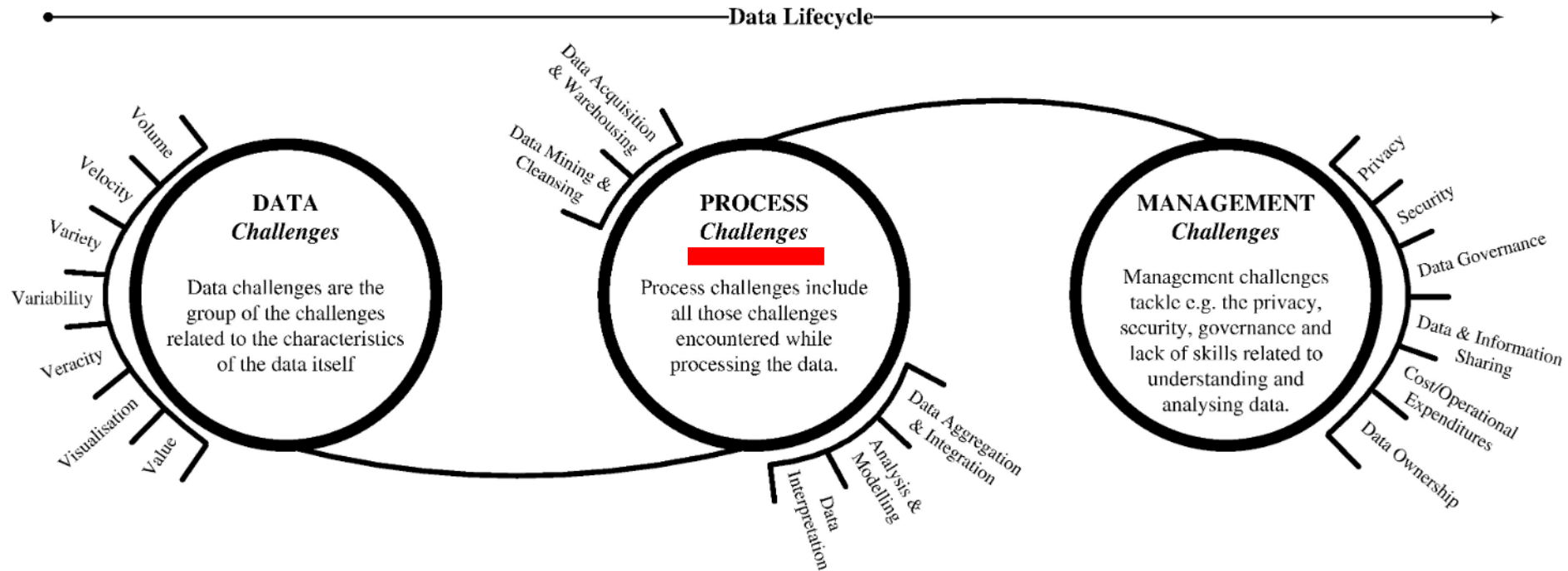


Big Data Processes and Management

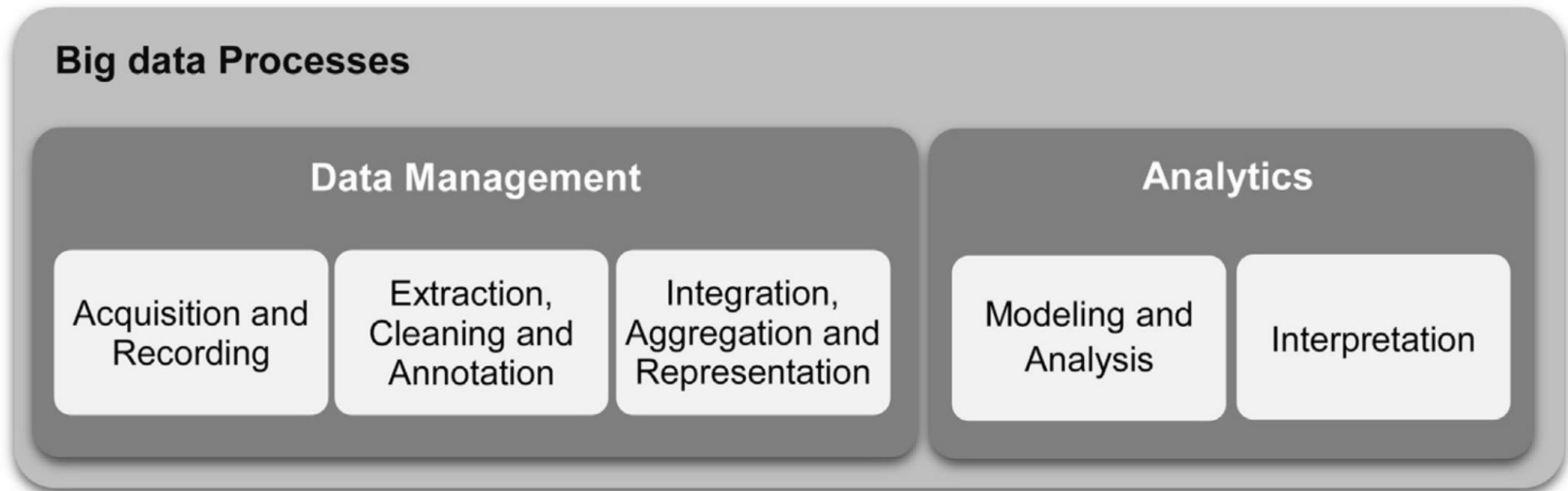
COMP9313: Big Data Management

Big Data Lifecycle

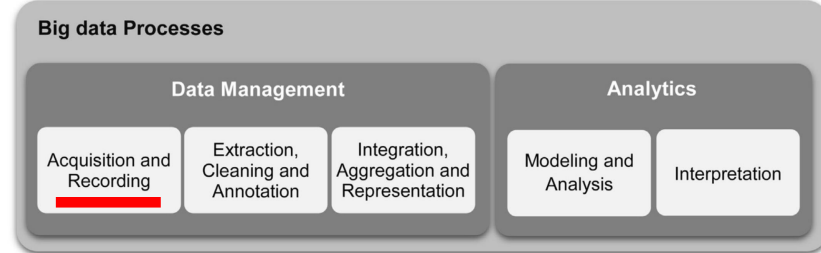


Big Data Processes

Big Data Processes



Data Management: Acquisition and Storage



Data Acquisition:

- Samples of a physical phenomenon (from real-world sources)
- Conversion into digital representation (suitable for information systems)
- Sources: Smart phones, social media, IoT devices, online retail systems, etc.

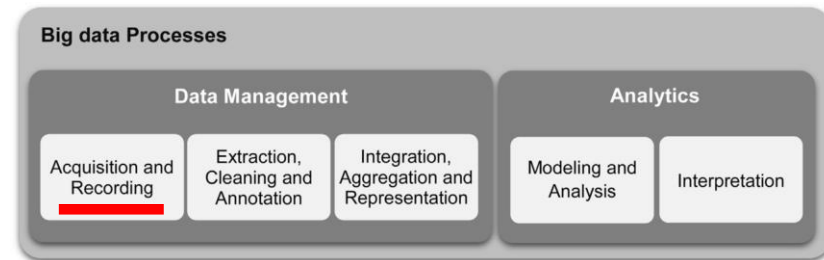


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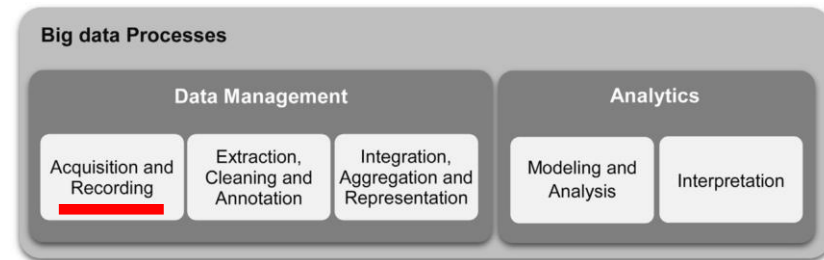
Data Management: Acquisition and Storage



Sources of Big Data:

- User generated content
 - Applications with massive users
 - Unstructured data
 - Raw data -> Information extraction techniques needed
- Transactional data
 - Data generated by large scale systems
 - Web logs, bank transactions, sensor readings
 - Typically structured (pre-defined schema)
- Scientific Data
 - Data-intensive experiments (e.g. physics and genome data)
 - Structured, semi-structured and unstructured data
 - Provenance is important (e.g. for reproducibility)

