YYT-C3002 lecture 11: Interoperability of software, systems, systems of systems, and tools

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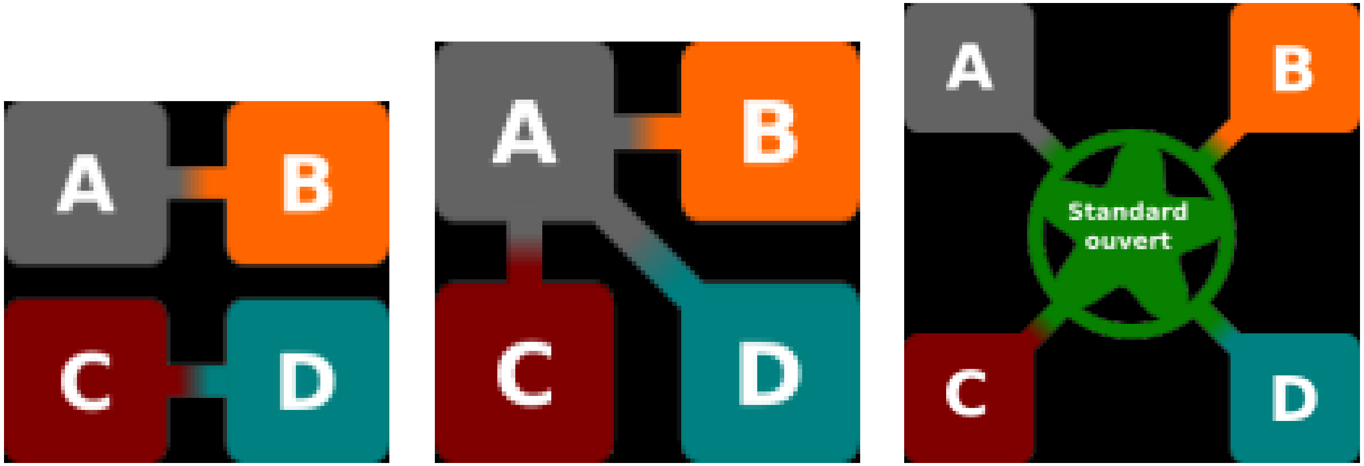
Contents of this lecture

- Interoperability and its importance
  - Systems, domains
  - Basics, sequential and parallel access
  - Interoperability between different software domains
- Interoperability and standards
  - How standards can support or hinder interoperability
  - Standards example: ISO 11783
- Interoperability example: CAD and GIS

Interoperability and its importance

Interoperability

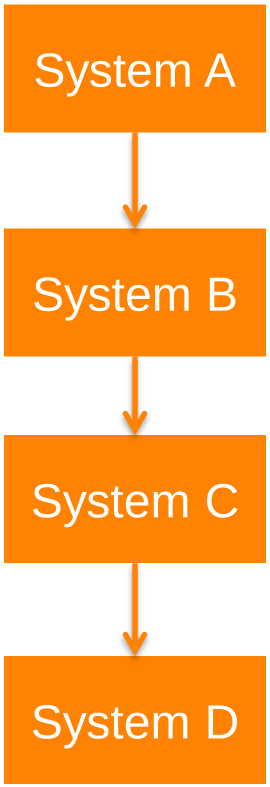
- Interoperability is a property of a product or system, whose **interfaces are completely understood**, to **work with other products or systems**, present or future, **without any restricted access or implementation**.



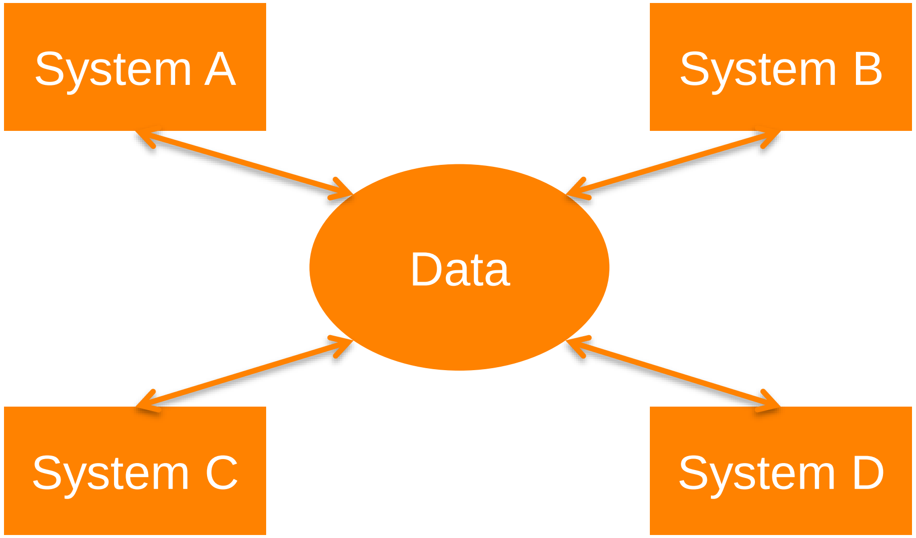
Source: http://interoperability-definition.info

Typical Interaction Scenarios Between Software Systems

Sequential access



Parallel (interleaved) access



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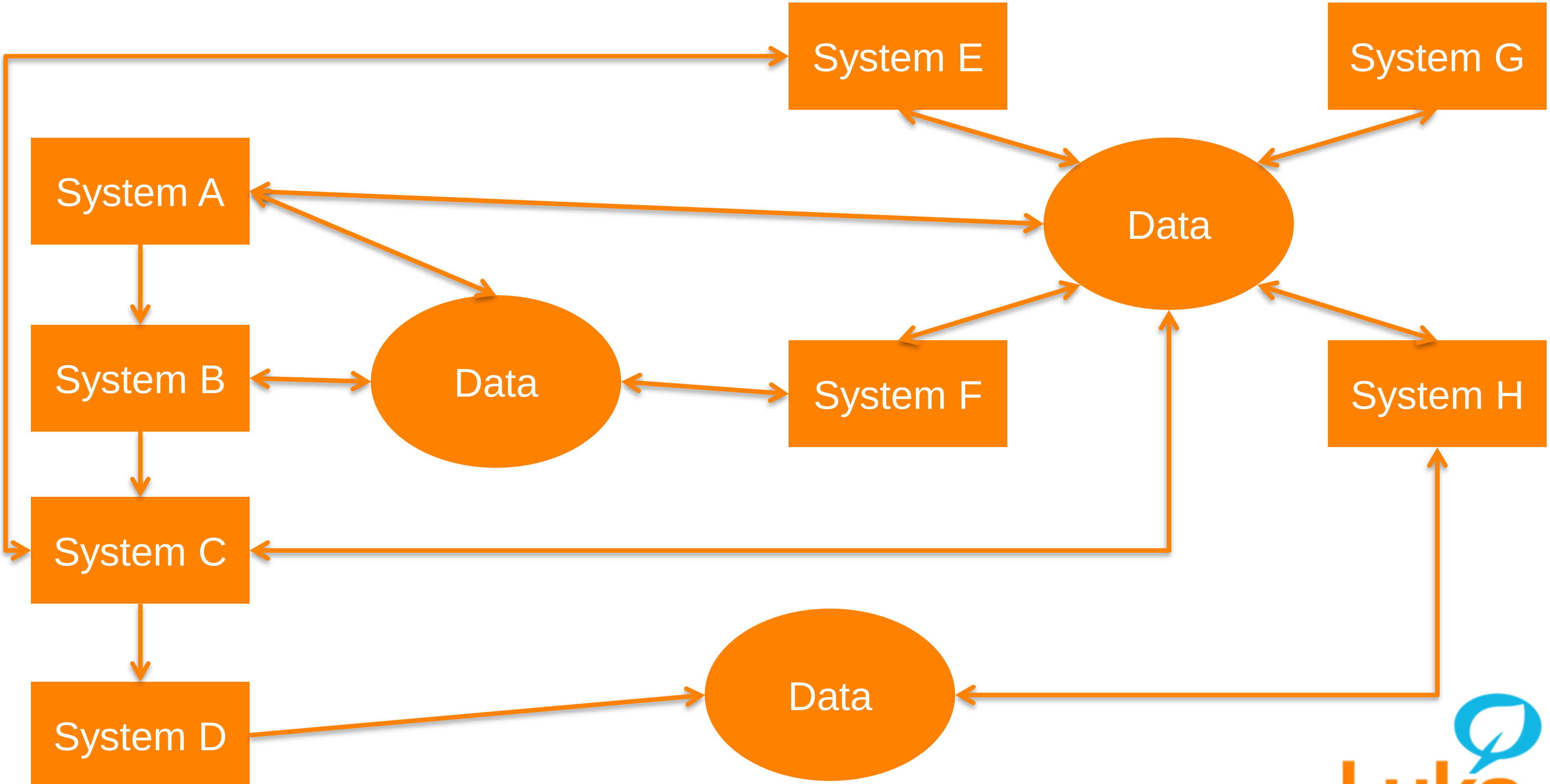
Typical Interaction Scenarios Between Software Systems



