

A Note on NCP Diagnosis Number Prediction Model

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Abstract

In December 2019, pneumonia infected with the novel coronavirus burst in Wuhan, China. We aimed to use a mathematical model to predict number of diagnosed patients in future to ease anxiety on the emergent situation. In this retrospective, all diagnosis number from Jan 21 to Feb 10, 2020 reported from China was included and downloaded from WHO website. We develop a simple but accurate formula to predict the next day diagnosis number: $\frac{N_i}{N_{i-1}} = \left(\frac{N_{i-1}}{N_{i-2}}\right)^\alpha$, where N_i is the total diagnosed patient till the i th day, and α was estimated as 0.904 at Feb 10. Based on this model, it is predicted that the rate of disease infection will decrease exponentially. The total number of infected people is limited; thus, the disease will have limited impact. However, new diagnosis will last to March.

Introduction

In December of 2019, the increasing number of patients with pneumonia of unknown cause emerged in Wuhan, the capital of Hubei province, Central China. Most of the early patients had directly or indirectly related to wild animal source in the seafood and wet animal wholesale market through epidemiological survey¹⁻⁵. Then laboratory tests found that the infection was caused by a novel coronavirus (now named as NCP⁶⁻⁷).

The spread of NCP is expeditious. According to WHO statistics, the total number of diagnosed people in China was 309 in Jan 21⁸, but rapidly grew to 4537 in Jan 27⁹. Considering a simple constant exponential growth rate model¹⁰⁻¹¹, the diagnosis number will be unimaginable soon. This triggered a major concern and motivated this study¹²⁻¹⁴. A mathematical model is required to predict the spread trend and emergent situation.

Over the last few decades, mathematical models of disease transmission have been useful to gain insights into the transmission dynamics of infectious diseases and the potential role of intervention strategies¹⁵. Epidemic transmission models focused on the spread of an infectious disease through a population. But this spread can be modeled in two fundamental ways: by looking at the entire population as a single group or set of linked subgroups (population-based) or by considering everyone that makes up the population and how interactions between unique individuals facilitate disease spread (individual-based). Common models of infectious disease included meta-population models, individual-based network models, and simple SIR-type models that incorporate the effects of reactive behavior changes or inhomogeneous mixing¹⁶.

Considering the limited number of data points and the complexity of the real situation, a simple but robust model is expected to work better than sophisticated epidemiology models. In this paper, we propose a robust model for next day diagnosis number predict. This model had excellent performance on prediction of infected patients in past few days. The prediction is expected to provide practical significance

on social and economic application.

Results

Estimation of α

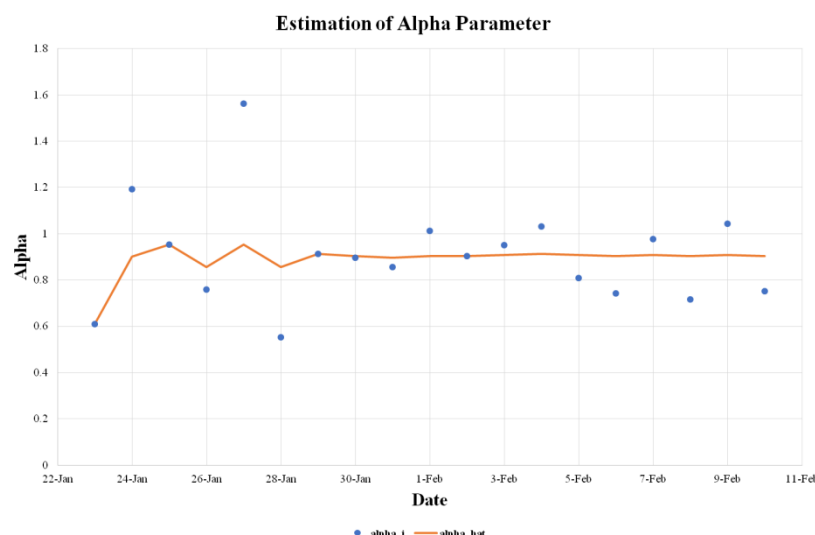


Fig.1|Estimation of Alpha Parameter.

$\hat{\alpha}_i$ and its median aggregates were calculated (Fig.1). It was observed that $\hat{\alpha}_i$ manifests a random fluctuation around a constant center. It is reasonable to assume that α is a constant. The estimation of α currently (Feb 10) is 0.904. A future diagnosis number formula is obtained based on this estimation:

$$\frac{N_i}{N_{i-1}} = \left(\frac{N_{i-1}}{N_{i-2}}\right)^{0.904}$$

Next Day Prediction Table

Previous numbers of diagnoses in China are used to predict the number for the next day. The prediction is started from Jan 29 as several data points are needed to build the model (Table 1). We obtain nice concordance ($<2.5\%$ error) with the real numbers next day.

Table 1| Observed and Predicted number of diagnosis in China

Date	WHO	Predict	error%
21-Jan	309		
22-Jan	571		
23-Jan	830		
24-Jan	1297		
25-Jan	1985		
26-Jan	2741		
27-Jan	4537		
28-Jan	5997		

29-Jan	7736	7602	-1.73%
30-Jan	9720	9760	0.41%
31-Jan	11821	11950	1.09%
1-Feb	14411	14088	-2.24%
2-Feb	17238	17240	0.01%
3-Feb	20438	20269	-0.83%
4-Feb	24363	23857	-2.08%
5-Feb	28086	28600	1.83%
6-Feb	31211	31959	2.40%
7-Feb	34598	34335	-0.76%
8-Feb	37251	37992	1.99%
9-Feb	40235	39824	-1.02%
10-Feb	42708#	43152	1.04%
11-Feb		45075	

latest number from <http://www.nhc.gov.cn/>

New Diagnosis Number Prediction

We predict the new diagnosis number in China according to our model as Fig.2. The model predicts that new diagnosis will last to March.

