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Map Conflation using Piecewise Linear Rubber-Sheeting Transformation between Layout and As-Built Plans in Kumasi Metropolis.

[1]Nathaniel Kojo Mensah Dawuso, [1]John Ayer, [1] Bright Acheampong

[1] Kwame Nkrumah University of Science and technology, GHANA?
dawusogolo60@gmail.com

dawusogolo60@gmail.com

vanasarnarastus@gmail.com

ABSTRACT

Context and background:

Accurately integrating different geospatial data sets remain a challenging task because diverse geospatial data may have different accuracy levels and formats. Surveyors may typically create several arbitrary coordinate systems at local scales, which could lead to a variety of coordinate datasets causing such data to remain unconsolidated and in-homogeneous.

Methodology:

In this study, a piecewise rubber-sheeting conflation or geometric correction approach is used to accomplish transformations between such a pair of data for accurate data integration. Rubber-sheeting or piecewise linear homeomorphism is necessary because the different plans' data would rarely match up correctly due to various reasons, such as the method of setting out from the design to the ground situation, and/or the non-accommodation of existing developments in the design.

Results:

The conflation in ArcGIS using rubber sheet transformation achieved integration to a mean displacement error of 1.58 feet (0.48 meters.) from an initial mean displacement error of 71.46 feet (21.78 meters) an improvement of almost 98%. It is recommended that the rubber sheet technique gave a near exact point matching transformation and could be used to integrate zone plans with As-built surveys to address the challenges in correcting zonal plans in land records. It is further recommended to investigate the incorporation of the use of textual information recognition and address geocoding to enable the use of on-site road names and plot numbers to detect points for matching.

Keywords:

Geospatial dataset, As Built Surveyed, ArcGIS, Rubber Sheet transformation, Geocoding

1.0 INTRODUCTION

Overlapping datasets from different sources could have positional discrepancies or potential conflicts between similar objects. These conflicts may be spatial even when the data sets cover the same areas and categories. The underlying process that generates these discrepancies is usually not all known and is most often non-homogenous in nature. The major challenges in aligning differing datasets accurately and automatically are from the fact that:

- the different data products may not align because they might have been collected at different resolutions;
- the data might have been collected and processed based on different spheroids, projections or coordinate systems;
- the data sets may have been collected using different procedures or methodologies which might lead to different precision or accuracy.

Using a uniform spatial reference when creating multiple spatial datasets could prevent these conflicts to a great extent. Nonetheless, using one spatial reference is almost impossible especially when there are several independent agencies creating the spatial layers based on their own internal needs and purposes. If the geographic projections of the various datasets are known, then they could be converted to the same geographic projections. However, often these are not known for most local coordinates especially. Furthermore, just converting datasets into the same projection would not address the inaccuracies between spatial datasets. Neither would it account for the non-homogeneity or distortions within the same datasets.

It becomes quite important to be able to effectively relate these spatial data sources with each other especially in GIS so as to re-create them within a common matching coordinate frame. However, the non-homogeneity of distortions between different datasets suggest that registration of the datasets should be performed using local transformations. The conflation process can involve:

i). feature matching of finding a set of conjugate point pairs in the datasets;

ii). match checking to detect inaccurate control point pairs from the set of control point pairs for quality control, and

iii). alignment or the use of the accurate control points to align the rest of the geospatial objects (points or lines) in both datasets by using the triangulation and rubber-sheeting techniques.

1.1 Research Problem

Over the years, local plans designed by the Physical Planning Department, when set out on ground and surveyed in some parts of Kumasi metropolis and its peri-urban environs, usually reveal distortions in positions on ground in conflict to the positions on the approved local plans. These occurrences have contributed enormously to the rampant land litigation in most of these areas where such distortions had occurred. Non-conformity of positions measured on ground from the approved planning schemes could often be the result of the generalised and exaggerated small scale maps used as base for the design of the zone plans which could have distorted positions of developments existing on site and perhaps to some extent also setting out errors in implementing schemes on site.