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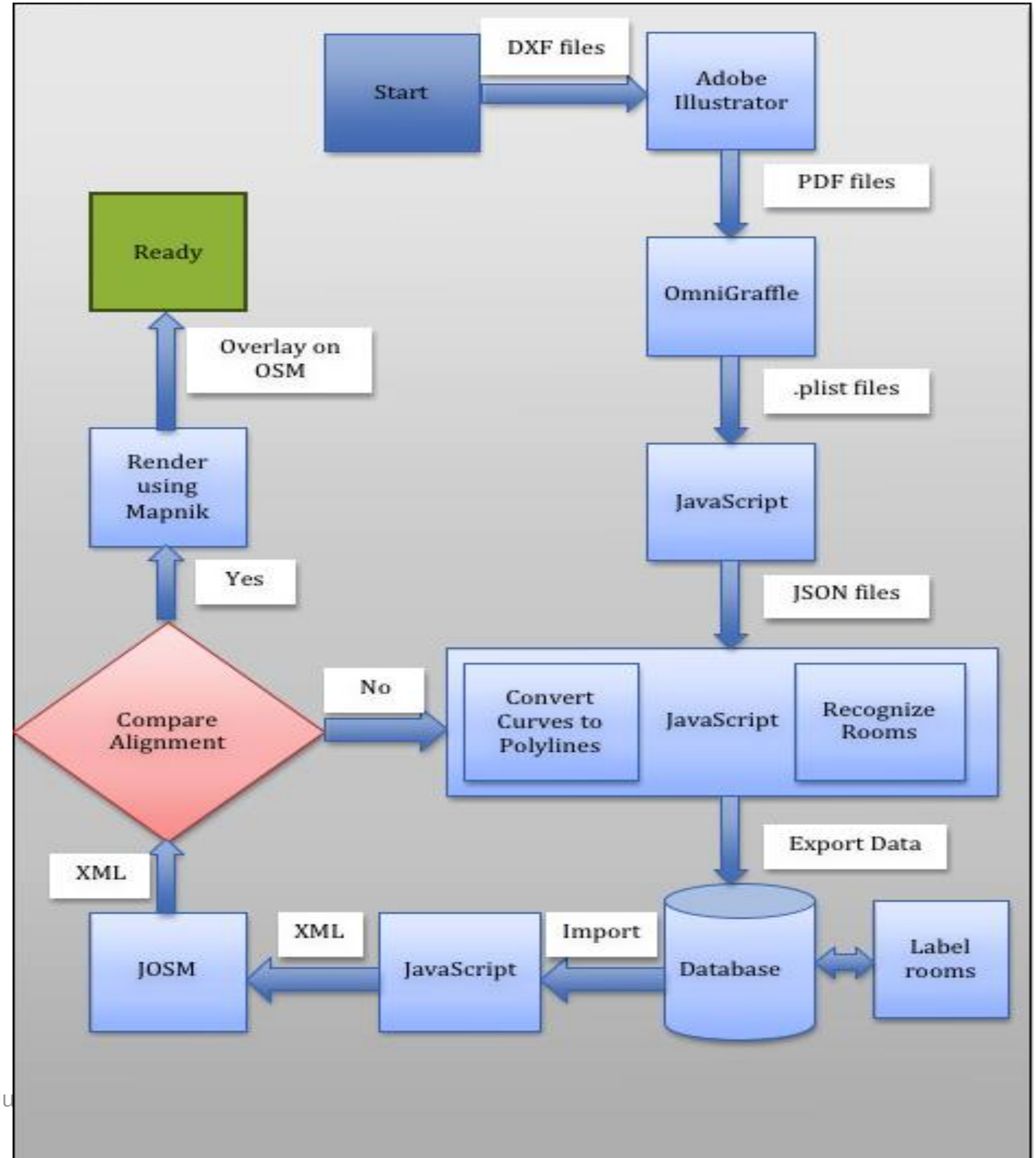
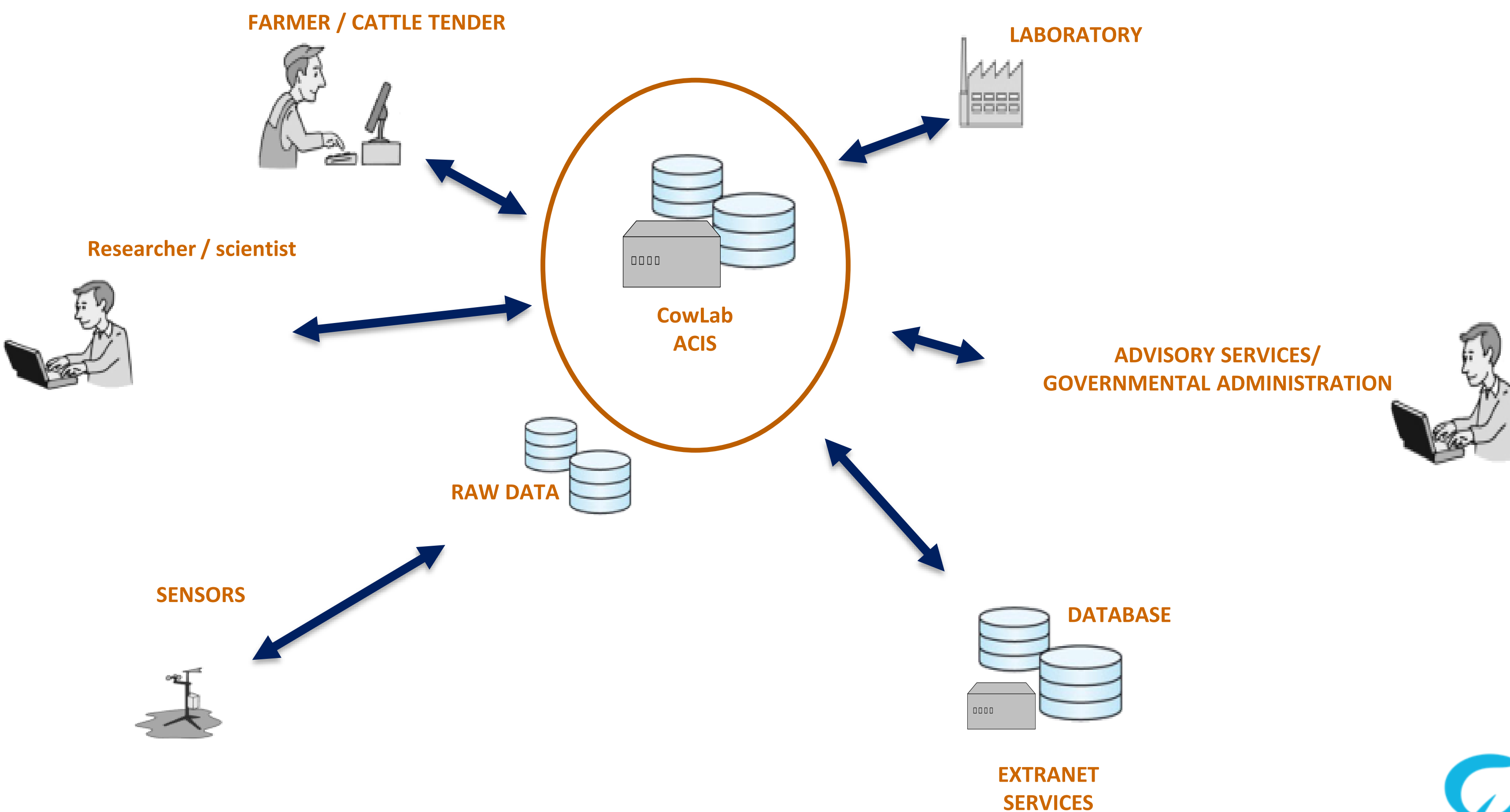
Sequential interaction example



Parallel interaction example



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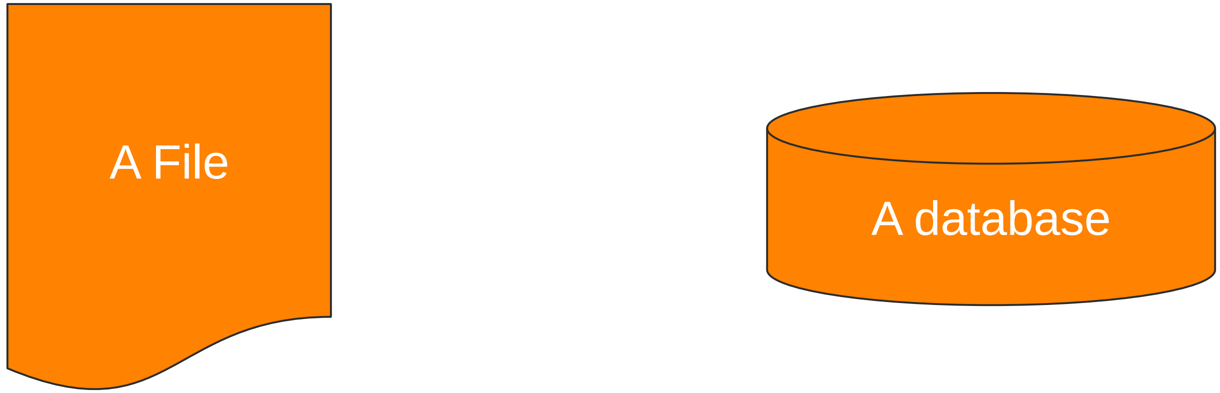
Data storage: file versus database

