John F. Watkins
Department of Geography and Institute of Behavioral Science
University of Colorado
Boulder, CO 80309

The Effect of Residential Structure Variation on Dwelling Unit Enumeration from Aerial Photographs

Structure-specific accuracy levels were computed to illustrate the effect of structure variation on overall dwelling unit count accuracy.

Abstract: *This research focuses on identifying and reducing the amount of error caused by multiple unit structure types in an overall aerial survey of urban dwelling units. Aerial photographs at a scale of 1:20,000 and 1:6,000 were coupled with an interpretation key developed to enhance the interpretation of multiple unit structures. Overall accuracy was tested first in a study comparing dwelling unit counts from 1970 photographs with 1970 census block data, resulting in a cumulative underestimate of 0.79 percent. Dwelling unit counts for 1979 were also compared with census data for 1980, resulting in a 3.36 percent underestimate. The counts were further tested for structure-specific housing count accuracy using field verification, resulting in errors ranging from a 5.51 percent underestimate of apartment structure dwelling units to an 8.45 percent overestimate of converted structure dwelling units.*

Introduction

Much of the residential development currently taking place in urban areas is in the form of high-density housing. High-rise apartment buildings and condominiums are now being found in or near downtown areas, and land at the urban fringe is being developed for townhouses and other similar multiple unit structures. Furthermore, some neighborhoods characterized by detached single-family structures are increasing in density as these structures are partitioned into multiple private dwelling units.

The value of dwelling unit enumeration techniques using aerial photographs may be assessed in light of these current trends in urban growth, as community planners continually search for better methods of accurately monitoring the pattern and magnitude of new residential developments. The increase in number and diversity of structures, however, brings about several problems that traditional aerial photographic interpretation techniques are ill-equiped to handle. First there is the problem of correctly identifying the number of units within multiple unit structures. Nearly all of the classic studies have cited multiple unit structures as a probable source of enumeration error. A further problem is that no studies to date have explicitly investigated the nature of multiple dwelling unit counting errors with respect to the ways in which they relate to different structure types, nor have they considered the actual impact that multiple unit structures as a whole have on the accuracy of enumerations of all dwelling units within a residential area.

The study described in this paper addresses the problems stated above. It develops an aerial dwelling unit interpretation key that focuses specifically on improving counts of multiple unit structures. The key is evaluated by means of an analysis of results obtained from two applications in Boulder, Colorado—a city that, like many others in the United States, is experiencing the pressures of a

Photogrammetric Engineering and Remote Sensing,
Vol. 50, No. 11, November 1984, pp. 1599-1607.
0099-1112/84/5011-1599$02.25/0

rapidly increasing population and an expanding supply of multifamily housing units.

Background

Several studies have considered multiple unit structures to be a major cause of dwelling unit count errors. The pioneering work of Green (1956) in Birmingham, Alabama, and Green and Monier (1959) in Rochester, New York, revealed a significant relationship between areas with numerous multiple unit structures and high absolute counting errors. In this context, absolute counting error referred to errors in accurately differentiating between residential and nonresidential structures. A later study in Chicago by Binsell (1967) also directly attributed increased dwelling unit counting errors to an increase in the number of multiple unit structures within an area. Other authors have also alluded to the difficulty of enumerating the dwelling units within these structures, but they have taken no further steps to investigate the enumeration errors involved (Mumbower and Donoghue, 1967; Eyre *et al.*, 1970; Hsu, 1971; Lindgren, 1971; Horton, 1972; Henderson, 1979).

Of the studies mentioned above, only two give any indication of the nature of the multiple dwelling unit count errors. Green (1956) concluded that there was a tendency to consistently underestimate total dwelling units, with the bulk of the underestimate being attributable to multiple unit structure misinterpretation. Green subdivided multiple unit structure types into the following categories:

- double unit, either "duplexes" or "two-flat,"
- multiple unit: 3 to 5 households, 6 to 8 households, 9 to 11 households, etc., and
- mixed occupancy: commercial and residential.

However, he did not look specifically at the accuracy of the counts made of the number of units within these structures. Lindgren (1971) used a similar subdivision of structure types in his study of the Boston area, although he also chose not to identify structure-specific counting errors. Lindgren reported underestimated counts in two of his study areas, which were comprised almost exclusively of multiple unit structures. A third area, however, was slightly overestimated. Analyzing Lindgren's data more closely shows that five out of the fifteen blocks used in his study were overestimated from the photos, but no detailed information was given as to the actual composition of the blocks by structure type. Although Lindgren's sample size was quite small, this result may indicate that count errors are not as predictable as concluded earlier by Green.

