

# DEVELOPMENT OF AN INTEGRATED PHOTOGRAMMETRIC CAD BASED SYSTEMS (IPCBS) WITH EMPHASIS ON REAL-TIME PRODUCING OF GIS-READY DATA

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## ABSTRACT:

Photogrammetry offers suitable, reliable and accurate methods for gathering data and making 3D digital models, which have vast applications in design and implementation of information systems such as GIS. On the other hand, Computer Aided Design (CAD) systems are used for drawing, editing, and representing 3D geometric models of features. CAD editing functions are used for simplifying data-cleaning tasks before using them in GIS systems and topology building.

In the traditional photogrammetric procedures, after drawing raw map by photogrammetric instrument, several man-hours are needed for editing outputs and making them ready to be usable in CAD software or GIS environments. While for saving time and costs, if similar project is implemented by using integrated photogrammetric CAD-based systems, in real-time then map drawing and data editing steps to make it ready for GISs are carried simultaneously. A number of integrated systems have been developed so far, but they don't support all the data-cleanup tasks at the time of digitizing.

In this research, using a comprehensive logical data model and rules, IPCBS (an Integrated Photogrammetric CAD Based System) was designed, developed and implemented at Khaje-Nasir-Toosi University of technology. In order to minimize the editing procedure before using data for CAD purposes or GIS applications, IPCBS eliminates geometric and topologic errors, exactly at the same time of object digitization. Output of system can be directly entered to GIS or automatic cartography systems without any need for further editing process. Using IPCBS, there is no need for replacing traditional systems with completely digital ones and existing semi-analytical stereoplotters and analytical plotters, which are generally familiar for operators, can easily use these facilities. IPCBS can be accommodated by existing standard hardware and operating systems in IRAN and from financial point of view is economic.

IPCBS uses event-driven functions to process raw signals, which are received by encoders of plotters (semi-analytical, analytical and digital photogrammetric systems), and then modifies them according to predefined tolerance and its topological cleanup rules and finally converts them to standard format readable for CADs and GISs in real-time (during the digitizing time). These techniques were tested using simulated and real data on Zeiss Planicomp-P33 analytical plotter and MicroStation V5 (embedded CAD software). Output file of IPCBS were successfully tested in several GIS softwares.

## 1. INTRODUCTION

In traditional photogrammetric methods for map production, after drawing (from stereo models), a great deal of time should be spent for editing duties before being able to do simple works such as cartography or complex ones such as proximity analysis in GIS systems. Editing phase not only wastes the time and cost, but also decreases precision of data in some cases. However, systematic errors of CAD softwares due to improper setting of editing functions (e.g. thresholds, tolerance values, etc) and human mistakes always threaten data precision in editing phase. In the other hand, because of CAD user-friendly interfaces and other CAD tools (drawing, editing, storing, retrieving and 3D model creating of geometric data) users usually try to reduce geometric errors by applying CAD functions to simplify data cleaning tasks before importing data to GIS softwares. These data can be directly used in GIS systems for topology building and other analysis and processes. So, new trend is toward integrated systems.

Our implementation method in designing of integrated "CAD-based Photogrammetry" systems is to develop a modelling CAD functions inside a Photogrammetric instruments. This integration increases efficiency of Photogrammetry because of using advanced CAD modelling techniques at the same time of photogrammetric digitizing and improving user interface and possibility of working with data interactively.

### 1.1 Research Objective

Geometric process and topological error correction are our primitive goals of designing a CAD-based Photogrammetric system. Our objectives in this research are:

1. To examine theoretical problems and limitations associated with the use of traditional photogrammetric equipments and how CAD software can be combined to facilitate its evolution and subsequent automation;
2. To develop the necessary cleanup models and tools, ensuring the highest possible degree of applicability of system;

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3. To explain the feasibility and performance of the proposed integrated system, using simulated and real data. So, an integrated photogrammetric CAD-based system has designed and implemented, which can overcome most of deficiencies of existing integrated systems. Using existing (available) standard photogrammetric instruments and CAD systems, the operation design of this new integrated system is prepared. According to the operational design, required softwares are developed and finally designed system is completely tested on sample data and real digital data. After testing the operation of designed system, output data is exported to GIS environments successfully.