Data Management: Acquisition and Storage



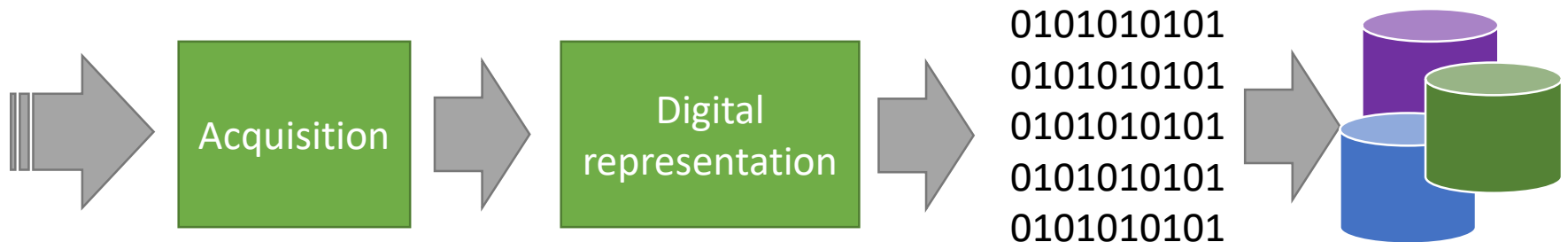
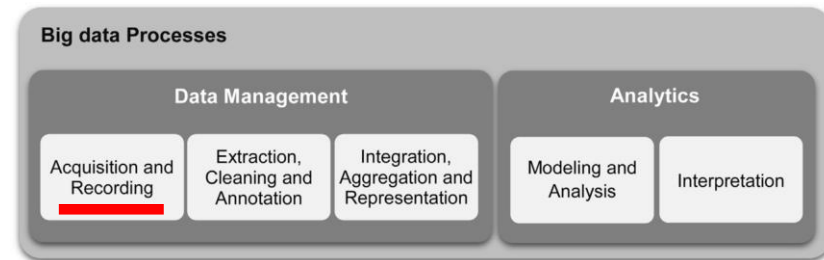
Sources of Big Data:

- Web data
 - Crawled data (e.g. for web search and indexing)
 - Unstructured and semi-structured in nature
- Graph data
 - Knowledge graphs (e.g. babelnet.org)
 - Large number of nodes and relationships
 - Ad-hoc topology -> harder to process

Data Management: Acquisition and Recording

Storage:

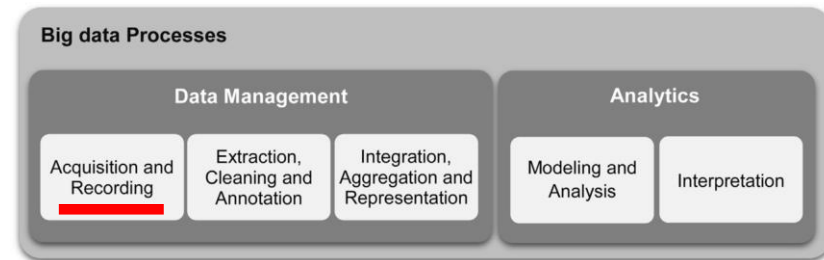
- Different storage technologies
 - Traditional RDMS (e.g. Postgres and MySQL)
 - NoSQL (e.g. HBase and Hive)
 - Distributed file systems (e.g. HDFS)
 - Graph databases (e.g. Neo4J)
- Different data representations
 - Structured (e.g. relational data)
 - Semi-structured (e.g. JSON)
 - Unstructured data (e.g. text and images)



Data Management: Acquisition and Recording

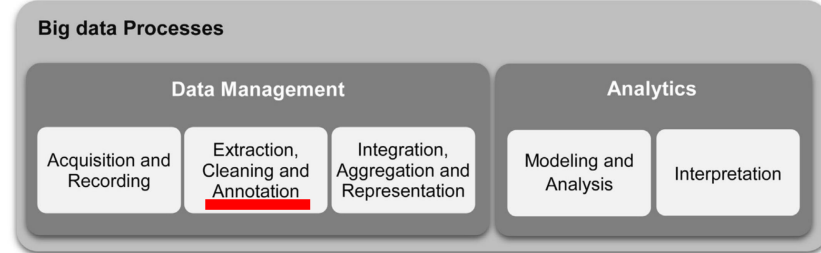
Storage:

- Three Big Data Vs to consider:
 - Volume: How large is (will be) the data we acquire?
 - Velocity: At what pace are we sampling the data?
 - Variety: How diverse is the sampled data?



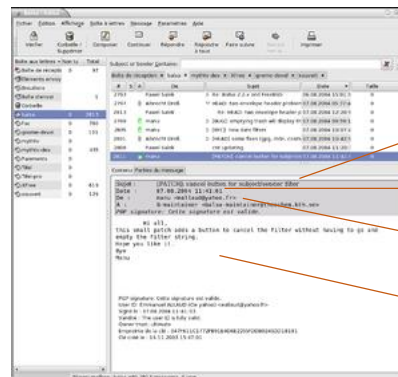
Data Management: Extraction, Cleaning and Annotation

Big data Processes



Extraction:

- Extract only relevant information (e.g. metadata in emails or named-entities from a corpus)
- Handling duplicate data (e.g. papers in arXiv.org vs. digital libraries)
- Use of complex techniques for data extraction (e.g. pattern matching and ML techniques)



subject

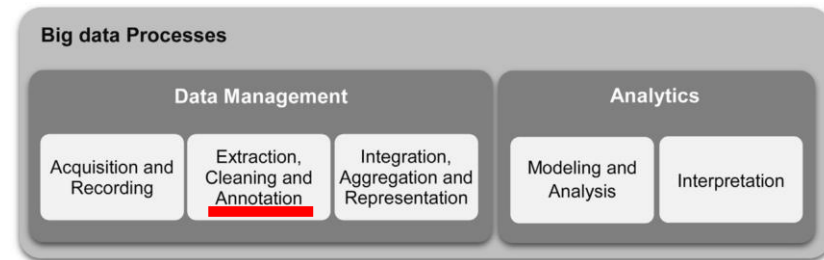
date / time

sender

body

[source](#)

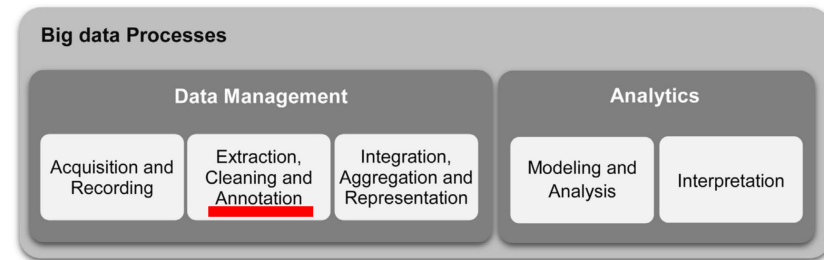
Data Management: Extraction, Cleaning and Annotation



Example: Web Data Extraction

- Mostly HTML documents -> Semi-structured data
- Extraction techniques
 - Tree-based techniques
 - Leverages the tree-based structure of HTML documents
 - Typically uses XPath + Tree matching algorithms
 - Web wrappers
 - Wrappers -> extracts structured data from unstructured or semi-structured data
 - Based on regular expressions, logic (wrapping languages), machine learning (e.g. supervised learning)

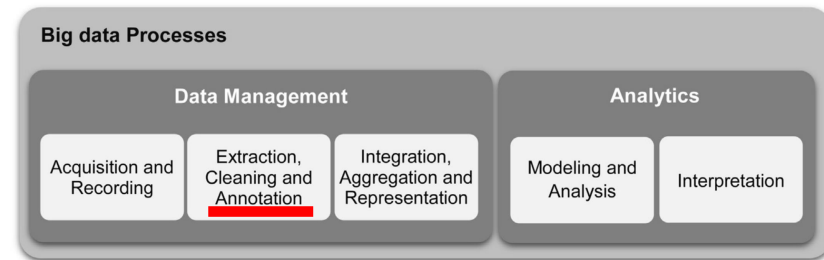
Data Management: Extraction, Cleaning and Annotation



Cleaning:

- Any good big data project needs to satisfy certain quality criteria (garbage in -> garbage out)
- Examples of data quality dimensions:
 - Completeness
 - Timeliness
 - Free-of-error
 - Relevancy
 - Value-added
 - Believability
 - Interpretability
 - ... and more

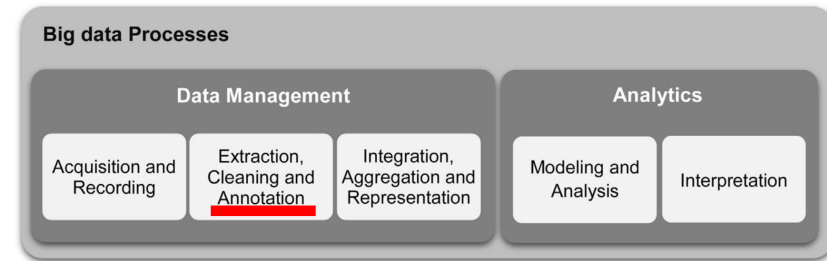
Data Management: Extraction, Cleaning and Annotation



Cleaning Phases:

