Nationaal Lucht- en Ruimtevaartlaboratorium

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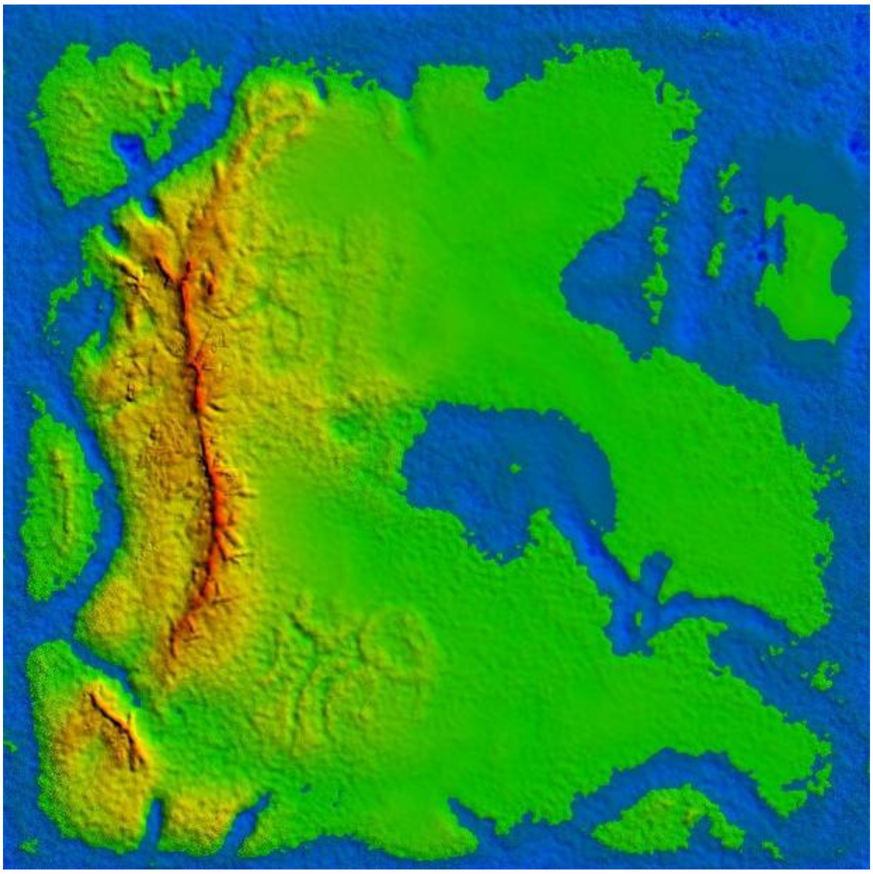
Executive summary

Environment data for a high fidelity fictitious continent



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Problem area
Training via distributed mission simulation has the potential to enhance force readiness and operational effectiveness in coalition operation. An essential condition for an effective mission simulation environment is a correlating representation of the real-world natural and cultural environment in the distributed simulations. Correlating existing environment databases is costly, both in effort and in money, and the end result will always be hampered by technical incompatibilities. A generic and geo-unspecific, widely available simulation environment could overcome these problems.

The NATO RTO task group MSG-071 Missionland started to evaluate how such a dataset can be constructed. It is however no easy task to generate high quality data of a fictitious continent.

This report is based on a presentation held at the Spring SIW, Boston, 5 April 2011.

Description of work
Procedural techniques for elevation data are promising because they can automatically generate data for large areas according to parameters. This approach is often used in games as well. Unfortunately, the level of user control is currently limited and the realism of the output can be questioned. Even so, the need for large amounts of data renders the use of procedural methods inevitable at this point in time.

User controlled blending of real elevation data is a promising technique to enhance procedural generated terrain to higher levels of realism. The technique gives a user a large level of control.

The task group evaluated these two approaches for generation of the elevation data and the tools available to do so.

Production of the vector data and imagery of the dataset is subject to many of the same challenges as the production of the elevation data. The task group has also evaluated the techniques available in this area, but did not yet experiment with them.

Results and conclusions
The task group concluded that there is not one single tool available that can handle the total generation of the elevation data of a fictitious continent. However different COTS tools have been identified to produce parts of the data and the task group has also designed some custom tools to fill other gaps.

A base elevation dataset has been produced using one of these tools and it proved capable to generate an entire continent. However the realism of this data was not at the level expected.

Therefore the technique of blending real world elevation data has been tried using a prototype tool. With a rich library of real word data, it should be possible to include all terrain characteristics and avoid repetition. The task group decided to proceed with this approach.

For the vector data and imagery possible tools to use in the production phase have also been identified. However it still has to be seen if these can be integrated into the process for generating the Missionland dataset.

Applicability
With the experiences gained the task group could start developing the tools and techniques to make the production of elevation data using the blending approach for Missionland possible. Besides that the techniques and approach identified can also be applied in the process of making simulations environments for other projects or simulators.

