MODIFIED GRAVITY MODEL FOR VARIABLE-SPECIFIC CLASSIFICATION

B.S. DAYA SAGAR

http://www.isibang.ac.in/~bsdsagar

Systems Science and Informatics Unit (SSIU)
Indian Statistical Institute-Bangalore Centre

EQUATIONS

$$X_i \cap \left(\bigcup_{\substack{j=1 \\ j \neq i}}^{N} X_j \right) = \varnothing .$$

$$FX_{ij} = G \frac{mX_i mX_j}{\left(dX_{ij}\right)^2}$$

$$F\left(X_{ij}\right) = \frac{\left(mX_i mX_j\right)}{\left(d\left(X_{ij}\right)\right)^2 \left(\varphi X_i \varphi X_j\right)}$$

$$\left(\varphi X_i\right) = \left(\frac{\max_{\forall j}\left(d\left(X_{ij}\right)\right)}{\max_{\forall i}\left(\max_{\forall j}\left(d\left(X_{ij}\right)\right)\right)} \right)$$

$$F\left(X_{ji}\right) = \frac{\left(mX_j mX_i\right)}{\left(d\left(X_{ji}\right)\right)^2 \left(\varphi X_j \varphi X_i\right)}$$

SPATIAL INTERACTIONS

$$d\left(X_{ij}\right)=\begin{bmatrix} & X_1 & X_2 & \cdots & X_N \\ X_1 & d\left(X_{11}\right) & d\left(X_{21}\right) & \cdots & d\left(X_{N1}\right) \\ X_2 & d\left(X_{12}\right) & d\left(X_{22}\right) & \cdots & d\left(X_{N2}\right) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_N & d\left(X_{1N}\right) & d\left(X_{2N}\right) & \cdots & d\left(X_{NN}\right) \end{bmatrix} \quad (9)$$

$$\left(\varphi X_i \varphi X_j\right)=\begin{bmatrix} & \varphi X_1 & \varphi X_2 & \cdots & \varphi X_N \\ \varphi X_1 & \left(\varphi X_1 \varphi X_1\right) & \left(\varphi X_2 \varphi X_1\right) & \cdots & \left(\varphi X_N \varphi X_1\right) \\ \varphi X_2 & \left(\varphi X_1 \varphi X_2\right) & \left(\varphi X_2 \varphi X_2\right) & \cdots & \left(\varphi X_N \varphi X_2\right) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \varphi X_N & \left(\varphi X_1 \varphi X_N\right) & \left(\varphi X_2 \varphi X_N\right) & \cdots & \left(\varphi X_N \varphi X_N\right) \end{bmatrix} \quad (10)$$

$$\left(mX_i mX_j\right)=\begin{bmatrix} & mX_1 & mX_2 & \cdots & mX_N \\ mX_1 & \left(mX_1 mX_1\right) & \left(mX_2 mX_1\right) & \cdots & \left(mX_N mX_1\right) \\ mX_2 & \left(mX_1 mX_2\right) & \left(mX_2 mX_2\right) & \cdots & \left(mX_N mX_2\right) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ mX_N & \left(mX_1 mX_N\right) & \left(mX_2 \varphi mX_N\right) & \cdots & \left(mX_N mX_N\right) \end{bmatrix} \quad (11)$$

Level of interaction matrix is

$$F\left(X_{ij}\right)=\begin{bmatrix} & X_1 & X_2 & \cdots & X_N \\ X_1 & F\left(X_{11}\right)=\frac{\left(mX_1 mX_1\right)}{\left(d\left(X_{11}\right)\right)^2\left(\varphi X_1 \varphi X_1\right)} & F\left(X_{21}\right)=\frac{\left(mX_2 mX_1\right)}{\left(d\left(X_{21}\right)\right)^2\left(\varphi X_2 \varphi X_1\right)} & \cdots & F\left(X_{N1}\right)=\frac{\left(mX_N mX_1\right)}{\left(d\left(X_{N1}\right)\right)^2\left(\varphi X_N \varphi X_1\right)} \\ X_2 & F\left(X_{12}\right)=\frac{\left(mX_1 mX_2\right)}{\left(d\left(X_{12}\right)\right)^2\left(\varphi X_1 \varphi X_2\right)} & F\left(X_{22}\right)=\frac{\left(mX_2 mX_2\right)}{\left(d\left(X_{22}\right)\right)^2\left(\varphi X_2 \varphi X_2\right)} & \cdots & F\left(X_{N2}\right)=\frac{\left(mX_N mX_2\right)}{\left(d\left(X_{N2}\right)\right)^2\left(\varphi X_N \varphi X_2\right)} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_N & F\left(X_{1N}\right)=\frac{\left(mX_1 mX_N\right)}{\left(d\left(X_{1N}\right)\right)^2\left(\varphi X_1 \varphi X_N\right)} & F\left(X_{2N}\right)=\frac{\left(mX_2 mX_N\right)}{\left(d\left(X_{2N}\right)\right)^2\left(\varphi X_2 \varphi X_N\right)} & \cdots & F\left(X_{NN}\right)=\frac{\left(mX_N mX_N\right)}{\left(d\left(X_{NN}\right)\right)^2\left(\varphi X_N \varphi X_N\right)} \end{bmatrix} \quad (12)$$