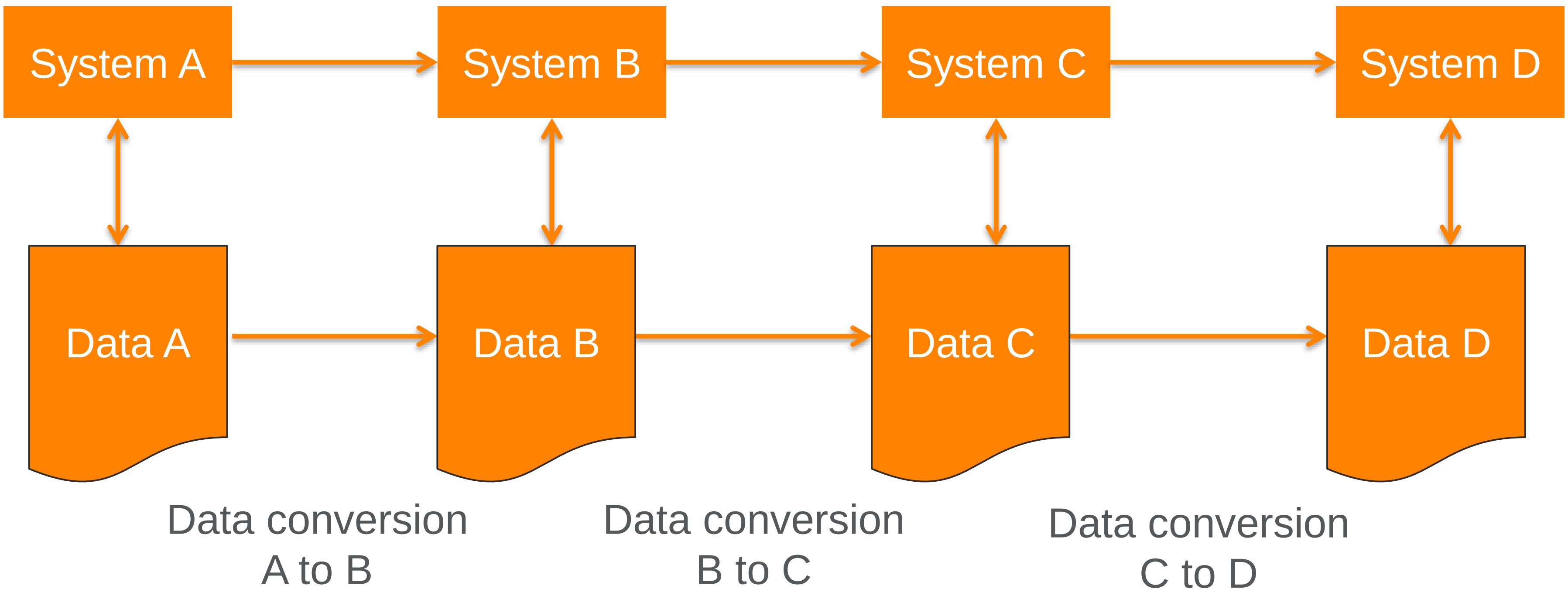
- Files reside on a storage media and can be directly accessed by programs
- Parallel access to files can managed by locks
  - Only the program that holds the lock can access the file
- Databases are more sophisticated data management solutions
- Parallel access is managed on data item level
  - All modifications follow ACID principles
- **A**tomicity: a modification is done completely, or not at all
- **C**onsistency: database is in a valid state after modification
- **I**solation: only one modification at a time
- **D**urability: faults do not cause loss of data

Data storage: file versus database

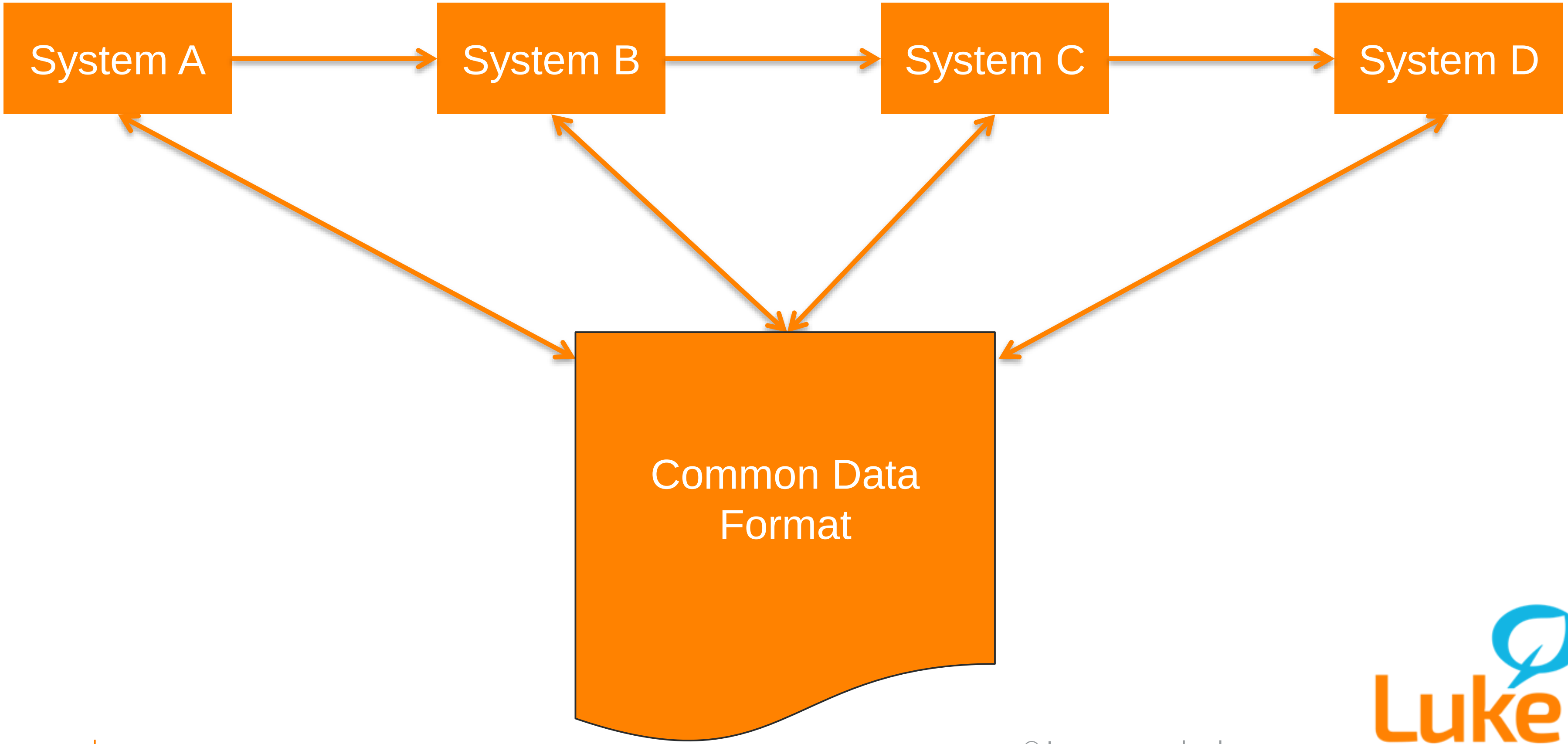


I will use these symbols to describe files and databases.
The symbols originate from flowcharts

