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COMPARATIVE ANALYSIS OF RASTER AND VECTOR GRAPHICS

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The article presents a comparative analysis of raster and vector images in the context of modern trends in computer graphics development. The relevance of the study is determined by the rapid advancement of digital technologies, the need to enhance visualization quality, and to optimize the storage of graphic data across various fields. The key differences between these two types of graphics are identified based on a range of criteria, including storage efficiency, scaling quality, color accuracy, texture detailing, editing simplicity, and typical areas of application. The principles of image formation, fundamental elements, and the regularities of graphic information representation in the digital environment are examined. Particular attention is devoted to the practical aspects of applying different types of graphics. An experimental comparison of one hundred images (fifty raster and fifty vector) demonstrated the clear advantages of vector graphics in terms of scalability, contour sharpness, and file compactness, while raster images maintain leading positions in reproducing photorealistic scenes and smooth color transitions. The method of expert evaluation of illustrative information was applied. The results of data processing are presented in the form of a histogram. The study highlights the growing popularity of hybrid solutions, in which raster and vector elements are used simultaneously. This approach allows combining the realism of raster structures with the precision and scalability of vector objects, creating an integrated environment for the development of graphic projects. The findings of the study have practical value for software developers, designers, and engineers working with graphic systems, as well as for improving educational courses in computer graphics.

Keywords: *raster graphics, vector graphics, computer graphics, images, comparative analysis, expert evaluation.*

Problem Statement. The modern digital environment is characterized by a growing demand for the creation, processing, and storage of high-quality graphic materials. Among the numerous means of computer graphics, raster and vector technologies occupy a particularly important place. The development of hardware and software systems aimed at integrating different graphic data formats necessitates a renewed analysis of the properties of the main types of images. The need for such analysis is driven by the expanding areas of computer graphics application, the transition to multimedia formats, and the demand for optimizing graphic information processing.

Analysis of Recent Research and Publications. Recent scientific studies demonstrate a growing interest in an in-depth examination of the properties of raster and vector

graphics, as well as in the development of new methods for their integration. The study [1] analyzed the efficiency of vectorization algorithms that ensure contour accuracy and file size reduction. In [2], methods for integrating raster and vector elements within unified graphic environments were considered, with particular attention to format compatibility and object editability. The authors emphasize that hybrid solutions enhance productivity and flexibility in design processes. Research [3] focused on a comparative analysis of raster and vector image quality parameters based on sharpness, detail, color reproduction, and file size criteria. The results showed a significant advantage of vector graphics in tasks requiring scalability and geometric precision. In [4], an improved approach to automatic vectorization based on machine learning methods was proposed. Study [5] examined the influence of file format on the performance of image processing software tools.

A synthesis of previous research indicates that contemporary science is directed toward finding optimal solutions that combine the advantages of both types of graphics and formalize their creation processes. Therefore, conducting a comparative analysis of raster and vector images, taking into account their functional characteristics, remains relevant and practically significant for the development of computer graphics and digital visualization technologies.

Purpose of the Article. The aim of this study is to compare the features of raster and vector images.

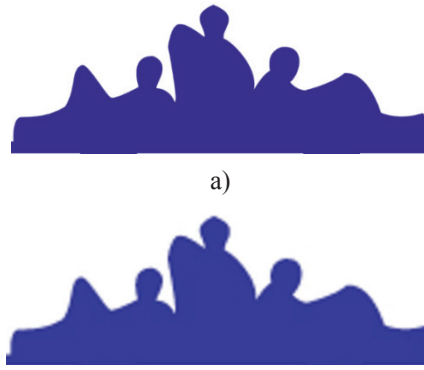
Presentation of the Main Research Material. Digital images are divided into several basic types that differ in their properties and characteristics. The most common are raster and vector images. Raster images, in particular, provide a high level of detail and the ability to reproduce complex color transitions, while vector images allow scaling without loss of quality [6]. Digital images also include three-dimensional models, fractal structures, and hybrid forms of computer graphics, which are used to create complex visual effects, realistic modeling, and the integration of different techniques into a unified visual system [7]. Considering the limited application areas of other types of graphics, this study focuses on raster and vector images.

