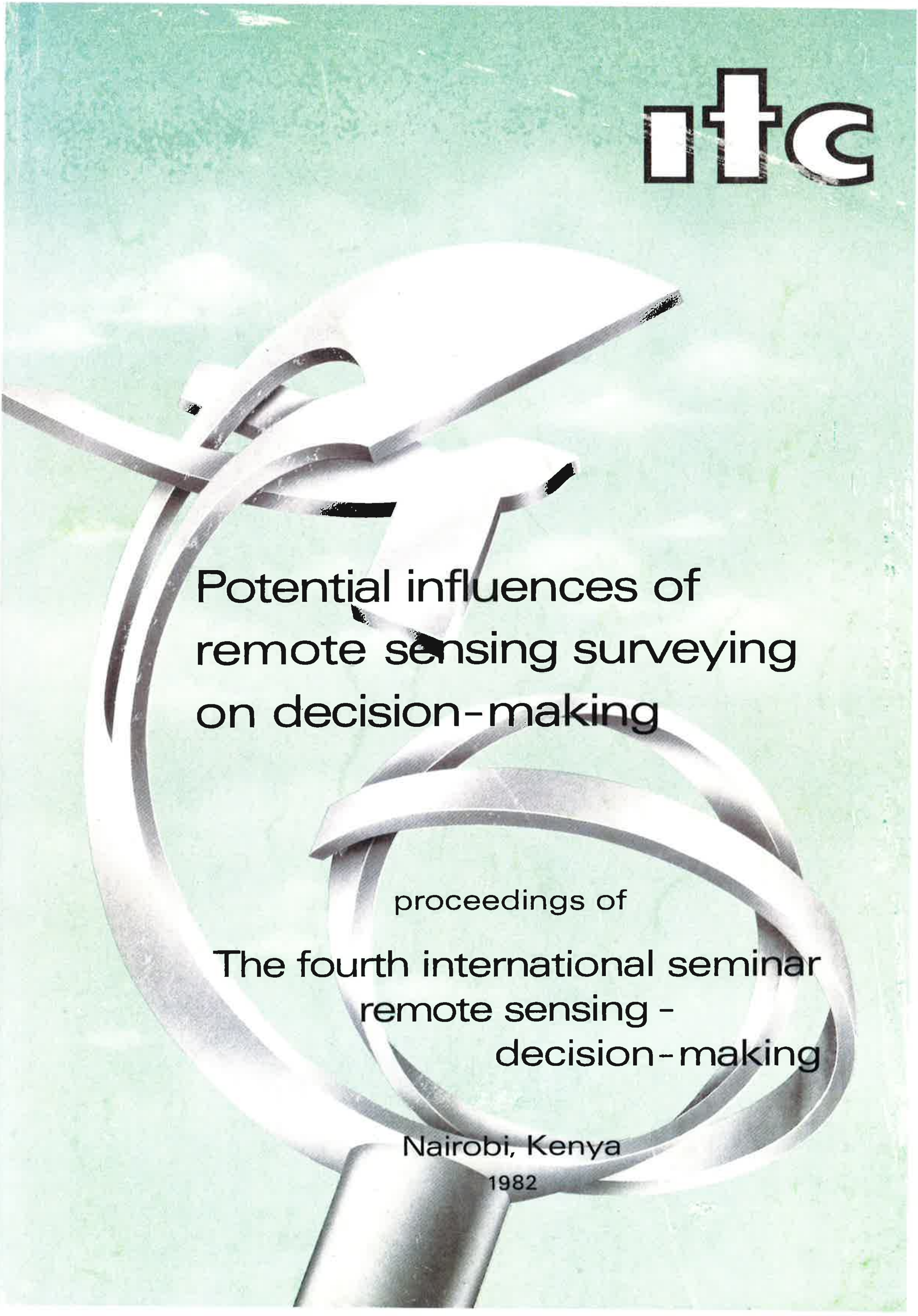

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Potential influences of remote sensing surveying on decision-making

proceedings of

The fourth international seminar remote sensing - decision-making

Nairobi, Kenya

1982

REVIEW OF POSITIONING TECHNIQUES FOR REMOTE SENSING

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The following is a short review on positioning for remote sensing. It is intended for establishing geodetic networks and two and three-dimensional coordinates.

