USING TOPOLOGY FOR:

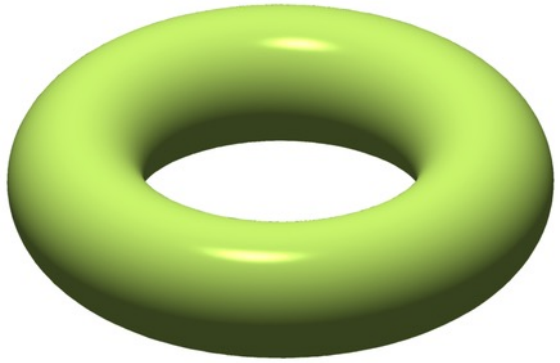
Pattern Recognition in Mineral Exploration & an Alternative Approach to Road Center Lines

by Humphrey Boogaerdt

Presented at GeoGeeks Meeting in Perth on 14 Sep 2023

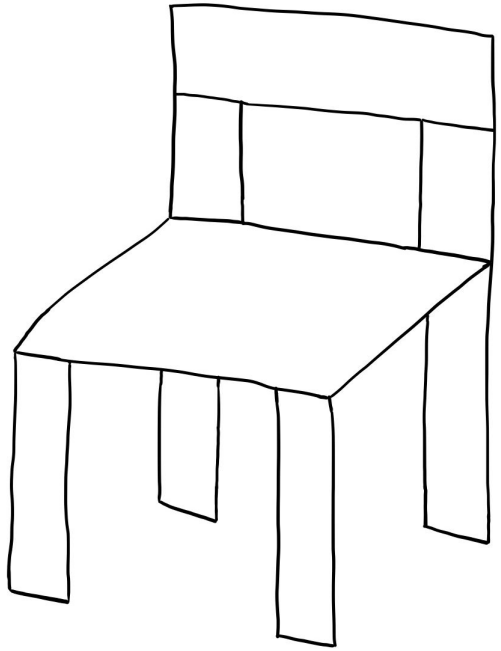
This meeting takes place on Whadjuk Noongar Boodja and I recognise that sovereignty was never ceded – this was and always will be Aboriginal Land.

What is Topology?

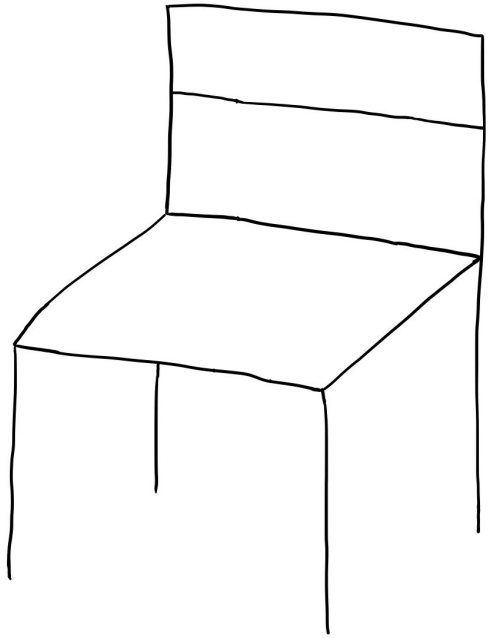


"In mathematics, topology is concerned with the properties of a geometric object that are preserved under continuous deformations, such as stretching, twisting, crumpling, and bending; that is, without closing holes, opening holes, tearing, gluing, or passing through itself. "

