# Methods for the specification and verification of business processes

## MPB (6 cfu, 295AA)

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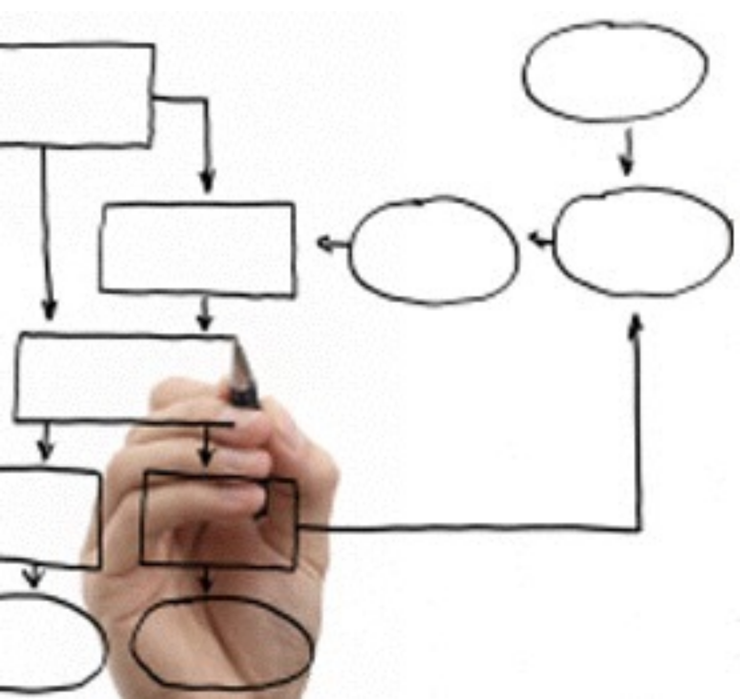

## 01 - Introduction

# Contact information

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Wednesday 16:00-18:00
(or by appointment)

# Classes

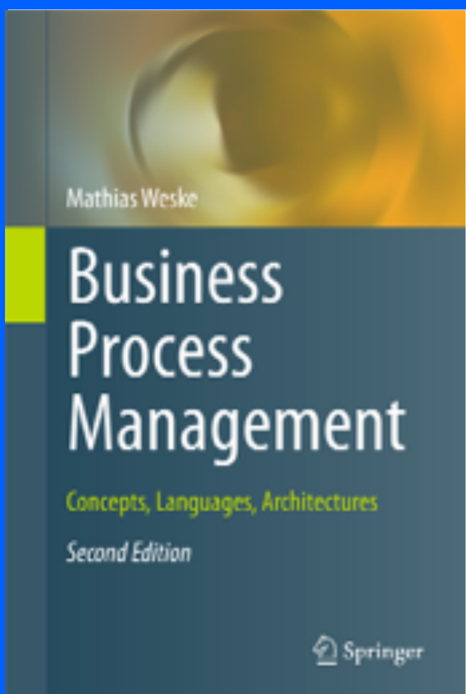
Wednesday 14:00-16:00 Room N1

Friday 11:00-13:00 Room L1

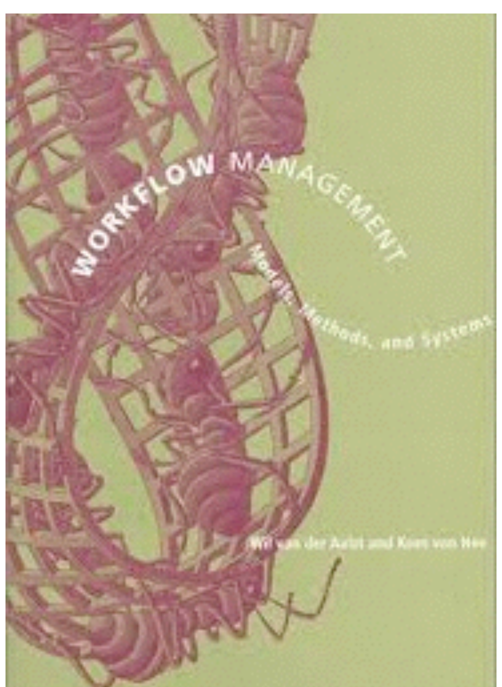
# Course objectives

- main issues in Business Process management
- patterns and architectures
- representation languages & visual notation (BPMN, BPEL, ...)
- problematic issues (dead tasks, deadlocks, livelocks, ...)
- formal models (Workflow Nets, YAWL, ...)
- structural & behavioural properties
- correctness by construction
- analysis techniques
- tool-supported verification (WoPeD, YAWL, ProM, ...)
- [ process mining and performance analysis (bottlenecks, capacity planning) ]

# Textbook(s)




Mathias Weske
Business Process Management: Concepts, Languages, Architectures
(2nd ed.) Springer 2012
http://bpm-book.com/




Wil van der Aalst, Kees van Hee
Workflow Management: Models, Methods, and Systems
MIT Press (paperback) 2004
http://www.workflowcourse.com/

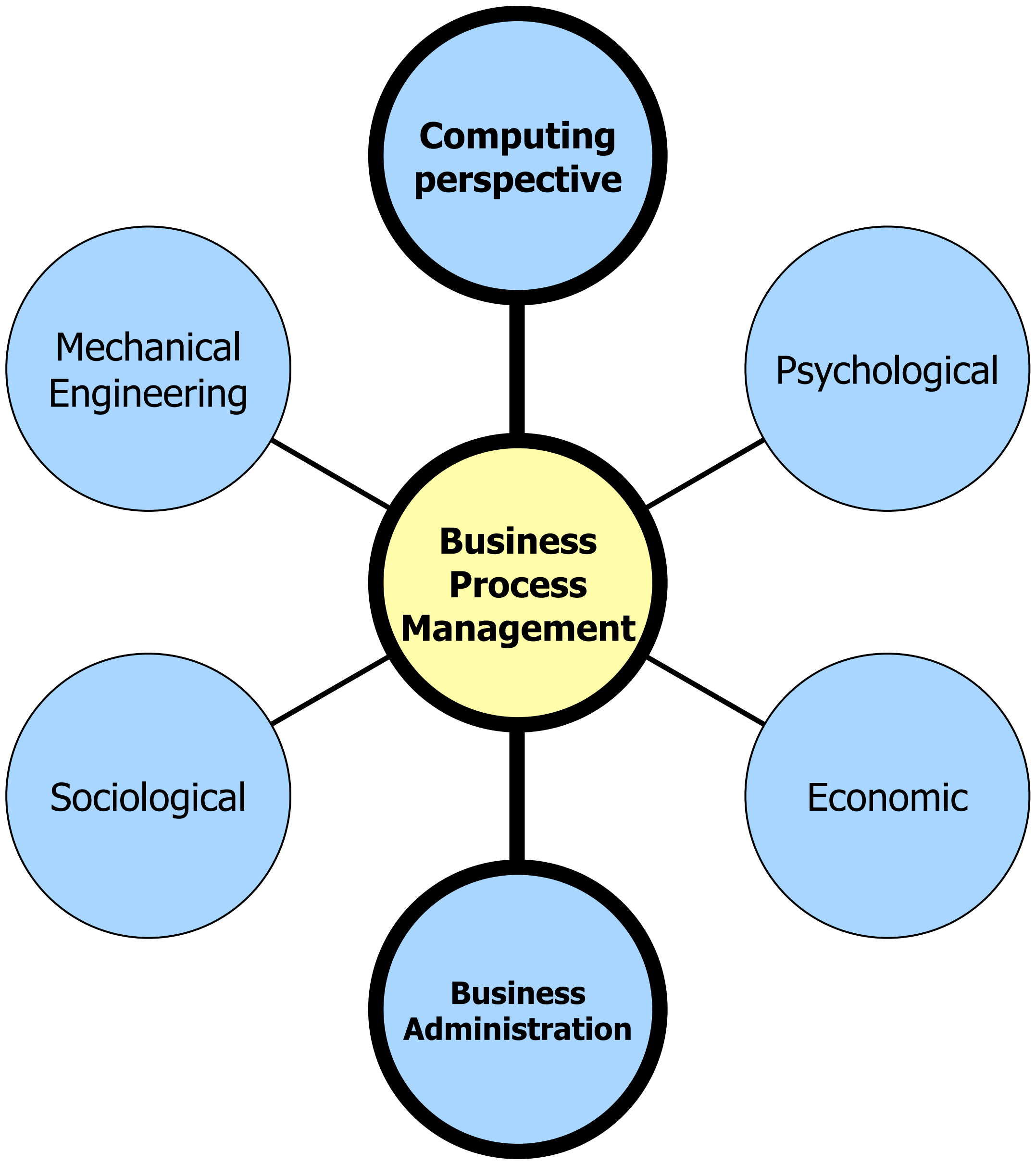
# Main resources

- Workflow Patterns
  - http://www.workflowpatterns.com/
- BPMN
  - http://www.bpmn.org/
- BPEL
  - http://www.oasis-open.org/committees/wsbpel
- Petri nets
  - http://www.informatik.uni-hamburg.de/TGI/PetriNets/

# More resources (tools)

- Woped
  - http://www.woped.org/
  - http://www.win.tue.nl/woflan/
  - http://www.pnml.org/
  - Diagnosing workflow processes using Woflan. H.M.W.Verbeek, T.Basten, W.M.P. van derAalst. Computer J. 44(4): 246-279 (2001) http://wwwis.win.tue.nl/~wvdaalst/publications/p135.pdf
- YAWL
  - http://www.yawlfoundation.org/

# Focus




Different educational backgrounds and interests are in place

# You, the classroom

| Name | email | MSc degree program |
| --- | --- | --- |
| | | |
| | | |
| | | |

Please, send your data to rbruni@cli.di.unipi.it
with object "**MPB**"

# Preferred language?

# Why BPM?

Highly relevant from a practical point of view

Offers many challenges for software developers and computer scientists

# Quoting Michelangelo

*Every block of stone has a statue inside it*
*and it is the task of the sculptor to discover it*

# What is BPM about?

Giving shape to ideas, organizations, processes, collaborations, practices

To communicate them to others

To analyse them

To change them if needed

# What is the BPM maturity of your organization?

**1 initial**

**No structured BPM activities** in the area of responsibility of the stakeholder.

**2 awareness**

**Awareness of BPM** exists in the organization.

**(Planning) activities have started for the definition of the subject.**

**3 defined**

**BPM is defined.**

**Implementation is yet missing or ongoing.**

**4 managed**

**BPM is implemented.** (People assigned. Communication to relevant people done. Training done. etc.)

**5 excellence**

**BPM is implemented enterprise-wide. A continuous review & improvement process is implemented** to exchange lessons-learned & address required changes proactively.

