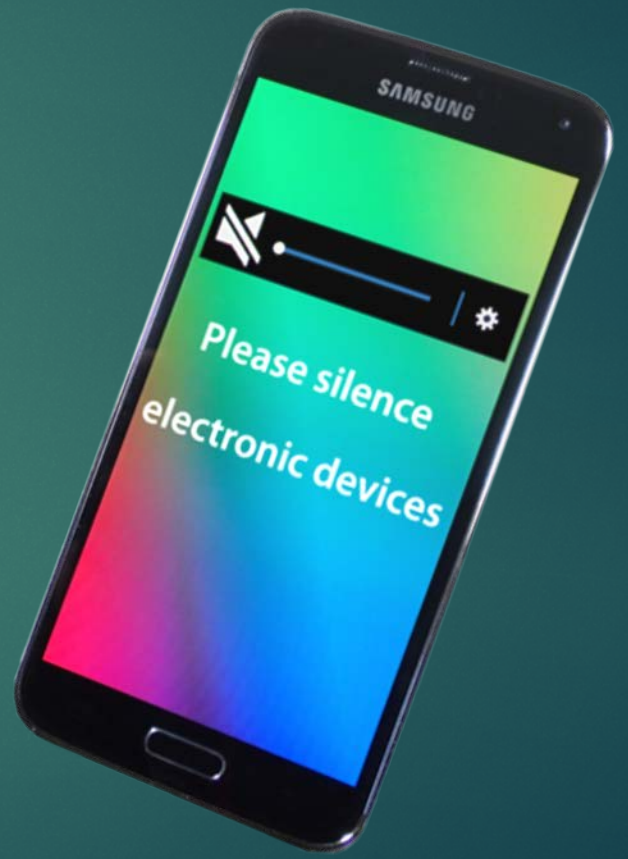

21st Annual
GIS/CAMA
Technologies Conference
Chattanooga Convention Center
GIS/CAMA • Chattanooga, TN
IAAO
URISA
March 6–9, 2017

Continuing Education (CE) Credit

Recertification Credit forms for CE credit can be collected from the Registration Desk on Thursday.

Housekeeping

The conference proceedings will be available approximately 8 weeks after the conference.



Geographically, Temporally, and Characteristically Weighted Regression (GTCWR)

Goals of this Presentation

- Discuss general appraisal theory and justification for methodology
- What's been done before?
- Demonstrate performance with respect to IAAO valuation standards
- Limitations and next steps
- The presentation avoids:
  - Claiming wide-spread superiority (this is just a demonstration of a new AVM)

Modeling

- What are we trying to do?
  - Price Determinants
  - Supply and Demand
  - Demand → Tastes and Preferences
  - Demand → Willingness *and* ability to buy

  - Model buying patterns of markets. Markets are comprised of people with similar tastes, preferences, willingness, and abilities to buy.
  - Models are based on sales, and each sale had a buyer, who has tastes, preferences, and purchasing power.
  - At the end of the day we are, in a very large part, modeling *human behavior.*
  - What if we could bring all buyers of a dataset into a room?
  - This is arguably what you are doing when segmenting a market. You are segmenting PEOPLE who would buy in that area.

Modeling

- Models should be more reflective of the buyer's mindset and the mindsets of their counterparts in their respective market
- Comparable sales valuation approaches understands this
- While models often *do* take this into consideration (variables for location, condition, house style, etc.), is there a way we can improve without increasing time, cost, etc. of data collection?
  - Only so many hours in a day
  - Specification vs. Calibration. Can we just alter the *method* of modeling, as opposed to going out and getting as much data as we possibly can?

Locally Weighted Regression (LWR)

- Locally weighted regression creates a regression at each observation.
- A dataset with 500 sales? Five hundred regressions (same variables)
- This allows for more specific, accurate valuations for each observation.
- Essentially this automates a loop, allowing for a model at each observation that is more in line with the comparable sales valuation approach.

Time Variation

- Seasonality
- Inflation
- Market cycles

Geographic Variation

- Location, location, location (sorry)

LWR by Location AND Similarity

- Besner, Claude. "A spatial autoregressive specification with a comparable sales weighting scheme." *Journal of Real Estate Research* (2002)
- Shi, Haijin, Lianjun Zhang, and Jianguo Liu. "A new spatial-attribute weighting function for geographically weighted regression." Canadian Journal of Forest Research 36.4 (2006) → Basal area growth
- Moore, J. Wayne, and Joshua Myers. "Using geographic-attribute weighted regression for CAMA modeling." *Journal of Property Tax Assessment & Administration* 7, no. 3 (2010)

LWR by Location AND Time

- Borst, R. 2013. Optimal market segmentation and temporal methods. Spatio-temporal Methods in Mass Appraisal, seminar presented by the International Property Tax Institute, Fairfax, VA, April 23–25.

- Huang, Bo, Bo Wu, and Michael Barry. "Geographically and temporally weighted regression for modeling spatio-temporal variation in house prices." *International Journal of Geographical Information Science* 24, no. 3 (2010)
- Wu, Bo, Rongrong Li, and Bo Huang. "A geographically and temporally weighted autoregressive model with application to housing prices." *International Journal of Geographical Information Science* 28, no. 5 (2014): 1186-1204.
- Fotheringham, A. Stewart, Ricardo Crespo, and Jing Yao. "Geographical and temporal weighted regression (GTWR)." *Geographical Analysis* 47, no. 4 (2015): 431-452.

