

Interoperability: A Holistic Approach

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Interoperability: Introductory concepts

Interoperability intended as the ability of two entities to work together very much depends on:

- The **working context** in which the two entities are embedded (web services, digital libraries, cultural heritage, control and command systems, e-Science, etc.)
- The **nature** of the interoperable entities (people, software components, organizations, etc.)

Interoperability: introductory concepts (II)

Due to its inherent complexity and multifaceted nature, interoperability has been often misunderstood:

- Simple information/data **exchangeability** has been confused with interoperability
- Several forms of **compatibility** (composability, replaceability) have also been confused with interoperability
- when addressing interoperability between two entities the fact that often these belong to two different organizations which have their own **policies** has been ignored

Interoperability: Definition

“The ability of two or more systems to **exchange** information and to **use** the information that has been exchanged” (IEEE)

- (i) The two entities must be able to exchange **meaningful** information objects (**exchangeability**)
- (ii) The two entities must be able to exchange **logically consistent** information objects (when the exchanged information objects are descriptions of functionality, policy, or behavior (**compatibility**))
- (iii) The consumer entity must be able to **use** the exchanged information in order to perform a set of tasks that depend on the utilization of this information (**usability**)

Exchangeability

The **heterogeneity** Problem

Different sources of heterogeneity can be encountered depending on:

- How the information objects are represented
- How information objects are requested
- The semantic meaning of each information object
- The use of different terminologies
- How information objects are actually transported over a network

Exchangeability (II)

Three types of heterogeneity to be overcome in order to achieve a meaningful exchange of information objects:

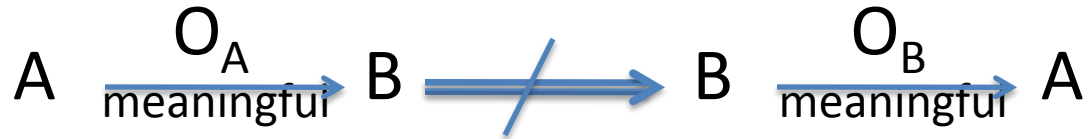
- Heterogeneity between data languages/query languages
(*syntactic exchangeability*)
- Heterogeneity between the data models adopted for representing information objects
(*structural exchangeability*)
- Heterogeneity between the “semantic universe of discourse” of the producer and consumer entities
(*semantic exchangeability*)

Exchangeability (III)

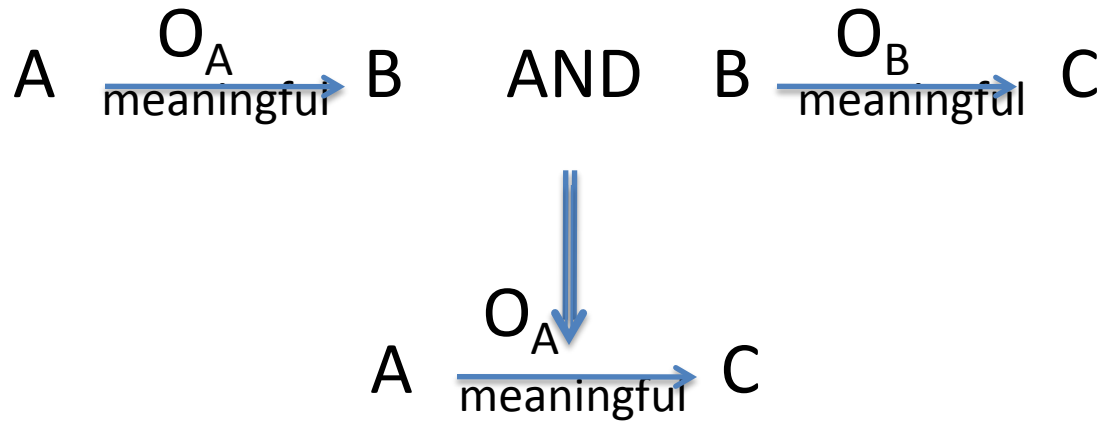
The three levels of **exchangeability** i.e., **syntactic**, **structural**, and **semantic** allow a **meaningful** exchange of information objects between the two entities and thus guarantee the **exchangeability** between them.

