Business Processes Modelling

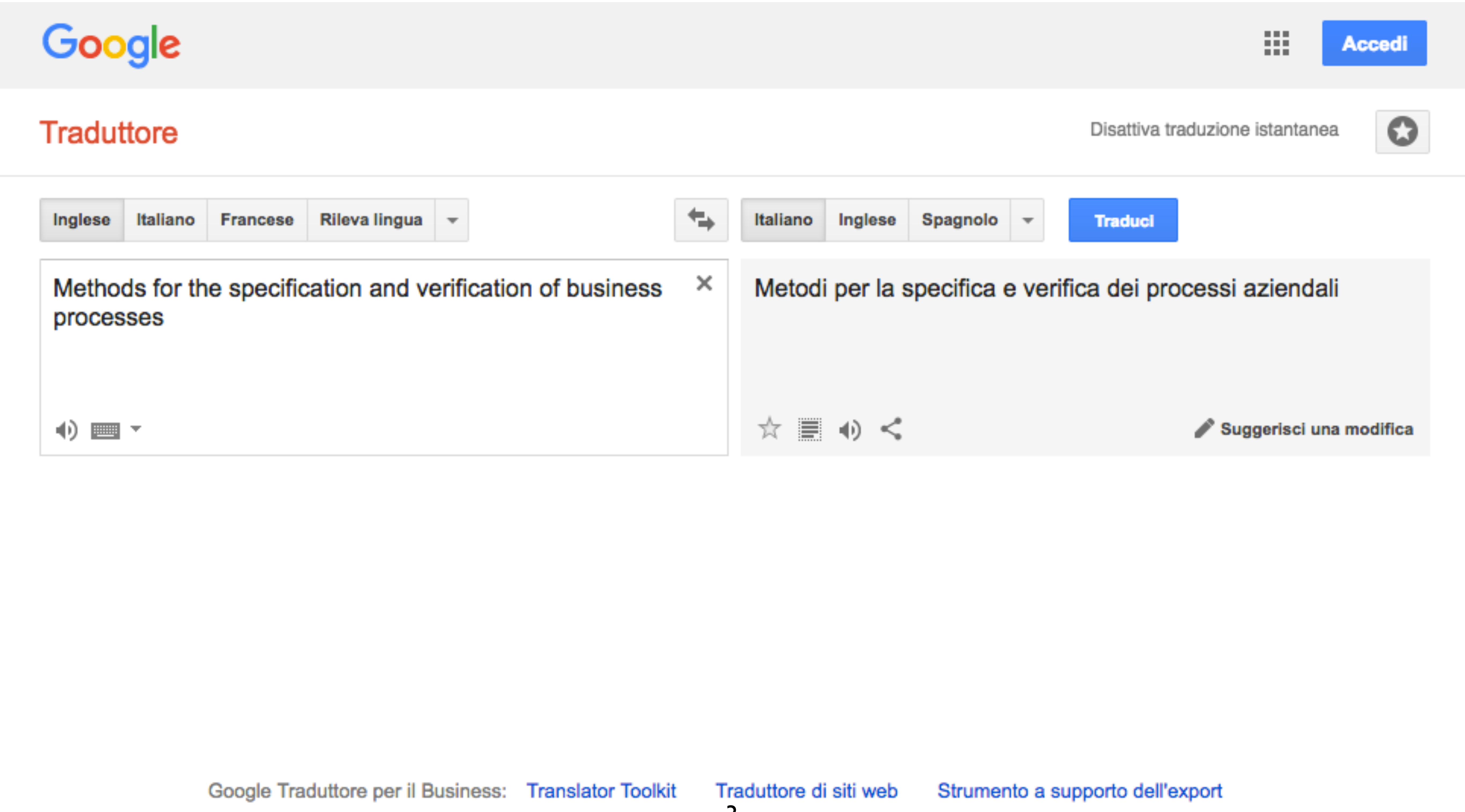
MPB (6 cfu, 295AA)

Roberto Bruni
http://www.di.unipi.it/~bruni

01 - Introduction

Gabitê
Witaj
Welkom
Velkommen
benvenuto
Welcome
Bem-vindo
Välkommen
歡迎
Bienvenue
Καλώς ήλθατε
Maeva
Marhaban
Selamat
मैं आपका स्वागत है
Vítejte
Welkom
Hosgeldiniz
добро пожаловать
Willkommen
Yôkoso
Bienvenido

English vs Italian



Methods for the specification and verification of business processes

Metodi per la specifica e verifica dei processi aziendali

Google Traduttore per il Business: Translator Toolkit Traduttore di siti web Strumento a supporto dell'export

Classes

Every

Monday: 11:00-12:45, Microsoft Teams

Wednesday: 16:15-18:00, Microsoft Teams

Who am I?

http://www.di.unipi.it/~bruni

bruni@di.unipi.it

Office hours: by appointment
preferably
Wednesday 14:00-16:00

Who are you?

First Name:	
Last Name:	
Enrollment number	
email:	
Bachelor degree:	
MSc course of enrollment:	
Subjects of interest:	

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

Who are you?

First Name:	John
Last Name:	Smith
Enrollment number	123456
email:	john.smith@email.com
Bachelor degree:	Comp. Sci., Stanford, US
MSc course of enrollment:	Data Science & BI
Subjects of interest:	Statistics

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

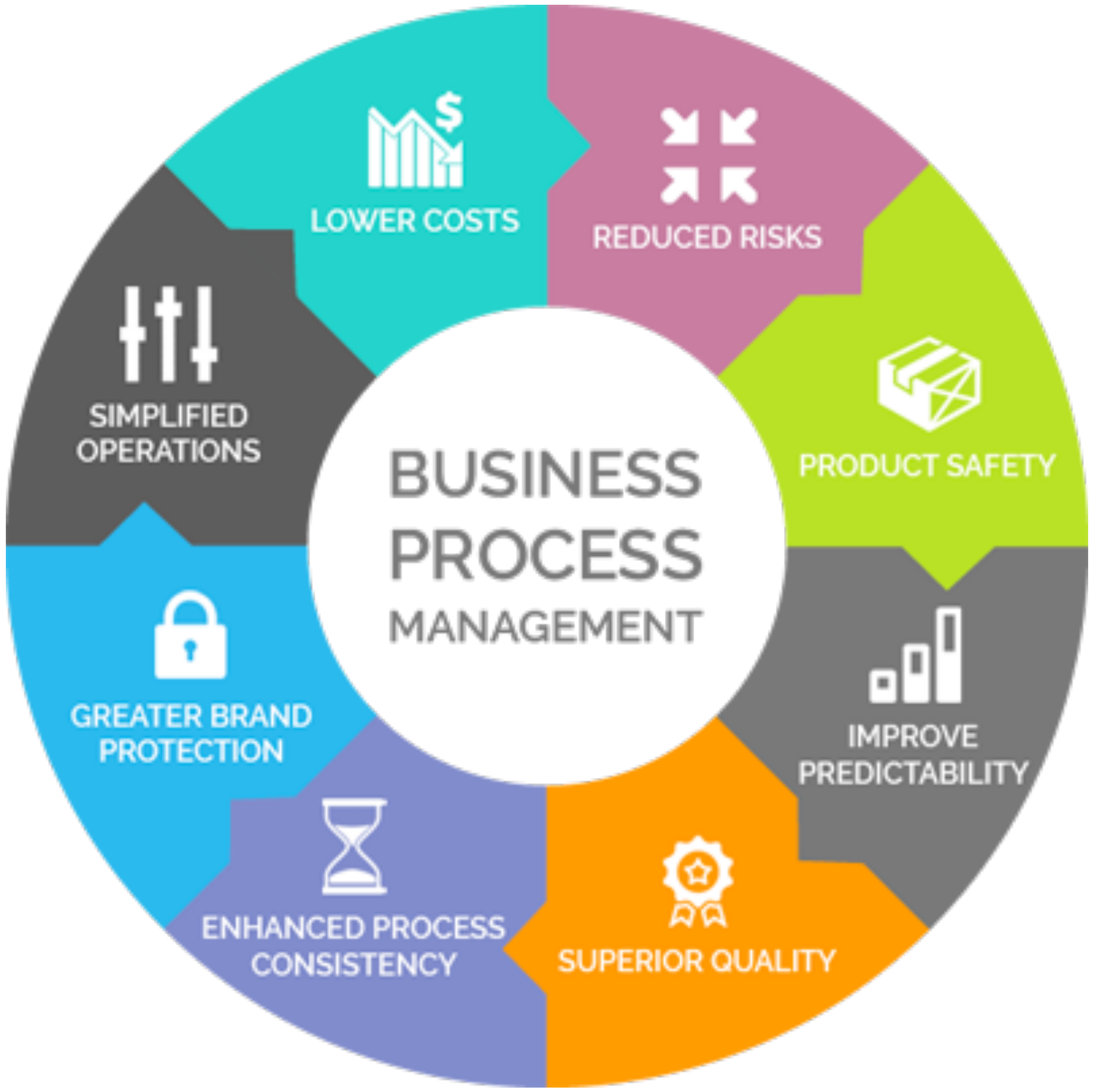
What is a BP?

Any set of steps aimed to reach some outcome

from opening an account

to processing a custom order

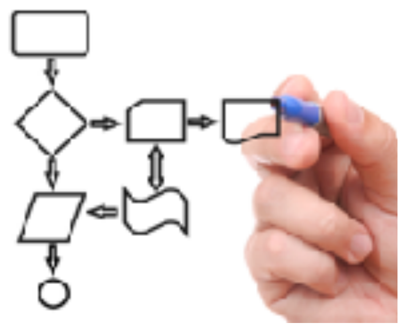
What is BPM about?



Course objectives

Key issues in Business Process Management (patterns, architectures, methodologies,…)

Analysis techniques and correctness by construction (soundness, boundedness, liveness, free-choice,…)



Graphical languages & visual notation (BPMN, EPC, ...)

Tool-supported verification (WoPeD, ProM, Woflan, ...)

Structural properties, behavioural properties and problematic issues (dead tasks, deadlocks, ...)

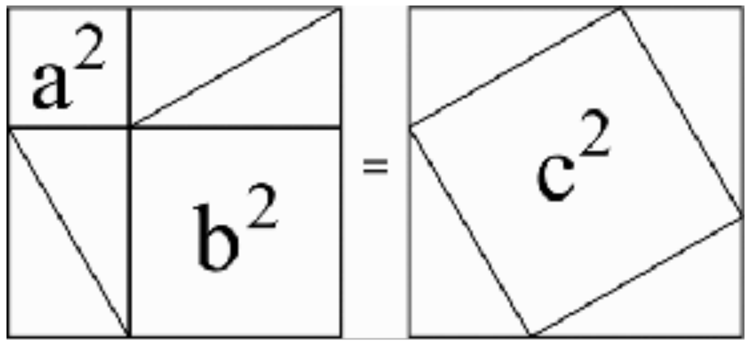
Performance analysis (bottlenecks, simulation, capacity planning,…)

Formal models (automata, Petri nets, workflow nets, ...)

Process mining (discovery, conformance checking, enhancement,…)

Course activities

attend virtual
classrooms:
ask questions!
(sleep quietly)



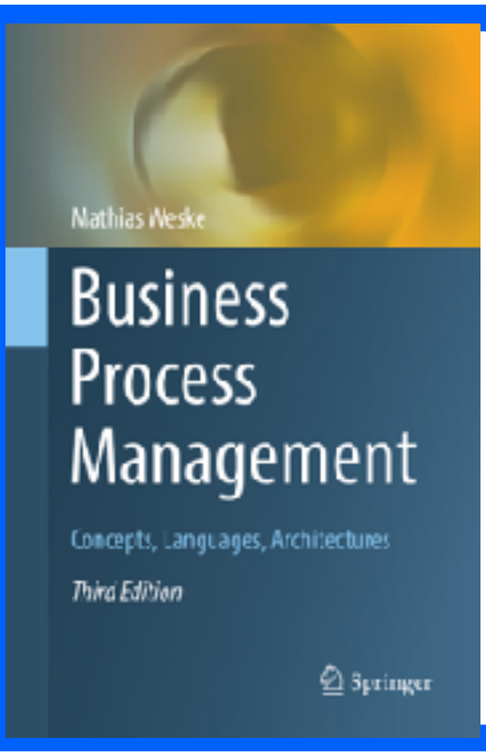
learn theorems:
(drink many coffees)

do some thinking:
solve ALL exercises
(at least try to)

deliver a project:
practice with concepts,
experiment with tools

give the exam:
time for a party!

Main Textbook

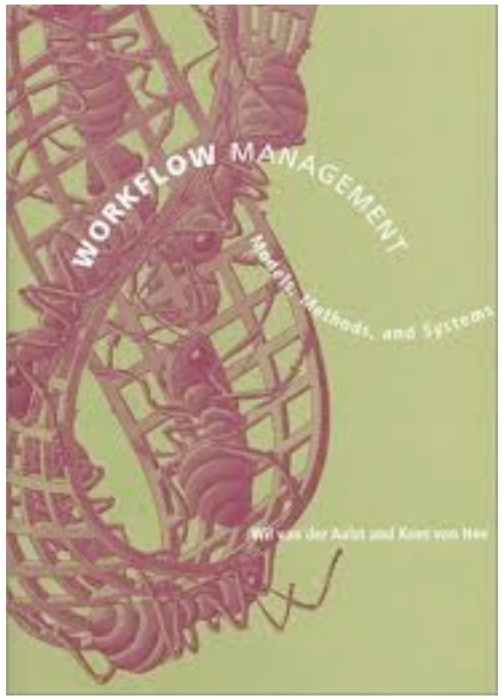

Mathias Weske
Business Process Management
Concepts, Languages, Architectures
Third Edition
Springer

Mathias Weske
Business Process Management: Concepts, Languages, Architectures
(3rd ed.) Springer 2019
http://bpm-book.com

Other Textbooks

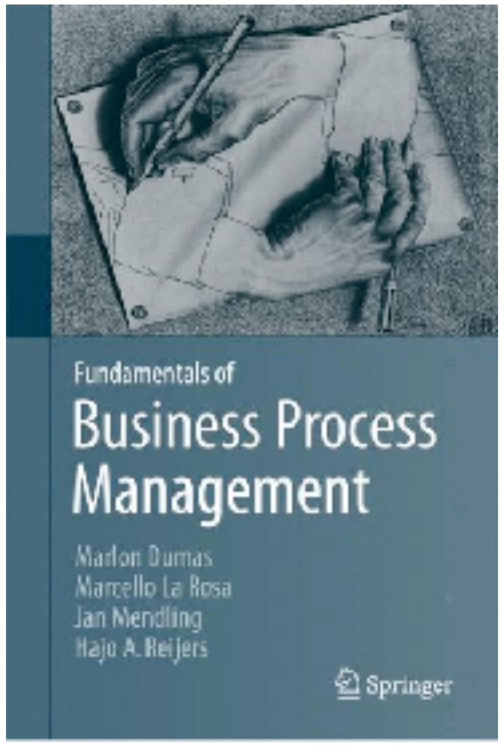
Free Choice Petri Nets
Jörg Desel and Javier Esparza
Cambridge Tracts in Theoretical Computer Science 40

Joerg Desel and Javier Esparza
Free Choice Petri Nets
Cambridge Tracts in Theoretical Computer Science 40, 1995
https://www7.in.tum.de/~esparza/bookfc.html

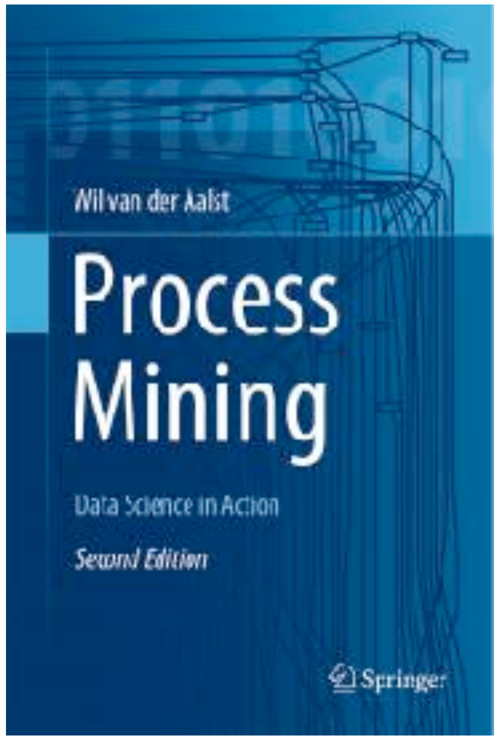

WORKFLOW MANAGEMENT
Models, Methods, and Systems
Wil van der Aalst and Kees van Hee