Photointerpretation

This study was conducted to develop a means for improving the accuracy of dwelling unit counts made for multiple unit structures, and to more confidently identify the causes and characteristics of counting errors. The first step was to develop a more suitable means by which housing unit inventories may be carried out. In the studies of Green, Green and Monier, and Lindgren that were previously discussed, multiple unit structures were classified by the number of households contained within the structure. While this classification scheme may be useful for post-inventory book keeping, it does little to assist the interpreter; it does not provide a way to visually distinguish the actual structure classes independently of their household numbers, nor does it focus on any consistent relationships that may exist between specific structure types and the number of dwelling units located therein.

The main departure of this research from the established literature is the classification of multiple unit structures by their original purpose, either apartment structures built originally to house several families, or structures built to house a single family but since modified to accommodate several households. These two basic structure types can usually be clearly identified from large and medium scale aerial photographs because they possess such dissimilar visual characteristics. Furthermore, the features that best serve as indicators of the number of households within structures tend to be quite different for each of these structure types. Grouping the salient factors by structure allows an enumerator using aerial photographs to concentrate more fully on only those factors that are most relevant to a particular structure.

The interpretation key developed in this study is based on several features found in the literature (Green, 1956; Binsell, 1967; Lindgren, 1971). The key was developed and then taken into the field along with black-and-white aerial photographs with scales ranging from 1:1,200 to 1:43,000. Field surveys were conducted for selected blocks in several communities in the Denver metropolitan area, and new interpretation keys were formulated that incorporated the two generalized residential structure types. Revisions were then made in the interpretation keys based on visual comparisons between aerial and ground characteristics of a variety of specific structural and architectural types within the two categories.

The interpretation key used in this study was divided into two primary categories: (1) residential/nonresidential differentiation, and (2) multiple unit structure dwelling unit enumeration. The complete key is given in Table 1. The key as a whole was of the selective type with the factors being descriptive in nature and functioning in concert to aid the interpreter. The purpose of the first category was to initially differentiate between residential and nonresidential structures, and particularly between multiple storied professional or commercial buildings and similarly constructed apartment buildings. Nearly all of the factors listed in this section have appeared in other keys in some form and have

TABLE 1. INTERPRETATION KEY FOR URBAN RESIDENTIAL DWELLING UNITS

Differentiating Residential from Nonresidential
- —relative location
- —structure size and shape
- —number of sidewalks, pathways, and entranceways to the structure and their apparent importance (amount of use)
- —amount, type, and location of associated parking facilities
- —contiguous structures
- —lot line
- —front and back yards
- —amount and quality of vegetation
- —roof detail (venting units or plumbing)

Dwelling Unit Enumeration Within Multiple Unit Structures

Apartment Structures
- —size, shape, and height of structure
- —roof divisions
- —number and location of chimneys and similar vents
- —outside porches or fire escapes
- —number and location of entrances to the structure
- —number of parking spaces and their location relative to the structure
- —apparent socio-economic level

Converted Structures
- —number of sidewalks or pathways between structure and roadway—any side of structure
- —number of sidewalks or pathways leading from a single side of the structure to another side of the same structure
- —size, shape, and height of structure
- —symmetry of structure
- —number and location of chimneys and similar vents
- —division of property area
- —relative location
- —size of parking area or garage
- —amount and quality of vegetation
- —apparent socio-economic level

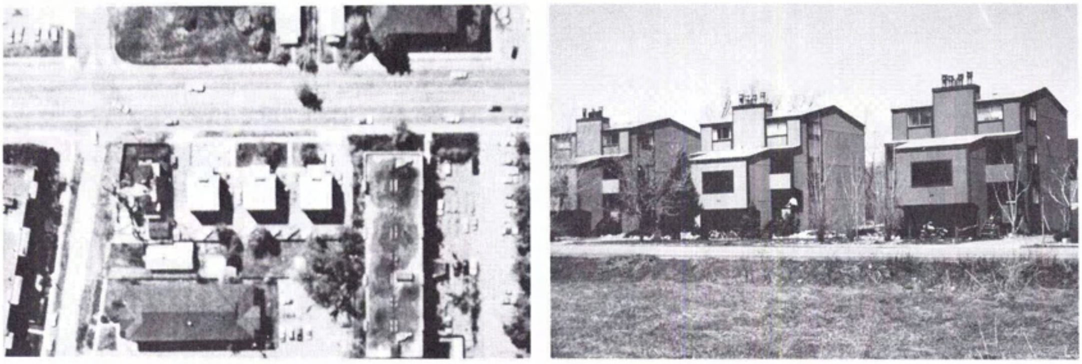
proven successful. The most problematic identification is between multiple storied apartment structures and office structures. To address this difficulty, two original features were added to the key. First, an analysis of the sidewalks and entrances was added because it was noted that apartment structures tend to have more high-use entrances for the convenience of the residents, and office structures have fewer and more ornate entranceways with wider sidewalks. Second, parking facilities were defined in more detail with respect to the size and type of facilities, e.g., covered or uncovered, and their location relative to the building.

