Utilization of network centrality measures for risk based surveillance

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Abstract

Central nodes in scale-free contact networks are relevant for contagious disease spread. These nodes are therefore well suited for targeted surveillance. If farms under surveillance are selected according to the in degree centrality measure, the probability of disease detection is increased [1].

In our analysis we demonstrate that the trade network of German pig holdings (June 2006- December 2008) was a scale-free network and that high indegree farms could be readily identified.

Keywords: Pork production, trade network, centrality measures, risk based surveillance.

Introduction

Since 2001, EU Member States are obliged to collect and record information on livestock trade activities [2]. Since trade of farm animals is an essential pathway for infectious diseases spread [3], detailed information on trade structures is important. This additional information can be used to improve the management of livestock diseases.

To utilize information on livestock trade activities, it is first necessary to convert the documented information in a network of contacts. We applied this approach to pig holdings in Germany and investigated their trade activities for the period June 2006- December 2008. In the trade network, pig holdings are represented by the network nodes and the edges between the nodes represent the movement of animals. Since animal trade is always directed, the resulting network is a directed network.

The properties of contact networks are characterized by using centrality measures. An important measure is the degree centrality measure. Many real world contact networks exhibit specific properties: they are scale-free small world networks. Networks of this class feature properties which are also important for animal disease surveillance.

Focusing surveillance on the central nodes within a network results in a significant reduction of the duration of the high-risk period [1]. Degree and betweenness centrality were identified as the relevant measures.

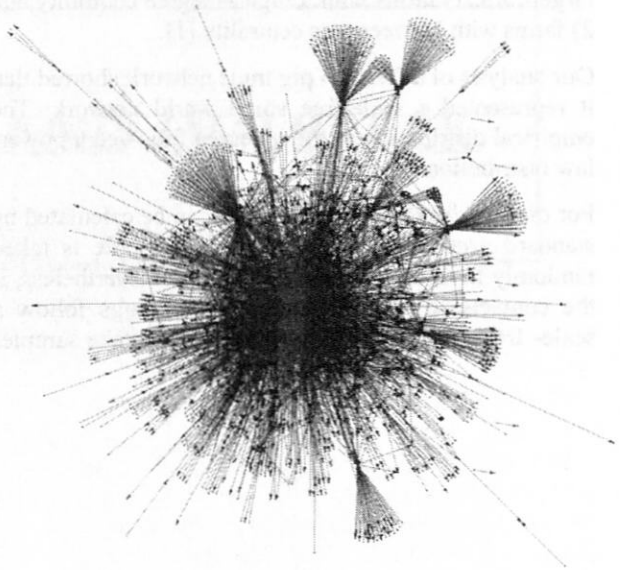
Materials and methods

The trade network between pig herds in Germany was set up using data on recorded trade activities of the years 2006 to 2008 and intensively analyzed [4]. In Germany, the "Herkunftssicherungs- und Informationssystem für Tiere" (HI-Tier) runs a database documenting all trade movements of cattle and pigs. In this analysis, we used data collected since 01-06-2006, because measure taken to control an outbreak of classical swine fever that had occurred earlier in 2006 might have altered the usual trade patterns. The network structure was established and the centrality measures calculated with the Python programming language using the library NetworkX.

Result

The examined network consisted of 121,000 nodes (farms) and 330,000 edges (animal movements between farms). Due to the large number of nodes and edges in Figure 1, only a portion of the network is presented.

Figure 1: Illustration of a part of the German trade network between pig holdings. The total network consists of 120,000 nodes and 330,000 edges. Because of its size, it cannot be displayed in the 2D plane.



On the basis of Figure 1 it is obvious that the trade network is very well structured. Farms with high degrees are immediately recognizable.

The degree distribution (in- and out-degree) of the nodes is shown in Figure 2.

The theoretical power-law distribution, which is scale-free, could be fitted well to the empirically found distributions. The considered network is therefore a scale-free network.

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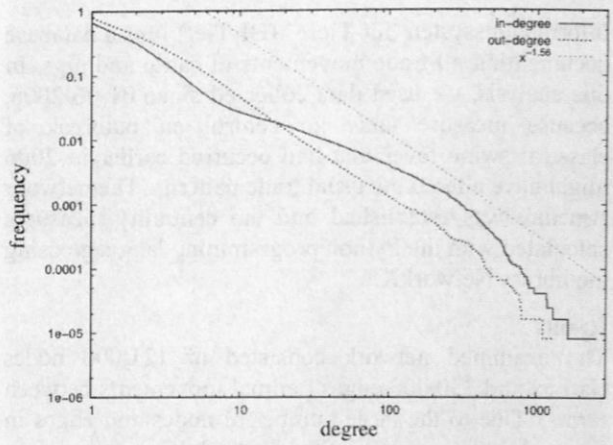
Figure 2: Empirical distribution of the in- and outdegree on a log-log scale together with the theoretical power law distribution with the estimated parameter



Discussion

Real world networks are often scale-free small world networks. Scale free networks exhibit properties which can be utilized for risk-based surveillance. Suitable targets are: 1) farms with a high indegree centrality and 2) farms with betweenness centrality [1].

Our analysis of a German pig trade network showed that it represented a scale-free small world network. The empirical distribution of the indegree followed a power-law distribution.

For disease detection, sample sizes can be calculated by standard procedures, and usually the sample is taken randomly from the population of farms. Nevertheless, if the contacts structure between pig holdings follow a scale- free distribution, it is reasonable to take samples according to the degree of the distribution. Farms with a high degree should be preferentially sampled, which increases the probability of disease detection. Such a targeted sampling approach could also be used to lower sample sizes.

It is important to note that our analysis considered only trade, although many other possible transmission routes exist. Other means of transmission such as neighborhood contacts or vehicles are well described. In order to include these transmission routes in the network analysis, further investigations on the contact structures are needed.

References

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