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New Remote Sensing Systems For Urban Use

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ABSTRACT

Remote sensing has a promising career in the urban scene. This paper describes several applications of remote sensing for urban research and operations. The paper also describes an automatic data analyzer, which provides the fast analysis of stationary and moving objects in (aerial) photographs and with modification in tapes required for frequent and regular monitoring by remote sensing. The uses suggested here include preventing traffic jams, detecting infrastructure faults, deficient heating systems, other building code violations, and abandoned housing, and performing building censuses.

The application of remote sensing to urban purposes has been slow in coming. True, most land-use studies take advantage of aerial photography and some even utilize infrared and thermal remote sensing, but little research has been conducted on applications other than data recording.

As long as urban remote sensing is dependent on agricultural research and outdated, declassified military technology, rather than urban-directed research, remote sensing is unlikely to produce more than occasional soil and land surveys in the near future.

Moreover, data analysis is still generally a slow, manual task. The slow pace and high cost of analysis prevents more frequent use of remote sensing as a monitor and as an operational control. Such uses cannot begin without automation and without urban-oriented research.

The following pages describe several new systems for the application of remote sensing to urban problems. Uses offered here include automating

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data analysis, preventing traffic jams, detecting infrastructure faults, deficient heating systems, other building code violations, and abandoned housing, and performing building censuses (detecting new structures by use and type).

Automating data analysis promises to make remote sensing a large-scale monitor of urban activity on a frequent, even regular, basis. The system described here uses film, but a system can be designed to interface with tape. The simplest use of the system.is counting objects, the second use is discriminating and counting by groups, and the most sophisticated use is discriminating, counting, and recognizing movements. The first and second uses, requiring less sophisticated instrumentation, are most appropriate for stationary objects, such as instantaneous information on structures and vehicles (see other new systems below). The third use allows analysis of movement and is, therefore, useful in transportation studies and monitoring. This extraction and analysis system can be used with some of the other new recording systems discussed below to speed their efficiency. These other systems are designed to monitor urban activity, especially to trouble-shoot. For example, thermal and infrared sensors may be used to prevent traffic jams by stalled, overheated vehicles, detect infrastructure faults, prevent tragedy caused by faulty heat-releasing equipment, detect insufficiently-heated dwellings, where the amount or change in pattern of heat release indicates trouble, detect abandoned buildings, and detect new construction. These tasks can be performed without interfering with or entering either the vehicle or building.

Automating Data Analysis

Remote sensing (e.g., aerial photography and magnetic taping) and its analysis can be viewed as a seven step process: ground recording (e.g., photographing, taping), developing, discriminating, identifying, interpreting, data recording, and comparing. That is, taking the pictures, developing the negatives, enhancing the image of the subject, identifying the subject image, extracting the data, recording the data, and comparing data to establish relationships. Of course, elements of these stages often intermix. For example, enhancement may be one of the goals in developing the negatives.

The present state of the art allows ground recording and comparing to be machine-assisted, machine-dominated, or automated. Discriminating, identifying, interpreting, and recording, however, can be relieved only to the extent of machine-assisting the human interpreter. All approaches to aerial photography either emphasize one of the seven–usually one of the first six–steps of the process, which step is more advanced than the others and around which the other steps are designed, or emphasize a more efficient coordinating technique of two or more steps of the process. Moreover, the earlier discrimination occurs, the simpler the other analysis steps of the system.

Analysis is usually the costliest, longest, and most limiting procedure of the process and automating it has been most difficult and least successful. Reliance on the human interpreter has been almost total, except for some machine assistance in enhancement and comparison of data. But recently some new technology in discrimination, identification, interpretaion, recording, and comparison promise not only to assist the photo interpreter, but, by combining and simplifying the new equipment, promise to automate analysis.

