Exploring Transition Textures for Pseudo-natural Maps

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Abstract

Pseudo-natural maps show land cover information in a compelling style that combines cartographic abstraction with natural appearance. To make this style available to the modern cartographer, a (semi-) automatic method that generates pseudo-natural textures for rendering land cover categories on maps would be helpful. This article focuses on a single aspect of pseudo-natural map creation, namely the generation of gradual, natural looking transitions between land cover categories, so called transition textures. We give a survey on how texture synthesis algorithms are used in computer graphics to handle transitions between textures and point out how they could be useful for creating textured maps. By pointing out promising approaches, we aim to contribute to the development of (semi-) automatic methods for the generation of textured pseudo-natural maps in 2D and 3D for static perspective views.

1 Pseudo-realistic Maps

A sterile, technical style as shown in Figure 1 (left) is the look most people associate with topographic maps. Yet, cartographic representations of the landscape have been created in more compelling styles that provide the observer with an attention-gripping, immersive experience. We call this map style pseudo-natural because it combines natural appearance with cartographic abstraction. Examples of such maps are natural-colour relief maps and winter maps in 2D, or hand-painted panorama maps in 3D (Figure 1, right).

Important and well-known 20th century cartographic artists that we consider to have created pseudo-natural maps include, for example, Hal Shelton (USA), Richard E. Harrison (USA), and Heinrich C. Berann (Austria); contemporary artists include Tibor Tóth (USA), Arne Rohweder (Switzerland), Winfried Kettler (Switzerland) and James Niehues (USA). Most pseudo-natural maps of high quality were created manually, either by using traditional pens and brushes, or by applying digital-manual tools (e.g. digital paint brushes). Pseudo-natural design can be applied to maps with traditional two-dimensional map projections, or panoramic 3D maps.

Using standard graphics editing software (e.g. Adobe Photoshop), pseudo-natural maps can be generated that combine characteristics of aerial photography, computer-generated textures and/or standard topographic map elements to depict land cover information in pseudo-natural look (Figure 2).

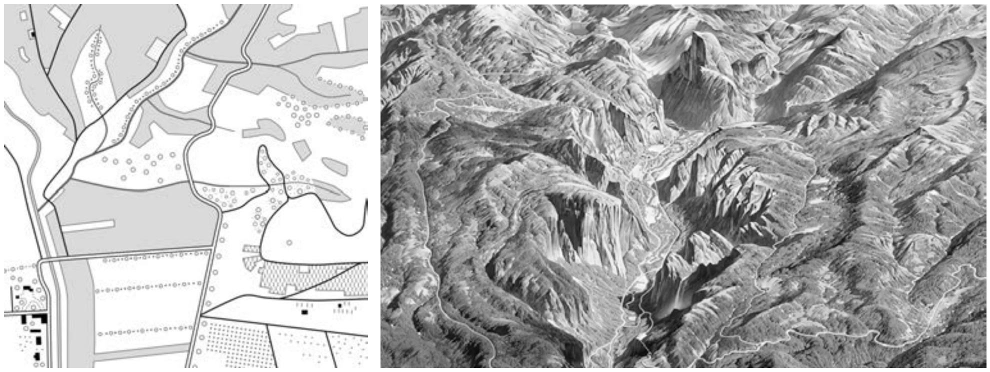

Fig. 1: Excerpts of a topographic map (left) and a hand-painted panorama map; compare the technical look of land use categories (left) versus the natural depiction of the landscape (right). Left: SPIESS et al. 2002; right: Yosemite National Park by H.C. Berann (PATTERSON 2000).