- Error detection:
 - Error type: Definition of what errors should be detected
 - Automation: To what extent the task is automated (are humans involved at all?)
 - Business Intelligence Layer: Where in the data processing pipeline should the error be detected?
- Error repairing:
 - Repair target: What errors to focus on? Interactions among errors?
 - Automation: Again, to what extent the task is automated (are humans involved at all?)
 - Repair model: In-situ repairs vs. Models for repairs

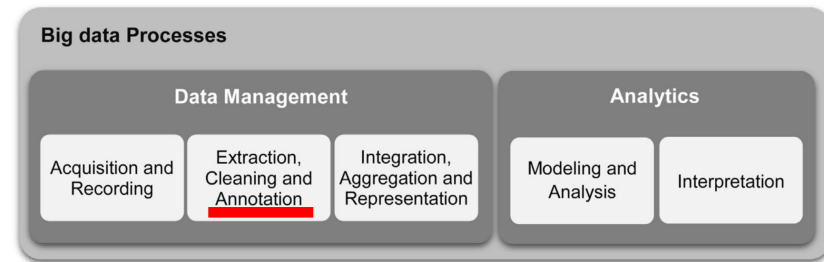
Data Management: Extraction, Cleaning and Annotation



Annotation:

- Sometimes annotation comes from the sources (e.g. tags in Twitter)
- Annotation helps with:
 - Adding semantics to data
 - Structuralizing raw, unstructured data
- Big data -> Automated techniques for annotation / tagging
 - Video tagging (e.g. lecture videos)
 - Text tagging (e.g. part-of-speech tagging)
 - Speech audio tagging (e.g. radio program tagging)

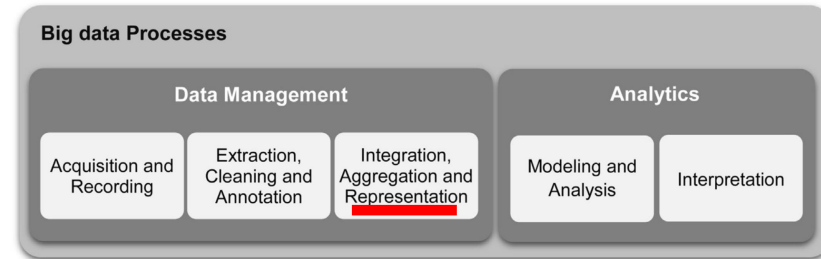
Data Management: Extraction, Cleaning and Annotation



Annotation techniques:

- Crowd-based annotation
 - Tags provided by the source (e.g. Twitter, Stack Overflow)
 - Tagging through Crowdsourcing platforms (e.g. Mturk)
- Automated annotation:
 - Using ad-hoc Machine Learning techniques
 - NLP-based tagging (e.g. POS tagging)
- Hybrid approach
 - Combine crowd-based annotation (labeling) and automated techniques (e.g. ML/Classification)

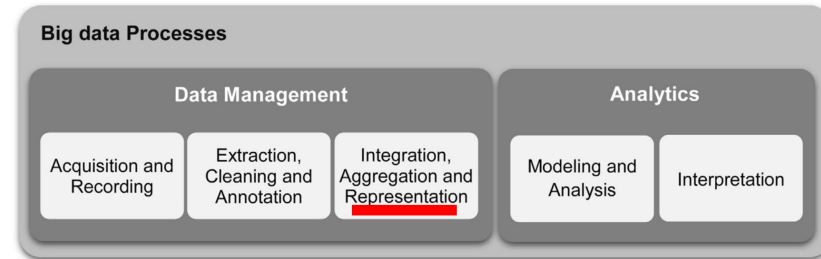
Data Management: Integration, Aggregation and Representation



Integration:

- Involves combining data from multiple, complex, heterogeneous resources
- Main goal -> Provide a uniform view of data
- Mature field in traditional databases (ETL, data federation)
- Existing traditional approaches -> Based on traditional models
- The Vs of Big Data pose challenges to traditional approaches

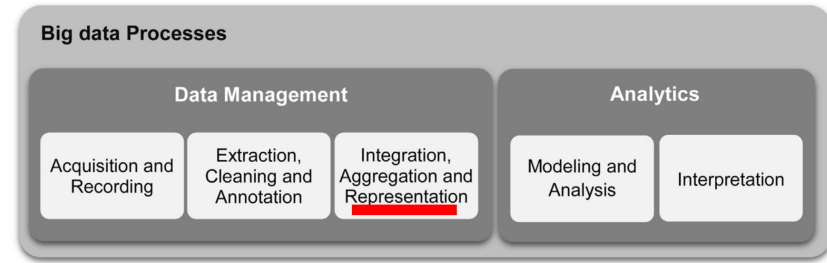
Data Management: Integration, Aggregation and Representation



Integration:

- Schema mapping
 - Global schema creation
 - Mapping of global-to-local schema
- Record linkage
 - Same logical entities, different data sources
 - Traditional Record Linkage -> static/structured records, same schema
 - Record Linkage in Big Data -> heterogenous sources, dynamic and continuously evolving
- Data fusion
 - Resolving conflicts
 - Finding truth about real-world -> veracity of data

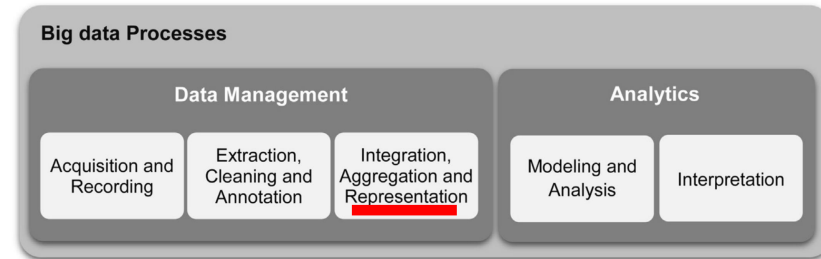
Data Management: Integration, Aggregation and Representation



Aggregation:

- Aggregation of heterogeneous information sources
- Distributed, collaborative aggregation (e.g. using Hadoop / MapReduce)
- Privacy, security and compliance (e.g. EU/GDPR)

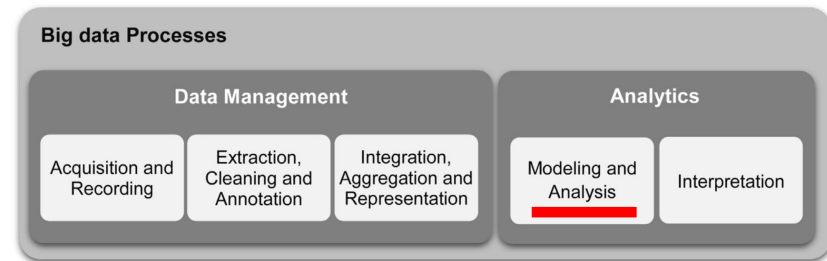
Data Management: Integration, Aggregation and Representation



Representation:

- Different representation models
 - Structured (e.g. relational data)
 - Unstructured (e.g. text and images)
 - Semi-structured (e.g. JSON)
- Mapping from one representation to another
 - Relational to JSON (e.g. MySQL tables to JSON)
 - Text to graph (e.g. Wikipedia corpus to knowledge graphs)
 - Actions/Interactions to graph (e.g. underlying networks in Twitter)

Analytics: Modeling and Analysis



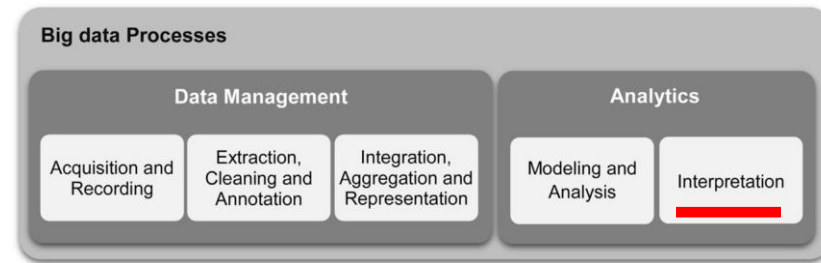
Modeling and Analysis:

- Different modeling techniques based on the analytics goals
 - Descriptive statistics (e.g. histograms, measures of centrality)
 - ML (e.g. classification, regression, clustering)
 - Data mining (e.g. sequential patterns, frequent items)
 - Graph mining (e.g. sub-graph mining)
 - Outliers detection (e.g. clustering)
 - Recommendation (e.g. collaborative filtering)
 - Process mining (e.g. process discovery)

