BIOGRAPHICAL SKETCH

Frank E. Horton

Dr. Horton is Director of the Institute of Urban and Regional Research and Professor of Geography, at the University of Iowa. He is principal investigator of a contract with the Geographic Applications Program, U.S.G.S.: The Application of Remote Sensing to Intra and Inter-Urban Systems. In addition he is on the research and training staff of the Center for Urban Transportation Research and Training, a member of the research team dealing with Quantitative Spatial Methodology, a member of the research staff on an Urban Policy Study for the State of Iowa. Amoug his many committee memberships, Dr. Horton is currently serving as Chairman of the Remote Sensing Commission, of the Association of American Geographers, is a member of the International Committee on Remote Sensing and Data Processing, International Geographical Union, is a member of the National Highway Research Board's Travel Forecasting Committee, and is a member of the Urban Symposium Subcommittee, Committee on Geography, National Academy of Sciences; and in the past year served as a member of the Urban Information Systems and Measurement Committee of the National Highway Research Board. Also during the past year Dr. Horton served as Associate Director for the Institute for Comparative Urban Analysis, sponsored by the National Science Foundation; a member of the Earth Observations Committee, Study on Space Science and Earth Observation Priorities, Space Science Board, National Academy of Sciences. In April 1970 Dr. Horton's book entitled: <u>Geographic Perspectives on Urban Systems</u>: With Integrated Readings, (with Brian J.L. Berry), was published by Prentice Hall. He has written numerous articles dealing with remote sensing of urban environments, urban planning and geography, and urban transportation analysis.

THE APPLICATION OF REMOTE SENSING TECHNIQUES TO URBAN DATA ACQUISITION

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Introduction

Current research related to the application of remote sensing techniques to problems concerning the acquisition of data useful in urban and regional planning, management, and research clearly indicates a potentially powerful data acquisition system is feasible. One of the most perplexing problems facing urban planners, managers, and analysts is the dearth of pertinent, timely, and reliable information. In an earlier paper it was stated " . . .data performs a vital, two-fold task: (1) it provides a basis for testing research hypotheses. . ." about processes ". . .and (2) it provides a basis for current decision-making as well as a means of monitoring the outcome of past decision."[1] The collection of data concerning a variety of urban phenomenon is a continuing and costly problem.

Recently there has been in this country an increasing concern with the development of information systems, data handling procedures, and data processing technology. In my opinion, and in the opinion of others, it can truthfully be stated that our ability to handle data is much greater than our ability to collect reasonably accurate data for input to operating urban information systems. It is in this context that remote sensing offers a significant opportunity to help improve the effectiveness of urban management, to help guide urban growth and development, and to help maintain and improve the quality of metropolitan environments.[2]

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[1]Frank E. Horton and Duane F. Marble, "Regional Information Systems: Remote Sensing Inputs," Technical Papers, Proceedings of the 35th Annual Meeting of the American Society of Photogrammetry, March, 1969, p. 262.

[2]Duane F. Marble and F. E. Horton, "Remote Sensing: A New Tool for Urban Data Acquisition," Urban and Regional Information Systems: Federal Activities and Specialized Programs, J. Rickert (ed.), Kent State University, 1969, pp. 252 - 257.

It should be pointed out that of all the remote sensing technology available to us, remote sensing applications in urban environments has been primarily restricted to photographic sensors. This is not to say that others may not be more useful, nor that new remote sensing technologies not yet applied may not provide greater utility to urban analysts, rather this statement rests upon the fact that we have been unable, at least to date, to mount a major research program in evaluating alternative remote sensing technology applications in an urban context. In addition, and just as important, is the fact that no large scale operational demonstration programs of the utility of remote sensing in urban data acquisition have been completed to date.

While the above comments may seem somewhat negative, they should not deter us from research goals and the development of a continuing research program, nor should they be construed to mean that positive developments in this area have not occurred. Utilizing primarily photographic sensors, and for the most part fairly primitive straight forward photo interpretation techniques, we have learned a great deal about the amount of data which can be extracted and converted into useful information for decision-makers and analysts in metropolitan areas.