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Environment data for a high fidelity fictitious continent

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ABSTRACT: *NATO RTO task group MSG-071 "Missionland" is in the process of developing an environment dataset for a fictitious continent located in the Atlantic Ocean. The objective is to generate a dataset for use in (distributed) simulation systems for training and experimentation. To satisfy the heterogeneous needs of the users the continent should contain a wide variety of terrain and climate types. The dataset should be shared freely among NATO and Partnership for Peace (PfP) countries without political or legal restrictions. Therefore MSG-071 is focusing on producing high fidelity geo-typical data. Ideally one could procedurally generate geo-typical data with the correct specifications in cases where available geo-specific data is not suitable. There are numerous published works concerned with procedurally generating geographical content like elevation data, culture data and imagery.*

This paper describes MSG-071's efforts to produce high fidelity geo-typical data that has the same characteristics as real world areas. The group has investigated the availability of tools for procedurally generating elevation data, culture data and imagery, and has tested some of the tools. A blending technique for interactively creating geo-typical elevation data from geo-specific samples is also presented. This technique and other possible approaches for generating geo-typical elevation data, imagery and culture data are evaluated in this paper.

1 Introduction

Distributed mission simulation is nowadays more and more used for military training, concept development and experimentation. An essential condition for an effective mission simulation environment is a realistic and correlated Synthetic Natural Environment (SNE). An SNE consists of representations of different types of objects, like terrain skin, vegetation and man-made structures. SNEs are also an important part of commercial computer games.

This paper introduces the NATO Research and Technology Organisation (RTO) task group MSG-071 "Missionland" and discusses possible ways to develop a dataset that will meet the requirements established for the SNE of the Missionland continent.

The paper is organized as follows: First the background of MSG-071 and its past and coming tasks and needs are accounted for. Then section 3 discusses procedural content generation. Section 4 discusses elevation data production and introduces some of the tools and techniques MSG-071 has reviewed and used so far. Vector data and imagery are discussed in section 5, while a conclusion and the way forward for MSG-071 are presented in section 6.

2 MSG-071 Missionland Task Group

This section explains the objectives of the Missionland task group and outlines the requirements for the generation of the environmental data.

2.1 Objectives

When performing distributed (joint) simulations, selecting a suitable and correlated SNE for all participants is usually a challenge. The participants often have different requirements or different technical possibilities. Besides that legal and political restrictions often apply limitations in sharing the environmental data. An example of such a political restriction is that countries often do not want to share high resolution environmental data about their own country with others. Another example of political concerns is when an SNE is composed of real world data and one of the participants in an international exercise using the SNE has a troublesome history with the respective real world areas.

The NATO RTO task group MSG-071 was formed in 2008 by the following countries and centres: Belarus, Canada, Germany, Netherlands, Norway, Sweden, Turkey, United Kingdom and the NATO Joint Warfare Centre. The objective of the task group is to ease the identified difficulties in creating suitable and correlated SNEs, by creating an environmental dataset that can be freely shared by NATO and Partnership for Peace (PfP) countries [1;2].

Missionland will provide a fictitious continent in the middle of the Atlantic Ocean, of roughly 2000 x 2000 km in size. Because the continent is fictitious, there are less political limitations on sharing the data. This continent will have a variety of climate and terrain types. To support a wide range of M&S needs, the environment will be richly populated with data representing different aspects of the real world. The size of the continent and its coastline allow for joint synthetic training, while high resolution areas make the dataset attractive for simulation of local ground based operations.

Besides the requirements for a visual representation of the environment, the dataset also needs to contain the information needed by other applications in the simulation. For example for infrared or radar sensors or for computer generated forces applications. So it will be a multispectral dataset.

2.2 Missionland products

The Missionland dataset will provide a number of products to the end users. The end user will have to make a runtime database of the environment for the specific simulation system used. The Missionland dataset will be delivered in common formats, to ease the process of creating this runtime version. At the moment it has not yet been decided which formats will be used.

The dataset will contain a number of core products: elevation data, vector data, 3D models and material textures. Other products, like maps or imagery, will be derived from these core products.

The elevation data is provided as a regular grid. The resolution of the elevation data varies, with the highest resolution being provided in the areas of interest. Possible formats for storing the elevation data are Digital Terrain Elevation Data (DTED) and GeoTIFF.

The vector data represents different features in the environment. Vector data consists of point, linear and areal features. The point features are used to define the location of objects, like a house. The linear features are used to define roads, rivers or power lines, while areal features are used to define areas with certain land cover types, for example forest or city, or to define the footprint of a building. Additional information of the feature is captured by the meta data, often called feature attributes. Examples of these feature attributes are the width of a road, the height of a building or the maximum load for a bridge. The most common format to store vector data is the ESRI Shapefile format. For the feature attributes there are different schemas, including Feature and Attribute Coding Catalogue (FACC) and DGIWG Feature Data Dictionary (DFDD) from the Defence Geospatial Information Working Group (DGIWG) and the Environmental Data Coding Specification (EDCS) from SEDRIS.

