CHAPTER 1 INTRODUCTION

1.1 Motivation

During this past decade, nanotechnologies are widely research and develop in many fields. In medical field, researchers concentrate on finding the new treatments by using the advantages of nano devices size. Medical nanorobotics is the one of interesting area. Although nanorobots have not been yet constructed, it seems promising to become available in the near future [1, 2]. Thus, many researches on medical nanorobots have been introduced in many applications based on computer simulation studies for examining and guiding the construction of nanorobots in the future. For example, Cavalcanti et al. [3] proposed a way to release nanorobots into blood vessel and detect the aneurysm in the brain. Al-Arif et al. [4] presented the possibility of using nanorobots to find the damaged nerve and deliver drug to repair the nerve. In dentistry, nanorobots can be used as a local anesthetic for stopping the nerve from sending the pain signal. The effected periods are control by the operating doctor [5]. Another example of nanorobot application is for cancer therapy. Lohcharoenkal et al. [6] proposed the protein-based nanocarrier that can detect the cancer cells and release the drug to kill cancer cells without affecting the normal healthy cells. There are many researchers currently concentrated on the development of the nanocomponents from many technologies including DNA-based technology [7, 8], bacteria-based technology [9] and mechanical technology. Most of nanocomponents are in the theoretical aspect. However, some nanocomponents are practically built; this increases the possibility of nanorobots to be built in the near future. It could be anticipated that the idea of using early stage nanorobots which comprise only essential characteristics to provide movement, programmability and interaction could be more practically enabled.

In this study, platelet are selected to be the model for nanorobots because the platelets and their role in primary hemostasis are simple enough to be modeled for early stage nanorobot. Moreover, the blood vessel repair application using nanorobots is existing, called *clottocytes*. A clottocyte [10] is a spherical nanorobot. It is designed to carry a folded fiber mesh to the injury site. When the clottocytes are at the wound, they will unleash the mesh in order to trap the blood cells and accelerate the clotting process. Then, they will activate other clottocytes using acoustic pulses. With this design, the clottocytes could stop bleeding faster than the actual platelets. This could be the new therapy for patients who have low platelet counts such as thrombocytopenia patients. The traditional methods that generally used together are the platelet transfusion and taking some medicine to promote the platelet creation process. However, the frequent platelet transfusion might result in resistant to platelets from others. Using medicine can make platelet count slowly increase but cannot be used for weak patients.

Nevertheless, the ability of carrying the fiber mesh might too advance for early stage nanorobots. Boonrong and Kaewkamnerdpong [11] proposed another idea of using nanorobots that can self-assembly and close the wound. This early stage version requires less ability than the clottocytes. In [11], the early-stage nanorobots were demonstrated in a rigid tube model with the simplification of Newtonian blood flow. However, blood can usually be assumed as Newtonian fluid, which has constant viscosity, only for a blood vessel larger than 100 μm [12]; in a small blood vessel, blood would rather behave like non-Newtonian fluid. In computer simulation studies, the realistic of simulation is the one of main concerned issues. The more the simulation model is closer to the real environment as well as situation, the greater chance that the result from the study could apply to the real applications. Thus, blood in small blood vessel should be simulated as non-Newtonian fluid. This study aims to improve the simulated environment of nanorobots.

The behavior of simple nanorobots collaborating to perform difficult tasks is similar to ants or termites which each of them did not have much complex ability but can build a strong and large hive. This concept, which is called swarm intelligence (SI), has been successfully introduced in various applications including robotics [13, 14]. Hence, swarm intelligence is plausible to be employed as a control algorithm for nanorobots in this study. In addition, the canonical PSO algorithm has been investigated as the nanorobot control mechanism in blood vessel repair application with Newtonian blood model [11]. And the experimental result shows the satisfying performance. Thus, this study aims to investigate the performance of canonical PSO-based nanorobot control in non-Newtonian blood flow.

1.2 Objective

The purposes of this study are to identify characteristics of early stage nanorobots that are sufficient for working within a rigid blood vessel and non-Newtonian blood flow. With defined characteristics, nanorobots should find the wound and self-assemble into a mass at the wound at least within the average time used by normal platelets. It is hypothesized that PSO can be suitably used as a control algorithm for nanorobots working inside rigid blood vessel with non-Newtonian blood flow. Moreover, this study aims

1) to investigate the effect of different nanorobot capabilities, including perception range, maximum velocity and response speed, to the wound coverage performance and
2) to suggest the appropriate parameter setting of each value in order to achieve the satisfied performance in non-Newtonian blood flow.

1.3 Scope of Study

1. In this study, the essential characteristics of early stage nanorobots are identified by researching the current works in nanotechnology literature. The characteristics and abilities relating to nanorobots that are commonly found in the literature are considered to be employed in the model.
2. The circulatory system simulation is researched for contemplating the assumptions of non-Newtonian blood flow. The fluid model is selected suitably to the assumptions.
3. An arteriole is interested as it is a smallest and thinnest vessel in artery system, which needs to handle higher pressure so its thinner wall has more chance to break [15]. The diameter of an arteriole is around 30 μm [16].
4. This study investigated the performance of PSO algorithm to control swarm of nanorobots working in dynamic non-Newtonian blood flow. In addition, the suggestions of the nanorobot characteristic settings including perception range, maximum velocity and response speed to achieve a satisfying result are generated.

1.4 Contribution

1. The identification of the essential characteristics and abilities of early stage nanorobots that allow nanorobots to perform their tasks effectively could be useful for the realization of future nanorobots.
2. The non-Newtonian blood model make the simulation closer to the real blood characteristics inside small vessel, which improves the realistic of simulation that also increase the reliability of the result.
3. The performance of PSO algorithm to control the swarm of nanorobots inside the non-Newtonian bloodstream will show the suitability of the algorithm to the dynamic environment. The satisfying result implies that this algorithm can be used as the control algorithm for more realistic simulation.

In order to identify the characteristics and control technique of nanorobots for blood vessel repair, the research of nanorobots in biomedical areas are investigated and described in chapter 2. The general characteristics of platelets and their roles in hemostasis are also explained in chapter 2. Chapter 3 describes the identified characteristics of nanorobots, the PSO-based control algorithm, and the circulatory system with non-Newtonian blood model. The experimental setting and result discussion are discussed in chapter 4. Finally, the conclusion of this study is in Chapter 5.