University of Redlands

Creating an Automation Tool for Checking Data Integrity of CAD Files

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

by

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February 2016

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Acknowledgements

I first want to thank the Lord Jesus Christ for giving me the strength and perseverance to make it through this program. I would also like to thank my lovely wife Molly, for standing by my side day-in and day-out through the last two years. You made getting through this program easier, and I love you more now than when I started. My kids; I would like to say thanks for allowing me to spend the last two years of my life finishing this degree. You knew how important it was to me and allowed me to spend time away from our quality time together. I would like to say a special thanks to Ed Hunt, Rick Lantis, and the County of Riverside for being flexible with my work schedule so I could accommodate this demanding program. Lastly, I would like to thank my advisor Dr. Ruijin Ma, Professor Nate Strout, and the MS GIS faculty for mentoring me and providing me the tools and skills to succeed.

Abstract

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Boundaries of land have been documented and recorded throughout history dating back over 2000 years ago. Land has been an important commodity throughout time, and a move toward building a coordinate-based land cadastre has been implemented in other countries across the world. It is used in parts of Europe, British Columbia, and the Middle East to manage land records. The County of Riverside needed a process for checking and reporting surveyed land divisions that were submitted in the form of computer aided design (CAD) files, and loading them into a geographic information system (GIS). The current CAD data submitted had errors with the geometry, and in most cases did not have a projected coordinate system. Most of the CAD files were not used for their intended purpose: which was to be shared with the Riverside County Assessor's staff to aid them in creating and updating their Assessor Parcel Layer. Without the digital data the Assessor's staff followed its business practice of re-entering the parcels one at a time. This created redundancy of work since the same data supplied by the Land Surveyor or Civil Engineer was identical. Some of the problems listed above uncovered the need to come up with a digital submission standard, and an automation tool to help prepare the data for loading into the Parcel Fabric. The goal of the project was to create a tool that will automatically check the surveyed land division for compliance prior to approval; this tool is named County Automated Terrestrial CAD Helper (CATCH). CATCH uses GIS technology to automatically identify mapping errors and report these errors back to the Land Surveyor or Civil Engineer who created the data. CATCH has been well received by the professional engineering community, from a series of stakeholder meetings held at county offices to introduce the project to private industry professionals and county staff. These meetings were critical in the success of CATCH, and helped bring up issues that the industry have had in submitting their digital files in the past. Also, CATCH could be well suited as the platform for tracking and maintaining other county assets in a GIS such as: grading plans, storm drains, gas lines, and other critical utilities that come in the form of digital CAD files. The problem that was solved was having an accurate foundation: and that being the boundary survey tied to a CAD file that utilized global navigation satellite system (GNSS) and global positioning system (GPS) technology.

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List of Acronyms and Definitions

AGOL	ArcGIS Online
AEC	Architecture Engineering and Construction
BLM	Bureau of Land Management
CAD	Computer Aided Design
CATCH	County Automated Terrestrial CAD Helper
CCS	California Coordinate System
COGO	Coordinate Geometry
CONUS	Coterminous United States
CORS	Continuously Operating Reference System
COTS	Consumer off the Shelf Solution
DXF	Digital Exchange Format
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GRS80	Geographic Reference System of 1980
GUI	Graphical User Interface
LGIM	Local Government Information Model
NAD83	North American Datum of 1983
NGS	National Geodetic Survey
ORTHO	A digital rectified image that has distortion removed making the image scalable and measurable
OS	Operating System
PRC	Public Resources Code
XML	Extensible Markup Language

Chapter 1 - Introduction

The Parcel Fabric is a layer developed by the Earth Science Research Institute (Esri), for use in their GIS products that help maintain land records for local government entities across the world. Typically, the county or city surveyor is in charge of maintaining and checking land divisions for their respective municipalities which are submitted for approval and recordation. These physical records come in the form of linens, mylar, and paper. Figure 1-1 is a snap shot of a recorded Tract Map in the County of Riverside.

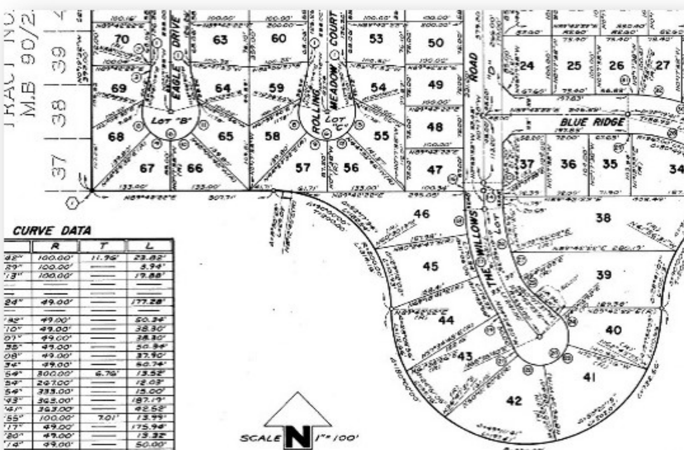

Figure 1-1: Image of a Recorded Tract Map

Most local government agencies have moved toward scanning their records and making them available digitally in the form of GIS web maps or web mapping applications. Some agencies have taken this one step further by accepting computer aided drafting (CAD) data to be used in their respective GIS systems. Being able to bring these highly accurate CAD files into the Parcel Fabric improves the accuracy of the land records system.

1.1 Client

The County of Riverside is located in southern California. The county was established in 1893 and, according to the 2010 census, the population was 2,189,641 (Registration Services, Registries Alberta Government Services, 2000). Riverside County covers an area of approximately 7,300 square miles and consists of over 800,000 assessed parcels. Both maintenance and input of these parcels are managed by the Riverside County Assessor, Clerk, and Recorders offices.

The Transportation Land Management Agency (TLMA) is made up of five departments: Building and Safety, Code Enforcement, Planning, Environmental Programs, and Transportation. Mr. Rick Lantis, the County Surveyor for the County of Riverside, was the client for this project. He manages the County Surveyor Division and is responsible for all land surveying functions within the Transportation Department. The client's department reviews land divisions (Parcel and Tract Maps), rights-of-way, parcel mergers, records of surveys, and lot line adjustments. These land divisions are submitted by applicants seeking to subdivide or build upon their respective parcel(s). Currently, Parcel Maps or Tract Maps (survey-plat) are submitted to the client in a digital format. This survey-plat comes in the form of a CAD file as depicted in Figure 1-2, which is a replica of the hardcopy map. After submittal, the file is reviewed, approved, and the survey-plat is entered into the County's parcel layer by the Assessor's office.

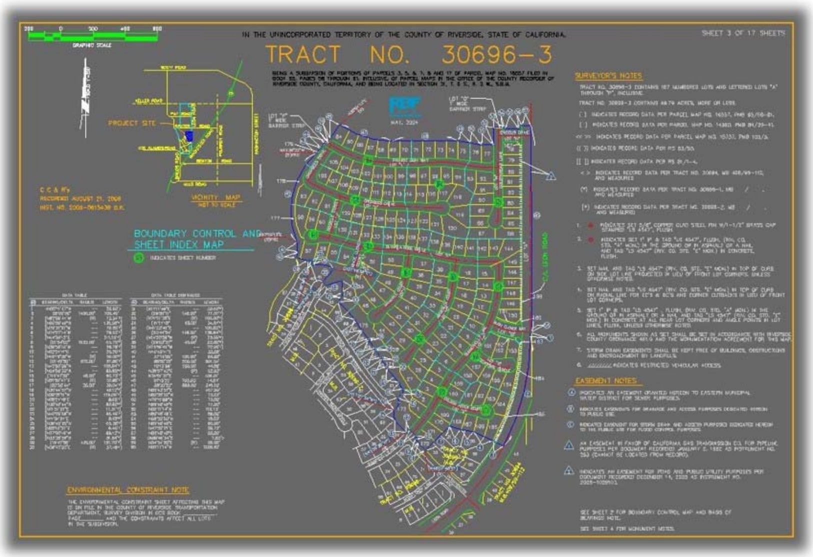

Figure 1-2: Example Survey-Plat Submitted to the County Surveyor

The client was responsible for providing the digital survey-plats used in this project. The client supplied periodic input and also provided the software and hardware needed to complete this project.

1.2 Problem Statement

Departments at the County of Riverside rely on digital parcel data to make day-to-day decisions that affect county residents. Currently these departments are using a GIS that is inaccurate, as parcel lines are not accurately displayed. In one instance county staff approved a grading permit for a parcel that was in a flood plain. The GIS showed that the parcel was outside the flood plain, but the GIS parcel lines being over 250 feet from their correct location caused an incorrect decision to be made, thus costing tax payer's precious time and money, and stalling the permit process for the applicant. Figure 1-3 depicts an example where the survey controlled imagery does not line up with the parcel lines.

Figure 1-3: Survey Controlled Imagery vs. Parcel Lines

A separate project named The Assessor Parcel Accuracy Project (APL) was implemented to improve the accuracy of the County's parcel layer. The APL project used high-accuracy survey control, CAD data from the client, and survey-grade ortho-imagery to adjust the parcel lines. To make all this work, the APL used Esri's software product named the Parcel Fabric as a solution to adjust the County of Riverside's inaccurate parcel lines. Figure 1-4 depicts an example of the final outputted information in the Parcel Fabric.

Figure 1-4: Example Parcel Fabric

The APL also used some of the CAD data from the client, but due to format and other errors with the data, the APL project could utilize only a few of the hundreds of survey-plats that were provided. This created a problem for the client, and revealed that the current business practices in place to submit the digital survey-plats were not working. In their current state, the CAD files could not be used by the APL project or the County Assessor. In order for the client to keep up with the current technologies and be able to check whether CAD data is ready to load into the Parcel Fabric, an automation process was needed to help make the process more efficient.

1.3 Proposed Solution

The approach to this problem was to develop a tool that can automatically check the digital survey-plat prior to approval. The tool that was developed for this solution was named County Automated Terrestrial CAD Helper (CATCH). CATCH is an ArcGIS geoprocessing tool written in Python. This tool created an automation script that reads the digitally submitted survey-plat and reports errors back to the industry professional Land Surveyor or Civil Engineer (applicant) who submitted the CAD file. These errors are sent back to the applicant as a Zipped file containing a PDF map, report, and a CAD file containing line, point, or polygon errors. Once the errors are fixed, the applicant can re-submit the survey-plat for approval. After the file is approved by CATCH it is then forwarded to the Assessor's office for input into the County's Parcel Fabric layer.