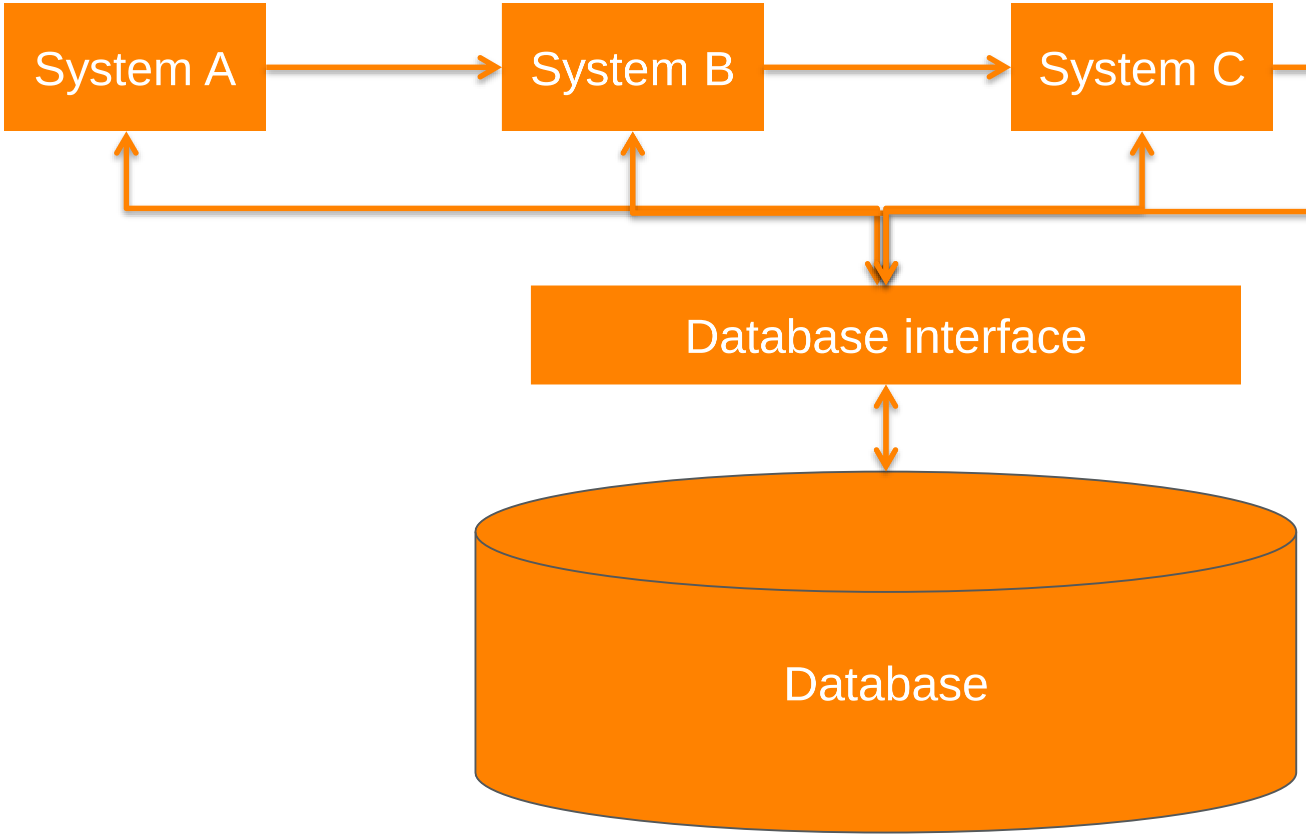
Interoperability in practice



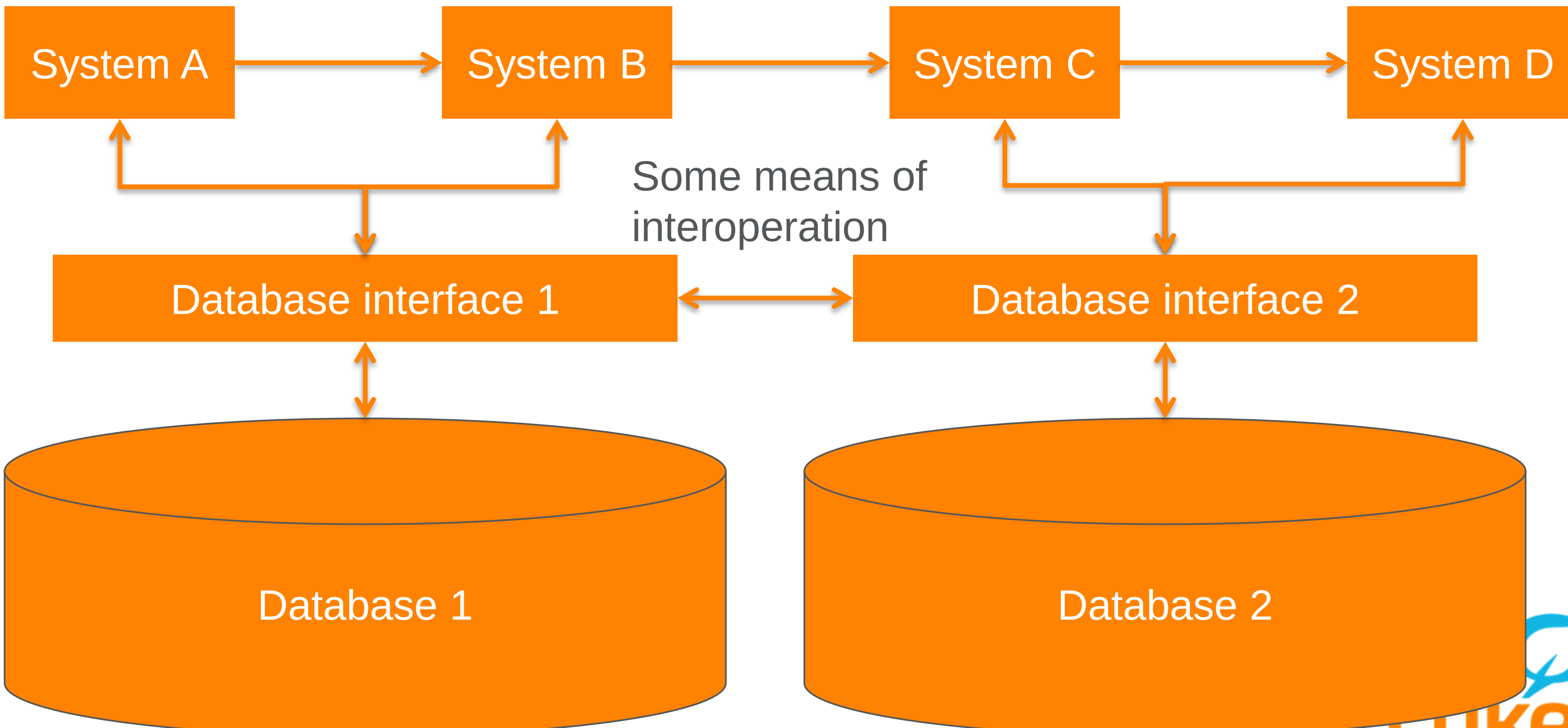
Interoperability in practice



Interoperability in practice



Interoperability in practice



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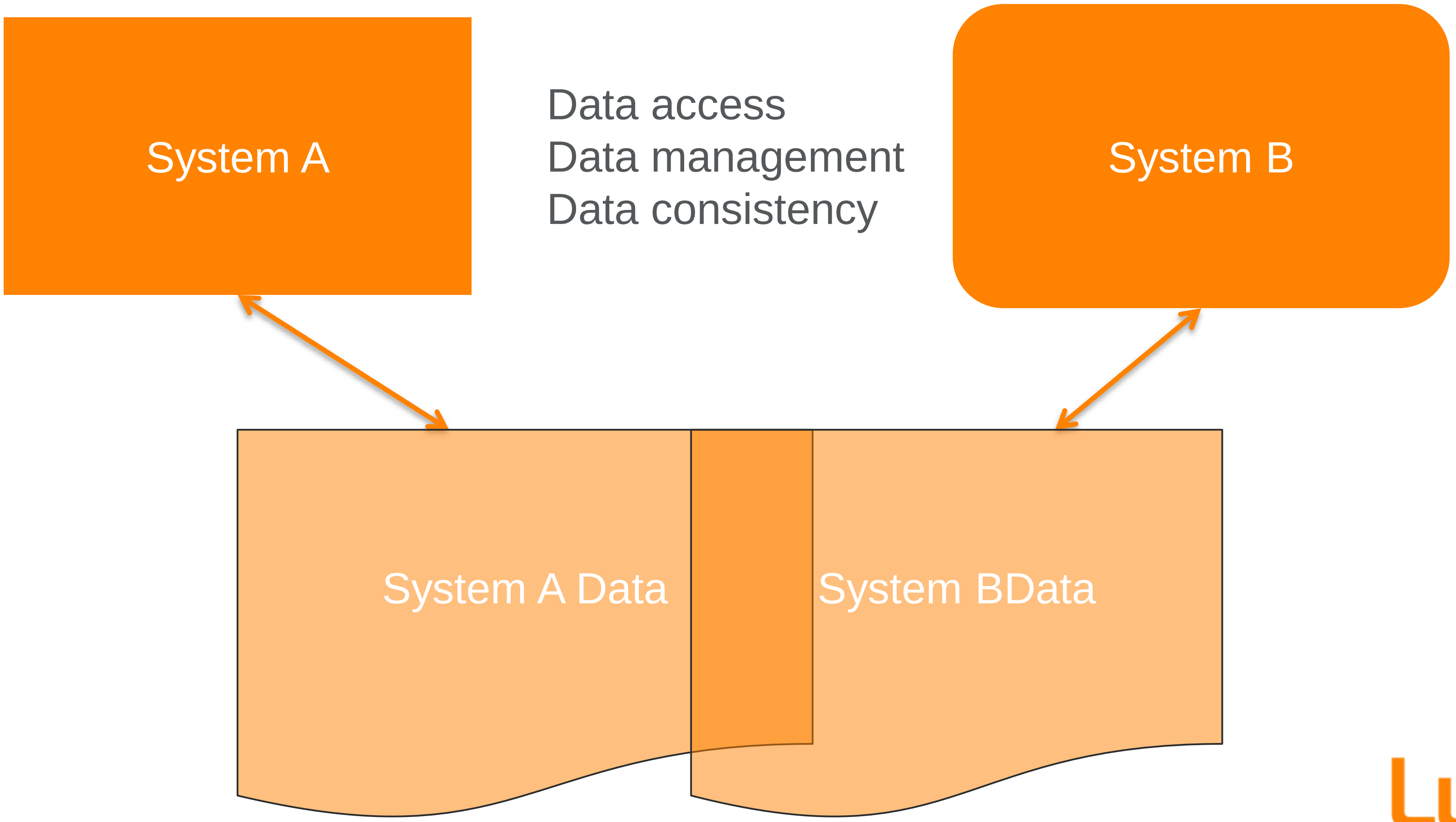
Notes on sequential interaction

- Depending on the case, having a common database may not be the ideal solution
  - System B works on the results of analysis done by System A. What happens if we have to revert to System A?
  - What if Systems A and B handle different types of data?
  - Database may require some sort of version control beyond standard DB ACID functionality
- If systems use separate data formats, data conversion can be a bottleneck
  - You may need to be able to implement your own conversion scripts
  - Standard data formats simplify the data management – conversion functionality more likely to exist

