Practical Notebook

Geographical Information System LAB

BS-SS-021-F21

BS Morning, Fifth Semester
Departement of Space Science
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This document of consists of GIS lab practicals and their solutions that we have performed til January 7, 2024 in class. It mostly focus on what the practical is and how it works along with figures to visualize the solutions. The figures are snapshots from performances on ArcGIS Pro software. All inputs and outputs are in separate geodatabases and in feature class format and can be provided if need be.

The theoretical portion of the text, description of tools and opreations is based on **ArcGIS Pro documentation** (Link Here), **Essentials of Geographic Information Systems chapter:7** (Link Here), **GIS Wiki** (Link here) and **Introduction to Geographic Information Systems chapter 11.**

If you find some error or something wrong in this Practical Notebook, Let me know.

This document was generated by LaTeX and written by me.

Contents

P1: Vector Overlay

1.1 Introduction

In GIS, **Overlay** is defined as *"the process of taking two or more different thematic maps of the same area and placing them on top of one another to form a new map"*. It is a GIS operation that superimposes multiple datasets (representing different themes) together for the purpose of identifying relationships between them. It does not only combines the spatial features of the datasets but also the attribute information in them as well. In simple, It creates a composite map by combining the geometry and attributes of the input datasets. Tools are available in most GIS software for overlaying both vector or raster data.

1.1.1 Feature types and Overlay

In general, Overlay methods can be performed on two or more layers of same or different geometry, depending on method. As Point, Line and Polygon are the three basic and simple feature types in vector data, grouping them by two gives nine different combinations, while allowing repetition. Based on these, Overlay Opreations can be classified into:

- point-on-point overlay
- point-on-line overlay
- point-in-polygon overlay
- line-on-point overlay
- line-on-line overlay
- line-in-polygon overlay
- polygon-on-point overlay
- polygon-on-line overlay
- polygon-in-polygon overlay

where, first is the input layer and the later is the overlay layer. However, most overlay methods don't permit all of them. So, they are often reduced to the three with polygon as overlay ones, i.e. 3, 6, 9.

1.1.2 Overlay Methods

There are various methods and opreations of overlay for that can be applied on vector data based on the kind of outcome required. These methods in foundation are based on logic connectors like AND, OR, NOT & their combinations etc. In accordance with them, there are 3 major methods that are used in overlaying. GIS softwares provide tools that follow these methods and performed them on the given inputs. As we are using ArcGIS enviorment, we will be discusing the tools that work using those methods simultaneously as well. These three main opreations and the ArcGIS tools for them are as follows:

Union Union tool

Intersection Intersect tool

Subtract Erase tool

Note: Different GIS softwares may implement these opreations a bit differently or the name of the tool can be different. It is to be noted the implementation of these methods along with tools are exclusive to ArcGIS however, the core concept of the method is defined in general terms.

Other than these, there are several other overlay opreations as well like **Symmetrical Difference**, **Update**, **Clip**, **Identity** etc. These opreations can be performed as the combination of the main three in different configuration. The major ones from these will be described later on.

1.2 Union

In Union, the output layer consists of all the features that occur in any one of the inputs or in all of them as well as the features that formed due to the overlapping of the features between input layers along with all their attributes and spatial extents. Simply, It preserves all features and make new ones for the overlaps.

The working and backend opreation for Union is analogous to:

Logic Or
Arithematics Addition

In ArcGIS, the **Union Tool** can be accesed by following these steps:

⇒ Go to *Geoprocessing Tools*.
⇒ Expand *Analysis Toolbox*
⇒ Expand *Overlay Toolset*.
⇒ Select *Union*.

⇒ *Union* Tool dialog window opens.

Note: All other overlay tools in ArcGIS can be accessed by following the same steps with relative changes in step four.

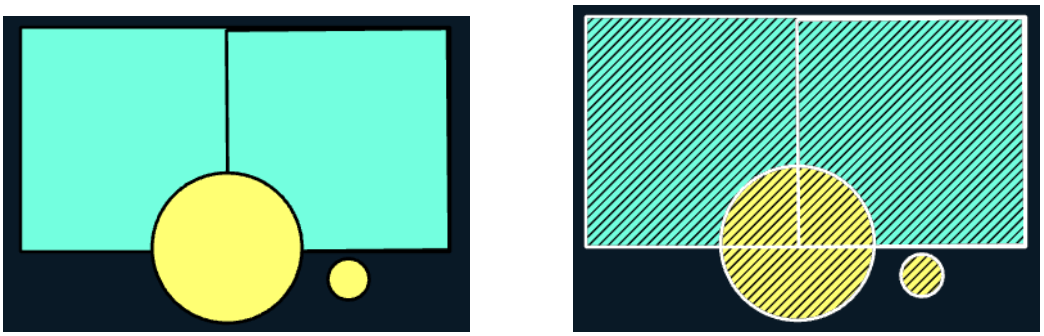
Parameters

Union tool's input parameter is named as **Input Features**, which has following properties:

Geometry All Inputs must have Polygon Geometry.
No of inputs One or more.
Order The order of inputs doesn't matter, as $A \cup B = B \cup A$.
Coordinate system By default, same as the first input layer.

There is no separate overlay layer parameter as Union includes features from all the inputs without any distinction. It can also run with a single input layer. In that case, instead of discovering overlap between the polygons from the different layers, it will discover the overlap between polygons within the single input. The areas where polygons overlap will be separated into new polygons with all the attribute information of the input polygon. This can be very useful in finding errors during digitaization.

Example Figures



(a) Input B on Input A (b) Output on Input A and Input B

Figure 1.1: Union

(a) displays Input B layer (Yellow circles) on top of Input A (Blue Squares). Both layers has two features each.

(b) displays the union output for these inputs (hatched symbology) on top of them, clearly showing that all features are included. This layer has eight features in total in accordance with the number of overlapping features.

1.3 Intersect

In Intersect, the output layer consists of only the features or parts of them that appear in both or all of the inputs. Features or portions of features that overlap in all layers will be written to the output.

The working and backend opreation for Intersect is analogous to:

Logic AND
Arithematics Multiplication

In ArcGIS, the **Intersect Tool** can be accesed by following the steps in (1.2), and selecting intersect in step 4.

Parameters

Intersect tool's input parameter is named as **Input Features**, which has following properties:

Geometry Can be Point, Line, Polygon, Can be same or different
No of inputs Two or more.
Order The order of inputs doesn't matter, As $A \cap B = B \cap A$.
Coordinate system By default, same as the first input layer. Changeable.

Inputs and Outputs: Combinations

As the geometry of input files can be of any type. So, it is better if we set all possible combinations for them before starting experiments with them.