1.3.1 Goals

The goals of this project were to set a digital submission standard for the County, automate the checking process, prepare parcels for loading into the Parcel Fabric, and improve the integrity of the GIS for the County of Riverside.

1.3.2 Scope

The scope of this project was defined by the client. He wanted to create a tool that would automatically check the survey-plat, report any errors back to the applicant, and have the data in a format that is ready to load into the Parcel Fabric. The tool is not responsible for correcting CAD files; it identifies any corrections required and the applicant is responsible to make revisions and resubmit the digital files through the developed tool until approved.

The process begins when the applicant submits a digital file to CATCH in the form of an e-mail or CD delivered to County staff, who then input the information into CATCH. The results are sent back to the applicant in the form of an e-mail containing the Zipped results.

The hardware used were County Servers, and a laptop provided by the client for development and testing of the tool. The software used was ArcGIS for Desktop version 10.3, Model Builder, ArcPy, Python Scripter 2.7, MicroStation V8i Select Series 2, Autodesk Civil 3d 2016, and ArcGIS SQL server 2014. The data consisted of previously submitted survey-plats in the form of MicroStation and Autodesk CAD files.

1.3.3 Methods

The general steps that were used to achieve the objectives for this project included implementing the waterfall approach for project management. This approach takes into consideration the following four steps: identify the functional requirements for CATCH, design the geoprocessing script, create ArcMap map document files as templates with dynamic tables and text, write the Python script, and create the graphical user interface.

1.4 Audience

This report is intended for any local government agency wanting to adopt a digital submission standard for land divisions. This report does not use any consumer off the shelf solutions (COTS) other than Esri's ArcGIS for Desktop version 10.3. The audience should be well versed in the variety of products developed by Esri and should have a working knowledge of Python. Anyone should be able to read and understand the concepts introduced, but CATCH is designed to be used by Land Surveyors, Civil Engineers, or GIS professionals who use highly accurate survey grade digital data on a day to day basis.

1.5 Overview of the Rest of this Report

The rest of this report is broken down into the following chapters. Chapter 2 describes the background, the literature review, and similar projects related to CATCH. Chapter 3 introduces the systems analysis and design. Chapter 4 introduces the database design. Chapter 5 discusses the implementation. Chapter 6 covers the results. Chapter 7 discusses the conclusions and future work.

Chapter 2 – Background and Literature Review

Digital information flows through all aspects of our daily lives. Most businesses rely on digital data as a fundamental product for consumption and delivery (Haanen, Bevin, & Sutherland, 2002). Digital technology moves fast, and with the ever-changing software packages and product releases, efficiency is more necessary than ever before. These efficiencies have made the lives of the GIS professional easier, and have given them the ability to handle larger projects with more complex designs. To adapt to these changes, an investigation was undertaken by the project team into how other counties, cities, and local governments were accepting digital land survey data for placement into their GIS land records databases. This literature review helped the project team stay on track when developing CATCH.

The purpose of this project was to create an automation tool to inspect the integrity of digital survey-plats and report those results to the applicant. The following sections show previous work that was done on digital survey plan submissions across North America and New Zealand. Section 2.1 will focus on the digital submission of survey plans, plats, and CAD data. Section 2.2 will discuss the Parcel Fabric and how other local governments are using it for maintaining their GIS systems. Section 2.3 looks at coordinate systems and how Global Navigation Satellite System (GNSS) can help tie these land records together, and Section 2.4 summarizes the literature discussed in this chapter.

2.1 Digital Submissions

Computer aided design (CAD) files have been an industry standard for civil engineering and land surveying professionals for decades. Integrating CAD data with GIS technology has evolved rapidly over the last five years. Accuracy with parcel data has been more accessible with the integration of CAD data.

The British Columbia Ministry of Sustainable Resource Management implemented a web-based system that land surveyors used to submit their electronic survey-plans for registration into their land records system (Feary, 2004). This system captured the survey measurements in the form of an extensible markup language (XML) file. The system built by British Columbia utilized the Esri Survey Analyst extension, an early version of what is now known as the Parcel Fabric. The problem that British Columbia faced was that prior to this, all survey plans were submitted in a hardcopy format similar to the CATCH project for the client. The hardcopy survey plan was then entered, either by digitizing the parcel or using coordinate geometry (COGO) techniques, and then placed into "the provincial cadastral base map, known as the Parcel Fabric " (Feary, 2004, p. 2). This caused errors in the base map, and the need to move toward a more accurate land cadastre was realized by the Ministry. The digital survey plan project helped the Ministry eliminate the need to store physical hard-copy survey plans, improved efficiencies, gave open access to land records, automated the checking and reporting process for survey plans, and improved the accuracy of the Parcel Fabric (Feary, 2004).

The City of Calgary in the province of Alberta, Canada, created a similar tool for checking, reporting, and loading CAD data into the Parcel Fabric. Digital submissions have been in place for Calgary since 1997, and Calgary has maintained a land cadastre since 1978 (Registration Services, Registries Alberta Government Services, 2000). Calgary adopted MicroStation, AutoCAD, or Digital Exchange Format (DXF), as their digital submission format. The scope of their tool allowed the surveying community to verify the survey plan information prior to submission to the city. This streamlined the approval process for the digitally submitted survey plans, helped the city establish a digital submission standard, and create a checking and reporting tool for the surveying community. This tool also helped enter their CAD files into the City of Calgary's legal survey fabric (City of Calgary, 2015).

Other counties in the United States adopted digital submission guidelines for CAD data and its integration with GIS technology. For example, Richland County, South Carolina, is using digitally submitted CAD files to expedite the design and plan review processes within their county. For this to succeed the county had to establish a set of standards for the CAD data to be integrated into Richland's GIS database (Richland County, 2015). Their goal was to improve the checking process while maintaining a digital database of GIS information for their county. They also wanted to make these data sets available to the engineering community as a base map layer. This layer could not be used for construction, but could be used as a guide to aid in the location of assets within the County of Richland.

2.1.1 Map Automation

According to Waldo R. Tobler, "Automation, it would seem is here to stay" (Tobler, 1959, p. 1). This statement rings true today as it did over 50 years ago. His article, published by the American Geographical Society's journal, described the software systems that are in place today to perform map automation tasks and workflows. Tobler recognized the importance of gathering, storing, and the utilizing these data sets. He also understood that computer information systems would continue to improve, thus making map automation more affordable by achieving the needed accuracy. Map automation still has its challenges, but the possibilities are huge when it comes to improving efficiencies, speeding up map production and work flows, improving accuracy, and improving the quality of the outputted data sets. Some of the same questions Tobler asked came up for the client's project, such as: "Do possibilities for automation exist in cartography? If so, where can they be found?" (Tobler, 1959, p. 1).

Map production, map automation, and production workflows have different terms and meanings. According to Buckley and Watkins (November, 2009), automation is the operation of control or equipment, and map production includes fitting all elements and geographical data onto a map page. Map production also includes compiling all this information and creating a map book or compiled images.

The goal of using map automation is to minimize the time it takes to create meaningful maps. Being able to adopt a workflow that automates and standardizes the process of map outputs for external customers' benefits large and small enterprises (Rajagopalan & Richardson, 2011). An excellent example of utilizing map automation techniques is the City of Mesquite, Nevada. This city created an annual map book as a reference guide for local residents, developers, utility personnel, and the general public.

This map book typically took three weeks to create. The city wanted a way to make these maps more efficiently and standardize the process. So the city utilized Esri's map automation production software to achieve this goal. Now maps from the city are available for download on their web site. By automating the production mapping, Mesquite was able to save time, cut operating costs, and reduce storage space for older systems and files on their internal servers (Rajagopalan & Richardson, 2011).

2.2 Parcel Fabric

The Parcel Fabric is a "continuous surface of parcels or parcel network" (ESRI, 2015, p. 1) which stores and maintains a land cadastre. The parcels inside the fabric are made up of parcel line, point, and polygon features. These features can be entered into the fabric in different formats, such as Esri shapefiles, feature classes, and CAD data. No matter what type of data used, it has to be clean topologically before it can be entered into the fabric (ESRI, 2015). The Parcel Fabric solution is not a new idea and has been in development by Esri for decades. Esri introduced the Parcel Fabric with the release of ArcGIS 10 in June of 2010. The advantage of this system is that it takes data and lines them up against other data sets and fits parcels into a seamless network of connected boundaries integrated with survey control and highly accurate ortho-imagery. Having the ability to utilize highly accurate, survey-controlled CAD data into this system helped the client achieve the goal of improving the County of Riverside's land cadastre one parcel at a time (Riverside County Surveyor, 2015).

Surveyors historically made measurements tied to other maps, but seldom connected their surveys into a large scale land cadastre. "Each project, once completed, is filed away as a separate data set. At a later date, if another project is commenced nearby, parts of that old data may or may not be used in the new project and so the cycle continues" (Elfick & Hodson, 2006, p. 9). Now is the time to break that cycle and utilize the Global Navigation Satellite System (GNSS) along with emerging GIS technologies. Esri has the market for managing a large scale land cadastre. No competitor has landed this market to the level of success of Esri. Esri president and founder Jack Dangermond stated in his interview in Professional Surveyor Magazine that "surveyors are well suited for GIS, perhaps better than any of the other geo-sciences. But he also feels that surveyors couldn't really be fully integrated into a GIS until the data model existed" (Cheves, 2000, pp. 8-9). Now that the Parcel Fabric data model exists, the chance to integrate highly accurate CAD data is possible.

The Parcel Fabric has proven to be an effective solution to manage and maintain large or small parcel databases. For example, the City and County of Denver, Colorado, was an early adopter of this methodology and has used the Parcel Fabric to maintain its land records since 2007 (DeMeritt, 2012). They converted over 450,000 lots, parcels, easements, and subdivisions into the fabric. They also built their system from 8,000 survey control points and CAD data supplied to them by their survey department. This allowed the city and the surrounding areas access to the updated and accurate information now available from this solution.

Improving the cadastral framework over time can also be achieved by implementing the full functionality of the Parcel Fabric. Adding accurate survey control and highly accurate CAD data to the fabric can be achieved relatively quickly by using the built in adjustments from Esri's software. A study conducted in Rapid City, South Dakota, showed the results of the improvement of their parcel layer by incorporating the least squares adjustment methodology, along with survey control and CAD data (Foster & Blanford, 2013). “Once the cadastre has been created it can be continuously improved over time and effectively associated with parcel-based layers” (Foster & Blanford, 2013, p. 71). For Rapid City, this helped update parcels, manage resources, improve emergency response, and identify important infrastructures.

