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NEW TRENDS IN THE USE OF ARTIFICIAL INTELLIGENCE IN RELIEF TEXTURING TASKS

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In modern computer graphics, complex relief textures are considered one of the key means of achieving a high level of visual realism. In the context of video games, augmented and virtual reality, architectural visualization, and engineering simulations, it is the micro-relief of the surface that determines how convincingly the material interacts with light, shadows, and the surrounding environment. Simply increasing the polygon count of a geometric mesh allows for detailed relief modeling, but quickly leads to unacceptable computational costs. Therefore, visualizers increasingly rely on relief map systems - height maps, displacement maps, normal maps, and related variants - that encode the 3D structure of the surface as 2D data. For a long time, such maps were created mainly by hand or with semi-manual digital sculpting tools, but with the development of complex algorithmic methods, in particular statistical and neural network methods, it became possible to automate both the construction of the relief and its scaling and adaptation to different rendering conditions.

In this context, relief texture is an intermediate link between geometry and lighting model. The height map sets the scalar field of heights, the displacement map determines the displacement of vertices or surface points relative to the base mesh, and the normal map encodes the orientation of microfacets that affect the direction of light reflection. The combination of these representations effectively models the microgeometry of the material: pores, scratches, fibers, graininess, protrusions, and depressions. In physically correct material rendering models (physically based rendering), micro-relief is directly related to the distribution of reflected light energy, so the accuracy and stability of relief maps determines not only visual detail, but also the correctness of reflections, glitters, translucent effects, etc. The task of forming relief textures thus goes beyond the purely artistic stage and becomes a separate scientific and technical problem related to the restoration and generation of microgeometry based on limited input data.

Algorithmic methods for forming relief can be divided into several groups. The first group consists of applied geometric processing approaches, where elevation or displacement maps are calculated from a series of images or scans using classical computer vision methods: stereovision, photogrammetry, laser scanning, structured light, or photometric stereo. In such systems, the relief is directly linked to the real physical surface; the output is data that can be interpreted as displacement or height maps and used directly in engines such as Unity or Unreal Engine. The second group consists of statistical and applied texture processing methods, where relief is derived from one or more 2D projections. Here algorithms study local patterns, gradients, noise structures, correlations between brightness and texture, and on this basis reconstruct a depth map that matches the visual structure of the input image. Finally, a separate group consists of modern neural network models that combine the ideas of texture synthesis, depth reconstruction, and training on large data sets, enabling the transfer of micro-relief between materials, the generation of new texture variations, and the restoration of elevation maps in situations where classical methods produce overly coarse results [3; 4].

Compared to manual modeling, algorithmic approaches have several decisive advantages. First, they allow the process to be scaled: from a small number of reference texture samples, dozens and hundreds of relief variants can be automatically generated that preserve the macroscopic properties of the material but differ at the micro level. This is especially important for procedural landscapes, urban scenes, fabric and plant materials, where repeating the same tile creates a noticeable artificiality in the image. Second, algorithms can compensate for the shortcomings of the source data: eliminate noise, even out lighting, and reconstruct areas that are inaccessible for direct scanning. Third, they rely on clear, formalized quality criteria - from statistical similarity metrics to perceptual indicators - which allows for predictable control of the result and the construction of automated pipelines for large projects.

One of the key subproblems in forming relief textures is restoring a height map or displacement map from a limited number of images. In classical photometric stereo, several images of an object were taken under different lighting conditions, and then the inverse problem was solved to obtain a normal map and, if necessary, integrate it into a height map. Modern approaches supplement analytical reflection models with training data: complex neural network structures are capable of directly mapping a combination of intensities into normal and elevation maps, including both diffuse and specular components, and providing reconstruction even for highly reflective materials. An example is the DPPS method, in which the surface is reconstructed from a set of images, and the output is both a normal map and a height map with accuracy comparable to industrial 3D scanners [5]. For computer graphics tasks, such methods allow the construction of libraries of relief textures for metal, lacquered, or other complex surfaces without the need for expensive optical systems.

Another direction is height mapping from single images. Although such a task seems not clearly defined at first glance, modern models use contextual features, shape statistics, sensor information, and scene geometry to reconstruct a height map even from a single frame. In remote fields such as remote sensing of the Earth, similar methods are already demonstrating the possibility of creating digital relief models of urban development from single high-resolution radar or optical images, combining information about the angle, signal characteristics, and spatial context [2]. For computer graphics tasks, such developments are important because they indicate the fundamental possibility of reconstructing relief maps from limited photographs of real surfaces, which can then be converted into displacement maps, normal maps, or height maps for use in real-time engines.

Among the methods for increasing relief detail, texture synthesis methods focused on restoring high-frequency components occupy a special place. If the source image has low resolution or has undergone heavy filtering, it lacks the fine details that are critical for realistic relief. Systems that combine super-resolution with texture synthesis learn from pairs of low and high detail samples and are subsequently able to “draw in” the microstructure while preserving the overall style and macro-level structure of the surface [3]. For relief maps, this means that a refined version can be algorithmically obtained from a rough height map, which will contain additional micro-irregularities consistent with the source material but not tied to a specific scene. In fact, such approaches form a link between traditional height maps and microgeometry models used in physically correct rendering, reducing the gap between artistic resources and physical scattering models.

