



King Fahd University of Petroleum & Minerals

Integrating GPS with GIS for an Airport Design

CRP 514: Introduction to GIS
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Contents

Abstract

1. Introduction

2. Problem Definition

3. Methodology

- **selection of site criteria**
- **onsite explorations**
- **Collecting and Mapping Real-World Data.**
- **making the layout**

4. Review of Literature

5. Integrating Process

- **Coordinate access**
- **Tools of study**

7. Conclusion

8. Reference/URLs

Abstract

The original concept of cartography in Geographical Information System can be again used with the help of modern applications and technology. This can be done by using Global Positioning System commonly known as GPS. In the field of Aeronautical Engineering, the need to find data related to terrain obstruction (topography), meteorological data (like Mean daily maximum temperature), etc., is usually encountered. To overcome this need ArcGIS software helps to find a particular area which satisfies the requirements of the airport site construction. Apart from the usage of the software in obtaining the resource information, it also helps significantly in processing the data (by converting it into the required format) and giving the outputs as desired by the engineer. It is by making the map (cartography). Drawing the coordinates of the site on the map is very difficult for the engineer, hence using the software ArcMap he can produce the result by feeding the global coordinates of the site. This project is an attempt to show how the use of GIS(Geographical Information System) can be made in Aeronautical Engineering field using the modern technology used by GPS (Global Positioning System).

Introduction

The **Global Positioning System**, usually called **GPS**, is the only fully-functional satellite navigation system. A constellation of more than two dozen GPS satellites broadcasts precise timing signals by radio, allowing any **GPS receiver** (abbreviated to **GPSr**) to accurately determine its location (longitude, latitude, and altitude) in any weather, day or night, anywhere on Earth.

GPS has become a vital global utility, indispensable for modern navigation on land, sea, and air around the world, as well as an important tool for map-making and land surveying. GPS also provides an extremely precise time reference, required for telecommunications and some scientific research, including the study of earthquakes. GPS receivers can also gauge altitude and speed with a very high degree of accuracy

In the attempt to make the the field of Aerospace Engineering aquanted of Geographic Information system through Global Positioning System, the following project of a typical site selection of an airport in Saudi Arabia and digitizing it by making a map through ArcMap is made. The selection of a site for the laying of an airport is mostly done by ArcMap; but in addition to this help from the software, we can actually use the it in positioning the site at a remote place to the surveyor in order to make it easier and faster for him to find the location and work on it as desired by the Aerospace officials.

Following is the process of obtaining the global coordinates of the boundaries of the site through the help of GPS and locating them on the geographic map of the world or the particular area with the help of the tool ArcMap provided by ESRI.

Objective

GPS and GIS are not a new technology that the field of Aeronautical engineering uses. Navigation, wind direction, location of the aircraft and many more needs makes the aerospace engineers to depend upon the technology of GPS, obviously with the base of GIS, without which the objective of any use of GPS would be inaccurate. Apart from the many applications of GIS and GPS individually, there is one such application that makes the use of these technologies together and the same is been explained in the further part of the report. Exploring the usage of these both technologies integrated with each other and used in the field of Aerospace Engineering is the motto of this project. The project will have a specific objective for each session of the methodology as stated below.

- To show the usage of ArcGIS in finding the sites suitable for building a Small community single runway airport. However the main objective is the next point.
- **To show how GPS with GIS gives birth to a new usage of so called hybrid technology which is so easy to use and advanced in producing results which match exactly to the desired understanding.**
- To comprehensively explain the method how the conversion of the coordinates can be done and plotted on the map using ArcGIS and producing the copy of expected understandable layout.

Methodology of Study

The process of methodology consists of few steps which are essentially distinguished as they make the sequence of explanation clear. These steps can be figures as

- » Selection of site as per FAA requirements.
 - » Collecting and Mapping Real-World Data.
 - » Using ArcGIS to locate the points on the map with suitable representations.
 - » Making the layout of the airport required according to the understanding of the surveyor.
- The methodology is mostly based on the efficient usage of the software with a very little effort to again the onsite values used as an inputs. The details about the selection of the site of airport using ArcGIS is not so comprehensive were as the main objective of the project that is the integrated usage of GPS with GIS in the design of airport will be discussed in detail next.

Selection of site as per FAA requirements

Criteria for the selection of an airport site for a type of aircraft is typically a responsible work to do as all the other factors go in vain eventually if this task is based on wrong assumptions and data

There are many requirements that Federal Aviation Administration put on the owner as per the usage. Some of them are listed below.

1. **Site Selection Report Requirements**
2. **Aeronautical Requirements**
3. **Environmental Requirements**
4. **Financial Evaluation**
5. **Public Involvement**
6. **Evaluation of sites and Recommendation**
7. **Coordination**
8. **Detailed Site Planning**

Apart form these criteria analysis of each site is done on the basis of

1. Approximate runway end coordinates and elevations.
2. Section, township, range.
3. Wind rose data.
4. Primary runway approach end.
5. Proposed type of approach to each runway end (Visual, Non precision, Precision).

