Alternatives for Economic Boundary Determination in the Establishment of a Cadastral System

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Summary

Efficient cadastral and land information systems are a prerequisite for security and protection of land transactions. However, they only exist in about half the countries of the world. Where they do not exist land is dead capital. This has two aspects, first, the legal issue to regulate land registration and subsequent transactions based on uniquely defined land objects. Second, the creation of the geometry of the land objects, which is the topic of the paper. The establishment of such systems can be expensive and slow, unless new technological advances are being made use of. These are: GPS-GNSS used in reference networks as the most accurate, but most costly and time consuming option. Another efficient possibility is to use aerial ortho-mapping to produce preliminary parcel boundaries from image interpretation during adjudication procedures. While this method has deficiencies in accuracy of boundaries, it does not prevent the legal aspects to be completed quickly. But it offers the possibility to conduct accurate GPS-GNSS surveys only in those transactions, where accuracy is demanded. With the proper design of the geodatabase, permitting to preserve the topology of the parcel fabric, but to change boundary point coordinates, when higher accuracy surveys are demanded, it is possible to speed up the registration process. It is even possible in extreme circumstances to utilize high resolution satellite imagery for this purpose, rather than the mor accurate and reliable aerial images. In this manner it should be possible for the countries not yet benefiting from an efficient and reliable land registration to complete the system in less time than one generation for the benefit of the economy of these countries.

1. INTRODUCTION

The establishment of effective land registration and cadastral systems has in the past decades gained momentum. Hernando de Soto, an economist of the third world, has demonstrated in his book “The Mystery of Capital”, that insecure land rights deprive the economy of a country of the capacity of land to serve as collateral for mortgages. If an effective land registration system does not exist in a country, land becomes “dead capital”.

International funding agencies, and foremost the World Bank, have spent more than 1.2 billion US$ during the last 10 years for the introduction and the renewal of land registration and cadastral systems in the transformation and developing countries.

Cadastral Surveys and Land Registration have always been the preoccupation of FIG activities. In Commission 3 Jürg Kaufmann has propagated “Cadastre 2014” as the ideal system, according to which land registration is to be carried out:

- It assures that land objects (parcels, buildings, easements) are uniquely defined and numbered on the earth surface
- Once the parcel boundaries are uniquely defined by its boundary points, topological relations of the boundary lines between them assure, that there is no overlap of land objects
- Information technology permits to represent the parcel boundaries in digital form. This means that each boundary point along the boundary is known by its georeferenced coordinates. The geometric parcel fabric may represent reality with 1:1 accuracy, if the reality is surveyed with sufficient accuracy. This is an engineering task for the land surveyor or a survey administrator.

- All uniquely defined land objects are contained in a relational database with a great number of attributes, characterizing the legal, natural and environmental status of the object, such as ownership of a claimant, lease to a person, mortgage between a lender of capital to a person with the land object serving as collateral, access right. The administration of these attributes is essentially a legal matter and the responsibility of lawyers, notaries or land registrars.

The dual nature of the responsibility is often separated in existing administrative structures in the different countries, but can also be combined within one administration, which is easier to manage.

In any case, the cadastral survey and land administration system will only function, if it is continuously maintained from transaction to transaction.

FIG found by its surveys in Commission 3, that only about 50 countries of the 190 in the world have functioning cadastral systems, and about another 50 countries are in the process of establishing one.

This still leaves about 90 countries without a cadastral system.

While it took more than 100 years in the traditional countries with cadastral systems in place to establish them, the technological advances of the last decades made it possible to create them in a fraction of the time and cost.

This is a challenge for these 90 countries without cadastre, so that they may share a geospatial infrastructure with legal applicability with the rest of the world. But the technological possibilities also permit to develop strategies for the existing cadastral systems in the other 50 countries which are currently developing them (or even in the traditional 50 countries) to improve their accuracies and to develop tools for quality control.

The task to establish efficient cadastral and land registration systems is of course of dual nature:

First, laws have to be drafted and passed by the legislature to enable the land registration agency to collect and to administer the relevant land related data on a continuing basis.

In this respect those drafting the legislation and those enacting it have the responsibility to make use of modern technology to assure reliability and cost-effectiveness for the collection and the maintenance of the land related data.