Wil van der Aalst, Kees van Hee
Workflow Management: Models, Methods, and Systems
MIT Press (paperback) 2004
https://mitpress.mit.edu/books/workflow-management

Other Textbooks



Marlon Dumas, Marcello La Rosa, Jan Mendling, Hajo Reijers
Fundamentals of Business Process Management
Springer 2013
http://fundamentals-of-bpm.org



Wil van der Aalst
Process Mining
Springer 2011 / 2016
http://springer.com/978-3-662-49850-7

Main resources

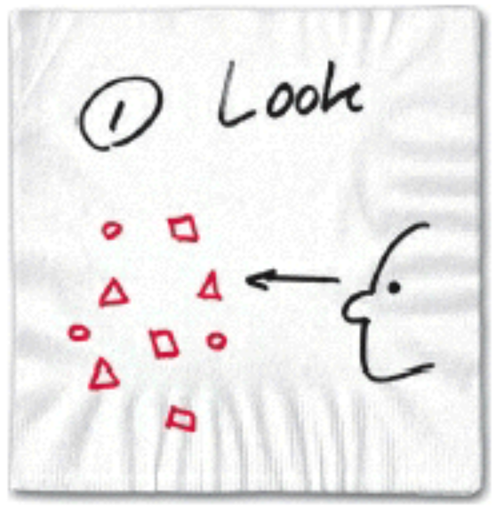
- Petri nets
  - http://www.informatik.uni-hamburg.de/TGI/PetriNets
- BPMN
  - http://www.bpmn.org
- BPEL
  - http://www.oasis-open.org/committees/wsbpel
- Workflow Patterns
  - http://www.workflowpatterns.com

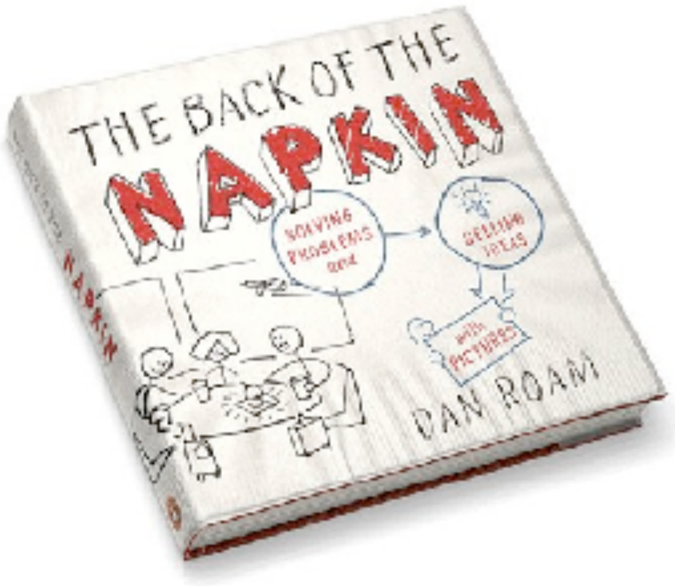
Main resources (tools)

- Woped
  - http://www.woped.org
- ProM
  - http://http://www.promtools.org/prom6
  - http://www.win.tue.nl/woflan
  - Diagnosing workflow processes using Woflan. H.M.W.Verbeek, T.Basten, W.M.P. van der Aalst. Computer J. 44(4): 246-279 (2001) http://www.padsweb.rwth-aachen.de/wvdaalst/publications/p110.pdf
- YAWL
  - https://yawlfoundation.github.io

What is BPM about?

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





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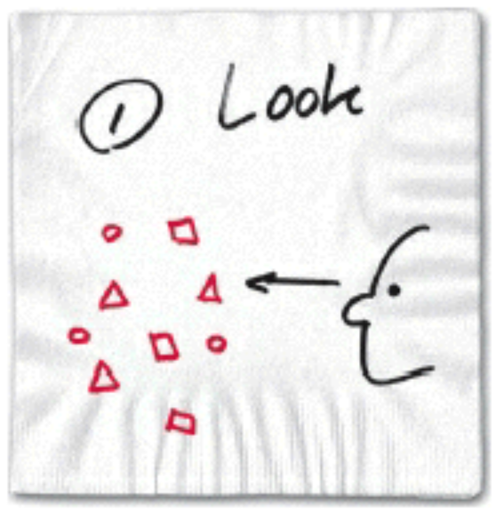

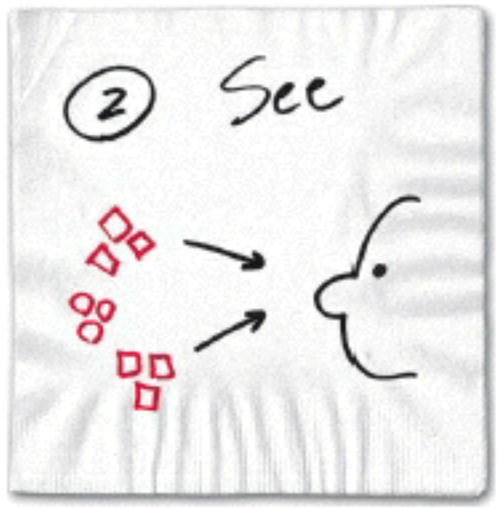

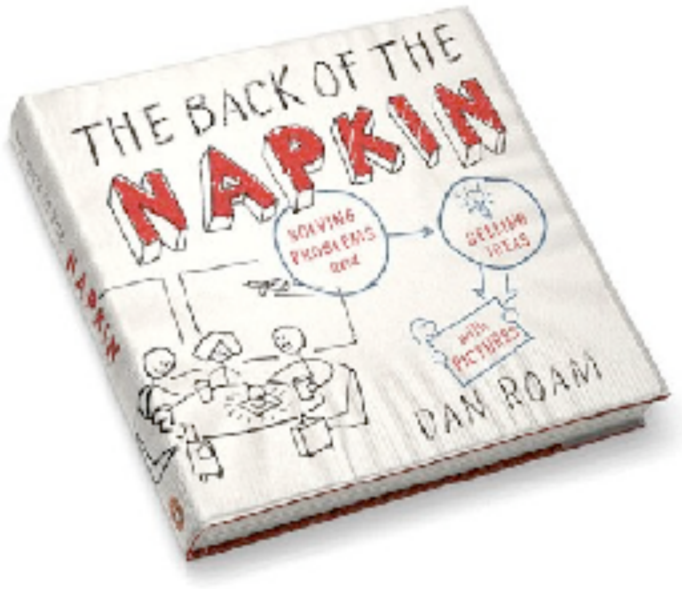

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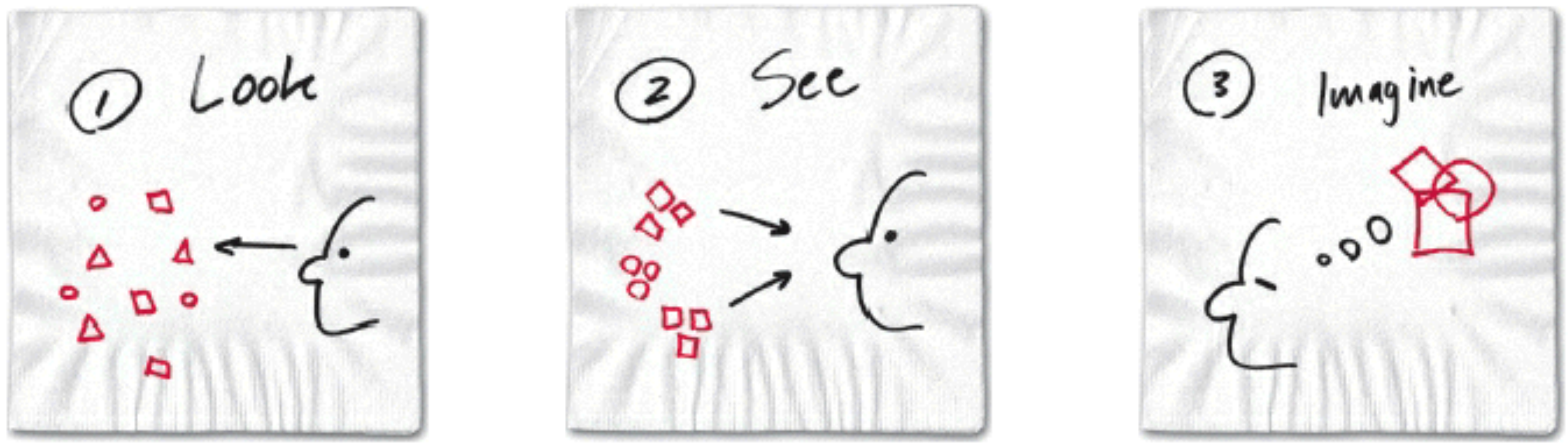
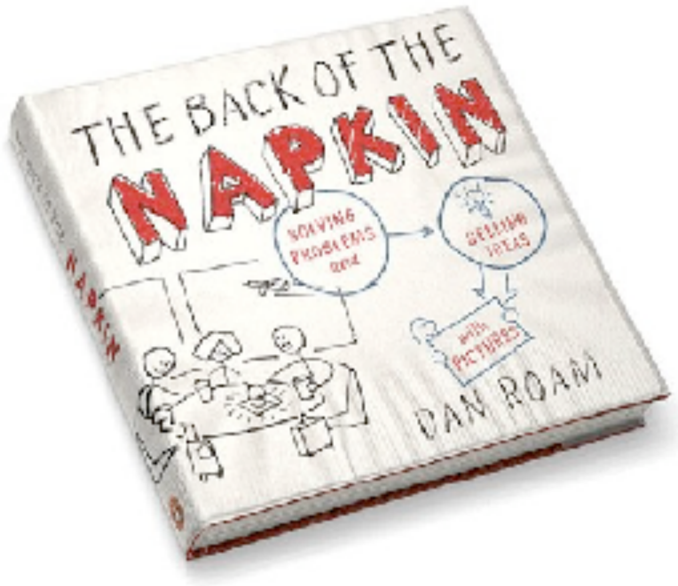
Giving shape to ideas, organizations, processes, collaborations, practices

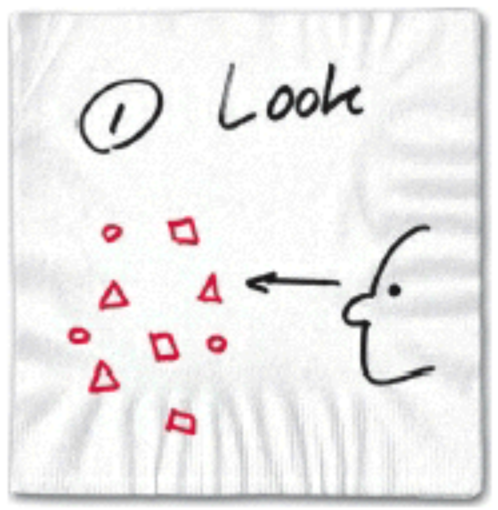


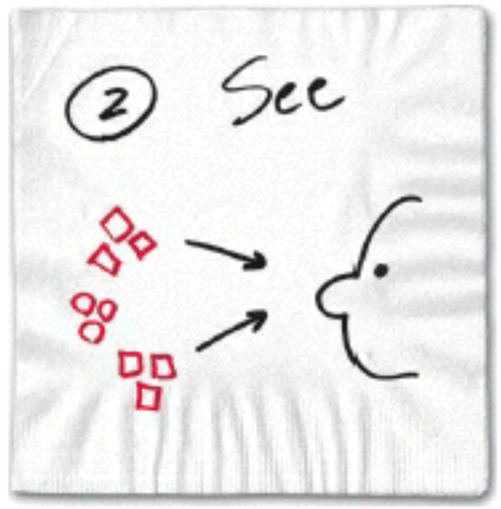


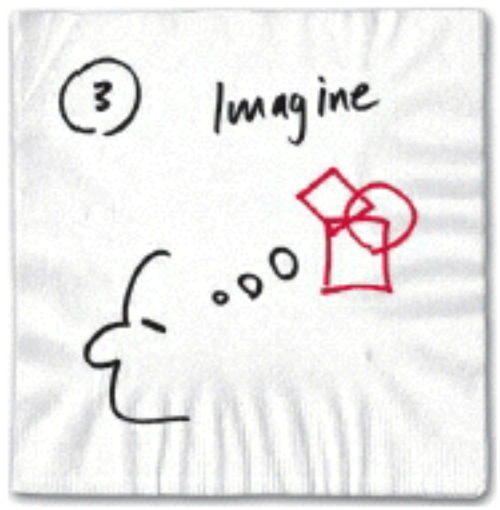
To analyse them

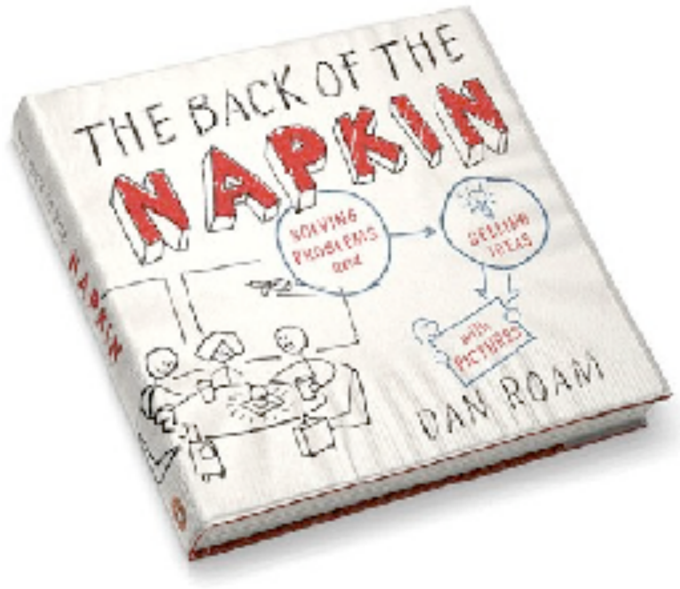
What is BPM about?