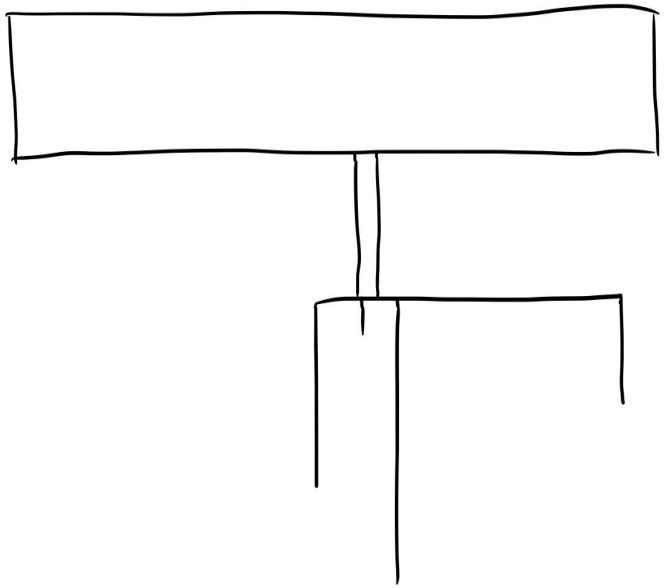
Topology does not change during changes in geometry



Stylised chair from previous slide



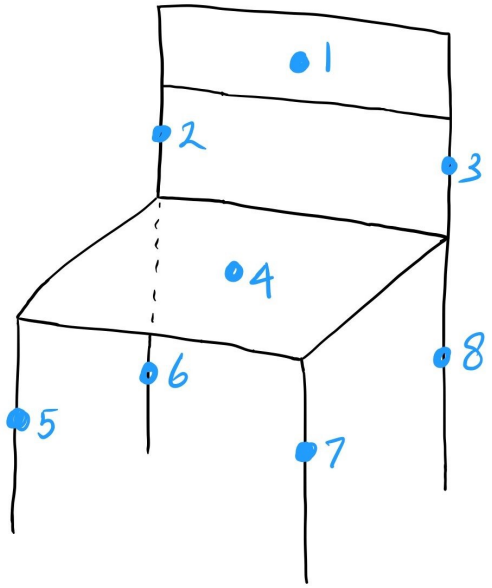
Same chair reduced to simple lines



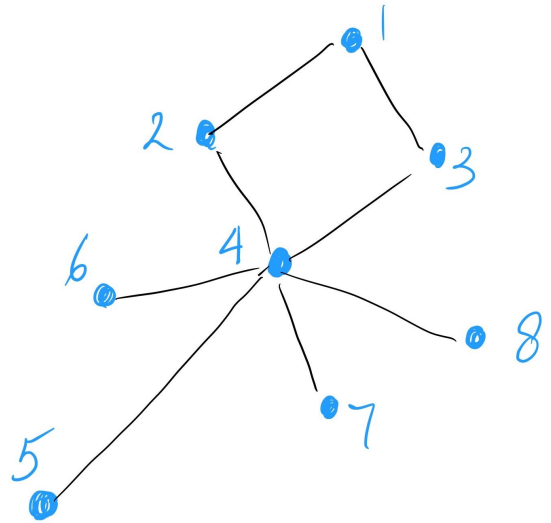
Caricature of the same chair

Graph Theory and **Topology** are both branches of mathematics.

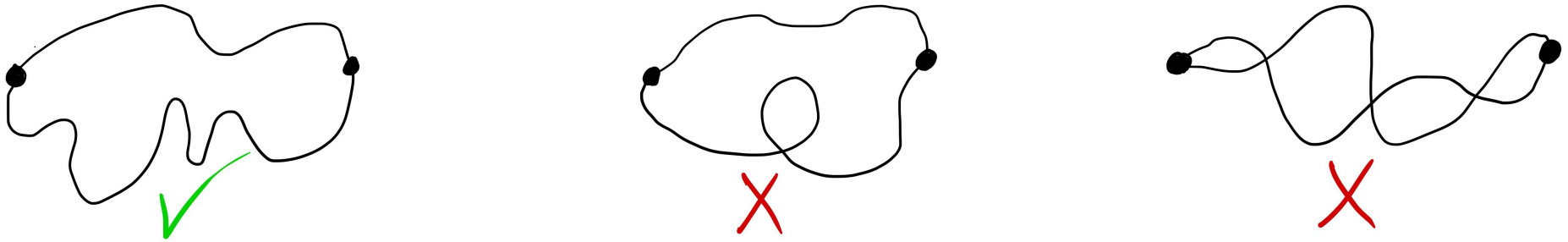
Topology has no dimension but only relationships which can be represented as **graphs.**



