Using a Social Survey to Define Preferences for Residential Locations in an Agent-Based Model

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Collaborators

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Project SLUCE

- Spatial Land Use Change and Ecological Effects at the Rural-Urban Interface
- Goals
  - Model land-use dynamics at the urban-rural fringe (i.e., the Detroit metropolitan area)
  - Evaluate impacts of changing land-use on ecosystem structure and function

Introduction

- Informing a simple ABM of residential location with empirical data derived by the 2001 Detroit Area Survey.

- Requires two considerations
  - How to match conceptual agent-decision model with survey questions and responses
  - How to create agents that reflect heterogeneity in population

Agent-Based Modeling

- Uses object-oriented programming …
- to represent and simulate the attributes, decisions, and behaviors of multiple interacting and heterogeneous actors…
- and their collective impacts.
  - Model outcomes can be measured at the level of the landscape (e.g., spatial patterns) or individual agents (e.g., agent utility).

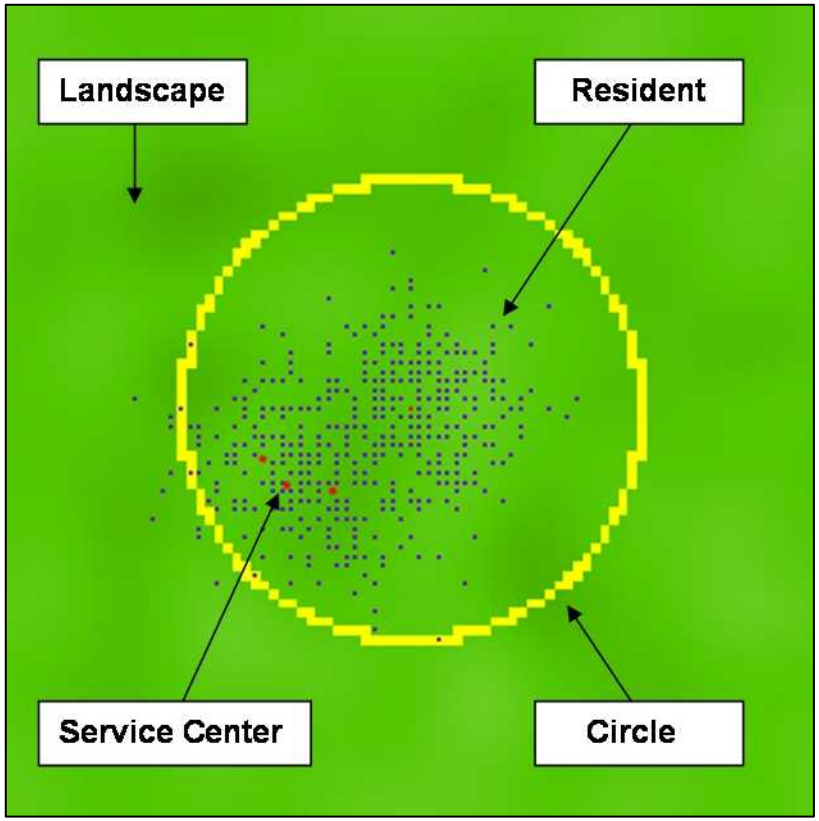
Challenge

- Informing a simple ABM of residential location and sprawl with empirical data derived by the 2001 Detroit Area Survey.

- Two considerations
  - How to match conceptual agent-decision model with survey questions and responses
  - How to create agents that reflect heterogeneity in population

The "SOME" Model

- Simple model of residential location.
- An initial service center at map center of 151x151 area.
- Constant rate of growth of resident population.
- Utility maximization bounded by sampling landscape.
- A new service center enters and locates near each 100th resident.
- Results summarized over 30 runs.



Location Evaluation

Calculate utility of a location based on 2 variables:

1) Distance to nearest service Center

2) Aesthetic Quality

- Assume that all agents prefer high aesthetic quality and proximity to service centers.
- Agents weight the importance of each variable in order to calculate utility of a location.