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







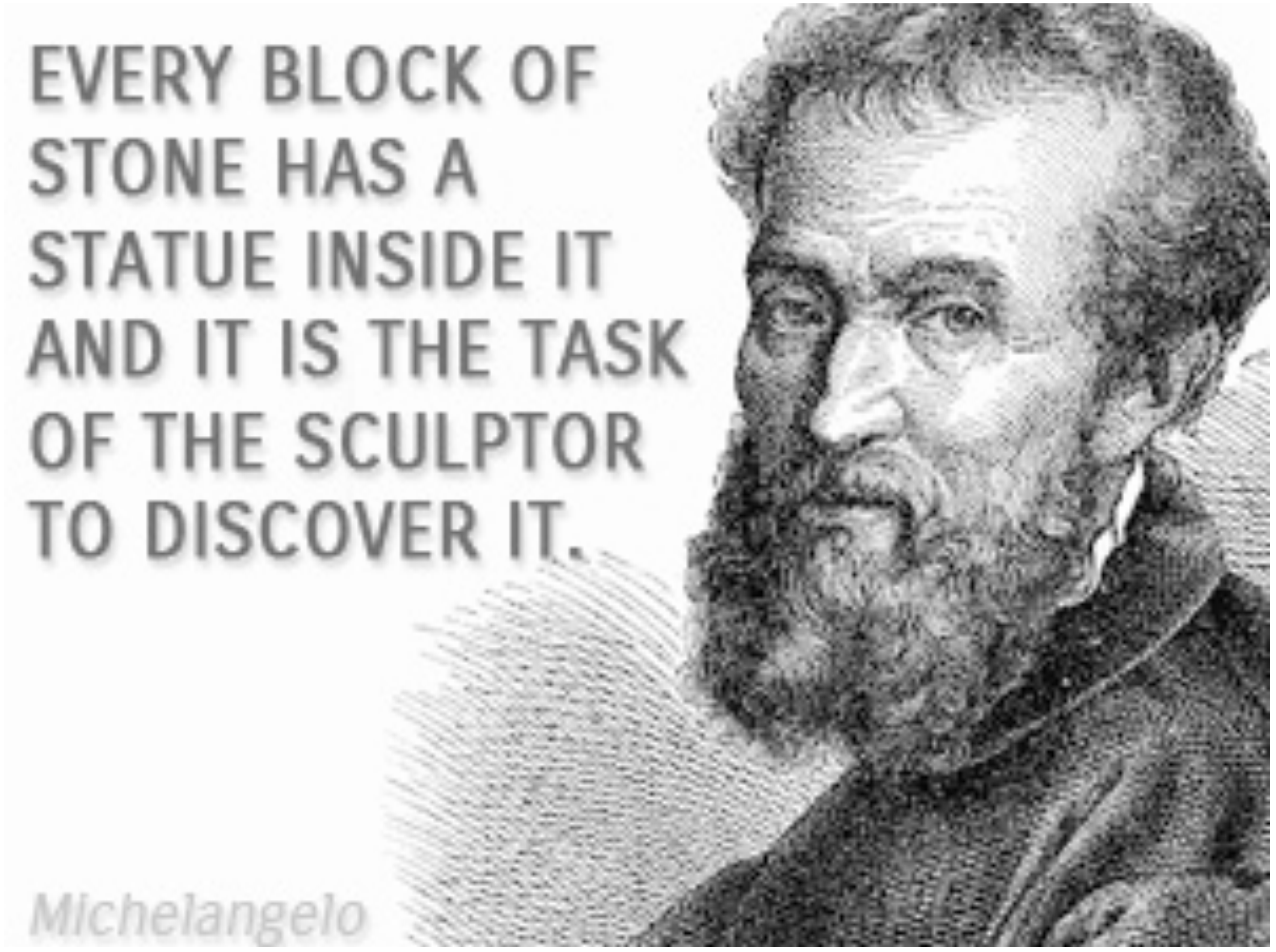


To analyse them

To communicate them to others

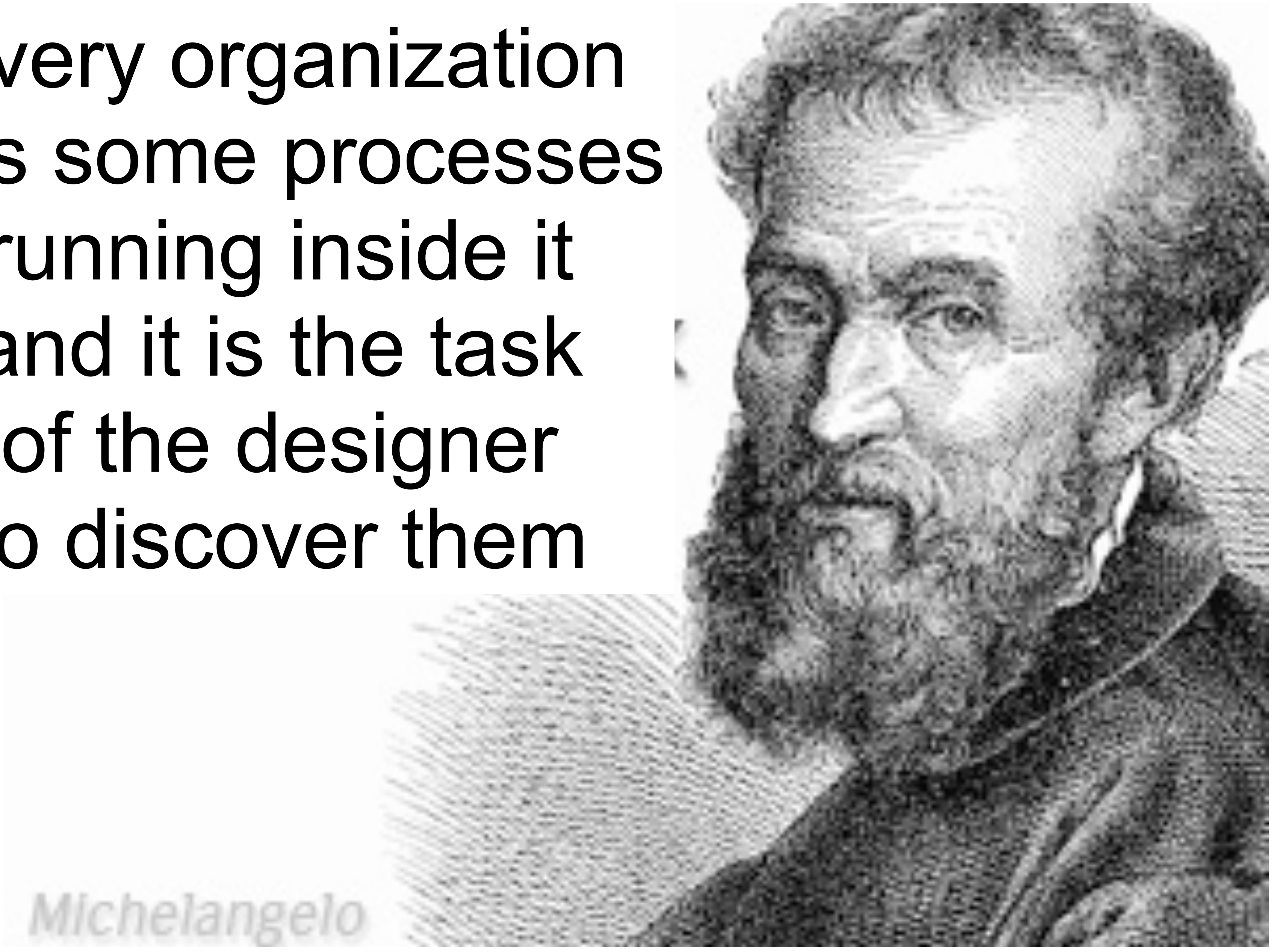
To change them if needed

Quoting Michelangelo

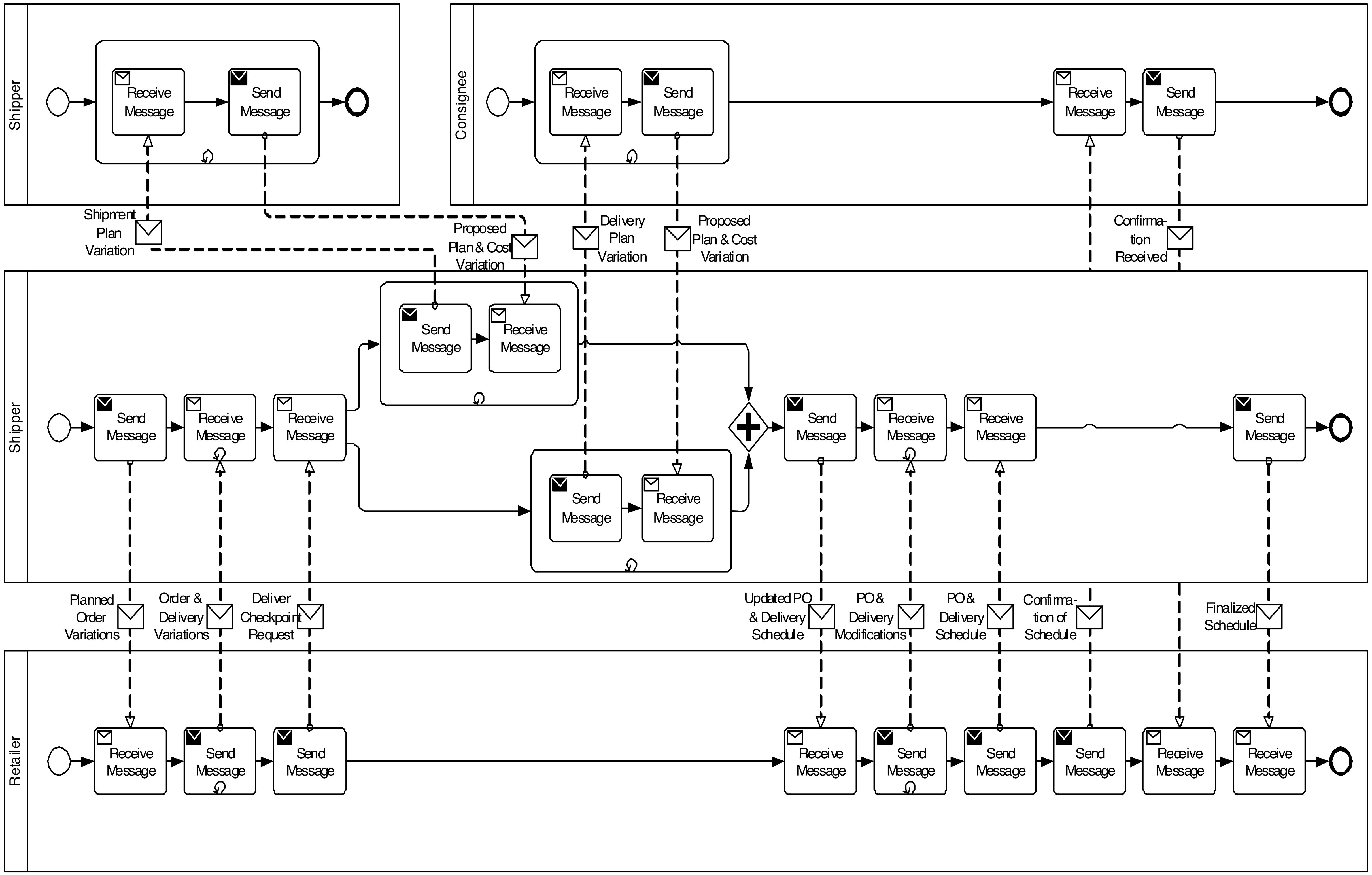

EVERY BLOCK OF STONE HAS A STATUE INSIDE IT AND IT IS THE TASK OF THE SCULPTOR TO DISCOVER IT.
Michelangelo

Quoting Michelangelo

Every organization
has some processes
running inside it
and it is the task
of the designer
to discover them

