Framework for Optimal Budget Allocation of HIV Intervention Policies

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1 Abstract

HIV has been responsible for over 35 million deaths. Over 37.9 million people around the world live with HIV (PLHIV). Due to the development of different intervention strategies, HIV is no longer a death sentence. In this paper, we propose a framework to optimally allocate capital to those intervention strategies subject to budget constraints. The framework uses the Epidemic MODel (EMOD) model to evaluate the effectiveness of any suggested intervention policy and uses the second-order gradient-based Newton's Method algorithm for the optimization. To improve the computational efficiency of our framework, we approximate the complex EMOD model using a tensor-train-based surrogate model. Tensor trains allow us to escape the curse of dimensionality and enable efficient evaluation of the first and second order gradients. Our framework is adaptive and iterative in the sense that it efficiently improves the accuracy of the surrogate model with every optimization cycle. As such, at convergence, we are guaranteed to reach an optimum with respect to the full EMOD model and not with respect to the approximate surrogate model. We used our algorithm to optimally allocate the intervention budget for the specific cases of South Africa and Kenya. The Kenya problem is particularly high-dimensional (42-dimensional). The results show that, under a constrained budget, AntiRetroviral Therapy (ART) medication is the most effective investment in reducing HIV-related death. This is a far more effective investment than other popular intervention strategies such as Pre-Exposure Prophylaxis (PrEP), Voluntary Male Medical Circumcision (VMMC), or Home Counseling and Testing (HCT) programs.