The Science Engineering Research Group at C. W. Post College, Long Island University, Greenvale, N.Y., has developed a stereo, multispectral photographic camera and viewer system. Four 4½ X 2¼ inch black-and-white photos may be exposed on either one roll of film or on individual rolls. The results, taken from a specially-designed aerial camera, may be independently illuminated, filtered, enlarged, and registered on a special multispectral viewer. The viewer allows optical overlaying of up to four images, resulting in a real or false color rendition of the scene. The viewer filters employed are generally green, blue, red, and cyan. The viewer allows adjustment of various optical characteristics for optimum illumination. The film may be conveniently rolled through the viewer or mounted as individual transparencies.

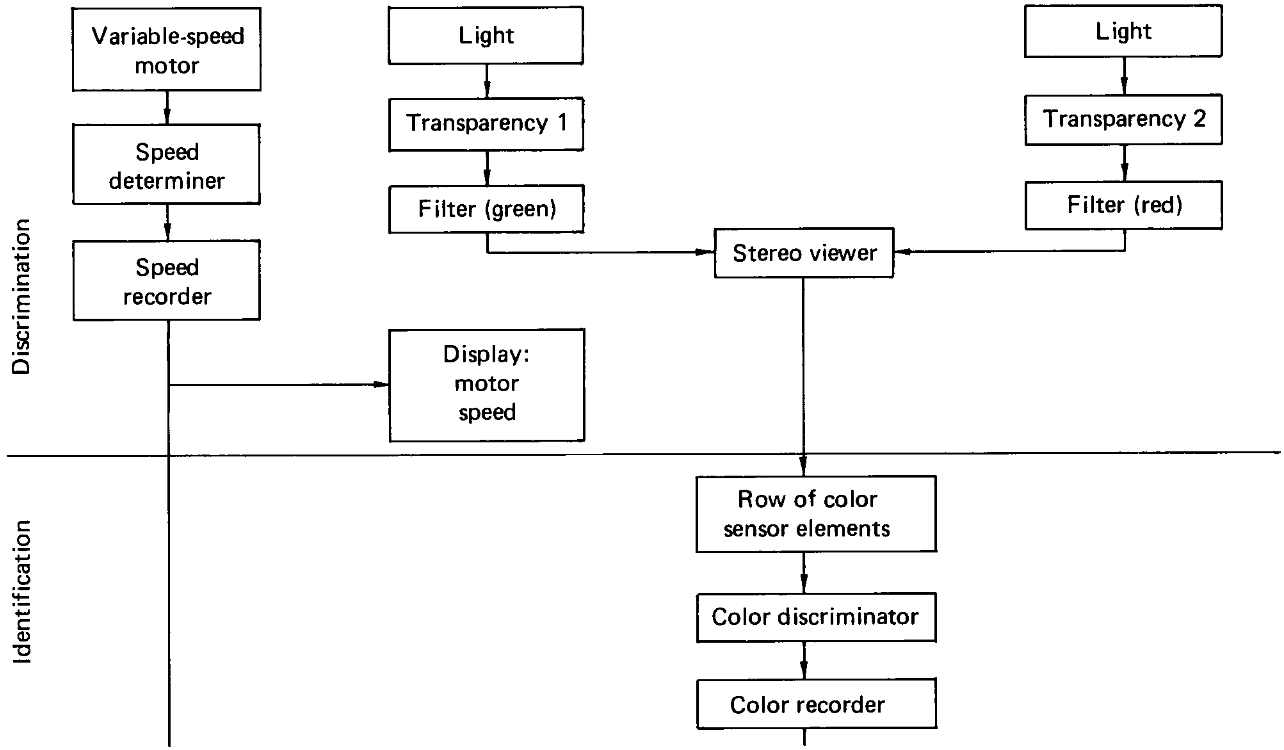
The Science Engineering Research Group's system is based on stereo and multispectral discrimination. The group has incorporated more sophisticated discrimination in its equipment than is necessary for automation if its technology is combined with the equipment described below. This simplification allows us to describe a stereo, multispectral system that will automatically *D*iscriminate, *I*dentify, *I*nterpret, *R*ecord, and in conjunction with a computer, compare data on familiar movable objects form (a) black-and-white transparency(ies).