Man-made features like buildings, bridges and light posts are represented by geometric 3D models in the Missionland dataset. The dataset will also contain similar 3D models for vegetation object like trees and bushes. These models should be stored in common file formats like OpenFlight or the COLLADA format. The position of such 3D models in the environment is defined using point features in the vector data.

Material textures are used to give the environment and objects the right representation. This can be in the form of a texture used by the visualization, but also by providing the right parameters to be able to generate a sensor image. For visual textures a common format like RGB is used. For the information for the sensor representation a common and widely used standard does not yet exist, but the task group will try to provide this information in such a way that most end users can easily use it in their systems. The task group is looking into initiatives like SEDRIS and CDB to evaluate if these can provide means to deliver the dataset in a common way that most end users can work with effectively.

3 Procedural Terrain

According to [3], research concerned with procedural content generation for virtual environments have been conducted since the 1980's. The efforts were first concerned with elevation and vegetation, but later work has also focused on urban environments. Even though procedural techniques and tools have been around for a long time, the usage of procedural methods for creating content for games and simulations is not as widespread as more manual methods [4]. Lack of sufficient user control can be reasons why [3;5]. MSG-071 have used procedural methods for elevation data production, and looked into the possibilities of using similar methods for generation vector data, 3D models and textures.

3.1 Definition

Procedural modelling methods are characterized by their ability to produce relatively large amounts of data from a relatively small number of parameters. A tool for procedural generation of geometric building models would typically take parameters as: number of floors, type of roof, shape of foot print, etc. as input, and then generate all the polygons that make up the geometric model and the textures that are applied to it. Other geometric models, like terrain skins, road networks or vegetation models can be generated in the same way.

In this paper, the definition of procedural modelling is modelling through a computer program that takes a set of parameters as input and outputs data that represent an instance of an object class (terrain elevation, geometric models of vegetation or man-made structures, etc.).

Algorithms for generating synthetic elevation data can be separated into two groups: those based on simulation of geological phenomenon like erosion, and those based on mathematical concepts in stochastic and fractal theory. Some call these two groups physically-based methods and procedural methods respectively [5;6], others refer to the first group as simulation algorithms and the seconds as procedural synthesis algorithms [7]. This paper refers to the first class as erosion based methods and the second class as procedural methods.

3.2 Advantages and disadvantages

Procedural modelling, as opposed to manual modelling, offloads some of the work from the modeller to a computer program. Instead of adjusting all details of an object, the modeller specifies how the object being designed should turn out by adjusting parameters. A computer program then generates the object according to the specifications. If the computer program produces satisfactory result, the modeller can save much time because there are fewer operations he or she has to perform before the result is ready.

Procedural methods for terrain elevation are often based on fractal theory and random noise distributions. These methods are efficient in the sense that they can produce data for large areas in a relatively small amount of time [5;7].

Current procedural terrain elevation methods are hard to configure and control, which makes it hard to produce the intended results [3;5]. Another drawback with current methods is that the random nature of the algorithms does not model all the structures found in nature well enough [8] to make the result indistinguishable from real areas. Structures that are hard to model are typically formed over many years of natural occurring phenomena like erosion. Unfortunately, implementations of erosion based methods run much slower than their procedural counterparts [7]. It may seem that current procedural methods and even erosion based methods are not able to produce elevation data that really look natural [6].

An example of the difference between real and procedural terrain is displayed Figure 3.1. Sea level is rendered in black. The elevation then goes from blue through green and yellow to red. The highest areas are rendered in white. The colour legend has been chosen individually for the two data sets to best visualize the topologies found in the two, not to compare the elevations. The highest point in the procedural terrain is considerably higher than in the real terrain. Both terrains are however 100 x 100 km. The purpose of this figure is mainly to illustrate the topological differences often seen between real and procedural terrain. All real elevation data used in illustrations and examples in this paper was delivered by Norge digitalt, a Norwegian geo data supplier.

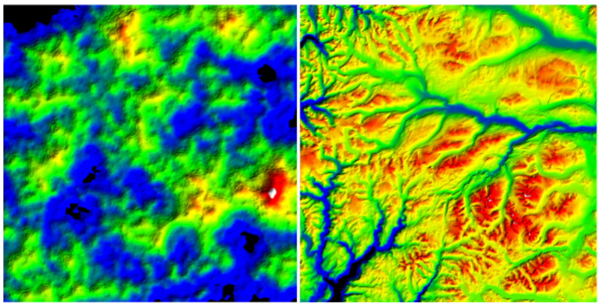

Figure 3.1 Visualizations of procedural terrain on the left and real terrain on the right.