Nonetheless, the integration of cadastral plans and documents with the Local plans in creating a credible land records for management have become an albatross on Land Administration affecting the land records, the surveyor and the general public as a whole.

2.0 METHODOLOGY

The research methodology is categorized into two stages namely; Spatial Adjustment (Rubber-sheeting method) using Arc Map and Spatial Statistics (Least-squares) for modelling spatial relationship.

The first step is to standardise the input data sets by ensuring that the conflation data sets have the same data format, the same map projection, and the same coordinate systems. The data sets should have a number of conjugate features or points that would form the basis of common objects matching.

Map Alignment and edge matching - In this step, the spatial features in different data sets are put together and some transformation may be done to either so that the data describing the same object coincide. This step may use simple feature matching like node to node matching. The Rubber-sheeting iteration is performed at this stage. Feature Matching and Checking- This step recognizes the spatial feature correspondence of the two data sets by a criterion such as the nearest distance, or topological similarity and associated attributes. Object matching tolerances are set to ensure accuracy. To ensure the match is correct, match checking by other criteria is necessary in cases.

Spatial feature transfer involves recognizing common features of the different maps which and also those features which are not matched, new features can be added into the old map, or old coordinates can be updated. This application mainly exists in GIS spatial data updating.

Attribute transfer – The attributes in the source map file are transferred into the new or target files. Usually, attributes are transferred from the lower spatial accuracy map file to a higher accuracy map file. Spatial discrepancy elimination: a global adjustment of spatial feature coordinates in one or both data sets so as to eliminate the feature position discrepancies such as sliver polygons, shifts of features, etc. prior to final compilation.

3.0 RESULTS

The procedure presented in the methodology was tested with a survey of an as-built location within the study area using a set of spatially distributed homologous (conjugate) points spread throughout the test region as given in Table 1.

Figure 1 shows a composite map of the As-built ground situation and the zone plan (layout). The composite plan shows clearly the conflict between the designed zone plan and what is actually implemented on the ground. These differences result in difficulties in reconciling land records, as properties as built and surveyed, would not be appropriately recorded because of non-conformity to layouts. Most often however, these developments precede the layouts and ought to have been taken into account when the designs were being made. The result of these are that most plans occupied on the ground are never registered or recorded in the records and the records as held cannot be said to be accurate for conflict resolutions.

Table 1: Homologous (Conjugate) Points within study area.