6. Glide angle available for each approach after obstructions have been cleared.
7. List of obstructions that must be cleared for each runway end.
8. Existing zoning and zoning needed for airport (include name of jurisdiction having zoning authority).
9. Availability of utilities - electricity, gas, telephone, water and sewer.
10. Access road availability and travel time to nearest community.
11. Potential Environmental Impacts

Collecting and Mapping Real-World Data

Collect GPS data around the site on an Excel sheet, and import them to ArcView to create shapefiles and grids.

Gathering data in the field allows us to make maps of your own neighborhood. Collect GPS data, use Microsoft Excel to process their data, and import that information into ArcView to make maps of the campus. Connecting the spatial data to the real world, is the central concepts in GIS.

In order to do this exercise we will need:

- To think about useful ways to use GIS to map and analyze the features on our campus or in our neighborhood
- A Global Positioning System receiver.
- Microsoft Excel or another program that can generate database or delimited text files (instructions are given here for Excel)
- If we wish to create line or polygon files with our data, we will need an extension that allows us to convert points to lines or polygons. There are a few such extensions available on the web. I used the ET-Tools extension which is available for free from the web site at <http://www.ian-ko.com> (they offer a Spatial Tools extension, as well). Instructions are given here for using the ET-Tools extension.

- Field Data Sheets (provided in Excel format: *Field_Ex_Data_Sheet.xls*) I collected data on paper even if I have a GPS that will store data points for few reasons which are out of our study.

Using the software to locate the points on the map with suitable representations.

This is the most crucial task in this project which involves few of the main steps in the procedure of mapping the data. ArcView reads and understands coordinates in decimal degrees. As a further information on this regard few steps in this process are named briefly so as to give the reader an idea about the happening things. Entering the data into Microsoft Excel, Converting the data, Preparing the database file, importing the data and Working with the data to create shapefiles and grids are few of the major steps taken for the accomplishment. Creating a shapefile is an important task that requires a thorough knowledge about the software, hence it will be explained in detail in future.

Making the layout of the airport required according to the understanding of the surveyor.

- This section as well is to be done with the help of the software and consists of images at the end of the project. This also contains the representation of the results. A clear layout of the site with respect to the references, scale, direction and gridlines with respect to the latitudinal or longitudinal axes is given which is the output of this project and the data of the surveyor for the construction to be done.

Review of Literature

Before beginning of this section we need to know what is GPS. Global Positioning System is an advanced technology which is widely used by many fields related to geographical

sciences as well as technical engineering. The **Global Positioning System**, usually called **GPS**, is a satellite navigation system. More than two dozen GPS satellites orbit the Earth and transmit radio signals which allow any **GPS receiver** near the planet to determine its **location**, speed and direction. Hence we are concerned with *location parameter* now, we through some light on the background of this field, also we look how both GPS and GIS are advancing together or individually in the field of Aerospace Engineering. However usage of GPS is not a new thing for the field of Aerospace engineering. We can site hundreds of publication mentioning the usage of GPS in different aspects of Aerospace engineering field.

GPS applications in AE field

- Filtered Dual-Frequency Carrier-Phase Differential GPS for Relative Navigation of High-Altitude Spacecraft(Ref6).
- Integrated Hardware Investigations of Precision Spacecraft Rendezvous Using the Global Positioning System(Ref8).
- Satellite Orbit Determination Using a Single-Channel Global Positioning System Receiver(Ref7).
- Applications of Global Positioning System Velocity-Based Attitude Information(Ref9).
- Global Positioning System Sensor with Instantaneous-Impact-Point Prediction for Sounding Rockets(Ref10).
- A GPS Tracking System with Onboard IIP Prediction for Sounding Rockets(Ref11).
- Comparison of Relative Navigation Solutions Applied Between Two Aircraft(Ref12).

GIS applications in AE field

- Mission planning and simulation of unmanned aerial vehicles with a GIS-based framework. Mission Planning software uses Geographic Information Systems (GIS) sources and dynamic aggregation of geo-referenced data to provide an information-

rich context for human-directed creation of missions that are, for the most part, vehicle-independent.(Ref1)

- Global Navigation Satellite Systems and Telecommunications Satellites are also shown to be key technologies in contributing to a Malaria Information System (MIS) capable of creating and disseminating thematic maps that identify risk early and accurately.(Ref2)
- The WRAM(Wind resource assessment model) is used to produce a wind resource map of gridded wind power density values with a 1-km" resolution. The WRAM as developed with ArcInfo™, a powerful GIS software package developed by Environmental Systems Research Institute Inc.(ESRI) ArcInfo™ contains a large number of routines for scientific analysis.(Ref3)
- Geographic information systems (GIS), and their associated databases, already have had substantial impact on government and business throughout the world. Increasingly, spatial data constitute the core of the information management systems of both private companies and public agencies. The spatial data and processing capabilities supplied by the technology also constitute a significant component of the emerging National Spatial Data Infrastructure (NSDI).(Ref4)
- Current targeting systems such as AFATDS (Advanced Field Artillery Tactical Data System) do not have the ability to predict future locations of moving targets being tracked within the Common Operating Picture (COP). Although these systems can perform some limited terrain and mobility analysis calculations that are static in nature, they do not address the key issue of how to apply terrain and mobility factors to attack a moving target. The objective of this paper is to introduce a targeting system that investigates and demonstrates the feasibility of 4D Geographical Information System (GIS)-based tracking, prediction and visualization of ground moving targets. The system uses 3D GIS to provide a virtual 4D scenario of ground moving targets' tracking, prediction and possible hitting point within the COP.(Ref5)