Interoperability in Practice



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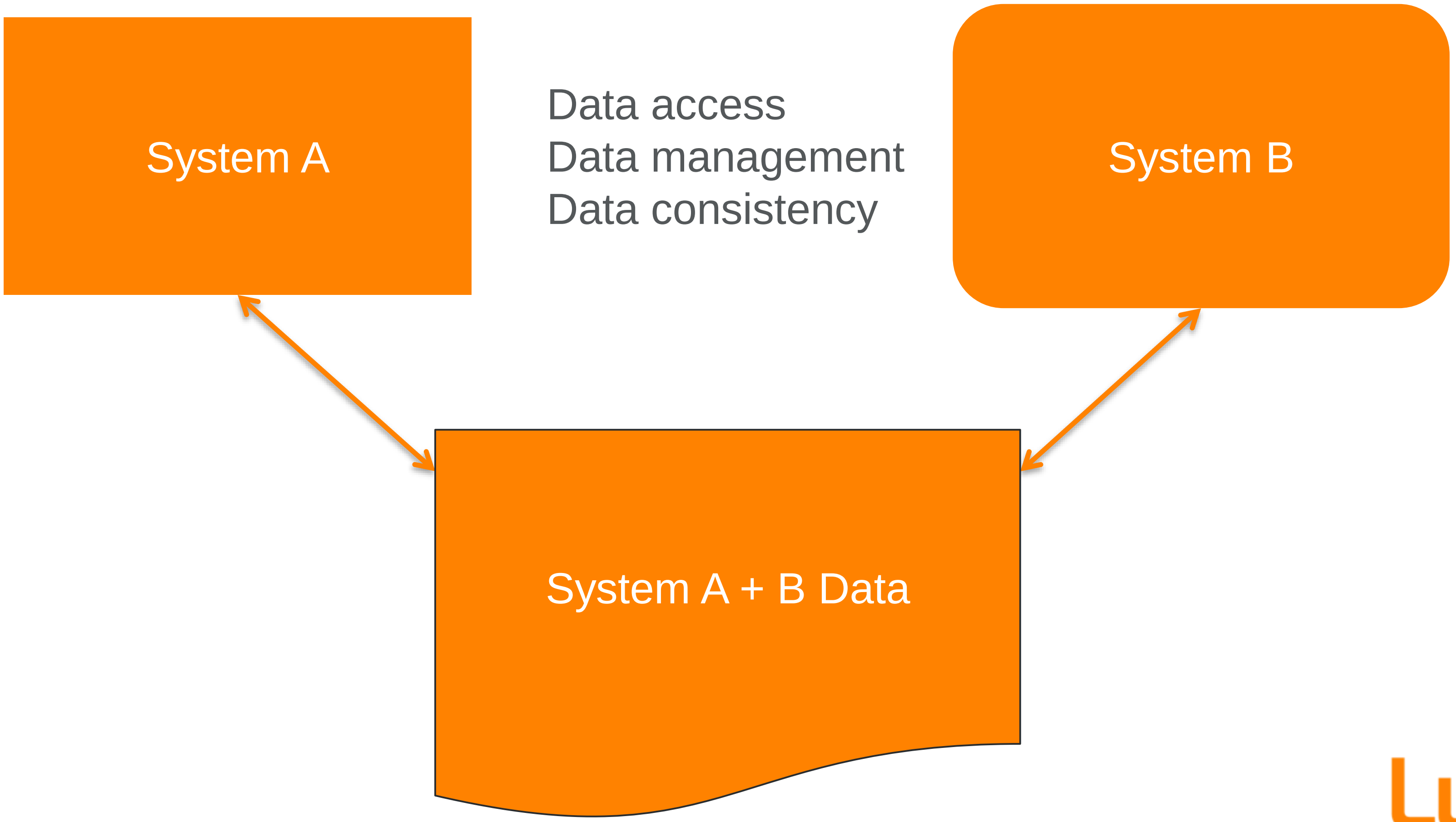
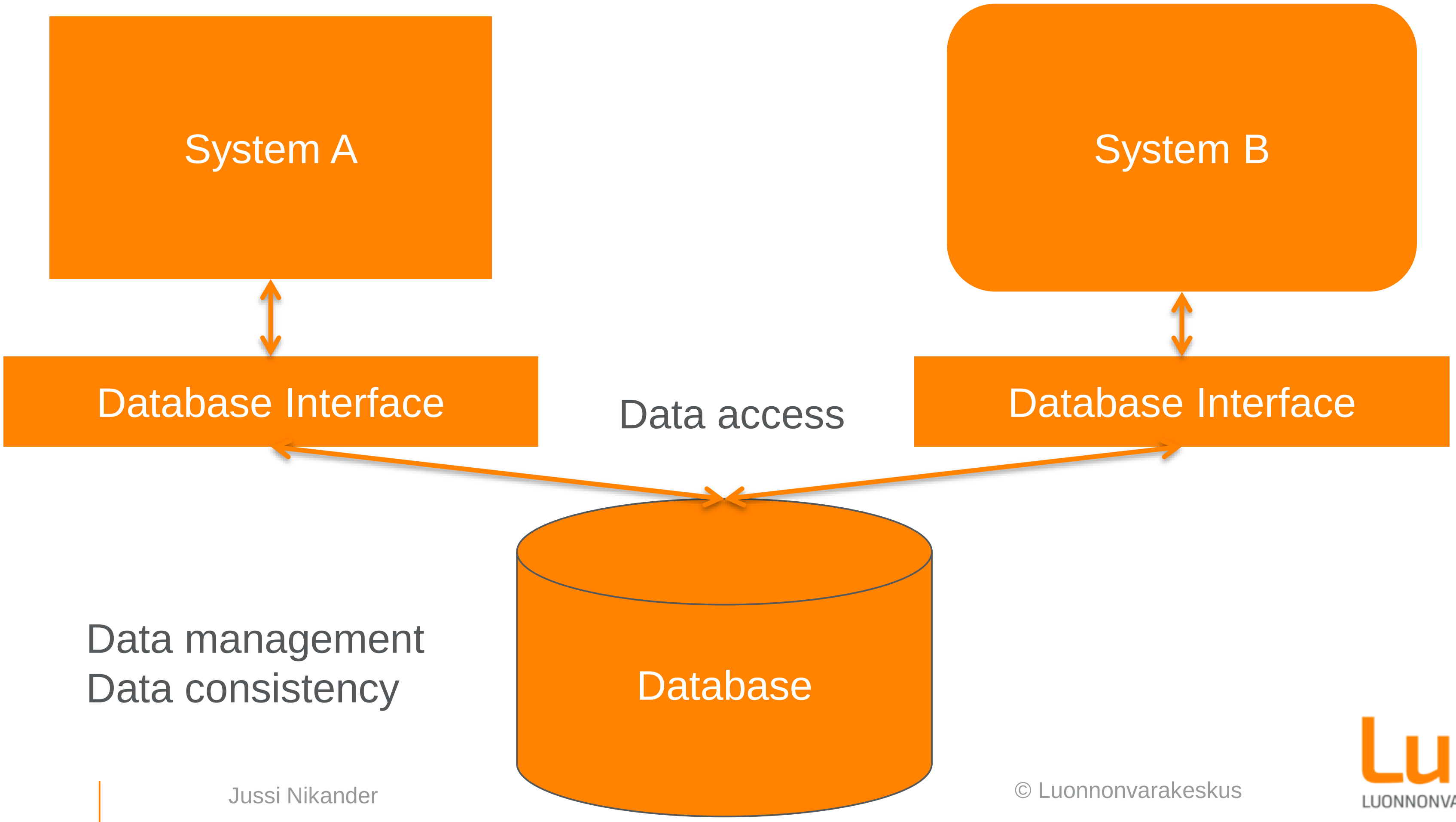
Interoperability in Practice

