MANAGING THE TRANSITION FROM A METES AND BOUNDS LAND TENURE SYSTEM TO A COORDINATE BASED CADASTRE

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ABSTRACT

Land ownership is a fundamental layer in most geographic information systems (GIS). Many attributes are located with respect to these boundaries and the accuracy of these data sets depends on the accuracy of the land ownership layer.

Surveyors use original subdivision data (survey plats and land descriptions) to define boundaries to a high degree of accuracy, but this data is not in a form that can be readily used in a GIS. If this data is captured and converted to coordinates for all property boundaries it will not only produce an accurate base layer for GIS systems but will also provide the basis for moving from a "Metes and Bounds" to a coordinate based cadastral system.

This paper discusses techniques and software that we have developed to accurately coordinate the corners of property boundaries using limited control and the original subdivision data. They are being used in Australia and New Zealand on property records similar to those in the USA.

INTRODUCTION

The definition of boundaries for most parcels of land in the USA is by "Metes and Bounds". These are the dimensions and the common boundary with the adjacent parcel. The system has evolved during a period when it was relatively easy to measure lines but very difficult to find the exact location of a point on the Earth's surface.

The dimensions and reference to physical objects on or near the boundaries are shown on survey plats and legal descriptions. While local subdivision regulation has had some impact, in general, the accuracy of data in these documents is a reflection of the measurement technology at each point in time. For example, prior to 1880, survey transits were not commonly in use and angles were measured to the nearest half degree. Over the years, developments in angle measurement technology in survey transits and theodolites have improved this accuracy and many of the modern instruments in use have an accuracy close to five seconds of arc. Similarly, the technology for manually measuring distances steadily improved until about 1970 when electronic distance measurement was introduced. Modern instruments can now measure distances of 1000 meters to a precision of better than five millimeters.

Currently, the most common method of building the land ownership layer in GIS systems is by digitizing administrative documents such as tax maps. The accuracy of this data depends on the maps and the quality of the digitizing process. Many of these maps were designed simply to show the relationship of the various attributes to each other rather than being compiled to an accurate coordinate base. Consequently, the accuracy of position varies from place to place and any mistakes in the original map compilation are also carried forward into the digitized records.

There are many systems in use to improve the accuracy of this type of data and these include “rubber sheeting” or adjusting to extra control from GPS or photogrammetric data such as orthophoto maps. These systems improve positional accuracy near to each control point but overall they do nothing to correct the inaccuracies in the base data. To overcome that problem it would be necessary to have a control point at nearly every corner.

While most GIS managers appreciate the limitations of this data set, it has generally been considered too complicated and costly to build the property ownership layer directly from source documents. The reasons for this relate partly to the lack of systems for processing this type of data and partly to the lack of understanding as to the structure and characteristics of this data.

BOUNDARY DEFINITION DATA

The survey plats and legal descriptions describe each parcel of land by the bearings and distances around its boundary. The basic module for the data is therefore a closed polygon and this polygon may have additional “connections” to corners of other parcels or survey reference marks.

The dimensions may be measurements taken by the surveyor in the field and the figure may not “close” exactly. Consequently, if you compute around the boundaries using the dimensions, you will not come back exactly to the starting point. This difference is often referred to as the “misclose”. The size of the misclose in each parcel is a measure of the accuracy of the data and is used by surveyors as a check on their work. The dimensions on a line may also be different on adjacent or overlapping plats reflecting a new measurement of the line.

The data can be considered as a series of “observations” grouped in sets with each set being a closed polygon. These polygons can be linked at the connection points indicated by the plats and legal descriptions to form a boundary network. The connections can be by common points or by a point lying on another line.

There is redundant data and if this is weighted according to the measurement accuracy which was available at the date of each survey, it can be processed by a “least squares” adjustment to generate the most likely coordinate of each parcel corner. The adjustment must take into account that the data is a series of polygons and not individual lines. It must also include all of the data and not just the latest information.

In such a system, coordinates are a derived quantity and are held as an attribute to a point rather than a definition of the point itself.

The boundary definition layer is constantly changing as land is subdivided and consolidated. Each new plat will change the boundary network and may also influence the coordinates of points outside of the plat even though this influence is limited. In practice however, the size of change becomes very limited as the proportion of modern plans is increased or if the area is stabilized with additional GPS control.

