arpat, 2005). A non-stationary training image, (a). A stationary training image, (b).

Training images should be stationary; that is, the spatial patterns are reasonably homogeneous all over the training image (Strebelle and Zhang, 2005; Maharaja, 2008). Some implementations of MPG do however provide tools to use non-stationary training images (Caers and Zhang, 2004; Arpat, 2005; Liu, 2006; Strebelle, 2006; Wu, 2007; de Vries et al., 2009, Hu et al., 2014). Fig. 1 shows stationary and non-stationary training images for a channel system. In Fig. 1(a) the channel converges in the upper left corner and splays out across the area as the channel approaches the lower right corner.

Similar to the variogram model, the training image provides statistics relating unsampled values to conditioning data, but jointly in multiple locations. In other words, the MPG technique accounts for correlations between three or more locations at a time. Thus, the MPG technique is capable of producing complex curvilinear geological structures accurately (Strebelle, 2002). The simulation carried out by the MPG technique takes the patterns from the training image and anchors them to the actual data (Liu, 2003; Liu et al., 2005). This process when first proposed by Guardiano et al. (1993) was slow and CPU demanding because it required rescanning of training image for each new data event. However, the development of the SNESIM of Strebelle (2000), which scans the training image only once, significantly speeded up the MPG simulation process and decreased its CPU demand.

Training images can be constructed in different ways. For example, they can be hand-drawn then numerically digitized (Strebelle and Remy, 2005), or obtained from nearby field analogs, outcrop photographs, core imaging, or remote sensing images. They can also be obtained from process-based models such as the one created by Koltermann and Gorelick (1992), process-mimicking (or -imitating) models (Koltermann and Gorelick, 1996), or created using unconditional object-based simulations such as the ones proposed by Deutsch and Wang (1996), Holden et al. (1998), Viseur (1999), and Maharaja (2008). For a detailed discussion on the available construction methods of training images, the reader is referred to Mariethoz and Caers (2014). For training images to be used in MPG applications, they should be represented numerically and in the correct format of the software that they will be used in. However, some of the methods mentioned above do not provide the images in the correct formats to be used as training images. In addition, images that are obtained from outcrop photographs, core imaging, or remote sensing should first be segmented before converting them into the correct numerical format. To do so, both commercial (e.g. Avizo, FEI Company, 2015; and Photoshop, Adobe Systems Inc.) and free software (e.g. ImageJ, Rasband, 2015; and GNU Image Manipulation Program (GIMP), Kimball and Mattis, 2014) can be used.

For example, to use a training image in SGeMS, it has to be either in the geostatistical software library (GSLIB) or in the (*.sgems) binary format. To convert this image into one of these formats, say the GSLIB format, users could choose to write their own codes in the geostatistical Matlab toolbox (mGstat) or use an image manipulating software. The former, however, is not a practical option since not every MPG user is comfortable with writing codes. The latter, on the other hand, as mentioned earlier might either be commercial (e.g. Photoshop) or free (e.g. GIMP). The use of both software to convert the image into numerical representation text file is straightforward. However, the user still needs to use an external text editor to change the headers of the generated file to make it a GSLIB file. The main goal of the present study is to provide a standalone and handy tool that eliminates the need for code writing, eases the conversion of images, and offers different file saving formats for more simplified applications of MPG simulation technique. For this purpose we introduce the TiConverter and demonstrate its advantages and usage with examples from the literature.

2. TiConverter

TiConverter, as its name implies, is a training image converting tool developed using the Visual Basic.NET (VB.NET) programing language. It supports all image files having a Graphic Device Interface (GDI+) pixel format, and it allows the conversion of 2D training images into numerical representations in four different file formats, namely, ASCII (.txt), GSLIB (.txt), Isatis (.dat), and VTK formats. The ASCII (.txt) format is merely the numerical representation of an image with no specific headers. So, TiConverter converts images not only for MPG applications, but also for all reservoir modeling applications. It is based on the RGB color system which includes 16,777,216 (i.e. $256 \times 256 \times 256$) different colors, and it detects each color based on its RGB value ranges which are obtained using a built-in color picker. TiConverter is developed with the aim to provide a standalone tool to ease the generation of training images. Therefore, TiConverter is equipped with many tools including resizing, denoising, color picking, previewing, and segmenting tools. In addition, it allows to save the manipulated image before converting it to its numerical representation, and finally saving it in one of the four available file formats. All these are provided in a user-friendly interface.

2.1. User interface and tools

The user interface of the TiConverter is divided into six main parts, namely, main tab, “Current” image window, “Processed” image window, previewing part, processing part, and details and exporting window (See Fig. 2). These parts are explained in detail in the following subsections.