It is secondly the task of the survey professionals to select adequate technical procedures for defining the geometry of the land objects with sufficient accuracy, to make certain, that the establishment of cadastral systems is not delayed by inadequate procedures.

While the first task to draft adequate laws and regulations is an important aspect, this is not an issue for this paper.

Instead the paper wants to clarify, which modern technical tools are available and recommendable to generate an adequate parcel fabric, which can serve as a geometric base for the cadastral system.

2. Land Boundaries

Historically there is evidence of land ownership by individuals as early as the Babylonian times 1200 B.C. While most of the agricultural land then was used for crops by temples, some of the land was leased or sold (Baker, Heather D. , 2011). The boundaries of these fields were marked by stone monuments, examples of which can be seen in the British Museum in London.

While Roman surveyors such as Marcus Vitruvius Pollio (20 B.C.) and Sextus Julius Frontinus (35 – 104 A.D.) were preoccupied with construction survey tasks, their activities also included demarcation of lands, given to soldiers as a reward in occupied territories (Cuomo, Serafina, 2000).

This procedure repeated itself in the Americas, when land was granted to new settlers. Land boundaries were established on the basis of a plan, but they were marked on the ground by monuments, most of which became deteriorated in the course of years.

In Britain, where fields used for agriculture were originally full of stones, these were accumulated at the field edges through the years for better agricultural production; one speaks then of "unsharp boundaries" marked by the piled up stones, which cannot geometrically be defined better than in the order of several decimeters.

While monuments were able to define boundaries with decimeter precision on the ground, the difficulties arose, when the monuments became lost due to natural decay and sometimes due to greedy neighbours.

Even in countries with a traditional cadastre, such as Germany, boundaries are still marked on the ground on a voluntary basis at the cost of the owners. (see fig.1).

Fig.1 Boundary Marker in Germany, not coinciding with the wall

The boundary markers, which can be surveyed with cm-accuracy now demonstrate, that the erected walls and fences along the boundary do not coincide with the precisely surveyed boundary points defining the extent of ownership. The discrepancy is in the order of a decimeter.

In Arabic countries new parcels are generally staked out according to plans with relative cm accuracy (computer planning could today also yield cm accuracy). The boundary points are temporarily marked by iron bars (see fig.2). These are often not placed stable enough to

Fig.2. Iron bar as boundary marker in Saudi Arabia

preserve cm accuracy. When fences and walls are built after the stakeout the relative accuracy of reconstructing the boundaries is also not better than within the range of decimeters.

Nevertheless most existing specifications prescribe cm precision for the fixing of boundaries. This is clearly an overspecification.

3. MONUMENTATION OF BOUNDARIES

Monumentation of boundaries has been the classical way to describe them. It had the disadvantage of its volatility due to changes of the land by water erosion, land slides, vocanic activity or possible destruction by humans.

But it had the advantage of fixing the boundary to thr earth´s surface. The was no need to georeference the boundary unless the security of recovery of the monuments demanded it.

This need for recovery was the greatest weakness of monumentation. This weakness was overcome in the past generations by the state of technology used in these times:

- Astronomic positioning in new continents to about 100m. practiced in the
- 1700´s to 1800´s
- The buildup of networks of geodetic triangulation using angular measurements, used in Europe in the nineteenth and early 20th century.
- The buildup of traverse networks by electronic distance measuring devices in the latter 20th century

Even the latter two improved methods did not permit absolute georeferencing to better than 10m and relative georeferencing to better than 1m.

4. MODERN TECHNOLOGICAL TOOLS FOR THE ESTABLISHMENTOF A PARCEL FABRIC

4.1 GPS

The Global Positioning System Navstar GPS was developed since the 1970´s by the U.S, Defense Department. It became operational in 1985. The codes signals from at least 4 of the 24 satellites received simultaneously permit global positioning at 10 m precision with inexpensive code receivers. Satellite based augmentation systems (EGNOS, WAAS, MSAS, GAGAN and OMNISTAR) permit a higher relative accuracy in the range of a few meters.