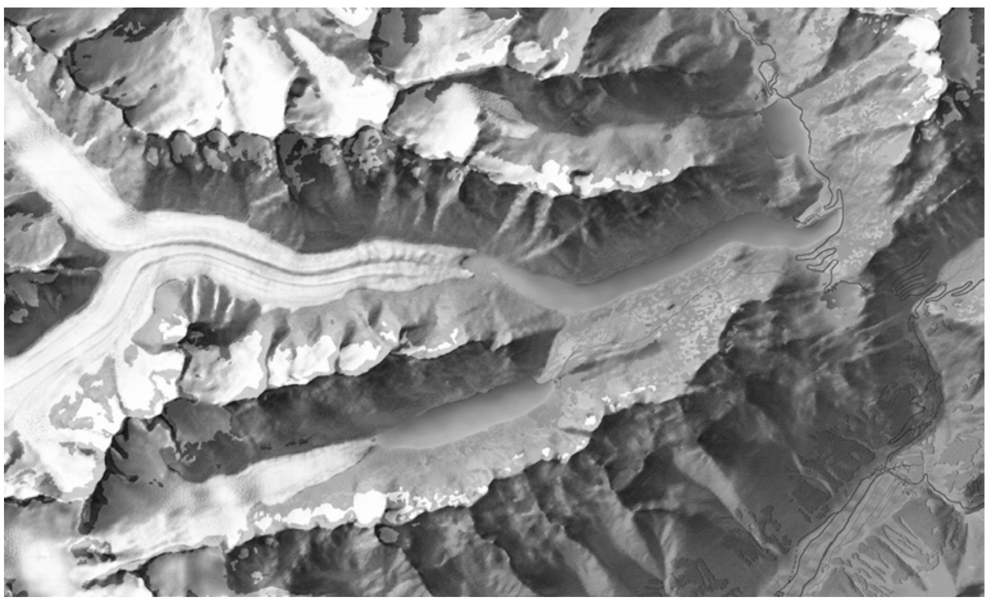

Fig. 2: A pseudo-natural map of the Grimsel area, created with Adobe Photoshop using land cover data, orthoimagery, and a digital elevation model; original in colour (KÄGI, 2003).

PATTERSON and KELSO (2004) followed such an approach to create small and middle scale maps in natural colours, using raster graphics tools and filters in Adobe Photoshop. They created a pseudo-natural collage by reclassifying and replacing the colours of land cover raster datasets, by piecewise pasting of coloured satellite images, by adding digital shaded relief, and by creating illuminated relief through colour enhancement.

Unfortunately, the creation process of the aforementioned manual and digital pseudo-natural maps cannot be easily and automatically applied to arbitrary regions. Yet, this is what the modern cartographer needs: a (semi-) automatic method to generate a digital map of an arbitrary region in pseudo-natural style without requiring artistic training or many-step preprocessing. Few efforts have been undertaken so far towards this goal: Bratkova et al. (2009) suggest a stroke-based painterly rendering approach to design panoramic maps in Berann and Niehues style. In a semi-automatic approach, Dachsbacher et al. (2006) use a clustering approach to find color distribution in satellite images. They use the resulting colour histograms to generate four classes of procedural land cover textures. Mantler and Jeschke (2006) experiment with adding three-dimensional effects to forest areas of 3D terrains by manipulating the underlying terrain model and adding special illumination effects.

In this article, we assume that different raster textures are used to symbolize land cover categories, and concentrate on a single aspect of (semi-) automatic pseudo-natural map creation that so far has been neglected by the aforementioned approaches: we focus on natural looking transitions between these textures, and how these transitions can be adapted – either interactively by the cartographer or automatically by an algorithm – to look natural and plausible.

After shortly discussing transitions in nature and terminology related to transition textures, we describe the different types of texture transitions that are useful in the context of map making. Subsequently, we explore how texture synthesis algorithms used in computer graphics handle transitions between textures and how they could be useful to design textured maps. By pointing out promising approaches, we aim to contribute to the development of (semi-) automatic methods for the generation of pseudo-natural maps.

2 Transitions in Nature and Texture

In nature, transitions between different vegetation classes generally do not happen as abruptly as suggested by the sharp edges on many traditional topographic maps. For instance, transitioning from forest to grasslands in reality involves forest becoming less dense towards the grassland, then a declining number of tree islands and possibly some shrubs mixed with grass and gradually a dominance of grass; or, there may be clearances surrounded by dense forest.