One observation made by MSG-071 is that most methods for generation of elevation data seem to focus on mountainous scenery. In general it seems that procedural techniques are best suited to produce mountainous or hilly areas. Another observation is that most screen shots of terrains produced by procedural methods are from a low flight/ground perspective. Methods based on real world data more often use screenshot of larger areas and of the raster data to show structural differences between procedural terrain and real world data, similar to what is done in Figure 3.1. In other words: publications on procedural terrain generation provide examples of their techniques' usefulness for generating small areas, not for areas with sizes comparable to the size of the Missionland continent.

4 Elevation Data

When all parts of an SNE are manufactured synthetically, elevation data is in many ways the most natural part to start out with. In a real-world GIS context, much information is derived from imagery. Because there is no imagery to derive information from, MSG-071 found it natural to start with elevation data and then create correlating imagery and vector data.

Even though research into possible techniques and tools for manufacturing vector data and imagery has been conducted in parallel, the work on elevation data has been prioritized by MSG-071. The subject of elevation data is therefore described in more detail in this paper.

MSG-071 first looked into using real elevation data contributed by the members of the group. Parts of such datasets could be combined to make an elevation dataset that would meet the requirements of the Missionland SNE. The lack of tool support for this kind of work makes the process hard to manage for such large amounts of data. Cutting and gluing would not suffice, as this would result in unmatched borders (walls) in the terrain. Manual adjustment of elevation elements to smooth such unmatched borders would require many man hours of work. Use of large, continuous areas of real world data to make the process easier, would conflict with the requirement of geo-typical terrain because large areas would be easier to recognize.

Due to the difficulties in combining areas of real world data, MSG-017 looked into procedural terrain. The ideal solution in this case would be a tool with parameters that could be adjusted to create a whole continent in the required resolution and with the wanted terrain characteristics in different areas of the continent. The output would also have to be common file formats, so the data could be loaded into other tools for further enhancements or analysis. A candidate tool would have to handle large amounts of data (65536 x 65536 data points or more), to be able to generate the whole dataset with 30m resolution.

4.1 Special requirements

The requirements for an SNE can be somewhat different when it is to be used in military M&S than what would be the case for most commercial games. Most games focus more on smaller playable areas than military operations, and game levels are often subject to a great deal of manual work. The playable area is relatively small so a level designer is able to manually adjust placements of man-made structures, trees and plants, as well as shape the elevation data using simple low level brushes. The size of the Missionland continent means that manual shaping of the terrain using low level brushes can only be done in very small parts of the overall terrain.

Logistics is a very important part of military operations, so is movement in natural terrain with heavy machinery. Preferably, military personnel should be able to use the same type of terrain analysis in Missionland as in real world areas. Missionland should provide the same challenges in establishing logistics chains and planning routes for advancing through the terrain as real terrains do. In this sense, a procedural algorithm that can produce plausible terrains of 10km x 10km with two or three mountain peaks and a few short ridges, does not necessarily produce realistic terrains of 100km x 100km. The long valleys that provide manoeuvrable paths through otherwise impassable terrain are missing. The 10km x

10km area would probably still be suitable for most first person shooter games as well as training military operations that are situated within such a relatively small area.

Another issue is navigation. If one were to remove all man-made structures from a map of a procedurally generated area of 100 km x 100 km, one might find that the same missing large, global terrain structures makes navigating quite hard. In this sense, elevation data that works well for some types of military operations might not be usable for another group of operations. These concerns have to be taken into account when the Missionland elevation data is to be produced, as Missionland is intended to support a diversity of types of operations. A contour example is shown in Figure 4.1. The contours were generated from the elevation data shown in Figure 3.1 using Global Mapper.

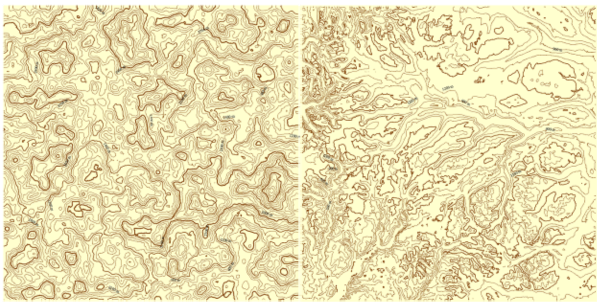

Figure 4.1 Contours (300 m) for procedural (left) and real (right) terrain.

4.2 Related work

A tool that has caught MSG-071's attention is Sketchaworld [4;9]. Sketchaworld is a prototype tool implemented by TNO in the Netherlands, in cooperation with the Delft University of Technology. The tool implements a new modelling process called declarative modelling [10;11]. By using a sketch based interface, a user can declare how an environment should look and thereby control the underlying procedural algorithms. This way the less intuitive parameters of the algorithms are translated into parameters the user can understand and make effective use of. Because the tool is under development and not publicly available it has not been utilized by MSG-071.

Procedural algorithms have also been implemented for execution on Graphics Processing Units (GPUs), achieving interactive processing rates and local user control [7]. By allowing procedural algorithms to work in user defined areas of a height field at interactive rates, a user is provided a substantial increase in control of the outcome.

