CHAPTER 5 CONCLUSION/SUGGESTION

According to the advance of nanotechnology, it exhibits the possibility of using nanorobots for medical applications in the near future. There are many simulation studies that could provide guidelines for fabricating nanorobots. However, most of simulated nanorobots are designed to have advanced abilities in order to perform difficult tasks. However, in order to construct nanorobots in the near future, the early-stage nanorobots which comprise only essential characteristics could be more practically enabled. This study adopted the concept of early-stage nanorobots to investigate the control mechanism for future nanorobots operating in the role of platelets in primary hemostasis for blood vessel repair. The reason is that the platelet role in primary hemostasis is simple enough to be modeled for the early-stage version of nanorobots.

This study demonstrated the simulation of early-stage nanorobots acting as an artificial platelet for blood vessel repair in non-Newtonian blood model for the purpose of identifying characteristics of nanorobots and investigating the possibility of using PSO as the control algorithm. The non-Newtonian blood model is used for improving the realistic of the simulated circulatory system. In this study, nanorobots were simulated to move along the blood vessel seeking for the wound and assemble together for covering the injury site as nature platelets. In consideration of increasing the possibility of constructing nanorobots in the near future, the only essential characteristics of nanorobots are identified and used in the simulation. The supporting nanodevices and materials are identified by researching the current literature in nanotechnology field. The PSO technique was selected based on the concept of using the cooperation of many simple particles for accomplishing the complex tasks. Moreover, PSO has been employed to control artificial platelets inside Newtonian blood flow with satisfied result. Thus, this study investigated the performance of PSO algorithm by comparing the result from PSO-based nanorobots with random-movement based nanorobots and by comparing the performance of PSO-based nanorobots in non-Newtonian blood model and Newtonian blood model.

From the experimental results in chapter 4, the effect of different nanorobot capabilities that could reflect the complexity of nanorobot characteristics including perception range, maximum velocity and nanorobot execution time are concluded as follows:

- The higher perception range of nanorobots improves the performance of covering the wound. The wider perception range increases the observed area of nanorobots which consequently increases the chance of nanorobots to find the wound from further attraction signal and more information from neighbors.
- The higher maximum velocity enables nanorobots to move more freely along the environment. Even though nanorobots may step over the wound, the high power actuator will allow nanorobots to move back against the bloodstream that could lead higher chance for nanorobots to arrive at the wound site.
- The faster nanorobot response time could not guarantee the better wound coverage. However, the faster nanorobot response time implies the higher speed to reach the wound site due to the faster adaptation under the influence of blood flow.

Although the result shows the higher ability has the higher chance to reach the wound, the higher performance of the nano-parts also requires more complexity in construction;

this conflicts with the purpose of the study. To provide guidelines for constructing nanorobots in the near future, the suggestions on characteristics of early-stage nanorobot are concluded as follows:

- The perception range should be set at 1/8 of blood vessel radius, which is the lowest value that is experimented. Nevertheless, nanorobots may work effectively with lower perception range.
- The maximum velocity should not be set lower than 1/4 of blood velocity for all algorithms. However, if the random movement is used, the maximum velocity should set at 1/2 of blood velocity.
- The response time should be set at 0.01 s which is the lowest value that is experimented. Nevertheless, nanorobots may work effectively with slower response time.

For the comparison between the PSO control mechanism and the random movement, PSO-based nanorobots obtain the better results than those with random movement. In term of accuracy, PSO-based nanorobots performed slightly better than the nanorobots with random movement. In term of speed, PSO1-based nanorobots performed 14% faster than the nanorobots with random movement. Moreover, PSO2-based nanorobots performed 19% faster than the nanorobots with random movement. It could be concluded that the PSO can be used as control mechanism for nanorobots in non-Newtonian blood model.

For the comparison of PSO-based nanorobots between working inside Newtonian and non-Newtonian bloodstream, PSO1 based nanorobots in the non-Newtonian bloodstream performed worse than the canonical PSO-based nanorobots in the Newtonian bloodstream due to the higher complexity from larger area with high flow velocity. However, the PSO2 based nanorobots that adjust the acceleration constants according to the state of nanorobots could achieve the better result than PSO1 and more proximate results compare to the canonical PSO-based nanorobots. Hence, the performance of nanorobots could be further improved if the control algorithm is modified to better adjusting the acceleration constants based on the current condition of nanorobots.

For improving the study in the future, the environment system should be more realistic when particles in the blood vessel are elastic particles; in that case, blood will become the viscoelastic fluid due to the characteristic of the elastic particles. Moreover, in this study, the blood vessel is assumed to be rigid tube; in the reality, the blood vessel is elastic. If there are good models of blood flow in elastic blood vessel, the simulation would be more realistic and the results from the simulation studies would be truly useful in the realization of nanorobots in the future.