Given a set of three basic geometry types, i.e. **Point**, **Line**, and **Polygon**. Now, for all the possible combinations from this set with two members and repetition gives us nine groups in total which are:

1. (Point, Point)
2. (Point, Line)
3. (Point, Polygon)
4. (Line, Point)

5. (Line, Line)
6. (Line, Polygon)
7. (Polygon, Point)
8. (Polygon, Line)
9. (Polygon, Polygon)

As, $A \cap B = B \cap A$, so set 2, 3, 6, are same as 4, 7, 8. So, based on input geometry we have six different combinations of inputs for all three geometry types.

However, The tool also provides an optional parameter value **Output Type**, with values *Same as Input (default), Line and Point* as geometry type for output layer. The output layer can only have geometry same as the input layer with lowest number of dimensions or geometry less that than. For example if inputs are polygon and line, the output can have geometry line or less, i.e. point. This means if the lowest dimension geometry in input is.

Polygon $\rightarrow$ the ouput can be Polygon, Line, Point.

Line $\rightarrow$ the ouput can be Line, Point.

Point $\rightarrow$ the ouput can be only be Point.

Based on all these, we have nine possible scenarios as can be shown in the given table:

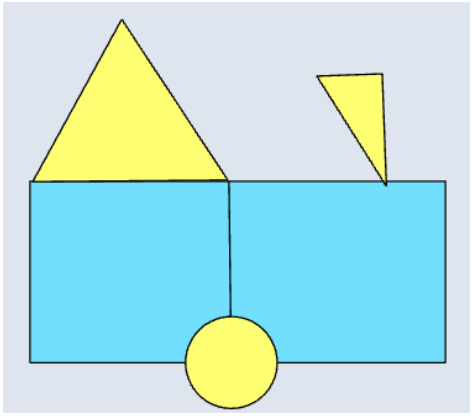
Input A	Input B	Output
Polygon	Polygon	Polygon
Polygon	Polygon	Line
Polygon	Polygon	Point
Polygon	Line	Line
Polygon	Line	Point
Polygon	Point	Point
Line	Line	Line
Line	Line	Point
Line	Point	Point
Point	Point	Point

Table 1.1: Intersect Combinations

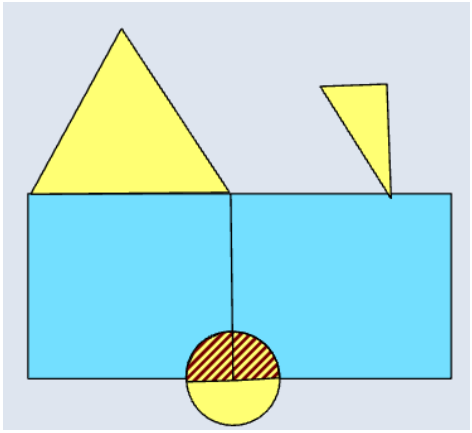
Example Figures

Figure 1.2: Polygon Polygon Intersect

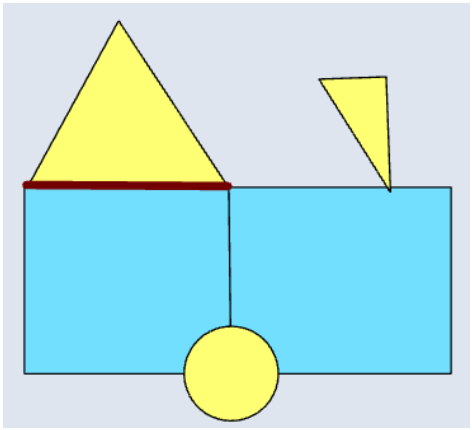
(a) Polygon on Polygon (input)



(b) Polygon Output (hatched)



(c) Line Output (red line)



(d) Point Output (red points)

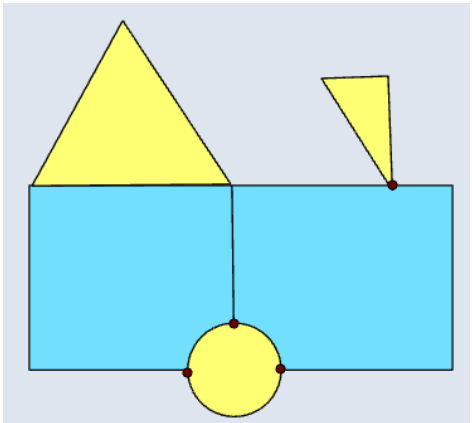
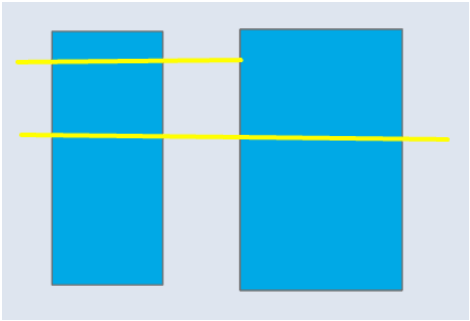
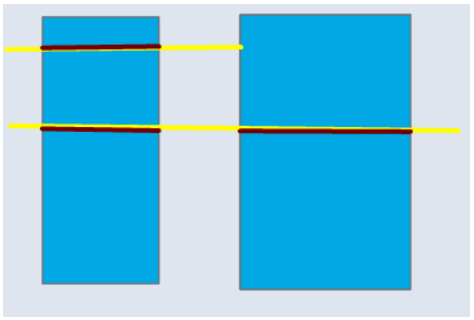


Figure 1.3: Polygon Line Intersect

(a) Line on Polygon (Input)



(b) Line Output (red lines)



(c) Point Output (red points)

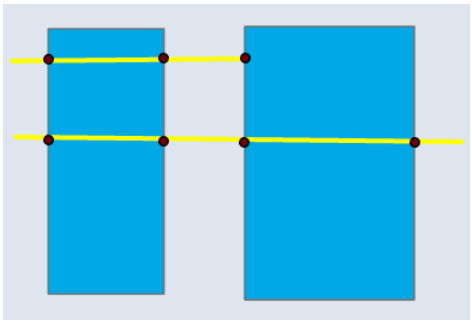
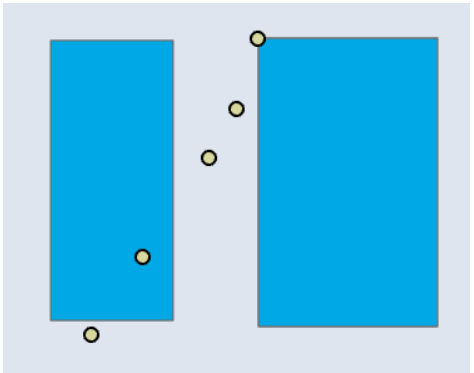