Others have experimented with the use of real world elevation data to create artificial areas [5;6;12]. The use of agent based approaches and genetic algorithms have also been researched [5;13]. The size of the Missionland elevation dataset excludes otherwise interesting and useful techniques. The reported performance of the implementation in [13] is 20 seconds for .5k x .5 k vertices which, if one assumes O(n) running time where n is the number of vertices, would result in about 90 hours for the 65k x 65k 30 m resolution elevation dataset of Missionland. This limits the possibility to try out the effect of parameter adjustments on such a large area, and thus makes the approach unsuited for use in MSG-071.

After some research into available tools two main candidates for procedural generation of elevation data were identified: L3DT and GenMap. The latter is developed by the Turkish company SimBT which has a representative in MSG-071. A third tool, Interactive Terrain Editor (ITED) under developed by FFI (Norwegian Defence Research Establishment), has also been used in MSG-071. ITED is not a procedural terrain generator, but it provides a user the ability to produce fictitious terrains with use of real-world elevation data. These three tools will be discussed further in subsequent sections.

4.3 L3DT

Large 3D Terrain Generator is a commercial tool that provides a user with an interface to a procedural terrain generator [14]. The interface provides functionality to edit elevations and other parameters in a design map. The design map is then processed by the generator. The elevations in the design map are used as guidelines when it is processed by the generator, and the other parameters as means of giving the user local control over properties of the terrain (roughness, etc.).

L3DT can handle a total of 131072 x 131072 data points. This capability was one of the reasons why L3DT was chosen. The algorithm used to generate the elevation data is based on a diamond-square fractal algorithm and Perlin noise. The height field is generated in several iterations, at different resolutions, to capture low frequency shapes like rolling, smooth hills and high frequency shapes like terraces.

Erosion simulation is also included in L3DT and the level of erosion simulation is controlled through a parameter in the design map. The parameter affects the number of iterations of erosion simulation and thus the total running time of the generation process. The erosion simulation is an order of magnitude slower than the rest of the computations. This rendered the erosion simulation hard to use in the context of Missionland. The erosion simulation is also quite simple, with little or no global structural effects (river networks, etc.).

MSG-071 has used L3DT for generating elevation data. First a design map outlining the shape of the continent was created. A visualization of the design map is shown in Figure 4.2. The elevation data of the design map also encoded a mountain chain, hills, flats, islands and fjords. Erosion simulation was turned off and the resolution set to 30 m (65536 x 65536 data points). The result matched the shape of the continent and islands quite well. Unfortunately, the terrain stood out as synthetic when compared to real data. It was too homogeneous and lacked large natural structures like long valleys, ridges and rivers. It also gave an impression that the same algorithm, designed to create one type of terrain, was used everywhere but with different parameters (steepness, roughness, etc.). This is in fact the case, even though L3DT has overlays for terraces and plateaus that are run after the “base” terrain is generated.

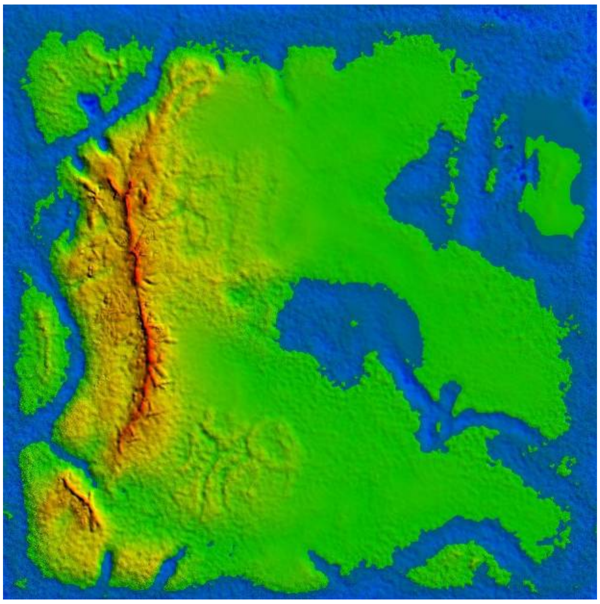

Figure 4.2 The Missionland design map.

The terrain was in general too smooth. Most of the blame for this can be put on MSG-071. We used a fairly high resolution design map, which we tried to encode with the overall terrain structures (mountains, fjords, flats, etc.). It turns out that the design map strongly dictates the elevations of the resulting terrain. This might be preferable when precise placement of individual peaks, etc. is wanted, but not when one wants to outline areas with mountain ranges with tens, maybe hundreds or thousands of peaks. More skilled users might work around this problem somehow, but it seems there is a conflict between design control and natural variations. In other experiments with L3DT there has also been a very strong correlation between the design map and the resulting terrain. This means there was little or no new terrain structures like small mountain ridges or even peaks not already in the design map. From our observations it seems the placement of all such structures would have to be done in the design map. When generating a new world in L3DT, the tool generates the design map based on a set of global parameters. These parameters do not give control over the placement of terrain structures like mountain peaks and ridges, fjords or lakes. To manually change the design map to incorporate a wanted design, while preserving the more natural look of the generated design map, proved difficult with the tools provided in L3DT.