In computer graphics, the passage from one visual surface structure to another has been designated with different terms. A *composite texture* describes a texture where multiple subtextures interact spatially (Criminisi et al. 2004; Zalesny et al. 2002, 2005), emphasizing the presence of two or more textures. Gradual convergence and change from one structure into another is clearer in the term *transition texture* (Lai et al. 2005 and 2008), while *blend texture* (Hardy and Roberts 2006) and *mixed texture* (Bar-Joseph et al. 2001) evocate the resulting new texture appearance based on several input textures. In this contribution we are interested in all of the above aspects. We prefer the term *transition* *texture* because we assume that it illustrates best a gradual change between land cover categories in contrast to the sharp boundaries typical for standard topographic maps.

3 Design Parameters for Natural-looking Transitions in Maps

In the following, we assume that the cartographer is working with two or more land cover categories from a generalized land cover dataset and that a different texture was assigned to each category. We adopt the terminology of ZALESNY et al. (2002; 2005) and address different textures present in transition zones as *subtextures*. To create natural looking transition textures, the cartographer needs to be able to influence the global distribution of the subtextures in the transition zone as well as their local interaction.

3.1 Global Distribution of Subtextures in Transition Textures

To avoid a technical look of the land cover category boundary, the subtextures could dissolve into subtexture islands. The number and size of these subtexture islands within the neighbouring subtexture should be arranged naturally e.g. become smaller with increasing distance from the boundary. The width of this patchy transition zone should appear plausible. The boundary between the subtextures should vary naturally (e.g., undulate), but also must not diverge too much from the category boundary defined in the underlying land cover dataset.

The map author may also whish to create transitions that are not included in the land cover dataset. For example, texturing a large forest area uniformly may look disturbingly repetitious. Including a few grassy clearances or slight variations in texture granularity and colour may improve the natural appearance.

3.2 Local Subtexture Interactions

If viewed from further away, it may be enough to break up subtextures into islands along boundaries to achieve a natural looking transition. If observed more closely – at the scale of a few pixels – the question arises how one texture should change gradually into another or interact with it, such that the synthesized textures appears plausible and natural. The methods for achieving plausible transitions at a pixel level depend on the type of texture used.

Feature textures are made up of recognizable elements (e.g. individual trees) and a number of their characteristics can be varied (e.g. the size of a tree). With decreasing distance to the transition boundary, the features of a subtexture can change in size to simulate natural sorting or composition (e.g. dominance of smaller trees). They can also change in form and colour to morph into the features of the neighbouring subtexture (e.g., trees could morph to bushes). Features of different subtextures can also overlap, or a mosaic of features of both subtextures can be created.

For stochastic textures without discernable features (e.g. sand or a continuous canopy texture) a transition may be achieved by a weighted blending. The weight can be a function of both subtextures.

We are aware that feature textures are rarely used in cartography and that computer games often represent terrain at considerable larger scale than is common in cartography. Yet, we think that cartographers should experiment more with natural textures from computer graphics and adapt them to their own needs. For this reason, we do not exclude specific types of transition textures as not being suited for pseudo-natural maps.

4 Raster-based Approaches for Creating Transition Textures

In this section we present approaches from computer graphics, which could be applied in cartography to design natural looking transition textures. We favour raster-based approaches because they are flexible: they can be combined with raster datasets from other sources (e.g. aerial photography) that are of interest to pseudo-natural map generation, can be easily used to texture extensive areas, and can consider many kinds of textures (e.g. natural, procedural, non-photorealistic). Raster-based approaches can also synthesize large, slightly varying natural looking textures without needing additional information, as will be explained in the following paragraphs.

4.1 Texture Synthesis by Example

The term *texture synthesis by example* describes a family of methods that create visually similar textures based on an input exemplar without unnatural repetitions or artefacts (see WEI et al. 2009). Simple versions of this approach aim at producing an arbitrarily large texture from a small texture input. More refined versions allow to control where specific subtextures go in the output texture. This way, the appearance of one location (e.g. a landscape photograph or textured land cover dataset as input) can be transferred to a different location. The output could be a land cover texture of a different region that shares the appearance of the input landscape. Most algorithms of this type reassemble the output texture from pixels or patches from the input texture (Figure 3).