When the carrier phases of the signals are received by considerably more expensive phase receivers, precisions in the cm or even mm range become possible in the real time kinematic mode (RTK) using differential GPS (DGPS). The accuracy of GPS phase signals is essentially limited during transmission of the signals through the ionosphere and the troposphere. To reach cm or even mm precision DGPS observations are required not only by observations at an object point, but also within a network of reference stations in networks (preferentially continuous reference stations CORS) transmitting their observations or their corrections for ionospheric and tropospheric influences. In order to reach cm precision differential GPS observations are needed with reference stations 50km apart. In the mm accuracy range networks with 10km distances between stations are required.

In order to reach absolute positions the networks need to be connected to the global observation services WGS, fixing them with respect to the International Terrestrial Reference Frame ITRF.

This technology sets currently the limit to absolute global positioning to the dm to m level and to relative geopositioning to the cm to dm level.

If boundary points are observed with GPS carrier phase receivers, then monumentation of them does not become necessary for the replacement of a point, except as a matter of convenience for use.

While the technical means to achieve this accuracy are currently available, there is still the open question, whether such a high geometric accuracy is required for land registration. This high accuracy serves more the individual land owner in densely populated areas, rather than a public need for registering property with an ownership title.

But it has been shown in the cadastral practices of European countries, as well as in transformation and development countries, such as Georgia, Cambodia and a few more, that cadastral boundaries have been established for about 40 000 km^2 in 5 years (Salukvaze, Joseph, 2006).

4.2 DIGITAL ORTHOPHOTO MAPPING

The tools of aerial mapping have likewise rapidly been advanced.

Aerial surveys are now possible by high resolution digital aerial cameras, such as the Leica-Hexagon DMC or ADS 80 or the Microsoft Vexcel Ultracam.

Semiautomatic processing systems for calibration, aerial triangulation, digital terrain model generation and orthophoto mapping by Leica-Erdas, Trimble-Inpho, Microsoft Vexcel Ultramap, Racurs or Socetset and others have become generally available. Even nearly fully automated systems, such as EADS-Pixel Factory and its equivanent in China have been developed.

What is significant is, that the aerial surveys can be controlled by in-flight GPS combined wit IMU with exposure station determination to the decimeter level.

With the inclusion of signalized ground control points, measured by DGPS, the accuracy of an imaged point becomes a function of the ground sample distance GSD. Depending on the flying height GSD´s of 10 to 15cm are usually acquired for urban areas and of 40cm for rural areas. The planimetric accuracy of an imaged pont therefor becomes at least 10 to 15cm for urban areas and 40cm for rural areas.

The difficulty remains, that only “unsharp boundaries” may be derived for buildings, walls, fences or cultivation borders. These features may be interpreted from the orthophotos, but these interpreted features do not constitute actual property boundaries on the ground. They are only an indication for a “preliminary boundary”.

Nevertheless, the image identification of features on the orthophotos, in combination with field adjudication procedures, may diminish the cost per parcel down to the 1$ per parcel level and increase the speed significantly, at which a parcel fabric may be created,

Large countries with presently no cadastre (e.g. Saudi Arabia or African Sahel zone countries) would otherwise never be able to establish a cadastral system in less than a generation.

It should be realized, that the preliminary parcel fabric does not fix the boundaries on the ground in terms of a cadastral system, but it permits to restrict accurate measurements in the field via the DGPS method on transaction to those areas where it is really needed. In the meantime the preliminary graphical boundary is sufficient to create unique parcels and land objects, which can be the basis of the registration of ownership, lease, mortgage, easements and land use information.

It should further be realized, that an orthophoto production may well be an effective means of quality control for cadastral ground surveys by electronic tacheometers or even DGPS. In the transformation countries, such as the Ukraine or the Russian Federation such ground survey were outsourced to local surveyors. The superposition of the Orthophoto with the digital parcel framework surveyed on the ground resulted in 17% errors for the ground surveyed parcels in the Odessa Oblast of the Ukraine , which had to be corrected (Fig.3 and Fig.4)