Raster images are formed from a set of pixels (elementary points with individual color and brightness values). Each pixel represents the smallest structural unit of an image. Such images are typically obtained using digital devices such as cameras and scanners. One of the main advantages of raster graphics is the simplicity and technical accessibility of image input. The digitization of visual information is supported by a well-developed system of peripheral devices. Raster images are optimal for reproducing photorealistic objects due to their ability to accurately convey color nuances, perspective, depth, and sharpness. However, it is difficult to represent real-world objects adequately in a vector, mathematically formalized form. It should be noted that raster images have a fixed resolution that determines their quality and detail when scaled. Increasing the size leads to a loss of sharpness and the appearance of visible pixels. Another disadvantage is the significant file size, as high-quality images may occupy tens of megabytes of memory, complicating their storage, transmission, and processing. Editing raster graphics is also challenging, as modifications to individual elements require adjustments to a large

number of pixels. Although raster editors offer a wide range of artistic processing tools, they are inferior to vector editors in terms of the speed of structural modifications.

Vector graphics are based on the mathematical description of objects using control points (nodes), curves, lines, segments, and contours. The basic elements are points and lines. Segments consist of two nodes connected by a line or a curve, and sets of segments form contours. A contour represents the outline of a graphic object created using vector editing tools. Contours can be closed (all points connected by lines or curves) or open (two arbitrary points among the set are not connected). An important element of vector images is the Bézier curve, constructed using two control handles extending from each segment's nodes, allowing precise control of the curve's shape. Each element is described by formulas defining its shape, size, and spatial position [8].

As noted above, scaling vector images occurs without quality loss. Figure 1 presents a comparison of a scaled fragment of the Lviv Polytechnic National University logo in raster and vector formats. The vector image (a) maintains sharp edges even at a significantly enlarged scale, while the raster image (b) shows visible pixels and noticeable quality degradation. An 800% scale factor was applied for magnification.



a)

b)

Fig. 1. Scaled fragment of the Lviv Polytechnic National University logo:
(a) in vector format; (b) in raster format.

When vector images are printed, their quality depends not on the initial resolution of the image but on the resolution of the output devices (such as printers or plotters). The same principle applies to displaying vector images on monitor screens. This characteristic highlights another significant advantage of vector graphics — file compactness. A mathematical description requires considerably less memory than storing each individual pixel, which simplifies data transmission and reduces computational demands. Moreover, vector objects are easily editable: changes in color, shape, or proportions do not affect the overall file structure. Consequently, vector graphics are widely used in the creation of logos, icons, diagrams, cartographic materials, and technical documentation. However, vector graphics are less suitable for reproducing complex, multicolored, and photorealistic scenes [8].

Table 1 presents a comparative analysis of raster and vector graphics according to the following criteria: storage efficiency, quality when scaled, color accuracy, texture detailing, ease of editing, and typical areas of application.

Table 1

Comparison of raster and vector graphics

Comparison criterion	Raster graphics	Vector graphics
Storage efficiency	Large file sizes that increase with higher resolution and color depth	Compact file sizes due to mathematical object representation
Quality when scaling	Loss of sharpness and detail occurs during scaling	Image clarity and stability are preserved regardless of scale
Color accuracy	Capable of reproducing smooth tonal gradations and creating photorealistic effects	Limited reproduction of color and tonal gradations
Texture detailing	Enables representation of complex visual effects and texture transitions	Mainly used for schematic models where complex texture is not essential
Ease of editing	Any modification requires adjusting a large number of pixels, making the process more complex	Editing is performed by changing object parameters, which simplifies and accelerates processing
Typical areas of application	Most commonly used in digital photography, printing, and artistic visualizations	Used for creating logos, fonts, cartography, technical drawings, and iconography

A comparative analysis of raster and vector images was also conducted. For this purpose, 100 images were examined (50 raster and 50 vector). The evaluation was carried out using the criteria listed in Table 1, excluding the “typical areas of application” criterion, as it cannot be quantitatively assessed and does not represent an advantage or disadvantage. Each criterion was evaluated on a ten-point scale, where higher scores indicate a stronger manifestation of the characteristic. The summarized results were obtained by averaging the scores. The distribution of values illustrating the advantages of both types of graphics is presented in Figure 2.

The obtained results demonstrate clear distinctions between raster and vector images. The choice of the appropriate graphic format depends primarily on the intended purpose. For instance, when scalability and data compactness are prioritized, the use of vector images is more appropriate [9]. Conversely, when realistic image reproduction is required, raster graphics represent the optimal solution [10]. The results obtained confirm the theoretical assumptions presented earlier.

Combined approaches that integrate the advantages of both raster and vector graphics are increasingly being applied. Modern graphic editors provide tools for working with both types simultaneously. Thus, raster and vector elements can be used within a single project, ensuring flexibility and efficiency in the creation of graphical materials [11].