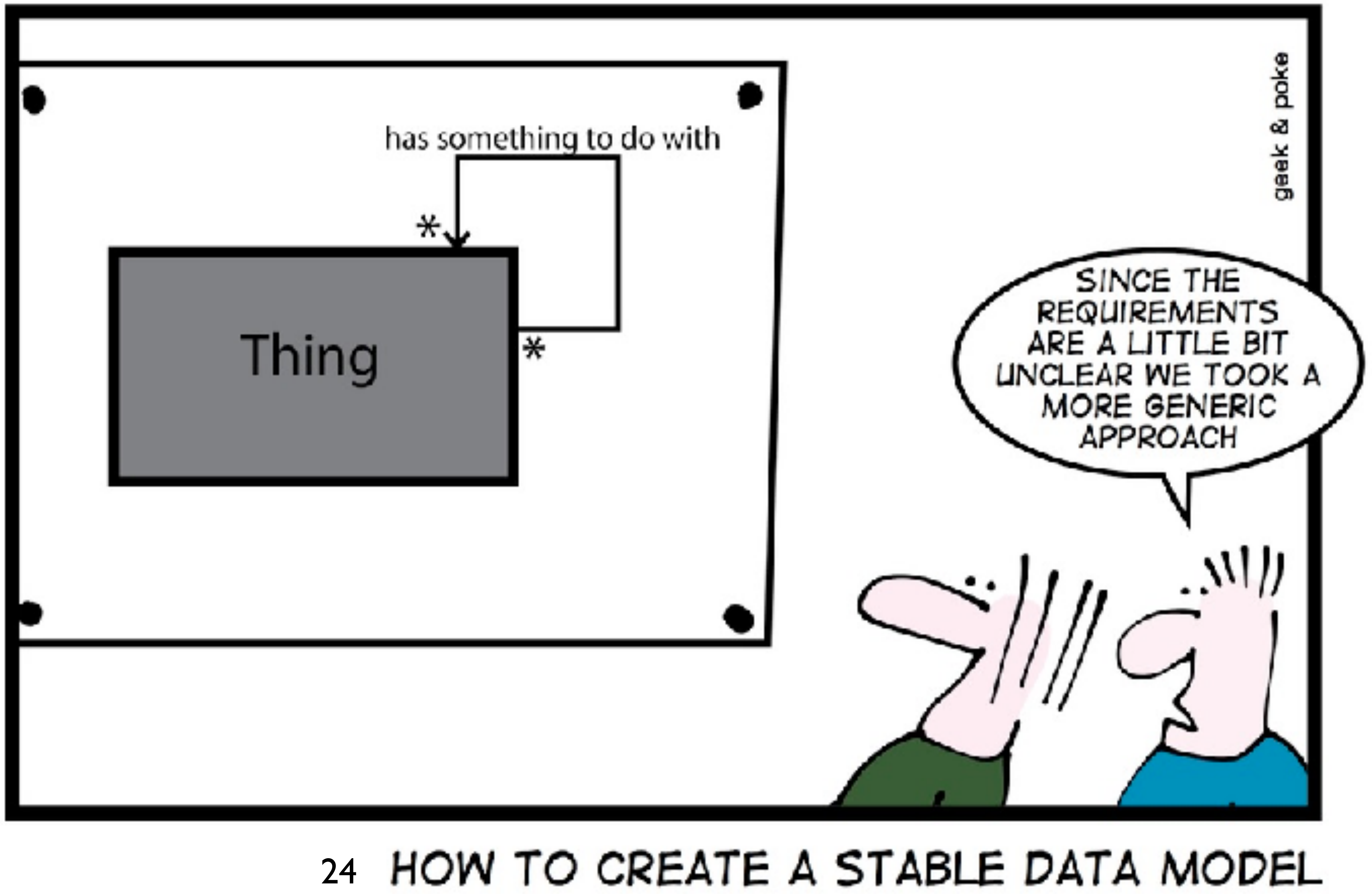


A taste of BPMN



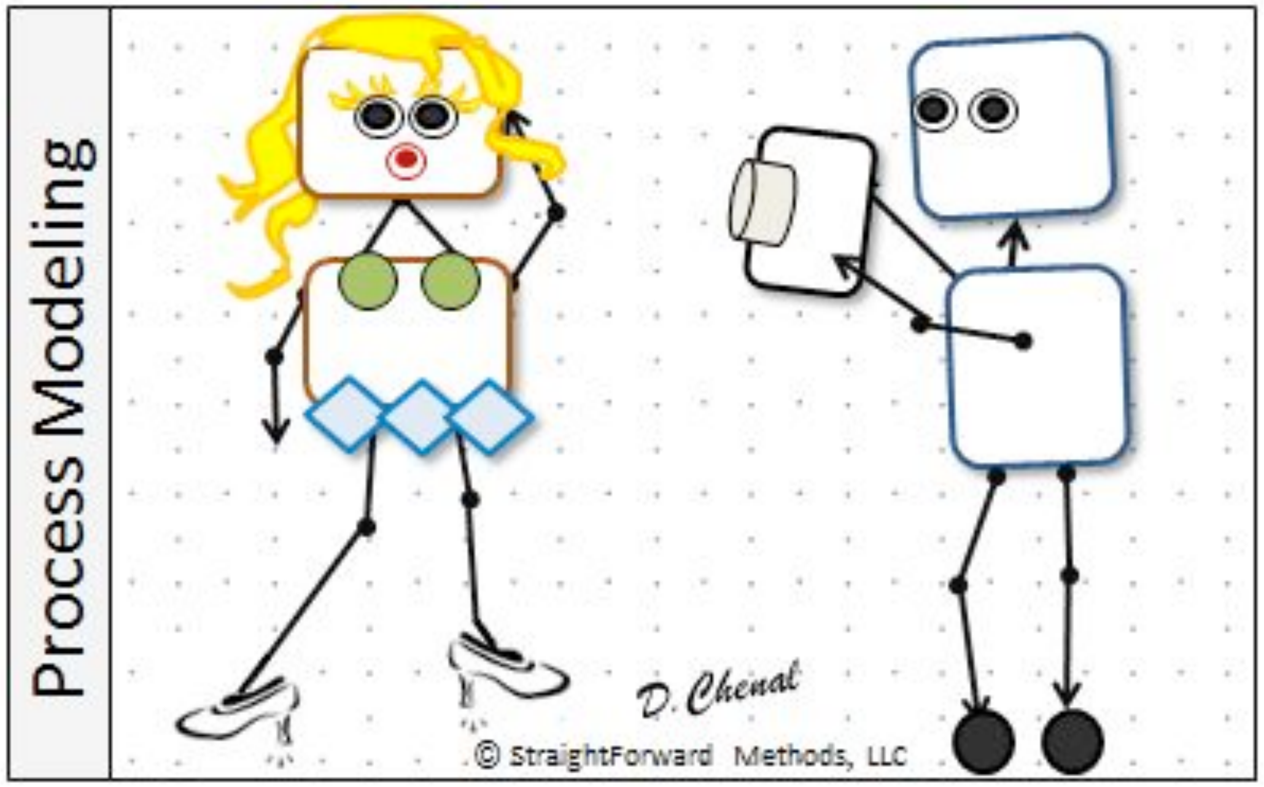
Data and processes

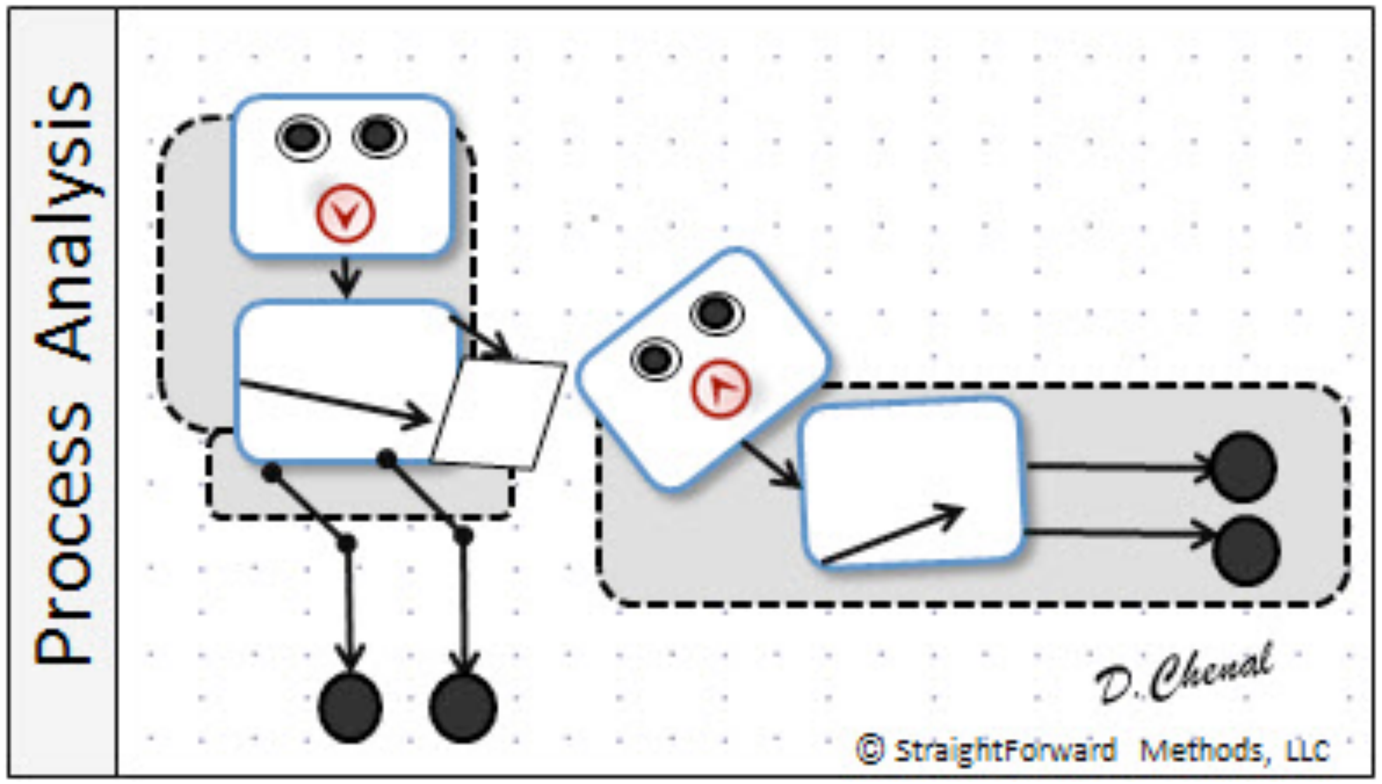
Traditionally, information systems
used **information modelling** as a starting point


has something to do with
*
*
Thing
geek & poke
SINCE THE REQUIREMENTS ARE A LITTLE BIT UNCLEAR WE TOOK A MORE GENERIC APPROACH
HOW TO CREATE A STABLE DATA MODEL

Data and processes

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

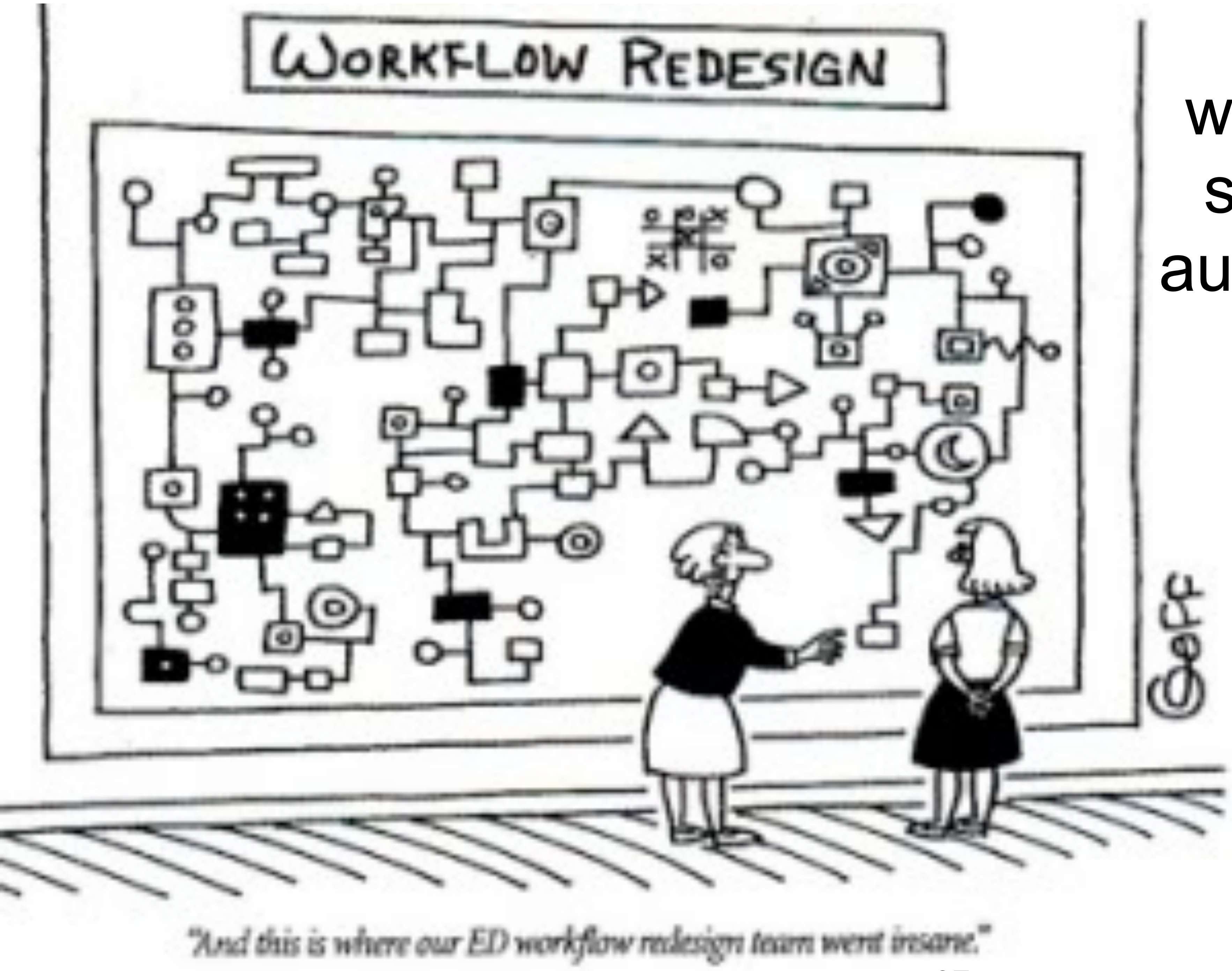




Motivation

- 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

Workflow wave



"And this is where our ED workflow redesign team went insane."

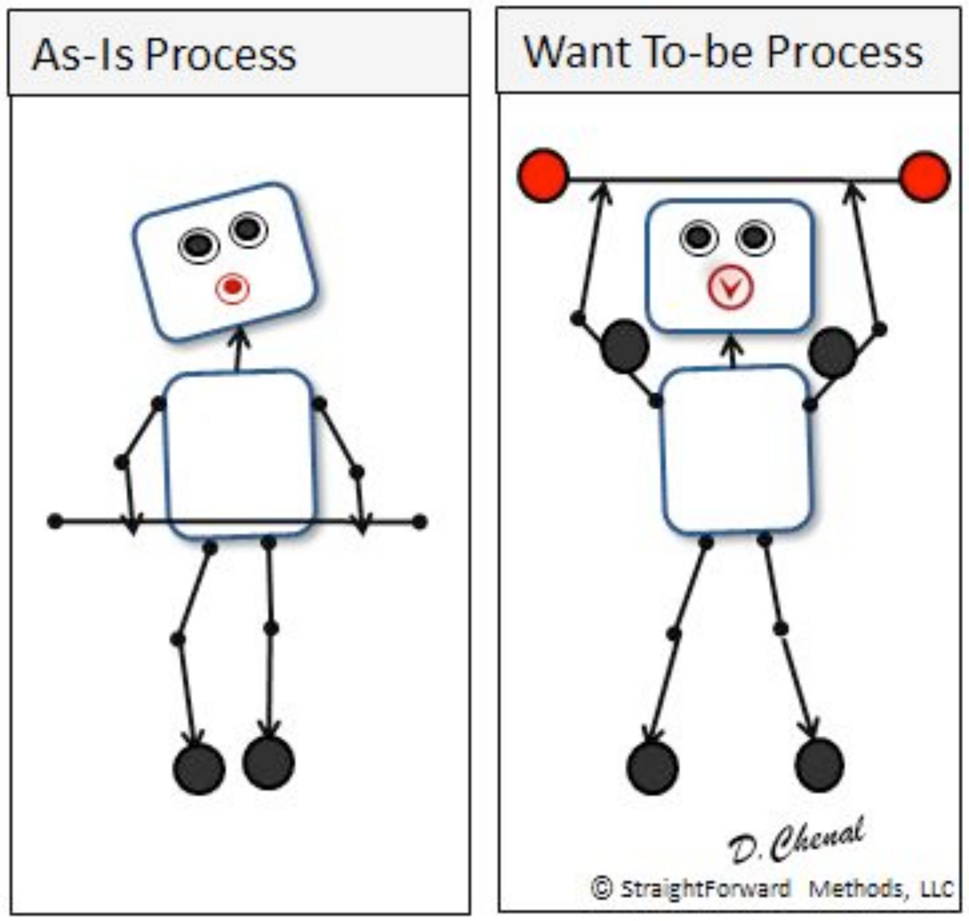
In the mid-nineties, workflow management systems aimed to the automation of structured processes

but their application was restricted to only a few application domains

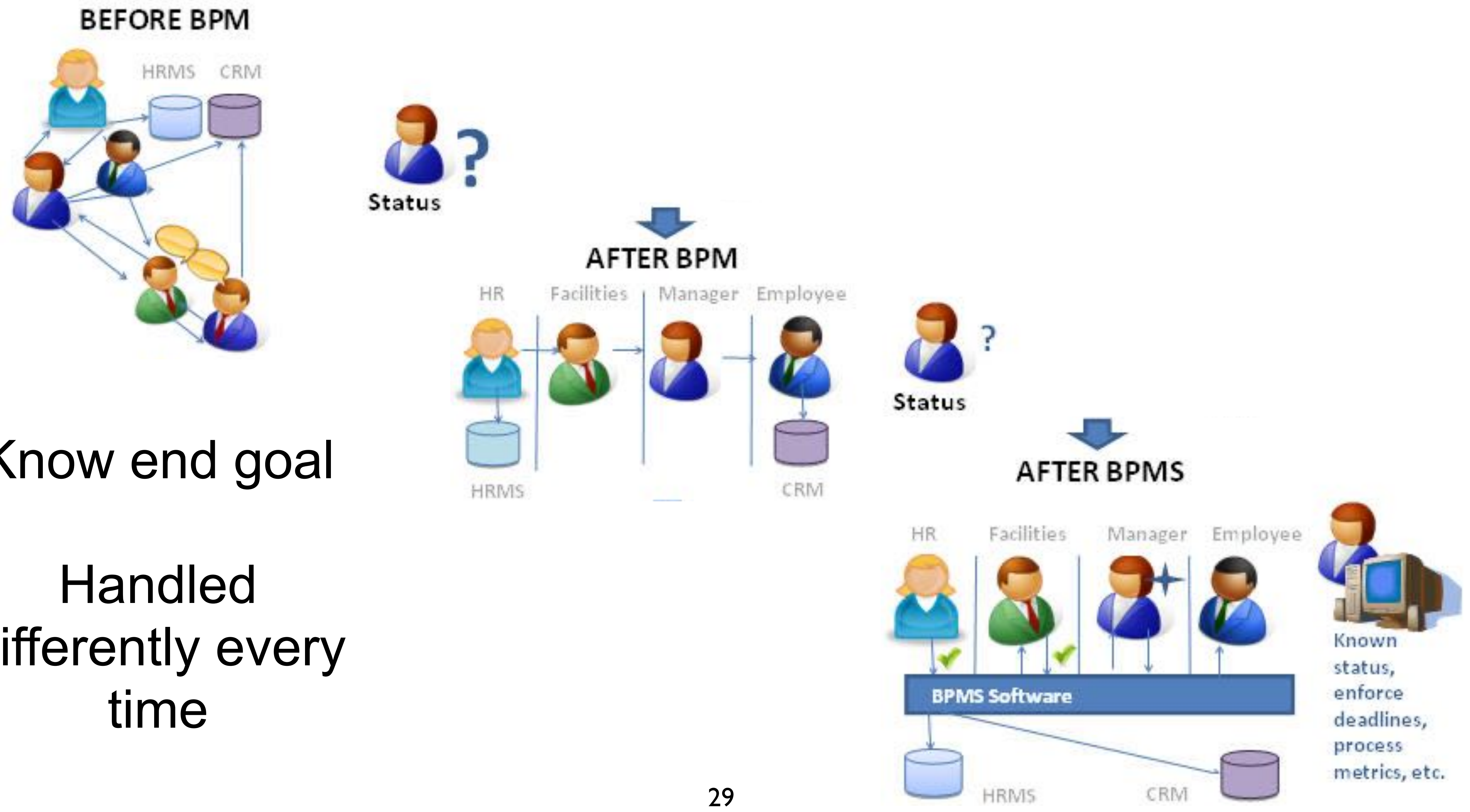
Process awareness

BPM moves
from
workflow management systems
(intra-organization)

to the broader perspective of
process-aware information
systems
(inter-organizations)



Process awareness



Know end goal

Handled differently every time

Benefits of BPM

automate workflow and
orchestrate processes,
reduce risk of errors,
provide metrics,
real time status,
enforce deadlines,
validate data,
reduce training costs,
…

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.

Why BPM?

Highly relevant for pratictioners

Offers many challenges for software developers and computer scientists

BPM angles

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

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

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

Essential concepts

Different educational backgrounds and interests are in place

This course is not about a particular XML syntax (e.g., BPMN) or tool (e.g. ProM)

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

Which target?