# Data and processes

Traditionally, information systems used information modelling as a starting point

Nowadays, processes are of equal importance and need to be supported in a systematic manner

# Workflow wave

In the mid-nineties, workflow management systems aimed to the automation of structured processes

but their application was restricted to only a few application domains

# Process awareness

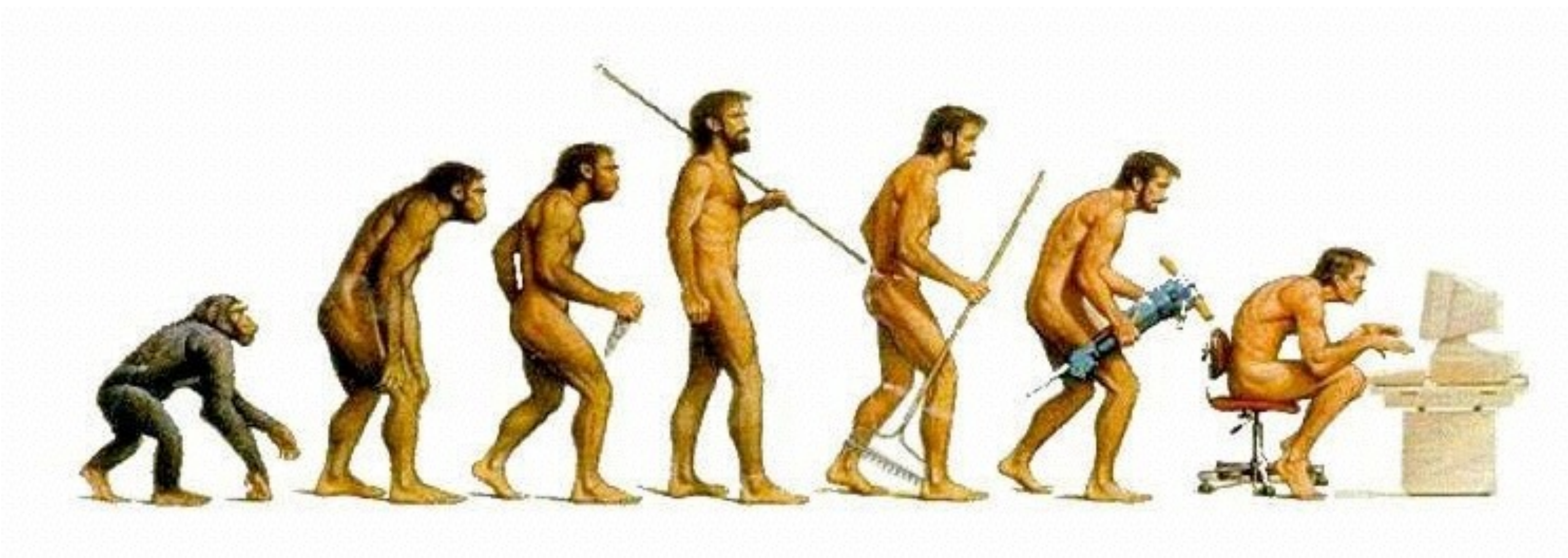
BPM moves from workflow management systems to process-aware information systems

a broader perspective is now possible

# Motivation

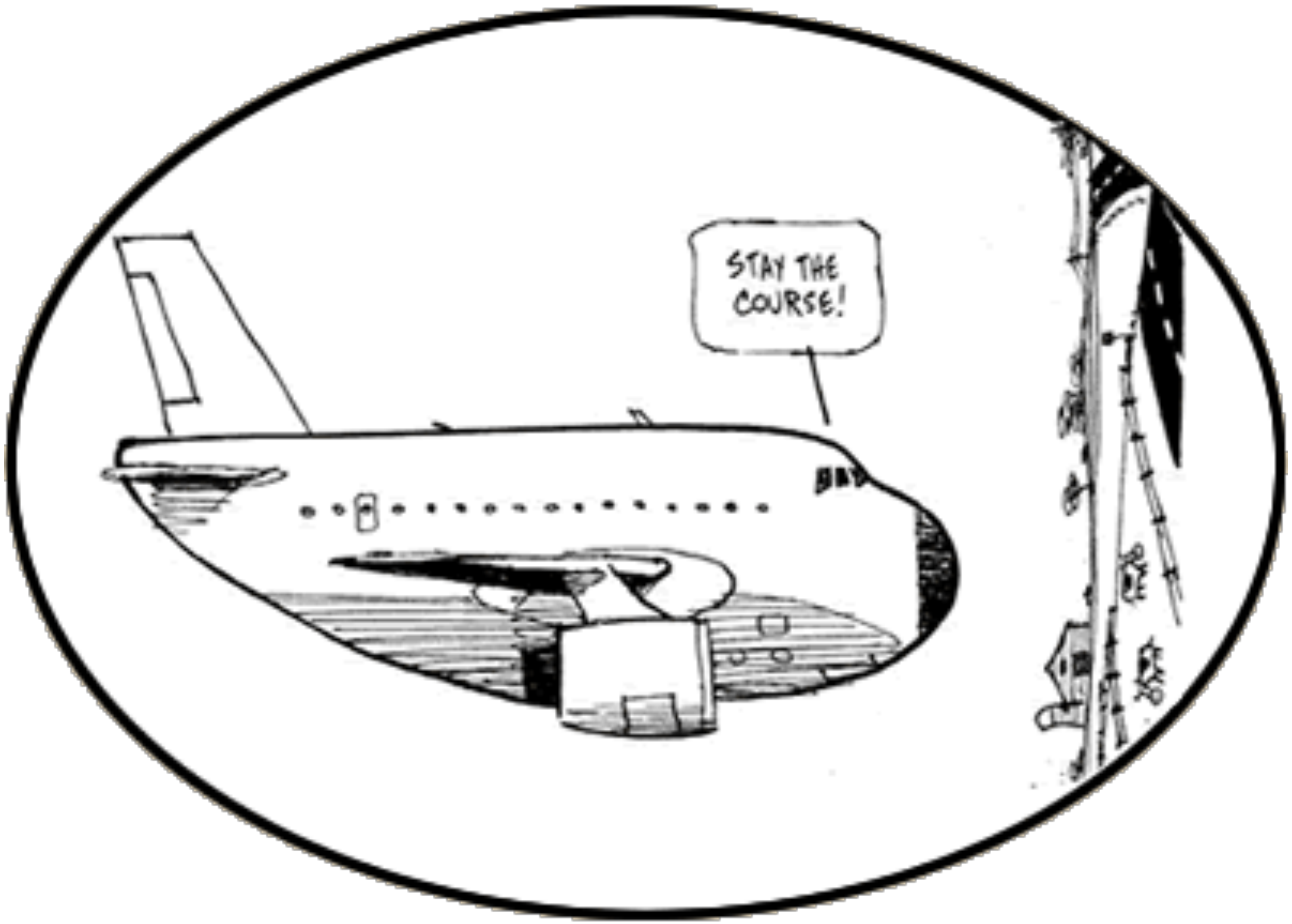
- Each product is the outcome of a number of activities performed
- Because of modern communication facilities:
  - traditional product cycles not suitable for today's dynamic market
- Competitive advantages of successful companies:
  - the ability to bring new products to the market rapidly and
  - the ability to adapt an existing product at low cost
- Business processes are the key instrument:
  - to organize these activities
  - to improve the understanding of their relationships
- IT is an essential support for this aim