Figure 1.4: Polygon Point Intersect

(a) Points on Polygon (Input)



(b) Point Output (red points)

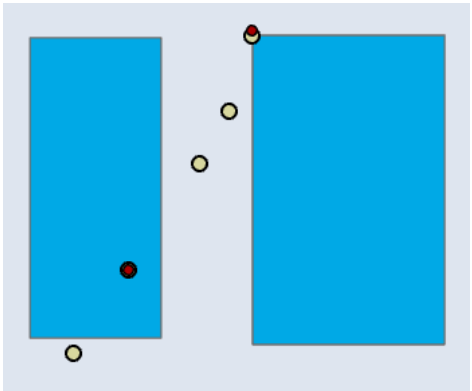
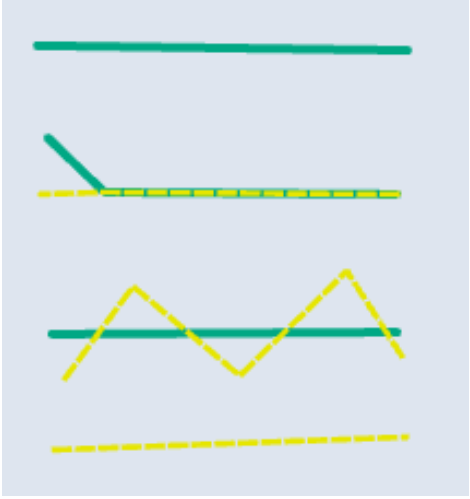
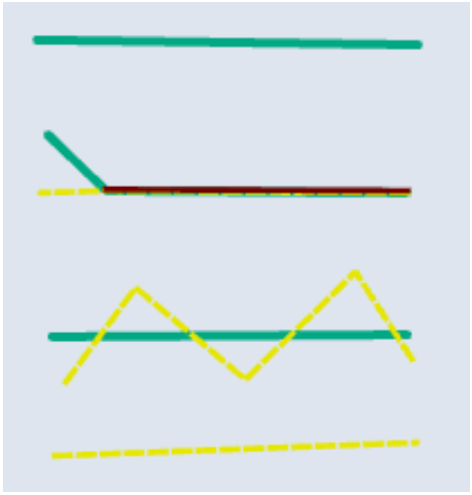


Figure 1.5: Line Line Intersect

(a) Line on Line (Input)



(b) Line Output (red line)



(c) Point Output (red points)

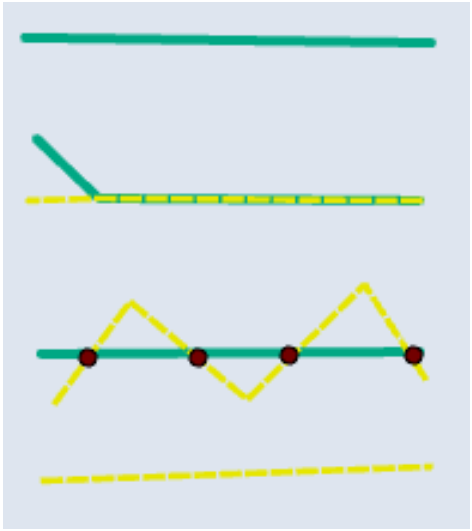


Figure 1.6: Line Point Intersect

(a) Points on Line (Input)

(b) Point Output (red points)

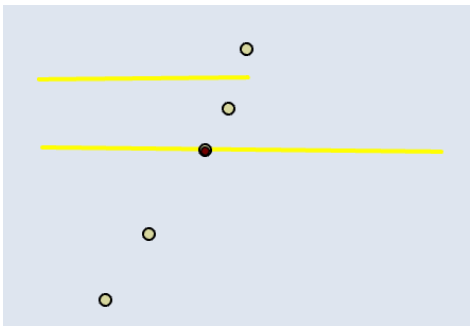
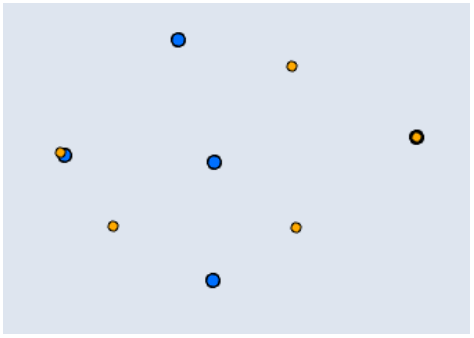
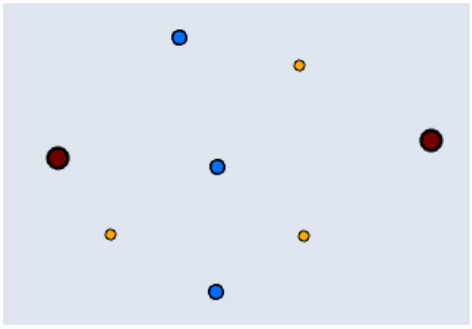


Figure 1.7: Point Point Intersect

(a) Point on Point (Input)



(b) Point Output (red points)



1.4 Erase

In Erase, the output layer consists of only those portions of the input features falling outside the erase features. Geometries that are coincident between the Input Features and Erase Feature parameter values will be removed.

The working and backend opreation for Intersect is analogous to:

Logic AND NOT (how?)
Arithematics Subtract

In ArcGIS, the **Erase Tool** can be accesed by following the steps in (1.2), and selecting Erase in step 4. This tool is synonoumous to Difference or Subtract in other GIS softwares.

Parameters

Erase tool's input layer parameter is named as **Input Features**, which has following properties:

> **Geometry** Can be Point, Line, Polygon, Can be same or different
> **No of inputs** One or more.

The second required parameter, the overlay parameter that will define the erasure extent is named as **Erase Features** and can have any geometry as long as it has either same or greater dimensions than input layer. An erase feature with point geometry type can not be used on polygon input.

The output layer has same geometry type as input.

Input and Erase: Combinations

Given the restriction that Erase Features parameter value must either be same as of Input Feature or higher, we have these possible combinations [**Format:** (Input, Erase)],

1. (Point, Point)
2. (Point, Line)
3. (Line, Line)
4. (Point, Polygon)
5. (Line, Polygon)
6. (Polygon, Polygon)

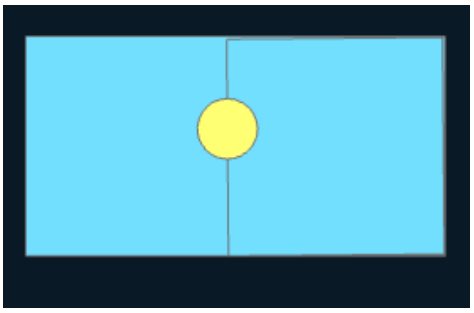
The geometry type hirearchy based on dimensions is $Polygon > Line > Point$, with they have dimensions 2, 1, 0, respectively.