The second primary category of the interpretation key enumerates dwelling units within structures, and includes several important features not found in the classic studies. The first subcategory looks specifically at apartment structures constructed originally as high density, connected housing units. There are several factors included in this section that play an especially instrumental role in the dwelling unit enumeration. The location of roof details such as chimneys or vents, for example, was used to aid in mental sectioning of the roof into approximate unit sizes, and to indicate apartments on different floors. Figure 1 illustrates this with corresponding aerial and ground photographs. The bunched chimneys are visible on the aerial photograph and, together with parking, symmetry, and height factors, give evidence of four dwelling units within each structure. The number and location of entrances were used in this subcategory to determine the pattern and extent of hallways within or alongside larger structures, and the apparent socio-economic level was added as a possible indicator of apartment unit size. Although this last factor should be readily known to individuals familiar with the areas of study, it may also be observed from planning records or through field checks. The socio-economic level may also be approximated from aerial photographs using indicators such as sidewalk and street conditions, vegetation analysis, and structure size and quality (Mumbower and Donoghue, 1967; Henderson, 1979).

A second subcategory was developed for investigating those structures that were originally intended to house a single family. The partitioning of these structures into several dwelling units has caused recurring problems in dwelling unit counts in the past, and the factors used in this key mark a significant departure in their focus on the visible structural indicators of dwelling units within these buildings.

An important consideration in the identification of these dwelling units is a detailed analysis of walkways. Paths worn in grassy areas may indicate the presence of a side entrance or second front entrance, and sidewalks leading from the front to another side of the structure may also indicate another entrance. Figure 2 illustrates one particular walkway and shadow configuration that indicates a second entrance at the side of the structure. The ground photograph verifies that a second dwelling unit has been added on the second floor. It should be noted that pathways leading from the structure to any other contiguous structure are not reliable enough to be used as an expression of additional dwelling units. Figure 3, for example, has dwelling units defined to some extent by walkways or paths. Single walkways leading from both structures to garages, however, are not indicative of individual households.

Roof detail is often changed in converted houses, as new units may require the addition of venting in some form. Chimneys from fireplaces, wood burning stoves, or furnaces; bathroom and kitchen vents; and plumbing vents are examples of additions that are detectable from aerial photographs. The amount and quality of vegetation may also change with the addition of new rental units, and the



(a) (b)

Fig. 1. (a) Aerial and (b) ground photographs illustrating roof venting and structure size factors.

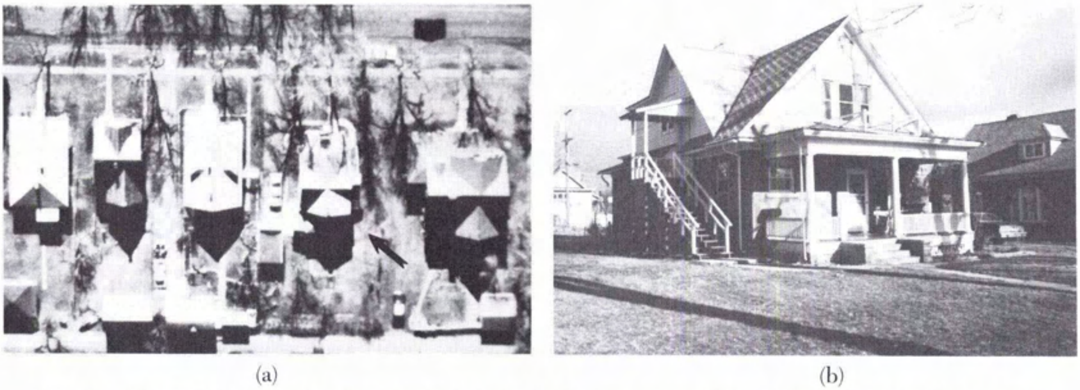
amount of area dedicated to parking may change depending on local street parking ordinances. Finally, the relative location and apparent socio-economic level of the neighborhood may indicate whether or not converted structures are likely to be found. The factors in this last category not only allowed the enumeration of units within a converted structure, they also allowed differentiation between single family houses that had or had not been converted.