## 1.2 Organization of the Dissertation

In the following chapters, at first we'll explain IPCBS software, which is designed and implemented at the Geodesy and Geomatics Engineering Department of Khaje-Nasir-Toosi technical university. IPCBS is a powerful On-line CAD Based Photogrammetric system, which eliminates geometric and topologic errors, exactly at the same time of object digitizing. New real-time data cleanup method which is invented for IPCBS will be described in next chapter. In chapter 4, successful test of IPCBS on real data and its efficiency will be explained. We'll have a detail conclusion on subject of this research and then we will recommend future exploration that should be performed to improve data extraction ways in Photogrammetry, especially using integrated systems in the final chapter.

## 2. REAL-TIME PRODUCING OF GIS-READY DATA

### 2.1 IPCBS and Its Necessity

Extracting data and drawing maps by photogrammetric or integrated instruments often take long time. Raw output data should be edited to become usable for cartographic purposes and other applications (i.e. GIS). Therefore, there is a need for supplementary software to omit or modify the editing phase. If edit-step could be done exactly in time of object drawing then plenty of cost and time will be saved. This is our target. For this purpose a program called "Integrated Photogrammetric CAD-Based System", IPCBS has been written. This program is run on a computer which is connected to a PlaniComp analytical stereoplottor with MicroStation V5 platform as CAD system, under Microsoft Windows or MS-DOS operating system. IPCBS's output data are in DGN format, that can be easily imported to GIS systems (i.e. ArcInfo, LaserScan, Caris, ...) to be analysed, without need to any post-processing procedure.

### 2.2 Conceptual Model/Design of IPCBS

In IPCBS, PlaniComp P33's photogrammetric tools are embedded within MicroStation, thus with this system many modification (i.e. data cleanup) can be performed on objects and some topological relationships can be assigned to objects before inputting data to CAD kernel. According to this specification, the conceptual model is as follows:

1. PlaniComp P33 sends raw data to computer. When user digitizes by P-Cursor, PlaniComp's encoders convert these motions to electric signals and send these raw data to computer [Carl Zeiss Division of Photogrammetry, 1993].

2. These data is received through I/O port of computer and CAD program gets them as input.
3. Supplementary program (IPCBS) which is loaded in CAD program gets raw data and processes it. Data will change according to predefined cleanup rules.
4. IPCBS sends refined data to CAD database and features will be drawn in DGN file.
5. Final DGN file can be imported in any GIS software without any post-processing.

### 2.3 Technical Specification of IPCBS

First version of IPCBS is written in MDL version 5. MDL is MicroStation Development Language, which is a complete development environment that lets applications take full advantage of the power of the MicroStation's CAD engine. With MDL, we developed tightly integrated interactive application that run inside MicroStation. The user-friendly interface of IPCBS application gets required information (i.e. tolerance values and level settings, ...) from user. This application can be easily ported between hardware platforms. PCAP interface program of P33 analytical plotter should be residence in the memory, just after start of MicroStation. After that IPCBS program should be loaded and be residence in the memory [Carl Zeiss Division of Photogrammetry, 1994]. The IPCBS is an EVENT-driven program. An event may be any user input, for example when user sends keystroke or clicks buttons of mouse or tablet (P-Cursor) to send a datapoint or reset or even when user moves the tablet (P-Cursor) or mouse an event occurs and dynamically changes. All events input to MicroStation are gathered by the input handlers and put in the input queue. When the event reaches the head of the queue, the task ID dispatcher processes it. The dispatcher sends the event to the appropriate application for fully processing the event. Then PCAP interface will interpret the received data and convert it to another data, which is readable and acceptable for MicroStation. Now, IPCBS will take all the system under its control. IPCBS will get EVENT data from PCAP and compile it according to active command requirement.

After all, a customized command which is activated and needed arguments for running can start its work. For example, "phLStr" is a customized command, which is defined in IPCBS program, for drawing a new LineString, using P-Cursor's datapoints. Setting of level, color, style, weight and class will be according to IPCBS user settings. It works according to the following steps:

1. Performing initial photogrammetric tasks, which are orientations (interior, relative and absolute) and configuring the system settings using PCAP program;
2. Starting MicroStation and loading P33 interface program. MicroStation now is configured and recognizes P33 as an input/output device;
3. When user moves P-Cursor or sends a datapoint or reset by P-Cursor, PCAP's I/O interrupt handling module can sense and interpret it (MicroStation always would be suspicious for P-Cursor events while is running);
4. Next step is loading IPCBS program. This program will be resident in memory and suspicious for PCAP events (what PCAP interprets from status of P-Cursor);
5. IPCBS's customized commands can be entered by keyboard or user interface menu;
6. IPCBS's event handling function makes a decision on event, which is received from PCAP event handling function. If user input was 'Reset', then control will