Survey Research: DAS

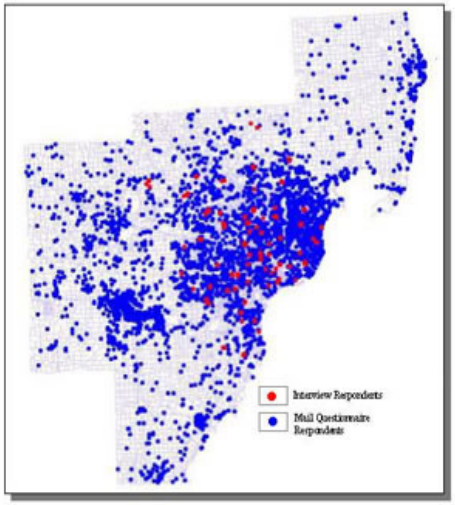
We used the 2001 Detroit Area Study (DAS) to provide information about agents

Interview and mail surveys of residents.

Asked about most recent residential-location decision

Nearly 500 respondents from exurban Southeastern Michigan who've moved w/in the last 10 years.

DAS Respondents



DAS Preference Question

- How important was each of the following in your decision to move here? Was it very important, somewhat important, not very important, or not important at all?
  - Close to work
  - Good Schools
  - Housing costs/value
  - Convenient to shopping / schools
  - Lots of recreation opportunities
  - Appearance of nbrhood
  - Close to natural areas
  - Openness of area
  - Close to family / friends
  - Familiar with area

Results from DAS Analysis

- Some variation in preferences according to life stage (age, marital and parental status), especially parental status.
- Relatively weak (insignificant) fit of life stage variables to preferences, suggests importance of additional factors, e.g., life style, in determining preference.

More details: Fernandez et al. 2005. Characterizing location preferences in an exurban population: Implications for agent based modeling. *Environment and Planning B*, 32(6): 799-820.

Using Survey to Populate Model

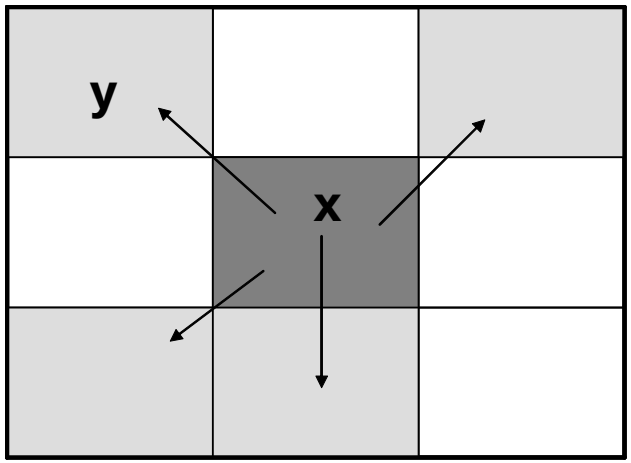
- We used survey responses to characterize heterogeneity in residential preferences.
- Four factors described decision variables
  1. Social Comfort – people like me, family/friends, familiar with area
  2. Openness/Naturalness – openness, near natural areas, rec. opportunities
  3. Neighborhood Aesthetics – appearance/layout of house/neighborhood
  4. Schools/Work – close to work, good schools
- Seven clusters of similar residents with respect to preferences.

Relating Survey Factors to Model

- Factor analysis provides some support for the two factors in utility equation.
  - *Schools/Work* ≈ Distance to Service Centers
  - *Openness/Naturalness* ≈ Aesthetic Quality
- *Residential Aesthetics* operates at too small a scale, referring to dwelling and neighborhood design
- *Social Comfort* was consistently important enough for some people that we had to consider it.