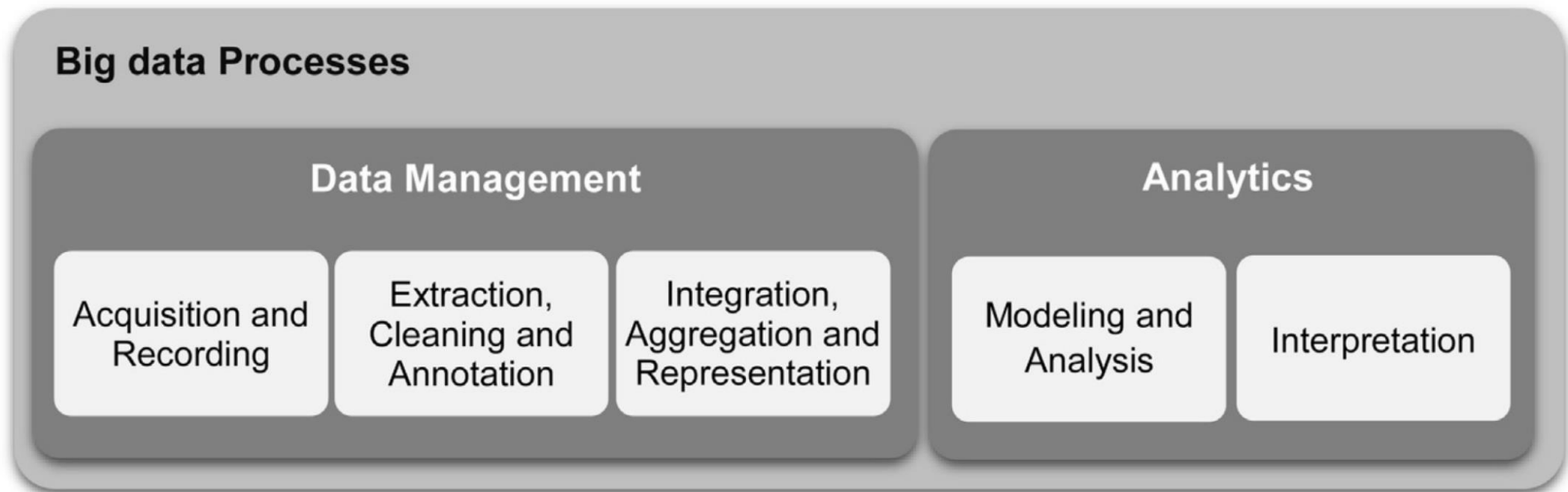
Analytics: Interpretation

Interpretation:

- Domain experts involvement
- Data/results visualization
 - Spatial data (e.g. bacteria spread over tissue)
 - Geospatial data (e.g. heat map forecast for weather temperatures)
 - Time-oriented data (e.g. interest rates forecast)
 - Multivariate Data (e.g. individual income vs. literacy)
 - Trees, Graphs, Networks (e.g. social network visualization)
 - Text / Document visualizations (e.g. sentiment analysis)

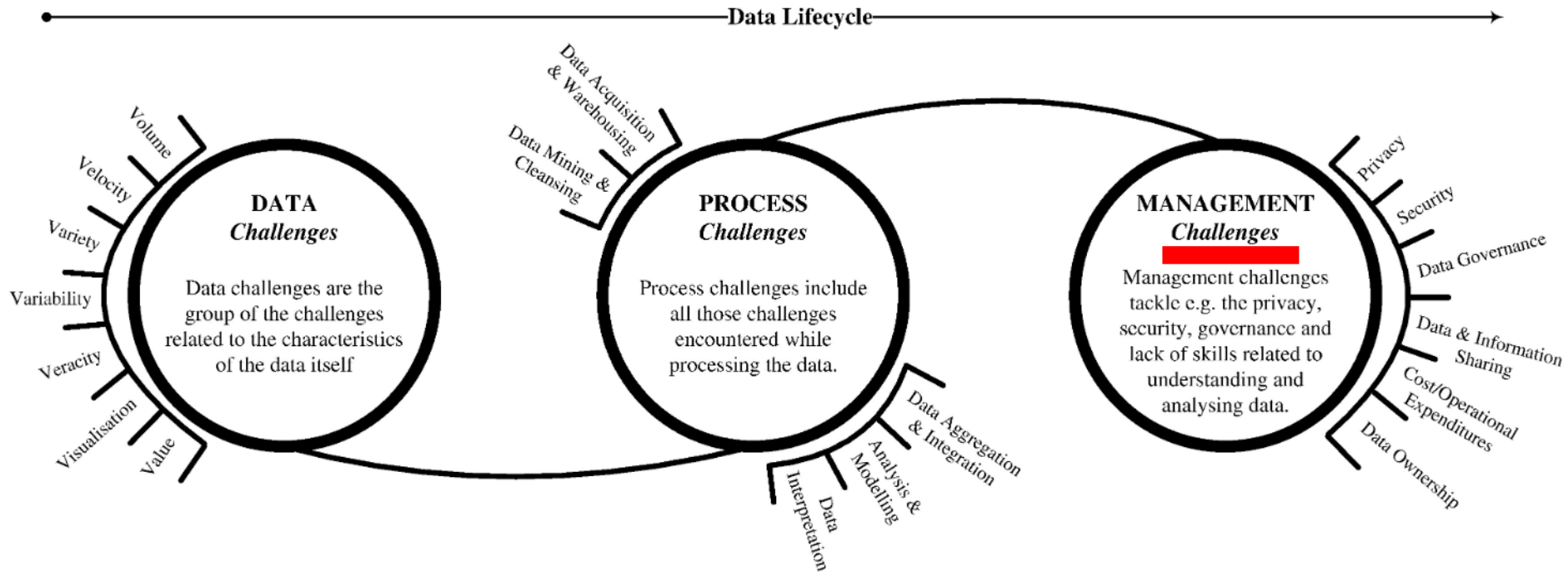


Recap: Big Data Processes

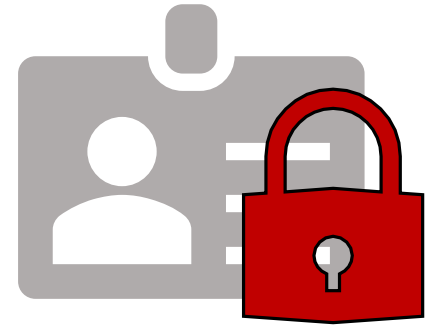


Big Data: Management Challenges

Data Lifecycle



Big Data Privacy



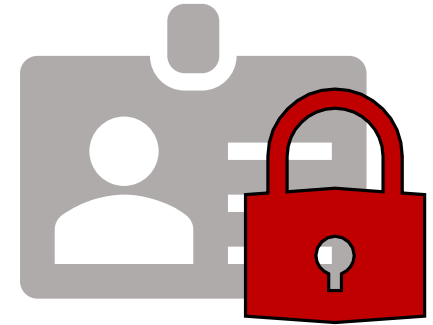
Big Data from two perspectives:

- As a technological challenge
 - Dealing with huge amounts of data
 - The 6 Vs: Volume, Velocity, Variety, Veracity, Visibility, Value
- As a sociological problem
 - Collection of personal data
 - Social media, business, healthcare, government, etc.

Big Data Privacy

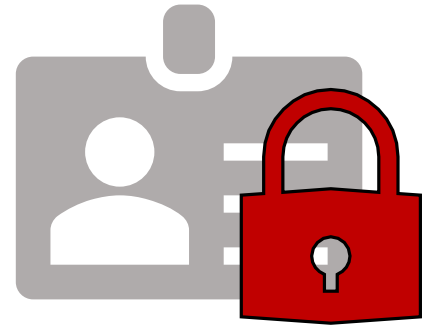
Uses of Big Data:

- Market research
- Targeted advertisement
- Workflow improvements
- National security
- Taxation
- and more...



How can we be sure that our data is not used for (intended / unintended) “questionable” purposes?

Big Data Privacy



The case of social media

- People uploading their data voluntarily
 - Profiles
 - Pictures
 - Activities
 - and more...
- **Small Data** problem:
 - How can I control access to my own data?
- **Big Data** problem:
 - What can the controlling company do with our data?