- be going to step 3, but if user sends 'datapoint', cleanup module will be running;
7. After modifying the input signal according to cleanup rules, IPCBS sends required commands/data to MicroStation to draw Current point, as a part of a feature and this point's coordinates will be added to feature's point-list and we can see digitized point on screen, which is first point of a LineString;
  8. If MicroStation's active command is not being finished, then dynamic motion event hook will be activated, and one temporary dotted line will be drawn and when P-Cursor moves around the screen, this dotted line will be changes dynamically;
  9. Steps 6 to 9 will continue, until user sends 'Reset'. In this case, MicroStation's active command will be terminated. Next PCAP's data will say which command should be run by IPCBS;
  10. IPCBS will be pending until user closes the program. So, IPCBS always goes to step 5 and waits for another event;

Figure 1 illustrates flowchart of IPCBS program.

### 3. IPCBS'S DATA CLEANUP METHOD

#### 3.1 IPCBS Cleanup Module

"Cleanup module" is heart of IPCBS program. The main purpose of this module is REAL-TIME data cleaning. Assume that user has already picked a point by P-Cursor. Now, this point should be checked from cleanup and topological points of view. The main steps are as following:

1. Setting a search criterion surrounding the point, and beginning to search for linear objects;
2. Snap to nearest linear feature if exists in the search area using these rules:
  - a. If a node/vertex of linear feature exists, that node/vertex would be selected as start point;
  - b. If none of vertices of founded linear feature are exist in the search area; then it would be snapped to the linear feature perpendicularly, and one node will be generated at that point on the linear feature;
3. Store this point in the LineString's point list, and in buffer of DGN also;
4. Draw a temporary dotted rubber band line from previous point to anywhere user moves the P-Cursor, (erase last temporary line at each motion of P-Cursor);
5. Request for another point;
6. Check if this point is not located at the location of previous point; (Caused by double click). If X and Y of second point are as same as the first point, another module checks whether the Z values are different then a warning will be send to user to check his input data, because the spatial distance is not zero and in this case, duplication may be correct (for example in digitizing building with different floors in different elevation). But if X, Y and Z of both points are almost same then program will give a message to user and ask him to confirm whether he needs this point, or not. If user needs this point, it will be added to the DGN buffer and point list of LineString for drawing in future. If user does not need this duplicate/near point, then this point will be ignored and control will go to step 4;