Unlike Union or Intersect, interchannging input and erase layer will result in different output, as $A - B \neq B - A$. In case of combination 2 and 4, 5, i.e. with different geometries output won't be possible. In case the geometry type is same, the result will differ. This gives us nine possible scenarios for start.

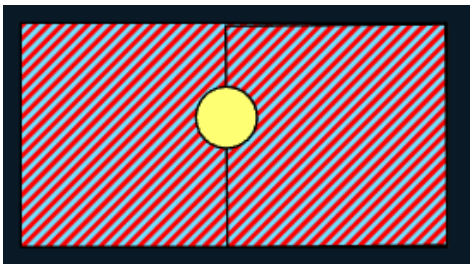
Example Figures

Figure 1.8: Polygon Polygon Erase

(a) Polygon on Polygon (input)



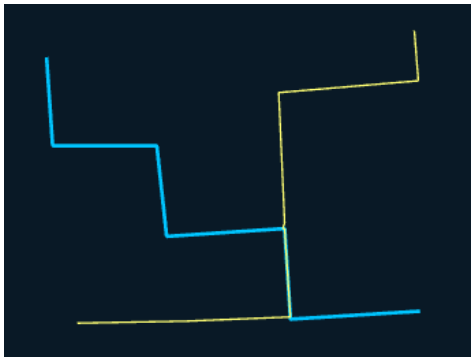
(b) Polygon Output (hatched)



(Note:) Reverse in this case, gives an empty output.

Figure 1.9: Line Line Erase

(a) Line on Line (input)



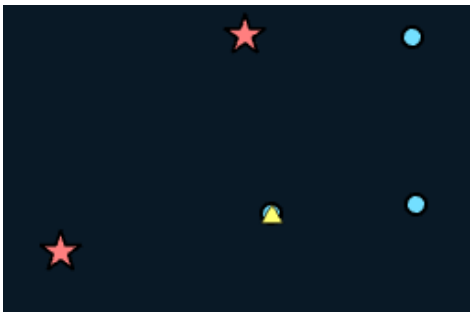
(b) Line Output (erase by yellow)

(c) Line Output (erase by blue)

Figure 1.10: Point Point Erase

(a) Point on Point (input)

(b) Point Output (red stars)

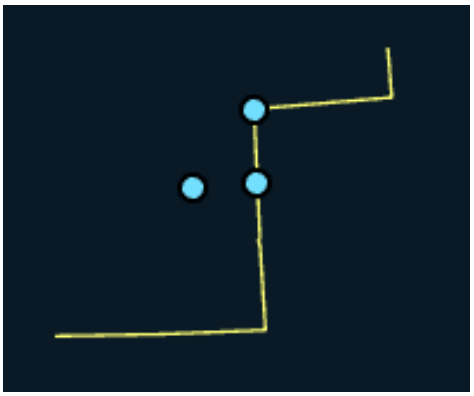


(c) Point Output (red plus)

(Note:) In (b), blue circles are erase feature and yellow triangles input, in (c) vice versa.

Figure 1.11: Point Line Erase

(a) Point on Line (input)



(b) Point Output (red star)

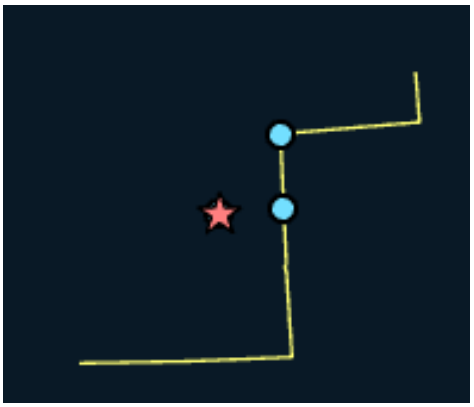
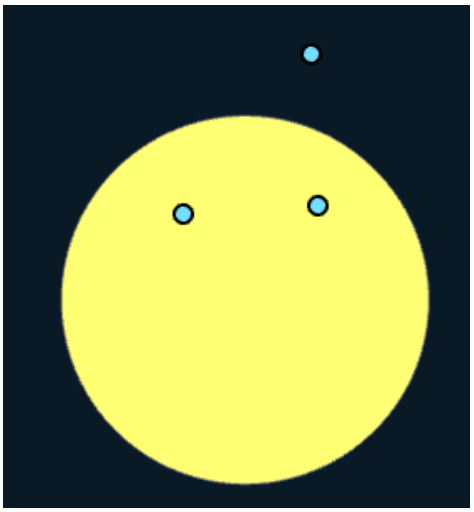
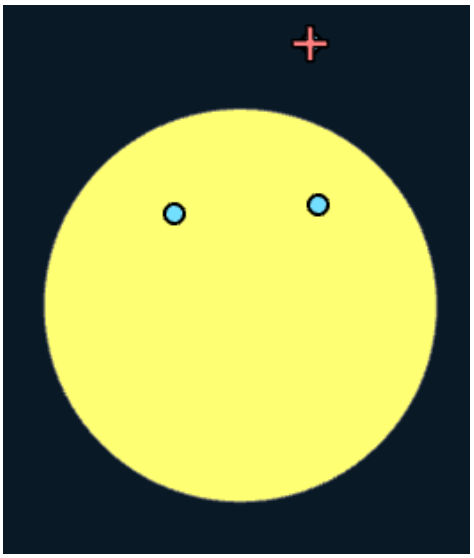


Figure 1.12: Point Polygon Erase

(a) Point on Polygon (input)



(b) Point Output (red star)



1.5 Further Tools in Overlay

Introduction

As was mentioned in the begining, There are many other overlay opreations as well as tools for geospatial analysis. The major difference is that every other tool can be formed by using these three, like in Logic, AND, OR & NOT. The same is the case here. Other important overlay methods that have tools in ArcGIS overlay toolset are, Identity, Update, Symmetrical Difference. Another commonly known tool is Clip, which is in **Extract Toolset** in **Analysis Toolbox**. Some other tools in **Overlay Toolset** are Remove Overlay (multiple), Count Overlay Features, Spatial Join, which is a hybrid etc.

1.5.1 Identity

The output of Identity has the extent and all the features of input layer, with the geometery and attributes merged in the area where input and identity layer overlaps. At the places of overlaps, Input layer features will get the attributes of Identity layer.

