

A FAST TECHNIQUE FOR LARGE SCALE DIGITAL MAP REVISION CASE STUDY – UNIVERSITY COLLEGE OF LANDS AND ARCHITECTURAL STUDIES (UCLAS) CAMPUS

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ABSTRACT:

The need of making map revision arises due to the addition or removal of terrain features. The amount or percentage of features added or disturbed on the surface, plus their rate of change, may assist in the selection of the method to make revision. Basic principles, the procedures used and data collection techniques for up-dating digital topographical maps are discussed. The source map used in this study is the existing UCLAS paper map of 1994, which was drawn at a scale of 1:2,500. A conceptual model for digital map revision was developed and implemented in this study. The study was begun by digitising the source map. New features were added, features that no longer exist were deleted and changed features were amended to reflect the new situation. The Up-dated UCLAS digital map was finally printed (produced hardcopy) at the same scale as that of the source map. The results of the statistical analysis done show that 95% of the time, features will be less than 8.5 mm from their true positions, and only 5% of the time they will be more than 8.5 mm from their true positions. It was concluded that ground survey methods are sufficiently economical compared to other source of data (aerial or satellite imagery) in the revision of large-scale digital maps. Finally it is recommended that the Surveys and Mapping Division of Tanzania, and any other organizations that manage sizeable areas of land can use the procedure tested in this study.

1. INTRODUCTION

1.1 Background

With the primary scale of mapping becoming larger in order to cope with the developments, the work involved in keeping maps up-to-date has increased considerably. The rapid changes in the map contents and the need for up-to-date maps have compelled surveyors to focus their attention to the development of faster and more economical map revision processes. The UCLAS base map, which was used in this study, was produced from Aerial photographs dated 1982 and July 1992 at a scale of 1:2500. It was produced in the department of Geography and Topographic science, University of Glasgow, Scotland under supervision and direction of Dr. J A Briggs and Mr. M C Shend, senior Cartographer, 1994. It was printed by M & M Press Limited, Glasgow Scotland, 1994. Regular updating of printed products is not always practical because of the cost and time involved. However digital maps are so easily modified that they can be revised as frequently as one wishes.

1.2 Objectives

The objective of this study was to establish a procedure/system that will facilitate a fast (near to ON-LINE) and economical revision of maps. The system will also be used to make map information available at the required scale in forms appropriate to users need, i.e. maps can be produced at different scale and content depending on the purpose of the map. In the future, the system might be up-graded to have on-line communication with field crew.

In order to accomplish the above-mentioned objectives the following tasks have to be done. The first task is to make a digital map of UCLAS through digitisation of the existing current base map. Second is to design a documented procedure/system that will facilitate a quick and economic revision of maps. Third is to use the system to revise the current UCLAS base map as a case study.

2. MAP RESOLUTION AND ACCURACY

2.1 Map Resolution

In general terms, resolution is the ability to resolve, or separate, a particular object from other objects on a map. When used to describe vector data, resolution is the size of the smallest geographic entity that can be mapped at a given scale and still effectively communicate the entity's location and shape. When used to describe raster data, resolution typically refers to the size of the grid cell, or pixel; an object smaller than the pixel size cannot be resolved, or identified by the sensor as being separate from the object's surroundings. Similarly, the resolution of the computer screen used has an impact on the detail and accuracy of maps that are drawn on that screen. The screen uses pixels to draw maps, and can't draw features or parts of features that are less than a pixel wide.

2.2 Map Accuracy

The more accurate the map, the more it costs in time and money to produce. Some measurements of a map's accuracy are listed below:

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- The absolute accuracy of a map refers to the relationship between a geographic position on a map (a street corner, for instance) and its real-world position measured on the surface of the earth.
- Relative accuracy refers to the displacement between two points on a map (both distance and angle), compared to the displacement of those same points in the real world.
- Attribute accuracy refers to the precision of the attribute database linked to the map's features. For example, if the map shows road classifications, are they correct? If it shows street addresses, how accurate are they?
- A map's currency refers to how up-to-date it is. Currency is usually expressed in terms of a revision date.
- A map is complete if it includes all the features a user would expect it to contain. For example, does a street map contain all the streets? *Completeness* and *currency* usually are related because a map becomes less complete as it gets older.