# Evolve...



# Adapt...

# ...or good luck!



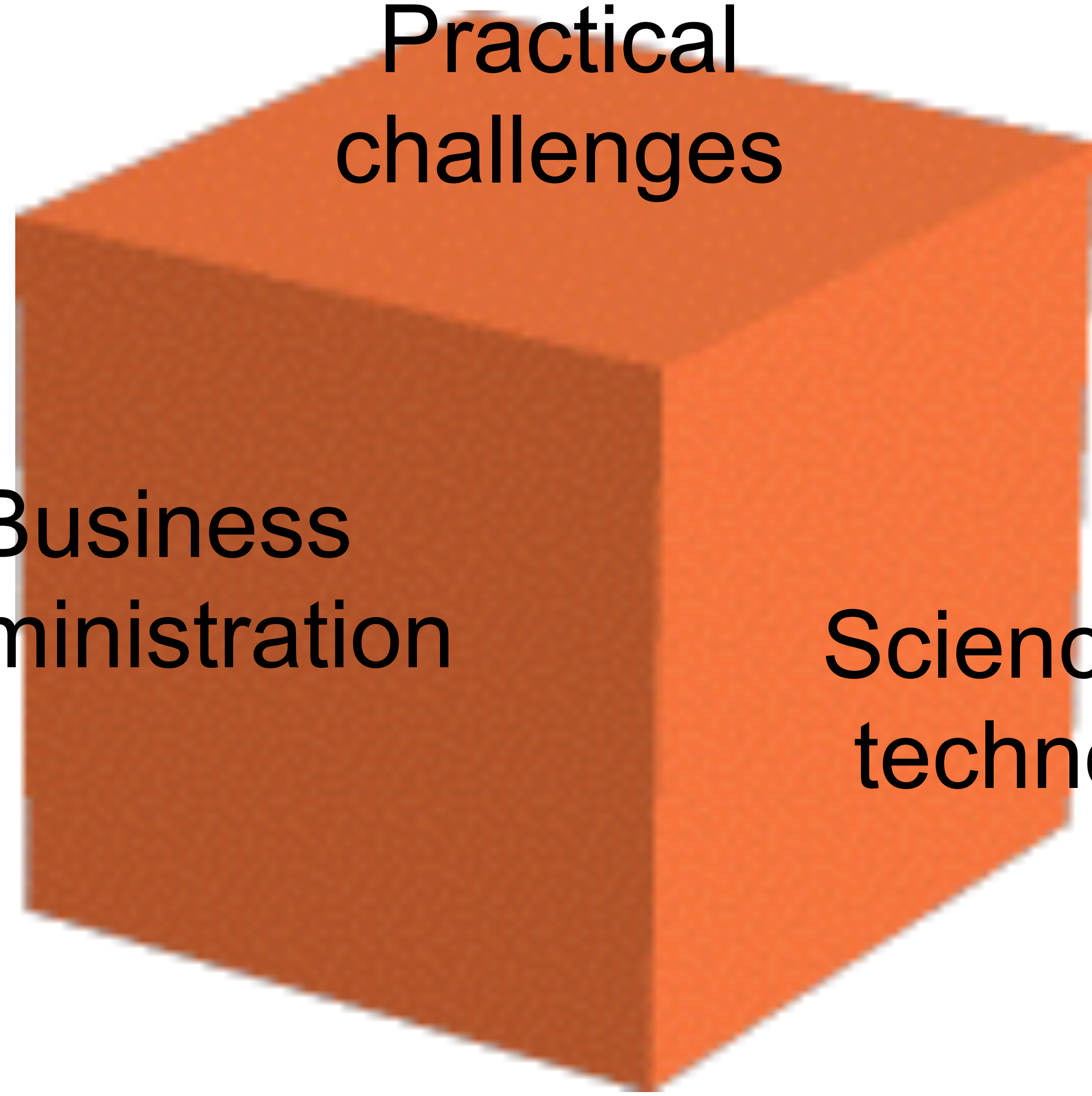
# BPM angles

**Analysis**: simulation, verification, process mining, ...

**Influences**: business aspects, social aspects, education, ...

**Technologies**: service orientation, standardization efforts, interoperability, ...

# Trade-offs




NEW business opportunities, models, process languages and standard will emerge in the future!

# Essential concepts

This course is not about a particular XML syntax

It is about using some process languages to describe, single out, relate, compare essential concepts

# Which target?

## Business admin people

care about improving the operations of companies:
- -increase customer satisfaction
- -reducing costs
- -establishing new products

## Software develop people

- -provide robust and scalable sw
- -integration of existing sw
- -look at tiny technical details

## Formal methods people

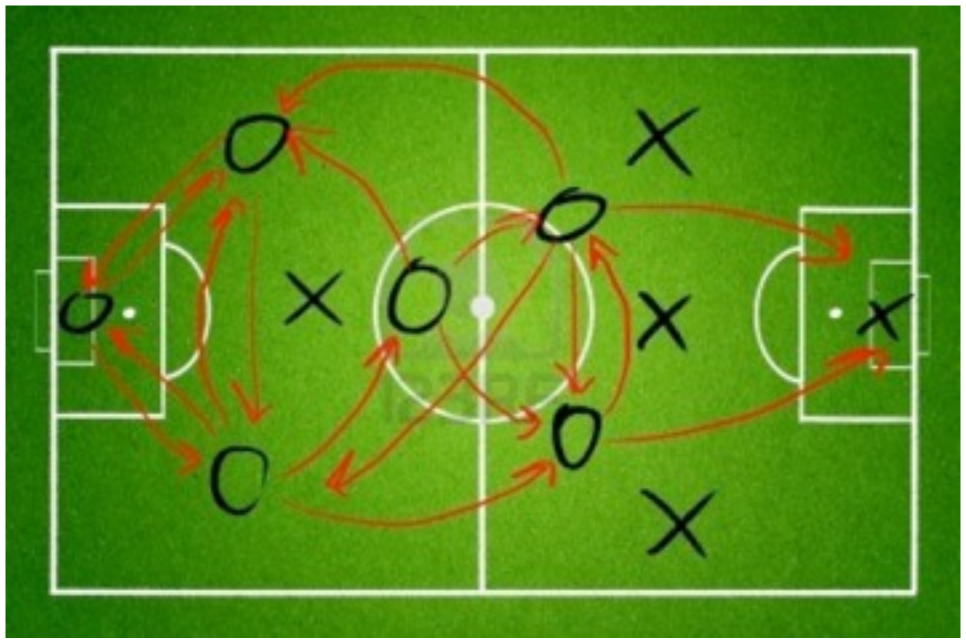
- -investigate structural properties
- -detect and correct deficiencies
- -abstract from "real world"

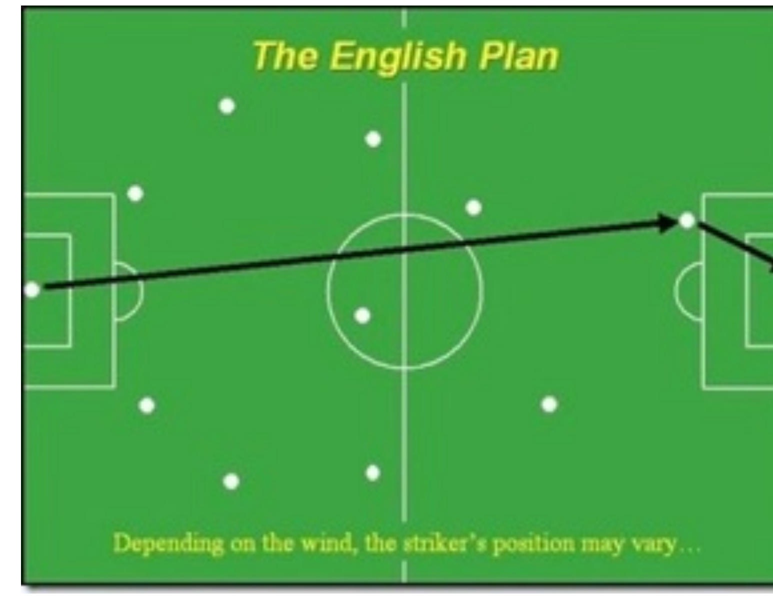
# Aim

Robust and correct realization of business processes in software that increases customer satisfaction and ultimately contributes to the competitive advantage of an enterprise