In studies supported by the Geographic Applications Program, United States Geological Survey, and NASA, photographic sensors, and to a limited extent radar, have been evaluated in terms of their ability to provide information about cities. These include the application of remote sensors to the acquisition of data concerning housing and population characteristics, urban travel, identification of urban land use and activities, general evaluation of urban change detection systems, utility of space photography in urban data acquisition, the identification of intra-urban commercial centers and their functions, identification of the economic position of single cities with respect to all other cities within a region or nation, and with respect to the latter, the use of that knowledge in monitoring regional economic growth.[3] In addition, research activities are being carried out which relate to urban geographic information systems and the interface between imagery and operational urban information files.

In the time available to me here today it is impossible for me to detail all of the projects completed and underway. Therefore, I will discuss the application of remote sensing techniques useful in acquiring data concerning housing quality.

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[3] Many of these topics are discussed in detail in Duane F. Marble and Frank E. Horton, Remote Sensors as Data Sources for Urban Research and Planning, Remote Sensing Laboratory, Northwestern University, Evanston, Ill. (forthcoming).

Remote Sensing Applications to Housing Quality Definition[4]

Federal and local agencies have shown an increasing interest in methods for the rapid survey of housing conditions over large urban areas in order to: (1) evaluate the magnitude of such problems within the city, (2) identify those neighborhoods most in need of immediate remedial action and (3) to qualify for Federal funds for neighborhood improvement. At present expensive ground surveys covering a large number of parcels, and involving many variables, are required. Recent research at Northwestern University attempted to evaluate the following hypotheses with respect to housing quality and surveys and potential remote sensing inputs: (1) due to high redundancy levels, an excessive number of variables are currently collected by public agencies in their attempt to identify housing quality areas; (2) a reduced set of these variables exists which are potentially observable via remote sensing techniques; (3) a viable classification algorithm can be developed utilizing the reduced variable set which would quantitatively assign a particular areal unit of observation to a unique quality class; (4) measures of the reduced variable set can be extracted from remote sensor imagery.

Analysis of Ground Data

Ground data was obtained from a survey conducted by the Los Angeles County Health Department in the spring of 1968 covering some 1,300 city blocks in three districts in the Los Angeles area containing some of the country's worst housing. This data set constituted the basic ground truth information for the Northwestern University participation in NASA's Earth Resources Aircraft Mission 73 and were used to explore the hypotheses noted above.

A 1% sample of parcels (478 parcels) was drawn from the Los Angeles housing data set (A parcel is a piece of land under single ownership). The 37 structural and environmental variables utilized are given in Table 1. It is unfortunate that many of these variables are subjectively defined and hence suffer from severe scaling problems. However, they are representative of the current state of the art of housing studies. A statistical technique called principle axes factor analysis was applied to the sample set. This analysis produced a factor structure which indicated that the basic factors produced were consistent with those found in existing public agency statements. However, this analysis also demonstrated that for each basic housing element, the variables acting as indicators of that element tended to be highly correlated with other variables within the element. This strongly suggests that a more critical evaluation is needed of the cost effectiveness of collecting data on large numbers of variables as practiced in existing housing quality studies.

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[4] The major portion of this section has been taken from Duane F. Marble and F. E. Horton, "Extraction of Urban Data from High and Low Resolution Images," <u>Proceedings of the Sixth International Symposium on Remote Sensing of Environment</u>, Vol. II, October, 1969, pp. 807 - 814.

Of particular interest was that, for the observations which made up the parcel sample, the structural variables emerged as a single set of variables which were uncorrelated with environmental variables. This led to the rejection, for this study area, of the notion of estimating overall housing quality (as currently defined by public agencies) at the parcel level based only upon remote sensor observation of environmental variables. It is felt, however, that such a finding may be unique to Los Angeles (or at least to cities of the Southwest) which are dominated by single-family structures with a high degree of variation in the level of maintenance of individual parcels. In other U.S. cities, particularly those of the East and Midwest, the set of relationships between structures and environment may be substantially modified in those poorer areas possessing a predominance of apartment buildings, town houses, and other kinds of multi-unit structures.