A separate group of tasks is related to tiling and seamless extension of relief textures. The classic approach involves manual or semi-automatic editing of seams, but for complex structures - such as tree bark, stone surfaces, or textiles - this becomes a lengthy and laborious process. Modern algorithmic methods of applied texture synthesis solve this problem differently: the model receives a texture fragment at the input and learns to create new tiles that preserve the statistical and structural characteristics of the sample but can be seamlessly placed in any direction. This approach is implemented, in particular, in deep tiling algorithms, where synthesized patterns are combined with the source data to form extended texture maps suitable for covering large surfaces without noticeable repetitions [4]. If height or normal maps are synthesized along with the color texture, the developer gets a complete set of maps for relief texturing of any scale.

Closely related to the synthesis task is the issue of multi-scale representation of terrain. Real materials exhibit different types of structure at different levels: from large folds or cracks to fine-grained inhomogeneities. Effective rendering requires models that are optimized to work with these levels of detail. Modern approaches often encode relief information into compact representations that allow queries to be executed quickly for different scales of observation. For example, in the case of fabrics, the relief is formed by the weaving of fibers, and the model must simultaneously take into account both the geometry of individual threads and the macrostructure of the fabric. Developments focused on realistic real-time reproduction of fabrics demonstrate that lightweight neural network representations are capable of encoding the multiscale structure of weaving and providing a smooth transition between different levels of detail without loss of visual quality and without excessive computational costs [1]. Transferring such ideas to other classes of materials - stone, metal, organic surfaces - opens the way to more universal relief texturing systems.

The practical integration of algorithmic methods for forming relief textures into production pipelines is associated with performance requirements. In real-time engines, the use of complex displacement textures can cause a sharp drop in FPS, especially on weaker devices. Therefore, one of the main tasks is to develop hierarchical detail level schemes, where full displacement is applied only to foregrounds, and in the background, it is replaced by normal maps or even ordinary diffuse textures. In this case, the algorithmic methods that form the relief must not only restore the microgeometry, but also ensure consistency between different representations: height map, normal map, displacement map, soft shading, BRDF parameters, etc. The ideal approach is one in which all microgeometry is encoded in a single compact representation from which, if necessary, any type of relief map can be calculated with a given balance between accuracy and speed.

Another practical requirement is the ability to edit surfaces interactively. In the context of games and interactive applications, artists or technical designers often adjust the relief during the work process: they change the scale and depth of irregularities, combine several types of micro-relief, and add local details. Algorithmic methods can speed up this process by offering, for example, automatic texture completion when changing the scale, reconstruction of normals after editing the height map, or transferring micro-relief from one material to another with partial preservation of statistical characteristics. It is important that in such scenarios, systems should not act as a “black box” that completely replaces manual work, but as a tool that complements the creative process, allowing the author to focus on compositional and artistic decisions.

In a scientific context, the formation of relief textures based on algorithmic and neural network methods also becomes important as a means of communication between physical measurements and virtual scenes. The development of 3D scanning, photometric reconstruction, and remote elevation data measurement systems has led to the emergence of large amounts of information about real surfaces, which are not always directly suitable for use in real-time engines. Algorithmic procedures allow this data to be converted into formats that are convenient for rendering, while preserving the characteristic properties of materials: anisotropy, glitter, hierarchical relief. This approach facilitates the creation of material libraries that have both a physical basis (due to their origin from measurements) and an optimized representation (due to processing into relief maps and PBR parameters).

Therefore, the use of complex algorithmic, statistical, and neural network methods for forming relief textures can be considered one of the central directions in the development of modern computer graphics. These methods enable the transition from labor-intensive manual modeling to scalable procedures in which surface relief is reproduced based on learning from real data, interpretation of structural patterns, and multi-scale representations. The development of photometric reconstruction, elevation mapping, depth texture synthesis, and multiscale neural relief models demonstrates that combining geometric and statistical approaches makes it possible to achieve both high visual quality and acceptable performance. In the future, this will lay the foundation for even closer integration of measured microgeometry in the real world with virtual scenes, where each surface will not only look realistic but also reproduce the complex optical properties of materials at different scales [1-5].

References

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ДОСТОВІРНІСТЬ ІНФОРМАЦІЇ: ВІД ВИЗНАЧЕННЯ ДО КРИТЕРІЇВ

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Вступ

Нещодавно світ увійшов у нову епоху споживання інформації. Те, що раніше можна було побачити лише по телебаченню чи в газетах, тепер може бути доступне та опубліковане в Інтернеті будь-ким. З розвитком Інтернету в цілому, а також зростанням популярності соціальних мереж та онлайн-новин, зросла також потреба перевіряти факти про інформацію, яку ми споживаємо. Хоча було розроблено багато методів перевірки достовірності інформації, складається враження, що немає єдиного консенсусу щодо її визначення, а також на основі яких критеріїв слід проводити ці перевірки. Це є предметом цієї роботи. Буде обговорено такі англомовні поняття, як authenticity, credibility, reliability та veracity, в контексті інформації. Також буде розглянуто загальновживані критерії перевірки достовірності інформації як з точки зору українського розуміння, так і з точки зору міжнародної спільноти.