2.3 Coordinate System

Choosing a coordinate system for a project includes a proper projection and horizontal and vertical datum. This can seem like a daunting task due to the number of projections and datums available in ArcMap. The client for this project and the project team had to agree on which coordinate system to implement. The important question that came up from the team was how to stay current with coordinate values while the Earth’s surface is constantly moving. Fortunately the scientists and geodesists at the National Geodetic Survey (NGS) had already solved this problem by re-adjusting the survey control points used for geodetic surveying projects in the coterminous United States (CONUS) (National Geodetic Survey, 2015). The NGS made adjustments to these survey control points over time. These adjustments were typically based on large scale seismic events within a network of ground stations named Continuously Operating Reference Stations (CORS) as pictured in Figure 2-1.

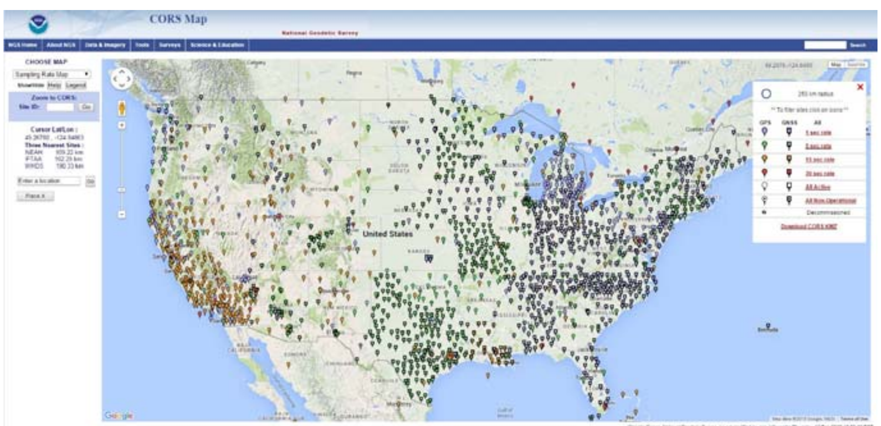

Figure 2-1: Snap Shot of CORS Stations in the United States from the NGS

The CORS stations or sites are measured after a major seismic event. This is referred to as an Epoch Date, this date refers to when the positions are held fixed (National Geodetic Survey, 2015). These CORS sites stream GNSS survey data and are used for adjusting survey control that is post-processed using sophisticated software supplied by GNSS equipment manufacturers. The industry professional Land Surveyor or Civil Engineer (applicant) used such software to create the coordinate ties to their subdivision map that were submitted to client.

The client mandated that the applicant tie into a minimum of three CORS sites on every map recorded within the County of Riverside as illustrated in Figure 2-2.

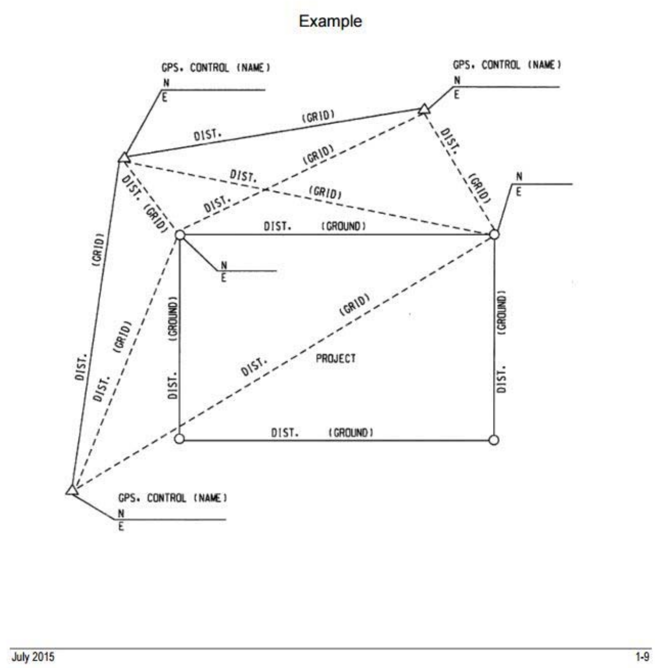

Figure 2-2: GNSS Ties on Recorded Maps for the County of Riverside (Riverside County Surveyor, 2015)

This ensures that the parcels from these recorded maps are projected in the proper locations on the ground. This helps users to view, analyze, make decisions, and create maps in a GIS that is up-to-date and accurate.

2.3.1 Datum [NAD 83, CCS83]

The datum used for this project is the North American Datum of 1983 (NAD83) as depicted in Figure 2-3. This datum is a best fit for North America, and is the horizontal control datum for the United States, Canada, Mexico, and Central America. This datum is geocentric, meaning by definition it is centered at the center of the Earth and uses the geodetic reference system of 1980 (GRS80) as the reference ellipsoid (Ghilani, 2012).

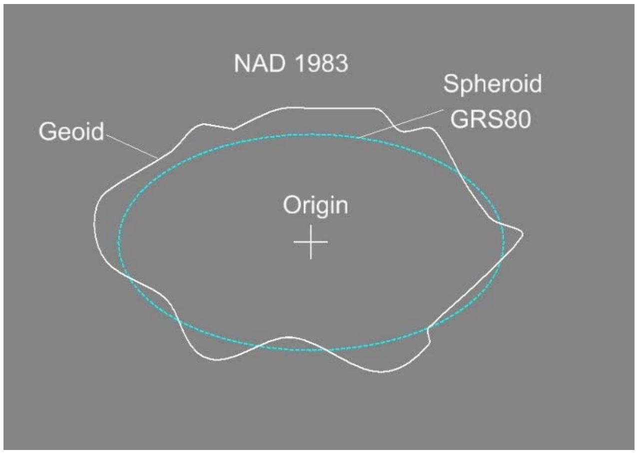

Figure 2-3: NAD 83 Datum Definition

In California the NAD 83 datum is referred to as the California Coordinate System of 1983 (CCS83) (State of California, 2015). CCS83 adjustments by the NGS are based on this reference frame and labeled by different naming conventions. These adjustments are referred to as realizations of NAD83. Since the NGS still used the defined parameters of the NAD83 datum, only the observations of the control positions were transformed. The current adjustment realization of CCS83 by the NGS is named NAD83 (2011) for North America and is tied to static control points that utilize GNSS technology. Thousands of CORS sites were part of this nationwide adjustment.

2.3.2 SPCS83 [Map Projection, CA Zone VI, Grid vs. Ground Distance]

Another big question for the project team was which map projection was going to be used. Of course when dealing with a curved surface being the Earth, there are many map projections that preserve shape, distance, or area. Luckily for this project the map projection was the Lambert Conformal Conic projection. The term conformal means true angular relationships are preserved for all areas (Ghilani, 2012). The scale in this projection varied from north to south, but not east to west. So the zone limits were limited north and south as depicted in Figure 2-4.

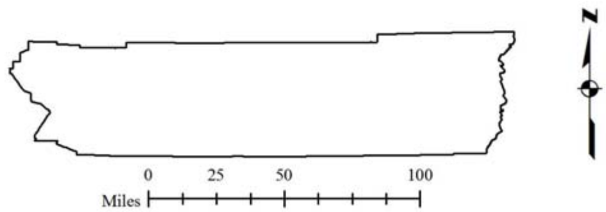

Figure 2-4: Riverside County

Riverside County is an ideal shape for this projection due to its long east-west and narrow north-south directions. The State Plane Coordinate System used for this project is also NAD 83 State Plane Coordinates Zone VI as shown in Figure 2-5. Having this projection defined for the CAD data ensures that it lines up with the polylines and polygons for the County of Riverside's land cadastre.

Figure 2-5: California SPCS83 Zones

All measured values using the CCS83 NAD CA Zone VI used measurements based off of a developed surface or projection grid. The projection grid was purely mathematical. Distortion across the CCS83 was at a scale factor of 1:10,000 for any point measured across the grid. The grid may be above the mean design surface, in which the scale factor would be above one, or the grid may be below the design surface, in which this case would yield a value less than one. Combining this value with the elevation factor creates a project wide combination factor. This is important information to know because this project's coordinate system was on the grid-based coordinate system, and Figure 2-6 showed that measurements from the same points have different ground values as compared to the grid values.

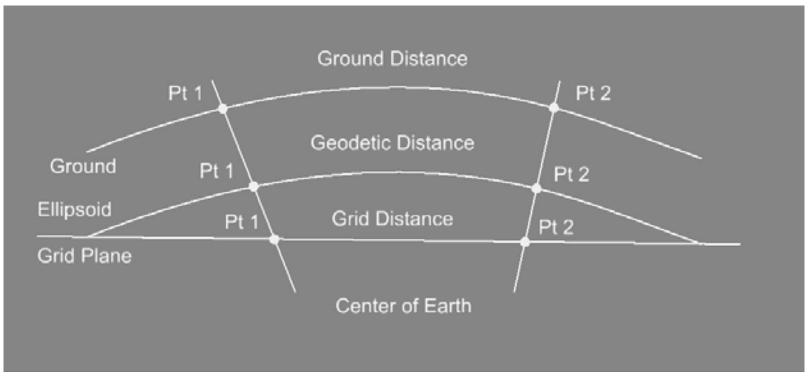

Figure 2-6: Grid versus Ground

Many survey plats in the County of Riverside are tied to CC83 survey control and show these values on the recorded subdivision maps, but all the distance values shown on these maps are ground. All areas from recorded deeds and assessed parcels from the Riverside County Assessor are also based on ground areas and measurements.

2.3.3 GNSS [CORS, Epoch Date]

Global navigation satellite systems (GNSS) take into account the USA system GPS, Russian system GLONASS, Chinese system COMPASS, European Union system GALILEO, Japanese system QZSS, and other countries that are launching their respective satellite constellations (Sickle, 2008).

GNSS technology laid the foundations for implementing a CAD standard for this project, and ensured that the data line up in the correct locations on the face of the Earth. The project team agreed that this technology was the best choice to base measurement values on. Being able to achieve accuracies at the 1 cm level for a ground-based survey constrained to three CORS sites met the criteria for this project. It was understood that not all recorded maps will achieve this level of accuracy, but at a minimum recorded maps tied to CORS sites would meet 2 cm or better as defined by the Public Resources Code (PRC) section 8856 (State of California, 2015).

Another important piece to the GNSS measurement is the epoch date. The epoch date is referred to a time stamp for a particular GNSS measurement on a control point. This time stamp is useful for providing a date when the position of the point is referred to. In Figure 2-6 is a diagram of a GPS CORS station with measurements taken at different points in time or epoch dates. Figure 2-7 shows how the point has moved significantly: e.g., 2.67’ feet over a period of 10 years.