Several comments should be made on the use of this interpretation key to count dwelling units. First, as in most selective keys, the order in which the descriptive factors are listed does by no means reflect the importance of the factors. Their applicability is dictated by several elements including image scale, geographic location of the area under study, the architecture of the structures, and the experience of the interpreter. All of these variables preclude a viable statistical test of the individual factors. Second, a situation will seldom be encountered when a single interpretation factor can be an accurate surrogate for the number of dwelling units within a structure. All of the factors should be considered in order to maintain the highest possible accuracy. Finally, the importance of field checks cannot be over-stressed. A ground level survey of the structure types, completed in advance of the final dwelling unit count, is an excellent tool for calibrating the keys and familiarizing the interpreters with the key factors. Furthermore, a quick field check may be essential during the interpretation phase to fill gaps in the interpretation caused by situations such as obscuring summer tree cover or gross inability of the key factors to identify unusual structures or to enumerate their dwelling units.

Methodology

STUDY AREAS

The interpretation key was applied at two points in time to three study areas in Boulder, Colorado (Figure 4). The study areas were selected to include a broad diversity of structure and neighborhood types and ages. Study Area 1 is an area in transition between rural, farm type settlements in the north to high density urban apartments in the south. Of the three areas, this is the one that is experiencing the most rapid growth of residential development. Study Area 2 is part of the city's original residential core. It is experiencing a push from city planners to further increase its housing density, and is an area where many homeowners have sectioned off their homes into several smaller apartments. Study Area 3 exemplifies an area of uniform single family tract



(a) (b)

Fig. 2. (a) and (b), Example of an original single family structure subdivided into two dwelling units.

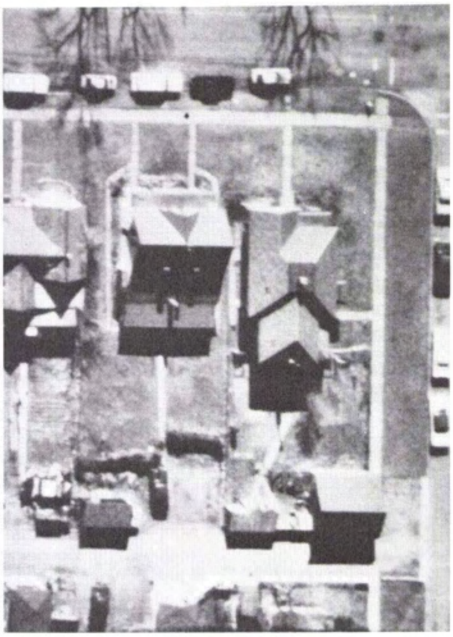


FIG. 3. Walkway configuration as an indicator of dwelling units.

housing built in the 1950s and 1960s. Multiple unit structures are only evident in its extreme northwest and southeast portions.

The enumeration procedures incorporated decennial census data for both applications, and field data for the most recent application. The analysis of the results was structured after guidelines put forward by the National Research Council's Panel on Small Area Estimates of Population and Income (1980). The panel suggests that three criteria should ideally be met in an estimation procedure. The procedure should result in (1) a low average relative error, (2) few extreme relative errors, and (3) an absence of bias for subgroups. The first criterion, in a slightly modified form, is most often used to compare the results of photographic estimation methods. This commonly used form—overall relative error—is the percent error of the total household count against the standard data, or the census data and field data in this application (i.e., [census count − photo count]/census count). The second criterion refers to the range and frequency of deviations from the detailed standard data. It too is used in the literature, but not as often as the first. In this study, it is used at two levels of data disaggregation: individual study areas and distinct structures within each area. The basic equation is identical to that used for the first criterion but, instead of complete tract counts, the area was reduced to individual blocks. The last criterion refers to the applicability of the procedure to all data types in the survey. In this study, it refers to how well the technique functions with respect to both single unit, multiple unit apartment, and multiple unit converted structures and is indicated by the absolute accuracy, or the ability to correctly identify the number of units within a single structure. The relative error of structure-specific dwelling unit counts is also a good indicator of bias and is used in this study.

