Pathwalker: A New Individual-Based Movement Model for Conservation Science and Connectivity Modelling

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A The effect of autocorrelation on movement density

In this supplementary analysis, we demonstrate a result of theoretical interest for movement modelling, which is to derive the movement density function for different degrees of autocorrelation in the movement. The knowledge of the correct function, which this analysis provides, is essential for accurately configuring movement and connectivity models (such as resistant kernels) which use different kernel functions to represent different levels of dispersal ability.

A.1 Analysis

We look at the average distribution of movement density for four values of the correlation parameter C - 0 (no autocorrelated movement), 0.25, 0.5 and 0.75 - on a landscape with 500-by-500 pixels, and uniform resistance value 1. We use the energy movement mechanism and no spatial scaling, noting that the landscape is uniform and thus using a different spatial scale, or using the attraction movement mechanism, results in the same distribution of movement.

For each of the four values of C we will simulate 1000 movement paths from the source point, each of length 500 steps, and aggregate these 1000 paths into a density surface. We can visualise these surfaces in both two-dimensions (as a heatmap) and three-dimensions. Then, to these distributions we fit two functions - the exponential function ae^{bx} and the power function $a(x+c)^b$ - and compute the optimum parameters for these two functions, along with the resulting r^2 value of the fit. This allows us to derive a prediction for the kernel shape of movement density under different levels of autocorrelated movement. Since the distribution will be radially symmetric about the source point, we need only perform this computation on the 1-dimensional x-axis, rather than on a 2-dimensional grid. For this analysis, we use the scipy and scikit-learn packages for Python 3.8.

A.2 Results

The first two columns of Table 1 display the extent of the paths, and also the percentage of total possible area covered on the 500-by-500 pixel resistance surface, for the four different density surfaces produced from 1000 runs of length 500 steps. We see that both statistics increase as the correlation value increases. Figure 1 displays the four density surfaces, with extent visibly increasing as correlation increases.

Figure 2 displays the three-dimensional movement density distributions. For ease of visualisation, we remove the source point, since (as we may expect) its density value is much higher than the surrounding points. Taking into account minor stochastic variation, we observe a radially symmetric function resembling a negative exponential or power function. The fit of the power and exponential functions vary depending on whether or not we include the source point in the data: (1) with the source point included, we find the power function to result in a higher r^2 value than the exponential, with the margin between these two r^2 values varying between 0.03 and 0.14, but (2) without the source point, optimum parameters for the power function could not be found, and the exponential is seen to fit much better without rather than with the source point. The latter two rows of Table 1 provide the parameter and r^2 values resulting from fitting these two functions, in which (out of the two functions) we display only the function with the higher r^2 value.

Table S1. Statistics for the four density surfaces produced from the four different correlation values. The first row gives the overall extent of the movement paths on the 500-by-500 resistance surface, and the second row gives the percentage of the total area covered by these paths. The latter two rows give the parameters and r^2 value for the fitted power and exponential functions respectively.

	$C = 0$	$C = 0.25$	$C = 0.5$	$C = 0.75$
Extent of paths	118×120	170×142	197×208	319×320
Percentage of surface covered	3.1268	5.0944	8.1736	15.5456
Power function parameters and r^2 value	$a = 29.975$ $b = -1.751$ $c = 4.240$ $r^2 = 0.991$	$a = 4.3470$ $b = -1.126$ $c = 1.938$ $r^2 = 0.973$	$a = 1.249$ $b = -0.924$ $c = 0.753$ $r^2 = 0.963$	0.512 $b = -0.780$ $c = 0.236$ $r^2 = 0.977$
Exponential function parameters and r^2 value	$a = 1.541$ $b = -0.150$ $r^2 = 0.986$	$a = 0.926$ $b = -0.125$ $r^2 = 0.992$	$a = 0.522$ $b = -0.085$ $r^2 = 0.984$	0.288 $b = -0.071$ $r^2 = 0.956$

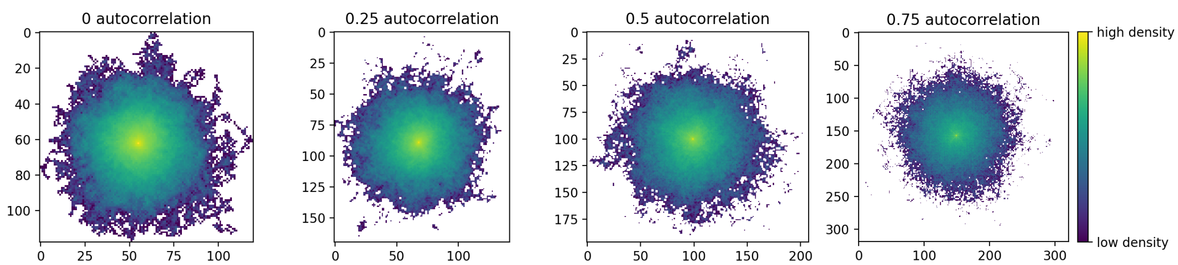

Figure S1. The four density surfaces produced from the four different correlation values.

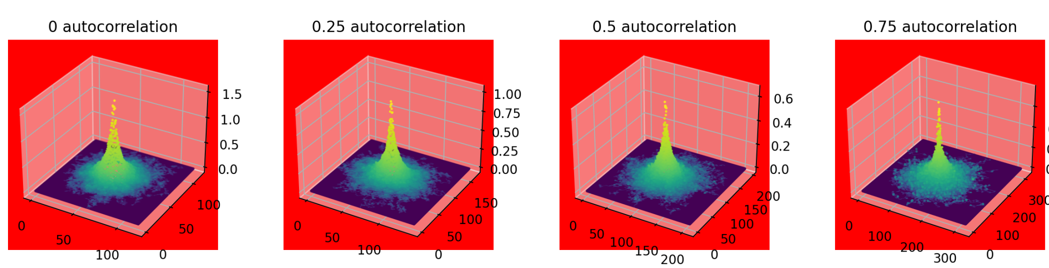

Figure S2. The same four density surfaces, now plotted in three-dimensional space with the same colouring as above.