CO-ORDINATE BASED PROPERTY BOUNDARIES

If the Land Ownership layer is built directly from the dimensions shown on subdivision plats, it will not only provide a complete and accurate base layer, but will open the way for coordinate based property boundaries.

Current methods of boundary definition have been adequate for a long period of time. However, the techniques are a very indirect way of defining a point and disputes arise when different surveyors use different data to determine the location of a boundary.

Alternatively, a coordinate can provide a unique and unambiguous definition of a point and GPS can provide the necessary technology to quickly and accurately locate that point. At present most surveyors compute new subdivisions by coordinates, lay in the corners by coordinates, then prepare “metes and bounds” documents to satisfy the legal requirements for land transfer. Technology has allowed surveyors to adopt a coordinate based approach and this can be used to reform the land ownership record system.

To gain maximum benefit from existing data, the building process should not only extract data from the plats and build the boundary network, but it should also analyze the data and provide a measure as to the reliability and accuracy of the computed coordinates. This will then open the way for these coordinates to become the definition of property boundaries.

The problem that every surveyor faces when redefining an old boundary is what to adopt as evidence to the original marking. Clearly, the subdivision plats are documentary evidence as to the original intention and survey marks placed at the time of subdivision give evidence as to the location of specific corners and the quality of the survey work. Other physical objects which may be shown on the plat such as fences and structures (often referred to as "monuments") can also be used to provide guidance if the original marking is gone.

As time progresses and evidence of the original subdivision marks are lost, the original subdivision pattern becomes irregular and disjointed. The aim of each survey is often to find a solution to minimize the chance of litigation rather than try and define the true location of a boundary. Many surveys are carried out under tight cost constraints and therefore are limited in area and in the amount of detailed investigated.

The process of assembling and analyzing all of the dimensional data for an area is not only a comprehensive way of assessing the documentary evidence, but it also allows the surveyor to check on marks which may be physical evidence of boundary position
Many local anomalies can only be explained by looking at the complete picture.

IMPLEMENTATION

The quality of data will vary from place to place and will to a large extent depend on the age of surveys and the degree of regulation of the subdivision process. In countries where the state guarantees title (such as Australia and New Zealand), there is a higher standard of data and less likelihood that there will be gross mathematical errors in plats. However, even without this regulation, the surveying community has to work with the plats that they produce and it is in their interest to maintain a standard apart from the professional pride in their workmanship. The main problems occur in the smaller subdivisions which have not been designed by a surveyor or engineer.

The key to success therefore is to progressively test the data as it is entered and assembled so that any problems are detected very early and dealt with appropriately. The data entry operators should be able to key in “what they see” with the software managing all the interpretation. If a plan is in feet, inches and fractions, the operator enters these figures, the direction of lines can be in “whole circle” bearings or “quadrant” bearings, and the initial orientation of each plat should not matter.

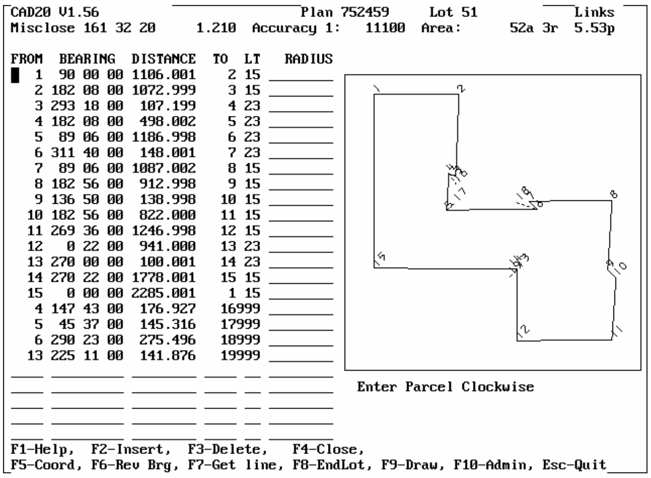
The traditional approach to building a property boundary layer from the source data has been to first set in place a control network, then progressively add data to the control and finally adjust the total data set. Such an approach can be very costly to implement and requires staff with considerable expertise in the management of boundary data.