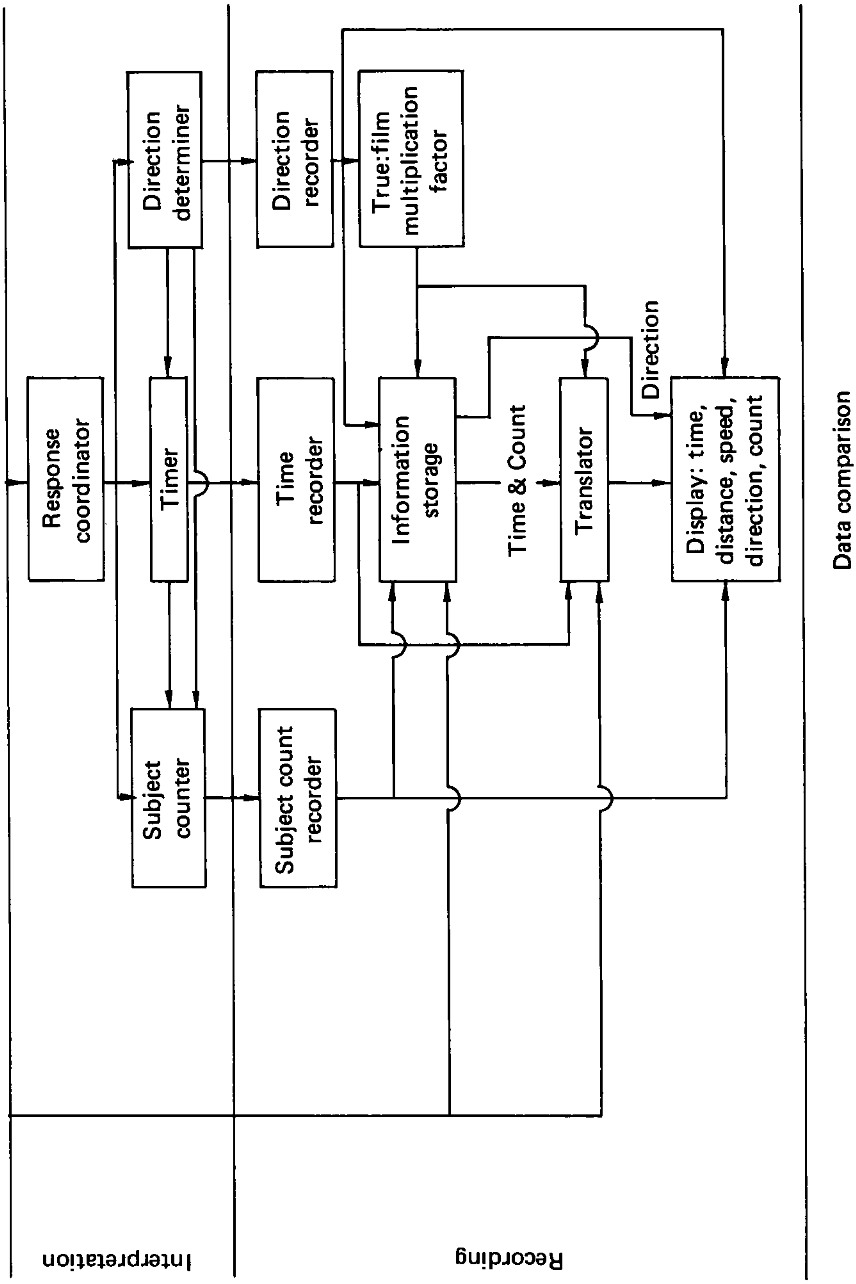
DIIR automates four steps: discrimination, identification, interpretation, and recording. By following the schematic and describing the parts of each step in operational order, we can trace the data gathering process. (See Table 1.)