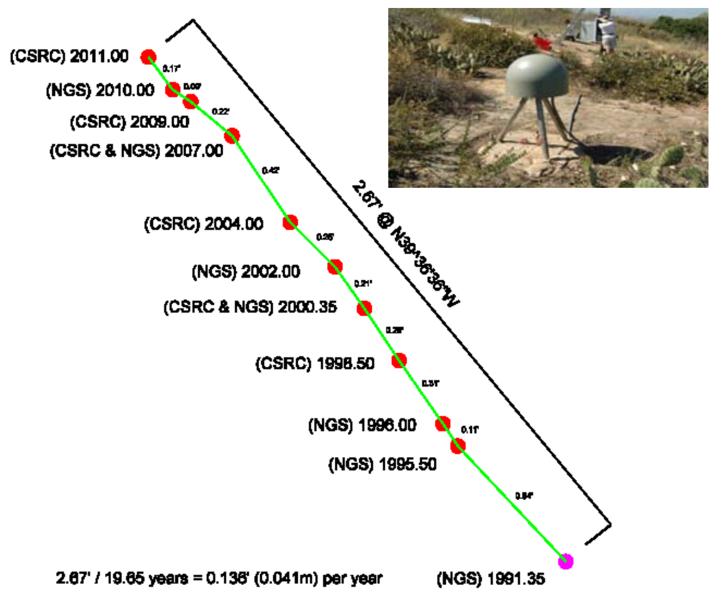

Figure 2-7: Epoch Dates Showing Crustal Movement

Incorporating the epoch date defined along with the coordinate system is important for the data to be constrained to the same points at the same time. One important item to note regarding an epoch date is that the reference datum does not change. By definition the datum has a set of fixed parameters that define the reference ellipsoid, and the realization of this datum was based on the observations and adjustments to the control points. The epoch date indicates the exact point in time the measurement was taken on the Earth’s crust. This crustal movement changes year after year. The realization of the datum does not measure the crustal movement of a position, but the positions adjustment due to the observations from the control points.

That way any future measurements can be constrained to this coordinate systems epoch date. In California “when CCS83 coordinates are shown on any map, a mapping angle, combined grid factor, and the elevation used to determine the combined grid factor be shown on the map for at least one representative point” (State of California, 2015, p. 8815.5). The mapping angle and combined grid factor are necessary when trying to line up CAD data in a GIS. The Parcel Fabric uses the mapping angle, and combined grid factor for the land survey data to line up with adjacent recorded maps (ESRI, 2015).

If CAD data are in ground coordinates and placed into Esri's grid based system, then without the combined factor and mapping angle, the positions would be misaligned. To keep the data in alignment the user only needed to use the ground to grid correction tool in ArcMap (ESRI, 2015). Applying this information in an edit session ensured that the datasets lined up correctly.

If the combined grid factor and convergence angle is not known for CAD data that is tied to GNSS, then data will not line up correctly in the Parcel Fabric. No matter if the data were submitted in grid or ground coordinates, the Parcel Fabric uses the transformation parameters and converts the measurements to ground.

2.4 Summary

There are many ways to place data into a GIS. When managing large land records databases, the data that come in need to be clean topologically (ESRI, 2015), should follow a digital submission standard, and need to have some form of spatial accuracy (Feary, 2004). To help with the process of maintaining such a large system, map automation should also be used. Automating the map checking process minimizes staff time for review, reduces duplication by county departments, and saves costs for the applicant submitting the project (Rajagopalan & Richardson, 2011). The project team realized that the literature reviewed in this chapter helped confirm that the project was on the correct path and could be implemented as a long term solution for the client.

Coordinates also play an important role in the Parcel Fabric. Due to the earth's crust movement and more accurate surveys being performed, coordinates may change over time. It is important to note that these coordinates should not replace the legal definitions of the parcel boundaries. Surveyors are the ones responsible for determining boundaries on the ground, a GIS is just a tool to aide in the decision making process.

Chapter 3 – Systems Analysis and Design

This chapter revisits the problems encountered by the client and analyzes the requirements before designing the system. Section 3.1 reintroduces the problem statement, Section 3.2 explains the requirement analysis of the functional and non-functional requirements, Section 3.3 explains the system design, Section 3.4 discusses the project plan, and Section 3.5 summarizes all of this.

3.1 Problem Statement

Digital CAD data can be a valuable resource for integrating survey information into a GIS. However, CAD data come in a variety of projected or non-projected coordinate systems and often contain topologic errors such as gaps, duplicate line work, and overlapping lines. One of the main problems for the client was that no digital submission standard was in place to consistently check the digital submissions. However, even with the submission standard in place, the way the GIS brought the data in was neither consistent nor accurate.

3.2 Requirements Analysis

The requirements for the digital submission standard had to be implemented before the project team created the functional and non-functional requirements. Having the digital submission standard in place helped ensure that the automation tool checked the data consistently. The digital submission standards are described in more detail in Chapter 5.

The functional requirements that were identified with the client are listed in Table 3-1. These requirements helped create the system design. The project team helped confirm these requirements.

Table 3-1: Functional Requirements

Requirement	Description
Map Template	Create four mxds (Title, Level Check, Topology Boundary Check, and Topology Lot Check) with legends, dynamic text, pictures and layout. These will be called in the script. Using ArcGIS desktop 10.3 and made compatible for earlier releases of ArcGIS 10.x
User Input	Accept user input of e-mail address, CAD file (dwg or dgn), file name, professional license number, name of Applicant, and projection file (.prj)
Make Directories	Create folder location and sub-directories for project data
Create Geodatabase Schema	Create File geodatabase schema
Create Log Report	Create report log of the results of submitted project
Create Layer Files	Create layer files that act as a template for the tool to call and use to generate the PDF reports
Check Naming Convention	Check Naming convention for Tract and Parcel Maps CAD file
Check Layers	Check Layer names and compare to digital submission guideline standard for layer names.
Check Inside County	Check to make sure project is within the County of Riverside
Check Coordinate System	Check to make sure feature classes coordinate system are in NAD 83(2011) SPC Zone 6, Epoch 2010.00
Create Topology	Create a Geodatabase Topology feature Class
Create Polyline/Polygon	Create Polyline and polygon feature classes from the Polyline CAD dataset
Load Topology	Load the polylines and polygons into the topology and compare to the 7 topology rules for Esri's Parcel Fabric
Validate Topology	Validate the Geodatabase topology
Export Topology Errors	Export a feature class containing the topology errors (point, line, or polygon errors)
Create PDF Map Title	Generate PDF Title map based on user input use acrpy.mapping and dynamic tables to produce unique title sheet, with results of the digital check.
Create PDF Map Layer Check	Generate PDF map that checks if layer names passed or failed
Create PDF Map Boundary	Generate PDF map that checks the topology of the boundary and lists the errors
Create PDF Map Lots	Generate PDF map that checks the topology the lots, boundary, CL, and right-of-ways an reports any errors and whether this check passed or failed
Append PDF Pages	Take four separate PDF maps and append into a final PDF
Output	Export to the user via e-mail a zip file containing a PDF report showing the project, contact info, location, errors, results pass or fail, a CAD file with the topology point, line, polygon errors.

The non-functional requirements listed in Table 3-2 were needed for the automation tool to operate. The tool required ArcGIS version 10.3, Python version 2.7, the ArcPy.mapping module, the Operating System (OS) module, and the smtp.lib module. The CAD data required MicroStation version V8i select series 2, and Autodesk Civil 3d version 2016. The server requirements were set by the client's current configurations from the County of Riverside's Information Technology Department. The CAD data supplied by the client were in the form of previous versions of MicroStation or Autodesk.

Table 3-2: Non-Functional Requirements

Requirement	Description
Software	ArcGIS version 10.1 or higher, Python, Pyscripter 2.7, MicroStation V8i SS2, Autodesk 2016
Server	ArcGIS for Server 2014, SQL Server 2014, ARC SDE, smtp e-mail
CAD data	CAD files in the form of MicroStation V7 and higher , and Autodesk R14 and higher, tied to GPS Survey Control NAD 83 (2011) Zone VI

3.3 System Design

CATCH was designed in four separate phases shown in Figure 3-1. The first phase was the digital submission supplied by an industry professional Land Surveyor or Civil Engineer (applicant); the second phase was the ArcGIS script tool (CATCH); the third phase was the attributes generated by CATCH; and the fourth phase was the output. Participants from the stakeholder meetings and the client (project team) approved the final system design.

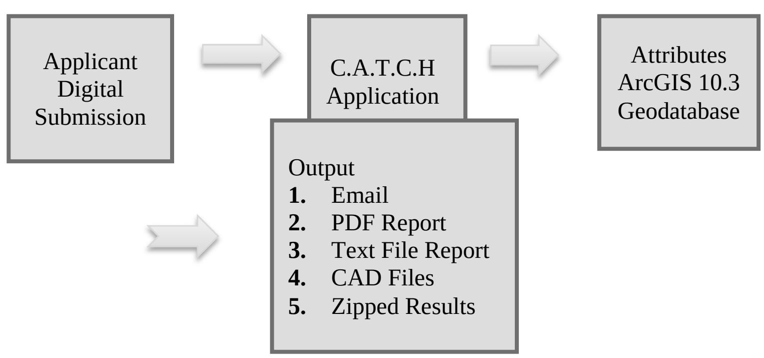

Figure 3-1: System Design

An applicant's digital submission was input to the ArcGIS geoprocessing script and run through CATCH. Feature classes and attributes were written to an ArcGIS version 10.3 file geodatabase and organized into a file structure for the client. This design was chosen because the client wanted to have a way to identify, locate, and store the digital submissions.

3.4 Project Plan

The steps used to produce the objectives for this project included implementing the waterfall approach for project management. This approach took into consideration the following four steps: planning, designing, developing and testing, and deployment.

The first part of the planning stage was to set the project schedule. The client recommended a series of stakeholder meetings with private Land Surveyors, Civil Engineers, GIS professionals, and other Riverside County Departments. These meetings helped revise the digital submission standard for the client and set up the project plan schedule as shown in Table 3-3. The reality of the outcome of these meetings is described in more detail in chapters 6 and 7.