Add Similarity Factor

- We constructed a new measure to include in the residents' utility equation that described similarity to neighbors.
- *Social Comfort* ≈ Neighborhood Similarity

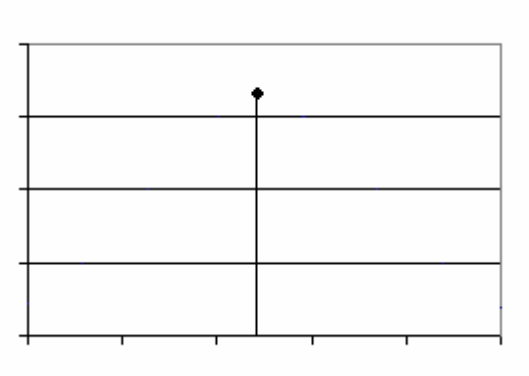


Modified Resident Utility

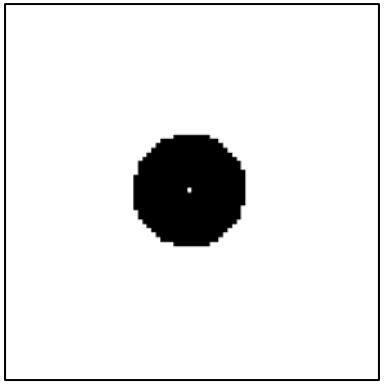
- Utility function incorporates three variables that residential agents can measure at each location
  - distance to service centers, aesthetic quality, and neighborhood similarity.
- Values are weighted by the importance (α) that each resident places on those variables.
- Factor scores are normalized because units are not meaningful.

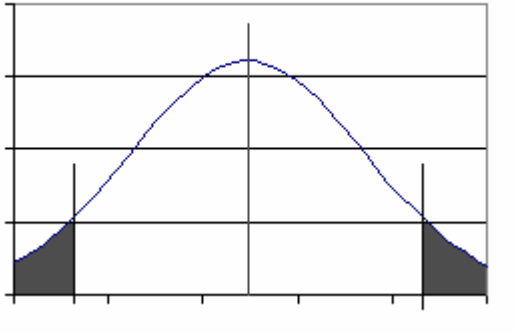
$$u_{r(x,y)} = \prod_{i=1}^{m} (1 - \left| \beta_{ir} - \gamma_{i(x,y)} \right|)^{\alpha_{ir}}$$

Homogeneous vs. Heterogeneous Agents?

