

ISA

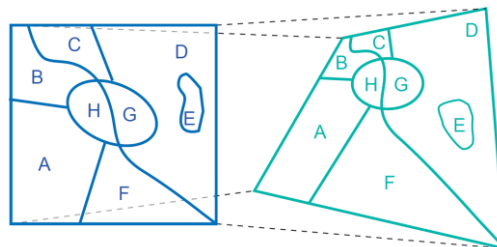
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Lesson 12 - Topology



Topology

- Topology in GIS refers to the spatial relationships and geometric properties of geographic features (points, lines, polygons) that remain invariant under transformations like stretching or bending



Topology

- Topology in GIS refers to the spatial relationships and geometric properties of geographic features (points, lines, polygons) that remain invariant under transformations like stretching or bending
- Collection of rules that, coupled with a set of editing tools & techniques, enables the geographic data to more accurately model geometric relationships
- Key GIS requirement for data management and integrity
- Used to ensure data quality of the spatial relationships & to aid in data compilation

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Why is topology important?

- **Data Integrity:** Ensures features adhere to real-world relationships (e.g., roads connecting)
- **Analysis Accuracy:** Enables reliable network routing, adjacency analysis, and overlay operations
- **Efficient Editing:** Simplifies updates (e.g., shared boundaries update automatically)
- **Visual Consistency:** Prevents slivers/overlaps in maps

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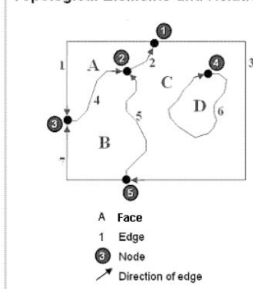
Topology applications

- **Network Analysis:** Optimizing routes for utilities or transportation
- **Urban Planning:** Ensuring zoning boundaries align with infrastructure
- **Environmental Modeling:** Tracking habitat connectivity
- **Cadastral Mapping:** Maintaining parcel accuracy for legal records

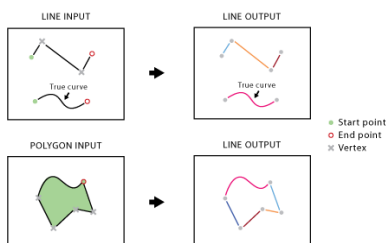
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Topological elements

Topological Elements and Relationships



- **Nodes:** Endpoints of edges (e.g., intersections)
- **Edges:** Line segments connecting nodes (e.g., roads, rivers)
- **Faces (Polygons):** Closed areas bounded by edges (e.g., land parcels)



<https://pro.arcgis.com/en/pro-app/latest/help/data/topologies/topology-basics.htm>

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Topological Spatial Relationships

- **Connectivity:** How features are linked (e.g., roads connecting at intersections)
- **Adjacency:** Features sharing boundaries (e.g., neighboring countries)
- **Containment:** Features within others (e.g., a lake inside a forest polygon)
- **Coincidence:** Features sharing coordinates (e.g., a city point on a river line)

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Topology rules

- Topological rules are inherently context-dependent
- Their relevance depends on the GIS dataset's purpose, the real-world phenomena being modeled & analytical requirements
- Certain rules are critical for specific applications but irrelevant or counterproductive for others

<https://itb.itc.utwente.nl/page/498/concept/81728>

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Topology rules

Topology Rule	Description	Relevant For	Discarded For
Must Not Overlap	Ensures polygons (e.g., parcels, administrative boundaries) do not overlap.	Cadastral mapping, zoning regulations, legal boundaries.	Ecological maps (overlapping habitats), layered thematic maps (soil + vegetation).
Must Not Have Gaps	Prevents unclosed spaces between adjacent polygons.	Census tracts, contiguous political boundaries (e.g., states).	Non-contiguous features (e.g., islands, disconnected habitats).
Must Not Have Dangles	Ensures lines (e.g., roads, utilities) connect properly at endpoints.	Utility networks (water pipes), road networks requiring connectivity.	Standalone features (e.g., hiking trails, rivers terminating naturally).
Must Be Covered By	Requires points/lines to align with other features (e.g., cities in states).	Address points within property polygons, monitoring stations along rivers.	Independent features (e.g., standalone landmarks).