Our approach has been to enter all the data, assemble and analyze the boundary network and only then apply control according to the results of the analysis. While this is almost the inverse of “standard surveying practice”, it does allow for checks to be carried out on the internal consistency of the data before the complications imposed by the addition of geodetic control.

We have developed proprietary software to manage these processes and its use for accurately coordinating property boundaries. This software which is distributed by Geodata has been extensively tested and validated in Australia and New Zealand and trialled successfully in the United States. There are progressive quality assurance (Q/A) checks at each stage in its operation and standard processes to manage problems which may become apparent in the data.

Some of the key features of the system are as follows:

The Input program is designed to facilitate the direct input of data from survey plats with a minimum of decision making by the operator.



Bearings and distances are entered in sequence around the parcel, and the lines and their local reference numbers are displayed on the screen as the data is being entered. Bearings can be input as “whole circle” or “quadrant bearings” and either mode can be displayed as required.

Point numbers are automatically incremented to speed input and the "From", "To", "Line Type" and "Radius" fields skipped over, but the arrow keys can be used to access any field.

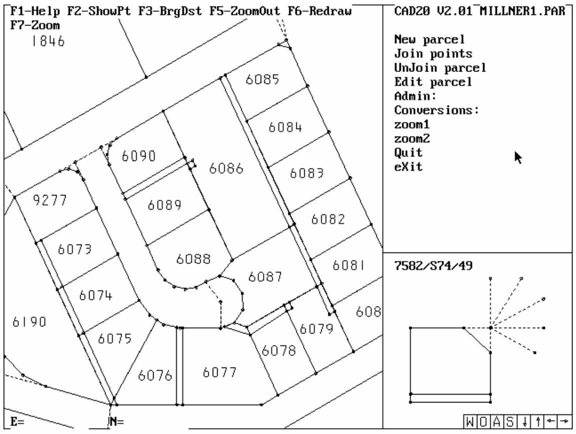
Function keys are provided for operations such as to reverse a bearing, recall a previous line, insert or delete a line etc. Connections shown on survey plats can be included to assist in the joining process and these may take the form of a traverse.

At the completion of input of each parcel, the misclose vector, area, and “order of accuracy” is displayed

The Parcel Joining Program is designed to define the "connectivity" between parcels in the property boundary layer.

Joining is carried out interactively with the joined parcels being displayed in one window and the parcel to be joined in another. The main menu items down one side, individual pan and zoom is provided for each window and operations can be selected with a keystroke or by pointing with a mouse.

At the end of the selection process transformation parameters are computed by a least squares procedure and the residuals displayed in the information box. The operator can accept the result, or reject it and try other points for the join. If it is accepted the parcel is added to the network and the parcel point numbers changed to network point numbers.



The joining process establishes the topology of the network and it has checks to ensure the integrity of the system. For instance reports are made if there are joined points close to each other but not joined and where points are close to lines.

The Network Adjustment program is a rigorous least squares procedure to generate coordinates using plan data (bearings and distances) from the parcel file and selected control points.

It uses the topology generated by the joining process and treats the dimensions from the survey plat data as “observations”. Closed parcels are treated like direction sets in a geodetic network adjustment in that they have a common orienting parameter.

A report file is written showing the adjusted co-ordinates and comparisons made with each line in each parcel. Lines with significant differences are tabulated and a statistical estimate is made of the precision of the coordinate data.

EXAMPLE DATA SETS

The land ownership pattern is often complex with a great deal of "connectivity" between the parcels which creates a very redundant data set. Under these circumstances, errors can be isolated provided that all of the data is used. Perhaps this can be best illustrated with two typical examples, one from New Zealand and one from Texas.

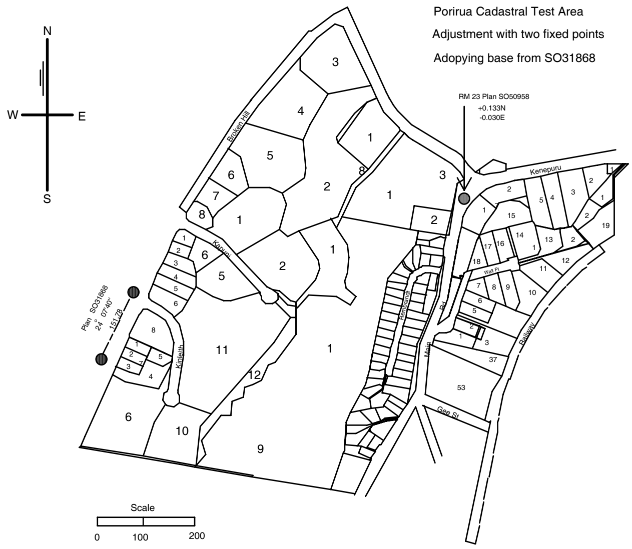
Porirua a suburb of Wellington New Zealand

This site is about a kilometer square and is partly rural with intruding urban areas. The topography is quite steep in places and the plats date from 1880 to 1992.