Big Data Privacy

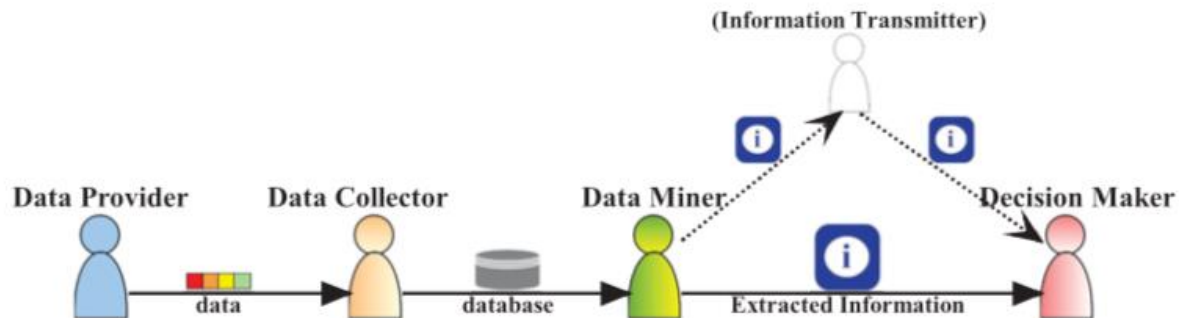
Different user roles and their concerns

- Data Provider

- Can I control the sensitivity of the data I provide?
- Control what the collector can get access to
- Compensation for privacy loss

- Data Collector

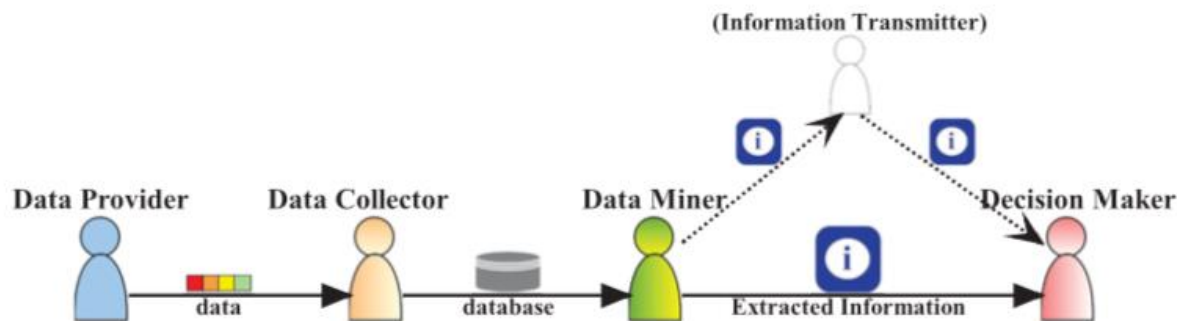
- Prevent releasing sensitive information to data miner
- Data must be modified / adapted
- Modified data that is still useful



Big Data Privacy

Different user roles and their concerns

- Data Miner
 - Mines data provided by Data Collector
 - Protection of sensitive mining results
- Decision Maker
 - Are the mining results credible?



Big Data Privacy

Data Breaches

Date Range

2018 2017 2016 2015 2014 2013

SHOW 10 ENTRIES SEARCH:

Showing 1 to 10 of 1,505 entries

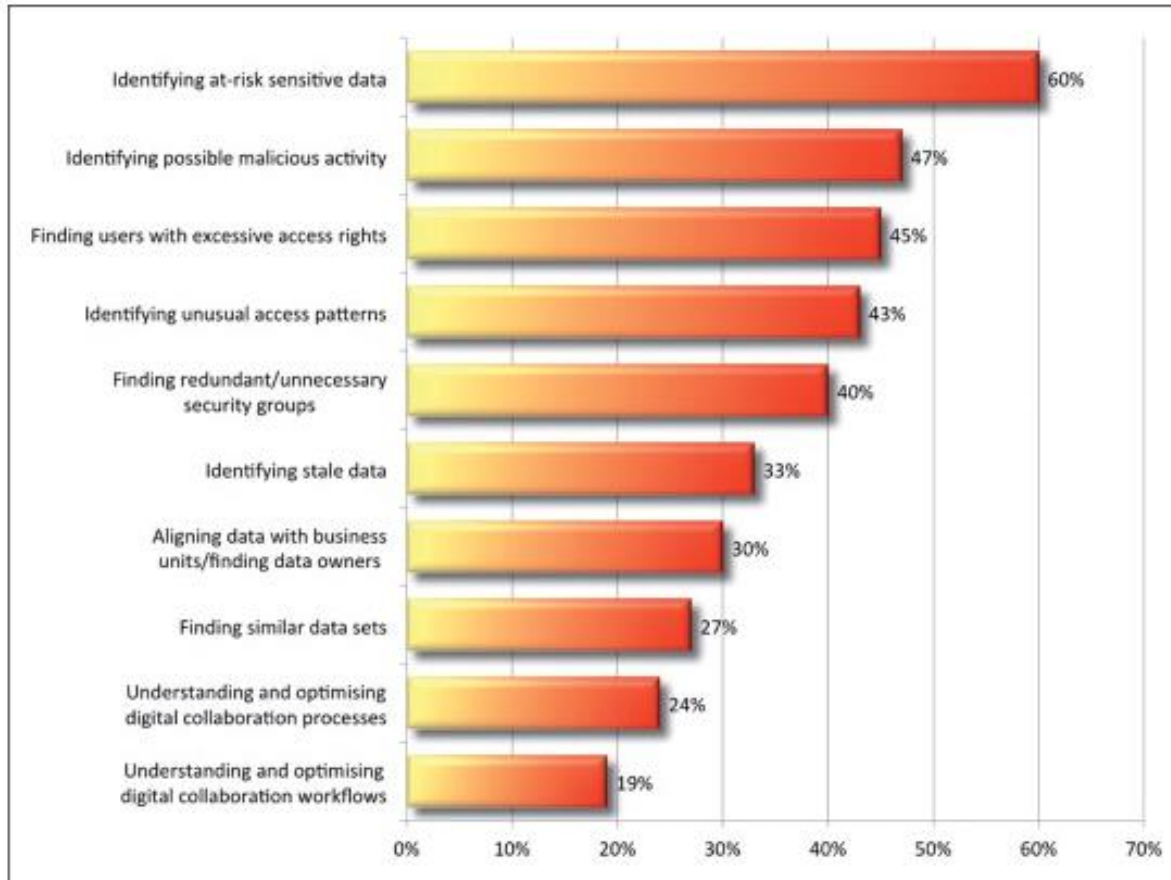
Rank	Risk Score	Industry	Records Breached	Date of Breach	Type of Breach	Source of Breach	Location
1	10.0	Social Media	2,200,000,000	04/04/18	Identity Theft	Malicious Outsider	United States
2	9.8	Hospitality	383,000,000	09/08/18	Identity Theft	Malicious Outsider	United States
3	9.5	Other	200,000,000	07/01/18	Identity Theft	Malicious Outsider	United States
4	9.3	Hospitality	130,000,000	08/28/18	Identity Theft	Malicious Outsider	China
5	9.1	Other	340,000,000	06/01/18	Identity Theft	Accidental Loss	United States
6	9.1	Retail	150,000,000	02/01/18	Account Access	Malicious Outsider	United States
7	9.0	Social Media	336,000,000	05/03/18	Financial Access	Accidental Loss	United States
8	8.9	Other	180,104,892	11/12/18	Identity Theft	Accidental Loss	Brazil
9	8.9	Social Media	100,000,000	11/30/18	Account Access	Malicious Outsider	United States

Big Data Security



- Big Data -> Big amount of sensitive information
 - Personal information
 - Intellectual property
 - Trade secrets
 - Financial information
- Huge data breaches
 - Security risks
 - Reputation loss
 - Financial loss

Big Data Security



Most significant challenges in managing big data (survey: 151 federal IT professionals, US Government IT community)

Big Data Security



Data Anonymization

- Removal of sensitive data from records
- Data utility vs. Data privacy
- Removing unique identifiers -> Privacy not guaranteed
- Cross-references and de-anonymization

Big Data Security



Data Encryption

- Encrypt stored data
- Attribute-based encryption -> fine-grained access control

Big Data Security



Access control and Monitoring

- Access control policy for privileged operations (e.g. encrypt / decrypt)
- Authentication mechanisms not always available in big data frameworks
- Real-time security monitoring -> Attacks detected in real-time and mitigated properly

Big Data Security



Policy approaches

- Identification of sensitive pieces of information
- Isolation of sensitive information
- Third-party involvement -> Compliance with regulations and standards
- Processes to manage and protect data effectively

Big Data Security



Governance and Frameworks

- Use of governance frameworks to protect data (e.g. ISO/IEC 27001 - Information Security)
- Big data is relatively new -> No major frameworks with policies and procedures specifically addressing the security big data challenges
- Main Challenge:
 - Variety -> Difficulty in categorizing, modeling and mapping big data

Big Data Security



Some good practices

- Cloud provider vetting (i.e. assessment)
- Adequate access control policies
- Data protection (e.g. using encryption)
- Communications protection (e.g. for confidentiality and integrity)
- Real-time security monitoring

Compliance



- **The Oxford dictionary¹:**
 - “The state or fact of according with or meeting rules or standards”
- **Wikipedia²:**
 - “Conforming to a rule, such as a specification, policy, standard or law”

¹ <https://www.oxforddictionaries.com/>

² https://en.wikipedia.org/wiki/Regulatory_compliance

Compliance

Example regulations:



[source](#)

- Health Insurance Portability & Accountability Act
- Protection of Personal Identifiable Information from fraud and theft
- Mainly applicable to healthcare and healthcare insurance companies
- Consists of 5 "Titles"
- Privacy is treated mostly under Title II - *Preventing Health Care Fraud and Abuse*