# Different views are common

# Everybody wants to be the Italian soccer team coach



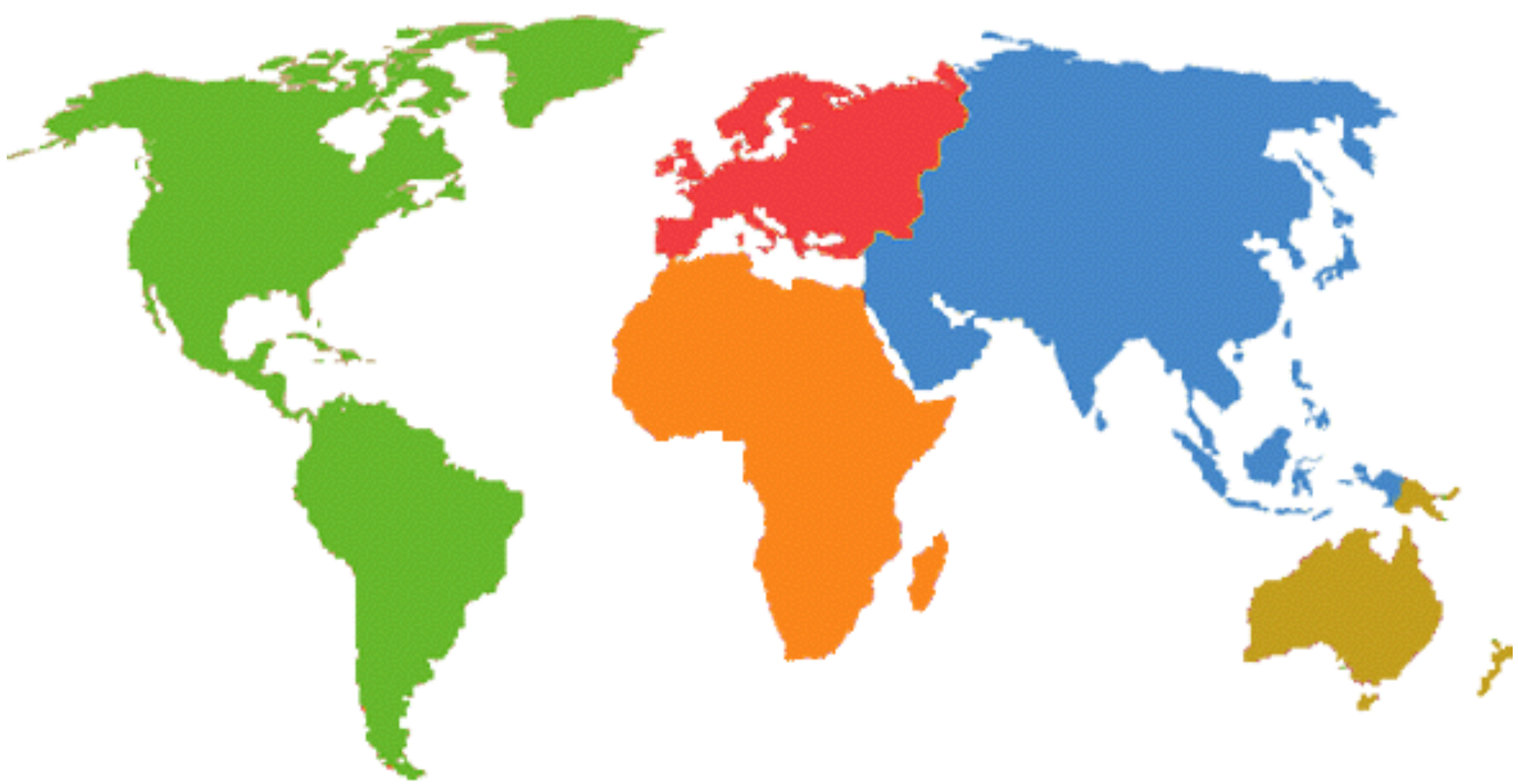

# What about the adversaries?

Can we find out their plan?

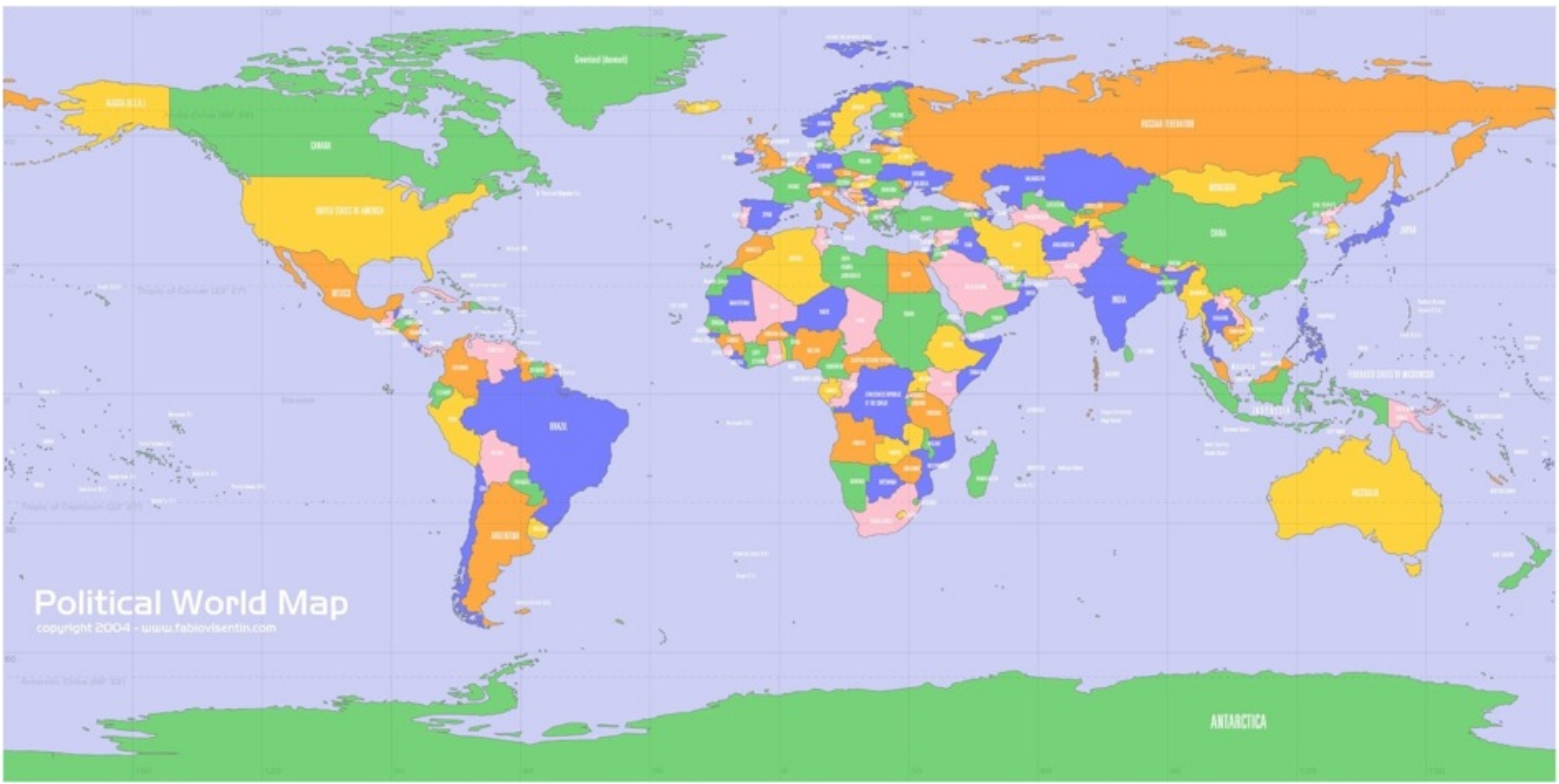
Knowing it would be quite helpful

Any idea how to?

# Levels of abstractions



# Levels of abstractions



# Levels of abstractions

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# Abstraction

- Business admin people
  - IT as a subordinate aspect (for expert technicians)
  - This course: too technical!
- Software develop people
  - Current technology trend as main concern
  - This course: too abstract!
- Formal methods people
  - Underestimate business goals and regulations
  - This course: too imprecise!

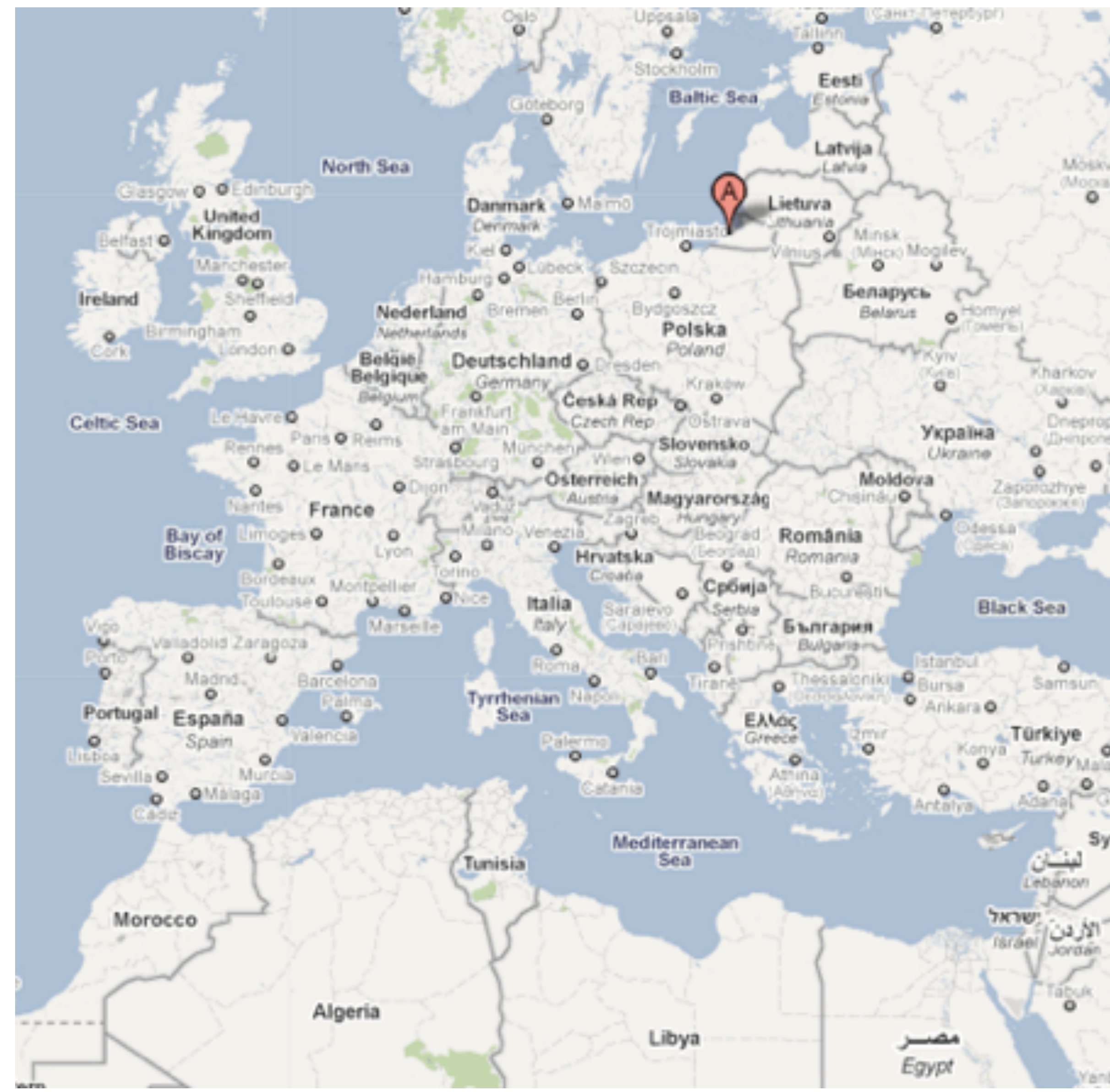
Abstraction as the key to achieve some common understanding, to build a bridge between views...

