ABSTRACT

Cancer is a major threat to human life. Researchers are looking for improved cancer treatments over the existing methods of surgery, radiotherapy and chemotherapy. Hyperthermia, the heating of cancerous tumours, can improve complete response rates when added as an adjuvant treatment to radiation therapy.

This research features the modelling and design of multirate output feedback controller via reduced order model for a scanned focused ultrasound hyperthermia system. A simple one dimensional inhomogeneous tissue of 13cm in length is modelled as a tumour layer surrounded by muscle layer on either side by Pennes’ bioheat transfer equation. Assuming 131 nodes in the tumour tissue model, a state space model of order 131x131 for this bio-heat transfer problem is formulated based on explicit finite difference scheme, meeting the stability requirements. The higher order state space model is reduced to 4th order based on dominant Eigen value retention and Davison technique.

A stabilizing controller, designed from this reduced order model and applied to the higher order system by aggregation, results in a stabilizing controller for the higher order system but these controllers need the states to
be estimated. The multi rate output feedback controllers such as Periodic Output Feedback (POF) and Fast Output Sampling (FOS) feedback controllers are designed. In Fast Output Sampling the system, output is sampled faster than the control input and in Periodic Output Feedback controller the control input is sampled faster than the system output. For these controllers state estimation is not needed and this improves the reliability and stability of the system. The designed multirate controllers give a gain matrix with large magnitude which may lead to poor error dynamics and noise sensitivity. So a quadratic performance index is minimized for POF controller and a set of Linear Matrix Inequality constraints are solved for FOS to get a better gain. Closed loop temperature responses are simulated for systems with different perfusion cases. The performance of the controller is evaluated by framing a desired trajectory which meets the goals of hyperthermia feedback control system. The closed loop error norm and open loop error norm are calculated for systems with varying blood perfusion. The FOS Controller is also tested for tissue property variability by ±3%. Simulations proved that the output feedback controllers designed are effective in meeting the goals of hyperthermia system.

To compensate for the lack of robustness in the face of uncertainty in blood perfusion of the designed controllers a Discrete Sliding Mode Controller using Fast Output Sampling (DSMCFOS) is designed. By proper choice of tuning parameters in the reaching law, the dynamic response of the
closed-loop system is improved. Simulations proved that designed Discrete Sliding Mode Controller using FOS efficiently adapts to uncertainties and model mismatch during the course of treatment. Through the results of applications, the proposed discrete sliding mode control scheme using fast output sampling is shown to be very effective and useful.