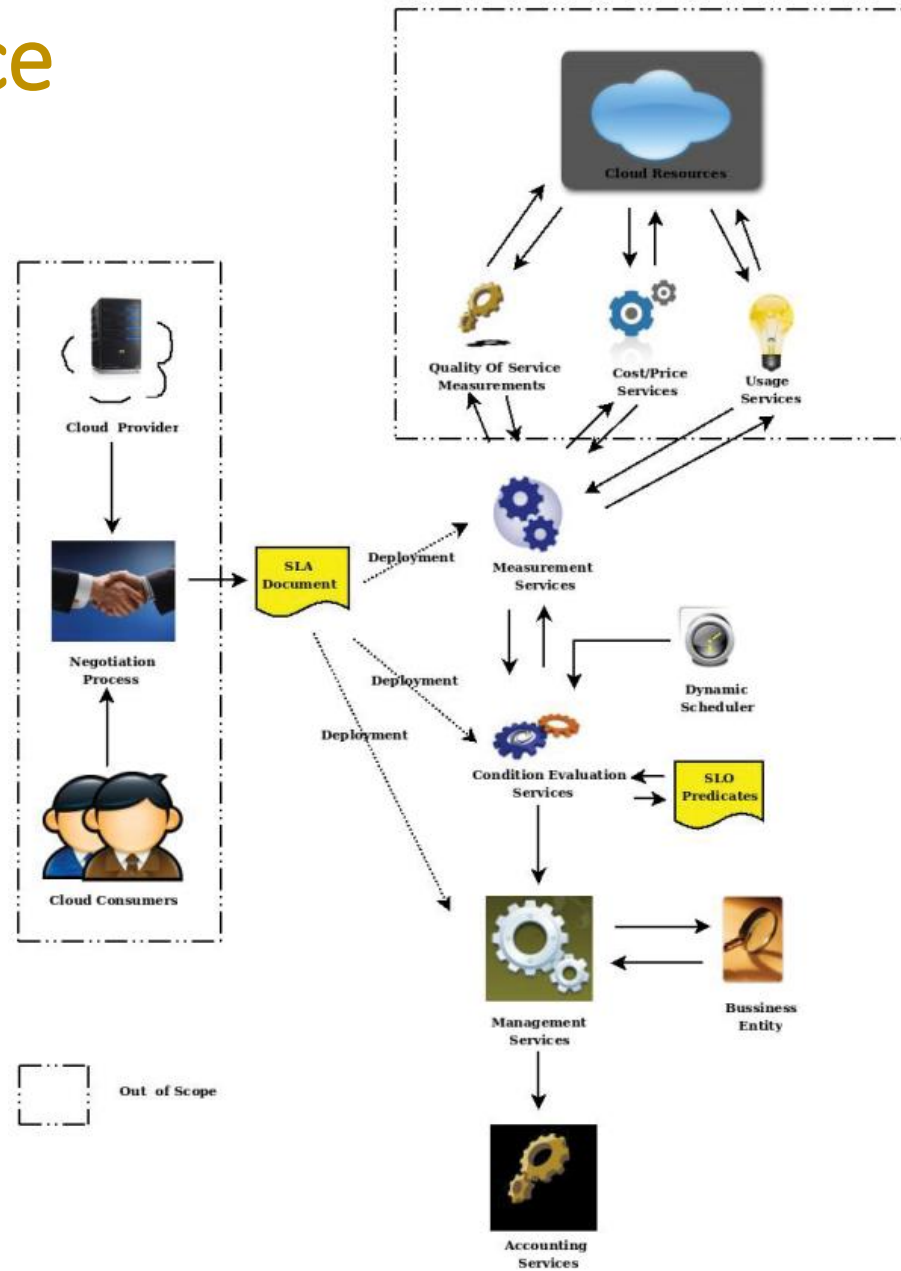
- General Data Protection Regulation
- EU regulation on data protection and privacy for citizens of the EU and EEA
- Export of data outside EU and EEA
- Gives controls to individuals over their personal data
- Data Controllers -> Must provide technical and organizational measures to implement GDPR
- Hefty fines for violations of GDPR

Compliance

Big Data SLAs (Service-Level Agreements)

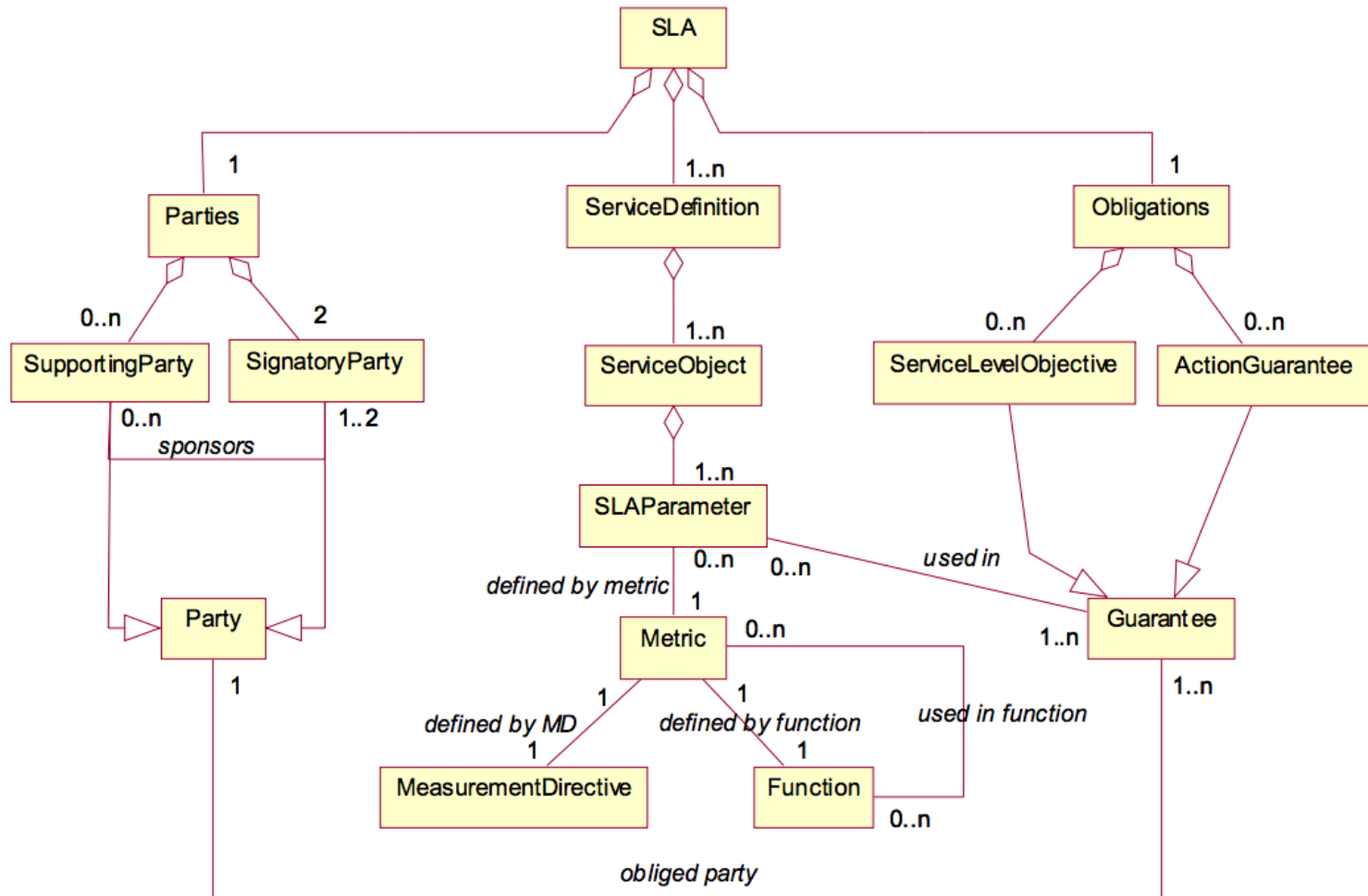
- Companies moving from experimentation to production (mission critical)
- Getting more serious about QoS (Quality of Service)
- Minimum performance and service levels required (e.g. response time and throughput)
- Service-Level Agreements:
 - Commitment between a provider and a user of service

Compliance



Compliance

Web Service Level Agreement (WSLA)