There exists today a series of techniques to determine the position of a point on the ground. These are based on
(a) astrogeodetic observations;
(b) conventional angle and distance measurements;
(c) doppler satellite receiving methods;
(d) inertial surveying;
(e) laser tracking of satellites;
(f) global positioning system.

In addition, we can define coordinates of points from imagery from today's systems for
(a) photogrammetry;
(b) satellite scanning;
(c) radar.

a. <u>Astrogeodetic methods</u>
are based on observations of stars (angles and time) and gravity. One important technique is based on photographs of stars and satellites. Bulky ballistic cameras have been used in the past to generate these photographs for positioning. These cameras must be housed in stable observatories. However, they can currently be complemented by light, transportable zenith cameras for star and satellite observations. These can be used to establish a national network of high order using photographs of the night sky, achieving absolute accuracies of perhaps 2 m. The fact that zenith cameras are light and portable results in the possibility of using astrogeodetic methods not only for the establishment of one or several basic points per nation, but also to build up an entire set of points at reasonable expense.

Astrogeodetic observations are still the essential techniques for first order point positioning because of the independence of the coordinate system and the use of an inertial coordinate system of stars.

b. <u>Conventional angle and distance measurements</u>
serve to build up a denser national network of points by many detailed observations, using theodolites and electro-magnetic distance measurements, where the new points are made to fit into the astrogeodetically determined basic observations. The densification can be accomplished in steps. The role of the conventional techniques in first order triangulation tends to decline because of improved astrogeodetic, Doppler satellite and intertial surveying techniques.

c. Doppler satellite surveying
is the result of U.S. positioning technology based on a set of TRANSIT satellites. These transmit signals of the earth. A portable light receiving set is placed over a point for which coordinates are to be determined. Observation of signals from one satellite provides a measure of relative velocity between receiving antenna and satellite using the Doppler frequency of the transmitted signal. From the Doppler frequency, we can compute a hyperbolic surface. The receiving antenna is on that surface. Since we know the satellite position and velocity, we can determine the surface as the "locus" for our point of interest.

For a point on the sea surface, it would be sufficient to observe two satellites and to compute the unique intersection point between three surfaces - two hyperbolical surfaces, each from one satellite, and the earth's spheroid. Normally, we will observe points that are not on sea level. Then at least three satellites must be observed to provide a unique solution. Generally, however we will want as much accuracy as is feasible. We therefore observe as many satellites or satellite passes as possible; the redundancy builds up over several days of observation to result in an absolute accuracy of several meters, at best approximately ± 1 m.

The result consists of cartesian coordinates XYZ in a coordinate system selected for communicating the positions of the TRANSIT-satellites: the system of the U.S. Nerval Weapons Laboratory of 1972 (WGS 72).

There are techniques for using several receiving devices simultaneously on more than one point. This can lead to higher accuracies, of perhaps ± 0.5 to ± 1.0 m for points with respect to one another ("relative" accuracy). Doppler satellite surveying has nearly entirely eliminated the need for conventional surveying in developing countries when establishing first order points (points spaced 50 to 100 km or so apart). The logistics, time and thus cost are considerably more modest for Doppler surveying.

d. Inertial surveying
is based on technology developed for aircraft navigation using the precise measurement of acceleration. Thus a vehicle must be moving to measure acceleration and subsequently to compute distances between points.

This basic principle is used in aircraft in the form of inertial navigation systems (INS) is now available for surveying with cars and helicopters with considerable accuracy (± 0.2 m per 100 km) and speed. Typically, a network of points is monumented, whereby a few are measured with Doppler surveying. These may be 100 km or so apart. This is then densified with points perhaps 2 to 10 km apart using a helicopter that hops quickly from monument to monument, stopping at each point to read its position and height.