3. MAP REVISION – AN OVERVIEW

A map of an area to be revised, it has to be outdated. The information whether the landscape has undergone changes or not can be obtained from different sources such as:

- Field check of existing map as compared to the real situation of the landscape
- The collection of changes reported by other authorities that use the map such as planners, engineers, travellers, etc.
- A new set of aerial photograph (in case of large/medium scale maps) and satellite imagery (in case of small-scale maps), by comparing the information on these with the existing features on the map.

3.1 Categories of Map Revision Systems

Continuous revision is not limited to certain time interval. The frequency of revision is determined by the amount of changes. For areas where changes in general are infrequent and minor in nature the continuous revision method becomes less efficient because uneconomic units of work would be surveyed. The method is applicable particularly for large-scale maps, and this is the system used in this study.

Cyclic revision is carried out in fixed time intervals. The major disadvantages of cyclic revision is in failure to take into account of variations in the rate of development between different areas or with different periods of time and inability of the mapping organization to meet users needs once the map begin to get out of date. This method of revision is applied particularly to maps at medium and small scales.

The periodic revision system combines some of the advantages of the continuous and cyclic methods but at the same time provides for a substantial reduction in the cost, which would be incurred if the continuous revision method were applied throughout areas of relatively slow change. The revision is related to an order of priority, the priority being determined by the urgency of the demand or the rate of change and not by fixed period of time.

3.2 Methods of Map Revision

There are three main methods applicable for map revision: Photogrammetric method, Satellite techniques and Ground survey methods.

3.2.1 Photogrammetric Techniques: The situation regarding map revision in Africa including Tanzania is that aerial photographs are costly and not readily available hence slow down the exercise of map revision.

3.2.2 Satellite Techniques: The advantages of using satellite images for map revisions are:

- They have a global coverage; fewer images are required to cover an area and hence reduce the number of control points required.
- Possibility of getting the data of an area after a short period of time (e.g. 26 days for SPOT satellite).

The satellite technique has a problem in identification and delineation of minor linear features e.g. streams, footpaths, bridges, power lines, telecommunication lines etc. Point features such as scattered trees and individual buildings, cannot be positively identified due to their relatively small dimensions compared to the resolution of the satellite images. Therefore satellite data can be used in map revision for small and medium scales only.

3.2.3 Ground Survey Method: The method is more useful and economical for revision of large-scale maps but it is impractical for small-scale maps. The method has the advantage of enabling the observation of information directly from the ground measurements instead of an image, but has the disadvantage of being time consuming and costly in term of manpower required to capture the data. Since the revised map in this study was a large-scale map, ground survey method was used in collecting data for the revision. A hand held GPS receiver combined with offsets would be ideal but due to lack of supply, a combination of bearing and distance method with chain survey method have been used. Bearing and distance have been used to fix the controls for picking of the new details and also to pick some of important details e.g. buildings like the library, department of architecture building etc. Other details e.g. electric and telephone poles were picked by chain survey method. The two methods have been used because they are easy to carry out and the surveyed area is small enough to make these techniques suitable.

4. METHODOLOGY

The methodology as conceptualised and implemented in this study is summarized in Appendix A.

4.1 Preparation of the Paper Map for Digitisation

Four distinct points were chosen and marked on the map with a pencil. Each point was given a unique number and the actual map coordinates of each point were recorded. The map was fixed with masking tape on the tablet. The layers identified in the existing map were boundaries, major contours, minor contours, hard bound surface roads, loose bound surface roads, footpaths, walkways, sports grounds, vegetation, text, administration buildings, classrooms, staff residential buildings, students hostels and services.