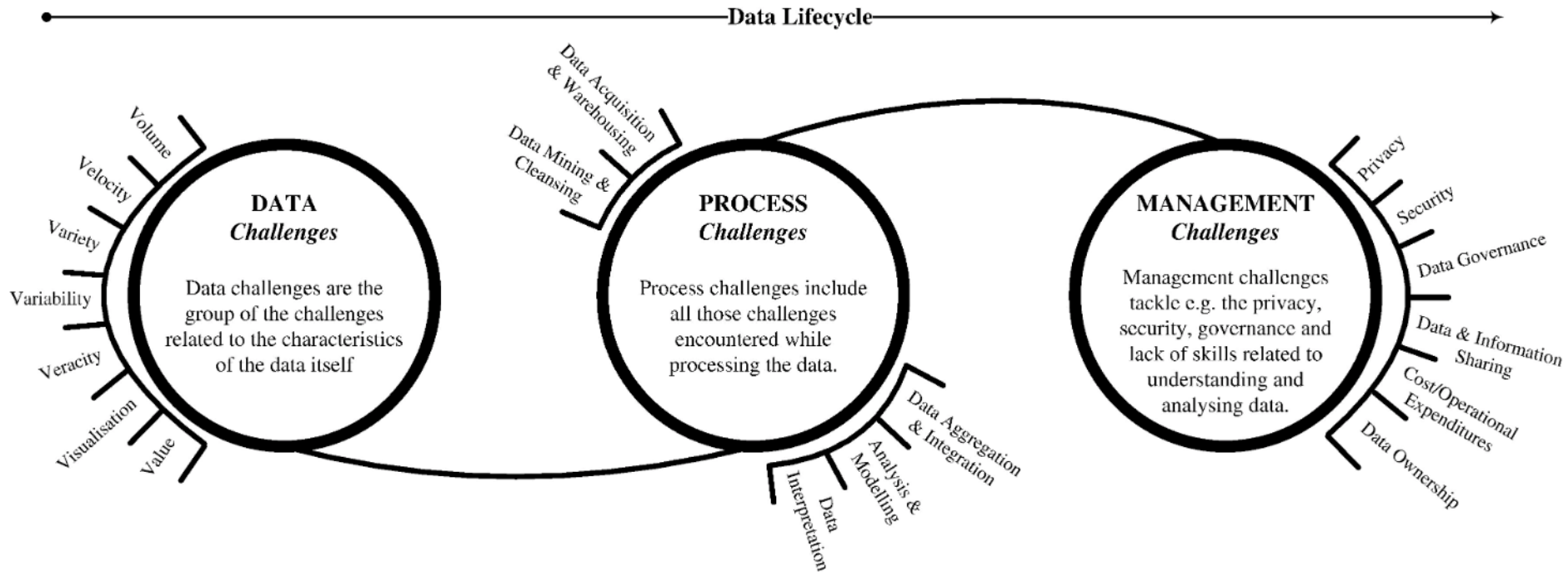
Compliance

Web Service Level Agreement (WSLA)

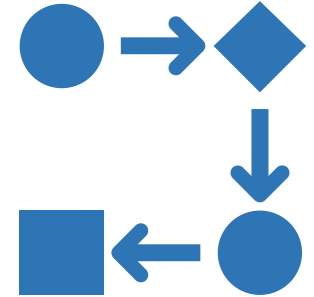
```
<ServiceProvider
  name="ACMEProvider">
  <Contact>
    <Street>PO BOX 218</Street>
    <City>Yorktown, NY 10598, USA</City>
  </Contact>
  <Action name="notification"
    partyName="ACMEProvider"
    xsi:type="WSDLSOAPActionDescriptionType">
    <WSDLFile>notification.wsdl</WSDLFile>
    <SOAPBindingName>soapnotification</SOAPBindingName>
    <SOAPOperationName>notification</SOAPOperationName>
  </Action>
</ServiceProvider>
<ServiceConsumer
  name="XInc">
  <Contact>
    <Street>30 Saw Mill River RD</Street>
    <City>Hawthorne, NY 10532, USA</City>
  </Contact>
  <Action name="notification"
    partyName="XInc"
    xsi:type="WSDLSOAPActionDescriptionType">
    <WSDLFile>notification.wsdl</WSDLFile>
    <SOAPBindingName>soapnotification</SOAPBindingName>
    <SOAPOperationName>notification</SOAPOperationName>
  </Action>
</ServiceConsumer>
```

Example: Definition of service provider and consumer

Big Data Lifecycle



Data Governance



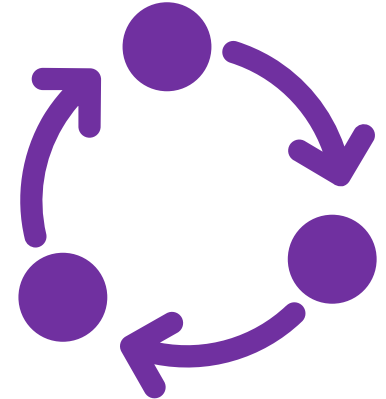
Definition:

“Data governance is the overall management of the availability, usability, integrity and security of data used in an enterprise. A sound data governance program includes a governing body or council, a defined set of procedures and a plan to execute those procedures.”

<https://searchdatamanagement.techtarget.com/definition/data-governance>

- Data Governance as an approach to:
 - Warranting data quality
 - Improving / leveraging information
 - Support for insights into business decisions and operations

Data and Information Sharing



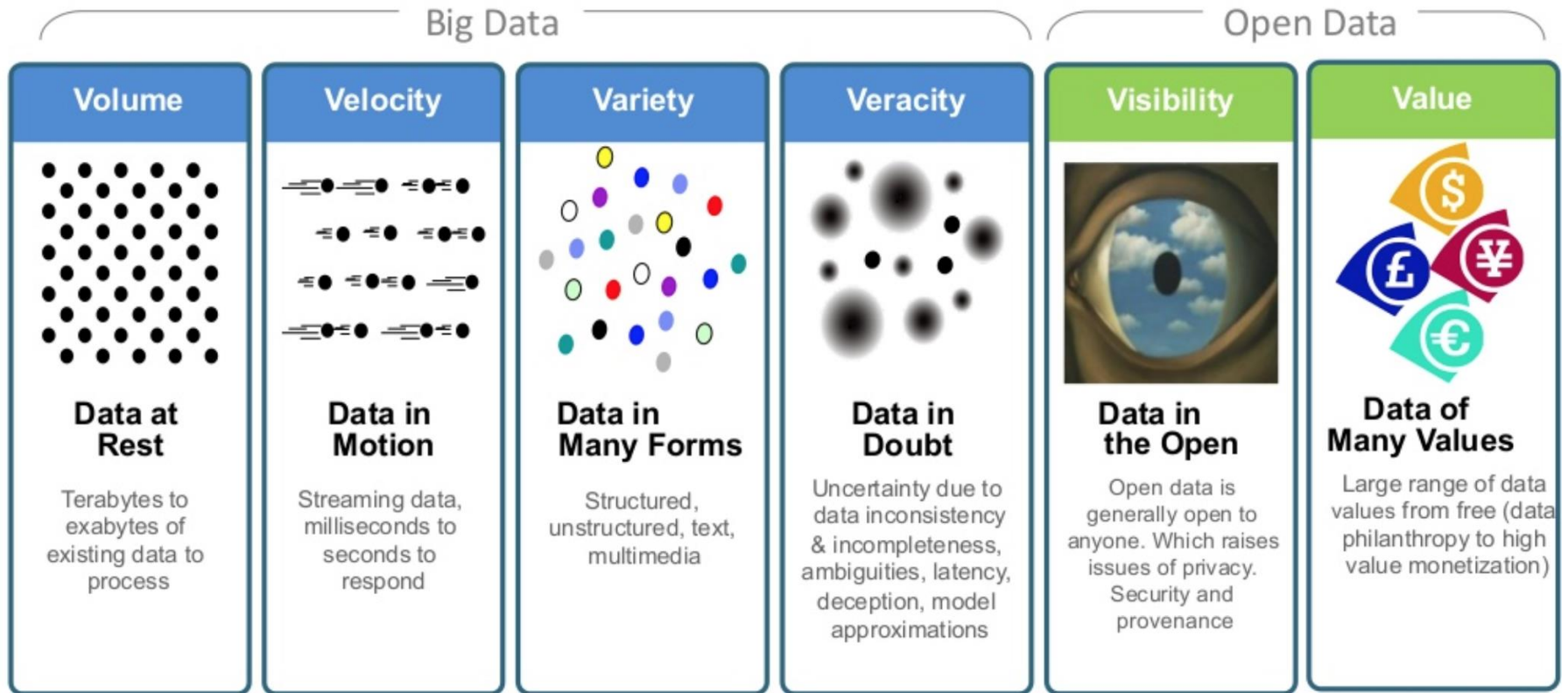
- Helps establish close connections with business partners
- Main challenges:
 - Sharing / integration of key information across different organizations
 - Disparate information / Data warehouses
 - Sensitive information / User privacy rights

Cost / Operational Expenditure



- Rising demand for Big Data processing
- Spread through geographical regions -> Build resilience and spread risk
- Big IT companies -> Data centers in different countries and continents
- Resources allocated to key operations:
 - Acquisition
 - Warehousing
 - Mining and cleaning
 - Aggregation and integration
 - Processing and interpretation