The realism of the data produced with use of L3DT was not satisfactory, but because of the manual work performed on the design map, the overall shape of the continent, placement of the inland lake and islands, etc. all were. This caused us to keep the data and focus on incrementally enhancing areas of the continent instead of starting over with another tool.

4.4 GenMap

GenMap is a procedural terrain generator with a clever data management system that for example allows previews during build time. GenMap also has a promising imagery generator, but unfortunately, there are yet some obstacles in creation of realistic looking imagery with encoded terrain features that match the underlying elevation data. This is due to the use of relatively large pieces of real imagery that contain mountain ridges, rivers and valleys that do not exist in the elevation data.

GenMap produces elevation data that qualitatively matches the data produced with L3DT. However, the L3DT data was more correlated with the original design map elevation data (also used by GenMap). For that reason the L3DT data is used as a basis.

GenMap will be used to enhance some of the areas in this basis terrain.

4.5 ITED

ITED is an application and framework for processing of elevation data under development by FFI (Norwegian Defence Research Establishment). ITED was developed as a prototype tool for research in ways to enhance existing elevation data and as an aiding tool for MSG-071. The elevation data of the design map used in L3DT was edited in ITED.

ITED uses the GPU to interactively process raster elevation data loaded from common GIS format files. The processing pipeline in ITED is quite similar to the one described in [7], but ITED does not implement procedural algorithms. Instead a user can edit the terrain using simple, but smooth and effective low level brushes in much the same way as a user can edit an image using air brushes in an image editor. ITED is also a framework in the sense that new brushes and ways to process elevation data can quite easily be implemented.

ITED implements one function that is very interesting in the context of MSG-071 and the design of large and realistic looking virtual worlds. This function is the ability to blend pieces of existing elevation data into the terrain. The blending is completely interactive and user controlled, and no visual borders or edges are left. The concept of blending elevation data is not new [5;15], but to the knowledge of MSG-071 no one has implemented this type of interactive, seamless and user controlled blending before.

Results from elevation blending in ITED are displayed in Figure 4.3. The left shows a rendering of the target terrain with a downscaled, rotated and translated sample terrain on top. The image is just a rendering of two individual data sets, with one positioned over the other. No changes had been written to any of the data sets at the time when the screen dump was taken. To produce the terrain to the right, the sample terrain was scaled to its normal size (equal to the size of the target terrain), rotated and translated into different positions over the target terrain. The user then blended selected part of the sample terrain into the underlying target terrain using a blend brush. The areas are 100 km x 100 km with 20 m horizontal resolution and the blending process took less than five minutes to complete.

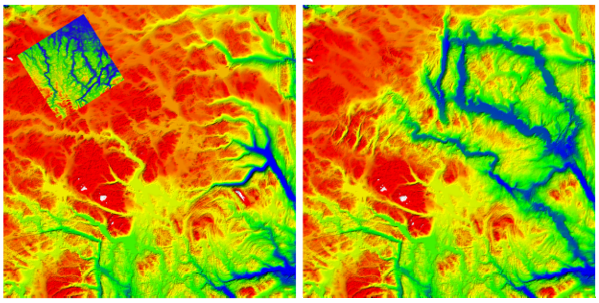

Figure 4.3 Renderings of elevation data from real areas (left) and the result of user controlled blending operations (right).

A short work session is also visualized in Figure 4.4. The first image is a rendering of the target terrain and the second shows a sample terrain positioned over the target terrain. The third image is a screen shot from the middle of the blending process. The pink square visualizes the outer boundaries of a mouse controlled blend brush operated by a user. The sample terrain is rendered transparently so the target terrain shines through from below. The rendering of the terrain formation (blue structure) being blended into the target terrain is sharper than the surrounding areas, as this formation now is part of both data sets. The last image shows the target terrain after the blending has taken place.

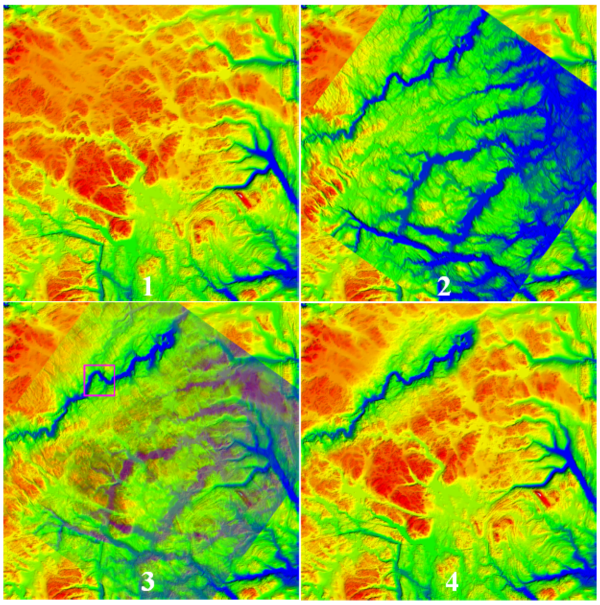

Figure 4.4 A blend sequence.