Initially only two control points about 200 meters apart were used at the eastern edge of the area. This was used to determine how the network fitted internally as well as deriving initial geodetic coordinates for all points.

After this adjustment, a check was made on a known point on the western side of the area and this showed coordinate differences of 133mm in the north and 30mm in the east. These differences represent a scale error of about 1:22000 and an azimuth error of 30 seconds of arc which is approximately 20mm on the baseline.

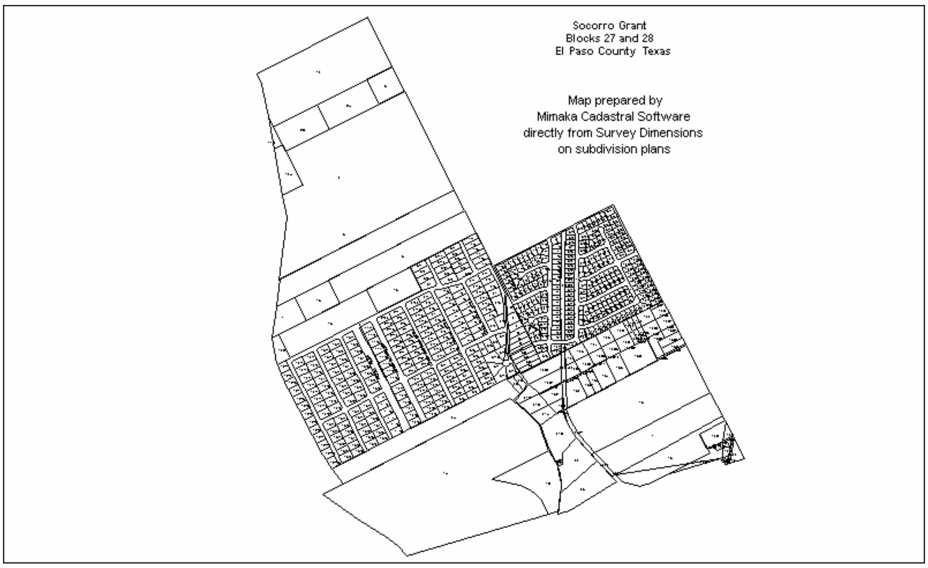
After adopting this third point and readjusting the network, comparisons were made with ten other points whose coordinates had been provided from other surveys. Those points inside the control had coordinate differences of less than 50mm while some points outside the control along the railway had errors up to 141mm by 92mm. These errors would have been greatly reduced if additional control was placed on the eastern side of the area.



Boundary lengths were computed from the adjusted corners and the average difference from plan dimensions was less than 10mm with a few old plans (dating prior to 1900) having differences of over 50mm.

This example shows how the boundary data can be used as a network to propagate coordinates over a broad area. It also shows the inherent strength of this type of network when there is a high degree of connectivity between all the subdivision plats.

El Paso USA - Socorro Grant Blocks 27 and 28



This data set was built in two areas (Paso-1 and Paso-2), with production times as follows:

Paso-1 This area has a large number of identical parcels which reduced the data entry time.
Processing details: 274 parcels, 1191 lines, 173 connections, 86 radial lines

Data Entry:	6h 58m,	1.5 minutes per lot
Parcel Joining:	5h 23m	1.2 minutes per lot
Network Adjustment:	0h 11m	
Total elapsed time:	21h 50m	4.8 minutes per parcel, or 12 per hour

Paso-2 This area has many irregular parcels and curved blocks around cul-de-sacs which increased the data entry time. Time was also spent in correcting obvious errors. These occurred when a parcel was re-subdivided by a later plat with incorrect dimensions along the subdivision line. In these plats the bearing and distance along the subdivision line appears to have been scaled off a plot rather than calculated from the remainder of the parcel dimensions.