Formal methods people

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

Software develop people

- -provide robust and scalable sw
- -integration of existing sw
- -look at new technology trends

Business admin people

- -increase customer satisfaction
- -reducing costs
- -establishing new products

Aim

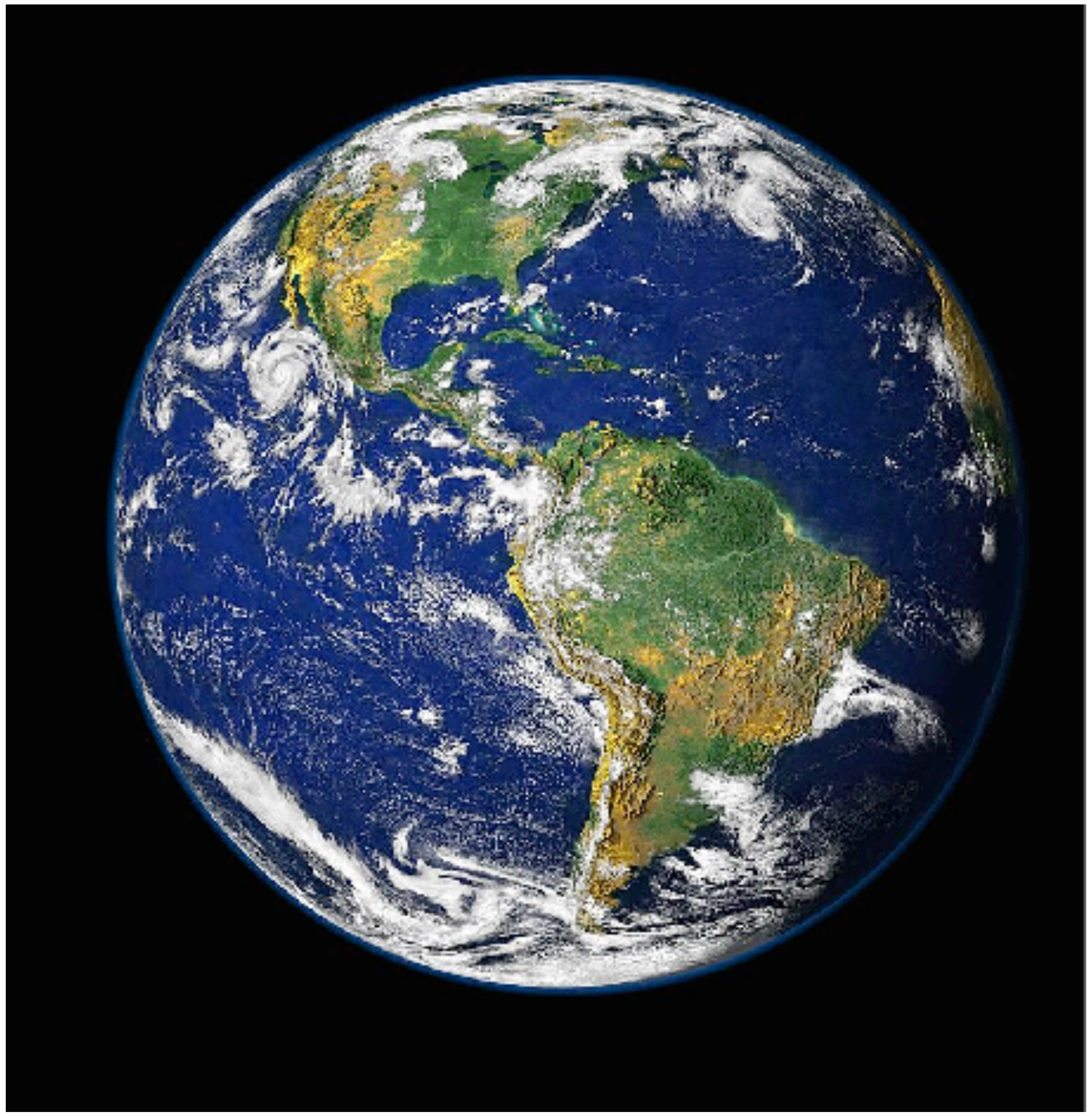
Robust and correct realization of business processes in software that increases customer satisfaction and ultimately contributes to the competitive advantage of an enterprise

Abstraction

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

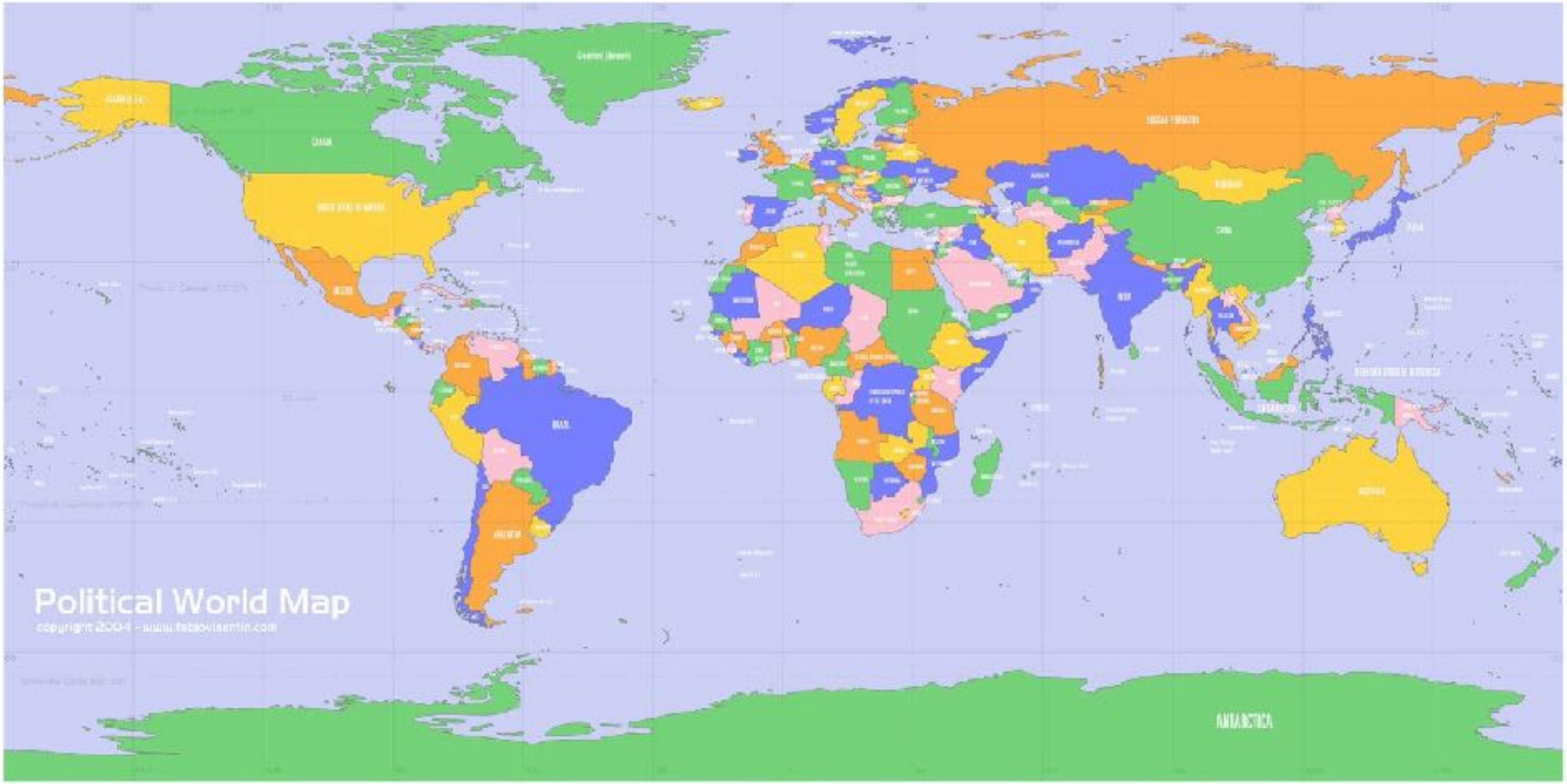
Abstraction as the key to achieve some common understanding, to build a bridge between views...

Levels of abstractions



Levels of abstractions

Levels of abstractions



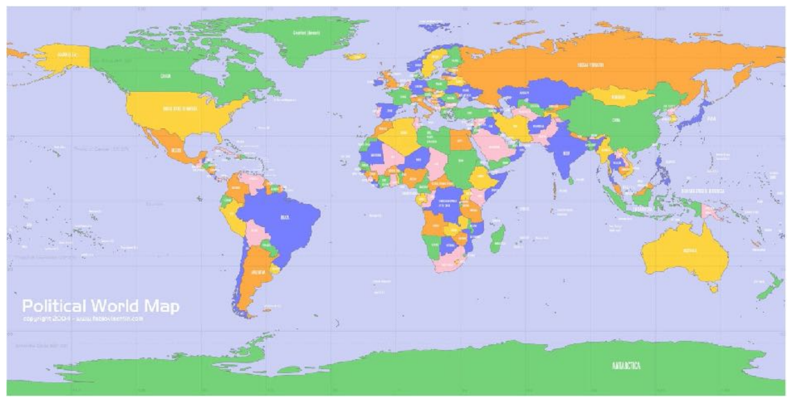
Levels of abstractions

Upside down
World Map
SOUTHERN OCEAN
SOUTH PACIFIC OCEAN
INDIAN OCEAN
SOUTH ATLANTIC OCEAN
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
ARCTIC OCEAN
AUSTRALIA
BRAZIL
UNITED STATES OF AMERICA
CANADA
CHINA
INDIA
MONGOLIA
KAZAKHSTAN
RUSSIAN FEDERATION
GREENLAND

Levels of abstractions

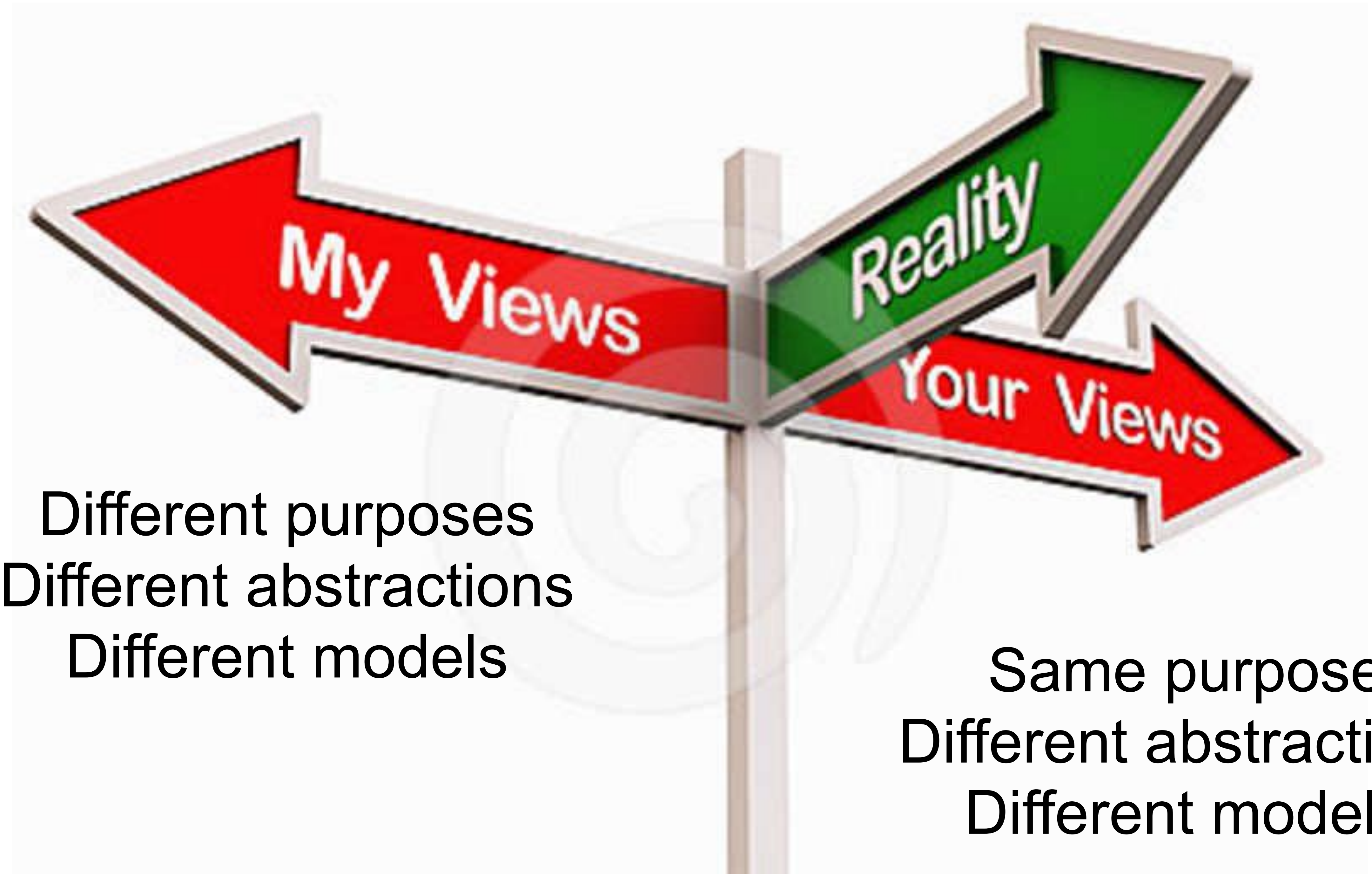
Levels of abstractions

Levels of abstractions



One object, many views

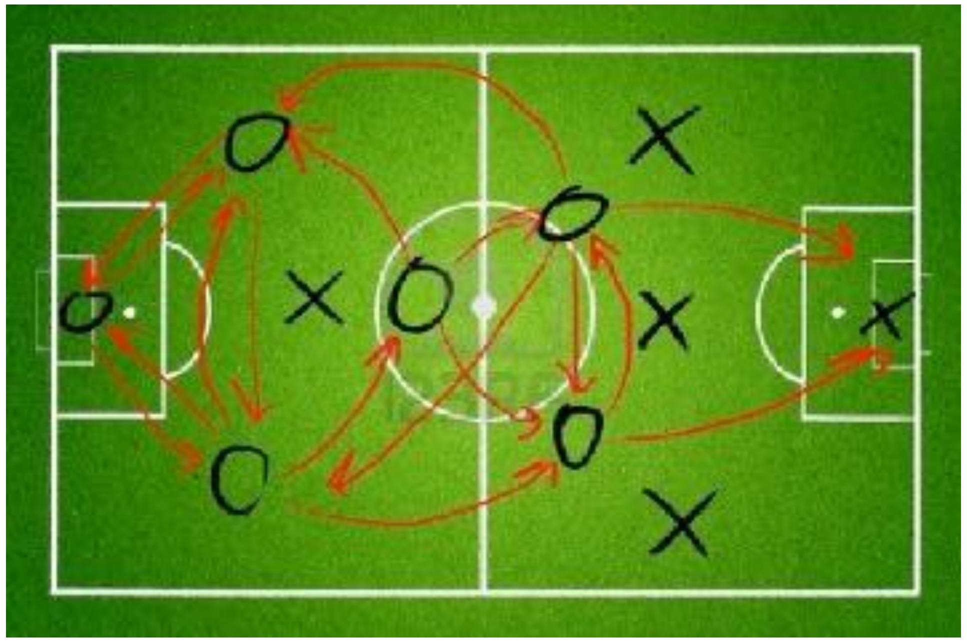
Different views are common

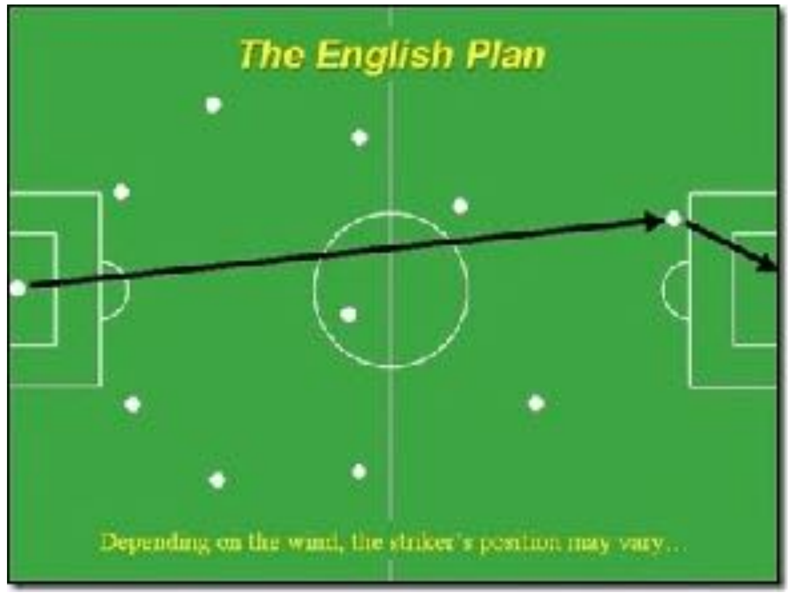


Different purposes
Different abstractions
Different models

Same purpose
Different abstractions
Different models

Everybody wants to be the Italian soccer team coach





What about the adversaries?

