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Uncertainty analysis applied to model peristalsis to understand evolution

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Biologists are interested in functional performance based on complicated mechanical systems to understand how structures may have evolved. Since direct manipulation of these systems in an organism are not always possible, many functional systems are modelled using computational methods, such computational fluid dynamics. These functional systems and their simplified models involve many parameters which may or may not affect the performance output of the system in strong ways, in other words, the functional output often has varying sensitivity to each input parameter in the system. Therefore variation, both a natural consequence of development and the raw material on which natural selection operates, is difficult to quantify with typical methods on computational models, such as single parameter sweeps of simulations while other parameters are held constant. In this work, we apply existing uncertainty quantification methods on CFD models of a functional system to answer the question: how does variation in the input parameter space affect model output in a way similar to what natural selection would act upon? Through the use of generalized polynomial chaos and calculation of Sobol indices, we quantify the uncertainty on a model of circulatory flow using two methods of driving peristaltic motion (two opposing sine waves and a traveling pinch). Sensitivities of three input parameters are discussed: Womersley number, compression ratio (the percent occlusion of the tube during a compression), and compression frequency. Specific predictions about natural diversity are made based on sensitivities; those parameters that are very sensitive should be highly constrained versus those that are insensitive should exhibit high levels of diversification.

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