Computational modeling of tumor angiogenesis: simulation of abnormal vascular morphogenesis

One of the key characteristics of tumors is their ability to form new blood vessels. This process, known as tumor angiogenesis, allows tumors to absorb oxygen and nutrients from the body, contributing to their continued growth. What distinguishes the blood vessel networks in tumors from those in healthy tissues is that tumor vessels are chaotic—leaky, full of loops, and ending in dead ends.

The aim of this project is to create a computer simulation of the growth of such pathological blood vessel networks. The main question is why tumors develop these deformed networks and what role various biochemical signals play in this process. How can we describe the phenomena occurring at the level of cell groups using physics and computer modeling to recreate the abnormal structure of these vascular networks?

To achieve this goal, a numerical model capable of approximating cellular behavior is planned for use. One well-known approach that allows relatively simple simulation of cell behavior is the cellular Potts model. In this method, each cell is represented as a cluster of connected points on a grid, enabling the simulation of how endothelial cells—the primary building blocks of blood vessels—move, adhere to one another, and respond to their environment. The model incorporates chemical and mechanical factors, as well as interactions with tumor tissue, to replicate the characteristic features of tumor blood vessels. This approach also allows for expansion to include additional elements, such as drug delivery to cells, or inclusion of other vascular components like pericytes, which form the outer layer of blood vessels.

The model will be validated against real biological data from publicly available databases to assess how accurately it reflects actual phenomena. At a fundamental level, this will contribute to enriching the existing understanding of blood vessel formation. In the future, such models may assist researchers and clinicians in designing more effective therapies, making treatment less harmful for patients.