Dual Graph Spatial Cluster Detection for Syndromic Surveillance in Networks

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OBJECTIVE

We describe a model for cluster detection and inference on networks based on the scan statistic. Our aim is to detect as early as possible the appearance of an emerging cluster of syndromes due to a real outbreak (signal) amidst unrelated syndromes (noise).

BACKGROUND

Early warning systems must not always rely on geographical proximity for modeling the spread of contagious diseases. Instead, graph structures such as airways or social networks are more adequate in those situations. *Nodes*, associated to cities, are linked by means of *edges*, which represent routes between cities. Scan statistics [1] are highly successful for the evaluation of clusters in maps based on geographical proximity. The more flexible neighborhood structure of graphs presents difficulties for the direct usage of scan statistics, due to the highly irregular structures involved. Besides, the traffic intensity between connected nodes plays a significant role which is not usually present in scan statistic based models.

METHODS

We build the *dual graph* of the original graph, reversing the rules of nodes and edges in the original graph. In the dual graph, the new nodes are the edges of the original graph, and two nodes of the dual graph are linked by an edge when the corresponding two edges in the original graph have a node in common. Figure 1 shows the original graph of a simplified map of airways at the top, and the corresponding dual graph superimposed to the original one at the bottom. Thus, instead of forming clusters candidates by grouping neighboring nodes of the original graph, the cluster candidates are chosen among the connected subgraphs of the dual graph. That means we are now looking for collections of plausible pathways by which the disease could be transmitted. The most likely cluster is naturally the most structurally stable connected subgraph, or arrangement of pathways, meaning that adding or subtracting pathways to it should decrease the observed signal-to-noise proportion. In our model, *traffic between cities* is the analogous of population in the usual scan, and *the number of syndromic individuals traveling between cities* corresponds to the number of cases.

In order to evaluate the structural stability of the subgraphs we use a penalty function based on the presence of weak links, or low signal-to-noise nodes which disconnect the subgraph when removed from it [2]. The number of syndromic individuals traveling between cities cannot be observed directly. It is thus estimated based on a discrete approximation of the weighted (by traffic) space-time diffusion equation governing the system [3].

RESULTS

We present results of simulations that illustrate the concept of the dual graph scan.

CONCLUSIONS

The dual graph scan may be a useful tool for detection and inference of clusters of emerging diseases in networks and the study of patterns of outbreaks.

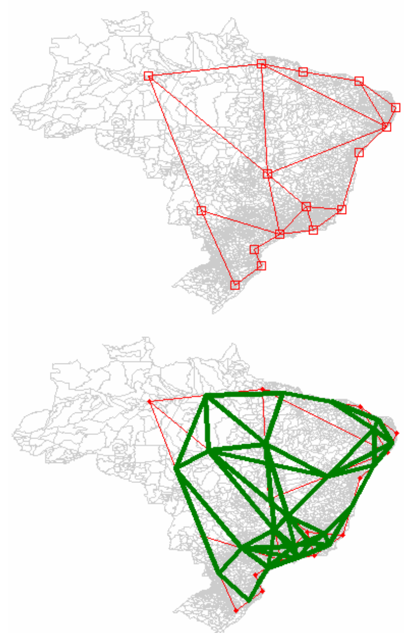

Figure 1 – Original graph of airways in Brazil (top) and the corresponding dual graph superimposed to the original graph (bottom).

REFERENCES

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