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NANOROBOTICS CONTROL FOR BIOMEDICAL APPLICATIONS

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ABSTRACT

Early successes in nanomedicine have created a growing demand for the development and application of advanced nanorobotic techniques with medical applications. This thesis presents the results of a proposed cooperative control strategy for a swarm nanorobot system in a human body environment in which the developed control schemes were applied in a nanorobot drug delivery scenario.

Part 1 of the study tested a proposed algorithm to solve the problem of communication between nanorobots and their movements in a swarm to a predefined target area. The nanorobots' communication and movement problems were solved in a self-organized way by modifying (1+1) Evolution Strategy (ES) with a 1/5th success rule, a method is herein referred to as the MES algorithm, which enables nanorobots to make decisions toward a predefined goal. The algorithm employs correspondence-based organization between nanorobots to allow them to find and reach the target area. A simulation of the performance and behavior of nanorobots was conducted to demonstrate the potential of the proposed algorithm. The simulator employed three mutation strategies applied randomly (straight strategy, swap strategy and high strategy) when a nanorobot optimized a movement plan.

The study applied the results of comparative study of these strategies to determine the most productive of the three, defined as the one requiring the least time on average to reach the target area. Simulation analyses indicated that the high mutation strategy is the most efficient mutation strategy for swarm nanorobots, resulting in optimum results in reaching predefined target sites. Part 1 of the proposed study tests this finding and demonstrated the benefits of high mutation strategy in action.

In Part 2 of the study, a proposed technique was tested to solve the path-planning problem of swarm nanorobots' navigation within the human environment. Blood

elements were treated as obstacles to nanorobot movement. Blood flow was also factored into the movement problem, as was the environment's physical properties, including blood viscosity and density, both of which can potentially affect nanorobot behavior. To account for all these considerations in a human body environment, two algorithms were combined, yielding a single algorithm responsible for the self-organized control of nanorobots to avoid obstacles during their movement trajectory. The technique is based on modification of the Particle Swarm Optimization algorithm, referred to as the MPSO algorithm, and modification of the Obstacle Avoidance Algorithm, referred to as the MOA algorithm. The proposed MPSO algorithm generated the best locations in a given operational area enabling nanorobots to detect the target areas. The proposed MOA algorithm allowed nanorobots to efficiently avoid collision with blood elements. The simulation results show that the combined MPSO-MOA algorithm safely routes all nanorobots past blood elements while navigating within the human body. The communication between nanorobots in a swarm was implemented as reported in this thesis through MES and MPSO algorithms.

Part 3 of the thesis incorporates a comparative study among these two algorithms. Comparisons show that communication using MPSO is more effective in determining the global optimal solution with significantly better computational efficiency (less function evaluations) by implementing statistical analysis and formal hypothesis testing.

In Part 4 of the study, a movement control algorithm was developed for nanorobots sensitive to the environmental acidity value (pH) of human cells, to deliver drugs in a tumor area while navigating in the bloodstream environment. The nanorobots were able to communicate with their neighbors using the proposed MPSO algorithm. Additionally, the proposed MOA algorithm allowed nanorobots to avoid collision with blood cells. Each nanorobot was able to measure the pH value at its current position using biosensors. Through

cooperation, nanorobots were able to drive the swarm to a tumor area defined by a pre-determined pH value (less than 7.0). Upon locating tumor cells, nanorobots released a drug that raised the pH value of the cell until it was destroyed. Graphical interface simulations have shown the effectiveness of the proposed algorithm. Validation of the designed system with simulated conditions proved that the drug delivery of nanorobots was robust during navigation, diagnosis, and curing of the tumor cells.

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