It can be derived as $(A - B) \cup (A \cap B)$.

In ArcGIS, the **Identity Tool** can be accesed by following the steps in (1.2), and selecting Identity in step 4. This tool is synonoumous to Minus in other GIS softwares.

Parameters

Identity tool's input layer parameter is named as **Input Features**, which has following properties:

Geometry Can be Point, Line, Polygon, Can be same or different

The second required parameter, the overlay parameter that will define the Identity layer is named as **Identity Features** and can either have polygon geometry or same as input layer. The output layer has the same geometry type as input.

Input and Identity: Combinations

Given the restriction that Identity Features parameter value must either be same as of Input Feature polygon, we have these possible combinations [**Format:** (Input, Identity)],

1. (Point, Point)
2. (Line, Line)
3. (Polygon, Polygon)
4. (Point, Polygon)
5. (Line, Polygon)

Like Erase, interchannging input and identity layer will result in different outputs. In case of combination 4, 5, i.e. with different geometries output won't be possible. In case the geometry type is same, the result will differ, as long as they have different extent. This gives us eight possible scenarios for start.

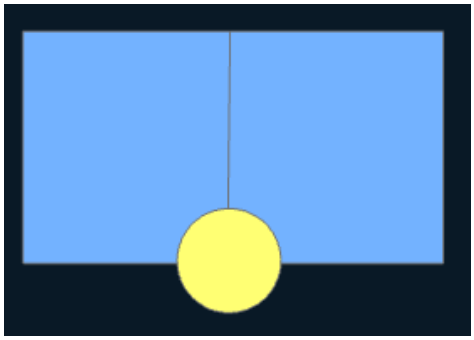
(Note:) Colour vary by attributes symbology used in outputs for identity tool, showing the change in features and attributes of input layer.

Example Figures

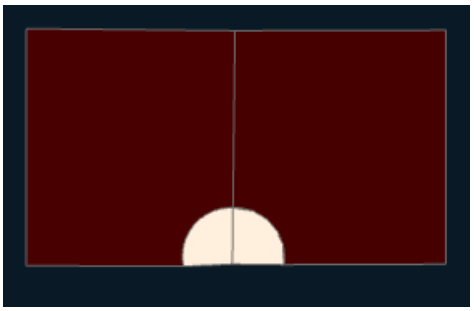
(Note:) Colour vary by attributes symbology used in outputs for identity tool, showing the change in features and attributes of input layer. Outputs are not displayed on inputs, but separately in case of same geometry. Colour in subcaption indicates the identity feature colour in input for same geometery, and changed features and attributes for different geometry.

Figure 1.13: Polygon Polygon Identity

(a) Polygon on Polygon (input)



(b) Polygon Output (by Yellow)



(c) Polygon Output (by Blue)

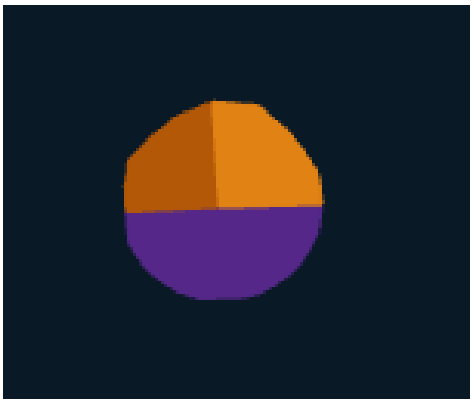
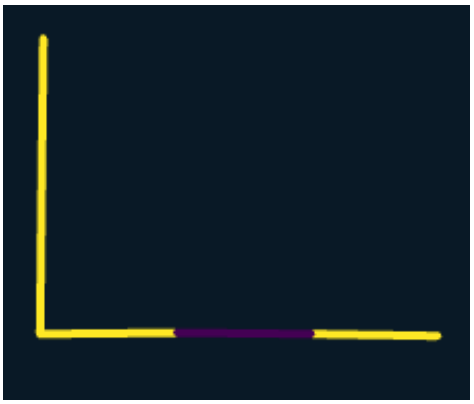


Figure 1.14: Line Line Identity

(a) Line on Line (input)

(b) Polygon Output (by purple)



(c) Polygon Output (by light Blue)

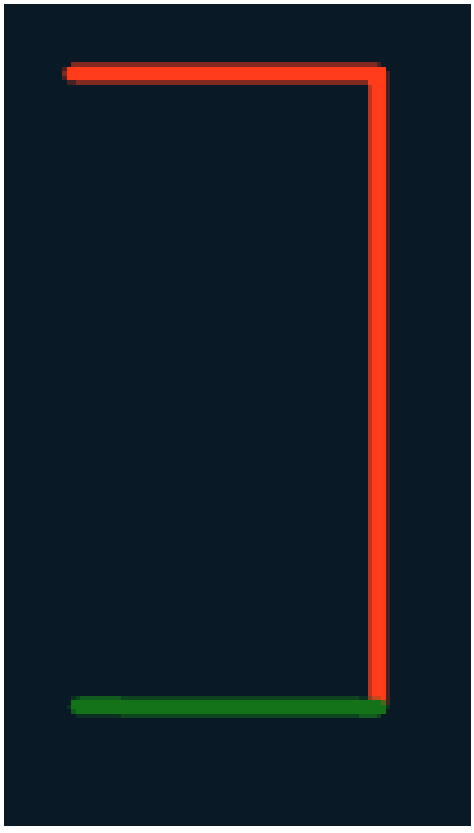
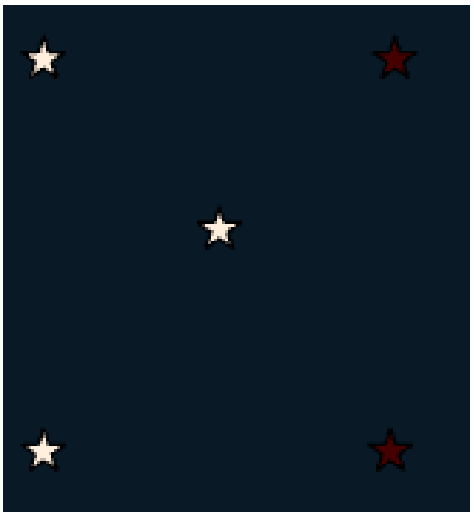


Figure 1.15: Point Point Identity

(a) Point on Point (input)

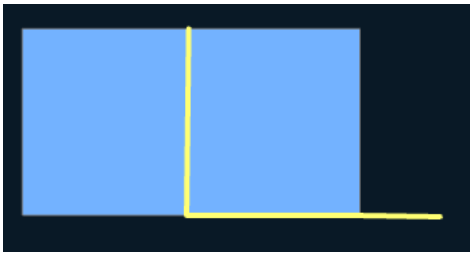
(b) Point Output (by Yellow)