POINT	NL	EL	NG	EG	POINT	NL	EL	NG	EG
A1	717507.7	669904.2	717540.6	669805.2	B7	717480.8	670304.5	717510.8	670244.1
A2	717444.2	669925.1	717449.7	669847.7	B8	717509.3	670395.6	717530	670331
A3	717428.6	669966.8	717440.4	669866.4	B9	717537.2	670484	717557.3	670430.2
A4	717447.1	670017.7	717464.7	669935.4	B10	717572.7	670598.6	717595.3	670510.9
A5	717469.2	670100.4	717488.5	670027.6	B11	717459	670628.9	717478.1	670563.6
A6	717500.1	670186.3	717515.4	670114.6	B12	717423.1	670519.9	717441.8	670467.4
A7	717529.6	670280.4	717542.9	670220.3	B13	717398.1	670432.3	717406.5	670368.1
A8	717558.7	670373.2	717566.6	670301.7	B14	717365	670344.3	717382.2	670284.2
A9	717585.6	670461	717604.8	670401.5	B15	717339.8	670268.2	717354.6	670203.6
A10	717621.5	670559.5	717631.6	670486.3	B16	717312.4	670184	717329.4	670121.5
A11	717631.9	670612.8	717659.2	670567.7	B17	717285.1	670100.4	717276.5	670081.1
A12	717682.7	670635	717691	670581.6	B18	717261.1	670026.7	717219.7	670043.2
A13	717733.9	670608.6	717782.1	670546.2	B19	717235.9	669947.7	717227.7	669908.9
A14	717704.6	670517.2	717749	670453.3	B20	717192.7	669871.6	717138.1	669832.5
A15	717675.3	670428	717721.9	670360.3	B21	717295.2	669812.2	717312.6	669732.7
A16	717647.8	670341	717685.9	670270.9	B22	717128.6	669956.2	717122.9	669858.7
A17	717619.2	670250.6	717657.2	670183.2	B23	717103.8	670007.9	717094.2	669941.2
A18	717567	670151.3	717621.9	670083.4	B24	717066.2	670125.5	717041.4	670068.4
A19	717558.7	670064.8	717587.7	669998.6	B25	717076.1	670157.1	717088.7	670111.4
A20	717534.4	669985.2	717564.6	669905.6	B26	717125.2	670197.7	717137.6	670136
B1	717332.1	669829.8	717342.1	669738.6	B27	717162.8	670233.2	717157.2	670173.9
B2	717356.4	669906.4	717370.5	669823.9	B28	717223.9	670305	717243.4	670242.1
B3	717379.5	669984.3	717402.6	669921.9	B29	717262.4	670378	717287.2	670314.4
B4	717406.4	670064.8	717427.3	670001.9	B30	717282.9	670467.4	717299.3	670402.3
B5	717430.8	670145.2	717452.1	670081.6	B31	717292.3	670561.8	717325.2	670503.3
B6	717456.4	670227.3	717478	670157.8	B32	717303	670652.9	717344.7	670586.4

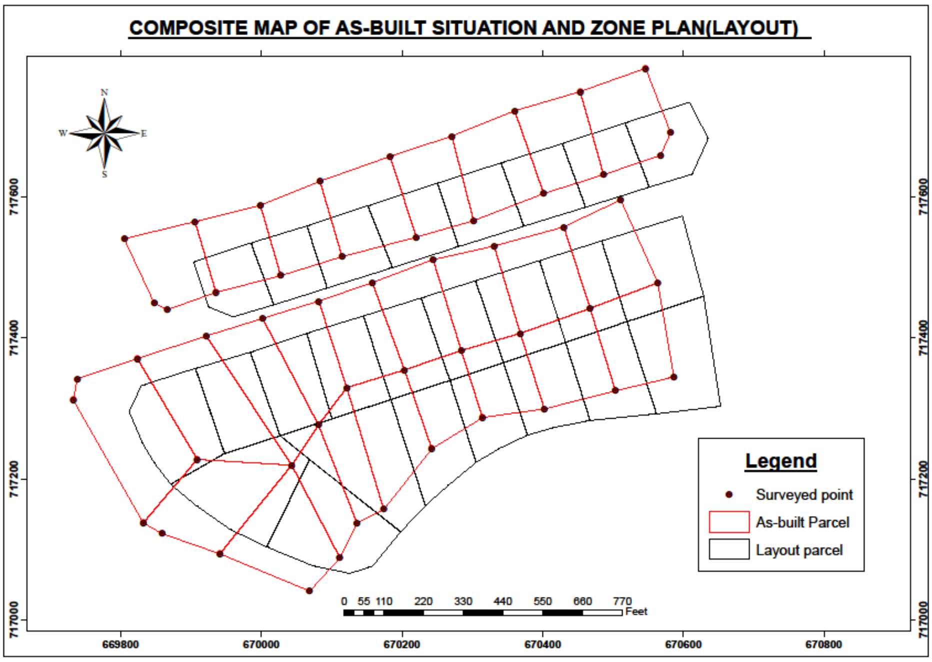

Figure 1: Composite Map of As-Built Situation and Zone Plan (Layout)

Analysis of the two plans show positional shifts as shown in Table 3:

Table 2 Discrepancies in Conjugate Point positions.