Figure 4.5 shows a 3D rendering of a cut from the target terrain after the blending process was completed. This is the same data that is rendered in 2D in the bottom right image in Figure 4.4. The white square approximates the position of the pink square in the bottom left image in Figure 4.4. Inspection of the terrain shows no unnatural borders or other artefacts create by the blending operations.

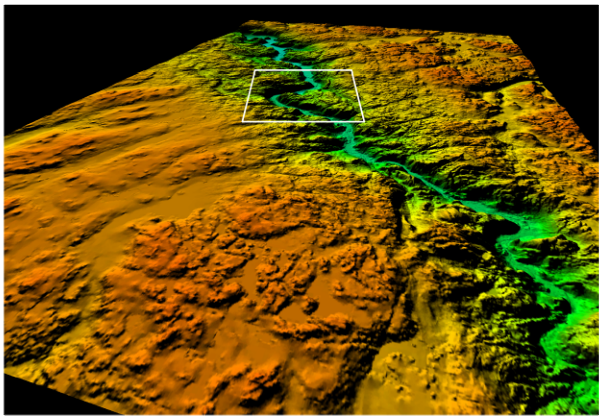

Figure 4.5 A 3D visualization of an area composed by blending in ITED. The rendering was done in Global Mapper.

Interactive blending of elevation data supports an artistic approach to designing new terrains. A user can choose exactly the features he or she wants from a library of existing (real) terrains and position them with precise position and orientation in the terrain being developed. Figure 4.6 shows the results of about five minutes of work. This time the target terrain was blank (zero elevation in all data points). The real terrain was blended into the target terrain as explained earlier. As a last step the coastline and fjords were created by using another brush to lower the terrain.

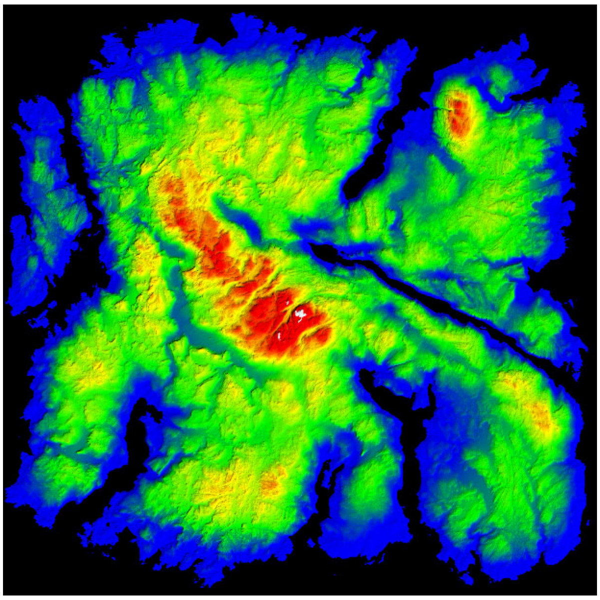

Figure 4.6 A result of blending and lowering operations. Sea level is rendered as black.

The blending process has so far proven itself as a promising approach in enhancing areas of the Missionland elevation data produced by L3DT. With the large datasets of elevation data now available in the public domain [16], such uses of real data can be good alternatives to procedural methods.

5 Vector Data and Imagery

Once the terrain elevation data has been generated, the next stage is to add vector data and imagery.

5.1 Vector data

As already described, vector data consists of the following:

- Linear features such as roads, fences, tracks, rivers, canals and the line of electricity wires.
- Areal features such as forests, fields, building outlines and lakes.
- Point features which often represent buildings, farms and individual trees.

It is important to note that vectors of natural features need to follow the terrain elevation to be believable, one obvious issue being rivers that flow 'up-hill'. Also it is unnatural for forests to be placed on steep mountain cliffs. During the process of generating Missionland vectors we have found it useful for this process to be advised by an expert in physical geography.

The generation of a set of realistic vectors is important to ensure the overall result looks correct. For instance a city which is not connected to any other city by road and other transportation links is not likely to be successful. Mountainous cities do not generally have harbours. Jungle areas are not generally built up.

The process of generating vectors is somewhat iterative; for example, once the line of a road is agreed, embankments and cuttings will be added to ensure the slope of the road is smooth, this is no different from the geo-engineering that occurs in the construction of a real road. Some COTS tools do offer help in this process, however their output must be checked for realism.