Table 3-3: Project Plan Schedule

Phase	Task Title	Start Month	End Month	Labor Hours
1	**Plan**			
1.1	Analyze tools used for Parcel Fabric	1	1	10
1.2	Review Python tutorial guide books and practice writing geoprocessing scripts	1	1	40
2	**Design**			
2.1	Place tools used to load CAD data into model builder	2	2	15
2.2	Place tools used to load point data into model builder	2	2	15
2.3	Organize and document model builder	2	2	20
2.4	Design staging geodatabase	2	3	5
3	**Develop/Test**			
3.1	Create Python Script	3	3	30
3.2	Test CAD data types	3	4	10
3.2	Test Error Types	3	5	10
3.4	Create Staging geodatabase	4	5	5
3.5	Create Reporting Functionality			5
4	**Deploy**			
4.1	Create geoprocessing script	5	5	20
4.2	Load data	5	6	10
4.3	Create production geodatabase for Parcel Fabric	6	6	8
4.4	QC final product	6	7	15
			Total	**218**

The project plan was an estimate of the time needed to complete the project as requested from the client. The actual time spent on the project went according to the project plan schedule except for the following categories: reviewing the python materials from phase 1.2 took 80 hours instead of 40, creating the python script in phase 3.1 took 372 hours instead of 30, and testing the CAD data types took 20 hours instead of 10 as illustrated in Table 3-4.

Table 3-4: Actual Hours Worked

Phase	Task Title	Start Month	End Month	Labor Hours	Actual Time Worked
1	**Plan**				
1.1	Analyze tools used for Parcel Fabric	1	1	10	
1.2	Review Python tutorial guide books and practice writing geoprocessing scripts	1	1	40	**80**
2	**Design**				
2.1	Place tools used to load CAD data into model builder	2	2	15	
2.2	Place tools used to load point data into model builder	2	2	15	
2.3	Organize and document model builder	2	2	20	
2.4	Design staging geodatabase	2	3	5	
3	**Develop/Test**				
3.1	Create Python Script	3	3	30	**372**
3.2	Test CAD data types	3	4	10	**80**
3.2	Test Error Types	3	5	10	
3.4	Create Staging geodatabase	4	5	5	
3.5	Create Reporting Functionality			5	**80**
4	**Deploy**				
4.1	Create geoprocessing script	5	5	20	
4.2	Load data	5	6	10	
4.3	Create production geodatabase for Parcel Fabric	6	6	8	
4.4	QC final product	6	7	15	
			Total	**218**	**612**

The second step of the planning stage consisted of analyzing Esri's Parcel Fabric software to load the parcel data sets. This meant that the parcel data had to be tested and run in ArcMap prior to placing them into Python. The client also wanted a reporting mechanism to generate professional quality reports. The ArcPy.mapping module was investigated to see if it could solve the mapping problem for the client. The ArcPy.mapping module did solve the problem, and helped move the project to the design phase.

The next step of the project plan was the design phase. Which involved designing the Python script. Before the Python script was started, the pseudo code of the automation tool was written. A schematic was also created using ArcGIS Model Builder to show how the parcels were loaded into the Parcel Fabric.

Next came the development and testing stage where the logic from the Model Builder schematic and the pseudo code were used to write the Python script. The Python script was by far the bulkiest portion of the project because a graphical user interface needed to be developed, and the individual functions that met the functional requirements were created. The CAD data supplied by the client were loaded and tested after each Python function was developed. The ArcPy.mapping, smtp.lib, and Operating System (OS) modules were used to develop the Python script. During this phase the geodatabase design, script parameters with descriptions, and folder locations were designed. Prototypes of the tool were also tested by county staff. A PDF document was created so a user could deploy and use the tool on his or her personal computer.

Finally, after the CAD data were tested for various topology violations, the project moved to the deployment phase. This phase consisted of project sign off of the functional requirements by the client, and the final project close out.

3.5 Summary

This chapter discussed the project schedule, requirements, system design, and the plan that was implemented by the project team. To meet the 21 functional requirements and the three non-functional requirements involved meeting the project plan. The final system design was also discussed along with the introduction to the project plan schedule. Having a well-defined plan and schedule helped the project team move forward with the database design. Chapter 4 discusses the data sources and the features used to create the final geodatabase for CATCH.

Chapter 4 – Database Design

This chapter introduces the data that were used for this project and how the database was designed. In Section 4.1 the conceptual data model is introduced; Section 4.2 discusses the logical data model; Section 4.3 describes the data sources used for the project; Section 4.4 shows the data scrubbing and loading that was involved; and Section 4.5 concludes with a summary of the database design.

4.1 Conceptual Data Model

The first step in the database design was to come up with a conceptual data model. This model described the highest level relationships among the different entities of the data. Figure 4-1 is a representation of the project's data semantics, and shows the characteristics of what needed to be stored in the database. The respective entities and their attributes are also depicted.

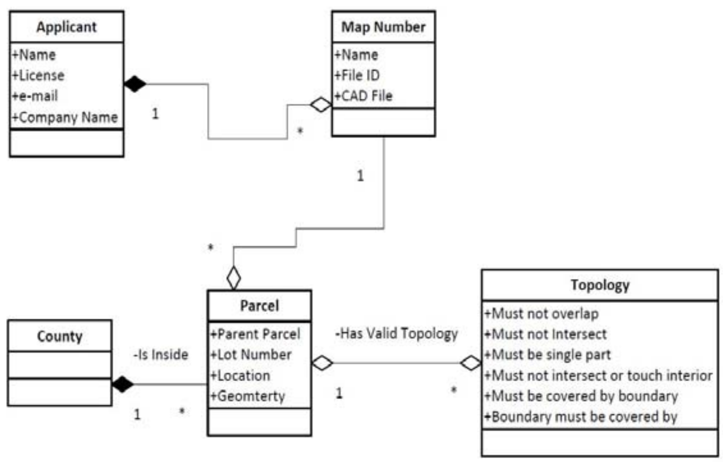

Figure 4-1: Conceptual Data Model

The conceptual model showed the information contained in a digital submission package submitted to the county for review. The industry professional Land Surveyor or Civil Engineer (applicant) contained a name, license, company name, and contact information. The parcel was tied to a map number, and validated for correctness by the topology rules. The information collected from the topology showed if parcels had any errors. All the parcels were contained within the county boundary had a map number and file ID, and were tied to a CAD file. All of this information was run through the automation tool, and the results were returned to the applicant.

4.2 Logical Data Model

After creating a conceptual model for the data, the client and the stakeholders (project team) came up with an organizational structure for the automation tool. The current business practices for the client consisted of a filing cabinet to store the digital survey-plats, so forming a logical data model was a new concept. The logical data model is depicted in Figure 4-2.

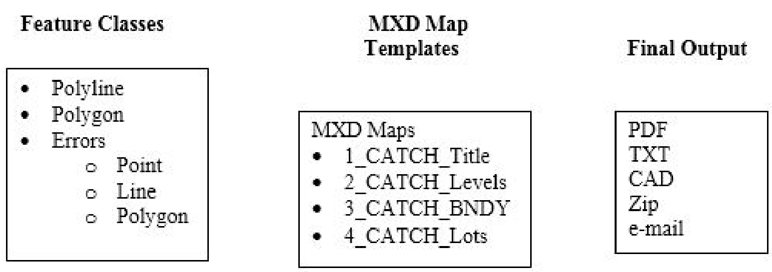

Figure 4-2: Logical Data Model

Utilizing an Esri ArcGIS file geodatabase allowed the parcel data to conform to the data types that are required by Esri's Parcel Fabric. The feature classes that resulted from the logical model are named after the survey-plat, and are of the geometry type polyline and polygon. The attributes from the feature classes were used to take the necessary information and check them against a set of seven topology rules defined by the Parcel Fabric. After the validation of the geodatabase topology, the polyline and polygon feature classes were exported as three separate topology error feature classes: errors_point, errors_line, and errors_poly shown in Figure 4-3.

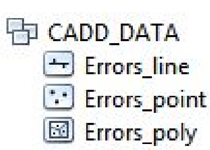

Figure 4-3: Exported Error Feature Classes from Topology

After the data checks were run the data needed to be displayed. The project team designed the four Esri map documents identified in Figure 4-4. These map documents were created with dynamic text element objects, data frames, and data driven pages. The map document maps were used with the ArcPy.mapping module to add, remove, and change items that were displayed on the final output of the PDF documents. The ArcPy.mapping process is described in more detail in Chapter 5.

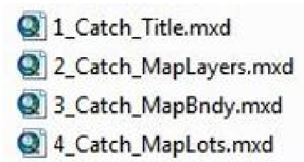

Figure 4-4: Map Documents Templates

The final report generated from the CATCH application contained a PDF report generated from the map documents, a text file that contained an overview of the results, and three separate CAD files that showed any exported errors from the validated topology.

4.3 Data Sources

The County of Riverside boundary was supplied by the client and was used to perform the inside county check from the conceptual data model. The parcel data were submitted by the industry professional Land Surveyor or Civil Engineer (applicant), and the seven topology rules were defined by Esri's Parcel Fabric Team.

4.4 Data Scrubbing and Loading

The parcel data supplied by the applicant needed the layer names and line types changed to conform to the digital submission standard set by the client, which will be described in Chapter 5. The county boundary, also supplied by the client, was in the proper coordinate system and was easily loaded into the file geodatabase.

4.5 Summary

This chapter focused on the relationships between the data and the database system. The system needed to be organized so data could be stored, retrieved, and verified in an effective manner. Knowing the entities and characteristics of the data was fundamental during this stage of the project. This chapter described the conceptual database and the functions and classes that made up the database design for the project. The dependencies of the data were also introduced, as well as the logical database model. The data were introduced, along with how they were loaded into the database.

From the stakeholder meetings the project's conceptual data model took the form of the logical data model. The logical data model was then broken down further into describing the feature classes, map document templates, and final output generated by the CATCH.

Chapter 5 – Implementation

After the system and database design requirements were approved by the project team, the next stage consisted of implementing the project requirements and developing the CATCH automation tool. The development and final implementation were broken down as follows: Section 5.1 introduces the digital submission standards; Section 5.2 discusses the directory structure and the geodatabase; Section 5.3 discusses the geoprocessing tool; and Section 5.4 concludes with the project implementation summary.

5.1 Creating the Digital Submission Standard

Stakeholder meetings with the project team and client identified the need for a set of digital submission standards, consisting of a layer naming standard, a file type standard, a coordinate system standard, and a line type standard. These guidelines helped satisfy the functional requirements and guaranteed consistency across the submittals of the CAD data from the industry professional Land Surveyors or Civil Engineers (applicants).