Discrimination

Following the development of the roll of black-and-white transparencies, the roll is steadily pulled through the viewer by a variable-speed motor. The motor speed is displayed to the operator and is recorded for translation into "true" (ground) movement–time, distance, and speed–of

Table 1. Schematic of Stereo, Multispectral Photography Discrimination, Identifier, Interpreter, and Recorder (DIIR)





Interpretation
Recording
Data comparison
Response coordinator
Direction determiner
Timer
Subject counter
Direction recorder
Time recorder
Subject count recorder
True:film multiplication factor
Information storage
Time & Count
Translator
Direction
Display: time, distance, speed, direction, count

objects in the transparency(ies). The transparent frames (limited to two here for the simplest stereo effect) are illuminated by independent, variable-intensity light sources. (Science Engineering Research Group's light sources have other variable characteristics as well.) The illuminated images are filtered—for example, green for initial position and red for second position—and projected on a viewing screen so that immobile objects are congruent. The resulting composite image is a yellow, green, red, and monochromatic montage. Stationary objects wash out yellow (i.e., green plus red), and moving objects appear twice, their initial positions in green and their second positions in red. Where the initial and second positions overlap, the overlap area also appears yellow. Naturally achromatic areas do not change color under a filter. The discrimination step distinguishes mobile objects from immobile objects, enhances the mobile objects, and distinguishes the initial and second positions of mobile objects. These color discriminations are the effects of overlaying two differently color-filtered, black-and-white transparencies of the same scene photographed a short time apart. Overlaying other color filters can eliminate ground shadow, revealing previously hidden objects in city "canyons" and at low sun angles. Other films and filters reveal thermal and infrared data.

Identification

The identifying and interpreting steps complete the data extraction via selective and coordinated sensing. As the film is steadily pulled through the viewer, the composite images steadily pass under a row of color-sensitive elements arranged on a stationary bar in front of the viewing screen. The color-sensitive elements react to selected colors of the composite images. In our example, the sensor elements identify and differentiate green, red, yellow, and black.

Interpretation

To translate these responses into subjects (i.e., objects in the transparencies under investigation), the responses are coordinated so that responses to the same color from neighboring elements are combined to indicate a dimension of only one subject. For example, if the smallest vehicle is five elements long and three elements wide and the sensor elements are positioned across the width and scanning along the length of a street, the responses can be coordinated so that only three or more similar (i.e., similar in color), neighboring responses count as a vehicle. A wider vehicle or a vehicle at an angle, both of which would "trip" more than three neighboring responses would register as single vehicles. The coordinator monitors a response for combination with other responses until a sensor element in this similarly-responding group passes over a different color, responds accordingly, and releases the coordinator for another "fix" on the next response.

The sensors may be instructed to respond to yellow or not. Yellow may be desirable, together with shape characteristics, to identify stationary subjects, e.g., vehicles and pedestrians, and to differentiate them from moving subjects and objects; or yellow i.e., stationary, images and black, i.e., non-color, images may be disregarded as one group.

The subject counter determines the number of subjects. It may be directed to any one or combination of the sensed colors. A more sophisticated form of DIIR may be directed to count only subjects of certain shapes and positions by counting the number of similar combinations of responses of the same range of duration. These controls allow counting only certain size and shape subjects and subjects in certain positions, such as large, turning trucks.

The Timer measures the duration of or interval between particular responses, which is translatable into "true" (ground) data: time, distance, and speed of the subjects, distance between subjects, and by comparing composite images, time for a faster subject to overtake a slower subject. Using only one filtered transparency, the distance between subjects and the time that one subject can overtake another subject at a given speed can be determined automatically. In conjunction with the Direction Determiner, the Timer can measure the length, distance, and speed characteristics of turning vehicles at the vehicles' various angles of turn.

The Direction Determiner "reads" the direction the vehicle is moving in terms of the movement's angle to the direction of scan of the sensor elements. The Direction Determiner is connected to the Timer and the Subject Counter to obtain the results described above, as well as to determine the direction of subject movement and thereby, together with speed, to determine velocity.

Recording

Subject count, time, and direction are all recorded and available for storage and retrieval in the future for display or, in the case of time, for translation. Count and direction are also available for translation without having to store the information first.