4.2 Digitisation

The beginning of digitisation sequence involves interactive entering of the terrain coordinates of the four selected distinct points. The digitiser coordinates are referenced to x and y coordinates of the table. Since the required coordinates are terrain coordinates, the digitiser coordinates are transformed to the map coordinates using affine transformation equation, which involves rotation (to align the map with the table axes), scale change, translations, and skewness (non-perpendicularity of the axes).

$$\begin{aligned} x &= aX + bY + c \\ y &= dX + eY + f \end{aligned} \quad (1)$$

Where: X, Y = coordinates of the points in the ground/map reference system
 x, y = digitiser coordinates
 a, b, d, and e = functions of rotation β , two scale factors S_x and S_y , and non-perpendicularity (or affinity (δ)) between the two axes of the digitising system
 c and f = translations

The relevant transformation parameters are computed by using the coordinates of the four digitised control points. In this study, the software used in digitising is AutoCAD release 12 and the tablet used is SUMMASKETCH III PROFESSIONAL. Point mode of digitising was used, which simply means that the operator selects the point to be digitised, after which he/she presses a button on the cursor to record the coordinates of the position of the cross hair. After the digitisation of the whole map, the results were stored in Data Exchange Format (DXF). Thereafter the results were transferred to the ArcView software for editing and further processing. Feature attributes were entered via keyboard after the topology had been checked and corrected. The original digitised UCLAS map is shown in Appendix B.

4.3 Inspection for Changes

This was done using manual field inspection involving the earlier produced map of UCLAS. Changes were marked on a copy of that map using a coding system to distinguish between additions and deletions of features. The procedure was done in a planned manner in which the map was divided into three blocks, and inspection done one block at a time.

4.4 Reconnaissance and Data Search

During reconnaissance, the following control points were identified UCLAS 013, UCLAS 014 and UCLAS 015. These were used as references to fix some more points, which were used to pick details. Data search was done to identify existing control points. In which sets of coordinates for UCLAS boundary points were obtained from the Ministry of Lands and Human Settlements. Also the coordinates for the ground control points, which exist in this area were obtained from UCLAS survey store.

4.5 Field Data Collection and Processing

The method used here is the ground survey method in which data were collected using a Total Station WILD TC1610 Number 372539. Points were fixed by bearing and distance

method from the reference points i.e. UCLAS 013, UCLAS 014 and UCLAS 015, located around UCLAS area. Then measurements to the details were picked from those fixed points in form of bearing and distances. Other details were picked by offset method from the existing permanent features. The measurements were processed using the Microsoft excel software, and the resulting position coordinates stored in database IV format i.e. dbf.

4.6 Entering the Changes in the Digital Map

The resulting positions above were added as tables in the ArcView Software. The tables were added as event themes in the View (i.e. the view containing the digital UCLAS map), and thereafter converted into shape files. ArcView uses the information in the table to locate features.

4.7 Cartographic Processing and Map Layout

The updated digital map was polished by editing the lines to make them neat, and place on it all necessary cartographic elements such as scale, border, text, inserts, legend, title, colour and patterns. Factors considered in order to balance the elements include the weight of the elements, line width, colour, text font etc. Proper arrangement of the elements produces appealing aesthetics and the look of the final map.

5. ANALYSIS OF RESULTS

5.1 Positional Accuracy Measure

The differences between the original control point coordinates and the new control point locations calculated by the transformation process, were used to calculate the Root Mean Square Error and the Standard Deviation as follows:

$$RMS_x = \left[\frac{1}{n} \sum (\delta x_i)^2 \right]^{\frac{1}{2}} \quad (2)$$

$$RMS_y = \left[\frac{1}{n} \sum (\delta y_i)^2 \right]^{\frac{1}{2}} \quad (3)$$

$$RMS_{xy} = \left[RMS_x^2 + RMS_y^2 \right]^{\frac{1}{2}} \quad (4)$$

Where: δx_i = x residual of the i^{th} ground control point
 δy_i = y residual of the i^{th} ground control point
 n = number of control points

A statistically more sound estimation of the accuracy is the standard deviation (σ)

$$\sigma_x = \left[\frac{1}{r} \sum (\delta x_i)^2 \right]^{\frac{1}{2}} \quad (5)$$

$$\sigma_y = \left[\frac{1}{r} \sum (\delta yi)^2 \right]^{\frac{1}{2}} \tag{6}$$

$$\sigma_{xy} = \left[\sigma_x^2 + \sigma_y^2 \right]^{\frac{1}{2}} \tag{7}$$

Where r is the redundancy, which depends on the degrees of freedom. A RMS Error (RMS_{xy}) of 0.0202m and standard deviation (σ_{xy}) of 0.0001m were obtained.