5.1.1 Layer Naming Standard

CAD data come in many forms and can possess unique file naming conventions for layers and levels. For this project, the National CAD layer standards for Architecture, Engineering, and Construction (A/E/C) was chosen. Autodesk Civil 3-d was the preferred CAD platform because it comes with the (A/E/C) layer naming standards built in, so that using these would not add an additional burden on the applicant. The National CAD standards include naming conventions from different engineering disciplines. The Survey/Mapping disciplines were designated with the letter V and were further broken down into major and minor groups. A typical layer within the survey and mapping discipline would be broken down in the following way: V-MajorGroup-MinorGroup. For example, the layers that were deemed mandatory in this project were subdivision boundary (V-PROP-LINE), lot lines (V-PROP-SUBD), right-of-way lines (V-RWAY-LINE), centerlines (V-RWAY-CNTR), map annotation streets (V-ANNO-STREET), and map annotation lots (V-ANNO-LOT) (See Table 5-1).

Table 5-1: Digital Submission Standards for Level Names

Designator	Major	Minor	Description
V			Survey/Mapping
V	PROP		Property Boundary
V	PROP	LINE	Property Boundary: Property Lines, Property Corners
V	PROP	SUBD	Property Boundary: Subdivision (interior) Lines
V	RWAY		Right-of-Way
V	RWAY	CNTR	Right-of-Way: Centerline
V	RWAY	LINE	Right-of-Way: Lines
V	ANNO		Annotation
V	ANNO	STREET	Street Names
V	ANNO	LOT	Lot Numbers

5.1.2 File Type Standard

The next standard was the file type. CAD files submitted were either an Autodesk (.dwg) or Bentley MicroStation V8i (.dgn) format. The filename associated with the CAD file was chosen so that no spaces or extra characters were allowed. Figure 5-1 depicts the proper use of the file type and naming convention.

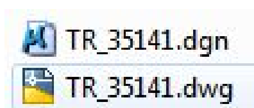

Figure 5-1: CAD File Types and Names

5.1.3 Coordinate System Standard

All CAD data used in CATCH were based on the California coordinate system, CCS83 Zone 6 (Public Resource Code, Sections 8801-8819), utilizing the NAD 83 (NSRS2011) adjustment, and the published epoch of 2010.00. CAD files that were added to ArcMap could not transfer the proper projection parameters and display a spatial reference warning, as shown in Figure 5-2.

Commented [AU6]: wc?

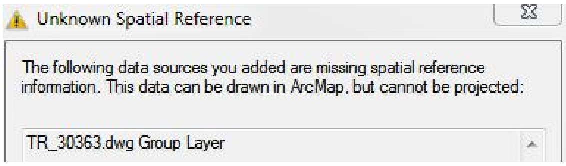

Figure 5-2: Spatial Reference Error

To ensure that this standard was upheld, a separate projection file (.prj) was used across all data sets and defined by the name "esri_cad.prj" (ESRI, 2015). Having a universal projection file eliminated the need for the applicant to create it.

Since the parcel data supplied by the applicant were already tied to a minimum of three CORS sites, the applicant made sure their data conformed to the public resources code sections 8801-8819 (State of California, 2015), and to the County of Riverside's Map Preparation Manual (Riverside County Surveyor, County of Riverside, 2015). Now the parcel data needed only two extra pieces of information for the data to be ready to load into the Parcel Fabric. These two pieces of information were the rotation and scale parameters. These items were found on the recorded subdivision plat in the form of the basis of bearings statements. These two pieces of information were entered through the graphical user interface (GUI) and were shown on the title sheet of the PDF report. Figure 5-3 depicts the transformation information shown on sheet one of the final PDF report.

Transformation DATA

Combination Factor For	*TR30000_CP2*	*0.99555112*
Convergance Angle For	*TR30000_CP2*	*0.02325544*

Figure 5-3: Transformation Data

5.1.4 Line-Type Standard

All line types for the digital submission standard were comprised of solid and individual line segments. Any line connected to multiple parcel corners would cause errors to show up in the final report. These errors were shown in more detail in the final results of this report and discussed in Chapter 6.

5.2 Designing the Directory Structure

In order to use the CATCH application across different PC's, the file folders, scripts, and tools needed to be mapped. The ArcGIS geoprocessing tool was created so all scripts, tools, and file folders used relative paths. Thus no other modifications were required when unzipping the components of the script. Using this technique allowed the tool to run on any desktop or laptop computer running the correct versions of the software, as described in Chapter 4. Figure 5-4 depicts the directory structure of CATCH; this information will reside on a shared drive at the client's office which will act as the server.

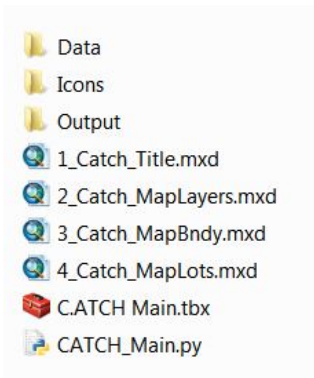

Figure 5-4: CATCH Directory Structure

A data folder was contained within the directory structure of CATCH. Within the data folder are an ArcMap file geodatabase and layer (.lyr) template files. Another folder within the directory structure was named "Icons". Icons contained all the graphics used within the map documents. An output folder was also created within the directory structure, and was used to store the results from CATCH. Each file name within the output folder was uniquely named per the subdivision plat name and check print ID, as illustrated in Figure 5-5.

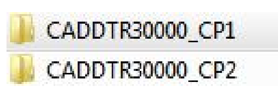

Figure 5-5: Output File Name

The other items within the directory structure were four map documents, an Arctoolbox (.tbx) which ran the geoprocessing application, and the Python script (.py).

5.3 CATCH Geoprocessing Tool

Developing the pseudo code for the Python script was the first step in creating the geoprocessing tool. After the pseudo code was written, the development of the Python script could begin. A main file was set up with a series of functions that acted as the loading, checking, and reporting functions of CATCH. In the end CATCH had four checking functions, two loading, four reporting, and one e-mail function.

Next the parameters for the graphical user interface (GUI) were developed. An e-mail address, CAD file, projection file, combination factor, convergence angle, applicant name and Professional License number, and a company name were adopted as the input parameters.

The flow chart illustrated in Figure 5-6 depicts the workflow of the CATCH automation tool.

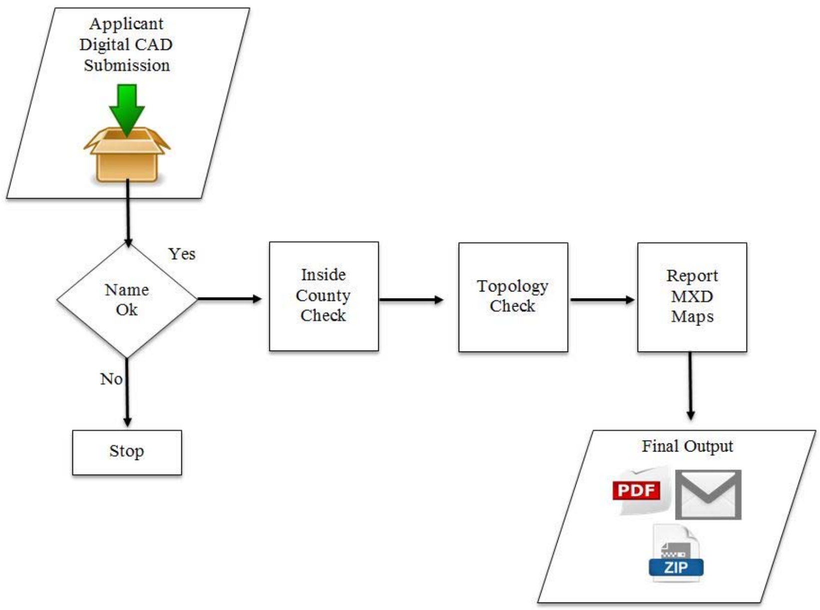

Figure 5-6: CATCH Workflow

The workflow diagram takes the applicant information entered through the GUI. The script then checks if the file name contains any spaces and if it conforms to the naming convention standard. If the check fails, the program stops and alerts the user that the file name is incorrect and cannot continue. Any spaces that are used in file names for ArcMap do not work and are rejected. The script then checks if the parcel data are within the County of Riverside.

Whether the check passed or failed, it was reported on the final PDF report. After the inside county check, the script loaded the parcel data into the geodatabase topology, and checked them against the seven topology rules described in Chapter 4. Finally, the error messages were placed on the appropriate map document and exported to the corresponding PDF report sheets.

The functions within the Python script were the backbone of the system. As stated in the pseudo code, there were five checking functions, two loading, four reporting, and one e-mail function. The functions used a series of “if else” logic, search cursors, true or false returns, and ArcPy.mapping functions that made the Python script perform according to the functional requirements.

The final output from CATCH was an e-mail sent to the applicant with a zip file containing the merged PDF report, the exported CAD files, and a text file containing an overall summary of the digital submission.

5.4 Summary

This chapter discussed how the components of CATCH were developed as a solution to meet the client’s specifications. The digital submission guidelines were introduced, together with the development of the Python script. The basic directory structure and the workflow process of the tool was shown and described in detail. The final output from CATCH was also discussed.

Chapter 6 – Results

The results from the development of the CATCH checking, reporting, and loading tool are discussed in this chapter. The client was pleased with the tool and found it very useful for the County Survey Division staff to implement and use on a daily basis. “This tool will help save precious time and money in the map recordation process. This parcel data will help improve the accuracy of the GIS parcel layer for the county, and provide employees and residents the data needed to make better informed decisions regarding land development” (Lantis, Personal Communication, 2015).

The results of the tool were based on the checks that it performs, and whether the checks pass or fail. Section 6.1 discusses the graphical user interface and the user input; Section 6.2 looks at the final report and Section 6.3 summarizes all of this.

6.1 GUI

The first step in the script takes the industry professional Land Surveyors or Civil Engineers (applicant) e-mail address, a CAD file, a projection file, a file named after the check print submitted (e.g.; CP1, CP2), a numeric value for the combination factor, a numeric value for the convergence angle, the applicant’s name, company name, and license number. This information is then entered into CATCH by the graphical user interface (GUI), as shown in Figure 6-1.