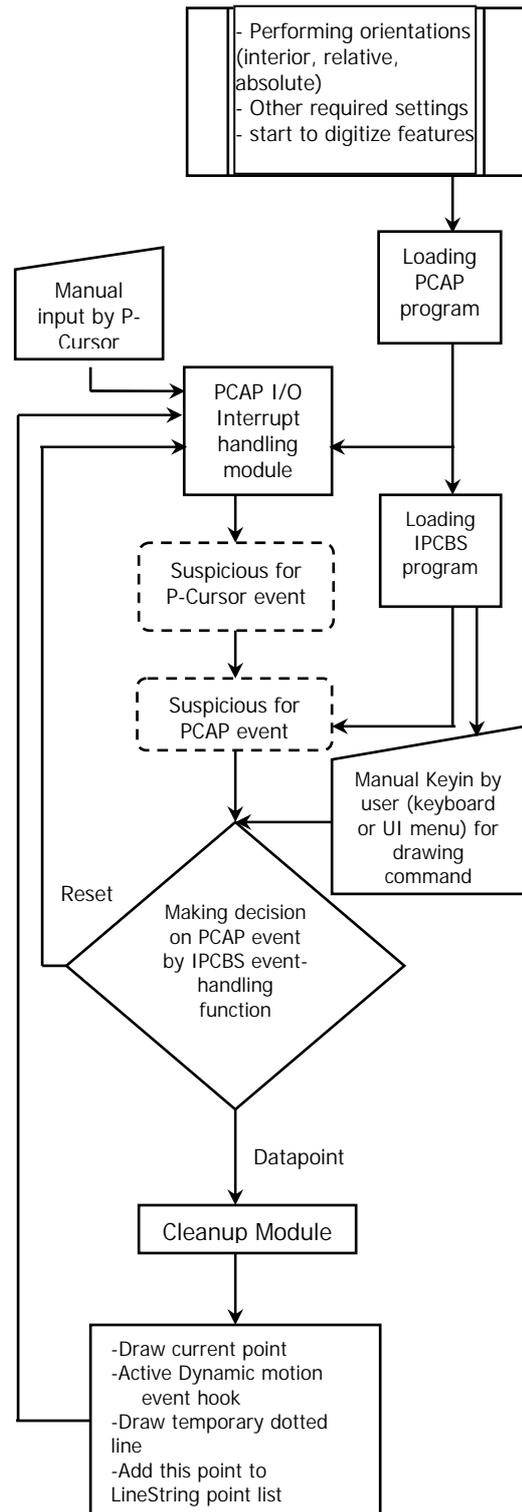


Figure 1. Flowchart of IPCBS program

7. Setting a search criterion surrounding this point, and beginning to search for linear objects (with tolerance dimension);
8. Snap to nearest linear feature in the search area if any exists (using rules mentioned in step 2), go to step 3;
9. If no linear feature exists in the search area, then go to step 3;
10. Go to step 4 and repeat the entire task from step 4 to 8. After third datapoint, if distance between current

point and first point is less than the predefined tolerance, then LineString will be closed and, all points of LineString will be drawn from DGN buffer and control will go to step 14;

11. If user sends a RESET by P-Cursor, then LineString's point list will be closed and all of its points from DGN buffer will be drawn in file and on screen;
12. The assigned buffer of DGN will be free now;
13. Another search area will be defined according to range box of the newly drawn LineString and program will search in this new criterion area to find intersected linear features. For each linear feature in the new search criteria, program will do these steps:
  - a. Finds the intersection point(s) between this (new) element and founded feature and store these points in an array;
  - b. Generates node at each intersection points of array on the newly created element and splits these elements to two elements;
14. Program will automatically call the Active Command again, and control will go to step 1 (while user does not close the program, and while user doesn't change the Active Command).

Figure 2 illustrates flowchart of cleanup module.

### 3.2 Errors and IPCBS's Solutions

In IPCBS, an errorless automatic cleanup method has organized to cover data editing tasks categorized in table 1.

IPCBS program doesn't cover the following errors, because some of them just can be corrected after digitization and other ones are optimization tasks rather than critical errors:

1. Converting features with complex geometry (i.e. B-Spline) to simple one (i.e. LineString);
2. Editing of hydrographical features (editing streamlines and ridgelines according to ridges of contour line);
3. Best fitting curves (replacing sharp polylines by smooth one);
4. Squaring Angles that are near quadrant angle;
5. Height-point editing according to elevation of its adjacent contours;
6. Alignment editing (e.g. building features alignment error).

## 4. QUALITY OF IPCBS'S OUTPUTS AND ITS EFFICIENCY

### 4.1 Test of IPCBS's Output

Several tests were carried out on simulated and real data (aerial photographs) for examining outputs of IPCBS (under Zeiss Planicomp-P33 analytical plotter). After debugging and testing the operation of IPCBS with simulated data, program was installed to be checked by real data. In the main test, two photographs were used with the following specifications:

Camera: WILD 15/4 UAGA-F (Nr 13180)  
 Focal length: 153.4 mm  
 Time of imaging: Feb 1994  
 Region: Tehran  
 Scale: 1:3000

Output file after data reduction using IPCBS was tested in two famous GIS software, ArcInfo 8.0 and ArcView 3.1. The results were completely satisfactory. No geometric error (i.e.