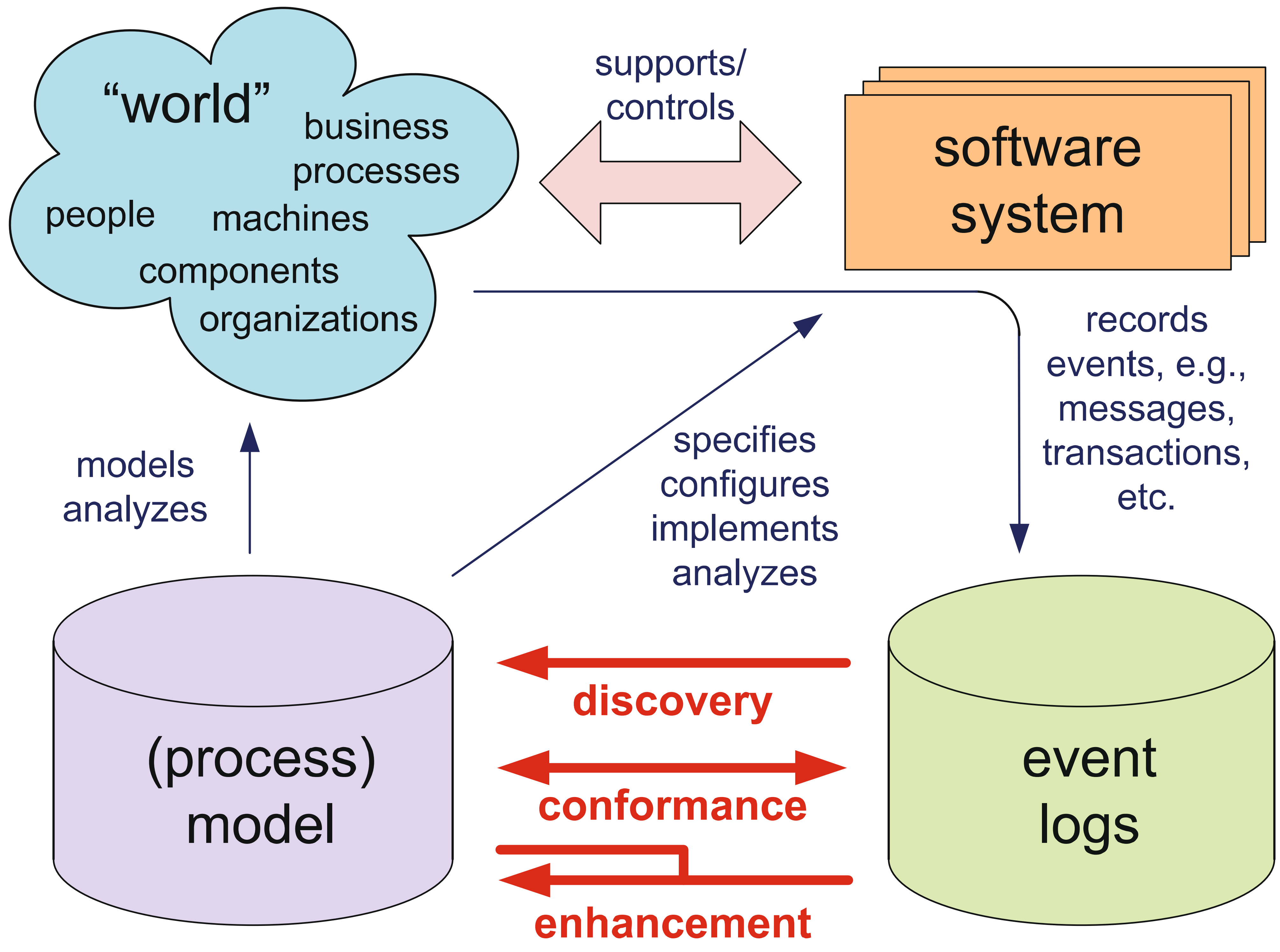
Can we find out their plan?

Knowing it would be quite helpful

Any idea how to?

(abstractions can be designed but can also be derived)

A taste of Process Mining

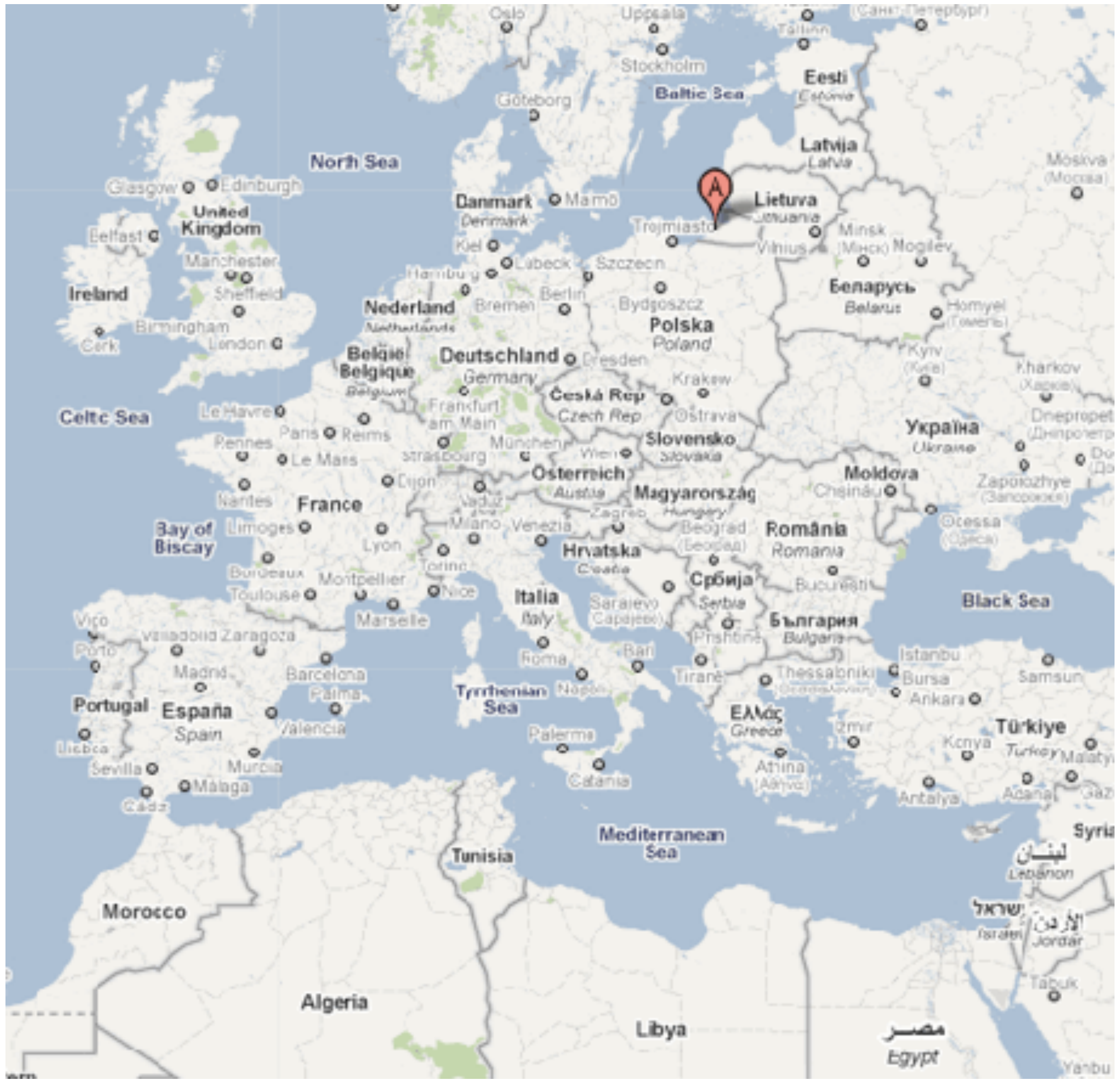


Digression...

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.

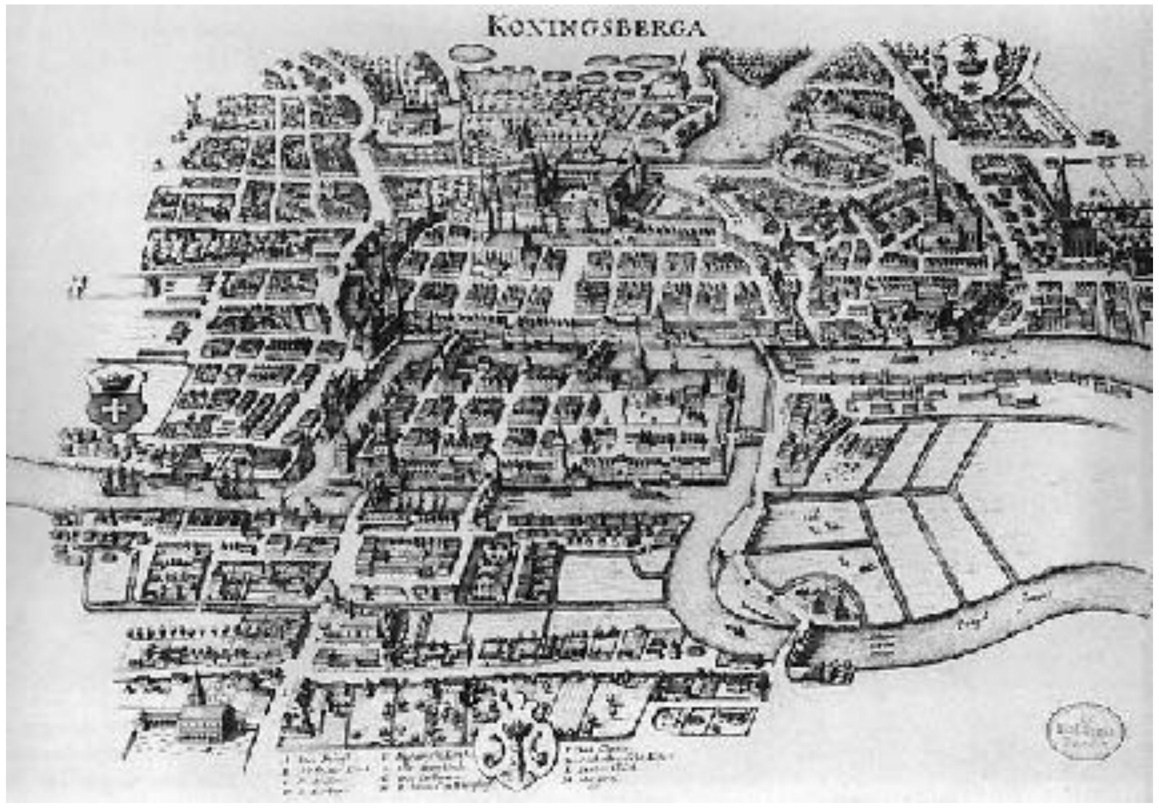
Little remains of the beautiful Prussian city of Königsberg, as it was formerly known.



Digression...

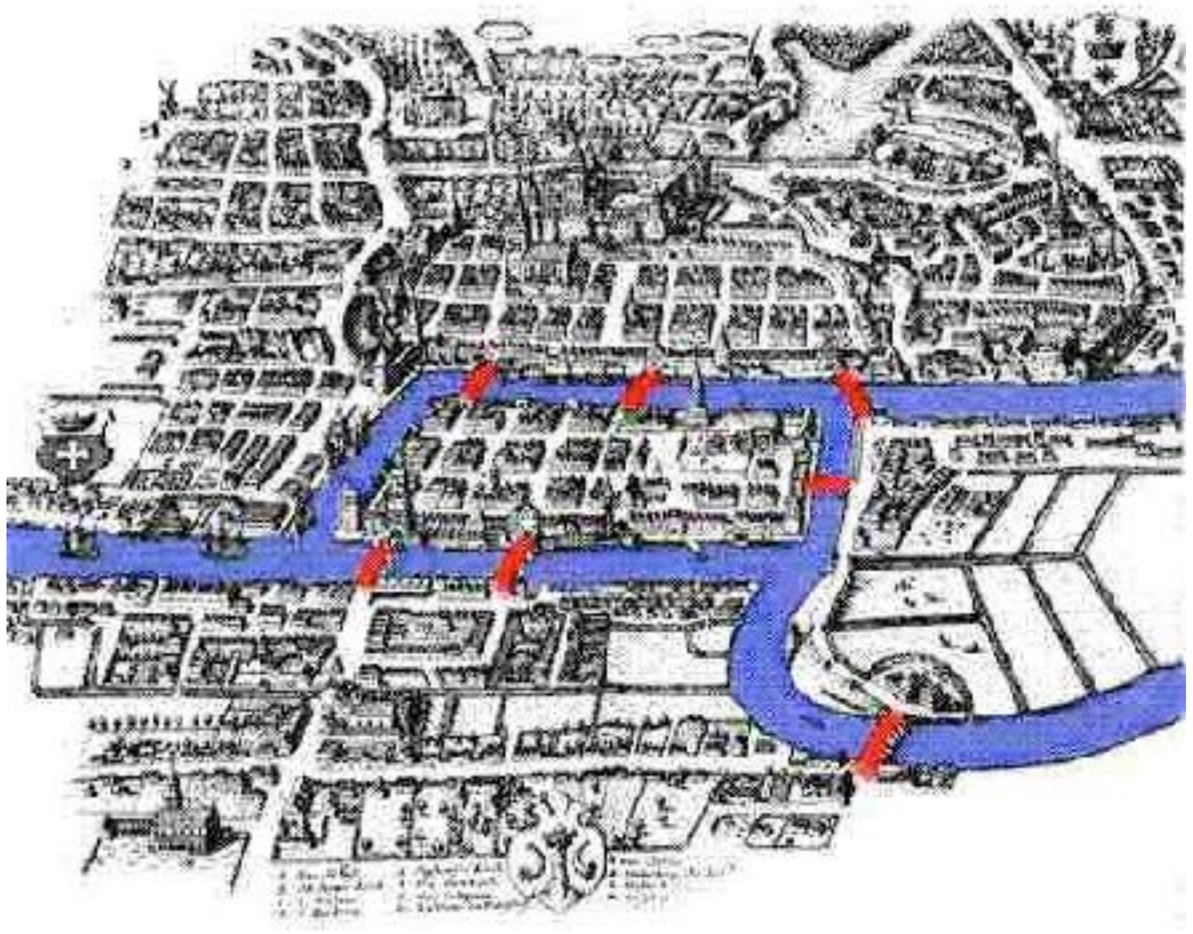
This is sad not only for lovers of architecture, but also for nostalgic mathematicians:

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).