(c) Point Output (by Blue)

Figure 1.16: Line Polygon Identity

(a) Line on Polygon (input)



(b) Line Output (Red)

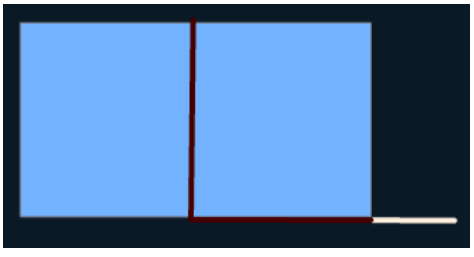
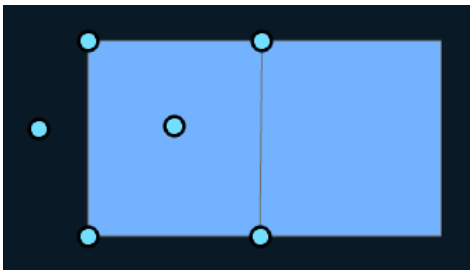
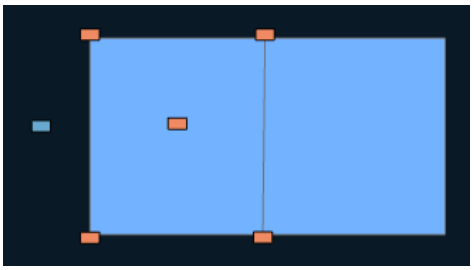


Figure 1.17: Point Polygon Identity

(a) Point on Polygon (input)



(b) Point Output (light red)



1.5.2 Update

Update is similiar to Union in extent but in the area where the two layers overlap, only the geometry and attributes of update layer is retained.

It can be derived as $A \cup (B - A)$.

In ArcGIS, the **Update Tool** can be accesed by following the steps in (1.2), and selecting Update in step 4. This tool is synonoumous to Cover in other GIS softwares.

Parameters

Update tool's input layer parameter is named as **Input Features**, which has following properties:

Geometry Must be Polygon.

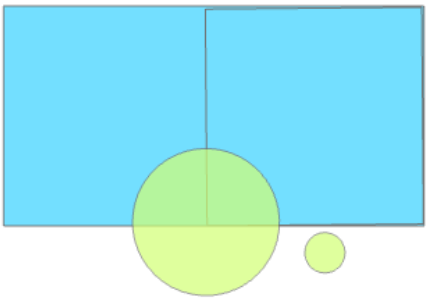
The second required parameter, the overlay parameter that will define the updating geometrics is named as **Update Features** and also must have polygon geometry like in Union. The output is polygon in nature as well.

Unlike, Union interchannging layers will result in different output, giving two possible different combination for this tool to start.

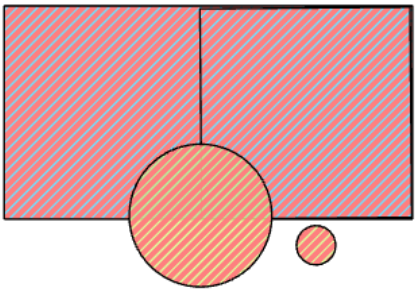
Example Figures

Figure 1.18: Polygon Polygon Update

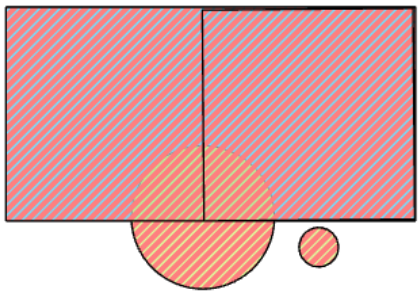
(a) Polygon on Polygon (input)



(b) Polygon Output (by yellow)



(c) Polygon Output (by blue)



1.5.3 Symmetrical Difference

Symmetrical Difference is opposite to Intersect with results having features or portions of features in the input and update features that do not overlap written to it. In simple, which includes features that occur in one of the layers but not both.

It is analogous to **XOR- Exclusive OR**, & can be derived as $(A \cup B) - (A \cap B)$ or $(A - B) \cup (B - A)$.

In ArcGIS, the **Symmetrical Difference Tool** can be accesed by following the steps in (1.2), and selecting Symmetrical Difference in step 4.

Parameters

Symmetrical Difference tool's input layer parameter is named as **Input Features**, which has following properties:

Geometry Point, Line, Polygon

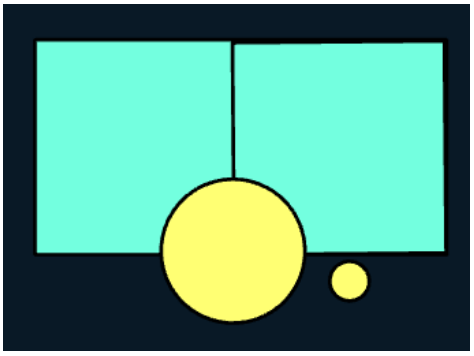
The second required parameter, the overlay parameter that will define the updating geometrics is named as **Update Features**, just as in *Update Tool* and must have same geometry as "Input Features". Output has same geometery as well.

As in Intersect, interchannging layers will not effect the output. So, that gives us three possible combination for this.

Example Figures

Figure 1.19: Polygon Polygon Symmetrical Difference

(a) Polygon on Polygon (input)



(b) Polygon Output (hatched)

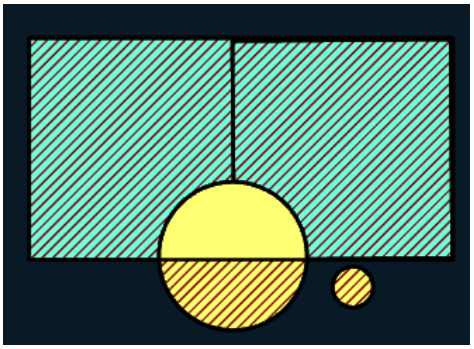
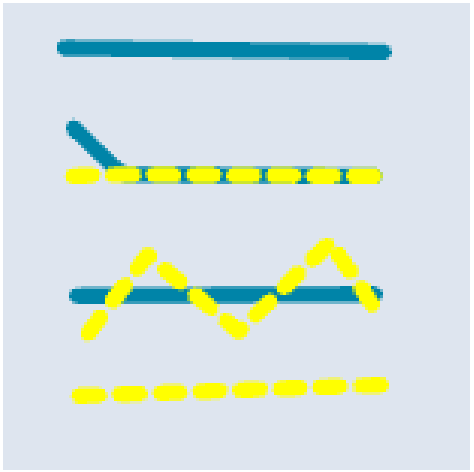