Common causes of big RMS error are - incorrectly digitised control points, careless placement of control points on the map sheet, and digitising from a wrinkled map. For accurate results, when digitising a control point, care was taken to make sure that the crosshairs of the digitiser puck was centred on the control point.

Positional accuracy of features was tested by overlaying some features e.g. boundaries, roads etc with a plot of the same features obtained from field measurements. When overlaying on the original digital map, discrepancies are seen as open spaces between the features on the original digital map and the plotted features. The discrepancies were measured and the results are shown in Tables 1 and 2.

Mid-interval value (m)	Frequency
0.010	1
0.307	5
0.604	6
0.901	11
1.198	14
1.495	9
1.793	2
More	2

Table 1. Discrepancies from overlaying operation

Statistic	Value (m)
Mean	0.702
Standard Error	0.072
Standard Deviation	0.519
Sample Variance	0.269
Minimum	0.010
Maximum	2.090
Sum	35.802
Count	51

Table 2. Summary of discrepancies from overlaying operation

5.2 Relative Accuracy from Distance Comparisons

Distances were measured on the ground and compared with their corresponding distances measured on the digital map using the “measure” tool in ArcView. The results obtained are shown in Tables 3 and 4.

Mid-interval value (m)	Frequency
-0.230	1
0.045	3
0.320	10
0.595	11
0.870	16
1.145	14
1.420	9
1.695	3
More	1

Table 3. Discrepancies from distance comparison

Statistic	Value (m)
Mean	0.572
Standard Error	0.064
Standard Deviation	0.545
Sample Variance	0.297
Minimum	-0.230
Maximum	1.970
Sum	40.619
Count	71

Table 4. Summary of discrepancies from distance comparison

5.3 Attribute Accuracy

A map may be perfect as far as spatial appearance is concerned, but the roads or rivers could both be mislabelled as power lines. Defined as the closeness of attribute values to their true value, note that while location does not change with time, attributes often do. Attribute accuracy must be analysed in different ways depending on the nature of the data. This type of error can be treated as misclassification. A thorough check was conducted to ensure that all the features are correctly classified.

5.4 Results

The results of this study are:

- A system that can be used for continuous revision of digital maps as shown in Appendix A
- A hardcopy of revised UCLAS map at a scale of 1:2500 (can be obtained on request)
- A revised digital UCLAS map with its database, which can be used, and also revised further

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Field survey is useful in digital map revision for large scales. The advantage of the use of field survey method is that both planimetric and vertical accuracy obtained is good enough for revision of large-scale maps. For small areas, field methods are fast enough and relatively low cost. However, in addition to the limitation to large-scale maps, the use of the method in remote inaccessible areas will be a problem.

6.2 Recommendations

Some local governments have or are in the midst of developing GIS but few of them have digital maps. From this study, in order to solve the problem of map revision, it is advised to use digital mapping techniques. Due to the large time gap between data capture in the field and produced map in analogue cartography, some maps become out-dated even at the time of their publication. Therefore with the use of digital mapping techniques, the time gaps between data capture and produced map will be minimised.

There are a lot of underground features at UCLAS, which need to be shown on this map in order to assist administrators, planners, managers, engineers, building contractors etc in their various planning and development issues. Therefore the system conceptualised in this study can be used to map the underground features onto the current UCLAS digital map.

In the future, there is a need of up-grading the conceptualised system so that it can have on-line communication with field crews. Then there will be established an on-line digital map revision system.

Any organization that manages a sizeable amount of land might use the system for revision of their maps. For example, the University of Dar-es-salaam, Sokoine University, Wazo Hill Cement Factory, Tanzania Breweries Limited (TBL), Coca-Cola Kwanza Company, Muhimbili National Hospital (MNH), Dar es salaam International Airport, Lugalo Military Barracks, Dar es Salaam Institute of Technology (DIT), Kilimanjaro Christian Medical Centre (KCMC), The Kilimanjaro International Airport (KIA), Kibo Breweries Ltd (KBL) and so on.