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Topology rules

Topology Rule	Description	Relevant For	Discarded For
Boundary Must Be Covered By	Polygon edges must align with lines (e.g., parcel boundaries with survey lines).	Cadastral maps, geological maps aligning faults with formations.	Thematic maps where boundary precision is secondary (e.g., vegetation zones).
Must Be Single Part	Ensures features (e.g., administrative regions) are not split into segments.	Administrative regions (counties), continuous infrastructure (highways).	Archipelagos (multiple islands), disconnected road segments under construction.
Points Must Be Covered By Line Endpoints	Points (e.g., transformers) must align with line endpoints.	Utility networks (manholes at sewer lines), transportation hubs (bus stops).	Freestanding landmarks (e.g., monuments).

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Topology rules

Topological consistency in 2D should follow the following rules:

1. every line should be bounded by two points



Rule (1)

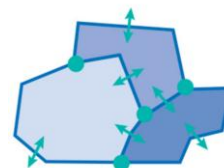
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Topology rules

Topological consistency in 2D should follow the following rules:

1. every line should be bounded by two points
2. two adjacent polygons should be bordered by the same line



Rule (2)

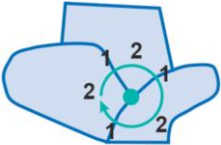
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Topology rules

Topological consistency in 2D should follow the following rules:

1. every line should be bounded by two points
2. two adjacent polygons should be bordered by the same line
3. every polygon has a closed boundary consisting on an alternate sequence of points and lines
4. around a every point exists an alternating sequence of lines and polygons



Rule (4)

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Topology rules

Topological consistency in 2D should follow the following rules:

1. every line should be bounded by two points
2. two adjacent polygons should be bordered by the same line
3. every polygon has a closed boundary consisting on an alternate sequence of points and lines
4. around a every point exists an alternating sequence of lines and polygons
5. lines only intersect at their bounding nodes



Rule (5)

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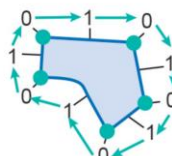
Topology rules



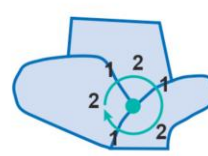
Rule (1)



Rule (2)



Rule (3)



Rule (4)



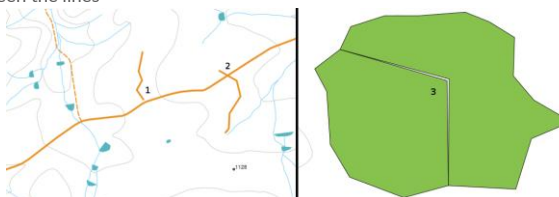
Rule (5)

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Topology errors

- Topological errors break the relationship between features, hampering vector data analysis & measurements
- Errors with polygon features can include unclosed polygons, gaps between polygon borders or overlapping polygon borders
- A common error with polyline features is that they do not meet perfectly at a point (node)
 - undershoot if a gap exists between the lines
 - overshoot if a line ends beyond the line it should connect



https://docs.qgis.org/3.34/en/docs/gentle_gis_introduction/topology.html

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Topology errors

	Before cleanup							
	After cleanup							
Description	Erase duplicates or sliver lines	Erase short objects	Break crossing objects	Dissolve polygons	Extend undershoots	Snap clustered nodes	Erase dangling objects or overshoots	Dissolve nodes into vertices

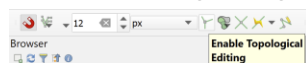
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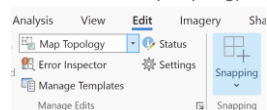
Topology tools

The use of topological tools ensure quality in digitization, avoiding topology errors.

QGIS - Enable topological editing



ArcGIS - Set Map Topology



1 When moving a vertex, all features that share that vertex are updated



2 When a new polygon is digitised (shown in red) it is clipped to avoid overlapping neighbouring areas

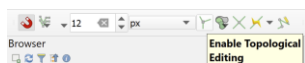
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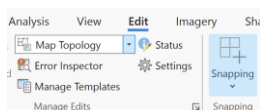
Topology tools - Snapping

- **Snapping** allows creating features that connect to each other so that edits are more accurate, with fewer errors
- With snapping active, your mouse pointer will jump to the closest vertex or edge, if it is within the **snapping tolerance** (set in screen pixels or in map units)

QGIS



ArcGIS



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Credits



The structure and content of the course, including most of the slides and exercises was developed by Professor Graça Abrantes (SIG 2021_2022) and Professor Rui Figueira (SIG 2023_2024)