Processing Details:	322 parcels, 1370 lines, 139 connections, 156 radial lines
Data Entry :	17h 16m, 3.2 minutes per parcel
Parcel Joining:	9h 2m, 1.7 minutes per parcel
Network Adjustment:	0h 10m
Total elapsed time:	45h 1m, 9.8 minutes per Parcel, or 6 per hour

The total elapsed time includes time for general administration and preparation of final GIS files.

Details of the problem lines and the overall accuracy (in metres) for both areas are as follows:

Paso-1

PLAN	Parcel	Parcel Misclose East	North	Point	dX	dY
Socorro 28	1A	-0.964	-0.270	36	0.032	0.097
Socorro 28	1A	-0.964	-0.270	49	-0.020	0.148
Socorro 28	1A	-0.964	-0.270	24	-0.124	-0.068
Socorro 28	1A	-0.964	-0.270	23	-0.143	-0.059
Socorro 28	4D	0.002	-0.001	145	-0.069	-0.187
Socorro 28	4C	1.235	0.626	142	-0.054	-0.443
Socorro 28	4B	0.000	0.000	139	-0.089	-0.396
Socorro 28	4A	0.002	0.001	136	-0.007	-0.249
Socorro 28	3A	0.004	0.002	130	-0.064	0.113
Socorro 28	3B	0.013	0.006	130	0.034	-0.146
Socorro 28	3C	0.013	0.006	120	0.040	-0.148
Socorro 28	3D	0.013	0.006	121	-0.080	0.133
Socorro 28	3E	0.013	0.006	17	-0.087	0.182
Socorro 28	15	0.000	0.000	14	0.160	-0.146
Socorro 28	16	0.000	0.000	77	-0.454	-0.337
Socorro 28	14	-0.279	-0.015	88	-0.003	-0.204
Socorro 28	14	-0.279	-0.015	91	-0.414	0.234
Socorro 28	13	0.000	0.000	88	0.470	0.114
Socorro 28	5	0.000	0.000	1	-0.800	-0.743
Socorro 28	6	0.159	-0.245	84	-0.059	-0.175
Socorro 28	6	0.159	-0.245	91	0.214	-0.009
Socorro 28	6	0.159	-0.245	93	0.054	0.156
Socorro 28	6	0.159	-0.245	94	-0.129	0.002
Socorro 28	7	0.029	-0.423	93	-0.577	-0.389
Socorro 28	7	0.029	-0.423	98	0.351	-0.459
Socorro 28	7	0.029	-0.423	99	0.264	-0.312
Socorro 28	7	0.029	-0.423	100	-0.163	1.061
Socorro 28	7	0.029	-0.423	96	-0.035	0.361
Socorro 28	10	0.003	0.002	102	0.041	-0.121
Socorro 28	10	0.003	0.002	109	0.492	-0.789
Socorro 28	9B	0.000	0.000	106	0.107	0.014
Socorro 28	9B	0.000	0.000	100	0.636	-0.831
Socorro 28	9B	0.000	0.000	107	-0.099	-0.075
Socorro 28	12A	-0.118	-0.098	99	0.061	0.620
Socorro 28	17C	0.001	0.008	82	-0.456	-0.187

Paso-2

PLAN	Parcel	Parcel Misclose East	North	Point	dX	dY
E-275W	Lateral	-0.002	0.000	293	-0.023	-0.002
E-275W	Lateral	-0.002	0.000	296	-0.034	-0.003
E-275W	Lateral	-0.002	0.000	297	-0.048	-0.002
E-275W	Lateral	-0.002	0.000	298	0.047	0.000
E-275W	Lateral	-0.002	0.000	299	0.033	0.002
E-275W	Lateral	-0.002	0.000	300	0.023	0.004
E-275W	Lateral	-0.002	0.000	301	-0.050	-0.003
E-275W	Lateral	-0.002	0.000	286	0.051	-0.001
E-275W	Lateral	0.007	0.003	301	-0.042	0.004
E-275W	Lateral	0.007	0.003	303	-0.058	-0.055
E-275W	Lateral	0.007	0.003	281	0.058	-0.001
E-275W	Lateral	0.007	0.003	286	0.042	0.007
E-275W	Lateral	0.007	0.003	298	0.039	0.023
E-275W	Lateral	0.007	0.003	297	-0.039	0.021
E-275-W	11-1	0.007	0.005	303	-0.013	-0.027
O-27-2	Lateral	0.000	-0.001	979	-0.012	0.014
O-27-2	Lateral	0.000	-0.001	980	-0.013	0.013
O-27-2	Lateral	0.000	-0.001	281	-0.029	-0.025
O-27-2	Lateral	0.000	-0.001	303	0.028	0.006