point	NL	EL	NG	EG	ΔN	ΔE	Distance Displacement (feet)
A1	717507.7	669904.2	717540.6	669805.2	-32.892	99.012	104.3324485
A10	717621.5	670559.5	717631.6	670486.3	-10.093	73.106	73.79943011
A13	717733.9	670608.6	717782.1	670546.2	-48.203	62.353	78.81259936
A16	717647.8	670341	717685.9	670270.9	-38.018	70.052	79.70351955
A19	717558.7	670064.8	717587.7	669998.6	-29.089	66.2	72.30912751
A4	717447.1	670017.7	717464.7	669935.4	-17.607	82.2427	84.1062908
A7	717529.6	670280.4	717542.9	670220.3	-13.352	60.1174	61.58228387
B11	717459	670628.9	717478.1	670563.6	-19.077	65.3	68.02956658
B14	717365	670344.3	717382.2	670284.2	-17.206	60.098	62.51252706
B17	717285.1	670100.4	717276.5	670081.1	8.67	19.317	21.17345954
B2	717356.4	669906.4	717370.5	669823.9	-14.05	82.543	83.73021766
B20	717192.7	669871.6	717138.1	669832.5	54.641	39.092	67.18499345
B22	717128.6	669956.2	717122.9	669858.7	5.748	97.526	97.69524134
B23	717103.8	670007.9	717094.2	669941.2	9.667	66.721	67.41767372
B24	717066.2	670125.5	717041.4	670068.4	24.849	57.044	62.22130453
B26	717125.2	670197.7	717137.6	670136	-12.431	61.687	62.92706675
B29	717262.4	670378	717287.2	670314.4	-24.844	63.63	68.30813448
B32	717303	670652.9	717344.7	670586.4	-41.723	66.404	78.42384806
B5	717430.8	670145.2	717452.1	670081.6	-21.321	63.645	67.12131603
B8	717509.3	670395.6	717530	670331	-20.634	64.57	67.78677493

Mean distance error = 71.46 - Standard deviation=16.56

As seen from these results, the displacements are not uniform but vary from place to place both in the eastings and northings. However, the distance displacement can be as much as over a hundred (104.33) feet at some places but also as low as twenty-one (21) feet at other areas (Figure 1). Also, the rotations as reflected in the easting and northing differences is also not uniform. This suggests that a simple similarity or affine transformation equation may not be appropriate for conflating the two results. To achieve an improved conflated result therefore, a piecewise rubber sheeting approach is suggested and used.

Figure 1 shows the results of the conflated or rubber sheeted map as overlaid with the as built-situation map. It is evident that the localized deformations have been appropriately filtered out by the rubber sheet conflation with the consequence of the improved intersection between the two maps.