# Digression...

On the shores of the Baltic Sea wedged between Lithuania and Poland is a region of Russia known as the Kaliningrad Oblast.

The city of Kaliningrad is, by all accounts, a bleak industrial port with shoddy grey apartment buildings built hastily after World War II, when the city had been obliterated first by Allied bombers and later by the invading Russian forces.

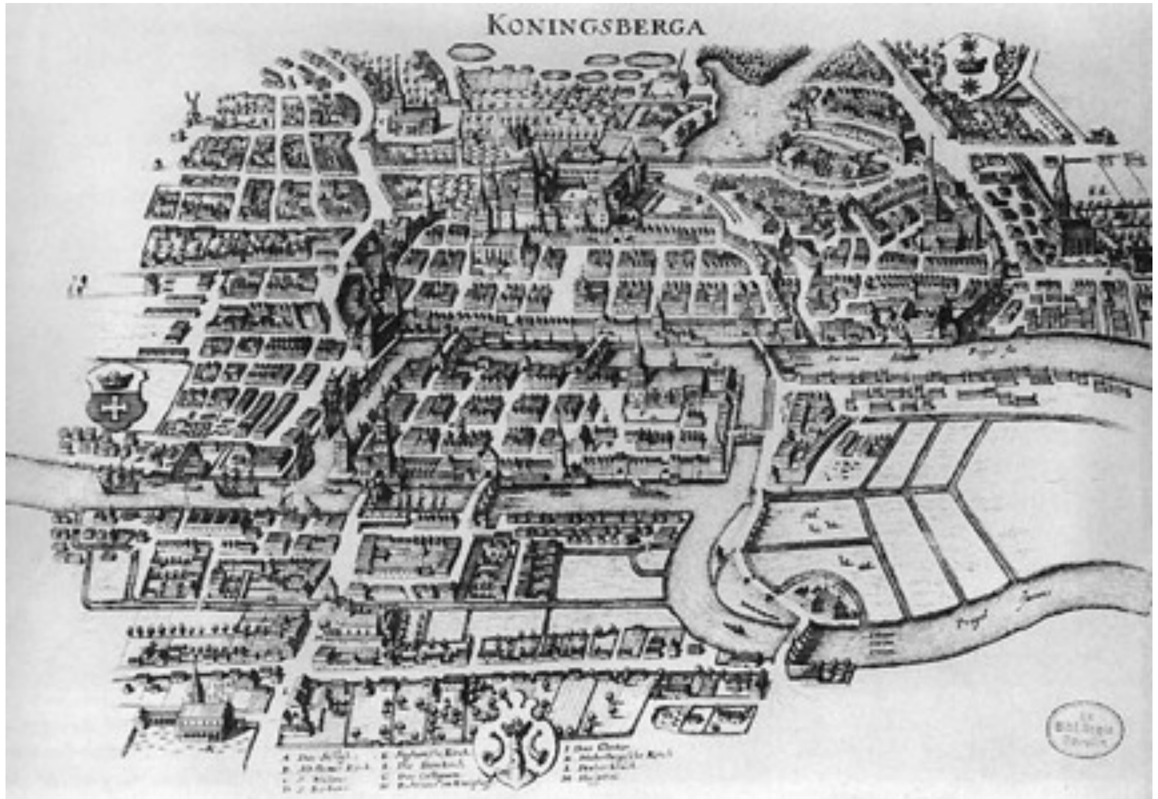
Little remains of the beautiful Prussian city of Königsberg, as it was formerly known.



# Digression...

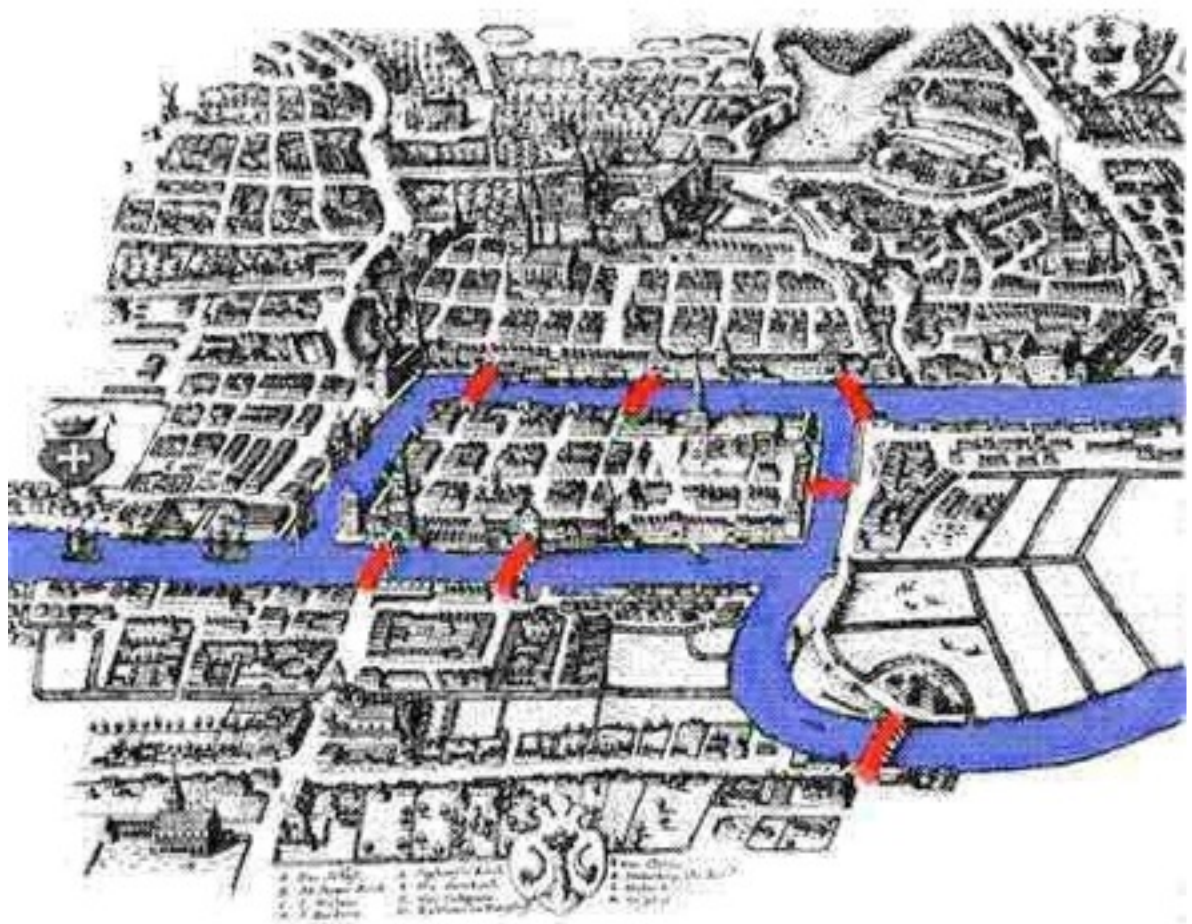
This is sad not only for lovers of architecture, but also for nostalgic mathematicians:

it was thanks to the layout of 18th century Königsberg that Leonhard Euler answered a puzzle which eventually contributed to two new areas of maths known as topology and graph theory.



# Digression…

Königsberg was built on the bank of the river Pregel. Seven bridges connected two islands and the banks of the river (see map).

