Multi-objective optimization of a vibro-impact capsule moving in small intestine

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Abstract. In order to promote the controllability of a self-propelled capsule moving in digestive tract and thus improve the detection efficiency of wireless capsule endoscope, a capsule-small intestine coupling model is developed by integrating the dynamic model of a vibro-impact capsule with a small intestinal model. During the optimization, five different target moving speeds (including fast, slow, forward, backward and hovering), the minimal impact force acting on the small intestine, and the minimal energy consumption of the capsule are considered as the optimization objectives. Furthermore, the uncertainty of small intestine environment is considered by varying the radius of small intestine.

Introduction

Under the environment of intestinal peristalsis[1] and radius fluctuation[2], NSGA-II, Monte Carlo, and Six-Sigma algorithms are combined to conduct the multi-objective optimization of capsule both the control and structure parameters[3].as shown in Fig. 1. Based on nonlinear dynamics analysis and sensitivity analysis, the framework of multi-parameter multi-objective optimization algorithm is determined. And the optimization example obtained from the algorithm framework is substituted into the boundary analysis, we can get the relationship between the three optimization objectives and their respective optimization ratio d. Then, by using the response surface (RSM), the relationship between the optimization objective and each optimization parameter is determined. Finally, the neural network algorithm is used to induce the distribution of optimization parameters, and the structure parameter range and control parameter range of capsule design are determined. as shown in Fig. 2.Based on all analysis, we can identify the structural parameter values e_1 = 1 mm and e_2 = 0.5 mm as suitable choices. In this case, our investigation reveals that all the objective can be achieved optimally.

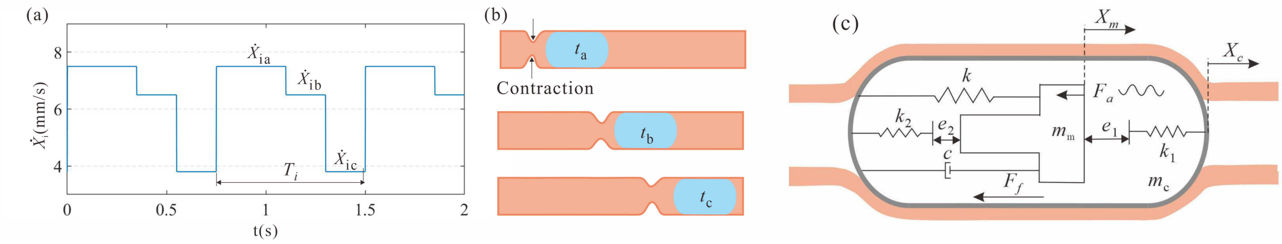

Figure 1: Coupled model (a) Peristalsis velocity profile. (b) Capsule motion under a single peristaltic wave.(c)Coupled dynamic model

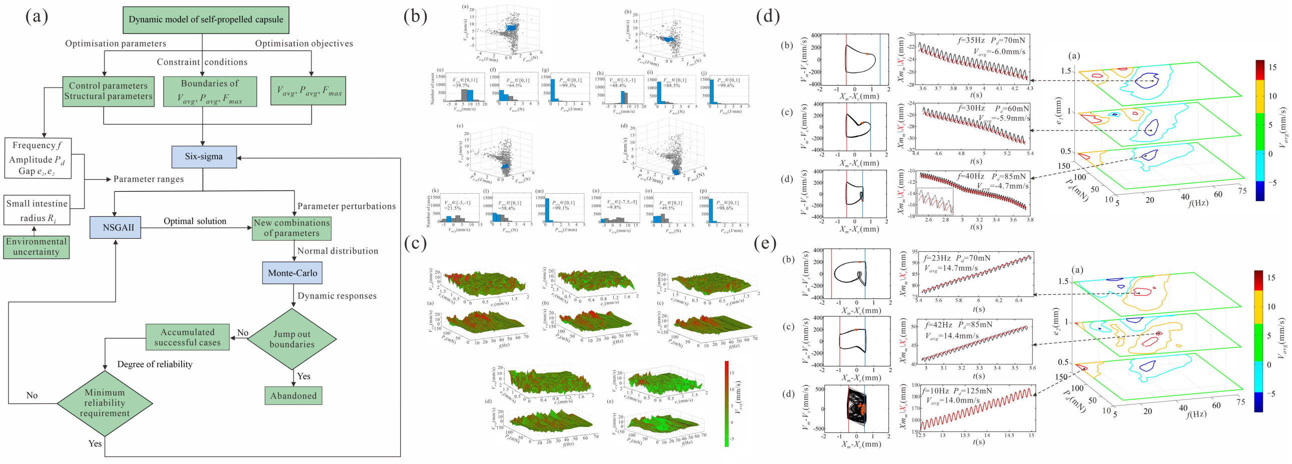

Figure 2: Muti-objective optimization, (a) algorithm framework. (b) Pareto boundary analysis.(c) Response surface (RSM) analysis. (d)-(e) Neural network fitting.

References

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[3] Liu,Y.,Wiercigroch,M., Pavlovskaia, E., et al (2013). Modelling of a vibro-impact capsule system *Int. J. Mech* **66**: 2-11.