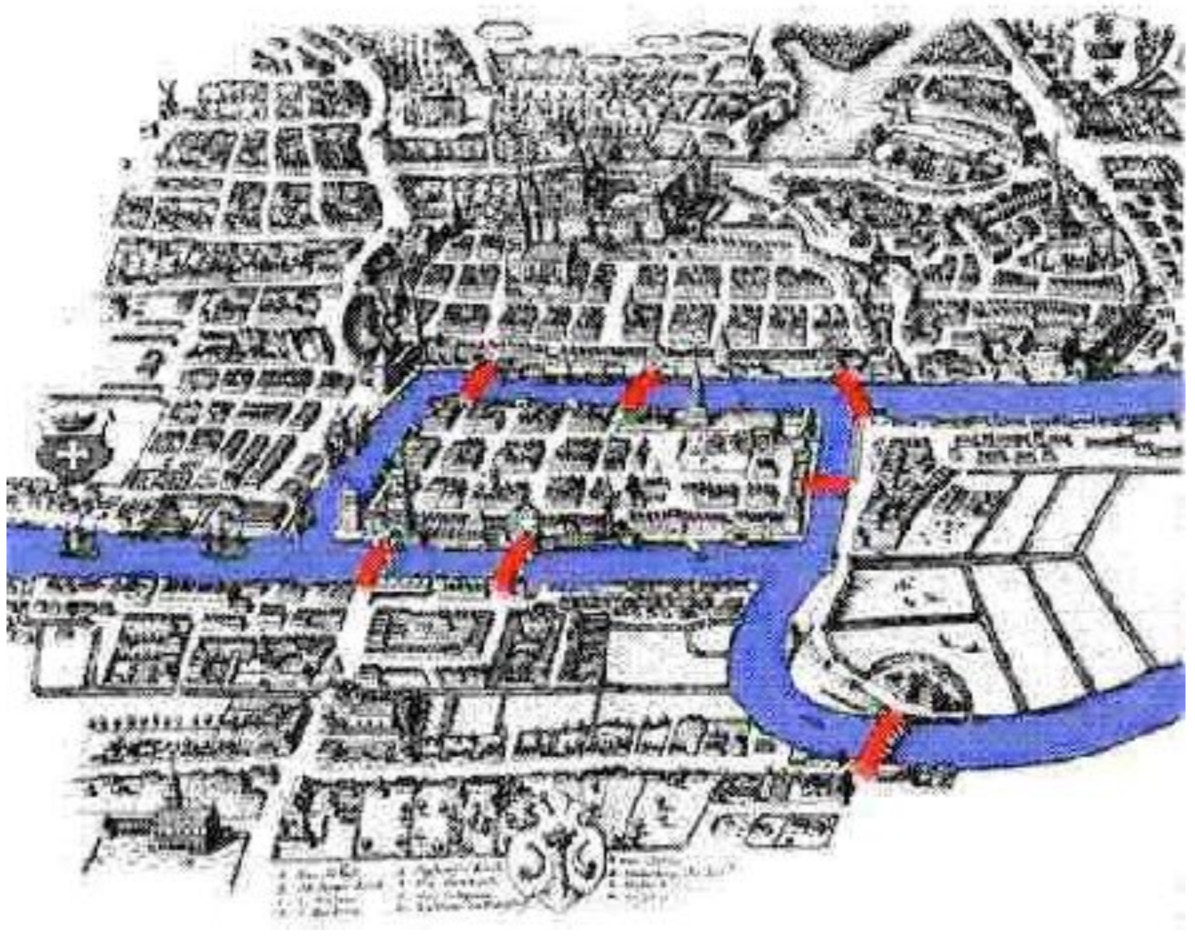


A popular pastime of the residents was to try to cross all the bridges in one complete circuit (without crossing any of the bridges more than once).

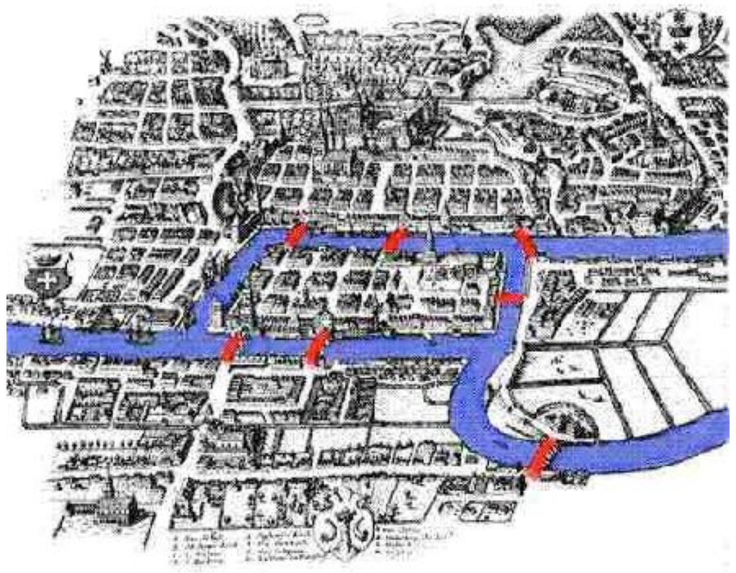
Digression...

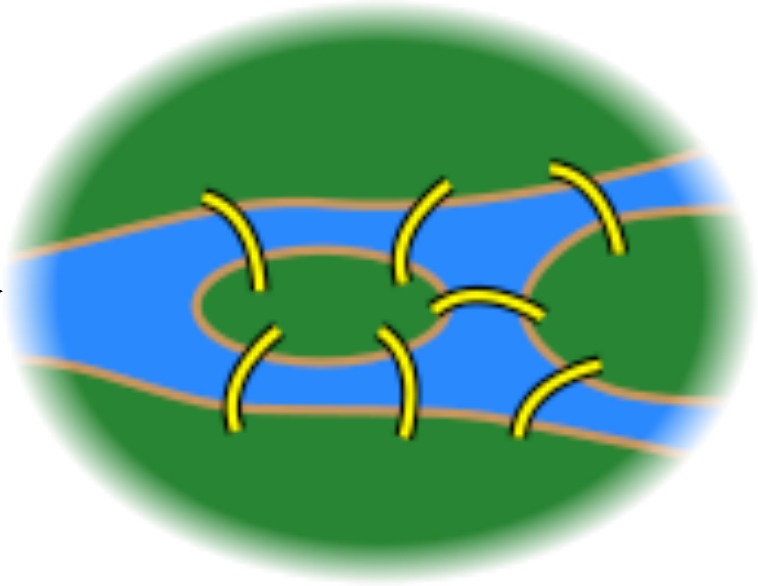
A seemingly simple task was more than tricky...

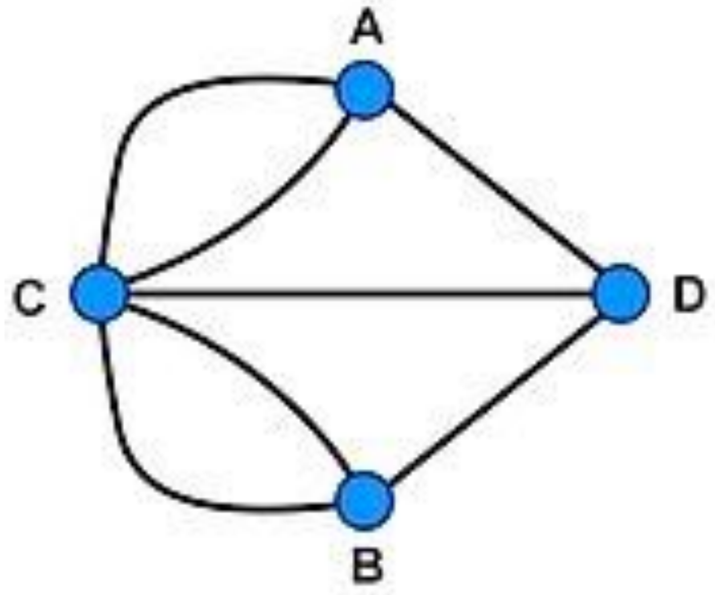
Nobody had been able to find a solution to the puzzle when Euler first heard of it and, intrigued by this, he set about **proving** that no solution was possible!



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.

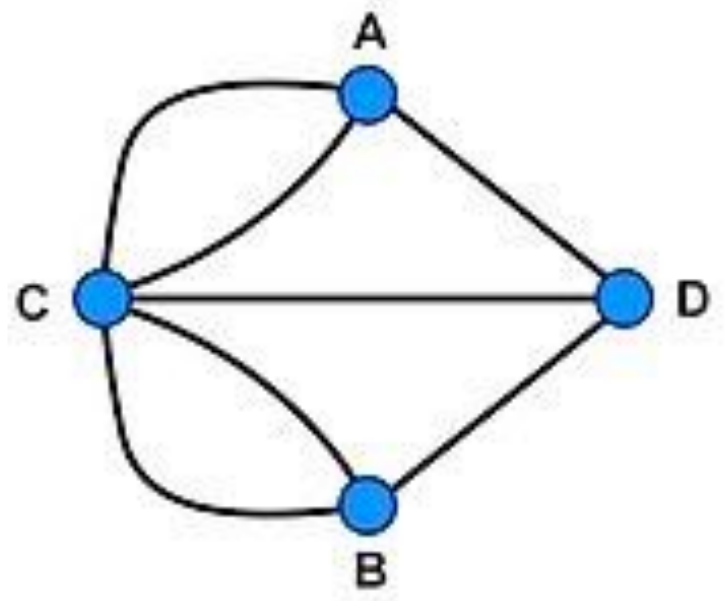
The bridges became arcs between nodes.

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

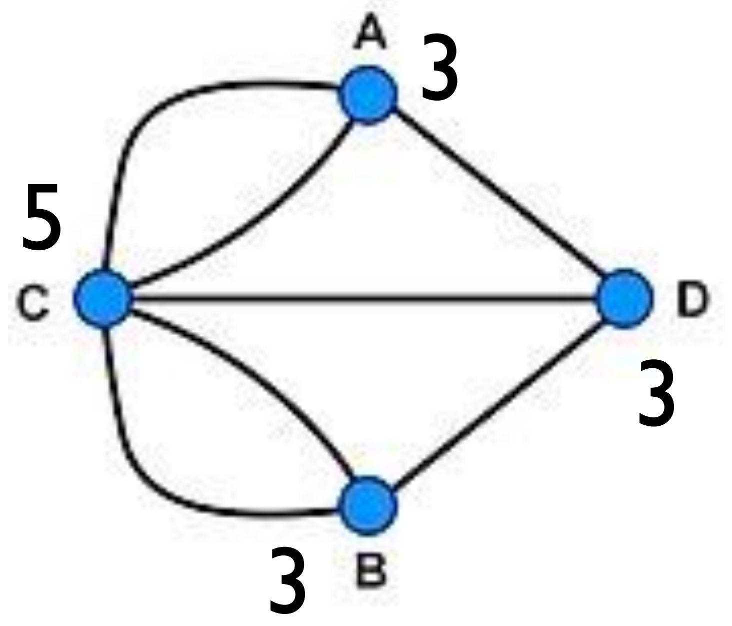
Graph problem: redrawing this picture without retracing any line and without picking your pencil up off the paper



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...

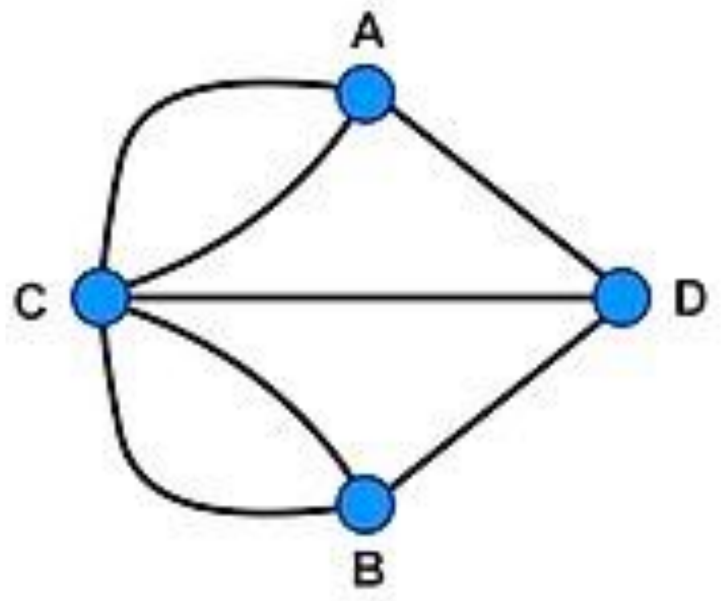
Informal reasoning:
All the vertices in the above picture have an odd number of arcs connected to them.

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!



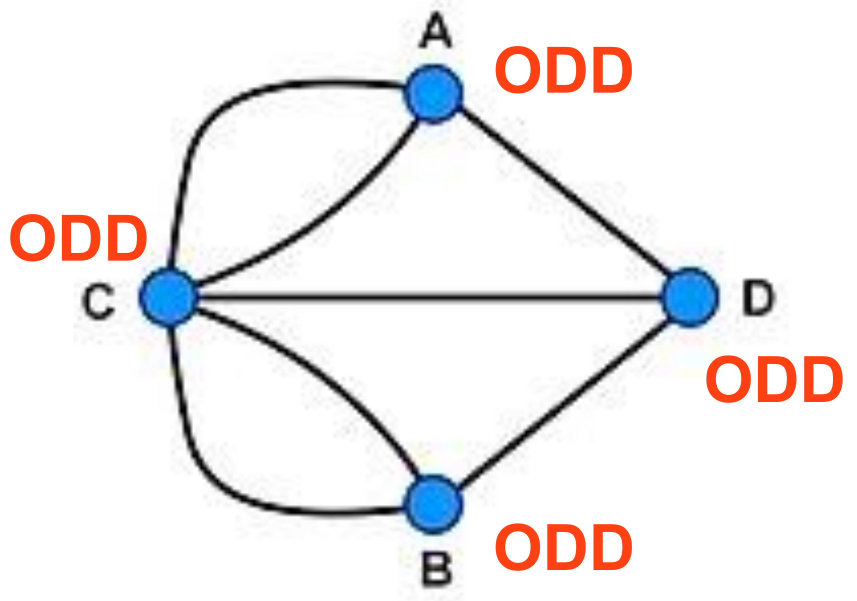
Digression...

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.

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



Digression...

Proof of necessity: (existence of Eulerian circuit implies any vertex has even degree)

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.

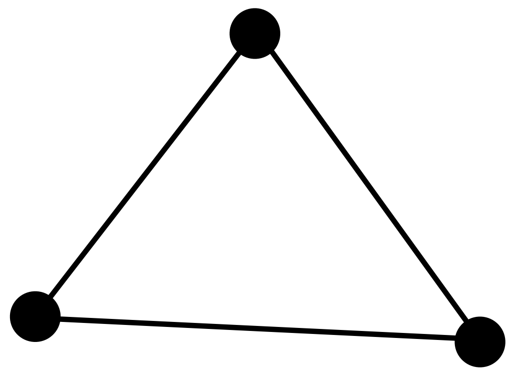
While this proof of necessity was given by Euler, the proof of converse is not stated in his paper.

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.



Digression...

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

<u>Inductive case</u>:
Inductive hypothesis: 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.
We want to prove G has an Eulerian circuit

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

...

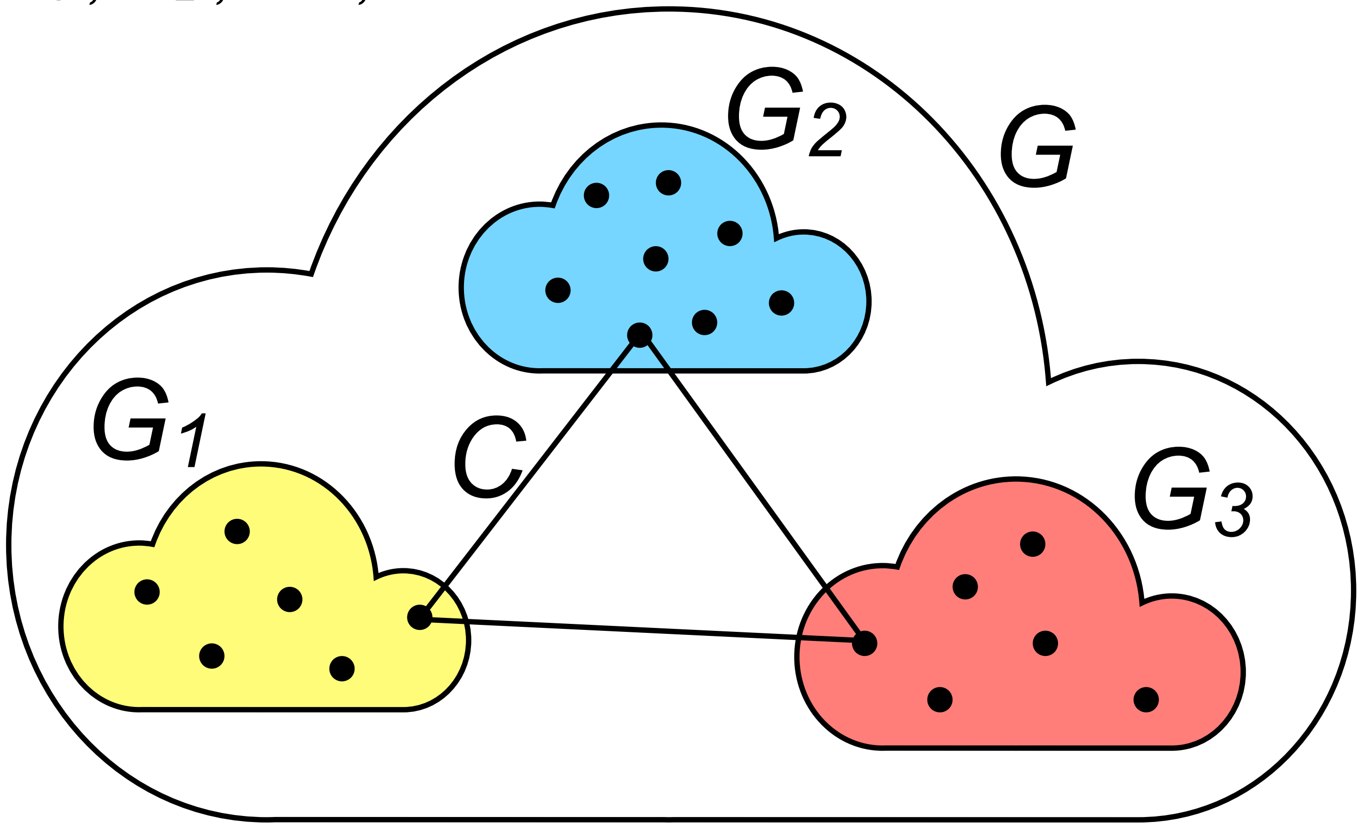
Digression...