The above references clearly show that much use has been taken from GIS and GPS individually in the field of Aerospace engineering but integrating them and using in such a

task where both of them gives the best and the accurate results is the idea that cannot be neglected by the engineers. If we put a site more deeply on the references we can view the interpreting effect. GPS is the helping the aerospace engineers in such a way that without GPS the flight and the pilot is lost in the atmosphere. GPS gives the engineers the location of the aircraft and helps the pilot in the aircraft as well as the engineers on the ground to help each other find the references to fly and coordinate with each other. Not only coordination between the ground station and the pilot but pilots in two aircraft can have coordination with each other through GPS(Ref12).

On the other hand when it is the matter of combating, GIS give the pilot and the planners a detailed view of the topology of the war land which helps them to target the enemy accurately and understand the war land comprehensively so as to minimize the errors(Ref 1). Indirectly GIS is giving a base or a background to Air Defense Academy to do their work accurately. This give the authorities to understand not only the war land but at times when the military is to help the civilian on emergency missions this gives them the detailed view of the effected areas and how to accomplish their target(Ref2). Scientific analysis by the authorities is an important task so as to know the different aspects of geographical features which help the pilot to fly the aircraft in an appropriate atmospheric areas(Ref3). It could be concluded from the above discussion that GIS and GPS are two independently helping hands in the field of aerospace engineering field but this is the first attempt to integrate both of them to help the field do better and accurate with a small innovation in the technique. A further research can also be done on how to make the integrated use of GPS and GIS in not only the field of Aerospace engineering but also in other fields. Because the GPS is concerned only with finding the location of the feature and GIS is concerned with both the location and the attributes of the feature, both of them can explore a new world of integrated science and make visible changes in the world of technology.

Integrating Process

- **Coordinate access**

Collecting GPS data around the site, and import it into ArcView to create shapefiles and grids. Field Exercises are a great way to learn about spatial data. Gathering data in the field

allows you to make maps of your own neighborhood. Collect GPS data, use Microsoft Excel to process their data, and import that information into ArcView to make maps of the campus. Connecting the spatial data to the real world, is the central concepts in GIS.

In order to do this exercise, we will need:

- To think about useful ways to use GIS to map and analyze the features on your campus or in your neighborhood
- A Global Positioning System receiver (inexpensive models are great for classroom exercises, but if you need very accurate data, or if you are collecting large amounts of data, you may need to invest in a more expensive model)
- Microsoft Excel or another program that can generate database or delimited text files (instructions are given here for Excel)
- ArcView GIS
- If we wish to create raster files with the available data, we will need the Spatial Analyst extension
- If we wish to create line or polygon files with your data, we will need an extension that allows us to convert points to lines or polygons. There are a few such extensions available on the web. I used the ET-Tools extension which is available for free from the web site at <http://www.ian-ko.com> (they offer a Spatial Tools extension, as well). I recommend this extension because it is easy to use, very versatile, and comes at the right price. Instructions are given here for using the ET-Tools extension.
- Field Data Sheets (provided in Excel format: *Field_Ex_Data_Sheet.xls*) I collected data on paper even if I have a GPS that will store data points. This is for two reasons: electronic equipment can fail, and I learn important lessons in recording the data that I don't get by just pushing buttons.
- Clipboards and pencils.
- Good weather is not required, but it sure helps.

The following resources are available for the collection of the data:

- Detailed instructions on how to collect, process, import, and visualize GPS data (below).
- A blank field exercise data sheet: (.xls format)
- A few shapefiles to use with the data provided in the Excel examples.
- A Power Point presentation (GPS To GIS.ppt)

Collect GPS data around your school, and import it into ArcView to create shapefiles and grids.

Preparing to collect the data:

First going over the following information before we go out into the field to collect data.

Review Cartesian coordinate systems:

- The x coordinate is longitude or the distance east or west from the prime meridian
- The y coordinate is latitude or the distance north or south from the equator
- There are 360 degrees in a circle. There are 60 minutes in a degree, and there are 60 seconds in a minute. So there are 3600 seconds in a degree.