The Translator converts film time, motor speed, and the supplied multiplication factor relating the film parameters to the true (ground) parameters into true distance, true time, and true speed.

Comparison

These true characteristics can then be compared manually or automatically in a variety of ways. By comparing sequential transparencies of the same subjects, we can study particle paths, mode flows, and their characteristics. These transparencies may be compared optically by repeating the above stereo, multispectral overlay with the second transparency and a third transparency and relating the results to the first composite, or the transparencies may be compared mathematically by relating the data from two composites. In a sophisticated version of DIIR, the sensor elements may be "locked on" to a vehicle in a multiple composite. This technique yields an instantaneous optical and mathematical picture of the vehicle's path. But regardless whether the Discriminator in a particular version of DIIR can superimpose two transparencies or more, DIIR can efficiently and quickly distinguish moving and stationary objects and can analyze particle movements, mode flows, and their characteristics through automatic analysis of aerial photographs.

DIIR is only a concept; it is not yet a machine. However, the technology to develop it is available now. It has applications in urban planning, for which it is designed, and possibly in military reconnaissance. This paper is, then, a call for unclassified development of DIIR.

Preventing Traffic Jams

One of the most exasperating, costly, and dangerous traffic events is a jam caused by a stalled vehicle or vehicles which stalled in sequence. Especially on bridges, in tunnels, and at other potential bottlenecks, a traffic jam can last for hours. However, if the tie-up was caused by the stalling of an overheated vehicle, the jam may have been prevented.

Many bottlenecks are created by bridges, tunnels, and multiple highway feeders. These configurations usually require traffic to reduce speed. Often, they are preceded by toll booths. An example of a slow road section is the bottleneck on the New Jersey Turnpike exit to the Lincoln Tunnel, where one can spend a typical morning (non)rush (quarter)hour. Three examples of jam-prone configurations preceded by toll booths are the George Washington Bridge on the New Jersey side, the New Jersey Turnpike exit mentioned above, and the Lincoln Tunnel on the New Jersey side. Jams in the Lincoln Tunnel caused by stalled, overheated vehicles are frequent enough, major enough, and potentially dangerous enough to make prevention worthwhile. Similar situations around the country (world) make a stall-detection device of general interest. Thanks to advanced remote sensing devices, detection is possible.

To develop an appropriate thermal detector, a relationship between heat-release by vehicle motors and motor efficiency must first be established. The danger point of overheating must be coordinated with the amount of heat-release or a change in heat-release. Other factors, such as engine size, can be considered by sensing the weight, density, or size of the vehicle with an in-motion weighing device, such as a scale (now being used to weigh trucks) or remote sensing technique. A scale which would require a vehicle to stop and pause and which would require extensive installation is not necessary.

Second, a heat sensor is hung over each approach lane from the roofs of the toll booths or from a cross-highway structure (e.g., a sign) in a reduced-speed area. The sensing equipment records the heat-release of each engine and the size or weight of the vehicle passing under it, compares these data, and determines whether the heat-release is at a dangerous level. If so, a light and/or bell signals the driver, toll plaza attendant, and/or police to pull the vehicle over to the side of the road and to take corrective measures.

In an existing traffic jam, additional stalled vehicles may be avoided by inspecting each slowed vehicle with a portable heat detector and notifying the driver of an overheating vehicle to take corrective action.

Detecting Infrastructure Faults

A similar portable detector can be used to "read" the condition of the infrastructure systems under the street without going underground. Such a device might be hand-held or might be located in a motor vehicle and tour the rights-of-way for heat- and infrared-detectable faults in wires, pipes, and structures. The device would operate like the infrared inspectors used in industry.

Detecting Deficient Heating Systems

Similarly, deficient heating equipment in buildings may be detectable by using calibrated, portable heat detectors from the right-of-way outside the building. Such inspection should be helpful to conscientious manufacturers, builders, managers, and owners, and to public enforcement authorities and community organizations to detect excessive heat leakage, prevent fires and explosions, and detect insufficient provision of heat to occupants. The readings can be recorded by and locked into the machine for later analysis and for sealed and unalterable evidence.

