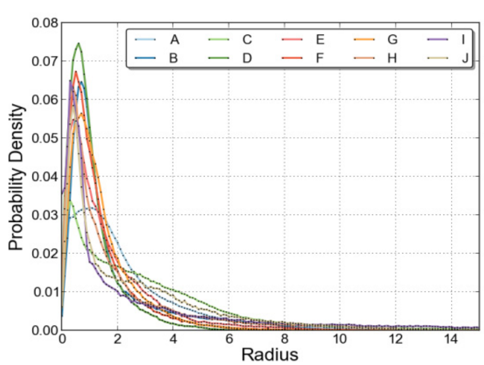
Investigating the distribution of human activity space from mobile phone usage

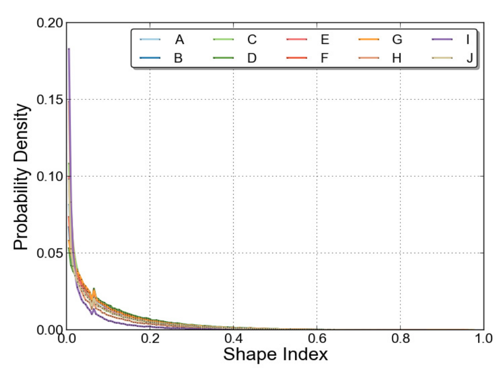
Yihong Yuan[1,2], Martin Raubal[1]

[1] Institute of Cartography and Geoinformation, ETH Zurich, 8093 Zurich, Switzerland
[2] Department of Geography, University of California, Santa Barbara, CA, 93106, USA
Phone: +41 44 633 76 91, Email: yyuan@ethz.ch

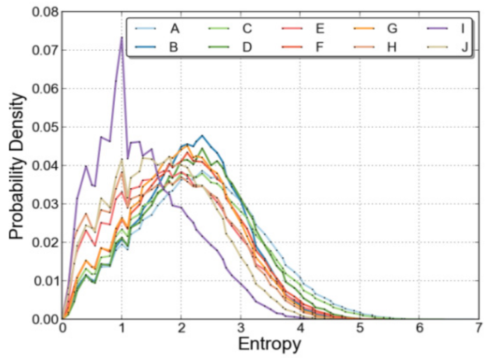
The measurement of activity space is an important topic when studying the spatial distribution of individual behavior, which is defined as the local areas within which people travel during their daily activities (Mazey 1981). Meanwhile, the development of information and communication technologies have provided broader data sources (e.g., georeferenced mobile phone datasets) regarding where, when, and how people travel to different places. This research aims at a deeper understanding of how individual activity spaces are distributed in ten Chinese cities (marked as *A*-*J*) and how these distributions correlate with the size of each city. We employ three indicators to represent different aspects (scale, shape, and randomness) of activity behavior: (1) radius, (2) shape index (SI, defined as 1-eccentricity), and (3) entropy. The first two measure the basic descriptive characteristics of individual activity space, whereas the third one depicts the internal structure of activity space by measuring the regularity of individual trajectories. In Figure 1 the probability density distributions of the three measurements for the mentioned Chinese cities (*A*-*J*) are shown.



(a)



(b)



(c)

Figure 1. Probability density of three indicators (a) Radius; (b) Shape Index; (c) Entropy

In Figure 1, it can be observed that the shape of all three distributions can be approximated by a Weibull distribution, which is defined as:

$$f(x;\lambda,k)=\frac{k}{\lambda}(\frac{x}{\lambda})^{k-1}e^{-(\frac{x}{\lambda})^{k}} \quad (x\geq 0)$$

where $k > 0$ is the shape parameter and $\lambda > 0$ is the scale parameter of the distribution. The combination of simplicity and flexibility in the shape of the Weibull distribution has made it an effective model in various applications such as industrial engineering. With k=1, the Weibull distribution turns into an exponential distribution. Table 1 lists the parameters of Weibull distribution fitting for Figure 1.

Table 1. The parameters of Weibull distribution

	k_1 *(entropy)*	λ_1 *(entropy)*	k_2 *(Radius)*	λ_2 *(Radius)*	k_3 *(Shape Index)*	λ_3 *(Shape Index)*
A	2.41	2.64	1.13	2.62	0.57	0.07
B	2.74	2.4	1.13	1.96	0.57	0.08
C	2.33	2.51	1.03	3.25	0.48	0.05
D	2.64	2.5	1.37	1.24	0.62	0.09
E	2.1	2.13	1.15	1.84	0.41	0.05
F	2.42	2.32	1.18	1.52	0.51	0.07
G	2.52	2.27	1.35	1.65	0.52	0.07
H	1.98	2.02	0.98	2.06	0.32	0.02
I	1.86	1.58	0.73	2.96	0.22	0.01
J	2.13	1.94	1.03	2.65	0.33	0.04
Average	2.31	2.23	1.11	2.18	0.46	0.055

The results indicate that the distribution of radius is close to an exponential distribution (k_2≈1), whereas the decay of SI is faster than exponential (k_3<1). It also shows that the distribution of Entropy is similar to a skewed normal distribution (k_1≈2). We have also constructed a regression model showing that k_2 is significantly correlated with the size of the cities, indicating that bigger cities have a faster decay trend for individual activity radii. However, city size is not significantly correlated with either entropy or SI. In summary, this research presents a study to mathematically model the distribution of activity space. The results can be considered as a generalization of the work by Kang et al. (2012).

Kang, C., X. Ma, D. Tong & Y. Liu (2012) Intra-urban human mobility patterns: An urban morphology perspective. *Physica A: Statistical Mechanics and its Applications,* 391**,** 1702-1717.

Mazey, M. E. (1981) The Effect of a Physio-Political Barrier Upon Urban Activity Space. *Ohio Journal of Science,* 81**,** 212-217.