ArcView reads and understands coordinates in decimal degrees. Practice converting decimal minutes and degrees/ minutes/ seconds to decimal degrees

We will use a Global Positioning System receiver unit to collect position information about features in your neighborhood. The unit receives transmissions from satellites overhead and triangulates its position based on that information. The more satellites the unit can “see” from its position on Earth, the more accurate its read-out of latitude, longitude, and elevation will be.

Setting our GPS units to the coordinate system, datum, and units of measurement that we prefer. Before we set out into the field, take a few minutes to develop a data dictionary. For

instance, if our group is collecting a point theme of tree species and tree heights, we will first want to establish a code or an abbreviation for each species you will encounter (and leave room for the unexpected). For a polygon theme of buildings, the data dictionary could include codes or fields for building type, uses, owner, address, etc.. (Hint: CAD drawings or blueprints of school buildings can provide building heights. These can be added to your GPS data to build 3D maps of your campus buildings.)

Some GPS tips:

- Each GPS has some way of indicating how accurate the position is at any given time, giving you the number of satellites it is picking up and a range of accuracy in feet or in meters. Your unit may allow you to average your readings over time. Be sure you understand how to read the accuracy of the data and to obtain the most accurate readings possible. Read the manual for recommendations on how to collect the most accurate data.
- There are several ways you can increase the accuracy of your data: Stand still for a minute or more before taking a reading, and average your position if your GPS unit will do averages. If you cannot stop and stand, move as slowly as possible. Thick trees and buildings may block the GPS unit's "view" of satellites overhead-- if possible avoid them, and if you must use your GPS among trees or buildings, average your position over longer periods of time or consider using an external antenna.
- Collect point line and polygon features on separate data sheets, and collect them in the order that they should appear when they are mapped. In other words, if you want a road to appear as a straight line, walk down the road from one end to the other to collect the points. If you collect points out of order, your nice straight road will appear as a crazy zigzag on your map. The same goes for a polygon, walk around the polygon and collect the points as you go.

Collect our data:

Here are a few hints for collecting data:

- Take some time to glance at your data sheets while you are doing this exercise. If a GPS unit is not initialized properly, or if you are not paying attention to accuracy, you may collect some erroneous readings. Are all your recorded positions in the right hemisphere? Is there one reading that is very very different from all the others?
- Remember to collect data in the order it is to appear on the map.
- Remember to stand in position for 30 seconds or more to increase the accuracy of their data.
- Respect private property and the privacy of individuals.
- In this project in order to have an accurate set of coordinates I have gone through different constraints and websites to match the coordinate set with both the ArcMap software and also which resemble the real world data. The constraints which imply here for the purpose of taking the coordinates for the airport runway are
 - Length of the runway is approximately 1.3 km or 1300 m.
 - Width of the runway is about 60 m.
 - The coordinates taken into account with respect to the format which ArcMap accepts are four. Since the objective of the project is to show the usage of GPS and GIS together in Aerospace engineering we take a simple example of a rectangle (polygon) which resemble a simple runway (without any taxi ways) and thus we need four coordinates i.e four corners of the rectangle desired in the geographical output. The coordinates which sets in all the parametric constraints are

No. of the Point	X coordinate	Y coordinate
1	405766	2912464

2	406062	2911268
3	406057	2912464
4	405763	2911268

- The above points are to be copied in an Excel sheet and saved in .dbf format (DBF4 dBASE) so as to export in ArcMap. This process is done in further steps.

- **Tools of study**

Tools utilized for a particular project to take place are very important to specify as they are the guidelines for further work that can be done. One who explore the tools and utilizes them in a productive time saving manner has the responsibility of listing them in accordance to the process took place in his project. This helps the future users to take fast action on the procedure and know how to optimize the solutions using different tools in their subject of concern.

In this session we look about the new tools that are been used in ArcMap but were not in the course as their utility is not covered for the students part of program. But these tools are currently been used by the cartographers to optimize their work. The tools are

- › Coordinate system tab in Data frame properties.
- › Editor Toolbar.

