MODELING AND FORECASTING OF INFECTION SPREAD IN WAR AND POST WAR SETTINGS USING EPIDEMIOLOGICAL, BEHAVIORAL AND GENOMIC SURVEILLANCE DATA

In recent years, the interplay between conflict and disease has come to the forefront of global concerns, with war-afflicted regions becoming unfortunate hotspots for epidemic outbreaks. Amidst the backdrop of warfare, numerous factors converge to exacerbate the spread of infectious diseases. In particular, the disintegration of health infrastructure cripples disease surveillance and response. Massive displacements of populations, often into crowded makeshift settlements, provide a fertile ground for diseases to spread and limited access to medical care means that even preventable illnesses can escalate to deadly epidemics. Weakened governance structures further impede systematic interventions and aid delivery. In this situation modeling and forecasting epidemics within conflict-stricken areas hold paramount significance. By accurately predicting the trajectory of disease spread in these contexts, we can proactively mitigate potential outbreaks, fine-tune the distribution of resources, and direct humanitarian efforts more effectively.

The primary objective of this project is to create a modeling and optimization framework specifically designed to provide accurate predictions of epidemiological trends during and after military conflicts, coupled with actionable public health guidance. This framework aims to support public health decision-making during conflicts, reducing the overall health impact. Furthermore, it will be an important resource in post-conflict phases, facilitating the effective rebuilding of healthcare infrastructure. Recently epidemiological modeling has become pivotal in addressing and mitigating disease outbreaks and pandemics. Traditionally, underpinned by epidemiological or viral genomics data, these models have consistently guided researchers and public health officials in their pursuit of effective interventions. However, these models often falter when faced with the intricate realities of war-torn settings. They grapple with the challenges posed by scanty and unreliable data, intricate patterns of population movement, nuanced social interactions, and fluctuating trust in institutions. The upheaval of healthcare infrastructures, sporadic access to medical care, shifting environmental contexts, evolving political dynamics, and the complexities of resource distribution further compound the issue. Recognizing these gaps, our endeavor focuses on enhancing the modeling capabilities to resonate with the challenges posed by conflict zones.

The project is expected to be one of the pioneering efforts to develop computational models and algorithms for analyzing epidemiological dynamics under conflict and post-conflict scenarios. We propose an interdisciplinary approach that integrates current advances in computational biology, mathematical epidemiology, machine learning, and operations research, consistent with current trends in incorporating human behavior into epidemiological models. As a result, we plan to develop models that encompass the diverse biological and epidemiological factors of pre-conflict, active conflict, and post-conflict stages. These factors include: the dynamics of forced population movements and migrations; population concentrations, particularly in high-density refuges such as shelters and refugee camps; the robustness and expanse of supply networks, with an emphasis on medical provisions; disruptions to healthcare services and infrastructure, including the deliberate targeting of medical establishments as a wartime tactic; psychological ramifications, which can impact community behaviors, resilience, and compliance with health interventions.

During the implementation of the project, the main attention will be paid to following generalized problems: (i) developing epidemiological models tailored for conflict zones; (ii) merging war-centric epidemiological models with population genetics within a phylodynamics framework; (iii) developing algorithms for optimized public health resource allocation.

The project will be implemented within the framework of international cooperation between Lodz University of Technology, Làukasiewicz-Polish Center for Technology Development (Wroclaw), Georgia State University, University of Connecticut in the USA, as well as Kharkiv National Medical University and Kharkiv Region Center for Diseases Control and Prevention of the Ministry of Health of Ukraine. American scientists have significant expertise and research experience in mathematical epidemiology, genomic epidemiology and computational biology projects. The Polish team includes experts in mathematical modeling in epidemiology, dynamical systems and nonlinear analysis, machine learning and fractal analysis, optimisation and operations research. Ukrainian colleagues have contextual knowledge and will provide statistical data on the spread of infectious diseases in the Kharkiv region, which will be complemented by information from publicly available sources. While the immediate focus is on the Kharkiv region, the results and findings are envisioned to be applicable to other conflict-affected regions, both within Ukraine and globally.