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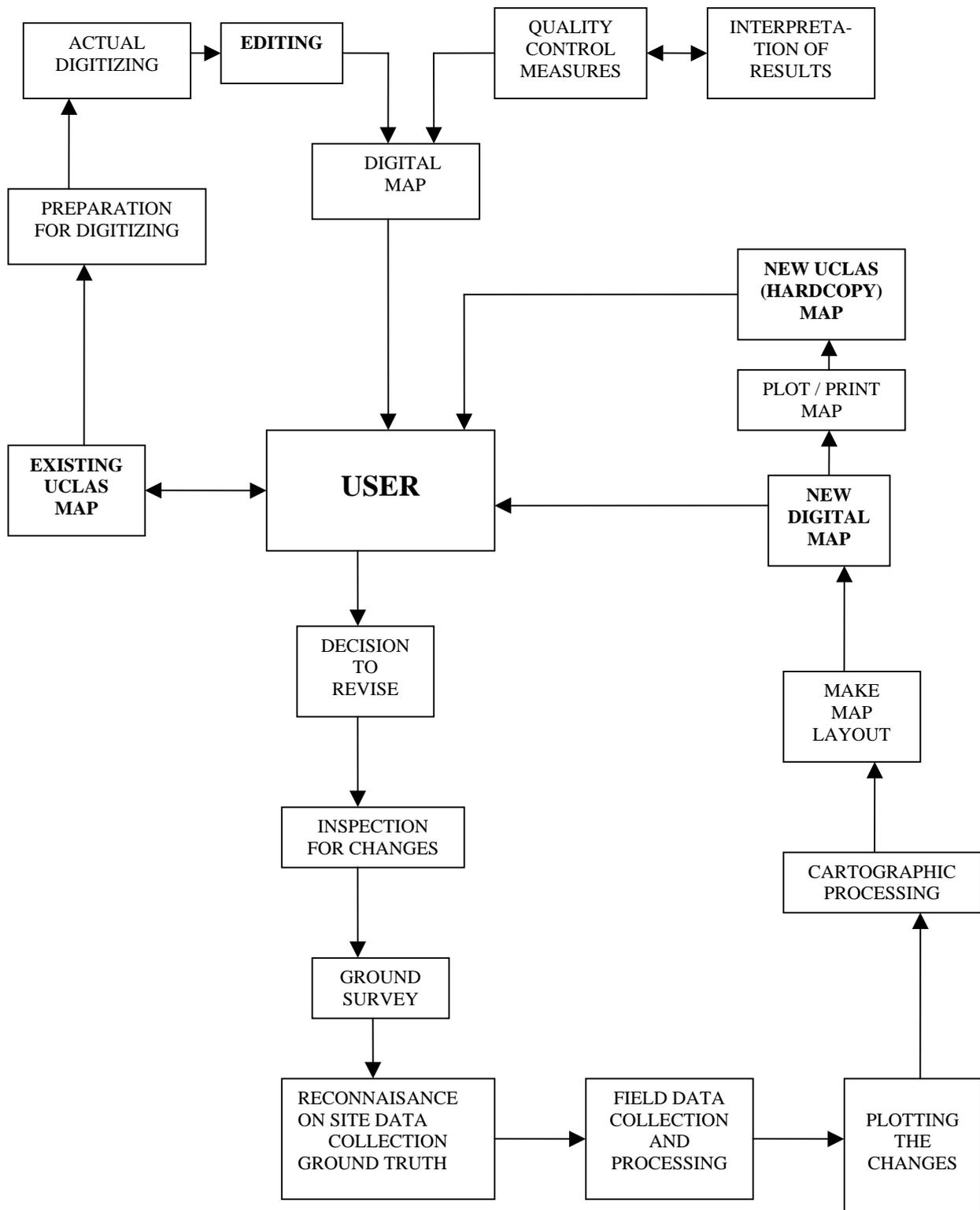
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APPENDIX A. AN IMPLEMENTATION MODEL FOR DIGITAL MAP REVISION



APPENDIX B. ORIGINAL DIGITISED UCLAS MAP