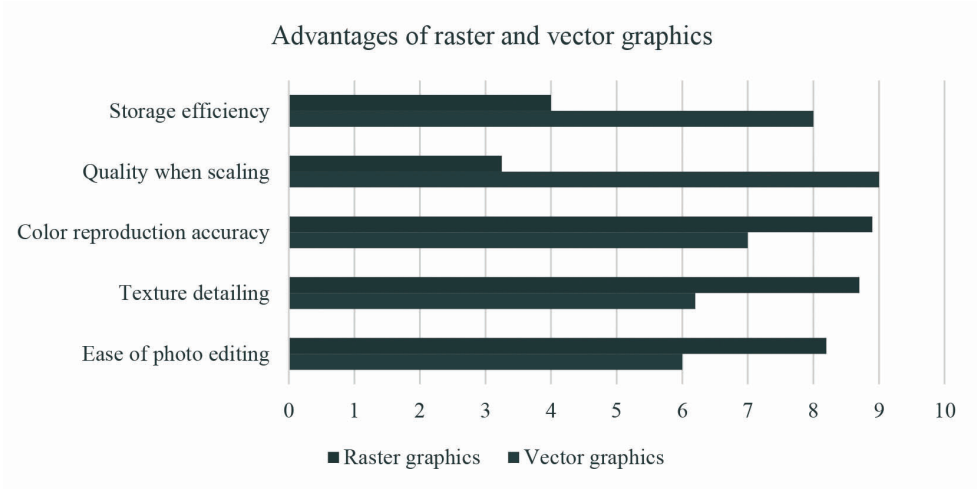


Fig. 2. Comparison of the advantages of raster and vector graphics

Conclusions. The conducted study made it possible to systematize the properties of raster and vector graphics and to identify their respective advantages and limitations. It was established that raster images provide high detail and realistic reproduction but are characterized by large data volumes and a loss of quality during scaling. Vector images, in contrast, are noted for their compactness, stability under scaling, and ease of editing, though they are less suitable for rendering complex color transitions and textures.

The results of the comparative analysis confirmed the appropriateness of selecting the type of graphics depending on the specific task: raster graphics — for photorealistic visualizations, and vector graphics — for precise, scalable, and structurally organized objects. Considering current trends in the field, the use of combined approaches that integrate the advantages of both types of graphics is advisable. Such hybrid methods ensure high quality, flexibility, and efficiency in the processing of visual data.

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ПОРІВНЯЛЬНИЙ АНАЛІЗ РАСТРОВОЇ ТА ВЕКТОРНОЇ ГРАФІКИ

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У статті здійснено порівняльний аналіз растрових і векторних зображень з огляду на сучасні тенденцій розвитку комп'ютерної графіки. Актуальність дослідження зумовлена стрімким розвитком цифрових технологій, потребою у підвищенні якості візуалізації та оптимізації зберігання графічних даних у різних галузях. Визначено ключові відмінності між цими двома видами графіки за низкою критеріїв, що охоплюють ефективність зберігання, якість при масштабуванні, точність передачі кольору, деталізацію текстур, простоту редагування та типові сфери застосування. Розглянуто принципи формування зображень, базові елементи та закономірності відтворення графічної інформації у цифровому середовищі. Особливу увагу приділено питанням практичного застосування різних типів графіки. Проведене експериментальне порівняння ста зображень (п'ятдесяти растрових та п'ятдесяти векторних) продемонструвало чіткі переваги векторної графіки щодо масштабованості, чіткості контурів і компактності файлів, тоді як растрові зображення зберігають провідні позиції у відтворенні фотореалістичних сцен і плавних колірних переходів. Використано метод експертного оцінювання ілюстративної інформації. Результати опрацювання представлено у

вигляді гістограми. Вказано на зростання популярності комбінованих рішень, у яких растрові та векторні елементи використовуються одночасно. Такий підхід дає змогу поєднувати реалістичність растрових структур із точністю та масштабованістю векторних об'єктів і створити єдине інтегроване середовище для розроблення графічних проєктів. Результати дослідження мають практичну цінність для розробників програмного забезпечення, дизайнерів та інженерів, що працюють із графічними системами, а також для вдосконалення навчальних курсів із комп'ютерної графіки.

Ключові слова: *растрова графіка, векторна графіка, комп'ютерна графіка, зображення, порівняльний аналіз, експертне оцінювання.*

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