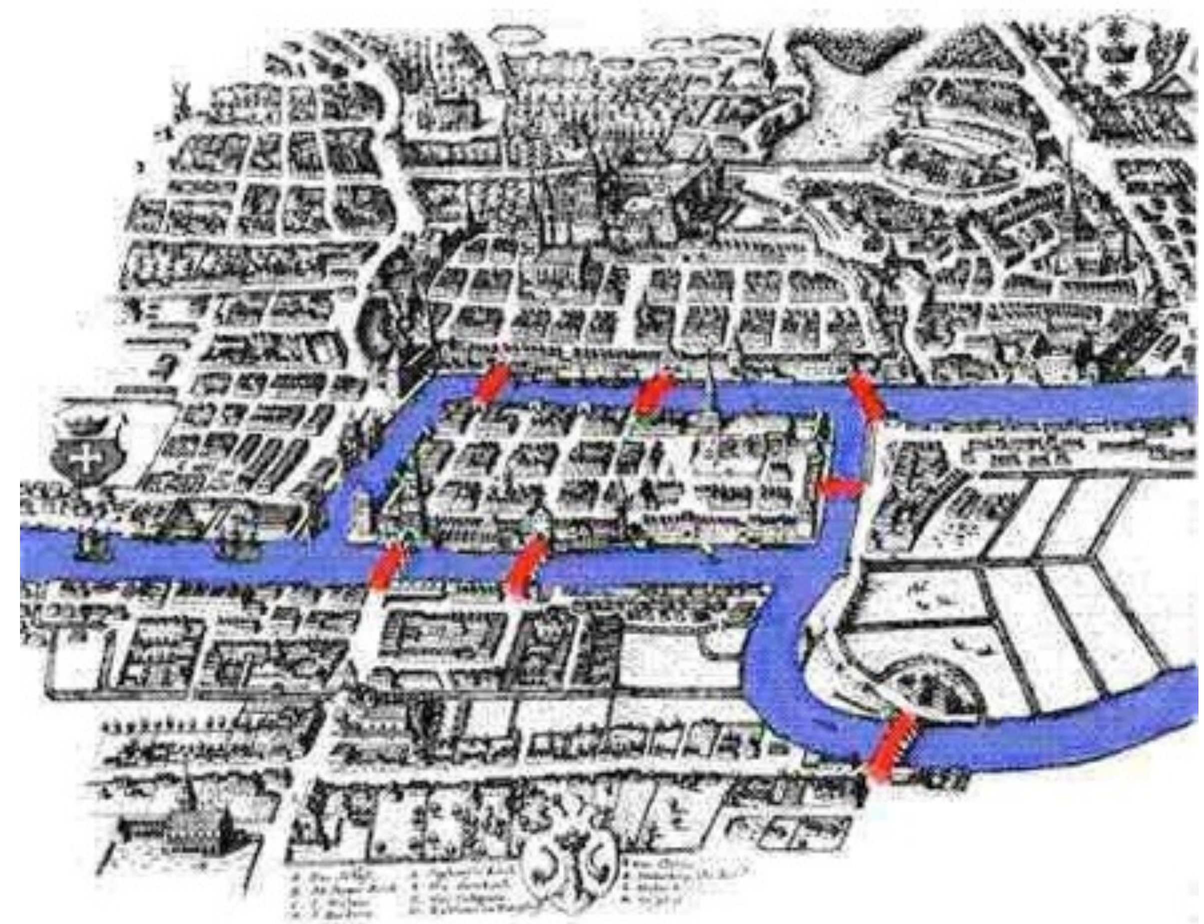


A popular pastime of the residents was to try to cross all the bridges in one complete circuit (without crossing any of the bridges more than once).

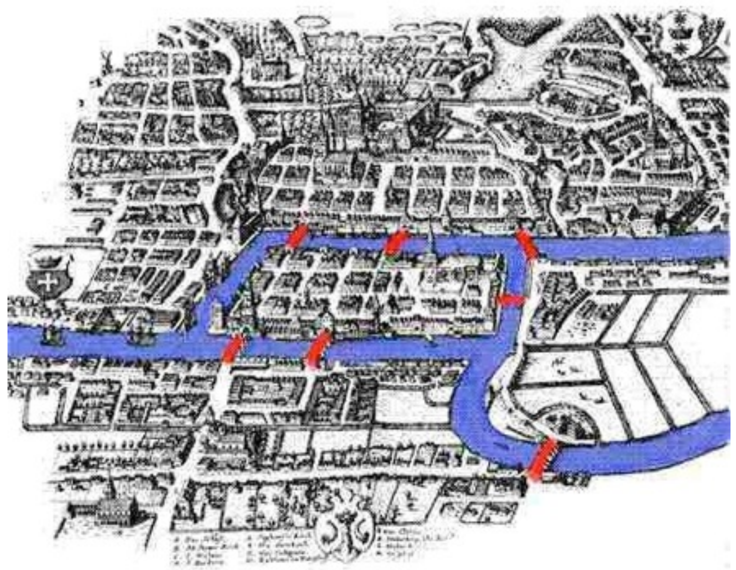
# Digression...

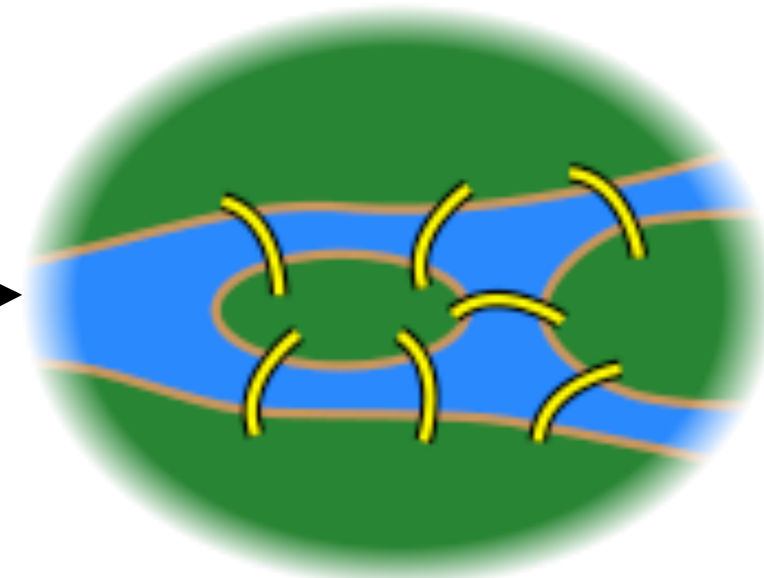
This seemingly simple task proved to be more than tricky...

Nobody had been able to find a solution to the puzzle when Euler first heard of it and, intrigued by this, he set about **proving** that
no solution was possible!



# Digression...

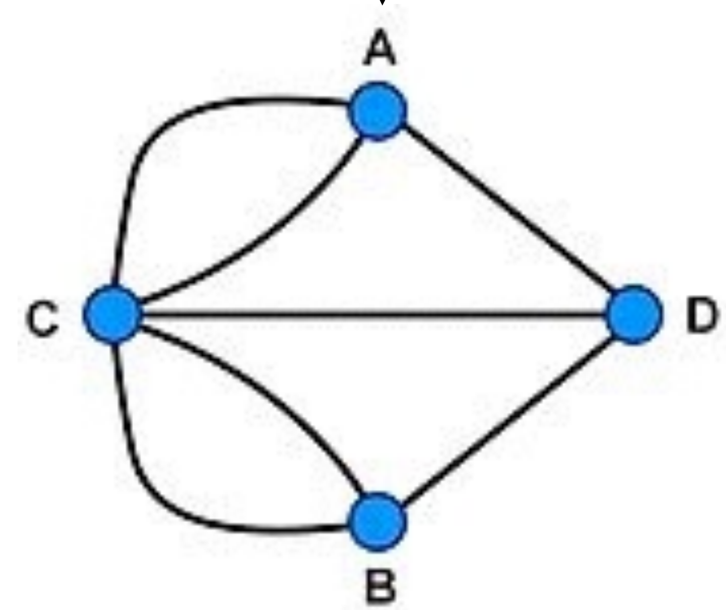




In 1736, Euler analysed the problem by converting the map into a more abstract diagram...
and then into a graph (a formal model):

areas of land separated by the river were turned into points, which he labelled with capital letters. Modern graph theorists call these vertices or nodes.

The bridges became arcs between nodes.

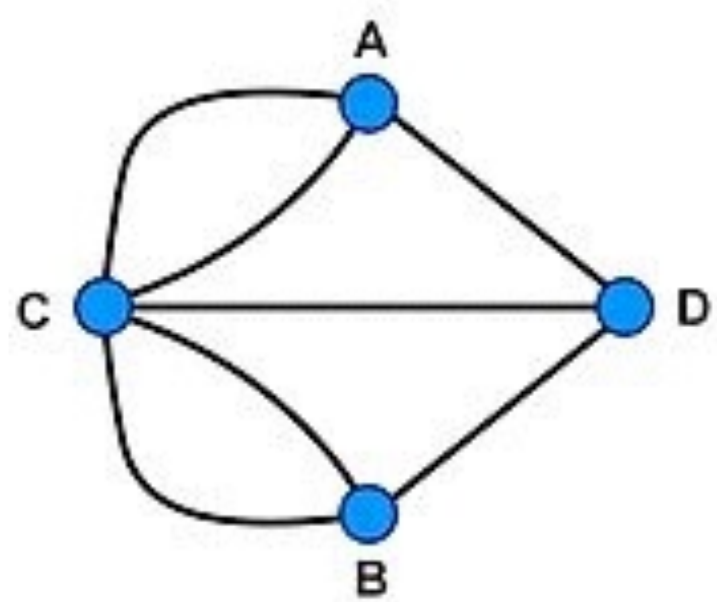


# Digression...

Modeling activities require several steps of abstraction that must preserve the set of solutions: in other words the abstractions must preserve the topology of the problem.