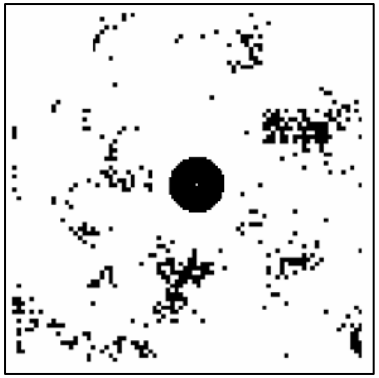


Homogeneous Preference





Heterogeneous Preference

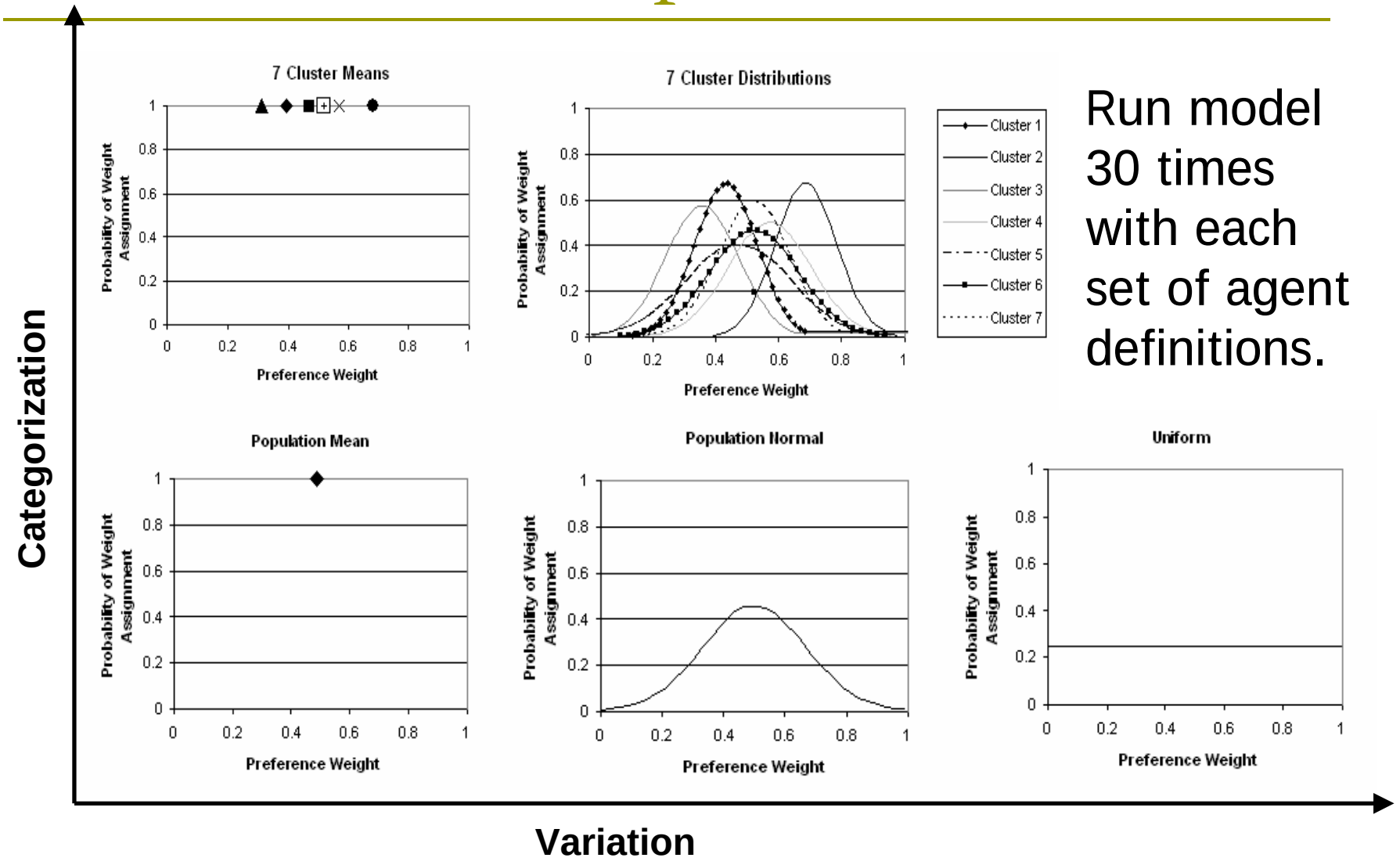


Using Survey to Populate Model

- We used factor scores from survey responses for preference weights in the model.
  - Distance to Service Centers
  - Aesthetic Quality
- Cluster analysis identified 7 types of agents, in terms of profile of preference weights.
- Model experiments explored effects of agent variability and categories on development patterns, assuming a constant level of environmental variability.

Details: Fernandez et al. 2005. Characterizing location preferences in an exurban population: Implications for agent based modeling. *Env. & Planning B*, 32(6): 799-820.