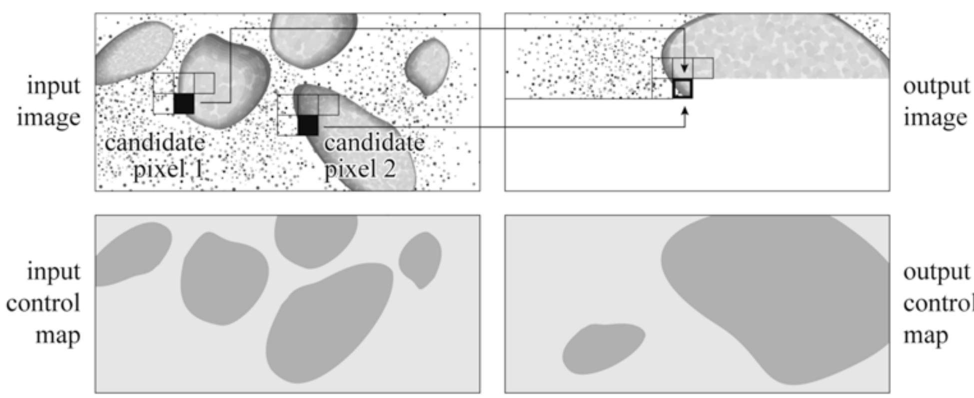

Fig. 3: Principal of texture synthesis by example: elements of the input image are reassembled into a new texture. The best fitting candidate pixel is selected based on neighbourhood similarity, control maps and the partly generated output.

That is, they copy elements from the input texture and reassemble these elements to generate the output image. The selection of input elements is based on a similarity measure. For a given area in the output image, the algorithm uses the input element with the best similarity measure. As similarity measure, parameters related to colour are usually selected, but additional characteristics can be included.

To model global structures, algorithms need additional guidance, which can be given in form of a *control map*. With a control map, elements of the input texture are not assigned to any area in the output texture, but they are placed in or close to regions specified by the control map (Figure 3).

ZALESNY et al. (2002, 2005) approach transition texture generation using an algorithm based on texture synthesis by example. As input, they choose landscape photographs and the output is a natural looking fictional landscape displaying the same kind of land cover in the style of the photograph. To guide the global distribution of subtextures (see Section 3.1), ZALESNY et al. (2002, 2005) use a control map showing land cover type distribution. The control map is extracted from the landscape photograph using an unsupervised segmentation algorithm. They use this first control map to derive other control maps describing the subtexture distribution of fictional landscapes. The resulting subtexture distributions and boundaries look natural and include texture islands.

To create plausible local transitions between subtextures in the output texture (see Section 3.2), transition areas of the input image are transferred to the output texture using the synthesis by example approach described above. In this way only subtextures and subtexture transitions can be reassembled in the output texture that are also present in the input image. ZALESNY et al. (2002, 2005) implemented a workaround when two neighbouring subtextures in the output do not have a common boundary in the input. The subtexture interaction is then accomplished using texture knitting, which is based on statistical models of the subtextures.

For creating pseudo-natural maps with the method by ZALESNY et al. (2002, 2005), a control map with natural boundary geometry could be extracted from aerial imagery (provided that a satisfying segmentation or filter procedure could be found). The cartographer would need to create an exemplar input texture (e.g. in Photoshop) containing all subtexture types and subtexture transitions that will appear in the pseudo-natural map. This map could show a synthetic area. Its design – including textures and texture transitions – would then be transferred to a geographic region for which a control map was extracted. The visual variety of the subtextures would also be carried over to the output, giving areas of uniform land cover a more natural, varied appearance.

4.2 Preserving Features in Transition Textures

Simple linear blending is a quick way to compute a smooth boundary between two subtextures. Blending computes a weighted average of two colours. The influence of a texture colour on the colour of a pixel in a transition zone is in inverse ratio to the distance to the texture. On textures that look similar to random noise and have no structure (e.g. sand or canopy), linear blending is a fast option to create smooth transitions. For feature textures (e.g., trees with individual trunks), linear blending is not optimal, because it does not ensure that the features remain consistent and discernable (HARDY & MC ROBERTS 2006). Feature structures of one subtexture may disturbingly shine through features of the neighbouring subtexture.