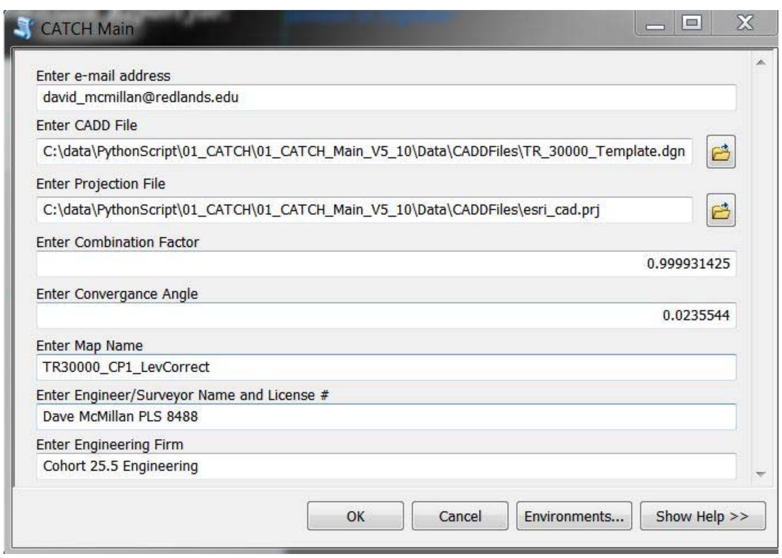

Figure 6-1: CATCH Graphical User Interface

6.2 Final Report

After the user input the information into the GUI, the final report can be generated. This report was broken down into four individual sheets based off of the map document templates as discussed in Chapter 5. The first sheet consisted of the title sheet, the second was the layer name check, the third was the boundary topology report, and the fourth sheet was the lot topology report. The results were based on a sample file that was provided by the client, the following results were written to the corresponding report sheets.

6.2.1 Title Sheet

The title sheet contained the overall project results at a glance. The applicant information, the date the project was submitted and reviewed, the transformation information, a key map of where the project was located, and the overall results were shown as illustrated in Figure 6-2.

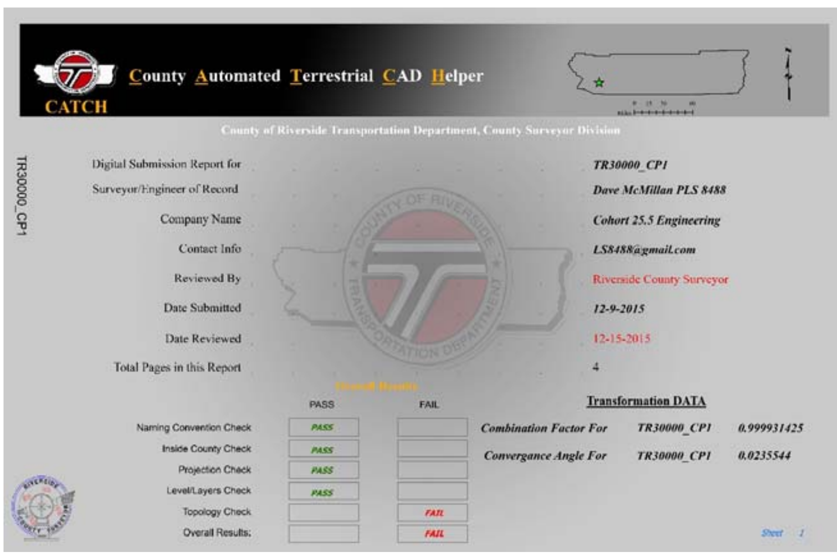

Figure 6-2: Sample Title Sheet

The file name was also checked and the results displayed on the title sheet. When a file name had a space or extra character instead of an underscore, the geoprocessing script stopped running and showed an error message to the user as illustrated in Figure 6-3.

```
Name check failed, File is named incorrectly,
 and needs to be in the following format
 "TR_32154.dwg or PM_32514.dwg"
Completed script MainInterface22...
Failed to execute (MainInterface22).
Failed at Sat Nov 14 16:25:53 2015 (Elapsed Time: 0.17 seconds)
```

Figure 6-3: Sample File Name Check

When a file was correctly named, the tool ran as expected, completed its operation, and placed a "PASSED" notification on the title sheet in the overall results table, as pictured in Figure 6-4.

Figure 6-4: Sample File Name Check

After the naming check was performed, the script performed the inside county check, and wrote the final results on the title sheet. This check verified that the parcel data submitted by the applicant was inside the County of Riverside and was in the proper coordinate system. If the project was outside the County, then a "FAILED" was written onto the title sheet for the projection check and the inside the county check as illustrated in Figure 6-5.

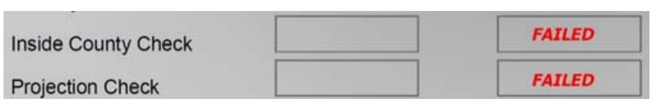

Figure 6-5: Sample Projection and Inside County Check

The graphic that showed the survey-plat in the upper right corner of the title sheet will also be missing in the county boundary graphic if the project was outside the County of Riverside, as illustrated in Figure 6-6.

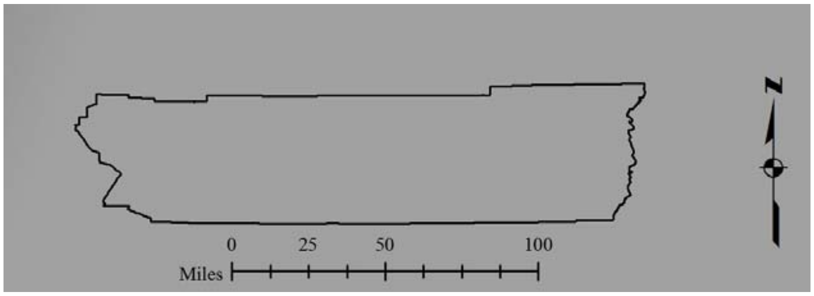

Figure 6-6: Sample County Graphic Failed Inside County Check

When the project was inside the county the tool worked as expected and the county graphic showed where the survey-plat was in relation to the county boundary, and a "PASSED" was written onto the overall results for the projection and inside the county check, shown in Figure 6-7.

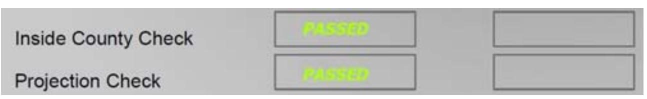

Figure 6-7: Sample Inside County and Projection Check

Figure 6-8 graphically showed where the project was located within the county boundary.

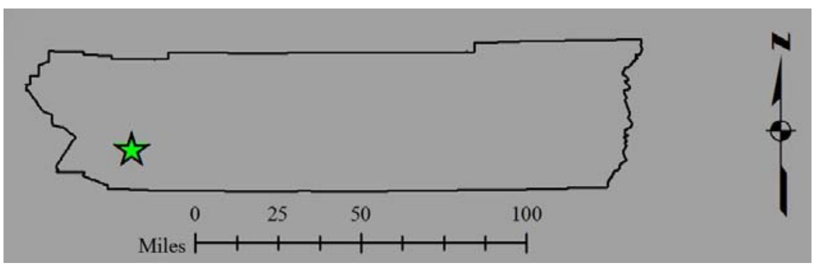

Figure 6-8: Sample County Graphic with Location of Survey-Plat

The projection check verified that the proper projection file was used for the project. Since the map documents were set up in the "NAD 1983 (2011) State Plane California VI

FIPS 0406 (US Feet)” and were constrained to fit within the County Boundary, the projection file (.prj) then added an extra verification that the data submitted were in the proper coordinate system. This check returned as PASSED if the file was submitted within the County of Riverside and FAILED if the file was outside the County.

The last check was if the e-mail was sent. It turns out that this check was much more difficult to achieve than expected. If the e-mail address was entered and the tool ran, then it returns a pass. If the e-mail was not sent, then a mail return failure would be sent to the sender. Since the tool was sent from the client’s e-mail server, the e-mail return was sent back to the client.

6.2.2 Layer Name Check Sheet

To verify that the tool loaded the parcel data correctly, the CAD data had to be tested with wrong level names and the correct level names. This check verified that the parcel data level names met the requirements, as stated in Chapter 5. Parcel data that did not contain all the correct layers resulted in a statement labeled “FAILED” that was written on the title sheet of the PDF, as illustrated in Figure 6-9.

Figure 6-9: Sample Level Check Results

A graphic for the level check was also shown on sheet two of the PDF indicating the correct layers, and showed any missing or optional layers as depicted in Figure 6-10. The digital survey-plat submission shown in Figure 6-10 is missing the layers named V-PROP-SUBD and V-PROP-CNTR. A “FAIL” or “PASS” notification was written in the PDF for the areas that passed or failed this check.

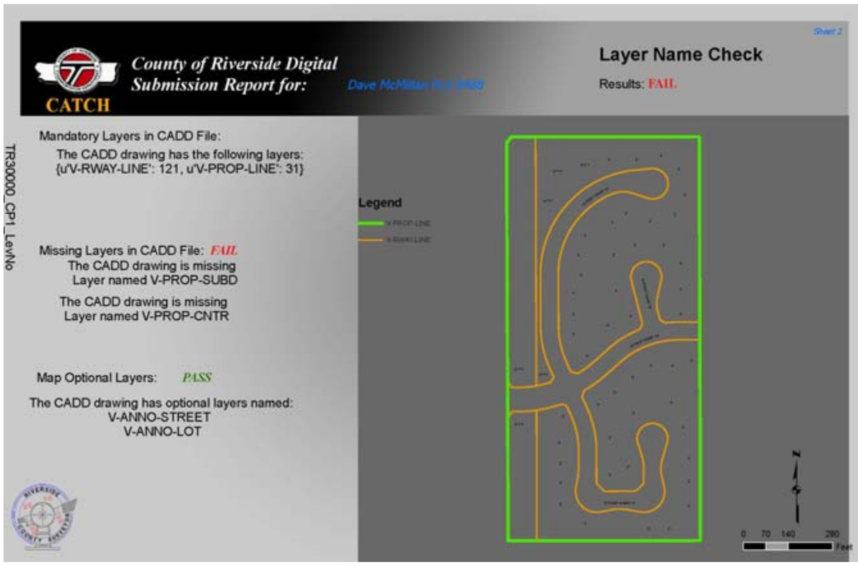

Figure 6-10: Sample Level Check Sheet Results "FAIL"

Next, the layer check was run with all the line and text on the correct layers. The results passed the layer check as illustrated in Figure 6-11 for the title sheet.

Figure 6-11: Sample Layer Check "PASSED"

Also, figure 6-12 showed the graphical results from the layer check that passed this check.

