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A spatial model for social networks

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Abstract

We study spatial embeddings of random graphs in which nodes are randomly distributed in geographical space. We let the edge probability between any two nodes to be dependent on the spatial distance between them and demonstrate that this model captures many generic properties of social networks, including the "small-world" properties, skewed degree distribution, and most distinctively the existence of community structures.
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1. Introduction

Complex social networks arise in a wide range of contexts, for example as corporate partnership networks [1], scientist collaboration networks [2], company director networks [3], film actors networks [4], sexual contact networks [5], etc. Indeed, a lot of attention has been given by both physical and social scientists in recent years to model these networks so as to gain better understandings of their general structures as well as their various functions like information flow [6],

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locating individuals [7], disease spread [5], etc. (for a review of recent efforts, see for example Refs. [8–10]). While there is an apparent increase in the number of network models in the literature, not all of these models have taken full advantage of the sociological and psychological insights on how social networks may be formed.

1.1. Spatial characteristics of social ties

The principle of *homophily*, or in essence "birds of a feather flock together," has been firmly established by many empirical studies [11]. While we clearly tend to befriend those who are like us, there are many situations where having a lot of friends like us is simply because we are *stuck* with people who are like us in the first place. For example if you are a millionaire and all your friends are millionaires, it might simply be because you were born into an elite family and live in an elite area so you only know millionaires in your life, even though you do not actively choose to befriend millionaires over non-millionaires. Therefore, it is useful to divide homophily into two main types: *baseline* homophily and *inbreeding* homophily [11]. Baseline homophily is attributed to the fact that we have a *limited potential tie pool* due to factors like demography and foci of activities [12]. Inbreeding homophily is conceptualised as any other kind of homophily measured over that potential tie pool—this may include homophily regarding gender, religion, social class, education, and other intra-personal or behavioural characteristics. While many network models have taken inbreeding homophily into account [13–18], they have generally assumed that there are no baseline homophily effects, i.e., the potential tie pool for all actors equals the *entire* population. However, this is obviously not very realistic and baseline homophily effects can potentially have profound consequences on the structure of social networks.

A basic source of baseline homophily is the *geographical space*. As a matter of simple opportunity and/or the need to minimise efforts to form and maintain a social tie [19], we can expect that we tend to form ties with those who are geographically close to us. Thus, intuitively, this creates a very strong constraint on our potential tie pool. In fact, there is ample empirical evidence that demonstrates this claim. The earliest studies of which we are aware of date back to Festinger et al. [20] and Caplow and Forman [21] both on student housing communities. The results showed that in these rather homogeneous communities, spatial arrangement of student rooms/units was an important factor in predicting whether two dwellers have at least weak ties. Many other network studies also reached similar results (for example see Refs. [22,23]). More recently, Wellman [24] and Mok et al. [25] re-analysed Wellman's earlier dataset on Torontorian personal communities [26,27] and noted that most personal friendships were indeed "local," contrary to the beliefs that recent technological advances have freed us from spatial constraints. For instance, in Ref. [26] it was found that on average 42% of "frequent contact" ties live within a mere 1 mile radius of a typical person, while the rest of his/her ties could be directed to anywhere in the rest of the world.