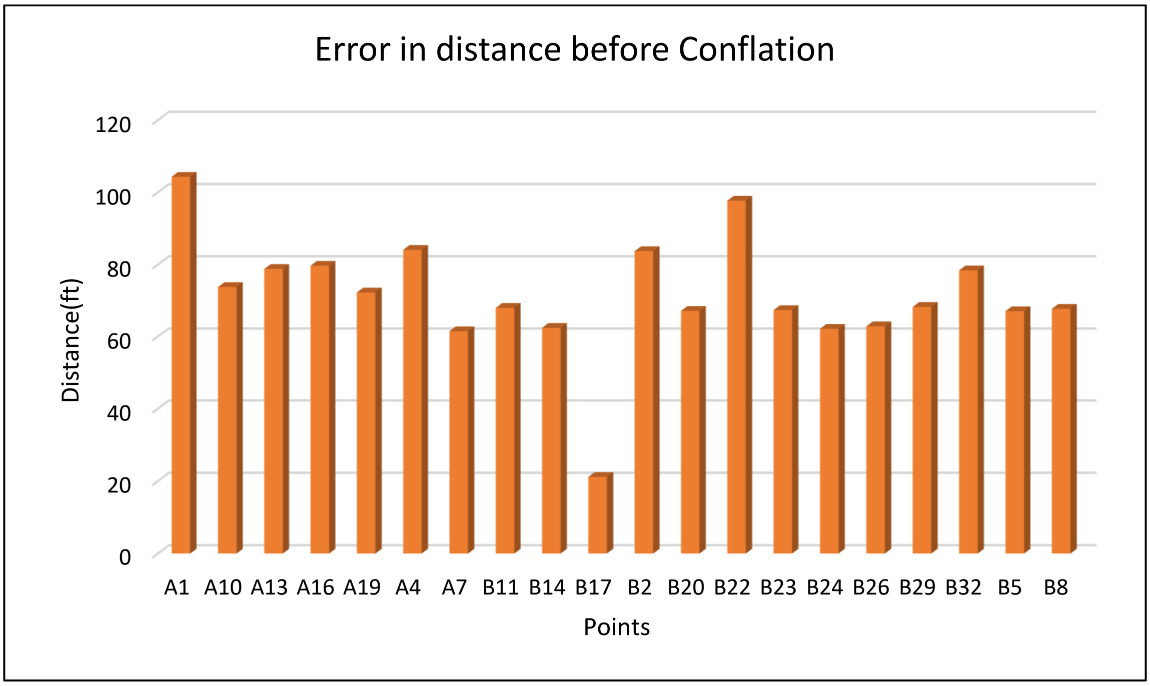

Figure 2: Errors in displacement before conflation

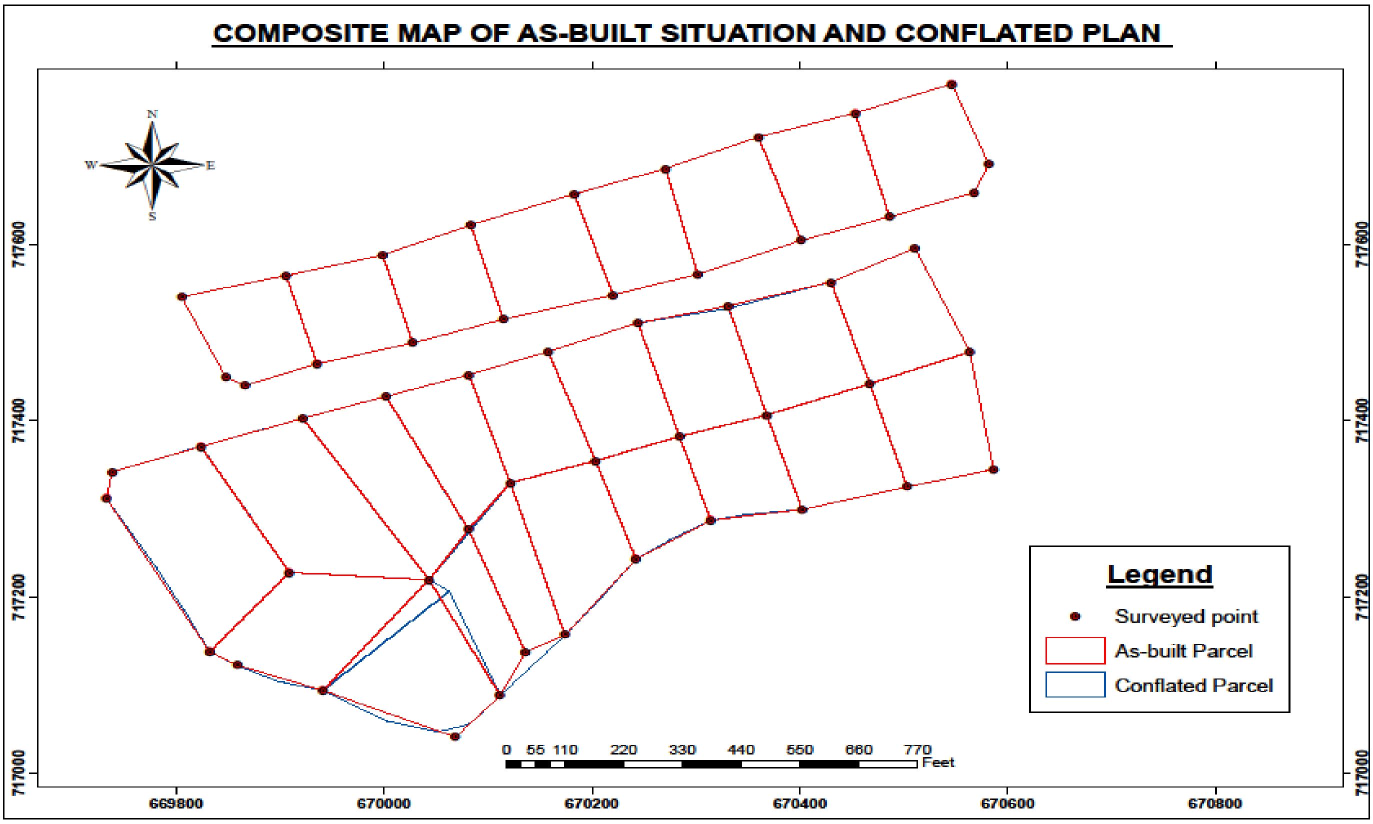

Figure 3 Composite Map of As-Built Situation and Conflated Plan.

The results (Figure 3) show only slight displacements after the application of the rubber-sheet transformation. The conjugate points used had exact fittings and hence show no displacement errors.

Some points in twenty (20) further points used as validation points have displacements of between zero feet and fifteen feet. The mean distance error after the transformation is 1.58 feet (Figure 2).

Table 3: Residual Errors after Rubber-sheet transformation.

point	POINT_E	POINT_N	NG	EG	ΔE	ΔN	Distance errors
A1	669805.2	717540.6	717540.6	669805.2	0	0	0
A10	670486.3	717631.6	717631.6	670486.3	0	0	0
A13	670546.2	717782.1	717782.1	670546.2	0	0	0
A16	670270.9	717685.9	717685.9	670270.9	0	0	0