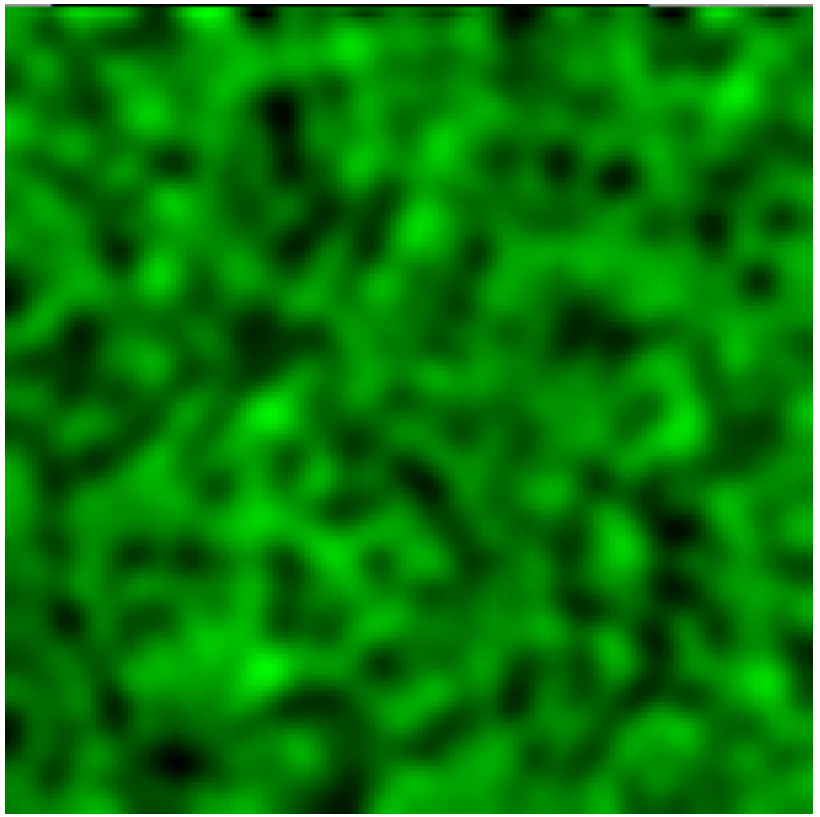
Five Different Experiments



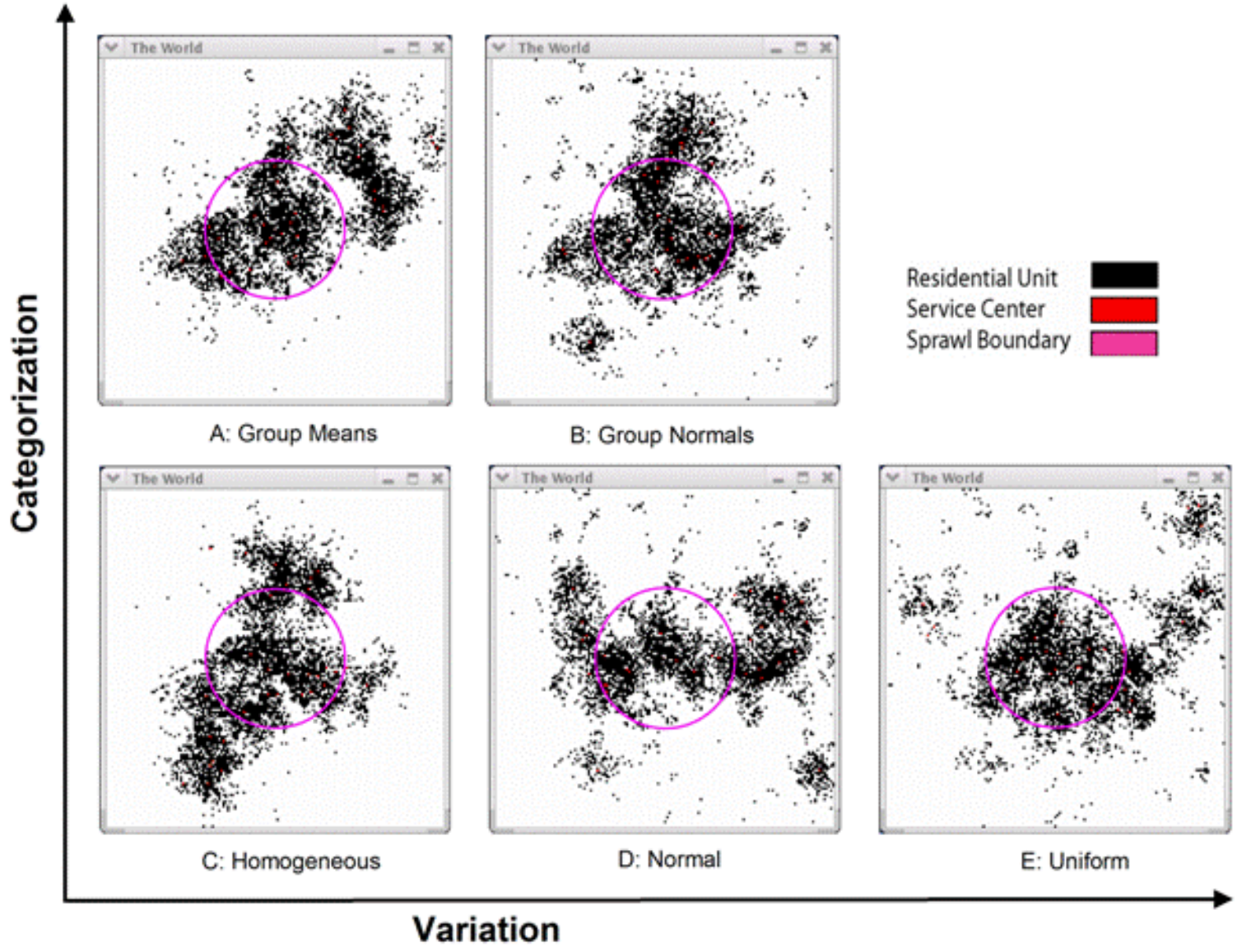
Run model 30 times with each set of agent definitions.