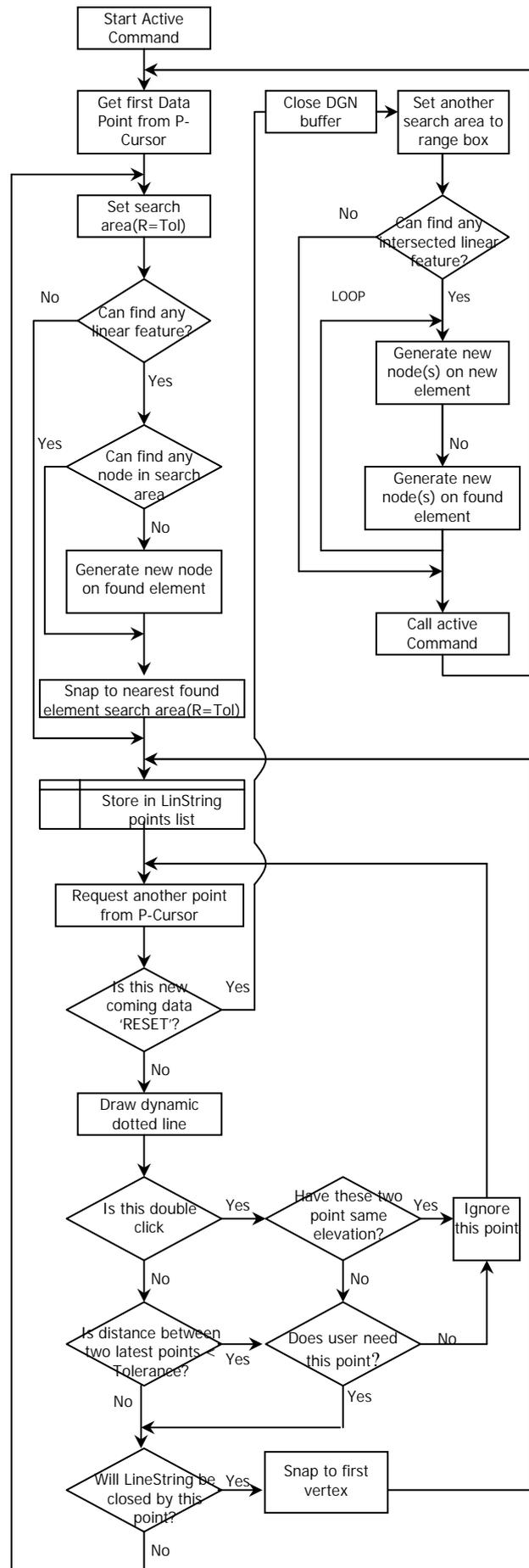


Figure 2. Flowchart of Cleanup module

overshoot, undershoot, pseudo node, intersection error, etc.) has been seen and data were ready to create topology in ArcInfo. Also output DGN file coming from Planicomp-P33 analytical plotter was imported in ArcView 3.1 directly using CADReader extension of ArcView (that extends ArcView to support viewing, querying and analyzing CAD drawings). All the polygon features were imported as polygon shapes that clearly shows there is no need for post-processing (i.e. removing dangles, extending undershoots, etc.) to make closed polygon objects. Linear objects also were imported to ArcView environment without any problem.

Error Type	Error Description [Molkaraei, 1999]	IPCBS's Correction Method
Duplicate objects	Objects that share the same start and end points as well as all other points (even if two objects have different linear directions) within the tolerance.	Puts error flag (user must confirm for deleting one of those)
Short objects	Any objects (not small texts and centroids) shorter than the specified tolerance.	Doesn't let to draw(or gives warning)
Crossing objects	Objects that cross each other with no nodes at crossing.	Breaks those at their intersection.
Undershoots and Overshoots	Objects that come within the specified tolerance radius of each other but do not meet (Undershoot). Objects that pass each other within the specified tolerance (Overshoot).	Extends undershoots and snaps overshoots; generates a new node at intersection if there is no node.
Clustered nodes	Any nodes within the specified tolerance radius distance of each other.	Snaps those to centremost node.
Sliver polygons	One segment of one linear feature is located near another, which they generate a small narrow virtual polygon.	Doesn't let to occur (treats those as same as duplicate objects)
Polygon closure [Neto, 2001]	Polygon edges does not reach each other at their endpoints	Snaps two endpoints of polygon.
Pseudo nodes	Any nodes shared by only two objects.	Dissolves pseudo nodes and joins two objects.
Dangling objects	Objects with at least one end point that is not shared by another object.	Doesn't let to draw (or puts error flag).
Complex linear objects (line weeding)	Complex linear objects are those that contain many interior vertices fall within the specified corridor tolerance. (Branching points, dead ends, and endpoints of polylines are not generalized.)	Doesn't let to draw (or sends a warning message)

Table 1. Cleanup errors and corresponding correction methods

## 4.2 IPCBS's Efficiency

For comparison between traditional photogrammetric procedures and using an integrated system like IPCBS, a real case is chosen. Tehran GIS Center (TGIC) has started to establish an urban Geographical Information System for Tehran metropolis the capital of IRAN. Main purpose of this project is managing Tehran municipality services and implementing the Master Plan of Tehran. For this purpose, during years 1993-1995, a project was scheduled and they started to prepare large-scale maps (1:2,000) of Tehran using photogrammetric method. This project was scheduled according to existing traditional equipments. So, the main designed steps for producing maps were:

1. Planning;
2. Image reduction (Photogrammetry phase);
3. Data editing (Editing for cartography and making data GIS-ready);
4. GIS analyses.

