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A framework for CyberGIS-enabled multi-scale space-time index for analyzing urban social vulnerability dynamics

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Outline

- Urban Social Vulnerability
- Dynamics of Social Vulnerability
- Framework for space-time vulnerability analysis
- Entropy-based indexing approach
- Conclusion

Urban Vulnerability



Urban Vulnerability

Vulnerability O Susceptibility to harm (Adger 2006, Füssel and Klein 2006)

• A function of exposure to a hazard, sensitivity to that hazard, and the ability to respond accordingly (Parry et al. 2007, Smit and Wandel 2006)



Social Vulnerability

Social vulnerability:

- Product of social inequalities, where social factors influence or shape the susceptibility of various groups (Blaikie et al. 1994, Cutter et al. 2003)
- Disaster outcomes vary by socioeconomic characteristics like age, race, income, etc. (Fothergill, 2004; Mileti & Darlington, 1997; W. G. Peacock, 2003)



Social Vulnerability

Political Economy of Vulnerability Production:

 Focuses on political economies of resource use and normative planning and management interventions (Dooling & Simon, 2012)



 Spatial distribution of social vulnerability changes over time



Changing patterns of Social Vulnerability Index (SoVI) in Harris County, Texas

(Kashem, 2015)

 Spatial distribution of social vulnerability changes over time



Temporal trends of SoVI in Harris County, TX (1980–2010)

(Kashem et al., 2016)

Relative
 importance of
 indicators like age,
 race, ethnicity,
 and gender also
 fluctuates over
 time.



(Kashem, 2015)

 Relative importance of indicators like age, race, ethnicity, and gender also fluctuates over time.



Principal components analysis results on social vulnerability factors for Harris County (Houston), Texas

(Kashem et al., 2016)

Limitations of current social vulnerability research

- O Uncertain geographic
 context problem
 (UGCoP) (Kwan, 2012)
- Reliance on traditional authoritative data (Census, ACS, etc.)
- Limited applicability for plan analysis and emergency response



(Gulliver and Briggs, 2005; Kwan, 2012)

Key Objectives:

 Developing a multi-scale framework for vulnerability analysis

• Creating Space-time vulnerability index

 Harnessing the capability of CyberGIS and Geospatial Big Data

Key Components:

Data aggregation module



Key Components:

Data aggregation module

Population disaggregation module



Key Components:

- Data aggregation module
- Population disaggregation module
- o S-T Index calculation module



Key Components:

- Data aggregation module
- Population disaggregation module
- o S-T Index calculation module
- Visualization module





Entropy based spatio-temporal vulnerability index

• Based on Shannon's entropy (Shannon, 1948; Shannon and Weaver 1949): $V(2) = V \sum_{n=1}^{\infty} p_n I_n(n)$

$$H(C) = -K \sum_{c} P_c \log(P_c)$$



Three spatial patterns with same Shannon entropy (after Leibovici and Birkin, 2014)

• Entropy in a spatial context (Batty 1974, 2010):

$$H_B(c(R)) = -\sum_r P_{\frac{r}{c}} \log\left(\frac{P_r}{c}/\Delta r\right)$$

 Δr = size of area r

$$P_{\frac{r}{c}} = \frac{P_{cr}}{P_c}$$

• Co-occurrence based spatial entropy (Leibovici and Birkin, 2014; Leibovici et. al., 2014)

Considers contiguity of observation

$$H_{ks}(C_{oo}, d) = -\frac{1}{\log(m_{c_{oo}})} \sum_{c_{oo}} P_{c_{oo}}, d\log(P_{c_{oo}}, d)$$

multinomial distribution $P_{c_{oo}}$, d, derived from the cooccurrence counts of order k at distance d.

• Discriminant-ratio based spatial entropy (Leibovici and Birkin, 2014; Leibovici et. al., 2014)

$$H_{ds}(C) = -\frac{1}{\log(n_c)} \sum_c d_c^{\rho} \log(d_c^{\rho})$$

$$d_c^{\rho} = \left(\frac{d_c^{ext}}{d_c^{int}}\right) / \left(\sum \frac{d_c^{ext}}{d_c^{int}}\right)$$
, is the normalized ratio of distances.

Conclusion

 Space-time urban dynamic models are yet to consider the social vulnerability aspects

- Harnessing the capability of CyberGIS and Big Data, social vulnerability research can be better applied for policy applications and emergency response
- Proposed framework integrates urban space-time research with social vulnerability research

Thank you!

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