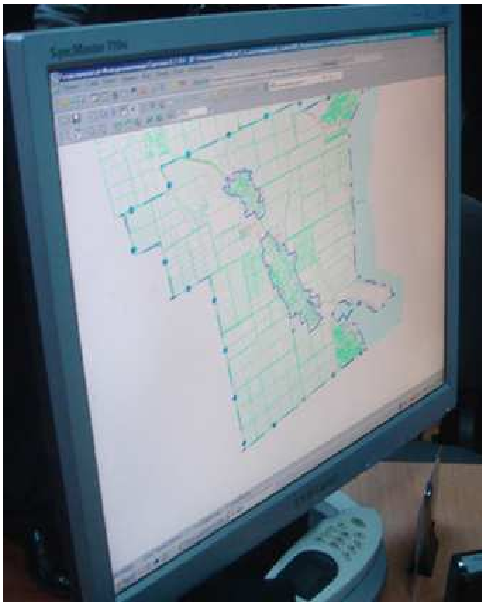

Fig.3 Ground Survey Graphics in the Ukraine (Odessa Oblast)

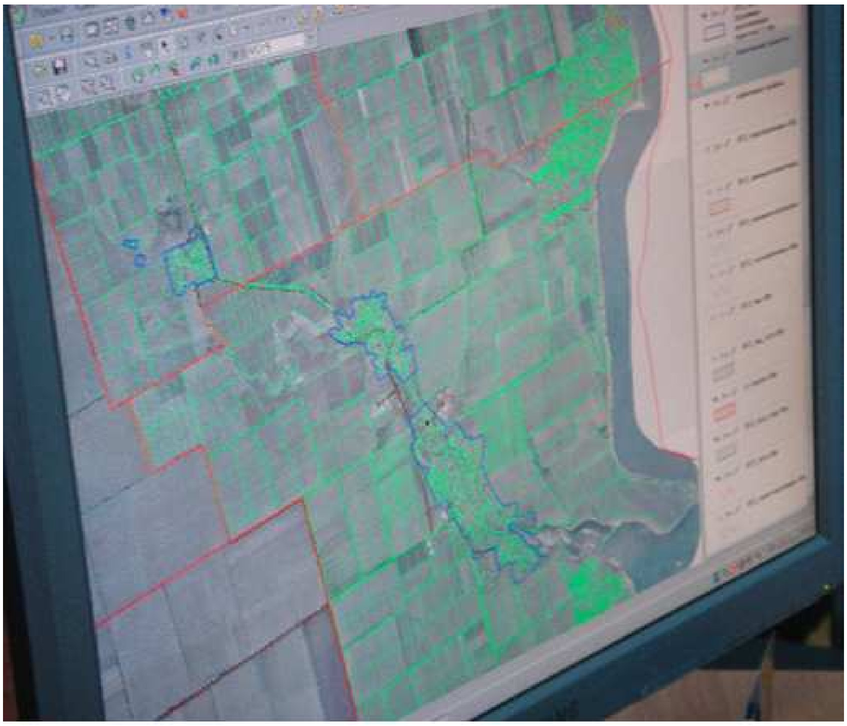

Fig.4 Superposition of Survey Graphics with Orthophoto in the Ukraine (Odessa Oblast) with 17% errors of the survey records

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4.3 DIGITAL GEODATABASE STRUCTURE

Use of a preliminary parcel fabric with less accurate parcel boundaries of course requires the design of a suitable relational database structure with addressable boundary points and boundary lines, which within the existing topological structure may be changed in their coordinate values by sporadic accurate adjudication surveys later.

4.4 HIGH RESOLUTION SATELLITE IMAGERY

The methodology applied for preliminary boundary extraction from aerial orthophoto mapping may easily be expanded for use with high resolution satellite imagery, such as GeoEye, Ikonos, WorldView and others.

Of corse the resolution of these images with GSD´s between 0.5m and 1m is even mor limited than the ise of aerial orthoimages due to the generally less favourable atmospheric conditions for space images. But likewise, land objects may be extracted as “preliminary parcels” with about 1m accuracy.

5. CONCLUSION

The technologies of GPS-DGPS, of orthoimaging from aircraft and high resolution satellites, as well as a proper design of the geodatabase permit the unique technical possibilities to solve the problem of describing land boundaries, which in the past have prevented countries to create effective land registration systems.

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