LAI ET AL. (2005) and LAI & TAI (2008) create transition textures between two (LAI ET AL. 2005) and more (LAI & TAI 2008) dissimilar feature subtextures. When two subtextures interact locally (see 3.2), one subtexture is assigned to dominate over the other subtexture in an opaque overlay (2005 contribution). In the context of this approach a natural border is one where features of the dominant subtexture are not cut off. To keep the features intact along their borders, an edge map of the dominant subtexture (e.g. pebble outlines) is extracted. One or multiple pieces of the dominant subtexture are copied in the output texture along closed paths in the edge map (Figure 4, lower left). Multiple closed paths create subtexture islands. To make the algorithm also aware of features of the non-dominant subtexture, a later version of the algorithm (2008) allows some features of the non-dominant subtexture at the transition border to be included in the output image (Figure 4, lower left). An example-based texture synthesis approach is used to fill the rest of the output texture with non-dominant subtexture. The global subtexture distribution (see 3.1) is modelled after a limited number of predefined layouts and the cut on the edge map is guided by these distribution patterns.

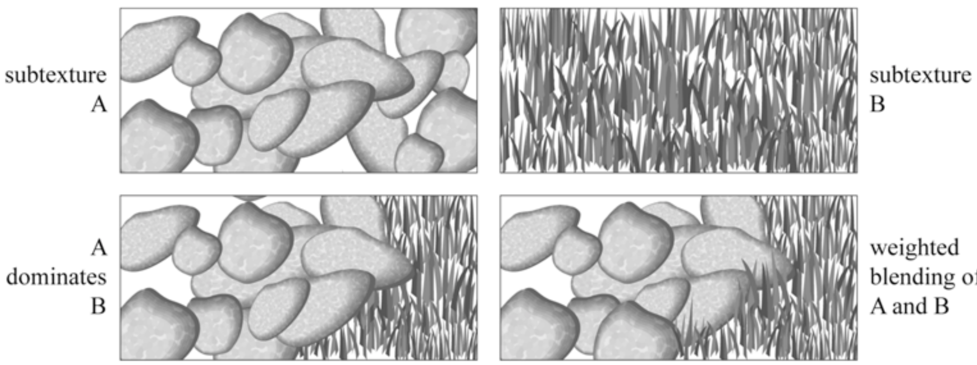

Fig. 4: Preserving subtexture features: only feature outlines of subtexture A are preserved in the transition region (lower left); features of both subtextures are preserved using weighted blending or by tracing elements of the non-dominant texture (lower right).

HARDY & MC ROBERTS (2006) suggest an algorithm that improves linear blending for terrain texturing to avoid the disadvantages of traditional linear blending. Like LAI ET AL. (2005) and LAI & TAI (2008) they concentrate on preserving features of subtextures at transition borders. They use an importance map to give more weight to prominent features in subtextures when these are blended with other subtextures (Figure 4, lower right). One way to automatically deduce the importance map is to use luminance (e.g. for pebbles and grass blades). Weighted blending formulas are provided to blend more than two textures.

The methods described in this section are potentially useful for creating pseudo-natural maps. For example, feature-preserving transitions would be an interesting approach for synthesizing forest textures for panoramic 3D maps. Such forest textures consist of an accumulation of miniature trees, each with individual, albeit highly stylized, trunk and crown. The US-American panorama painter James Niehues fills large areas on his maps with miniature trees and has perfected this type of texture. An automated method could bring these very aesthetic textures to the reach of other mapmakers.

4.3 Texture Morphing and Progressive Shape Variation

MATUSIK et al. (2005) did not have land cover transitions in mind when developing their algorithm for morphing a subtexture gradually into another. Instead, the authors wanted to imitate the spatially varying surface patterns of weathering in natural materials or the creation of new textures based on other similar textures. Their algorithm extracts features from the input subtextures and creates a warp function that optimizes feature alignment in the subtextures. A small residual alignment error is an indicator that the subtextures are similar enough to be successfully interpolated. The method then performs geometry morphing and colour interpolation between pairs of texture elements. In this way, new textures can be created that share similarities with both input textures, but look somewhere in between (e.g. between a pebble and a coffee bean). RAY et al. (2009) create similar results for morphed textures that can be placed at user-specified positions on a textured object.