Properties of Exchangeability

Asymmetry



Transitivity



Compatibility

The Logical Inconsistent Problem

Logical inconsistencies between:

- **functional** descriptions of services (producer) and requests (consumer)
- **policy** descriptions
- **behavioral** descriptions

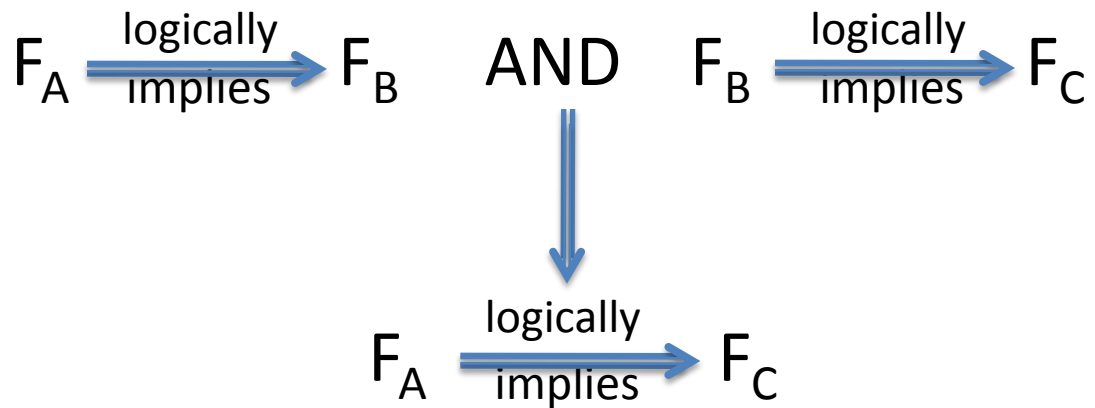
Compatibility

Properties of Compatibility

Asymmetry



Transitivity



Usage

The Usage Inconsistent Problem

“The consumer’s goal cannot be achieved by using the producer’s resources”

Possible causes of inability of the consumer entity to use the exchanged information objects :

Quality mismatching

Policy mismatching

Data-incomplete mismatching

Usage (II)

Quality mismatching

The quality profile associated with the exported information object does not meet the quality expectations of the consumer entity

Policy mismatching

The data policies of the organizations to which the two entities belong are incompatible

Data-incomplete mismatching

The exported information object is lacking some useful information to enable the consumer to fully exploit the received information object

Usage (III)

The exchanged information objects must be complemented with some **descriptive information** (contextual, provenance, security, privacy, etc.) which gives additional meaning.

The descriptive information should be modeled by **purpose-oriented** descriptive data models (**metadata models**).

In a **multidisciplinary context** it could be necessary to associate different descriptive metadata models with the exchanged information object.

Usage (IV)

If the producer entity of an information object is willing to export/publish it, its possible uses by the potential consumer entities must be carefully taken into account and it must be endowed with appropriate descriptive information.

Appropriate purpose (discipline)-oriented metadata models must be chosen and used.

Relationships between exchangeability, compatibility, usability and interoperability

Exchangeability is a necessary but not sufficient condition for achieving interoperability

Exchangeability is a necessary but not sufficient condition for assuring compatibility of functions/policies/behaviors