Using the city block as the unit of study, a similar analysis was undertaken for observations on a 20% sample of blocks (268 units). The resulting factor structure was markedly different from that generated at the parcel level. Other research has indicated that simple correlations between variables tend to increase as the units of observation encompass larger and larger areas; in the several variable case this also results in a larger proportion of the differences being accounted for by a small number of factors and also increasing correlation levels between previously uncorrelated variable sets. In particular, in the present case, the factor comprised of structural variables no longer represented an isolated variable set, but was associated with a number of environmental variables, primarily those which identified the level of upkeep of lots and the existence of land uses which are generally thought to be inappropriate for location near residential developments. This finding is extremely important since it implies that overall housing quality may be estimated at the block level utilizing observations on environmental condition variables alone.

The results of the two analyses indicated not only that the clear factors defined at the individual parcel level had been lost at the block level, but also that the factors used to judge housing quality must be examined anew each time the observational units are made larger, such as the traffic zone or census tract. The results of this study lead to a research concentration upon the assignment of blocks to housing quality classes through remote sensor generation of environmental variables appeared most feasible.

An objective grouping of the sample blocks into five quality classes ranging from high quality to extremely poor housing was made based on similar profiles of factor scores derived from an analysis of observations on all 37 variables. Comparing this grouping with the subjective evaluations made by individuals working on the ground, it was found that the general trends of the two classification structures were similar, with the most deficient blocks being well identified on both; however, considerable differences existed in the drawing of boundaries between the higher rated blocks. The objective grouping is more compact than that of the enumerators, suggesting that the latter did not utilize the full range of data recorded in making their subjective assignments. Further, it suggests that the ground enumerators tend to be somewhat conservative in assigning blocks to the highest or lowest categories.

The blocks were classified on the basis of scores generated by a factor analysis of the environmental variables. The results showed a strong agreement with those of the previous state with 75.4% of the block assignments being the same in both groupings. The errors occurred in the assignment of a number of marginal blocks and do not constitute a major problem.

The final stage of the ground data analysis examined the feasibility of further reducing the set of 21 environmental variables in effecting the classification. Using a statistical method called stepwise multiple discriminant analysis it was found that a high level of performance (82.2% correct assignment) could be attained using only seven environmental variables, namely measures relating to:

1. On-street parking
2. Loading and parking hazards
3. Street width
4. Hazards from traffic
5. Refuse
6. Street grade
7. Access to buildings

Table 2 displays the linear discriminant coefficient, pertaining to each of the five quality classes.

Although it is not claimed that these results possess complete generality in the sense that an analysis of all urban areas would result in the same variables being selected for use in classification, it is highly encouraging that the seven variables listed above, all presumably measurable using remote sensing techniques, can effect a classification of city blocks which is very similar to that obtained by using all 37 environmental and structural variables in combination. This, in itself, is an extremely important finding of the research which could lead to large financial savings in urban data acquisition.

Imagery Analysis

The imagery analysis consisted of an evaluation of black and white, color, and color infrared photography obtained as part of NASA Aircraft Mission 73 with respect to the identification of the reduced variable set listed above. Color infrared photography was found to be the most useful in estimating the seven variables important in housing quality identification. (Photography was from an RC-8 camera flown at 3,000 feet).

After some interpreter training, sub-sample of 53 contiguous blocks in the Firestone area was chosen for an evaluation experiment. Definition of the variables and subsequent assignment using the multiple discriminant functions made up of the coefficients shown in Table 1 satisfactorily classified 50% of the blocks, when compared to the 37 variable classification, into the five housing groups. Because of the subjective nature of some of the variables, it was necessary to use three relatively inexperienced imagery interpreters and assign blocks on the basis of two out of three interpreters giving the same value. Further investigation indicated that within the area chosen, the differences between Groups 2 and 3 were not critical and upon aggregating Groups 2 and 3, thus reducing the number of housing quality classes to four, the level of accuracy was increased to 69%. Thus, when remote sensor imagery was utilized to estimate the values of the seven variables, it was possible to correctly classify 69% of the blocks into four classes when compared to the four-way classification based upon use of all 37 variables. Once again this percentage is based on a two out of three interpreter agreement, with individual interpreters scoring higher and higher.