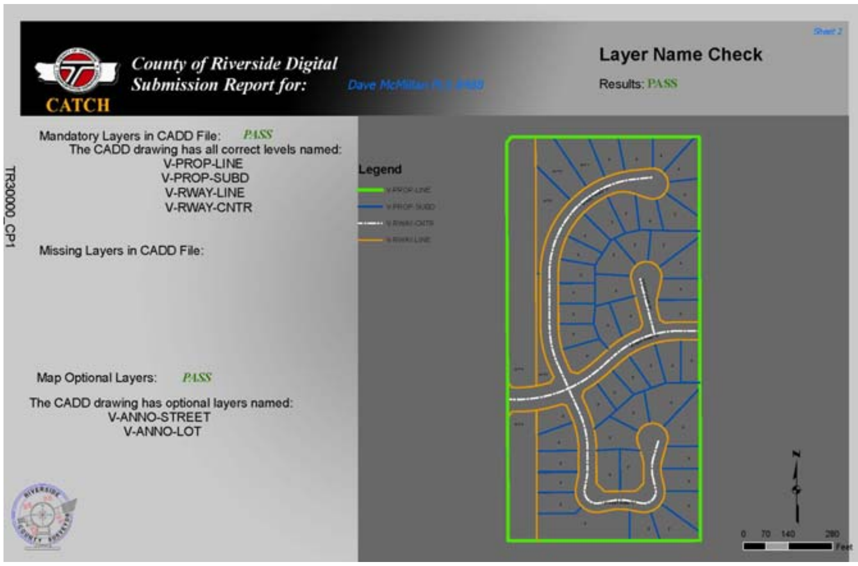

Figure 6-12: Sample Level Check Pass

6.2.3 Boundary Topology Sheet

Once the CAD data were loaded into CATCH and a geodatabase topology was created from the geoprocessing script, the results from the topology were displayed on the map documents. These map documents were exported from the geoprocessing script and a final PDF report was generated.

The results from the topology check used the seven topology rules defined by Esri (described in Chapter 4). Once the topology was validated, the script exported the topology errors, and the attributes from the feature classes were placed on the map document. A description of the error was listed, along with a total number count for the point, line, or polygon errors. A search cursor was also used to iterate through the field named “Rule Description” from the exported topology feature class, and the errors were counted for each violation. The results from the search cursor were then placed on the map document using the add elements command from the ArcPy.mapping module. Figure 6-13 illustrates the boundary topology report that resulted from the CAD file submitted through CATCH.

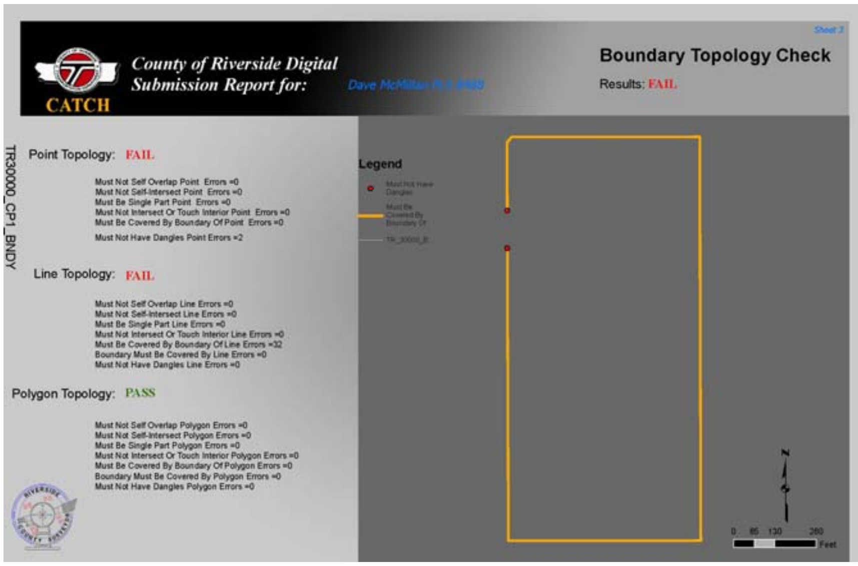

Figure 6-13: Sample Boundary Topology Report

During this check the exterior boundary of the map was checked first and the topological checks were reported on the map document and exported to the PDF boundary topology report sheet. Any point, line, or polygon errors were shown with a total count, together with a pass or fail for each type. An overall status PASS or FAIL was also written in the upper right hand corner of the sheet and was labeled "Boundary Results". The PDF map also showed a graphic of the digital survey-plat, accompanied by a legend that explained the type of topological violation.

6.2.4 Lot Topology Sheet

Next, CATCH checked the lots, right-of-ways, and centerlines for the same topological point, line, or polygon violations and reported the results into the lot topology report PDF. As shown in Figure 6-14.

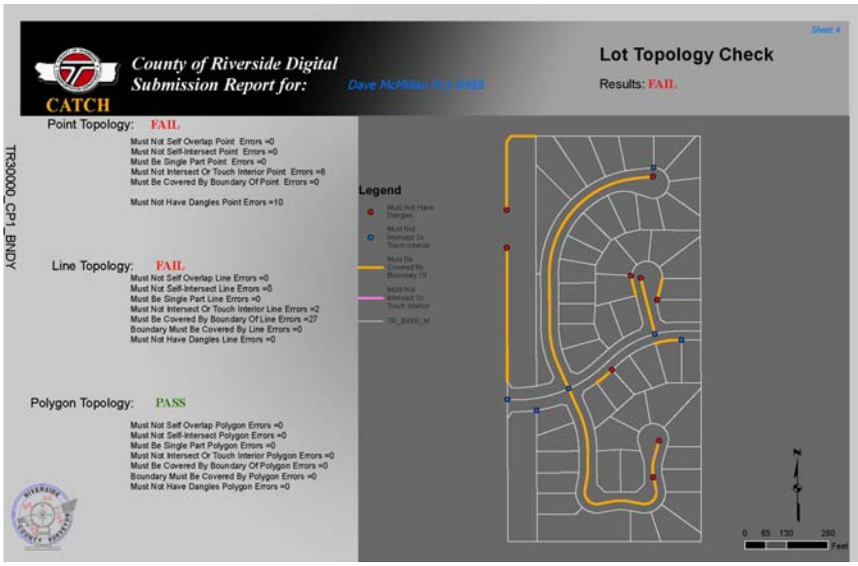

Figure 6-14: Sample Lot Topology Report

Each map topology report used the same search cursor technique to place the appropriate number of point, line, or polygon errors. The “add layer” command from the ArcPy.mapping module was also used, and allowed the script to place the layer files for the respective point, line, and polygon errors onto the PDF with a legend that showed the “Rule Description” field.

The seven topology rules depicted in Table 6-1 show which topology rules worked as expected, and those that did not. From the results, the “Boundary Must Be Covered By” topology rule could not be replicated with the CAD data. A reason for this was the polygons were created from the polyline CAD lines, so no overlaps or gaps would exist.

Line Type	Rule	Result
Polyline	Must Not Self-Overlap	Could not replicate Error with CAD Data. Error showed up with Must Not Self Intersect and Must Not Have Dangles Catches it as well
Polyline	Must Not Self-Intersect	Could not replicate Error with CAD Data. Error showed up with Must Not Intersect or Touch Interior Rule
Polyline	Must Be Single Part	Could not replicate Error with CAD Data. Error showed up with Must Not Have Dangles Rule
Polyline	Must Not Intersect Or Touch Interior	Works As Expected With CAD Data
Polyline-Polygon	Must Be Covered By Boundary Of	Works As Expected With CAD Data
Polygon-Polyline	Boundary Must Be Covered By	Could Not replicate error With CAD Data
Polyline	Must Not Have Dangles	Added to 6 topology rules for extra check and Works As Expected With CAD Data

Table 6-1: Seven Topology Rules

6.3 Summary

The automation tool created for this project helped the client achieve the goal of less review time for digital submissions, a higher level of consistency of the parcel data, and the ability to load data into the Parcel Fabric. Automating the process saved staff time and helped to facilitate the use of GIS technology in the County of Riverside.

The topology errors that were intentionally placed into the CAD data sets were caught by the tool from one of the seven listed topology rules. This confirmed that the tool was catching the errors, and preparing the data for loading into the Parcel Fabric.

Chapter 7 – Conclusions and Future Work

7.1 Conclusions

Utilizing survey-grade digital data is a method to help improve a land cadastre. This project created the County Automated Terrestrial CAD Helper (CATCH), an automation tool to check, report, and prepare CAD data for input into Esri's Parcel Fabric. However, applying a digital submission standard and being able to load high quality survey-grade digital data into the Parcel Fabric can be labor intensive and time consuming.

The project automated this process by creating a digital submission standard for the acceptance of the digital CAD files. These standards were implemented for the layer names, file types, line work, and the projection. The project also implemented seven topology rules as defined by the Parcel Fabric. These seven topology rules checked the line work for errors. During the testing phase the tool caught most of the errors as expected, but the polygon topology rules could not be violated from the sample data sets provided from the client. This turned out to be because the polygons generated from the tool were created from the polylines of the submitted CAD file. If the polygons were created from the polylines, then these lines would be coincident and would not cause any polygon errors to show up in the final report. The plan is to keep the rules and results as is and monitor the results from future submittals. The backbone of the system was built using ArcMap map document templates that acted as the base maps for the report creation. Python, ArcPy, and AcrPy.mapping were used to create the automation tool that satisfied the functional requirements for the client. The automation tool accepted input from the user and was able to read through the data, perform the data checks, package the data, and send results to a Land Surveyor or Civil Engineer who submitted the file. The final delivery consisted of a text file, PDF report, and CAD files showing any topology errors.

This project resulted in a great tool to check the quality of the data that were submitted through CATCH. The project met most of the client's requirements, and provided a solution for using the CAD data that will be submitted for Final Subdivision Maps. The client will be able to implement the CATCH tool into the checking of digital submissions for the County of Riverside. The digital submission standard that was created by this project helped the project team meet the goals of the client. The digital submission standard alleviated the discrepancies in the raw data and made the parcel data ready for input into the Parcel Fabric. The automation tool processes standardized CAD data and reports the results to the applicant. Once approved by CATCH, the data would be ready for input into the Parcel Fabric.

7.2 Future Work

The geoprocessing script for the CATCH automation tool works fine in the ArcGIS for Desktop environment, but could potentially be turned into a geoprocessing service (GP Service). This GP Service could then be hosted onto a customized web site built with JavaScript or some other web development program. The client has access to ArcGIS for

Server, so publishing the GP Service could be achieved by some reconfiguring to the Python script.

Another option would be to host the GP Service using ArcGIS Online (AGOL). The client has access to an AGOL organizational account, so the ability to host the GP Service could be achieved relatively easy, and would not need any additional web development or programming.

Once the Web Mapping Application is shared with everyone, then the general public could use CATCH via the web application. The applicant could then submit and check the data themselves; once the data pass the checks, the applicant could submit their CAD file for loading into the Parcel Fabric.

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