Original problem: seven bridges of Königsberg

Graph problem: redrawing this picture without retracing any line and without picking your pencil up off the paper

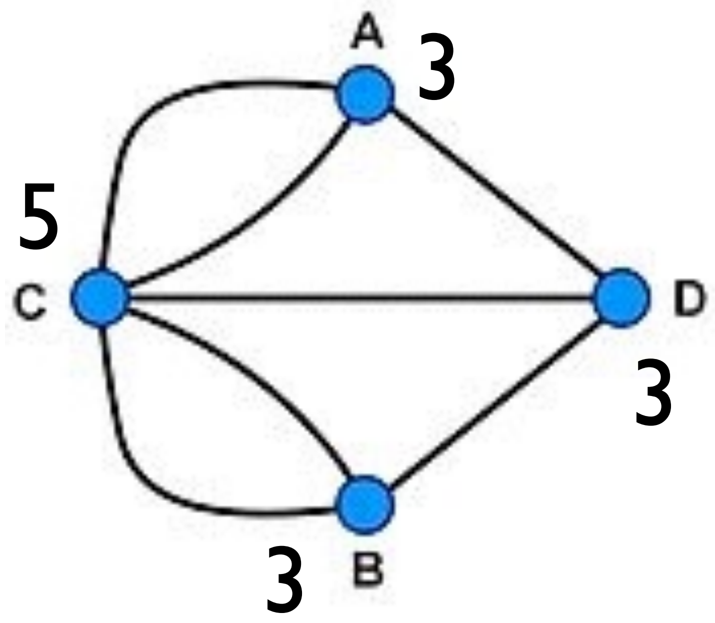



Generalized problem: given a connected graph, find a circuit that visits every edge precisely once, if it exists.

# Digression...

Informal reasoning:

All the vertices in the above picture have an odd number of arcs connected to them.



# Digression...

Informal reasoning:

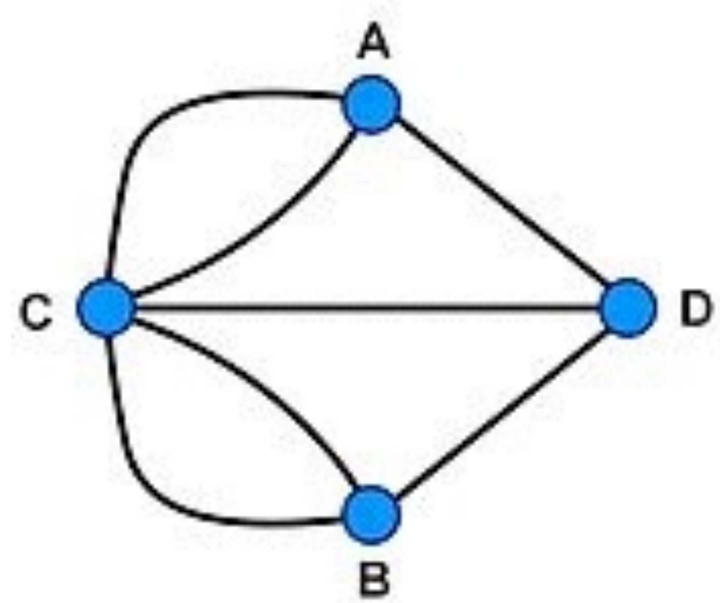
All the vertices in the above picture have an odd number of arcs connected to them.

Take one of these vertices, say D, and start trying to trace the figure out without picking up your pencil: then two arcs are left from/to D.

Next time you arrive in D, one arc will be left, and when you will leave D, no arc from/to it will be left!

Analogously for A, B, C.

No circuit possible!



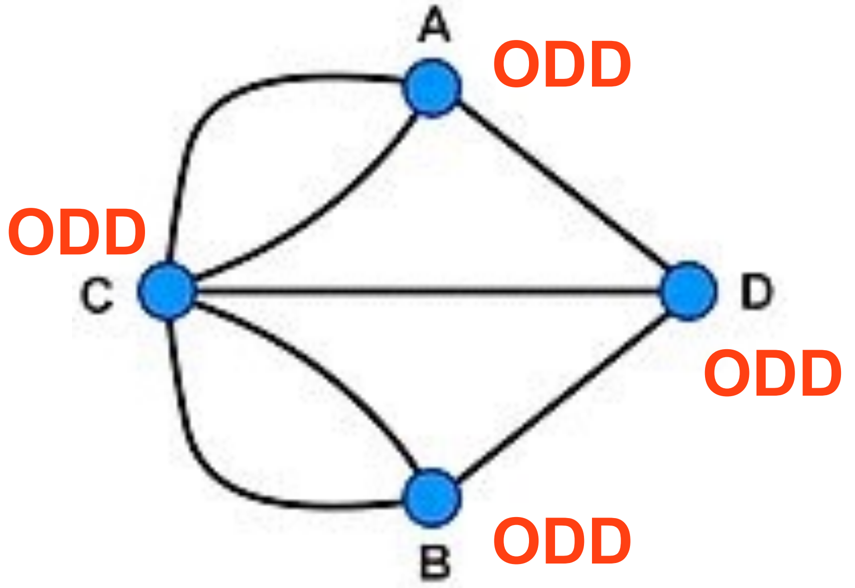
# Digression...

Formal reasoning:

**Definition**: An Eulerian path is a continuous path that passes through every arc once and only once. It is a circuit if it ends in the same vertex where it starts.

**Definition**: A vertex is called odd if it has an odd number of arcs leading to it, otherwise it is called even. The number of arcs attached to node v is called degree of v, deg(v).

**Theorem**: A (connected) graph G contains an Eulerian circuit if and only if the degree of each vertex is even.



# Digression...

**Proof of necessity:**

*Suppose G contains an Eulerian circuit C.*

*Then, for any choice of vertex v, C contains all the edges that are adjacent to v.*

*Furthermore, as we traverse along C, we must enter and leave v the same number of times, and it follows that v must be even.*

While this proof of necessity was given by Euler, the proof of converse is not stated in his paper.

It is not until 1873 (137 years later) when a young German mathematician, Carl Hierholzer published the proof of sufficiency.

# Digression...

**Proof of sufficiency: (by induction on the numbers of arcs)**

*<u>Base case</u>: the smallest possible number of edges is 3 (i.e. a triangle) and the graph trivially contains an Eulerian circuit.*

*<u>Inductive case</u>: Let us assume that any connected graph H that contains k or less than k arcs and such that every vertex of H has even degree, contains an Eulerian circuit.*

*Now, let G be a graph with k + 1 edges, and every vertex has an even degree.*

*Since there is no odd degree vertex, G cannot be a tree (no leaves). Thus, G must contain at least one cycle C.*

*...*

# Digression...

**Proof of sufficiency: (by induction on the numbers of arcs, continued)**

*...*

*Now, remove the edges of C from G, and consider the remaining graph G'.*

*Since removing C from G may disconnect the graph, G' is a collection of connected components, namely G'1 , G'2 , . . . , etc.*

*Furthermore, when the edges in C are removed from G, each vertex loses even number of adjacent edges. Thus, the parity of each vertex is unchanged in G'.*

*It follows that, for each connected component of G', every vertex has an even degree.*

*Therefore, by the induction hypothesis, each of G'1 , G'2 , . . . has its own Eulerian circuit, namely C1 , C2 , etc.*

*...*

# Digression...

**Proof of sufficiency: (by induction on the numbers of arcs, continued)**

*...*

*We can now build an Eulerian circuit for G.*

*Pick an arbitrary vertex v from C.*

*Traverse along C until we reach a vertex vi that belongs to one of the connected components G'i.*

*Then, traverse along its Eulerian circuit Ci until we traverse all the edges of Ci.*

*We are now back at vi, and so we can continue on along C.*

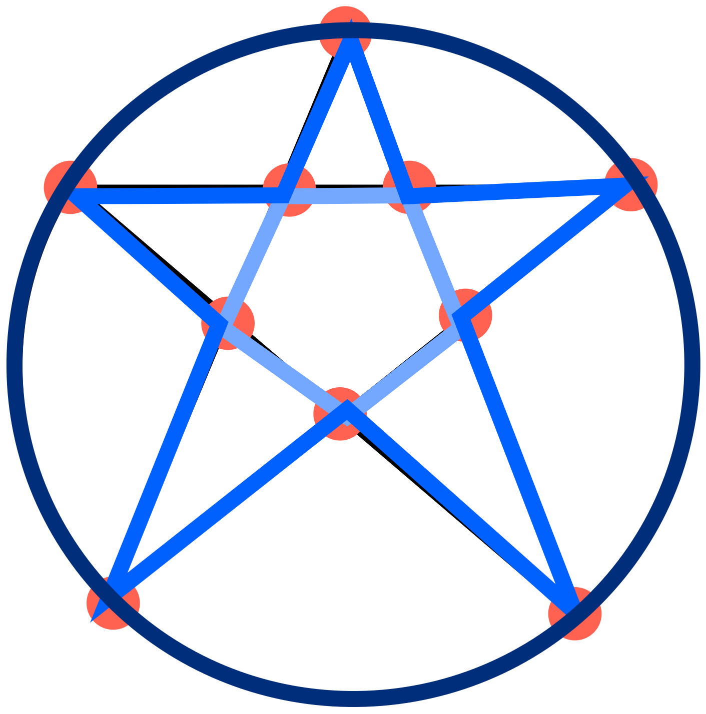
*In the end, we shall return back to the first starting vertex v, after visiting every edge exactly once.*

# Digression...

The theorem, as such, is only an existential statement.

If the necessary and sufficient condition is satisfied, we wish to find an Eulerian circuit.