A19	669998.6	717587.7	717587.7	669998.6	0	0	0
A4	669935.4	717464.7	717464.7	669935.4	0	0	0
A7	670220.3	717542.9	717542.9	670220.3	0	0	0
B11	670563.6	717478.1	717478.1	670563.6	0	0	0
B14	670284.2	717382.2	717382.2	670284.2	0	0	0
B17	670082.2	717274.3	717276.5	670081.1	1.142674	-2.13279	2.419610323
B2	669823.9	717370.6	717370.5	669823.9	0.051057	0.091574	0.104845671
B20	669832.5	717138.1	717138.1	669832.5	0	0	0
B22	669858.5	717122.6	717122.9	669858.7	-0.22351	-0.26409	0.34597665
B23	669941.2	717094.2	717094.2	669941.2	0	0	0
B24	670064.8	717050.8	717041.4	670068.4	-3.57447	9.456383	10.10940302
B26	670143.1	717123.5	717137.6	670136	7.132938	-14.1747	15.86819793
B29	670314.4	717287.2	717287.2	670314.4	0	0	0
B32	670586.4	717344.7	717344.7	670586.4	0	0	0
B5	670081.6	717452.1	717452.1	670081.6	0	0	0
B8	670331.8	717527.3	717530	670331	0.785496	-2.61711	2.732448344

Mean distance error= 1.58 ft.
Standard deviation = 4.09 ft.