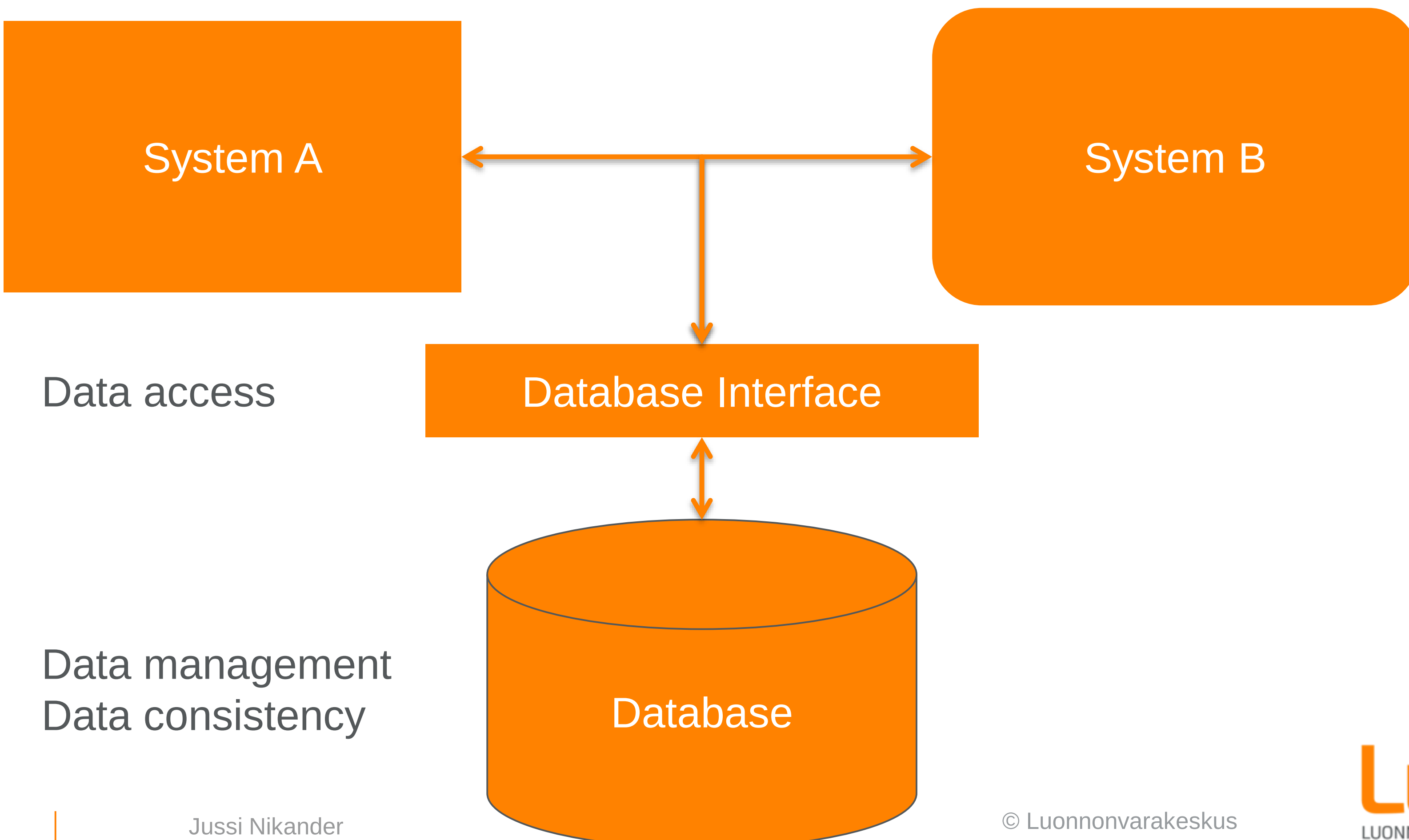


Interoperability in Practice



Data management
Data consistency

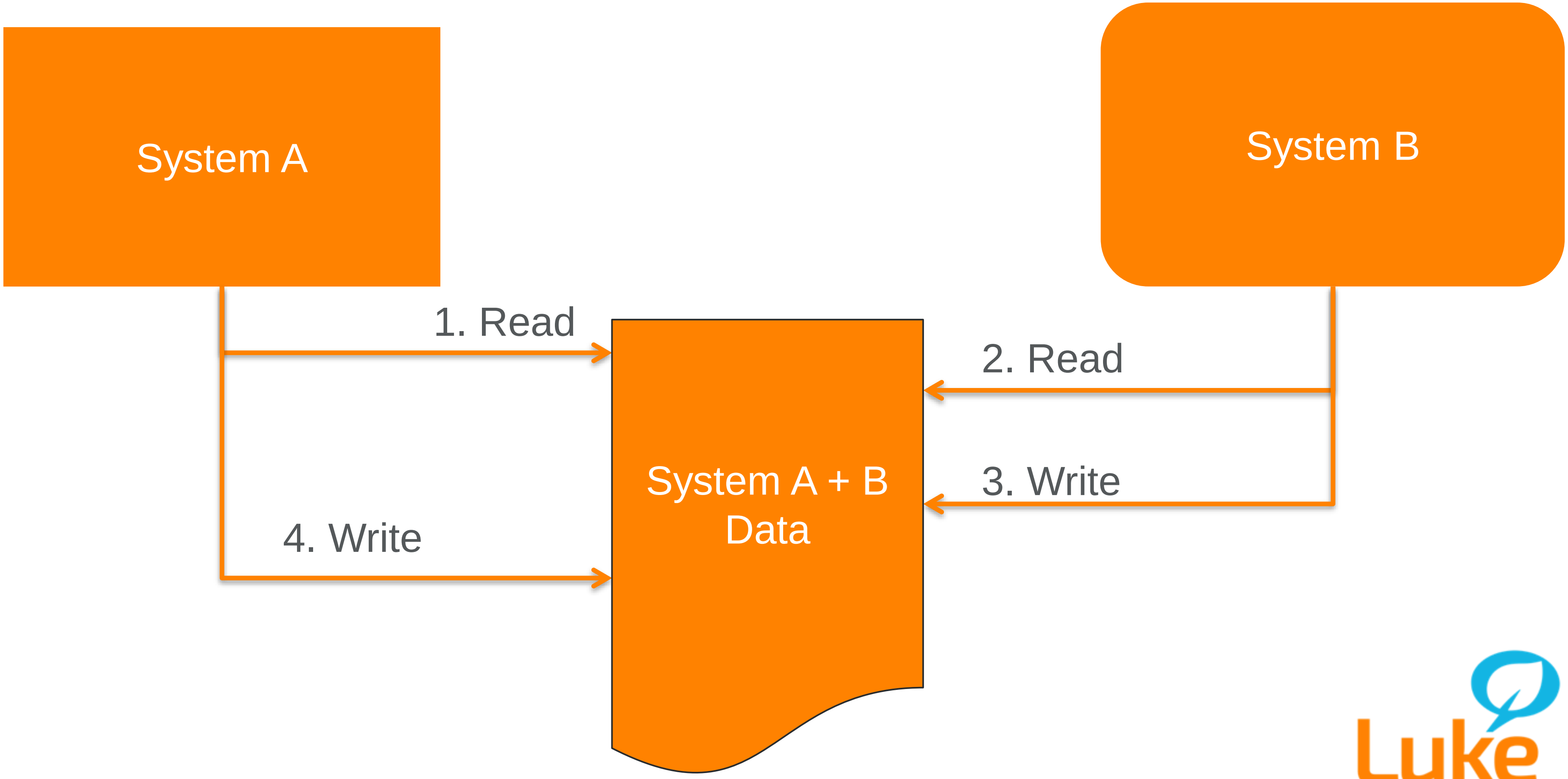
Interoperability in Practice



Notes on parallel interaction

- If several systems are accessing the same data in parallel, make certain that the systems don't interfere with each other
  - Accessing the same data is OK
  - Data modifications may cause problems
- Parallel access with modifications requires a database
  - As files do not have ACID functionality, modifications can make data inconsistent
- Database access also makes software development easier – each system does not need to develop file access functionality
- Standards further make development easier – different databases are likely to be able to work together

Data Inconsistency Example: parallel access to same data



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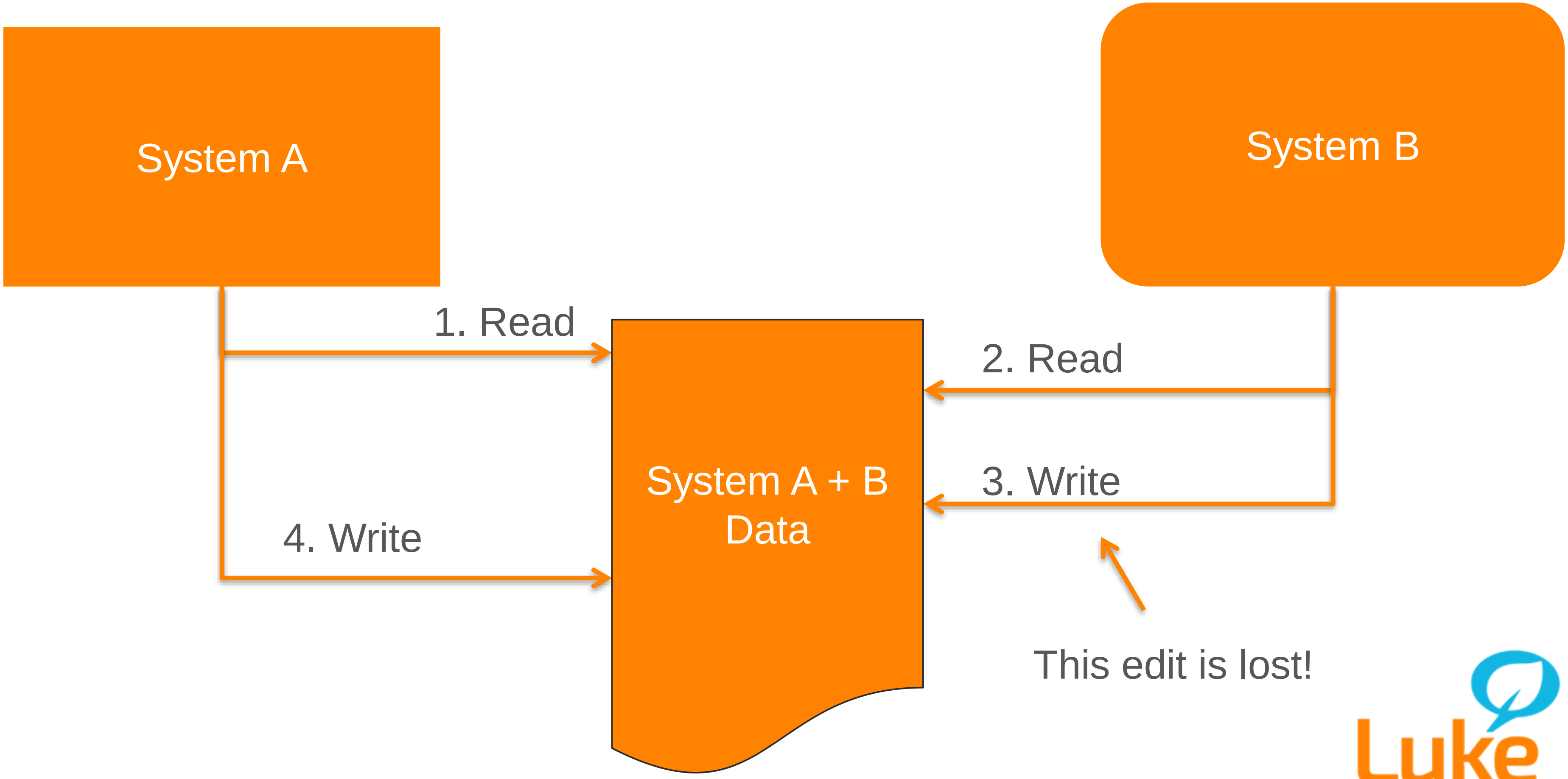
Data Inconsistency Example: parallel access to same data



Interoperability between Systems in Different Domains

- CAD, BIM, FEM, GIS, etc. are all in different domains
  - Different main goals, different vocabulary, different tools and techniques
- This makes interoperability more complex than between software in the same domain
  - ArcGIS and MapInfo both are GIS software: they use mostly the same vocabulary and have similar tools
    - Both support raster and vector GIS data
  - AutoCAD and ArcGIS are software in different domains
    - Data sharing or interoperability is more challenging
- More in the reading material

Summary of Basics of Interoperability

- In many engineering processes, several distinct software systems need to acceess the same data
  - One after another (sequentially)
  - Or at the same time (in parallel / interleaved)
- As the number of distinct systems increases, the complexity of the data management also increases
  - Each new interface or data conversion increases the likehood of bugs in the process, especially if such are added in ad-hoc manner
- Standardized data formats and data access methods decrease overall system complexity, promote safe data access, and can ensure data consistency
- Interoperability between different domains can be challenging

Interoperability and standards

Standards

- Standard is a set of norms or requirements that a software system needs to fulfill
- Software systems that fulfill the same data standard **should be able** to share data
  - In practice the standard may be defined too loosely, some implementations may not fulfill the standard completely, or mplementations may contain bugs that prevent interoperability
- There are many different kinds of standards for data
  - Industry standard, de facto standard, national standard, international standard, open and closed standards, etc.