Coordinate system tab in Data frame properties

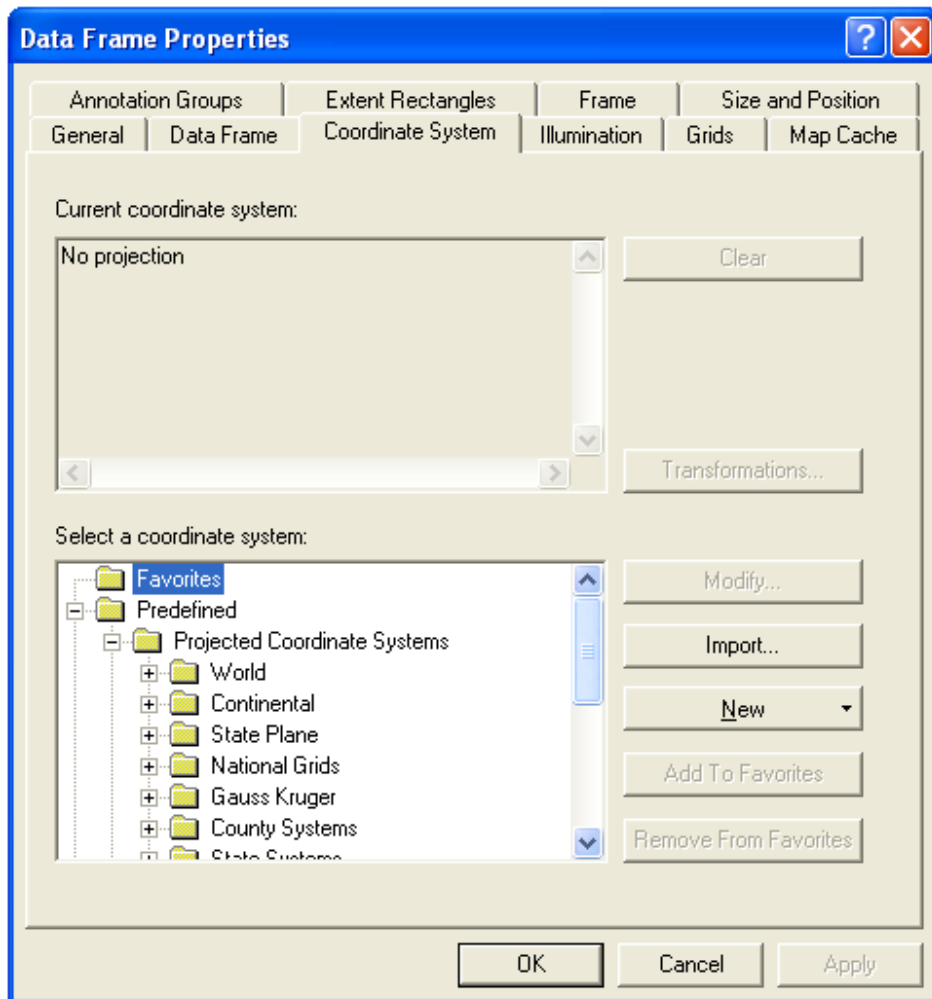
Before knowing about using the tab we need to know how and why this tab is used in this project. The basic necessity of using this tab is to locate the Zone and Datum of the area which is to be studied. Zones are nothing but country divided into few different areas resembling a number through which it is easy for the lab users to locate a particular point feature in a country. It particularly refines the search for a feature. Its use is also for different purposes in Cartography and related fields using GIS as their core processing software. Kingdom of Saudi Arabia is divided into four Zones namely zone numbers 37, 38, 39 and 40. The area we are choosing for our project comes under UTM (Universal Transverse Marketer) Zone 39 and the name of the Datum is Aein el Abd. We base our

coordinate system on a particular zone. And when we select this zone the pointer shows us the real world global coordinates at the bottom of the user interface of ArcMap. Hence the selection of the zone is to make a base of coordinate system which gives us the real world coordinates on the monitor.

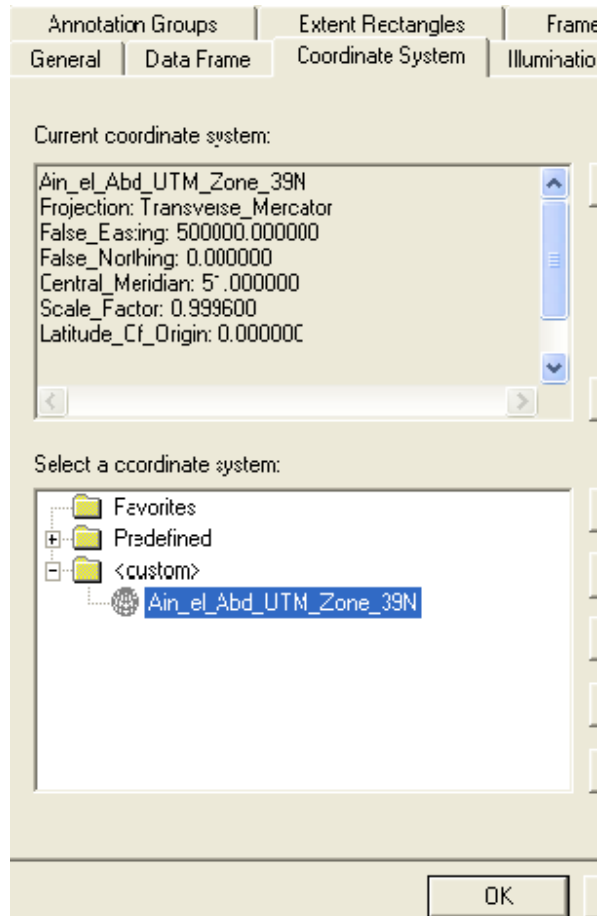
The reader need not be worried about from where we are going to get the map and the related data for the zonal distribution. We do not know till this moment that ArcMap has inbuilt list of zone and datum from where we can select our concerned area.

The process goes like this.