Figure 1.20: Line Line Symmetrical Difference

(a) Line on Line (input)



(b) Line Output (red)

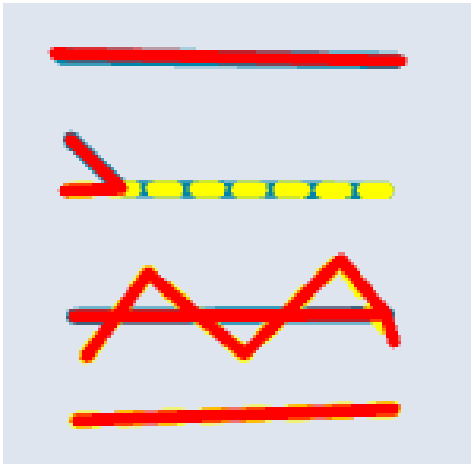
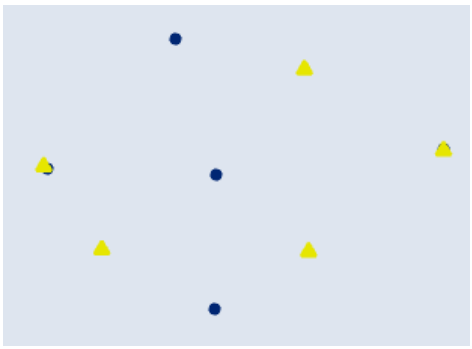
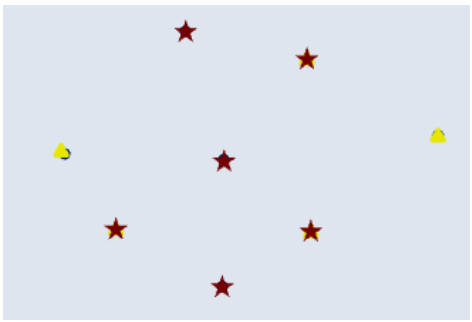


Figure 1.21: Point Point Symmetrical Difference

(a) Point on Point (input)



(b) Point Output (red stars)



1.5.4 Clip

Clip extracts input features that overlay the clip features. The output contains the same overall extent as the intersection, but only retains the geometry and attributes of one of the input layers. It is most commonly used to trim one layer by a polygon represent an area of interest.

It can be derived as $A - (A - B)$.

In ArcGIS, the **Clip Tool** can be accesed by following the steps in (1.2), and expanding **Extract toolset** in step 3 and selecting Clip in step 4.

Parameters

Clip tool's input layer parameter is named as **Input Features**, which has following properties:

Identity tool's input layer parameter is named as **Input Features**, which has following properties:

Geometry Can be Point, Line, Polygon.

The second required parameter, the overlay parameter that will define the spatial extent of output is named as **Clip Features** and can have any geometry as long as it has either same or greater in dimensions than input layer. A clip feature with point geometry type can not be used on polygon input.

The output layer has same geometry type as input.

Input and Clip: Combinations

Given the restriction that Erase Features parameter value must either be same as of Input Feature or higher, we have these possible combinations [**Format:** (Input, Clip)],

1. (Point, Point)
2. (Point, Line)
3. (Line, Line)
4. (Point, Polygon)
5. (Line, Polygon)
6. (Polygon, Polygon)

The geometry type hirearchy based on dimensions is $Polygon > Line > Point$, with they have dimensions 2, 1, 0, respectively.

Unlike Union or Intersect, interchannging input and clip layer will result in different output. In case of combination 2 and 4, 5, i.e. with different geometries output won't be possible. In case the geometry type is same, the result will differ, if the extent change. In case of point or line as clip features, only the coincident features respective to them will be included in output, as these features can't define extent in area terms.

This gives us nine possible scenarios for start.

Example Figures

Figure 1.22: Point Point Clip

(a) Point on Point (input)

(b) Point Output (red star)

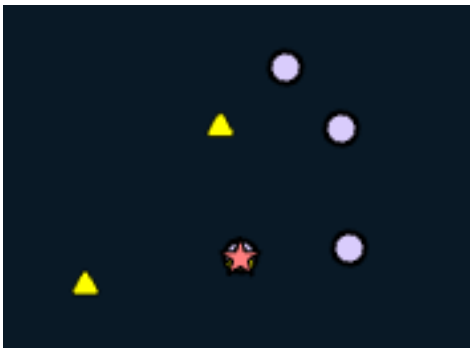
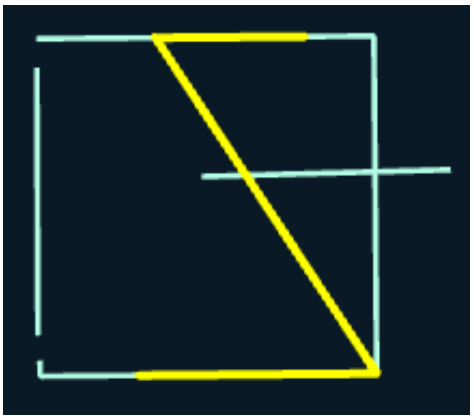


Figure 1.23: Line Line Clip

(a) Line on Line (input)



(b) Line Output (red)

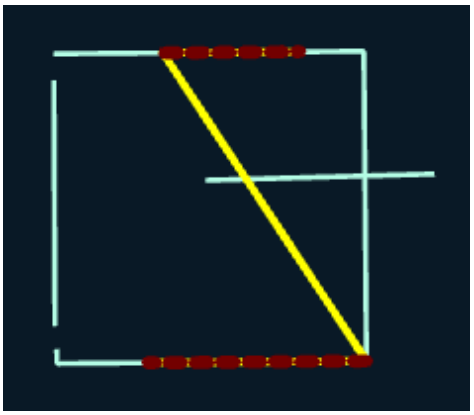
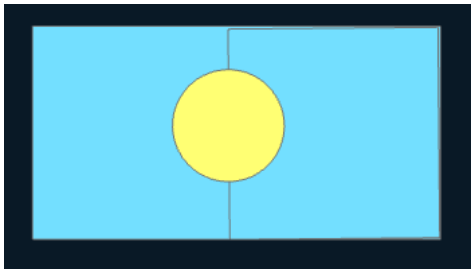
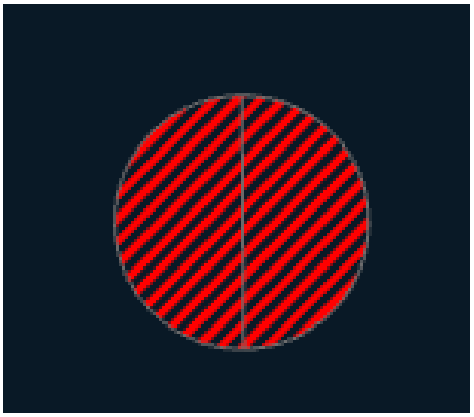