Good standards, bad standards

- Standardization is not a perfect guarantee that something is useful
- A good standard
  - Is precisely defined
  - Is easily understood and implemented
  - Is sufficiently general
  - Has a well-documented management procedures
  - Can be developed further
  - Is easily available for interested parties
  - Is supported by sufficient number of implementations

Good standards, bad standards

- A bad standard
  - Allows for too much interpretation in implementation
  - Is difficult to understand or very complex
  - Is controlled by an actor that is not interested in cooperation
  - Is not easily available
  - Is difficult to maintain or develop further
  - Is not supported

- **What is good or bad depends on the standard. These things must be assessed case by case**

Standards example ISO 11783 (ISOBUS)

- **Tractors and machinery for agriculture and forestry -- Serial control and communications data network**
  - A data communication standard for agricultural industry
- Extremely large, covers everything from plug design to data formats
- Development of the standard began in 1990s, standard was accepted in 2014
- Allows for tractors and farm implements (e.g. seeders, sprayers, etc.) from different manufacturers to communicate

Problems in ISOBUS

- Task file (field operation instructions) is loosely defined: task files by different manufacturers aren't interexchangeable
  - A Junkkari implement may not work with a CLAAS task file
- Data transfer is based CanBUS vehicle bus from 1990s
  - Data transfer rate is limited to around 1Mbit/s in high-speed mode; to 40-125kbits/s in low-speed mode
- Many features are already outdated or too specific
  - Larger bitrate is really needed (real-time video etc.)
  - Data communication follows a strict client-server model with limited interactions
    - Server cannot initiate communication
  - The Japanese feel that the physical layer is aimed at much too large machines, are developing their own variant for smaller machinery
  - Etc.
- Standard is difficult to modify due to it being managed by ISO
  - Revision procedure is time-consuming

Standards and interoperability are needed

- A current trend in industry is the development of large, integrated systems from standard pieces
  - Internet of Things
  - Industrial Internet
- More and more data is turned into digital format, and there is an increasing need to be able to exploit the data more
  - Industrial process management, customer management, health care, business planning, research and development, etc.
  - There is increasing need for interoperability between systems in different domains

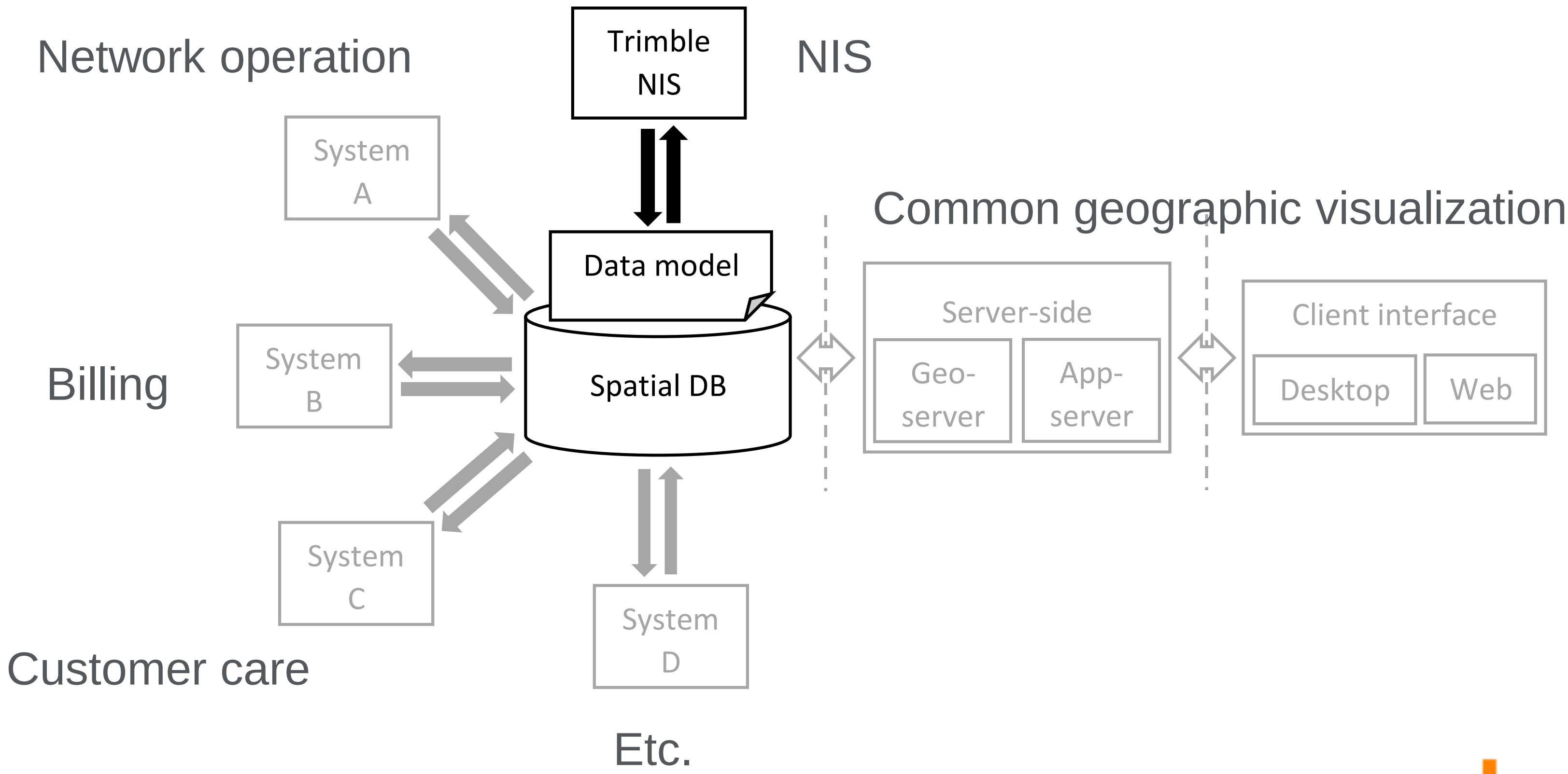
Standards example: management of municipal water utilities

- This example describes a (anonymized and slightly generalized) real-world example of municipal water network management
- The water network is used to deliver clean drinking water to customers (residents)
- There is a separate wastewater network for moving the waste water from the customers to processing
- There are plenty of operations involved in this work:
  - Network operation: see that water flows
  - Asset management: map and manage the network itself
  - Billing: get money
  - Customer care: interact with customers (handle complaints)
  - Etc.

Standards example : management of municipal water utilities

- Management of the actual water network is done using a Network Information System (NIS)
  - This system contains the spatial and topological data of the network (how pipes connect)
  - The NIS system is commercial, and other management software do not have direct access to its data model
- Spatial data is exported from the NIS, transformed into a open data format, and then used by other software
  - The conversion is lossy, for example topological information is lost
  - Water flow management is difficult without explicit topology, as connections between pipes are lost!

Standards example : management of municipal water utilities



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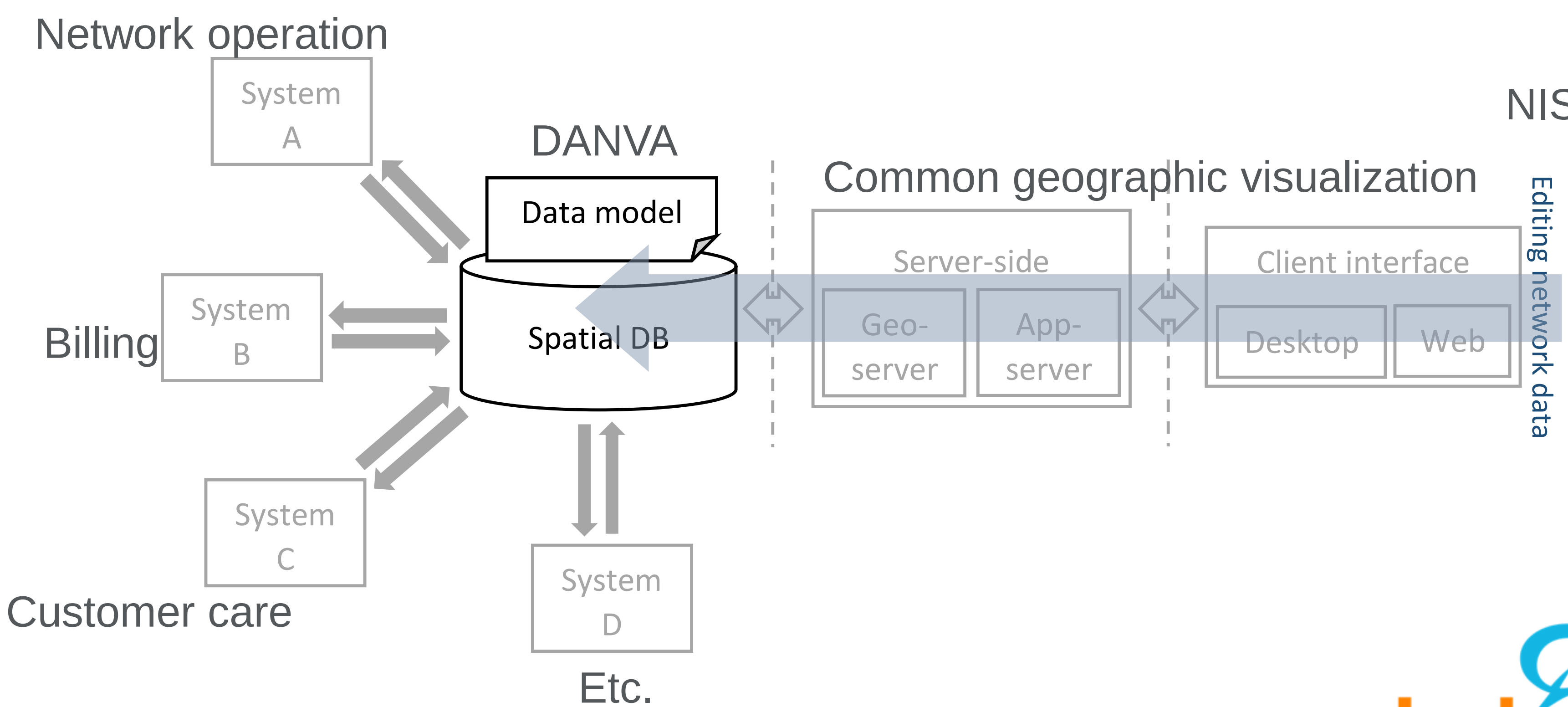
Standards example : problems

- Commercial NIS system makes it difficult to manage the network data
  - All modifications need to be done through the NIS
  - Data needs to be exported after each modification
  - There are no simple means to import information from other systems
- An open data standard would be more appropriate for this work!
  - Problem: where to find a widely-used, mature, open data standard for water networks that could easily be taken into use?
  - Best candidate: the DANVA standard

Standards example: DANVA

- DANVA is a water data network management standard created by the Danish Water and Wastewater Association
- Contains a standard for water (DANVAND) and wastewater (DANDAS), currently in version 3.0
- Material freely available
- Problems:
  - In Danish only, official English (or Finnish) translation would require resources the maintainer doesn't have
  - Everyone sees that expanding DANVA to cover Nordic Countries would be beneficial, but raises questions about maintenance and ownership of the standard
  - Increases risks of taking DANVA into use