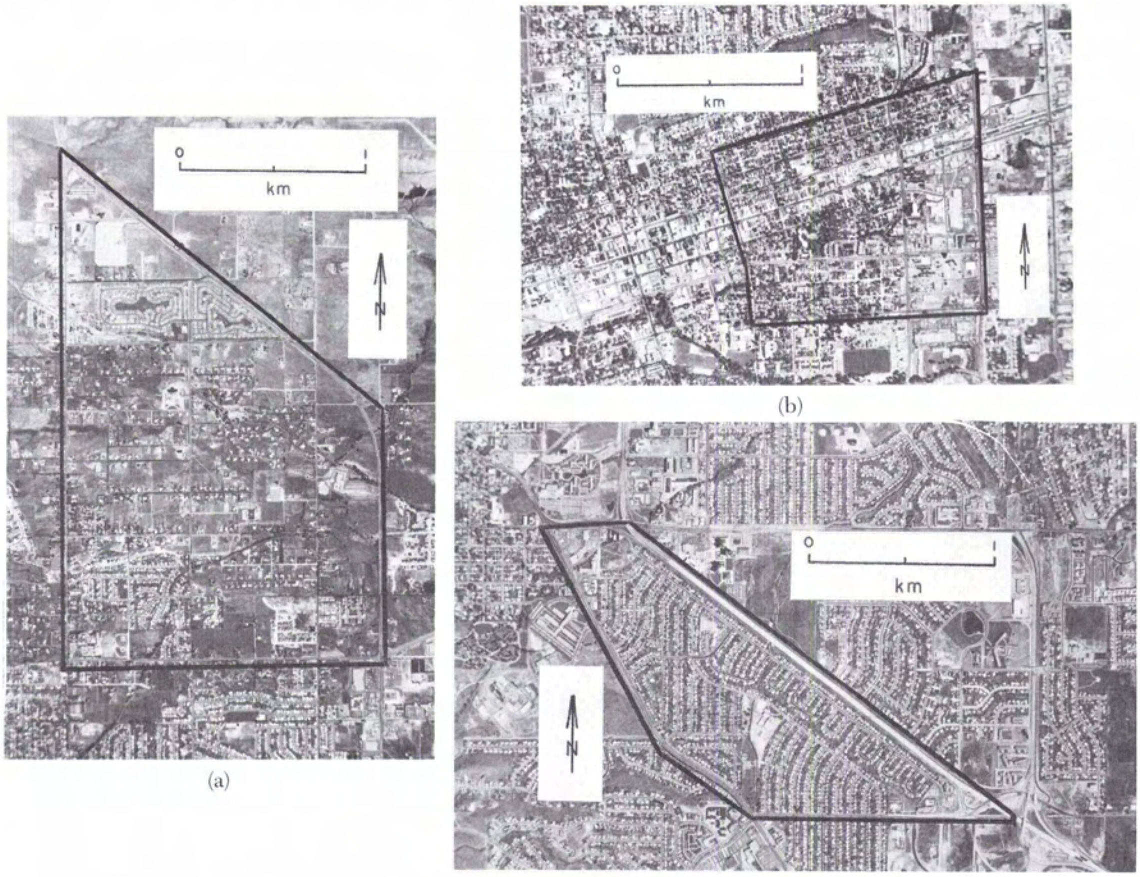
1970 CENSUS COMPARISON

The dwelling unit counts made in the first application were derived from black-and-white panchromatic aerial photographs taken in April, 1970, with an approximate scale of 1:20,000. Mission specifications are given in Table 2. This particular mission date provided an accurate account of the conditions found on the census date of 1 April. Contact prints from the original 1:20,000 negatives were optically enlarged for interpretation using a 7× monoscopic magnifying comparator. Stereo interpretation was used only with the second study area and utilized a mirror stereoscope and 3× binoculars. This step was helpful in reducing interference caused by large deciduous trees. An acetate overlay was placed on each image, and as each dwelling unit was counted it was marked on the overlay to avoid double counting. The number of units was recorded by blocks corresponding to the 1970 census block data. The counts were also classified into single unit structures and the number of dwelling units in multiple unit structures, both apartment and converted.

1980 CENSUS COMPARISON AND FIELD VERIFICATION

The second analysis made use of black-and-white aerial photographs taken in December, 1979, with an approximate scale of 1:6,000. Mission specifications are included in Table 2. These images were photographically enlarged full frame to a scale of 1:2,400 and transferred to a blue line paper product commonly used by city and county planners. Interpretation progressed in the same manner as in the first part of the study with the counts made at the block level to correspond to the census format. Dwelling units counted for each structure were marked directly on the images, however, to facilitate a structure by structure field inventory. The 1979 photographs were supplemented with black-and-white photos taken in May, 1980, to increase the overall compatibility of the data with the 1980 census information. These 1980 photos, with an approximate scale of 1:20,000, were optically enlarged using a mirror stereoscope and 3× binoculars. Unfortunately, the 1980 1:20,000 photographs were of poor quality and, therefore, of little help in actual dwelling unit enumeration. Their value was almost exclusively in identifying where new structures had been built or old structures demolished.