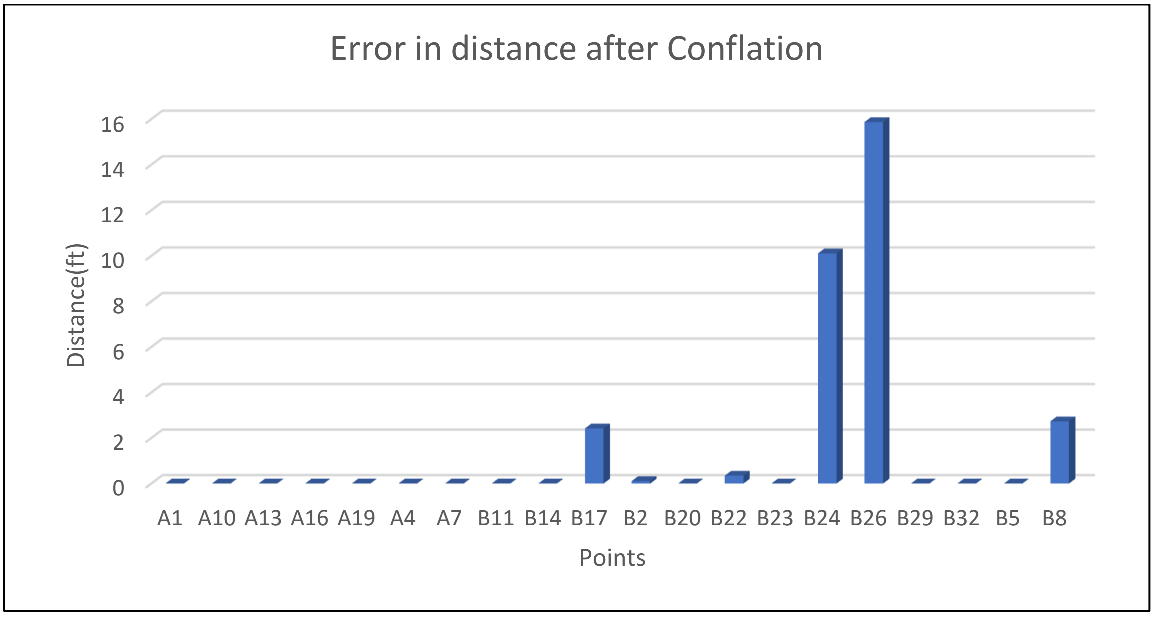

Figure 4 Error in displacement after conflation

5 CONCLUSIONS

In this work, vector to vector and vector to image conflation methods were used to achieve automatic and accurate registration between zonal plans and surveyed plans by exploiting multiple matched points and rubber sheeting tools in GIS. A set of conjugate point pairs, were identified in the zone plan.

For the vector to image approach, the image (scanned zone map) is georeferenced for correspondingly surveyed ground control points to generate as it were a template of vector data to match against corresponding points in the use of the rubber sheeting algorithms. Map and map conflation integrated multiple maps to generate a super map that integrates the attribution information from each of the individual maps, utilizing map intersection detection technique to identify matching points from each map. Then, selecting one as the source and the other as the target, the two-point sets are aligned using rubber sheeting technique.

The rubber-sheeting method was used to spatially adjust the Layout coordinates using ArcGIS desktop which was used to estimate coordinates for layout and Ground coordinates. This method of rubber- sheeting gave a good result which is more accurate in spatial adjustment. The developed model is a good model for transforming any layout coordinate to conform the one on the ground.

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Self funding

8. ROLE OF THE AUTHORS

Nathaniel Dawuso- Researcher

John Ayer- Supervisor

Bright Acheampong- Researcher

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10. KEY TERMS AND DEFINITIONS

Geospatial Dataset: This is a time-based data that is related to a specific location on the earth's surface

As-Built Survey: Is a record of location of the improvements as they are constructed on the earth's surface for Geospatial data capturing

ArcGIS: Is a family of client software, server software and online geographic information services developed and maintained by ESRI

Rubber Sheet Transformation: This is the process by which a distorted layer is allowed to be seamlessly joined to a adjacent geographic layer (vector cartographic data) of matching imagery

Geocoding: Is the process of determining geographic coordinates for place names, street addresses and codes