LWR by Location, Time, & Similarity

Weighting Example

- GWR (distance-based)
- Weight can have many calculations (tons of detailed research on the subject if you're interested, I'll send it to you).
- Here is a common one that spits out a weight between zero (not at all similar) and one (exactly similar):

$$w_{ij} = \exp\left(-\frac{|d_{ij}|}{b}\right)$$

Example of a Weighting Calculation: Location

Bi-square $$w_{ij} = \begin{cases} (1-(d_{ij}/b)^2)^2 & \text{if } |d_{ij}| < b, \\ 0 & \text{otherwise} \end{cases}$$

Distance between **subject** and **sale A** is **.2** miles.
Pre-determined bandwidth is 5 miles:

=(1-(**.2**/**5**)^2))^2
weight = 1.0

Distance between **subject** and **sale B** is **3** miles.
Pre-determined bandwidth is 5 miles.
=(1-(**3**/**5**)^2))^2
weight = 0.41

Distance between **subject** and **sale C** is **6** miles.
Pre-determined bandwidth is 5 miles.
=(1-(**6**/**5**)^2))^2
But weight = 0 (because distance is larger than bandwidth!)

Spatial Weights Matrix

$$\begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix}$$

Example of a Weighting Calculation: Characteristics

$$f(\tau) = e^{-|1-(A_j/A_i)|}$$

← Formula used in Moore & Myers (2010)

subject TLA = **2000**, **sale A** TLA = **2000**
=exp(-abs(1-(**2000**/**2000**)))
weight = 1.0

subject TLA = **2000**, **sale B** TLA = **2500**
=exp(-abs(1-(**2500**/**2000**)))
weight = 0.78

subject TLA = **2000**, **sale C** TLA = **1800**
=exp(-abs(1-(**1800**/**2000**)))
weight = 0.90

Similarity Weights Matrix

$$\begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix}$$

Example of a Weighting Calculation: Time

Gaussian $$w_{ij} = \exp\left(-\frac{1}{2}\left(\frac{d_{ij}}{b}\right)^2\right)$$

Time distance between **subject** and **sale A** is 60 days.
Pre-determined bandwidth is 720 days:

= exp(-.5*(**60**/**720**)^2)
weight = 1.0

Time distance between **subject** and **sale C** is 329 days.
Pre-determined bandwidth is 720 days:

= exp(-.5*(**329**/**720**)^2)
weight = 0.9

Time distance between **subject** and **sale C** is 817 days.
Pre-determined bandwidth is 720 days:

= exp(-.5*(**817**/**720**)^2)
weight = .53

Temporal Weights Matrix

$$\begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix}$$

Product Matrix

- Multiple all three

$$\begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix} \times \begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix} \times \begin{bmatrix} 0 & 0.4999 & 0.3105 & 0.1273 & 0.0623 \\ 0.4999 & 0 & 0.2414 & 0.1394 & 0.1194 \\ 0.3105 & 0.2414 & 0 & 0.1816 & 0.2666 \\ 0.1273 & 0.1394 & 0.1816 & 0 & 0.5517 \\ 0.0623 & 0.1194 & 0.2666 & 0.5517 & 0 \end{bmatrix}$$

The Variables

- Dependent:
  - Natural log of Selling Price
- Independent:
  - LandArea
  - Rooms
  - Beds
  - Baths
  - HalfBaths
  - Fire
  - Age
  - Age^2
  - Age^3

The Data

- Sales in Fairfax from 1967-1990
- Sample of 49,264
- Filtered out brand new sales (suspect!)
- Randomly selected 5,428
- Divided into train sample (n=4878) and test sample (n=542)

The Models

- OLS Model
- Time Weights Matrix (TWR)
- Characteristics Weights Matrix (CWR)
- Geographic Weights Matrix (GWR)
- Geographic & Time Weights Matrix (GTWR)
- Geographic & Characteristics Weights Matrix (GCWR/GAWR)
- Geographic, Characteristics,& Time Weights Matrix (GTCWR)

The Results

	COD	PRD	PRB	Adj. R^2	Median Ratio
OLS	38.41	1.22	1.09	0.19	0.99
TWR	15.23	1.04	-0.07	0.76	1.03
CWR	37.26	1.21	0.95	0.24	0.99
GWR	33.73	1.18	-0.68	0.29	1.00
GCWR	31.16	1.15	-0.51	0.39	0.99
GTWR	13.89	1.04	-0.06	0.80	1.01
GTCWR	13.18	1.03	-0.05	0.81	1.01

Concluding thoughts…

- When to use each?
  - Heterogeneity …
- What's next:
  - Comparison with other methods that account for time, location, and space
- Additional markets (Belfast, Calgary, Beijing, etc.)

Share your GIS innovations and success stories!

The editorial board of the *GIS for Assessment Professionals* book is looking for practitioners to share their GIS case studies. What do we mean by case studies?

We are looking for specific examples of how GIS was used to solve:

- an assessment or valuation problem,
- or made your office operations more efficient,
- or made information sharing easier for your jurisdiction,
- or improved the outcomes of your assessment duties.

Tell us your story and contribute to information sharing of the latest uses of GIS in the assessment industry.

Please send a brief description of 2 or 3 paragraphs and any exhibits or diagrams you wish to share of your GIS case study by March 1st to *cusack@iaao.org*. Your submission will be forwarded for consideration to the *GIS for Assessment Professionals* book editorial board.

If you have any questions, contact Margie Cusack, Research Manager at *cusack@iaao.org*.

Questions?

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