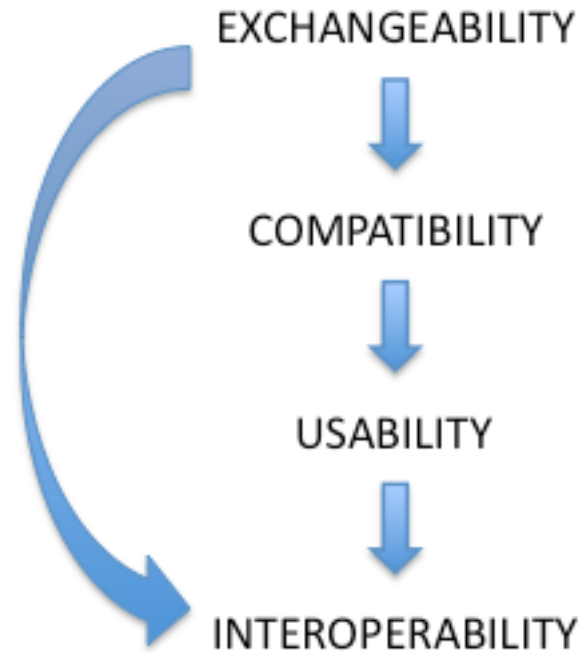
Compatibility is a weaker concept than the interoperability

Usability implies Exchangeability but the reverse is not true

Compatibility implies Exchangeability but the reverse is not true

Usability implies Compatibility but the reverse is not true

Relationships between exchangeability, compatibility, usability and interoperability (II)



Mediation

The main concept enabling “meaningful” exchange of information objects is **mediation**.

The mediation concept is implemented by a **mediator**, which is a software device capable of establishing exchangeability or compatibility of resources by resolving heterogeneities and inconsistencies

A key feature of the mediation process is the kind of intermediation function implemented by a mediator:

mapping

matching

consistency checking

Mediation (II)

Mapping refers to how information structures, properties, relationships are mapped from one representation scheme to another one, equivalent from the semantic point of view.

Matching refers to the action of verifying whether two strings /patterns match, or whether semantically heterogeneous data match.

Consistency checking refers to the action of checking whether the logical relationships between functional/policy/organizational descriptions of two entities share a logical framework.

Mediation Scenarios

Mediation of **data structures**: permits data to be exchanged according to syntactic, structural, and semantic matching.

Mediation of **functionalities**: makes possible to overcome mismatching of functional descriptions of two entities expressed in terms of pre- and post conditions.

Mediation of **policies**: employs techniques to solve policy mismatches.

Mediation of **protocols**: makes possible to overcome behavioral mismatches among protocols run by interacting parties.

Automated Mediation

Automated Mediation relies on:

- Adequate modeling of structural, formatting, and encoding constraints of the producer entity information resources
- Adequate modeling of data descriptive information (metadata)
- Adequate modeling of the consumer entity needs
- Formal domain-specific ontologies
- Abstract models and language for policy specification
- Formally defined transfer and message exchange protocols
- The definition of a matching relationship between the producer information resources and the consumer models

Automated Mediation (II)

Automated mediation heavily relies on adequate modeling of the exchanged information objects

The effectiveness, efficiency, and computational complexity of the intermediation function very much depend on the characteristics of the data models and languages:

expressiveness

levels of abstraction

semantic completeness

reasoning mechanisms

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The Final Objective

The ultimate aim should be the definition and implementation of an “**integrated mediation framework**” capable of providing means to handle and resolve all kinds of heterogeneities and inconsistencies that may hamper the effective usage of the resources of a data infrastructure

Standards

The role of **standards** for achieving data interoperability is of paramount importance.

Standards for:

(Meta) Data models

Languages

Discipline-specific metadata models

Domain-specific ontologies

Extensions to the Producer – Consumer Model

Asymmetric roles of producer/consumer

The process of information object exchange is not always a **one-way** flow:

producer  consumer

But it may be **bi-directional**:

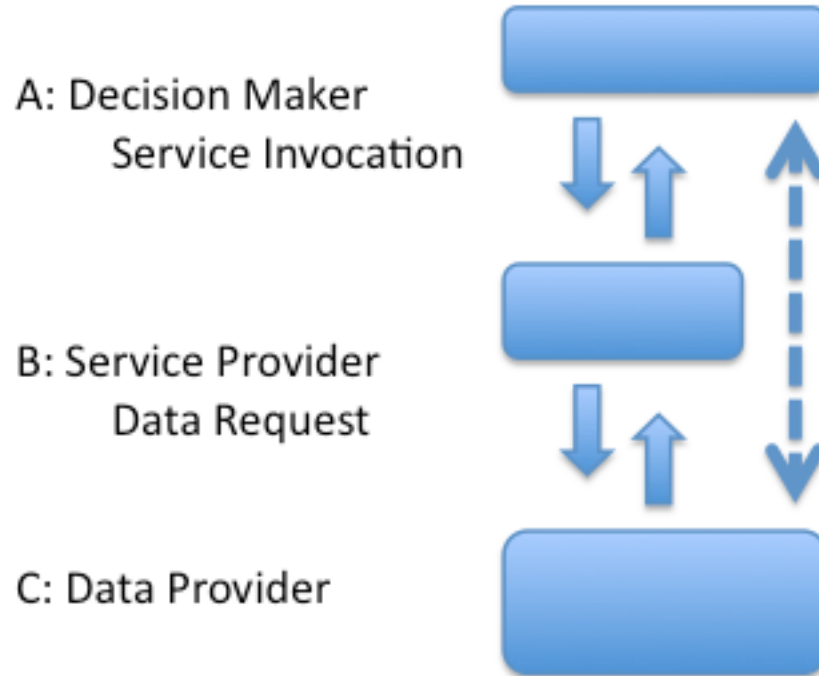
producer  consumer

Bilateral vs Multilateral or Direct vs Indirect Interoperability

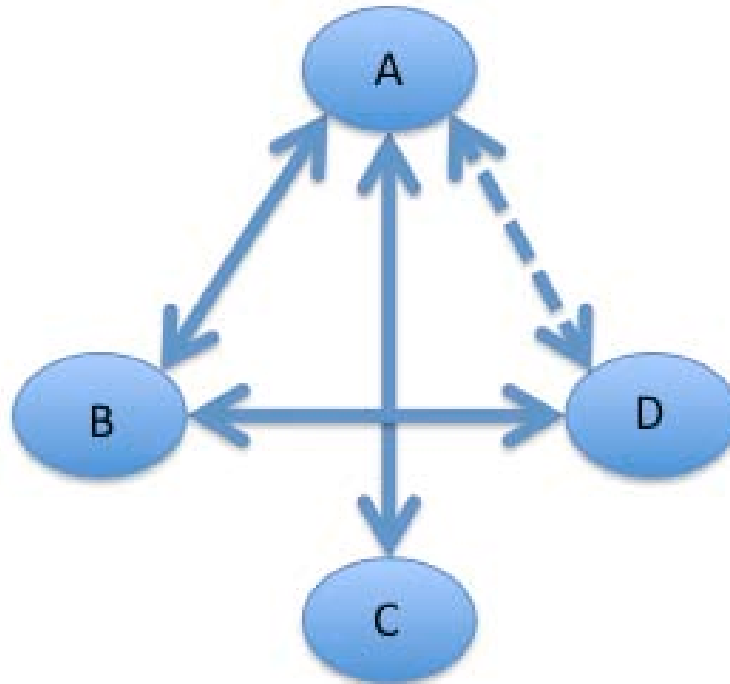
This criticism points out that the producer – consumer model conveys the idea that interoperability is a **binary problem**, i.e., it regards the ability of two entities to work together.

In a networked environment more than two entities may be involved in carrying out a task and therefore the scope of interoperability is wider than that of the binary problem.

Indirect Interoperability Scenario



Multilateral Interoperability Scenario



Data-Centrism of the Interoperability Definition

This criticism considers the definition of interoperability given by IEEE as **data-centric** and it does not adequately reflect the fact that the object of interoperability cannot only be data but also services, policies, behaviors, etc.

The objection is founded in the sense that this definition of interoperability has contributed to confusing interoperability with data exchangeability. In addition, the concept of compatibility as a weaker form of interoperability is not at all taken into consideration.

A more general and complete definition of the interoperability concept must be formulated.

End of the presentation!

Thank you