Aesthetic Quality Used in Experiments

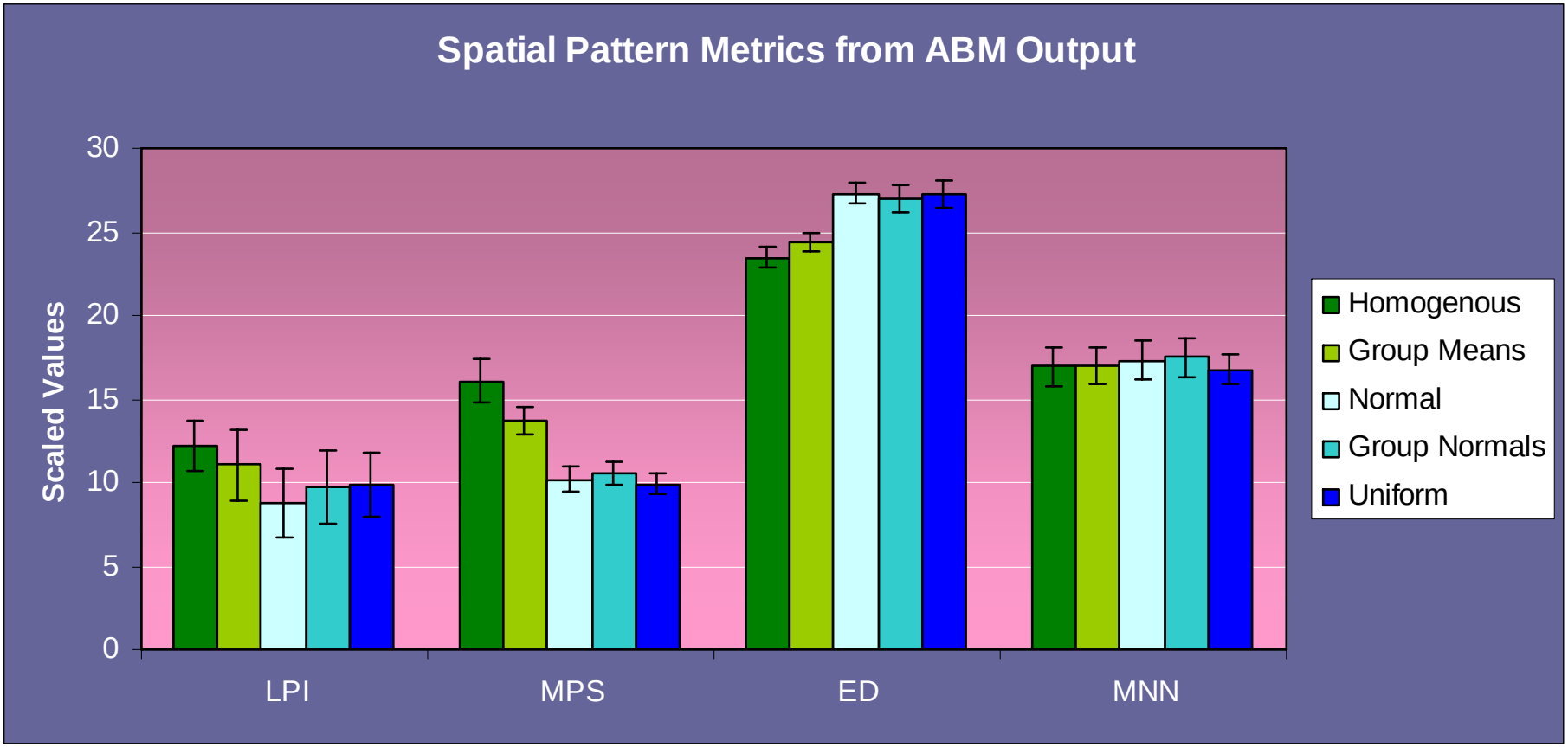
- We used a random map, smoothed to introduce spatial autocorrelation.
- Variability and spatial autocorrelation were somewhat arbitrary.
- We have also used GIS data to better reflect realistic environmental heterogeneity.