Further evaluation of the seven variables utilized suggested that a further reduction in their number would remove some which suffered from severe interpretation difficulties. The original 37 variable set was then reduced to four: (1) street width; (2) on-street parking; (3) street grade; and (4) hazards from traffic, by methods identical to those used in the original analysis. Comparison of the capability of the four variable discriminant functions to classify blocks correctly with respect to the 37 variable classification showed that use of the reduced variable set led to a correct assignment in 78% of the cases.

When estimates of these four variables were derived from the Firestone imagery and inserted into the new linear discriminant functions, 53% of the 53 block test area was correctly classified.

Conclusions with Respect to Housing Quality Studies

The use of individuals with a higher degree of training in photo interpretation should significantly increase the percentage of successful classifications. Other problems which remain but which seem to fall outside the purview of the Earth Resources Program are:

(1) Redefinition of variables into a more objective form.
(2) Development discriminant coefficients for major U.S. cities.
(3) More critical evaluation of the statistical methods used in the present study.
(4) Determine how sensitive the classification methods are when giving variables different weights.

Based upon the pilot study outlined here, it seems reasonable to conclude that small area classification of urban housing quality can definitely be accomplished via high resolution aerial photography. Such surveys, at the levels of accuracy demonstrated here, can be of major utility in quick look surveys. They will not replace ground surveys, but they can permit the ground surveys to function more efficiently by enabling them to focus on true problem areas within the city.

Total costs of the Los Angeles ground survey were over $50/block. Given the method outlined here, survey costs should be very significantly reduced even when the costs of image acquisition are included. The significant time savings are of at least equal importance since survey delays result in critical delays in implementing urgently needed social action programs. A significant amount of development and calibration work remains to be done before this approach can be considered operational in the context of the typical urban planning office, but there is little doubt of its ultimate validity.

A similar study is currently underway to delineate methodologies for identifying population density surfaces of cities. That is, how population density varies within metropolitan areas. This study is similar to the housing quality study in the sense that population density per se cannot be extracted directly from imagery but only through statistical analysis of other variables which can be acquired from imagery. In addition, variables are also used which are acquired from the 1970 census, such as number of persons per family. In other words, we cannot in all instances rely solely on data items generated by remote sensing techniques but from time to time we will have to fall back on secondary sources of information to help in the accurate definition of particular urban data sets. In the case of evaluating the level of transportation demand in different parts of the city, population density and land use are incorporated into data sets used to define travel demand. Thus, data derived from imagery in previous studies is then incorporated into studies to define other urban data sets. In this way, we can maximize the amount of information gained and minimize the costs of acquiring such information.

Final Comments

In addition to the problem of information about internal variation in cities, we are also interested in evaluating and defining relationships between sets of cities.[5] Changes in individual cities and their environs often are indicative of changing social and economic conditions within regions of a nation or the nation itself. Many of us are interested in the derivation and implementation of policies

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[5]An application of side looking airborne radar to this problem is discussed in the Marble and Horton paper cited in Footnote 4 and the utilization satellite imagery is discussed in Gerard Rushton and Nancy Hultquist, "Remote Sensing Techniques for Evaluating Systems of Cities: A Progress Report," Technical Report No. 2, Remote Sensing Project, Institute of Urban and Regional Research, University of Iowa, November, 1970.

related to economic development or regional growth. For example, in our own country we would like to evaluate the effect of certain policies on regional economic growth in Appalachia. Similarly, in other countries where a particular development policy is being pursued, it is appropriate and important to be able to evaluate the impact of alternative policy considerations. Does the policy we have implemented in fact generate the type of development we wanted or expected? In some parts of the world, it is difficult to collect information concerning the impact of specific policies. Either it is too costly or suitable mechanisms have not been developed to acquire such information. It is in this context that we are interested in defining changes in the economic and social characteristics of cities vis-a-vis one another within a region. In this case, geographers at the University of Iowa are evaluating various kinds of indices which can be measured from satellite imagery either manually or automatically which then can be evaluated statistically to define significant regional changes. We feel that this type of research will be particularly useful and feasible using the ERTS-A satellite returns.