Figure 1.24: Polygon Polygon Clip

(a) Polygon on Polygon (input)



(b) Polygon Output (by Yellow)



(c) Polygon Output (by blue)

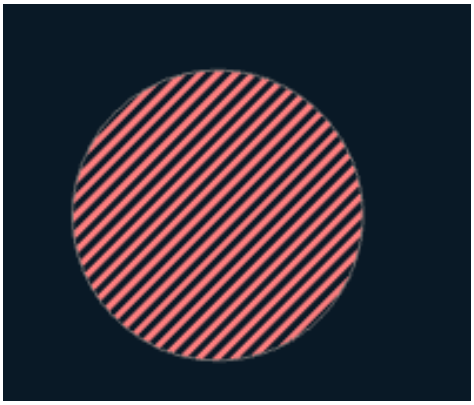
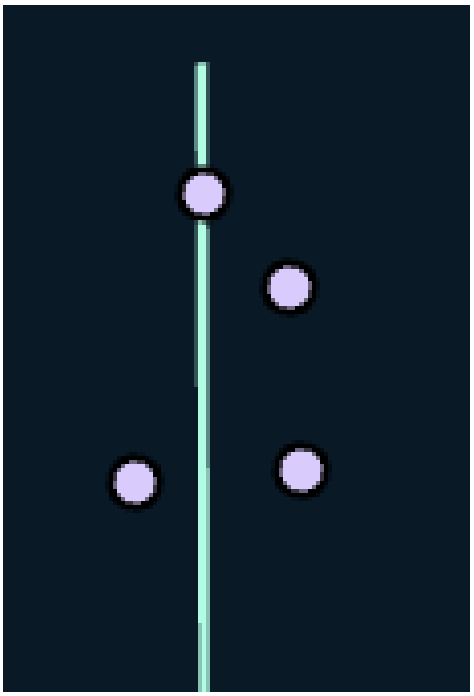


Figure 1.25: Point Line Clip

(a) Point on Line (input)



(b) Point Output (red stars)

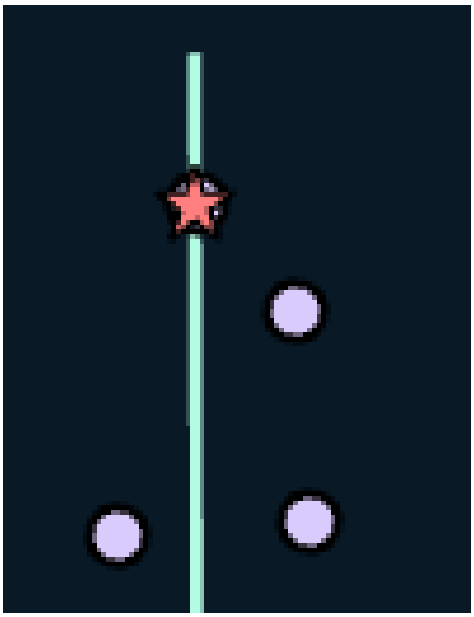
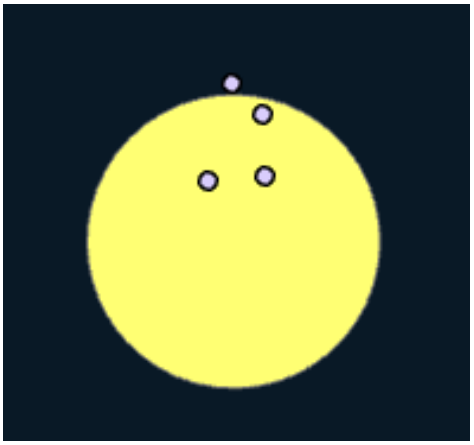
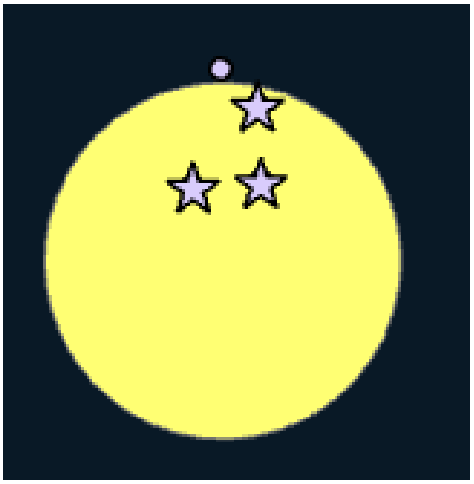


Figure 1.26: Point Polygon Clip

(a) Point on Polygon (input)



(b) Point Output (light red stars)



1.5.5 Count Overlapping Features

In ArcGIS Pro's Overlay toolset, there is a tool which counts the overlapping features in given layers and add there count in attributes accordingly. This tool computes both the overlapping features within a layers and between layers. The count of first is stored in the field **Count_** and later in **Count_ FC**.

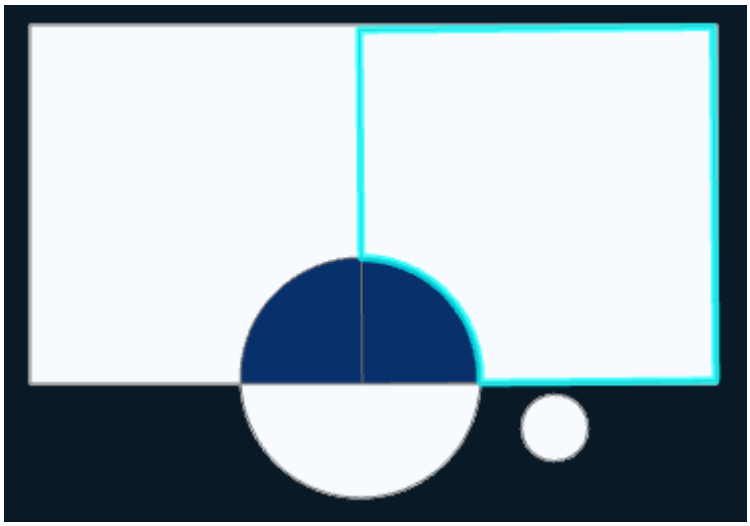


Figure 1.27: Count Overlapping Features Output for Union input

Figure 1.2 White colour represents one feature (no overlap in layers) and blue represent two features, overlapping features in between Input A and Input B.

Total Features $1+1+1+1+2+2=8$