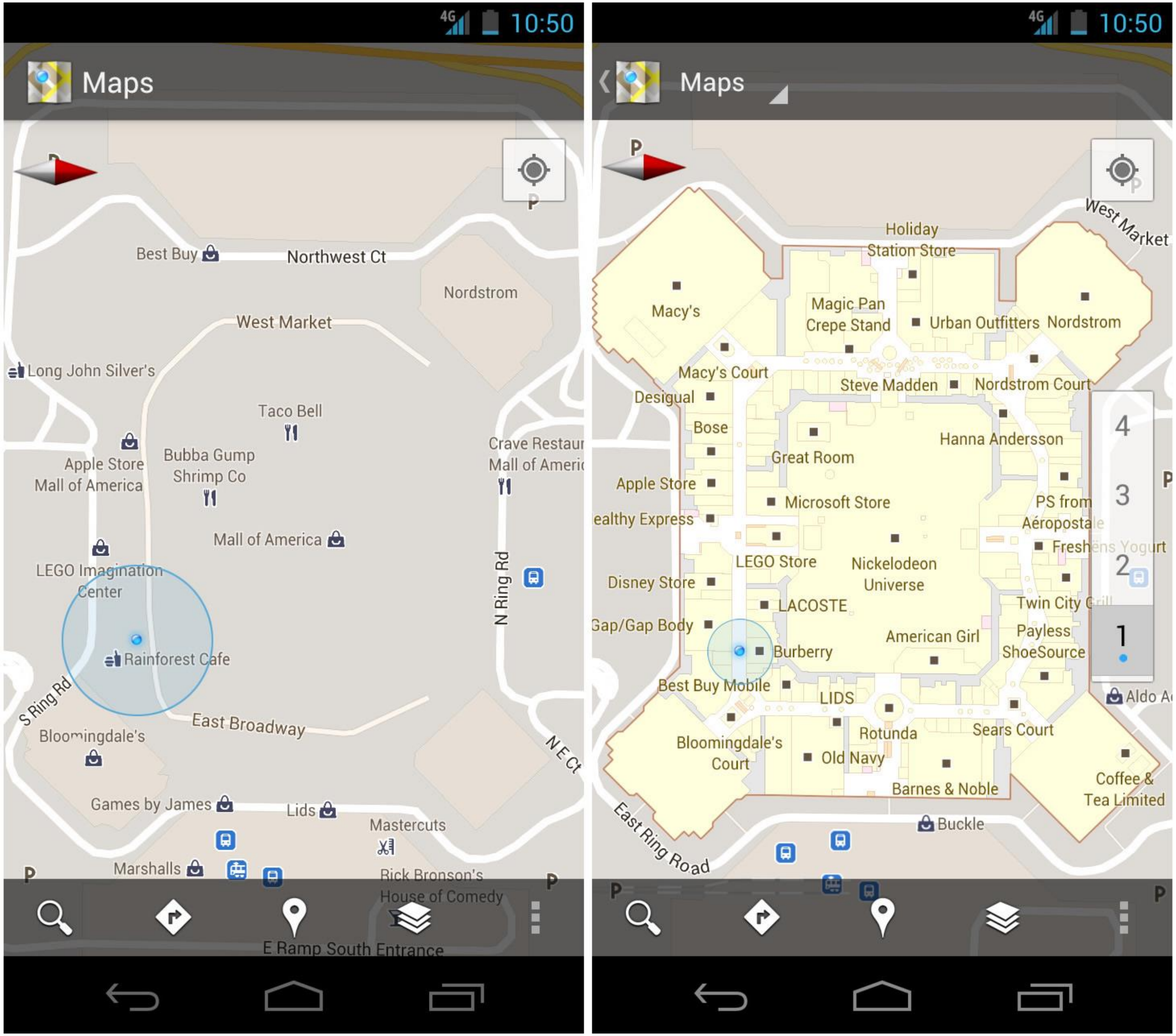
Standards example: Management with DANVA



Data Integration example: CAD floorplans to a web map

The goal of this example

- Combined indoor – outdoor overlays building maps over a background map
  - Both Google and Bing contain such maps
- Allows for easier navigation in urban environments
- In order to achieve we need to combine indoor and outdoor maps into the same map view seamlessly
  - Indoor and outdoor maps must overlay accurately
  - The indoor map must use similar cartographic style as the outdoor map
  - In case there are several floors in the building, there must be means to switch between floors



https://tctechcrunch2011.files.wordpress.com/2011/11/moa_before-after.jpeg

Combination of CAD and GIS data

- CAD and GIS can both be considered coordinate data
  - CAD uses typically local coordinates
  - GIS uses geographic coordinates
- In order to turn CAD data into a GIS map, the CAD coordinates must be turned into GIS coordinates
  - CAD is in Cartesian coordinates
  - CAD coordinates are often not aligned according to cardinal directions
- Thus a coordinate transformation from CAD to GIS coordinates is required

Cartesian to geographic coordinates

- Assumptions:
  - Cartesian coordiantes have an arbitrary origin
  - Cartesian coordinates are not aligned according to cardinal directions
- What needs to be done (in principle):
  1. Select geographic coordinate system to be used
  2. Establish the exact geographic location of a measurable position in the cartesian coordinates
  3. Establish how the cartesian coordinates must be transformed to conform to the geographic coordinates
     1. Rotation
     2. Projection

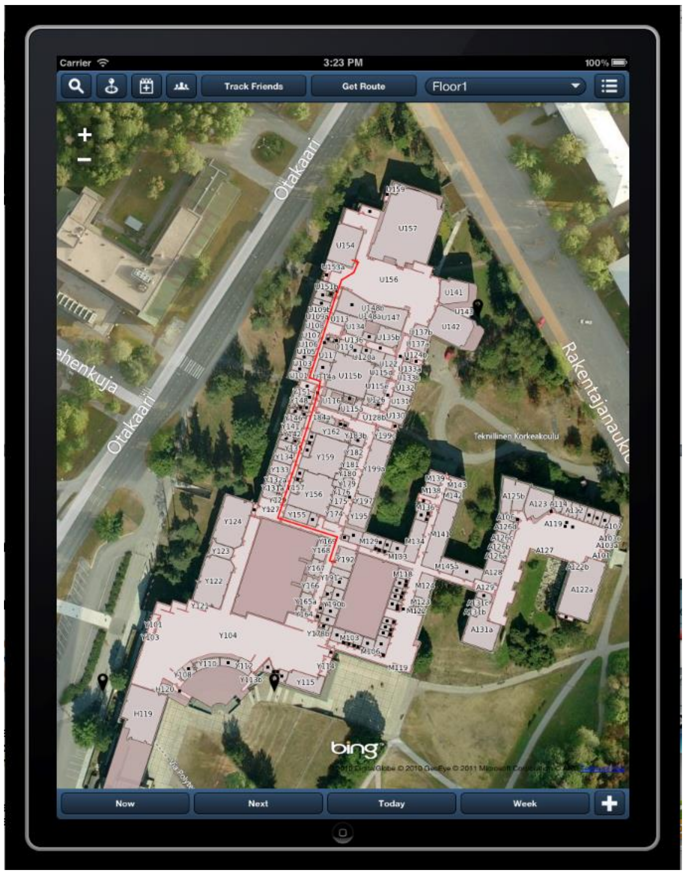
Cartesian to geographic coordinates

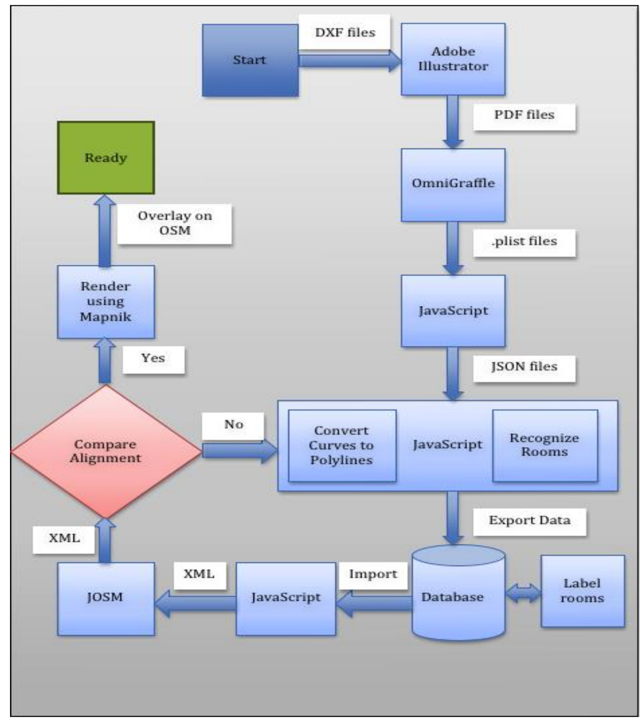
- In practice, typically the coordinates of two points need to be measured in order to find the transformation required
- Whether geographic projection needs to be taken into account depends on the size of the building as well as the precision of the overlay
  - The precision we have for measuring the two points that define the transformation establishes the maximum precision for the overlay
  - If we're doing just visualization, then precision that looks good is enough
  - If we're doing analysis, we need to take into account the possible errors induced

Problems in the conversion

- If we want to just overlay a CAD drawing on a map, the procedure is relatively simple
  - Position CAD drawing correctly, convert into a map layer
  - This procedure loses all CAD data and the resulting map layer can no longer be modified in CAD software or used for more detailed analysis
- If we wish to be able to operate CAD in a GIS environment, the procedure is much more complex
  - The CAD drawings need to be brought into the GIS environment with their CAD functionality preserved
    - GIS needs to include CAD functionality
    - Or GIS needs to be able to call CAD program

Conversion example: turning CAD into navigation-supporting indoor map layer





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Combined data in practice: Aalto Space (only about 5 years after a research prototype…)

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