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The Importance And Perspective Of Using Fractal Graphics In The Human Circulatory System

Berdiev G.R.[1]., Djurayeva A.I.[2]

[1]Doctor of philosophy of technical sciences. Head of the Department of Computer Systems, Karshi branch of the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi,
[2]Information educational technologies Karshi Branch of Tashkent University ofInformation technologies Karshi, Master's student

Abstract. *Symmetrical and asymmetrical tree—like structures of arterial systems have been the central point of experimental and theoretical investigation. Blood vessel models have been generated according to morphology and structural properties, such as segment radii and lengths, branching angle and their relation to segment diameter. Tree generation is performed by successively adding segments, straight cylindrical tubes, so that certain structural and geometrical constraints are fulfilled at each stage of construction.*

Keywords: Representation of Complexity, Efficiency in Transport, Understanding Scaling Laws, Medical Imaging and Diagnosis, Biologically-Inspired Engineering

Introduction

In this paper complex geometrical (fractal) models of human blood vessels have been proposed. The models have been creating according to Murray's law.

In the recent years fractal analysis of blood vessel in any different parts of human body has been described. Geometry of biological structure has suggested that fractal methods are well suited for modelling of such structures. Fractal model is a certain geometrical simplification but it suffices for acceptable blood flow analysis. This analysis permits understanding influence of hemodynamic forces and its role in the development of vascular diseases.

In the present work fractal blood vessels trees have been classified and examined according to the symmetry of branching. Asymmetrical vessel trees dominate in circulatory system. Symmetrical are concerned in capillary bed only.

Blood vessel models have been created according to principles of optimal network formation. The whole tree is approximated by dichotomously branching system of straight tubes known as a bifurcation.

The basic form of vascular connection is bifurcation in each node. Arteries bifurcate many times before they became capillaries. Scaling factor of vessel length, diameter and angle between two children branches is established at each level of recurrences. We simplify description assuming constant

Symmetry has a large impact on number of terminals. In a perfect symmetrical tree an exponentially increasing number of segments are found in each bifurcation level (2^n) and all terminals appear in the highest level only. In the asymmetrical tree the terminal segments emerge in the early stages of development as well.

Number of vessels after bifurcation level increase to 18 level for asymmetry trees. On higher levels decrease of vessel amount it follows that in most cases vessels achieve just

Fractals, due to their repeating patterns at different scales, have found application in various fields, including science, mathematics, art, and technology. When discussing the human circulatory system, fractals can offer unique insights and perspectives that aid in understanding its complexity and efficiency.

1. Representation of Complexity: Fractals can visually represent the intricate and complex nature of the human circulatory system. The branching patterns found in fractals are reminiscent of the branching structure of blood vessels in our bodies. The self-similarity property of fractals, where smaller parts resemble the whole structure, mirrors the hierarchical organization of arteries, arterioles, and capillaries in the circulatory system.
2. Efficiency in Transport: Fractal-like structures are known for their efficiency in transportation and distribution systems. In the circulatory system, this is essential for the efficient transport of oxygen, nutrients, hormones, and waste products throughout the body. The branching patterns of blood vessels help in optimizing the flow of blood, ensuring that vital substances reach all cells and tissues effectively.
3. Understanding Scaling Laws: Fractals help in understanding scaling laws within the circulatory system. For instance, as blood vessels branch out, their diameters change systematically. Fractal geometry provides a way to understand how these changes in diameter affect the overall flow dynamics and pressure distribution within the vascular network.
4. Medical Imaging and Diagnosis: Fractal analysis has been utilized in medical imaging techniques to quantify irregularities or abnormalities in blood vessel structures. This can aid in diagnosing conditions such as atherosclerosis, where changes in the fractal dimension of vessels might indicate certain pathologies or changes in the vascular system.

5. Biologically-Inspired Engineering: Studying the fractal nature of the circulatory system can inspire engineers in designing more efficient transportation networks, such as optimizing pipelines or traffic systems, by mimicking the principles found in nature's fractal-like structures.

In summary, the application of fractal geometry provides a valuable perspective for understanding the complexity, efficiency, and optimization principles inherent in the human circulatory system. It offers insights that can be applied across various disciplines, from biology and medicine to engineering and mathematics, fostering a deeper understanding of both natural and man-made systems.

Bifurcation symmetry depends on different types of blood transport function. In human arterial blood vessel system the most of vessel after bifurcation are asymmetrical. Bifurcation symmetry is found only for the smaller subtrees. This is concordant with the fact that they predominantly deliver blood to tissues [17]. Vessels with predominantly asymmetric bifurcations gives off comparatively little flow into its side branches along its way and is therefore able to carry the mainstream flow

Conclusion

Research has been performed on symmetry influence on blood vessel system parameters.

Vessel symmetry visibly affects spatial distribution of terminal vessels. Differences in structure of blood vessel trees, emphasised also by estimated fractal dimension, are a result of biological function. Main function of asymmetrical tree is conveying blood. Function of symmetrical trees is to deliver blood to all surrounding tissue so the tree should evenly coverage the space.

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