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Optimal Quarantine and Isolation Strategies for COVID-19 Based on a Mathematical Model

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Most of the countries in the world are currently suffering from the COVID-19 pandemic. Until researchers find medicines or vaccinations to suppress this disease, the most appropriate control techniques are wearing facial masks, frequently cleaning hands, social distancing, quarantining suspected close-contacts, and isolating infected people. A properly managed disease control process is very useful as it helps to minimize the economic and social issues that occur due to the spread of the disease. This paper aims to find optimal quarantine and isolation control strategies for COVID-19 based on a modified six compartments (susceptible(S), exposures (E), infectious (I), quarantined (Q), isolated (J), recovered (R)) mathematical model (SEQIJR-type). Modification to the model is done by considering quarantine and isolation rates as time-dependent parameters, in order to define optimal control problem which brings a novelty to the current study. The optimal control problem is designed to minimize the number of infections, quarantine, and isolated population sizes by proposing a suitable cost functional. Pontryagins Maximum Principle was applied to minimize cost functional. When there is no control, the infected population size was highly increased over time whereas it was reduced by a considerable amount with the presence of control strategies. Possible maximum strengths of the control strategies depend on the capacities of hospitals and quarantine centers as well as the economic strength of a disease spreading country or region. Therefore, controlling infectious population size in such a way that not exceeding the maximum hospital capacity is very important in the disease management process. Considering this fact, we subsequently insert an inequality state constraint to the problem to find optimal isolation and quarantine strategies that required controlling the disease. The observations indicated that the limited capacity of the isolation centers causes to increase in the size of the infected population which makes sense for real scenarios.

Keywords: COVID-19, Disease control strategies, Disease modelling, Optimal control, Pontryagin's maximum principle

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