Chair represented by edges and polygons, and each marked with an ID



A graph of the chair on the left. The seat (i.e. point 4) is used as the center of the graph



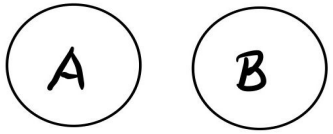
A requirement for a polygon is that it **cannot have crossing boundaries**.
The one on the left is **ok**, while the other 2 are **not polygons**.

GIS uses different file structures for points, lines or polygons, since these entities have different dimensions 0, 1 and 2 respectively.
To distinguish between these object files, it is suggested to use a suffix to indicate what dimension an object represents.

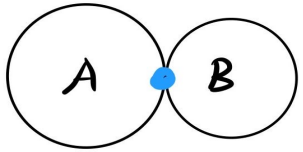
_0d	for a	point, vertex, node
_1d	for a	line, edge, string
_2d	for a	polygon
_3d	for a	3D surface

For example, chair_0d for vertices of a chair or chair_1d for edges of the chair.

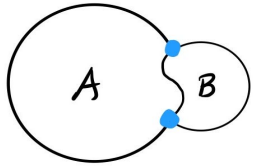
Intersection between polygons



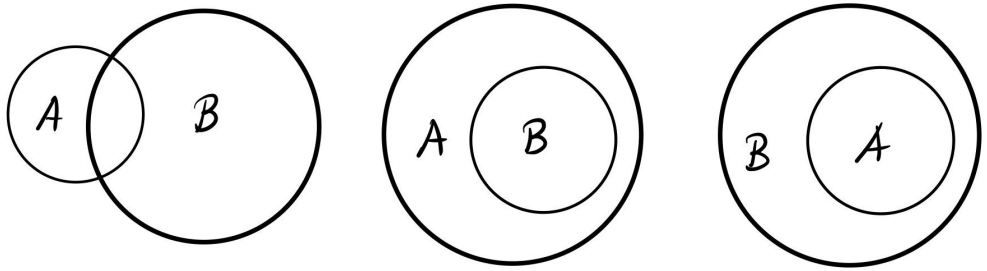
2 disjoint objects A & B



2 touching objects A & B that only have a point of 0-dimension in common.



2 polygons A & B that meet and have a 1-dimensional edge in common.



A & B Overlap / Cross, are Equal or are Inside / Covering / Containing / Covered By each other.