After correcting the obvious errors, most of the parcels were to an accuracy of about 1:8000 with the more modern parcels being substantially better and the older rural parcels being in the order of 1:5000

The previous examples show that subdivision plats can be used directly to coordinate the corners of property boundaries and that the framework itself can be used to assess the quality of the data. The coordinates which are generated can be made to reflect the shape of the original subdivision pattern, or fit closely to later boundary marks depending on the number of control points and their position. It then becomes a management decision as regards the form that the derived coordinated cadastre will take. To very closely follow the positions of all available survey marks is both costly and may not really reflect the original subdivision boundaries. By accepting the fact that any marks found will have errors in position and will not necessarily be exactly on the boundary, it is possible to more closely adhere to the original subdivision geometry.

MANAGEMENT OF SURVEY ACCURATE DATA BASES

A Survey accurate map base is undoubtedly a very valuable data-set, but unless it is kept up to date its value and relevance will decrease. This is particularly true for fast developing urban areas where their usefulness will degrade very quickly indeed. In these areas it is important to have the information as early as possible as most activity with respect to land takes place soon after each parcel is subdivided.

In Australia, the government in each state maintains a central Land Registry and a digital cadastral data set for mapping purposes. With the exception of the Australian Capital Territory (ACT), these are based on digitised maps, and their update is carried out some time after the registration of new subdivisions. Because of the accuracy of these data sets and the delay in their updating, many local government authorities and service utilities build and/or maintain their own map base.

Currently, some interesting concepts are being pursued with the aim of ensuring that survey accurate map bases can kept up to date.

The Northern Territory (which is about double the size of Texas) has coordinated all parcel corners from the metes and bounds data in their title registry. This work has been carried out progressively over a number of years partly by the government and partly by contract to local surveying companies. To facilitate updating, new work is now lodged in digital form as well as the paper documents. Legislation is being drafted to make coordinates the legal definition of parcel corners and so create a coordinate based land title system. This could eliminate the need for a subdivision plat as the numeric cadastral data base (NCDB) will define the boundaries of all parcels.

In Queensland, a private company called SDX (for Spatial Data eXchange) has been incorporated to create a seamless and complete survey accurate digital cadastral database over the whole state. Rather than waiting for new subdivisions to be registered by appropriate government authorities, SDX will receive spatial information directly from the surveyors who are carrying out each new development. The subdivision data will be captured once only, closest to the source, and managed from that point on in a digital environment.

SDX will integrate this new data into its survey accurate digital map base which will be accessed by other surveyors, land and spatial information professionals, utility companies, lawyers, property conveyancers, financial institutions, local, state and federal governments, and other commercial value adding enterprises. It will operate in close cooperation with the survey profession as a commercial enterprise and eliminate costly duplication of resources in the state.

New South Wales (NSW) has about 4 million parcels held in an efficient and well managed registry. Geodata Australia is developing proposals for the NSW registry to convert the paper plans to a numeric cadastral database and concurrently introduce electronic plan examination during the registration process. As custodian of the data base, this will allow the government in NSW to enhance the opportunities of their present business.

As the above three examples show, each state is adopting a slightly different approach and the determining criteria is often whether government or the private sector will accept the responsibility and cost to maintain the data base and distribute the data as a commercial proposition.

CONCLUSION

It is inevitable that property boundaries will be coordinate based in the future and that the transition from the current dimension based system will require careful thought and planning.

Using the techniques and software described in this paper, the existing geometric data can be used cost effectively to generate coordinates in a seamless parcel fabric for the fundamental land ownership layer in any GIS system.

The use of all documentary evidence such as plats and written boundary descriptions will facilitate the initial coordinate production and produce values which are likely to be very close to the intended position of each parcel corner.

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