Artificial life as cancer research: embodied agent modelling of blood vessel growth in tumours

Katie Bentley, Paul Bates and Holger Gerhardt

Cancer Research UK
katie.bentley@cancer.org.uk

Tumours need to signal the growth of new blood vessels (angiogenesis) in order to obtain an oxygen supply and continue to grow. Angiogenesis in tumours, as opposed to normal tissue, generates abnormal, tortuous and leaky vessels. The vessels poor quality keeps oxygen levels low in the tumour, which keeps mutation rates high, and causes metastases to develop and spread across the body.

Angiogenesis as a process is a fascinating example of adaptive, environment-driven, morphogenesis of a spatial network; the most suitable and practical approach, and framework for simulation, was artificial life. Our multidisciplinary research aims to 1) understand the mechanisms of angiogenesis, 2) understand why the tumour environment causes abnormal vessels and 3) develop novel cancer therapies which could normalise tumour angiogenesis and thereby prevent metastases through reduction in hypoxia and increased genetic stability.

We have developed a multiscale agent-based model of a blood vessel interacting with its environment in order to investigate the effects that different environmental factors have on the initial stages of angiogenesis. The simulated endothelial cells in the vessel exist across multiple grid sites in a 3D gridded lattice. Each cell is comprised of many autonomous agents, representing sections of the cell membrane. In the first incarnation of the model, agents create new agents to change cell morphology. In the current version they move and are connected by springs, which realistically mimics membrane tension during cell migration.

Each agent communicates with its local environment, including other agents, to decide whether to activate receptors, release ligands and/or alter the cells local morphology. Overall a cell's behaviour and morphology emerge from the low-level interactions of its agents with the environment, which in turn then determines the vessel network morphology and development.

With this approach we have realistically modelled the initial stages of angiogenesis and made interesting predictions concerning abnormal endothelial cell fate determination in tumours, which are now being tested in the laboratory. The model is now being developed further to fully simulate cell migration and fusion of cells as the network develops.