- Open ArcMap software with new empty map.
- Double click on the Data frame in the context menu to see it properties or by right clicking on the data frame and selecting the properties. The name of the data frame is 'Layers' by default.
- Selecting the Coordinate system tab on the window

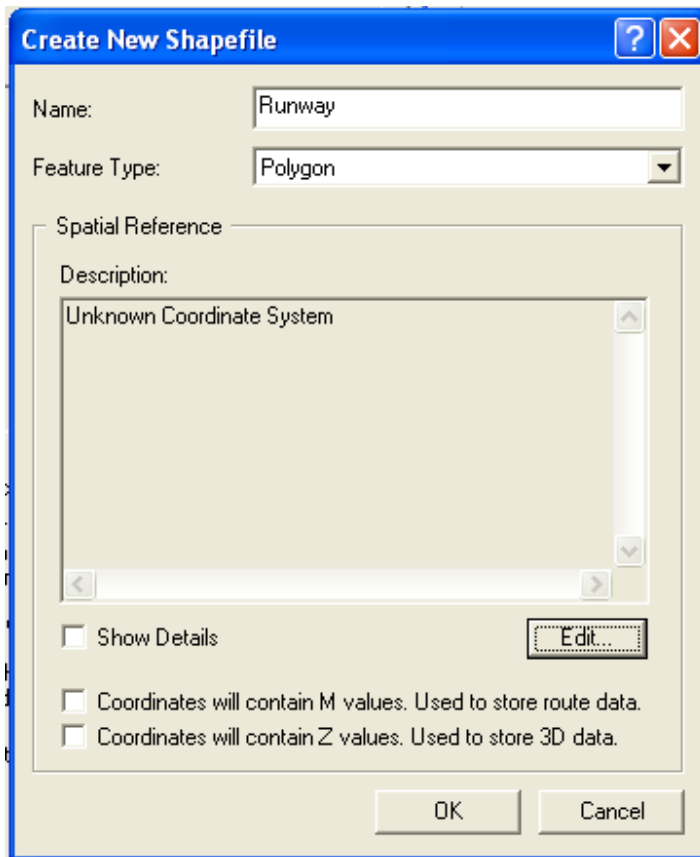


- We can see that there is no projection in the current coordinate system, but coming at the bottom of the dialogue box we can see that we are been give choice to select a coordinate system. Then in that sub window open the folders as stated below
 Predefines→ Projected Coordinate System→ UTM→ Others→ Ain el Abd 1970
 UTM zone 39 N
 When you select the last coordinate system file, you will see the specifications of that zone in the current coordinate system sub window like meridian, scale, latitude of origin.



Then click Apply and then OK.

- Now go to ArcCatalog. In the context menu right click in the free space and select "New" then "Folder". Name this folder as "My Project".
- Right click "My Project" folder and select "New" and then "Shape file"
- A dialogue box opens with heading "Create New Shapefile". Name the file as "Runway" and file type as "polygon" (because the shape of the runway is similar to rectangle which is nothing but a polygon, we are giving the file type as polygon) then press "Edit" as shown



- A new dialogue box opens by name " Spatial Reference Properties" which gives us an option to select a predefined coordinate system.
- When you press the *Select* button, you will see new window showing the same folders which were seen in the tab in selecting the coordinate system at the beginning of the process. Now do the same process of selecting the coordinate system as did before in the above steps.
- Press "Apply" then "OK" after selecting finally "Ain el Abd 1970 UTM zone 39N" then press OK in the create new shapefile window. You will see a shapefile in the *Content menu*.
- Drag this shapefile and drop it in the ArcMap window. It will set in the context menu automatically.

Editor Toolbar

Before editing geographic feature data within ArcMap, you must first add the Editor toolbar. In ArcMap, a set of tools that allows the creation and modification of features and their attributes.

Explore the Editor toolbar

Many times, your project may call for specific editing tasks to be used more than others. Task options can be added to or removed from the Task dropdown menu on the Editor toolbar. This will simplify your editing interface and facilitate your selection process.

To use more advanced editing tools, you must add other editing toolbars to ArcMap.

These include Topology, Annotation, Advanced Editing, Route Editing, Spatial Adjustment, Dimensioning, Versioning, and Geometric Network Editing