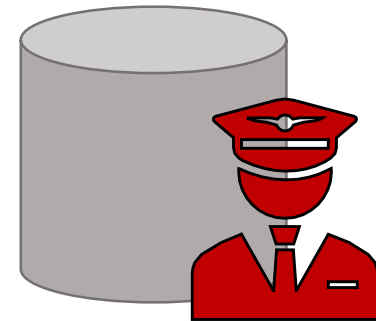
Cost / Operational Expenditure



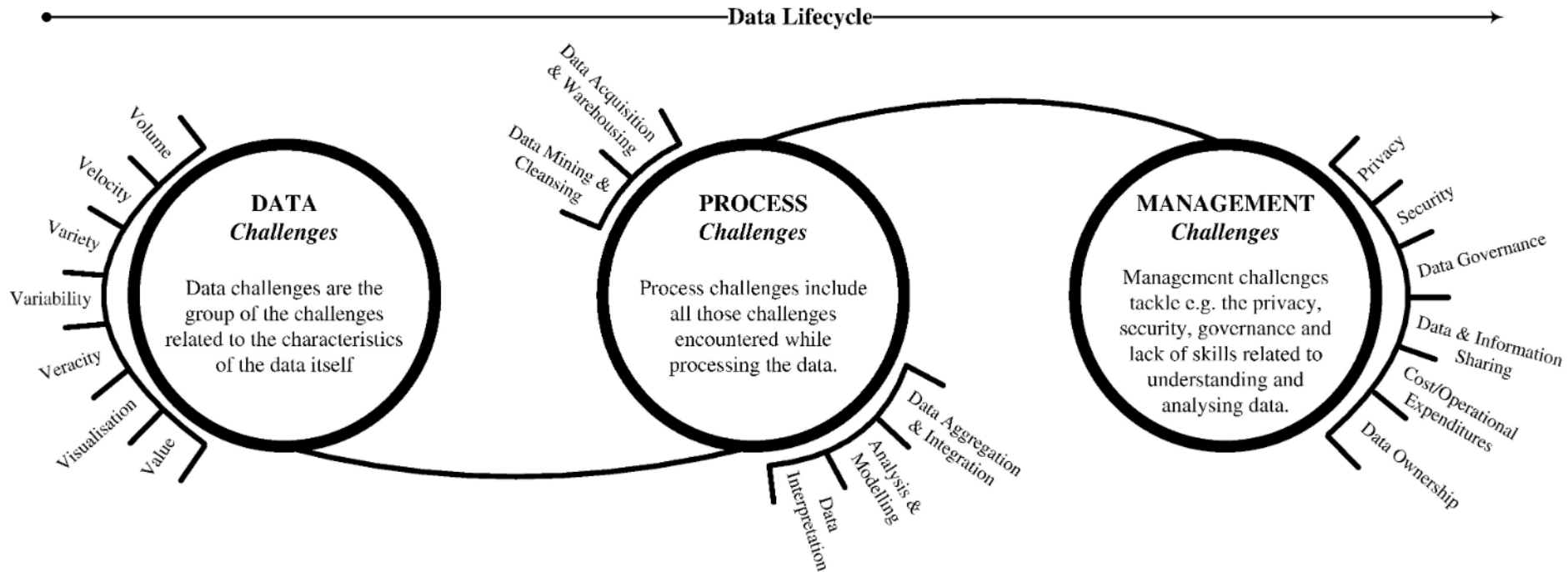
Transforming Energy and Utilities through Big Data & Analytics
By Anders Quitzau, IBM, 2014

Data Ownership

- Complex issue, specially in the context of real time sharing of data
- Social media:
 - What's own by users who post content?
 - What's own by social media providers?
- Data ownership also involves:
 - Monitoring data accuracy
 - Ensuring data data accuracy



Big Data Lifecycle



Big Data Management Dos and Don'ts

Big Data Management Don'ts...



Assume very ambitious approaches will result in best returns

- Embracing complex, heterogenous, rich data and trying to **do all at once**
- Instead:
 - Focus on smaller, useful pilot applications
 - Build on top of initial small successes
 - Pick “the right” project to test your organization’s capabilities

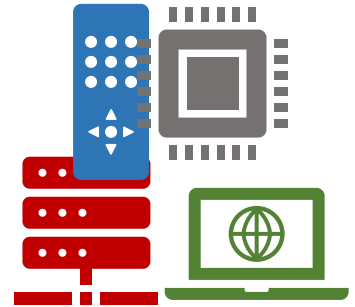
Big Data Management Don'ts...



Focusing all efforts on the needs of particular business units

- Think globally, act locally
- Safer to start by focusing on decreasing risks, than creating new opportunities
- The latter is harder, and takes longer to measure -> Requires experience

Big Data Management Don'ts...



Assuming that technology alone will guarantee desired results

- Lack of technology is one of the top obstacles for business success
- Technology is already there...
- How to properly leverage on technology in the organization ecosystem?
- Focus should be on achieving good ROI

Big Data Management Dos...



Building collaborative capabilities

- Processes and toolsets -> Instrumental to making big data more approachable
- Big data growing faster than capabilities
- Environment should facilitate ease of use
- Business and IT collaborations are key to harness opportunities of big data

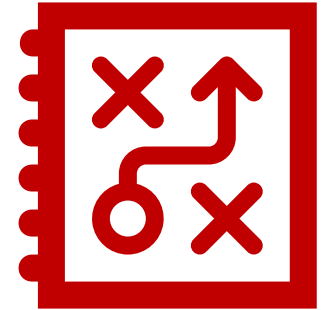
Big Data Management Dos...



Use a stepwise approach

- X** Tackling unknown problem with unknown data
 - More convenient:
 - Starting with a known problem
 - Solving it in an innovative way
 - Next: Solve same problem, use new data
 - Finally: Solve new problem, use new data
 - Stepwise approach -> Higher likelihood of success

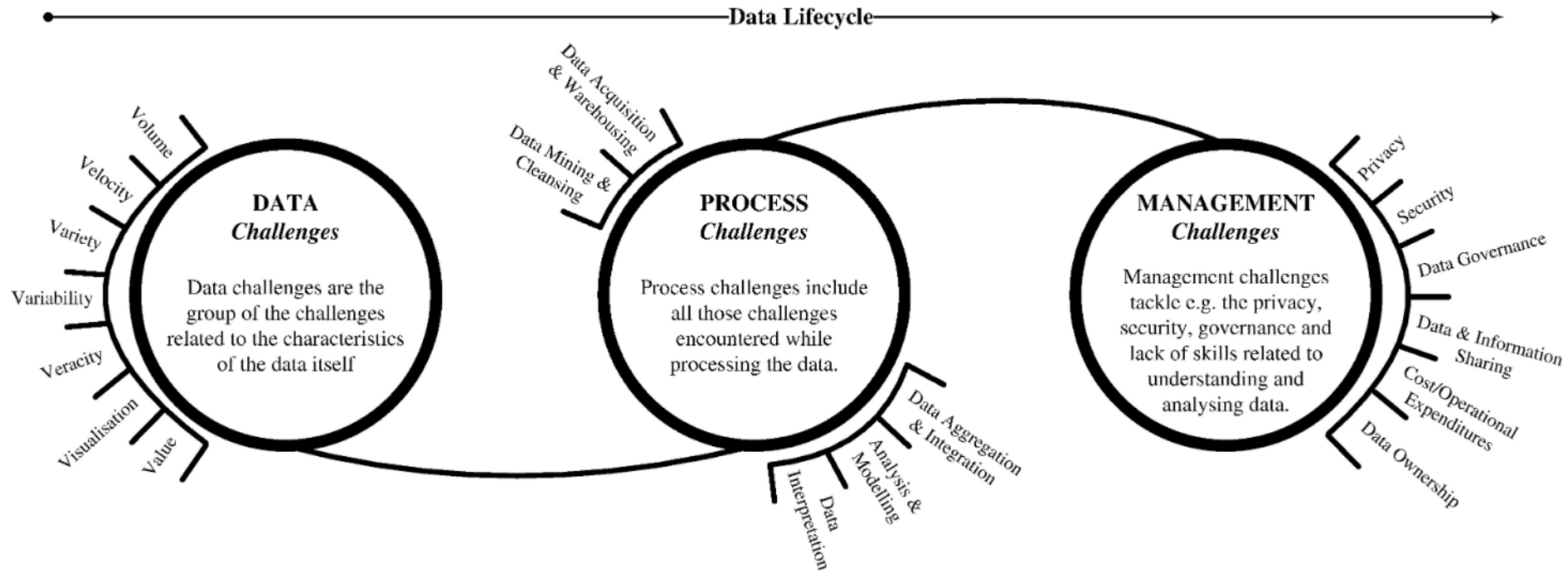
Big Data Management Dos...



Think strategically, act tactically

- Organizations tend to rush and build platforms to solve very specific problems:
 - Program seen as experiment only
 - Hard to evolve and integrate as a business asset
- **Better:** Establish strategic goals -> Makes it easier to envision other applications of Big Data
- Continuous application of Big Data -> Better realization of its true value and potential

Recap: Big Data Lifecycle



Thanks