Typical Model Runs



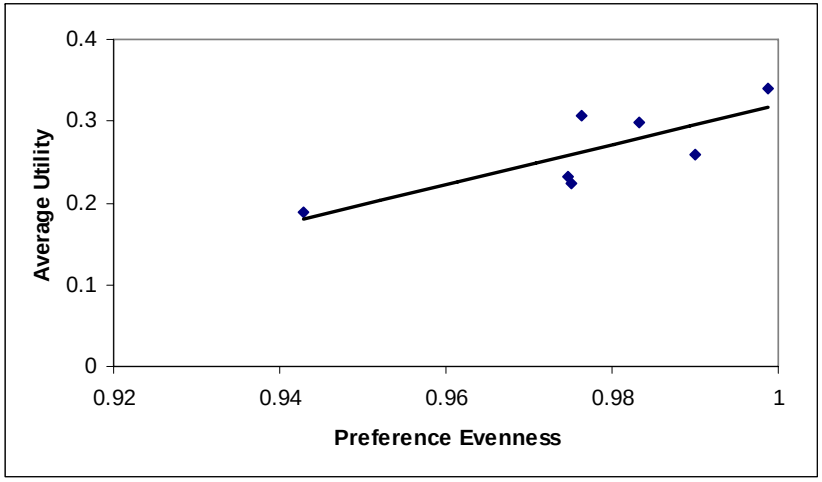
Example Numeric Results



LPI = Largest Patch Index, MPS = Mean Patch Size, ED = Edge Density, MNN = Mean Nearest Neighbor Distance

Evenness and Utility

- Evenness (based on entropy) measures the degree of specialization of a group in one location variable over the others.
- More specialized groups tended to achieve lower average utility (R^2=0.65 for means, and 0.35 for normals)



Conclusions

- Introducing heterogeneity of preferences increased sprawl on several spatial measures.
  - ↓ clustering and ↑ fragmentation.
  - Whether in the form of a uniform random distribution or variation observed in survey
  - Comparison suffers from limited amount of information in spatial metrics of pattern.
- Models assuming homogeneous population may underestimate sprawl and fragmentation.

Details: Brown and Robinson, 2006. Effects of heterogeneity in preferences on an agent-based model of urban sprawl. *Ecology and Society,* 11(1): 46.

Conclusions (cont.)

- Survey data allow us to characterize heterogeneity in a population we want to represent, but do little to validate the decision model used to represent these agents.
  - We needed to specify the specific decision approach, develop conceptual links between the survey and the model, then use the survey to characterize heterogeneity of the agents.