BEST PAIRS

$$BX_i = \max_{\forall i,\forall j}\left\{\sum_j F(X_{ij}),\sum_i F(X_{ji})\right\} = \max\left\{\max_{\forall i}\left(\sum_j F(X_{ij})\right),\max_j\left(\sum_i F(X_{ji})\right)\right\} .(13)$$

$$BX_{ij} = \max_{\forall i}\left(\max_{\forall j}\left(F\left(X_{ij}\right)\right)\right) \qquad (14a)$$

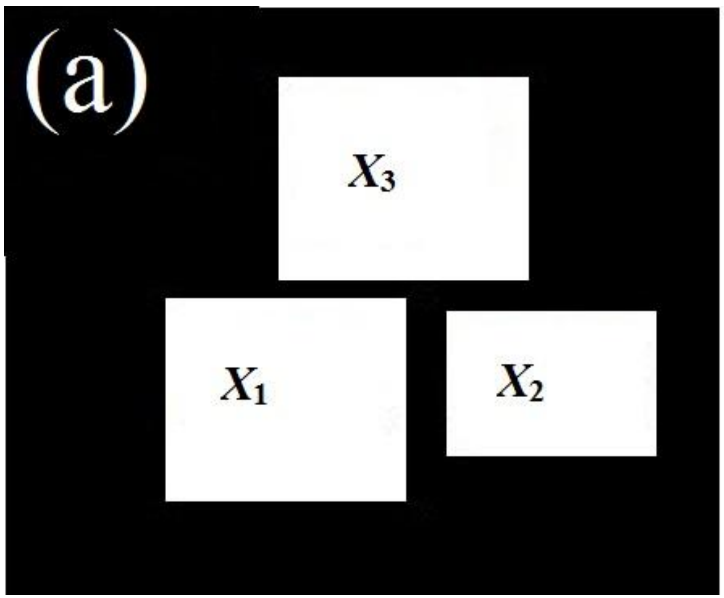
$$BX_{ji} = \max_{\forall j}\left(\max_{\forall i}\left(F\left(X_{ji}\right)\right)\right)$$

FORCE OF ATTRACTIONS

$$\sum_i \left(\sum_j FX_{ij} = \frac{\sum_j mX_i mX_j}{\sum_j \left(dX_{ij}\right)^2 \sum_j \left(\varphi X_i \varphi X_j\right)} \right) \qquad (16)$$

$$\sum_j \left(\sum_i FX_{ji} = \frac{\sum_i mX_j mX_i}{\sum_i \left(dX_{ji}\right)^2 \sum_i \left(\varphi X_j \varphi X_i\right)} \right) \qquad (17)$$

Figure 1 (a) Asian continent--Spatial system, (b) India-a cluster of the spatial system shown in (a), and (c) States of India-zones of the cluster shown in (b), which is a map of India (cluster of a spatial system) with 28 states (zones)—indexed according to alphabetical order—Andhra Pradesh (X_1), Arunachal Pradesh (X_2), Assam (X_3), Bihar (X_4), Chhattisgarh (X_5), Goa (X_6), Gujarat (X_7), Haryana (X_8), Himachal Pradesh (X_9), Jammu & Kashmir (X_{10}), Jarkhand (X_{11}), Karnataka (X_{12}), Kerala (X_{13}), Madhya Pradesh (X_{14}), Maharashtra (X_{15}), Manipur (X_{16}), Meghalaya (X_{17}), Mizoram (X_{18}), Nagaland (X_{19}), Orissa (X_{20}), Punjab (X_{21}), Rajasthan (X_{22}), Sikkim (X_{23}), Tamilnadu (X_{24}), Tripura (X_{25}), Uttarapradesh (X_{26}), Uttarakhand (X_{27}), West Bengal (X_{28}).