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.



...

Digression...

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

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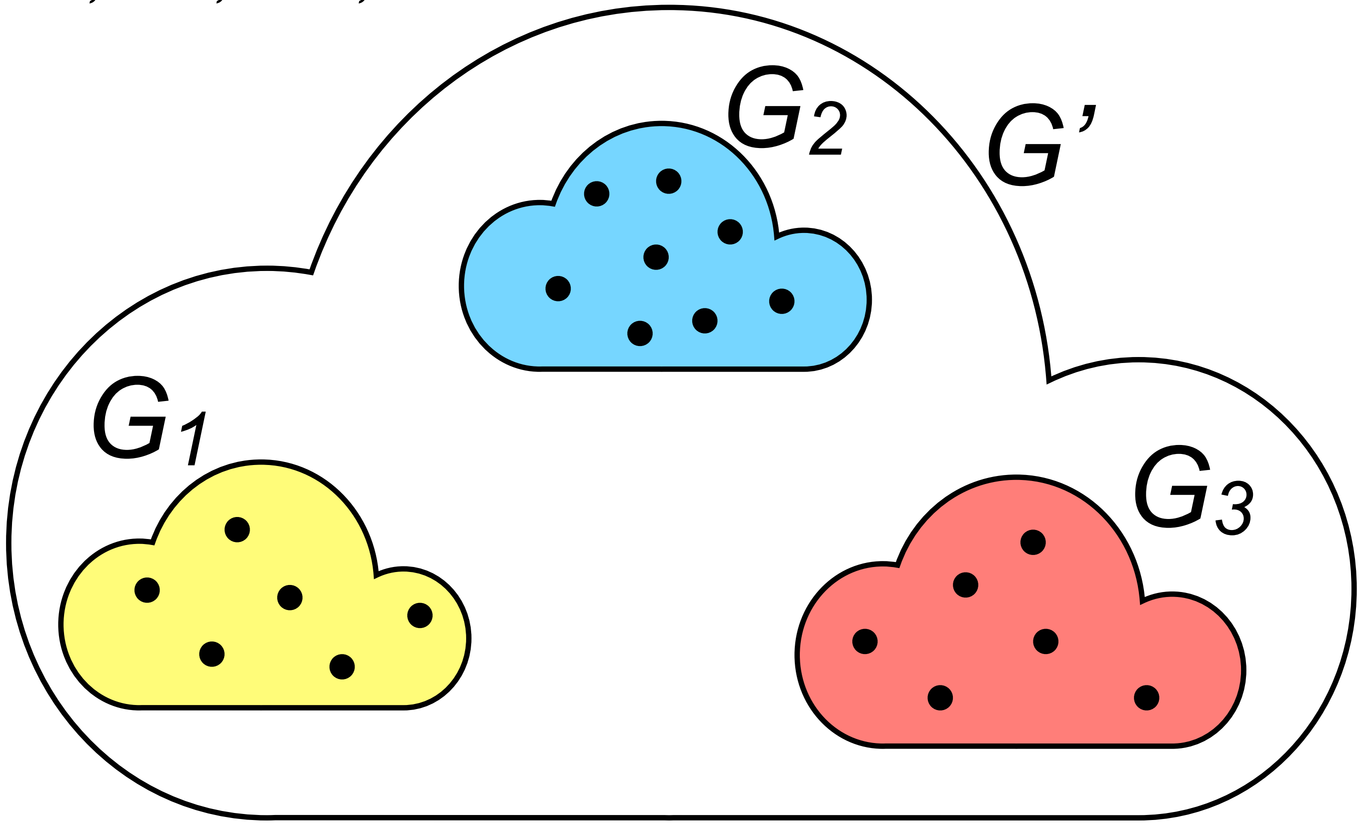


...

Digression...

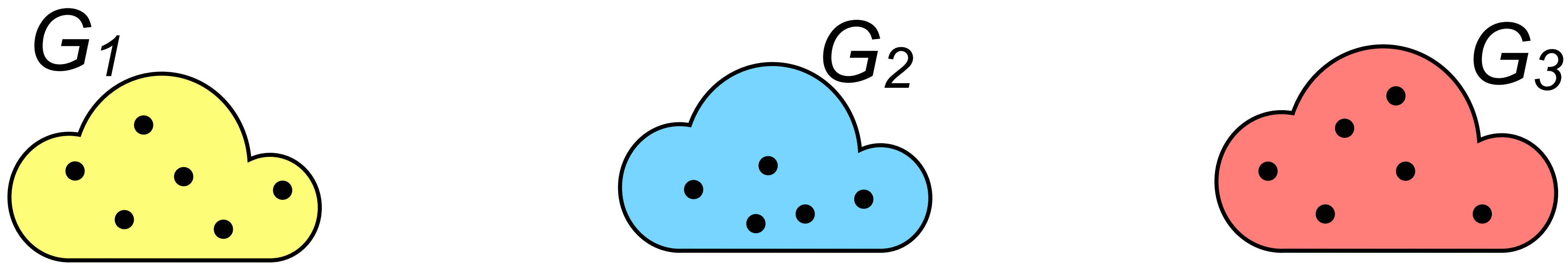
Proof of sufficiency: (by induction on the numbers of arcs, continued)

...

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 C_1 , C_2 , 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 v_i that belongs to one of the connected components G_i.

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

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

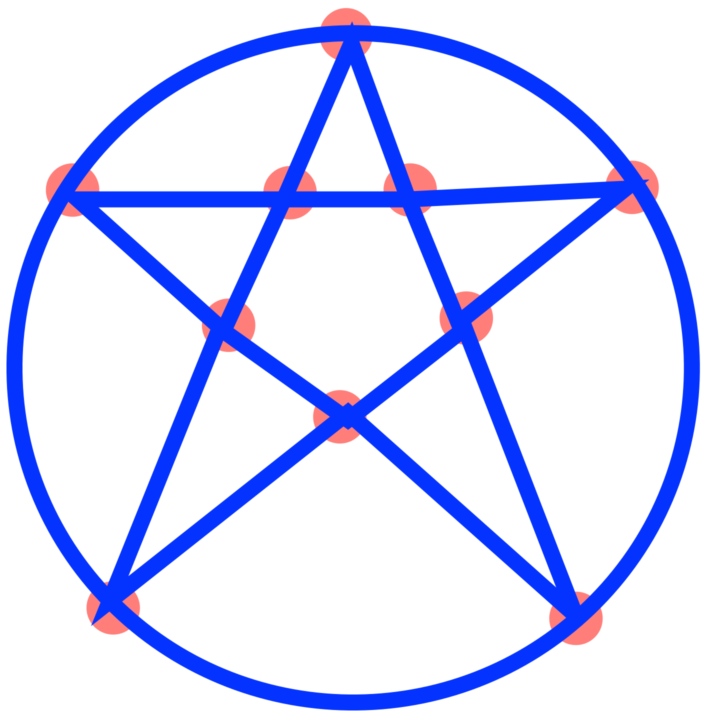
In the end, we shall return back to the first starting vertex v, after visiting every edge exactly once.

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.



Digression...

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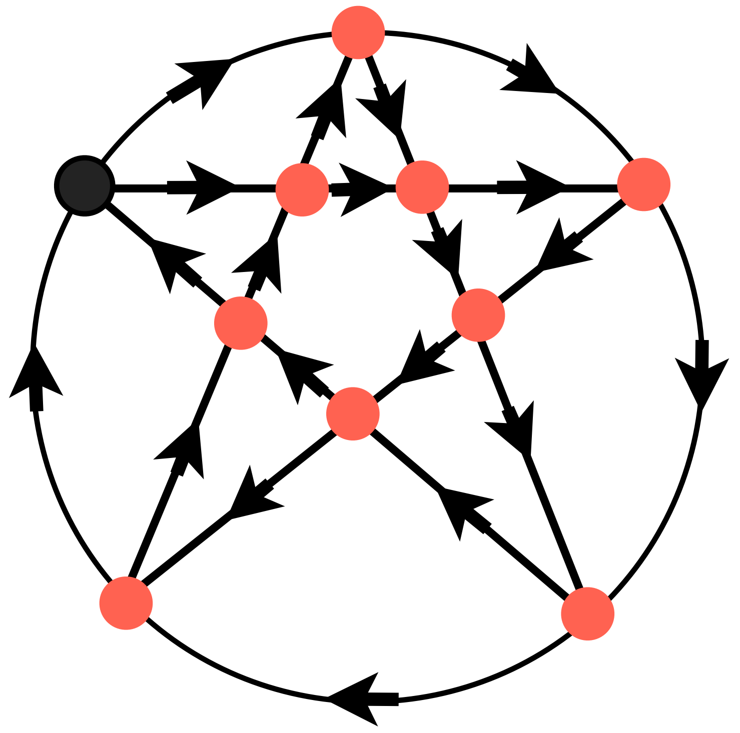


Digression...

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

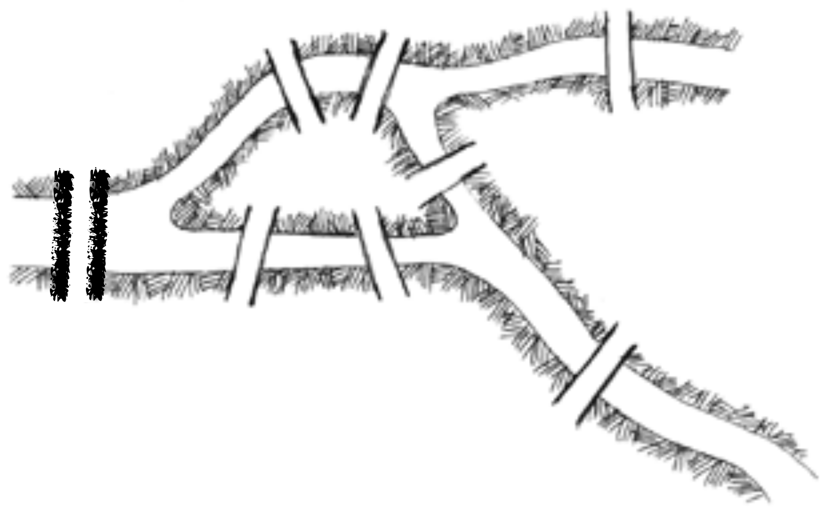
Proof.
Suppose a graph G contains an Eulerian path P.
Then, for every vertex v, P must enter and leave v the same number of times, except when it is either the starting vertex or the final vertex of P.
When the starting and final vertices are distinct, there are precisely 2 odd degree vertices.
When 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...

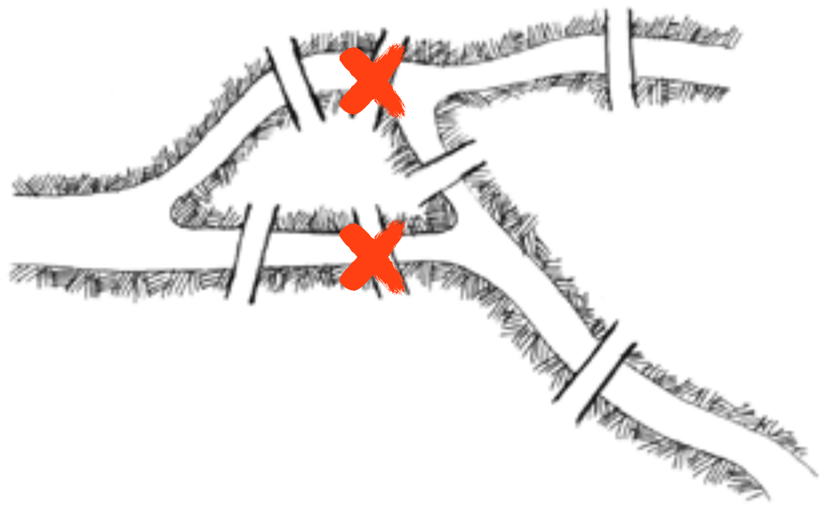
In the late 19th century an eighth bridge was built (see map).
As a result Königsberg had been Eulerised!

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

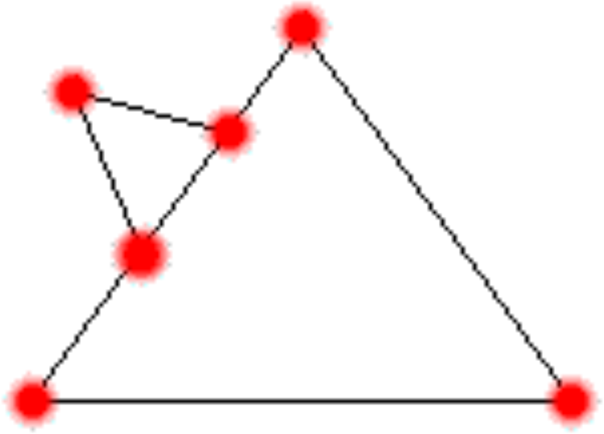


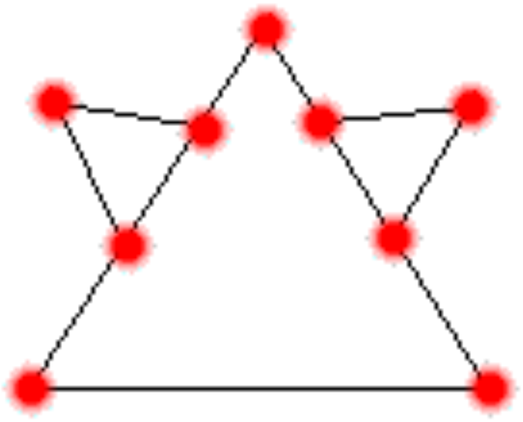
Sadly, in 1944 air raids obliterated most of the bridges. However, from the maps made available since, it appears that five bridges crossing were rebuilt in such a way that Kaliningrad was Eulerised once again!

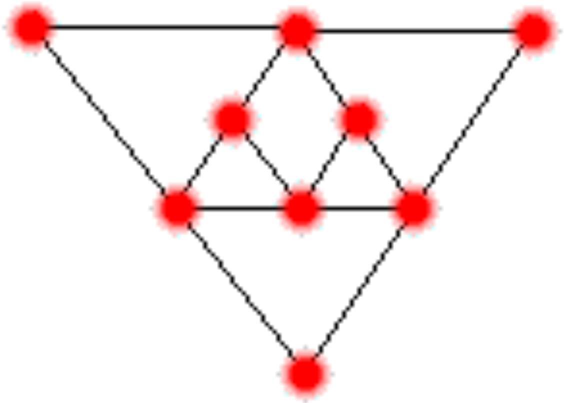
Exercise: prove that an Eulerian path can be found (but not a circuit)

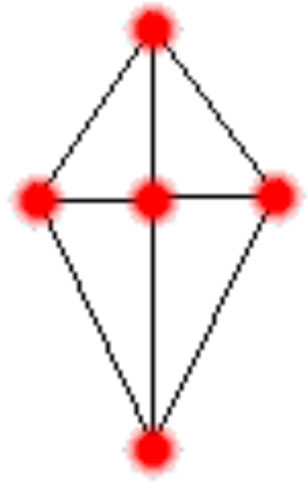


Digression...









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

Yet to learn

- Formal models used in prescriptive manner
- Correctness by design
- Separation of concerns
- Model discovery

Examples of bad design choices