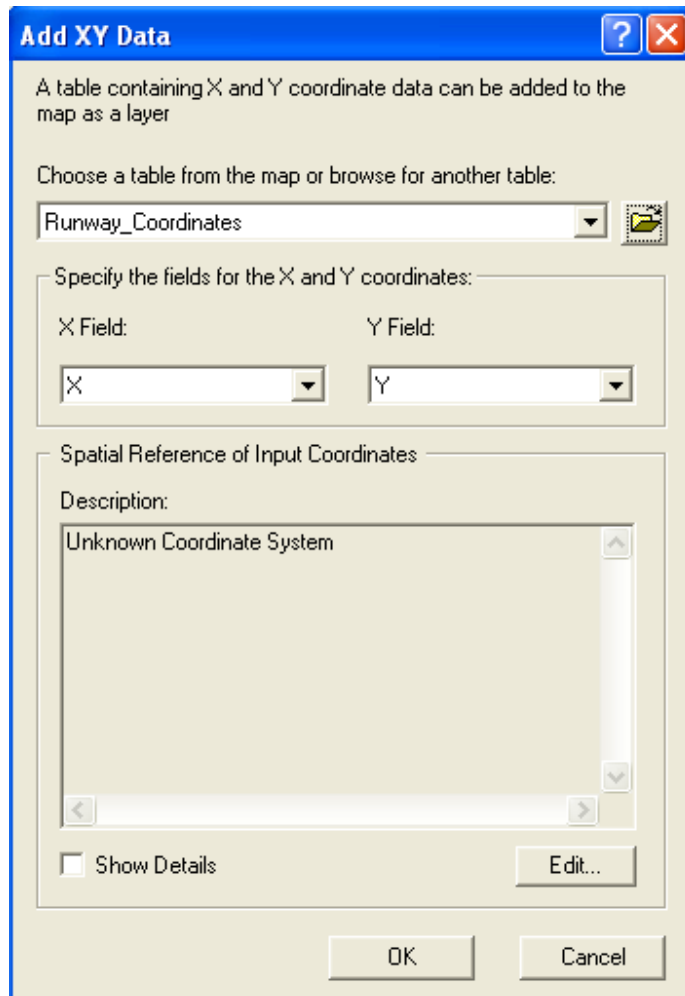
The procedure steps can be continued now after knowing the definition of the Editor toolbar.

Contd..(procedure steps)

- Toggle to ArcMap, In the main toolbar, go to *Tools*, then click on *Editor toolbar* . Now you will see a toolbar standing in front of the display section. Set it to the toolbars panel.

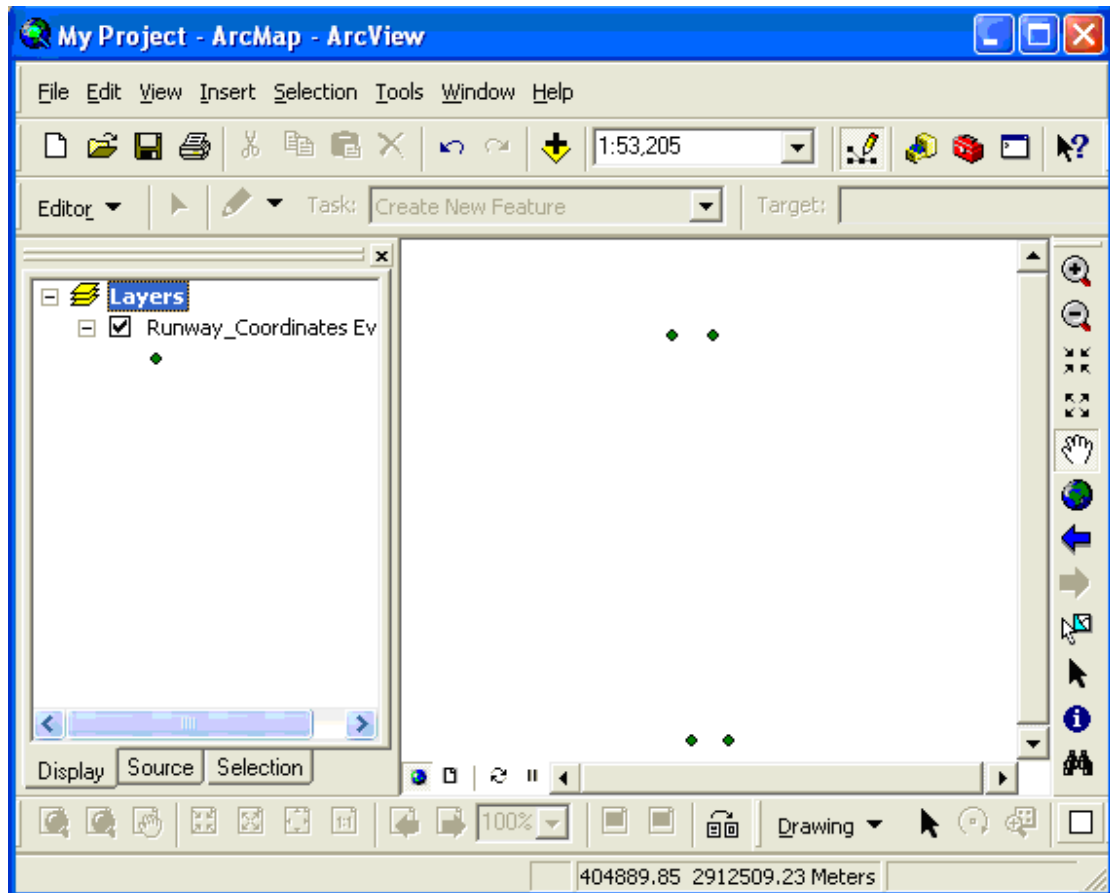
In order to add the coordinates data in the present selected zone we need to make ArcMap read the data in the stored Excel sheet. For this

- Go to *Tools* in the main toolbar and then click *Add XY data*. A dialogue box opens asking for the coordinates. Just browse to the coordinates excel sheet and say Add. Automatically the X and Y coordinates are set as shown in the figure provided that the cursor while saving the excel sheet is on the column of X coordinates.