Field verification of the 1980 dwelling unit counts from all three areas was conducted for a cumulative 35 percent sample of single unit structures, apartment structures, and converted structures as iden-



(a) (b) (c)

Fig. 4. Boulder study areas: (a) Study Area 1, (b) Study Area 2, and (c) Study Area 3.

tified from the photographs. This sample amounted to 695 buildings and 2046 individual dwelling units. The purpose of the field verification was to obtain per-structure comparisons in order to calculate structure-specific errors and absolute accuracies. Field counts were made using indicators such as mailboxes, utility meters, high-use entrances, and doorbells. Lawn furniture and window decorations were also useful when looking at converted structures where back or side doors served as primary entrances.

Table 2. Mission Specifications for 1970 and 1980 Studies

1970 Study
Date Flown: 27 April 1970
Scale: 1:20,000
Camera Type: Zeiss RMK A 15/23
Focal Length: 210 mm
Film Type: Kodak Plus-X Aerographic 2401
Frame Size: 23 cm × 23 cm
1980 Study
Date Flown: 9 December 1979
Scale: 1:6,000
Camera Type: Zeiss RMK A 15/23
Focal Length: 153 mm
Film Type: Kodak Double-X Aerographic 2405
Frame Size: 23 cm × 23 cm

Results and Analysis

The summarized results for the 1970 and 1980 photo/census comparisons are given in Tables 3 and 4. Of note are the low overall relative errors of −0.79 percent and −3.36 percent. These results compare favorably with the previous studies of Binsell (1967) with −12.60 percent, Lindgren (1971) with −7.00 percent, and Hsu (1971) with −3.00 percent relative counting errors. A check of Table 3 for extreme errors in 1970 lends further support to the overall accuracy of the technique. As might be expected, the area with the largest number of single unit structures, Study Area 3 with 97.4 percent single unit structures, experienced the lowest rela-

TABLE 3. COMPARISON BETWEEN PHOTO COUNTS AND CENSUS DATA—1970

Study Area	Census Blocks	Percent Multi-unit	Photo Count	Census Count	Relative Error (%)
1	20	7.0	857	871	−1.61
2	65	60.5	1305	1314	−0.68
3	49	2.6	1335	1340	−0.37
Total	134	25.27	3497	3525	−0.79

TABLE 5. CHANGE IN MULTIPLE UNITS AND TOTAL STRUCTURES—1970-1980

Study area	1970 Multi units	1980 Multi units	% Increase Multi units	% Increase All units
1	60	450	648.3	146.4
2	790	1783	125.7	57.2
3	35	292	734.3	21.7
Total	695	2525	185.3	65.5

tive counting error. The same general trend is observed in the 1980 data as well (Table 4). Interestingly, low relative errors of −0.68 percent and −3.07 percent for the two years were computed for study area 2, an area mainly comprised of multiple unit structures.

A temporal comparison of the results also raises some important issues. Of particular note is that accuracy falls both overall and for each study area from 1970 to 1980 despite an increase in the scale of the photographs used, from 1:20,000 to 1:6,000, respectively. Three reasons may account for the changing accuracy. First, tree cover was greater in 1980. Although foliation was almost nonexistent for both years because of the season, the increased size and branching of the trees by 1980 still acted to interfere with structure and ground detail. A second reason for the changing accuracy could be that all three study areas realized an increase in the number of households within multiple unit structures (Table 5). This finding corresponds with and supports the general conclusions of past studies that multiple unit structures are most influential in the degree of relative errors. A third possible explanation lies in the increase in total dwelling units enumerated within each study area. This explanation, in fact, appears to be quite strong as there is a direct relationship between total structures and relative errors. If the errors involved in enumerating dwelling units were random, then a greater pool of structures should cancel the over- and underestimates. This is contrary to the pattern observed in this study, however, and there is still insufficient evidence to fully support the validity of this finding.

Table 6 lists the results from the field check of the

TABLE 4. COMPARISON BETWEEN PHOTO COUNTS AND CENSUS DATA—1980

Study Area	Census Blocks	Percent Multi-unit	Photo Count	Census Count	Relative Error (%)
1	35	21.3	2112	2221	−4.91
2	64	86.9	2052	2117	−3.07
3	45	18.0	1624	1651	−1.64
Total	144	43.7	5788	5989	−3.36

1980 dwelling unit counts. As found with the census comparisons, the total relative error of −2.57 percent followed the trend toward underestimation. Structure-specific relative errors, on the other hand, revealed a large overestimate of dwelling units within converted structures, while apartment structure units were found to be underestimated.