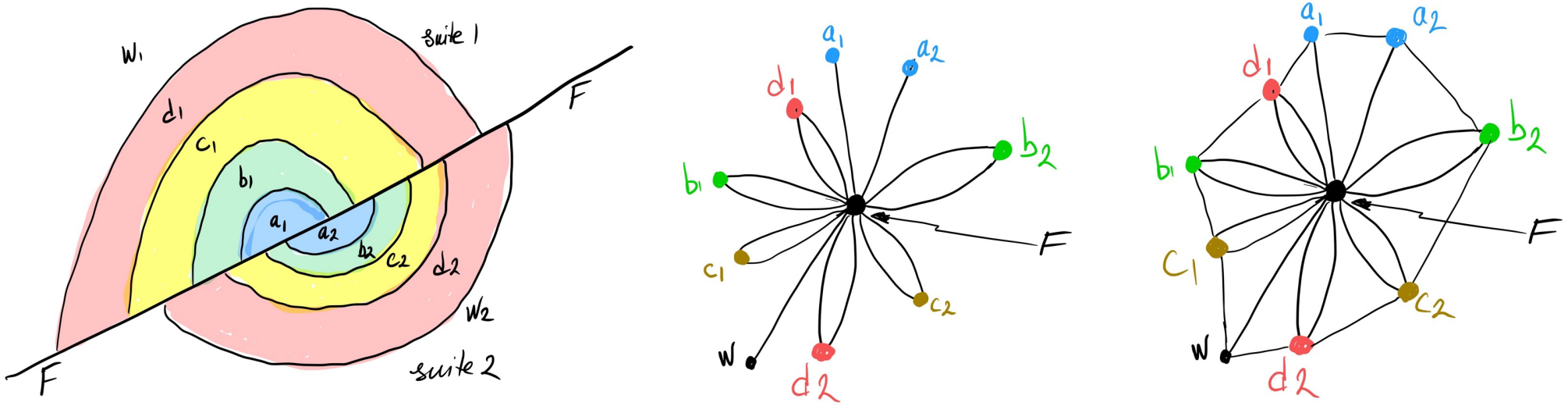
Pattern Recognition

This cartoon shows the caricatures of the main characters in “Yes Minister” TV series.

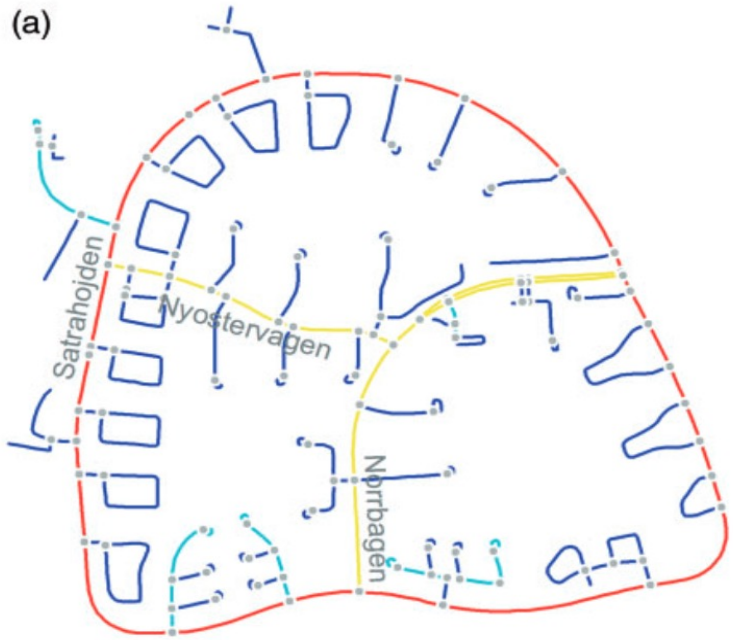
If one knows the series one will recognise them with any doubt.

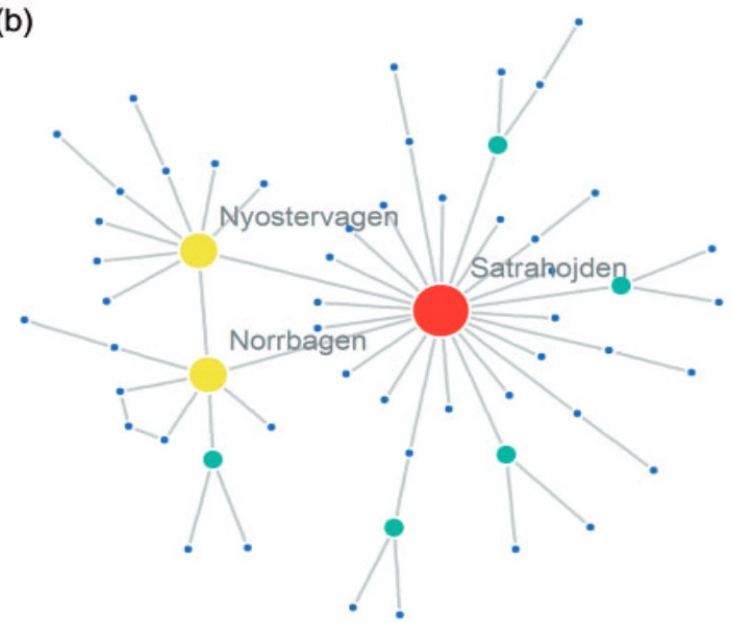
A caricature is typically an image of a person whose characteristics are exaggerated, but keeps that person recognizable

The caricature concept can be used to create **topological graphs**.