The latter problem denotes a new element important in all phases of current urban related remote sensing research endeavors. That is, an ability to detect change over time. Thus, the fact that specific data sets can be defined for one point in time would indicate that changes occurring between two points in time should be definable. While in their simplest form change detection systems would evaluate data acquired in the first time period and data acquired in the second time period in order to discern changes, but more sophisticated methods could be applied Generally, this area of research might fall under the general rubric of information systems. Issues to be resolved in the general area of geographic information systems based on remote sensing inputs are: (1) compatibility with the operational needs of a host of interested public agencies at the local, regional, federal, and international level, (2) the integration of urban and regional information systems requirements, (3) the setting of urban and regional information systems into a national or international program of land use or environmental monitoring, and (4) specific recommendations for hardware and software systems.[6] In addition to these considerations, there is a general problem of the development of imagery analysis procedures designed to automatically define changes which are occurring in metropolitan regions. In other words, if one bit of information did not change between the two observation points, it is unnecessary to recollect that information. Automated change detection systems would clearly be a step forward.

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[6] Kenneth J. Dueker and Frank E. Horton, "Remote Sensing and Geographic Urban Information Systems," Technical Report No. 3, Remote Sensing Project, Institute of Urban and Regional Research, University of Iowa, January 1971.

While I am not aware of the state of cities in all of your countries, it is clear that in my country, cities are moving toward unprecedented stagnation and even lower levels of efficiency. If we are to achieve solutions to our problems, we must acquire knowledge about the processes which lead to those problems. If theory is developed concerning urban processes and empirically verified and translated into operational programs for the alleviation of those problems, we will be in an excellent position to stem the blight and decay attacking our cities. While this latter discussion may seem somewhat esoteric, it is a plea for us, as well as for you, to continually be alert for new methods of acquiring information which can increase our knowledge of diverse processes and apply that knowledge in order to alleviate critical problems facing the world society.

TABLE 1

ENVIRONMENTAL AND STRUCTURAL VARIABLES

UTILIZED IN THE LOS ANGELES STUDY

1.	Land Use - Suitability for Residential Development	
2.	Condition of Street Lighting	
3.	Presence of On-Street Parking	
4.	Street Width	
5.	Street Maintenance	
6.	Street Grade	
7.	Condition of Parkways	
8.	Hazards from Traffic	Environmental
9.	Adequacy of Public Transportation	Variables
10.	Number of Buildings/Lot	Potentially
11.	Number of Units/Lot	Measurable
12.	Condition of Fences	Using Remote
13.	Adequacy of Lot Size	Sensors
14.	Access to Buildings	(1-21)
15.	Condition of Sidewalks	
16.	Condition of Landscaping	
17.	Refuse	
18.	Parcel Use	
19.	Adverse Effects of Residences	
20.	Nuisances from Loading/Parking	
21.	Unclassified Nuisances from Industry, etc.	
22.	Overall Block Rating	
23.	Noise/Glare (Block)	
24.	Smoke	
25.	Condition of Accessory Buildings	
26.	Premise Rating	
27.	Noise, Fumes and Odors (Parcel)	Structural
28.	Construction Type	Variables Not
29.	Age of Dwelling	Observable
30.	Condition of Structure	Using
31.	Condition of Walls	Remote Sensors
32.	Condition of Roofs	(22-37)
33.	Condition of Foundation	
34.	Condition of Electrical Installations	
35.	Condition of Paint	
36.	Other Exterior Factors	
37.	Overall Parcel Rating	

TABLE 2

ESTIMATED VALUES OF SEVEN VARIABLE DISCRIMINANT FUNCTION COEFFICIENTS FOR FIVE HOUSING QUALITY CLASSES

Variables Entered	Highest Quality				Lowest Quality
	Group 1	Group 2	Group 3	Group 4	Group 5
Street Parking	11.98	11.71	14.30	26.83	33.83
Street Width	9.58	12.75	12.84	23.94	29.37
Street Grade	-0.10	2.27	-2.14	-8.22	-15.35
Traffic	6.30	6.97	10.26	14.83	19.92
Access to Buildings	.74	7.53	.92	4.82	-23.01
Refuse (B)	.89	.32	1.45	2.78	8.69
Loading/Parking	-0.13	.15	.06	.19	13.68
Constant Term	-14.39	-23.73	-24.20	-66.00	-179.58