In image-reduction step, raw data were digitized using photogrammetric instruments while in data-editing step data were refined to become ready for cartographic or other purposes. These two steps were the main steps allocated themselves most of time and costs.

Extracting and drawing of maps by using photogrammetric instruments started in 1995 and finished in 1997. Editing step was started in early of 1996 and finished in 1998. After this step, one project was defined which was called "Organizing of Maps". The aim of this project was preparation data for importing to GIS environments, or making them "GIS-ready". This phase started in 1998 and finished in 2001. After all, GIS analysis and using these data for several applications have started in 2001.

While if similar project is designed to be implemented in future, we recommend using integrated systems like IPCBS, because 'data-editing' step and making 'GIS-Ready' step aren't necessary. This not only reduces the required time for map production, but also saves costs. Thus, in Tehran case, all of those five phases can be reduced to three phases and Editing for Cartography step and Making GIS-Ready step will not be necessary any more. This investigation shows the benefit of using integrated system (i.e. IPCBS) in saving time and cost.

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusion

Photogrammetry introduces the fastest, cheapest and most accurate methods for gathering data, analyzing them and making 3D models. In the other hand, CAD software has many utilities for viewing, maintaining and data editing (for example those offer us many viewports, perspective views, precise measuring of length and area and volume, etc.). Thus in many applications (e.g. industrial), integrated systems have shown their necessities, especially where we may be obliged to prepare a map or 3D model of some inaccessible objects, or where we are enforced to work in the hazardous environment and other techniques of data capturing (i.e. tachometry) are useless [Chapman et al, 1992].

In this research, due to advantages of integration of photogrammetric systems and CAD systems and in order to minimize the editing procedure before using data for CAD purposes or GIS applications, IPCBS (Integrated Photogrammetric CAD-Based System), a powerful On-line CAD Based Photogrammetric system were designed. IPCBS

eliminates geometric and topologic errors exactly, at the same time of object digitizing and drawing. IPCBS is the software which can be accommodated by any existing hardware, software and standards and also from financial point of view is truly economic. In this system, photogrammetric tools of an analytical plotter (i.e. PlaniComp P33) are embedded within CAD program (i.e. MicroStation), and in addition some modification can be performed on objects (i.e. data cleanup) and some definitions (i.e. some of topology relationships) can be assigned to objects before inputting data to CAD kernel. Outputs of this system can be entered to GIS systems or automatic cartography systems without need for further editing process. This software can be accommodated by existing hardware, software and standards and from financial point of view is economic. These techniques were tested using simulated and real data. Output file of this program tested in several GIS softwares (i.e. ArcInfo 8.0, ArcView 3.1). The results were completely satisfactory.

Following geometric errors can be removed by IPCBS program:

- Removing overshoots and undershoots;
- Nodes editing (clustered nodes or mismatches at nodes);
- Dissolving duplicates/overlaps;
- Removing virtual sliver polygons;
- Edge matching error;
- Intersection processing (crossing objects error and polygon closure error and dangle error);

Geometric data will also be optimized in the following ways:

- Thinning (line-weeding);
- Removing small elements.

## 5.2 Recommendations

Since, post-processing step for data editing will be omitted by using integrated systems, so we propose use of integrated systems in all the photogrammetric projects to collect accurate geometric data, without any topological and cleanup errors, in order to import data directly and real-time to CAD software or GIS environments. The future exploration would improve the performance of the cleanup techniques already discussed in previous chapters. Future studies should propose real-time solution for following tasks in IPCBS cleanup module:

- Converting features with complex geometry to simple one (stroking or simplifying features with complex geometry like B-Splines);
- Best fitting curves (replacing broken polylines with smooth one);
- Squaring angles near quadrant angles;
- Editing of hydrographical features (editing streamlines and ridgelines according to contour line);
- Contour-line editing;
- Height-point editing;
- Alignment editing (e.g. building features alignment error);
- Special functions for finding missed features at the time of digitizing (stroke);
- Some modules for classifying feature attributes (i.e. layer, color, style) at the time of digitizing;
- Defining priority for features according to predefined instructions and importance of features. Because some kind of features should be allowed to extend or snap more and some should be less.

Using knowledge-based techniques in integration of CAD and photogrammetry systems is the next target. Knowledge-based techniques provide constraint-based modelling in CAD

environment and accurate measurements in digital photogrammetric workstations [El-Hakim & Westmore, 1992].

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