These types of graphs can be used in searching maps for finding new mineral deposits.





On maps the center lines follow broadly the shape of the road, like example (**a**).

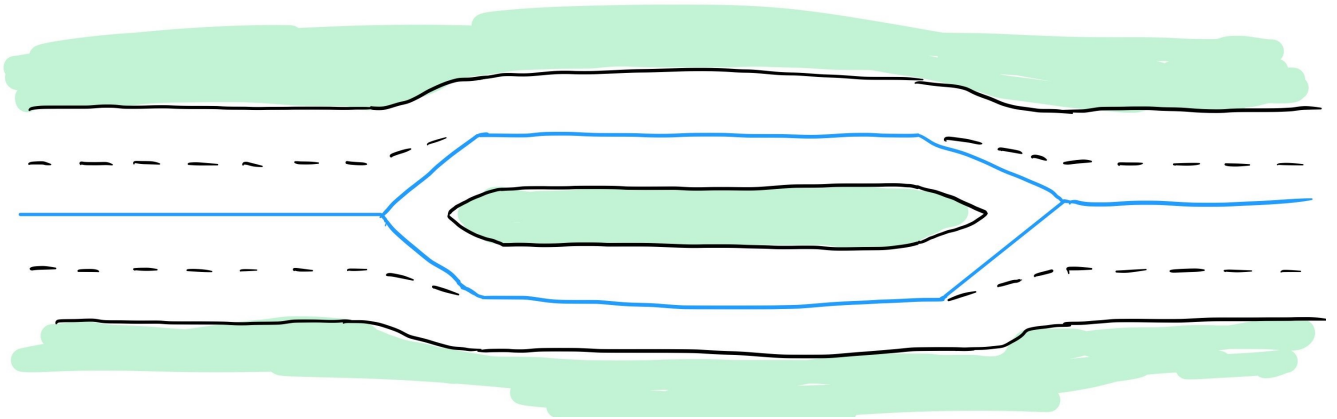
The presentation of roads, including their hierarchy, can be topologically shown like in (**b**).

This is a visualisation of various levels: a ring road (red), internal connecting roads (yellow), local streets (blue and aqua).

Alternative Topology for Road Center Lines

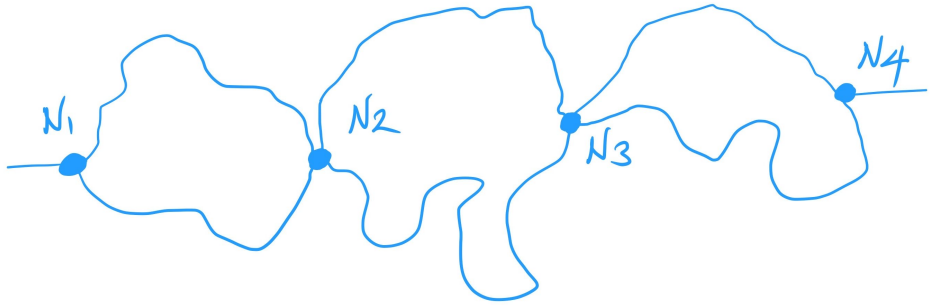
Here is an undivided 4-lane road.

The separation is marked by the blue lines (center lines, CL) and lanes by the dashed lines. Then it hits the median strip, which separates the lanes going left and right.