One problem in working with and comparing relative errors is that they are a net measurement; extreme deviations from the standard values may balance out and, therefore, never be visible. Disaggregation into small measurement units, such as specific structure types or individual structures, helps to uncover patterns that were previously obscured, as shown by the structure specific results above. Additional patterns or trends may also be discovered by incorporating a gross measurement such as absolute accuracy, or the percentage of individual structures by type correctly interpreted for dwelling units. These figures indicate that apartment structures were most often misinterpreted and may, therefore, have a potentially greater impact on overall enumeration accuracy than other structure types. Furthermore, a suprisingly low absolute accuracy of 88.4 percent was recorded for single unit structures. As noted earlier, converted structures and many single unit structures are of similar original construction in some areas, and it is not unusual for some structures to exhibit very little exterior change after being subdivided into two or more dwelling units. The structures in this category were found for the most part in the second study area, i.e., the older, core city area.

It is also of value to compare the relative errors and absolute accuracies of the counts. As the interpretation of individual structures increases in absolute accuracy, there will be fewer structures that contribute to the corresponding relative dwelling unit count error. Converted structures, which were more accurately interpreted with 87.8 percent accuracy, will therefore have fewer possibilities of offsetting other count errors in this particular situation than will apartment structures. Converted structures are further characterized as having a lower number of dwelling units per structure than apartments. They are, therefore, less likely to have single structure miscounts large enough to obscure under-

TABLE 6. FIELD VERIFICATION OF DWELLING UNIT COUNTS—1980

Structure Type	Total Structures	Photo Count	Field Count	Relative Error (%)	Absolute Accuracy (%)
Single Unit	368	350	368	−4.80	88.4
Converted	263	462	426	+8.45	87.8
Apartment	64	1234	1306	−5.51	56.6
Total	695	2046	2100	−2.57	85.8

lying trends in structure specific counting errors. Apartment structures, on the other hand, were found to have considerable variation among individual miscounts, ranging from several undercounts of 21 dwelling units to overcounts of up to 10 units per structure. The misinterpretation of a single apartment structure could, therefore, have a more pronounced effect on the structure-specific relative error and thus the total relative error.

CONCLUSIONS

An important result of this study is the high overall counting accuracy of this technique for urban dwelling units. This measure appears to be the yardstick with which housing inventory studies have been compared. This study also generated empirical evidence supporting past findings that multiple unit structures are a primary cause of enumeration error, and proceeded to investigate the actual composition of these structure-specific errors.

It was found that the nature of multiple dwelling unit errors may be better understood by disaggregating residential structures by type and analyzing specific structure types for both relative unit count error and absolute structure interpretation accuracy. Converted structure dwelling units, for example, were overcounted, producing a larger relative error. This, with the high absolute accuracy and the low number of dwelling units within each structure, however, leads one to conclude that, if a converted structure is miscounted, the miscount most often produces a figure higher than the actual number of dwelling units. This apparent systematic overcount could possibly be corrected by subsequent testing of pertinent interpretation factors used for converted structures. Apartment structures proved to be the most difficult to interpret correctly. The low absolute accuracy suggests that the potential for larger relative error is much greater, given the larger number of units within these structures. It is also much more difficult to determine the actual nature of the errors, whether they are continually over- or underestimated. Further research is needed to identify interpretation factors that could possibly be causing consistent problems.

An aerial enumeration technique should ultimately be able to provide a highly accurate dwelling unit count independently of the size and structure composition of the study area under investigation. As this study has shown, however, count accuracy will vary among structure types, and the overall accuracy of the technique will, therefore, rely heavily on the amount and distribution of certain structure types within the study area. There is also some evidence that the number of total dwelling units within an area may affect overall accuracy. Unfortunately, there have been very few, if any, investigations that look specifically at individual structure types and the problems associated with the enumeration of their dwelling units, or of the impacts of combined housing densities in an area. A more complete data base needs to be developed that addresses the nature of these structure specific errors. In addition, different disaggregation schemes need to be made to identify additional structure types or housing densities that have exceptional visual characteristics on aerial photographs, and the results need to be closely compared and analyzed to define any possible predictability and correctability of the associated counting errors.

ACKNOWLEDGMENTS

The author wishes to thank the City of Boulder Planning Department and Colorado Aerial Photo Service for supplying the photographs for this study, and Dr. Hazel A. Morrow-Jones, Dr. Robert H. Alexander, and Dr. Andrei Rogers for their valuable comments on earlier versions of this paper.