The inductive proof naturally gives an algorithm to construct Eulerian circuits:
**recursively find a cycle, and then remove the edges of the cycle.**



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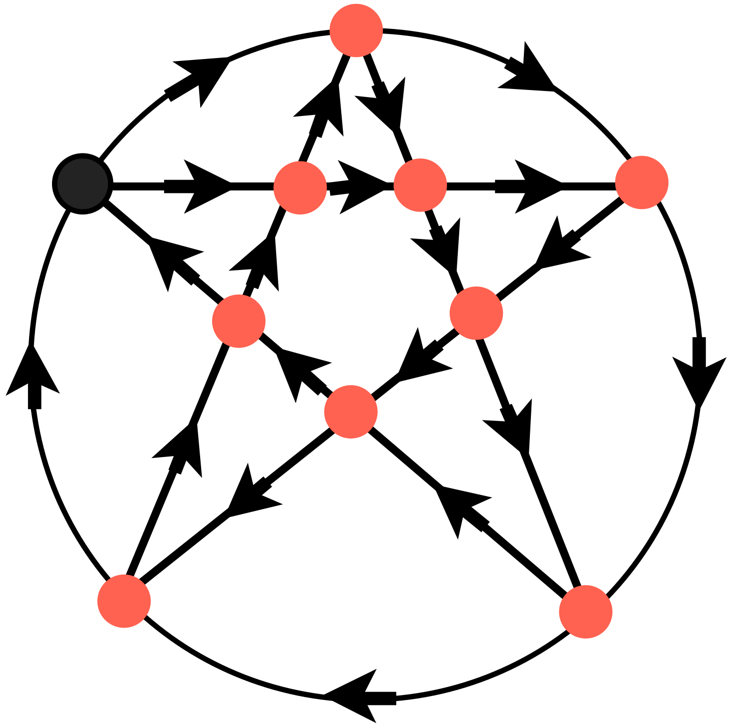


# Digression...

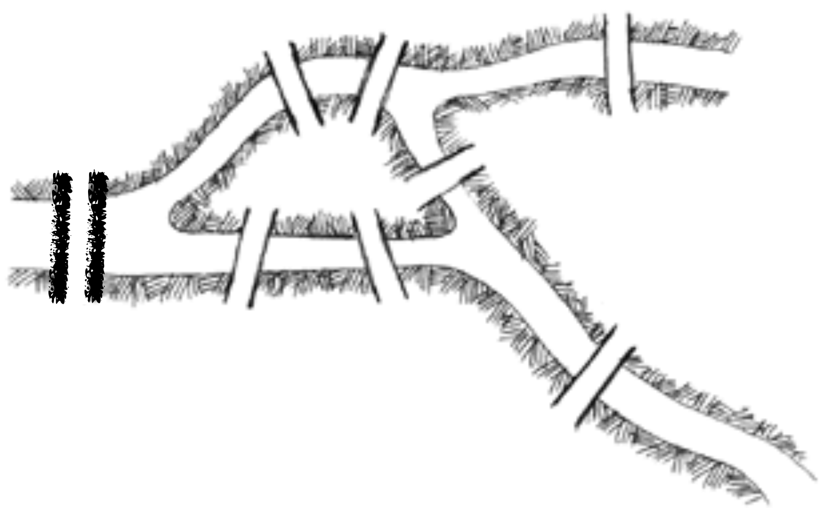
**Theorem**: A graph contains an **Eulerian path** if and only if there are 0 or 2 odd vertices.

**Proof**.
*Suppose a graph G contains an Eulerian path P.*
*Then, for every vertex v, P must enter and leave v the same number of times, except when it is either the starting vertex or the final vertex of P.*
*When the starting and final vertices are distinct, there are precisely 2 odd degree vertices.*
*When these two vertices coincide, there is no odd degree vertex.*

*Conversely, suppose G contains 2 odd degree vertex u and v.*
*(The case where G has no odd degree vertex is shown in the previous Theorem.)*
***Then, temporarily add a dummy edge (u, v) to G.***
*Now the modified graph contains no odd degree vertex.*
*By the previous Theorem, this graph contains an Eulerian circuit C that includes (u, v).*
*Remove (u, v) from C, and now we have an Eulerian path where u and v serve as initial and final vertices.*

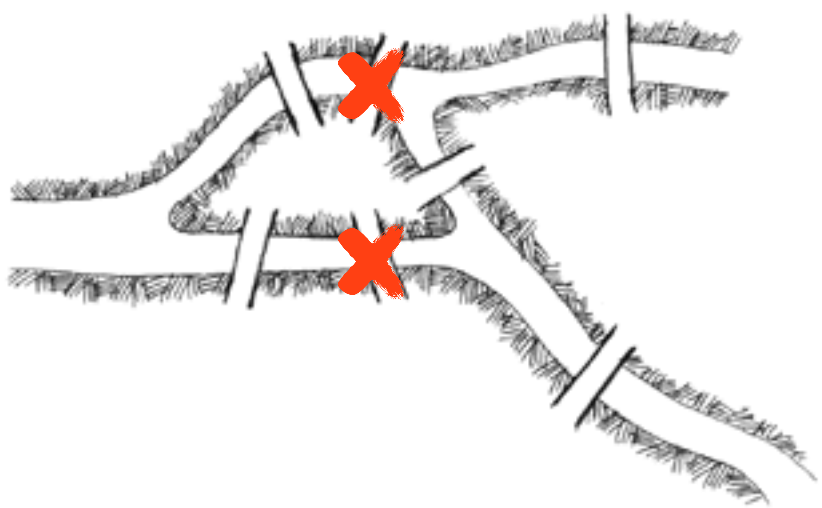
# Digression...

In the late 19th century an eighth bridge was built (see map).
As a result Königsberg had been Eulerised!



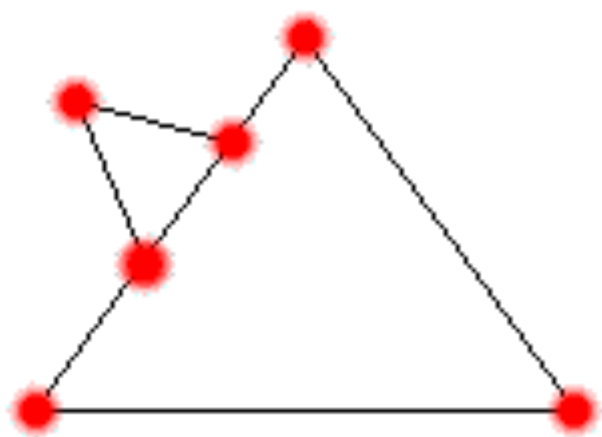
**Exercise**: prove that an Eulerian path can be found (but not a circuit)

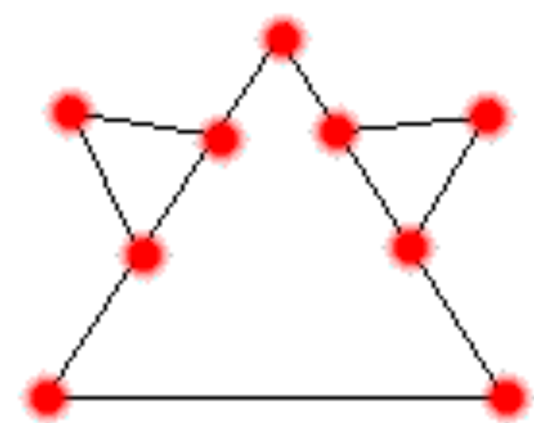
Sadly, in 1944 air raids obliterated most of the bridges. However, from the maps made available since, it appears that five bridges crossing were rebuilt in such a way that Kaliningrad was Eulerised once again!

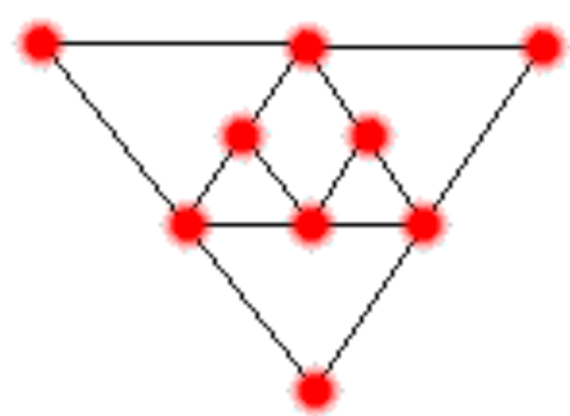


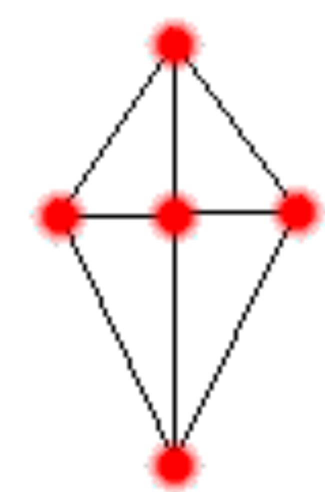
**Exercise**: prove that an Eulerian path can be found (but not a circuit)

# Digression…









**Exercises**: find Eulerian paths/circuits in the graphs above or prove that they cannot exist.

# Lessons learned

- Concrete instance of the problem
- Abstract modeling and generalization
- Visual notation, informal, intuitive
- Mathematical notation, rigorous, precise
- Solutions from formal reasoning, proofs
- Implementation and application to concrete instances

# Lessons to learn

- Formal models used in prescriptive manner
- Correctness by design
- Model-driven implementation
- Well-engineered systems
- High-level vision

# Examples of bad design choices