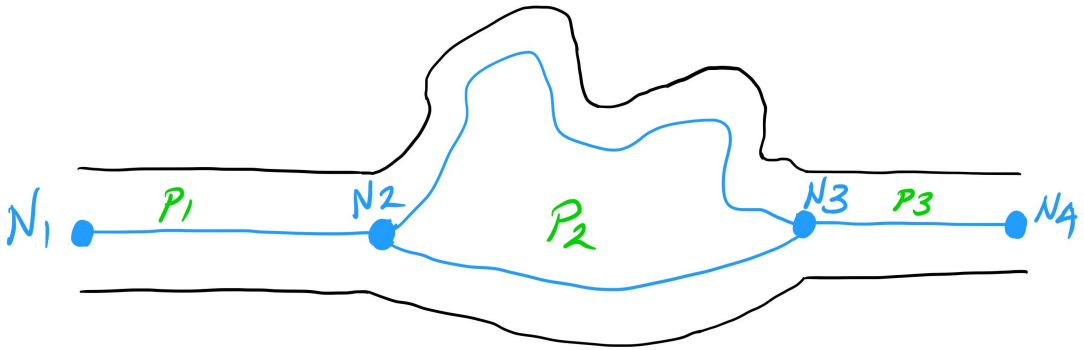
By nature of how CL are set up they now follow the middle of the 2 lanes going in the same direction.

This solution is messy, even in this simple example.



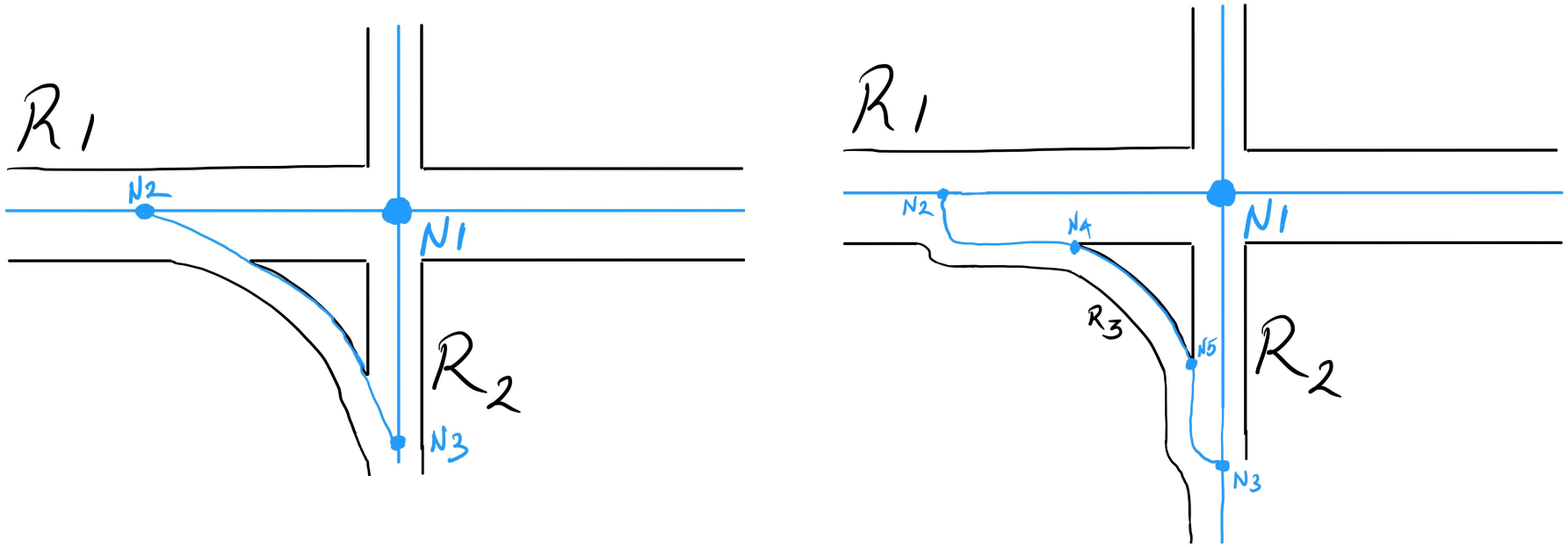
Here the **CL** is represented between the nodes, **N1** and **N4**, with polygons.

When the areas of these polygons are reduced to zero, they show up as **lines**.