Mass-Scale Analysis

Transportation, infrastructure, and buildings can be inspected and permanently recorded *en masse* by infrared aerial photography. In this way, one can derive on a large scale an approximate measure of the hazards of overheating for vehicles and subsurface and surface structures and can monitor underheated dwellings. A detailed inspection of particular subjects can be achieved with the portable detector. The results of these inspections can be analyzed by the automatic data analyzer.

Building Inspection

Remote sensing inspection achieves other advantages: greater production per manhour and greater honesty. Aerial inspection on the mass scale returns greater coverage with less labor at less overall cost than present labor-intensive inspection methods. Ground inspection with remote sensing equipment allows an inspector to cover more territory in the same time than he presently can. Higher production may mean more frequent inspection and may require fewer inspectors. Moreover, both remote sensing approaches lock the inspection data into the equipment so that the inspector cannot tamper with the information. Bribery must reach into the laboratory to succeed. A lab is a more easily secured situation than the field, making bribery more difficult. We can, therefore, expect that the effectiveness of inspection will rise.

To win the game of code enforcement inspection need only distinguish deception and compliance well enough to make deception at least as costly as compliance. Remote sensing, together with other inspection techniques, need only be good enough to keep the cost of covering up non-compliance, for example, with false signals, as high as the cost of compliance.

Monitoring Abandoned Buildings

Aerial and ground remote sensing can be useful in other ways, too. New York City, for example, is trying to keep track of thousands of abandoned buildings. By combining power, heat, sound, and light detection, a city can get a reading of occupied and unoccupied buildings. The use of several parameters cross-checks one against the other to insure that the cause of the signal is human activity and not something else. Moreover, since only a few parameters are necessary to insure accuracy of interpretation, other parameters that do not record or that record in unusual manners may indicate faulty or illegal practices, for example, as above, deficient heating.

Respecting Privacy

Unclassified remote sensing devices this sensitive have been developed for Viet Nam. There they are used to detect body heat, cigarette flames, campfires, and voices through the jungle canopy. Their urban use must not become an invasion of privacy. This precaution can be satisfied by using sensing equipment that only records which, how much, and from where energy is being emitted and does not transmit intelligible ideas. For example, sound sensors should record only noise levels, not words or music.

"Censing"

Multiple sensing cannot only indicate characteristics of human habitation, but characteristics of building use, too. It may be enough to be able to identify new and improved structures on a regular basis (as determined from comparison with a base map or data bank) as a way of taking a census. Only new buildings and improvements would have to be inspected for more detailed information. However, we may be able to characterize a structure according to its use by matching remote sensing recordings with characteristics of the building. For example, special arrangements and shapes suggest housing types. Still, apartment buildings can be confused with commercial and manufacturing. However, if the building is only lighted and heated during the day or only in the evening and other data correlates, we can assume that the building is a store or industry in the first instance and a residence in the second. Other data may distinguish stores from industry. Again, in a high density urban area, tall buildings stand out as white dots in the summer because their air-conditioning units occupy the roofs. If the heat emission of these units can be measured with any accuracy, we may be able to determine the volume of the buildings. Shadows may help determine volume and, therefore, floor space, too. By such multiple sensing we may be able to monitor the physical condition of cities on a frequent, regular, and low-cost basis. A version of the automatic data analyzer discussed above could automate the analysis, lower the cost, and allow frequent monitoring.

All these possibilities will be slow in coming unless remote sensing research is directed to urban use.

Robert Tanenhaus' Credentials

Mr. Tanenhaus is an urban planner, a program planner and manager for the New York City Environmental Protection Administration, an Assistant Adjunct Professor of Urban Systems at Farleigh Dickinson University this

fall, and president of the Center for Urban Simulation and Analysis, a private firm that uses multi-media and analysis as tools in the understanding and solution of urban and environmental issues.