ZHANG et al. (2003) create progressively variant textures. While continuous change from one subtexture into another can also be realized with their method, the focus lies on the gradual change of the elements within a texture. An example application of progressively variant textures is the imitation of pattern changes on animal coat. For 2D images, the authors suggest two methods that make use of example based texture synthesis. The input to both methods is a homogeneous texture. The field distortion synthesis method creates a progressively variant output texture by including scale and orientation control into a pixel-by-pixel example based synthesis approach. The feature-based method extracts a control map, called texton map that identifies the elements in the input texture. The input texton map is interactively adapted to show progressive variation of features. The output texture is created based on the adapted texton map using example based texture synthesis.

For pseudo-natural map creation, progressive variation of texture could be used to model the behaviour of elements within a subtexture or when approaching a transition boundary (Figure 5). For example, sorting processes in nature could be simulated (e.g. smaller to larger stones under gravitational influence, larger to smaller grain size when moved by water).

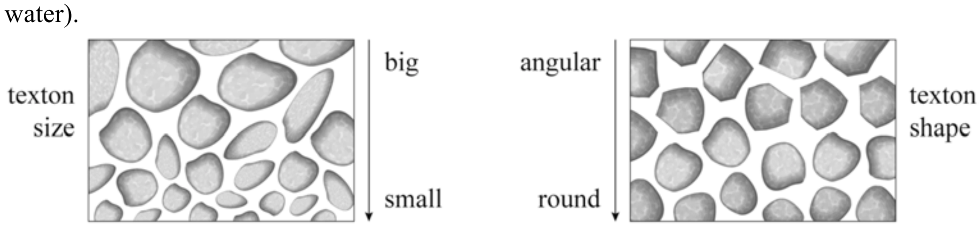

Fig. 5: Simplified principle of progressive texture variation by texton size and shape

Additional information could be expressed though texture variation. For example, based on soil maps, trees could appear smaller on poorer soils. Texture morphing as performed in the approach by MATUSIK et al. (2005) can be a better alternative to feature preservation (see 4.2) if the features of the two subtextures are similar enough.

Also, if no separate land cover texture is available, a well-controlled morphing between two subtextures can hint at a vegetation transition that was not captured by the underlying land cover dataset e.g. shrubs at a forest to grassland transition. Morphing could also be used to texture very small or distorted subtexture islands.

5 Conclusion and Outlook

The methods discussed in this survey have been developed for applications in computer graphics, mainly video games, where constraints for texture synthesis differ considerably from those in map making. Many video games aim at creating hyperrealistic textures, often for objects at comparatively very large scales. When a landscape is included in such scenes, it is frequently synthesised by an algorithm and is not geographically correct. (There are notable exceptions, such as some flight simulators). The same goes for textures applied to these landscapes. The goal is to generate a realistically looking image without aiming at an accurate rendition of geographic reality.

Textures applied to 2D and 3D maps, however, have to follow geometrical constraints implied by the underlying land cover data. It seems that the methods discussed in this survey could be adapted to these geometrical constraints, while adding some level of natural variability to the generated texture.

All presented methods seem to have interesting characteristics that could help create pseudo-natural maps. The various methods remain to be evaluated for cartographic applications. From a cartographer's point of view, some of the presented textures or methods may appear non-serious or gimmicky. Nevertheless, they might be useful for adding a touch of realism to a map, resulting in a more engaging appearance. Indeed, the general public seems to be very fond of orthoimagery, and apparently often prefers the natural colours of orthoimages to the more technical look of traditional topographic maps. Pseudo-natural maps can imitate this natural appearance, while avoiding the numerous drawbacks of orthophotos, such as an often-confusing amount of small details, inconsistent colouring, or an unfavourable direction of illumination. The techniques for transitional textures might be an essential element in automating the creation of alternative pseudo-natural maps.

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