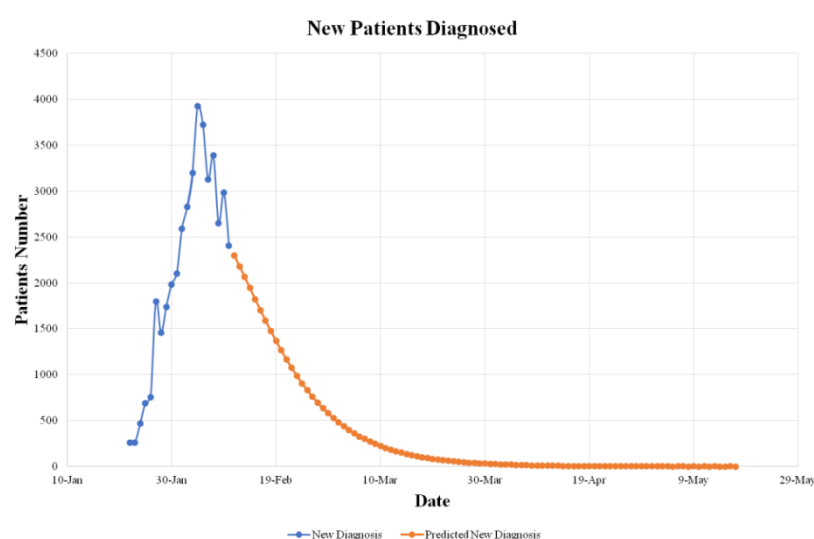


Fig. 2|Observed (Blue) and Predicted (Orange) number of daily new diagnosis.

Conclusion

Our model indicates that the NCP disease infection rate decreases exponentially. This model converges to a maximum number as time increases, indicating a limited impact of NCP. The model also predict that the new diagnosis number will last to March, indicating that the NCP disease will be well controlled.

Discussion

We only analyzed the total number of diagnoses in China. The province scale data is available but is not as complete as total number. Here, we did not show these details analyses.

Our model is attractive as it not only predicts data accurately but also is minimal. The minimal number of parameters and robust statistics make our model robust in the real-world scenario. We develop a formula to predict the next day diagnosis number:

$$\frac{N_i}{N_{i-1}} = \left(\frac{N_{i-1}}{N_{i-2}}\right)^\alpha, \text{ and estimate that } \alpha \text{ is } 0.904 (\alpha < 1) \text{ which shows that the diagnosis}$$

number of NCP patients will decrease. It is very effective in controlling the spread of infectious diseases that the Chinese health authorities have taken appropriate health care actions. If the outbreak is no longer controlled, the value of α will be around 1 indicating that the outbreak will wreak havoc.

We obtain this elegant formula with both curve plot visualization and mathematical intuition. We plot $\ln(N_i/N_{i-1})$ against time (Fig.3). First few observations showed a linear decay of spread rate. However, later data points realized us at Feb 4 that it is an exponential decay. Later data points further confirm our model.

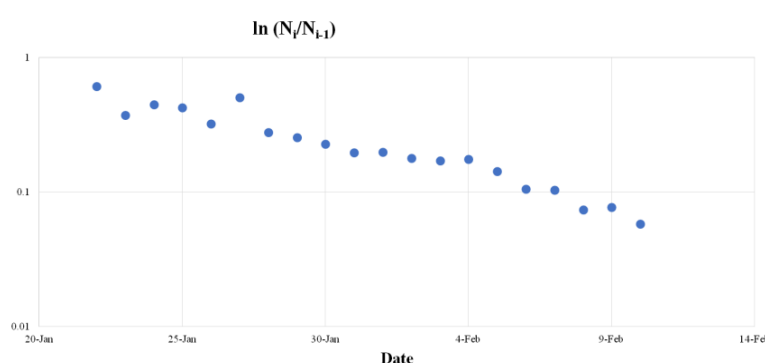


Fig. 3| $\ln(N_i/N_{i-1})$ against time.

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Methods

Data Download

Daily diagnosis number of China is download from WHO situation reports (<https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports>). The data starts from Jan 21 and currently it ends at Feb 10.

Model

The following model is proposed based on our observations:

$$\frac{N_i}{N_{i-1}} = \left(\frac{N_{i-1}}{N_{i-2}}\right)^\alpha,$$

where N_i is the number of diagnosed patients in China according to WHO at the i th day, α is a parameter modeling the decay of diagnosis growth rate.

A simple estimation of α at the i th day would be

$$\hat{\alpha}_i = \frac{\ln\left(\frac{N_i}{N_{i-1}}\right)}{\ln\left(\frac{N_{i-1}}{N_{i-2}}\right)}$$

As we have multiple days of observations, historical $\hat{\alpha}_i$ with the median statistic, which is well known for its robustness, can be aggregated.

$$\hat{\alpha} = \text{median}(\hat{\alpha}_i)$$

The source code of model estimation is at: https://github.com/wangyi-fudan/ncp_model

Author Contribution YW conceived the idea and wrote the source code. YL, XY and YW contributed data analysis, generating tables and figures, and manuscript writing. YL, XY, ML, MH, LX and YW contributed the theoretical analysis and manuscript revision. All authors contributed to final revision of the manuscript.

Competing interests The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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