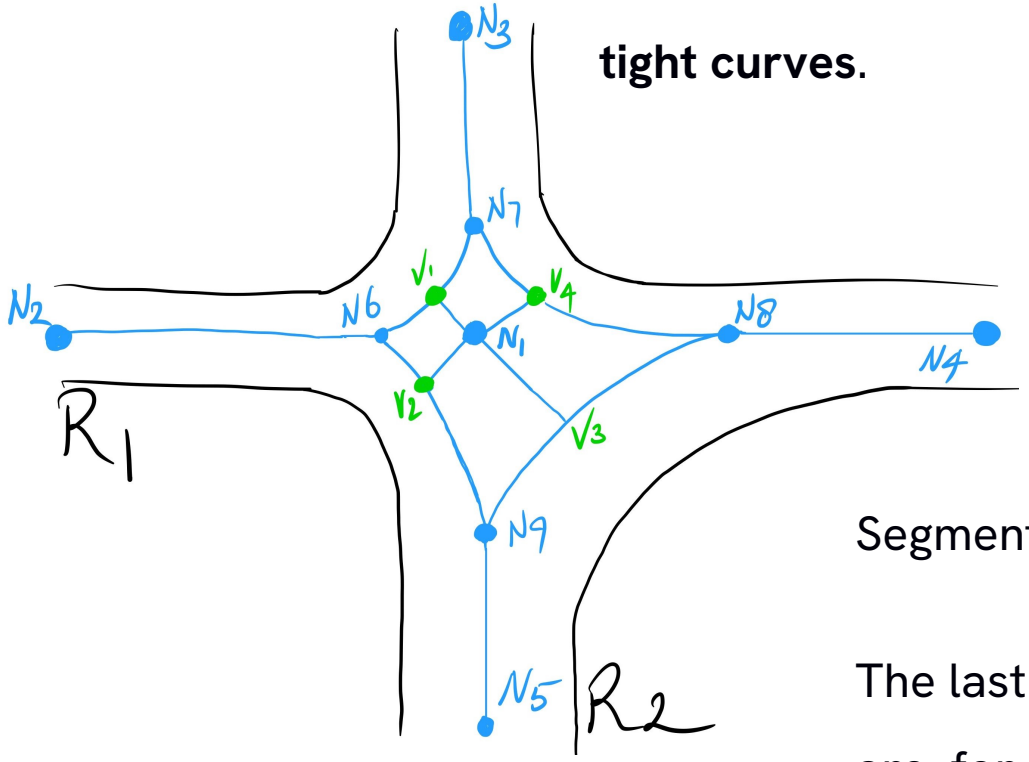
An **advantage** of using a polygon is that when the area of it is > 0, the width of the lanes associated with them stay the same and follow the edge smoothly.

It would be confusing to use two different types of center lines, so instead of using the term “center line (CL)” we propose to use “**side center line** (**SCL**)” which follows the CL when the road is “simple”.



When there is a median strip or a turning lane the SCL follows the **inside curve**.

Even at simple intersections non-zero polygons are created in the center. To demonstrate this, one corner has a **wide curve** while the other 3 have **tight curves**.



Traveling along road **R1** the 1st segment is **N2** to **N6**, the 2nd segment comprises of a polygon with start node **N6**, it has end node **N1** and vertices **V1**, **V2**.