At a rate of 2000/hr (exclusive of the vehicle!) this technique is not necessarily less expensive than conventional surveying; it is, however, significantly faster. Therefore one cannot necessarily conclude that inertial surveying at current rates will outperform in all circumstances. This applies particularly where manpower is available but foreign currency is not.

e. Laser tracking of satellite
is an expensive technique used in several observatories around the world. It is based on precisely measuring the distance to satellites from a fixed point on the earth. This is used to measure continental drift, define the rotation axis of the earth and monitor geodynamic processes. This technique is not applicable to positioning for remote sensing.

f. The Global Positioning System, GPS
is another U.S. development for instantaneous absolute positioning of points to within ± 10 m, approximately every 10 seconds. This differs from Doppler surveying which is not instantaneous. We may well expect that GPS will allow, perhaps after 1988 or so, when it is operational, a much greater accuracy to be achieved with extended observations. Measurements can thus be used for non-instantaneous positioning and can be employed in procedures similar to those in Doppler surveying. Such services are already available today, e.g., from Shelltech of Calgary, Canada, or from Macdoran Associates, Pasadena, U.S.A.

The GPS sponsoring organizations are still in the process of deciding how the military instantaneous 10 m GPS performance will be made open for civilian uses. What accuracy will be available for instantaneous positioning -500 m? It is fairly clear that non-instantaneous positioning with GPS will be feasible with higher accuracy, similar to that of Doppler surveying.

The GPS concept is also being discussed in Europe and is apparently being realized by the U.S.S.R.

g. Positioning from Remote Sensing Imagery
is the result of using photogrammetry, Landsat or radar to create maps. This allows us to scale off coordinates from these maps. This can be a goal in itself or it can be used to control other (newer) remote sensing imagery in a so-called image-image matching process.

Photogrammetric performance is well-documented, generally producing an accuracy of 1:10 000, i.e., a position or height error is committed that is equal to the flying height divided by 10 000 (with a 6" or 152 mm camera and from 6 km flying altitude, an image scale of 1:40 000 is obtained, resulting in positioning errors of approximately 60 cm).

Landsat: If we determine positions from Landsat-MSS imagery, then an error of approximately 50 m will be committed in the best cases (well controlled Landsat-MSS imagery, well-identifiable features). Positions from Landsat-RBV are better - an error of ± 13 m may be committed. Both these results relate to XY only. No height can be measured.

These Landsat-points could be used to control, for example, an imaging radar survey or they may be a geometric base for subsequent Landsat coverage.

Aircraft radar mapping results in maps from which points can be obtained with errors of approximately 100 to 150 m. These values are too large; the points cannot serve for control in other surveys.

Satellite radar could be more accurate than aircraft radar, as was shown by SEASAT. Errors can be near the ground resolution or better but this depends on precision processing and exceptionally well identifiable ground points. Results relate to planimetry (XY) only, no height is measured.

h. Positioning from future high resolution space images

The French SPOT system, the many proposed mapping satellites at resolutions of approximately 10 m and the space photography missions with the space shuttle and spacelab are expected to generate maps that will allow positioning with half a pixel diameter, thus with perhaps ± 5 m in planimetry. Height could be similar if a good stereo base-to-height ratio of 0.6 to 1 is achieved.

THE POTENTIAL INFLUENCES
OF REMOTE SENSING
ON DECISION MAKING

PROCEEDINGS OF THE FOURTH SEMINAR
REMOTE SENSING - DECISION MAKING
NAIROBI, KENYA

JAN M.M. VAN DEN BROEK
&
HELMUT EPP
(Editors)

8-19 NOVEMBER, 1982
(PRE-SEMINAR: 1-5 NOVEMBER, 1982)

INTERNATIONAL INSTITUTE for AERIAL SURVEY and EARTH SCIENCES
(ITC) - NETHERLANDS

KENYA RANGELAND ECOLOGICAL MONITORING UNIT (KREMU) - KENYA

NATIONAL COUNCIL for SCIENCE and TECHNOLOGY (NCST) - KENYA

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