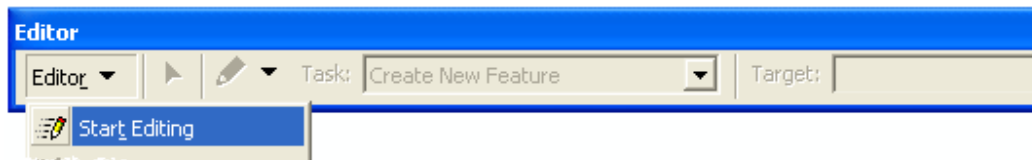
Till this moment we didn't specified that where the coordinates are to be mapped. For this..

- Press *Edit* before pressing OK, and browse for the coordinate system selected before till the Ain el Abd 1970 UTM zone 39N comes and then press Add, then Apply, then OK. You will see all the four points spotted on the map. We are near to done now. Your screen look something like this.

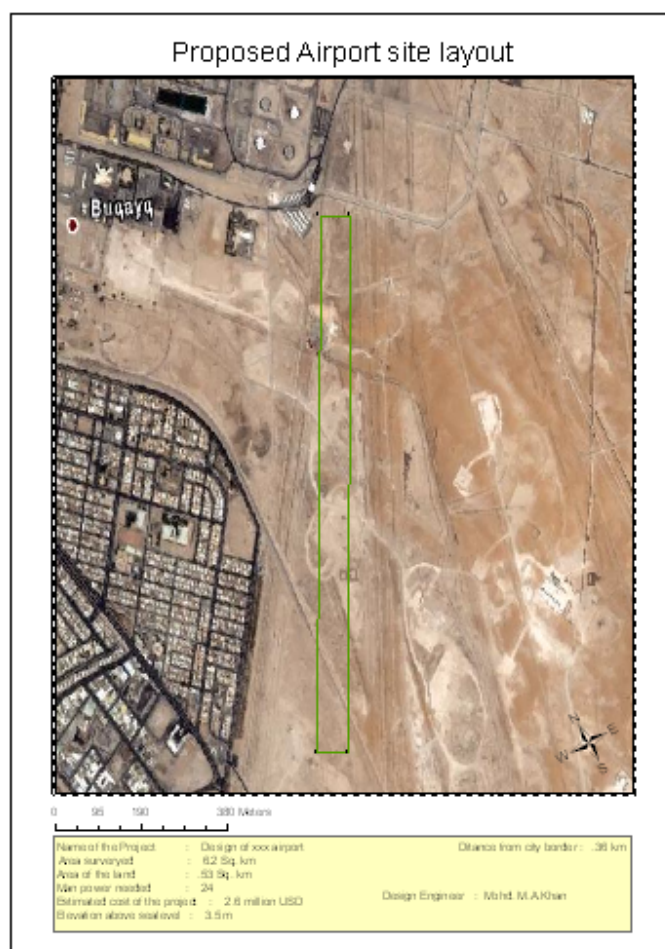


The layer Runway is removed as the coordinate system has been mapped on it. Not deleting this layer will make the data superfluous.

- Here the Editor toolbar comes into picture and help effectively. Switching the Editor tool ON can be done by going to the Tools menu and selecting it or just by pressing the button with a small pencil drawing angular lines on it in the main toolbar.
- Now press the first button called Editor as shown and Start Editing. Click on the pencil on the toolbar and join all the four points to make a complete rectangle.



- Use Georeferencing to connect the four coordinates of the made layer to the image got from www.google.earth.com to get the reality as the background and mainly to make the surveyer to understand the layout.
- Using chapter 19 of ArcGIS Desktop manual provided by the instructor complete layout of the map can be presented with appropriate scale, legend, directions and references.



Conclusion

This project gives a new dimension for the Aerospace Engineers who do a hectic job in the design of an airport. On one hand where he works with the conventional method of using cartography to design the airport where as on the other hand GPS and GIS integrate to develop a hybrid methodology to overcome the tiresome process of cartography. Again where the integration of GPS and GIS helps in the new way of cartography, they also help in the engineers in designing the same airport with more sophistication and representation. In this way the proposed methodology of the conventional cartographer is been permanently changed or we can say upgraded. GPS, though being a very small instrumentation with the latest technology helps satellite utility to not only give users the output of GIS but also the input which GIS needs to make and process the data. An example is been attempted successfully to show its integrated usage in the field of Aerospace Engineering, but the thought should be generalized in using this methodology for different fields. Thus upgrading the science offering a new hybrid methodology.

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