Given the size of the Missionland continent the process of adding vectors is a time consuming process that at the moment must be performed manually. However it is not necessary to generate high density vectors over the whole continent, instead it is possible to concentrate on areas where user activity might take place.

There are some COTS tools available to partly automate the process of generating vector data.. These are mainly focussing on the generation of built-up areas. The task group has looked at two of them, CityEngine by Procedural and CityScape by PixelActive, in more detail. The general concept of these tools is to generate a city based on limited input information. The user will for example provide the main road network and main terrain characteristics. Based on that the tools will generate the complete road network, including minor roads, and the 3D buildings to occupy the city automatically [17].

However most of the tools focus on outputting the synthetic environment in formats suitable for visualization, while MSG-071 is interested in the production of vector data that can be included in the dataset of Missionland. Of the tools we looked at only one was capable of exporting the vector data of the generated city again. Similar technologies are also applied in games in general, for example in the "Sim City" type games, but these also have the restrictions that their output is in the form of computer graphics and not source data for a synthetic environment.

Another possible technique to provide a dense vector set is to take vector sets of real locations and conform them to the Missionland terrain. Clearly it is important to ensure the vector set matches the terrain approximately before manual work is used to alter the vectors to the terrain or vice versa.

5.2 Imagery

The generation of imagery is the final stage of the system. There are a number of approaches to generate this imagery. As mentioned in section 4.4, GenMap offers one such approach where existing satellite imagery is applied. One area where care has to be taken with this approach, and a significant area of difficulty, is to ensure that the imagery matches the elevation and vector data. For example a valley in the image should match with the elevation data. Else false cues are provided to the end user of the environmental dataset.

Other attempts include work by CAE and its subsidiary Presagis, who have a toolset which they have used to generate geo-typical imagery for the entire world as part of their 'World-Wide Database' initiative. The technology appears quite mature; it uses rules-based approaches to generate imagery based on vectors, and elevation data, and allows the imagery to be changed for the time of year or for sensor imagery to be generated.

The tool (known as 'SEGen') includes generating changes to imagery based on elevation slope and the mixing of different generic images to reduce the effect of 'tiling'. An example is shown in Figure 5.1. Tiling shows up as the repetitive use of the same image texture over a large area, and attracts the human eye because it is unnatural.

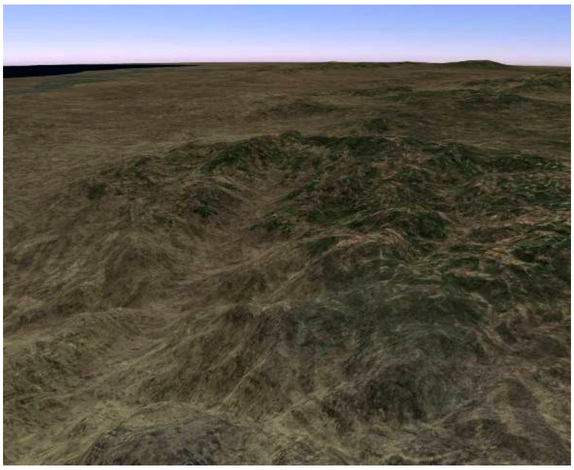

Figure 5.1 Example of a terrain generated with the Presagis SEGen tool.

6 Conclusion

Generating procedural terrain is a technique commonly used in games. But the special requirements for the Missionland continent, mainly its vast size and the special demands made by military training applications, make the generation of the Missionland dataset a novel and challenging idea.

The Missionland task group has evaluated different tools and there is not one single tool available that can handle the total generation of such a fictitious continent. However different COTS tools have been identified to produce parts of the data and the task group has also designed some custom tools to fill other gaps.

Procedural techniques for elevation data are promising in the sense that they can automatically generate data for large areas according to parameter settings provided by a user. Unfortunately, the level of user control is currently limited and the realism of the output can be questioned. Since Missionland is to be used for military M&S, the realism of the terrain is important. Even so, the need for large amounts of data renders the use of procedural methods inevitable at this point in time.

User controlled blending of real elevation data is a promising technique to enhance procedural generated terrain to higher levels of realism. The technique gives a user a large level of control, but an effective implementation is required for it to be usable for production of the whole Missionland continent. It would also require a rich library of real world data in order to include all terrain characteristics and avoid repetition.

Production of vector data and imagery is subject to many of the same challenges as production of elevation data. High level of user control comes with the expense of much manual work. This is maybe more true for vector data than imagery, since imagery are simpler data structures that in larger degree can be derived from synthetic elevation and vector data than vice versa. As mentioned, there are promising new commercial technologies for generating vector data of built-up areas and imagery. However it still has to be seen if these can be integrated into the process for generating the Missionland dataset.

MSG-071 is currently in a data production stage. A first version of the elevation data is produced. This version will be incrementally enhanced with high resolution/high detail areas and at the same time the emphasis on vector data and imagery will be increased. The Missionland dataset will be a high quality dataset produced with state of the art in artificial environment production methods.

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