(b)

	X_1	X_2	X_3	$d_{max}(X_{ji})$
X_1	0	6	7	7
X_2	5	0	4	5
X_3	7	5	0	7
$d_{max}(X_{ij})$	7	6	7	

Figure 5. India map with each state designated with a rank with respect to four different parameters. (a) φX_i, (b) $\max_i\left(\sum_j FX_{ij}\right)$, (c) $\max_j\left(\sum_i FX_{ji}\right)$, and (d) $\max\left(\max_i\left(\sum_j FX_{ij}\right), \max_j\left(\sum_i FX_{ji}\right)\right)$

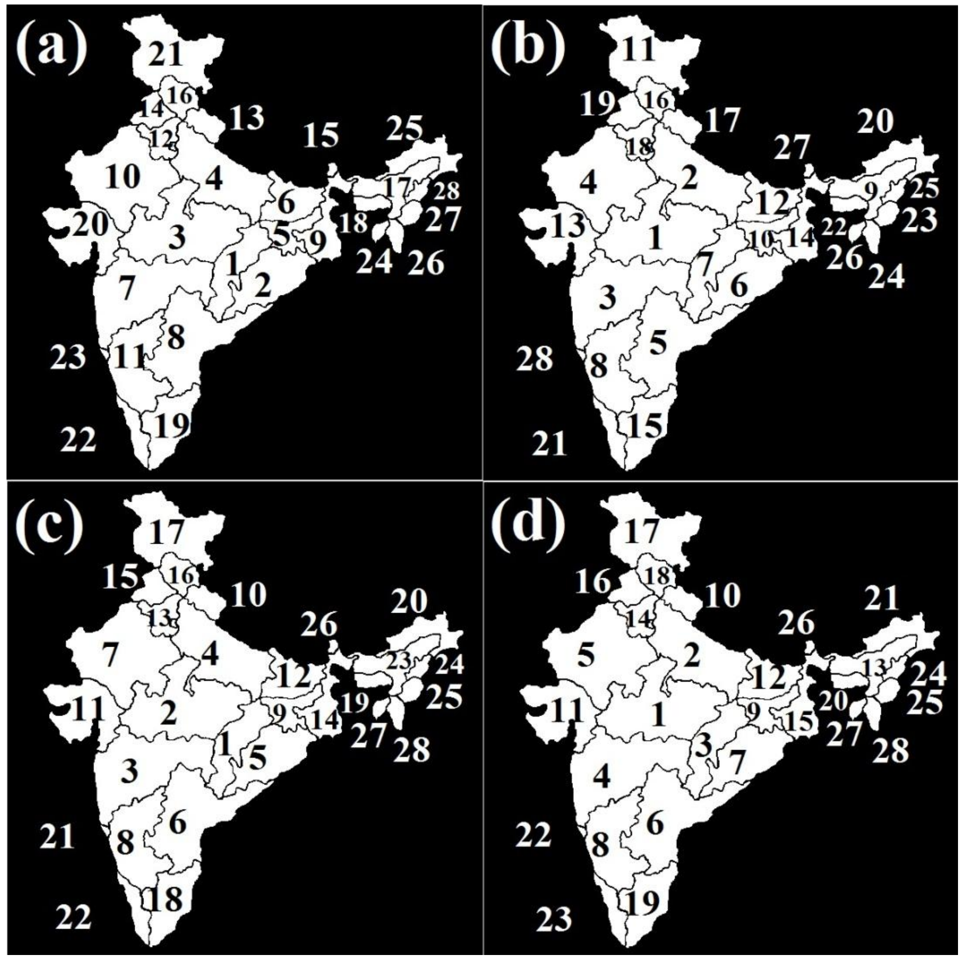


Figure 6. Five best pairs exhibited the high levels of interactions (a) $X_{20,5}$, (b) $X_{14,26}$, (c) $X_{26,27}$, (d) $X_{14,5}$, and (e) $X_{1,20}$. Five pairs exhibited the least levels of interactions (f) $X_{6,25}$, (g) $X_{25,6}$, (h) $X_{6,19}$, (i) $X_{6,23}$, and (j) $X_{23,6}$. Animation of the 756 successive interacting pairs can be seen at http://www.isibang.ac.in/~bsdsagar/MGM-Spatial-Interaction.avi.