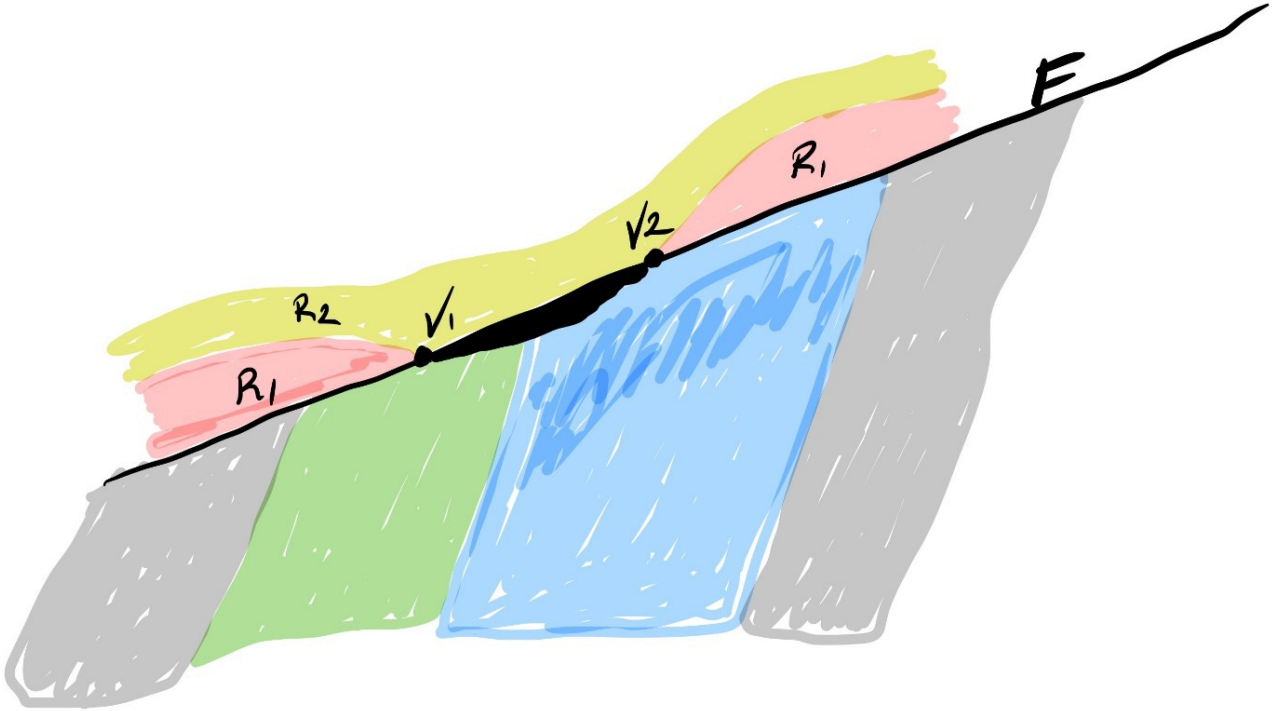
Segment **N1** to **N8** is a polygon with vertices **V3** and **V4**.

The last segment is **N8** to **N4**. The curvature of the corners are, for example, bordered by segments **N6**-**V2** and **V2**-**N9**.

This more complicated than when intersection have sharp corners like at node **N1**.

Now we have introduced **zero area polygons** – this feature may be useful in geology.

As shown in the sketch, part of the rock horizon containing **R1** has been removed by a fault and rocktype **R2** has not been affected by the fault.



In this case the polygons covering rocktype **R1** has zero width between vertices **V1** and **V2**.

It could be more useful in representing faults, normally shown by just a line but have a width that is visible when zooming in. Possibly also makes modelling easier since only dealing with polygons.

References

Boogaerdt, Humphrey, 1996. *Topology-Object-Relation-Graph*. Curtin University, thesis. www.payung.biz

Egenhofer, Max and Franzosa, Robert, 1991. *Point-set topological spatial relations*. Int J GIS. https://doi.org/10.1080/02693799108927841

Ma, Ding et al., 2019. *Why topology matters in predicting human activities*. Urban Analytics and City Science, 46(7), 1297–1313. https://doi.org/10.1177/2399808318792268

Ritter, Ben, 2023. *OpenStreetMap's big forking problem: OSM centrelines to full streets*. Presentation at Geogeeks, Perth.

Wiki, 2023-a. *Traveling Salesman Problem*. https://en.wikipedia.org/wiki/Travelling_salesman_problem

Wiki., 2023-b. *Seven Bridges of Königsberg*. https://en.wikipedia.org/wiki/Seven_Bridges_of_K%C3%B6nigsberg

"Yes Minister" cartoon https://socialistjazz.blogspot.com/2012_08_01_archive.html