REFERENCES

Binsell, R., 1967. Dwelling Unit Estimation from Aerial Photography, in Westerlund, F. W., *Remote Sensing for Planning: A Bibliography and Review of Literature*. Seattle: Department of Urban Planning, University of Washington, 1972, pp. 39-40.

Collins, W. C., and A. H. A. El-Beik, 1971. Population Census with the aid of Aerial Photographs: An Experiment in the City of Leeds. *Photogrammetric Record*. Vol. 7, No. 37, pp. 16-26.

Eyre, L. A., B. Adolphus, and M. Amiel, 1970. Census Analysis and Population Studies. *Photogrammetric Engineering*. Vol. 36, No. 5, pp. 460-466.

Green, N. E., 1956. Aerial Photographic Analysis of Residential Neighborhoods: An Evaluation of Data Accuracy. *Social Forces*. Vol. 35, pp. 142-147.

Green, N. E., and R. B. Monier, 1959. Aerial Photographic Interpretation and the Human Ecology of the City. *Photogrammetric Engineering*. Vol. 25, No. 5, pp. 770-773.

Henderson, F. M., 1979. Housing and Population Analysis, in Ford, K., (ed) *Remote Sensing for Planners*. Rutgers: The State University of New Jersey, pp. 135-154.

Horton, F. E., 1972. *The Application of Remote Sensing Techniques to Inter and Intra Urban Analysis; Final Report*. Iowa City: University of Iowa, pp. 120-138.

Hsu, Shin-Yi, 1971. Population Estimation. *Photogrammetric Engineering*. Vol. 37, No. 5, pp. 449-454.

Lindgren, D. T., 1971. Dwelling Unit Estimation with Color-Infrared Photos. *Photogrammetric Engineering*. Vol. 37, No. 4, pp. 373-377.

Mumbower, L., and J. Donoghue, 1967. Urban Poverty Study. *Photogrammetric Engineering*. Vol. 33, No. 5, pp. 460-466.

National Research Council, Panel on Small Area Estimates of Population and Income, 1980. *Estimating Population and Income of Small Areas*. Washington, D.C.: National Academy Press.

(Received 30 April 1983; revised and accepted 17 June 1984)

Forthcoming Articles

Stan Aronoff, The Minimum Accuracy Value as an Index of Classification Accuracy.
Stan Aronoff, Political Implications of Full Cost Recovery for Land Remote Sensing Systems.
G. Begni, *D. Leger*, and *M. Dinguirard*, An In-Flight Refocusing Method for the SPOT HRV Cameras.
George J. Edwards and *Carlos H. Blazquez*, Analysis of ACIR Transparencies of Citrus Trees with a Projecting Spectral Densitometer.
J. H. Everitt, *A. J. Richardson*, and *A. H. Gerbermann*, Identification of Rangeland Sites on Small Scale (1:120,000) Color-Infrared Aerial Photos.
D. C. Ferns, *S. J. Zara*, and *J. Barber*, Application of High Resolution Spectroradiometry to Vegetation.
C. S. Fraser and *L. Gruendig*, The Analysis of Photogrammetric Deformation Measurements on Turtle Mountain.
Bradford B. Henry, Automated Design in Minneapolis and Hennepin County, Minnesota.
Anne B. Kahle and *Ronald E. Alley*, Calculation of Thermal Inertia from Day-Night Measurements Separated by Days or Weeks.
Siamak Khorram, Development of Water Quality Models Applicable throughout the Entire San Francisco Bay and Delta.
Daniel H. Knepper, Jr., and *Gary L. Raines*, Determining Stretch Parameters for Lithologic Discrimination on Landsat MSS Band-Ratio Images.
M. L. Labovitz, *E. J. Masuoka*, and *S. G. Feldmann*, Changes in Vegetation Spectra with Leaf Deterioration under Two Methods of Preservation.
David B. Nash, Detection of Bedrock Topography Beneath a Thin Cover of Alluvium Using Thermal Remote Sensing.
Daniel B. Ramey and *James H. Smith*, Simulation of Errors in a Landsat Based Crop Estimation System.
David L. Toll, An Evaluation of Simulated Thematic Mapper Data and Landsat MSS Data for Discriminating Suburban and Regional Land Use and Land Cover.

Errata

The cover photograph for the August 1984 issue was taken by Richard Krawietz.

The following corrections should be made in the September 1984 issue:
Page 1219. Insert the following:

Page 1220. Make the following page corrections:

Page 1285. The date in the caption to Figure 1 should read 25 September 1929.

Page 1318. The photographs (or captions) for *Desi Eugene Slavoj* and *C. Eric Storms* should be switched.