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**Abstract :**

# From Agent-Based Models on Complex Networks to the Risk Assessement of Emergent Infectious Disease Dynamics: from Simple Mathematical Models to Real Epidemics

**avril 2017**

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**From Agent-Based Models on Complex Networks to the Risk Assessement of Emergent Infectious Disease Dynamics: from Simple Mathematical Models to Real Epidemics**

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Epidemics have shaped history and have been extinguished Civilizations through centuries. Characteristic cases are the biblical pharaonic plagues which hit Ancient Egypt in the middle of Bronze Age around 1715 B.C., the "λοιμός" (an unknown epidemic, probably plague) which swept through Athens from 430 to 425 B.C. and ended the Periclean golden era, the Black Death Bubonic Plague (1348-1353 A.C.) with a death toll of 25 million people just in Europe, the pandemic influenza of 1918–1919 that swept through the globe leaving a death-toll of around 40 million people[1,2]. The list goes on.

In the contemporary era, emerging and re-emerging infectious and parasitic diseases account for the 26% of the total deaths worldwide. Measles which is one of the leading causes of death among children, malaria and tuberculosis kill millions of people each year in the so-called developing countries. WHO reported that in 2015 nearly half of the world's population was at risk of malaria and 440,000 died because of the disease[3]; the related deaths from measles were about 134, 200, while 1.8 million died worldwide from tuberculosis[4]. Recently, the Ebola epidemic devastated the population in the countries of West Africa leaving behind more than 11,300 dead.

From a public policy/risk management perspective, poor understanding of the evolving emergent epidemic dynamics may have fatal consequences in the population. Clearly, during the past years mathematical models and methods have enhanced our efficiency in combating epidemics. Multidisciplinary groups from applied mathematicians, biologists and clinical epidemiologists have teamed up to develop state-of-the-art models to access the spreading risk and ultimately design control policies in a race against time. Agent-based models constitute the backbone of the current state-of-the-art in the field. However, on one hand. real-world epidemics and pandemics are characterized -due to their inherent complexity by the lack of good evolution models. On the other hand, what is usually done with detailed agent-based epidemic simulators is running many scenarios with different initial conditions and for long times to get the relative macroscopic information. However this is insufficient for systematic computations and analysis.

The systematic bridging of the scale where good and detailed agent-based models may be available and the emergent-macroscopic scale where we want to investigate the dynamics of the spread, design and control its behavior, constitutes a major challenge in contemporary epidemiology. Multi-scale computational methodologies that can tackle the above problem have the potential to advance further better mathematical modeling, understanding, predicting and designing of better public health strategies to combat emergent epidemics.

I will show how the so called Equation-Free multiscale modelling framework[5] can be used to effectively analyze certain aspects of the dynamics of agent-based epidemic simulators on networks. I focus on the efficient systematic investigation of the dependence of the emergent dynamics with respect to epidemiological and contact transmission network parameters by constructing the coarse-grained bifurcation diagram, the identification of critical points that mark the onset of outbreaks, and the analysis of rare-events that may trigger outbreaks of phenomenologically latent infectious diseases[6,7,8].

Based on the proposed methodology, I also present results on the analysis, forecasting and design of control policies for the Ebola epidemic that swept through the countries of West-Africa, especially in Liberia and Sierra Leone within 2014 and 2015[9,10].

To this end it should be highlighted that we should not overestimate the usefulness of mathematical models. Despite the huge technological progress and produced wealth in the 21th century this wealth remains concentrated in a few hands. According to the annual report of the Credit Suisse on the Global Wealth Pyramid, in 2016, 33 millionaires accounting for the 0.7% of the total earth own nearly the 50% percent of household wealth population[11]. On the other side, the rapid impoverishment of large parts of the population, which comes together with breakdowns and cuttings in public health infrastructures are the major reasons of fatal infectious disease epidemics.

## References


1. Siettos CI, Russo L, 2013, Mathematical Modeling of Infectious Disease Dynamics: A Review, *Virulence*, **4** (4), 295-306
2. Siettos, C.I., 2015, Mathematical Modeling of Infectious Disease Dynamics, Virulence, 7(2), 119-120. Doi: 10.1080/21505594.2016.1150402.
3. http://www.who.int/mediacentre/factsheets/fs094/en/
4. http://www.who.int/mediacentre/factsheets/fs104/en/
5. Kevrekidis et al., 2003, Equation-free, coarse-grained multiscale computation: enabling microscopic simulators to perform system-level analysis, Commun. Math. Sci. , 1 , 715-762.
6. Siettos, C. I., 2011, Equation-Free Multiscale Computational Analysis of Individual-Based Epidemic Dynamics on Networks, Applied Mathematics and Computation, 218, 324-336.
7. Reppas, A. I., Tsoumanis, A. C. and Siettos, C.I., 2010, Coarse-Grained Bifurcation Analysis and Detection of Criticalities of an Individual-Based Epidemiological Network Model with Infection Control, Applied Mathematical Modelling, 34,552-560.
8. Reppas, A., De Decker Y., Siettos, C.I., 2012, On the Efficiency of the Equation-Free Closure of Statistical Moments: Dynamical properties of a Stochastic Epidemic Model on Erdos-Renyi Networks, Journal of Statistical Mechanics: Theory and Experiment , 8 , P08020.
9. Siettos, et al., 2015, Modeling the 2014 Ebola Virus Epidemic – Agent-Based Simulations, Temporal Analysis and Future Predictions for Liberia and Sierra Leone, PLOS Currents, Mar 9,Doi:10.1371/currents.outbreaks.8d5984114855fc425e699e1a18cdc6c9.
10. Siettos et al., 2016, Modeling, Forecasting and Control Policy Assessment for the Ebola Virus Disease (EVD) Epidemic in Sierra Leone Using Small-World Networked Model Simulations, BMJ Open, , 6 , e008649.
11. https://www.credit-suisse.com/us/en/about-us/research/research-institute/news-and-videos/articles/news-and-expertise/2016/12/en/the-global-wealth-pyramid-2016.html